SYNTHESIS OF IMIDAZOLIDINONES AND INDOLINES VIA AZA-HECK CYCLIZATIONS & PHOSPHONATE-DIRECTED C–H BORYLATION

by

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PHOSPHONATE-DIRECTED C–H BORYLATION

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TABLE OF CONTENTS

LIST OF TABLES x
LIST OF FIGURES xi
ABSTRACT xviii

Chapter

1 SYNTHESIS OF IMIDAZOLIDINONES USING AZA-HECK CYCLIZATION 1

1.1 Introduction 1
1.2 Existing Methods to Synthesize Imidazolidinones 2

1.2.1 Aza-Wacker Cyclization and Related Reactions 3
1.2.2 Alkene Carboamination 7
1.2.3 Alkene Diamination 9
1.2.4 Cycloaddition of Aziridines and Isocyanates 10
1.2.5 Gold-Catalyzed Intramolecular Dihydroamination of Allenes 10
1.2.6 C-H Functionalization 11

1.3 Aza-Heck Cyclizations 12

1.3.1 Pyrrole and Imidazole Synthesis 13
1.3.2 Pyridine Synthesis 16
1.3.3 Cyclic Imine Synthesis 18
1.3.4 Pyrrolidine and Piperidine Synthesis 24
1.3.5 Secondary Lactam Synthesis 27

1.4 Propsoed Imidazolidinone Synthesis via Aza-Heck Cyclization 28
1.5 Optimization of Reaction Condition 31
1.6 Scope of Imidazolidinone-Forming Aza-Heck Cyclization 35

1.6.1 Examination of Functional Group Tolerance 35
1.6.2 Examination of Diastereoselectivity 37
1.6.3 Synthesis of Bicyclic Imidazolidinones 37
1.6.4 Synthesis of Bis-Unprotected Imidazolidinones 38
1.6.5 6-*exo* Cyclization 39

1.7 Rapid Access to Multi-Cyclic Heterocycles via Aza-Heck Cyclizations 40
1.8 Synthesis of Dihydroimidazolones Using Halide Additive 40
1.9 Demonstration of Factor Xa Inhibitor Synthesis 42
1.10 Lactam Synthesis Using the Improved Reaction Condition 43
1.11 Conclusion 44
1.12 Experimental Details 44

1.12.1 General Experimental Details 44
1.12.2 Instrumentation and Chromatography 45
1.12.3 Preparation of Allylic Amines 46
1.12.4 Synthesis of *N*-Phenoxy Ureas 67
1.12.5 Synthesis of Imidazolidinones 95
1.12.6 Synthesis of Dihydroimidazolones 133
1.12.7 Formal Synthesis of Factor Xa Inhibitor 139
1.12.8 Synthesis of Secondary Lactams 141
1.12.9 Crystallographic Details 146

REFERENCES 147

2 SYNTHESIS OF INDOLINES VIA AZA-HECK CYCLIZATION 153

2.1 Introduction 153
2.2 Current Methods to Synthesize Indolines 154

2.2.1 Intramolecular C–N Coupling 154
2.2.2 Intramolecular Aromatic C–H Activation 155
2.2.3 Dearomatization of Indoles 157

2.2.3.1 Asymmetric Hydrogenation of Indoles 157
2.2.3.2 Cycloaddition of Indoles 157
2.2.3.3 Electrophilic Addition of C3 Substituted Indoles 158

2.2.4 Annulation of *o*-Iodo Anilines with Alkenes 159
2.2.5 Aza-Wacker Cyclization 161
2.2.6 Intramolecular Tsuji-Trost Allylation 163

2.3 Optimization of Reaction Condition 164

2.3.1 Choice of *N*-Aryl Nitrogen Electrophiles 164
2.3.2 Examination of Ligand Effect 168

2.4 Exploration of Substrate Scope 169

2.4.1 Functional Group Tolerance 169
2.4.2 Synthesis of Indolines Bearing Fully-Substituted C2 Carbon Centers 171
2.4.3 Synthesis of Pseudo-Indoxyls 171
2.4.4 Synthesis of Indolines Bearing Heterocycles 172

2.5 Conclusion 173
2.6 Experimental Details 174

2.6.1 General Experimental Details 174
2.6.2 Instrumentation and Chromatography 175
2.6.3 Preparation of Nitroarenes 176
2.6.4 Synthesis of *N*-aryl-*N*-hydroxy Carbamates 204
2.6.5 Synthesis of Indolines 222
2.6.6 Crystallographic Details 241

REFERENCES 243

3 ARYL PHOSPHONATE-DIRECTED C–H BORYLATION 248

3.1 Introduction 248
3.2 Preparation of Aryl Phosphonates 249

3.2.1 Grignard Addition 249
3.2.2 Cross-Coupling of Aryl Electrophiles with Dialkyl Phosphites 250
3.2.3 Chan-Lam Coupling 253
3.2.4 Decarbonylative Phosphorylation of Carboxylic Acids 254
3.2.5 Aryl Phosphonate Synthesis from Diaryliodonium Salts 256
3.2.6 Summary of Existing Methods & Our Hypothesis 257

3.3 Our Design 257
3.4 Directed C–H Borylations 258

3.4.1 Carbonyl-Directed C–H Borylations 259
3.4.2 Lewis Basic Nitrogen as a Directing Group 265
3.4.3 Phenol-Directed C–H Borylation 267
3.4.4 Silane-Directed C–H Borylation 268
3.4.5 Thiane-Directed C–H Borylation 270
3.4.6 Phosphine-Directed C–H Borylation 271
3.4.7 Hypothesized Aryl Phosphonate-Directed C–H Borylation 276

3.5 Reaction Optimization 276
3.6 Examination of Substrate Scope 280
3.7 Product Downstream Functionalization 283

3.8 Conclusion 285
3.9 Experimental Details 286

3.9.1 General Experimental Details 286
3.9.2 Instrumentation and Chromatography 287
3.9.3 Preparation of Aryl Phosphonates 287
3.9.4 Unusual Product Signals in ^{31}P NMR Spectra 302
3.9.5 Synthesis of *Ortho*-Phosphonate Boronic Esters 303
3.9.6 In Situ Functionalization of Boronic Esters 322
3.9.7 Crystallographic Details 327

REFERENCES 329

Appendix

A SPECTRAL DATA FOR CHAPTER 1 334
B SPECTRAL DATA FOR CHAPTER 2 522
C SPECTRAL DATA FOR CHAPTER 3 663
D PRELIMINARY RESULTS 800

D.1 Preliminary Result of Enantioselective Imidazolidinone-Forming Aza-Heck Cyclization 800

D.1.1 General Procedure of Figure D.1 801

D.2 Preliminary Result of Enantioselective Indoline-Forming Aza-Heck Cyclization 802

D.2.1 General Procedure of Figure D.2 803

D.3 Preliminary Result of Intermolecular C-H Amination 805

D.3.1 General Procedure of Figure D.4 805

LIST OF TABLES

Table 1.1: Optimization of Imidazolidinone-Forming Aza-Heck Cyclization..... 32

Table 2.1: Ligand Examination of Indoline-Forming Aza-Heck Cyclization..... 169

Table 3.1: Preliminary Ligand Screen with $[(COD)_2Ir]BF_4$..... 277

Table 3.2: Preliminary Examination of Iridium Sources..... 278

Table 3.3: Examination of Ligand Effect..... 279

LIST OF FIGURES

Figure 1.1: Notable Bioactive Compounds Containing Imidazolidinone Fragment 1

Figure 1.2: Representative Example of Converting Imidazolidinone to Guanidine 2

Figure 1.3: Formation of Imidazolidinone via Nucleophilic Substitution 3

Figure 1.4: The Earliest Imidazolidinone-Forming Aza-Wacker Cyclization 3

Figure 1.5: Copper-Catalyzed Imidazolidinone-Forming Aza-Wacker Cyclization..... 4

Figure 1.6: Wacker-Type Aminocarbonylation of Allylic Ureas..... 5

Figure 1.7: Shi's Aminoacetoxylation of Allylic Ureas..... 5

Figure 1.8: Stahl's Mechanistic Proposal of Aza-Wacker Cyclization..... 6

Figure 1.9: Representative Example of Wolfe's Carboamination..... 7

Figure 1.10: Wang's Imidazolidinone Synthesis via Alkene Aminoalkynylation 8

Figure 1.11: Photocatalytic Alkene Aminoalkynylation from the Rueping Group..... 8

Figure 1.12: Example of Alkene Diamination and the Following Deprotection 9

Figure 1.13: Imidazolidinone Synthesis from Aziridines and Isocyanates 10

Figure 1.14: Imidazolidinone Synthesis via Gold Catalysis 11

Figure 1.15: Synthesis of N–H Bearing Imidazolidinones via Rhodium Catalysis 11

Figure 1.16: Synthesis of Mono-Protected Imidazolidinones via Allylic Amination .. 12

Figure 1.17: Heterocycles Synthesized via Aza-Heck Cyclizations 13

Figure 1.18: Narasaka's Study of N–O Bond Insertion by Palladium Catalyst 13

Figure 1.19: The First Use of Nitrogen Electrophile in Heck Cyclization..... 14

Figure 1.20: The Use of Oxime Esters in Heck Cyclization 14

Figure 1.21: Proposed Mechanism of Pyrrole-Forming Aza-Heck Cyclization 15
Figure 1.22: Synthesis of Imidazoles via Aza-Heck Cyclization 16
Figure 1.23: Transition States Comparison between 5-*exo* and 6-*endo* Cyclizations .. 16
Figure 1.24: 6-*endo* Aza-Heck Cyclization with Bu_4NCl as Additive 17
Figure 1.25: Synthesis of Isoquinolines Using Aza-Heck Cyclization 17
Figure 1.26: The First Isolation of Cyclic Imine in Aza-Heck Cyclization 18
Figure 1.27: Polycyclic Imine Synthesis via Tandem Heck Cyclization 18
Figure 1.28: Use of Aza-Heck Cyclization in Total Synthesis 19
Figure 1.29: Bower's Aza-Heck Cyclization for Bicyclic Imine Synthesis 20
Figure 1.30: Synthesis of Mono-Cyclic Imines via Aza-Heck Cyclization 20
Figure 1.31: Asymmetric Cyclic Imine-Forming Aza-Heck Cyclization 21
Figure 1.32: Mechanism of Aza-Heck Cyclization Proposed by Bower 22
Figure 1.33: Copper-Catalyzed Aza-Heck Cyclization 23
Figure 1.34: Tandem Aza-Heck Cyclization 23
Figure 1.35: Zhu's Tandem Aza-Heck Cyclization of Oxime Esters 24
Figure 1.36: Synthesis of Pyrrolidines via Aza-Heck Cyclization 25
Figure 1.37: Preliminary Result of Piperidine-Forming Aza-Heck Cyclization 25
Figure 1.38: General Aza-Heck Cyclization for the Synthesis of Piperidines 26
Figure 1.39: Bower's Asymmetric Aza-Heck Cyclization 26
Figure 1.40: Synthesis of Unprotected Lactams via Aza-Heck Cyclizations 27
Figure 1.41: Proposed Mechanism of Lactam-Forming Aza-Heck Cyclization 28
Figure 1.42: Potential Imidazolidinone Synthesis via Aza-Heck Cyclization 29
Figure 1.43: Attempt to Prepare *N*-Phenoxy Ureas via CDI Coupling 29

Figure 1.44: Beauchemin's Method to Prepare Asymmetric *N*-Oxy Ureas 30

Figure 1.45: Initial Attempt to Generate *O*-phenyl Isocyanate Intermediate **1.117** 30

Figure 1.46: Our Design of **1.118** to Prepare *N*-Phenoxy Ureas 31

Figure 1.47: Example of Pd^0 Catalyst Generation from (COD)Pd(CH_2SiMe_3)$_2$ 33

Figure 1.48: Working Hypothesis for the Formation of **1.122** 34

Figure 1.49: Overman's Isomerization Study in Heck Cyclization 35

Figure 1.50: Examination of Functional Group Tolerance 36

Figure 1.51: Diastereo-Control of the Imidazolidinone-Forming Aza-Heck Cyclization 37

Figure 1.52: Synthesis of Bicyclic Imidazolidinones 38

Figure 1.53: Synthesis of Doubly Unprotected Imidazolidinones 39

Figure 1.54: Attempt of Larger Ring Formation 40

Figure 1.55: Synthesis of Multi-Cyclic Heterocycles using Aza-Heck Cyclizations 40

Figure 1.56: Stabilities of Palladium Hydride Species with Different Anions 41

Figure 1.57: Synthesis of Dihyroimidazolones with the Use of Halide Additive 42

Figure 1.58: Formal Synthesis of Factor Xa Inhibitor 43

Figure 1.59: Synthesis of Unprotected Lactam Using the Improved Condition 43

Figure 1.60: nOe Studies of the Diastereomer of Imidazolidinone **1.145** 107

Figure 1.61: nOe Studies of the Diastereomer of Imidazolidinone **1.146** 108

Figure 1.62: nOe Studies of the Diastereomer of Imidazolidinone **1.147** 110

Figure 1.63: nOe Studies of the Stereochemistry of Imidazolidinone **1.144-*trans*** 120

Figure 1.64: nOe Studies of the Stereochemistry of Imidazolidinone **1.144-*cis*** 121

Figure 1.65: nOe Studies of the Diastereomer of Imidazolidinone **1.151** 125

Figure 1.66: Crystal Structure of Imidazolidinone **1.156** 128

Figure 1.67: E2-type Elimination of **1.S55** to Yield **1.156** 129

Figure 2.1: Representative Bioactive Indolines..... 153

Figure 2.2: Example of Indoline Formation via Alkyl C–N Bond Formation 154

Figure 2.3: Indoline Synthesis Using Intramolecular C–N Coupling 155

Figure 2.4: Preparation of Indolines via Directed C–H Activation..... 156

Figure 2.5: Alexanian's Aromatic C–H Alkylation to Access Indolines 156

Figure 2.6: Representative Example of Asymmetric Hydrogenation of Indoles 157

Figure 2.7: Dearomative Cycloaddition of Indoles 158

Figure 2.8: Representative Example of Electrophilic Addition of Indoles 159

Figure 2.9: Larock's Annulation Method of *o*-Iodo Anilines 159

Figure 2.10: Proposed Mechanism of Larock's Annulation 160

Figure 2.11: Jamison's Method Using Simple Alkenes 161

Figure 2.12: Aza-Wacker Cyclization for the Synthesis of Indolines..... 161

Figure 2.13: Asymmetric Indoline-Forming Aza-Wacker Cyclization..... 162

Figure 2.14: Only Example of Indoline Bearing Fully-Substituted C2 Carbon..... 163

Figure 2.15: Representative Example of Intramolecular Tsuji-Trost Allylation..... 163

Figure 2.16: Proposed Aza-Heck cyclization for Indoline Synthesis..... 164

Figure 2.17: Use of *N*-Chloroamides in Cross-Coupling Reactions 165

Figure 2.18: Cross-Coupling of Aryl Zinc Reagent and *N*-Hydroxylaniline Benzoate 165

Figure 2.19: Investigation of Cyclization of Aniline Electrophile **2.38** 166

Figure 2.20: Synthesis of *N*-Aryl-*N*-Hydroxy Carbamates from Nitroarenes..... 167

Figure 2.21: Use of *N*-Aryl-*N*-Hydroxy Carbamate **2.42** in Aza-Heck Cyclization .. 167

Figure 2.22: Hypothesized Mechanism of the Indoline-Forming Aza-Heck Cyclization 168

Figure 2.23: Examination of Functional Group Tolerance 170

Figure 2.24: Synthesis of Indolines Bearing Fully-Substituted C2 Carbon Centers .. 171

Figure 2.25: Synthesis of Pseudo-Indoxyls 172

Figure 2.26: Examination of Heterocycle Tolerance 173

Figure 2.27: Existing Aza-Heck Cyclizations and My Contribution to This Field 174

Figure 2.28: nOe Studies of the Diastereomer of Indoline **2.49-*trans*** 226

Figure 2.29: Crystal Structure of Indoline **2.65** 239

Figure 2.30: Crystal Structure of Indoline **2.66** 240

Figure 3.1: Aryl Phosphonates in Ligand Synthesis 248

Figure 3.2: Bioactive *Ortho*-Substituted Aryl Phosphonate and Related Molecules . 249

Figure 3.3: Synthesis of Aryl Phosphonates via Grignard Reaction 250

Figure 3.4: Synthesis of Aryl Phosphonates Using Cross-Coupling Reactions 251

Figure 3.5: Proposed Mechanism of the Hirao Coupling 252

Figure 3.6: Cross-Coupling of Aryl Sulfonates with Dialkyl Phosphites 252

Figure 3.7: Copper Catalysis in the Hirao Coupling 253

Figure 3.8: Chan-Lam Coupling for Aryl Phosphonate Synthesis 254

Figure 3.9: Synthesis of Aryl Phosphonates from Aryl Boronic Esters 254

Figure 3.10: Decarbonylative Phosphorylation of Carboxylic Acids 255

Figure 3.11: Proposed Mechanism of Szostak's Phosphorylation Method 256

Figure 3.12: Aryl Phosphonate Synthesis Using Hypervalent Iodine Reagents 257

Figure 3.13: Synthesis of *Ortho*-Phosphonate Boronic Esters via Miyaura Borylation 258

Figure 3.14: Miyaura's *Ortho* C–H Borylation of Aryl Esters 259
Figure 3.15: Proposed Mechanism of Directed C–H Borylation 260
Figure 3.16: Miyaura's *Ortho* C–H Borylation of Aryl Ketones 261
Figure 3.17: Smith's Directed C–H Borylation Strategy 261
Figure 3.18: Proposed Mechanism with Smith's Anionic Bidentate Ligand 262
Figure 3.19: Directed C–H Borylation with a Nitrogen/Silane-Based Ligand 263
Figure 3.20: Li's Nitrogen/Boron-Based Bidentate Ligand for C–H Borylation 263
Figure 3.21: Sawamura's Silicon-Supported Iridium Catalyst 264
Figure 3.22: Palladium-Catalyzed C–H Borylation of Aromatic Amides 265
Figure 3.23: C–H Borylation of 2-Aryl Pyridines 265
Figure 3.24: Benzylic Amine-Directed C–H Borylation 266
Figure 3.25: C–H Borylation of Aryl Aldehydes 267
Figure 3.26: C–H Borylation of *O*-Aryl Carbamates 267
Figure 3.27: Directed C–H Borylation of Unprotected Phenols 268
Figure 3.28: Benzyl Silane-Directed C–H Borylation 269
Figure 3.29: Use of Diethylsilane as a Traceless Directing Group 269
Figure 3.30: C–H Borylation of Indolines at 7-Position 270
Figure 3.31: Aryl Sulfide-Directed C–H Borylation 271
Figure 3.32: Benzyl Thioether-Directed C–H Borylation 271
Figure 3.33: Benzyl Phosphine-Directed C–H Borylation 272
Figure 3.34: Limited Reactivity for Bis-Borylation 273
Figure 3.35: Benzyl Phosphine-Directed C–H Borylation Using $[(COD)_2Ir]BF_4$ 273
Figure 3.36: Shi's Aryl Phosphine-Directed C–H Borylation 274

Figure 3.37: Takaya's Aryl Phosphine-Directed C–H Borylation 275

Figure 3.38: Notable Examples of *Ortho*-Substituted Aryl Phosphine Ligands 276

Figure 3.39: Hypothesized Aryl Phosphonate-Directed C–H Borylation 276

Figure 3.40: Examination of Functional Group Tolerance 280

Figure 3.41: Examination of Substitution Patterns and Electronic Effects 282

Figure 3.42: In Situ Downstream Functionalizations 284

Figure 3.43: Suzuki Coupling of *Ortho*-Boryl Aryl Phosphonate **3.39** 285

Figure 3.44: ^{31}P NMR Experiments of **3.103** under Varied Temperatures 303

Figure 3.45: Crystal Structure of **3.103** 311

Figure D.1: Preliminary Asymmetric Imidazolidinone-Forming Aza-Heck Cyclization 801

Figure D.2: Preliminary Asymmetric Indoline-Forming Aza-Heck Cyclization 802

Figure D.3: Promising Enantioselectivity with the Use of PHOX Ligand 803

Figure D.4: Preliminary Intermolecular C–H Amination of Terminal Olefines 805

ABSTRACT

Nitrogen-containing heterocycles are prevalent in bioactive natural products and synthetic molecules. For this reason, the discovery of new methods to prepare those fragments is an important research field in organic synthesis. In this thesis, I will describe the synthesis of imidazolidinones and indolines via the strategies of Heck cyclization using nitrogen electrophiles. In addition, the development of iridium-catalyzed *ortho* C–H borylation of aryl phosphonates will be presented. This method provides rapid access to aryl phosphonates bearing complex *ortho* substitutions from simple starting materials.

The first chapter will describe the development of imidazolidinone-forming aza-Heck cyclization. Using easily accessible starting materials, this method allows the synthesis of unprotected imidazolidinones, including the ones containing two free N–H groups. This reaction uses commercially available catalytic components, has broad functional group tolerance, and can be applied to complex ring topologies. The synthesis of a factor Xa inhibitor was demonstrated using this method. With the addition of halide source, dihydroimidazolones can be accessed from the same starting materials via in situ isomerization. Moreover, this improved reaction condition can also be used for the preparation of unprotected lactam substrates.

In Chapter 2, I will describe the development of aza-Heck cyclization to synthesize indolines and related heterocycles. Using palladium catalysis and *N*-hydroxy anilines as electrophiles, which can be easily prepared from nitroarenes in a single step, this reaction provides steady access to indolines. Difficult substrates, such as the ones

containing fully-substituted carbon centers at the C2 position, which is known to be a synthetic challenge, can also be prepared via this strategy. This is the first time that the use of *N*-aryl amine electrophiles has been demonstrated in the field of aza-Heck cyclization.

The third chapter will describe the development of aryl phosphonate-directed C–H borylation. This method provides quick access to *ortho*-phosphonate aryl boronic esters from simple aryl phosphonates. Those borylated products can serve as versatile intermediates for the synthesis of highly-substituted aryl phosphonates, which can be easily converted into aryl phosphine ligands. The in situ downstream functionalization of products will also be discussed in this chapter.

Chapter 1

SYNTHESIS OF IMIDAZOLIDINONES USING AZA-HECK CYCLIZATION

1.1 Introduction

The imidazolidinone scaffold can be frequently found in synthetic bioactive molecules and natural products. Many compounds containing this structure have been shown to exhibit interesting biological activities and been recognized as effective or potential treatment for a number of diseases, including hair loss,[1] leukemia,[2] picornavirus,[3] lung cancer,[4] metabolic disorders,[5] and HIV.[6] Among those molecules, the ones bearing free N–H groups or unsaturation vicinal to one of the nitrogen atoms are particularly common (Figure 1.1).[6-11] For example, Sch 425078, a potent NK_1 antagonist, contains an imidazolidinone fragment with two free N–H groups.[7]

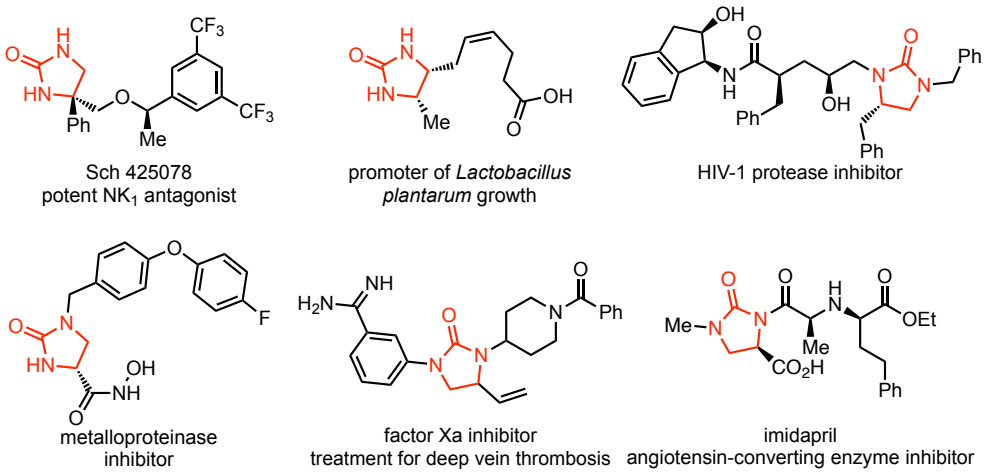


Figure 1.1: Notable Bioactive Compounds Containing Imidazolidinone Fragment

Besides their biological value, imidazolidinones are versatile synthetic intermediates, and can be rapidly converted into other functional groups, such as diamines[12] and guanidines.[13] For example, Feldman and co-workers synthesized the imidazolidinone intermediate **1.1** and used it as a guanidine precursor during the total synthesis of dragmadicin E (Figure 1.2).[14]

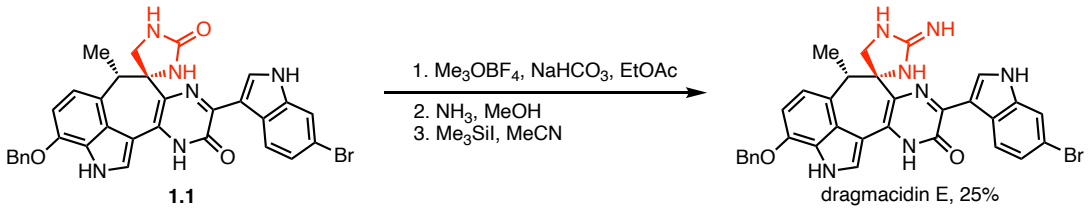


Figure 1.2: Representative Example of Converting Imidazolidinone to Guanidine

1.2 Existing Methods to Synthesize Imidazolidinones

The most straightforward way to prepare the imidazolidinone fragment is the treatment of diamine with phosgene equivalent,[15] but such a synthetic route is not very efficient considering the starting material diamine is as difficult to make as the imidazolidinone. Another classic method is to use nucleophilic ureas to do intramolecular nucleophilic substitution. Towards the synthesis of a CRF-1 antagonist, for example, an N–H bearing urea with a leaving group at the β carbon **1.2** was used to synthesize the imidazolidinone **1.3** under basic condition (Figure 1.3).[16] However, the imidazolidinones prepared using this strategy are structurally limited due to the inherent drawbacks of S_N2 reactions, such as low reactivity with highly-substituted electrophiles. To expand the access to imidazolidinones, therefore, several transition metal-catalyzed methods have been designed.

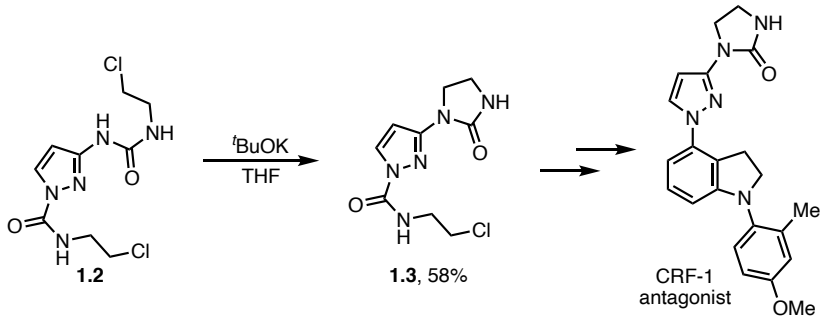


Figure 1.3: Formation of Imidazolidinone via Nucleophilic Substitution

1.2.1 Aza-Wacker Cyclization and Related Reactions

The Wacker-type cyclization and related reactions could afford a number of heterocycles, including imidazolidinones, via Pd^{II}-catalyzed oxidative cyclization of nucleophilic nitrogen centers onto pendent alkenes. In 1998, Weinreb and co-workers reported the first imidazolidinone-forming aza-Wacker cyclization.[17] Using this strategy, they were able to prepare the multi-cyclic imidazolidinone **1.5** through the cyclization of allylic urea **1.4** (Figure 1.4). To date, this is still the only example of palladium-catalyzed aza-Wacker cyclization for the synthesis of imidazolidinone.

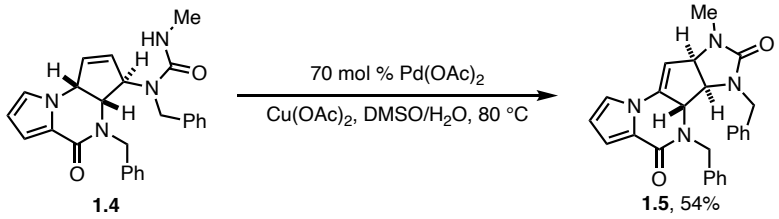


Figure 1.4: The Earliest Imidazolidinone-Forming Aza-Wacker Cyclization

Several years ago, the Xu group was able to generalize this method using copper catalysis.[18] With catalytic amount of $Cu(eh)_2$ and DMP as oxidant, allylic urea **1.6** can

be readily cyclized to afford imidazolidinone **1.7** as single diastereomer (Figure 1.5). In this method, high level of diastereoselectivity was observed across the board. Besides, difficult imidazolidinone substrates, such as the ones bearing fully-substituted carbon centers, can also be prepared. Under the same reaction condition, oxazolidones can also be prepared from allylic carbamates. However, this method requires protections on both nitrogen centers, which results in imidazolidinones in protected form. Moreover, limited functional group tolerance was demonstrated in this work, which is a common limitation of many aza-Wacker cyclizations.

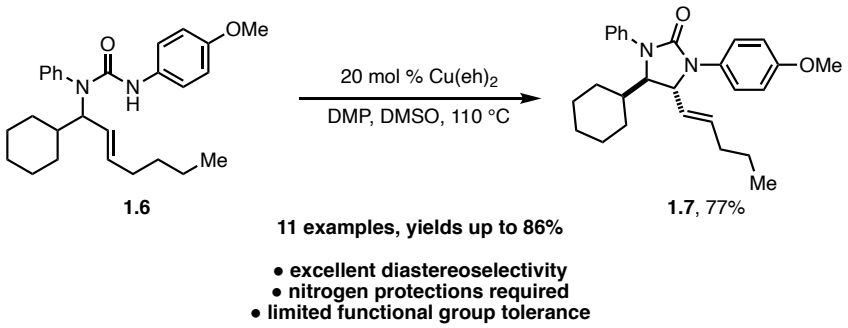


Figure 1.5: Copper-Catalyzed Imidazolidinone-Forming Aza-Wacker Cyclization

Besides those two reports, there are also a few Wacker-like cyclizations that can deliver the imidazolidinone structure, such as aminocarbonylation.[19-20] Using $PdCl_2$ as catalyst and $CuCl_2$ as oxidant, Yoshida and co-workers reported the first example in this field (Figure 1.6).[19] Notably, this method allows the formation of 6-membered ring, which is known to be difficult for aza-Wacker cyclizations. Similar to other aza-Wacker or related strategies, nevertheless, this reaction does not produce imidazolidinones bearing free N–H groups.

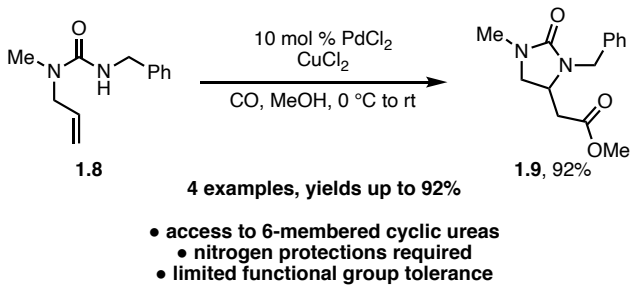


Figure 1.6: Wacker-Type Aminocarbonylation of Allylic Ureas

The imidazolidinone fragment is also accessible via the Wacker-like aminoacetoxylation reported by the Shi group (Figure 1.7).[21] Interestingly, the products prepared using this method can be further reduced to provide the synthetically valuable amino alcohols. However, this reaction suffers from several limitations. First of all, it still requires protection on both nitrogen atoms, so cannot provide access to N–H bearing imidazolidinones. Moreover, this reaction does not work well with highly-substituted alkenes, which would produce imidazolidinones bearing fully-substituted carbon centers. Finally, no diastereoselectivity was observed in this those reactions. As demonstrated by the synthesis of imidazolidinone **1.11**, two diastereomers were isolated as a ratio of 50:50.

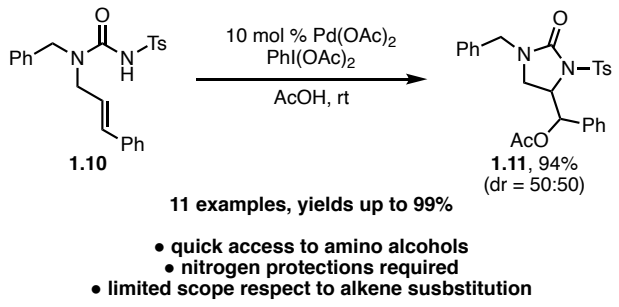


Figure 1.7: Shi's Aminoacetoxylation of Allylic Ureas

Although a mechanistic study specific to imidazolidinone-forming aza-Wacker reaction has not been reported, the mechanism of lactam-forming aza-Wacker cyclization has been extensively studied (Figure 1.8).[22] The mechanism proposed by the Stahl group initiates with the ligation of the nitrogen at the amide **1.13** to the electrophilic Pd^{II} catalyst **1.12**, followed by the deprotonation of nitrogen to give the amidate-alkene chelate palladium intermediate **1.15**. The kinetic isotope studies revealed that both steps are reversible. Thus, the cyclization efficiency is highly related to ease of the nitrogen deprotonation. To improve the efficiency of aza-Wacker cyclization, therefore, a common strategy is to increase the acidity of nitrogen source, which usually requires pre-activation at the reacting nitrogen, such as the installation of sulfonyl groups. As a result, the aza-Wacker cyclization typically only produces protected nitrogen-containing heterocycles.

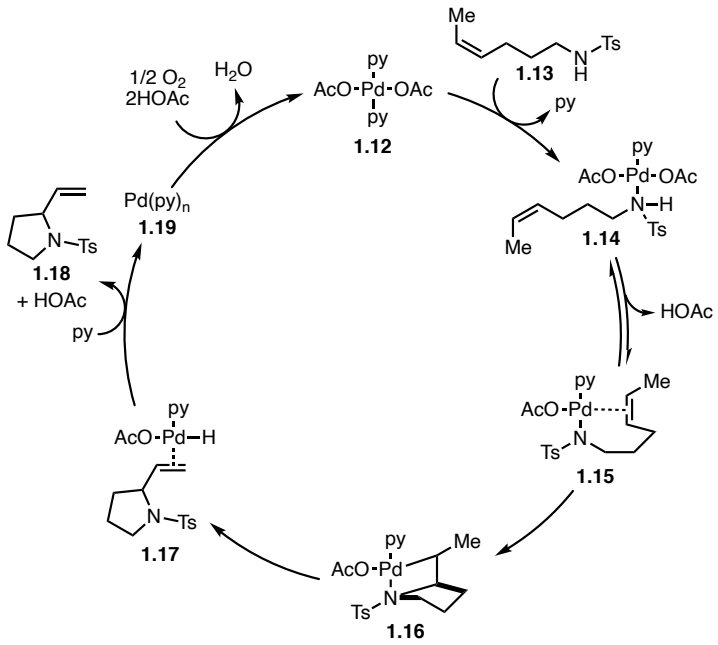


Figure 1.8: Stahl's Mechanistic Proposal of Aza-Wacker Cyclization

1.2.2 Alkene Carboamination

Another method to prepare imidazolidinone is the carboamination of alkene. As one of the pioneers in this field, the Wolfe group has reported a series of alkene carboamination reactions for the synthesis of imidazolidinones.[23-27] Like the aza-Wacker cyclizations, however, those reactions also failed to deliver imidazolidinones in unprotected form (Figure 1.9). The attempt to use primary urea as starting material resulted in the arylation of nitrogen and low cyclization yield.[23]

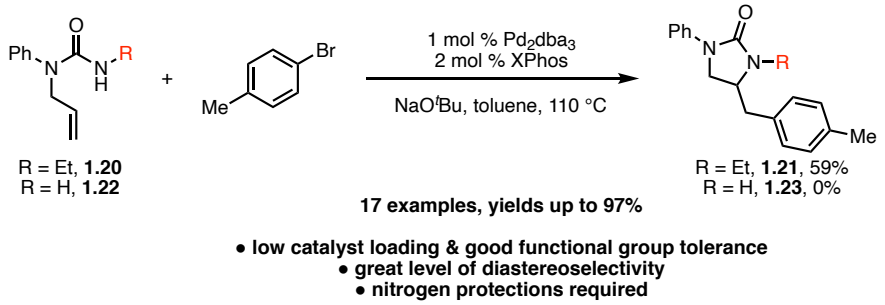


Figure 1.9: Representative Example of Wolfe's Carboamination

In addition to the work discovered by Wolfe, there are two independent reports of alkene aminoalkynylation. Several years ago, Wang and co-workers reported reaction conditions for the cyclization of allylic ureas via a copper-catalyzed aminoalkynylation strategy (Figure 1.10).[28] This method can also be used to prepare other nitrogen-containing heterocycles, such as lactams and oxazolidones. One advantage of this reaction is that it allows the formation of 6-membered heterocycles, which is known to be challenging in this field. Similar to the previously mentioned methods, unfortunately, this reaction also requires protections on both nitrogen atoms. Another obvious

limitation is the use of hypervalent iodide reagents, which requires extra steps for starting material synthesis and limits the scope of alkyne substitutions.

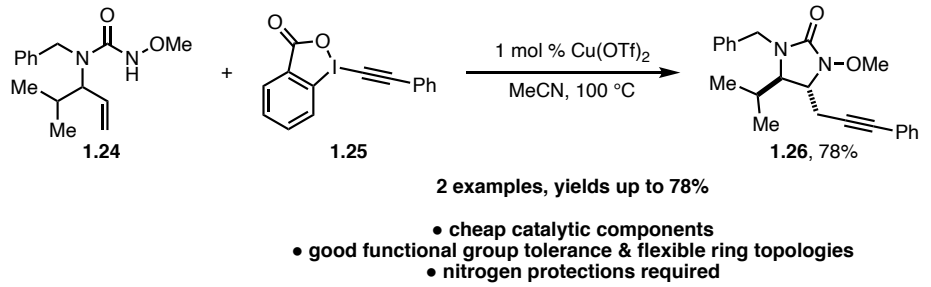


Figure 1.10: Wang's Imidazolidinone Synthesis via Alkene Aminoalkynylation

A year later, Rueping and co-workers were able to improve this transformation with photoredox conditions, which allows the use of more accessible alkynyl sulfones as electrophiles (Figure 1.11).[29] Although there is only one example of imidazolidinone synthesis in the entire paper, the scope of lactam substrates demonstrated in this work is broad, showing the generality of this method. Therefore, this work has provided a good complement to Wang's aminoalkynylation method.

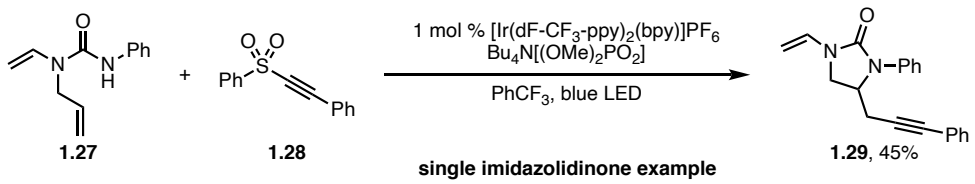


Figure 1.11: Photocatalytic Alkene Aminoalkynylation from the Rueping Group

1.2.3 Alkene Diamination

Over the last two decades, the diamination of alkene has emerged as a powerful tool for the synthesis of diamines and related heterocycles, including imidazolidinones.[30] Those reactions usually use di-*tert*-butyldiaziridinone as the diamine source, which consequently give bis-*tert*-butyl substituted imidazolidinones. The protection of nitrogen not only adds more steps for deprotection, but more importantly, the deprotection step often involves harsh reaction conditions. During the synthesis of Sch 425078, demonstrated by Shi and co-workers, the target precursor **1.31** was prepared from a terminal alkene **1.30** using a diamination strategy.[31] To remove the protecting groups, however, they needed to reflux **1.31** in trifluoroacetic acid (Figure 1.12). In addition to those intermolecular reactions, several intramolecular alkene diamination methods were also reported.[32-33] Those reactions allow the quick construction of multi-cyclic imidazolidinones, but again, N–H bearing imidazolidinones are not accessible through those methods.

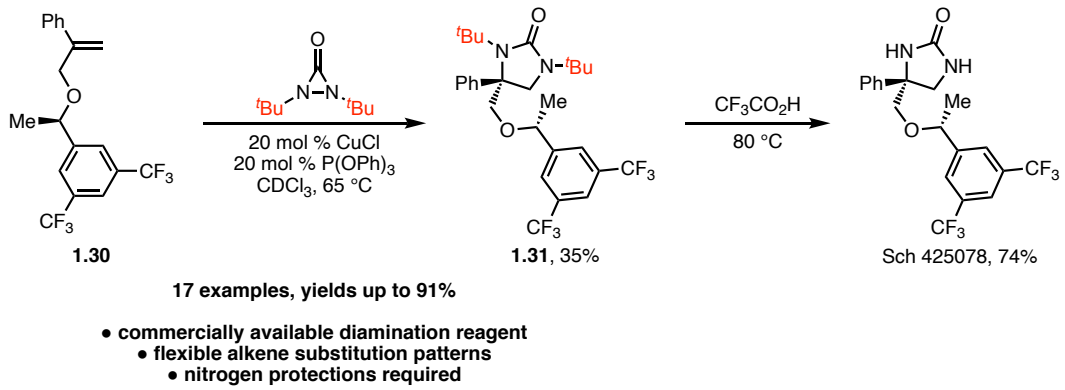


Figure 1.12: Example of Alkene Diamination and the Following Deprotection

1.2.4 Cycloaddition of Aziridines and Isocyanates

Imidazolidinones can also be prepared from aziridines and isocyanates via metal-catalyzed cycloaddition.[34-36] For example, the Trost group was able to activate the racemic vinyl aziridine **1.32** using chiral palladium catalysis, followed by a formal [3+2] cycloaddition with isocyanate **1.33** to offer the enantioenriched imidazolidinone **1.35** in 82% yield with a great level of enantioselectivity (Figure 1.13).[35] However, both vinyl aziridines and isocyanates are not very accessible and usually require several steps to prepare, limiting the scope and practicality of this method.

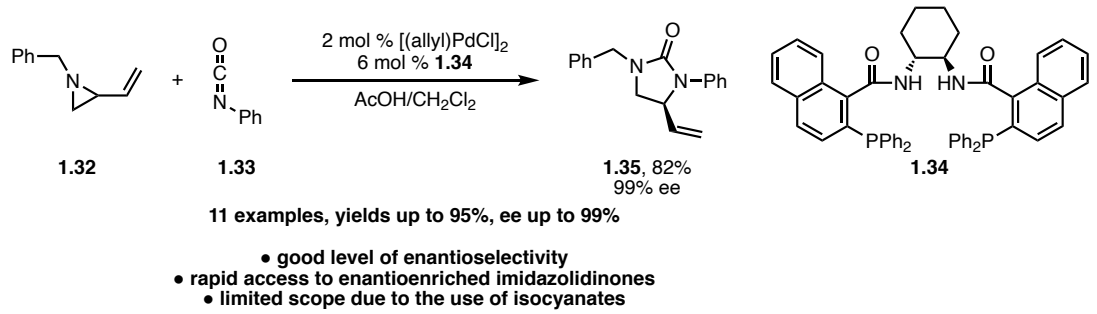


Figure 1.13: Imidazolidinone Synthesis from Aziridines and Isocyanates

1.2.5 Gold-Catalyzed Intramolecular Dihydroamination of Allenes

As demonstrated by the Widenhoefer group, *N*-allenyl ureas can cyclize via gold catalysis to provide bicyclic imidazolidinones (Figure 1.14).[37] The cyclization condition is very mild, and can take place at ambient temperature to provide imidazolidinones bearing many functional groups. Also, this reaction is highly diastereoselective and in most cases only produces one diastereomer. Like the methods mentioned earlier, however, the protection of nitrogen centers is necessary for this chemistry. Besides, the synthesis of allene starting materials is not trivial.

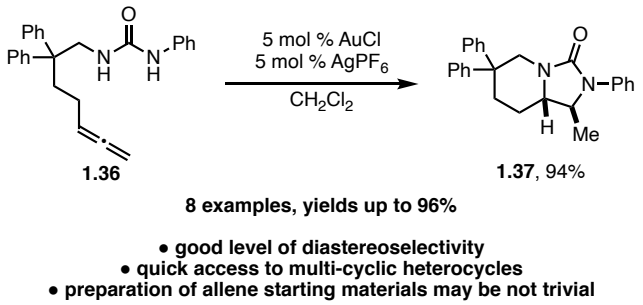


Figure 1.14: Imidazolidinone Synthesis via Gold Catalysis

1.2.6 C-H Functionalization

Prior to our work, there are only two metal-catalyzed methods allowing the preparation of mono-unprotected imidazolidinones. In 2006, Du Bois and co-workers reported the use of rhodium catalysis for the oxidative cyclization of simple aliphatic urea **1.38**, which allows the synthesis of unprotected imidazolidinone **1.39** (Figure 1.15).[38] This marks the first time that the preparation of N–H bearing imidazolidinones occurs through a metal-catalyzed method. Although the reactive nitrogen is unprotected, the other nitrogen requires protection. The subjection of doubly unprotected substrate resulted in multiple products and none of the imidazolidinone product was observed due to the competing side reactions.

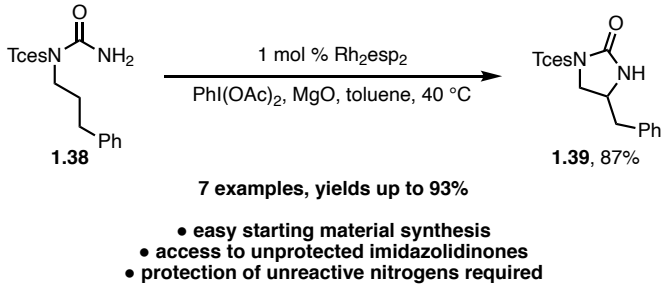


Figure 1.15: Synthesis of N–H Bearing Imidazolidinones via Rhodium Catalysis

More recently, the White group developed an intramolecular allylic C–H amination reaction to prepare mono-unprotected imidazolidinone **1.40** from allylic urea **1.41** (Figure 1.16).[39] In contrast to the previous C–H activation method, this reaction requires pre-activation of the reacting nitrogen to increase its acidity. Therefore, both methods have provided the access to mono-protected imidazolidinones, but none can deliver imidazolidinones with two free N–H groups.

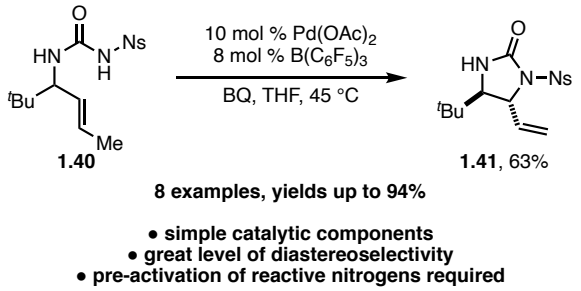


Figure 1.16: Synthesis of Mono-Protected Imidazolidinones via Allylic Amination

1.3 Aza-Heck Cyclizations

Since the first example of a Heck-type cyclization using nitrogen electrophile was reported by the Narasaka group in 1999, this strategy has been expanded to prepare a number of heterocycles, including pyrroles and imidazoles, pyridines, cyclic imines, saturated pyrrolidines and piperidines, and lactams (Figure 1.17).[40-42] Those methods have shown successes in the construction of difficult carbon-nitrogen bonds and complex ring systems. Besides, a few asymmetric aza-Heck cyclizations have been developed in the recent years, which shows the feasibility of enantioenriched heterocycle synthesis via this strategy.

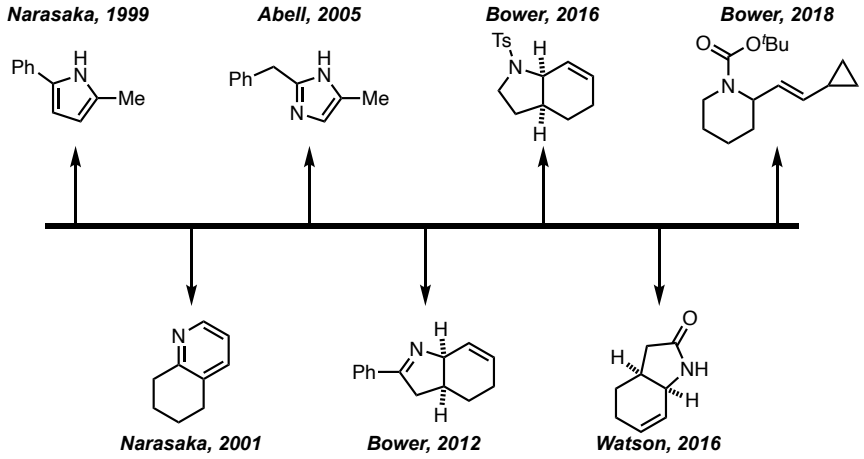


Figure 1.17: Heterocycles Synthesized via Aza-Heck Cyclizations

1.3.1 Pyrrole and Imidazole Synthesis

In 1999, Narasaka and co-workers reported the reaction of a stoichiometric amount of a Pd^0 complex with oxime sulfonate **1.42**. When quenched with water, the reaction provided the reduced product **1.44** (Figure 1.18).[43] This result suggested that the reaction went through an oxidative addition intermediate **1.43** via the N–O bond activation by palladium catalyst. Based on this discovery, the Narasaka group realized the opportunity for the use of these nitrogen electrophiles in the Heck reaction.

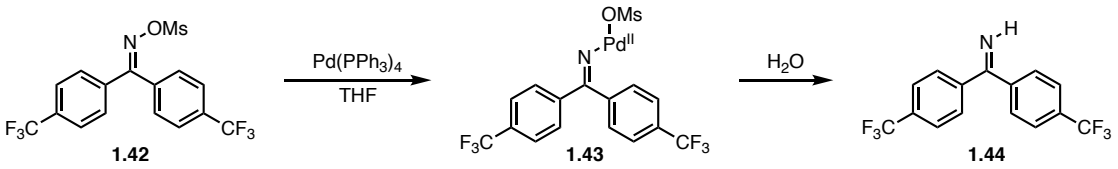
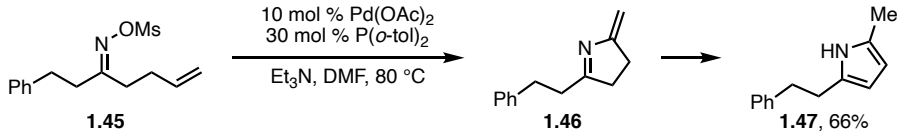


Figure 1.18: Narasaka's Study of N–O Bond Insertion by Palladium Catalyst

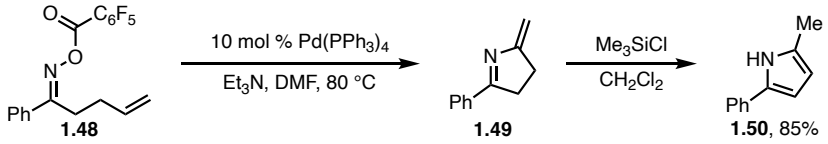
In the same paper, Narasaka described the reaction condition for the cyclization of oxime sulfonate **1.45** in Heck reaction to make cyclic imine **1.46**, which then easily isomerized to the more stable aromatic pyrrole **1.47** (Figure 1.19). This is the first example of Heck cyclization using a non-carbon electrophile. Despite the promising reactivity, the starting material **1.45** is relatively unstable and not trivial to prepare.



1.45 **1.46** **1.47**, 66%

Figure 1.19: The First Use of Nitrogen Electrophile in Heck Cyclization

To make the reaction more practical, they discovered a similar imine electrophile **1.48**, which employs the fluorinated ester as leaving group. Those oxime esters are more stable and can be purified through chromatography. Using those substrates, pyrroles can be steadily prepared through the aza-Heck cyclization (Figure 1.20).



1.48 **1.49** **1.50**, 85%

6 examples, yields up to 88%

- **first example of aza-Heck cyclization**
- **rapid access to highly-substituted pyrroles**
- **bench stable starting materials**

Figure 1.20: The Use of Oxime Esters in Heck Cyclization

Following the initial work, the Narasaka group further expanded the scope of the pyrrole-forming aza-Heck cyclization and suggested a reaction mechanism (Figure 1.21).[44] It is proposed that the reaction initiates with the oxidative addition of Pd^0 catalyst **1.51** with the imine electrophile **1.45** to give the Pd^{II} intermediate **1.52**, which undergoes migratory insertion to make the new C–N bond. The β-hydride elimination of **1.53** provides the cyclic imine product **1.46**, which then quickly isomerized to the observed pyrrole product **1.47**.

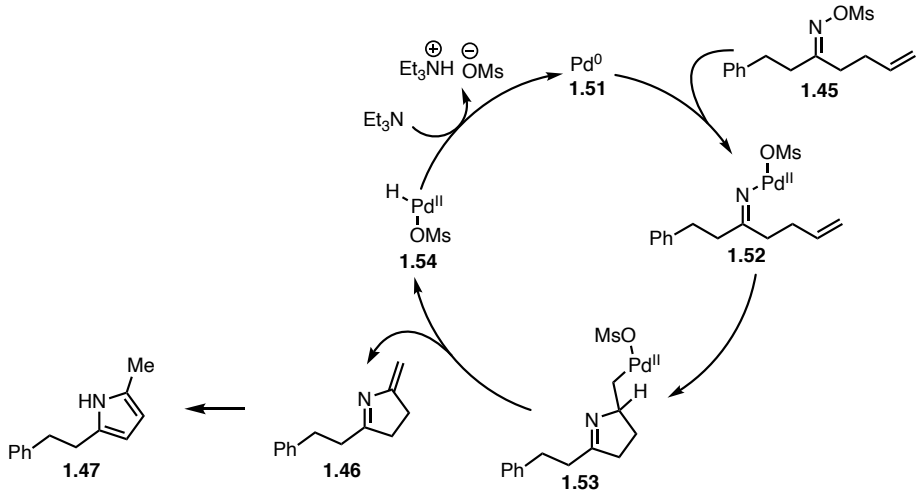


Figure 1.21: Proposed Mechanism of Pyrrole-Forming Aza-Heck Cyclization

Based on this mechanism, Abell was able to design the synthesis of imidazoles through a similar strategy (Figure 1.22).[45] Using the same reaction condition reported by Narasaka, the cyclization of amidoxime ester **1.55**, which can be easily prepared from the corresponding aldehyde, provided the highly-substituted imidazole **1.56** in good efficiency. More complex product, such as amino acid derived substrates, can also be prepared using this method.

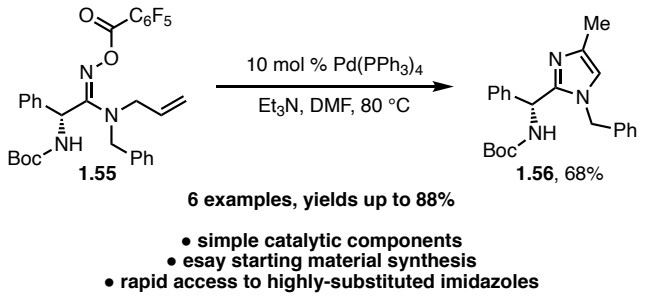


Figure 1.22: Synthesis of Imidazoles via Aza-Heck Cyclization

1.3.2 Pyridine Synthesis

For intramolecular Heck reactions, 5-*exo* cyclization is usually faster than 6-*endo* cyclization because of the lower energy transition state in the migratory insertion step (Figure 1.23).[46] For the migratory insertion to proceed, the C–Pd bond has to align with the alkene. While forming small rings, the 5-*exo* transition state has a much smaller strain energy comparing to 6-*endo* transition state.

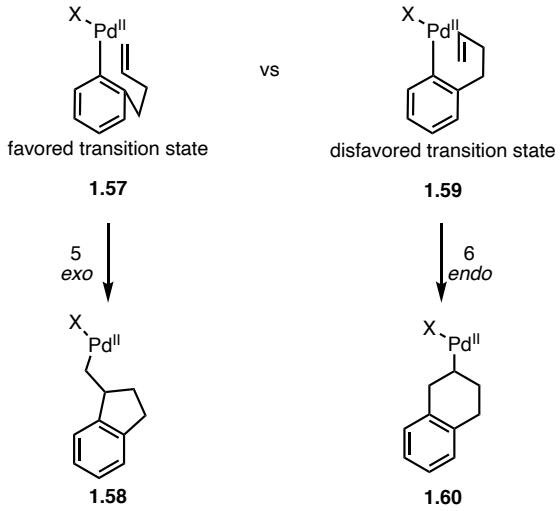


Figure 1.23: Transition States Comparison between 5-*exo* and 6-*endo* Cyclizations

In most cases, this trend is observed in the aza-Heck cyclization as well. In the Heck cyclization of oxime esters, however, Narasaka found that the addition of halide source, such as Bu_4NCl, can flip the selectivity and make 6-*endo* cyclization preferable.[47] Without the use of Bu_4NCl, for example, the cyclization of **1.61** produces the highly-substituted pyrrole **1.62** as the major product; on the other hand, in the presence of Bu_4NCl, the cyclization of **1.61** produces the pyridine **1.63** as the major product (Figure 1.24). Other substrates, such as oxime esters bearing dienes can also participate in those reactions to produce pyridines.

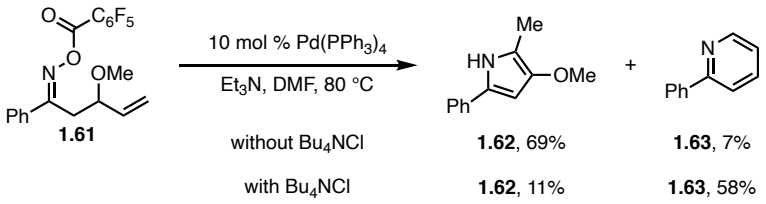


Figure 1.24: 6-*endo* Aza-Heck Cyclization with Bu_4NCl as Additive

Other related heterocycles, such as isoquinoline, can also be prepared using the same reaction condition. The cyclization of benzofused oxime ester **1.64** provides access to the highly-substituted isoquinoline **1.65** in 77% isolated yield (Figure 1.25).

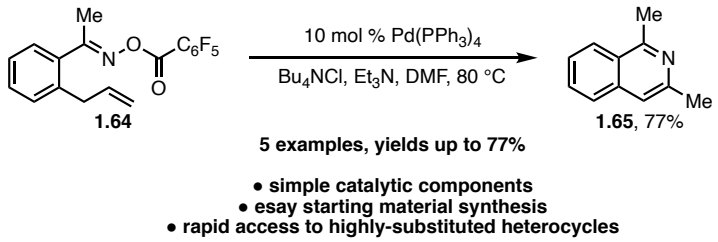


Figure 1.25: Synthesis of Isoquinolines Using Aza-Heck Cyclization

1.3.3 Cyclic Imine Synthesis

Back to the earliest report of aza-Heck cyclization, direct formation of cyclic imine **1.68** is followed incompletely by isomerization to pyrrole **1.67** with di-substituted alkene substrate **1.66** as starting material (Figure 1.26).[43] Such a result suggests the possibility for the synthesis of cyclic imine using oxime ester bearing more substituted alkene as the imine product will be more stable and less likely to undergo isomerization.

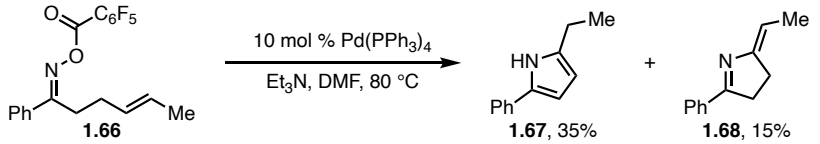


Figure 1.26: The First Isolation of Cyclic Imine in Aza-Heck Cyclization

Several years later, Narasaka discovered tandem Heck cyclization using oxime esters as electrophiles (Figure 1.27).[48] Starting with the substrate bearing two distinct alkenes **1.69**, the first aza-Heck cyclization makes the cyclic imine ring to give **1.70**. Such an intermediate still contains the active palladium intermediate, which can undergo another migratory insertion to make the second five-membered ring and produce the polycyclic imine **1.71** in 82% yield.

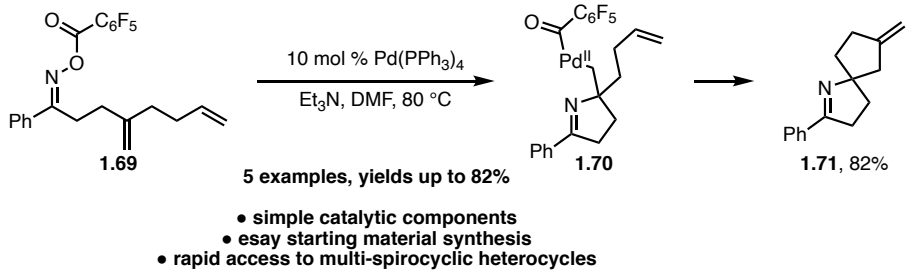


Figure 1.27: Polycyclic Imine Synthesis via Tandem Heck Cyclization

Despite the short history of aza-Heck cyclization, it has already been used in total synthesis. During the total synthesis of butylcycloheptylprodigiosin, Fürstner and co-workers were able to prepare the fluorinated oxime ester **1.72** as electrophile, which then cyclized to provide the bicyclic imine **1.73** as a key intermediate using the aza-Heck cyclization reported by Narasaka (Figure 1.28).[49] It is noteworthy that the product **1.73** was stable enough in the reaction that the isomerization is not a problem.

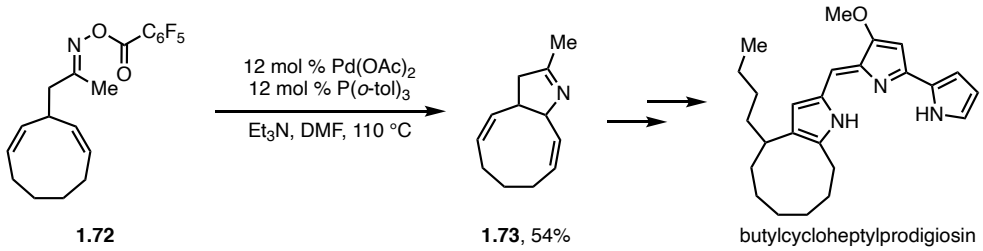


Figure 1.28: Use of Aza-Heck Cyclization in Total Synthesis

Over the last decade, the Bower group has done extensive work to improve the cyclization efficiency for the synthesis of cyclic imines. Following the initial result reported by Narasaka and Fürstner, Bower and co-workers developed a general reaction condition to prepare cyclic imines using aza-Heck cyclization (Figure 1.29).[50] Comparing to the previous report, the reaction condition is milder with lower catalyst loading. In those reactions, the electron-deficient triaryl phosphine ligand P[3,5-$(CF_3)_2$-$C_6H_3]_3$ was identified as the optimal ligand, which was suggested to be the key to improve the reactivities. The Bower group hypothesized that such a ligand can stabilize the oxidative addition palladium complex and reduce the amount of depalladation,

which provides the reduced starting material as the major by-product, by making the palladium center more electron-deficient and stabilizing the Pd^{II}–N bond.

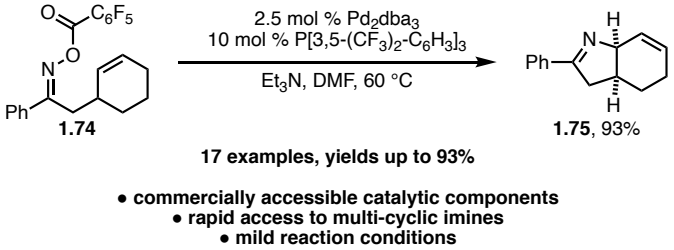


Figure 1.29: Bower's Aza-Heck Cyclization for Bicyclic Imine Synthesis

Later, the Bower group found that the same reaction condition can also be used to synthesize mono-cyclic imines (Figure 1.30). This method can prepare cyclic imines bearing fully-substituted carbon centers, such as **1.77**, which is known to be a synthetic challenge. Besides, this reaction generates a chiral center, which provides the opportunity for the development of asymmetric method.[51-52]

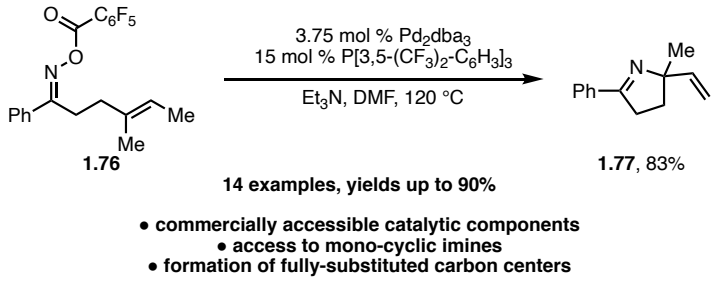


Figure 1.30: Synthesis of Mono-Cyclic Imines via Aza-Heck Cyclization

This goal was then successfully realized in 2017. Using the SIPHOX-type ligand, Bower and co-workers developed an asymmetric aza-Heck cyclization to prepare enantioenriched cyclic imines (Figure 1.31).[53] The scope of this reaction is broad, but its enantioselectivity is somewhat modest as most of products are obtained in around 85% ee. Additionally, the complex SIPHOX ligand is not highly accessible and takes several steps to prepare.

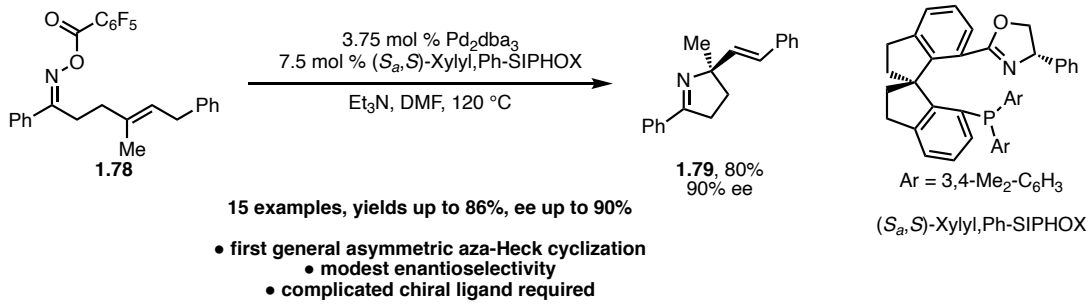


Figure 1.31: Asymmetric Cyclic Imine-Forming Aza-Heck Cyclization

The mechanistic studies of those reactions suggest a Heck-like mechanism (Figure 1.32).[54] Unlike the mechanism proposed by Narasaka, however, Bower proposes a cationic palladium intermediate **1.82**, which is generated via the dissociation of leaving group from the oxidative addition complex **1.81**. Although this step is reversible, the subsequent decarboxylation of leaving group provides the driving force for the formation of cationic palladium **1.82**. This accelerates the migratory insertion step, the typical rate-limiting step of Heck reactions. Such a mechanistic proposal also explains the use of electron-deficient ester as leaving group in those reactions considering its ease of decarboxylation.

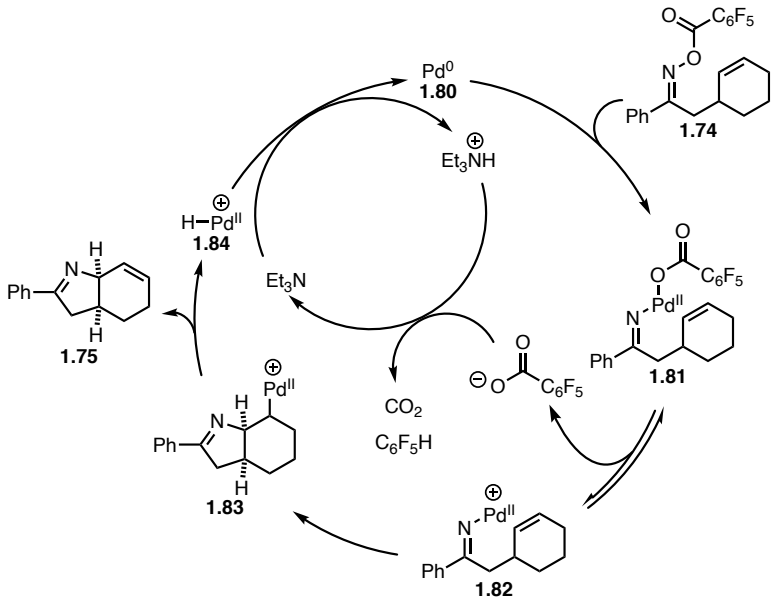


Figure 1.32: Mechanism of Aza-Heck Cyclization Proposed by Bower

In addition to palladium catalysis, Bower has shown that those reactions can also be catalyzed by copper catalysis.[55] Comparing to the palladium-catalyzed reactions, most reaction yields are either comparable or higher (Figure 1.33). Using palladium catalysis, for example, only 31% cyclization of **1.85** was observed; with copper catalyst, however, the cyclic imine **1.86** was isolated in 76% yield. The product **1.86** is particularly interesting because it is an unnatural cyclic amino acid derivative. Moreover, those reactions can use pivalate as leaving group, which makes the starting materials easier to prepare and lowers the reaction cost. Preliminary mechanistic studies suggest that this reaction goes through a radical process.

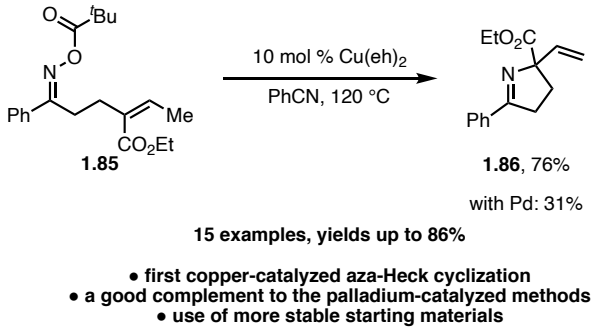


Figure 1.33: Copper-Catalyzed Aza-Heck Cyclization

Finally, the Bower group demonstrated the use of oxime esters in tandem aza-Heck/Suzuki reaction, which can make a C–N bond and a C–C bond in the same transformation (Figure 1.34).[56] Other transformations, such as carbonylation and alkynylation, can also be achieved in the tandem aza-Heck cyclization. Notably, only terminal alkenes have been used in this method. The use of more substituted alkenes was not demonstrated in this work.

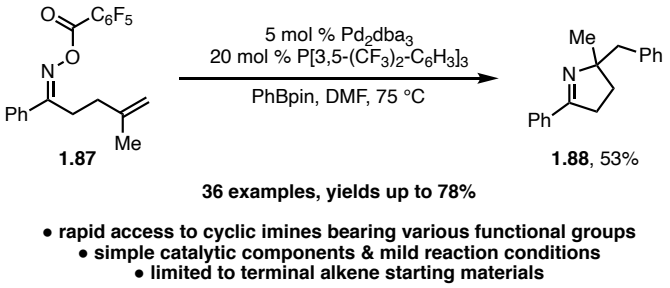


Figure 1.34: Tandem Aza-Heck Cyclization

In addition to Bower's work, Zhu and co-workers reported an asymmetric tandem aza-Heck cyclization with the arylation of oxadiazole **1.89** (Figure 1.35).[57]

Different from Bower's asymmetric method, this reaction uses commercially available SynPhos as chiral ligand. Similar to the asymmetric aza-Heck cyclization reported by Bower, however, the enantioselectivity of this method is modest.

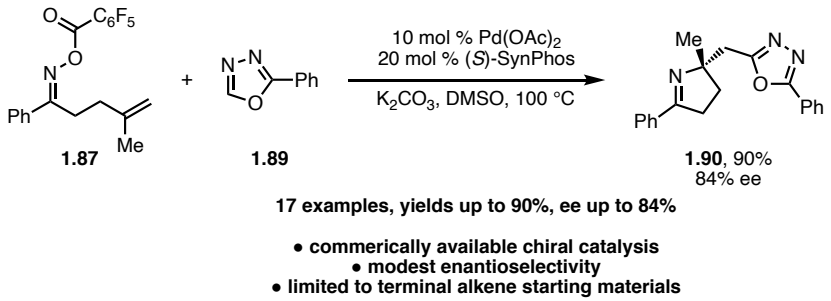


Figure 1.35: Zhu's Tandem Aza-Heck Cyclization of Oxime Esters

1.3.4 Pyrrolidine and Piperidine Synthesis

Several years ago, the Bower group was able to expand the power of aza-Heck cyclization to prepare pyrrolidine **1.92** with the use of alkyl nitrogen electrophile **1.91** (Figure 1.36).[58] The starting materials can be easily prepared from the corresponding bishomoallyic alcohols using Mitsunobu reactions. This reaction can be used to construct several complex ring topologies, such as spirocyclic and bridged ring systems. One of the obvious limitations, however, is that this reaction only produces pyrrolidines in protected form, and the removal of sulfonyl protecting group usually requires harsh reaction condition.

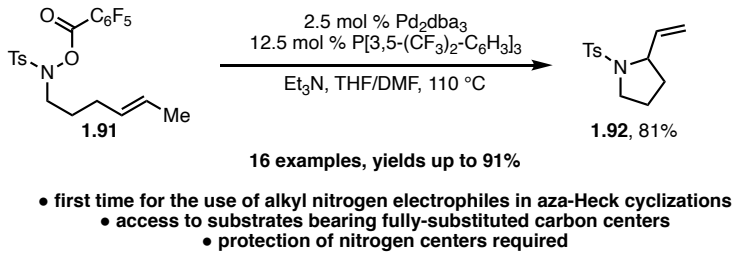


Figure 1.36: Synthesis of Pyrrolidines via Aza-Heck Cyclization

In this method, the transformation is largely limited to the formation of 5-membered rings. The only example of 6-membered ring formation is the benzofused product **1.94** via the cyclization of **1.93** (Figure 1.37). It is likely that the 6-*exo* cyclization of this substrate works because the aromatic ring limits the conformational rotation of alkene, which lowers the energy for migratory insertion.

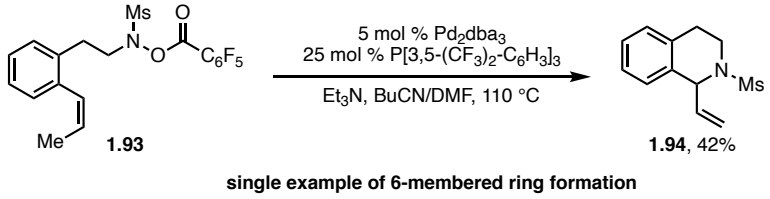


Figure 1.37: Preliminary Result of Piperidine-Forming Aza-Heck Cyclization

To improve the ease of deprotection, the Bower group identified the use of bulky electron-deficient phosphine **1.96** in those reactions, which allows the use of more user-friendly carbamate protecting groups (Figure 1.38).[59] Under this reaction condition, more importantly, 6-membered ring formation can proceed to provide piperidine **1.97** in good yield, which is the first general 6-*exo* aza-Heck cyclization. The scope of this reaction is broad, but the reaction requires elevated temperature (130 °C) to proceed. It

is notable that this temperature is significant above the boiling point of the reaction solvent (THF).

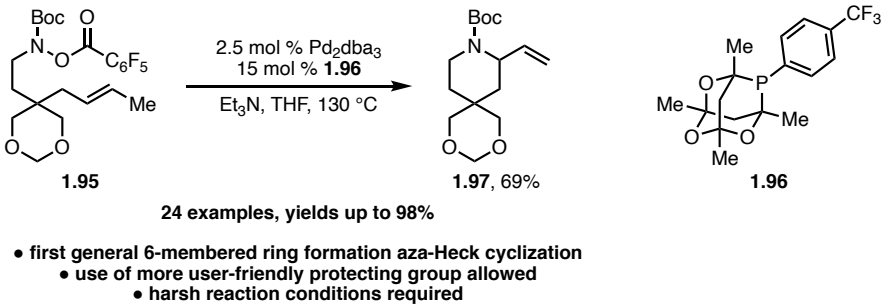


Figure 1.38: General Aza-Heck Cyclization for the Synthesis of Piperidines

More recently, the asymmetric version of this reaction was reported by the Bower group to prepare enantioenriched pyrrolidines and piperidines using chiral phosphoramidite ligand (Figure 1.39).[60] For those reactions, the use of more reactive substrates **1.98**, the ones bearing tosylate as leaving group, is required to achieve high enantioselectivities. Unlike the imine electrophiles, surprisingly, those alkyl nitrogen tosylates are bench stable and can be prepared from the alcohols in single steps.

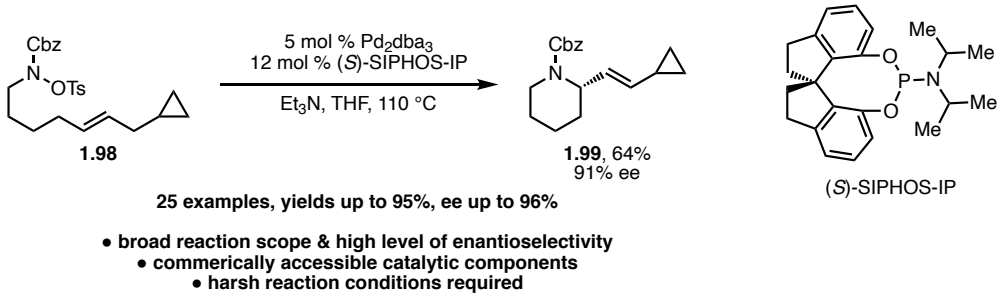


Figure 1.39: Bower's Asymmetric Aza-Heck Cyclization

1.3.5 Secondary Lactam Synthesis

Recently, our group introduced the use of *O*-phenyl hydroxamic ethers as electrophiles in this field. These reactions allow the preparation of secondary lactams (Figure 1.40).[61] Comparing to the previously reported methods that provide similar transformation, this cyclization can directly synthesize lactams in unprotected form. This reaction has a broad functional group tolerance and provides access to products that are difficult to prepare. Using this method, for example, secondary lactams bearing complex ring topologies, such as fused bicyclic substrate **1.102**, can be prepared in good yield. Even tetra-substituted alkene can engage in this reaction (**1.103**), which is known to be difficult in the Heck reaction. Finally, the cyclization of substrate bearing heterocycles also provides the lactam product **1.104** in great efficiency.

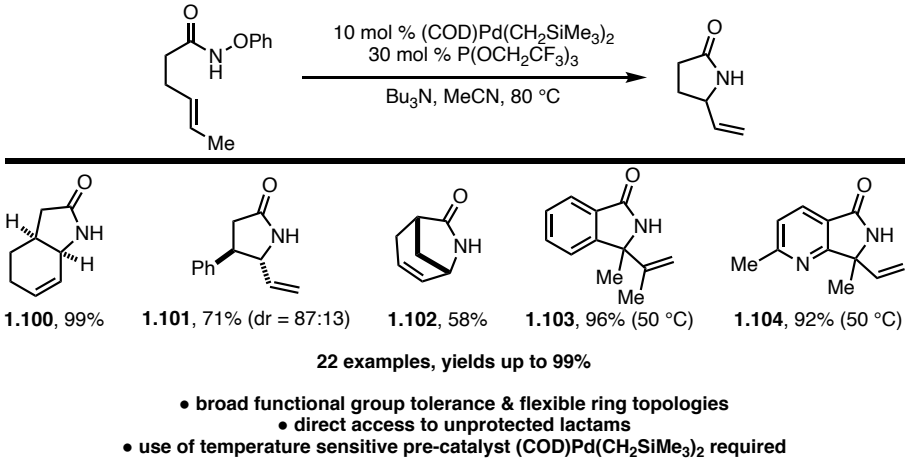


Figure 1.40: Synthesis of Unprotected Lactams via Aza-Heck Cyclizations

Preliminary mechanistic studies suggest that this reaction initiates with the activation of N–O bond to generate the oxidative addition palladium complex **1.107**,

followed by migratory insertion and *β*-hydride elimination to produce the unprotected lactam **1.100** (Figure 1.41).

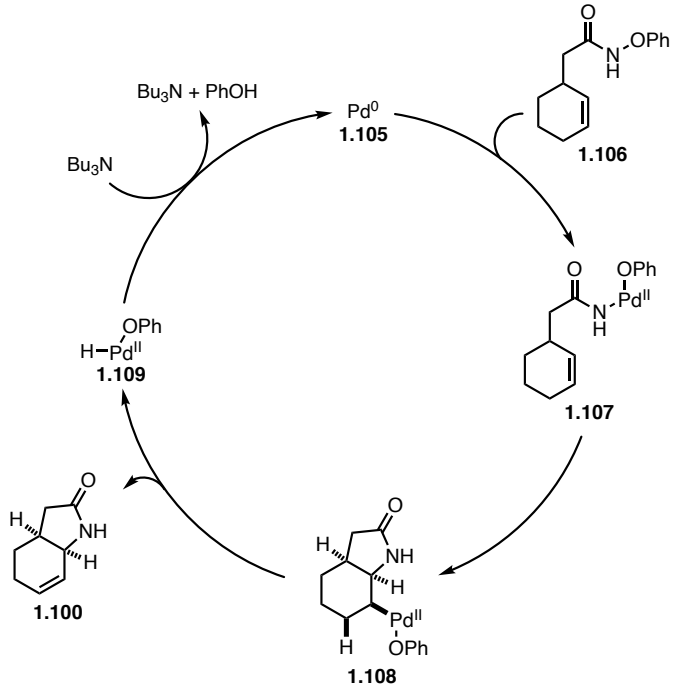


Figure 1.41: Proposed Mechanism of Lactam-Forming Aza-Heck Cyclization

1.4 Propsoed Imidazolidinone Synthesis via Aza-Heck Cyclization

Due the limited access to unprotected imidazolidinones, we wished to design a method to prepare those motifs. Considering the successful history of aza-Heck cyclizations in nitrogen-containing heterocycle synthesis, we envisioned that this strategy could also be used to synthesize imidazolidinones. In the previous work of unprotected lactam synthesis, our group has shown that the N–O bonds of *O*-phenyl hydroxamic ethers can be activated by palladium catalysis.[61] Encouraged by this success, we hypothesized that the *N*-phenoxy urea substrates can serve as electrophiles

in aza-Heck cyclization to prepare imidazolidinones as their N–O bonds could be activated by palladium catalysis (Figure 1.42). Such a method would allow the direct preparation of imidazolidinones bearing free N–H groups, which is difficult to access using the existing imidazolidinone-forming methods.

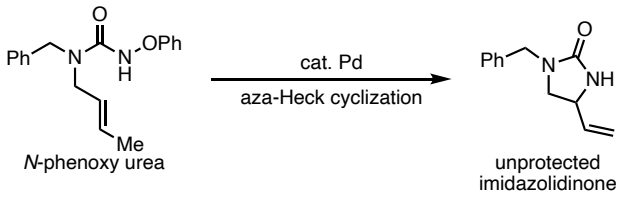


Figure 1.42: Potential Imidazolidinone Synthesis via Aza-Heck Cyclization

To investigate this idea, a general method to synthesize the starting materials, *N*-phenoxy ureas, is required. The initial attempt used the classic coupling reagent carbonyldiimidazole (CDI) to couple *N*-phenoxy amine **1.110** with an allylic amine. Unfortunately, this reaction resulted low yield for the formation of desired product **1.111** due to the competing homo-coupling, which provided the symmetric urea **1.112** as the major by-product (Figure 1.43).

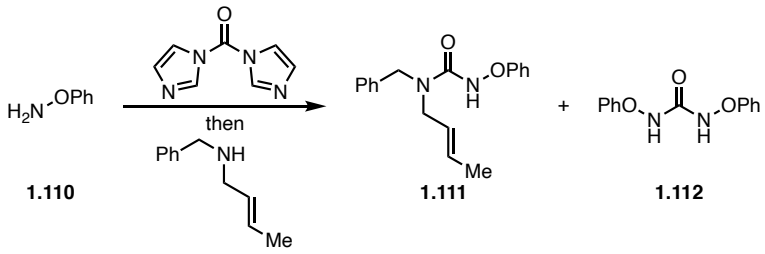


Figure 1.43: Attempt to Prepare *N*-Phenoxy Ureas via CDI Coupling

Previously, the Beauchemin group was able to generate *O*-isocyanates **1.114** from *N*-oxy carbamates **1.113** under thermal conditions, then trap with amine nucleophiles in situ to produce asymmetric *N*-oxy ureas **1.115** (Figure 1.44).[62] Such a transformation allows rapid access to *N*-oxy urea substrates from simple starting materials. However, one drawback of this reaction condition is its elevated temperature (120 °C), especially in the case that MeCN is used as reaction solvent.

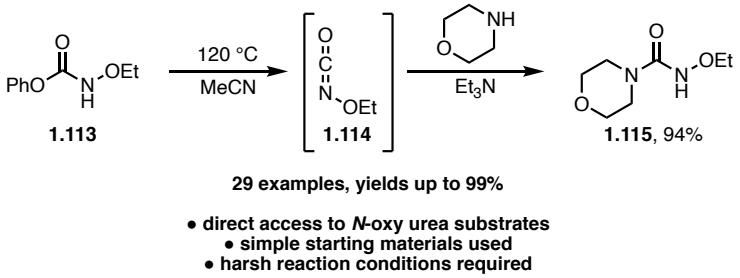


Figure 1.44: Beauchemin's Method to Prepare Asymmetric *N*-Oxy Ureas

Inspired by this work, we envisioned the synthesis of *N*-phenoxy ureas through a similar intermediate, *O*-phenyl isocyanate **1.117**. Using the *N*-phenoxy carbamate reagent **1.116**, however, we did not observe any conversion at ambient temperature (Figure 1.45), and the attempt to increase the reaction temperature leads to the decomposition of **1.116**.

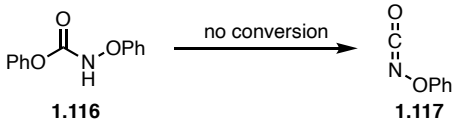


Figure 1.45: Initial Attempt to Generate *O*-phenyl Isocyanate Intermediate **1.117**

To increase the reactivity of the coupling reagent, we decided to replace the phenoxy with a better leaving group by putting nitro group at the *para* position (**1.118**), which would lead to an easier formation of *O*-phenyl isocyanate **1.117**. Gratefully, using this newly designed coupling reagent **1.118**, the *N*-phenoxy urea **1.119** could be easily prepared in a single step with good efficiency (Figure 1.46).

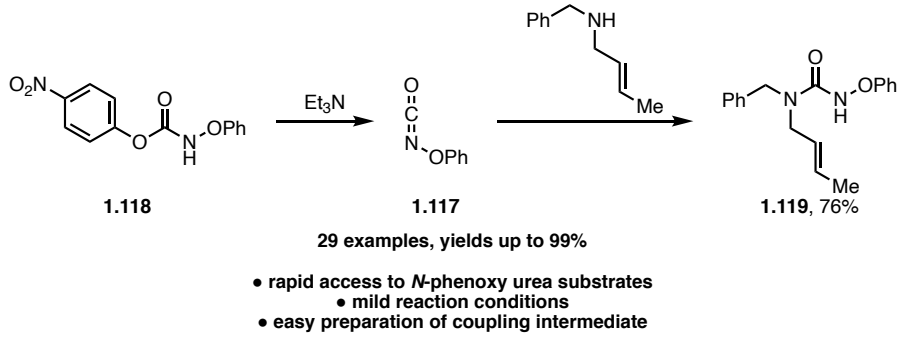
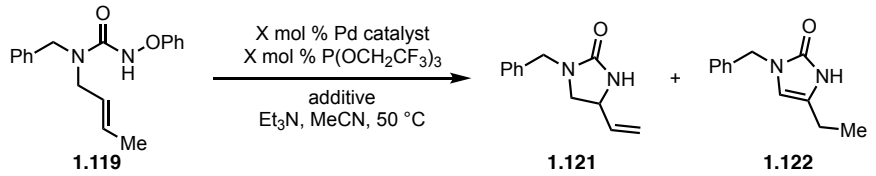


Figure 1.46: Our Design of **1.118** to Prepare *N*-Phenoxy Ureas

1.5 Optimization of Reaction Condition

With the starting material **1.119** on hands, we began our investigation with the previously published reaction condition for the lactam synthesis. Using the easily reduced palladium pre-catalyst (COD)Pd(CH_2SiMe_3)$_2$ (**1.120**) and electron-poor phosphite ligand P(OCH_2CF_3)$_3$, I was able to observe 79% cyclization of **1.119** (Table 1.1, entry 1).

Table 1.1: Optimization of Imidazolidinone-Forming Aza-Heck Cyclization



1.119 **1.121** **1.122**

entry	Pd Catalyst [mol %]	Additive [mol %]	Yield of **1.121** [%]	Yield of **1.122** [%]
1	$(COD)Pd(CH_2SiMe_3)_2$ [10]	none	79	4
2	$(MeCN)_2PdCl_2$ [5]	none	0	6
3	$(MeCN)_2PdCl_2$ [5]	Mg^0 [300]	9	18
4	$(MeCN)_2PdCl_2$ [5]	PhMgBr [10]	29	31
5	$[(cinnamyl)PdCl]_2$ [2.5]	PhMgBr [5]	62	24
6	$[(cinnamyl)PdCl]_2$ [2.5]	PhMgBr [5] AgOTs [10]	86	6

Despite the encouraging result using **1.120**, we continued to explore other options as we recognized that use of a more accessible palladium source for this chemistry instead would expand the utility of the reaction. With the addition of external ligands, **1.120** can undergo reductive elimination to generate active Pd^0 catalyst, and so is a very reliable Pd^0 source (Figure 1.47).[63] Despite its merits, however, **1.120** is expensive and not highly accessible. Moreover, this pre-catalyst is known to be unstable, which slowly decomposes at room temperature.[64] Thus, it will make this method more practical and reduce the cost if it allows the use of more accessible catalytic components.

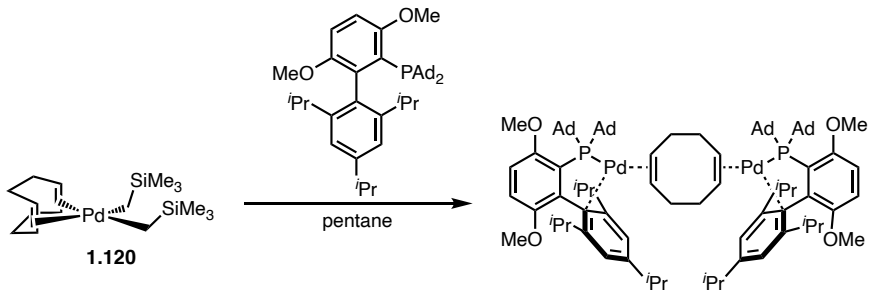


Figure 1.47: Example of Pd^0 Catalyst Generation from $(COD)Pd(CH_2SiMe_3)_2$

Switching to commercially available and bench stable $(MeCN)_2PdCl_2$, no desired imidazolidinone product **1.121** was observed (Table 1.1, entry 2). This result is consistent with the Heck mechanism requires a Pd^0 catalyst. Under the current reaction condition, however, it is challenging to reduce the Pd^{II} pre-catalyst to Pd^0 due to the lack of reducing agent. To generate the active catalyst, therefore, we hypothesized that the addition of external reductant is necessary. Gratifyingly, a small amount of the desired product was observed with the use of magnesium (Table 1.2, entry 3). Switching to a homogenous reductant, such as PhMgBr, the cyclization of **1.119** is more efficient, providing the imidazolidinone **1.121** in 29% yield (Table 1.1, entry 4). With further optimization, $[(cinnamyl)PdCl]_2$ was identified as the optimal palladium source, which improved the cyclization yield to 62%. I also identified the dihydroimidazonone **1.122** as the major by-product, which was presumably formed via alkene isomerization of the imidazolidinone product **1.121** by palladium hydride species **1.123** (Figure 1.48).

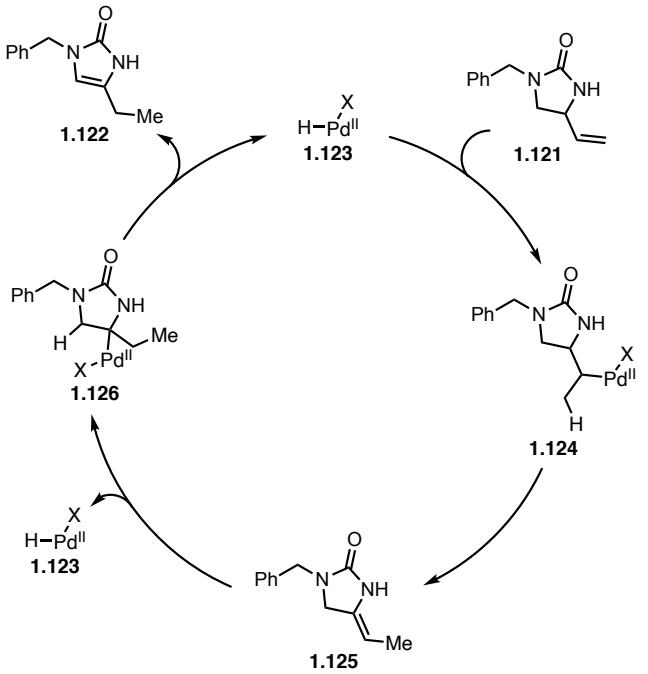


Figure 1.48: Working Hypothesis for the Formation of **1.122**

Prior to this work, the isomerization of product is already a known side reaction in Heck cyclizations. The earliest example was reported by the Overman group in 1987.[65] The attempt to prepare spirocycle **1.128** using the Heck cyclization gave the alkene isomer **1.129** as the major by-product (Figure 1.49). The solution found by Overman and co-workers is the addition of silver salt. With $AgNO_3$ as additive, only little isomerized product **1.129** was observed. The role of silver additive is suggested to be quenching the halides in the reaction and limiting the lifetime of palladium hydride species, which are responsible for the isomerization.

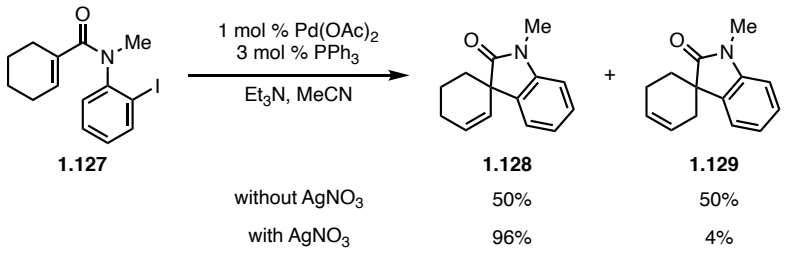


Figure 1.49: Overman's Isomerization Study in Heck Cyclization

In our case, the addition of a soluble silver salt, such as AgOTs, was able to minimize the amount of isomeric product **1.122** and increase the yield of imidazolidinone **1.121** to 86% (entry 6). Comparing to the reaction condition using **1.120** as pre-catalyst, this condition only requires the use of commercially available and bench stable catalytic components.

1.6 Scope of Imidazolidinone-Forming Aza-Heck Cyclization

1.6.1 Examination of Functional Group Tolerance

Using the newly discovered reaction condition, many imidazolidinones bearing a number of functional groups were prepared (Figure 1.50). The model substrate was cyclized to provide **1.121** in 84% isolated yield. Using this cyclization, imidazolidinones bearing different functional groups were synthesized with similar efficiencies, including ethers (**1.130**-**1.131**), trifluoromethyl (**1.132**), ester (**1.133**), and halogens (**1.134**-**1.135**). For the substrates bearing more substituted alkenes, the isomerization is no longer a problem and the use of silver additive is not necessary. For example, the *N*-phenoxy urea bearing tri-substituted alkene can cyclize to provide imidazolidinone **1.136** in 92% yield without the addition of AgOTs. More interestingly, imidazolidinones bearing fully-substituted carbon centers can also be synthesized using

this method (**1.137**), which are known to be difficult to prepare. Even tetra-substituted alkene can participate in this reaction to provide imidazolidinone **1.138** in 62% isolated yield. Simple aliphatic substitution on nitrogen (**1.139**) and heterocycles, such as indole (**1.140**) and thiophene (**1.141**), are well-tolerated under this reaction condition. Finally, allylic ether can also cyclize with the urea electrophile to offer imidazolidinone bearing vinyl ether (**1.142**). One limitation of this method is that the substrate with bulky substitution on the non-reacting nitrogen does not allow any cyclization product to be produced, likely due to steric effects (**1.143**).

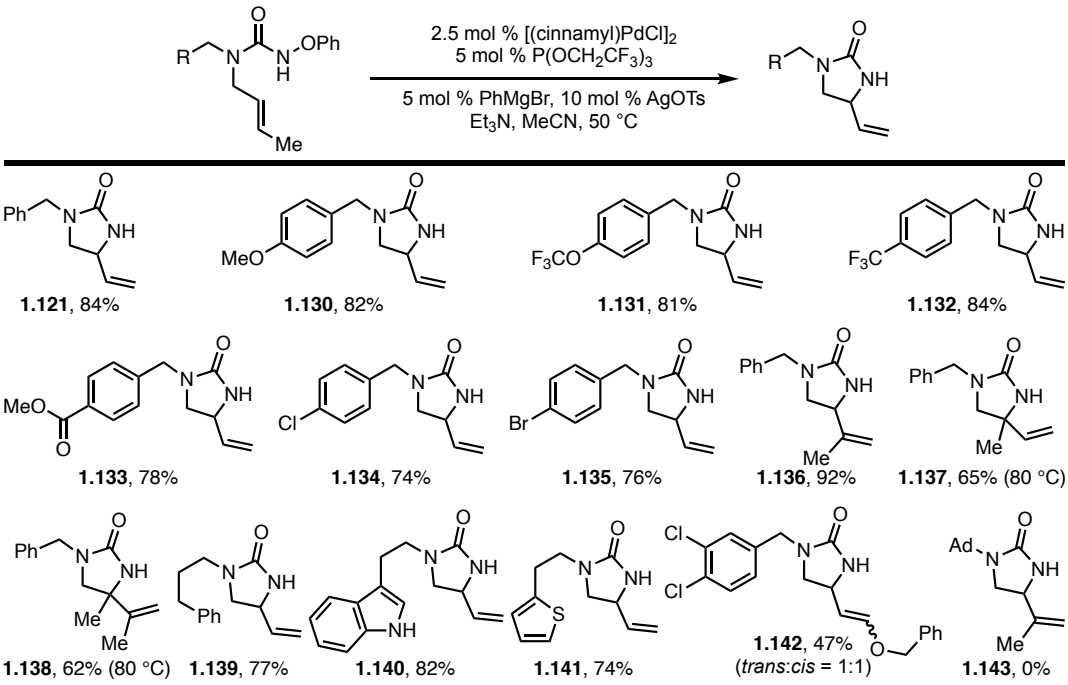


Figure 1.50: Examination of Functional Group Tolerance

1.6.2 Examination of Diastereoselectivity

Chiral substitution on the non-reacting nitrogen (**1.144**) did not provide any stereo-control to the cyclization (Figure 1.51). Substitutions at the α position, however, offered good diastereoselectivies in the reaction (**1.145**-**1.147**). Interestingly, in contrast to the lactam substrates synthesized using the aza-Heck cyclization, the *cis*-imidazolidinones are the preferable diastereomers.

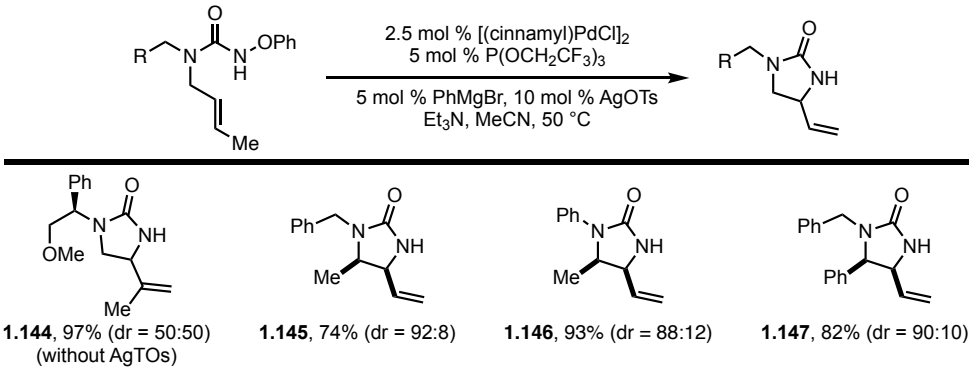


Figure 1.51: Diastereo-Control of the Imidazolidinone-Forming Aza-Heck Cyclization

1.6.3 Synthesis of Bicyclic Imidazolidinones

Imidazolidinones containing more complicated ring systems can also be made using this method. For example, the fused bicyclic imidazolidinone bearing a Lewis basic heterocycle **1.148** can be prepared in quantitative yield (Figure 1.52). However, a significant amount of alkene isomerization was observed with this substrate. We hypothesized that this unexpected result was due to the ligation of pyridine to palladium hydride species, which caused the alkene isomerization. The isolation of a closely related imidazolidinone **1.149** as single isomer supported this idea. It is noteworthy that both **1.148** and **1.149** were produced as single diastereomers.

Spirocyclic imidazolidinone **1.150** could also be prepared using this method, but a significant amount of product was isomerized under this reaction condition. Switching back to the dialkyl palladium pre-catalyst **1.120**, fortunately, circumvented this problem, providing the desired product in 79% isolated yield as singe alkene isomer.

Natural product derived *N*-phenoxy ureas can also cyclize to provide the imidazolidinones in great yields. The bicyclic imidazolidinones **1.151** and **1.152** were synthesized from proline and carvone respectively, showing the capability of this method for late-stage functionalization of complex molecules.

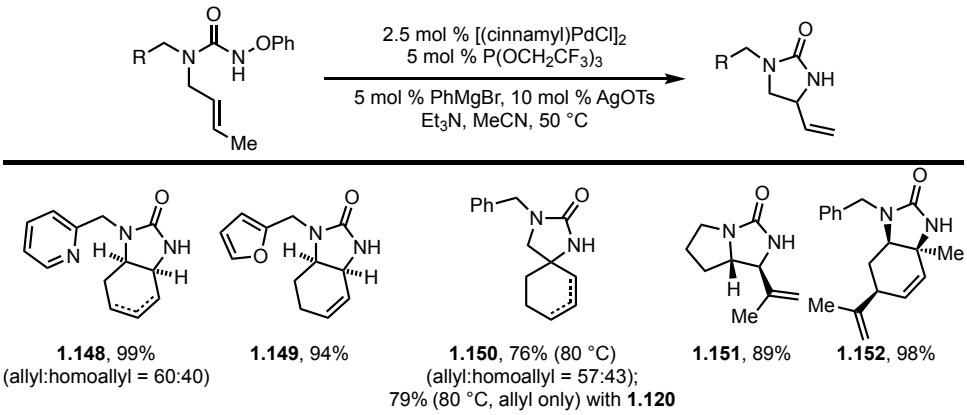


Figure 1.52: Synthesis of Bicyclic Imidazolidinones

1.6.4 Synthesis of Bis-Unprotected Imidazolidinones

Previously, none of the existing methods using metal catalysis allowed for the synthesis of imidazolidinones bearing two N–H groups. Using this reaction, however, doubly unprotected imidazolidinones can be prepared (Figure 1.53). For example, the simple linear bis-unprotected imidazolidinone **1.153** and highly-substituted product **1.154** were isolated in good yields. The *N*-phenoxy urea bearing non-equivalent *β*-

hydrides can also cyclize to provide imidazolidinone **1.155** as a mixture of alkene isomers. Imidazolidinones bearing more complex ring systems, such as the bis-unprotected bicyclic imidazolidinone **1.156**, can also be synthesized via this cyclization method. Unfortunately, the attempt to prepare spirocyclic imidazolidinone **1.157** bearing two N–H groups resulted in a mixture of alkene isomers. Although using **1.120** for this substrate did not provide any cyclization yield, the use of protecting strategy can solve this problem, providing the desired spirocyclic product **1.158** in 71% yield.

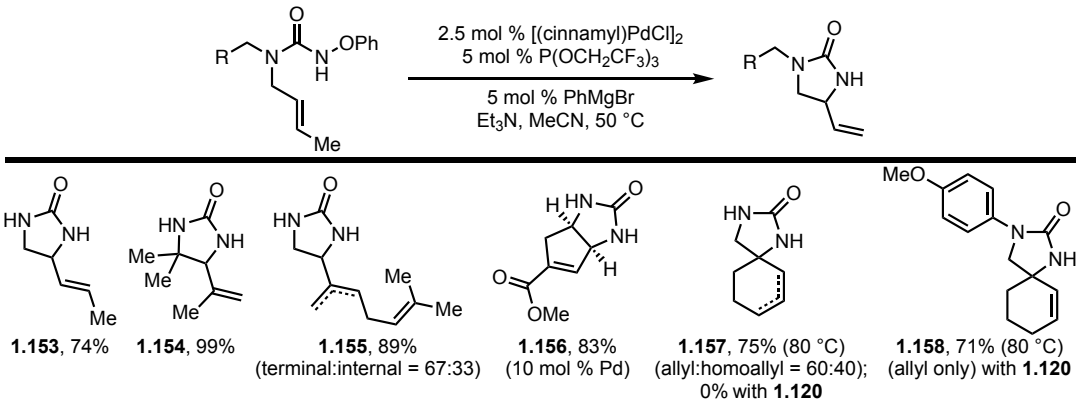


Figure 1.53: Synthesis of Doubly Unprotected Imidazolidinones

1.6.5 6-*exo* Cyclization

Similar to other aza-Heck cyclizations, the formation of 6-membered ring is less efficient. With higher catalyst loading, only 27% cyclization of **1.159** was observed (Figure 1.54). Future effort of this project is directed to improve the cyclization efficiency for larger ring formation.

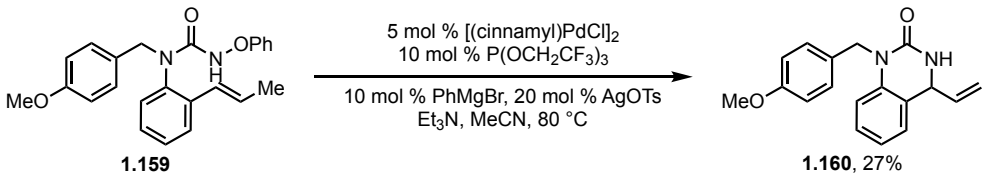


Figure 1.54: Attempt of Larger Ring Formation

1.7 Rapid Access to Multi-Cyclic Heterocycles via Aza-Heck Cyclizations

Previously, our group demonstrated the synthesis of unprotected spirocyclic lactam **1.162** via an aza-Heck cyclization (Figure 1.55). I was able to reduce the amide to amine, and then make the *N*-phenoxy urea substrate **1.163**. The following aza-Heck cyclization provided the multi-cyclic fused imidazolidinone **1.164** in 93% yield. Using this sequence, one can quickly build up complex heterocycles from relatively simple starting material using aza-Heck cyclizations.

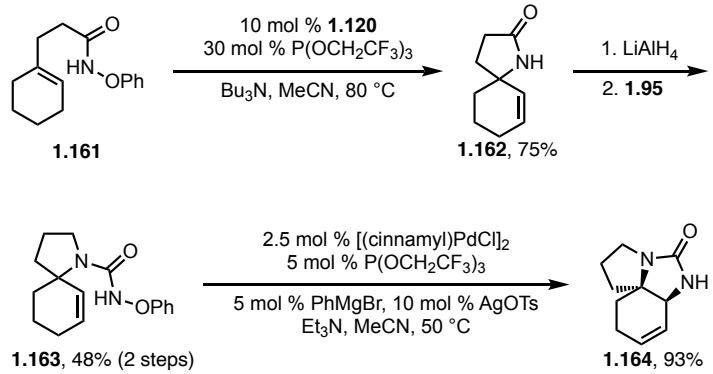


Figure 1.55: Synthesis of Multi-Cyclic Heterocycles using Aza-Heck Cyclizations

1.8 Synthesis of Dihydroimidazolones Using Halide Additive

During the reaction optimization, the dihydroimidazolone **1.122** was identified as the major by-product. The formation of this by-product was hypothesized to occur

through the isomerization of imidazolidinone **1.121** catalyzed by palladium hydride species. Thus, the amount of isomerized product is highly influenced by the concentration of palladium hydride in the reaction. Compared to halides, tosylate is a less coordinating ligand and binds less tightly to Pd^{II} complexes. Therefore, the tosylate-coordinated palladium hydride **1.166** is less stable and easier to get reduced to Pd^0 than the halide-coordinated palladium hydride **1.165** (Figure 1.56). As a result, the replacement of anionic ligand from halides to tosylate significantly reduced the lifetime of palladium hydride species in the reaction, which explains why the use of AgOTs as additive could suppress the formation of isomeric product **1.122**.

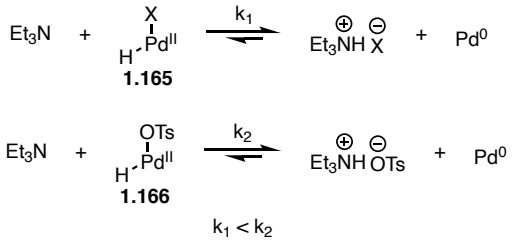


Figure 1.56: Stabilities of Palladium Hydride Species with Different Anions

Based on this theory, I was able to reverse the selectivity of this reaction by switching the additive to a homogeneous halide source, Bu_4NI, to prepare the isomeric product dihydroimidazolones (Figure 1.57). Such a transformation could be potentially useful considering the prevalence of dihydroimidazolone fragment in bioactive molecules.[66-68] Using this strategy, the isomeric product **1.122** was prepared in 80% yield. The synthesis of several related products was also demonstrated, including the highly-substituted substrate **1.168**.

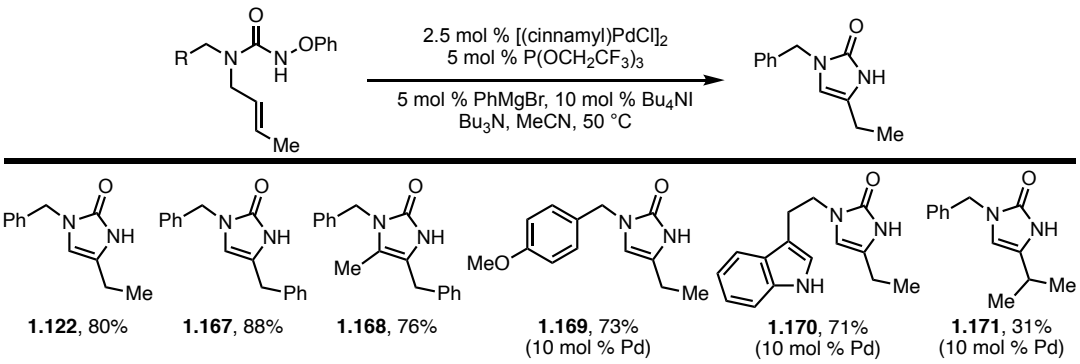


Figure 1.57: Synthesis of Dihyroimidazolones with the Use of Halide Additive

1.9 Demonstration of Factor Xa Inhibitor Synthesis

The imidazolidinone-containing factor Xa inhibitor mentioned previously (Figure 1.1) was firstly discovered by the DuPont Pharmaceutical Company.[10] This compound has shown potentials to serve as a treatment for deep vein thrombosis and acute pulmonary embolism. The previous synthesis of this compound involves the use of expensive 3-cyanophenyl isocyanate as starting material, and the overall yield is 4% over four steps. To improve this synthesis, we were able to use the imidazolidinone-forming aza-Heck cyclization. We prepared the *N*-phenoxy urea **1.172**, and then did the aza-Heck cyclization to make the N–H bearing imidazolidinone **1.173** in gram scale (Figure 1.58). Direct functionalization at the unprotected nitrogen yielded the target precursor **1.175** in 72% yield, which could be further converted into the factor Xa inhibitor using a known procedure.[10]

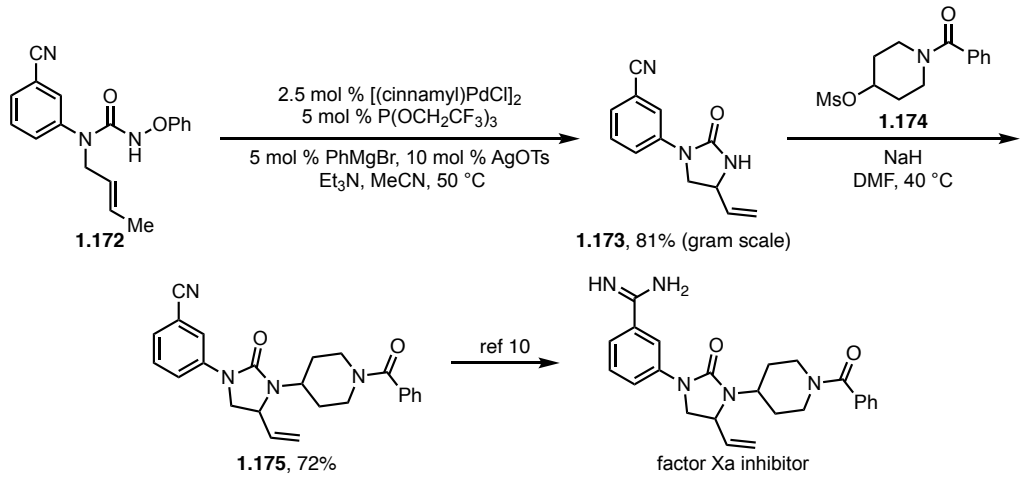
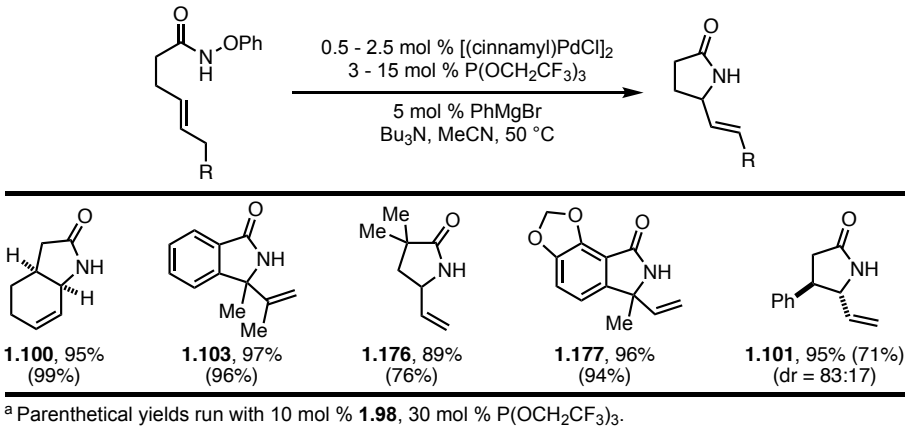


Figure 1.58: Formal Synthesis of Factor Xa Inhibitor

1.10 Lactam Synthesis Using the Improved Reaction Condition

Using this improved reaction condition, I was also able to make unprotected lactams (Figure 1.59). Comparing to the previously published reaction condition, the yields using this condition are either comparable or higher with less catalyst loading. Moreover, the newly discovered reaction condition only requires commercially available catalytic components and avoids the use of unstable pre-catalyst **1.120**.



[a] Parenthetical yields run with 10 mol % **1.98**, 30 mol % $P(OCH_2CF_3)_3$.

Figure 1.59: Synthesis of Unprotected Lactam Using the Improved Condition

1.11 Conclusion

In summary, we developed an aza-Heck cyclization that allows the preparation of unprotected imidazolidinones from *N*-phenoxy ureas, which can be easily prepared in a single step from the corresponding allylic amines.[69] This method shows broad functional group tolerance and is compatible with complex ring systems. Challenging imidazolidinones, such as the ones bearing two N–H groups, can also be prepared. In this method, commercially available and bench stable catalytic components can be used. Moreover, this improved reaction condition can be used for lactam synthesis. By the use of halide additive, isomeric dihydroimidazolones can be selectively synthesized. Additionally, the synthesis of a factor Xa inhibitor using this method is also demonstrated.

1.12 Experimental Details

1.12.1 General Experimental Details

THF, CH_2Cl_2, MeOH, MeCN, Et_3N, toluene, and DMF were dried on alumina according to a published procedure.[70] Tributylamine was distilled from calcium hydride, sparged with N_2, and stored under N_2 in a sealed vessel. $P(OCH_2CF_3)_3$ was purchased from Sigma-Aldrich, distilled from CaH_2, sparged with N_2, and stored under N_2 in a sealed vessel. (COD)Pd(CH_2SiMe_3)$_2$ (**1.120**) was prepared according to literature procedure, and stored in a sealed container of DrieRite at –20 °C when not in use.[71] All hot glassware was oven-dried for a minimum of 2 h or flame-dried under vacuum prior to use. The following substrates were synthesized according to published procedures: [*N*-benzyl-2,2,2-trifluoroacetamide,[72] *trans*-4-benzyloxy-2-butenal,[73] (*R*)-2-methoxy-1-phenylethylamine,[72] 2-bromo-*N*-(4-methoxybenzyl)aniline,[74] 7-methylene-1-azaspiro[4.4]nonan-2-one (**1.162**),[61] *O*-phenyl hydroxylamine hydrochloride,[61] *N*-

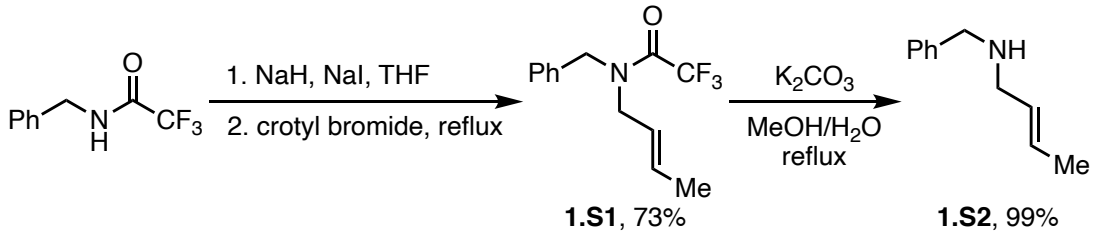
benzyl-2,3-dimethylbut-2-en-1-amine,[75] *trans*-*N*-benzyl-*N*-(1-methylbut-2-enyl)amine,[76] *trans*-*N*-(pent-3-en-2-yl)aniline,[77] 2-amino-2,4-dimethyl-3-pentene,[78] (–)-methyl (1*S*,4*R*)-4-amino-cyclopent-2-ene-1-carboxylate hydrochloride,[79] (4-methoxyphenyl)cyclohex-1-enylmethylamine,[80] (4-hydroxypiperidin-1-yl)(phenyl)methanone,[81] 2-(cyclohex-2-en-1-yl)-*N*-phenoxyacetamide (**1.106**),[61] 2-(3-methylbut-2-en-2-yl)-*N*-phenoxybenzamide,[61] 4-*trans*-2,2-dimethyl-*N*-phenoxyhex-4-enamide,[61] 5-(2-but-2-en-2-yl)-*N*-phenoxy-2H-1,3-benzodioxole-4-carboxamide,[61] 4-*trans*-*N*-phenoxy-3-phenylhex-4-enamide[61]]. All other substrates and reagents were purchased in highest analytical purity from commercial suppliers and used as received. Reaction optimization was conducted in a glovebox (N_2 atmosphere) on a 200 μmol scale in 2-dram vials with Teflon lined caps and heated in an aluminum block with stirring. All yields determined by NMR analysis are reported using 1,3,5-trimethoxybenzene as an internal standard. All diastereoselectivities were determined by NMR analysis. All other reactions were set up using standard Schlenk technique and heated with stirring in temperature-controlled oil baths. "Double manifold" refers to a standard Schlenk-line gas manifold equipped with N_2 and vacuum (ca. 0.1 mm Hg).

1.12.2 Instrumentation and Chromatography

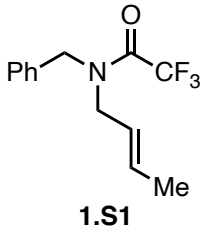
400 MHz ^{1}H, 101 MHz ^{13}C, and 376 MHz ^{19}F spectra were obtained on a 400 MHz FT-NMR spectrometer equipped with a Bruker CryoPlatform. 600 MHz ^{1}H and 151 MHz ^{13}C spectra were obtained on a 600 MHz FT-NMR spectrometer equipped with a Bruker SMART probe. All samples were analyzed in the indicated deutero-solvent and were recorded at ambient temperatures. All chemical shifts are reported in ppm. ^{1}H NMR spectra were calibrated using the residual protio-signal in deutero-solvents as a standard. ^{13}C NMR spectra were calibrated using the deutero-solvent as a

standard. IR spectra were recorded on a Nicolet Magma-IR 560 FT-IR spectrometer as thin films on KBr plates. High resolution MS data was obtained on a Thermo Q-Exactive Orbitrap using electrospray ionization (ESI) or a Micromass GCT Premier using liquid injection field desorption ionization (LIFDI). Unless otherwise noted, column chromatography was performed either by hand or by use of Isolera 4 Biotage unit with 40-63 μm silica gel, and the eluent reported in parentheses. Analytical thin-layer chromatography (TLC) was performed on precoated glass plates and visualized by UV or by staining ($KMnO_4$ or I_2).

1.12.3 Preparation of Allylic Amines



1.S1, 73% **1.S2**, 99%

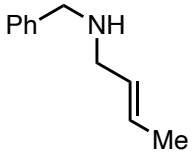


1.S1

(**1.S1**) This reaction was modified from a literature procedure.[75] A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. NaH (60% in mineral oil) (2.01 g, 45.0 mmol, 1.50 equiv) and NaI (0.51 g, 3.0 mmol, 0.10 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous THF (40 mL) was then added via syringe under N_2. A solution of *N*-benzyl-2,2,2-trifluoroacetamide (6.06 g, 30.0 mmol, 1.00 equiv) in anhydrous THF (40 mL) was added dropwisely to the suspension via syringe under N_2. Upon completion of addition, the mixture was allowed to stir for 1 h. Then crotyl bromide (4.2 mL, 40 mmol,

1.3 equiv) was added dropwisely and the mixture was brought to reflux. After reflux for 16 h, the reaction was cooled to rt, quenched with brine (50 mL), and extracted with Et_2O (50 mL) for three times. The combined organic extracts were dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo to yield **1.S1** (5.62 g, 73%) as yellow oil. The crude product was used directly in the next step with no further purification.

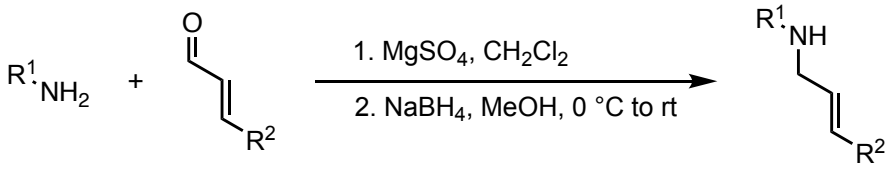
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.40 – 7.27 (m, 3H), 7.25 – 7.21 (m, 2H), 5.72 – 5.62 (m, 1H), 5.45 – 5.35 (m, 1H), 4.61 (s, 2H), 3.89 – 3.80 (m, 2H), 1.74 (dd, *J* = 6.5, 1.5 Hz, 3H).



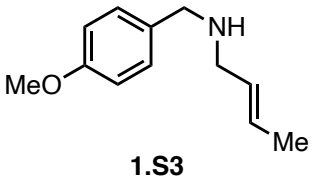
1.S2

(**1.S2**) This reaction was modified from a literature procedure.[75] In a 250 mL round-bottom flask, **1.S1** (4.25 g, 16.0 mmol, 1.00 equiv) was dissolved in a mixture of MeOH (58 mL), H_2O (7 mL), and KOH (4.47 g, 32.0 mmol, 2.00 equiv) under air. The resulting solution was refluxed for 2 h, then cooled to rt, quenched with brine, and extracted with EtOAc (50 mL) for three times. The combined organic extracts were dried over MgSO4, filtered through a glass frit, evaporated in vacuo to afford **1.S2** (2.52 g, 99%, 82:18 *trans*/*cis*) as clear colorless oil. The crude product was used directly in the next step with no further purification. The characterization data reported is for the major *trans*-alkene isomer; only characteristic ^{1}H peaks are reported for the minor *cis*-alkene isomer.

^{1}H NMR (600 MHz, $CDCl_3$) (*trans*-alkene) δ 7.36 – 7.30 (m, 4H), 7.26 – 7.23 (m, 1H), 5.70 – 5.44 (m, 2H), 3.78 (s, 2H), 3.21 (dt, *J* = 6.0, 1.2 Hz, 2H), 1.69 (dt, *J* = 6.2, 1.3 Hz, 3H); ^{1}H NMR (600 MHz, $CDCl_3$) (*cis*-alkene) δ 3.80 (s, 2H), 3.31 (dt, *J* = 6.6, 1.2 Hz, 2H), 1.64 – 1.60 (m, 3H).



General Protocol A: This reaction was modified from a literature procedure.[82] A round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Oven-dried $MgSO_4$ (2.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Unsaturated aldehyde (1.00 – 1.20 equiv) and anhydrous CH_2Cl_2 were added sequentially to the flask via syringe. Primary amine (1.00 equiv) was added dropwisely to the suspension via syringe. The mixture was stirred at rt for 1 h, then filtered through a glass frit and concentrated in vacuo. The crude material was dissolved in anhydrous MeOH and cooled to 0 °C in an ice bath under N_2. $NaBH_4$ (1.00 – 1.50 equiv) was added slowly in four portions. The reaction warmed up to rt and stirred for 16 h. The reaction was quenched with saturated aqueous $NaHCO_3$ solution and extracted with CH_2Cl_2 for three times. The combined extracts were dried over $MgSO_4$ and concentrated in vacuo to give the targeted allylic amine, which was used without further purification.

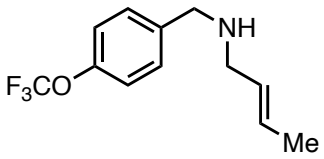


1.S3

(**1.S3**) According to general protocol A: oven-dried $MgSO_4$ (12.00 g, 100.0 mmol), *trans*-crotonaldehyde (4.5 mL, 55 mmol), and 4-methoxy-benzylamine (6.5 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.92 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine

1.S3 (9.19 g, 96%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

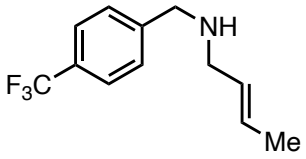
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 – 7.18 (m, 2H), 6.89 – 6.79 (m, 2H), 5.72 – 5.46 (m, 2H), 3.79 – 3.77 (m, 3H), 3.70 (d, J = 1.5 Hz, 2H), 3.22 – 3.14 (m, 2H), 1.71 – 1.66 (m, 3H).



1.S4

(**1.S4**) According to general protocol A: oven-dried $MgSO_4$ (12.04 g, 100.0 mmol), *trans*-crotonaldehyde (4.9 mL, 55 mmol), and 4-(trifluoromethoxy)benzylamine (7.6 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.96 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S4** (11.75 g, 96%) as dark yellow oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 – 7.32 (m, 2H), 7.18 – 7.15 (m, 2H), 5.65 – 5.58 (m, 1H), 5.58 – 5.51 (m, 1H), 3.77 (s, 2H), 3.20 (dt, *J* = 6.0, 1.3 Hz, 2H), 1.69 (dq, *J* = 6.2, 1.3 Hz, 3H).

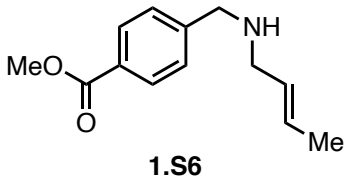


1.S5

(**1.S5**) According to general protocol A: oven-dried $MgSO_4$ (12.10 g, 100.0 mmol), *trans*-crotonaldehyde (4.5 mL, 55 mmol), and 4-trifluoromethylbenzylamine (7.1 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in

anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.95 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S5** (11.19 g, 98%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

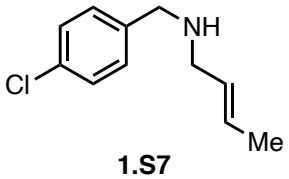
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.59 (d, *J* = 8.1 Hz, 2H), 7.46 (d, *J* = 8.0 Hz, 2H), 5.68 – 5.61 (m, 1H), 5.61 – 5.55 (m, 1H), 3.85 (s, 2H), 3.22 (dt, *J* = 6.0, 1.4 Hz, 2H), 1.72 (dd, *J* = 6.2, 1.4 Hz, 3H).



1.S6

(**1.S6**) Methyl 4-(aminomethyl)benzoate hydrochloride (5.00 g, 25.0 mmol) was dissolved in wet EtOAc (50 mL), washed with 1 M NaOH (50 mL), brine (50 mL), dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give a yellow oil. According to general protocol A: oven-dried $MgSO_4$ (6.02 g, 50.0 mmol), *trans*-crotonaldehyde (2.2 mL, 28 mmol), and the resulting yellow oil were combined in anhydrous CH_2Cl_2 (25 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (25 mL), cooled to 0 °C, and then added $NaBH_4$ (1.50 g, 37.5 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S6** (3.12 g, 59%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

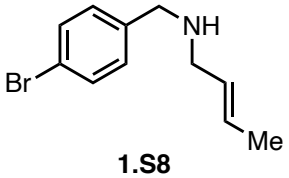
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 8.2, 1.3 Hz, 2H), 7.33 (d, *J* = 7.9 Hz, 2H), 5.71 – 5.40 (m, 2H), 4.56 (bs, 1H), 3.84 (s, 3H), 3.75 (s, 2H), 3.13 (dq, *J* = 4.1, 2.0 Hz, 2H), 1.64 (d, *J* = 5.1 Hz, 3H).



1.S7

(**1.S7**) According to general protocol A: oven-dried $MgSO_4$ (4.00 g, 30.0 mmol), *trans*-crotonaldehyde (1.5 mL, 18 mmol), and 4-chlorobenzylamine (1.8 mL, 15 mmol) were combined in anhydrous CH_2Cl_2 (15 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (15 mL), cooled to 0 °C, and then added $NaBH_4$ (1.00 g, 22.5 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S7** (2.69 g, 92%) as dark yellow oil. The crude product was used directly in the next step with no further purification.

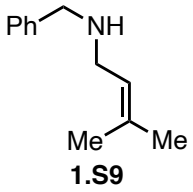
^{1}H NMR (400 MHz, CD_3CN) δ 7.40 – 7.14 (m, 4H), 5.63 – 5.55 (m, 1H), 5.55 – 5.48 (m, 1H), 3.68 (s, 2H), 3.10 (dp, J = 5.9, 1.2 Hz, 2H), 1.66 (dq, J = 6.2, 1.3 Hz, 3H).



1.S8

(**1.S8**) According to general protocol A: oven-dried $MgSO_4$ (12.00 g, 100.0 mmol), *trans*-crotonaldehyde (4.5 mL, 55 mmol), and 4-bromobenzylamine (6.1 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.96 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S8** (10.97 g, 91%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

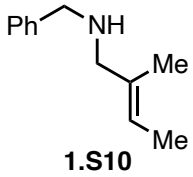
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.41 – 7.38 (m, 2H), 7.16 (d, J = 8.2 Hz, 2H), 5.61 – 5.55 (m, 1H), 5.55 – 5.48 (m, 1H), 3.68 (s, 2H), 3.15 (dt, J = 6.0, 1.4 Hz, 2H), 1.67 (dd, J = 6.1, 1.4 Hz, 3H).



1.S9

(**1.S9**) According to general protocol A: oven-dried $MgSO_4$ (12.04 g, 100.0 mmol), 3-methyl-2-butenal (5.2 mL, 55 mmol), and benzylamine (5.5 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.92 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S9** (8.03 g, 92%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

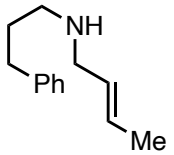
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 4H), 7.26 – 7.22 (m, 1H), 5.32 – 5.27 (m, 1H), 3.79 (s, 2H), 3.23 (d, J = 6.9 Hz, 2H), 1.73 (s, 3H), 1.62 (s, 3H).



1.S10

(**1.S10**) According to general protocol A: oven-dried $MgSO_4$ (12.00 g, 100.0 mmol), tiglic aldehyde (5.4 mL, 55 mmol), and benzylamine (5.5 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.91 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S10** (8.05 g, 95%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

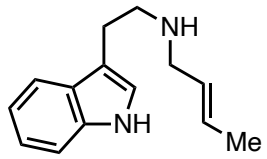
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 – 7.29 (m, 4H), 7.26 – 7.22 (m, 1H), 5.41 (qq, J = 6.7, 1.4 Hz, 1H), 3.73 (s, 2H), 3.16 (s, 2H), 1.66 (s, 3H), 1.62 (dq, J = 6.7, 1.1 Hz, 3H).



S11

(**1.S11**) According to general protocol A: oven-dried $MgSO_4$ (4.91 g, 40.0 mmol), *trans*-crotonaldehyde (1.9 mL, 23 mmol), and 3-phenylpropan-1-amine (2.5 mL, 20 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (20 mL), cooled to 0 °C, and then added $NaBH_4$ (1.12 g, 30.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S11** (2.81 g, 74%) as dark yellow oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 – 7.26 (m, 2H), 7.22 – 7.14 (m, 3H), 5.64 – 5.50 (m, 2H), 3.16 (d, *J* = 5.4 Hz, 2H), 2.72 – 2.60 (m, 4H), 1.86 – 1.77 (m, 2H), 1.71 – 1.65 (m, 3H).

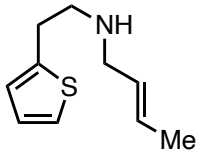


1.S12

(**1.S12**) According to general protocol A: oven-dried $MgSO_4$ (12.04 g, 100.0 mmol), *trans*-crotonaldehyde (4.6 mL, 55 mmol), and 3-aminomethylindole (8.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.84 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S12** (3.00 g, 28%) as red oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, DMSO-d_6) δ 10.75 (s, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.32 (d, *J* = 8.1 Hz, 1H), 7.11 (d, *J* = 2.3 Hz, 1H), 7.05 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 1H), 6.96 (td, *J* =

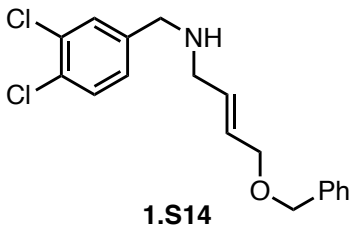
7.3, 6.8, 1.1 Hz, 1H), 5.56 – 5.40 (m, 2H), 3.11 (dt, *J* = 5.9, 1.3 Hz, 2H), 2.84 – 2.73 (m, 4H), 1.62 (dd, *J* = 6.1, 1.3 Hz, 3H).



1.S13

(**1.S13**) According to general protocol A: oven-dried $MgSO_4$ (7.60 g, 62.9 mmol), *trans*-crotonaldehyde (2.9 mL, 35 mmol), and 2-thiopheneethylamine (3.7 mL, 31 mmol) were combined in anhydrous CH_2Cl_2 (32 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (32 mL), cooled to 0 °C, and then added $NaBH_4$ (1.19 g, 31.4 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S13** (5.55 g, 97%) as orange oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (400 MHz, CD_2Cl_2) δ 7.13 (dd, *J* = 5.2, 1.2 Hz, 1H), 6.92 (dd, *J* = 5.1, 3.4 Hz, 1H), 6.85 – 6.81 (m, 1H), 5.64 – 5.44 (m, 2H), 3.16 (dt, *J* = 6.0, 1.2 Hz, 2H), 2.97 (t, *J* = 6.9 Hz, 2H), 2.88 – 2.81 (m, 2H), 1.69 – 1.64 (m, 3H).

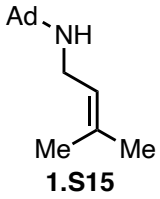


1.S14

(**1.S14**) According to general protocol A: oven-dried $MgSO_4$ (1.46 g, 12.0 mmol), *trans*-4-benzyloxy-2-butenal (1.06 g, 6.00 mmol), and 3,4-dichlorobenzylamine (0.8 mL, 6 mmol) were combined in anhydrous CH_2Cl_2 (12 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (12 mL), cooled to 0 °C, and then added $NaBH_4$ (0.37 g, 9.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S14** (1.92

g, 99%) as dark yellow oil. The crude product was used directly in the next step with no further purification.

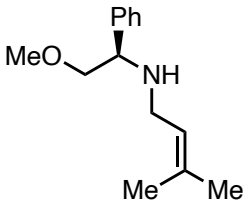
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.27 (m, 8H), 5.90 – 5.71 (m, 2H), 4.52 (s, 2H), 4.02 (d, *J* = 5.0 Hz, 2H), 3.75 (s, 2H), 3.26 (d, *J* = 5.1 Hz, 2H).



1.S15

(**1.S15**) According to general protocol A: oven-dried $MgSO_4$ (12.32 g, 100.0 mmol), 3-methyl-2-butenal (5.3 mL, 55 mmol), and 1-adamantylamine (7.55 g, 50.0 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (2.91 g, 75.0 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S15** (7.70 g, 70%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.27 (ddt, *J* = 6.9, 5.4, 1.5 Hz, 1H), 3.19 (d, *J* = 7.0 Hz, 2H), 2.13 – 2.04 (m, 3H), 1.72 (d, *J* = 1.3 Hz, 3H), 1.69 – 1.62 (m, 15H).

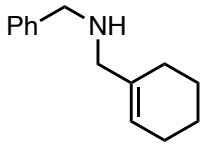


1.S16

(**1.S16**) According to general protocol A: oven-dried $MgSO_4$ (2.01 g, 16.0 mmol), 3-methyl-2-butenal (0.85 g, 8.0 mmol), and (*R*)-2-methoxy-1-phenylethylamine (1.2 mL, 8.0 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (20 mL), cooled to 0 °C, and then added $NaBH_4$ (0.49 g, 12 mmol). The reaction was worked up according to the general procedure to afford

allylic amine **1.S16** (1.69 g, 97%) as dark yellow oil. The crude product was used directly in the next step with no further purification.

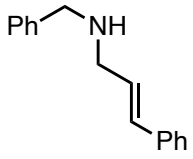
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.41 – 7.37 (m, 2H), 7.36 – 7.31 (m, 2H), 7.28 (dd, *J* = 7.6, 1.6 Hz, 1H), 5.29 – 5.24 (m, 1H), 3.93 (dd, *J* = 8.9, 4.2 Hz, 1H), 3.56 – 3.41 (m, 2H), 3.36 (s, 3H), 3.13 – 3.01 (m, 2H), 1.70 (s, 3H), 1.50 (s, 3H).



1.S17

(**1.S17**) According to general protocol A: oven-dried $MgSO_4$ (3.56 g, 30.0 mmol), cyclohexene-1-carboxaldehyde (2.01 g, 18.0 mmol), and benzylamine (1.6 mL, 15 mmol) were combined in anhydrous CH_2Cl_2 (15 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (15 mL), cooled to 0 °C, and then added $NaBH_4$ (0.99 g, 23 mmol). The reaction was worked up according to the general procedure to afford allylic amine **1.S17** (3.00 g, 99%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 – 7.28 (m, 4H), 7.26 – 7.21 (m, 1H), 5.59 – 5.50 (m, 1H), 3.75 (s, 2H), 3.14 (s, 2H), 2.07 – 1.95 (m, 4H), 1.68 – 1.61 (m, 2H), 1.61 – 1.55 (m, 2H).

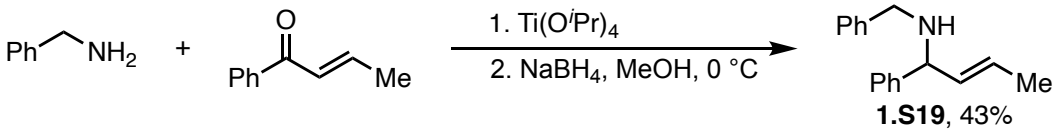


1.S18

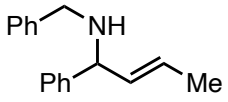
(**1.S18**) According to general protocol A: oven-dried $MgSO_4$ (12.52 g, 100.0 mmol), cinnamaldehyde (6.9 mL, 55 mmol), and benzylamine (5.4 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (50 mL). The mixture was worked up according to the general procedure. The crude material was dissolved in anhydrous MeOH (50 mL), cooled to 0 °C, and then added $NaBH_4$ (3.00 g, 75.0 mmol). The reaction was worked up according to

the general procedure to afford allylic amine **1.S18** (11.13 g, 99%) as clear yellow oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.59 – 7.52 (m, 2H), 7.42 – 7.36 (m, 4H), 7.36 – 7.31 (m, 1H), 7.31 – 7.27 (m, 2H), 7.27 – 7.22 (m, 1H), 6.61 (d, J = 15.8 Hz, 1H), 6.38 (dt, J = 15.8, 7.2 Hz, 1H), 4.03 (t, J = 5.4 Hz, 2H), 3.53 (q, J = 5.7 Hz, 2H).



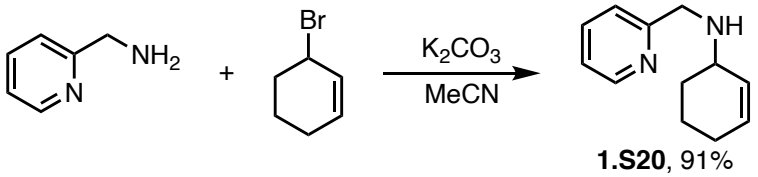
1.S19, 43%



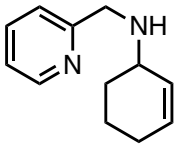
1.S19

(**1.S19**) This reaction was modified from a literature procedure.[83] A 100 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2. 1-phenyl-2-buten-1-one (1.4 mL, 10 mmol, 1.0 equiv), $Ti(O^iPr)_4$ (5 mL), and benzylamine (1.1 mL, 10 mmol, 1.0 equiv) were added to the flask via syringe under N_2. The reaction was stirred for 3 h, and then diluted with anhydrous MeOH (45 mL). The resulting solution was then cooled to 0 °C in an ice bath. $NaBH_4$ (0.59 g, 15 mmol, 1.5 equiv) was added slowly via removal and replacement of the septum. The reaction was stirred at 0 °C for 30 min, and then quenched with saturated aqueous $NaHCO_3$ solution (25 mL) and extracted with CH_2Cl_2 (50 mL) for three times. The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to afford **1.S19** (1.03 g, 43%) as orange oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.05 (m, 10H), 5.64 – 5.48 (m, 2H), 4.13 (d, J = 6.5 Hz, 1H), 3.66 (d, J = 3.9 Hz, 2H), 1.63 (d, J = 5.4 Hz, 3H).



1.S20, 91%



1.S20

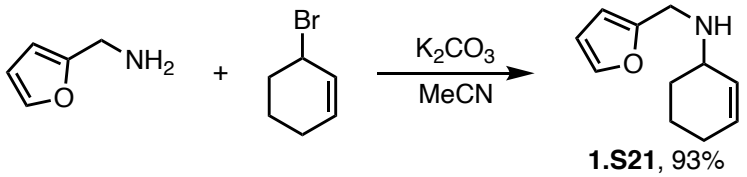
(**1.S20**) This reaction was modified from a literature procedure.[84] A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. K_2CO_3 (2.28 g, 16.5 mmol, 2.05 equiv) was added. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous MeCN (50 mL), 2-(aminomethyl)pyridine (2.6 mL, 24 mmol, 3.0 equiv), and 3-bromocyclohexene (0.9 mL, 8 mmol, 1 equiv) were added via syringe under N_2. The reaction mixture was then stirred for 3 h. It was quenched with brine (100 mL) and extracted with EtOAc (50 mL) for three times. The combined organic extracts were dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo and chromatographed (linear gradient, 2:98 MeOH/EtOAc to 20:80 MeOH/EtOAc) to afford allylic amine **1.S20** (1.37 g, 91%) as clear yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.47 (d, J = 4.3 Hz, 1H), 7.73 (td, J = 7.7, 1.9 Hz, 1H), 7.45 (d, J = 7.8 Hz, 1H), 7.26 – 7.18 (m, 1H), 5.69 (s, 2H), 3.84 (d, J = 1.6 Hz, 2H), 3.12 – 3.03 (m, 1H), 2.03 – 1.84 (m, 2H), 1.81 – 1.63 (m, 2H), 1.53 – 1.32 (m, 2H).

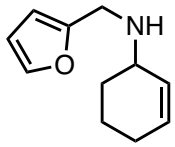
^{13}C NMR (101 MHz, DMSO-d_6) δ 160.7, 148.7, 136.4, 130.5, 128.0, 121.9, 121.8, 52.1, 51.8, 28.9, 24.9, 19.8.

FTIR (cm^{-1}): 2929, 1590, 1473, 1432, 756.

HRMS (ESI) m/z, calculated for $[C_{12}H_{17}N_2]^+$: 189.1386; found: 189.1386.



1.S21, 93%



1.S21

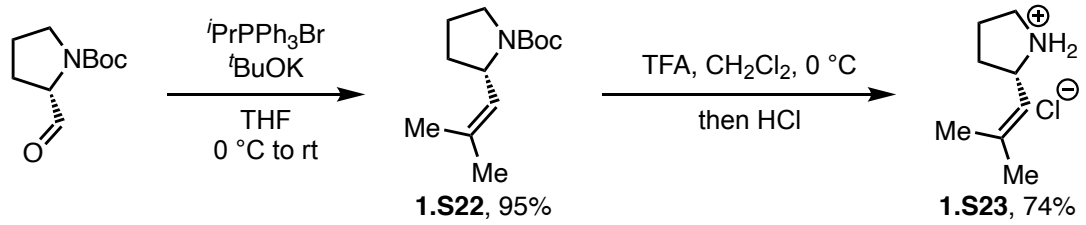
(**1.S21**) This reaction was modified from a literature procedure.[84] A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. K_2CO_3 (2.28 g, 16.5 mmol, 1.10 equiv) was added. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous MeCN (50 mL), furfurylamine (4.0 mL, 45 mmol, 3.0 equiv), and 3-bromocyclohexene (1.8 mL, 15 mmol, 1.0 equiv) were added via syringe under N_2. The reaction mixture was then stirred for 6 h. It was quenched with brine (100 mL) and extracted with EtOAc (50 mL) for three times. The combined organic extracts were dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo and chromatographed (linear gradient, 1:99 MeOH/EtOAc to 4:96 MeOH/EtOAc) to afford allylic amine **1.S21** (2.48 g, 93%) as clear yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.54 (dd, J = 1.9, 0.8 Hz, 1H), 6.36 (dd, J = 3.2, 1.9 Hz, 1H), 6.22 (dd, J = 3.2, 0.9 Hz, 1H), 5.73 – 5.56 (m, 2H), 3.70 (d, J = 2.9 Hz, 2H), 3.08 – 2.97 (m, 1H), 1.99 – 1.82 (m, 3H), 1.79 – 1.61 (m, 2H), 1.49 – 1.25 (m, 2H).

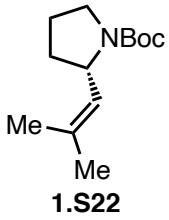
^{13}C NMR (101 MHz, DMSO-d_6) δ 154.8, 141.7, 130.5, 127.9, 110.3, 106.4, 51.6, 42.9, 28.8, 24.9, 19.7.

FTIR (cm^{-1}): 3020, 2930, 1506, 1451, 1147, 729.

HRMS (ESI) m/z, calculated for $[C_{11}H_{16}NO]^+$: 178.1226; found: 178.1226.



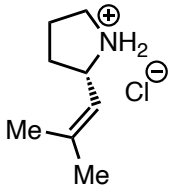
1.S22, 95% **1.S23**, 74%



1.S22

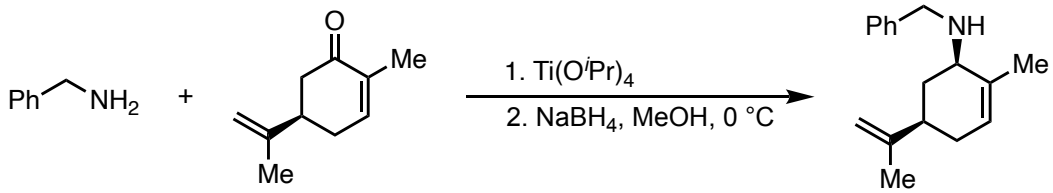
(**1.S22**) A 200 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Isopropyl triphenylphosphonium bromide (14.50 g, 37.70 mmol, 1.500 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous THF (84 mL) was added via syringe under N_2. The suspension was then cooled to 0 °C in an ice bath. ^{t}BuOK (4.20 g, 37.7 mmol, 1.50 equiv) was added via quick removal and replacement of the septum, and the resulting suspension was stirred at 0 °C for 1 h. *N*-Boc-*L*-prolinal (5.00 g, 25.1 mmol, 1.00 equiv) was added in one portion, then the reaction was warmed to rt and stirred for 16 h. The reaction was quenched with saturated aqueous NH_4Cl solution (150 mL) and diluted with Et_2O (200 mL). The layers were separated, and the aqueous layer was extracted two additional times with Et_2O (50 mL). The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated to give a crude oil. The oil was adsorbed onto Celite, and chromatographed (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford **1.S22** (5.40 g, 95%) as colorless oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 5.07 (s, 1H), 4.40 (s, 1H), 3.51 – 3.25 (m, 2H), 2.02 (dq, J = 12.4, 7.7 Hz, 1H), 1.90 – 1.82 (m, 1H), 1.77 (dp, J = 12.6, 6.3 Hz, 1H), 1.68 (s, 6H), 1.57 (dddd, J = 12.2, 6.6, 5.6, 4.2 Hz, 1H), 1.42 (s, 9H). The analytical data matched that previously reported in the literature.[85]

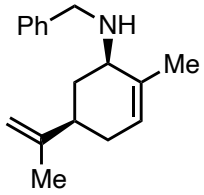


1.S23

(**1.S23**) In a 500 mL round-bottom flask, **1.S22** (5.20 g, 23.1 mmol, 1.00 equiv) was dissolved in CH_2Cl_2 (100 mL) under air, then cooled to 0 °C. TFA (100 mL) was pre-cooled to 0 °C, then added in one portion to the reaction mixture. The reaction was stirred at 0 °C for 1 h, then concentrated in vacuo. The crude material was neutralized with aqueous 1M NaOH (150 mL) and extracted three times with CH_2Cl_2 (100 mL). The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated to give a crude oil. The oil was re-dissolved in Et_2O (100 mL), cooled to 0 °C, and precipitated with the addition of 2 M HCl in Et_2O (25 mL). Filtration through a glass frit and subsequent drying in vacuo afforded allylic ammonium salt **1.S23** (2.76 g, 74%) as off-white powder. The crude product was used directly in the next step with no further purification.



1.S24, 96%

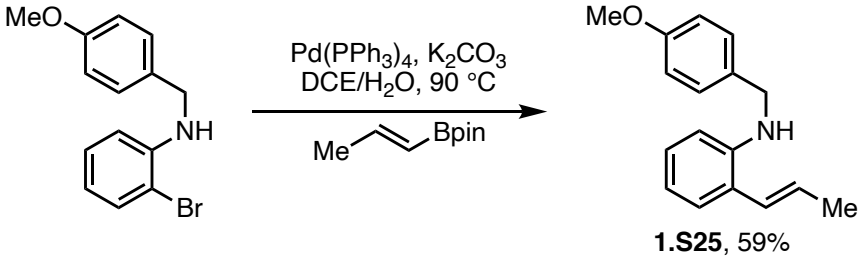


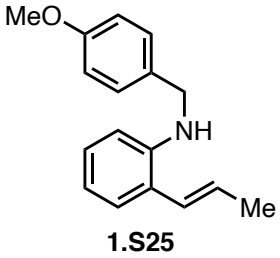
1.S24

(**1.S24**) This reaction was modified from a literature procedure.[83] A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2. (*R*)-(−)-carvone (3.2 mL, 20 mmol, 1.0 equiv), $Ti(O^iPr)_4$ (10 mL), and benzylamine (2.2 mL, 20 mmol, 1.0 equiv) were added to the flask via syringe under N_2. The reaction mixture was stirred for 3 h, and then diluted with anhydrous MeOH (90 mL). The resulting solution was then cooled to 0 °C in an ice bath. $NaBH_4$ (1.15 g,

30.0 mmol, 1.50 equiv) was added slowly via removal and replacement of the septum. The reaction was stirred at 0 °C for 30 min, and then quenched with saturated aqueous $NaHCO_3$ solution (50 mL) and extracted with CH_2Cl_2 (100 mL) for three times. The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to afford **1.S24** (4.62 g, 96%) as orange oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.37 (d, J = 7.6 Hz, 2H), 7.32 (t, J = 7.5 Hz, 2H), 7.24 (t, J = 7.5 Hz, 1H), 5.56 (d, J = 5.6 Hz, 1H), 4.73 (s, 2H), 3.83, 3.75 (AB system, J_{AB} = 13.0 Hz, 2H), 3.39 – 3.24 (m, 1H), 2.28 – 2.13 (m, 2H), 2.09 – 2.02 (m, 1H), 1.98 – 1.90 (m, 1H), 1.76 (s, 3H), 1.75 (s, 3H), 1.44 (q, J = 11.7 Hz, 1H).





1.S25

(**1.S25**) A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 2-bromo-*N*-(4-methoxybenzyl)aniline (2.76 g, 9.50 mmol, 1.00 equiv) and *trans*-1-propenylboronic acid pinacol ester (1.59 g, 9.50 mmol, 1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. DCE (114 mL) and a solution of K_2CO_3 (5.23 g, 38.0 mmol, 4.00 equiv) in H_2O (38 mL) was then added to the reaction

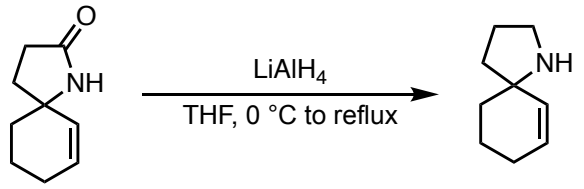
mixture slowly via syringe under N_2. At this point, the whole reaction solution was bubbled with N_2 for 1 h, followed by the addition of $Pd(PPh_3)_4$ (0.27 g, 0.24 mmol, 0.025 equiv). The resulting solution was heated to 90 °C and stirred for 24 h. The reaction mixture was allowed to cool down to rt and extracted with CH_2Cl_2 (50 mL) for three times. The combined organics were dried with MgSO4, filtered through a glass frit, and concentrated in vacuo to afford a crude mixture, which was purified by chromatography (linear gradient, hexanes to 10:90 EtOAc:hexanes) to yield the targeted aniline **1.S25** (1.40 g, 59%, 89:11 *trans*/*cis*) as colorless oil. The characterization data reported is for the major *trans*-alkene isomer.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.29 (m, 2H), 7.21 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.12 (td, *J* = 7.7, 1.6 Hz, 1H), 6.95 – 6.86 (m, 2H), 6.71 (td, *J* = 7.4, 1.1 Hz, 1H), 6.63 (dd, *J* = 8.2, 1.1 Hz, 1H), 6.40 (dq, *J* = 15.4, 1.8 Hz, 1H), 6.06 (dq, *J* = 15.4, 6.6 Hz, 1H), 4.28 (s, 2H), 4.05 (bs, 1H), 3.82 (s, 3H), 1.88 (dd, *J* = 6.6, 1.8 Hz, 3H).

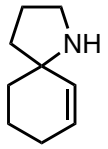
^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 145.0, 131.5, 129.0, 128.6, 128.2, 127.5, 126.7, 124.6, 117.6, 114.1, 110.8, 55.4, 48.0, 19.1.

FTIR (cm^{-1}): 3418, 3004, 1601, 1511, 1247, 1035.

HRMS (ESI) m/z, calculated for $[C_{17}H_{20}NO]^+$: 254.1545; found: 254.1537.



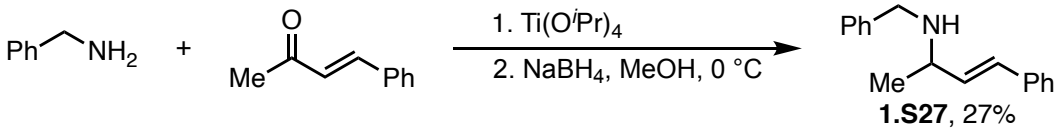
1.162 **1.S26**, 73%

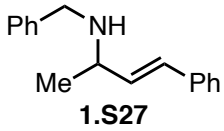


1.S26

(**1.S26**) A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $LiAlH_4$ (0.31 g, 8.0 mmol, 2.0 equiv) was added. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous THF (20 mL) was added via syringe under N_2, and the reaction mixture was cooled down to 0 °C in an ice bath. A solution of 7-methylene-1-azaspiro[4.4]nonan-2-one (**1.162**) (0.58 g, 4.0 mmol, 1.0 equiv) in anhydrous THF (10 mL) was slowly added to the $LiAlH_4$ solution via syringe. Once the addition was finished, the resulting mixture was heated to reflux and allowed to stir overnight. The reaction cooled down to rt, quenched with H_2O (0.3 mL), 15% aqueous NaOH solution (0.3 mL), and H_2O (0.9 mL). The reaction was filtered through a glass frit, and then concentrated in vacuo to afford **1.S26** (0.41 g, 73%) as colorless oil. The crude product was used directly in the next step with no further purification.

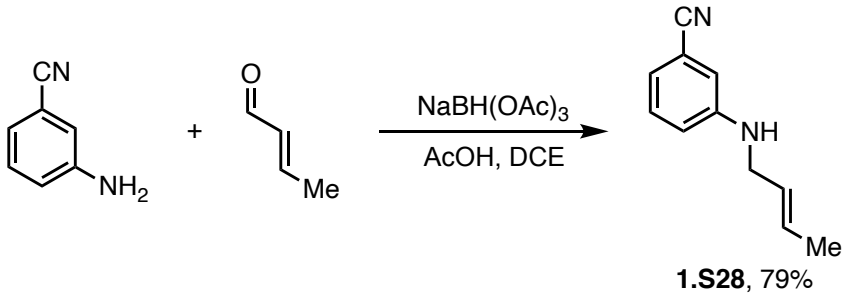
^{1}H NMR (600 MHz, $CDCl_3$) δ 5.65 (ddt, J = 13.7, 10.0, 3.7 Hz, 1H), 5.54 (tt, J = 9.9, 2.3 Hz, 1H), 3.02 (ddt, J = 13.7, 10.2, 6.8 Hz, 1H), 2.94 (ddt, J = 13.4, 10.2, 6.7 Hz, 1H), 2.07 – 1.88 (m, 3H), 1.82 – 1.76 (m, 2H), 1.76 – 1.66 (m, 1H), 1.65 – 1.55 (m, 4H).



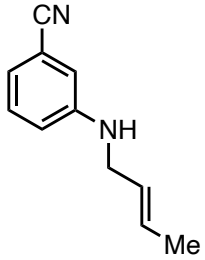


(**1.S27**) This reaction was modified from a literature procedure.[83] A 250 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2. 4-phenylbut-3-en-2-one (2.90 g, 20.0 mmol, 1.00 equiv), Ti(O^{i}Pr)4 (10 mL), and benzylamine (2.2 mL, 20 mmol, 1.0 equiv) were added to the flask via syringe under N_2. The reaction was stirred for 3 h, and then diluted with anhydrous MeOH (90 mL). The resulting solution was then cooled to 0 °C in an ice bath. $NaBH_4$ (1.12 g, 30.0 mmol, 1.50 equiv) was added slowly via removal and replacement of the septum. The reaction was stirred at 0 °C for 30 min, and then quenched with saturated aqueous $NaHCO_3$ solution (50 mL) and extracted with CH_2Cl_2 (100 mL) for three times. The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to afford **1.S27** (1.26 g, 27%) as colorless oil. The crude product was used directly in the next step with no further purification.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.37 (m, 2H), 7.35 – 7.29 (m, 6H), 7.28 – 7.21 (m, 2H), 6.49 (d, J = 15.9 Hz, 1H), 6.18 – 6.08 (m, 1H), 3.86, 3.74 (AB system, J_{AB} = 13.2 Hz, 2H), 3.42 (p, J = 6.2 Hz, 1H), 1.29 (dt, J = 6.5, 1.9 Hz, 3H).



1.S28, 79%



1.S28

(**1.S28**) This reaction was modified from a literature procedure.[83] To a 500 mL round bottom flask, 3-cyanoaniline (7.09 g, 60.0 mmol, 1.00 equiv), *trans*-crotonaldehyde (5.0 mL, 60 mmol, 1.0 equiv), and AcOH (3.4 mL, 60 mmol, 1.0 equiv) were dissolved in DCE (214 mL) under air. $NaBH(OAc)_3$ (17.80 g, 84.00 mmol, 1.400 equiv) was then added in one portion, and the pink suspension was stirred at rt for 16 h. The reaction was quenched with H_2O (10 mL) and saturated aqueous $NaHCO_3$ solution (150 mL), poured into a separatory funnel, and extracted. The aqueous layer was extracted two additional times with CH_2Cl_2 (100 mL). The combined organics were dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo. The crude orange oil was chromatographed (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford allylic aniline **1.S28** (8.20 g, 79%, 91:9 *trans*/*cis*) as colorless oil. The ^1H and ^{13}C data reported is for the *trans*-isomer only.

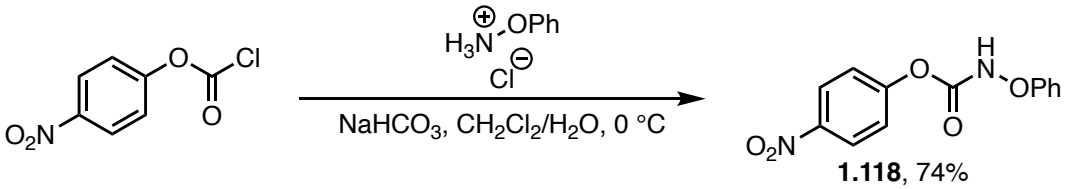
^1H NMR (400 MHz, $CDCl_3$) δ 7.21 (td, J = 7.6, 1.1 Hz, 1H), 6.95 (dt, J = 7.5, 1.3 Hz, 1H), 6.83 – 6.74 (m, 2H), 5.72 (dqt, J = 15.7, 6.4, 1.4 Hz, 1H), 5.54 (dtq, J = 15.0, 5.8, 1.6 Hz, 1H), 3.96 (bs, 1H), 3.68 (dt, J = 5.8, 1.4 Hz, 2H), 1.71 (dq, J = 6.4, 1.4 Hz, 3H).

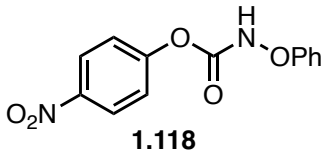
^{13}C NMR (101 MHz, $CDCl_3$) δ 148.4, 129.9, 128.9, 126.9, 120.8, 119.7, 117.5, 115.1, 113.0, 45.6, 17.9.

FTIR (cm^{-1}): 3395, 2228, 1603, 1582, 1514, 1491, 1334, 966, 780, 682.

HRMS (ESI) m/z, calculated for $[C_{11}H_{13}N_2]^+$: 173.1073; found: 173.1074.

1.12.4 Synthesis of *N*-Phenoxy Ureas





(**1.118**) This reaction was modified from a literature procedure.[86] Under air atmosphere, *O*-phenyl hydroxylamine hydrochloride (26.82 g, 180.0 mmol, 1.000 equiv) was added to a 1 L round-bottom flask, and then dissolved in H_2O (333 mL). The solution was cooled to 0 °C in an ice bath, followed by sequential addition of $NaHCO_3$ (25.49 g, 300.0 mmol, 1.700 equiv) and CH_2Cl_2 (200 mL). The suspension was stirred for 25 min at 0 °C. *p*-nitrophenyl chloroformate (36.11 g, 180.0 mmol, 1.000 equiv) was added as a solution in CH_2Cl_2 (130 mL) via slow-addition funnel over 25 min. Upon full addition, the reaction was stirred at 0 °C for 20 min, and the precipitate was directly filtered through a glass frit while still cold. The precipitate was washed with H_2O (112 mL) and dried under high vacuum to yield **1.118** (36.21 g, 74%) as colorless powder.

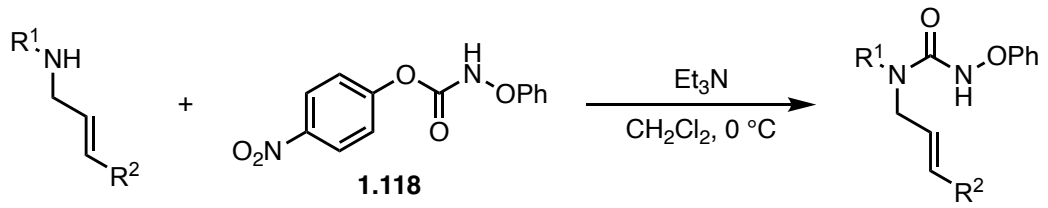
^{1}H NMR (400 MHz, CD_2Cl_2) δ 8.33 – 8.26 (m, 2H), 8.24 (bs, 1H), 7.47 – 7.33 (m, 4H), 7.23 – 7.15 (m, 2H), 7.15 – 7.08 (m, 1H).

^{13}C NMR (101 MHz, CD_2Cl_2) δ 159.9, 155.4, 154.5, 145.9, 130.1, 125.8, 123.9, 122.5, 113.6.

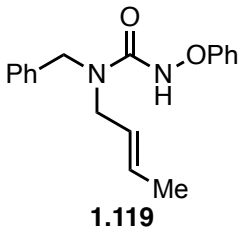
FTIR (cm^{-1}): 3175, 1739, 1524, 1349, 1192.

mp = 155-158 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{11}N_2O_5]^+$: 275.0662; found: 275.0654.



General Protocol B: A round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2. The septum was quickly removed, and **1.118** (1.00 – 1.20 equiv) was added, followed by replacement of the septum. The flask was cooled to 0 °C in an ice bath, with subsequent addition of anhydrous CH_2Cl_2; the resulting heterogeneous solution was stirred at 0 °C for 15 min. Allylic amine (1.00 equiv) was added via syringe, followed by anhydrous Et_3N (5.00 equiv). The resulting solution was allowed to warm up to rt and stirred for 16 h. The reaction was then concentrated in vacuo and re-dissolved in EtOAc, which was poured into a separatory funnel and washed sequentially with 1 M aqueous HCl solution, saturated aqueous 3 solution for three times, and brine. The organic layer was dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product. The product was purified by chromatography to yield pure product.



1.119

(**1.119**) According to general protocol B: **1.118** (4.23 g, 15.0 mmol), **1.S2** (2.42 g, 15.0 mmol), and Et_3N (10.4 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 15:85 EtOAc:hexanes) to yield *N*-phenoxy urea **1.119** (3.40 g, 76%, 84:16 *trans*/*cis*) as

colorless solid. The characterization data reported is for the major *trans*-alkene isomer; only characteristic ^{1}H and ^{13}C peaks are reported for the minor *cis*-alkene isomer.

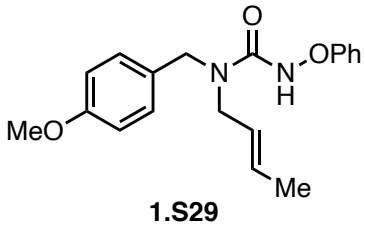
^{1}H NMR (400 MHz, DMSO-d_6) (*trans*-alkene) δ 10.47 (s, 1H), 7.40 – 7.33 (m, 2H), 7.32 – 7.23 (m, 5H), 7.01 – 6.93 (m, 3H), 5.69 – 5.52 (m, 1H), 5.50 – 5.37 (m, 1H), 4.42 (d, J = 3.7 Hz, 2H), 3.75 (d, J = 6.0 Hz, 2H), 1.67 (dd, J = 6.2, 1.5 Hz, 3H); ^{1}H NMR (400 MHz, DMSO-d_6) (*cis*-alkene) δ 3.85 (d, J = 6.9 Hz, 2H), 1.53 (dd, J = 6.8, 1.7 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) (*trans*-alkene) δ 160.5, 158.0, 138.0, 129.3, 128.5, 128.3, 127.4, 127.1, 126.1, 121.6, 112.9, 48.3, 47.4, 17.6; ^{13}C NMR (101 MHz, DMSO-d_6) (*cis*-alkene) δ 160.5, 158.2, 137.9, 127.2, 125.9, 48.5, 42.2, 12.7.

FTIR (cm^{-1}): 3203, 1657, 1593, 1489, 1208, 751.

mp = 89-91 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{21}N_2O_2]^+$: 297.1598; found: 297.1595.



1.S29

(**1.S29**) According to general protocol B: **1.118** (6.85 g, 25.0 mmol), **1.S3** (5.74 g, 30.0 mmol), and Et_3N (18.0 mL, 125 mmol) were combined in anhydrous CH_2Cl_2 (100 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S29** (3.41 g, 42%) as colorless solid.

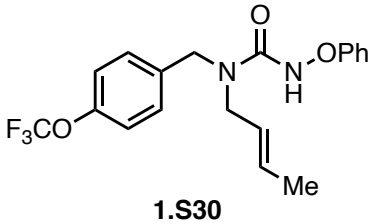
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.44 (s, 1H), 7.33 – 7.23 (m, 2H), 7.22 – 7.15 (m, 2H), 7.02 – 6.89 (m, 5H), 5.66 – 5.52 (m, 1H), 5.52 – 5.34 (m, 1H), 4.34 (s, 2H), 3.75 (s, 3H), 3.72 (d, J = 6.1 Hz, 2H), 1.68 (dd, J = 6.3, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.5, 158.0, 129.8, 129.3, 128.9, 128.2, 126.1, 121.5, 113.9, 112.9, 55.1, 47.7, 47.0, 17.6.

FTIR (cm^{-1}): 3205, 1656, 1513, 1247, 1207, 1207.

mp = 94-96 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{23}N_2O_3]^+$: 327.1703; found: 327.1696.



1.S30

(**1.S30**) According to general protocol B: **1.118** (4.11 g, 15.0 mmol), **1.S4** (4.07 g, 16.5 mmol), and Et_3N (10.4 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S30** (1.64 g, 29%) as viscous yellow oil.

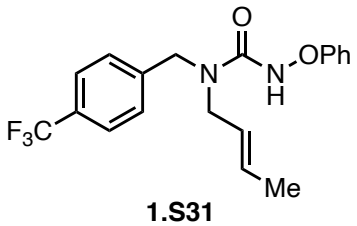
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.49 (s, 1H), 7.43 – 7.33 (m, 4H), 7.31 – 7.23 (m, 2H), 7.01 – 6.91 (m, 3H), 5.70 – 5.52 (m, 1H), 5.50 – 5.38 (m, 1H), 4.44 (s, 2H), 3.79 (d, J = 6.0 Hz, 2H), 1.66 (dd, J = 6.4, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 158.0, 147.3 (q, J = 1.8 Hz), 137.8, 129.3, 129.2, 128.4, 126.1, 121.6, 121.2, 120.6 (q, J = 255.9 Hz), 112.9, 47.9, 47.8, 17.5.

^{19}F NMR (376 MHz, DMSO-d_6) δ –56.84.

FTIR (cm^{-1}): 3206, 1658, 1508, 1263, 1210.

HRMS (ESI) m/z, calculated for $[C_{19}H_{20}N_2O_3F_3]^+$: 381.1421; found: 381.1406.



1.S31

(**1.S31**) According to general protocol B: **1.118** (4.14 g, 15.0 mmol), **1.S5** (4.19 g, 18.0 mmol), and Et_3N (10.5 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S31** (3.09 g, 57%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.53 (s, 1H), 7.73 (d, J = 8.0 Hz, 2H), 7.47 (d, J = 8.0 Hz, 2H), 7.35 – 7.22 (m, 2H), 7.05 – 6.88 (m, 3H), 5.68 – 5.53 (m, 1H), 5.52 – 5.40 (m, 1H), 4.51 (s, 2H), 3.80 (d, J = 6.0 Hz, 2H), 1.66 (dd, J = 6.4, 1.4 Hz, 3H).

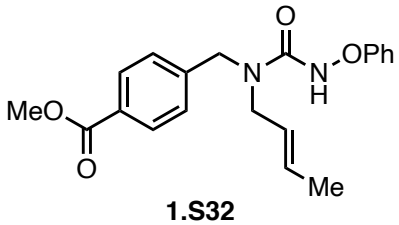
^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 158.0, 143.3, 129.3, 128.5, 128.0, 127.7 (q, J = 31.9 Hz), 126.0, 125.7, 125.4 (q, J = 3.8 Hz), 124.4 (q, J = 272.1 Hz), 121.6, 48.3, 47.9, 17.6.

^{19}F NMR (376 MHz, DMSO-d_6) δ –60.78.

FTIR (cm^{-1}): 3444, 3216, 1658, 1327, 1124, 1067, 753.

mp = 103-105 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{20}N_2O_2F_3]^+$: 365.1471; found: 365.1461.



1.S32

(**1.S32**) According to general protocol B: **1.118** (2.73 g, 10.0 mmol), **1.S6** (2.63 g, 12.0 mmol), and Et_3N (7.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by chromatography

(linear gradient, 7:93 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S32** (1.41 g, 40%) as colorless solid.

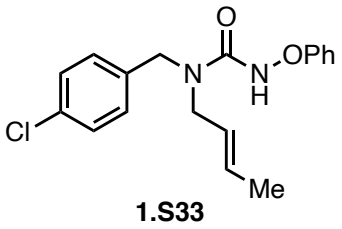
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.52 (s, 1H), 7.96 (d, J = 8.3 Hz, 2H), 7.39 (d, J = 8.3 Hz, 2H), 7.32 – 7.24 (m, 2H), 7.04 – 6.93 (m, 3H), 5.67 – 5.51 (m, 1H), 5.51 – 5.38 (m, 1H), 4.50 (s, 2H), 3.85 (s, 3H), 3.79 (d, J = 6.0 Hz, 2H), 1.66 (dd, J = 6.3, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 166.1, 160.4, 158.0, 144.0, 129.4, 129.3, 128.5, 128.4, 127.5, 126.0, 121.6, 112.9, 52.2, 48.4, 47.8, 17.6.

FTIR (cm^{-1}): 3211, 1721, 1660, 1489, 1281, 1207.

mp = 71-73 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{20}H_{23}N_2O_4]^+$: 355.1658; found: 355.1640.



1.S33

(**1.S33**) According to general protocol B: **1.118** (2.73 g, 10.0 mmol), **1.S7** (2.20 g, 12.0 mmol), and Et_3N (7.00 mL, 50.0 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S33** (1.52 g, 46%) as colorless solid.

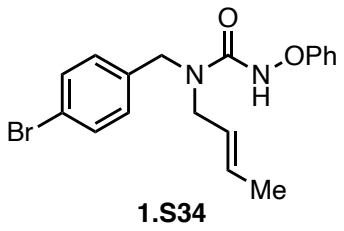
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.48 (s, 1H), 7.43 (dd, J = 8.4, 4.1 Hz, 2H), 7.33 – 7.23 (m, 4H), 7.03 – 6.92 (m, 3H), 5.66 – 5.51 (m, 1H), 5.43 (dtd, J = 15.3, 6.1, 1.7 Hz, 1H), 4.40 (s, 2H), 3.76 (d, J = 6.0 Hz, 2H), 1.67 (dd, J = 6.3, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 160.0, 159.4, 135.8, 133.6, 130.0, 129.5, 129.4, 129.0, 125.6, 122.6, 113.4, 49.9, 48.7, 17.9.

FTIR (cm^{-1}): 3437, 3213, 1658, 1490, 1207, 752.

mp = 109-112 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{20}N_2O_2Cl]^+$: 331.1208; found: 331.1198.



1.S34

(**1.S34**) According to general protocol B: **1.118** (4.13 g, 15.0 mmol), **1.S8** (4.89 g, 18.0 mmol), and Et_3N (10.5 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S34** (3.29 g, 58%) as colorless solid.

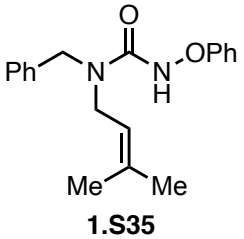
^1H NMR (400 MHz, DMSO-d_6) δ 10.49 (s, 1H), 7.59 – 7.53 (m, 2H), 7.32 – 7.25 (m, 2H), 7.24 – 7.18 (m, 2H), 6.96 (dd, J = 8.2, 6.9 Hz, 3H), 5.65 – 5.50 (m, 1H), 5.49 – 5.37 (m, 1H), 4.38 (s, 2H), 3.75 (d, J = 6.0 Hz, 2H), 1.67 (dd, J = 6.4, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 158.0, 137.7, 131.3, 129.6, 129.3, 128.4, 126.0, 121.6, 120.1, 112.9, 47.9, 47.6, 17.6.

FTIR (cm^{-1}): 3208, 1654, 1488, 1207, 752.

mp = 109-111 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{20}N_2O_2Br]^+$: 375.0703; found: 375.0690.



1.S35

(**1.S35**) According to general protocol B: **1.118** (2.74 g, 10.0 mmol), **1.S9** (2.11 g, 12.0 mmol), and Et_3N (7.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by

chromatography (linear gradient, 7:93 EtOAc:hexanes to 10:90 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S35** (2.36 g, 76%) as colorless solid.

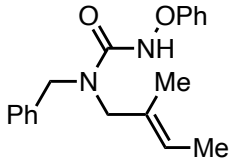
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.48 (s, 1H), 7.42 – 7.33 (m, 2H), 7.32 – 7.21 (m, 5H), 7.01 – 6.90 (m, 3H), 5.18 (tt, J = 6.9, 1.3 Hz, 1H), 4.41 (s, 2H), 3.78 (d, J = 6.9 Hz, 2H), 1.69 (s, 3H), 1.52 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.2, 138.0, 135.4, 129.3, 128.5, 127.3, 127.1, 121.5, 120.0, 112.9, 48.3, 43.2, 25.6, 17.7.

FTIR (cm^{-1}): 3204, 1656, 1593, 1489, 1209.

mp = 83-85 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{23}N_2O_2]^+$: 311.1754; found: 311.1744.



1.S36

(**1.S36**) According to general protocol B: **1.118** (4.17 g, 15.0 mmol), **1.S10** (3.16 g, 18.0 mmol), and Et_3N (10.0 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 6:94 EtOAc:hexanes to 15:85 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S36** (4.66 g, 87%) as yellow solid.

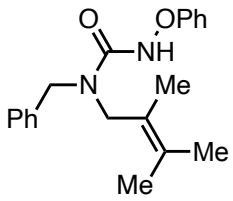
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.48 (s, 1H), 7.40 – 7.33 (m, 2H), 7.32 – 7.21 (m, 5H), 6.99 – 6.91 (m, 3H), 5.35 – 5.22 (m, 1H), 4.37 (s, 2H), 3.75 (s, 2H), 1.61 (d, J = 6.6 Hz, 3H), 1.55 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.3, 137.9, 131.0, 129.3, 128.5, 127.3, 127.1, 121.5, 120.7, 112.8, 52.4, 48.0, 13.7, 13.1.

FTIR (cm^{-1}): 3202, 1656, 1489, 1208, 751.

mp = 94-95 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{23}N_2O_2]^+$: 311.1754; found: 311.1751.



1.S37

(**1.S37**) According to general protocol B: **1.118** (1.69 g, 6.00 mmol), *N*-benzyl-2,3-dimethylbut-2-en-1-amine (1.12 g, 6.00 mmol), and Et_3N (4.2 mL, 30 mmol) were combined in anhydrous CH_2Cl_2 (24 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S37** (0.78 g, 40%) as colorless solid.

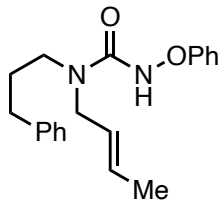
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.53 (s, 1H), 7.42 – 7.33 (m, 2H), 7.31 – 7.24 (m, 3H), 7.24 – 7.19 (m, 2H), 7.00 – 6.93 (m, 3H), 4.32 (s, 2H), 3.89 (s, 2H), 1.64 (s, 3H), 1.58 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 160.4, 158.5, 137.8, 129.04, 129.02, 128.2, 126.9, 126.8, 123.0, 121.4, 112.8, 47.2, 46.9, 20.7, 19.6, 15.5.

FTIR (cm^{-1}): 3201, 1653, 1489, 1210, 751.

mp = 77-79 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{20}H_{25}N_2O_2]^+$: 325.1911; found: 325.1905.



1.S38

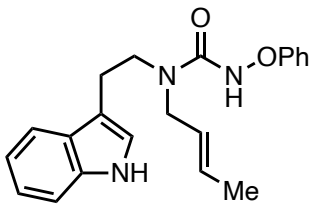
(**1.S38**) According to general protocol B: **1.118** (3.26 g, 12.0 mmol), **1.S11** (2.81 g, 15.0 mmol), and Et_3N (8.0 mL, 60 mmol) were combined in anhydrous CH_2Cl_2 (48 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 40:60 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S38** (1.73 g, 44%) as viscous yellow oil.

^{1}H NMR (600 MHz, DMSO-d_6) δ 10.26 (s, 1H), 7.31 – 7.26 (m, 4H), 7.23 – 7.20 (m, 2H), 7.18 (t, J = 7.4 Hz, 1H), 6.99 (d, J = 8.1 Hz, 2H), 6.96 (t, J = 7.3 Hz, 1H), 5.59 – 5.50 (m, 1H), 5.46 – 5.36 (m, 1H), 3.77 (d, J = 6.0 Hz, 2H), 3.19 (t, J = 7.6 Hz, 2H), 2.55 (t, J = 7.8 Hz, 2H), 1.87 – 1.77 (m, 2H), 1.65 (dd, J = 6.5, 1.6 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 157.7, 141.6, 129.3, 128.34, 128.25, 127.8, 126.7, 125.8, 121.5, 112.9, 47.5, 45.1, 32.4, 29.4, 17.5.

FTIR (cm^{-1}): 3202, 1656, 1489, 1208, 751.

HRMS (ESI) m/z, calculated for $[C_{20}H_{25}N_2O_2]^+$: 325.1911; found: 325.1907.



1.S39

(**1.S39**) According to general protocol B: **1.118** (3.19 g, 11.6 mmol), **1.S12** (2.74 g, 12.8 mmol) and Et_3N (8.1 mL, 58 mmol) were combined in anhydrous CH_2Cl_2 (47 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 60:40 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S39** (2.16 g, 53%) as colorless solid.

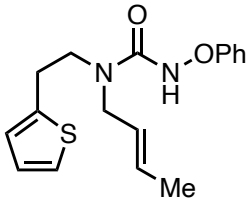
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.84 (s, 1H), 10.31 (s, 1H), 7.56 (d, J = 7.9 Hz, 1H), 7.38 – 7.32 (m, 1H), 7.32 – 7.24 (m, 2H), 7.15 (d, J = 2.3 Hz, 1H), 7.07 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 7.02 – 6.92 (m, 4H), 5.69 – 5.53 (m, 1H), 5.51 – 5.38 (m, 1H), 3.80 (d, J = 6.0 Hz, 2H), 3.49 – 3.37 (m, 2H), 3.02 – 2.85 (m, 2H), 1.68 (dd, J = 6.4, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.6, 157.7, 136.2, 129.3, 127.9, 127.2, 126.9, 122.9, 121.4, 121.0, 118.32, 118.28, 112.9, 111.4, 111.3, 47.7, 46.3, 23.7, 17.6.

FTIR (cm^{-1}): 3738, 3317, 1636, 1487, 1454, 739.

mp = 134-136 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{21}H_{24}N_3O_2]^+$: 350.1863; found: 350.1860.



1.S40

(**1.S40**) According to general protocol B: **1.118** (5.48 g, 20.0 mmol), **1.S13** (4.35 g, 24.0 mmol), and Et_3N (13.9 mL, 100 mmol) were combined in anhydrous CH_2Cl_2 (80 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 40:60 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S40** (2.60 g, 41%) as waxy, beige semi-solid.

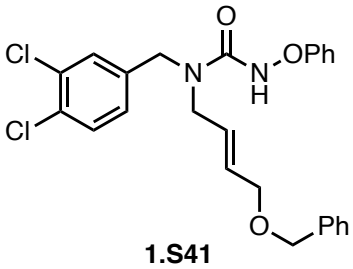
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.37 (s, 1H), 7.36 (dd, J = 5.1, 1.2 Hz, 1H), 7.32 – 7.25 (m, 2H), 7.01 – 6.93 (m, 4H), 6.90 (dd, J = 3.4, 1.1 Hz, 1H), 5.69 – 5.54 (m, 1H), 5.43 (dtd, J = 14.8, 5.9, 1.7 Hz, 1H), 3.77 (d, J = 6.1 Hz, 2H), 3.41 (dd, J = 8.6, 6.3 Hz, 2H), 3.04 (dd, J = 8.7, 6.3 Hz, 2H), 1.68 (dd, J = 6.4, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 157.6, 141.0, 129.3, 128.0, 127.0, 126.6, 125.5, 124.2, 121.5, 112.9, 47.8, 47.2, 27.9, 17.6.

FTIR (cm^{-1}): 3457, 1653, 1489, 1206, 752, 690.

mp = 52-54 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{17}H_{21}N_2O_2S]^+$: 317.1318; found: 317.1309.



1.S41

(**1.S41**) According to general protocol B: **1.118** (1.37 g, 5.00 mmol), **1.S14** (1.57 g, 5.00 mmol), and Et_3N (3.5 mL, 25 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear

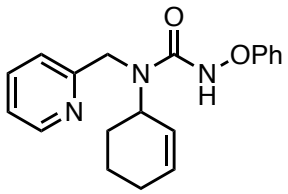
gradient, 10:90 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S41** (0.74 g, 35%) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.57 (s, 1H), 7.62 (d, J = 8.3 Hz, 1H), 7.51 (d, J = 2.1 Hz, 1H), 7.40 – 7.20 (m, 8H), 6.99 – 6.91 (m, 3H), 5.76 – 5.68 (m, 2H), 4.46 – 4.42 (m, 4H), 4.02 – 3.98 (m, 2H), 3.90 (d, J = 3.4 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 158.0, 139.7, 138.4, 131.0, 130.7, 129.6, 129.4, 129.34, 129.29, 128.3, 127.8, 127.53, 127.47, 127.2, 121.7, 112.9, 71.2, 69.3, 48.2, 47.7.

FTIR (cm^{-1}): 3223, 2857, 1663, 1489, 1471, 753.

HRMS (ESI) m/z, calculated for $[C_{25}H_{25}N_2O_3Cl_2]^+$: 471.1237; found: 471.1231.



1.S42

(**1.S42**) According to general protocol B: **1.118** (1.37 g, 5.00 mmol), **1.S20** (0.94 g, 5.0 mmol), and Et_3N (3.5 mL, 25 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The resulting solution was allowed to warm up to rt and stirred for 16 h. The reaction was then concentrated in vacuo and re-dissolved in EtOAc (40 mL), which was poured into a separatory funnel and washed sequentially with saturated aqueous Na_2CO_3 solution (40 mL) for three times and brine (40 mL). The organic layer was dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product, which was purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to EtOAc) to yield *N*-phenoxy urea **1.S42** (1.32 g, 81%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.62 (s, 1H), 8.53 (d, J = 4.7 Hz, 1H), 7.89 – 7.73 (m, 1H), 7.39 – 7.18 (m, 4H), 6.94 (t, J = 7.2 Hz, 3H), 5.94 – 5.77 (m, 1H), 5.49 (d, J =

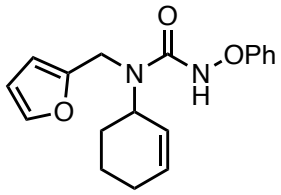
10.2 Hz, 1H), 4.86 – 4.67 (m, 1H), 4.46, 4.39 (AB system, J_{AB} = 17.4 Hz, 2H), 2.12 – 1.78 (m, 3H), 1.76 – 1.63 (m, 1H), 1.62 – 1.37 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 159.0, 158.4, 148.8, 136.9, 131.8, 129.2, 128.0, 122.1, 121.5, 121.2, 112.9, 52.2, 47.4, 27.8, 24.0, 21.0.

FTIR (cm^{-1}): 2933, 1689, 1593, 1490, 1208, 752.

mp = 104-106 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{22}N_3O_2]^+$: 324.1707; found: 324.1703.



1.S43

(**1.S43**) According to general protocol B: **1.118** (2.77 g, 10.0 mmol), **1.S21** (1.77 g, 10.0 mmol), and Et_3N (7.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S43** (2.32 g, 74%) as yellow solid.

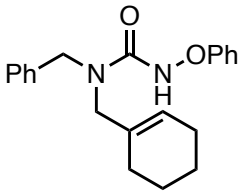
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.42 (s, 1H), 7.66 – 7.53 (m, 1H), 7.27 (t, J = 7.8 Hz, 2H), 6.94 (d, J = 7.8 Hz, 3H), 6.42 (t, J = 2.4 Hz, 1H), 6.25 (d, J = 3.2 Hz, 1H), 5.95 – 5.84 (m, 1H), 5.54 (d, J = 10.2 Hz, 1H), 4.76 – 4.53 (m, 1H), 4.39, 4.29 (AB system, J_{AB} = 16.9 Hz, 2H), 2.07 – 1.88 (m, 2H), 1.88 – 1.66 (m, 2H), 1.63 – 1.43 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 157.8, 152.4, 141.8, 131.5, 129.3, 128.0, 121.5, 112.9, 110.6, 107.2, 52.3, 39.2, 27.5, 24.0, 21.1.

FTIR (cm^{-1}): 3205, 2936, 1659, 1490, 1208, 752.

mp = 93-95 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{21}N_2O_3]^+$: 313.1547; found: 313.1534.



1.S44

(**1.S44**) According to general protocol B: **1.118** (2.75 g, 10.0 mmol), **1.S17** (2.00 g, 10.0 mmol), and Et_3N (7.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S44** (1.85 g, 55%) as colorless solid.

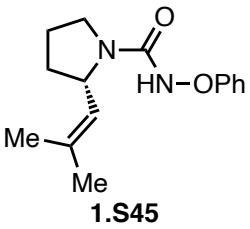
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.46 (s, 1H), 7.42 – 7.33 (m, 2H), 7.32 – 7.20 (m, 5H), 7.03 – 6.88 (m, 3H), 5.55 – 5.45 (m, 1H), 4.40 (s, 2H), 3.73 (s, 2H), 2.06 – 1.92 (m, 2H), 1.91 – 1.79 (m, 2H), 1.61 – 1.45 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.3, 138.0, 133.0, 129.3, 128.4, 127.4, 127.1, 123.3, 121.5, 112.8, 51.4, 48.4, 25.6, 24.6, 22.1, 22.0.

FTIR (cm^{-1}): 3199, 2926, 1656 1489, 1207, 750.

mp = 94-96 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{21}H_{25}N_2O_2]^+$: 337.1911; found: 337.1915.



1.S45

(**1.S45**) According to general protocol B: **1.118** (4.92 g, 17.9 mmol), **1.S23** (2.76 g, 17.1 mmol), and DIPEA (6.2 mL, 37.6 mmol) were combined in anhydrous CH_2Cl_2 (68 mL). The mixture was worked up according to the general procedure and purified by reverse phase chromatography (Note: **1.S45** decomposes on silica gel) (linear gradient, 10:90 MeCN:H_2O to 90:10 MeCN:H_2O) to yield *N*-phenoxy urea **1.S45** (1.50 g, 34%) as viscous colorless oil.

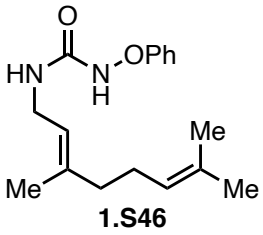
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.86 (s, 1H), 7.31 – 7.24 (m, 2H), 7.03 – 6.98 (m, 2H), 6.95 (tt, J = 7.2, 1.1 Hz, 1H), 5.07 (dt, J = 9.0, 1.5 Hz, 1H), 4.54 (ddd, J = 8.7, 7.4,

3.6 Hz, 1H), 3.41 – 3.26 (m, 2H), 2.05 – 1.78 (m, 3H), 1.66 (t, *J* = 1.4 Hz, 6H), 1.53 (tt, *J* = 10.4, 4.4 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 160.6, 156.6, 131.7, 129.2, 126.5, 121.4, 112.9, 54.8, 45.2, 32.2, 25.6, 23.7, 17.9.

FTIR (cm^{-1}): 3195, 2969, 1665, 1491, 1387, 1214, 752.

HRMS (ESI) m/z, calculated for $[C_{15}H_{21}N_2O_2]^+$: 261.1598; found: 261.1587.



1.S46

(**1.S46**) According to general protocol B: **1.118** (2.79 g, 10.0 mmol), geranylamine (1.9 mL, 10 mmol) and Et_3N (7.0 mL, 50 mmol) were combined in anhydrous CH_2Cl_2 (40 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S46** (2.87 g, 99%) as colorless solid.

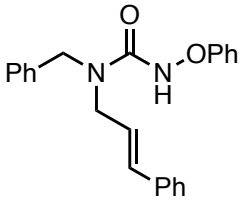
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 9.75 (s, 1H), 7.38 – 7.27 (m, 2H), 7.14 (t, *J* = 5.8 Hz, 1H), 7.11 – 7.05 (m, 2H), 7.00 (tt, *J* = 7.2, 1.1 Hz, 1H), 5.17 – 5.09 (m, 1H), 5.06 (tt, *J* = 6.8, 1.4, 1H), 3.66 (t, *J* = 6.2 Hz, 2H), 2.08 – 1.97 (m, 2H), 1.97 – 1.89 (m, 2H), 1.63 (s, 3H), 1.61 (s, 3H), 1.55 (s, 3H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 159.9, 159.3, 136.1, 130.9, 129.3, 124.0, 122.3, 122.0, 113.6, 39.0, 36.9, 26.0, 25.6, 17.6, 16.0.

FTIR (cm^{-1}): 3177, 1653, 1544, 1201, 755.

mp = 56-58 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{25}N_2O_2]^+$: 289.1911; found: 289.1908.



1.S47

(**1.S47**) According to general protocol B: **1.118** (4.13 g, 15.0 mmol), **1.S18** (4.02 g, 18.0 mmol), and Et_3N (10.5 mL, 75.0 mmol) were combined in anhydrous CH_2Cl_2 (60 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S47** (2.97 g, 55%) as colorless solid.

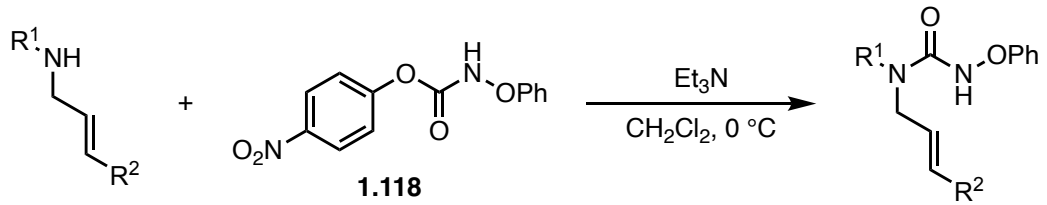
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.58 (s, 1H), 7.46 – 7.21 (m, 12H), 7.05 – 6.89 (m, 3H), 6.51 (d, J = 15.9 Hz, 1H), 6.27 (dt, J = 15.9, 5.9 Hz, 1H), 4.52 (s, 2H), 4.02 (d, J = 5.9 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.1, 138.1, 136.4, 131.6, 129.3, 128.7, 128.5, 127.7, 127.4, 127.2, 126.3, 125.2, 121.6, 112.9, 48.8, 47.7.

FTIR (cm^{-1}): 3203, 1653, 1494, 1206, 751, 691.

mp = 93-95 °C (CH_2Cl_2).

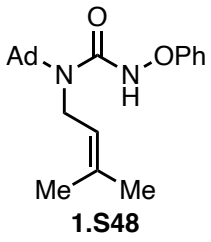
HRMS (LIFDI) m/z, calculated for $[C_{23}H_{22}N_2O_2]^+$: 358.1681; found: 358.1696.



1.118

General Protocol C: A round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Anhydrous CH_2Cl_2, allylic amine (1.00 equiv), and Et_3N (1.00 – 5.00 equiv) were added to the flask via syringe. The resulting homogenous solution was cooled to 0 °C in an ice bath, and then stirred at 0 °C for 15 min. **1.118** (1.00 – 1.20 equiv) was added in four portions

every 15 min. The resulting solution was allowed to warm up to rt and stirred for 16 h. The reaction was then concentrated in vacuo and re-dissolved in EtOAc, which was poured into a separatory funnel and washed sequentially with 1 M aqueous HCl solution, saturated aqueous Na_2CO_3 solution for three times, and brine. The organic layer was dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product. The product was purified by chromatography to yield pure product.



1.S48

(**1.S48**) According to general protocol C: **1.S15** (1.12 g, 5.00 mmol), Et_3N (3.5 mL, 25 mmol), and **1.118** (1.40 g, 5.00 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure and purified by recrystallization (EtOAc/hexanes) to yield *N*-phenoxy urea **1.S48** (1.32 g, 75%) as colorless solid.

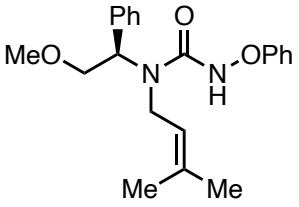
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.92 (s, 1H), 7.34 – 7.22 (m, 2H), 7.02 – 6.87 (m, 3H), 5.17 (t, J = 4.5 Hz, 1H), 3.86 (d, J = 5.8 Hz, 2H), 2.10 (d, J = 3.0 Hz, 6H), 2.03 (s, 3H), 1.71 (s, 3H), 1.59 (s, 9H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.6, 158.1, 131.5, 129.2, 124.1, 121.2, 112.8, 57.2, 40.7, 39.9, 36.0, 29.6, 25.5, 17.8.

FTIR (cm^{-1}): 3228, 2909, 1662, 1489, 1211, 751.

mp = 124-125 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{22}H_{31}N_2O_2]^+$: 355.2380; found: 355.2380.



1.S49

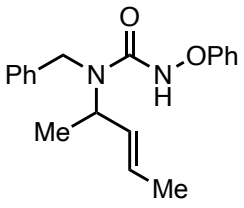
(**1.S49**) According to general protocol C: **1.S16** (1.69 g, 8.00 mmol), Et_3N (5.5 mL, 40 mmol), and **1.118** (2.21 g, 8.00 mmol) were combined in anhydrous CH_2Cl_2 (32 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S49** (1.31 g, 46%) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.26 (s, 1H), 7.41 – 7.25 (m, 7H), 7.05 – 6.92 (m, 3H), 5.38 (t, J = 7.0 Hz, 1H), 5.00 (dt, J = 6.2, 3.9 Hz, 1H), 3.93 – 3.73 (m, 3H), 3.61 (dd, J = 16.7, 6.5 Hz, 1H), 3.31 (s, 3H), 1.62 (s, 3H), 1.49 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.4, 138.3, 132.5, 129.3, 128.4, 127.7, 127.4, 122.2, 121.5, 112.9, 71.1, 58.1, 56.6, 40.9, 25.5, 17.6.

FTIR (cm^{-1}): 3255, 1653, 1597, 751, 691.

HRMS (ESI) m/z, calculated for $[C_{21}H_{27}N_2O_3]^+$: 355.2022; found: 355.2011.



1.S50

(1.S50) According to general protocol C: *trans*-*N*-benzyl-*N*-(1-methylbut-2-enyl)amine (0.71 g, 4.0 mmol), Et_3N (2.8 mL, 20 mmol), and **1.118** (1.08 g, 4.00 mmol) were combined in anhydrous CH_2Cl_2 (16 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 25:75 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S50** (0.51 g, 42%) as viscous yellow oil.

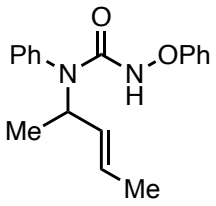
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.37 (s, 1H), 7.38 – 7.29 (m, 2H), 7.29 – 7.20 (m, 5H), 6.98 – 6.91 (m, 1H), 6.90 – 6.84 (m, 2H), 5.67 – 5.39 (m, 2H), 4.73 – 4.62 (m, 1H),

4.46, 4.30 (AB system, J_{AB} = 16.9 Hz, 2H), 1.63 (d, J = 5.9 Hz, 3H), 1.16 (d, J = 6.8 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.2, 139.7, 131.5, 129.2, 128.2, 126.7, 126.5, 126.4, 121.5, 112.8, 52.0, 45.0, 18.2, 17.7.

FTIR (cm^{-1}): 3203, 1653, 1592, 1489, 1202, 751.

HRMS (ESI) m/z, calculated for $[C_{19}H_{23}N_2O_2]^+$: 311.1760; found: 311.1745.



1.S51

(**1.S51**) According to general protocol C: *trans*-*N*-(pent-3-en-2-yl)aniline (0.89 g, 5.5 mmol), Et_3N (0.83 mL, 6.0 mmol), and **1.118** (1.51 g, 5.50 mmol) were combined in anhydrous CH_2Cl_2 (22 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 15:85 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S51** (1.15 g, 71%) as colorless solid.

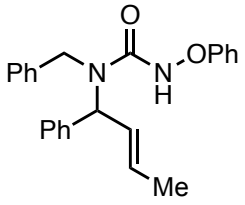
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.50 (s, 1H), 7.46 – 7.40 (m, 2H), 7.39 – 7.34 (m, 1H), 7.30 – 7.20 (m, 4H), 6.97 – 6.88 (m, 3H), 5.54 – 5.41 (m, 2H), 5.01 – 4.90 (m, 1H), 1.65 – 1.57 (m, 3H), 1.07 (d, J = 6.9 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 157.0, 136.9, 132.0, 130.5, 129.2, 129.0, 128.0, 126.1, 121.4, 112.8, 52.6, 18.3, 17.6.

FTIR (cm^{-1}): 3233, 1692, 1491, 1450, 1210, 752.

mp = 90-92 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{21}N_2O_2]^+$: 297.1598; found: 297.1584.



1.S52

(**1.S52**) According to general protocol C: **1.S19** (1.02 g, 4.00 mmol), Et_3N (2.8 mL, 20 mmol), and **1.118** (1.11 g, 4.00 mmol) were combined in anhydrous CH_2Cl_2 (16 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 12:88 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S52** (0.52 g, 35%) as colorless solid.

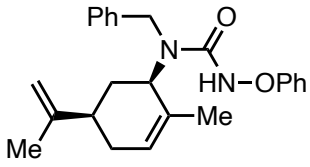
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.48 (s, 1H), 7.36 (t, J = 7.5 Hz, 2H), 7.32 – 7.24 (m, 5H), 7.23 – 7.10 (m, 5H), 6.90 (t, J = 7.3 Hz, 1H), 6.71 (d, J = 8.1 Hz, 2H), 5.87 – 5.75 (m, 2H), 5.74 – 5.62 (m, 1H), 4.58, 4.40 (AB system, J_{AB} = 17.0 Hz, 2H), 1.66 (d, J = 6.2 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 158.2, 140.1, 139.0, 129.7, 129.2, 128.7, 128.5, 128.0, 127.4, 127.2, 126.7, 126.5, 121.5, 112.7, 60.7, 46.7, 17.7.

FTIR (cm^{-1}): 3453, 1647, 1494, 1207, 751.

mp = 51-53 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{24}H_{25}N_2O_2]^+$: 373.1916; found: 373.1907.



1.S53

(**1.S53**) According to general protocol C: **1.S24** (1.25 g, 5.00 mmol), Et_3N (2.8 mL, 20 mmol), and **1.118** (1.10 g, 4.00 mmol) were combined in anhydrous CH_2Cl_2 (16 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 3:97 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S53** (0.74 g, 51%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.46 (s, 1H), 7.35 (t, J = 7.5 Hz, 2H), 7.30 – 7.18 (m, 5H), 6.93 (t, J = 7.5 Hz, 1H), 6.87 (d, J = 7.9 Hz, 2H), 5.74 (s, 1H), 4.81 (s, 1H),

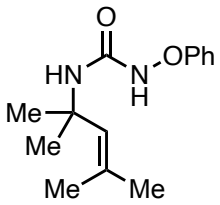
4.68 (d, J = 18.4 Hz, 1H), 4.64 (s, 1H), 4.55 (s, 1H), 3.86 (d, J = 17.2 Hz, 1H), 2.20 (t, J = 10.6 Hz, 1H), 2.05 – 1.74 (m, 3H), 1.62 (s, 3H), 1.60 (s, 3H), 1.29 (q, J = 11.9 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.9, 148.4, 139.5, 133.0, 129.2, 128.2, 127.1, 126.5, 126.3, 121.5, 112.8, 109.1, 56.6, 44.8, 40.6, 33.4, 30.0, 20.5, 19.4.

FTIR (cm^{-1}): 3208, 1659, 1593, 1488, 1399, 1208, 1159.

mp = 56-58 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{24}H_{29}N_2O_2]^+$: 377.2229; found: 377.2214.



1.S54

(**1.S54**) According to general protocol C: 2-amino-2,4-dimethyl-3-pentene (0.40 g, 3.5 mmol), Et_3N (2.5 mL, 18 mmol), and **1.118** (0.98 g, 3.5 mmol) were combined in anhydrous CH_2Cl_2 (14 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S54** (0.53 g, 61%) as colorless solid.

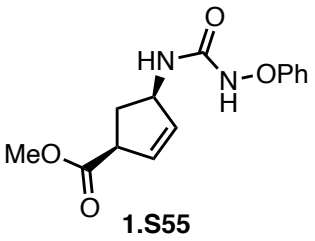
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.58 (s, 1H), 7.39 – 7.23 (m, 2H), 7.17 – 7.05 (m, 2H), 7.00 (tt, J = 7.3, 1.1 Hz, 1H), 6.28 (s, 1H), 5.31 – 5.21 (m, 1H), 1.61 (d, J = 1.4 Hz, 3H), 1.59 (d, J = 1.3 Hz, 3H), 1.37 (s, 6H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.0, 157.7, 131.8, 131.1, 129.4, 122.1, 113.5, 51.9, 28.8, 26.9, 18.3.

FTIR (cm^{-1}): 3440, 3192, 2971, 1680, 1522, 1489, 753.

mp = 84-86 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{21}N_2O_2]^+$: 249.1603; found: 249.1593.



1.S55

(**1.S55**) According to general protocol C: (–)-methyl (1*S*,4*R*)-4-amino-cyclopent-2-ene-1-carboxylate hydrochloride (0.91 g, 5.0 mmol), Et_3N (3.5 mL, 25 mmol), and **1.118** (1.38 g, 5.00 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure and purified by recrystallization (EtOAc/hexanes) to yield *N*-phenoxy urea **1.S55** (1.25 g, 91%) as brownish solid.

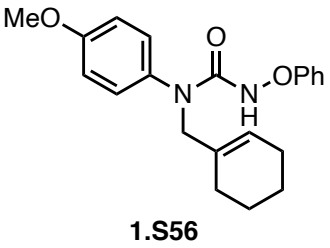
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.84 (s, 1H), 7.38 – 7.27 (m, 2H), 7.10 – 7.05 (m, 2H), 7.05 – 6.97 (m, 2H), 5.84 (dt, J = 5.3, 1.8 Hz, 1H), 5.79 (dt, J = 5.6, 2.3 Hz, 1H), 4.84 – 4.68 (m, 1H), 3.59 (s, 3H), 3.56 – 3.49 (m, 1H), 2.44 (dt, J = 13.1, 8.3 Hz, 1H), 1.80 (dt, J = 13.3, 6.8 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 173.8, 159.9, 158.7, 134.9, 130.5, 129.3, 122.1, 113.6, 54.7, 51.8, 48.4, 33.9.

FTIR (cm^{-1}): 3191, 3065, 1727, 1669, 1532, 1204.

mp = 124-125 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{17}N_2O_4]^+$: 277.1188; found: 277.1176.



1.S56

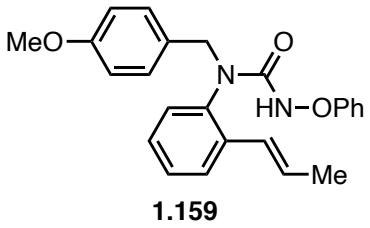
(**1.S56**) According to general protocol C: (4-methoxyphenyl)cyclohex-1-enylmethylamine (0.40 g, 1.8 mmol), Et_3N (0.28 mL, 2.0 mmol), and **1.118** (0.52 g, 1.8 mmol) were combined in anhydrous CH_2Cl_2 (8 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 20:80 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S56** (0.39 g, 62%) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 9.75 (s, 1H), 7.32 – 7.22 (m, 2H), 7.25 – 7.16 (m, 2H), 7.02 – 6.89 (m, 5H), 5.39 – 5.33 (m, 1H), 4.06 (s, 2H), 3.75 (s, 3H), 1.97 – 1.83 (m, 4H), 1.55 (tq, J = 6.5, 4.1, 2.6 Hz, 2H), 1.48 (dq, J = 6.0, 3.8 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.0, 157.6, 133.6, 133.0, 129.22, 129.15, 123.8, 121.5, 114.4, 112.9, 55.4, 55.3, 25.8, 24.6, 22.2, 22.0.

FTIR (cm^{-1}): 3446, 1636, 1510, 1247, 1204.

HRMS (ESI) m/z, calculated for $[C_{21}H_{25}N_2O_3]^+$: 353.1865; found: 353.1850.



1.159

(**1.159**) According to general protocol C: **1.S25** (1.01 g, 4.00 mmol), Et_3N (0.56 mL, 4.0 mmol), and **1.118** (1.10 g, 4.00 mmol) were combined in anhydrous CH_2Cl_2 (16 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 4:96 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.159** (0.98 g, 63%, 89:11 *trans*/*cis*) as colorless solid. The characterization data reported is for the major *trans*-alkene isomer.

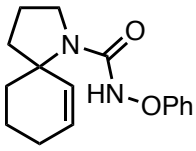
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.76 (s, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.26 (q, J = 7.3 Hz, 3H), 7.17 (t, J = 7.6 Hz, 1H), 7.08 (d, J = 8.3 Hz, 2H), 6.93 (dd, J = 8.7, 5.8 Hz, 4H), 6.87 – 6.79 (m, 2H), 6.37 – 6.22 (m, 2H), 4.94, 4.28 (AB system, J_{AB} = 15.5 Hz, 2H), 3.71 (s, 3H), 1.85 (d, J = 4.7 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.5, 157.5, 136.6, 135.6, 130.0, 129.8, 129.5, 129.2, 128.3, 127.8, 127.7, 126.1, 126.0, 121.5, 113.6, 112.8, 55.0, 52.3, 18.8.

FTIR (cm^{-1}): 3222, 2032, 1934, 2836, 1698, 1513, 1247.

mp = 114-115 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{24}H_{25}N_2O_3]^+$: 389.1865; found: 389.1852.



1.163

(**1.163**) According to general protocol C: **1.S26** (0.41 g, 3.0 mmol), Et_3N (2.8 mL, 20 mmol), and **1.118** (0.82 g, 3.0 mmol) were combined in anhydrous CH_2Cl_2 (12 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 45:55 EtOAc:hexanes) to yield *N*-phenoxy urea **1.163** (0.53 g, 65%) as colorless solid.

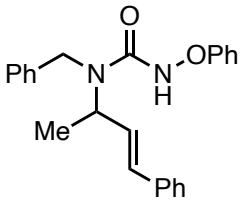
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.77 (s, 1H), 7.35 – 7.24 (m, 2H), 7.03 – 6.98 (m, 2H), 6.95 (td, J = 7.3, 1.0 Hz, 1H), 5.60 (dt, J = 10.4, 3.6 Hz, 1H), 5.42 (dd, J = 10.3, 1.8 Hz, 1H), 3.51 – 3.42 (m, 1H), 3.38 – 3.30 (m, 1H), 2.28 – 2.14 (m, 1H), 1.92 – 1.78 (m, 5H), 1.76 – 1.59 (m, 2H), 1.60 – 1.44 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.6, 155.5, 133.9, 129.2, 126.1, 121.4, 113.0, 63.2, 45.9, 38.3, 30.5, 23.8, 22.4, 21.2.

FTIR (cm-1): 3216, 2940, 1669, 1490, 1371, 1214.

mp = 121-123 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{16}H_{21}N_2O_2]^+$: 273.1603; found: 273.1596.



1.S57

(**1.S57**) According to general protocol C: **1.S27** (1.21 g, 5.00 mmol), Et_3N (3.5 mL, 25 mmol), and **1.118** (1.39 g, 5.00 mmol) were combined in anhydrous CH_2Cl_2 (20 mL). The mixture was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S57** (0.97 g, 52%) as a colorless solid.

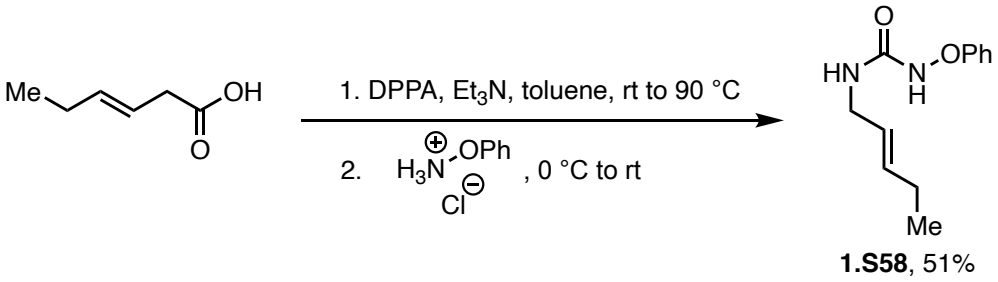
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.46 (s, 1H), 7.36 – 7.26 (m, 8H), 7.23 (t, J = 7.6 Hz, 4H), 6.97 – 6.86 (m, 3H), 6.51 (d, J = 16.1 Hz, 1H), 6.32 (dd, J = 16.1, 5.5 Hz, 1H), 4.93 (p, J = 6.5 Hz, 1H), 4.54, 4.41 (AB system, J_{AB} = 17.1 Hz, 2H), 1.30 (d, J = 6.8 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.5, 158.2, 139.6, 136.5, 130.3, 130.1, 129.2, 128.6, 128.2, 127.6, 126.7, 126.6, 126.3, 121.5, 112.9, 52.3, 45.2, 18.1.

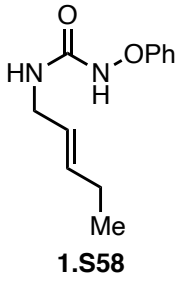
FTIR (cm^{-1}): 3442, 1653, 1593, 1491, 1203, 752.

mp = 59-61 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{24}H_{25}N_2O_2]^+$: 373.1916; found: 373.1906.



1.S58, 51%



1.S58

(**1.S58**) A 100 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was quickly removed. *trans*-3-hexenoic acid (1.8 mL, 15 mmol, 1.0 equiv) was added to the flask, followed by replacement of the septum. Anhydrous toluene (15 mL) was added via syringe. Diphenylphosphoryl azide (DPPA) (4.3 mL, 20 mmol, 1.3 equiv) and anhydrous Et_3N (3.5 mL, 23 mmol, 1.5 equiv) were added to the reaction mixture under N_2. The mixture was allowed to stir at rt for 3 h and 90 °C for 2.5 h. The solution was then cooled to 0 °C in an ice bath and added *O*-phenyl hydroxylamine hydrochloride (2.20 g, 15.0 mmol,

1.00 equiv). The resulting reaction mixture was allowed to warm up to room temperature and stirred for 16 h under N_2, which was then quenched with H_2O (50 mL) and diluted with EtOAc (100 mL). The solution was poured into a separatory funnel and washed sequentially with 1 M aqueous HCl solution (100 mL), saturated aqueous $NaHCO_3$ solution (100 mL), and brine (100 mL). The organic layer was dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product. The product was purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S58** (1.67 g, 51%) as colorless solid.

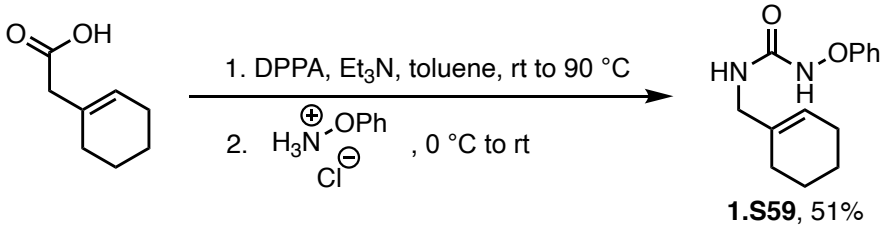
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.79 (s, 1H), 7.31 (t, J = 7.8 Hz, 2H), 7.19 (t, J = 6.0 Hz, 1H), 7.08 (d, J = 8.1 Hz, 2H), 7.00 (t, J = 7.3 Hz, 1H), 5.52 (dt, J = 15.4, 6.1 Hz, 1H), 5.38 (dt, J = 15.4, 5.7 Hz, 1H), 3.62 (t, J = 5.9 Hz, 2H), 1.97 (p, J = 7.2 Hz, 2H), 0.91 (t, J = 7.4 Hz, 3H).

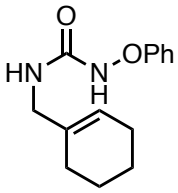
^{13}C NMR (101 MHz, DMSO-d_6) δ 160.0, 159.2, 132.4, 129.3, 126.4, 122.1, 113.6, 40.7, 24.6, 13.4.

FTIR (cm^{-1}): 3177, 1653, 1544, 1201, 755.

mp = 56-58 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{16}N_2O_2]^+$: 221.1285; found: 221.1279.




1.S59

(**1.S59**) A 100 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was quickly removed. 1-cyclohexenylacetic acid (2.11 g, 15.0 mmol, 1.00 equiv) was added to the flask, followed by replacement of the septum. Anhydrous toluene (15 mL) was added via syringe. Diphenylphosphoryl azide (DPPA) (4.3 mL, 20 mmol, 1.3 equiv) and anhydrous Et_3N (3.5 mL, 23 mmol, 1.5 equiv) were added to the reaction mixture under N_2. The mixture was allowed to stir at rt for 3 h and 90 °C for 2.5 h. The solution was then cooled to 0 °C in an ice bath and added *O*-phenyl hydroxylamine hydrochloride (2.21 g, 15.0 mmol, 1.00 equiv). The resulting reaction mixture was allowed to warm up to room temperature and stirred for 16 h under N_2, which was then quenched with H_2O (50 mL) and diluted with EtOAc (100 mL). The solution was poured into a separatory funnel and washed sequentially with 1 M aqueous HCl solution (100 mL), saturated aqueous $NaHCO_3$ solution (100 mL), and brine (100 mL). The organic layer was dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product. The product was purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 30:70 EtOAc:hexanes) to yield *N*-phenoxy urea **1.S59** (1.86 g, 51%) as colorless solid.

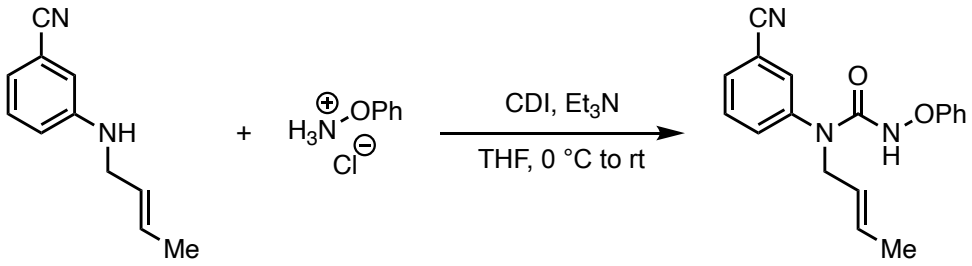
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.79 (s, 1H), 7.40 – 7.26 (m, 2H), 7.15 (t, J = 6.1 Hz, 1H), 7.11 – 7.06 (m, 2H), 7.00 (td, J = 7.3, 1.1 Hz, 1H), 5.40 (tt, J = 3.8, 1.7 Hz, 1H), 3.54 (d, J = 5.4 Hz, 2H), 1.96 – 1.87 (m, 2H), 1.87 – 1.76 (m, 2H), 1.62 – 1.37 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.0, 159.4, 135.4, 129.3, 122.0, 120.4, 113.6, 44.4, 25.9, 24.3, 22.2, 22.1.

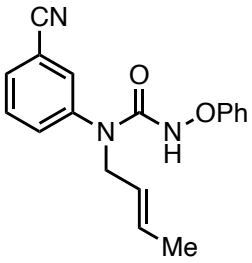
FTIR (cm^{-1}): 3425, 3162, 2933, 1657, 1546, 750.

mp = 99-100 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{19}N_2O_2]^+$: 247.1441; found: 247.1434.



1.S28 **1.172**, 46%



1.172

(**1.172**) A 200 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2. The septum was quickly removed. CDI (0.85 g, 5.5 mmol, 1.1 equiv) and *O*-phenyl hydroxylamine hydrochloride (0.76 g, 5.5 mmol, 1.1 equiv) were added to the flask, followed by replacement of the septum. Anhydrous THF (56 mL) was added, and the reaction was cooled to 0 °C in an ice bath. After stirring for 15 min, anhydrous Et_3N (0.73 mL, 5.5 mmol, 1.1 equiv) was added dropwisely. The reaction was stirred at 0 °C for 1 h, then warmed to rt. **1.S28** (0.86 g, 5.0 mmol) was then added in one portion. The reaction was stirred for 16 h, and then diluted with EtOAc (150 mL) and H_2O (25 mL). The layers were separated, and the organic layer was washed with brine (30 mL). The organics were then dried with $MgSO_4$, filtered through a glass frit, and concentrated in vacuo to give crude product, which was purified by chromatography (linear gradient,

5:95 EtOAc:hexanes to 50:50 EtOAc:hexanes) yielded *N*-phenoxy urea **1.172** (0.70 g, 46%, 90:10 *trans*/*cis*) as off-white solid. The reported ^{1}H and ^{13}C data are for the *trans*-isomer only.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.24 (s, 1H), 7.82 (t, J = 1.9 Hz, 1H), 7.75 – 7.64 (m, 2H), 7.62 – 7.55 (m, 1H), 7.33 – 7.24 (m, 2H), 7.02 – 6.93 (m, 3H), 5.62 – 5.39 (m, 2H), 4.21 (d, J = 3.1 Hz, 2H), 1.69 – 1.53 (m, 3H).

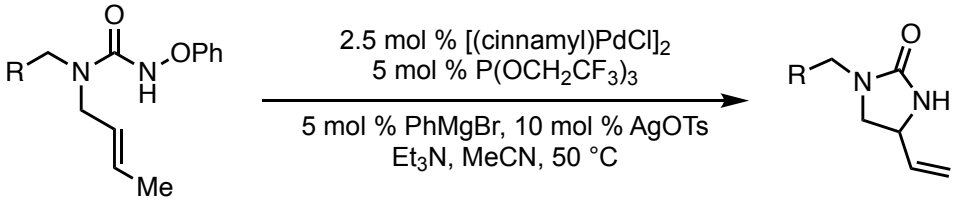
^{13}C NMR (101 MHz, DMSO-d_6) δ 160.1, 156.7, 141.8, 132.8, 131.3, 130.5, 130.4, 129.3, 128.5, 126.3, 121.7, 118.4, 112.9, 112.0, 51.0, 17.5.

FTIR (cm^{-1}): 3132, 2230, 1675, 1484, 1210, 755.

mp = 96-98 °C (EtOAc).

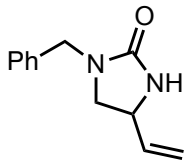
HRMS (ESI) m/z, calculated for $[C_{18}H_{18}N_3O_2]^+$: 308.1394; found: 308.1392.

1.12.5 Synthesis of Imidazolidinones



General Protocol D: A Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $[(cinnamyl)PdCl]_2$ (0.025 equiv) and *N*-phenoxy urea (1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (0.05 equiv), anhydrous MeCN (0.067 M with respect to the *N*-phenoxy urea), and anhydrous Et_3N (2.00 equiv) were added sequentially to the flask via syringe. PhMgBr (0.05 equiv) was then added with stirring, followed by addition of AgOTs (0.10 equiv) in MeCN (0.02 M with respect to AgOTs). The resulting suspension was placed

in a pre-heated oil bath, and stirred at the indicated temperature for 24 h. Upon completion, the reaction was cooled to rt, opened to air, and then diluted with EtOAc (10 mL). The suspension was transferred to a round bottom flask, and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed on silica gel (5-20 μm particle size) to yield the desired product.



1.121

(**1.121**) According to general protocol D: *N*-phenoxy urea **1.119** (295.9 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 mmol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 μL, 50.0 ummol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.121** (170.5 mg, 84%) as colorless powder.

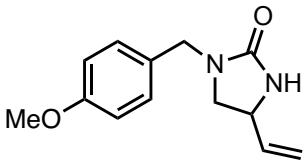
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.40 – 7.29 (m, 2H), 7.27 (d, *J* = 7.3 Hz, 1H), 7.25 – 7.18 (m, 2H), 6.86 (s, 1H), 5.79 (ddd, *J* = 16.8, 10.2, 6.4 Hz, 1H), 5.21 (dt, *J* = 17.1, 1.4 Hz, 1H), 5.08 (dt, *J* = 10.2, 1.3 Hz, 1H), 4.22 (s, 2H), 4.07 (q, *J* = 7.5 Hz, 1H), 3.38 (t, *J* = 8.8 Hz, 1H), 2.85 (dd, *J* = 8.7, 6.7 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 161.2, 138.8, 137.7, 128.5, 127.6, 127.1, 115.7, 51.5, 49.7, 46.5.

FTIR (cm^{-1}): 3234, 1697, 1494, 1448, 1253, 702.

mp = 66-68 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for [$C_{12}H_{15}N_2O$]$^+$: 203.1179; found: 203.1169.



1.130

(**1.130**) According to general protocol D: *N*-phenoxy urea **1.S29** (328.8 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 ummol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.130** (188.9 mg, 82%) as colorless powder.

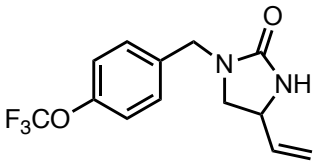
^{1}H NMR (400 MHz, CDCl$_3$) δ 7.23 – 7.15 (m, 2H), 6.92 – 6.81 (m, 2H), 5.79 (ddd, *J* = 17.2, 10.1, 7.3 Hz, 1H), 5.23 (dt, *J* = 17.1, 1.1 Hz, 1H), 5.13 (dt, *J* = 10.1, 0.9 Hz, 1H), 4.61 (bs, 1H), 4.34, 4.26 (AB system, J_{AB} = 14.8 Hz, 2H), 4.12 (dd, *J* = 7.0, 6.5 Hz, 1H), 3.80 (s, 3H), 3.42 (t, *J* = 8.8 Hz, 1H), 2.96 (dd, *J* = 9.2, 6.4 Hz, 1H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 161.6, 159.1, 137.5, 129.5, 129.0, 117.2, 114.1, 55.4, 52.8, 50.3, 47.0.

FTIR (cm^{-1}): 3236, 1696, 1493, 1457, 1442, 1245.

mp = 92-94 °C (CH$_2$Cl$_2$).

HRMS (ESI) m/z, calculated for [C$_{13}$H$_{17}$N$_2$O$_2$]$^+$: 233.1285; found: 233.1282.



1.131

(**1.131**) According to general protocol D: *N*-phenoxy urea **1.S30** (382.1 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M,

46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.131** (230.9 mg, 81%) as yellow powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.35 (s, 4H), 6.91 (s, 1H), 5.80 (ddd, J = 16.8, 10.2, 6.4 Hz, 1H), 5.21 (dt, J = 17.1, 1.4 Hz, 1H), 5.09 (dt, J = 10.2, 1.3 Hz, 1H), 4.29, 4.22 (AB system, J_{AB} = 15.4 Hz, 2H), 4.09 (dtd, J = 8.9, 6.6, 1.3 Hz, 1H), 3.40 (t, J = 8.7 Hz, 1H), 2.88 (dd, J = 8.7, 6.7 Hz, 1H).

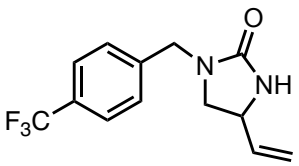
^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 147.4 (q, J = 1.8 Hz), 138.7, 137.4, 129.5, 121.2, 120.1 (q, J = 255.9 Hz), 115.8, 51.5, 49.8, 45.8.

^{19}F NMR (376 MHz, DMSO-d_6) δ –52.08.

FTIR (cm^{-1}): 3243, 1699, 1509, 1260, 1222.

mp = 54-56 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}N_2O_2F_3]^+$: 287.0999; found: 287.1002.



1.132

(**1.132**) According to general protocol D: *N*-phenoxy urea **1.S31** (364.4 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.132** (226.0 mg, 84%) as off-white powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.71 (d, J = 8.0 Hz, 2H), 7.45 (d, J = 8.0 Hz, 2H), 6.94 (s, 1H), 5.81 (ddd, J = 16.9, 10.2, 6.4 Hz, 1H), 5.22 (dt, J = 17.1, 1.4 Hz, 1H), 5.09 (dt, J = 10.3, 1.3 Hz, 1H), 4.39 – 4.26 (m, 2H), 4.17 – 4.04 (m, 1H), 3.42 (t, J = 8.8 Hz, 1H), 2.89 (dd, J = 8.7, 6.7 Hz, 1H).

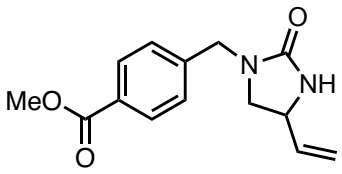
^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 142.9, 138.7, 128.3, 127.8 (q, J = 31.9 Hz), 125.4 (q, J = 3.8 Hz), 124.4 (q, J = 271.3 Hz), 115.8, 51.5, 49.9, 46.1.

^{19}F NMR (376 MHz, DMSO-d_6) δ –60.85.

FTIR (cm^{-1}): 3221, 1708, 1330, 1158, 1106, 820.

mp = 81-84 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}N_2OF_3]^+$: 271.1053; found: 271.1043.



1.133

(**1.133**) According to general protocol D: *N*-phenoxy urea **1.S32** (354.9 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 μL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.133** (203.7 mg, 78%) as colorless powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.96 – 7.91 (m, 2H), 7.40 – 7.32 (m, 2H), 6.94 (s, 1H), 5.81 (ddd, J = 16.6, 10.1, 6.3 Hz, 1H), 5.23 (dt, J = 17.1, 1.4 Hz, 1H), 5.10 (dt, J =

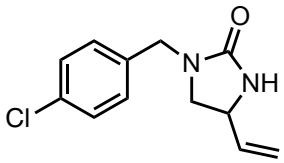
10.2, 1.3 Hz, 1H), 4.34, 4.31 (AB system, J_{AB} = 15.7 Hz, 2H), 4.11 (q, J = 6.7Hz, 1H), 3.83 (s, 3H), 3.43 (t, J = 8.7 Hz, 1H), 2.89 (dd, J = 8.7, 6.8 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 166.1, 161.2, 143.6, 138.7, 129.5, 128.5, 127.8, 115.8, 52.2, 51.5, 49.9, 46.3.

FTIR (cm^{-1}): 3232, 1717, 1703, 1277, 1253.

mp = 130-132 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{17}N_2O_3]^+$: 261.1234; found: 261.1231.



1.134

(**1.134**) According to general protocol D: *N*-phenoxy urea **1.S33** (331.0 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.134** (174.0 mg, 74%) as off-white powder.

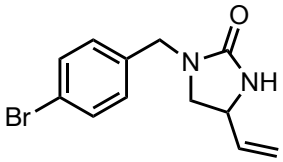
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.43 – 7.38 (m, 2H), 7.28 – 7.22 (m, 2H), 6.90 (s, 1H), 5.79 (ddd, J = 16.9, 10.2, 6.4 Hz, 1H), 5.21 (dt, J = 17.1, 1.4 Hz, 1H), 5.08 (dt, J = 10.2, 1.3 Hz, 1H), 4.21 (d, J = 2.7 Hz, 2H), 4.08 (dtd, J = 9.0, 6.6, 1.3 Hz, 1H), 3.38 (t, J = 8.7 Hz, 1H), 2.85 (dd, J = 8.7, 6.8 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 138.7, 136.9, 131.7, 129.5, 128.5, 115.8, 51.5, 49.7, 45.8.

FTIR (cm^{-1}): 3233, 1698, 1491, 1447, 1252, 932.

mp = 96-99 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{12}H_{14}NO_2Cl]^+$: 237.0789; found: 237.0781.



1.135

(**1.135**) According to general protocol D: *N*-phenoxy urea **1.S34** (375.0 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et_3N (0.27 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.135** (213.0 mg, 76%) as off-white powder.

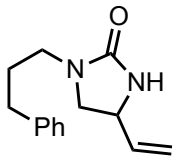
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.56 – 7.51 (m, 2H), 7.22 – 7.16 (m, 2H), 6.90 (s, 1H), 5.79 (ddd, J = 16.9, 10.2, 6.4 Hz, 1H), 5.21 (dt, J = 17.2, 1.4 Hz, 1H), 5.08 (dt, J = 10.2, 1.3 Hz, 1H), 4.20 (d, J = 2.8 Hz, 2H), 4.08 (dtd, J = 8.8, 6.6, 1.3 Hz, 1H), 3.38 (t, J = 8.7 Hz, 1H), 2.85 (dd, J = 8.7, 6.7 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 138.7, 137.3, 131.4, 129.9, 120.2, 115.8, 51.5, 49.7, 45.9.

FTIR (cm^{-1}): 3224, 1692, 1488, 1265, 934, 738.

mp = 121-122 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{12}H_{14}N_2OBr]^+$: 281.0284; found: 281.0275.



1.139

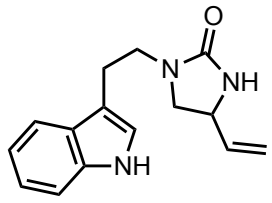
(**1.139**) According to general protocol D: *N*-phenoxy urea **1.S38** (331.0 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 ummol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 18:82 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.139** (178.1 mg, 77%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.30 – 7.23 (m, 2H), 7.23 – 7.14 (m, 3H), 6.68 (s, 1H), 5.81 (ddd, *J* = 16.9, 10.2, 6.5 Hz, 1H), 5.22 (dt, *J* = 17.2, 1.4 Hz, 1H), 5.10 (dt, *J* = 10.2, 1.3 Hz, 1H), 4.05 (dtd, *J* = 8.2, 6.8, 1.3 Hz, 1H), 3.50 (t, *J* = 8.7 Hz, 1H), 3.14 – 2.90 (m, 3H), 2.53 (dd, *J* = 8.6, 6.6 Hz, 2H), 1.77 – 1.64 (m, 2H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 161.4, 141.8, 138.9, 128.4, 128.3, 125.8, 115.7, 51.7, 50.0, 42.4, 32.5, 29.1.

FTIR (cm^{-1}): 3242, 2930, 1696, 1494, 1453.

HRMS (ESI) m/z, calculated for [C$_{14}$H$_{19}$N$_2$O]$^+$: 231.1492; found: 231.1490.



1.140

(**1.140**) According to general protocol D: *N*-phenoxy urea **1.S39** (349.7 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at

50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.140** (207.1 mg, 82%) as colorless powder.

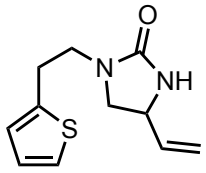
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.82 (s, 1H), 7.53 (dd, J = 7.9, 1.1 Hz, 1H), 7.33 (dt, J = 8.1, 0.9 Hz, 1H), 7.16 (d, J = 2.4 Hz, 1H), 7.06 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 6.97 (ddd, J = 7.9, 6.9, 1.1 Hz, 1H), 6.68 (s, 1H), 5.78 (ddd, J = 16.9, 10.2, 6.6 Hz, 1H), 5.21 (dt, J = 17.1, 1.4 Hz, 1H), 5.08 (dt, J = 10.2, 1.3 Hz, 1H), 4.04 (dtd, J = 8.5, 7.0, 1.4 Hz, 1H), 3.55 (t, J = 8.7 Hz, 1H), 3.43 – 3.21 (m, 2H), 3.01 (dd, J = 8.6, 7.0 Hz, 1H), 2.82 (t, J = 7.5 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 138.9, 136.2, 127.2, 122.7, 120.9, 118.3, 118.2, 115.8, 111.6, 111.4, 51.7, 50.1, 43.5, 23.3.

FTIR (cm^{-1}): 3265, 1684, 1491, 1456, 742.

mp = 119-121 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}N_3O]^+$: 256.1444; found: 256.1442.



1.141

(**1.141**) According to general protocol D: *N*-phenoxy urea **1.S40** (316.4 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et_3N (0.26 mL, 2.0 mmol) were combined under N_2, followed by addition of PhMgBr (1.44 M, 34.7 μL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 15:85 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.141** (164.0 mg, 74%) as waxy beige solid.

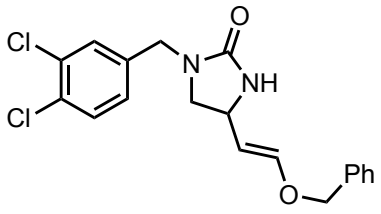
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.34 (dd, J = 5.1, 1.2 Hz, 1H), 6.95 (dd, J = 5.1, 3.4 Hz, 1H), 6.89 (dd, J = 3.4, 1.1 Hz, 1H), 6.73 (s, 1H), 5.79 (ddd, J = 16.9, 10.2, 6.7 Hz, 1H), 5.21 (dt, J = 17.1, 1.4 Hz, 1H), 5.09 (dt, J = 10.2, 1.3 Hz, 1H), 4.04 (dtd, J = 8.2, 6.8, 1.3 Hz, 1H), 3.50 (t, J = 8.7 Hz, 1H), 3.33 – 3.27 (m, 1H), 3.23 (dt, J = 13.7, 7.1 Hz, 1H), 3.01 – 2.91 (m, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.1, 141.4, 138.8, 126.9, 125.2, 124.2, 115.9, 51.7, 50.1, 44.5, 27.7.

FTIR (cm^{-1}): 3245, 1695, 1490, 1438, 1253, 698.

mp = 67-70 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{11}H_{15}N_2OS]^+$: 223.0900; found: 223.0893.



1.142-*trans*

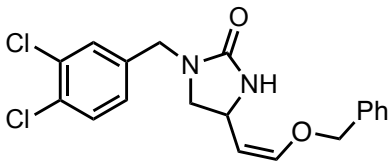
(**1.142-*trans***) According to general protocol D: *N*-phenoxy urea **1.S41** (471.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.142** (179.2 mg, 47%, 50:50 *trans*/*cis*) as yellow oil. The *trans* alkene isomer **1.142-*trans*** was separated by Lotus Technologies, and the following data is of the *trans* alkene isomer **1.142-*trans*** only.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, J = 8.2 Hz, 1H), 7.39 – 7.29 (m, 6H), 7.12 (dd, J = 8.2, 2.1 Hz, 1H), 6.52 (d, J = 12.6 Hz, 1H), 4.86 (dd, J = 12.6, 9.0 Hz, 1H), 4.74 (s, 2H), 4.40 (bs, 1H), 4.38, 4.24 (AB system, J_{AB} = 15.3 Hz, 2H), 4.11 (q, J = 8.1 Hz, 1H), 3.43 (t, J = 8.6 Hz, 1H), 2.96 (dd, J = 8.8, 7.2 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.4, 149.3, 137.6, 136.3, 132.8, 131.7, 130.8, 130.0, 128.8, 128.4, 127.7, 127.5, 104.2, 71.7, 51.8, 49.8, 46.7.

FTIR (cm^{-1}): 3427, 1696, 1661, 1453, 1254, 698.

HRMS (ESI) m/z, calculated for $[C_{19}H_{19}N_2O_2Cl_2]^+$: 377.0818; found: 377.0821.



1.142-*cis*

(**1.142-*cis***) According to general protocol D: *N*-phenoxy urea **1.S41** (471.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et_3N (0.26 mL, 2.0 mmol) were combined under N_2, and followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.142** (179.2 mg, 47%, 50:50 *trans*/*cis*) as yellow oil. The *trans* alkene isomer **1.142-*cis*** was separated by Lotus Technologies, and the following data is of the *trans* alkene isomer **1.142-*cis*** only.

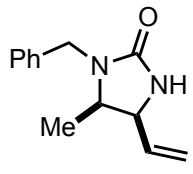
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.32 (m, 5H), 7.28 (dd, J = 8.0, 1.8 Hz, 2H), 7.11 (dd, J = 8.2, 2.1 Hz, 1H), 6.14 (dd, J = 6.1, 1.2 Hz, 1H), 4.80 (s, 2H), 4.67 (td, J = 8.3,

6.9 Hz, 1H), 4.48 (dd, J = 8.1, 6.2 Hz, 1H), 4.46 (bs, 1H), 4.35, 4.23 (AB system, J_{AB} = 15.3 Hz, 2H), 3.43 (t, J = 8.5 Hz, 1H), 2.91 (dd, J = 8.6, 7.0 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.7, 147.7, 137.7, 136.7, 132.8, 131.6, 130.8, 130.0, 128.8, 128.5, 127.7, 127.5, 107.1, 74.5, 51.2, 46.7, 45.1.

FTIR (cm^{-1}): 3259, 1699, 1652, 1452, 1396, 1168.

HRMS (ESI) m/z, calculated for $[C_{19}H_{19}N_2O_2Cl_2]^+$: 377.0818; found: 377.0821.



1.145

(**1.145**) According to general protocol D: *N*-phenoxy urea **1.S50** (310.4 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford imidazolidinone **1.145** (159.3 mg, 74%, 92:8 dr) as colorless powder. The following data is of the major diastereomer only.

$_1$H NMR (400 MHz, DMSO-d_6) δ 7.38 – 7.29 (m, 2H), 7.29 – 7.22 (m, 3H), 6.82 (s, 1H), 5.78 (ddd, J = 17.2, 10.3, 7.1 Hz, 1H), 5.21 (dt, J = 17.2, 1.5 Hz, 1H), 5.17 (dt, J = 10.4, 1.4 Hz, 1H), 4.51 (d, J = 15.5 Hz, 1H), 4.04 – 3.92 (m, 2H), 3.57 – 3.47 (m, 1H), 0.93 (d, J = 6.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.2, 138.1, 135.8, 128.5, 127.7, 127.1, 117.0, 55.8, 53.1, 43.9, 13.8.

FTIR (cm^{-1}): 3440, 2057, 1642, 1496, 1425, 1252.

mp = 109-112 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{17}N_2O]^+$: 217.1341; found: 217.1332.

After isolation, the relative stereochemistry of imidazolidinone **1.145** (crude dr = 92:8) was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.60) reveal that the major diastereomer bears the cis configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

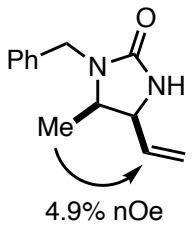
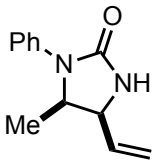


Figure 1.60: nOe Studies of the Diastereomer of Imidazolidinone **1.145**



1.146

(**1.146**) According to general protocol D: *N*-phenoxy urea **1.S51** (296.4 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et_3N (0.26 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford imidazolidinone **1.146** (188.4

mg, 93%, 88:12 dr) as colorless powder. The major diastereomer was separated by Lotus Technologies, and the following data is of the major diastereomer only.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.52 – 7.43 (m, 2H), 7.36 – 7.26 (m, 2H), 7.19 (s, 1H), 7.02 (tt, J = 7.3, 1.1 Hz, 1H), 5.87 (ddd, J = 17.0, 10.3, 6.6 Hz, 1H), 5.33 (dt, J = 17.2, 1.5 Hz, 1H), 5.25 (dt, J = 10.3, 1.4 Hz, 1H), 4.53 (dq, J = 8.3, 6.3 Hz, 1H), 4.31 (ddt, J = 8.1, 6.7, 1.3 Hz, 1H), 0.98 (d, J = 6.4 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 158.4, 139.0, 135.0, 128.6, 122.6, 120.3, 117.6, 55.2, 53.9, 13.7.

FTIR (cm^{-1}): 3237, 1703, 1500, 1402, 760.

mp = 102-105 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{12}H_{15}N_2O]^+$: 203.1179; found: 203.1171.

After isolation, the relative stereochemistry of imidazolidinone **1.146** (crude dr = 88:12) was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.61) reveal that the major diastereomer bears the cis configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

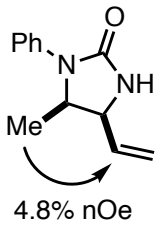
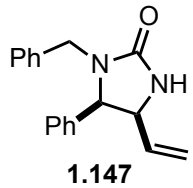


Figure 1.61: nOe Studies of the Diastereomer of Imidazolidinone **1.146**



1.147

(**1.147**) According to general protocol D: *N*-phenoxy urea **1.S52** (371.9 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.1 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.0 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.38 M, 36.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 3:97 EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford imidazolidinone **1.147** (227.9 mg, 82%, 90:10 dr) as colorless powder. The following data is of the major diastereomer only.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.40 – 7.22 (m, 6H), 7.12 – 7.05 (m, 4H), 7.03 (s, 1H), 5.16 (ddd, *J* = 16.8, 10.0, 6.7 Hz, 1H), 5.04 (dd, *J* = 17.4, 2.0 Hz, 1H), 4.89 – 4.82 (m, 1H), 4.75 (d, *J* = 15.2 Hz, 1H), 4.57 (d, *J* = 8.8 Hz, 1H), 4.35 (t, *J* = 7.8 Hz, 1H), 3.48 (d, *J* = 15.3 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 161.4, 137.2, 135.99, 135.95, 128.5, 128.4, 128.0, 127.9, 127.8, 127.2, 116.7, 62.0, 56.7, 44.4.

FTIR (cm-1): 3232, 1697, 1446, 1361, 1244, 703.

mp = 108-112 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for [$C_{18}H_{19}N_2O$]$^+$: 279.1497; found: 279.1489.

After isolation, the relative stereochemistry of imidazolidinone **1.147** (crude dr = 90:10) was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.62) reveal that the major diastereomer bears the cis configuration

as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

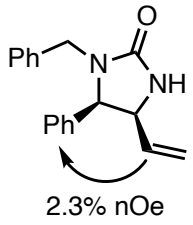
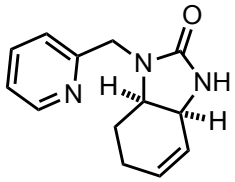


Figure 1.62: nOe Studies of the Diastereomer of Imidazolidinone **1.147**



1.148-allyl

(**1.148-allyl**) According to general protocol D: *N*-phenoxy urea **1.S42** (323.5 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 5 umol), $P(OCH_2CF_3)_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et_3N (0.26 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.148** (227.8 mg, 99%, 60:40 allylic/homoallylic) as colorless solid. The isomers were separated with the same column conditions (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to yield imidazolidinone **1.148-allyl** (135.0 mg, 60%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.54 – 8.46 (m, 1H), 7.77 (td, J = 7.7, 1.8 Hz, 1H), 7.35 – 7.18 (m, 2H), 6.65 (s, 1H), 5.91 – 5.74 (m, 1H), 5.54 – 5.42 (m, 1H), 4.52, 4.14

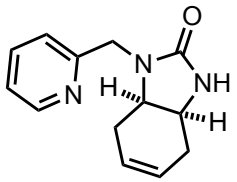
(AB system, J_{AB} = 15.8 Hz, 2H), 3.87 (d, J = 7.6 Hz, 1H), 3.69 (dd, J = 7.7, 4.3 Hz, 1H), 1.96 – 1.69 (m, 3H), 1.64 – 1.45 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.6, 157.8, 149.0, 136.8, 128.6, 126.4, 122.3, 122.0, 53.1, 47.3, 46.0, 21.7, 19.6.

FTIR (cm^{-1}): 3236, 2926, 1694, 1591, 1435, 1260, 755.

mp = 63-66 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}N_3O]^+$: 230.1288; found: 230.1281.



1.148-homoallyl

(**1.148-homoallyl**) According to general protocol D: *N*-phenoxy urea **1.S42** (323.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.148** (227.8 mg, 99%, 60:40 allylic/homoallylic) as colorless solid. The isomers were separated with the same column conditions (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to yield imidazolidinone **1.148-homoallyl** (92.8 mg, 39%) as colorless solid.

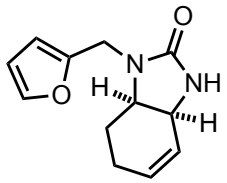
^{1}H NMR (400 MHz, DMSO-d_6) δ 8.50 (ddd, J = 4.8, 1.9, 1.0 Hz, 1H), 7.76 (td, J = 7.7, 1.8 Hz, 1H), 7.36 – 7.15 (m, 2H), 6.56 (s, 1H), 5.94 – 5.81 (m, 1H), 5.80 – 5.68 (m, 1H), 4.46, 4.13 (AB system, J_{AB} = 16.2 Hz, 2H), 3.90 – 3.74 (m, 2H), 2.23 – 1.96 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.1, 158.1, 149.0, 136.8, 127.4, 126.6, 122.3, 121.6, 53.6, 47.9, 46.1, 28.9, 25.1.

FTIR (cm^{-1}): 3243, 2915, 1693, 1435, 1273, 1085.

mp = 87-89 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}N_3O]^+$: 230.1288; found: 230.1282.



1.149

(**1.149**) According to general protocol D: *N*-phenoxy urea **1.S43** (312.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (15 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.44 M, 35.0 µL, 50.0 mmol), and AgOTs (27.9 mg, 0.10 mmol) in anhydrous MeCN (5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.149** (205.5 mg, 94%) as yellow powder.

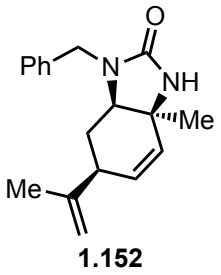
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.63 – 7.56 (m, 1H), 6.64 (s, 1H), 6.39 (dd, J = 3.2, 1.9 Hz, 1H), 6.31 (d, J = 3.2 Hz, 1H), 5.82 (dd, J = 10.2, 4.1 Hz, 1H), 5.46 (dt, J = 10.1, 2.4 Hz, 1H), 4.44, 4.04 (AB system, J_{AB} = 15.8 Hz, 2H), 3.88 – 3.76 (m, 1H), 3.46 (dt, J = 7.4, 3.6 Hz, 1H), 1.97 – 1.74 (m, 3H), 1.68 – 1.53 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 161.3, 151.2, 142.6, 128.6, 126.4, 110.4, 108.2, 52.9, 47.1, 37.2, 21.7, 19.4.

FTIR (cm^{-1}): 3235, 1696, 1432, 1258, 704.

mp = 95-97 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{15}N_2O_2]^+$: 219.1134; found: 219.1124.



1.152

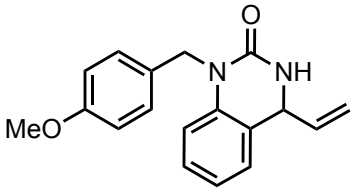
(**1.152**) According to general protocol D: *N*-phenoxy urea **1.S53** (1.13 g, 3.00 mmol), $[(cinnamyl)PdCl]_2$ (39.0 mg, 75 umol), $P(OCH_2CF_3)_3$ (33.1 μL, 0.15 mmol), anhydrous MeCN (45 mL), and anhydrous Et_3N (0.83 mL, 6.0 mmol) were combined under N_2, followed by PhMgBr (0.99 M, 151.0 μL, 150.0 umol), and AgOTs (83.7 mg, 0.30 mmol) in anhydrous MeCN (15 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 12:88 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.152** (828.8 mg, 98%, contains 8% diene isomer) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.41 – 7.31 (m, 2H), 7.31 – 7.21 (m, 3H), 6.68 (s, 1H), 5.63 (dd, J = 10.0, 1.9 Hz, 1H), 5.58 (dd, J = 10.0, 2.3 Hz, 1H), 4.77 (t, J = 1.9 Hz, 1H), 4.69 (s, 1H), 4.61, 3.91 (AB system, J_{AB} = 15.5 Hz, 2H), 3.14 (dd, J = 10.2, 4.4 Hz, 1H), 2.63 – 2.57 (m, 1H), 1.93 (dt, J = 12.5, 4.5 Hz, 1H), 1.70 (s, 3H), 1.28 (dt, J = 12.5, 10.1 Hz, 1H), 1.13 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 158.8, 147.4, 138.3, 130.7, 129.5, 128.5, 127.6, 127.1, 110.9, 59.0, 52.2, 43.1, 39.4, 28.9, 27.8, 20.6.

FTIR (cm^{-1}): 3229, 2966, 1694, 1444, 1236, 702.

HRMS (ESI) m/z, calculated for $[C_{18}H_{23}N_2O]^+$: 282.1732; found: 282.1802.



1.160

(**1.160**) According to general protocol D: *N*-phenoxy urea **1.159** (389.1 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (26.0 mg, 50.0 umol), $P(OCH_2CF_3)_3$ (22.1 μL, 100 umol), anhydrous MeCN (10 mL), and anhydrous Et_3N (0.28

mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (0.99 M, 101.0 µL, 100.0 umol), and AgOTs (55.8 mg, 0.20 mmol) in anhydrous MeCN (10 mL). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 60:40 EtOAc:hexanes) to afford imidazolidinone **1.160** (80.9 mg, 27%) as brown solid.

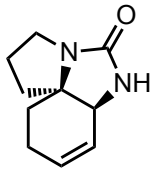
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.56 (d, J = 2.8 Hz, 1H), 7.16 (td, J = 7.1, 1.7 Hz, 3H), 7.13 – 7.06 (m, 1H), 6.92 (t, J = 7.4 Hz, 1H), 6.87 – 6.81 (m, 2H), 6.77 (d, J = 8.2 Hz, 1H), 5.89 (ddd, J = 17.0, 10.1, 5.6 Hz, 1H), 5.24 – 4.83 (m, 5H), 3.69 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 158.1, 154.2, 139.9, 137.2, 129.7, 127.9, 127.7, 126.5, 122.6, 121.6, 114.1, 113.91, 113.88, 55.0, 54.6, 43.6.

FTIR (cm^{-1}): 3402, 1672, 1512, 1410, 1247, 751.

mp = 123-125 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{19}N_2O_2]^+$: 295.1447; found: 295.1440.



1.164

(**1.164**) According to general protocol D: *N*-phenoxy urea **1.163** (406.1 mg, 1.50 mmol), [(cinnamyl)PdCl]$_2$ (19.6 mg, 38 umol), P(OCH$_2$CF$_3$)$_3$ (16.5 µL, 75.0 umol), anhydrous MeCN (22.5 mL), and anhydrous Et$_3$N (0.42 mL, 3.0 mmol) were combined under N_2, followed by PhMgBr (0.99 M, 76.0 µL, 75.0 umol), and AgOTs (41.9 mg, 0.15 mmol) in anhydrous MeCN (7.5 mL). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.164** (248.5 mg, 93%) as colorless powder.

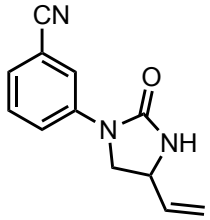
^{1}H NMR (400 MHz, DMSO-d_6) δ 6.91 (s, 1H), 5.83 (ddd, J = 10.0, 5.6, 2.1 Hz, 1H), 5.56 (dt, J = 10.1, 2.4 Hz, 2H), 3.77 (s, 1H), 3.49 (ddd, J = 11.8, 9.1, 5.3 Hz, 1H), 2.81 (ddd, J = 11.9, 9.0, 5.8 Hz, 1H), 2.10 – 1.95 (m, 1H), 1.91 – 1.68 (m, 4H), 1.68 – 1.50 (m, 2H), 1.42 (ddd, J = 13.9, 11.3, 5.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 164.5, 128.4, 128.1, 66.4, 51.5, 43.5, 34.5, 28.0, 23.2, 21.1.

FTIR (cm^{-1}): 3246, 2928, 1698, 1385, 1090, 800.

mp = 187-188 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{10}H_{15}N_2O]^+$: 179.1184; found: 179.1179.



1.173

(**1.173**) According to general protocol D: *N*-phenoxy urea **1.172** (2.00 g, 6.50 mmol), [(cinnamyl)PdCl]$_2$ (84.2 mg, 0.16 mmol), P(OCH$_2$CF$_3$)$_3$ (71.8 µL, 0.330 mmol), anhydrous MeCN (130 mL), and anhydrous Et$_3$N (1.8 mL, 13 mmol) were combined under N$_2$, followed by addition of PhMgBr (1.09 M, 0.30 mL, 0.33 mmol), and AgOTs (181.6 mg, 0.650 mmol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 80:20 EtOAc:hexanes) to afford imidazolidinone **1.173** (1.13 g, 81%) as yellowish solid.

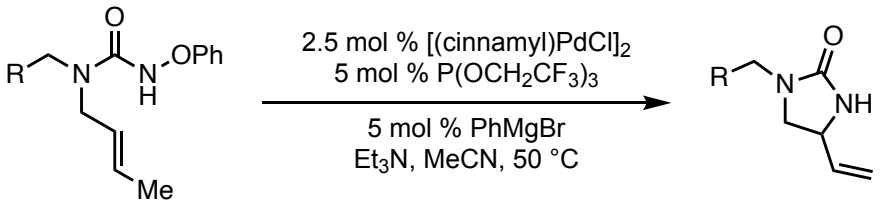
^{1}H NMR (400 MHz, DMSO-d_6) δ 8.00 (t, J = 1.9 Hz, 1H), 7.86 (ddd, J = 8.5, 2.4, 1.1 Hz, 1H), 7.65 (s, 1H), 7.55 – 7.47 (m, 1H), 7.42 (dt, J = 7.6, 1.3 Hz, 1H), 5.90 (ddd, J = 17.0, 10.2, 6.6 Hz, 1H), 5.31 (dt, J = 17.1, 1.3 Hz, 1H), 5.18 (dt, J = 10.2, 1.2 Hz, 1H), 4.35 – 4.24 (m, 1H), 4.06 (t, J = 9.3 Hz, 1H), 3.56 (dd, J = 9.5, 6.3 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 157.9, 141.2, 138.3, 130.0, 124.9, 121.3, 119.6, 119.0, 116.6, 111.5, 50.6, 49.6.

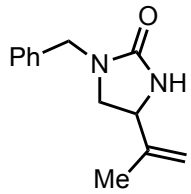
FTIR (cm^{-1}): 3227, 2227, 1707, 1444, 1258, 786.

mp = 150-152 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{12}H_{12}N_3O]^+$: 214.0975; found: 214.0971.



General Protocol E: A Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $[(cinnamyl)PdCl]_2$ (0.025 equiv) and *N*-phenoxy urea (1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (0.05 equiv), anhydrous MeCN (0.05 M with respect to the *N*-phenoxy urea), and anhydrous Et_3N (2.00 equiv) were added sequentially to the flask via syringe. PhMgBr (0.05 equiv) was then added with stirring, and the resulting suspension was placed in a pre-heated oil bath, and stirred at the indicated temperature for 24 h. Upon completion, the reaction was cooled to rt, opened to air, and then diluted with EtOAc (10 mL). The suspension was transferred to a round bottom flask, and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed on silica gel (5-20 μm particle size) to yield the desired product.



1.136

(**1.136**) According to general protocol E: *N*-phenoxy urea **1.S35** (315.4 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.136** (199.6 mg, 92%) as colorless powder.

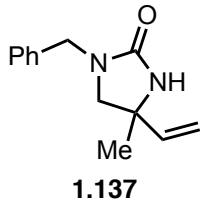
^{1}H NMR (400 MHz, DMSO-*d6*) δ 7.37 – 7.29 (m, 2H), 7.29 – 7.17 (m, 3H), 6.85 (s, 1H), 4.92 (dt, *J* = 2.0, 1.0 Hz, 1H), 4.79 (t, *J* = 1.8 Hz, 1H), 4.24 (s, 2H), 4.07 (t, *J* = 8.1 Hz, 1H), 3.41 (t, *J* = 9.0 Hz, 1H), 2.86 (dd, *J* = 8.8, 6.9 Hz, 1H), 1.62 (t, *J* = 1.1 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-*d6*) δ 161.2, 144.9, 137.7, 128.5, 127.6, 127.2, 111.0, 53.9, 48.8, 46.5, 17.6.

FTIR (cm^{-1}): 3236, 1696, 1493, 1457, 1442, 1245.

mp = 100-101 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for [$C_{13}H_{17}N_2O$]$^+$: 217.1335; found: 217.1334.



1.137

(**1.137**) According to general protocol E: *N*-phenoxy urea **1.S36** (312.9 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.09 M, 46.0 µL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and

purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.137** (130.7 mg, 65%) as colorless powder.

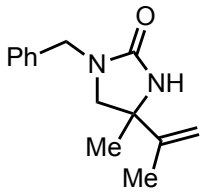
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.40 – 7.30 (m, 2H), 7.29 – 7.23 (m, 1H), 7.23 – 7.17 (m, 2H), 6.90 (s, 1H), 5.88 (dd, J = 17.3, 10.5 Hz, 1H), 5.15 (dd, J = 17.3, 1.3 Hz, 1H), 5.03 (dd, J = 10.6, 1.2 Hz, 1H), 4.23 (s, 2H), 3.02, 2.99 (AB system, J_{AB} = 8.7 Hz, 2H), 1.23 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 143.0, 137.8, 128.5, 127.5, 127.1, 112.4, 55.9, 55.1, 46.3, 25.9.

FTIR (cm^{-1}): 3224, 1696, 1490, 1446, 1293.

mp = 97-100 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{17}N_2O]^+$: 217.1335; found: 217.1334.



1.138

(**1.138**) According to general protocol E: *N*-phenoxy urea **1.S37** (322.1 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.138** (143.7 mg, 62%) as colorless powder.

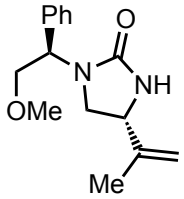
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.39 – 7.30 (m, 2H), 7.31 – 7.21 (m, 1H), 7.25 – 7.15 (m, 2H), 6.93 (s, 1H), 4.89 (s, 1H), 4.76 (t, J = 1.5 Hz, 1H), 4.27, 4.21 (AB system, J_{AB} = 8.8 Hz, 2H), 3.04, 3.00 (AB system, J_{AB} = 8.8 Hz, 2H), 1.65 (s, 3H), 1.26 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.2, 148.2, 137.9, 128.5, 127.5, 127.1, 109.9, 57.4, 55.0, 46.3, 26.0, 18.7.

FTIR (cm^{-1}): 3223, 1697, 1495, 1447, 1296, 701.

mp = 88-90 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{19}N_2O]^+$: 231.1497; found: 231.1488.



1.144-*trans*

(**1.144-*trans***) According to general protocol E: *N*-phenoxy urea **1.S49** (355.2 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.0 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.144** (253.0 mg, 97%, 50:50 dr) as viscous yellow oil. The isomers were separated with the same column conditions (linear gradient, 17:83 EtOAc:hexanes to 70:30 EtOAc:hexanes) to yield imidazolidinone **1.144-*trans*** (125.7 mg, 48%) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.48 – 7.12 (m, 5H), 6.73 (s, 1H), 5.02 (dd, J = 8.8, 5.7 Hz, 1H), 4.92 (dt, J = 2.0, 1.0 Hz, 1H), 4.79 (t, J = 1.8 Hz, 1H), 4.07 (t, J = 8.1 Hz, 1H), 3.82 – 3.64 (m, 2H), 3.37 (t, J = 9.0 Hz, 1H), 3.28 (s, 3H), 3.08 (dd, J = 8.7, 6.9 Hz, 1H), 1.67 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6, 144.5, 137.6, 128.8, 127.8, 127.7, 112.4, 71.7, 58.9, 55.4, 53.9, 46.7, 17.4.

FTIR (cm^{-1}): 3228, 2875, 1693, 1433, 1254, 1113.

HRMS (ESI) m/z, calculated for $[C_{15}H_{21}N_2O_2]^+$: 261.1603; found: 261.1603.

After isolation, the relative stereochemistry of imidazolidinone **1.144-*trans*** was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.63) reveal that the major diastereomer bears the cis configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

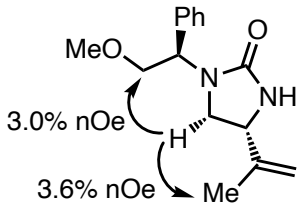
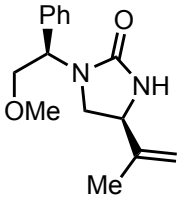


Figure 1.63: nOe Studies of the Stereochemistry of Imidazolidinone **1.144-*trans***



1.144-*cis*

(**1.144-*cis***) According to general protocol E: *N*-phenoxy urea **1.S49** (355.2 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.0 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.28 mL, 2.0 mmol) were combined under N_2, and followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 17:83 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford imidazolidinone **1.144** (253.0 mg, 97%, 50:50 dr) as viscous yellow oil. The isomers were separated with the same column conditions (linear

gradient, 17:83 EtOAc:hexanes to 70:30 EtOAc:hexanes) to yield imidazolidinone **1.144-*cis*** (127.3 mg, 49%) as viscous yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.40 – 7.29 (m, 2H), 7.29 – 7.22 (m, 3H), 6.77 (s, 1H), 5.02 (dd, J = 8.5, 5.8 Hz, 1H), 4.87 (s, 1H), 4.75 (d, J = 1.8 Hz, 1H), 4.06 (dd, J = 9.1, 7.0 Hz, 1H), 3.80 (dd, J = 10.3, 8.5 Hz, 1H), 3.72 (dd, J = 10.3, 5.9 Hz, 1H), 3.58 (t, J = 9.1 Hz, 1H), 3.30 (s, 3H), 2.76 (dd, J = 8.8, 6.7 Hz, 1H), 1.52 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6, 144.3, 137.3, 128.7, 127.8, 127.7, 112.2, 71.9, 59.0, 55.3, 53.8, 46.5, 17.6.

FTIR (cm^{-1}): 3428, 1653, 1489, 1436, 1257, 1111, 700.

HRMS (ESI) m/z, calculated for $[C_{15}H_{21}N_2O_2]^+$: 261.1603; found: 261.1599.

After isolation, the relative stereochemistry of imidazolidinone **1.144-*cis*** was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.64) reveal that the major diastereomer bears the cis configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

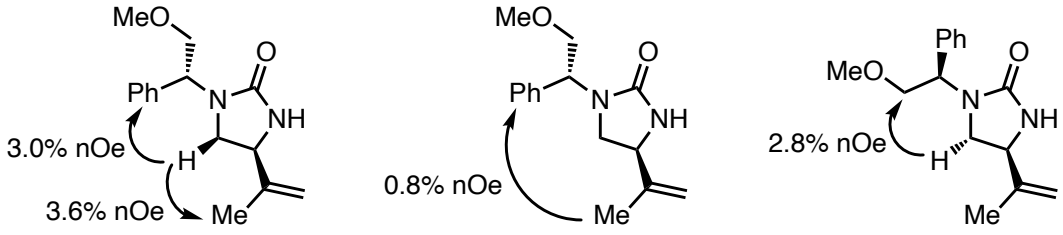
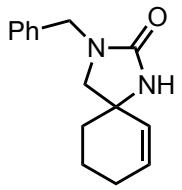


Figure 1.64: nOe Studies of the Stereochemistry of Imidazolidinone **1.144-*cis***



1.150-allyl

(**1.150-allyl**) According to general protocol E: *N*-phenoxy urea **1.S44** (336.2 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 mmol), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.28 mL, 2.0 mmol) were combined under N_2, followed by addition of PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford imidazolidinone **1.150** (183.6 mg, 76%, 57:43 allylic/homoallylic) as colorless powder. The isomers were separated with the same column conditions (linear gradient, 10:90 EtOAc:hexanes to 40:60 EtOAc:hexanes) to yield imidazolidinone **1.150-allyl** (103.1 mg, 43%) as colorless solid.

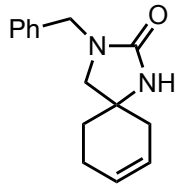
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.35 (t, J = 7.4 Hz, 2H), 7.30 – 7.19 (m, 3H), 6.85 (s, 1H), 5.74 (dt, J = 10.1, 3.7 Hz, 1H), 5.51 (d, J = 10.0 Hz, 1H), 4.23 (d, J = 2.9 Hz, 2H), 3.03, 2.96 (AB system, J_{AB} = 15.8 Hz, 2H), 2.05 – 1.77 (m, 2H), 1.77 – 1.57 (m, 3H), 1.56 – 1.40 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 137.9, 131.7, 129.4, 128.6, 127.5, 127.1, 55.7, 52.7, 46.3, 35.0, 24.2, 19.1.

FTIR (cm^{-1}): 3439, 2932, 1646, 1489, 699.

mp = 151-153 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{19}N_2O]^+$: 243.1497; found: 243.1497.



1.150-homoallyl

(**1.150-homoallyl**) According to general protocol E: *N*-phenoxy urea **1.S44** (336.2 mg, 1.00 mmol), $[(\text{cinnamyl})PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 mmol), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.28 mL, 2.0 mmol) were combined under N_2, followed by addition of PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford imidazolidinone **1.150** (183.6 mg, 76%, 57:43 allylic/homoallylic) as colorless powder. The isomers were separated with the same column conditions (linear gradient, 10:90 EtOAc:hexanes to 40:60 EtOAc:hexanes) to yield imidazolidinone **1.150-homoallyl** (80.5 mg, 33%) as colorless solid.

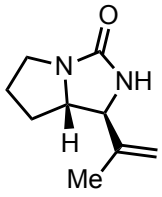
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.38 – 7.30 (m, 2H), 7.30 – 7.19 (m, 3H), 6.73 (s, 1H), 5.64 – 5.56 (m, 1H), 5.56 – 5.46 (m, 1H), 4.27, 4.19 (AB system, J_{AB} = 15.2 Hz, 2H), 2.98, 2.89 (AB system, J_{AB} = 8.7 Hz, 2H), 2.27 – 1.92 (m, 4H), 1.70 – 1.50 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.2, 138.0, 128.6, 127.6, 127.1, 126.6, 124.3, 54.5, 52.2, 46.4, 37.2, 32.7, 22.5.

FTIR (cm^{-1}): 3440, 1695, 1636, 1491, 1454.

mp = 142-144 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{19}N_2O]^+$: 243.1497; found: 243.1485.



1.151

(**1.151**) According to general protocol D: *N*-phenoxy urea **1.S45** (260.2 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by addition of PhMgBr (1.44 M, 34.7 µL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.151** (148.0 mg, 89%) as colorless powder.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.02 (s, 1H), 4.93 (s, 1H), 4.79 (t, *J* = 1.8 Hz, 1H), 3.88 – 3.84 (m, 1H), 3.41 – 3.35 (m, 1H), 3.33 – 3.27 (m, 1H), 2.81 (ddd, *J* = 11.1, 8.7, 4.7 Hz, 1H), 2.00 – 1.90 (m, 1H), 1.78 (ddt, *J* = 12.5, 8.3, 4.1 Hz, 1H), 1.74 – 1.63 (m, 4H), 1.35 (dq, *J* = 12.0, 9.1 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 164.4, 145.8, 110.7, 63.8, 60.3, 44.8, 30.8, 24.5, 17.5.

FTIR (cm^{-1}): 3235, 2967, 1699, 1404, 1251, 898.

mp = 83-87 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_9H_{15}N_2O]^+$: 167.1179; found: 167.1180.

After isolation, the relative stereochemistry of imidazolidinone **1.151** was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 1.65) reveal that the major diastereomer bears the trans configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

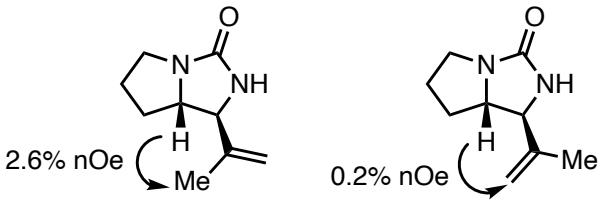
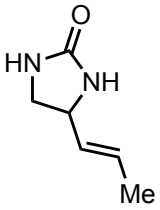


Figure 1.65: nOe Studies of the Diastereomer of Imidazolidinone **1.151**



1.153

(**1.153**) According to general protocol E: *N*-phenoxy urea **1.S58** (219.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.09 M, 46.0 μL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.153** (92.9 mg, 74%) as colorless powder.

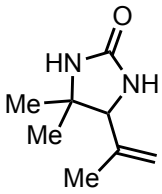
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 6.42 (s, 1H), 6.13 (s, 1H), 5.59 (dq, *J* = 15.1, 6.3 Hz, 1H), 5.42 (ddd, *J* = 15.2, 7.3, 1.5 Hz, 1H), 4.06 (q, *J* = 7.7 Hz, 1H), 3.38 (t, *J* = 8.7 Hz, 1H), 2.91 (ddd, *J* = 8.8, 7.4, 1.4 Hz, 1H), 1.64 (dd, *J* = 6.4, 1.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 163.3, 132.2, 126.4, 54.1, 46.3, 17.4.

FTIR (cm^{-1}): 3213, 1706, 1488, 1448, 1247, 966.

mp = 114-116 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_6H_{11}N_2O]^+$: 127.0866; found: 127.0867.



1.154

(**1.154**) According to general protocol E: *N*-phenoxy urea **1.S54** (248.3 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.1 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.0 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.154** (152.3 mg, 99%) as colorless powder.

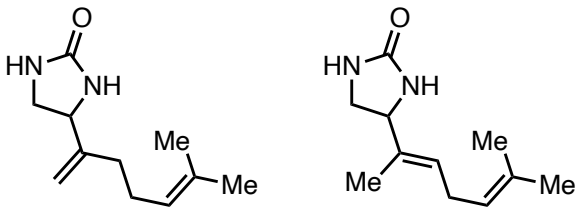
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 6.38 (s, 1H), 6.28 (s, 1H), 4.95 (s, 1H), 4.90 (s, 1H), 3.71 (s, 1H), 1.69 (s, 3H), 1.24 (s, 3H), 0.92 (s, 3H).

13C NMR (101 MHz, DMSO-*d*$_6$) δ 161.4, 142.8, 112.5, 66.8, 56.6, 29.2, 23.2, 20.2.

FTIR (cm^{-1}): 3203, 2969, 1706, 1443, 1207.

mp = 168-170 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for [$C_8H_{15}N_2O$]$^+$: 155.1184; found: 155.1176.



1.155-terminal 67:33 **1.155-internal**

(**1.155**) According to general protocol E: *N*-phenoxy urea **1.S46** (288.4 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.09 M, 46.0 μL, 50.0 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography

(linear gradient, 25:75 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.155** (173.0 mg, 89%, 67:33 terminal/internal) as brownish powder.

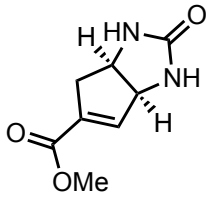
Terminal: ^{1}H NMR (600 MHz, DMSO-d_6) δ 6.46 (s, 1H), 6.12 (s, 1H), 5.10 (ddt, J = 7.1, 5.6, 1.5 Hz, 1H), 4.98 (s, 1H), 4.80 (s, 1H), 4.13 (t, J = 8.1 Hz, 1H), 3.47 (td, J = 8.9, 1.0 Hz, 1H), 2.67 (t, J = 7.3 Hz, 1H), 2.10 (q, J = 7.5 Hz, 2H), 1.96 (dt, J = 15.9, 7.7 Hz, 2H), 1.64 (s, 3H), 1.57 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6) δ 163.3, 149.1, 131.1, 124.1, 109.1, 56.4, 45.5, 31.1, 25.8, 25.5, 17.7.

Internal: ^{1}H NMR (600 MHz, DMSO-d_6) δ 6.35 (s, 1H), 6.08 (s, 1H), 5.32 – 5.25 (m, 1H), 5.05 (dt, J = 7.2, 1.5 Hz, 1H), 4.07 (t, J = 8.2 Hz, 1H), 3.42 – 3.36 (m, 1H), 2.99 – 2.88 (m, 3H), 1.64 (s, 3H), 1.59 (s, 3H), 1.57 (s, 3H); ^{13}C NMR (101 MHz, DMSO-d_6) δ 163.4, 134.6, 131.2, 123.9, 122.6, 58.4, 44.9, 26.3, 25.5, 17.7, 11.6.

FTIR (cm^{-1}): 3240, 1704, 1492, 1450, 1255.

mp = 67-69 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{11}H_{19}N_2O]^+$: 195.1492; found: 195.1492.



1.156

(**1.156**) According to general protocol E: *N*-phenoxy urea **1.S55** (276.0 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (26.0 mg, 50 umol), P(OCH$_2$CF$_3$)$_3$ (22.0 µL, 100 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.28 mL, 2.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.38 M, 73.0 µL, 100 umol). The reaction was stirred at 50 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, EtOAc to 5:95 MeOH:EtOAc) to afford imidazolidinone **1.156** (151.9 mg, 83%) as colorless powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 6.55 (s, 1H), 6.52 (s, 1H), 6.46 (q, J = 1.9 Hz, 1H), 4.62 (d, J = 7.7 Hz, 1H), 4.30 (ddt, J = 7.8, 6.4, 1.3 Hz, 1H), 3.69 (s, 3H), 2.74 (dddd, J = 16.9, 6.3, 2.6, 1.3 Hz, 1H), 2.41 (dq, J = 16.9, 1.5 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 164.9, 161.8, 141.2, 135.0, 61.7, 53.9, 51.8, 39.4.

FTIR (cm^{-1}): 3419, 1684, 1440, 1288, 1215, 748.

mp = 187-188 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_8H_{11}N_2O_3]^+$: 183.0770; found: 183.0763.

A small sample of **1.156** was dissolved in MeOH under air and recrystallized via slow vapor diffusion of hexanes at rt to give an X-ray quality crystal (Figure 1.66, see below for full crystallographic details).

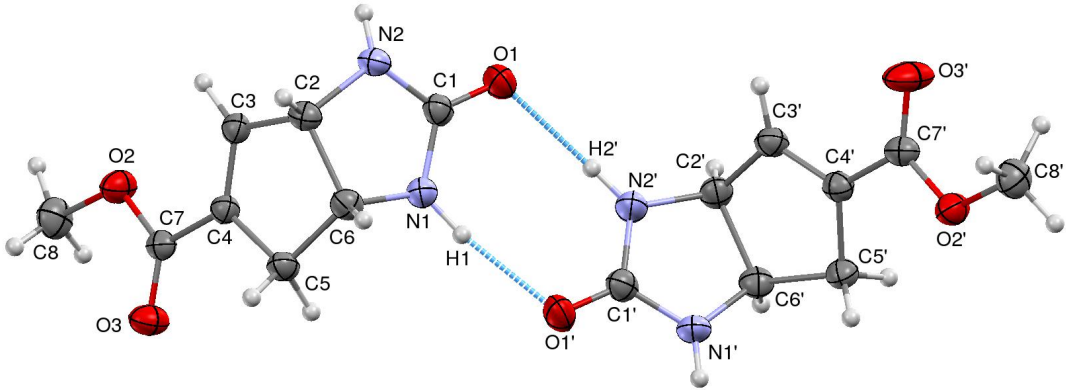


Figure 1.66: Crystal Structure of Imidazolidinone **1.156**

Note: The structure and stereochemistry of product **1.156** compared to that of starting material **1.S55** is consistent with anti-β-hydride elimination (Figure 1.67).[87-88] Such events are rare, but have been observed in other Heck-type reactions, and maybe assisted

by the increased acidity of the hydrogen atom in the starting material due to the adjacent ester.

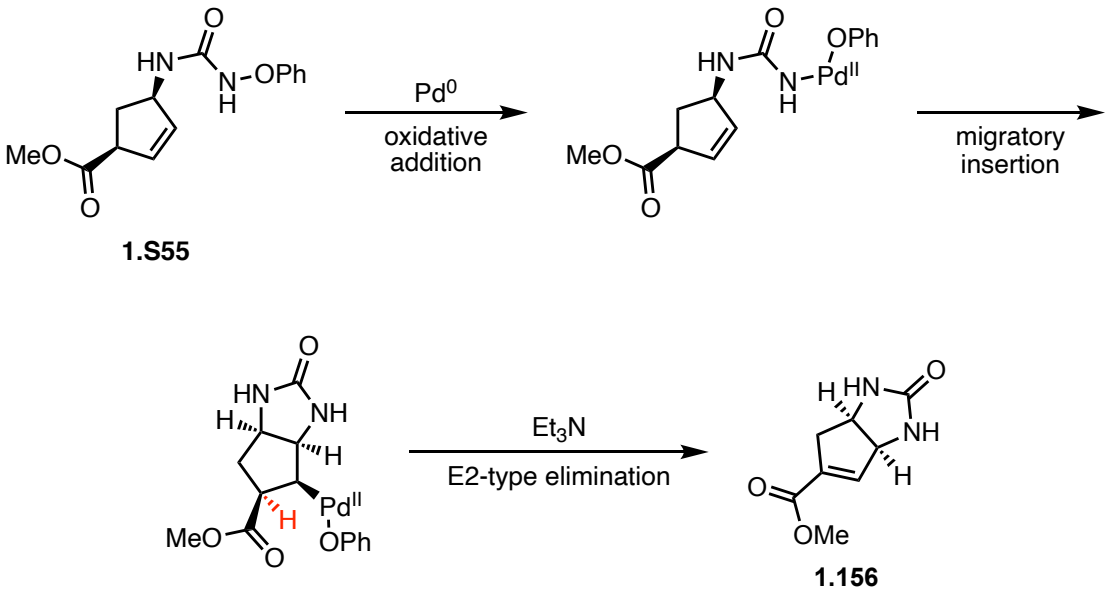
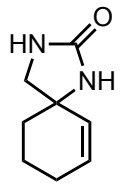


Figure 1.67: E2-type Elimination of **1.S55** to Yield **1.156**



1.157-allyl

(**1.157-allyl**) According to general protocol E: *N*-phenoxy urea **1.S59** (249.3 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.26 mL, 2.0 mmol) were combined under N_2, followed by addition of PhMgBr (1.44 M, 35.0 µL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.157** (113.6 mg, 75%, 60:40 allylic/homoallylic) as colorless powder. The isomers were separated with the same column conditions (linear gradient, 10:90

EtOAc:hexanes to EtOAc) to yield imidazolidinone **1.157-allyl** (67.9 mg, 45%) as colorless solid.

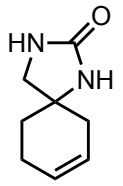
^{1}H NMR (400 MHz, DMSO-d_6) δ 6.51 (s, 1H), 6.13 (s, 1H), 5.74 (dt, J = 10.0, 3.7 Hz, 1H), 5.56 (dt, J = 10.0, 2.2 Hz, 1H), 3.06 (qd, J = 8.9, 1.2 Hz, 2H), 1.97 – 1.82 (m, 2H), 1.74 – 1.48 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 162.4, 132.1, 128.9, 55.4, 51.7, 34.8, 24.3, 19.1.

FTIR (cm^{-1}): 3202, 2926, 1707, 1487, 1299.

mp = 152-155 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_8H_{13}N_2O]^+$: 153.1022; found: 153.1019.



1.157-homoallyl

(**1.157-homoallyl**) According to general protocol E: *N*-phenoxy urea **1.S59** (249.3 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (11.1 µL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Et$_3$N (0.26 mL, 2.0 mmol) were combined under N$_2$, followed by addition of PhMgBr (1.44 M, 35.0 µL, 50.0 umol). The reaction was stirred at 80 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.157** (113.6 mg, 75%, 60:40 allylic/homoallylic) as colorless powder. The isomers were separated with the same column conditions (linear gradient, 10:90 EtOAc:hexanes to EtOAc) to yield imidazolidinone **1.157-homoallyl** (45.7 mg, 30%) as colorless solid.

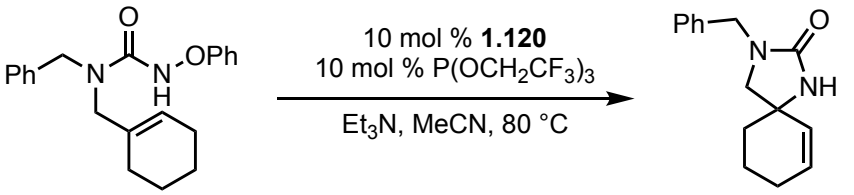
^{1}H NMR (400 MHz, DMSO-d_6) δ 6.39 (s, 1H), 6.11 (s, 1H), 5.67 – 5.58 (m, 1H), 5.58 – 5.50 (m, 1H), 3.07, 2.96 (AB system, J_{AB} = 8.7 Hz, 2H), 2.24 – 1.99 (m, 4H), 1.60 (t, J = 6.4 Hz, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 162.2, 126.6, 124.5, 54.9, 50.6, 37.1, 32.7, 22.6.

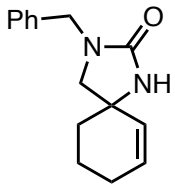
FTIR (cm^{-1}): 3213, 2926, 1703, 1491, 1439.

mp = 141-144 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_8H_{13}N_2O]^+$: 153.1022; found: 153.1018.



1.S44 **1.150-allyl**, 79%



1.150-allyl

(**1.150-allyl**) A 25 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. *N*-phenoxy urea **1.S44** (336.7 mg, 1.00 mmol, 1.00 equiv), **1.120** (39.2 mg, 0.10 mmol, 0.10 equiv), were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (22.0 μL, 0.100 mmol, 0.100 equiv), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.28 mL, 2.0 mmol, 2.0 equiv) were added sequentially to the flask via syringe. The reaction was stirred at 80 °C for 24 hours. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford imidazolidinone **1.150-allyl** (192.3 mg, 79%) as colorless powder.

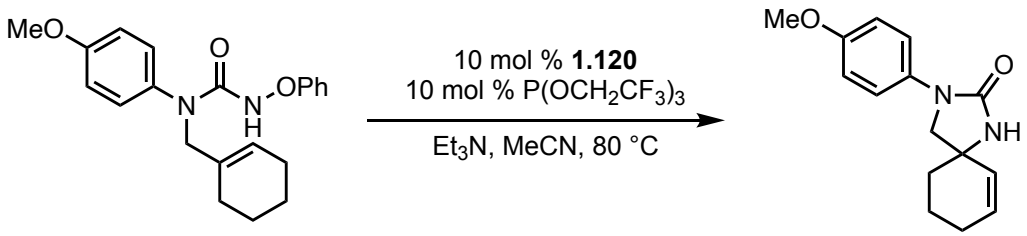
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.35 (t, J = 7.4 Hz, 2H), 7.30 – 7.19 (m, 3H), 6.85 (s, 1H), 5.74 (dt, J = 10.1, 3.7 Hz, 1H), 5.51 (d, J = 10.0 Hz, 1H), 4.23 (d, J = 2.9 Hz, 2H), 3.03, 2.96 (AB system, J_{AB} = 15.8 Hz, 2H), 2.05 – 1.77 (m, 2H), 1.77 – 1.57 (m, 3H), 1.56 – 1.40 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 160.4, 137.9, 131.7, 129.4, 128.6, 127.5, 127.1, 55.7, 52.7, 46.3, 35.0, 24.2, 19.1.

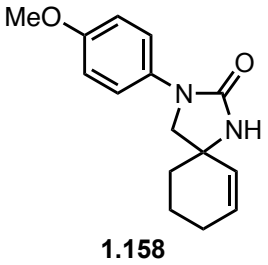
FTIR (cm^{-1}): 3439, 2932, 1646, 1489, 699.

mp = 151-153 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{19}N_2O]^+$: 243.1497; found: 243.1497.



1.S56 **1.158**, 71%



1.158

(**1.158**) A 25 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. *N*-phenoxy urea **1.S56** (351.9 mg, 1.00 mmol, 1.00 equiv), **1.120** (39.2 mg, 0.10 mmol, 0.10 equiv), were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (22.0 μL, 0.100 mmol, 0.100 equiv), anhydrous MeCN (20 mL), and anhydrous Et_3N (0.28 mL, 2.0 mmol, 2.0 equiv) were added sequentially to the flask via syringe. The reaction was stirred at 80 °C for 24 hours. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 12:88 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford imidazolidinone **1.158** (183.7 mg, 71%) as brown powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.51 – 7.40 (m, 2H), 7.22 (s, 1H), 6.93 – 6.79 (m, 2H), 5.83 (dt, J = 10.0, 3.7 Hz, 1H), 5.62 (dt, J = 9.9, 2.1 Hz, 1H), 3.71 (s, 3H), 3.62, 3.56 (AB system, J_{AB} = 9.3 Hz, 2H), 2.02 – 1.88 (m, 2H), 1.86 – 1.54 (m, 4H).

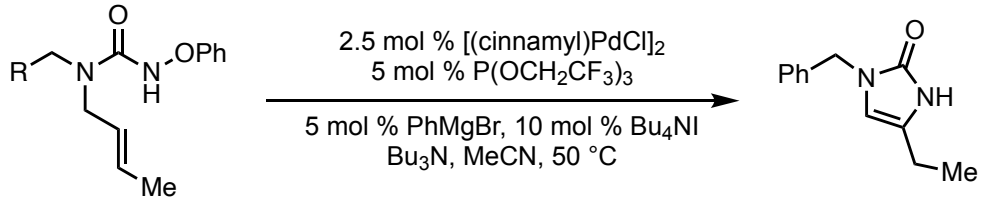
^{13}C NMR (101 MHz, DMSO-d_6) δ 157.6, 154.2, 134.0, 131.5, 129.9, 118.7, 113.8, 56.2, 55.2, 52.0, 35.2, 24.2, 19.0.

FTIR (cm^{-1}): 3450, 1646, 1513, 1409, 1245.

mp = 149-152 °C (CH_2Cl_2).

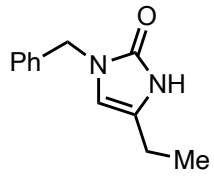
HRMS (ESI) m/z, calculated for $[C_{15}H_{19}N_2O_2]^+$: 259.1447; found: 259.1436.

1.12.6 Synthesis of Dihydroimidazolones



General Protocol F: A Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $[(cinnamyl)PdCl]_2$ (0.025 equiv), Bu_4NI (0.10 equiv), and *N*-phenoxy urea (1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (0.05 equiv), anhydrous MeCN (0.05 M with respect to the *N*-phenoxy urea), and anhydrous Bu_3N (2.00 equiv) were added sequentially to the flask via syringe. PhMgBr (0.05 equiv) was then added with stirring, and the resulting suspension was placed in a pre-heated oil bath, and stirred at 50 °C for 24 h. Upon completion, the reaction was cooled to rt, opened to air, and then diluted with EtOAc (10 mL). The suspension was transferred to a round bottom flask, and adsorbed

onto Celite via rotary evaporation. The resulting powder was directly chromatographed on silica gel (5-20 μm particle size) to yield the desired product.



1.122

(**1.122**) According to general protocol F: *N*-phenoxy urea **1.119** (295.9 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), Bu_4NI (36.8 mg, 0.10 mmol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.38 M, 36.0 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:6:93 AcOH:EtOAc:hexanes to 1:49:50 AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.122** (161.8 mg, 80%) as yellowish powder.

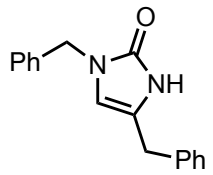
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.01 (s, 1H), 7.37 – 7.29 (m, 2H), 7.29 – 7.25 (m, 1H), 7.25 – 7.19 (m, 2H), 6.08 (dt, J = 2.4, 1.3 Hz, 1H), 4.61 (s, 2H), 2.24 (qd, J = 7.5, 1.3 Hz, 2H), 1.04 (t, J = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.6, 138.5, 128.5, 127.4, 127.2, 122.8, 106.0, 45.4, 18.5, 12.3.

FTIR (cm^{-1}): 3142, 1677, 1453, 1422, 1166, 705.

mp = 122-124 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{15}N_2O]^+$: 203.1184; found: 203.1187.



1.167

(**1.167**) According to general protocol F: *N*-phenoxy urea **1.S47** (359.1 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), Bu_4NI (36.8 mg, 0.10 mmol), $P(OCH_2CF_3)_3$ (11.1 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.38 M, 36.0 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:9:90 AcOH:EtOAc:hexanes to 1:39:60 AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.167** (233.1 mg, 88%) as yellowish powder.

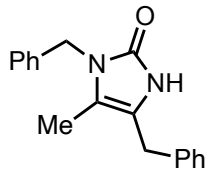
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.10 (s, 1H), 7.36 – 7.25 (m, 5H), 7.24 – 7.15 (m, 5H), 6.07 (dd, J = 2.3, 1.1 Hz, 1H), 4.62 (s, 2H), 3.57 (s, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.6, 138.5, 138.4, 128.53, 128.48, 128.4, 127.4, 127.2, 126.4, 120.3, 107.8, 45.4, 31.3.

FTIR (cm^{-1}): 3221, 1678, 1496, 1453, 1360, 701.

mp = 62-64 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{17}N_2O]^+$: 265.1335; found: 265.1333.



1.168

(**1.168**) According to general protocol F: *N*-phenoxy urea **1.S57** (371.9 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), Bu_4NI (37.1 mg, 0.10 mmol), $P(OCH_2CF_3)_3$ (11.0 μL, 50.0 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (0.99 M, 50.5 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:6:93 AcOH:EtOAc:hexanes to 1:59:40

AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.168** (210.7 mg, 76%) as colorless powder.

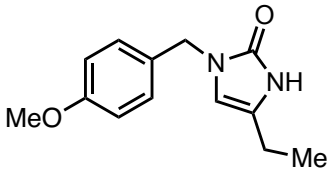
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.92 (s, 1H), 7.36 – 7.22 (m, 5H), 7.22 – 7.12 (m, 5H), 4.71 (s, 2H), 3.60 (s, 2H), 1.89 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.5, 139.5, 138.8, 128.6, 128.4, 128.1, 127.1, 126.7, 126.2, 114.6, 114.2, 43.1, 29.5, 8.4.

FTIR (cm^{-1}): 3440, 2083, 1641, 1111, 618.

mp = 154-156 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{19}N_2O]^+$: 279.1497; found: 279.1491.



1.169

(**1.169**) According to general protocol F: *N*-phenoxy urea **1.S29** (326.3 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (26.0 mg, 50.0 umol), Bu_4NI (74.0 mg, 0.20 mmol), $P(OCH_2CF_3)_3$ (22.1 μL, 100 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.38 M, 72.5 μL, 100 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:6:93 AcOH:EtOAc:hexanes to 1:49:50 AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.169** (169.1 mg, 73%) as colorless powder.

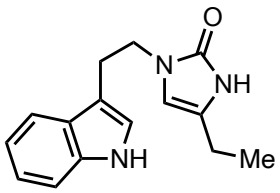
^{1}H NMR (400 MHz, DMSO-d_6) δ 9.97 (s, 1H), 7.22 – 7.13 (m, 2H), 6.97 – 6.83 (m, 2H), 6.03 (q, J = 1.5 Hz, 1H), 4.52 (s, 2H), 3.72 (s, 3H), 2.22 (qd, J = 7.5, 1.3 Hz, 2H), 1.03 (t, J = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 158.5, 153.5, 130.4, 128.9, 122.6, 113.9, 105.8, 55.1, 44.8, 18.4, 12.3.

FTIR (cm^{-1}): 3192, 2970, 1674, 1514, 1248, 1177, 1034.

mp = 97-101 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{17}N_2O_2]^+$: 233.1290; found: 233.1285



1.170

(**1.170**) According to general protocol F: *N*-phenoxy urea **1.S39** (350.0 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (26.0 mg, 50.0 umol), Bu_4NI (74.0 mg, 0.20 mmol), $P(OCH_2CF_3)_3$ (22.0 µL, 100 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.38 M, 72.5 µL, 100 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:6:93 AcOH:EtOAc:hexanes to 1:49:50 AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.170** (182.1 mg, 71%) as colorless powder.

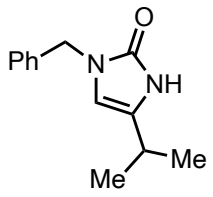
^1H NMR (400 MHz, DMSO-d_6) δ 10.83 (s, 1H), 9.90 (s, 1H), 7.55 (d, J = 7.8 Hz, 1H), 7.33 (d, J = 8.1 Hz, 1H), 7.15 (d, J = 2.3 Hz, 1H), 7.06 (ddd, J = 8.1, 6.9, 1.2 Hz, 1H), 6.97 (ddd, J = 7.9, 7.0, 1.1 Hz, 1H), 6.14 (p, J = 1.2 Hz, 1H), 3.68 (dd, J = 8.7, 6.6 Hz, 2H), 2.94 (t, J = 7.6 Hz, 2H), 2.23 (qd, J = 7.5, 1.2 Hz, 2H), 1.05 (t, J = 7.5 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.4, 136.2, 127.2, 122.7, 122.3, 121.0, 118.32, 118.29, 111.4, 111.1, 105.9, 42.4, 25.3, 18.5, 12.4.

FTIR (cm^{-1}): 3736, 3247, 2916, 2845, 1653, 745.

mp = 175-177 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}N_3O]^+$: 256.1450; found: 256.1441.



1.171

(**1.171**) According to general protocol F: *N*-phenoxy urea **1.S35** (310.0 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (26.0 mg, 50.0 umol), Bu_4NI (73.9 mg, 0.20 mmol), $P(OCH_2CF_3)_3$ (22.0 μL, 100 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (0.48 mL, 2.0 mmol) were combined under N_2, followed by PhMgBr (1.38 M, 72.5 μL, 100 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:4:95 AcOH:EtOAc:hexanes to 1:49:50 AcOH:EtOAc:hexanes) to afford dihydroimidazolone **1.171** (66.2 mg, 31%) as colorless powder.

^{1}H NMR (400 MHz, DMSO-d_6) δ 10.06 (s, 1H), 7.38 – 7.30 (m, 2H), 7.29 – 7.25 (m, 1H), 7.25 – 7.19 (m, 2H), 6.05 (dd, J = 2.3, 1.2 Hz, 1H), 4.61 (s, 2H), 2.59 – 2.51 (m, 1H), 1.06 (d, J = 6.8 Hz, 6H).

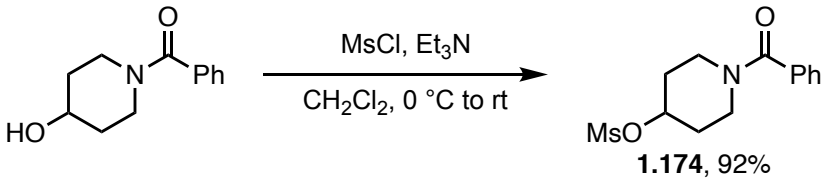
^{13}C NMR (101 MHz, DMSO-d_6) δ 153.6, 138.5, 128.5, 127.5, 127.4, 127.2, 104.9, 45.4, 25.0, 21.0.

FTIR (cm^{-1}): 3224, 2966, 1715, 1496, 1451, 1074.

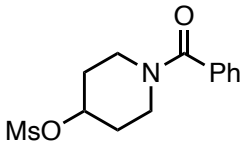
mp = 117-121 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{17}N_2O]^+$: 217.1341; found: 217.1327.

1.12.7 Formal Synthesis of Factor Xa Inhibitor



1.174, 92%



1.174

(**1.174**) A 200 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. (4-hydroxypiperidin-1-yl)(phenyl)methanone (4.10 g, 20.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous CH_2Cl_2 (72 mL) was added to the flask via syringe. The solution was cooled to 0 °C in an ice bath, followed by sequential addition of anhydrous Et_3N (4.2 mL, 30 mmol, 1.5 equiv) and MsCl (4.6 mL, 60 mmol, 3.0 equiv). Upon full addition, the reaction was warmed to rt and stirred for 2 h. The reaction was quenched with H_2O (150 mL), and washed with CH_2Cl_2 (150 mL) for three times. The organics were dried over $MgSO_4$, filtered through a glass frit, and concentrated to give orange oil, which was chromatographed (linear gradient, 30:70 EtOAc:hexanes to EtOAc) to yield **1.174** (5.19 g, 92%) as colorless powder.

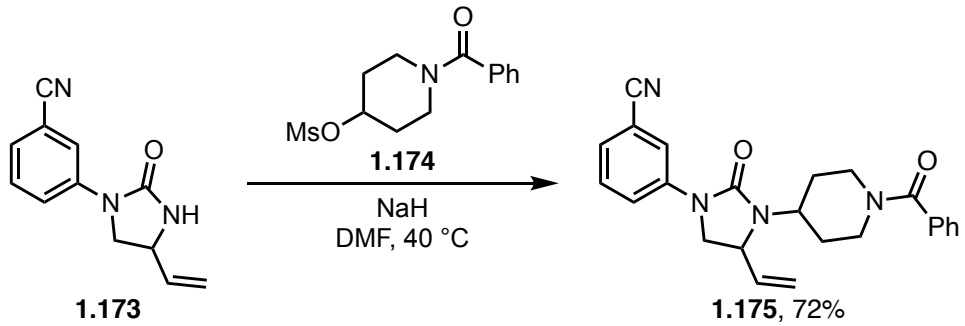
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.51 – 7.35 (m, 5H), 4.92 (tt, J = 8.0, 3.8 Hz, 1H), 3.93 (s, 1H), 3.42 (s, 2H), 3.28 (s, 1H), 3.22 (s, 3H), 1.97 (d, J = 32.4 Hz, 2H), 1.72 (s, 2H).

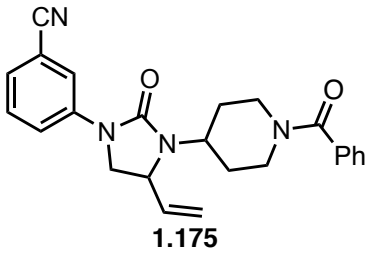
^{13}C NMR (101 MHz, DMSO-d_6) δ 169.1, 136.0, 129.6, 128.5, 126.8, 77.6, 44.1, 38.4, 37.9, 31.7, 31.0.

FTIR (cm^{-1}): 2935, 1631, 1437, 1350, 1175, 946, 912.

mp = 75-79 °C (EtOAc).

HRMS (ESI) m/z, calculated for $[C_{13}H_{18}NO_4S]^+$: 284.0951; found: 284.0940.





(**1.175**) A 100 mL round-bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Unprotected imidazolidinone **1.173** (500.0 mg, 2.30 mmol) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous DMF (18 mL) was added, followed by careful addition of NaH (60% dispersion in mineral oil, 282.0 mg, 7.00 mmol, 3.00 equiv) through quick removal and replacement of the septum. The suspension stirred for 20 min, then **1.174** (1.99 g, 7.00 mmol, 3.00 equiv) was added by quick removal and replacement of the septum. The reaction stirred at rt for 16 h. Additional NaH (60% dispersion in mineral oil, 282.0 mg, 7.000 mmol, 3.00 equiv) and **1.174** (1.99 g, 7.00 mmol, 3.00 equiv) were added sequentially. The reaction was then heated to 40 °C for 48 h, cooled to rt, and quenched with brine (100 mL). EtOAc (100 mL) was added, and the layers separated. The organic layer was washed with brine (100 mL) for four times, dried with $MgSO_4$, and filtered. The solution was concentrated onto

Celite, and purified by chromatography (linear gradient, 15:85 EtOAc:hexanes to EtOAc) to afford imidazolidinone **1.175** (677.0 mg, 72%) as colorless powder.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (dd, *J* = 10.0, 1.7 Hz, 2H), 7.47 – 7.35 (m, 6H), 7.31 (dt, *J* = 7.7, 1.3 Hz, 1H), 5.85 (dt, *J* = 17.9, 9.4 Hz, 1H), 5.43 (d, *J* = 17.0 Hz, 1H), 5.35 (d, *J* = 10.0 Hz, 1H), 5.09 – 4.68 (m, 1H), 4.29 (d, *J* = 9.0 Hz, 1H), 4.06 – 3.70 (m, 3H), 3.47 (dd, *J* = 9.2, 6.5 Hz, 1H), 3.20 – 2.92 (m, 1H), 2.91 – 2.66 (m, 1H), 2.22 – 1.67 (m, 4H).

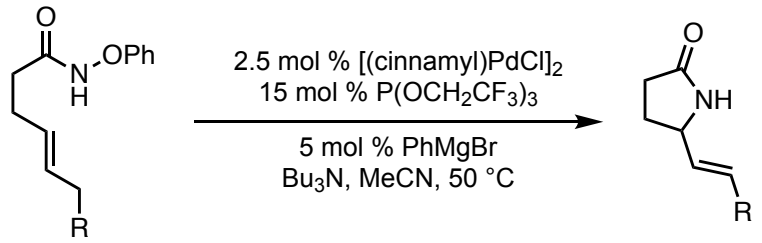
^{13}C NMR (101 MHz, $CDCl_3$) δ 170.5, 156.4, 140.9, 137.9, 135.9, 129.83, 129.81, 128.6, 126.9, 125.8, 121.3, 120.2, 119.7, 118.9, 112.9, 55.2, 52.0, 48.8 [for piperidine carbon signals, please see the spectrum].

FTIR (cm^{-1}): 2932, 2864, 2229, 1703, 1630, 1442, 1410, 1252, 734.

mp = 95-100 °C (EtOAc).

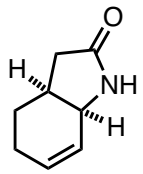
HRMS (ESI) m/z, calculated for $[C_{24}H_{25}N_4O_2]^+$: 401.1972; found: 401.1938.

1.12.8 Synthesis of Secondary Lactams



General Protocol G: A Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $[(cinnamyl)PdCl]_2$ (0.025 equiv) and *O*-phenyl hydroxamate (1.0 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 for four times. Anhydrous $P(OCH_2CF_3)_3$ (0.15 equiv), anhydrous MeCN (0.05 M with respect to the *O*-phenyl

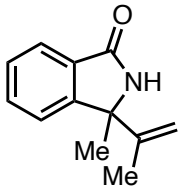
hydroxamate), and anhydrous Bu_3N (5.0 equiv) were added sequentially to the flask via syringe. PhMgBr (0.05 equiv) was then added with stirring, and the resulting suspension was placed in a pre-heated oil bath, and stirred at 50 °C for 24 h. Upon completion, the reaction was cooled to room temperature, opened to air, and the reaction mixture was then diluted with EtOAc (10 mL). The suspension was transferred to a round bottom flask, and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed on silica gel (5-20 μm particle size) to yield the desired product.



1.100

(**1.100**) According to general protocol G: 2-(cyclohex-2-en-1-yl)-*N*-phenoxyacetamide (**1.106**) (231.5 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.2 mg, 25 umol), $P(OCH_2CF_3)_3$ (33.0 μL, 150 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (1.2 mL, 5.0 mmol) were combined under N_2, and followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 40:60 EtOAc:hexanes to EtOAc) to afford lactam **1.100** (130.7 mg, 95%) as colorless powder.

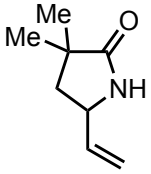
^{1}H NMR (400 MHz, $CDCl_3$) δ 5.96 (dddd, J = 9.5, 4.6, 3.3, 1.4 Hz, 1H), 5.87 (bs, 1H), 5.66 (ddt, J = 10.0, 3.7, 2.1 Hz, 1H), 4.03 (ddq, J = 6.6, 3.3, 1.5 Hz, 1H), 2.56 (tdd, J = 8.6, 6.4, 4.2 Hz, 1H), 2.48 (dd, J = 16.4, 8.2 Hz, 1H), 2.13 (dd, J = 16.4, 4.9 Hz, 1H), 2.10 – 1.93 (m, 2H), 1.79 – 1.66 (m, 1H), 1.65 – 1.52 (m, 1H). The analytical data matched that previously reported in the literature.[61]



1.103

(**1.103**) According to general protocol G: 2-(3-methylbut-2-en-2-yl)-*N*-phenoxybenzamide (282.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (2.6 mg, 5 umol), P(OCH$_2$CF$_3$)$_3$ (6.6 μL, 30 umol), anhydrous MeCN (20 mL), and anhydrous Bu$_3$N (1.2 mL, 5.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 7.0 μL, 10 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 7:93 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford lactam **1.103** (182.5 mg, 97%) as colorless powder.

^{1}H NMR (400 MHz, CDCl$_3$) δ 7.83 (dt, *J* = 7.5, 1.0 Hz, 1H), 7.55 (td, *J* = 7.5, 1.2 Hz, 1H), 7.46 (td, *J* = 7.5, 1.0 Hz, 1H), 7.30 (dt, *J* = 7.7, 0.9 Hz, 1H), 6.24 (bs, 1H), 5.26 (t, *J* = 0.9 Hz, 1H), 5.05 (t, *J* = 1.2 Hz, 1H), 1.69 (s, 3H), 1.47 (dd, *J* = 1.5, 0.7 Hz, 3H). The analytical data matched that previously reported in the literature.[61]

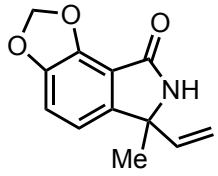


1.176

(**1.176**) According to general protocol G: 4-*trans*-2,2-dimethyl-*N*-phenoxyhex-4-enamide (233.1 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (33.0 μL, 150 umol), anhydrous MeCN (20 mL), and anhydrous Bu$_3$N (1.2 mL, 5.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc:hexanes to 60:40 EtOAc:hexanes) to afford lactam **1.176** (123.6 mg, 89%) as colorless powder.

^{1}H NMR (600 MHz, CDCl$_3$) δ 5.76 (ddd, *J* = 17.2, 10.2, 7.0 Hz, 1H), 5.61 (bs, 1H), 5.23 (d, *J* = 17.1 Hz, 1H), 5.12 (d, *J* = 10.2 Hz, 1H), 4.08 (q, *J* = 7.4 Hz, 1H), 2.15 (dd,

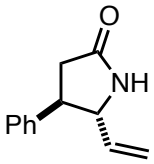
J = 12.7, 7.1 Hz, 1H), 1.70 (dd, *J* = 12.7, 7.8 Hz, 1H), 1.19 (s, 3H), 1.18 (s, 3H). The analytical data matched that previously reported in the literature.[61]



1.177

(**1.177**) According to general protocol G: 5-(2-but-2-en-2-yl)-*N*-phenoxy-2H-1,3-benzodioxole-4-carboxamide (310.9 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (2.6 mg, 5 umol), P(OCH$_2$CF$_3$)$_3$ (6.6 µL, 30 umol), anhydrous MeCN (20 mL), and anhydrous Bu$_3$N (1.2 mL, 5.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 7.0 µL, 10 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 60:40 EtOAc:hexanes) to afford lactam **1.177** (208.9 mg, 96%) as colorless powder.

^{1}H NMR (400 MHz, CDCl$_3$) δ 6.97 (d, *J* = 7.9 Hz, 1H), 6.75 (d, *J* = 7.9 Hz, 1H), 6.47 (bs, 1H), 5.94, 5.90 (AB system, J_{AB} = 10.4 Hz, 2H), 5.92 (dd, *J* = 17.2, 10.5 Hz, 1H), 5.32 (d, *J* = 17.2 Hz, 1H), 5.12 (d, *J* = 10.5 Hz, 1H), 1.61 (s, 3H). The analytical data matched that previously reported in the literature.[61]

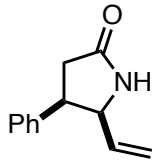


1.101-*trans*

(**1.101-*trans***) According to general protocol G: 4-*trans*-*N*-phenoxy-3-phenylhex-4-enamide (281.5 mg, 1.00 mmol), [(cinnamyl)PdCl]$_2$ (13.0 mg, 25 umol), P(OCH$_2$CF$_3$)$_3$ (33.0 µL, 150 umol), anhydrous MeCN (20 mL), and anhydrous Bu$_3$N (1.2 mL, 5.0 mmol) were combined under N$_2$, and followed by PhMgBr (1.44 M, 35.0 µL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford lactam **1.101** (178.9 mg, 96%, 83:17 dr) as colorless solid. The diastereomers were separated with the same

column conditions (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to yield lactam **1.101-*trans*** (149.1 mg, 80%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 – 7.32 (m, 2H), 7.31 – 7.23 (m, 3H), 6.21 (bs, 1H), 5.89 – 5.78 (m, 1H), 5.16 (d, *J* = 1.0 Hz, 1H), 5.13 (dt, *J* = 6.5, 1.0 Hz, 1H), 4.13 (t, *J* = 7.2 Hz, 1H), 3.28 (td, *J* = 9.3, 7.3 Hz, 1H), 2.78 (dd, *J* = 17.0, 8.9 Hz, 1H), 2.60 (dd, *J* = 17.1, 9.6 Hz, 1H). The analytical data matched that previously reported in the literature.[61]



1.101-*cis*

(**1.101-*cis***) According to general protocol G: 4-*trans*-*N*-phenoxy-3-phenylhex-4-enamide (281.5 mg, 1.00 mmol), $[(cinnamyl)PdCl]_2$ (13.0 mg, 25 umol), $P(OCH_2CF_3)_3$ (33.0 μL, 150 umol), anhydrous MeCN (20 mL), and anhydrous Bu_3N (1.2 mL, 5.0 mmol) were combined under N_2, and followed by PhMgBr (1.44 M, 35.0 μL, 50.0 umol). The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford lactam **1.101** (178.9 mg, 96%, 83:17 dr) as a colorless solid. The diastereomers were separated with the same column conditions (linear gradient, 10:90 EtOAc:hexanes to 70:30 EtOAc:hexanes) to yield lactam **1.101-*cis*** (29.8 mg, 16%) as a colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.29 (m, 2H), 7.29 – 7.22 (m, 1H), 7.21 – 7.12 (m, 2H), 5.69 (bs, 1H), 5.31 (ddd, *J* = 16.6, 10.1, 6.3 Hz, 1H), 5.15 (dt, *J* = 17.1, 1.3 Hz, 1H), 5.04 (dt, *J* = 10.1, 1.2 Hz, 1H), 4.43 (t, *J* = 7.0 Hz, 1H), 3.88 (q, *J* = 8.3 Hz, 1H), 2.70 (dd, *J* = 16.7, 8.9 Hz, 1H), 2.63 (dd, *J* = 16.7, 8.4 Hz, 1H). The analytical data matched that previously reported in the literature.[61]

1.12.9 Crystallographic Details

X-ray structural analysis for **1.156**: Crystals were mounted using viscous oil onto a plastic mesh and cooled to the data collection temperature. Data were collected on a Bruker-AXS APEX II DUO CCD diffractometer with Cu-Kα radiation (λ = 1.54178 Å) focused with Goebel mirrors. Unit cell parameters were obtained from 36 data frames, 0.5º ω, from three different sections of the Ewald sphere.[89] The systematic absences in the diffraction data are consistent with $P2_1$, and $P2_1/m$. Although Platon ADDSYM[90] detected a potential inversion center and c-glide, refinement in $P2_1/c$, the space group with these additional symmetry elements, resulted in 251 systematic absence violations corresponding to the expected c-glide with high final residuals ($R1$ = 12.4%; $wR2$ = 37.1%) suggesting pseudo symmetry. Only refinement in the non-centrosymmetric space group option, $P2_1$, yielded chemically reasonable and computationally stable results of refinement. The data were treated with multi-scan absorption corrections.[89] The structure was solved using intrinsic phasing methods[91] and refined with full-matrix, least-squares procedures on F^2.[92] Two compound molecules forming an H-bonded pair are located in the asymmetric unit apparently centered at a pseudo inversion center. A closer inspection of the structure reveals the ring methylene carbon atoms C5 and C5' on the same side of the H-bonded dimer with clearly localized C–C and C=C bonds which would be averaged if the inversion center were genuine. Non-hydrogen atoms were refined with anisotropic displacement parameters. Hydrogen atoms were treated as idealized contributions with geometrically calculated positions and with U_{iso} equal to 1.2 U_{eq} (1.5 U_{eq} for methyl) of the attached atom. Atomic scattering factors are contained in the SHELXTL program library.[92] The structures have been deposited at the Cambridge Structural Database under the following CCDC depositary number: 1856458.

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Chapter 2

SYNTHESIS OF INDOLINES VIA AZA-HECK CYCLIZATION

2.1 Introduction

As one of the most prevalent heterocycles in bioactive molecules, the indoline scaffold can be found in numerous of natural products and synthetic drugs.[1-6] Many compounds containing this fragment have shown interesting bioactivities against a number of conditions, including depression,[7] hyperplasia,[8] migraines,[9] hypertension,[10] and cancers.[11] Notable indoline-containing bioactive compounds are listed in Figure 2.1.[12-18] Among those molecules, many share a common characteristic as bearing a fully-substituted carbon center at the C2 position. Moreover, those C2 substitutions are not limited to simple alkyl groups but are found to be a range of functional groups, including nitrile and ester.

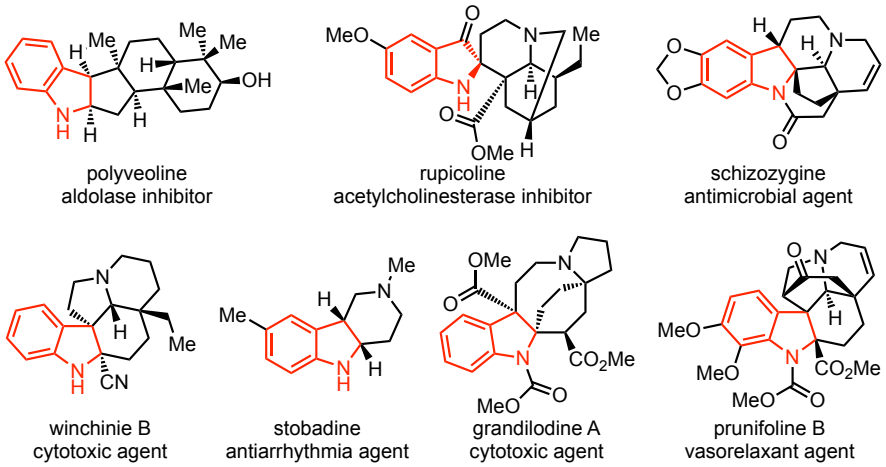
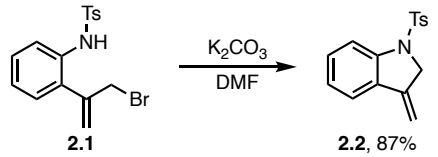


Figure 2.1: Representative Bioactive Indolines

2.2 Current Methods to Synthesize Indolines

The most straightforward way to make the indoline structure is via the alkyl C–N bond formation using the nucleophilic nature of N–H bearing nitrogen atoms (Figure 2.2).[19] However, the scope of indoline substrates prepared through this strategy is limited due to the drawbacks of nucleophilic substitution reactions. The most obvious example is that indolines bearing fully-substituted C2 carbon centers cannot be made through this strategy. Furthermore, the nucleophiles and electrophiles used in those reactions usually require pre-activation, which introduces difficulties for starting material preparation and for further functionalization of products.



2.1 **2.2**, 87%

Figure 2.2: Example of Indoline Formation via Alkyl C–N Bond Formation

2.2.1 Intramolecular C–N Coupling

An alternative strategy is to prepare *o*-halo homobenzylic amines, then form the aryl C–N bond using intramolecular cross-coupling reactions, such as Buchwald amination, to construct the heterocycles.[20] Those reactions can readily prepare complex indoline structures under mild conditions, and therefore, have been extensively used in total synthesis. During the total synthesis of (+)-vallesamidine, the Anderson group was able to cyclize the homobenzylic amine **2.3** to make the multi-cyclic indoline intermediate **2.4** using copper catalysis (Figure 2.3).[21] Although complex indoline scaffolds are accessible via this method, complicated starting materials are required. To prepare **2.4**, an indoline bearing fully-substituted C2 carbon center, Anderson and co-

workers had to prepare the fully-substituted carbon center **2.3** first, which is known to be a synthetic challenge.

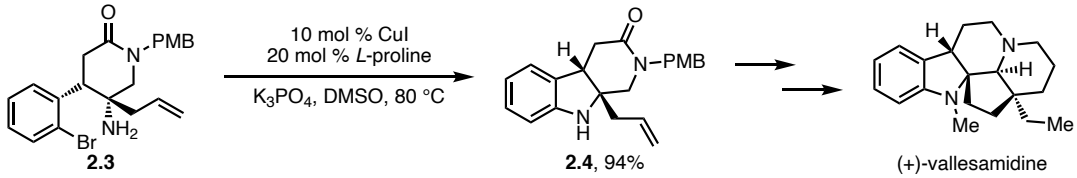


Figure 2.3: Indoline Synthesis Using Intramolecular C–N Coupling

2.2.2 Intramolecular Aromatic C–H Activation

Another disadvantage of intramolecular C–N coupling is that it requires the starting material to bear a halogen or equivalent at the *ortho* position, which usually takes additional steps to prepare. To simplify the starting material and improve the ease of the reaction, the strategy of C–H activation using nucleophilic nitrogen as a directing group has been proposed for the synthesis of indoline fragment. Based on this idea, Yu and co-workers have reported several palladium-catalyzed intramolecular C–H amination reactions, which allow the synthesis of indolines from simple aromatic starting materials (Figure 2.4).[22-23] Compared to the intramolecular C–N coupling reactions, however, those methods require harsh reaction conditions. Besides, pre-activation of nitrogen atoms is required to increase the ease of deprotonation, which results in indolines in protected form.

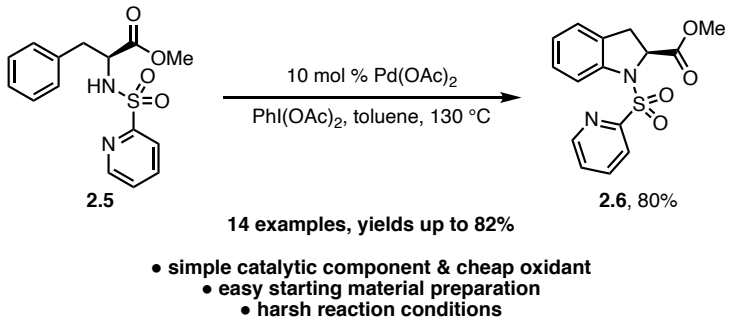


Figure 2.4: Preparation of Indolines via Directed C–H Activation

In contrast to the C–H activation strategies reported by the Yu group, the Alexanian group envisioned the synthesis of indolines from a different perspective.[24] They were able to prepare the indoline ring via the construction of the C–C bond through aromatic C–H alkylation (Figure 2.5). Using the secondary alkyl iodide **2.7**, the *ortho* C–H bond can be cleaved by palladium catalysis and subsequent cyclization provides the indoline product **2.8** in good yield. Similar to Yu's C–H activation strategies, this reaction also requires elevated temperature to proceed. Although those methods can provide quick access to the indoline scaffold, the synthesis of indolines bearing complex structures, such as the ones that are highly-substituted at the C2 position, would be difficult using those reactions.

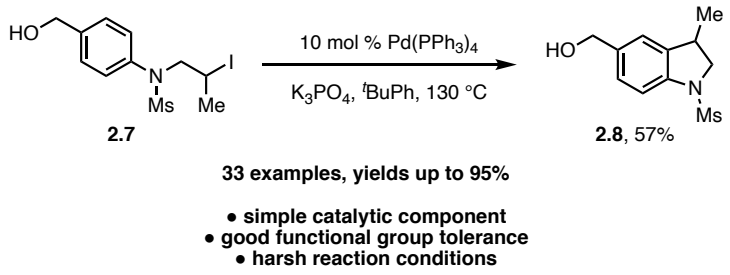


Figure 2.5: Alexanian's Aromatic C–H Alkylation to Access Indolines

2.2.3 Dearomatization of Indoles

2.2.3.1 Asymmetric Hydrogenation of Indoles

As a closely related heterocycle, indoles can be easily converted to indolines through the treatment with strong reductants, such $LiAlH_4$. For C2 or C3 substituted indoles, their reductions generate new stereocenters and provide opportunities to prepare enantioenriched indolines. Therefore, the asymmetric reduction of indoles has drawn a lot of research interests and been developed into a reliable method to prepare enantioenriched indoline scaffolds. For example, the simple indole substrate **2.9** can be reduced using palladium catalysis to afford the indoline **2.10** in nearly quantitative yield with good enantioselectivity, which can then further be converted into an antidepressant in two steps (Figure 2.6).[25] However, it is obvious that this strategy does not deliver indolines bearing highly-substituted carbon center at the C2 position.

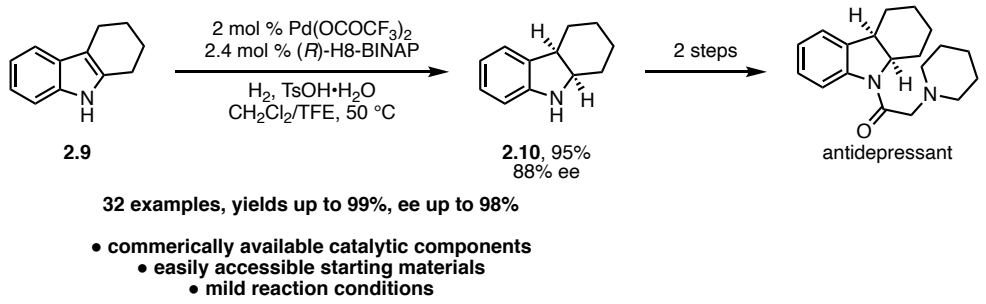


Figure 2.6: Representative Example of Asymmetric Hydrogenation of Indoles

2.2.3.2 Cycloaddition of Indoles

The dearomative annulation of indoles with many reagents, such as alkynes and vinyl carbenes, have been extensively studied, which can rapidly build up complex multi-cyclic heterocycles.[26] During the total synthesis of (+)-minfiensine, for example,

MacMillan and co-workers were able to use an organocatalytic Diels-Alder cycloaddition to prepare the fused multi-cyclic indoline **2.12** from the relatively simple indole starting material **2.11** (Figure 2.7).[27] For this reaction to proceed, however, it usually requires pre-functionalization of the starting materials, such as inclusion of an alkyl amide substitution at the C3 position.

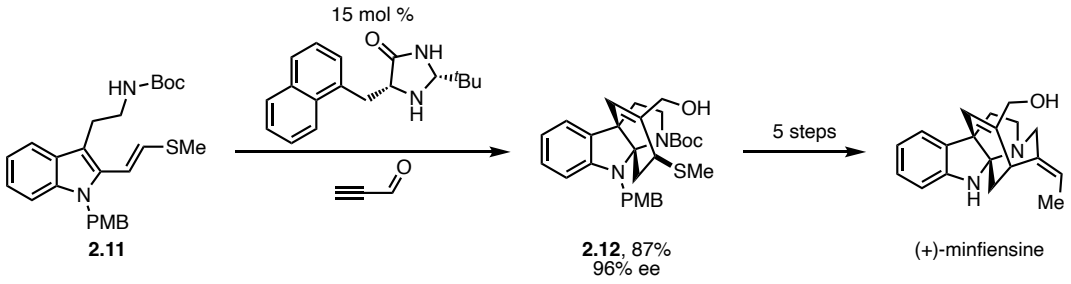


Figure 2.7: Dearomative Cycloaddition of Indoles

2.2.3.3 Electrophilic Addition of C3 Substituted Indoles

One of the most important characteristics of indole is its nucleophilicity in deprotonated form, especially at the C3 position, which allows the electrophilic addition to take place. For indoles bearing substitutions at the C3 position, the electrophilic addition typically results in the corresponding dearomatized indolines. For example, the Rawal group was able to alkylate the C3 position of **2.13** under basic conditions to make the cyclic imine **1.24**, which was then easily converted into the indoline-containing natural product tabersonine in one step (Figure 2.8).[28]

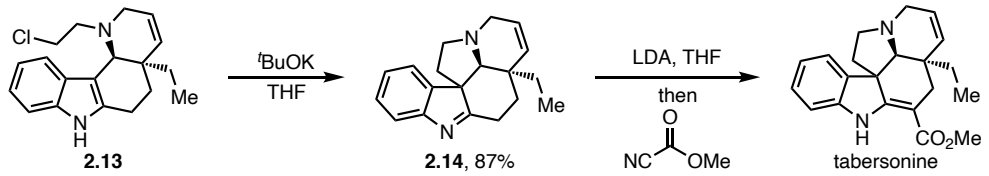


Figure 2.8: Representative Example of Electrophilic Addition of Indoles

2.2.4 Annulation of *o*-Iodo Anilines with Alkenes

In 1990, Larock and co-workers reported reaction conditions for palladium-catalyzed annulation to synthesize indolines and related heterocycles from *o*-iodo aniline (Figure 2.9).[29] This method provides quick construction of indoline core with good efficiencies, but it requires the use of dienes as annulation partners, which limits the accessibility to complex indoline structures.

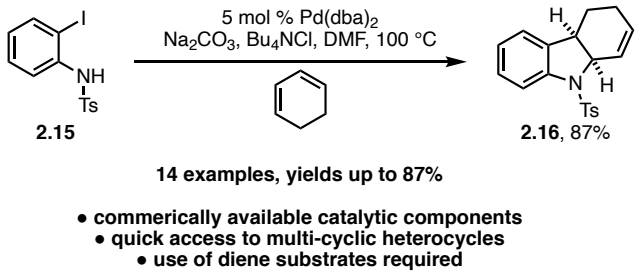


Figure 2.9: Larock's Annulation Method of *o*-Iodo Anilines

The use of diene is necessary for this chemistry as the palladium catalyst, after migratory insertion giving **2.19**, can be stabilized as the π-allyl palladium complex **2.20**, which prevents the fast β-hydride elimination to give the Heck product (Figure 2.10). The use of simple alkenes under this reaction condition resulted in the formation of Heck products without the cyclization to indolines.

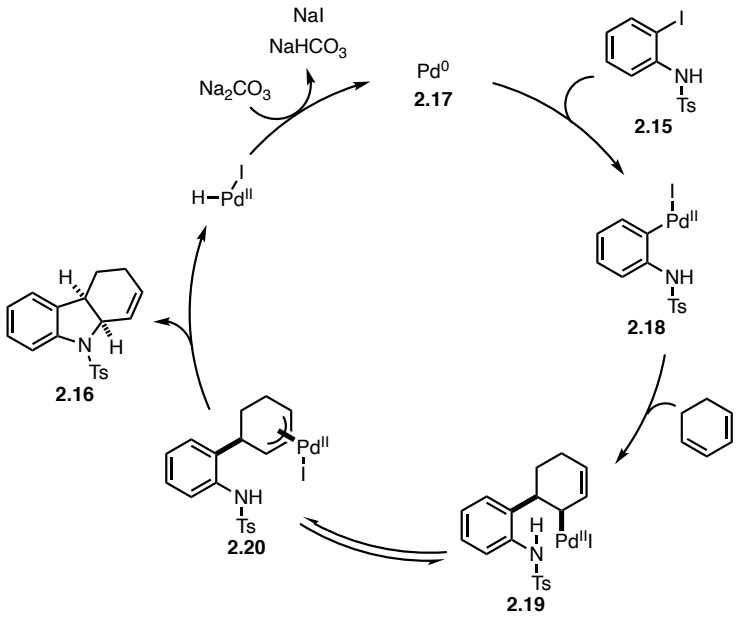


Figure 2.10: Proposed Mechanism of Larock's Annulation

Recently, the Jamison group was able to overcome this limitation and expand the scope of coupling partners to simple alkenes by using nickel catalysis under photoredox condition (Figure 2.11).[30] It is noteworthy that this reaction is very regioselective, as the new C–N bond only forms at the terminal carbon of the alkene. The use of internal alkenes, however, was not demonstrated in this chemistry, which would deliver C2 substituted indolines.

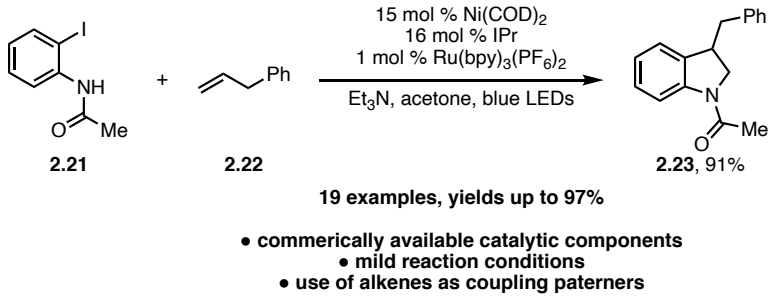


Figure 2.11: Jamison's Method Using Simple Alkenes

2.2.5 Aza-Wacker Cyclization

As a powerful tool to access heterocycles, the aza-Wacker cyclization can be used to deliver the indoline fragment from simple starting materials.[31-40] Larock and co-workers reported the first transformation to prepare indolines using this strategy (Figure 2.12).[31] Following the earliest work, several other methods have been developed, including a few asymmetric reactions.

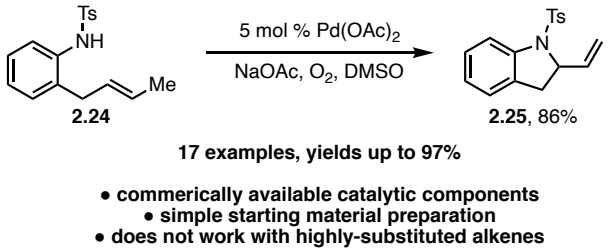


Figure 2.12: Aza-Wacker Cyclization for the Synthesis of Indolines

Zhang and co-workers reported the first asymmetric indoline-forming aza-Wacker cyclization (Figure 2.13). The enantioselectivity in this reaction is somewhat modest, with the highest ee reported as 74%.[37] Therefore, there is a clear need for further

development in this field. In addition to this work, people have shown that the use of chiral sulfonic acid in this cyclization can also provide some enantioselectivity.[39]

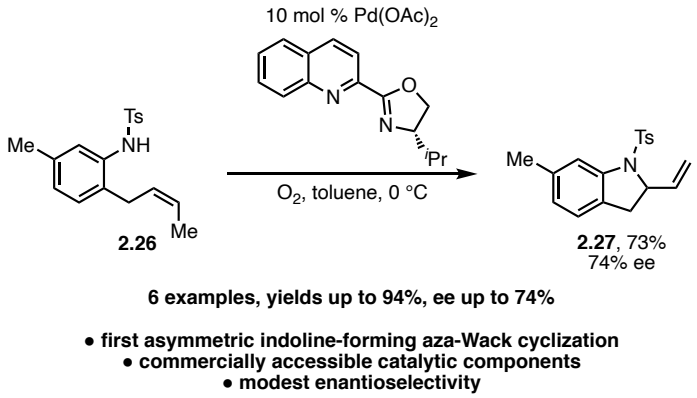


Figure 2.13: Asymmetric Indoline-Forming Aza-Wacker Cyclization

One limitation of the aza-Wacker cyclization is its limited reaction scope, especially the scope of alkenes. In general, those reactions are very sensitive to alkene substitution patterns; the majority of substrates suitable for the aza-Wacker cyclization are mono- or 1,2-di-substituted alkenes, which creates difficulties for the preparation of indolines bearing complex structures. Moreover, the aza-Wacker cyclization is not efficient for the formation of indoline ring bearing fully-substituted C2 carbon center, which is the core structure of many natural products. Until today, only one isolated example of indoline bearing fully-substituted carbon center at C2 position is reported, drawing into question the generality of this method (Figure 2.14).[32]

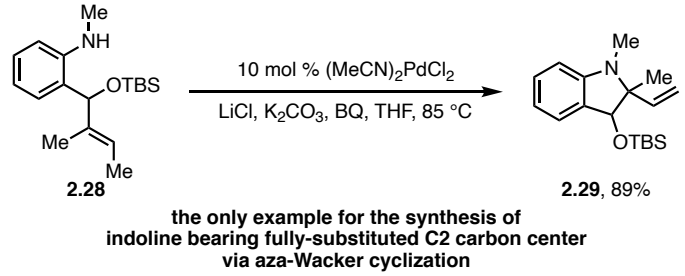


Figure 2.14: Only Example of Indoline Bearing Fully-Substituted C2 Carbon

2.2.6 Intramolecular Tsuji-Trost Allylation

The intramolecular Tsuji-Trost allylation and related reactions are reliable methods to access indoles bearing fully-substituted C2 carbon centers (Figure 2.15).[41-44] Despite the broad substrate scope observed in those methods, they all require highly activated allylic electrophiles as starting materials. This not only introduces difficulties for the synthesis of starting materials but limits the accessible indoline structures. For example, indolines bearing complex ring topologies, such as fused bicyclic structure, just cannot be prepared using this strategy.

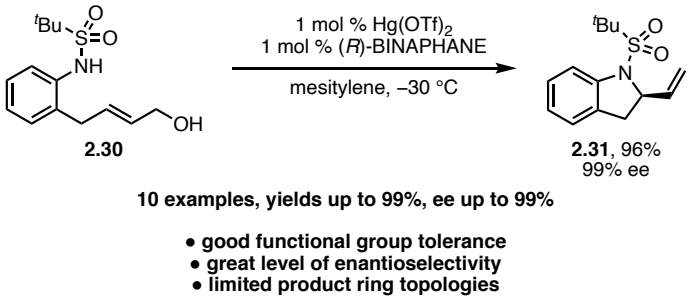


Figure 2.15: Representative Example of Intramolecular Tsuji-Trost Allylation

2.3 Optimization of Reaction Condition

Due to the difficulties to synthesize indoline substrates bearing fully-substituted C2 carbon centers, we wished to develop a general method to expand the access to those molecules. Encouraged by the previous success of lactam and imidazolidinone syntheses,[45-46] we hypothesized that the synthesis of indolines is also possible via an aza-Heck cyclization using *N*-aryl nitrogen electrophiles (Figure 2.16). Such a method would provide access to difficult indoline substrates, such as the ones containing complex ring topologies and highly-substituted C2 carbons.

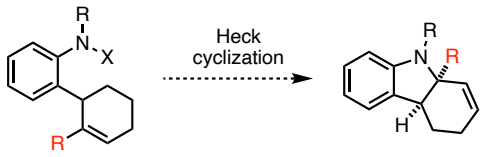


Figure 2.16: Proposed Aza-Heck cyclization for Indoline Synthesis

2.3.1 Choice of *N*-Aryl Nitrogen Electrophiles

To begin the investigation of this idea, we need to identify an electrophile for this reaction. However, the use of nitrogen electrophiles bearing aromatic substitution is surprisingly underdeveloped in the field of cross-coupling reactions. Prior to our work, there are only two cross-coupling methods using aniline electrophiles. In 2007, Lei and co-workers reported a copper-catalyzed electrophilic amination method, which cross-couples *N*-chloroamide **2.32** and aryl boronic acid **2.33** to provide *N*,*N*-diaryl amide **2.34** (Figure 2.17).[47] One advantage of this strategy is that it allows the preparation of products bearing halogen groups, including iodide, which cannot be synthesized via the existing nucleophilic amination of aryl halides.

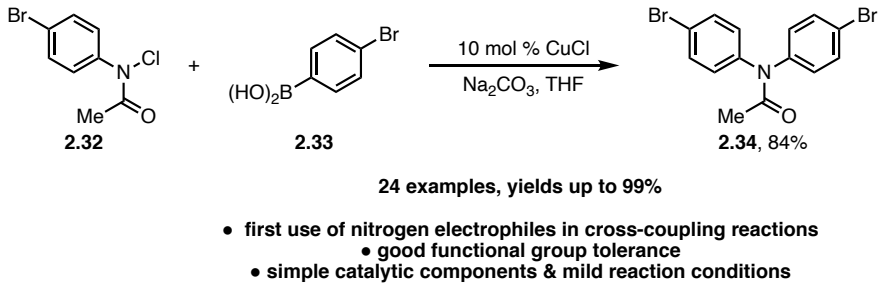


Figure 2.17: Use of *N*-Chloroamides in Cross-Coupling Reactions

More recently, the Knochel group was able to use cobalt catalysis to activate the N–O bond of *N*-hydroxylaniline benzoate **2.35**, which then cross-coupled with aryl zinc reagent **2.36** to deliver the *N*,*N*-diaryl amine **2.37** (Figure 2.18).[48] Previously, we and others have shown success of N–O bond activation in aza-Heck cyclizations.[49-51] Therefore, we envisioned that those *N*-hydroxylaniline esters could be potentially used as aniline electrophiles in an aza-Heck cyclization to prepare indoline substrates.

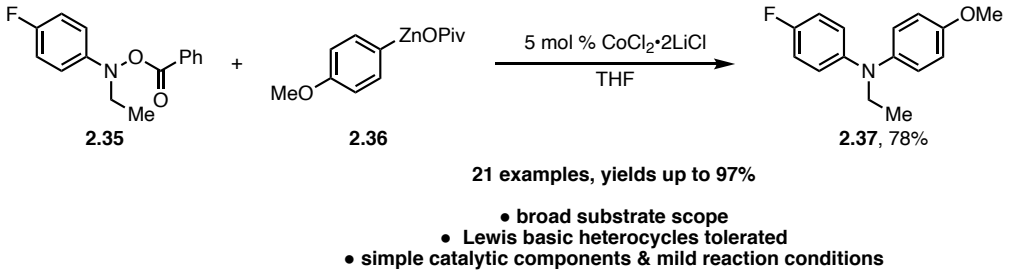


Figure 2.18: Cross-Coupling of Aryl Zinc Reagent and *N*-Hydroxylaniline Benzoate

To investigate this idea, we prepared the *N*-hydroxylaniline ester **2.38**. However, we did not observe any reactivity with this substrate under many reaction conditions,

including the previously used condition for lactam synthesis (Figure 2.19). Thus, we clearly need a more reactive electrophile for this chemistry.

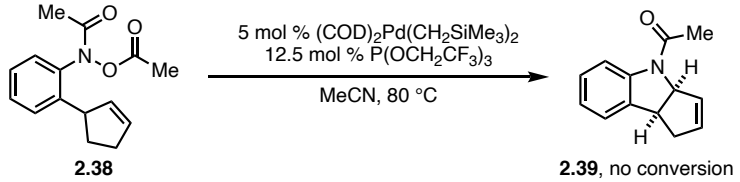


Figure 2.19: Investigation of Cyclization of Aniline Electrophile **2.38**

Several years ago, Tomkinson and co-workers reported a semi-reduction strategy that converts nitroarenes to *N*-aryl-*N*-hydroxy carbamates in single steps (Figure 2.20).[52] This reaction has shown good functional group tolerance and flexible substitution patterns on the aromatic ring, which provides the opportunity to introduce allyl groups at *ortho* position. We envision that those substrates could potentially serve as electrophiles in the targeted indoline-forming aza-Heck cyclization as the carbonate leaving group could undergo irreversible decarboxylation to generate cationic palladium intermediate, which is known to accelerate the rate-limiting migratory insertion step in the Heck reactions.[53] Furthermore, it is notable that those aniline carbonates are prepared from nitroarenes, which can be easily accessed via many strategies due to the versatility of aromatic nitro group.[54]

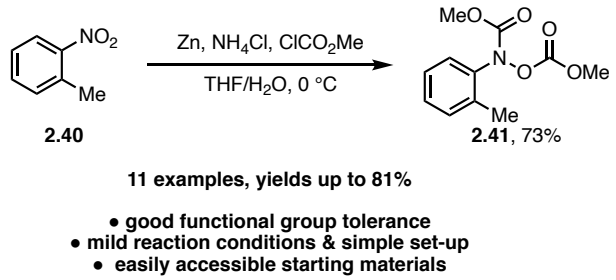


Figure 2.20: Synthesis of *N*-Aryl-*N*-Hydroxy Carbamates from Nitroarenes

Excitingly, we started to observe a yield of cyclized product **2.43** using the *N*-aryl-*N*-hydroxy carbamate **2.42** as electrophile under the previously published aza-Heck reaction condition (Figure 2.21). This marks the first time for the use of carbonate leaving group in heteroatomic cross-coupling reactions.

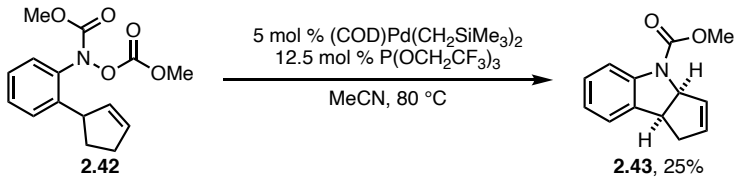


Figure 2.21: Use of *N*-Aryl-*N*-Hydroxy Carbamate **2.42** in Aza-Heck Cyclization

We hypothesize that the carbonate leaving group works better than the ester because it can dissociate from the oxidative addition Pd^{II} complex **2.44** to generate a more electrophilic cationic palladium intermediate **2.45**. Although this step is reversible, the following decarboxylation of carbonate leaving group is irreversible, providing the driving force for the formation of **2.45** (Figure 2.22). The electrophilic nature of cationic palladium makes **2.45** more favorable to undergo migratory insertion, presumably the

rate-limiting step, to construct the indoline ring **2.46**, followed by β-hydride elimination to afford the observed cyclization product **2.43**.

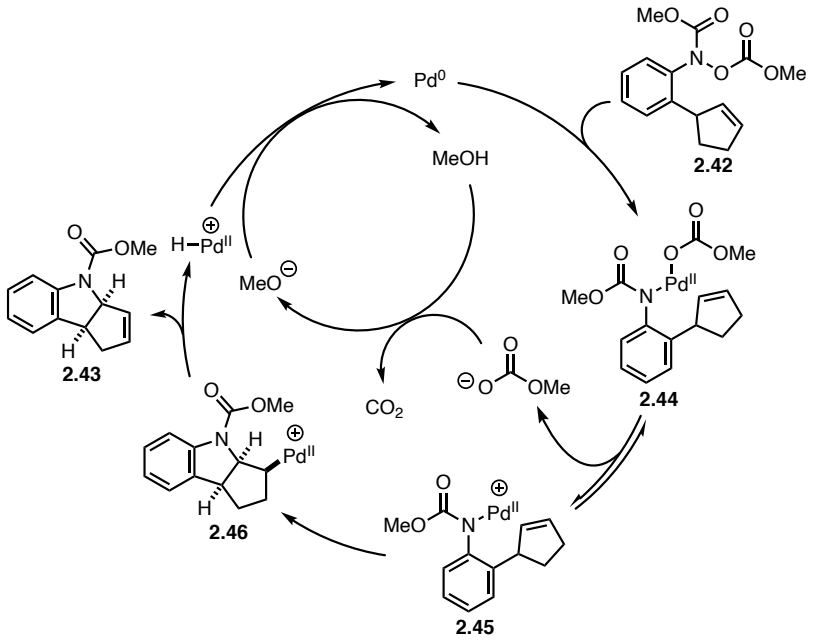


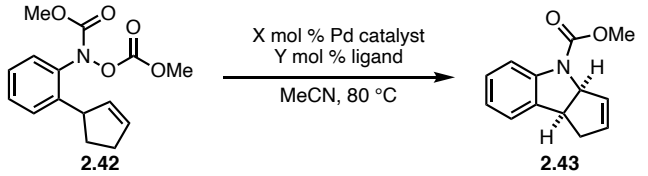
Figure 2.22: Hypothesized Mechanism of the Indoline-Forming Aza-Heck Cyclization

2.3.2 Examination of Ligand Effect

Following up the preliminary result (Table 2.1, entry 1), we further optimized this reaction via the examination of ligands. Switching to P[3,5-$(CF_3)_2$-C_6H_3]$_3$, a bulky and electron-deficient triaryl phosphine ligand, 53% cyclization of **2.42** was observed (entry 2). This phosphine has been previously recognized as the optimal ligand in many aza-Heck cyclizations, particularly common in the reactions using ester leaving groups.[49-51] Further studies revealed the superior steric and electronic balance of P(4-CF_3-C_6H_4)$_3$ for this chemistry, providing the indoline product **2.43** in 85% yield (entry 3). Other closely related phosphine ligands did not provide better cyclization efficiency

(entry 4-6). Finally, bench stable Pd_2dba_3•$CHCl_3$ can be used as pre-catalyst in this reaction with only 3 mol % palladium loading, which makes this method highly practical for indoline synthesis (entry 7).

Table 2.1: Ligand Examination of Indoline-Forming Aza-Heck Cyclization



2.42 **2.43**

entry	Pd Catalyst [mol %]	Ligand [mol %]	Yield of **2.43** [%]
1	$(COD)Pd(CH_2SiMe_3)_2$ [5]	$P(OCH_2CF_3)_3$ [12.5]	25
2	$(COD)Pd(CH_2SiMe_3)_2$ [5]	$P[3,5\text{-}(CF_3)_2\text{-}C_6F_3)_3$ [12.5]	53
3	$(COD)Pd(CH_2SiMe_3)_2$ [5]	$P(4\text{-}CF_3\text{-}C_6H_4)_3$ [12.5]	85
4	$(COD)Pd(CH_2SiMe_3)_2$ [5]	PPh_3 [12.5]	61
5	$(COD)Pd(CH_2SiMe_3)_2$ [5]	$P(4\text{-}F\text{-}C_6H_4)_3$ [12.5]	65
6	$(COD)Pd(CH_2SiMe_3)_2$ [5]	$P(C_6F_5)_3$ [12.5]	0
7	Pd_2dba_3•$CHCl_3$ [1.5]	$P(4\text{-}CF_3\text{-}C_6H_4)_3$ [12.5]	84

2.4 Exploration of Substrate Scope

2.4.1 Functional Group Tolerance

Using this method, a library of indoline substrates bearing various functional groups can be prepared (Figure 2.23). The model substrate **2.43** was isolated in 84% yield. With a larger cycloalkene ring, this cyclization provided **2.47** in great yield as single diastereomer. *N*-aryl-*N*-hydroxy carbamate bearing simple aliphatic alkene can also be cyclized to afford indoline product **2.48** with good efficiency. Substitution at C3 position is well tolerated, providing 73% yield of cyclized product **2.49** with good level of diastereoselectivity.

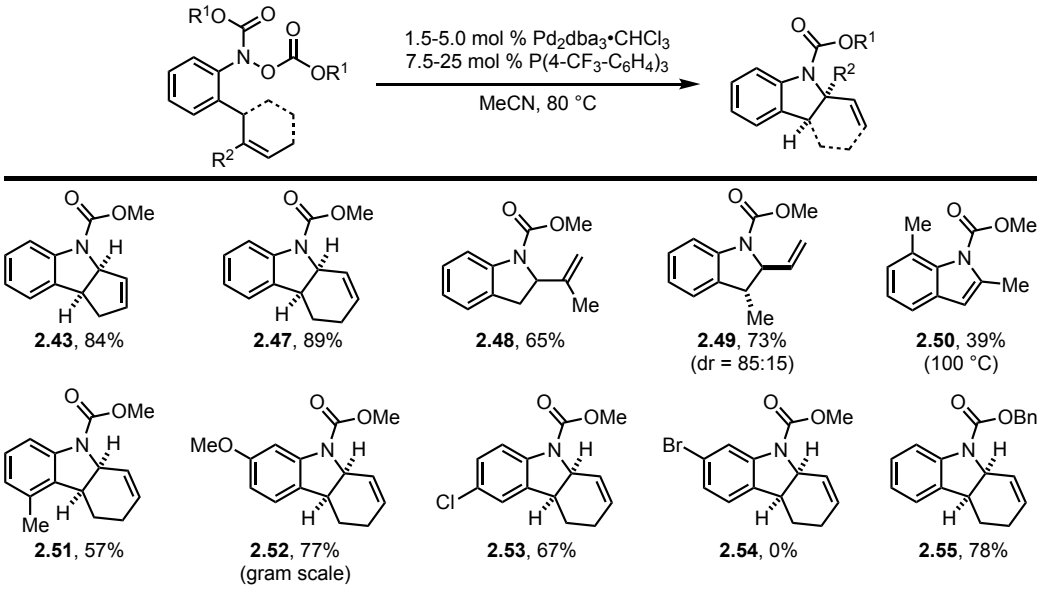


Figure 2.23: Examination of Functional Group Tolerance

With an aromatic substitution *ortho* to the nitrogen electrophile, the cyclization efficiency significantly dropped (**2.50**). It is also noteworthy that the substrate bearing less substituted alkene results in facile product isomerization to give the indole product **2.50**. Surprisingly, we also observed a lower cyclization yield with the substrate bearing aromatic substitution *ortho* to the alkene (**2.51**). This result was hypothesized as the outcome of limited conformational rotation of cyclohexene due to the *ortho*-substitution, which retarded the rate of migratory insertion. However, functional groups, such as ether (**2.52**) and chloride (**2.53**), substituted at other positions are well tolerated. One limitation of this method is its incompatibility with aryl bromide (**2.54**), presumably due to competing oxidative addition. Finally, other protecting group, such as cbz, can also be utilized in this chemistry (**2.55**).

2.4.2 Synthesis of Indolines Bearing Fully-Substituted C2 Carbon Centers

As mentioned earlier, the indoline structure containing fully-substituted C2 carbon is a common motif in many natural products, but there is currently no easy way to prepare them. Using the aza-Heck cyclization, indolines bearing fully-substituted C2 carbon centers can be readily prepared (Figure 2.24). With a simple alkyl substitution, for example, the indoline product **2.56** was isolated in 73% yield. More complex functional groups can also be substituted at this position, such as aromatic group (**2.57**), ester (**2.58**), and nitrile (**2.59**). For the synthesis of **2.58** and **2.59**, higher catalyst loading and the use of DCE as solvent are necessary because of the instabilities of the starting materials in MeCN under this reaction condition.

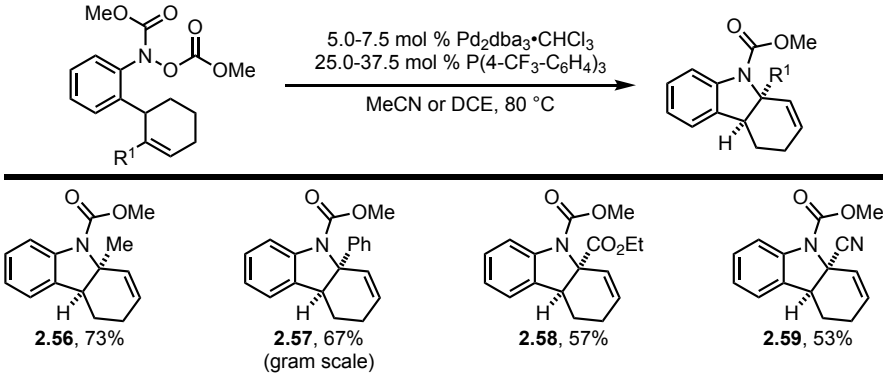
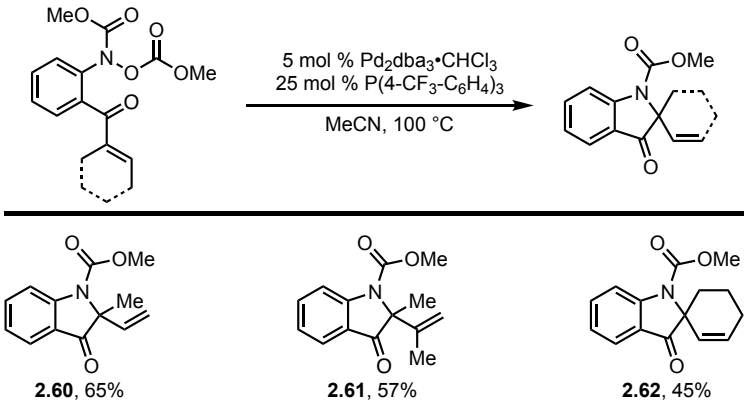


Figure 2.24: Synthesis of Indolines Bearing Fully-Substituted C2 Carbon Centers

2.4.3 Synthesis of Pseudo-Indoxyls

Indoline-related heterocycles can also be accessed via this strategy. For the substrates bearing carbonyl at C3 position, the cyclizations proceeded with good efficiencies to provide pseudo-indoxyls as products. It is notable that the structure of pseudo-indoxyl is prevalent in many natural products, but its preparation is not easy.

Almost the only way to synthesize this heterocycle is through the oxidation of indole.[55] Using the aza-Heck cyclization, however, the pseudo-indoxyl containing fully-substituted C2 carbon **2.60** is produced in 65% yield. Even the substrate bearing tetra-substituted alkene can cyclize in the chemistry to afford product **2.61** in good yield. Excitingly, pseudo-indoxyl containing more complex ring topologies, such spirocycle **2.62**, can also be prepared using this strategy. Such a spirocyclic structure is particularly common in pseudo-indoxyl natural products.[13]



2.60, 65% **2.61**, 57% **2.62**, 45%

Figure 2.25: Synthesis of Pseudo-Indoxyls

2.4.4 Synthesis of Indolines Bearing Heterocycles

A number of heterocycles are well-tolerated in this reaction (Figure 2.26). For example, indolines bearing thiophene (**2.63**) and furan (**2.64**) can be synthesized using this method. More interestingly, the substrates containing heteroatoms in the alkene chains can also be cyclized under this reaction condition. The formation of bridged bicyclic hemiaminal **2.65** occurs via a 6-*exo* cyclization. To our knowledge, this is the first time that such a structure has ever been reported, showing the generality of this method. The substrate bearing allylic ether can also participate in this reaction,

providing the vinyl ether product **2.66** in 69% yield. Finally, the dihydrophenanthridine **2.67** can be synthesized via the 6-*exo* cyclization of a biaryl substrate. Due to its instability, unfortunately, loss of material was observed during product purification.

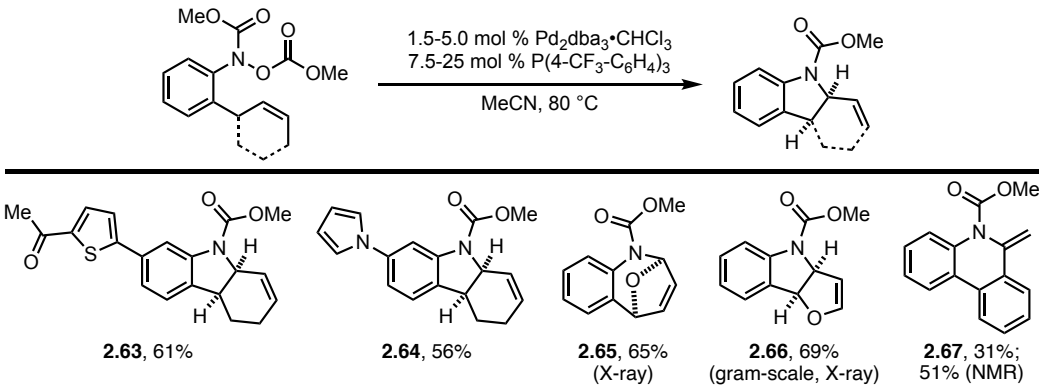


Figure 2.26: Examination of Heterocycle Tolerance

2.5 Conclusion

In conclusion, we developed an aza-Heck cyclization allowing the preparation of indolines and related derivatives. Using commercially available catalytic components, indolines bearing various functional groups and complex ring topologies can be steadily accessed; difficult substrates, such as the ones containing fully-substituted C2 carbon centers, can also be synthesized, which is known to be challenging in this field. This reaction employs *N*-aryl-*N*-hydroxy carbamates as electrophiles, which can be easily prepared from nitroarenes in single steps using a semi-reduction strategy. This marks the first time for the use of carbonate leaving groups in heteroatomic cross-coupling reactions.

Since the first example of aza-Heck cyclization reported in 1999, this strategy has been used to synthesize a number of heterocycles. During my Ph.D. career, I was able to further expand this power to two additional heterocycles (Figure 2.27).

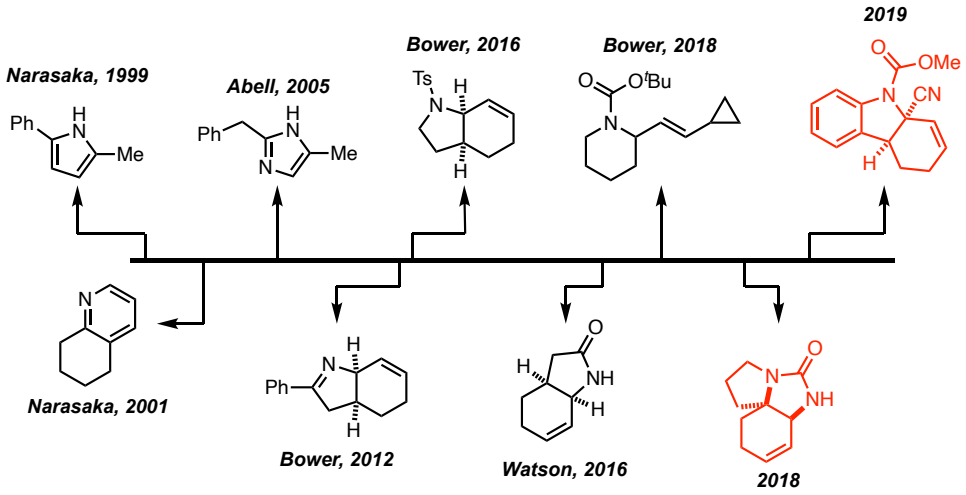


Figure 2.27: Existing Aza-Heck Cyclizations and My Contribution to This Field

2.6 Experimental Details

2.6.1 General Experimental Details

THF, CH_2Cl_2, Et_3N, dioxane, toluene, DMF, MeOH, and MeCN were dried on alumina according to a published procedure.[56] (COD)Pd(CH_2SiMe_3)$_2$ was prepared according to a literature procedure, and stored in a sealed container of DrieRite at –20 °C when not in use.[57] Pd_2dba_3•$CHCl_3$ was prepared according to a literature procedure. All hot glassware was oven-dried for a minimum of 2 h or flame-dried under vacuum prior to use.[58] The following substrates were synthesized according to published procedures: [*trans*-4-bromopent-2-ene,[59] 3-iodo-2-nitrotoluene,[60] 1-methylcyclohex-1-enyl-6-bromide,[61] 6-bromo-1-phenylcyclohex-1-ene,[61] 6-

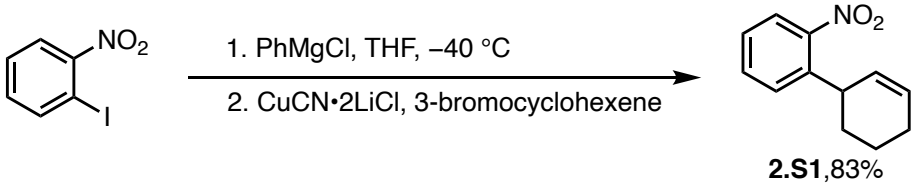
bromocyclohex-1-enecarboxylic acid ethyl ester,[61] 6-bromo-1-cyanocyclohex-1-ene,[61] 2′-bromo-2-nitro-biphenyl,[62] 3-(2-nitro)cyclopentene,[63] 2-(3-methylbut-2-enyl)-nitrobenzene[64]]. All other substrates and reagents were purchased in highest analytical purity from commercial suppliers and used as received. Reaction optimization was conducted in a glovebox (N_2 atmosphere) on a 100 μmol scale in 1-dram vials with Teflon lined caps and heated in an aluminum block with stirring. All NMR chemical yields and diastereoselectivities are reported using 1,3,5-trimethoxybenzene as an internal standard. All other reactions were set up using standard Schlenk technique and heated with stirring in temperature-controlled oil baths. "Double manifold" refers to a standard Schlenk-line gas manifold equipped with N_2 and vacuum (ca. 0.1 mm Hg).

2.6.2 Instrumentation and Chromatography

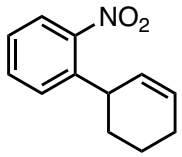
400 MHz ^{1}H, 101 MHz ^{13}C, and 376 MHz ^{19}F spectra were obtained on a 400 MHz FT-NMR spectrometer equipped with a Bruker CryoPlatform. 600 MHz ^{1}H and 151 MHz ^{13}C spectra were obtained on a 600 MHz FT-NMR spectrometer equipped with a Bruker SMART probe. All samples were analyzed in the indicated deutero-solvent and were recorded at ambient temperatures. All chemical shifts are reported in ppm. ^{1}H NMR spectra were calibrated using the residual protio-signal in deutero-solvents as a standard. ^{13}C NMR spectra were calibrated using the deutero-solvent as a standard. IR spectra were recorded on a Nicolet Magma-IR 560 FT-IR spectrometer as thin films on KBr plates. High resolution MS data was obtained on a Thermo Q-Exactive Orbitrap using electrospray ionization (ESI) or a Micromass GCT Premier using liquid injection field desorption ionization (LIFDI). Unless otherwise noted, column chromatography was performed either by hand or by use of Isolera 4 Biotage unit with 40-63 μm silica gel, and the eluent reported in parentheses. Analytical thin-

layer chromatography (TLC) was performed on precoated glass plates and visualized by UV or by staining ($KMnO_4$ or I_2).

2.6.3 Preparation of Nitroarenes



2.S1,83%



2.S1

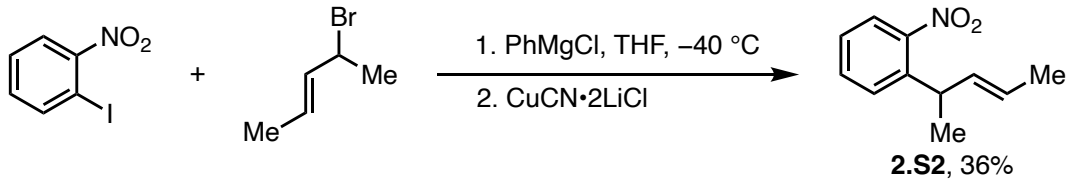
(**2.S1**) This reaction was modified from a literature procedure.[65] A 500 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (4.98 g, 20.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (80 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (11.0 mL, 2.0 M in THF, 22.0 mmol, 1.10 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (22.0 mL, 1.0 M in THF, 22.0 mmol, 1.10 equiv) and 3-bromocyclohexene (2.8 mL, 24 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 1:99 EtOAc/hexanes) to afford **2.S1** (3.36 g, 83%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.52 (td, *J* = 7.6, 1.4 Hz, 1H), 7.45 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.32 (ddd, *J* = 8.5, 7.3, 1.6 Hz, 1H), 5.97 (dtd, *J* = 9.9, 3.7, 2.4 Hz, 1H), 5.76 – 5.46 (m, 1H), 3.94 (ddt, *J* = 8.3, 5.6, 2.8 Hz, 1H), 2.21 (dtd, *J* = 12.8, 6.3, 2.8 Hz, 1H), 2.11 (ddq, *J* = 8.1, 5.5, 3.1 Hz, 2H), 1.81 – 1.70 (m, 1H), 1.70 – 1.60 (m, 1H), 1.60 – 1.47 (m, 1H).

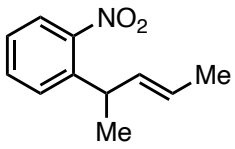
^{13}C NMR (101 MHz, $CDCl_3$) δ 149.8, 140.7, 132.6, 130.4, 129.8, 129.0, 127.0, 124.2, 36.9, 31.8, 25.0, 21.2.

FTIR (cm^{-1}): 2930, 1524, 1351, 746, 651.

HRMS (ESI) m/z, calculated for $[C_{12}H_{14}NO_2]^+$: 204.1025; found: 204.1018.



2.S2, 36%



2.S2

(**2.S2**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.5 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.00 M in THF, 11.0 mmol, 1,10 equiv) and *trans*-4-bromopent-2-ene (1.78 g, 12.0 mmol, 1.20 equiv) were

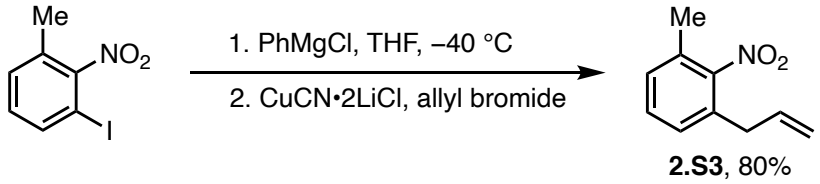
added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 4:96 EtOAc/hexanes) to afford **2.S2** (0.69 g, 36%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.55 – 7.49 (m, 1H), 7.42 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.34 – 7.27 (m, 1H), 5.67 – 5.45 (m, 2H), 4.00 (q, *J* = 6.7 Hz, 1H), 1.68 (d, *J* = 5.4 Hz, 3H), 1.37 (d, *J* = 6.9 Hz, 3H).

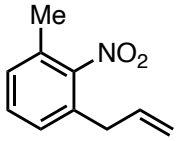
^{13}C NMR (101 MHz, $CDCl_3$) δ 149.7, 140.5, 134.1, 132.6, 129.1, 126.8, 125.5, 124.1, 36.4, 21.3, 18.1.

FTIR (cm^{-1}): 2970, 1526, 1356, 970, 747.

HRMS (ESI) m/z, calculated for $[C_{11}H_{13}NO_2]^+$: 192.1025; found: 192.1012.



2.S3, 80%



2.S3

(**2.S3**) This reaction was modified from a literature procedure.[65] A 100 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 3-iodo-2-nitrotoluene (3.16 g, 12.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (48 mL) was added to the flask via syringe, and the resulting reaction

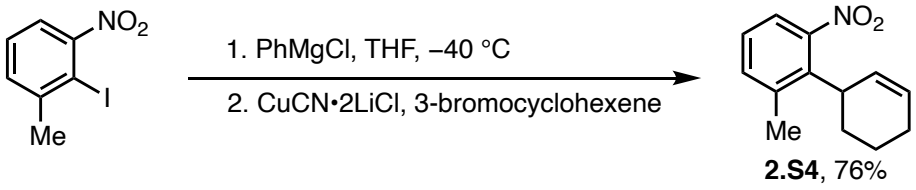
mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (6.6 mL, 2.0 M in THF, 13.2 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (13.2 mL, 1.0 M in THF, 13.2 mmol, 1.10 equiv) and allyl bromide (1.2 mL, 14.4 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 1:99 EtOAc/hexanes) to afford **2.S3** (1.70 g, 80%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (t, *J* = 7.7 Hz, 1H), 7.21 – 7.12 (m, 2H), 5.88 (ddt, *J* = 16.9, 10.3, 6.6 Hz, 1H), 5.12 (h, *J* = 1.6 Hz, 1H), 5.08 (dq, *J* = 10.0, 1.5 Hz, 1H), 3.36 (dt, *J* = 6.7, 1.5 Hz, 2H), 2.32 (s, 3H).

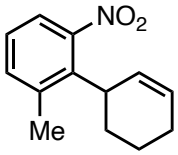
^{13}C NMR (101 MHz, $CDCl_3$) δ 151.6, 134.9, 131.5, 130.3, 129.8, 129.5, 128.4, 117.5, 35.7, 17.6.

FTIR (cm^{-1}): 2982, 1527, 1369, 1039, 851.

HRMS (ESI) m/z, calculated for $[C_{10}H_{12}NO_2]^+$: 178.0863; found: 178.0858.



2.S4, 76%



2.S4

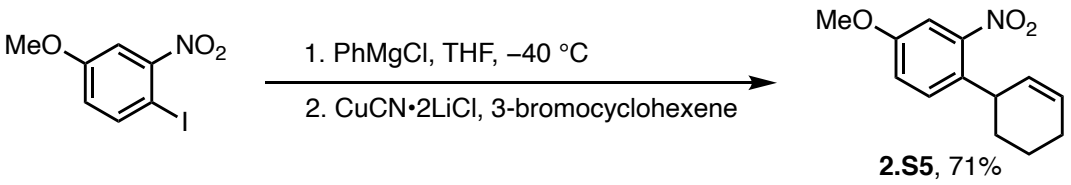
(**2.S4**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 2-iodo-3-nitrotoluene (2.63 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.5 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol, 1.10 equiv) and 3-bromocyclohexene (1.4 mL, 12 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 5:95 EtOAc/hexanes) to afford **2.S4** (1.66 g, 76%) as yellow oil.

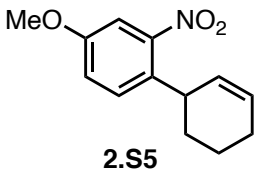
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.29 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.20 (t, *J* = 7.8 Hz, 1H), 5.86 – 5.78 (m, 1H), 5.55 (dt, *J* = 10.4, 2.0 Hz, 1H), 3.77 – 3.66 (m, 1H), 2.45 (s, 3H), 2.15 – 2.01 (m, 3H), 1.92 (ddd, *J* = 11.9, 6.6, 3.4 Hz, 2H), 1.68 (ddd, *J* = 13.6, 6.6, 3.4 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 152.6, 139.7, 135.7, 134.5, 128.6, 128.3, 126.7, 121.4, 38.1, 28.2, 24.6, 23.0, 20.3.

FTIR (cm^{-1}): 2933, 1528, 1457, 1364, 742.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_2]^+$: 218.1176; found: 218,1176.





2.S5

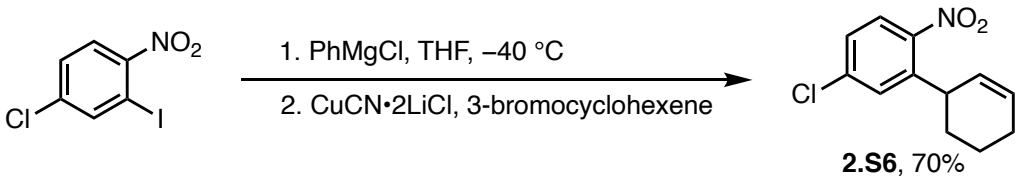
(**2.S5**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-4-methoxy-2-nitrobenzene (5.00 g, 18.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (72 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (10.0 mL, 2.0 M in THF, 20.0 mmol, 1.10 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (20.0 mL, 1.0 M in THF, 20.0 mmol, 1.10 equiv) and 3-bromocyclohexene (2.5 mL, 22 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (hexanes) to afford **2.S5** (2.99 g, 71%) as yellow oil.

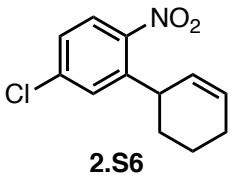
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 8.7 Hz, 1H), 7.30 (d, *J* = 2.7 Hz, 1H), 7.08 (dd, *J* = 8.7, 2.7 Hz, 1H), 5.94 (dtd, *J* = 10.0, 3.7, 2.4 Hz, 1H), 5.62 – 5.50 (m, 1H), 3.88 (tt, *J* = 5.4, 2.7 Hz, 1H), 3.85 (s, 3H), 2.16 (dtd, *J* = 12.9, 6.3, 3.0 Hz, 1H), 2.09 (ddq, *J* = 6.8, 3.7, 2.0, 1.4 Hz, 2H), 1.80 – 1.58 (m, 2H), 1.50 (dddd, *J* = 13.4, 10.4, 8.1, 3.2 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.0, 150.0, 132.7, 131.3, 129.6, 129.3, 119.5, 108.6, 55.9, 36.3, 31.8, 25.0, 21.2.

FTIR (cm^{-1}): 2931, 1621, 1529, 1355, 1250.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_3]^+$: 234.1125; found: 234.1115.





2.S6

(**2.S6**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-5-chloro-2-nitrobenzene (2.83 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.5 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol, 1.10 equiv) and 3-bromocyclohexene (1.4 mL, 12 mmol,

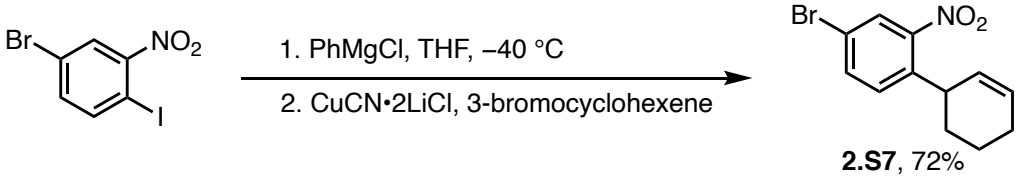
1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (hexanes) to afford **2.S6** (1.67 g, 70%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.6 Hz, 1H), 7.42 (d, *J* = 2.3 Hz, 1H), 7.30 (dd, *J* = 8.7, 2.3 Hz, 1H), 6.01 (dtd, *J* = 9.9, 3.7, 2.4 Hz, 1H), 5.67 – 5.42 (m, 1H), 3.99 (ddp, *J* = 8.3, 5.6, 2.7 Hz, 1H), 2.21 (dtt, *J* = 12.0, 5.7, 2.7 Hz, 1H), 2.16 – 2.03 (m, 2H), 1.79 – 1.59 (m, 2H), 1.50 (dddd, *J* = 13.4, 10.4, 8.1, 3.2 Hz, 1H).

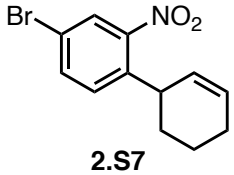
^{13}C NMR (101 MHz, $CDCl_3$) δ 147.9, 143.1, 139.1, 130.6, 130.5, 128.2, 127.2, 125.9, 37.0, 31.6, 24.9, 21.1.

FTIR (cm^{-1}): 2931, 1601, 1567, 1522, 1344.

HRMS (ESI) m/z, calculated for $[C_{12}H_{12}NO_2Cl - H]^+$: 236.0473; found: 236.0476. Mass spectra of this compound were collected using several different ionization methods. However, in all cases, only the mass of product minus hydride was observed. However, we are confident in the structural assignment, as downstream as characterization of downstream products meet normal expectations. It is unclear what the unusual ionization pathway is in this molecule.



2.S7, 72%



2.S7

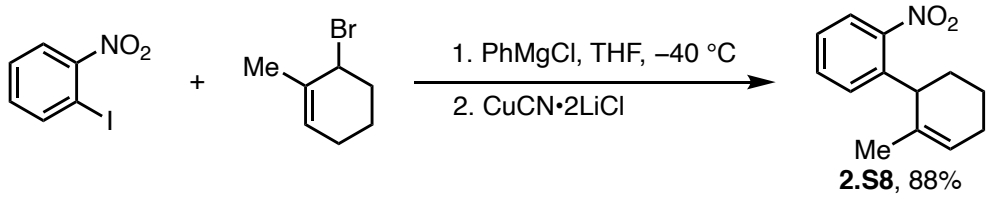
(**2.S7**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-4-bromo-2-nitrobenzene (9.84 g, 30.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (120 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (16.5 mL, 2.0 M in THF, 33.0 mmol, 1.10 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (33.0 mL, 1.0 M in THF, 33.0 mmol, 1.10 equiv) and 3-bromocyclohexene (4.1 mL, 36 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 5:95 EtOAc/hexanes) to afford **2.S7** (6.12 g, 72%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.92 (d, J = 2.1 Hz, 1H), 7.64 (dd, J = 8.4, 2.1 Hz, 1H), 7.34 (d, J = 8.4 Hz, 1H), 5.99 (dq, J = 10.0, 3.5 Hz, 1H), 5.55 (dq, J = 10.1, 2.6 Hz, 1H), 3.90 (ddp, J = 8.3, 5.5, 2.7 Hz, 1H), 2.18 (dtd, J = 12.9, 6.4, 2.9 Hz, 1H), 2.11 (ddq, J = 8.7, 6.1, 3.1 Hz, 2H), 1.78 – 1.70 (m, 1H), 1.70 – 1.61 (m, 1H), 1.49 (dddd, J = 13.4, 10.9, 8.2, 3.1 Hz, 1H).

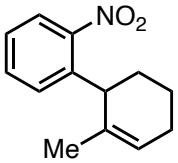
^{13}C NMR (151 MHz, $CDCl_3$) δ 150.2, 139.8, 135.6, 132.0, 130.4, 128.3, 127.1, 119.9, 36.7, 31.7, 24.9, 21.1.

FTIR (cm^{-1}): 2930, 2860, 1529, 1350, 1094.

HRMS (ESI) m/z, calculated for $[C_{12}H_{12}NO_2Br - H]^+$: 279.9968; found: 279.9968. Mass spectra of this compound were collected using several different ionization methods. However, in all cases, only the mass of product minus hydride was observed. However, we are confident in the structural assignment, as downstream as characterization of downstream products meet normal expectations. It is unclear what the unusual ionization pathway is in this molecule.



2.S8, 88%



2.S8

(**2.S8**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.5 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.00 M in THF, 11.0

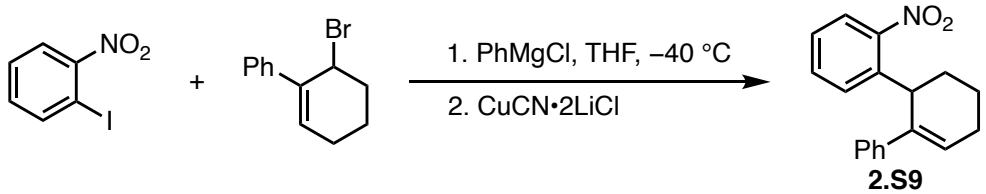
mmol, 1.10 equiv) and 1-methylcyclohex-1-enyl-6-bromide (2.10 g, 12.0 mmol, 1.20 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes) to afford **2.S8** (1.92 g, 88%) as yellow oil.

^1H NMR (600 MHz, $CDCl_3$) δ 7.78 (dd, J = 8.1, 1.3 Hz, 1H), 7.51 (td, J = 7.6, 1.3 Hz, 1H), 7.37 (dd, J = 7.9, 1.4 Hz, 1H), 7.33 (td, J = 7.7, 1.4 Hz, 1H), 5.76 (tt, J = 3.9, 1.7 Hz, 1H), 3.81 (t, J = 6.1 Hz, 1H), 2.17 – 1.98 (m, 3H), 1.74 – 1.65 (m, 1H), 1.59 – 1.49 (m, 2H), 1.46 (s, 3H).

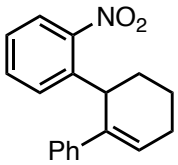
^{13}C NMR (101 MHz, $CDCl_3$) δ 150.4, 139.3, 133.4, 132.3, 130.5, 126.9, 126.2, 124.3, 40.4, 31.6, 25.4, 22.7, 18.9.

FTIR (cm^{-1}): 2933, 2860, 1525, 1351, 854.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_2]^+$: 218.1176; found: 218.1174.



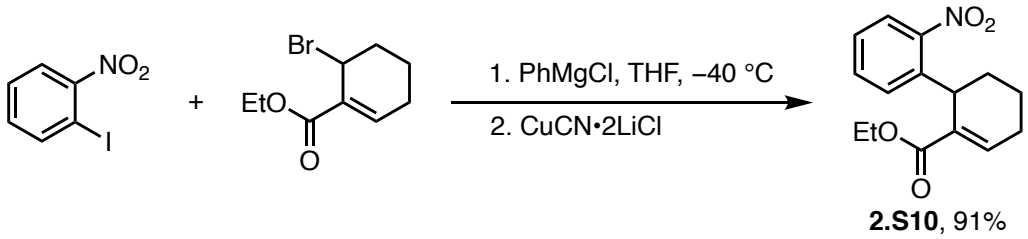
2.S9



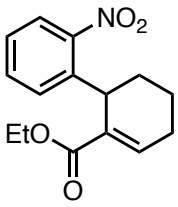
2.S9

(**2.S9**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (4.98 g, 20.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (80 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (11.0 mL, 2.0 M in THF, 22.0 mmol, 1.10 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (22.0 mL, 1.0 M in THF, 22.0 mmol, 1.10 equiv) and 6-bromo-1-phenylcyclohex-1-ene (5.69 g, 24.0 mmol, 1.20 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and evaporated in vacuo to afford **2.S9** as yellow oil. The crude product was directly used in next step without further purification.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.28 – 8.20 (m, 1H), 7.76 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.58 – 7.52 (m, 1H), 7.33 (dd, *J* = 4.6, 1.6 Hz, 1H), 7.26 – 7.22 (m, 2H), 7.20 – 7.15 (m, 2H), 7.12 – 7.07 (m, 1H), 6.43 (td, *J* = 4.0, 1.3 Hz, 1H), 4.77 (ddd, *J* = 6.2, 4.3, 2.0 Hz, 1H), 2.34 (ttd, *J* = 5.9, 4.1, 2.0 Hz, 2H), 2.26 – 2.15 (m, 1H), 1.87 – 1.78 (m, 1H), 1.69 – 1.49 (m, 2H).



2.S10, 91%



2.S10

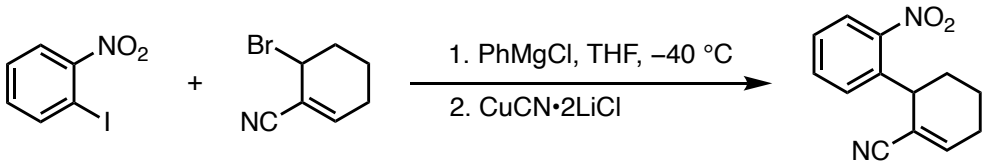
(**2.S10**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (2.50 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.6 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol, 1.10 equiv) and 6-bromocyclohex-1-enecarboxylic acid ethyl ester (2.35 g, 10.0 mmol, 1.00 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, hexanes to 4:96 EtOAc/hexanes) to afford **2.S10** (2.50 g, 91%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (dd, *J* = 8.1, 1.4 Hz, 1H), 7.45 (td, *J* = 7.6, 1.4 Hz, 1H), 7.35 – 7.27 (m, 2H), 7.22 (dd, *J* = 7.8, 1.4 Hz, 1H), 4.35 (ddt, *J* = 6.6, 4.6, 2.1 Hz, 1H), 4.06 – 3.80 (m, 2H), 2.43 – 2.21 (m, 2H), 2.20 – 2.08 (m, 1H), 1.85 – 1.75 (m, 1H), 1.68 – 1.56 (m, 2H), 0.95 (t, *J* = 7.1 Hz, 3H).

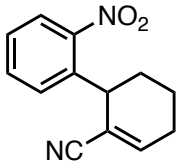
^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5, 149.8, 142.6, 139.9, 132.4, 131.8, 129.4, 126.9, 124.5, 60.3, 35.4, 30.3, 25.9, 18.2, 13.9.

FTIR (cm^{-1}): 3227, 1694, 1513, 1442, 1247.

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_4]^+$: 276.1230; found: 276.1228.



2.S11, 57%



2.S11

(**2.S11**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.5 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (11.0 mL, 1.0 M in THF, 11.0 mmol, 1.10 equiv) and 6-bromo-1-cyanocyclohex-1-ene (1.96 g, 11.0 mmol, 1.10 equiv)

were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 3 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S11** (1.30 g, 57%) as off-white solid.

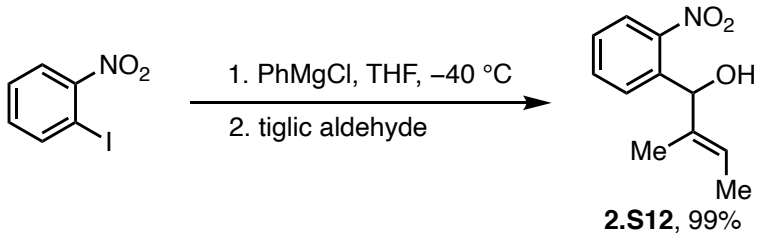
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dd, *J* = 8.2, 1.4 Hz, 1H), 7.62 (td, *J* = 7.6, 1.4 Hz, 1H), 7.44 (ddd, *J* = 8.1, 7.4, 1.4 Hz, 1H), 7.37 (dd, *J* = 7.8, 1.4 Hz, 1H), 6.97 (td, *J* = 4.1, 2.0 Hz, 1H), 4.36 – 4.21 (m, 1H), 2.38 – 2.31 (m, 2H), 2.30 – 2.22 (m, 1H), 1.79 – 1.64 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 149.5, 148.5, 136.6, 133.4, 130.1, 128.3, 125.4, 118.6, 114.8, 38.0, 30.7, 26.0, 18.8.

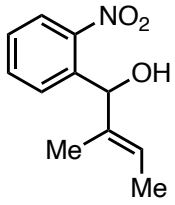
FTIR (cm^{-1}): 2935, 2217, 1719, 1525, 1348.

mp = 100-102 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{13}N_2O_2]^+$: 229.0972; found: 229.0967.



2.S12, 99%



2.S12

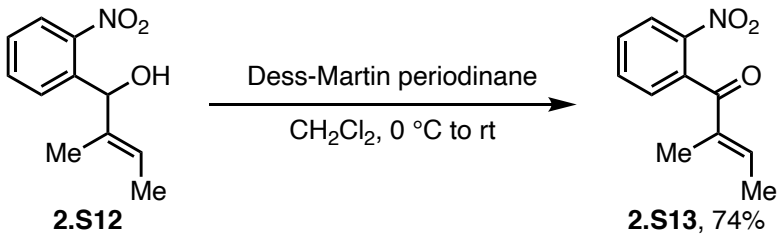
(**2.S12**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (40 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (5.6 mL, 2.0 M in THF, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C, followed by the addition of tiglic aldehyde (1.2 mL, 12 mmol, 1.2 equiv) via syringe. The reaction was stirred at −40 °C for 1 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S12** (2.05 g, 99%) as light yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (dd, J = 8.1, 1.4 Hz, 1H), 7.76 (dd, J = 7.9, 1.4 Hz, 1H), 7.60 (td, J = 7.6, 1.4 Hz, 1H), 7.41 (td, J = 7.8, 1.5 Hz, 1H), 5.70 (s, 1H), 5.52 (dddt, J = 8.1, 6.8, 5.4, 1.3 Hz, 1H), 2.51 (s, 1H), 1.60 (dt, J = 6.8, 1.1 Hz, 3H), 1.54 (t, J = 1.3 Hz, 3H).

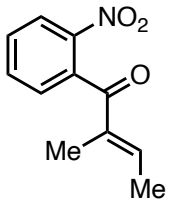
^{13}C NMR (101 MHz, $CDCl_3$) δ 148.7, 137.1, 135.6, 133.0, 128.8, 128.2, 124.5, 123.0, 73.7, 13.4, 13.2.

FTIR (cm^{-1}): 3381, 2919, 1526, 1444, 1353.

HRMS (ESI) m/z, calculated for $[C_{11}H_{14}NO_3 - H_2O]^+$: 190.0863; found: 190.0863.



2.S12 **2.S13**, 74%



2.S13

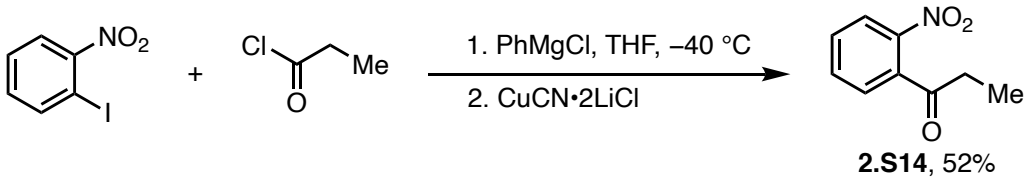
(**2.S13**) A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried, cooled under vacuum, and backfilled with N_2. **2.S12** (2.05 g, 10.0 mmol, 1.00 equiv) and anhydrous CH_2Cl_2 (50 mL) were added to the flask via syringe. The reaction mixture was cooled down to 0 °C in an ice bath under N_2 atmosphere. The septum was removed, and Dess-Martin periodinane (5.50 g, 13.0 mmol, 1.30 equiv) were added to the flask. The septum was replaced, and the resulting solution was allowed to warm up to rt and stir overnight. The reaction was quenched by saturated aqueous $NaHCO_3$ solution (100 mL). The aqueous layer was extracted with CH_2Cl_2 (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S13** (1.52 g, 74%) as light yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dd, J = 8.2, 1.2 Hz, 1H), 7.71 (td, J = 7.5, 1.2 Hz, 1H), 7.59 (ddd, J = 8.2, 7.5, 1.5 Hz, 1H), 7.38 (dd, J = 7.5, 1.5 Hz, 1H), 6.11 (qq, J = 6.9, 1.4 Hz, 1H), 1.99 (p, J = 1.2 Hz, 3H), 1.81 (dq, J = 6.8, 1.1 Hz, 3H).

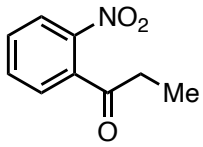
^{13}C NMR (101 MHz, $CDCl_3$) δ 195.5, 146.8, 142.1, 139.3, 136.9, 134.0, 130.1, 129.2, 124.5, 15.1, 11.3.

FTIR (cm^{-1}): 1664, 1641, 1527, 1347, 1283.

HRMS (ESI) m/z, calculated for $[C_{11}H_{12}NO_3]^+$: 206.0871; found: 206.0813.



2.S14, 52%

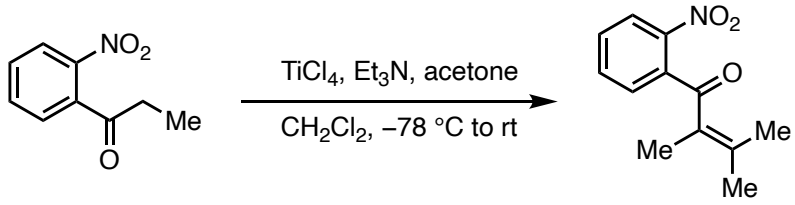


2.S14

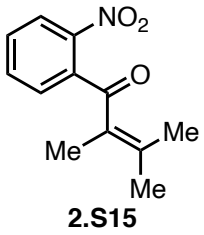
(**2.S14**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (7.47 g, 30.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (120 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (16.5 mL, 2.0 M in THF, 33.0 mmol, 1.10 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C. CuCN•2LiCl (33.0 mL, 1.0 M in THF, 33.0 mmol, 1.10 equiv) and propanoyl chloride (4.0 mL, 45 mmol, 1.5 equiv) were added sequentially to the flask via syringe. The reaction was stirred at −40 °C for 1 h, then diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and

chromatographed (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S14** (2.72 g, 52%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (dd, J = 8.2, 1.2 Hz, 1H), 7.71 (td, J = 7.5, 1.2 Hz, 1H), 7.59 (ddd, J = 8.3, 7.5, 1.5 Hz, 1H), 7.38 (dd, J = 7.5, 1.4 Hz, 1H), 2.79 (q, J = 7.2 Hz, 2H), 1.26 (t, J = 7.2 Hz, 3H). The analytical data matched that previously reported in the literature.[66]



2.S14 **2.S15**, 35%



2.S15

(**2.S15**) A 200 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried, cooled under vacuum, and backfilled with N_2. **2.S14** (2.58 g, 15.0 mmol, 1.00 equiv) and anhydrous CH_2Cl_2 (75 mL) were added to the flask via syringe. The reaction mixture was cooled down to −78 °C in a dry ice/acetone bath under N_2 atmosphere. $TiCl_4$ (4.0 mL, 30 mmol, 2.0 equiv) and anhydrous Et_3N (5.0 mL, 36 mmol, 2.4 equiv) were then added sequentially to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 30 min at −78 °C. Anhydrous acetone (3.4 mL, 45 mmol. 3.0 equiv) was added to the flask via syringe. The reaction was then warmed up and stirred overnight at rt. The reaction mixture was quenched by saturated aqueous H_2O (100 mL). The aqueous layer was extracted with CH_2Cl_2 (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear

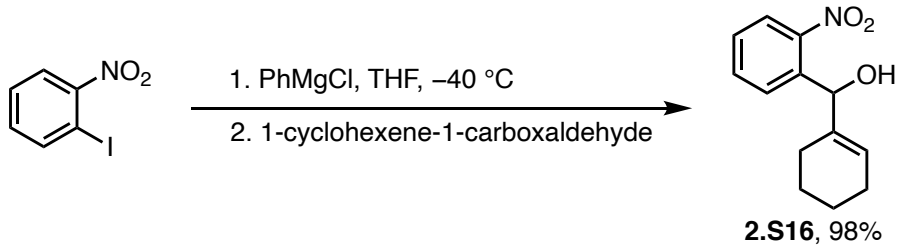
gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S15** (1.15 g, 35%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 8.2, 1.2 Hz, 1H), 7.67 (td, *J* = 7.5, 1.2 Hz, 1H), 7.61 – 7.52 (m, 1H), 7.44 (dd, *J* = 7.5, 1.5 Hz, 1H), 1.88 (d, *J* = 1.1 Hz, 3H), 1.84 (q, *J* = 1.5 Hz, 3H), 1.83 (q, *J* = 1.2 Hz, 3H).

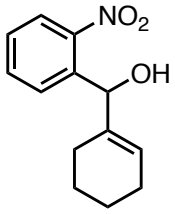
^{13}C NMR (101 MHz, $CDCl_3$) δ 196.0, 147.3, 147.1, 138.5, 133.8, 130.5, 129.4, 128.5, 124.4, 23.5, 23.4, 16.7.

FTIR (cm^{-1}): 2923, 1653, 1529, 1348, 1054.

HRMS (ESI) m/z, calculated for $[C_{12}H_{14}NO_3]^+$: 220.0968; found: 220.0965.



2.S16, 98%



2.S16

(**2.S16**) This reaction was modified from a literature procedure.[65] A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. 1-iodo-2-nitrobenzene (3.74 g, 15.0 mmol, 1.00 equiv) was added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF (60 mL) was added to the flask via syringe, and the resulting reaction mixture was cooled down to −40 °C in a dry ice/MeCN bath under N_2 atmosphere. PhMgCl (8.4 mL, 2.0 M in THF, 17 mmol, 1.1 equiv) was then added dropwisely to the reaction via syringe. Once the addition completed, the solution was allowed to stir for 5 min under −40 °C, followed by the addition of 1-cyclohexene-1-

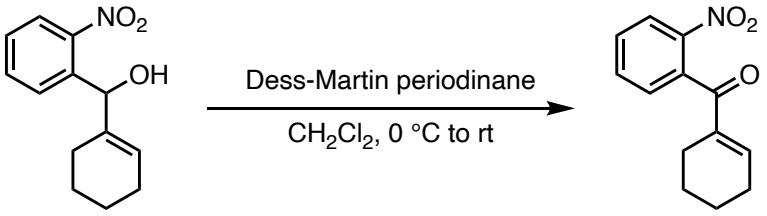
carboxaldehyde (2.0 mL, 18 mmol, 1.2 equiv) via syringe. The reaction was stirred at −40 °C for 1 h, then diluted with Et_2O (50 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 2:98 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S16** (3.47 g, 98%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (dd, J = 8.1, 1.3 Hz, 1H), 7.76 (dd, J = 7.8, 1.4 Hz, 1H), 7.60 (td, J = 7.6, 1.3 Hz, 1H), 7.40 (td, J = 7.8, 1.4 Hz, 1H), 5.70 – 5.55 (m, 2H), 2.61 (bs, 1H), 2.12 – 1.96 (m, 2H), 1.96 – 1.80 (m, 2H), 1.67 – 1.47 (m, 4H).

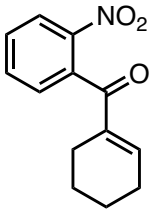
^{13}C NMR (101 MHz, $CDCl_3$) δ 148.6, 137.9, 137.3, 133.0, 128.8, 128.2, 125.2, 124.4, 72.8, 25.5, 25.0, 22.6, 22.2.

FTIR (cm^{-1}): 3387, 2930, 1526, 1352, 1013.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_3 - H_2O]^+$: 216.1019; found: 216.1016.



2.S16 **2.S17**, 72%



2.S17

(**2.S17**) A 250 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried, cooled under vacuum, and backfilled with N_2. **2.S16** (3.41 g, 15.0 mmol, 1.00 equiv) and anhydrous CH_2Cl_2 (75 mL) was added to the flask via syringe. The reaction mixture was cooled down to 0 °C in an ice bath under N_2 atmosphere. The septum was removed, and Dess-Martin periodinane (8.28 g, 19.5 mmol, 1.30 equiv) were added to the flask. The septum was replaced, and the resulting solution was allowed to warm up to rt and stir overnight. The reaction was quenched by saturated aqueous $NaHCO_3$ solution (100 mL). The aqueous layer was extracted with CH_2Cl_2 (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 8:92 EtOAc/hexanes) to afford **2.S17** (2.51 g, 72%) as yellow solid.

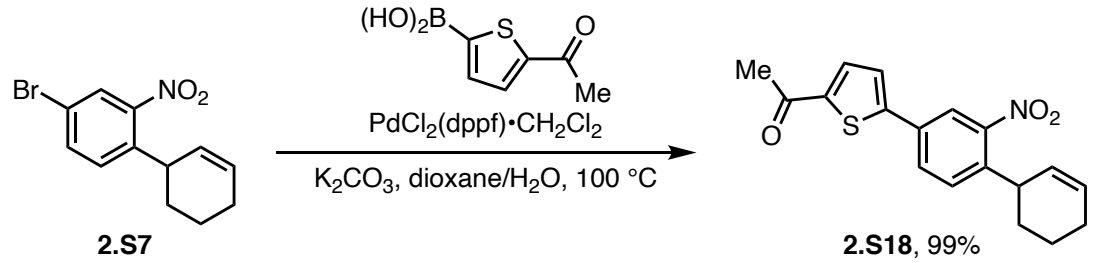
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dd, J = 8.2, 1.1 Hz, 1H), 7.71 (td, J = 7.5, 1.2 Hz, 1H), 7.59 (td, J = 7.9, 1.5 Hz, 1H), 7.40 (dd, J = 7.5, 1.4 Hz, 1H), 6.26 (tt, J = 3.8, 1.6 Hz, 1H), 2.45 (ddq, J = 6.5, 4.3, 2.2 Hz, 2H), 2.16 (ddt, J = 8.3, 6.3, 3.2 Hz, 2H), 1.78 – 1.68 (m, 2H), 1.68 – 1.59 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 194.9, 146.7, 144.5, 140.1, 136.6, 134.0, 130.1, 129.1, 124.3, 26.2, 23.2, 21.7, 21.5.

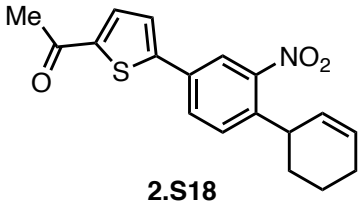
FTIR (cm^{-1}): 2935, 1660, 1636, 1347, 1281.

mp = 100-103 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}NO_3]^+$: 232.0968; found: 232.0967.



2.S7 **2.S18**, 99%



2.S18

(**2.S18**) A 50 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $PdCl_2(dppf)•CH_2Cl_2$ (0.82 g, 1.0 mmol, 0.10 equiv), **2.S7** (3.28 g, 10.0 mmol, 1.00 equiv), (5-acetylthiophen-2-yl)boronic acid (3.40 g, 20.0 mmol, 2.00 equiv), and K_2CO_3 (4.15 g, 30.0 mmol, 3.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous dioxane (40 mL) and degassed H_2O (10 mL) were added sequentially to the flask via syringe. The resulting solution was further degassed by bubbling through N_2 for 30 min, and then placed in a pre-heated oil bath to stir at 100 °C overnight. Upon completion, the reaction was cooled to rt, diluted with EtOAc (100 mL), and quenched by H_2O (100 mL). The aqueous layer was extracted with EtOAc (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 2:98 EtOAc/hexanes to 20:80 EtOAc/hexanes) to afford **2.S18** (3.25 g, 99%) as yellow oil.

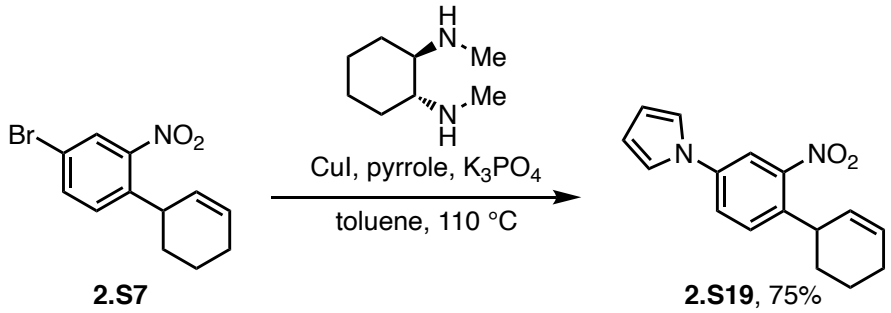
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, J = 2.0 Hz, 1H), 7.77 (dd, J = 8.2, 2.0 Hz, 1H), 7.68 (d, J = 4.0 Hz, 1H), 7.51 (d, J = 8.2 Hz, 1H), 7.37 (d, J = 4.0 Hz, 1H), 6.01 (dtd, J = 10.0, 3.7, 2.3 Hz, 1H), 5.59 (dq, J = 9.9, 2.4 Hz, 1H), 3.96 (ddq, J = 8.3, 5.6, 2.8 Hz,

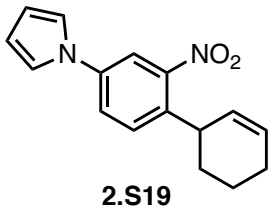
1H), 2.58 (s, 3H), 2.22 (dtd, *J* = 12.4, 6.1, 2.7 Hz, 1H), 2.12 (tq, *J* = 6.2, 3.5, 3.0 Hz, 2H), 1.82 – 1.60 (m, 2H), 1.57 – 1.48 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 190.7, 150.2, 149.5, 144.3, 141.2, 133.5, 132.6, 131.4, 130.3, 130.0, 128.4, 125.1, 121.6, 36.9, 31.7, 26.8, 24.9, 21.1.

FTIR (cm^{-1}): 2928, 1661, 1536, 1446, 1357, 1276.

HRMS (ESI) m/z, calculated for $[C_{18}H_{18}NO_3S]^+$: 328.1002; found: 328.0983.





(**2.S19**) This reaction was modified from a literature procedure.[67] A 25 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. CuI (57.1 mg, 0.30 mmol, 0.050 equiv), **2.S7** (1.96 g, 6.00 mmol, 1.00 equiv), (*R*,*R*)-*N*,*N*'-dimethyl-1,2-diaminocyclohexane (0.17 g, 1.2 mmol, 0.20 equiv), and K_3PO_4 (2.67 g, 12.6 mmol, 2.10 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous toluene (6 mL) and pyrrole (0.50 mL, 7.2 mmol, 1.2 equiv) were added sequentially to the flask via syringe. The resulting solution was then placed in a pre-heated oil bath to stir at 110 °C overnight. Upon completion, the reaction was filtered through a short plug of celite, evaporated in

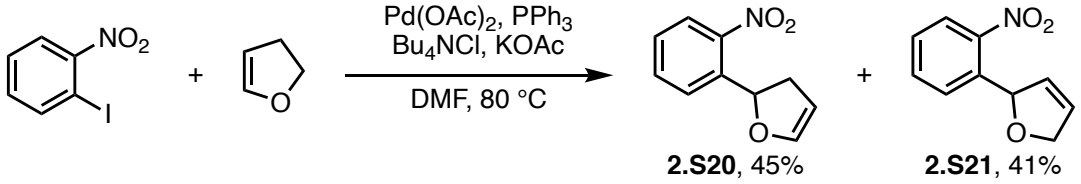
vacuo, and chromatographed (linear gradient, hexanes to 4:96 EtOAc/hexanes) to afford **2.S19** (1.21 g, 75%) as yellow oil.

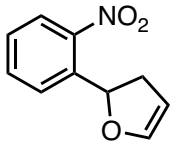
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, J = 2.3 Hz, 1H), 7.64 – 7.45 (m, 2H), 7.10 (t, J = 2.2 Hz, 2H), 6.38 (t, J = 2.2 Hz, 2H), 6.08 – 5.89 (m, 1H), 5.70 – 5.53 (m, 1H), 3.96 (ddt, J = 8.3, 5.6, 2.8 Hz, 1H), 2.22 (dtd, J = 12.8, 6.2, 2.9 Hz, 1H), 2.13 (ddp, J = 11.2, 5.9, 2.7 Hz, 2H), 1.81 – 1.61 (m, 2H), 1.60 – 1.50 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 150.1, 139.4, 137.6, 131.8, 130.2, 128.7, 124.0, 119.3, 115.7, 111.6, 36.6, 31.8, 25.0, 21.1.

FTIR (cm^{-1}): 1622, 1532, 1508, 1338, 1063.

HRMS (ESI) m/z, calculated for $[C_{16}H_{17}N_2O_2]^+$: 269.1285; found: 269.1279.





2.S20

(**2.S20**) This reaction was modified from a literature procedure.[63] A 50 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $Pd(OAc)_2$ (56.5 mg, 0.25 mmol, 0.025 equiv), PPh_3 (67.1 mg, 0.25 mmol, 0.025 equiv), Bu_4NCl (2.91 g, 10.0 mmol, 1.00 equiv), KOAc (2.95 g, 30.0 mmol, 3.00 equiv), and 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous DMF (20 mL) and 2,3-dihydrofuran (3.8 mL, 50 mmol, 5.0 equiv) were added sequentially to the flask via syringe. The resulting solution was placed in a pre-heated oil bath and stirred at 80 °C overnight. Upon completion, the reaction was cooled

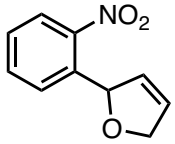
to rt, opened to air, and diluted with Et_2O (100 mL). The mixture was then washed with brine (100 mL) three times. The aquoes layers were combined and extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL) for additional three times. The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 4:96 EtOAc/hexanes) to afford **2.S20** (0.85 g, 45%) as dark yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.73 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.64 (td, *J* = 7.6, 1.3 Hz, 1H), 7.42 (ddd, *J* = 8.5, 7.3, 1.5 Hz, 1H), 6.33 (ddt, *J* = 6.0, 3.9, 1.9 Hz, 1H), 6.08 (dtd, *J* = 6.3, 2.4, 1.5 Hz, 1H), 6.01 (dt, *J* = 6.6, 2.0 Hz, 1H), 4.97 (dddd, *J* = 10.2, 6.2, 2.4, 1.2 Hz, 1H), 4.88 (dddd, *J* = 12.9, 3.9, 2.5, 1.6 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 147.0, 139.3, 134.2, 129.7, 128.22, 128.20, 126.9, 124.5, 84.4, 76.6.

FTIR (cm^{-1}): 1713, 1608, 1468, 1359, 1256.

HRMS (ESI) m/z, calculated for $[C_{10}H_{10}NO_3]^+$: 192.0655; found: 192.0651.



2.S21

(**2.S21**) This reaction was modified from a literature procedure.[63] A 50 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $Pd(OAc)_2$ (56.5 mg, 0.25 mmol, 0.025 equiv), PPh_3 (67.1 mg, 0.25 mmol, 0.025 equiv), Bu_4NCl (2.91 g, 10.0 mmol, 1.00 equiv), KOAc (2.95 g, 30.0 mmol, 3.00 equiv), and 1-iodo-2-nitrobenzene (2.49 g, 10.0 mmol, 1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times.

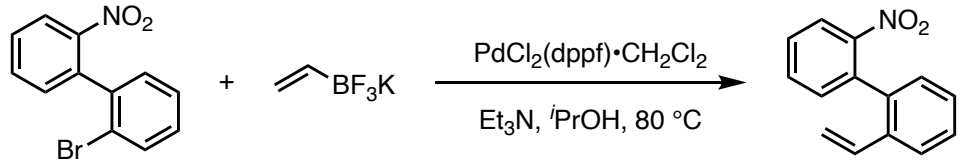
Anhydrous DMF (20 mL) and 2,3-dihydrofuran (3.8 mL, 50 mmol, 5.0 equiv) were added sequentially to the flask via syringe. The resulting solution was placed in a pre-heated oil bath and stirred at 80 °C overnight. Upon completion, the reaction was cooled to rt, opened to air, and diluted with Et_2O (100 mL). The mixture was then washed with brine (100 mL) three times. The aqueous layers were combined and extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL) for additional three times. The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 1:99 EtOAc/hexanes to 4:96 EtOAc/hexanes) to afford **2.S21** (0.79 g, 41%) as dark yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.73 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.66 (td, *J* = 7.6, 1.3 Hz, 1H), 7.44 (ddd, *J* = 8.5, 7.2, 1.6 Hz, 1H), 6.50 (q, *J* = 2.5 Hz, 1H), 6.10 (dd, *J* = 11.0, 7.3 Hz, 1H), 4.95 (q, *J* = 2.6 Hz, 1H), 3.41 (ddt, *J* = 15.8, 11.0, 2.4 Hz, 1H), 2.44 (ddt, *J* = 15.8, 7.3, 2.3 Hz, 1H).

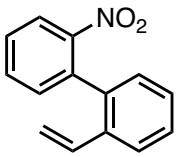
^{13}C NMR (101 MHz, $CDCl_3$) δ 146.6, 145.1, 139.9, 134.1, 128.2, 127.2, 125.0, 99.4, 78.6, 38.4.

FTIR (cm^{-1}): 1624, 1526, 1344, 1136, 1050.

HRMS (ESI) m/z, calculated for $[C_{10}H_{10}NO_3]^+$: 192.0655; found: 192.0648.



2.S22, 62%



2.S22

(**2.S22**) A 100 mL Schlenk flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. $PdCl_2(dppf)•CH_2Cl_2$ (0.82 g, 1.0 mmol, 0.10 equiv), 2′-bromo-2-nitro-biphenyl (2.78 g, 10.0 mmol, 1.00 equiv), and potassium vinyltrifluoroborate (2.68 g, 20.0 mmol, 2.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous ^{i}PrOH (100 mL) and anhydrous Et_3N (4.2 mL, 30 mmol, 3.0 equiv) were added sequentially to the flask via syringe. The resulting solution was placed in a pre-heated oil bath and stirred at 80 °C overnight. Upon completion, the reaction was cooled to rt and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed chromatographed (linear gradient, hexanes to 2:98 EtOAc/hexanes) to afford **2.S22** (1.40 g, 62%) as yellow oil.

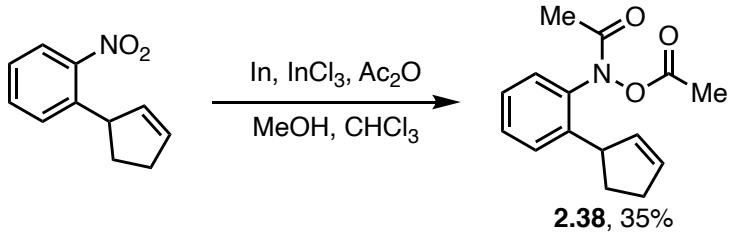
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.67 – 7.61 (m, 2H), 7.57 – 7.50 (m, 1H), 7.40 (td, *J* = 7.7, 1.4 Hz, 1H), 7.36 (dd, *J* = 7.6, 1.5 Hz, 1H), 7.32 (td, *J* = 7.5, 1.4 Hz, 1H), 7.16 (dd, *J* = 7.6, 1.4 Hz, 1H), 6.41 (dd, *J* = 17.4, 11.0 Hz, 1H), 5.66 (dd, *J* = 17.4, 1.1 Hz, 1H), 5.17 (dd, *J* = 11.0, 1.1 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 149.4, 136.4, 136.0, 135.8, 134.3, 132.9, 132.6, 128.8, 128.6, 128.5, 127.8, 125.5, 124.3, 116.3.

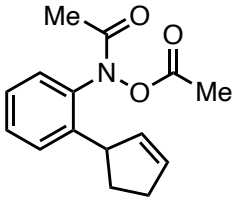
FTIR (cm^{-1}): 1526, 1471, 1351, 854, 748.

HRMS (ESI) m/z, calculated for $[C_{14}H_{12}NO_2]^+$: 226.0863; found: 226.0860.

2.6.4 Synthesis of *N*-aryl-*N*-hydroxy Carbamates



2.38, 35%



2.38

(**2.38**) This reaction was modified from a literature procedure.[68] A 10 mL round bottom flask equipped with a magnetic stir bar and a rubber septum was attached to a double manifold. It was flame-dried and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Indium powder (2.87 g, 25.0 mmol, 5.00 equiv) and $InCl_3$ (0.22 g, 1.0 mmol, 0.20 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. 3-(2-nitro)cyclopentene (0.95 g, 5.0 mmol), anhydrous Ac_2O (1.9 mL, 20 mmol, 4.0 equiv), anhydrous MeOH (0.40 mL, 10 mmol, 2.0 equiv), and anhydrous $CHCl_3$ (20 mL) were added sequentially to the flask via syringe. The reaction was stirred at rt overnight, then quenched by H_2O (50 mL) and extracted with CH_2Cl_2 (50 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed (linear gradient, 2:98 EtOAc/hexanes to 20:80 EtOAc/hexanes) to afford **2.38** (0.45 g, 35%) as off-white solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.57 – 7.12 (m, 4H), 6.01 (d, J = 24.3 Hz, 1H), 5.84 – 5.57 (m, 1H), 4.15 (d, J = 30.6 Hz, 1H), 2.57 – 2.44 (m, 1H), 2.43 – 2.28 (m, 2H), 2.25 – 2.08 (m, 4H), 1.92 – 1.77 (m, 2H), 1.71 – 1.51 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ (major rotamer) 167.4, 165.5, 145.4, 136.8, 133.1, 132.3, 131.2, 130.0, 128.2, 127.5, 45.1, 32.3, 32.0, 21.4, 18.1. (Please note that this

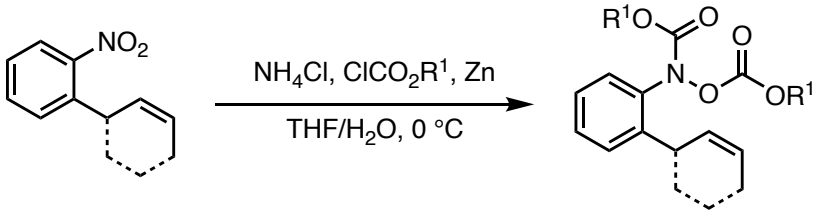
spectrum is highly complex due to rotomeric behavior. Major peaks are given for diagnostic purposes. Please see the spectrum for additional information.)

^{13}C NMR (101 MHz, DMSO-d_6) δ (minor rotamer) 145.7, 136.8, 133.5, 133.0, 132.1, 131.3, 139.1, 127.7, 45.4, 33.8, 20.6, 18.4. (Please note that this spectrum is highly complex due to rotomeric behavior. Major peaks are given for diagnostic purposes. Please see the spectrum for additional information.)

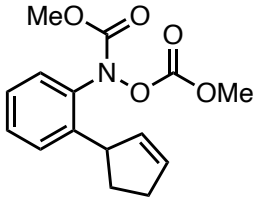
FTIR (cm^{-1}): 2940, 1795, 1694, 1486, 1370, 1178.

mp = 72-74 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_3]^+$: 260.1281; found: 260.1287.



General Protocol A: This reaction was modified from a literature procedure.[52] In a round bottom flask equipped with a magnetic stir bar, a solution of nitroarenes (1.00 equiv) in THF (0.25 M with respect to nitroarene) and H_2O (0.50 M with respect to nitroarene) was cooled down to 0 °C in an ice bath under air. NH_4Cl (1.10 equiv) and chloroformate (3.00 equiv) were added sequentially to the flask. After stiring at 0 °C for 5 min, Zn powder (4.00 equiv) was added, and the resulting suspension was allowed to stir at 0 °C for the indicated time. The reaction was then diluted with Et_2O and quenched by saturated aqueous $NaHCO_3$ solution. The aqueous layer was extracted with Et_2O twice. The organic layers were then combined and washed with brine. The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, evaporated in vacuo, and chromatographed to afford *N*-aryl-*N*-hydroxy carbamates.



2.42

(**2.42**) According to general protocol A: 3-(2-nitro)cyclopentene (0.95 g, 5.0 mmol), NH_4Cl (0.29 g, 5.5 mmol), methyl chloroformate (1.1 mL, 15 mmol), and Zn powder (1.31 g, 20.0 mmol) were combined in THF (20 mL) and H_2O (10 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 5:95 EtOAc/hexanes) to afford **2.42** (1.21 g, 83%) as colorless solid.

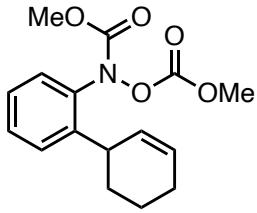
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.44 (td, *J* = 7.5, 1.4 Hz, 1H), 7.40 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.31 (td, *J* = 7.6, 1.6 Hz, 1H), 7.22 (dd, *J* = 7.7, 1.5 Hz, 1H), 5.99 (dq, *J* = 4.6, 2.2 Hz, 1H), 5.64 (dq, *J* = 6.0, 2.1 Hz, 1H), 4.25 – 4.04 (m, 1H), 3.85 (s, 3H), 3.73 (s, 3H), 2.48 – 2.43 (m, 1H), 2.43 – 2.25 (m, 2H), 1.64 – 1.50 (m, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 154.6, 154.1, 145.0, 136.6, 133.5, 132.5, 130.7, 128.6, 127.9, 127.2, 56.7, 54.1, 44.9, 32.9, 32.1.

FTIR (cm^{-1}): 2958, 1796, 1744, 1441, 1241, 1111, 930.

mp = 50-52 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_5]^+$: 292.1185; found: 292.1168.



2.S23

(**2.S23**) According to general protocol A: **2.S1** (3.01 g, 15.0 mmol), NH_4Cl (0.88 g, 17 mmol), methyl chloroformate (3.5 mL, 45 mmol), and Zn powder (3.97 g, 60.0 mmol) were combined in THF (60 mL) and H_2O (30 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general

procedure and purified by chromatography (linear gradient, 5:95 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S23** (3.32 g, 72%) as colorless solid.

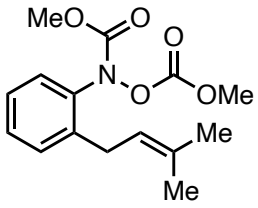
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.45 (td, J = 7.5, 1.5 Hz, 1H), 7.41 (dd, J = 7.9, 1.5 Hz, 1H), 7.35 – 7.27 (m, 2H), 5.88 (ddt, J = 10.0, 5.3, 2.8 Hz, 1H), 5.56 – 5.44 (m, 1H), 3.85 (s, 3H), 3.73 (s, 4H), 2.20 – 1.97 (m, 2H), 1.97 – 1.83 (m, 1H), 1.82 – 1.65 (m, 1H), 1.62 – 1.49 (m, 1H), 1.49 – 1.32 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.3, 154.8, 146.1, 137.0, 130.4, 130.1, 129.3, 129.1, 128.7, 127.0, 56.4, 54.2, 36.5, 31.8, 25.0, 21.7.

FTIR (cm^{-1}): 2958, 1796, 1744, 1441, 1241, 1111, 930.

mp = 64-66 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{16}H_{20}NO_5]^+$: 306.1341; found: 306.1332.



2.S24

(**2.S24**) According to general protocol A: 2-(3-methylbut-2-enyl)-nitrobenzene (1.70 g, 9.00 mmol), NH_4Cl (0.53 g, 9.9 mmol), methyl chloroformate (2.1 mL, 27 mmol), and Zn powder (2.35 g, 36.0 mmol) were combined in THF (36 mL) and H_2O (18 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S24** (2.01 g, 76%) as colorless solid.

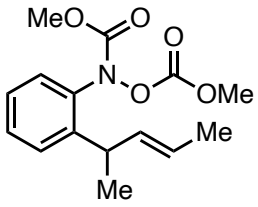
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.45 – 7.36 (m, 2H), 7.35 – 7.25 (m, 2H), 5.20 (tp, J = 7.3, 1.4 Hz, 1H), 3.85 (s, 3H), 3.71 (s, 3H), 3.35 (d, J = 1.4 Hz, 2H), 1.69 (d, J = 1.4 Hz, 3H), 1.66 (d, J = 1.4 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.4, 154.2, 140.3, 137.1, 132.7, 130.3, 130.0, 128.8, 127.1, 121.8, 56.6, 54.0, 29.0, 25.6, 17.6.

FTIR (cm^{-1}): 2960, 1796, 1742, 1442, 1243, 1115.

mp = 35-37 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{20}NO_5]^+$: 294.1341; found: 294.1327.



2.S25

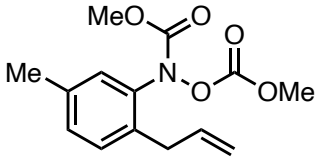
(**2.S25**) According to general protocol A: **2.S2** (0.67 g, 3.5 mmol), NH_4Cl (0.20 g, 3.8 mmol), methyl chloroformate (0.80 mL, 11 mmol), and Zn powder (0.92 g, 14 mmol) were combined in THF (14 mL) and H_2O (7 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S25** (0.89 g, 86%) as yellow solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.48 – 7.41 (m, 1H), 7.40 – 7.35 (m, 2H), 7.33 – 7.26 (m, 1H), 5.57 (dd, J = 15.3, 6.5 Hz, 1H), 5.40 (dq, J = 13.1, 6.3 Hz, 1H), 3.85 (s, 3H), 3.79 – 3.74 (m, 1H), 3.71 (s, 3H), 1.61 (d, J = 6.1 Hz, 3H), 1.23 (d, J = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.7, 154.1, 145.3, 136.3, 135.1, 130.6, 128.9, 128.1, 127.1, 123.7, 56.6, 54.0, 35.7, 21.3, 17.7.

FTIR (cm^{-1}): 2961, 1797, 1743, 1488, 1441, 1340, 1240, 1192.

HRMS (ESI) m/z, calculated for $[C_{15}H_{20}NO_5]^+$: 294.1341; found: 294.1323.



2.S26

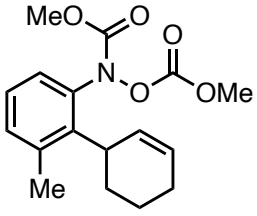
(**2.S26**) According to general protocol A: **2.S3** (1.70 g, 10.0 mmol), NH_4Cl (0.59 g, 11 mmol), methyl chloroformate (2.3 mL, 30 mmol), and Zn powder (2.61 g, 40.0 mmol) were combined in THF (40 mL) and H_2O (20 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S26** (1.20 g, 43%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.33 (t, J = 7.6 Hz, 1H), 7.27 – 7.18 (m, 1H), 7.15 (d, J = 7.4 Hz, 1H), 5.94 – 5.76 (m, 1H), 5.13 – 4.97 (m, 2H), 3.84 (s, 3H), 3.81 – 3.59 (m, 3H), 3.52 – 3.39 (m, 2H), 2.27 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 155.1, 153.9, 139.6, 137.7, 136.7, 136.2, 130.4, 129.2, 128.1, 116.2, 56.5, 54.2, 35.0, 17.5.

FTIR (cm^{-1}): 2959, 1797, 1748, 1441, 1239.

HRMS (ESI) m/z, calculated for $[C_{14}H_{18}NO_5]^+$: 280.1179; found: 280.1167.



2.S27

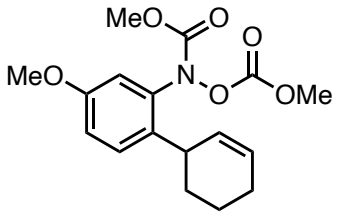
(**2.S27**) According to general protocol A: **2.S4** (500.0 mg, 2.30 mmol), NH_4Cl (135.0 mg, 2.53 mmol), methyl chloroformate (0.53 mL, 6.9 mmol), and Zn powder (602.0 mg, 9.21 mmol) were comobined in THF (9 mL) and H_2O (4.5 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S27** (377.0 mg, 51%) as colorless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 7.2 Hz, 1H), 7.21 – 7.13 (m, 2H), 5.78 (dq, *J* = 10.5, 3.6 Hz, 1H), 5.61 (d, *J* = 10.2 Hz, 1H), 4.22 – 3.95 (m, 1H), 3.88 (d, *J* = 5.3 Hz, 3H), 3.79 (d, *J* = 2.8 Hz, 3H), 2.43 (s, 3H), 2.15 – 2.06 (m, 2H), 1.91 – 1.66 (m, 4H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.1, 154.7, 142.9, 139.1, 138.0, 134.0, 130.4, 129.0, 127.0, 126.9, 126.8, 56.3, 54.1, 54.0, 37.4, 28.2, 24.8, 23.2, 23.1, 20.3, 20.2.

FTIR (cm^{-1}): 2955, 1795, 1746, 1441, 1240.

HRMS (ESI) m/z, calculated for $[C_{17}H_{22}NO_5]^+$: 320.1492; found: 320.1483.



2.S28

(**2.S28**) According to general protocol A: **2.S5** (2.80 g, 12.0 mmol), NH_4Cl (0.71 g, 13 mmol), methyl chloroformate (2.8 mL, 36 mmol), and Zn powder (3.14 g, 48.0 mmol) were combined in THF (48 mL) and H_2O (24 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S28** (3.06 g, 76%) as colorless solid.

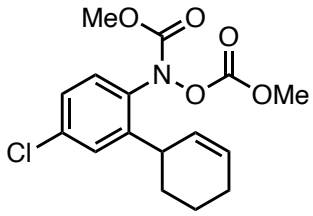
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.6 Hz, 1H), 6.98 (d, *J* = 2.7 Hz, 1H), 6.95 (dd, *J* = 8.6, 2.7 Hz, 1H), 5.90 – 5.81 (m, 1H), 5.55 – 5.49 (m, 1H), 3.89 (s, 3H), 3.81 (s, 3H), 3.78 (s, 3H), 3.77 – 3.67 (m, 1H), 2.20 – 2.04 (m, 2H), 2.04 – 1.86 (m, 1H), 1.82 – 1.71 (m, 1H), 1.71 – 1.55 (m, 1H), 1.51 – 1.39 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.2, 155.2, 154.8, 138.0, 137.5, 130.4, 129.9, 128.4, 117.1, 113.3, 56.4, 55.6, 54.2, 35.9, 31.9, 25.0, 21.7.

FTIR (cm^{-1}): 2937, 1796, 1754, 1442, 1281, 1248.

mp = 68-70 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{22}NO_6]^+$: 336.1442; found: 336.1432.



2.S29

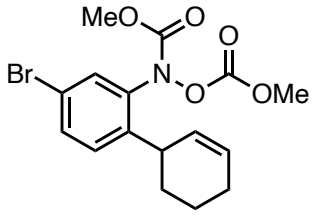
(**2.S29**) According to general protocol A: **2.S6** (1.67 g, 7.00 mmol), NH_4Cl (0.41 g, 7.7 mmol), methyl chloroformate (1.6 mL, 21 mmol), and Zn powder (1.83 g, 28.0 mmol) were combined in THF (28 mL) and H_2O (14 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S29** (2.08 g, 87%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.47 (d, J = 8.5 Hz, 1H), 7.40 (dd, J = 8.5, 2.5 Hz, 1H), 7.26 (d, J = 2.5 Hz, 1H), 5.91 (ddt, J = 10.0, 5.2, 2.7 Hz, 1H), 5.47 (dt, J = 10.2, 2.4 Hz, 1H), 3.86 (s, 3H), 3.81 – 3.70 (m, 4H), 2.15 – 1.95 (m, 2H), 1.90 (ddt, J = 12.5, 6.1, 3.4 Hz, 1H), 1.76 – 1.62 (m, 1H), 1.60 – 1.49 (m, 1H), 1.48 – 1.36 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.5, 154.0, 147.6, 135.7, 135.0, 130.8, 129.2, 128.7, 128.5, 127.5, 56.8, 54.3, 36.0, 30.9, 24.2, 21.0.

FTIR (cm^{-1}): 2957, 2931, 1797, 1749, 1442, 1340, 1241, 1094.

HRMS (LIFDI) m/z, calculated for $[C_{16}H_{18}NO_5Cl]^+$: 339.0860; found: 339.0874.



2.S30

(**2.S30**) According to general protocol A: **2.S7** (2.03 g, 7.20 mmol), NH_4Cl (0.42 g, 7.9 mmol), methyl chloroformate (1.7 mL, 22 mmol), and Zn powder (1.88 g, 28.8 mmol) were combined in THF (30 mL) and H_2O (15 mL), which was

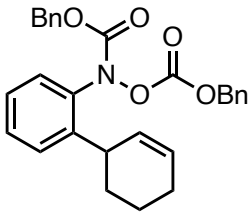
allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S30** (0.57 g, 21%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.61 (d, J = 2.2 Hz, 1H), 7.49 (dd, J = 8.4, 2.1 Hz, 1H), 7.22 (d, J = 8.4 Hz, 1H), 5.97 – 5.83 (m, 1H), 5.51 (dd, J = 10.2, 2.5 Hz, 1H), 3.90 (s, 3H), 3.82 (s, 3H), 3.80 – 3.71 (m, 1H), 2.17 – 2.05 (m, 2H), 2.05 – 1.95 (m, 1H), 1.81 – 1.71 (m, 1H), 1.71 – 1.57 (m, 1H), 1.48 – 1.35 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.9, 154.6, 145.2, 138.0, 133.4, 131.8, 130.8, 129.4, 129.1, 119.5, 56.5, 54.3, 36.3, 31.7, 24.9, 21.5.

FTIR (cm^{-1}): 2956, 2931, 1797, 1748, 1442, 1242.

HRMS (ESI) m/z, calculated for $[C_{16}H_{19}NO_5Br]^+$: 384.0441; found: 384.0428.



2.S31

(**2.S31**) According to general protocol A: **2.S1** (1.15 g, 5.00 mmol), NH_4Cl (0.29 g, 5.5 mmol), benzyl chloroformate (2.1 mL, 15 mmol), and Zn powder (1.31 g, 20.0 mmol) were combined in THF (20 mL) and H_2O (10 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S31** (0.99 g, 43%) as yellow oil.

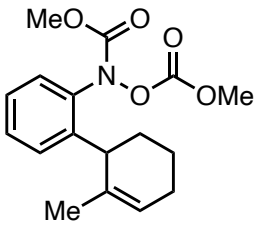
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.48 – 7.23 (m, 14H), 5.84 (ddd, J = 10.1, 4.3, 2.5 Hz, 1H), 5.42 (d, J = 10.1 Hz, 1H), 5.29 (s, 2H), 5.22 (s, 2H), 3.71 (d, J = 8.6 Hz, 1H), 2.14 – 1.92 (m, 2H), 1.84 – 1.71 (m, 1H), 1.69 – 1.59 (m, 1H), 1.51 – 1.28 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.1, 153.4, 145.2, 136.7, 135.5, 134.4, 130.7, 129.6, 128.9, 128.8, 128.63, 128.58, 128.5, 128.4, 128.3, 127.8, 127.3, 71.2, 68.2, 35.8, 31.1,

24.3, 21.1. (Due to the complexity of the spectrum in the aromatic region, one required signal cannot be resolved. However, we are confident in our structural assignment, as downstream compounds derived from this material have satisfactory analytical characteristics.)

FTIR (cm^{-1}): 3451, 2932, 1791, 1734, 1327, 1218.

HRMS (ESI) m/z, calculated for $[C_{28}H_{28}NO_5]^+$: 458.1962; found: 458.1953.



2.S32

(**2.S32**) According to general protocol A: **2.S8** (1.52 g, 7.00 mmol), NH_4Cl (0.41 g, 7.7 mmol), methyl chloroformate (1.7 mL, 21 mmol), and Zn powder (1.83 g, 28.0 mmol) were combined in THF (28 mL) and H_2O (14 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S32** (1.91 g, 57%) as colorless solid.

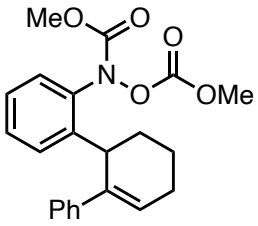
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.50 – 7.40 (m, 2H), 7.37 – 7.29 (m, 1H), 7.21 (dd, J = 7.8, 1.6 Hz, 1H), 5.70 (tt, J = 3.8, 1.6 Hz, 1H), 3.86 (s, 3H), 3.73 (s, 3H), 3.67 – 3.52 (m, 1H), 2.18 – 1.94 (m, 2H), 1.87 (ddd, J = 15.5, 8.4, 4.0 Hz, 1H), 1.63 – 1.51 (m, 1H), 1.51 – 1.39 (m, 2H), 1.34 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.8, 154.1, 144.2, 137.6, 133.7, 130.4, 129.2, 128.8, 127.3, 124.9, 56.7, 54.1, 39.4, 31.3, 24.8, 22.1, 19.1.

FTIR (cm^{-1}): 3449, 2933, 1796, 1744, 1441, 1240.

mp = 82-84 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{22}NO_5]^+$: 320.1492; found: 320.1490.



2.S33

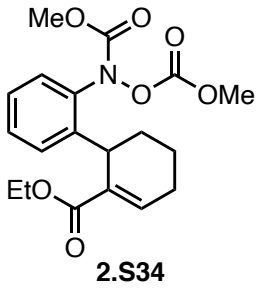
(**2.S33**) According to general protocol A: **2.S9** (5.59 g, 20.0 mmol), NH_4Cl (1.18 g, 22.0 mmol), methyl chloroformate (4.6 mL, 60 mmol), Zn powder (5.23 g, 80.0 mmol) were combined in THF (80 mL) and H_2O (40 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure, purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes), and then recrystallized from DCE/hexanes to afford **2.S33** (4.12 g, 54%) as colorless solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, J = 7.8 Hz, 1H), 7.26 – 7.20 (m, 4H), 7.20 – 7.03 (m, 4H), 6.38 (td, J = 4.0, 1.2 Hz, 1H), 4.51 (bs, 1H), 3.92 (s, 3H), 3.83 (s, 3H), 2.40 – 2.24 (m, 2H), 2.13 – 1.99 (m, 1H), 1.82 – 1.70 (m, 1H), 1.59 (td, J = 10.8, 9.5, 7.2 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 154.8, 154.8, 144.6, 141.8, 138.1, 137.1, 130.1, 130.04, 129.95, 128.9, 128.0, 127.0, 126.5, 126.2, 56.4, 54.2, 37.1, 31.1, 26.1, 17.8.

FTIR (cm^{-1}): 2957, 1794, 1739, 1487, 1441, 1056.

mp = 113-115 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{22}H_{24}NO_5]^+$: 382.1649; found: 382.1642.



2.S34

(**2.S34**) According to general protocol A: **2.S10** (2.20 g, 8.00 mmol), NH_4Cl (0.47 g, 8.8 mmol), methyl chloroformate (1.9 mL, 24 mmol), and Zn powder (2.09 g, 32.0 mmol) were combined in THF (32 mL) and H_2O (16 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure, purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 15:85 EtOAc/hexanes), and then recrystallized from DCE/hexanes to afford **2.S34** (2.02 g, 67%) as colorless solid.

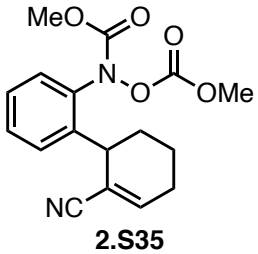
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, J = 7.8 Hz, 1H), 7.34 – 7.26 (m, 2H), 7.26 – 7.20 (m, 1H), 7.12 (dd, J = 7.7, 1.7 Hz, 1H), 4.38 (bs, 1H), 4.08 – 3.97 (m, 1H), 3.93 – 3.86 (m, 4H), 3.84 (s, 3H), 2.43 – 2.15 (m, 2H), 2.08 – 1.86 (m, 1H), 1.72 – 1.54 (m, 3H), 0.94 (t, J = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 166.9, 154.9, 154.9, 145.3, 142.1, 137.1, 132.3, 130.2, 129.9, 128.4, 127.0, 60.1, 56.3, 54.1, 34.9, 30.3, 25.9, 17.9, 13.9.

FTIR (cm^{-1}): 3450, 1711, 1647, 1524, 1355, 1243.

mp = 103-105 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{19}H_{24}NO_7]^+$: 378.1547; found: 378.1544.



2.S35

(**2.S35**) According to general protocol A: **2.S11** (1.14 g, 5.00 mmol), NH_4Cl (0.29 g, 5.5 mmol), methyl chloroformate (1.2 mL, 15 mmol), and Zn powder (1.31 g, 20.0 mmol) were combined in THF (20 mL) and H_2O (10 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure, purified by chromatography (linear gradient, 1:99

EtOAc/hexanes to 10:90 EtOAc/hexanes), and then recrystallized from DCE/hexanes to afford **2.S35** (0.96 g, 58%) as colorless solid.

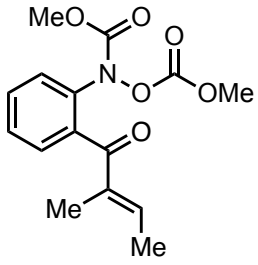
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (t, *J* = 6.8 Hz, 1H), 7.43 (dd, *J* = 7.6, 1.4 Hz, 1H), 7.34 (td, *J* = 7.6, 1.6 Hz, 1H), 7.29 – 7.25 (m, 1H), 6.88 (td, *J* = 4.0, 2.1 Hz, 1H), 4.40 – 3.99 (m, 1H), 3.90 (s, 3H), 3.83 (s, 3H), 2.31 (tt, *J* = 6.5, 3.5 Hz, 2H), 2.10 (dd, *J* = 12.2, 6.6 Hz, 1H), 1.78 (dt, *J* = 7.6, 5.1 Hz, 1H), 1.72 – 1.52 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.4, 154.8, 147.3, 141.6, 137.8, 130.7, 128.7, 128.7, 128.4, 118.8, 115.9, 56.5, 54.3, 37.2, 30.8, 26.0, 19.4.

FTIR (cm^{-1}): 3446, 1795, 1743, 1441, 1243.

mp = 112-114 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{19}N_2O_5]^+$: 331.1288; found: 331.1285.



2.S36

(**2.S36**) According to general protocol A: **2.S13** (1.52 g, 7.5 mmol), NH_4Cl (0.44 g, 8.3 mmol), methyl chloroformate (1.8 mL, 23 mmol), and Zn powder (2.01 g, 30.0 mmol) were combined in THF (30 mL) and H_2O (15 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S36** (1.22 g, 53%) as yellow solid.

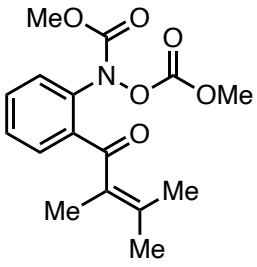
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 8.1, 1.3 Hz, 1H), 7.48 (td, *J* = 7.6, 1.7 Hz, 1H), 7.42 (td, *J* = 7.4, 1.4 Hz, 1H), 7.37 (dd, *J* = 7.6, 1.7 Hz, 1H), 6.30 (qd, *J* = 6.9, 1.4 Hz, 1H), 3.85 (s, 3H), 3.79 (s, 3H), 1.95 (p, *J* = 1.1 Hz, 3H), 1.82 (dq, *J* = 7.0, 1.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 197.2, 154.53, 154.51, 143.5, 138.6, 137.5, 136.8, 130.5, 129.4, 129.2, 128.7, 56.4, 54.2, 15.0, 11.3.

FTIR (cm^{-1}): 1798, 1747, 1657, 1640, 1442, 1242.

mp = 99-101 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_6]^+$: 308.1134; found: 308.1126.



2.S37

(**2.S37**) According to general protocol A: **2.S15** (1.10 g, 5.00 mmol), NH_4Cl (0.29 g, 5.5 mmol), methyl chloroformate (1.2 mL, 15 mmol), and Zn powder (1.31 g, 20.0 mmol) were combined in THF (20 mL) and H_2O (10 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure, purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 20:80 EtOAc/hexanes), and then recrystallized from EtOAc/hexanes to afford **2.S37** (0.53 g, 33%) as colorless solid.

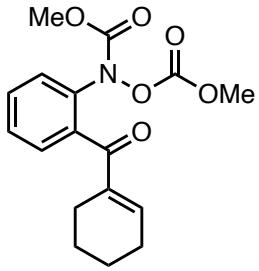
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.69 – 7.61 (m, 1H), 7.61 – 7.54 (m, 2H), 7.52 (d, *J* = 7.7 Hz, 1H), 3.84 (s, 3H), 3.69 (s, 3H), 1.80 (s, 3H), 1.75 (s, 3H), 1.59 (q, *J* = 1.4 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 198.0, 154.2, 154.0, 140.9, 136.3, 136.2, 132.3, 130.3, 130.1, 129.8, 129.5, 56.8, 53.9, 22.5, 21.7, 16.2.

FTIR (cm^{-1}): 3363, 2957, 2928, 1798, 1724, 1685, 1444.

mp = 112-114 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{16}H_{20}NO_6]^+$: 322.1285; found: 322.1281.



2.S38

(**2.S38**) According to general protocol A: **2.S17** (2.31 g, 10.0 mmol), NH_4Cl (0.59 g, 11 mmol), methyl chloroformate (2.3 mL, 30 mmol), and Zn powder (2.61 g, 40.0 mmol) were combined in THF (40 mL) and H_2O (20 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 15:85 EtOAc/hexanes) to afford **2.S38** (1.91 g, 57%) as yellow solid.

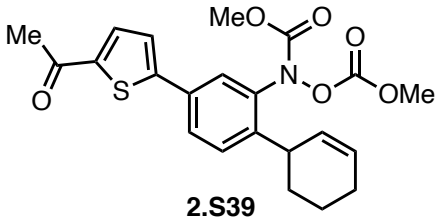
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.59 (td, J = 7.7, 1.7 Hz, 1H), 7.55 – 7.46 (m, 2H), 7.41 (dd, J = 7.5, 1.6 Hz, 1H), 6.34 (t, J = 3.6 Hz, 1H), 3.82 (s, 3H), 3.69 (s, 3H), 2.31 – 2.21 (m, 2H), 2.20 – 2.06 (m, 2H), 1.76 – 1.49 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 195.4, 153.8, 153.8, 145.5, 138.6, 136.6, 136.2, 130.8, 129.4, 129.1, 128.5, 56.8, 54.1, 25.7, 22.8, 21.4, 21.1.

FTIR (cm^{-1}): 3462, 1793, 1635, 1438, 1239.

mp = 98-100 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{20}NO_6]^+$: 334.1285; found: 334.1280.



2.S39

(**2.S39**) According to general protocol A: **2.S18** (3.25 g, 10.0 mmol), NH_4Cl (0.59 g, 11 mmol), methyl chloroformate (2.3 mL, 30 mmol), and Zn powder (2.62 g, 40.0 mmol) were combined in THF (40 mL) and H_2O (20 mL), which was allowed to stir for 10 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc/hexanes to 20:80 EtOAc/hexanes) to afford **2.S39** (3.49 g, 81%) as colorless powder.

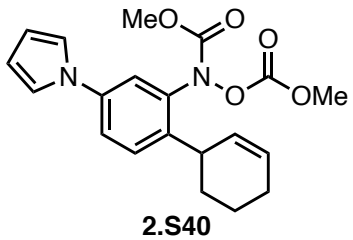
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.96 (d, J = 4.0 Hz, 1H), 7.87 – 7.79 (m, 2H), 7.69 (d, J = 4.0 Hz, 1H), 7.38 (d, J = 8.1 Hz, 1H), 5.92 (d, J = 10.0 Hz, 1H), 5.49 (d, J = 10.1 Hz, 1H), 3.87 (s, 3H), 3.83 – 3.67 (m, 4H), 2.55 (s, 3H), 2.17 – 2.04 (m, 2H), 1.97 – 1.86 (m, 1H), 1.81 – 1.69 (m, 1H), 1.63 – 1.51 (m, 1H), 1.50 – 1.39 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 190.7, 154.6, 154.0, 149.5, 146.0, 143.2, 137.7, 135.3, 132.0, 129.9, 129.2, 128.8, 128.0, 126.0, 125.8, 56.8, 54.3, 35.8, 31.0, 26.4, 24.3, 21.1.

FTIR (cm^{-1}): 1795, 1741, 1659, 1445, 1054.

mp = 126-128 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{22}H_{24}NO_6S]^+$: 430.1319; found: 430.1328.



2.S40

(**2.S40**) According to general protocol A: **2.S19** (1.21 g, 5.00 mmol), NH_4Cl (0.29 g, 5.5 mmol), methyl chloroformate (1.2 mL, 15 mmol), and Zn powder (1.31 g, 20.0 mmol) were combined in THF (20 mL) and H_2O (10 mL), which was allowed to stir for 6 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S40** (1.20 g, 65%) as colorless powder.

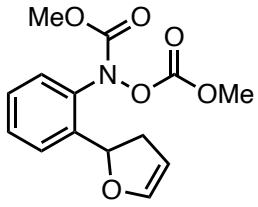
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.69 (dt, J = 8.6, 2.4 Hz, 1H), 7.63 (t, J = 2.3 Hz, 1H), 7.37 (q, J = 2.3 Hz, 2H), 7.34 (dd, J = 8.6, 2.1 Hz, 1H), 6.27 (q, J = 2.2 Hz, 2H), 6.00 – 5.78 (m, 1H), 5.50 (d, J = 10.1 Hz, 1H), 3.86 (d, J = 2.1 Hz, 3H), 3.81 – 3.71 (m, 4H), 2.18 – 2.00 (m, 2H), 1.96 – 1.86 (m, 1H), 1.81 – 1.71 (m, 1H), 1.63 – 1.50 (m, 1H), 1.45 (q, J = 11.0 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.7, 154.0, 141.7, 138.8, 137.7, 129.9, 129.5, 128.5, 121.4, 119.1, 119.1, 110.8, 56.8, 54.3, 35.4, 31.0, 24.3, 21.1.

FTIR (cm^{-1}): 1796, 1747, 1512, 1241, 1068.

mp = 108-110 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{20}H_{23}N_2O_5]^+$: 371.1601; found: 371.1600.



2.S41

(**2.S41**) According to general protocol A: **2.S20** (0.85 g, 4.5 mmol), NH_4Cl (0.27 g, 5.0 mmol), methyl chloroformate (1.05 mL, 13.5 mmol), and Zn powder (1.18 g, 18.0 mmol) were combined in THF (18 mL) and H_2O (9 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc/hexanes to 10:90 EtOAc/hexanes) to afford **2.S41** (0.84 g, 64%) as yellow solid.

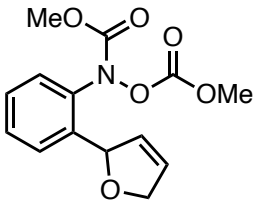
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (dd, J = 8.1, 1.6 Hz, 1H), 7.50 – 7.41 (m, 2H), 7.38 – 7.30 (m, 1H), 6.47 (q, J = 2.4 Hz, 1H), 5.92 (t, J = 9.7 Hz, 1H), 4.94 (q, J = 2.5 Hz, 1H), 3.89 (s, 3H), 3.81 (s, 3H), 3.13 (ddt, J = 15.7, 11.0, 2.4 Hz, 1H), 2.50 (ddt, J = 15.4, 8.2, 2.4 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.1, 154.7, 145.4, 142.5, 135.7, 130.7, 128.5, 128.3, 126.5, 99.3, 77.6, 56.5, 54.3, 38.0.

FTIR (cm^{-1}): 2959, 1797, 1743, 1441, 1240, 1051, 929.

mp = 77-79 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{16}NO_6]^+$: 294.0978; found: 294.0959.



2.S42

(**2.S42**) According to general protocol A: **2.S21** (5.74 g, 30.0 mmol), NH_4Cl (1.77 g, 33.0 mmol), methyl chloroformate (7.0 mL, 90 mmol), and Zn powder (7.85 g, 120 mmol) were combined in THF (120 mL) and H_2O (60 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc/hexanes to 20:80 EtOAc/hexanes) to afford **2.S42** (6.05 g, 69%) as off-white solid.

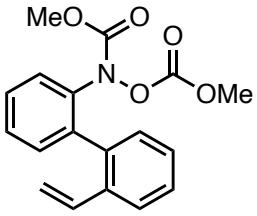
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.52 – 7.46 (m, 1H), 7.45 – 7.36 (m, 3H), 6.14 (dq, J = 5.9, 1.8 Hz, 1H), 6.06 – 5.96 (m, 1H), 5.85 (dq, J = 6.4, 2.3 Hz, 1H), 4.92 – 4.78 (m, 1H), 4.74 – 4.61 (m, 1H), 3.86 (s, 3H), 3.75 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.6, 154.0, 141.2, 135.7, 130.6, 129.3, 128.7, 128.0, 127.6, 127.2, 82.3, 75.6, 56.8, 54.3.

FTIR (cm^{-1}): 2959, 2853, 1795, 1744, 1441, 1244, 1068.

mp = 60-62 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{16}NO_6]^+$: 294.0978; found: 294.0962.



2.S43

(**2.S43**) According to general protocol A: **2.S22** (1.35 g, 6.00 mmol), NH_4Cl (0.35 g, 6.6 mmol), methyl chloroformate (1.4 mL, 18 mmol), and Zn powder (1.57 g, 24.0 mmol) were combined in THF (24 mL) and H_2O (12 mL), which was allowed to stir for 3 h at 0 °C. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc/hexanes to 7:93 EtOAc/hexanes) to afford **2.S43** (0.56 g, 29%) as colorless oil.

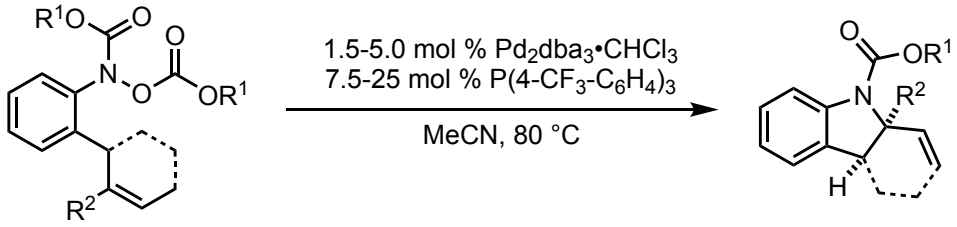
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.73 (dd, J = 7.8, 1.3 Hz, 1H), 7.61 – 7.50 (m, 3H), 7.40 (td, J = 7.6, 1.5 Hz, 1H), 7.33 (td, J = 7.5, 1.4 Hz, 1H), 7.28 – 7.24 (m, 1H), 7.12 (dd, J = 7.5, 1.5 Hz, 1H), 6.29 (dd, J = 17.6, 11.1 Hz, 1H), 5.77 – 5.71 (m, 1H), 5.15 (dd, J = 11.0, 1.3 Hz, 1H), 3.77 (s, 3H), 3.47 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 154.0, 153.6, 139.5, 136.9, 136.3, 135.4, 134.4, 132.0, 129.9, 129.7, 129.3, 128.9, 128.3, 127.3, 124.9, 115.2, 56.5, 53.6.

FTIR (cm^{-1}): 2957, 1795, 1744, 1441, 1244.

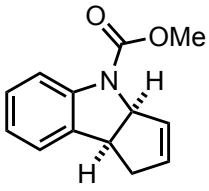
HRMS (ESI) m/z, calculated for $[C_{18}H_{18}NO_5]^+$: 328.1179; found: 328.1174.

2.6.5 Synthesis of Indolines



General Protocol B: A flame-dried Schlenk flask equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Pd_2dba_3•$CHCl_3$ (0.015 - 0.05 equiv), P(4-CF_3-C_6H_4)$_3$ (0.075 – 0.25 equiv), and *N*-aryl-*N*-hydroxy carbamate (1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous MeCN (0.05 M with respect to *N*-aryl-*N*-hydroxy carbamate) was added to the flask via syringe. The resulting solution was allowed to stir at rt for 1 h, and then placed in a pre-heated oil bath and stirred at the indicated temperature for 24 h. Upon completion, the reaction was cooled to rt, then added *L*-Cysteine ethyl ester hydrochloride (15 equiv to Pd_2dba_3•$CHCl_3$) and Et_3N (100 equiv to Pd_2dba_3•$CHCl_3$). The reaction mixture was stirred at rt for 1 h, then opened to

air and diluted with CH_2Cl_2 (10 mL). The suspension was transferred to a round bottom flask and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed on silica gel (5-20 μm particle size) to yield the desired product.



2.43

(**2.43**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.42** (291.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 15 umol), $P(4\text{-}CF_3\text{-}C_6H_4)_3$ (35.0 mg, 75 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.43** (181.9 mg, 84%) as colorless solid.

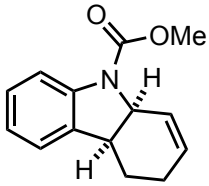
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.80 – 7.31 (m, 1H), 7.24 (d, J = 7.3 Hz, 1H), 7.17 (t, J = 7.7 Hz, 1H), 6.98 (td, J = 7.4, 1.1 Hz, 1H), 5.95 (dq, J = 6.0, 2.0 Hz, 1H), 5.82 (dt, J = 6.0, 2.3 Hz, 1H), 5.33 (dp, J = 8.8, 1.8 Hz, 1H), 4.01 (t, J = 8.8 Hz, 1H), 3.77 (s, 3H), 2.94 (ddq, J = 17.2, 8.6, 2.1 Hz, 1H), 2.50 – 2.43 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.5, 140.8, 135.4, 134.0, 129.1, 127.7, 124.9, 122.9, 114.2, 70.1, 52.5, 41.4, 40.1.

FTIR (cm^{-1}): 3440, 1698, 1485, 1391, 1062.

mp = 76-78 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}NO_2]^+$: 216.1019; found: 216.1013.



2.47

(**2.47**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S23** (305.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 15 umol), P(4-CF_3-C_6H_4)$_3$ (35.0 mg, 75 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.47** (run #1: 204.9 mg, 90%; run #2: 203.0 mg, 89%) as colorless solid.

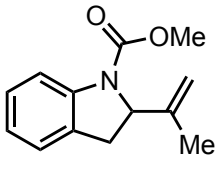
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.64 (bs, 1H), 7.25 (d, J = 7.4 Hz, 1H), 7.16 (t, J = 7.7 Hz, 1H), 7.00 (t, J = 7.4 Hz, 1H), 5.86 (dd, J = 10.5, 4.7 Hz, 1H), 5.70 (d, J = 10.4 Hz, 1H), 4.88 (d, J = 8.7 Hz, 1H), 3.77 (s, 3H), 3.70 – 3.64 (m, 1H), 2.27 – 2.13 (m, 1H), 1.98 – 1.68 (m, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.9, 141.8, 132.8, 131.4, 127.4, 124.8, 123.3, 122.7, 114.8, 58.0, 52.5, 37.6, 21.3, 20.0.

FTIR (cm^{-1}): 2967, 1708, 1484, 1384, 1272.

mp = 80-82 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{16}NO_2]^+$: 230.1176; found: 230.1174.



2.48

(**2.48**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S24** (293.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient,

hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.48** (141.3 mg, 65%) as colorless solid.

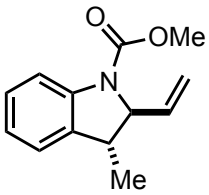
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.67 (bs, 1H), 7.22 – 7.14 (m, 2H), 6.95 (td, J = 7.9, 1.1 Hz, 1H), 4.82 (dd, J = 10.5, 2.9 Hz, 1H), 4.71 (t, J = 1.7 Hz, 1H), 4.66 (dd, J = 1.8, 0.9 Hz, 1H), 3.70 (s, 3H), 3.44 (dd, J = 16.4, 10.6 Hz, 1H), 2.79 (dd, J = 16.4, 2.9 Hz, 1H), 1.62 (t, J = 1.2 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.0, 144.7, 142.2, 130.0, 127.3, 125.0, 122.7, 114.1, 109.2, 63.1, 52.5, 33.8, 17.9.

FTIR (cm^{-1}): 1713, 1524, 1487, 1453, 1225, 1064.

mp = 40-42 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_2]^+$: 218.1181; found: 218.1174.



2.49-*trans*

(**2.49-*trans***) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S25** (293.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.49** (158.2 mg, 73%, dr = 85:15) as colorless oil. The diastereomers were separated with the same column conditions (linear gradient, hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.49-*trans*** (130.1 mg, 60%) as colorless oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.65 (m, 1H), 7.33 – 7.07 (m, 2H), 6.98 (t, J = 7.4 Hz, 1H), 5.86 (ddd, J = 16.7, 10.2, 6.1 Hz, 1H), 5.10 – 5.03 (m, 1H), 5.01 (s, 1H), 4.41 (dd,

J = 6.5, 2.8 Hz, 1H), 3.72 (s, 3H), 3.02 (dd, *J* = 7.3, 2.8 Hz, 1H), 1.22 (d, *J* = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.2, 140.7, 137.5, 135.2, 127.6, 124.5, 122.9, 114.3, 114.1, 68.4, 52.5, 41.3, 21.4.

FTIR (cm^{-1}): 2959, 1712, 1602, 1484, 1443, 1388, 1310.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_2]^+$: 218.1181; found: 218.1172.

After isolation, the relative stereochemistry of indoline **2.49-*trans*** was investigated via 1-dimensional nuclear Overhauser effect (nOe) studies. The critical observations (Figure 2.28) reveal that the major diastereomer bears the trans configuration as shown in the main text. Spectra for the nOe experiments are provided in the spectroscopic data section.

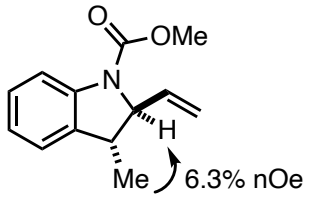
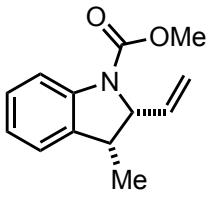


Figure 2.28: nOe Studies of the Diastereomer of Indoline **2.49-*trans***



2.49-*cis*

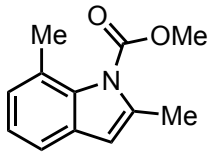
(**2.49-*cis***) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S25** (293.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.49** (158.2 mg, 73%, dr = 85:15) as colorless oil. The diastereomers were separated with the same column conditions (linear gradient, hexanes to 3:97 EtOAc:hexanes) to afford indoline **2.49-*cis*** (28.1 mg, 13%) as colorless oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.63 (bs, 1H), 7.22 – 7.15 (m, 2H), 6.99 (td, J = 7.4, 1.1 Hz, 1H), 5.67 (ddd, J = 17.3, 10.4, 7.1 Hz, 1H), 5.12 (dt, J = 10.3, 1.3 Hz, 1H), 5.05 (dt, J = 16.9, 1.4 Hz, 1H), 4.92 – 4.87 (m, 1H), 3.70 (s, 3H), 3.68 – 3.58 (m, 1H), 1.20 (d, J = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.8, 141.2, 135.2, 133.8, 127.5, 123.5, 123.0, 116.7, 114.2, 65.6, 52.5, 37.8, 12.9.

FTIR (cm^{-1}): 2958, 1712, 1484, 1465, 1388.

HRMS (ESI) m/z, calculated for $[C_{13}H_{16}NO_2]^+$: 218.1181; found: 218.1171.



2.50

(**2.50**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S26** (279.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 100 °C for 24 h under seal environment. The reaction was worked up according to the

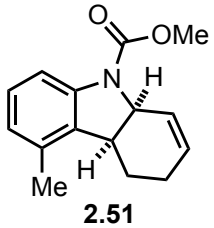
general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.50** (79.3 mg, 39%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.31 (d, J = 7.6 Hz, 1H), 7.09 (t, J = 7.5 Hz, 1H), 7.00 (d, J = 7.3 Hz, 1H), 6.43 (t, J = 1.2 Hz, 1H), 3.97 (s, 3H), 2.45 (s, 3H), 2.34 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.2, 137.3, 135.2, 130.1, 126.0, 123.6, 122.8, 117.6, 106.8, 54.2, 20.3, 15.1.

FTIR (cm^{-1}): 2956, 2927, 1743, 1440, 1094.

HRMS (ESI) m/z, calculated for $[C_{12}H_{14}NO_2]^+$: 204.1019; found: 204.1018.



2.51

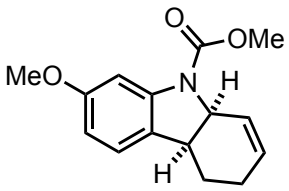
(**2.51**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S27** (319.4 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.51** (139.0 mg, 57%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.48 (d, J = 8.2 Hz, 1H), 7.05 (t, J = 7.8 Hz, 1H), 6.78 (d, J = 7.5 Hz, 1H), 6.01 (s, 2H), 4.65 (d, J = 8.3 Hz, 1H), 3.76 (s, 3H), 3.55 (td, J = 8.5, 2.8 Hz, 1H), 2.29 (s, 3H), 2.02 – 1.80 (m, 3H), 1.77 – 1.52 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.5, 141.7, 134.0, 131.9, 131.5, 127.3, 124.9, 124.6, 112.2, 57.5, 52.5, 38.3, 23.8, 22.1, 18.5.

FTIR (cm^{-1}): 2951, 2922, 1710, 1467, 1374, 1031.

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_2]^+$: 244.1332; found: 244.1331.



2.52

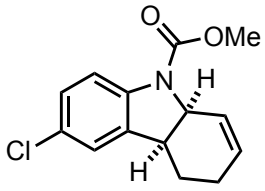
(**2.52**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S28** (2.68 g, 8.00 mmol), Pd_2dba_3•$CHCl_3$ (0.41 g, 0.40 mmol), P(4-CF_3-C_6H_4)$_3$ (0.93 g, 2.0 mmol), and anhydrous MeCN (160 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.52** (1.59 g, 77%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.27 (bs, 1H), 7.13 (dd, J = 8.2, 1.3 Hz, 1H), 6.56 (dd, J = 8.2, 2.4 Hz, 1H), 5.86 (dd, J = 10.3, 4.7 Hz, 1H), 5.69 (d, J = 10.4 Hz, 1H), 4.87 (d, J = 8.8 Hz, 1H), 3.76 (s, 3H), 3.71 (s, 3H), 3.64 – 3.55 (m, 1H), 2.17 (d, J = 12.3 Hz, 1H), 1.96 – 1.72 (m, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 159.1, 159.1, 152.8, 143.0, 131.4, 124.8, 123.6, 107.5, 101.9, 58.7, 55.2, 52.6, 36.9, 21.5, 19.9.

FTIR (cm^{-1}): 2951, 1709, 1498, 1453, 1382.

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_3]^+$: 260.1281; found: 260.1274.



2.53

(**2.53**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S29** (339.8 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was

worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 4:96 EtOAc:hexanes) to afford indoline **2.53** (177.0 mg, 67%) as colorless solid.

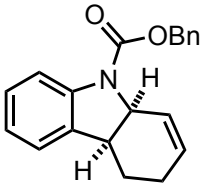
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.61 (bs, 1H), 7.34 (d, *J* = 2.0 Hz, 1H), 7.21 (dd, *J* = 8.4, 2.2 Hz, 1H), 5.88 (dd, *J* = 10.6, 4.7 Hz, 1H), 5.70 (d, *J* = 10.3 Hz, 1H), 4.89 (d, *J* = 8.7 Hz, 1H), 3.77 (s, 3H), 3.69 (d, *J* = 8.1 Hz, 1H), 2.24 (d, *J* = 12.3 Hz, 1H), 1.93 – 1.68 (m, 3H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 152.8, 140.7, 135.5, 131.6, 127.3, 126.7, 124.5, 123.7, 116.0, 58.3, 52.8, 37.7, 21.0, 19.9.

FTIR (cm^{-1}): 2917, 2850, 1710, 1478, 1382.

mp = 92-94 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{14}H_{14}NO_2Cl]^+$: 264.0786; found: 264.0778



2.55

(**2.55**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S31** (305.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 15 umol), P(4-CF_3-C_6H_4)$_3$ (35.0 mg, 75 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 4:96 EtOAc:hexanes) to afford indoline **2.55** (237.2 mg, 78%) as yellow oil.

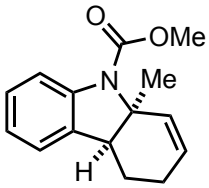
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.65 (bs, 1H), 7.51 – 7.32 (m, 5H), 7.30 – 7.22 (m, 1H), 7.16 (t, *J* = 7.7 Hz, 1H), 7.00 (t, *J* = 7.4 Hz, 1H), 5.86 (dd, *J* = 10.2, 5.2 Hz, 1H),

5.70 (d, J = 10.3 Hz, 1H), 5.25 (s, 2H), 4.93 (d, J = 8.5 Hz, 1H), 3.75 – 3.63 (m, 1H), 2.22 (d, J = 13.3 Hz, 1H), 1.97 – 1.84 (m, 2H), 1.83 – 1.70 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.2, 141.8, 136.5, 132.8, 131.6, 128.6, 128.1, 128.0, 127.5, 124.8, 123.4, 122.9, 114.9, 66.6, 58.1, 37.6, 21.3, 19.9.

FTIR (cm^{-1}): 2924, 1706, 1482, 1409, 1267, 751.

HRMS (ESI) m/z, calculated for $[C_{20}H_{20}NO_2]^+$: 306.1489; found: 306.1491.



2.56

(**2.56**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S32** (319.4 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 15.0 umol), P(4-CF_3-C_6H_4)$_3$ (35.0 mg, 75 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.56** (177.4 mg, 73%) as colorless solid.

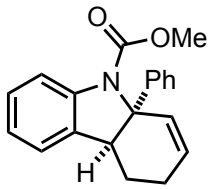
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.63 (bs, 1H), 7.30 – 7.23 (m, 1H), 7.19 – 7.11 (m, 1H), 6.99 (td, J = 7.4, 1.0 Hz, 1H), 6.04 (d, J = 10.3 Hz, 1H), 5.79 (dd, J = 10.3, 3.7 Hz, 1H), 3.77 (s, 3H), 3.16 (t, J = 5.1 Hz, 1H), 1.94 – 1.76 (m, 4H), 1.56 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.5, 141.5, 132.2, 129.0, 128.5, 127.5, 123.5, 122.7, 115.0, 65.2, 52.3, 46.4, 26.1, 23.3, 21.1.

FTIR (cm^{-1}): 3030, 2929, 1702, 1482, 1370, 1321.

mp = 59-61 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{18}NO_2]^+$: 244.1332; found: 244.1336.



2.57

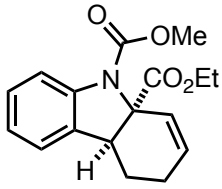
(**2.57**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S33** (1.91 g, 5.00 mmol), Pd_2dba_3•$CHCl_3$ (258.8 mg, 250 umol), P(4-CF_3-C_6H_4)$_3$ (582.9 mg, 1.25 mmol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.57** (1.03 g, 67%) as colorless oil.

^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 7.77 (bs, 1H), 7.42 – 7.30 (m, 2H), 7.30 – 7.15 (m, 5H), 7.03 (td, *J* = 7.4, 1.0 Hz, 1H), 6.13 (s, 2H), 3.53 (s, 3H), 3.35 – 3.16 (m, 1H), 2.15 – 1.83 (m, 3H), 1.73 (tt, *J* = 8.5, 3.9 Hz, 1H).

^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 153.3, 145.5, 142.0, 131.5, 131.1, 128.3, 127.9, 126.7, 126.2, 125.0, 123.4, 123.0, 114.8, 70.8, 52.2, 49.9, 21.4, 20.7.

FTIR (cm^{-1}): 2926, 1708, 1482, 1440, 1371, 1234.

HRMS (LIFDI) m/z, calculated for $[C_{20}H_{19}NO_2]^+$: 305.1404; found: 305.1416.



2.58

(**2.58**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S34** (377.4 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (77.6 mg, 75 umol), P(4-CF_3-C_6H_4)$_3$ (174.9 mg, 375 umol), and anhydrous DCE (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction mixture was cooled to rt, transferred to a 200 mL round bottom flask, and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed (linear gradient,

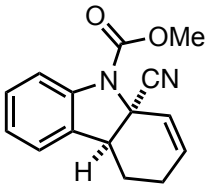
1:99 EtOAc:hexanes to 10:90 EtOAc:hexanes) on silica gel (5-20 μm particle size) to afford indoline **2.58** (172.0 mg, 57%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.00 – 7.36 (m, 1H), 7.29 – 7.24 (m, 1H), 7.24 – 7.18 (m, 1H), 7.04 (td, J = 7.5, 1.0 Hz, 1H), 6.20 – 5.65 (m, 2H), 4.34 – 4.10 (m, 2H), 3.74 (bs, 4H), 2.24 – 2.13 (m, 1H), 2.01 – 1.90 (m, 1H), 1.90 – 1.76 (m, 2H), 1.19 (t, J = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 171.7, 152.4, 141.5, 131.9, 130.2, 128.1, 123.8, 123.5, 123.2, 114.4, 69.1, 61.3, 52.6, 44.4, 21.5, 20.0, 14.1.

FTIR (cm^{-1}): 1713, 1483, 1442, 1369, 1244, 753.

HRMS (ESI) m/z, calculated for $[C_{17}H_{20}NO_4]^+$: 302.1387; found: 302.1391.



2.59

(**2.59**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S35** (330.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (77.6 mg, 75 umol), P(4-CF_3-C_6H_4)$_3$ (174.9 mg, 375 umol), and anhydrous DCE (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction mixture was cooled to rt, transferred to a 200 mL round bottom flask, and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed (linear gradient, 1:99 EtOAc:hexanes to 8:92 EtOAc:hexanes) on silica gel (5-20 μm particle size) to afford indoline **2.59** (136.0 mg, 53%) as yellow solid.

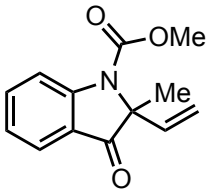
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.62 (bs, 1H), 7.34 (d, J = 7.4 Hz, 1H), 7.26 (t, J = 7.8 Hz, 1H), 7.10 (td, J = 7.5, 1.0 Hz, 1H), 6.19 (ddd, J = 10.2, 4.5, 3.0 Hz, 1H), 6.04 (d, J = 10.1 Hz, 1H), 4.01 (t, J = 5.0 Hz, 1H), 3.89 (s, 3H), 2.19 – 1.82 (m, 4H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.6, 139.5, 135.5, 129.5, 128.5, 123.82, 123.79, 120.3, 119.5, 114.9, 59.1, 53.5, 45.1, 21.5, 20.4.

FTIR (cm^{-1}): 3446, 2080, 1716, 1636, 1483, 1366.

mp = 101-103 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{15}N_2O_2]^+$: 255.1128; found: 255.1127.



2.60

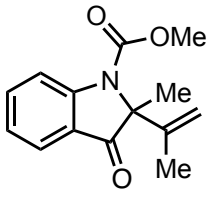
(**2.60**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S36** (307.5 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 100 °C for 24 h under sealed environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.60** (150.4 mg, 65%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.18 (bs, 1H), 7.81 (ddd, J = 8.6, 7.2, 1.5 Hz, 1H), 7.72 (d, J = 7.3 Hz, 1H), 7.27 (t, J = 7.4 Hz, 1H), 5.86 (dd, J = 17.3, 10.6 Hz, 1H), 5.21 (d, J = 10.6 Hz, 1H), 5.17 (d, J = 17.3 Hz, 1H), 3.81 (s, 3H), 1.62 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 197.7, 151.8, 151.6, 137.9, 135.8, 124.5, 123.8, 121.2, 116.6, 116.0, 70.9, 53.0, 20.5.

FTIR (cm^{-1}): 1713, 1608, 1468, 1359, 1256.

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}NO_3]^+$: 232.0974; found: 232.0963.



2.61

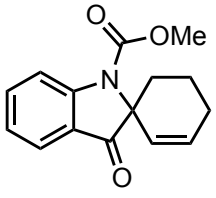
(**2.61**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S37** (321.3 mg, 1.000 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 0.250 mmol), and MeCN (20 mL) were combined under N_2. The reaction was stirred at 100 °C overnight under sealed environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 7:93 EtOAc:hexanes) to afford indoline **2.61** (139.4 mg, 57%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.20 (bs, 1H), 7.81 (ddd, J = 8.5, 7.2, 1.5 Hz, 1H), 7.73 (dd, J = 7.7, 1.4 Hz, 1H), 7.35 – 7.24 (m, 1H), 5.04 (s, 1H), 4.98 (s, 1H), 3.80 (s, 3H), 1.61 (s, 3H), 1.47 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 198.1, 152.0, 151.7, 141.2, 138.0, 124.4, 123.8, 121.5, 116.5, 113.3, 73.0, 53.1, 20.0, 18.3.

FTIR (cm^{-1}): 1955, 1711, 1608, 1357, 1069.

HRMS (ESI) m/z, calculated for $[C_{14}H_{16}NO_3]^+$: 246.1125; found: 246.1125.



2.62

(**2.62**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S38** (333.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 100 °C for 24 h under sealed environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.62** (115.3 mg, 45%) as colorless solid.

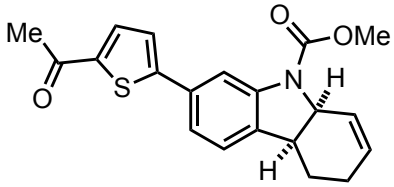
^{1}H NMR (400 MHz, DMSO-d_6) δ 8.14 (d, J = 8.5 Hz, 1H), 7.78 (ddd, J = 8.5, 7.2, 1.5 Hz, 1H), 7.70 (dd, J = 7.4, 1.3 Hz, 1H), 7.28 – 7.20 (m, 1H), 6.07 (dt, J = 9.9, 3.8 Hz, 1H), 5.34 (d, J = 10.0 Hz, 1H), 3.80 (s, 3H), 2.38 – 2.27 (m, 1H), 2.27 – 2.15 (m, 1H), 2.14 – 2.02 (m, 2H), 1.77 – 1.66 (m, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 198.8, 151.6, 151.4, 137.7, 132.0, 124.3, 124.3, 123.6, 121.5, 116.8, 69.1, 52.9, 27.9, 23.1, 17.5.

FTIR (cm^{-1}): 1711, 1608, 1468, 1440, 1368, 1348, 1253.

mp = 64-66 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{16}NO_3]^+$: 258.1125; found: 258.1130.



2.63

(**2.63**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S39** (429.5 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford indoline **2.63** (213.4 mg, 61%) as colorless solid.

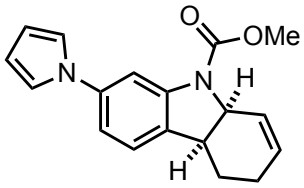
^{1}H NMR (400 MHz, DMSO-d_6) δ 8.00 (bs, 1H), 7.93 (d, J = 3.9 Hz, 1H), 7.56 (d, J = 4.0 Hz, 1H), 7.45 (dd, J = 7.7, 1.7 Hz, 1H), 7.36 (dd, J = 7.8, 1.2 Hz, 1H), 5.89 (dd, J = 10.4, 4.8 Hz, 1H), 5.72 (d, J = 10.5 Hz, 1H), 5.07 – 4.87 (m, 1H), 3.81 (s, 3H), 3.74 – 3.68 (m, 1H), 2.54 (s, 3H), 2.25 (d, J = 12.7 Hz, 1H), 2.00 – 1.87 (m, 2H), 1.87 – 1.74 (m, 1H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 190.6, 152.9, 151.8, 142.4, 142.4, 135.3, 134.6, 132.1, 131.6, 124.8, 124.7, 124.3, 121.0, 112.0, 58.4, 52.8, 37.6, 26.4, 21.2, 20.0.

FTIR (cm^{-1}): 1706, 1656, 1451, 1275, 1052.

mp = 73-75 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{20}H_{20}NO_3S]^+$: 354.1158; found: 354.1155.



2.64

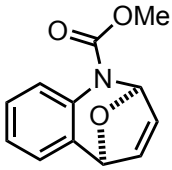
(**2.64**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S40** (370.4 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.64** (163.9 mg, 56%) as yellow oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.74 (bs, 1H), 7.34 – 7.30 (m, 1H), 7.23 (t, J = 2.2 Hz, 2H), 7.17 (dd, J = 8.0, 2.1 Hz, 1H), 6.24 (t, J = 2.2 Hz, 2H), 5.98 – 5.85 (m, 1H), 5.73 (d, J = 10.3 Hz, 1H), 4.94 (d, J = 8.6 Hz, 1H), 3.80 (s, 3H), 3.72 – 3.65 (m, 1H), 2.24 (d, J = 12.5 Hz, 1H), 2.02 – 1.75 (m, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.9, 142.9, 139.7, 131.7, 130.2, 124.7, 124.3, 119.3, 114.6, 110.3, 107.0, 58.7, 52.8, 37.2, 21.3, 20.0.

FTIR (cm^{-1}): 1708, 1613, 1502, 1337, 1272, 1072.

HRMS (ESI) m/z, calculated for $[C_{18}H_{19}N_2O_2]^+$: 295.1441; found: 295.1447.



2.65

(**2.65**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S41** (293.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 15 umol), P(4-CF_3-C_6H_4)$_3$ (35.0 mg, 75 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.65** (run #1: 142.4 mg, 66%; run #2: 136.2 mg, 63%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.14 (d, J = 8.4 Hz, 1H), 7.24 (ddd, J = 8.6, 7.4, 1.8 Hz, 1H), 7.17 (dd, J = 7.5, 1.7 Hz, 1H), 6.99 (td, J = 7.4, 1.2 Hz, 1H), 6.66 (dd, J = 5.7, 1.8 Hz, 1H), 6.61 (d, J = 1.5 Hz, 1H), 6.05 (dd, J = 5.8, 1.4 Hz, 1H), 5.48 (d, J = 1.7 Hz, 1H), 3.78 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.6, 136.0, 133.5, 128.2, 125.6, 123.7, 122.8, 122.1, 120.1, 88.7, 80.5, 53.1.

FTIR (cm^{-1}): 1720, 1482, 1439, 1371, 1287, 1027.

mp = 87-89 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{12}NO_3]^+$: 218.0817; found: 218.0802.

A small sample of **2.65** was dissolved in EtOAc under air and recrystallized via slow vapor diffusion of hexanes at rt to give an X-ray quality crystal (Figure 2.29, see below for full crystallographic details).

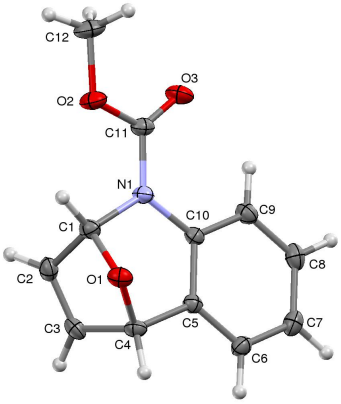
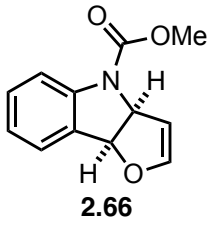


Figure 2.29: Crystal Structure of Indoline **2.65**



2.66

(**2.66**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S42** (2.93 g, 10.0 mmol), Pd_2dba_3•$CHCl_3$ (15.5 mg, 0.150 mmol), P(4-CF_3-C_6H_4)$_3$ (349.7 mg, 0.75 mmol), and anhydrous MeCN (200 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2 environment. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 6:94 EtOAc:hexanes) to afford indoline **2.66** (1.49 g, 69%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.96 – 7.78 (m, 1H), 7.49 – 7.45 (m, 1H), 7.40 – 7.34 (m, 1H), 7.07 (td, J = 7.4, 1.1 Hz, 1H), 6.74 (dd, J = 2.7, 1.3 Hz, 1H), 6.07 (d, J = 9.2 Hz, 1H), 5.53 (d, J = 9.1 Hz, 1H), 5.29 (t, J = 2.6 Hz, 1H), 3.78 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 152.2, 149.7, 141.7, 130.5, 128.9, 126.6, 122.9, 114.5, 100.2, 82.4, 66.7, 52.7.

FTIR (cm^{-1}): 1714, 1615, 1484, 1391, 1145, 1064.

mp = 102-104 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{12}NO_3]^+$: 218.0817; found: 218.0809.

A small sample of **2.66** was dissolved in EtOAc under air and recrystallized via slow vapor diffusion of hexanes at rt to give an X-ray quality crystal (Figure 2.30, see below for full crystallographic details).

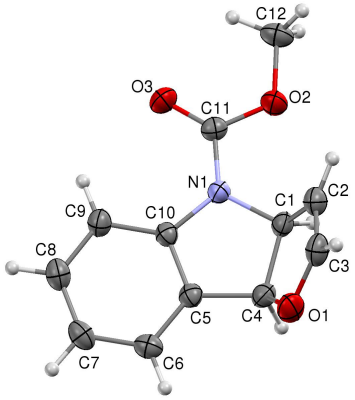
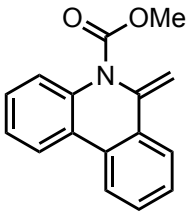


Figure 2.30: Crystal Structure of Indoline **2.66**



2.67

(**2.67**) According to general protocol B: *N*-aryl-*N*-hydroxy carbamate **2.S43** (327.3 mg, 1.00 mmol), Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol), P(4-CF_3-C_6H_4)$_3$ (116.6 mg, 250 umol), and anhydrous MeCN (20 mL) were combined under N_2. The reaction was stirred at 80 °C for 24 h under N_2. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) to afford indoline **2.67** (79.2 mg, 31%) as colorless oil.

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.99 (d, J = 7.8 Hz, 1H), 7.94 (dd, J = 7.9, 1.5 Hz, 1H), 7.72 (dd, J = 7.7, 1.3 Hz, 1H), 7.65 (dd, J = 8.1, 1.3 Hz, 1H), 7.50 (td, J = 7.6, 1.4

Hz, 1H), 7.42 (td, J = 7.6, 1.2 Hz, 1H), 7.37 (td, J = 7.8, 1.6 Hz, 1H), 7.29 (td, J = 7.5, 1.3 Hz, 1H), 5.81 (s, 1H), 5.40 (s, 1H), 3.70 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 153.2, 139.2, 136.3, 133.4, 129.8, 129.6, 128.5, 127.9, 126.7, 125.4, 125.0, 124.7, 123.9, 123.2, 111.6, 53.4.

FTIR (cm^{-1}): 2952, 1717, 1437, 1338, 1310, 1240, 762.

HRMS (ESI) m/z, calculated for $[C_{16}H_{14}NO_2]^+$: 252.1019; found: 252.1020.

2.6.6 Crystallographic Details

X-ray structural analysis for **2.65**: Crystals were mounted using viscous oil onto a plastic mesh and cooled to the data collection temperature. Data were collected on a Bruker-AXS APEX II DUO CCD diffractometer with fine focused Mo-Kα radiation (λ = 0.71073 Å). Unit cell parameters were obtained from 48 data frames, 0.5º ω, from different sections of the Ewald sphere. The unit-cell dimensions, equivalent reflections and systematic absences in the diffraction data are uniquely consistent with $P2_1/n$. The data were treated with multi-scan absorption corrections.[69] Structures were solved using intrinsic phasing methods[70] and refined with full-matrix, least-squares procedures on F^2.[71] The structures have been deposited at the Cambridge Structural Database under the following CCDC depositary number: 1922662.

X-ray structural analysis for **2.66**: Crystals were mounted using viscous oil onto a plastic mesh and cooled to the data collection temperature. Data were collected on a Bruker-AXS APEX II DUO CCD diffractometer with fine focused Mo-Kα radiation (λ = 0.71073 Å). Unit cell parameters were obtained from 48 data frames, 0.5º ω, from different sections of the Ewald sphere. The unit-cell dimensions, equivalent reflections and systematic absences in the diffraction data are uniquely consistent with $P2_1/n$. The

data were treated with multi-scan absorption corrections.[69] Structures were solved using intrinsic phasing methods[70] and refined with full-matrix, least-squares procedures on F^2.[71] Two symmetry-unique but chemically identical compound molecules were found in the asymmetric unit of **2.66** (i.e. Z = 2 and Z' = 2). Non-hydrogen atoms were refined with anisotropic displacement parameters. H-atoms treated as idealized contributions with geometrically calculated positions and with U_{iso} equal to 1.2-1.5 U_{eq} of the attached atom. Atomic scattering factors are contained in the SHELXTL program library.[71] The structures have been deposited at the Cambridge Structural Database under the following CCDC depositary number: 1922663.

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Chapter 3

ARYL PHOSPHONATE-DIRECTED C–H BORYLATION

3.1 Introduction

Aryl phosphonates are versatile functional groups in organic synthesis, as they can be quickly converted into a number of other functionalities, such as phosphines, phosphoramidates, phosphoric acids, and phosphorus oxides.[1-2] Those and related compounds are frequently used as important intermediates in phosphine ligand synthesis. For example, the Hartwig group identified aryl phosphonate **3.1** as a key intermediate, which could be converted into a library of SEGPhos-derived bidentate phosphine ligands (Figure 3.1).[3] In this way, they were able to quickly prepare many similar ligands with slight modification in a short period.

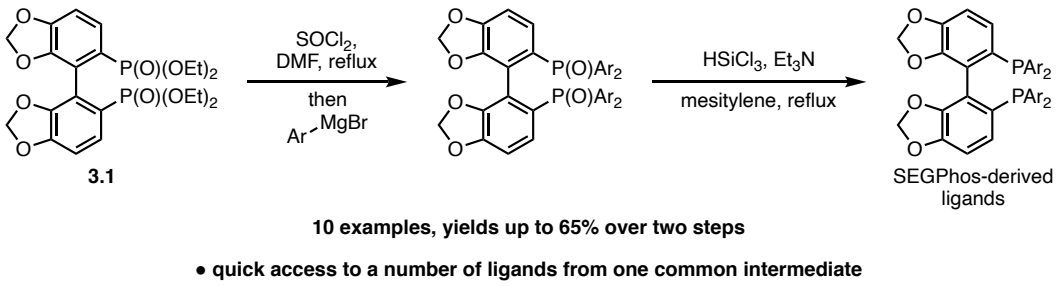


Figure 3.1: Aryl Phosphonates in Ligand Synthesis

Moreover, many aryl phosphonates and related compounds have shown interesting biological activities, including the ones bearing *ortho*-substitutions (Figure

3.2).[4-7] For example, brigatinib, containing an *ortho*-substituted aryl phosphorus oxide, is a commercial small-molecule drug used for lung cancer treatment.[7]

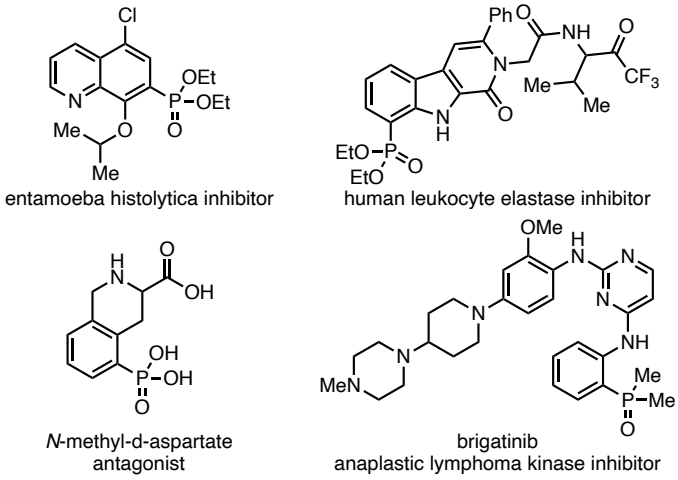


Figure 3.2: Bioactive *Ortho*-Substituted Aryl Phosphonate and Related Molecules

3.2 Preparation of Aryl Phosphonates

Due to the value of aryl phosphonates, several strategies have been developed to prepare them. The most straightforward and also the most common way is through the construction of C–P bonds.

3.2.1 Grignard Addition

As a reaction awarded the Nobel Prize, the Grignard reaction is a powerful tool to make C–C bonds.[8] Over the last several decades, the use of non-carbon electrophiles has been introduced to this reaction for the construction of carbon-heteroatom bonds, including C–P bonds. For example, one can use an aryl Grignard reagent **3.2** to attack a phosphorus electrophile **3.3** to synthesize aryl phosphonate **3.4** in good yield.[9] Because of the ease of reaction set-up, this is the most used method to prepare aryl phosphonate.

Other carbon nucleophiles, such as organolithium reagents, are also commonly used in this field. However, this reaction suffers several limitations. First of all, the functional group tolerance of those reactions is limited due to the use of sensitive reagents. Besides, the pre-formation of Grignard reagents is typically required, particularly for the synthesis of complex aryl phosphonates. Finally, this method sometimes results in over-arylation of phosphorus electrophiles and give a mixture of many products.

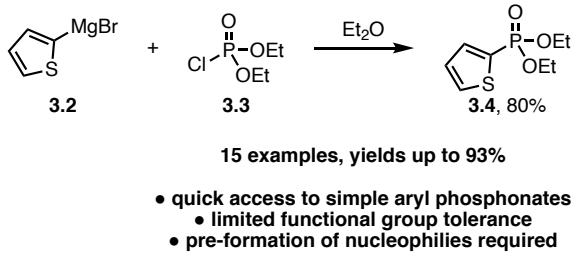


Figure 3.3: Synthesis of Aryl Phosphonates via Grignard Reaction

3.2.2 Cross-Coupling of Aryl Electrophiles with Dialkyl Phosphites

Aryl phosphonates can also be prepared using cross-coupling reactions, which allows the direct use of aryl halides without pre-activation.[10-23] The earliest report in this field was from the Hirao group, which is thusly called the Hirao Coupling (Figure 3.4).[19] Using palladium catalysis, Hirao and co-workers were able to directly transform aryl bromide **3.5** into aryl phosphonate **3.7** in 95% yield. One obvious advantage of this method over the Grignard reaction is its functional group tolerance. For example, aryl phosphonates bearing carbonyl groups, such as the product **3.7**, cannot be prepared using the Grignard reaction.

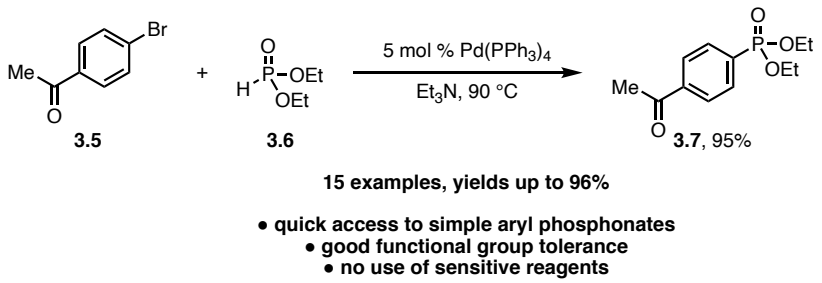


Figure 3.4: Synthesis of Aryl Phosphonates Using Cross-Coupling Reactions

The mechanism of the Hirao coupling is proposed as a typical Pd^0/Pd^{II} cross-coupling mechanism (Figure 3.5).[22] The reaction initiates with the activation of C–Br bond by Pd^0 catalyst to give the oxidative Pd^{II} complex **3.8**. The tautomerization of diethyl phosphite **3.6** generates the active P^{III} nucleophile **3.9**, which then attacks the electrophilic Pd^{II} complex **3.8** to provide the cationic intermediate **3.10**. This is typically the rate-determining step of the Hirao coupling. Thus, the concentration of P^{III} nucleophile **3.9** is significant to the reaction rate. To accelerate the transmetallation step, the addition of ethylene glycol is found to be useful in this reaction as it helps dialkyl phosphites to tautomerize from P^V to P^{III} forms.[18] Under basic condition, the phosphite is deprotonated to give the electron neutral complex **3.11**. The following reductive elimination produces the desired aryl phosphonate product **3.7**.

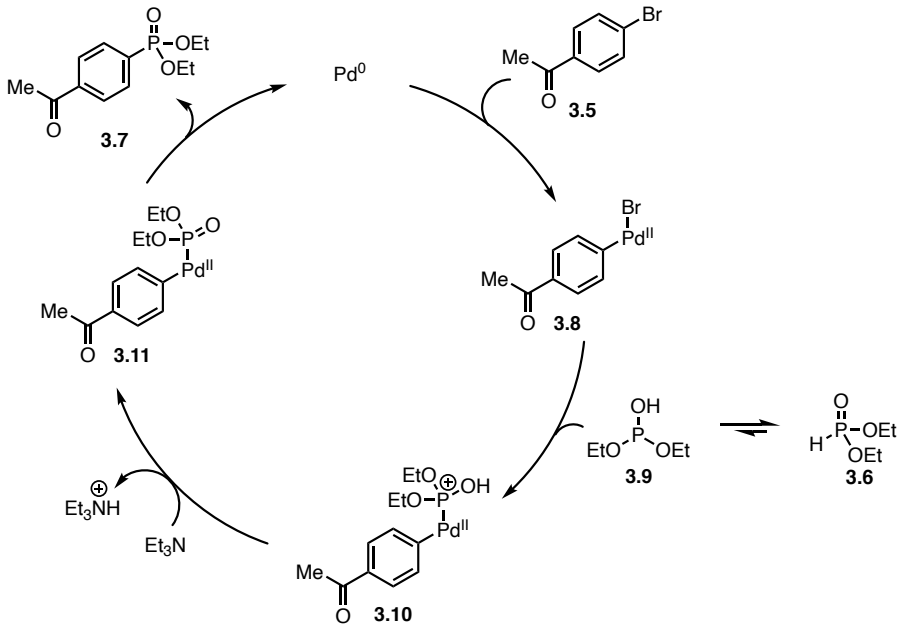


Figure 3.5: Proposed Mechanism of the Hirao Coupling

Based on this mechanism, the use of aryl sulfonates has also been demonstrated in this reaction (Figure 3.6).[24] By using these alternate electrophiles, aryl phosphonates bearing halogens can be prepared, which is another limitation that the Grignard reactions suffer from.

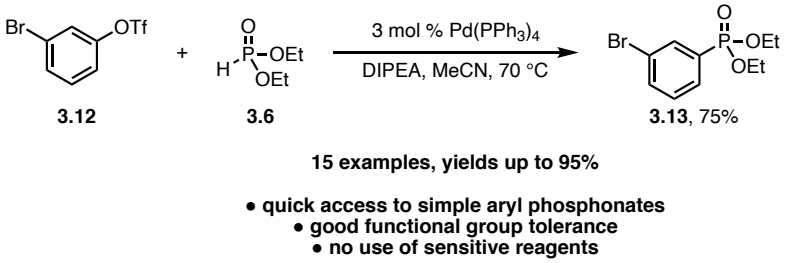


Figure 3.6: Cross-Coupling of Aryl Sulfonates with Dialkyl Phosphites

Recently, the Buchwald group found that this reaction can also be catalyzed by copper, which is attractively more affordable than palladium catalysis (Figure 3.7).[23] Using cheap and commercially accessible catalytic components, they could steadily convert aryl iodides to aryl phosphonates in good yields.

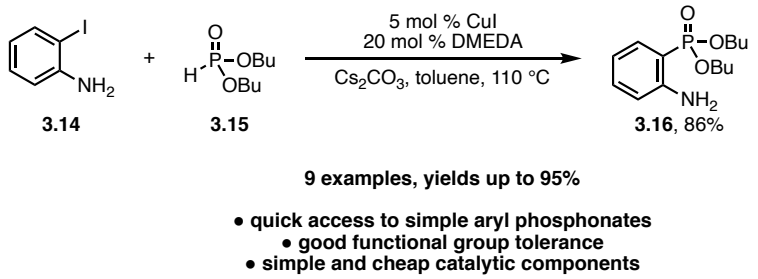


Figure 3.7: Copper Catalysis in the Hirao Coupling

3.2.3 Chan-Lam Coupling

Over the last couple decades, Chan-Lam type reactions have been extensively developed for the construction of carbon-heteroatom bonds.[25] Recently, Zhao and co-workers were able to expand this power for C–P bond formation (Figure 3.8).[26] Using copper catalysis, aryl phosphonates can be easily prepared from aryl boronic acids. Unlike the cross-coupling method reported by Buchwald, this copper-catalyzed reaction requires very mild condition and can be set up under air.

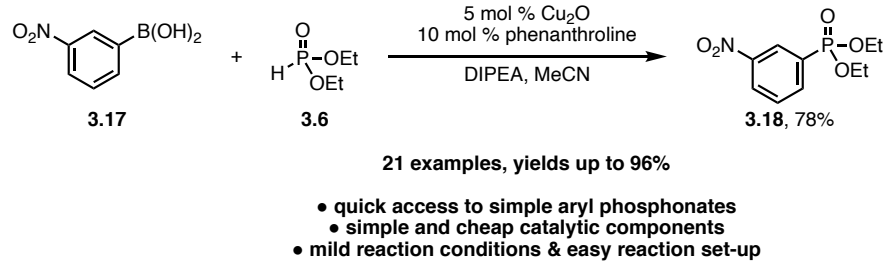


Figure 3.8: Chan-Lam Coupling for Aryl Phosphonate Synthesis

It is noteworthy that this transformation can also be catalyzed by other metals, including palladium catalysis.[27-31] Recently, the use of aryl boronic esters is reported in this field (Figure 3.9).[28] This further expands the scope of this reaction as aryl boronic esters are known to be more stable than aryl boronic acids.

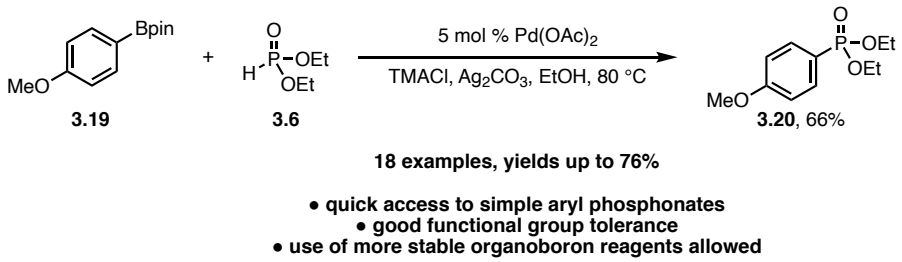


Figure 3.9: Synthesis of Aryl Phosphonates from Aryl Boronic Esters

3.2.4 Decarbonylative Phosphorylation of Carboxylic Acids

Compared to aryl halides and aryl boronic acids, aryl carboxylic acids are much more abundant. Due to this advantage, the value of aryl carboxylic acids as coupling partners have been greatly discovered in the recent years.[32] This leads to a number of decarboxylative reactions for the formation of carbon-carbon and carbon-heteroatom bonds, including C–P bonds. Szostak and co-workers were able to transform aryl

carboxylic acids to aryl phosphonates using palladium catalysis (Figure 3.10).[33] This reaction has a broad substrate scope and can be utilized for late-stage functionalization. Using this reaction condition, for example, they were able to decarboxylatively phosphorylate repaglinide, a commercial small-molecule drug used for antidiabetic treatment. However, the reaction condition is extremely harsh as it requires a reaction temperature of 160 °C, which leads to question about the practicability of this method.

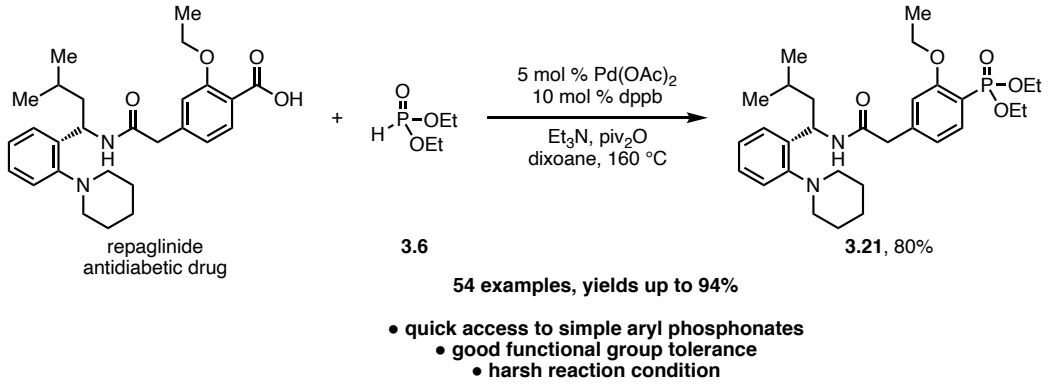


Figure 3.10: Decarbonylative Phosphorylation of Carboxylic Acids

Interestingly, the mechanism of this reaction is not proposed as a typical decarboxylation mechanism, although it provides such a transformation (Figure 3.11). The reaction starts with the acetylation of carboxylic acid **3.23** to form the mixed anhydride **3.24**. Now the C–O acyl bond is activated enough that palladium catalyst **3.22** can insert and give the oxidative addition complex **3.25**, followed by decarbonylation to provide the Pd^{II} complex **3.26**. The rest of this mechanism is similar to the mechanism proposed for palladium-catalyzed cross-coupling of aryl halides. In general, this

reaction is a good complement for the existing cross-coupling methods considering the natural abundance of aryl carboxylic acids.

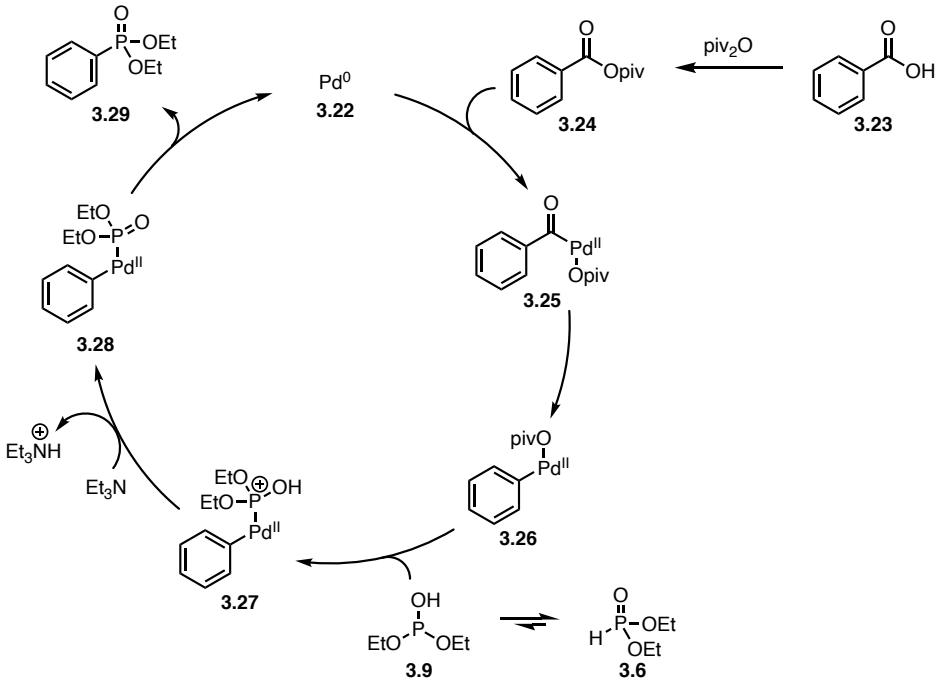


Figure 3.11: Proposed Mechanism of Szostak's Phosphorylation Method

3.2.5 Aryl Phosphonate Synthesis from Diaryliodonium Salts

Diaryliodonium salts can also be used to prepare aryl phosphonates. Zhao and co-workers demonstrated the synthesis of aryl phosphonate **3.31** from the hypervalent iodine reagent **3.30** using copper catalysis (Figure 3.12).[34] This reaction is fast and typically finishes in 10 minutes, and therefore is a quick way to prepare simple aryl phosphonates. However, the ease of this reaction highly depends on the availability of the diaryliodonium salt, which takes extra steps to prepare.

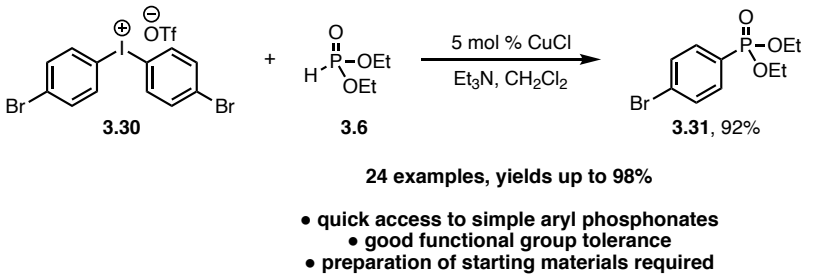


Figure 3.12: Aryl Phosphonate Synthesis Using Hypervalent Iodine Reagents

3.2.6 Summary of Existing Methods & Our Hypothesis

In general, all of those methods can quickly prepare aryl phosphonates bearing simple structures, but they may not be highly efficient for the synthesis of complex aryl phosphonates. They all require the use of pre-functionalized starting materials, including Grignard reagents, halides or equivalents, boronic acids, carboxylic acids, and hypervalent iodine reagents. Therefore, the efficiencies of those methods are significantly influenced by the availability of starting materials. For example, aryl phosphonates bearing complex substitutions at *ortho* position are not easy to synthesize via those methods.

3.3 Our Design

An alternative way to prepare structurally complex aryl phosphonates is to functionalize simple aryl phosphonates. We are particularly interested in the functionalization of aryl phosphonates at *ortho* positions considering the value of *ortho*-substituted aryl phosphonates mentioned earlier. We envisioned that *ortho*-phosphonate boronic esters can serve as common intermediates for those molecules as the versatility of boronic esters allows them to be transformed into a number of other functional groups, such as halogens, alcohols, amines, and aromatic groups.[35] However, there has

been no easy way to prepare those *ortho*-phosphonate boronic esters until today. Prior to this work there were only two examples of *ortho*-phosphonate boronic ester syntheses reported, and both make the use of *ortho*-phosphonate aryl bromides (Figure 3.13).[36] Thus, there is a clear need for a general method to prepare those molecules.

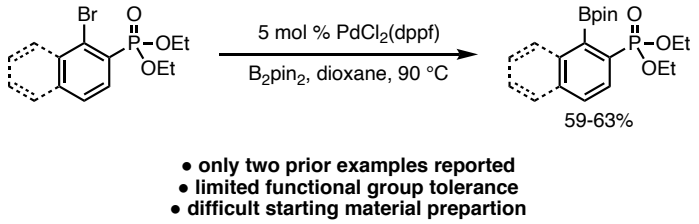


Figure 3.13: Synthesis of *Ortho*-Phosphonate Boronic Esters via Miyaura Borylation

3.4 Directed C–H Borylations

During the last decade, *ortho* C–H borylation of arenes using the strategy of directing groups have been extensively explored.[37-39] This technology has been recognized as a powerful tool to prepare aryl boronic esters bearing *ortho*-functionalities. A number of directing groups have been demonstrated in this field, including carbonyls, Lewis basic nitrogens, phenols, silanes, thianes, and phosphines. In general, all of those reactions have broad functional group tolerance, and can provide rapid access to complex aryl boronic esters from simple starting materials. The versatility of boronic esters allows the transformation of those borylated products into many other substrates.[35] Due to those advantages, this strategy has been frequently used for late-stage functionalization.

3.4.1 Carbonyl-Directed C–H Borylations

The carbonyl groups can coordinate to metal catalysts and serve as directing groups in C–H borylation reactions. For example, the Miyaura group was able to use iridium catalysis to activate the *ortho* C–H bond of aromatic ester **3.32** to provide the borylated aryl ester **3.33** in 95% yield (Figure 3.14).[40] Although the borylation yield looks good, this reaction uses the borylating reagent B_2pin_2 as the limiting reagent and requires large excess of aryl esters, typically five equivalence. Given that the accessibility of the aryl ester partner is limited compared to B_2pin_2, having to use it in large excess limits the practicality of the reaction.

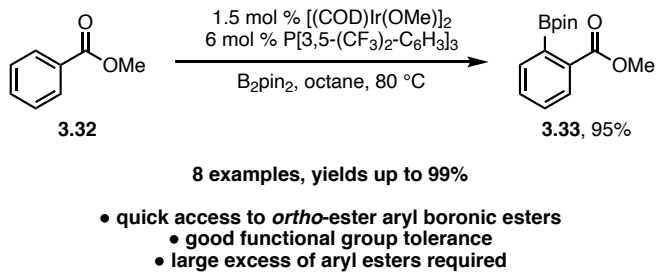


Figure 3.14: Miyaura's *Ortho* C–H Borylation of Aryl Esters

The mechanism of this reaction is proposed as an Ir^{III}/Ir^{V} catalytic cycle (Figure 3.15). First of all, the Ir^{I} pre-catalyst is oxidized to a trisboryl Ir^{III} complex **3.34** by B_2pin_2, which is the active catalyst and has an open coordination site. Therefore, the aryl ester **3.32** can bind to the metal catalyst, followed by the selective *ortho* C–H activation via oxidative addition to give the Ir^{V} intermediate **3.36**. It is notable that a second open coordination site is needed for the C–H activation step to take place, which requires one of the ligands to dissociate from the iridium/aryl ester complex **3.35**. This process is typically the rate-limiting step for directed C–H borylation reactions. The

consequent reductive elimination and dissociation from catalyst produce the observed borylated aryl ester **3.33**. Finally, the iridium hydride species **3.38** can be oxidized by B_2pin_2 to re-generate the active iridium catalyst **3.34**.

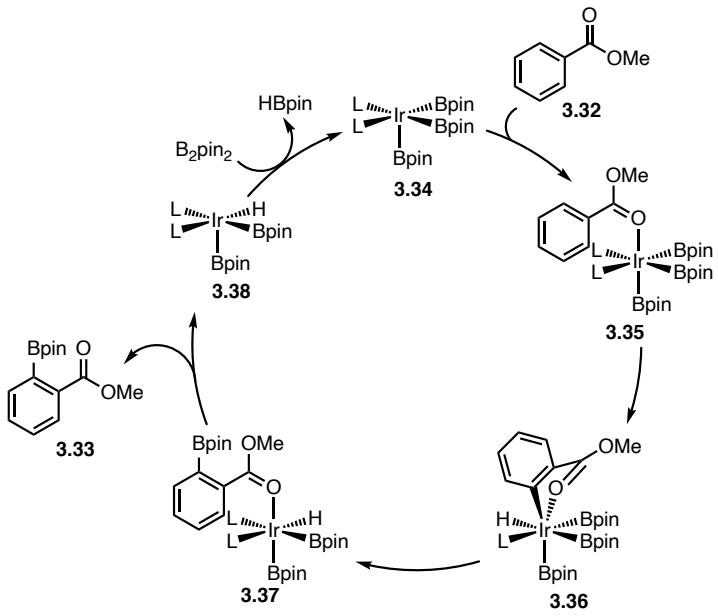


Figure 3.15: Proposed Mechanism of Directed C–H Borylation

Based on this mechanism, the Miyaura group was able to expand this chemistry to less Lewis basic aryl ketone substrates with the use of $AsPh_3$ as ligand (Figure 3.16).[41] The use of superstoichiometric amounts of aryl ketones, however, is also required in this chemistry, limiting the practicality of this method.

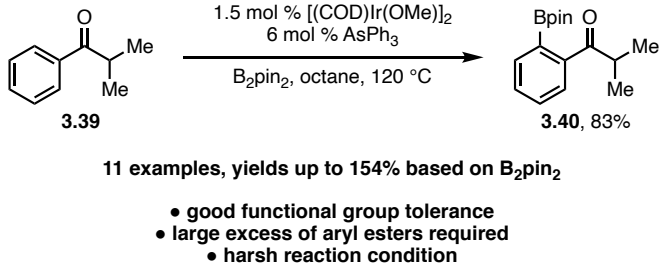


Figure 3.16: Miyaura's *Ortho* C–H Borylation of Aryl Ketones

To improve the borylation efficiency and reduce the waste of starting materials, Smith and co-workers designed a phosphine/silane-based anionic bidentate ligand, which allows the use of aryl esters as limiting reagents in C–H borylation reactions (Figure 3.17).[42] This reaction has a broad substrate scope and can be used to borylate aromatic esters bearing complicated structures, such as the ones containing heterocycles. Furthermore, aryl amides can also serve as directing groups in this reaction, including Weinreb amides. Unfortunately, the use of aromatic ketones results in low reactivity using this ligand.

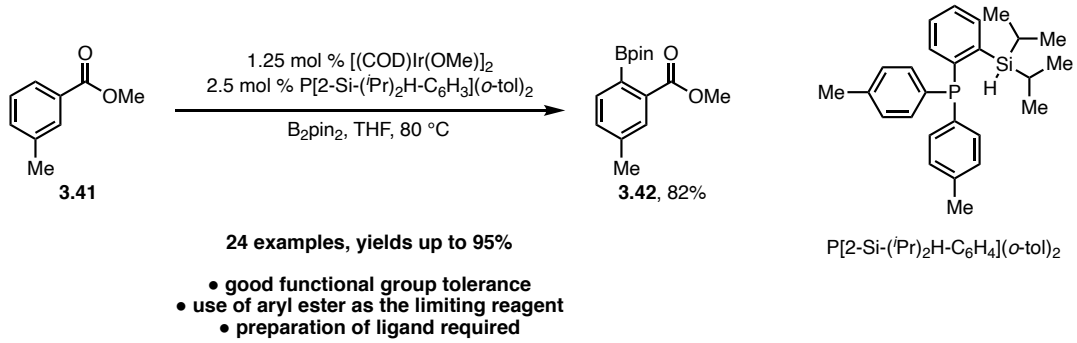


Figure 3.17: Smith's Directed C–H Borylation Strategy

This phosphine/silane-based anionic bidentate ligand is able to improve the borylation efficiency because it creates a second open coordination site (Figure 3.18). Due to the ligand's anionic nature, the corresponding active Ir^{III} catalyst **3.43** only has four occupied coordination sites and leaves the other two open. This greatly promotes the rate of C–H activation step as the second coordination site is the key to cleave the *ortho* C–H bond.

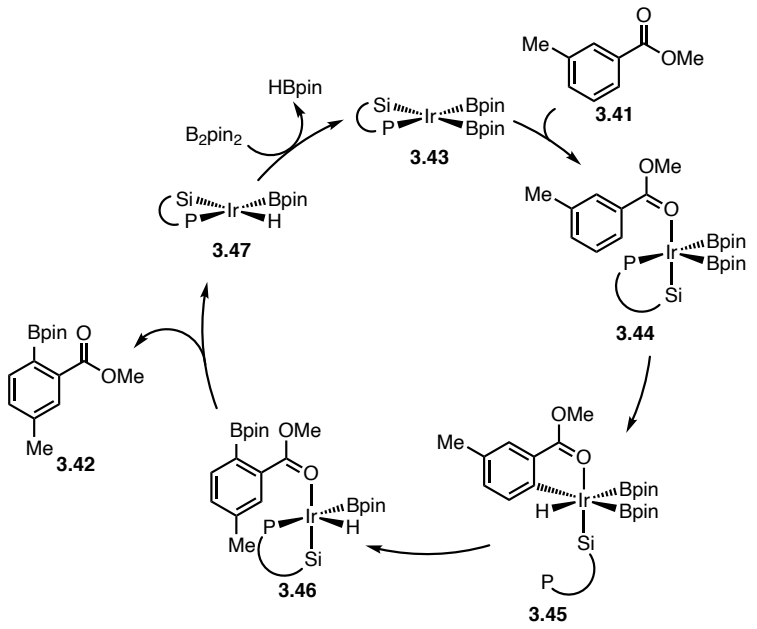


Figure 3.18: Proposed Mechanism with Smith's Anionic Bidentate Ligand

The Smith group was able to further improve the reactivity by using a nitrogen/silane-based anionic bidentate ligand (Figure 3.19). This reaction condition allows the *ortho* borylation of aryl ketone **3.48**, which does not work under the previous reaction condition using the phosphine/silane-based ligand. Other previously

unsuccessful substrates, such as *O*-aryl carbamates, can also work under this reaction condition.

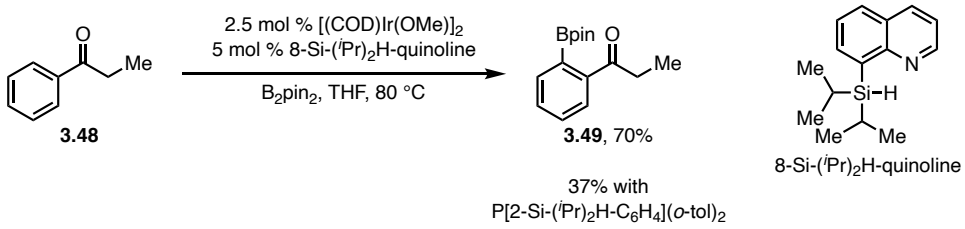


Figure 3.19: Directed C–H Borylation with a Nitrogen/Silane-Based Ligand

Another strategy to create active Ir^{III} catalyst containing two vacant coordination sites is to use the nitrogen/boron-based bidentate ligand **3.51** discovered by the Li group (Figure 3.20).[43] The weak Si–B bond can undergo oxidative addition with a low-valent iridium catalyst to provide the active Ir^{III} catalyst, which can *ortho* borylate many substrates, such as aryl ester **3.50**.

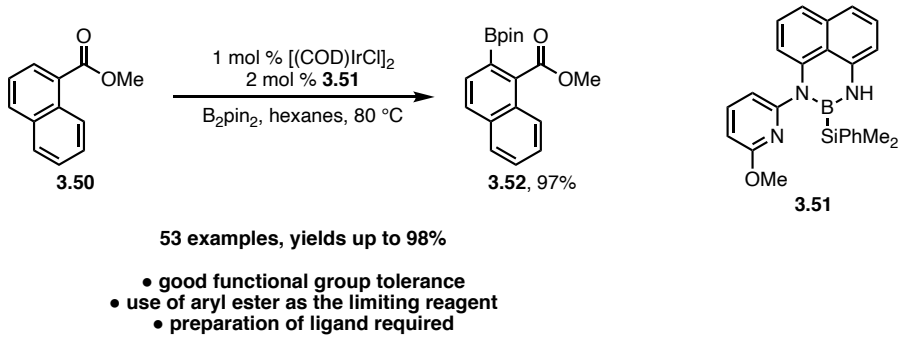


Figure 3.20: Li's Nitrogen/Boron-Based Bidentate Ligand for C–H Borylation

Besides those anionic bidentate ligands, Sawamura and co-workers have shown that the use of silicon-supported phosphine ligand can also improve the efficiencies of C–H borylation (Figure 3.21).[44] The addition of silicon polymer dramatically increases the ligand size, preventing the over-ligation of the iridium catalyst. Under this reaction, even highly-substituted aryl boronic esters can be prepared under mild condition, which is known to be a challenge in this this field. Other difficult substrates, such as the ones bearing heterocycles, also work under this C–H borylation condition. However, the synthesis of this silicon-supported ligand is not trivial.

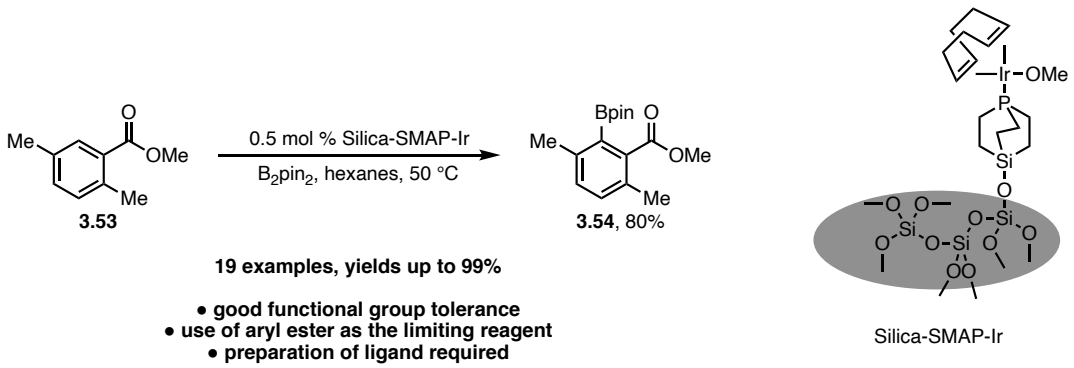


Figure 3.21: Sawamura's Silicon-Supported Iridium Catalyst

Finally, the Yu group has shown that palladium catalysis can also be used for C–H borylation of aryl amides (Figure 3.22).[45] Using the easily deprotonated aryl amide **3.55** as a directing group, the *ortho* C–H bond can be cleaved by palladium catalysis to provide the borylated product **3.56** in 85% isolated yield.

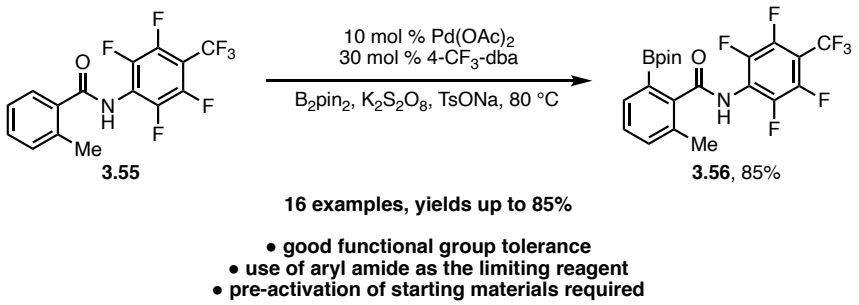


Figure 3.22: Palladium-Catalyzed C–H Borylation of Aromatic Amides

3.4.2 Lewis Basic Nitrogen as a Directing Group

Lewis basic nitrogen groups, such as pyridines, can serve as directing groups in iridium-catalyzed C–H borylation reactions. For example, Lassaletta and co-workers were able to use iridium catalysis to borylate 2-aryl pyridine **3.57** (Figure 3.23).[46] In this reaction, the addition of catalytic amount of HBpin can accelerate the reaction as it helps to generate the active catalyst, which has been used as a common strategy in many C–H borylation methods. It is worth-mentioning that those pyridine-based substrates can also be borylated under the reaction conditions reported by Sawamura, Smith, and Li.[42-44]

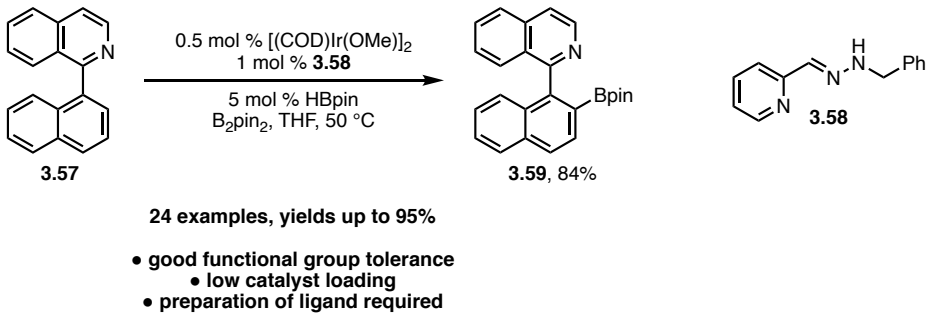


Figure 3.23: C–H Borylation of 2-Aryl Pyridines

In 2012, Clark and co-workers reported a benzyl amine-directed C–H borylation method.[47] Using commercially accessible catalytic components, they could quickly prepare *ortho*-substituted aryl boronic esters from simple benzylic amines (Figure 3.24). More recently, they developed reaction conditions for in situ Suzuki coupling to directly convert those borylated products to biaryl frameworks without purification of borylated products.[48] This is particularly interesting considering that often a loss of material is observed during product purification due to the unstable nature of boronic ester groups.

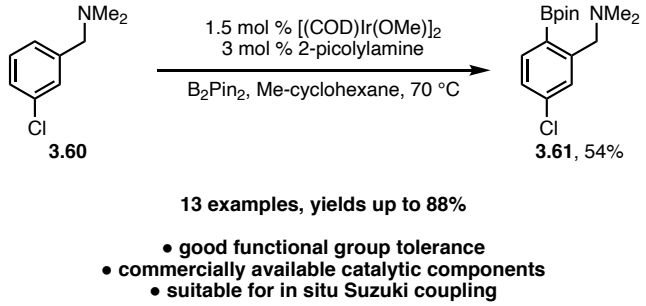


Figure 3.24: Benzylic Amine-Directed C–H Borylation

Recently, the Chattopadhyay group developed reaction conditions to do *ortho* borylation of aromatic aldehydes (Figure 3.25).[49] They were able to condense a bulky primary amine onto the aldehyde **3.62** to form a Lewis basic imine in situ, which then directed the catalyst to selectively borylate at the *ortho* position. The imine can then be easily hydrolyzed back to the aldehyde product **3.64** during the reaction work-up. In this way, one can quickly prepare *ortho*-formyl aryl boronic esters from simple starting materials.

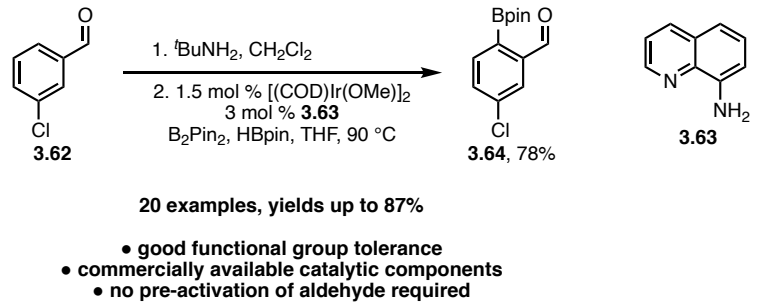


Figure 3.25: C–H Borylation of Aryl Aldehydes

3.4.3 Phenol-Directed C–H Borylation

As discussed earlier, *O*-aryl carbamate can be used as a directing group in several *ortho* C–H borylation conditions. For example, *O*-aryl carbamate **3.65** can be borylated at *ortho* position using the reaction condition reported by the Li group (Figure 3.26).[43] The removal of the carbonyl group could afford the *ortho*-borane phenol product, but this requires an additional step for deprotection. Moreover, the deprotection usually involves harsh reaction conditions, such as high reaction temperature, which may be incompatible with the unstable boronic ester group. Therefore, it will be more useful if there is a method that can directly access *ortho*-borane phenols in unprotected form.

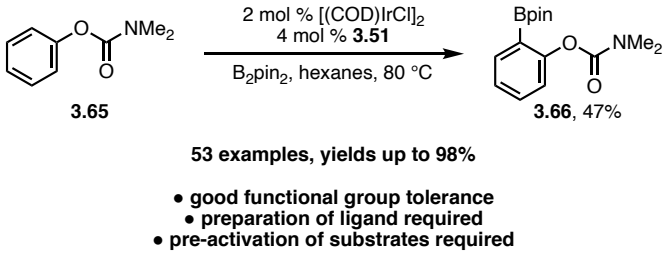


Figure 3.26: C–H Borylation of *O*-Aryl Carbamates

Recently, Smith and co-workers were able to realize this goal using a traceless protecting strategy. The treatment of free phenol **3.67** with HBpin provides a weak protection, allowing the *ortho* C–H borylation to take place. The boryl protecting group can be easily removed during reaction work-up to afford the desired unprotected product **3.68** in 74% yield (Figure 3.27).[50] Interestingly, this reaction is proposed as electrostatics-directed, instead of functional group-directed. It is also noteworthy that a relatively big substitution at *para* position is needed for the substrate to get selective *ortho*-borylation. For example, with a fluorine substituted at *para* position, *meta*-borylation was observed as the major product.

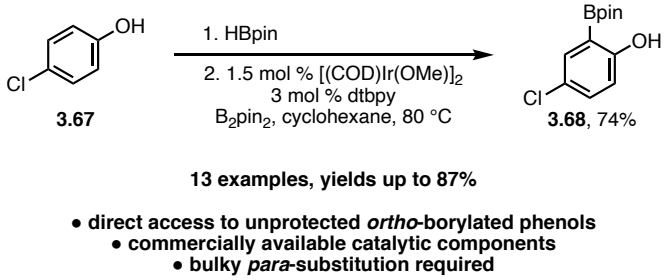


Figure 3.27: Directed C–H Borylation of Unprotected Phenols

3.4.4 Silane-Directed C–H Borylation

In 2008, Hartwig and co-workers developed a benzyl silane-directed C–H borylation reaction.[51] Using benzyldimethylsilane as a directing group, the *ortho*-borylated products can be steadily prepared with low iridium loading (Figure 3.28). Although benzyl silanes can be converted into several other functional groups, the Hartwig group envisioned this chemistry as an opportunity for the use of traceless directing groups in C–H borylation.

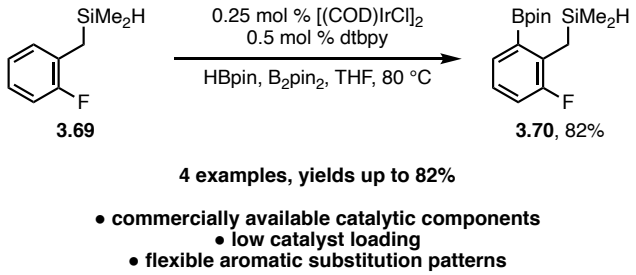


Figure 3.28: Benzyl Silane-Directed C–H Borylation

For example, they were able to install diethylsilyl group on phenols using the same iridium catalyst, which then serve as directing groups for *ortho* borylation (Figure 3.29). The crude reaction mixture could then be worked up with KHF_2 to remove the silyl group and provide the more stable trifluoroborate salt **3.71**. In this way, aryl boronic esters bearing *ortho*-unprotected alcohols can be quickly synthesized. Furthermore, other related compounds, such as anilines, can also be borylated using a similar strategy.

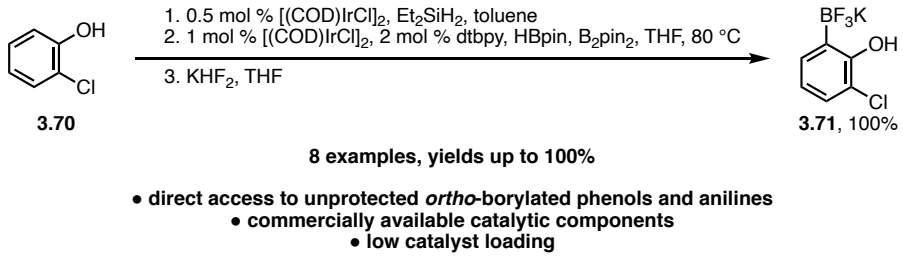


Figure 3.29: Use of Diethylsilane as a Traceless Directing Group

More interestingly, this method can be applied to protic heterocycles. The in situ formation of *N*-hydrosilyl indoles directed the C–H borylation at the 7-position (Figure 3.30).[52] Similarly, the silyl directing group could be easily removed during reaction

work-up. Other related heterocycles, such as phenothiazines, can also be selectively borylated under the same reaction condition.

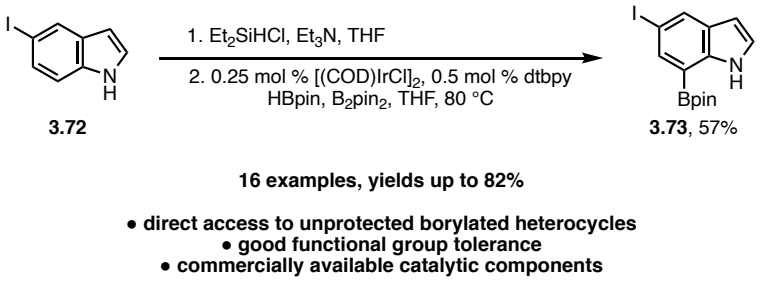


Figure 3.30: C–H Borylation of Indolines at 7-Position

3.4.5 Thiane-Directed C–H Borylation

The value of aryl sulfide as directing group has also been discovered in the C–H borylation reactions (Figure 3.31).[53] Unlike other directing group strategies, the aryl sulfide **3.74** does not directly coordinate to iridium catalyst; instead, it binds to the Lewis acidic borane in the ligand **3.75**. Such a Lewis acid-base interaction brings the iridium catalyst closer to the *ortho* C–H bond, which lowers the energy barrier of *ortho* C–H activation caused by steric effect. However, an obvious drawback is that the preparation of ligand **3.75** is required.

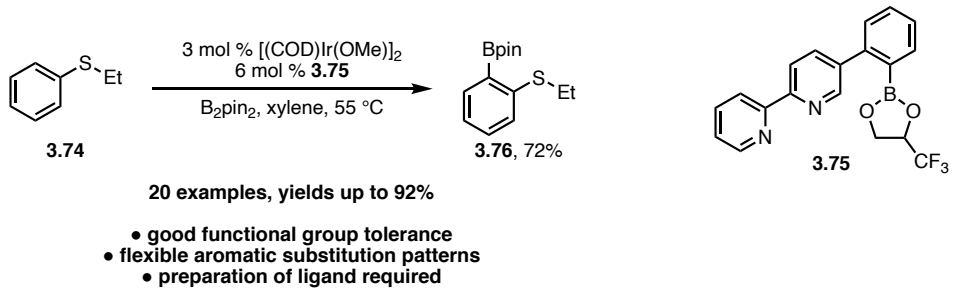


Figure 3.31: Aryl Sulfide-Directed C–H Borylation

The Li group also demonstrated the use of benzyl thioether as a directing group in this field (Figure 3.32).[54] The borylated products prepared using this method, such as **3.78**, can be further functionalized and deprotected to deliver benzaldehydes bearing *ortho*-substitutions. Notably, this reaction condition is very simple and does not require the addition of external ligands; in fact, the attempts to use external ligands in this reaction significantly dropped the borylation yield.

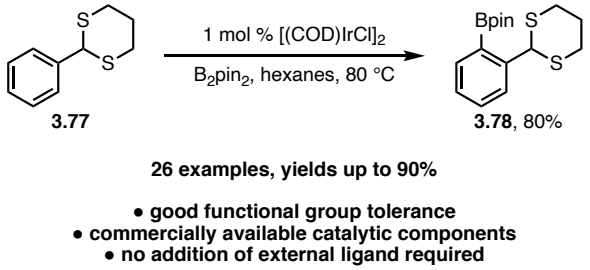


Figure 3.32: Benzyl Thioether-Directed C–H Borylation

3.4.6 Phosphine-Directed C–H Borylation

Previously, the Clark group designed an iridium-catalyzed benzyl amine-directed C–H borylation.[47] Several years ago, they were able to expand this power to

benzyl phosphines (Figure 3.33).[55] This method allows the rapid preparation of *ortho*-borylated benzyl phosphines, which could serve as versatile intermediates for phosphine-based ligand synthesis. To prevent the oxidation of phosphines, the treatment of crude mixture with BH_3 is required for the ease of purification. This is the first time that the use of phosphine directing group has been demonstrated in the field of C–H borylation.

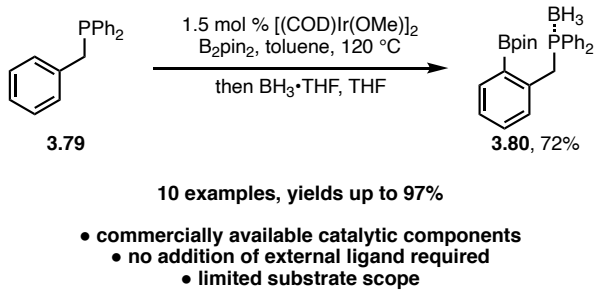


Figure 3.33: Benzyl Phosphine-Directed C–H Borylation

Interestingly, the phosphine substrates themselves can act as ligands for the iridium catalyst, avoiding the need for external ligand under this reaction condition. However, the dual role as ligand for substrates actually limits the scope of benzyl phosphines in this method. Furthermore, the synthesis of bis-borylated products is less efficient under this condition, which are interesting substrates with respect to ligand design (Figure 3.34). For example, with very harsh reaction condition, the attempt to bis-borylate CyJohnPhos **3.81** resulted in modest yield of desired product **3.83** with a significant amount of mono-borylated product **3.82** left.

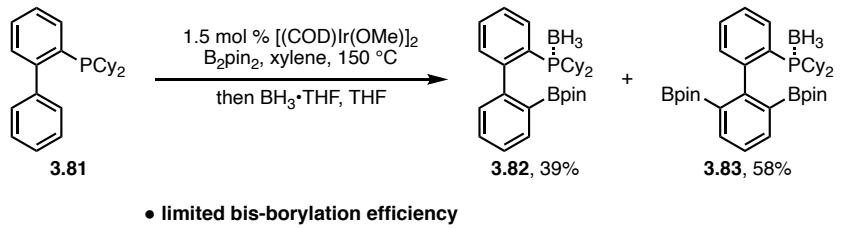


Figure 3.34: Limited Reactivity for Bis-Borylation

To overcome these limitations, Clark and co-workers recently revised the reaction condition with the use of a cationic iridium catalyst $[(COD)_2Ir]BF_4$.[56] The cationic nature of this pre-catalyst allows the active Ir^{III} catalyst to have two open coordination sites as there is a non-coordinating anionic ligand, BF_4^-, in the iridium complex. As mentioned earlier, the second open coordination site of iridium catalysis is the key for the rate-determining C–H activation step. Under this newly discovered condition, benzyl phosphines bearing more complex structures, such as heterocycle **3.84**, can now be borylated (Figure 3.35). Moreover, the synthesis of several bis-borylated products were demonstrated in this work.

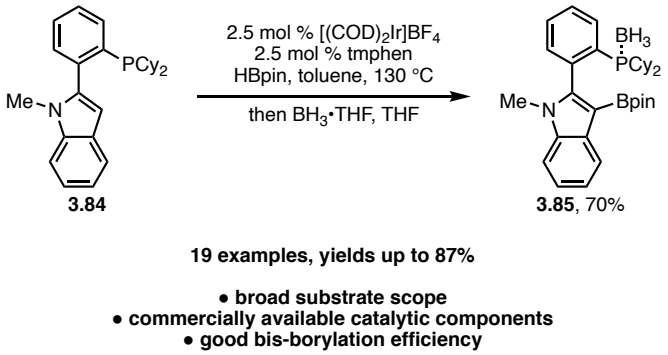


Figure 3.35: Benzyl Phosphine-Directed C–H Borylation Using $[(COD)_2Ir]BF_4$

Recently, Shi and Takaya independently described conditions for *ortho* C–H borylation of aryl phosphines. Using rhodium catalysis, the Shi group could directly synthesize *ortho*-phosphine aryl boronic esters from simple aryl phosphine substrates using a directed C–H borylation strategy (Figure 3.36).[57] However, this method suffers from several limitations. First, the scope of this reaction is limited. For the most part it works well only with symmetric triaryl phosphines. For aryl phosphines bearing different aromatic substitutions, this reaction results in a mixture of borylated products. Second, the borylation efficiency significantly drops while using alkyl substituted aryl phosphines. There is only one example for the borylation of dialkyl aryl phosphine in this paper. Finally, and most importantly, no reactivity was observed for the substrates bearing pre-existing *ortho* substitutions.

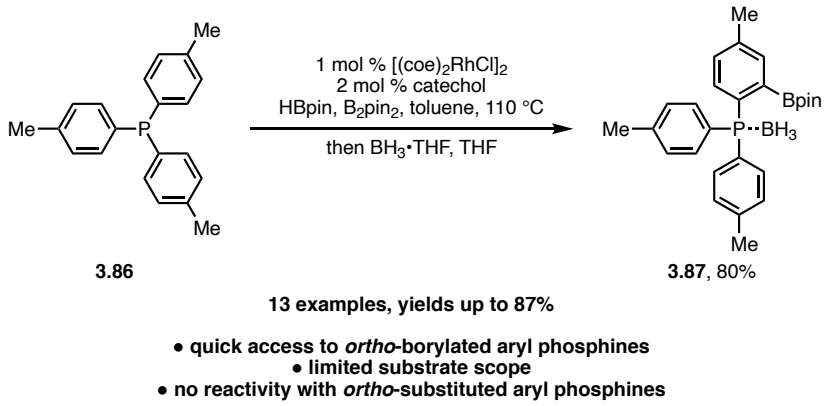


Figure 3.36: Shi's Aryl Phosphine-Directed C–H Borylation

Takaya and co-workers reported the use of ruthenium catalysis for a similar transformation (Figure 3.37).[58] However, this method shares the same limitations with Shi's C–H borylation strategy. For example, there is no example of borylation of aryl

phosphines bearing pre-existing *ortho* substitutions, which would produce highly-substituted aryl phosphines.

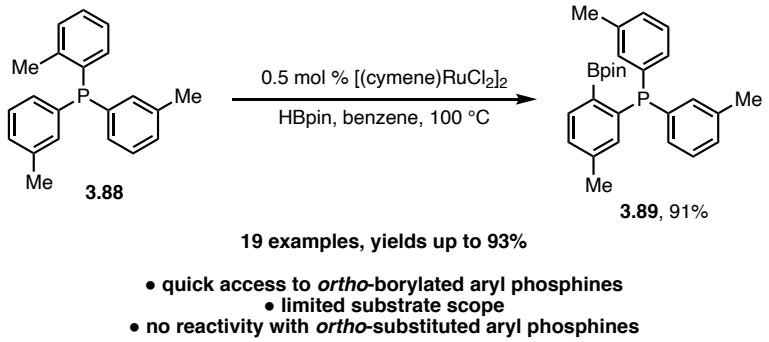


Figure 3.37: Takaya's Aryl Phosphine-Directed C–H Borylation

In terms of phosphine-based ligand synthesis, however, *ortho*-substitutions are important. Those substituents often afford crucial steric and electronic characteristics of phosphine ligands. For example, SPhos, a Buchwald-type dialkylbiaryl ligand bearing *ortho*-substitution, has been used extensively in palladium-catalyzed cross-coupling reactions (Figure 3.38).[59] The aryl substitution at the *ortho* position plays an important role in the stability of SPhos-derived palladium catalysts, as it prevents the catalyst oxidation and accelerates the rate of reductive elimination.

Moreover, *ortho*-substitution offers the opportunity to introduce chiral components to aryl phosphine ligands. Notable examples are the PHOX-type ligands, aryl phosphines bearing chiral oxazolines at the *ortho* position, which are commonly used in asymmetric catalysis (Figure 3.38).[60] Therefore, it would be significant to have a method able to borylate *ortho*-substituted aryl phosphorus compounds.

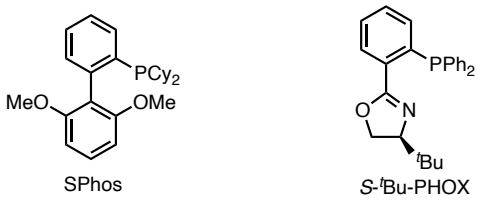


Figure 3.38: Notable Examples of *Ortho*-Substituted Aryl Phosphine Ligands

3.4.7 Hypothesized Aryl Phosphonate-Directed C–H Borylation

Due to the values of highly-substituted aryl phosphines, we would like to develop a general method that allows the *ortho* C–H borylation of aryl phosphorus compounds bearing pre-existing *ortho*-substitutions. As common precursors of aryl phosphines, aryl phosphonates can be quickly converted into the corresponding phosphines.[1-2] Therefore, we envisioned that an aryl phosphonate-directed C–H borylation could potentially be a solution to overcome the limitations of current methods (Figure 3.39). The borylated aryl phosphonate products can be further functionalized by the vast chemistry of aryl boronic esters. In this way, aryl phosphonates bearing complex structures can be rapidly prepared from simple substrates, which can be synthesized via many existing methods mentioned earlier.

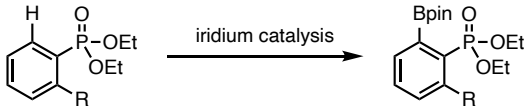


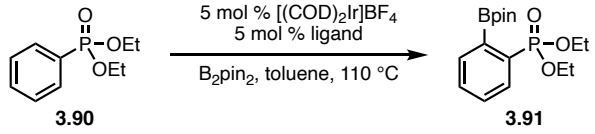
Figure 3.39: Hypothesized Aryl Phosphonate-Directed C–H Borylation

3.5 Reaction Optimization

To investigate this idea, I started with the borylation of commercially available aryl phosphonate **3.90** using the catalyst combination of cationic iridium source

[$(COD)_2Ir]BF_4$ and the ligands that have previously shown success in this field (Table 3.1). Through this preliminary screen, I observed around 7% yield with the use of electron-deficient triaryl phosphine $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ as ligand (entry 4).

Table 3.1: Preliminary Ligand Screen with [$(COD)_2Ir]BF_4$

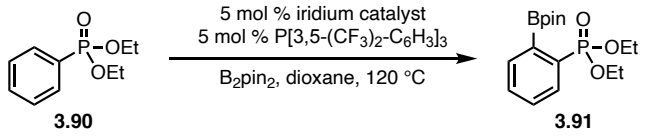


3.90 **3.91**

entry	Ligand	Yield of **3.91** [%]
1	dtbpy	0
2	tmphen	0
3	2-picolylamine	1
4	$P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$	7

With higher reaction temperature and the use of more polar solvent, I was able to improve the yield of borylated product **3.91** to 25% (Table 3.2, entry 1). The examination of other iridium pre-catalysts revealed that (COD)Ir(acac) was able to provide similar borylation efficiency (entry 5), and I decided to move forward with this iridium source. Comparing to the temperature sensitive pre-catalyst [$(COD)_2Ir]BF_4$, (COD)Ir(acac) is cheaper and bench stable.

Table 3.2: Preliminary Examination of Iridium Sources



3.90 **3.91**

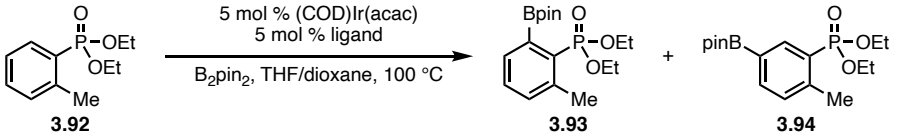
entry	Ir Catalyst	Yield of **3.91** [%]
1	$[(COD)_2Ir]BF_4$	25
2	$[(COD)_2Ir](BARF)$	0
3	$[(coe)_2IrCl]_2$	trace
4	(COD)Ir(indenyl)	0
5	(COD)Ir(acac)	26
6	$(CO)_2Ir(acac)$	0

Having identified the optimal iridium pre-catalyst, I switched to the model substrate **3.92**, an aryl phosphonate bearing *ortho*-substitution. The borylation of this substrate would afford the highly-substituted aryl phosphonate **3.93**, which is difficult to prepare using other methods. In the previous work of benzyl phosphine-directed C–H borylation, the addition of external ligand is not required. In this case, however, I did not observe any *ortho* borylation without external ligand; instead, the borylation took place at the *meta* position to give **3.94** (Table 3.3, entry 1). Using 2-picolylamine, a nitrogen-based bidentate ligand used for the borylation of benzylic amines, there was still no formation of *ortho*-borylated product **3.93** (entry 2). With bipyridine ligands, such as dtbpy and tmphen, the overall borylation was more efficient but only *meta*-borylated product **3.94** was produced (entry 3-4). This selectivity indicated that the reactivity was majorly controlled by the steric effect of substrate instead of directing group. However, it is noteworthy that no *para*-borylation was observed, suggesting that the electronic difference between methyl and phosphonate groups also plays an important role for the borylation selectivity.

Using the anionic phosphine/silicon based bidentate ligand designed by the Smith group,[42] I was very happy to observe promising reactivity at the *ortho* position (entry 5). However, this structurally complicated ligand is not commercially available and takes a few steps to synthesize. To make this method more user-friendly, therefore, I wished to discover the use of more accessible and simple ligands.

Switching to PPh_3, no desired *ortho*-borylated product **3.93** formed (entry 6); with more electron-deficient phosphine ligands, however, I began to observe borylation at the *ortho* position (entry 7-8). Following this trend, I finally identified $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ as the optimal ligand, providing the desired *ortho*-borylated aryl phosphonate **3.93** in 84% yield (entry 9).

Table 3.3: Examination of Ligand Effect

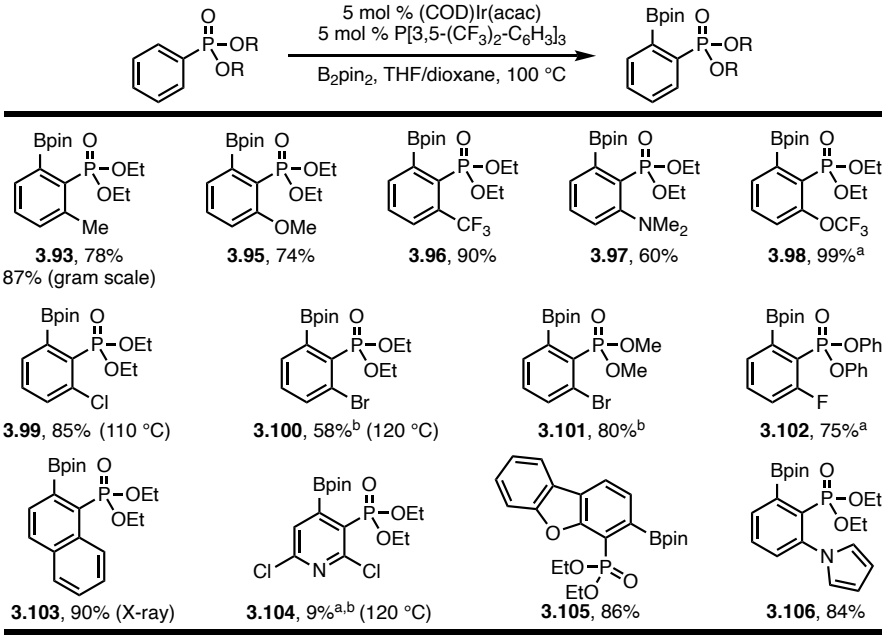


3.92 **3.93** **3.94**

entry	Ligand	Yield of **3.93** [%]	Yield of **3.94** [%]
1	no ligand	0	7
2	2-picolylamine	0	4
3	dtbpy	0	41
4	tmphen	0	38
5	$P[2\text{-}Si(^iPr)_2H\text{-}C_6H_4](p\text{-tol})_2$	31	0
6	PPh_3	0	7
7	$P(4\text{-}F\text{-}C_6H_4)_3$	4	0
8	$P(4\text{-}CF_3\text{-}C_6H_4)_3$	4	0
9	$P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$	84	0

3.6 Examination of Substrate Scope

Using this reaction condition, aryl phosphonates bearing various functional groups can be borylated at the *ortho* position (Figure 3.40). The borylation of model substrate provided **3.93** in 78% isolated yield on 1 mmol scale. During the product purification, the loss of material was observed due to the unstable nature of aryl boronic esters. However, such an effect can be minimized by scaling the reaction up. For example, running the same reaction at gram scale provided the borylated product in 87% isolated yield. Substrates substituted with several different functionalities could be borylated with good efficiencies under this reaction condition, providing those highly-substituted aryl phosphonates (**3.95**-**3.98**). Due to the instability of **3.98**, unfortunately, the attempt of product purification was unsuccessful.



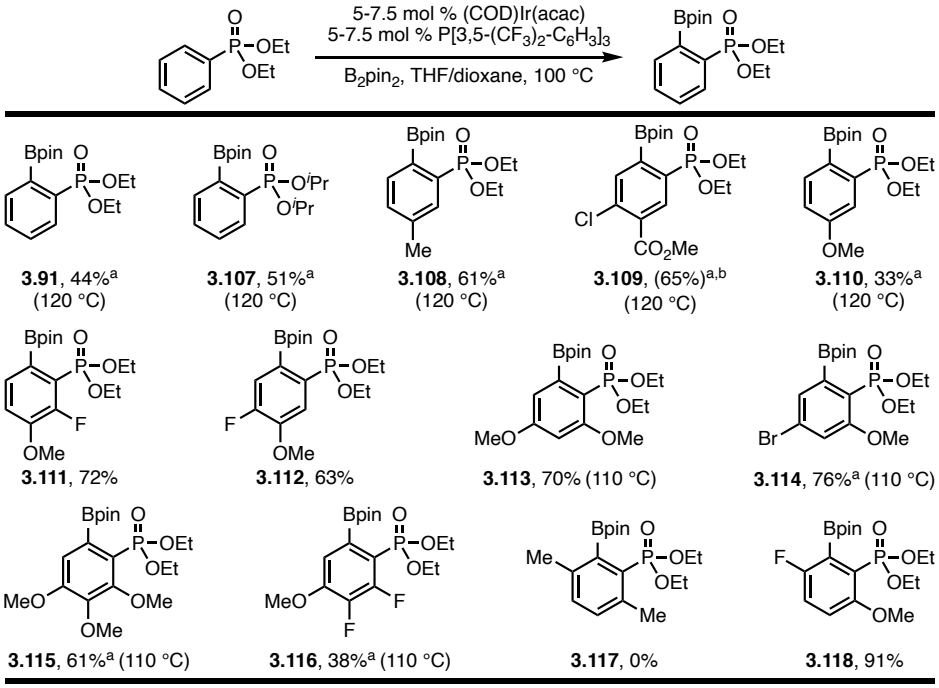
[a] Yields calculated by ^{1}H NMR analysis. [b] Run with $[(COD)_2Ir]BF_4$.

Figure 3.40: Examination of Functional Group Tolerance

Using this method, *ortho*-phosphonate aryl boronic esters bearing halides (**3.99-3.102**) can also be prepared. Those substrates will be very difficult to synthesize through the existing Miyaura borylation strategy, especially the ones containing aryl bromides (**3.100-3.101**). Notably, the borylation of aryl phosphonates bearing bulky substitutions at the *ortho* position require higher reaction temperature and the use of more active cationic pre-catalyst $[(COD)_2Ir]BF_4$ to proceed (**3.100**). We rationalized this observation as the bulky substitution limited the conformational rotation of the directing group. Based on this hypothesis, I was able to solve this problem by reducing the size of the phosphate group, which produced the borylated product **3.101** in higher yield under lower reaction temperature. The aryl phosphonate with aromatic substitutions was borylated in 75% yield (**3.102**), showing the generality of this method respect to the choices of directing group. The borylation of those diphenyl arylphosphonate is particularly interesting as those phosphonate groups can be directly converted into phosphorus oxides in single steps with the treatment of Grignard or organolithium reagents.

Other aromatic system, such as the naphthalene-based substrate, can also participate in this reaction, providing **3.103** in 90% isolated yield. One limitation that I found is that this method is not tolerated with Lewis basic heterocycles. Using a pyridine-based aryl phosphonate, only minimal amount of borylated product **3.104** was observed. However, other heterocycles worked pretty well under this reaction condition. For example, the benzofuran-based substrate was borylated in 86% yield (**3.105**), and the borylation of aryl phosphonate bearing pyrrole provided the product **3.106** with similar efficiency.

For the substrate without pre-existing *ortho* substitution (**3.91**), the reaction requires harsher conditions, including higher reaction temperature, higher catalyst loading, and the use of cationic iridium source $[(COD)_2Ir]BF_4$ (Figure 3.41). Moreover, under this reaction condition, a significant amount of bis-borylation at both *ortho* positions was observed, which yielded an unstable product that cannot be purified. To avoid this problem, we hypothesized that the use of a larger directing group could potentially limit the conformational rotation of the phosphonate group in the mono-borylated product **3.91**, which prevents the activation of the second *ortho* C–H bond. Excitingly, switching to larger isopropyl substituted phosphonate as a directing group, only mono-borylated product **3.107** was observed under the same reaction condition.



[a] Run with $[(COD)_2Ir]BF_4$. [b] Yields calculated by ^1H NMR analysis.

Figure 3.41: Examination of Substitution Patterns and Electronic Effects

For aryl phosphonates substituted at the *meta* position, the borylation only took place at the less steric site (**3.108**). Electron-withdrawing *meta*-substitution is well tolerated, proven by the good borylation efficiency of the *meta*-ester aryl phosphonate substrate (**3.109**). Smith and co-workers have shown that the rate of iridium-catalyzed C–H borylation is highly influenced by the electronic nature of the substrates, and we also observed this electronic effect for our method.[61] With a strong electron-donating group *para* to the reactive C–H bond, the borylation was less efficient (**3.110**). However, such an electronic effect is very sensitive, and can be minimized by substituting weak electron-withdrawing groups on the substrates, which provide good borylation yields (**3.111**-**3.112**).

Aryl phosphonates bearing substitutions at other positions can be borylated in good yields (**3.113**-**3.114**), including the highly-substituted ones (**3.115**-**3.116**). Unfortunately, a significant amount of product decomposition was observed during the product purification, resulting in lower isolated yields for **3.115** and **3.116**. One limitation of this method is its steric sensitivity, which is common for many C–H borylation reactions. With a methyl group adjacent to the reactive C–H bond, for example, no reactivity was observed (**3.117**). However, with a smaller substitution, such as fluorine, the aryl phosphonate can be borylated in 91% isolated yield (**3.118**).

A future direction for this project is to develop conditions for the preparation of highly-substituted boronic esters, such as **3.117**. Those products could be dimerized to deliver the framework of chiral bidentate phosphine ligands.

3.7 Product Downstream Functionalization

As a versatile functional group, aryl boronic ester can be converted into a number of other things. For example, I was able to directly transform the borylated

products into aryl phosphonates bearing *ortho*-functionalities, such as phenol (**3.119**), chloride (**3.120**), bromide (**3.121**), and nitrile (**3.122**), using the previously reported conditions (Figure 3.42).[62-64] It is noteworthy that the purification of aryl boronic esters is not necessary for those downstream functionalizations. This is important because the purification of borylated products sometimes results in the loss of materials due to the instabilities of boronic esters.

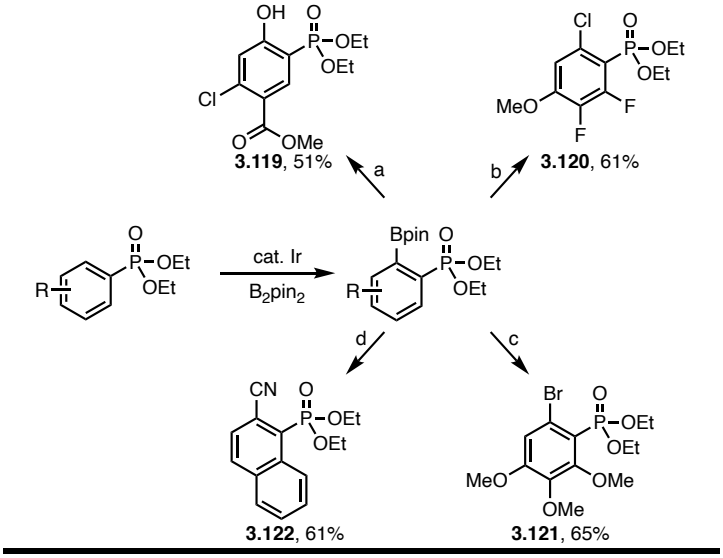
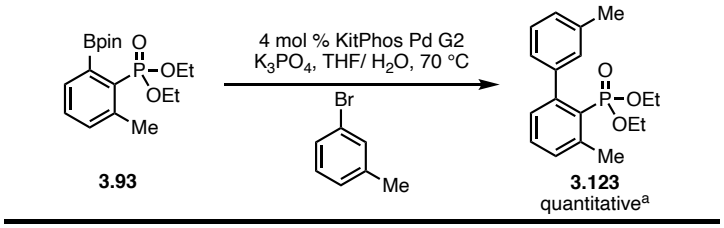


Figure 3.42: In Situ Downstream Functionalizations

Among those products, the *ortho*-nitrile aryl phosphonate **3.122** is particularly interesting in terms of PHOX-type ligand synthesis as the nitrile group can be transformed into a chiral oxazoline via the condensation with a chiral amino alcohol and the phosphonate group can be converted into a phosphine. In this way, one can

potentially rapidly build up a library of PHOX ligands through the modification of the same intermediates.

Finally, Suzuki coupling is among the most ubiquitous transformations of aryl boronic esters. Using the reaction conditions reported by Westcott and co-workers, I was able to transform the borylated product **3.93** into a biaryl phosphonate **3.123**, which is a framework common to many important phosphorous-based ligands (Figure 3.43).[36] For example, those biaryl phosphonates can be converted to phosphorus oxides and then reduced to provide dialkyl biarylphosphine ligands, which have been extensively used in many cross-coupling reactions.



[a] Yield calculated by ^{1}H-NMR with 1,3,5-trimethoxybenzene as internal standard.

Figure 3.43: Suzuki Coupling of *Ortho*-Boryl Aryl Phosphonate **3.39**

3.8 Conclusion

In summary, I developed reaction conditions for phosphonate-directed *ortho* C–H borylation of aryl phosphonates. Using commercially available catalytic components, this reaction provides steady access to *ortho*-phosphonate aryl boronic esters bearing various functional groups and flexible substitution patterns, which can serve as versatile intermediates for highly-substituted aryl phosphorus compounds. As demonstrated, the boronic esters can be converted into a number of functional groups through in situ downstream functionalizations. Comparing to the previous methods, this strategy uses

simple aryl phosphonates as starting materials. A future direction of this project is to explore its utility in ligand synthesis.

3.9 Experimental Details

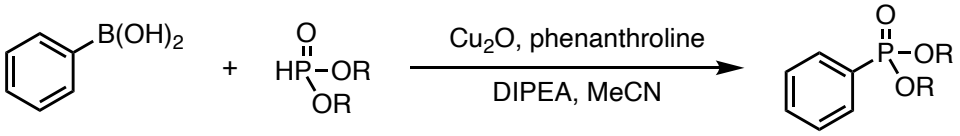
3.9.1 General Experimental Details

THF and dioxane were dried on alumina according to a published procedure.[65] All hot glassware was oven-dried for a minimum of 2 h or flame-dried under vacuum prior to use. The following substrates were synthesized according to published procedures: [diethyl *o*-toylphosphonate (**3.92**),[26] diethyl naphthalen-1-ylphosphonate,[26] diisopropyl phenylphosphonate,[26] diethyl *m*-toylphosphonate,[26] diethyl 3-methoxyphenylphosphonate,[66] diethyl 4-bromo-2-methoxyphenylphosphonate[26]]. Boric acid impregnated silica gel was prepared according to a published procedure.[67] B_2pin_2 [bis(pinacolato)diboron] was purified by recrystallization from pentane before use. All other substrates and reagents were purchased in highest analytical purity from commercial suppliers and used as received. Reaction optimization was conducted in a glovebox (N_2 atmosphere) on a 100 μmol scale in 1-dram vials with Teflon lined caps and heated in an aluminum block with stirring. All NMR chemical yields are reported using 1,3,5-trimethoxybenzene as an internal standard. All other reactions were set up using standard Schlenk technique and heated with stirring in temperature-controlled oil baths. "Double manifold" refers to a standard Schlenk-line gas manifold equipped with N_2 and vacuum (ca. 0.1 mm Hg). Teflon-sealed Schlenk tubes were purchased from ChemGlass (CG-AF-0523). The ^{13}C NMR singal for carbons attached to boron did not appear in the collected spectra due to the quadruple splitting of ^{11}B.[68]

3.9.2 Instrumentation and Chromatography

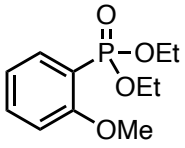
400 MHz ^{1}H, 101 MHz ^{13}C, 376 MHz ^{19}F, and 162 MHz ^{31}P spectra were obtained on a 400 MHz FT-NMR spectrometer equipped with a Bruker CryoPlatform. 600 MHz ^{1}H, 193 MHz ^{11}B, 565 MHz ^{19}F, and 243 MHz ^{31}P spectra were obtained on a 600 MHz FT-NMR spectrometer equipped with a Bruker SMART probe. All samples were analyzed in the indicated deutero-solvent and were recorded at ambient temperatures. All chemical shifts are reported in ppm. ^{1}H NMR spectra were calibrated using the residual protio-signal in deutero-solvents as a standard. ^{13}C NMR spectra were calibrated using the deutero-solvent as a standard. IR spectra were recorded on a Nicolet Magma-IR 560 FT-IR spectrometer as thin films on KBr plates. High resolution MS data was obtained on a Thermo Q-Exactive Orbitrap using electrospray ionization (ESI). Unless otherwise noted, column chromatography was performed either by hand or by use of Isolera 4 Biotage unit with 40-63 μm silica gel, and the eluent reported in parentheses. Analytical thin-layer chromatography (TLC) was performed on precoated glass plates and visualized by UV or by staining ($KMnO_4$ or I_2).

3.9.3 Preparation of Aryl Phosphonates



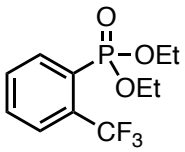
General Protocol A: This reaction was modified from a literature procedure.[26] In a round bottom flask equipped with a magnetic stir bar, Cu_2O (0.05 equiv), phenanthroline (0.10 equiv), and arylboronic acid (2.00 equiv) were added sequentially to the flask under air. H-phosphonate diester (1.00 equiv), DIPEA (3.00 equiv), and wet MeCN (0.25 M) were added sequentially to the flask via syringe. The resulting suspension was allowed to stir at rt overnight. The reaction was then filtered through a

short plug of celite, evaporated in vacuo, and chromatographed to afford the desired aryl phosphonate substrates.


3.S1

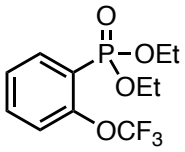
(**3.S1**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), 2-methoxyphenylboronic acid (3.04 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 50:50 EtOAc/hexanes to EtOAc) to afford **3.S1** (2.09 g, 86%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (ddd, J = 14.9, 7.5, 1.8 Hz, 1H), 7.50 (dddd, J = 8.4, 7.4, 1.8, 0.9 Hz, 1H), 7.01 (tdd, J = 7.5, 3.5, 0.9 Hz, 1H), 6.94 (dd, J = 8.1, 7.0 Hz, 1H), 4.25 – 4.05 (m, 4H), 3.90 (s, 3H), 1.33 (t, J = 7.1 Hz, 6H). The analytical data matched that previously reported in the literature.[69]


3.S2

(**3.S2**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 2-trifluoromethylphenylboronic acid (7.59 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S2** (3.80 g, 67%) as yellow oil.

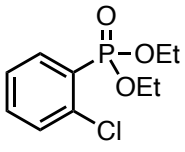
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.24 (ddt, *J* = 14.8, 7.0, 2.5 Hz, 1H), 7.81 (ddd, *J* = 7.1, 5.5, 1.9 Hz, 1H), 7.70 – 7.61 (m, 2H), 4.26 – 4.17 (m, 2H), 4.13 (ddtd, *J* = 15.4, 10.1, 7.1, 1.8 Hz, 2H), 1.34 (td, *J* = 7.1, 1.7 Hz, 6H). The analytical data matched that previously reported in the literature.[70]



3.S3

(**3.S3**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), 2-(trifluoromethoxy)phenylboronic acid (5.40 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S3** (1.18 g, 40%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (ddd, *J* = 14.7, 7.6, 1.8 Hz, 1H), 7.59 (tdd, *J* = 7.3, 1.9, 0.9 Hz, 1H), 7.41 – 7.32 (m, 2H), 4.26 – 4.16 (m, 2H), 4.16 – 4.03 (m, 2H), 1.33 (td, *J* = 7.2, 1.3 Hz, 6H). The analytical data matched that previously reported in the literature.[71]

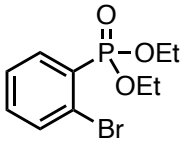


3.S4

(**3.S4**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), 2-chlorophenylboronic acid (3.13 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general

procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S4** (1.80 g, 73%) as yellow oil.

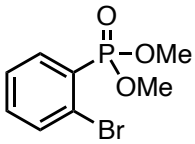
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07 – 7.95 (m, 1H), 7.51 – 7.42 (m, 2H), 7.38 – 7.30 (m, 1H), 4.24 – 4.17 (m, 2H), 4.14 (ddq, *J* = 10.2, 8.3, 7.1 Hz, 2H), 1.35 (t, *J* = 7.1 Hz, 6H). The analytical data matched that previously reported in the literature.[72]



3.S5

(**3.S5**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 2-bromophenylboronic acid (8.02 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S5** (4.38 g, 75%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.05 – 8.00 (m, 1H), 7.70 – 7.64 (m, 1H), 7.43 – 7.34 (m, 2H), 4.20 (ddq, *J* = 10.1, 7.9, 7.1 Hz, 2H), 4.13 (ddq, *J* = 10.1, 8.2, 7.1 Hz, 2H), 1.36 (td, *J* = 7.1, 0.6 Hz, 6H). The analytical data matched that previously reported in the literature.[69]

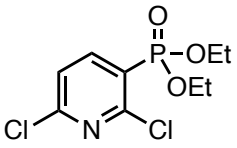


3.S6

(**3.S6**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 2-bromophenylboronic acid (8.04 g, 40.0 mmol), dimethyl phosphite (1.8 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the

general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S6** (3.41 g, 64%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 7.93 (m, 1H), 7.74 – 7.64 (m, 1H), 7.47 – 7.34 (m, 2H), 3.83 (s, 3H), 3.80 (s, 3H). The analytical data matched that previously reported in the literature.[72]



3.S7

(**3.S7**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), (2,6-dichloropyridin-3-yl)boronic acid (5.68 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 50:50 EtOAc/hexanes to EtOAc) to afford **3.S7** (0.76 g, 40%) as colorless oil.

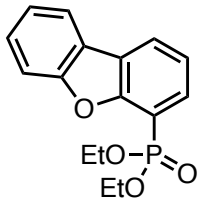
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (dd, J = 13.0, 8.0 Hz, 1H), 7.37 (dd, J = 8.0, 1.6 Hz, 1H), 4.29 – 4.20 (m, 2H), 4.20 – 4.11 (m, 2H), 1.36 (t, J = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 154.1 (d, J = 2.5 Hz), 152.5 (d, J = 7.2 Hz), 147.1 (d, J = 8.7 Hz), 123.8 (d, J = 196.5 Hz), 122.8 (d, J = 11.0 Hz), 63.4 (d, J = 5.7 Hz), 16.4 (d, J = 6.4 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 11.1.

FTIR (cm^{-1}): 2984, 1562, 1537, 1326, 1261.

HRMS (ESI) m/z, calculated for $[C_9H_{13}Cl_2NO_3P]^+$: 284.0005; found: 284.0000.



3.S8

(**3.S8**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), dibenzofuran-4-boronic acid (4.24 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 45:55 EtOAc/hexanes) to afford **3.S8** (1.81 g, 60%) as yellow oil.

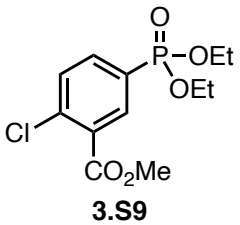
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dt, *J* = 7.7, 1.5 Hz, 1H), 8.02 – 7.92 (m, 2H), 7.69 (dt, *J* = 8.4, 0.9 Hz, 1H), 7.51 (ddd, *J* = 8.4, 7.3, 1.4 Hz, 1H), 7.44 (td, *J* = 7.6, 2.9 Hz, 1H), 7.39 (td, *J* = 7.5, 1.0 Hz, 1H), 4.34 – 4.24 (m, 2H), 4.24 – 4.14 (m, 2H), 1.36 (td, *J* = 7.1, 0.6 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 156.44, 156.38 (d, *J* = 2.0 Hz), 132.1 (d, *J* = 6.9 Hz), 127.9, 125.3 (d, *J* = 3.1 Hz), 125.1 (d, *J* = 9.1 Hz), 123.3, 122.7 (d, *J* = 13.5 Hz), 120.8, 113.4, 112.4, 111.5, 62.7 (d, *J* = 5.3 Hz), 16.5 (d, *J* = 6.6 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 14.5.

FTIR (cm^{-1}): 2983, 1472, 1407, 1254, 1190.

HRMS (ESI) m/z, calculated for $[C_{16}H_{18}O_4P]^+$: 305.0937; found: 305.0929.



3.S9

(**3.S9**) According to general protocol A: Cu_2O (71.6 mg, 0.50 mmol), phenanthroline (180.4 mg, 1.00 mmol), (4-chloro-3-(methoxycarbonyl)phenyl)boronic acid (4.29 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed

to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 60:40 EtOAc/hexanes) to afford **3.S9** (1.32 g, 43%) as yellow oil.

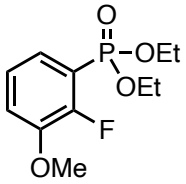
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (dt, *J* = 13.5, 1.4 Hz, 1H), 7.93 – 7.71 (m, 1H), 7.56 (ddd, *J* = 8.2, 3.6, 1.0 Hz, 1H), 4.26 – 4.03 (m, 4H), 3.95 (d, *J* = 1.1 Hz, 3H), 1.33 (td, *J* = 7.1, 1.0 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 165.3 (d, *J* = 1.5 Hz), 138.4 (d, *J* = 4.0 Hz), 135.5 (d, *J* = 10.2 Hz), 135.0 (d, *J* = 11.8 Hz), 131.6 (d, *J* = 15.0 Hz), 130.5 (d, *J* = 15.5 Hz), 127.8 (d, *J* = 192.0 Hz), 62.7 (d, *J* = 5.5 Hz), 52.9, 16.5 (d, *J* = 6.4 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 16.1.

FTIR (cm^{-1}): 2984, 2954, 1739, 1590, 1437.

HRMS (ESI) m/z, calculated for $[C_{12}H_{17}ClO_5P]^+$: 307.0497; found: 307.0499.



3.S10

(**3.S10**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 2-fluoro-3-methoxyphenylboronic acid (6.80 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 60:40 EtOAc/hexanes) to afford **3.S10** (2.15 g, 41%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.32 (m, 1H), 7.21 – 7.10 (m, 2H), 4.27 – 4.06 (m, 4H), 3.90 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 6H).

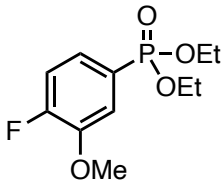
^{13}C NMR (101 MHz, $CDCl_3$) δ 153.2 (d, *J* = 253.2 Hz), 148.0 (dd, *J* = 12.1, 11.5 Hz), 125.5 (dd, *J* = 5.5, 2.8 Hz), 124.4 (dd, *J* = 16.2, 4.4 Hz), 118.0 (t, *J* = 2.6 Hz), 117.2 (dd, *J* = 185.4, 16.6 Hz) 62.7 (d, *J* = 5.6 Hz), 56.6, 16.4 (d, *J* = 6.7 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 13.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -126.4.

FTIR (cm^{-1}): 2984, 2940, 2907, 1578, 1476, 1255.

HRMS (ESI) m/z, calculated for $[C_{11}H_{17}FO_4P]^+$: 263.0843; found: 263.0839.



3.S11

(**3.S11**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 3-methoxy-4-fluorophenylboronic acid (6.80 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S11** (3.12 g, 60%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.29 (m, 2H), 7.15 (ddd, *J* = 10.8, 8.1, 4.5 Hz, 1H), 4.21 – 3.99 (m, 4H), 3.93 (s, 3H), 1.32 (t, *J* = 7.1 Hz, 6H).

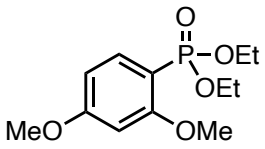
^{13}C NMR (101 MHz, $CDCl_3$) δ 155.1 (dd, *J* = 253.4, 4.0 Hz), 147.9 (dd, *J* = 19.4, 10.6 Hz), 125.2 (dd, *J* = 9.9, 7.7 Hz), 124.7 (dd, *J* = 191.2, 4.2 Hz), 116.7 (dd, *J* = 10.2, 2.5 Hz), 116.5 (t, *J* = 1.7 Hz), 62.4 (d, *J* = 5.4 Hz), 56.5, 16.5 (d, *J* = 6.5 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 18.0.

^{19}F NMR (376 MHz, $CDCl_3$) δ -128.4.

FTIR (cm^{-1}): 2983, 2940, 2907, 1603, 1513, 1395.

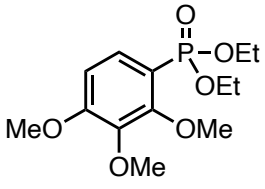
HRMS (ESI) m/z, calculated for $[C_{11}H_{17}FO_4P]^+$: 263.0843; found: 263.0838.



3.S12

(**3.S12**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 3,4-dimethoxyphenylboronic acid (7.30 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 50:50 EtOAc/hexanes to EtOAc) to afford **3.S12** (1.80 g, 33%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.76 (dd, J = 14.5, 8.5 Hz, 1H), 6.52 (dt, J = 8.5, 2.5 Hz, 1H), 6.46 (dd, J = 5.9, 2.2 Hz, 1H), 4.19 – 4.11 (m, 2H), 4.11 – 4.04 (m, 2H), 3.87 (s, 3H), 3.84 (s, 3H), 1.31 (t, J = 7.1 Hz, 6H). The analytical data matched that previously reported in the literature.[73]



3.S13

(**3.S13**) According to general protocol A: Cu_2O (143.1 mg, 1.00 mmol), phenanthroline (360.4 mg, 2.00 mmol), 2,3,4-trimethoxyphenylboronic acid (8.48 g, 40.0 mmol), diethyl phosphite (**3.6**) (2.6 mL, 20 mmol), and DIPEA (10.5 mL, 60.0 mmol) were combined in MeCN (80 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and

purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 70:30 EtOAc/hexanes) to afford **3.S13** (3.47 g, 57%) as yellow oil.

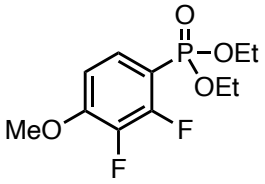
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 14.5, 8.6 Hz, 1H), 6.70 (dd, *J* = 8.6, 4.2 Hz, 1H), 4.25 – 4.06 (m, 4H), 3.97 (s, 3H), 3.89 (s, 3H), 3.86 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.9 (d, *J* = 3.3 Hz), 156.0 (d, *J* = 3.1 Hz), 142.4 (d, *J* = 14.1 Hz), 129.7 (d, *J* = 8.0 Hz), 114.6 (d, *J* = 193.9 Hz), 107.0 (d, *J* = 17.7 Hz), 62.1 (d, *J* = 5.5 Hz), 61.4, 60.9, 56.2, 16.6 (d, *J* = 6.5 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 17.4.

FTIR (cm^{-1}): 2982, 2941, 1588, 1490, 1460, 1407.

HRMS (ESI) m/z, calculated for $[C_{13}H_{22}O_6P]^+$: 305.1149; found: 305.1144.



3.S14

(**3.S14**) According to general protocol A: Cu_2O (71.6 mg, 0.50 mmol), phenanthroline (180.4 mg, 1.00 mmol), (2,3-difluoro-4-methoxyphenyl)boronic acid (3.76 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 50:50 EtOAc/hexanes to EtOAc) to afford **3.S14** (1.38 g, 49%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (dddd, *J* = 14.8, 8.8, 6.5, 2.3 Hz, 1H), 6.73 (dddd, *J* = 8.5, 6.8, 3.6, 1.6 Hz, 1H), 4.16 – 3.95 (m, 4H), 3.85 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 167.7 (dt, *J* = 7.7, 3.7 Hz), 166.5 (d, *J* = 252.8, 11.7 Hz), 155.5 (dt, *J* = 250.3, 14.6 Hz), 143.7 (dt, *J* = 6.2, 4.8 Hz), 124.0 (ddd, *J* = 193.6, 15.8, 1.8 Hz), 122.6 (dd, *J* = 16.5, 2.9 Hz), 77.1 (d, *J* = 5.6 Hz), 71.3, 30.8 (d, *J* = 6.6 Hz).

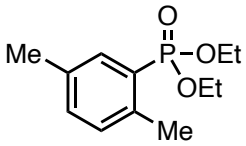
^{31}P NMR (162 MHz, $CDCl_3$) δ 12.9 (d, J = 8.4 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -129.5 (d, J = 20.5 Hz), -159.2 (dd, J = 20.6, 8.7 Hz).

FTIR (cm^{-1}): 2985, 1628, 1511, 1462, 1306.

mp = 48-50 °C (CH_2Cl_2).

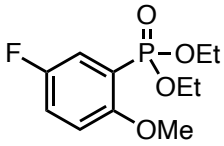
HRMS (ESI) m/z, calculated for $[C_{11}H_{16}F_2O_4P]^+$: 281.0749; found: 281.0751.



3.S15

(**3.S15**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), 2,5-dimethylphenylboronic acid (3.13 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 50:50 EtOAc/hexanes) to afford **3.S15** (1.50 g, 62%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.75 (dd, J = 14.7, 2.0 Hz, 1H), 7.23 (d, J = 7.8 Hz, 1H), 7.14 (dd, J = 7.7, 5.8 Hz, 1H), 4.15 (dp, J = 10.1, 7.2 Hz, 2H), 4.06 (ddq, J = 10.2, 8.2, 7.1 Hz, 2H), 2.51 (s, 3H), 2.34 (s, 3H), 1.32 (t, J = 7.1 Hz, 6H). The analytical data matched that previously reported in the literature.[74]



3.S16

(**3.S16**) According to general protocol A: Cu_2O (71.5 mg, 0.50 mmol), phenanthroline (180.2 mg, 1.00 mmol), 2-methoxy-5-fluorophenylboronic acid (3.40 g, 20.0 mmol), diethyl phosphite (**3.6**) (1.3 mL, 10 mmol), and DIPEA (5.3 mL, 30 mmol) were combined in MeCN (40 mL), which was allowed to stir at rt overnight. The reaction

was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc/hexanes to 70:30 EtOAc/hexanes) to afford **3.S16** (1.31 g, 50%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (ddd, *J* = 15.7, 8.2, 3.2 Hz, 1H), 7.18 (ddd, *J* = 9.1, 7.7, 3.2 Hz, 1H), 6.89 (ddd, *J* = 9.0, 7.5, 3.9 Hz, 1H), 4.25 – 4.08 (m, 4H), 3.88 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 6H).

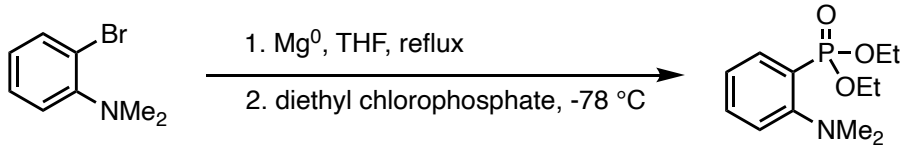
^{13}C NMR (101 MHz, $CDCl_3$) δ 157.5 (d, *J* = 3.0 Hz), 156.4 (dd, *J* = 240.8, 20.5 Hz), 121.4 (dd, *J* = 24.6, 7.4 Hz), 120.5 (dd, *J* = 23.1, 2.7 Hz), 118.5 (dd, *J* = 188.4, 6.0 Hz), 112.6 (dd, *J* = 11.5, 7.4 Hz), 62.5 (d, *J* = 5.6 Hz), 56.6, 16.5 (d, *J* = 6.4 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 14.7 (d, *J* = 6.9 Hz).

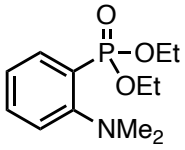
^{19}F NMR (376 MHz, $CDCl_3$) δ -123.4 (d, *J* = 6.8 Hz).

FTIR (cm^{-1}): 2983, 1490, 1403, 1265, 1026.

HRMS (ESI) m/z, calculated for $[C_{11}H_{17}FO_4P]^+$: 263.0843; found: 263.0830.



3.S17, 23%



3.S17

(**3.S17**) A flame-dried 100 mL round bottom flask equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The flask was backfilled with N_2, the spetum was removed. Magnesium turings (0.27 g, 11 mmol, 1.1 equiv) and a crystal of iodine were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. 2-bromo-*N*,*N*-dimethylaniline (1.4 mL, 10 mmol, 1.0 equiv) and anhydrous THF (20 mL) were added to the flask via syringe. The

reaction mixture was then refluxed in a pre-heated oil bath for 2 h. To a different flame-dried 100 mL round bottom flask, diethyl chlorophosphate (1.8 mL, 12 mmol, 1.2 equiv) and anhydrous THF (40 mL) were added via syringe. The reaction solution was cooled to -78 °C in a dry ice/acetone bath and added the freshly prepared Grignard solution dropwisely, which was allowed to stir at -78 °C for 3 h. Upon completion, the reaction was diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient, 10:90 EtOAc/hexanes to 60:40 EtOAc/hexanes) to afford **3.S17** (0.60 g, 23%) as yellow oil.

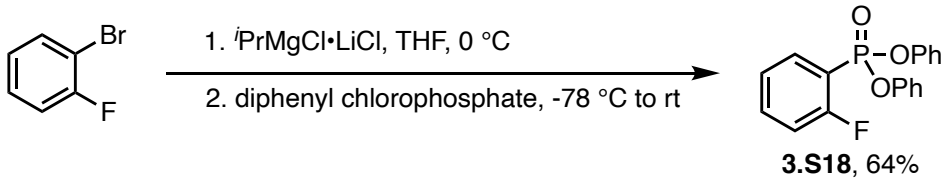
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (ddd, *J* = 14.4, 7.7, 1.7 Hz, 1H), 7.47 (ddt, *J* = 8.9, 8.1, 1.5 Hz, 1H), 7.25 (ddd, *J* = 8.0, 6.4, 1.2 Hz, 1H), 7.11 (tdd, *J* = 7.5, 3.6, 1.1 Hz, 1H), 4.22 – 4.08 (m, 4H), 2.78 (s, 6H), 1.34 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.1 (d, *J* = 6.0 Hz), 134.7 (d, *J* = 7.8 Hz), 133.4 (d, *J* = 2.5 Hz), 124.8 (d, *J* = 187.9 Hz), 123.6 (d, *J* = 14.6 Hz), 121.5 (d, *J* = 11.8 Hz), 62.1 (d, *J* = 5.8 Hz), 46.1, 16.6 (d, *J* = 6.8 Hz).

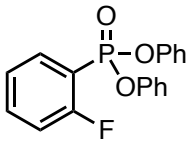
^{31}P NMR (162 MHz, $CDCl_3$) δ 18.0.

FTIR (cm^{-1}): 2981, 2940, 1590, 1481, 1242.

HRMS (ESI) m/z, calculated for $[C_{12}H_{21}NO_3P]^+$: 258.1254; found: 258.1243.



3.S18, 64%



3.S18

(**3.S18**) A flame-dried 100 mL round bottom flask equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The flask was backfilled with N_2, 1-bromo-2-fluorobenzene (1.1 mL, 10 mmol, 1.0 equiv) and anhydrous THF (20 mL) were added to the flask via syringe. The solution was cooled to 0 °C in an ice bath. A solution of isopropylmagnesium chloride lithium chloride complex (11.0 mL, 11.0 mmol, 1.10 equiv) was then added dropwisely to the reaction mixture, which was allowed to stir at 0 °C for 1 h. To a different flame-dried 100 mL round bottom flask, diphenyl chlorophosphate (2.5 mL, 12 mmol, 1.2 equiv) and anhydrous THF (10 mL) were added via syringe. The reaction solution was cooled to -78 °C in a dry ice/acetone bath and added the freshly prepared Grignard reagent dropwisely. The resulting mixture was then allowed to warm up to rt and stir overnight. Upon completion, the reaction was diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and recrystallized from EtOAc/hexanes to afford **3.S18** (2.15 g, 64%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dddd, J = 15.5, 7.9, 6.3, 1.9 Hz, 1H), 7.67 – 7.56 (m, 1H), 7.37 – 7.03 (m, 12H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 163.5 (d, J = 254.7 Hz), 150.3 (d, J = 7.5 Hz), 136.1 (dd, J = 8.6, 2.3 Hz), 135.8 (dd, J = 7.0, 3.0 Hz), 129.9, 125.4 (d, J = 1.6 Hz), 124.5 (dd, J = 14.8, 3.6 Hz), 120.8 (d, J = 4.7 Hz), 116.5 (dd, J = 22.1, 8.4 Hz), 114.9 (dd, J = 193.6, 17.8 Hz).

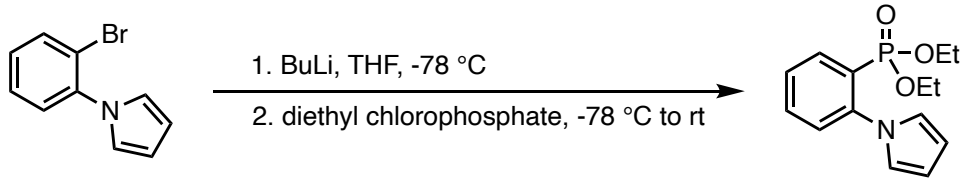
^{31}P NMR (162 MHz, $CDCl_3$) δ 7.0 (d, J = 2.8 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -102.2 (d, J = 2.3 Hz).

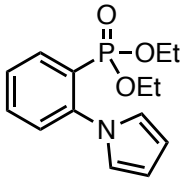
FTIR (cm^{-1}): 3069, 1606, 1590, 1489, 1274.

mp = 61-63 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{15}FO_3P]^+$: 329.0737; found: 329.0738.



3.S19, 54%



3.S19

(**3.S19**) A flame-dried 100 mL round bottom flask equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The flask was backfilled with N_2, 1-(2-bromophenyl)-1H-pyrrole (2.22 g, 10.0 mmol, 1.00 equiv) and anhydrous THF (40 mL) were added to the flask via syringe. The solution was cooled to -78 °C in an acetone/dry ice bath. A solution of BuLi (3.9 mL, 2.8 M in hexanes, 11 mmol, 1.1 equiv) was then added dropwisely to the reaction mixture, which was then to stir at -78 °C for 1 h, followed by the dropwise addition of diethyl chlorophosphate (1.8 mL, 12 mmol, 1.2 equiv). The resulting mixture was then allowed to warm up to rt and stir for 1 h. Upon completion, the reaction was diluted with Et_2O (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with Et_2O (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient,

10:90 EtOAc/hexanes to 60:40 EtOAc/hexanes) to afford **3.S19** (1.50 g, 54%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (ddd, *J* = 14.6, 7.7, 1.6 Hz, 1H), 7.59 (tt, *J* = 7.6, 1.5 Hz, 1H), 7.45 (tdd, *J* = 7.6, 3.1, 1.2 Hz, 1H), 7.33 (ddd, *J* = 7.6, 6.0, 1.2 Hz, 1H), 6.97 (t, *J* = 2.2 Hz, 2H), 6.29 (t, *J* = 2.2 Hz, 2H), 4.07 – 3.89 (m, 4H), 1.22 (td, *J* = 7.1, 0.6 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 143.7 (d, *J* = 4.2 Hz), 134.9 (d, *J* = 7.7 Hz), 133.3 (d, *J* = 2.6 Hz), 128.4 (d, *J* = 10.8 Hz), 127.3 (d, *J* = 14.2 Hz), 125.2 (d, *J* = 187.5 Hz), 123.3, 109.2, 62.5 (d, *J* = 6.0 Hz), 16.3 (d, *J* = 6.8 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 15.5.

FTIR (cm^{-1}): 2982, 1594, 1493, 1331, 1247.

HRMS (ESI) m/z, calculated for $[C_{14}H_{19}NO_3P]^+$: 280.1097; found: 280.1084.

3.9.4 Unusual Product Signals in ^{31}P NMR Spectra

NOTE: For the products bearing *ortho* substitutions, two signals are observed in ^{31}P NMR spectra. This unusual observation is the result of slow rotation of C–P bond, which leads to two different conformations. Coalescence of the two signals is observed in variable temperature ^{31}P NMR experiment (Figure 3.44). Furthermore, only a single signal is observed in the ^{31}P NMR spectra for the downstream functionalization products of those boronic esters.

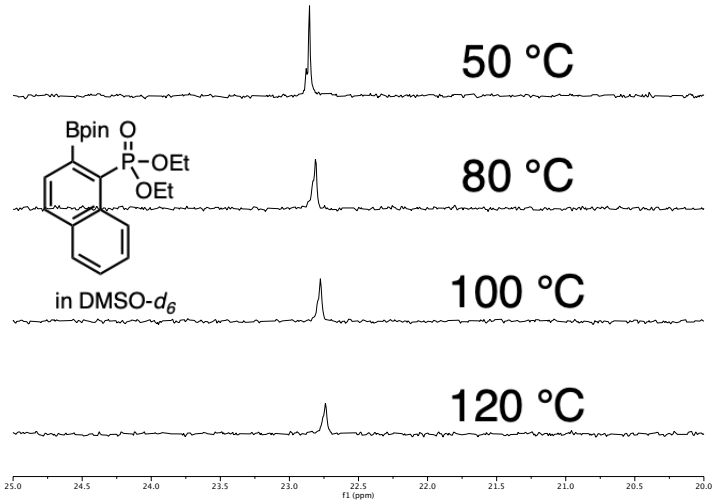
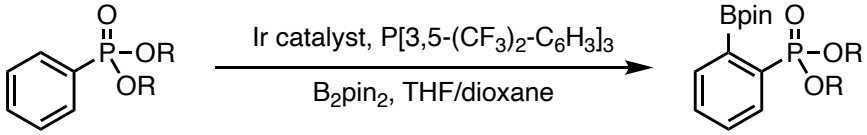


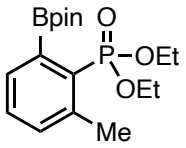
Figure 3.44: ^{31}P NMR Experiments of **3.103** under Varied Temperatures

3.9.5 Synthesis of *Ortho*-Phosphonate Boronic Esters



General Protocol B: A flame-dried Teflon-sealed Schlenk tube equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The reaction tube was backfilled with N_2, the septum was removed. The indicated iridium catalyst (0.050 – 0.075 equiv), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (0.050 – 0.075 equiv), and B_2pin_2 (2.00 – 5.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous THF/dioxane (1:3, 0.1 M with respect to phosphonate) and aryl phosphonate (1.00 equiv) were added to the flask via syringe. The septum was then replaced with a Teflon cap, and the reaction tube was sealed. The resulting solution was placed in a pre-heated oil bath and

stirred at the indicated temperature for the indicated time. Upon completion, the reaction was cooled to rt, then transferred to a round bottom flask and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed on boric acid impregnated silica gel to yield the desired product.



3.93

(**3.93**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (507.9 g, 2.00 mmol), diethyl *o*-toylphosphonate (**3.92**) (228.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.93** (276.3 mg, 78%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (td, *J* = 7.4, 1.6 Hz, 1H), 7.30 (dd, *J* = 7.3, 3.7 Hz, 1H), 7.20 (t, *J* = 6.5 Hz, 1H), 4.15 (dp, *J* = 10.2, 7.2 Hz, 2H), 4.05 – 3.90 (m, 2H), 2.49 (d, *J* = 1.9 Hz, 3H), 1.40 (s, 12H), 1.28 (t, *J* = 7.1 Hz, 6H).

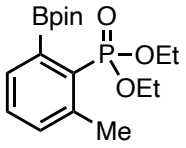
^{13}C NMR (101 MHz, $CDCl_3$) δ 141.0 (d, *J* = 11.1 Hz), 131.9 (d, *J* = 3.3 Hz), 131.3 (d, *J* = 14.4 Hz), 129.2 (d, *J* = 17.6 Hz), 128.8 (d, *J* = 177.8 Hz), 83.8, 62.1 (d, *J* = 4.3 Hz), 25.2, 21.3 (d, *J* = 3.6 Hz), 16.4 (d, *J* = 6.6 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 23.6 (d, *J* = 5.8 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 29.9.

FTIR (cm^{-1}): 2976, 2931, 1370, 1339, 1241, 1145.

HRMS (ESI) m/z, calculated for $[C_{17}H_{29}BO_5P]^+$: 355.1840; found: 355.1833.



3.93

(**3.93**) According to general protocol B: (COD)Ir(acac) (79.9 mg, 0.20 mmol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (134.1 mg, 0.200 mmol), B_2pin_2 (2.03 g, 8.00 mmol), diethyl *o*-toylphosphonate (**3.92**) (0.91 g, 4.0 mmol), anhydrous THF (10 mL), and anhydrous dioxane (30 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 5:95 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.93** (1.24 g, 87%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (td, *J* = 7.4, 1.6 Hz, 1H), 7.30 (dd, *J* = 7.3, 3.7 Hz, 1H), 7.20 (t, *J* = 6.5 Hz, 1H), 4.15 (dp, *J* = 10.2, 7.2 Hz, 2H), 4.05 – 3.90 (m, 2H), 2.49 (d, *J* = 1.9 Hz, 3H), 1.40 (s, 12H), 1.28 (t, *J* = 7.1 Hz, 6H).

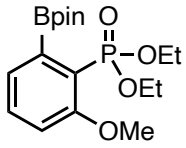
^{13}C NMR (101 MHz, $CDCl_3$) δ 141.0 (d, *J* = 11.1 Hz), 131.9 (d, *J* = 3.3 Hz), 131.3 (d, *J* = 14.4 Hz), 129.2 (d, *J* = 17.6 Hz), 128.8 (d, *J* = 177.8 Hz), 83.8, 62.1 (d, *J* = 4.3 Hz), 25.2, 21.3 (d, *J* = 3.6 Hz), 16.4 (d, *J* = 6.6 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 23.6 (d, *J* = 5.8 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 29.9.

FTIR (cm^{-1}): 2976, 2931, 1370, 1339, 1241, 1145.

HRMS (ESI) m/z, calculated for $[C_{17}H_{29}BO_5P]^+$: 355.1840; found: 355.1833.



3.95

(**3.95**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S1** (244.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general

procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 30:70 EtOAc:hexanes) to afford boronic ester **3.95** (273.1 mg, 74%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (ddd, *J* = 8.4, 7.3, 1.0 Hz, 1H), 7.07 (dd, *J* = 6.5, 3.2 Hz, 1H), 6.90 (dd, *J* = 8.2, 6.8 Hz, 1H), 4.25 – 4.06 (m, 2H), 3.98 (ddq, *J* = 10.2, 8.6, 7.0 Hz, 2H), 3.86 (s, 3H), 1.40 (s, 12H), 1.27 (t, *J* = 7.1 Hz, 6H).

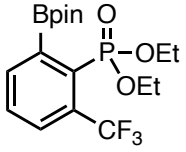
^{13}C NMR (101 MHz, $CDCl_3$) δ 160.8 (d, *J* = 3.7 Hz), 134.1 (d, *J* = 2.5 Hz), 124.2 (d, *J* = 17.4 Hz), 118.0 (d, *J* = 179.6 Hz), 111.3 (d, *J* = 9.1 Hz), 83.9, 62.4 (d, *J* = 4.3 Hz), 55.8, 25.2, 16.4 (d, *J* = 6.5 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 21.7 (d, *J* = 6.8 Hz).

^{11}B NMR (193 MHz, CDCl3) δ 29.6.

FTIR (cm^{-1}): 2976, 2932, 1567, 1423, 1343.

HRMS (ESI) m/z, calculated for $[C_{17}H_{29}BO_6P]^+$: 371.1789; found: 371.1781.



3.96

(**3.96**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (0.76 g, 3.0 mmol), **3.S2** (282.1 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.96** (367.6 mg, 90%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.79 (d, *J* = 6.9 Hz, 0H), 7.70 (t, *J* = 7.0 Hz, 1H), 7.65 (t, *J* = 7.5 Hz, 1H), 4.24 (dp, *J* = 10.1, 7.2 Hz, 2H), 4.06 (ddq, *J* = 10.1, 8.4, 7.1 Hz, 2H), 1.37 (s, 12H), 1.32 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 134.9 (dd, J = 17.7, 1.4 Hz), 132.8 (d, J = 3.1 Hz), 130.8 (qd, J = 33.0, 8.8 Hz), 126.8 (dq, J = 10.7, 5.3 Hz), 125.1 (q, J = 2.0 Hz), 123.5 (dq, J = 273.9, 4.6 Hz), 82.5 (d, J = 1.4 Hz), 64.3 (d, J = 5.1 Hz), 25.5, 16.0 (d, J = 6.9 Hz).

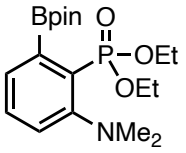
^{31}P NMR (162 MHz, $CDCl_3$) δ 27.0 (d, J = 13.1 Hz).

^{19}F NMR (565 MHz, $CDCl_3$) δ -59.8 (d, J = 5.9 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 21.1.

FTIR (cm^{-1}): 2952, 2849, 1597, 1456, 1250, 1144.

HRMS (ESI) m/z, calculated for $[C_{17}H_{26}BF_3O_5P]^+$: 409.1558; found: 409.1551.



3.97

(**3.97**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S17** (256.9 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C for 3 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford boronic ester **3.97** (230.8 mg, 60%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43 (ddd, J = 8.3, 7.2, 1.3 Hz, 1H), 7.19 (ddd, J = 7.2, 3.3, 1.0 Hz, 1H), 7.10 (ddd, J = 8.1, 6.9, 1.0 Hz, 1H), 4.18 (dp, J = 10.1, 7.1 Hz, 2H), 4.02 (ddq, J = 10.2, 8.2, 7.1 Hz, 2H), 2.77 (s, 6H), 1.38 (s, 12H), 1.31 (td, J = 7.1, 0.6 Hz, 6H).

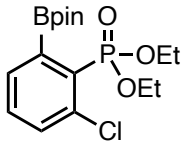
^{13}C NMR (101 MHz, $CDCl_3$) δ 156.8 (d, J = 6.7 Hz), 133.4 (d, J = 2.9 Hz), 126.4 (d, J = 17.8 Hz), 123.5 (d, J = 178.2 Hz), 120.3 (d, J = 11.5 Hz), 83.3, 62.7 (d, J = 4.8 Hz), 45.5, 25.3, 16.3 (d, J = 7.0 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 25.8 (d, J = 17.3 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 26.8.

FTIR (cm^{-1}): 2978, 2936, 1415, 1339, 1230.

HRMS (ESI) m/z, calculated for $[C_{18}H_{32}BNO_5P]^+$: 384.2106; found: 384.2088.



3.99

(**3.99**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S4** (248.6 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.99** (316.6 mg, 85%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.35 (m, 3H), 4.18 (dp, J = 10.1, 7.2 Hz, 2H), 4.02 (dp, J = 9.9, 7.2 Hz, 2H), 1.40 (s, 12H), 1.31 (t, J = 7.1 Hz, 6H).

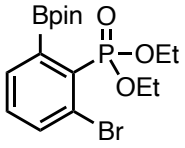
^{13}C NMR (101 MHz, $CDCl_3$) δ 136.4 (d, J = 4.0 Hz), 133.3 (d, J = 2.9 Hz), 130.7 (d, J = 9.9 Hz), 130.0, 128.9 (d, J = 183.3 Hz), 84.0, 62.9 (d, J = 4.4 Hz), 25.2, 16.3 (d, J = 6.6 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 19.3 (d, J = 5.0 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 28.8.

FTIR (cm^{-1}): 2977, 2931, 1405, 1333, 1241.

HRMS (ESI) m/z, calculated for $[C_{16}H_{26}BClO_5P]^+$: 375.1294; found: 375.1294.



3.100

(**3.100**) According to general protocol B: $[(COD)_2Ir]BF_4$ (37.2 mg, 75 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (50.3 mg, 75 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S5** (293.1 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C for 3 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.100** (run #1: 232.9 mg, 56%; run #2: 249.2 mg, 59%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (ddd, J = 7.9, 5.2, 1.1 Hz, 1H), 7.45 (ddd, J = 7.3, 3.0, 1.1 Hz, 1H), 7.35 (td, J = 7.6, 1.2 Hz, 1H), 4.18 (dp, J = 10.1, 7.1 Hz, 2H), 4.02 (ddq, J = 10.1, 8.2, 7.0 Hz, 2H), 1.39 (s, 12H), 1.32 (t, J = 7.1 Hz, 6H).

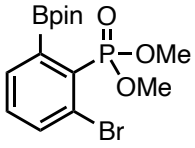
^{13}C NMR (101 MHz, $CDCl_3$) δ 134.1 (d, J = 10.8 Hz), 133.4 (d, J = 3.0 Hz), 130.6 (d, J = 184.3 Hz), 130.5 (d, J = 16.5 Hz), 124.7 (d, J = 5.0 Hz), 83.8, 63.0 (d, J = 4.4 Hz), 25.3, 16.3 (d, J = 6.7 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 20.5 (d, J = 7.9 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 27.6.

FTIR (cm^{-1}): 2976, 2930, 1400, 1331, 1240, 1136.

HRMS (ESI) m/z, calculated for $[C_{16}H_{26}BBrO_5P]^+$: 419.0789; found: 419.0790.



3.101

(**3.101**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S6** (265.0 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C for 7 h. The reaction was worked up according to the general

procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 25:75 EtOAc:hexanes) to afford boronic ester **3.101** (311.2 mg, 80%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (ddd, J = 7.9, 5.1, 1.1 Hz, 1H), 7.45 (ddd, J = 7.4, 3.0, 1.2 Hz, 1H), 7.36 (td, J = 7.7, 1.3 Hz, 1H), 3.78 (s, 3H), 3.75 (s, 3H), 1.41 (s, 12H).

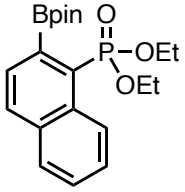
^{13}C NMR (101 MHz, $CDCl_3$) δ 134.3 (d, J = 10.9 Hz), 133.4 (d, J = 3.2 Hz), 130.7 (d, J = 16.5 Hz), 128.8 (d, J = 188.2 Hz), 125.0 (d, J = 4.9 Hz), 84.2, 53.2 (d, J = 4.8 Hz), 25.2.

^{31}P NMR (162 MHz, $CDCl_3$) δ 22.5 (d, J = 4.7 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 29.0.

FTIR (cm^{-1}): 2975, 1401, 1332, 1244, 1137.

HRMS (ESI) m/z, calculated for $[C_{14}H_{22}BBrO_5P]^+$: 391.0476; found: 391.0460.



3.103

(**3.103**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), diethyl naphthalen-1-ylphosphonate (264.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C for 16 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.103** (349.7 mg, 90%) as colorless solid.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.26 (d, J = 8.5 Hz, 1H), 8.16 (d, J = 9.0 Hz, 1H), 8.02 (dd, J = 6.0, 4.1 Hz, 1H), 7.67 (t, J = 6.9 Hz, 1H), 7.61 (t, J = 7.4 Hz, 1H), 7.49 (dd, J = 8.2, 3.5 Hz, 1H), 4.16 – 4.02 (m, 2H), 3.99 – 3.84 (m, 2H), 1.34 (s, 12H), 1.17 (t, J = 7.0 Hz, 6H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 132.9 (d, J = 12.1 Hz), 132.4 (d, J = 3.4 Hz), 131.4 (d, J = 11.9 Hz), 128.8 (d, J = 2.2 Hz), 127.6, 127.5, 127.4, 126.7, 125.7 (d, J = 3.8 Hz), 83.3, 62.0 (d, J = 4.6 Hz), 25.0, 16.1 (d, J = 5.6 Hz).

^{31}P NMR (162 MHz, DMSO-d_6) δ 22.9 (d, J = 4.2 Hz).

^{11}B NMR (193 MHz, DMSO-d_6) δ 20.3.

FTIR (cm^{-1}): 2976, 1376, 1309, 1239, 1103.

mp = 70-72 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{20}H_{29}BO_5P]^+$: 391.1840; found: 391.1830.

A small sample of **3.103** was dissolved in hexanes under air and recrystallized in a fridge at 0 °C to give an X-ray quality crystal (Figure 3.45, see below for full crystallographic details).

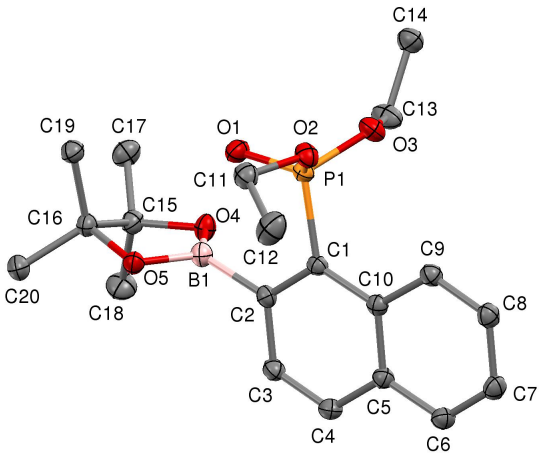
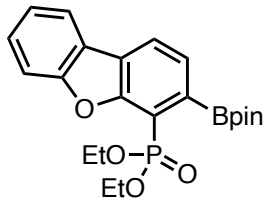


Figure 3.45: Crystal Structure of **3.103**



3.105

(**3.105**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S8** (304.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 15:85 EtOAc:hexanes to 35:65 EtOAc:hexanes) to afford boronic ester **3.105** (369.4 mg, 86%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.97 (dt, *J* = 7.6, 1.2 Hz, 1H), 7.66 (dt, *J* = 8.3, 0.9 Hz, 1H), 7.54 – 7.47 (m, 2H), 7.38 (td, *J* = 7.5, 1.0 Hz, 1H), 4.35 – 4.20 (m, 2H), 4.10 (ddq, *J* = 10.2, 8.5, 7.1 Hz, 2H), 1.46 (s, 12H), 1.33 (t, *J* = 7.1 Hz, 6H).

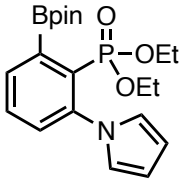
^{13}C NMR (101 MHz, $CDCl_3$) δ 156.4, 156.3 (d, *J* = 3.0 Hz), 128.0, 126.7 (d, *J* = 16.0 Hz), 125.3 (d, *J* = 8.9 Hz), 124.6 (d, *J* = 3.1 Hz), 123.4, 123.3, 121.0, 114.8 (d, *J* = 186.2 Hz), 112.3, 84.5, 62.7 (d, *J* = 4.5 Hz), 25.2, 16.4 (d, *J* = 6.6 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 16.6.

^{11}B NMR (193 MHz, $CDCl_3$) δ 31.6.

FTIR (cm^{-1}): 2978, 1459, 1371, 1345, 1247.

HRMS (ESI) m/z, calculated for $[C_{22}H_{29}BO_6P]^+$: 431.1789; found: 431.1785.



3.106

(**3.106**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S19** (281.0 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction

was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.106** (340.8 mg, 84%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 – 7.50 (m, 2H), 7.29 (ddd, *J* = 7.6, 5.9, 1.7 Hz, 1H), 6.90 (t, *J* = 2.1 Hz, 2H), 6.27 (t, *J* = 2.1 Hz, 2H), 4.10 – 4.01 (m, 2H), 4.00 – 3.88 (m, 2H), 1.42 (s, 12H), 1.18 (t, *J* = 7.1 Hz, 6H).

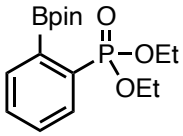
^{13}C NMR (101 MHz, $CDCl_3$) δ 143.1 (d, *J* = 5.1 Hz), 132.8 (d, *J* = 2.9 Hz), 131.1 (d, *J* = 16.9 Hz), 128.0 (d, *J* = 10.5 Hz), 126.6 (d, *J* = 182.4 Hz), 123.0, 109.2, 84.2, 62.8 (d, *J* = 5.3 Hz), 25.2, 16.2 (d, *J* = 7.0 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 19.6 (d, *J* = 7.6 Hz).

^{11}B NMR (193 MHz, CDCl3) δ 29.3.

FTIR (cm^{-1}): 2977, 1489, 1371, 1349, 1239.

HRMS (ESI) m/z, calculated for $[C_{20}H_{30}BNO_5P]^+$: 406.1949; found: 406.1929.

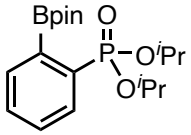


3.91

(**3.91**) According to general protocol B: $[(COD)_2Ir]BF_4$ (37.2 mg, 75 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (50.3 mg, 75 umol), B_2pin_2 (1.27 g, 5.00 mmol), diethyl phenylphosphonate (215.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C for 6 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.91** (150.0 mg, 44%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.75 (m, 1H), 7.61 (dddd, *J* = 5.6, 4.2, 1.9, 0.8 Hz, 1H), 7.50 (tt, *J* = 7.4, 1.6 Hz, 1H), 7.44 (tdd, *J* = 7.5, 4.0, 1.5 Hz, 1H), 4.26 – 4.12 (m,

2H), 4.12 – 4.01 (m, 2H), 1.40 (s, 12H), 1.32 (t, J = 7.1 Hz, 6H). The analytical data matched that previously reported in the literature.[36]



3.107

(**3.107**) According to general protocol B: $[(COD)_2Ir]BF_4$ (37.2 mg, 75 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (50.3 mg, 75 umol), B_2pin_2 (1.27 g, 5.00 mmol), diisopropyl phenylphosphonate (242.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C for 16 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 2:98 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.107** (186.2 mg, 51%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (ddd, J = 13.3, 7.5, 1.4 Hz, 1H), 7.58 (dt, J = 4.9, 3.0 Hz, 1H), 7.47 (tt, J = 7.4, 1.6 Hz, 1H), 7.42 (tdd, J = 7.5, 3.9, 1.5 Hz, 1H), 4.73 (dp, J = 7.9, 6.2 Hz, 2H), 1.41 (s, 12H), 1.38 (d, J = 6.2 Hz, 6H), 1.21 (d, J = 6.2 Hz, 6H).

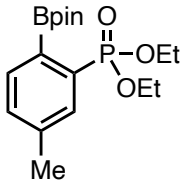
^{13}C NMR (101 MHz, $CDCl_3$) δ 133.4 (d, J = 187.0 Hz), 133.3 (d, J = 17.4 Hz), 132.0 (d, J = 10.6 Hz), 131.0 (d, J = 3.3 Hz), 129.0 (d, J = 14.4 Hz), 84.4, 70.7 (d, J = 5.3 Hz), 25.1, 24.1 (dd, J = 33.7, 4.5 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 17.8.

^{11}B NMR (193 MHz, $CDCl_3$) δ 31.4.

FTIR (cm^{-1}): 2977, 2931, 1374, 1348, 1246, 1146.

HRMS (ESI) m/z, calculated for $[C_{18}H_{31}BO_5P]^+$: 369.1997; found: 369.1989.



3.108

(**3.108**) According to general protocol B: $[(COD)_2Ir]BF_4$ (37.2 mg, 75 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (50.3 mg, 75 umol), B_2pin_2 (1.27 g, 5.00 mmol), diethyl *m*-toylphosphonate (228.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C for 6 h. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 30:70 EtOAc:hexanes) to afford boronic ester **3.108** (215.3 mg, 61%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (dd, *J* = 13.8, 1.7 Hz, 1H), 7.51 (dd, *J* = 7.6, 4.7 Hz, 1H), 7.30 (d, *J* = 7.7 Hz, 1H), 4.16 (dtd, *J* = 12.4, 8.1, 7.7, 4.1 Hz, 2H), 4.07 (ddt, *J* = 14.1, 10.1, 6.2 Hz, 2H), 2.37 (s, 3H), 1.39 (s, 12H), 1.32 (t, *J* = 7.1 Hz, 6H).

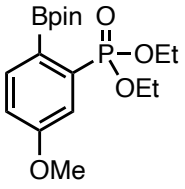
^{13}C NMR (101 MHz, $CDCl_3$) δ 139.2 (d, *J* = 14.6 Hz), 133.8 (d, *J* = 18.2 Hz), 133.2 (d, *J* = 11.1 Hz), 132.1 (d, *J* = 3.4 Hz), 131.7 (d, *J* = 186.3 Hz), 84.3, 62.1 (d, *J* = 5.2 Hz), 25.0, 21.5, 16.5 (d, *J* = 6.6 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 20.3.

^{11}B NMR (193 MHz, $CDCl_3$) δ 31.6.

FTIR (cm^{-1}): 2978, 2930, 1372, 1347, 1246.

HRMS (ESI) m/z, calculated for $[C_{17}H_{29}BO_5P]^+$: 355.1840; found: 355.1843.



3.110

(**3.110**) According to general protocol B: $[(COD)_2Ir]BF_4$ (37.2 mg, 75 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (50.3 mg, 75 umol), B_2pin_2 (1.27 g, 5.00 mmol), diethyl 3-methoxyphenylphosphonate (228.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C overnight. The

reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80 EtOAc:hexanes to 55:45 EtOAc:hexanes) to afford boronic ester **3.110** (121.5 mg, 33%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.59 (dd, *J* = 8.3, 5.5 Hz, 1H), 7.42 (dd, *J* = 15.3, 2.6 Hz, 1H), 7.01 (dd, *J* = 8.3, 2.6 Hz, 1H), 4.17 (dp, *J* = 10.2, 7.3 Hz, 2H), 4.09 (ddq, *J* = 14.0, 9.7, 7.2 Hz, 2H), 3.84 (s, 3H), 1.38 (s, 12H), 1.33 (t, *J* = 7.1 Hz, 6H).

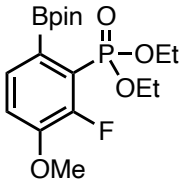
^{13}C NMR (101 MHz, $CDCl_3$) δ 160.3 (d, *J* = 18.7 Hz), 136.0 (d, *J* = 20.1 Hz), 133.8 (d, *J* = 186.3 Hz), 118.1 (d, *J* = 12.5 Hz), 117.1 (d, *J* = 3.3 Hz), 84.2, 62.2 (d, *J* = 5.4 Hz), 55.5, 25.0, 16.5 (d, *J* = 6.6 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 19.4.

^{11}B NMR (193 MHz, $CDCl_3$) δ 31.5.

FTIR (cm^{-1}): 2979, 1596, 1348, 1317, 1247.

HRMS (ESI) m/z, calculated for $[C_{17}H_{29}BO_6P]^+$: 371.1789; found: 371.1779.



3.111

(**3.111**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (0.76 g, 3.0 mmol), **3.S10** (263.4 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 25:75 EtOAc:hexanes) to afford boronic ester **3.111** (277.8 mg, 72%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (dd, *J* = 8.1, 4.1 Hz, 1H), 7.11 (t, *J* = 7.9 Hz, 1H), 4.20 (dp, *J* = 10.2, 7.2 Hz, 2H), 4.07 (ddq, *J* = 10.2, 8.3, 7.1 Hz, 2H), 3.89 (s, 3H), 1.40 (s, 12H), 1.31 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 153.0 (d, *J* = 253.5 Hz), 148.3 (t, *J* = 11.8 Hz), 128.4 (dd, *J* = 19.0, 4.4 Hz), 119.5 (dd, *J* = 181.5, 14.5 Hz), 117.1 (t, *J* = 2.7 Hz), 84.3, 62.7 (d, *J* = 5.0 Hz), 56.5, 25.1, 16.4 (d, *J* = 6.6 Hz).

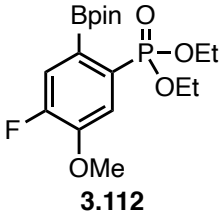
^{31}P NMR (162 MHz, $CDCl_3$) δ 15.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ -127.3.

^{11}B NMR (193 MHz, $CDCl_3$) δ 30.6.

FTIR (cm^{-1}): 2978, 1606, 1418, 1342, 1298, 1024.

HRMS (ESI) m/z, calculated for $[C_{17}H_{28}BFO_6P]^+$: 389.1695; found: 389.1684.



3.112

(**3.112**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S11** (263.1 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 35:65 EtOAc:hexanes) to afford boronic ester **3.112** (246.0 mg, 63%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (dd, *J* = 14.6, 8.3 Hz, 1H), 7.35 (dd, *J* = 11.5, 4.5 Hz, 1H), 4.24 – 4.02 (m, 4H), 3.93 (s, 3H), 1.37 (s, 12H), 1.33 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 154.2 (dd, *J* = 253.9, 4.1 Hz), 148.3 (dd, *J* = 19.3, 10.5 Hz), 128.9 (dd, *J* = 190.3, 4.1 Hz), 122.0 (dd, *J* = 20.9, 17.3 Hz), 118.3 (dd, *J* = 14.0, 2.8 Hz), 84.5, 62.3 (d, *J* = 5.3 Hz), 56.4, 25.0, 16.5 (d, *J* = 6.5 Hz).

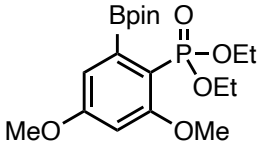
^{31}P NMR (243 MHz, $CDCl_3$) δ 18.7.

^{19}F NMR (565 MHz, $CDCl_3$) δ -130.9.

^{11}B NMR (193 MHz, $CDCl_3$) δ 31.0.

FTIR (cm^{-1}): 2979, 2933, 1607, 1396, 1328, 1270.

HRMS (ESI) m/z, calculated for $[C_{17}H_{28}BFO_6P]^+$: 389.1695; found: 389.1685.



3.113

(**3.113**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S12** (274.5 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford boronic ester **3.113** (280.0 mg, 70%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.57 (t, *J* = 2.3 Hz, 1H), 6.41 (dd, *J* = 5.9, 2.1 Hz, 1H), 4.17 – 4.05 (m, 2H), 3.96 (ddq, *J* = 10.3, 9.0, 7.0 Hz, 2H), 3.84 (s, 3H), 3.83 (s, 3H), 1.39 (s, 12H), 1.26 (t, *J* = 7.0 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.8 (d, *J* = 3.0 Hz), 162.4 (d, *J* = 5.1 Hz), 109.5 (d, *J* = 186.1 Hz), 107.8 (d, *J* = 18.3 Hz), 99.0 (d, *J* = 10.0 Hz), 83.7, 62.3 (d, *J* = 4.1 Hz), 55.8, 55.6, 25.3, 16.4 (d, *J* = 6.6 Hz).

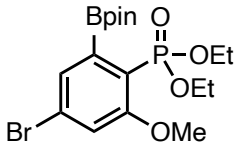
^{31}P NMR (243 MHz, $CDCl_3$) δ 23.2 (d, *J* = 10.4 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 28.1.

FTIR (cm^{-1}): 2975, 1588, 1350, 1212, 1121.

mp = 77-79 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{18}H_{31}BO_7P]^+$: 401.1895; found: 401.1885.



3.114

(**3.114**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), diethyl 4-bromo-2-methoxyphenylphosphonate (323.1 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 20:80 EtOAc:hexanes) to afford boronic ester **3.114** (339.8 mg, 76%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (dd, *J* = 2.6, 1.6 Hz, 1H), 7.04 (dd, *J* = 5.8, 1.6 Hz, 1H), 4.14 (ddq, *J* = 10.2, 8.2, 7.1 Hz, 2H), 3.98 (ddq, *J* = 10.2, 8.7, 7.0 Hz, 2H), 3.86 (s, 3H), 1.39 (s, 12H), 1.27 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.1 (d, *J* = 4.3 Hz), 129.0 (d, *J* = 3.8 Hz), 127.1 (d, *J* = 17.9 Hz), 117.2 (d, *J* = 181.9 Hz), 114.8 (d, *J* = 9.6 Hz), 84.1, 62.6 (d, *J* = 4.4 Hz), 56.1, 25.2, 16.4 (d, *J* = 6.5 Hz).

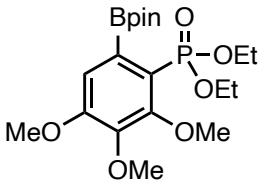
^{31}P NMR (162 MHz, $CDCl_3$) δ 21.0 (d, *J* = 5.0 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 28.0.

FTIR (cm^{-1}): 2976, 1554, 1332, 1144, 1045.

mp = 101-103 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{28}BBrO_6P]^+$: 449.0894; found: 449.0895.



3.115

(**3.115**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S13** (304.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 3:97 EtOAc:hexanes to 30:70 EtOAc:hexanes) to afford boronic ester **3.115** (run #1: 270.0 mg, 63%; run #2: 249.5 mg, 58%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.72 (d, J = 3.9 Hz, 1H), 4.17 (dt, J = 10.2, 7.3 Hz, 2H), 4.09 – 3.98 (m, 2H), 3.92 (s, 3H), 3.90 (s, 3H), 3.82 (s, 3H), 1.40 (s, 12H), 1.30 (t, J = 7.1 Hz, 6H).

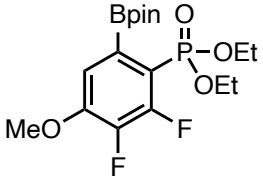
^{13}C NMR (101 MHz, $CDCl_3$) δ 157.4 (d, J = 3.4 Hz), 155.5 (d, J = 4.2 Hz), 142.5 (d, J = 13.9 Hz), 116.3 (d, J = 187.6 Hz), 110.2 (d, J = 21.0 Hz), 84.0, 62.3 (d, J = 4.7 Hz), 61.3, 60.9, 56.1, 25.3, 16.4 (d, J = 6.5 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 21.5 (d, J = 4.0 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 29.7.

FTIR (cm^{-1}): 2976, 2938, 1554, 1358, 1239.

HRMS (ESI) m/z, calculated for $[C_{19}H_{33}BO_8P]^+$: 431.2001; found: 431.1998.



3.116

(**3.116**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S14** (278.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined

under N_2. The reaction was stirred at 110 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 3:97 EtOAc:hexanes to 30:70 EtOAc:hexanes) to afford boronic ester **3.116** (153.9 mg, 38%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.79 (ddd, J = 7.0, 3.4, 1.5 Hz, 1H), 4.24 – 4.12 (m, 2H), 4.06 (ddq, J = 10.1, 8.4, 7.0 Hz, 2H), 3.95 (s, 3H), 1.41 (s, 12H), 1.31 (t, J = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 152.6 – 152.3 (m), 151.9 (dd, J = 254.0, 10.6 Hz), 141.2 (dt, J = 251.4, 14.7 Hz), 112.0 (dd, J = 190.0, 14.7 Hz), 111.5 (dd, J = 19.8, 2.9 Hz), 84.6, 62.7 (d, J = 5.0 Hz), 56.8, 25.2, 16.4 (d, J = 6.6 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 15.2 (d, J = 8.6 Hz).

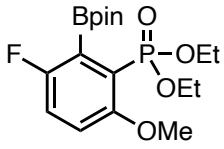
^{19}F NMR (565 MHz, $CDCl_3$) δ -129.3 (d, J = 20.7 Hz), -158.5 (dd, J = 20.9, 8.8 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 30.8.

FTIR (cm^{-1}): 2980, 1612, 1407, 1374, 1115.

mp = 105-107 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{17}H_{27}BF_2O_6P]^+$: 407.1601; found: 407.1592.



3.118

(**3.118**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S16** (262.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was worked up according to the general procedure and purified by chromatography (linear gradient, 20:80

EtOAc:hexanes to 40:60 EtOAc:hexanes) to afford boronic ester **3.118** (352.9 mg, 91%) as yellow oil.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.13 (dd, *J* = 9.0, 7.6 Hz, 1H), 6.86 (ddd, *J* = 9.0, 7.4, 3.9 Hz, 1H), 4.14 (ddq, *J* = 10.2, 8.2, 7.1 Hz, 2H), 3.99 (ddq, *J* = 10.2, 8.7, 7.1 Hz, 2H), 3.84 (s, 3H), 1.41 (s, 12H), 1.28 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 159.2 (dd, *J* = 236.6, 23.7 Hz), 157.2 (t, *J* = 2.4 Hz), 120.5 (dd, *J* = 26.2, 2.8 Hz), 120.1 (dd, *J* = 180.5, 7.4 Hz), 113.2 (dd, *J* = 11.1, 7.9 Hz), 84.5, 62.6 (d, *J* = 4.4 Hz), 56.5, 25.3, 16.4 (d, *J* = 6.5 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 19.1 (d, *J* = 5.9 Hz).

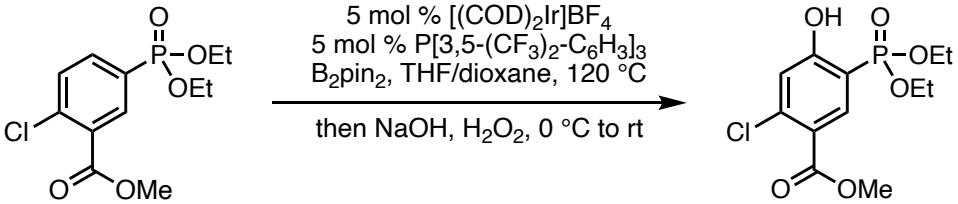
^{19}F NMR (376 MHz, $CDCl_3$) δ -116.2 (d, *J* = 6.3 Hz).

^{11}B NMR (193 MHz, $CDCl_3$) δ 29.2.

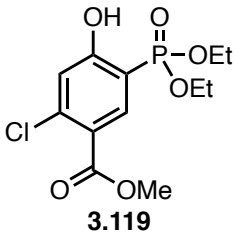
FTIR (cm^{-1}): 2978, 1462, 1421, 1318, 1233.

HRMS (ESI) m/z, calculated for $[C_{17}H_{28}BFO_6P]^+$: 389.1695; found: 389.1676.

3.9.6 In Situ Functionalization of Boronic Esters



3.S9 **3.119**, 51%



3.119

(**3.119**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S9** (308.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 120 °C overnight. The reaction was cooled to rt, transferred to a 250 mL round bottom flask using 10 mL Et_2O, and then cooled to

0 °C in an ice bath. 2 M aqueous NaOH (6 mL) and 30% H_2O_2 (6 mL) were added to the reaction slowly. The resulting solution was allowed to warm up to rt and stir for 1 h. Upon completion, the reaction was diluted with EtOAc (100 mL) and quenched by aqueous NH_4Cl solution (100 mL). The aqueous layer was extracted with EtOAc (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient, 3:97 EtOAc:hexanes to 25:75 EtOAc:hexanes) to afford **3.119** (165.0 mg, 51%) as colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 10.80 (s, 1H), 8.00 (d, *J* = 15.0 Hz, 1H), 7.07 (d, *J* = 5.7 Hz, 1H), 4.18 (ddq, *J* = 10.1, 8.1, 7.1 Hz, 2H), 4.07 (ddq, *J* = 10.1, 8.3, 7.1 Hz, 2H), 3.91 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 6H).

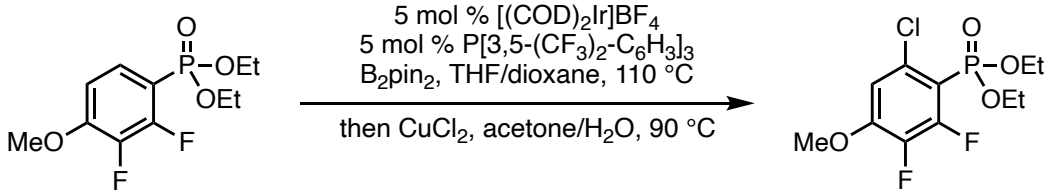
^{13}C NMR (101 MHz, $CDCl_3$) δ 164.9, 164.8 (d, *J* = 8.4 Hz), 141.3 (d, *J* = 3.3 Hz), 136.4 (d, *J* = 8.0 Hz), 121.3 (d, *J* = 14.0 Hz), 120.4 (d, *J* = 12.1 Hz), 108.3 (d, *J* = 184.0 Hz), 63.4 (d, *J* = 4.9 Hz), 52.5, 16.3 (d, *J* = 6.6 Hz).

^{31}P NMR (162 MHz, $CDCl_3$) δ 19.9.

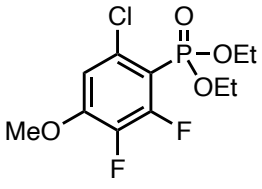
FTIR (cm^{-1}): 2989, 2739, 1732, 1593, 1385.

mp = 97-99 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{12}H_{17}ClO_6P]^+$: 323.0446; found: 323.0441.



3.S14 **3.120**, 61%



3.120

(**3.120**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S14** (280.2 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was cooled to rt, transferred to a 100 mL round bottom flask, and the volatile materials were evaporated under reduced pressue for 1 h. The residue was then dissolved in 12.5 mL acetone, followed by the addition of $CuCl_2$ (1.27 g, 10.0 mmol, 10.0 equiv) and 12.5 mL H_2O. The flask was sealed with a glass stopper, and then stirred in a pre-heated 90 °C oil bath for 3 h. Upon completion, the reaction was diluted with EtOAc (100 mL) and quenched by H_2O (100 mL). The aqueous layer was extracted with EtOAc (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 50:50 EtOAc:hexanes) to afford **3.120** (190.7 mg, 61%) as yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.86 (ddd, J = 6.7, 4.8, 2.1 Hz, 1H), 4.33 – 4.12 (m, 4H), 3.93 (s, 3H), 1.36 (t, J = 7.1 Hz, 6H).

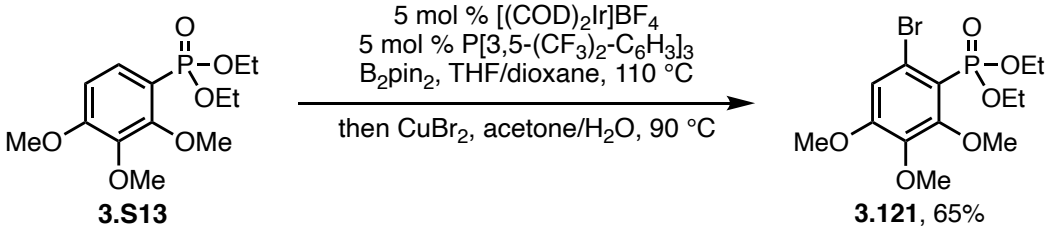
^{13}C NMR (101 MHz, $CDCl_3$) δ 153.2 (dd, J = 256.2, 11.7 Hz), 151.7 (ddd, J = 8.3, 5.2, 2.7 Hz), 140.1 (ddd, J = 250.6, 16.9, 12.9 Hz), 133.1 (dd, J = 6.9, 5.1 Hz), 111.6 (dd, J = 11.7, 2.9 Hz), 109.6 (ddd, J = 193.9, 15.8, 2.2 Hz), 63.0 (d, J = 5.8 Hz), 57.0, 16.4 (d, J = 6.7 Hz).

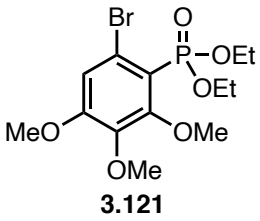
^{31}P NMR (162 MHz, $CDCl_3$) δ 8.8 (t, J = 6.3 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -125.5 (dd, J = 20.2, 5.6 Hz), -159.4 (dd, J = 20.1, 6.9 Hz).

FTIR (cm^{-1}): 2985, 1615, 1504, 1443, 1119.

HRMS (ESI) m/z, calculated for $[C_{11}H_{15}ClF_2O_4P]^+$: 315.0359; found: 315.0353.





(**3.121**) According to general protocol B: $[(COD)_2Ir]BF_4$ (24.8 mg, 50 umol), $P[3,5\text{-}(CF_3)_2\text{-}C_6H_3]_3$ (33.5 mg, 50 umol), B_2pin_2 (1.27 g, 5.00 mmol), **3.S13** (304.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 110 °C overnight. The reaction was cooled to rt, transferred to a 100 mL round bottom flask, and the volatile materials were evaporated under reduced pressue for 1 h. The residue was then dissolved in 12.5 mL acetone, followed by the addition of $CuBr_2$ (2.24 g, 10.0 mmol, 10.0 equiv) and 12.5 mL H_2O. The flask was sealed with a glass stopper, and then stirred in a pre-heated 90 °C oil bath for 3 h. Upon completion, the reaction was diluted with EtOAc (100 mL) and quenched by H_2O (100 mL). The aqueous layer was extracted with EtOAc (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient, 20:80 EtOAc:hexanes to 70:30 EtOAc:hexanes) to afford **3.121** (247.5 mg, 65%) as yellow oil.

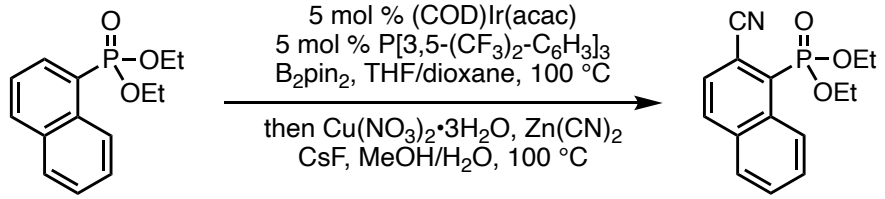
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.00 (d, J = 4.9 Hz, 1H), 4.28 – 4.20 (m, 2H), 4.19 – 4.13 (m, 2H), 3.92 (s, 3H), 3.88 (s, 3H), 3.84 (s, 3H), 1.36 (t, J = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.2 (d, J = 2.3 Hz), 156.6 (d, J = 3.3 Hz), 142.2 (d, J = 12.4 Hz), 120.4 (d, J = 2.8 Hz), 116.1 (d, J = 196.9 Hz), 114.8 (d, J = 14.3 Hz), 62.3 (d, J = 5.8 Hz), 62.1, 60.9, 56.4, 16.5 (d, J = 6.6 Hz).

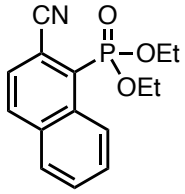
^{31}P NMR (162 MHz, $CDCl_3$) δ 13.3.

FTIR (cm^{-1}): 2981, 2939, 1578, 1480, 1366.

HRMS (ESI) m/z, calculated for $[C_{13}H_{21}BrO_6P]^+$: 383.0254; found: 383.0248.



3.122, 61%



3.122

(**3.122**) According to general protocol B: (COD)Ir(acac) (20.0 mg, 50 umol), P[3,5-$(CF_3)_2$-C_6H_3]$_3$ (33.5 mg, 50 umol), B_2pin_2 (761.8 mg, 2.00 mmol), diethyl naphthalen-1-ylphosphonate (264.3 mg, 1.00 mmol), anhydrous THF (2.5 mL), and anhydrous dioxane (7.5 mL) were combined under N_2. The reaction was stirred at 100 °C overnight. The reaction was cooled to rt, transferred to a 50 mL round bottom flask, and the volatile materials were evaporated under reduced pressue for 1 h. The residue was then dissolved in 5 mL MeOH, followed by the addition of $Cu(NO_3)_2$•$3H_2O$ (0.97 g, 4.0 mmol, 4.0 equiv), $Zn(CN)_2$ (0.70 g, 6.0 mmol, 6.0 equiv), CsF (0.30 g, 2.0 mmol, 2.0 equiv), and 2 mL H_2O. The flask was sealed with a glass stopper, and then stirred in a pre-heated 100 °C oil bath for 3 h. Upon completion, the reaction was diluted with EtOAc (100 mL) and quenched by saturated aqueous NH_4Cl solution (100 mL). The aqueous layer was

extracted with EtOAc (100 mL) twice. The organic layers were then combined and washed with brine (100 mL). The combined organic layer was dried over $MgSO_4$, filtered through a glass frit, and purified by chromatography (linear gradient, 10:90 EtOAc:hexanes to 30:70 EtOAc:hexanes) to afford **3.122** (174.9 mg, 61%) as yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.09 (d, *J* = 8.3 Hz, 1H), 8.09 (dt, *J* = 8.5, 1.3 Hz, 1H), 7.95 – 7.90 (m, 1H), 7.77 (dd, *J* = 8.5, 4.2 Hz, 1H), 7.75 – 7.66 (m, 2H), 4.43 – 4.12 (m, 4H), 1.38 (td, *J* = 7.1, 0.5 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 134.7 (d, *J* = 12.3 Hz), 133.6 (d, *J* = 3.1 Hz), 133.5 (d, *J* = 9.7 Hz), 130.8 (d, *J* = 180.2 Hz), 129.2, 128.98, 128.95 (d, *J* = 12.8 Hz), 128.8 (d, *J* = 1.4 Hz), 128.4 (d, *J* = 3.8 Hz), 118.8 (d, *J* = 7.1 Hz), 115.7 (d, *J* = 3.7 Hz), 63.3 (d, *J* = 5.9 Hz), 16.4 (d, *J* = 6.3 Hz).

^{31}P NMR (243 MHz, $CDCl_3$) δ 12.4.

FTIR (cm^{-1}): 2984, 2227, 1250, 1048, 1019.

mp = 61-63 °C (CH_2Cl_2).

HRMS (ESI) m/z, calculated for $[C_{15}H_{17}NO_3P]^+$: 290.0941; found: 290.0935.

3.9.7 Crystallographic Details

X-ray structural analysis for **3.103**: Crystals were mounted using viscous oil onto a plastic mesh and cooled to the data collection temperature. Data were collected on a Bruker-AXS APEX II DUO CCD diffractometer with Cu-Kα radiation (λ = 1.54178 Å) focused with Goebel mirrors. Unit cell parameters were obtained from 36 data frames, 0.5º ω, from different sections of the Ewald sphere. The unit-cell dimensions, equivalent reflections and systematic absences in the diffraction data are uniquely consistent with $P2_1/n$. The data were treated with multi-scan absorption corrections.[75] Structures were

solved using intrinsic phasing methods[76] and refined with full-matrix, least-squares procedures on F^2.[77] Two symmetry-unique but chemically identical compound molecules were found in the asymmetric unit. Non-hydrogen atoms were refined with anisotropic displacement parameters. H-atoms were treated as idealized contributions with geometrically calculated positions and with U_{iso} equal to 1.2-1.5 U_{eq} of the attached carbon atom. Atomic scattering factors are contained in the SHELXTL program library.[77] The structures have been deposited at the Cambridge Structural Database under the CCDC deposition number 1990724.

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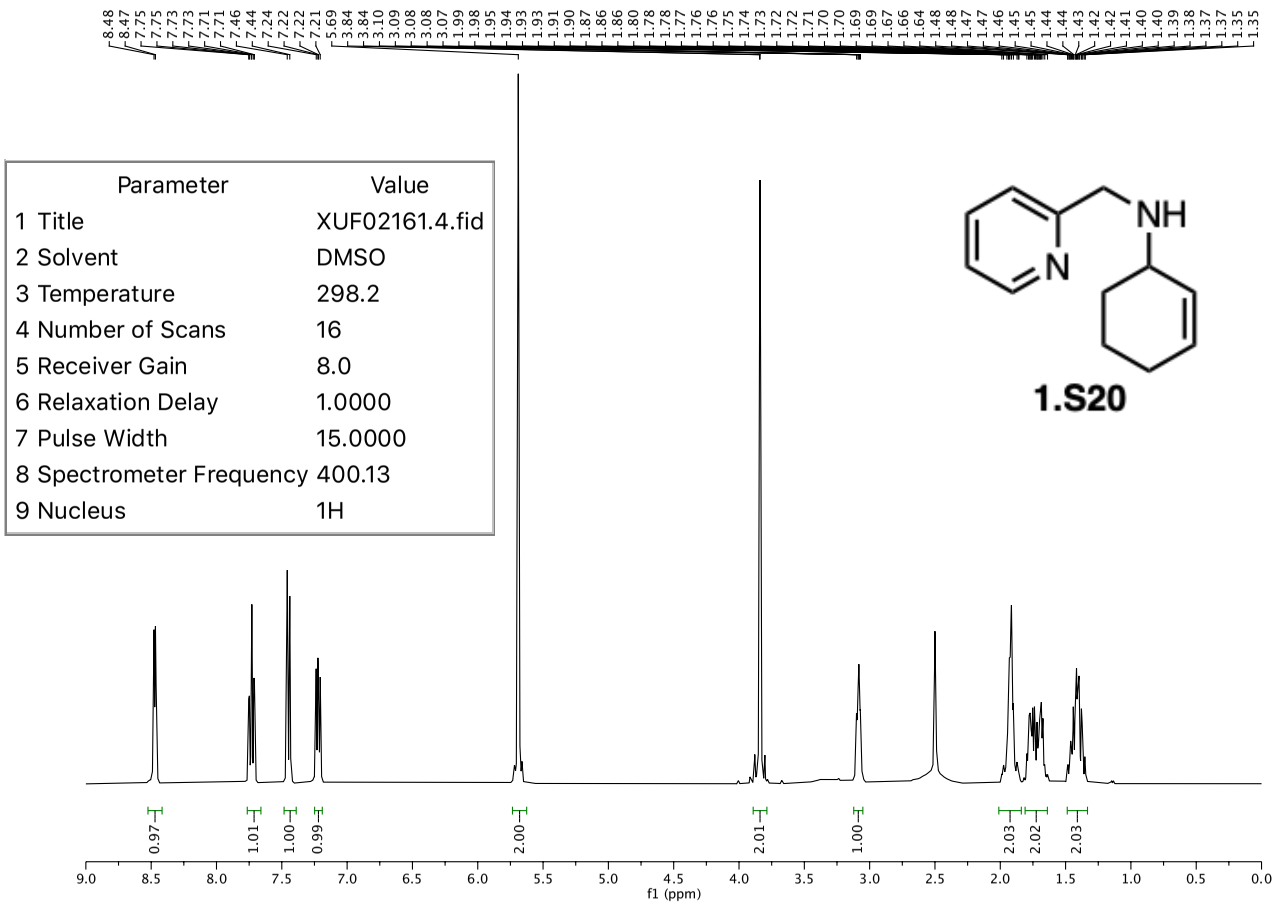
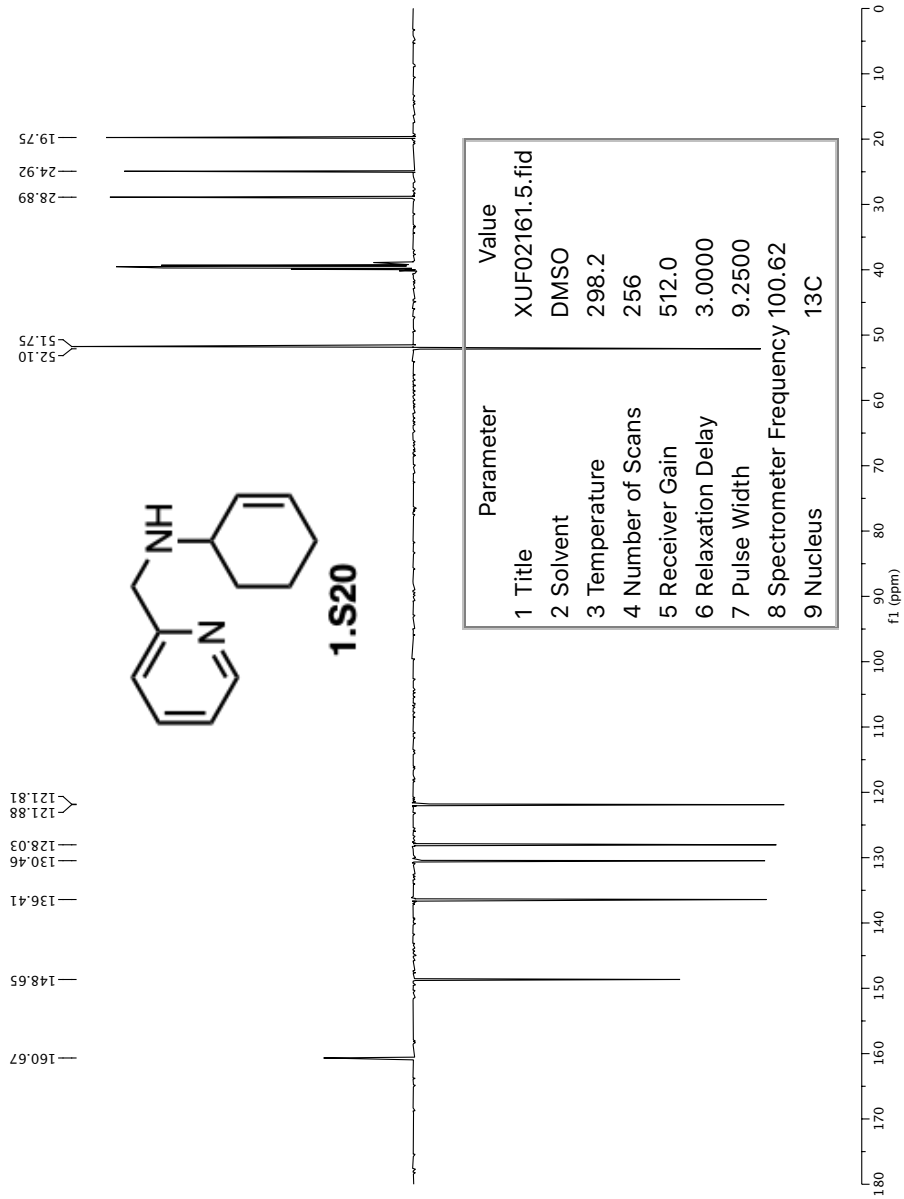
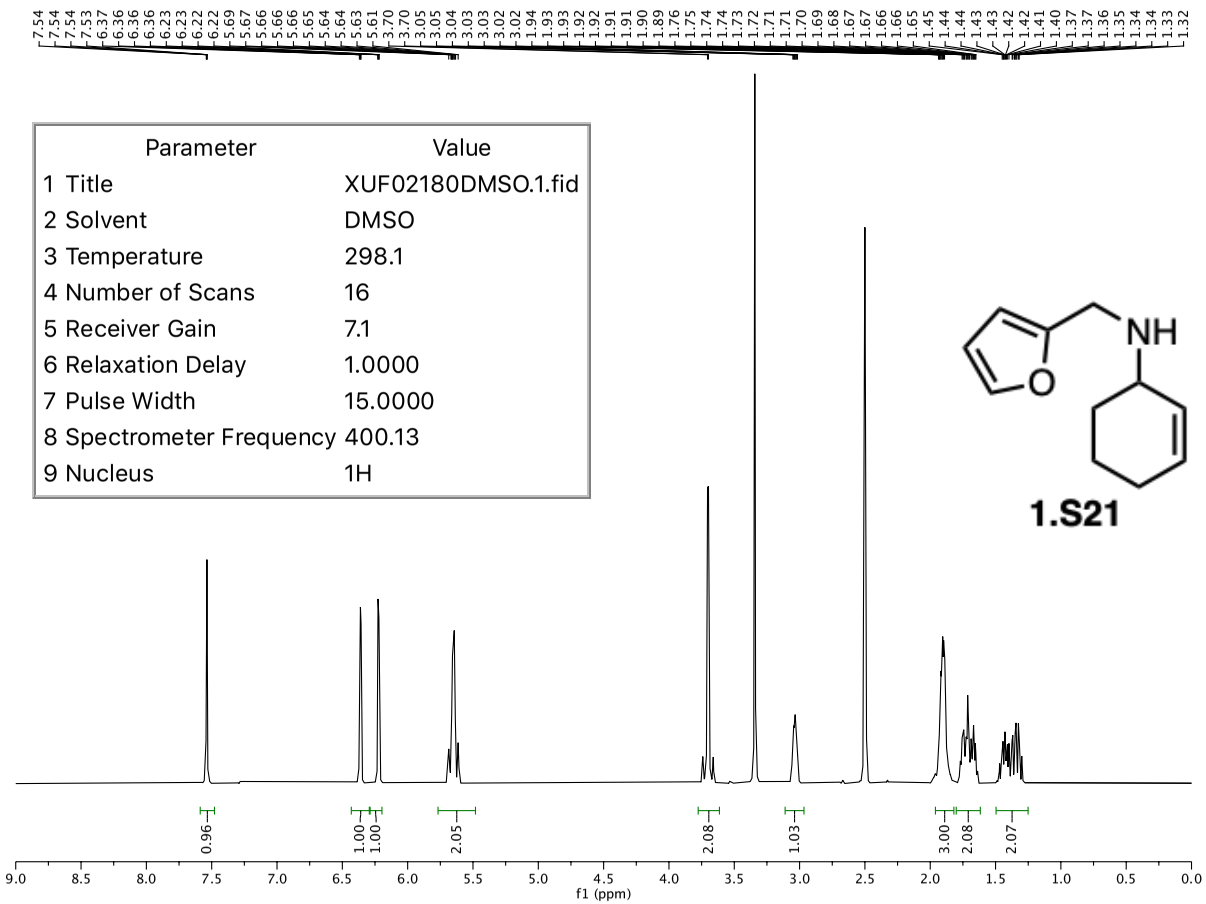
Appendix A

SPECTRAL DATA FOR CHAPTER 1


8.48 8.47 7.75 7.75 7.73 7.73 7.71 7.71 7.46 7.44 7.24 7.22 7.22 7.21 5.69 3.84 3.84 3.10 3.09 3.08 3.08 3.07 1.99 1.98 1.95 1.94 1.93 1.93 1.91 1.90 1.87 1.86 1.86 1.80 1.78 1.78 1.77 1.76 1.76 1.75 1.74 1.73 1.72 1.72 1.71 1.70 1.70 1.69 1.69 1.67 1.66 1.64 1.48 1.48 1.47 1.47 1.46 1.45 1.45 1.44 1.44 1.43 1.42 1.41 1.40 1.40 1.39 1.38 1.37 1.37 1.35 1.35
Parameter Value
1 Title XUF02161.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NH
N
1.S20
0.97 1.01 1.00 0.99 2.00 2.01 1.00 2.03 2.02 2.03
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


19.75
24.92
28.89
51.75
52.10
121.81
121.88
128.03
130.46
136.41
148.65
160.67
NH
N
1.S20
Parameter
Value
1 Title
XUF02161.5.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
256
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)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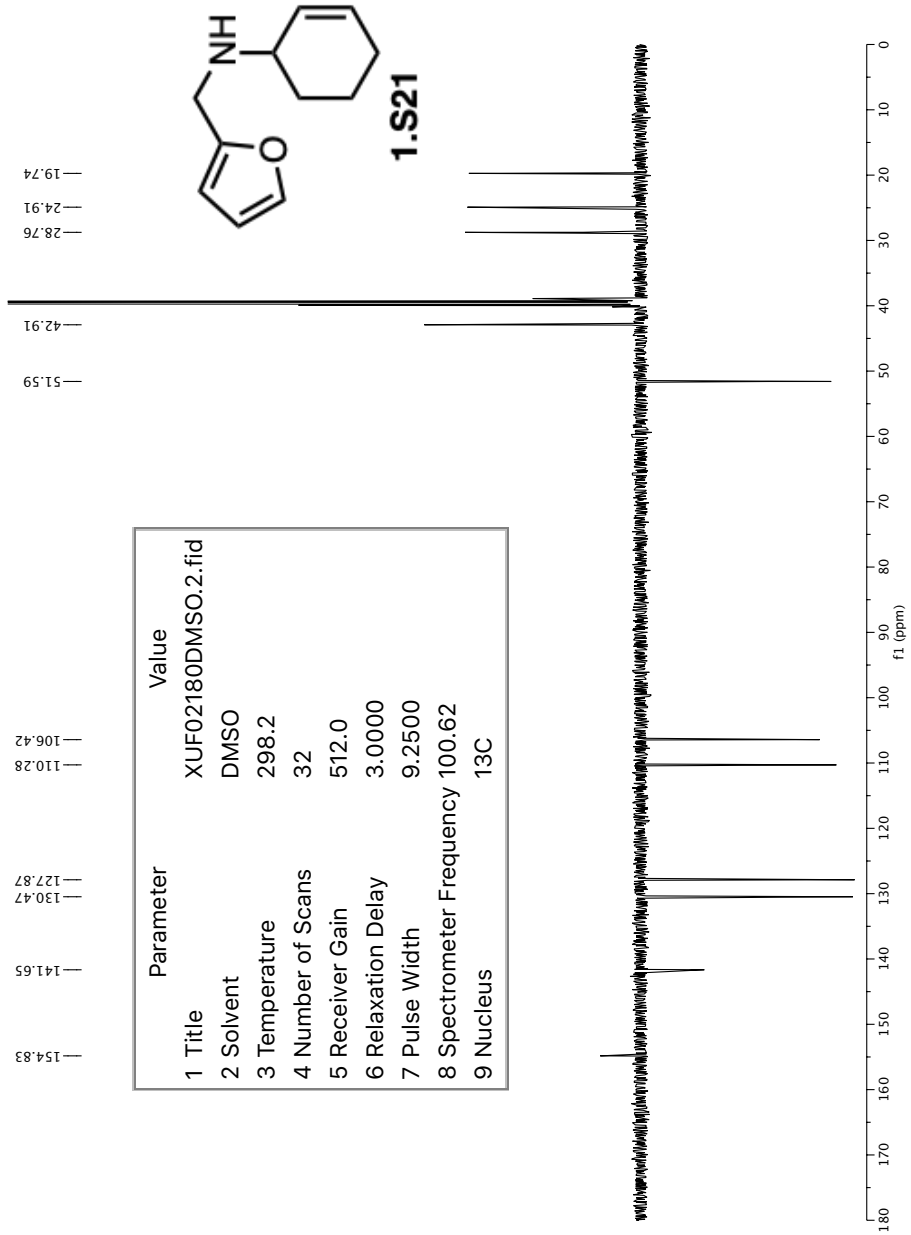
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NH
O
1.S21
0.96
1.00
1.00
2.05
2.08
1.03
3.00
2.08
2.07
f1 (ppm)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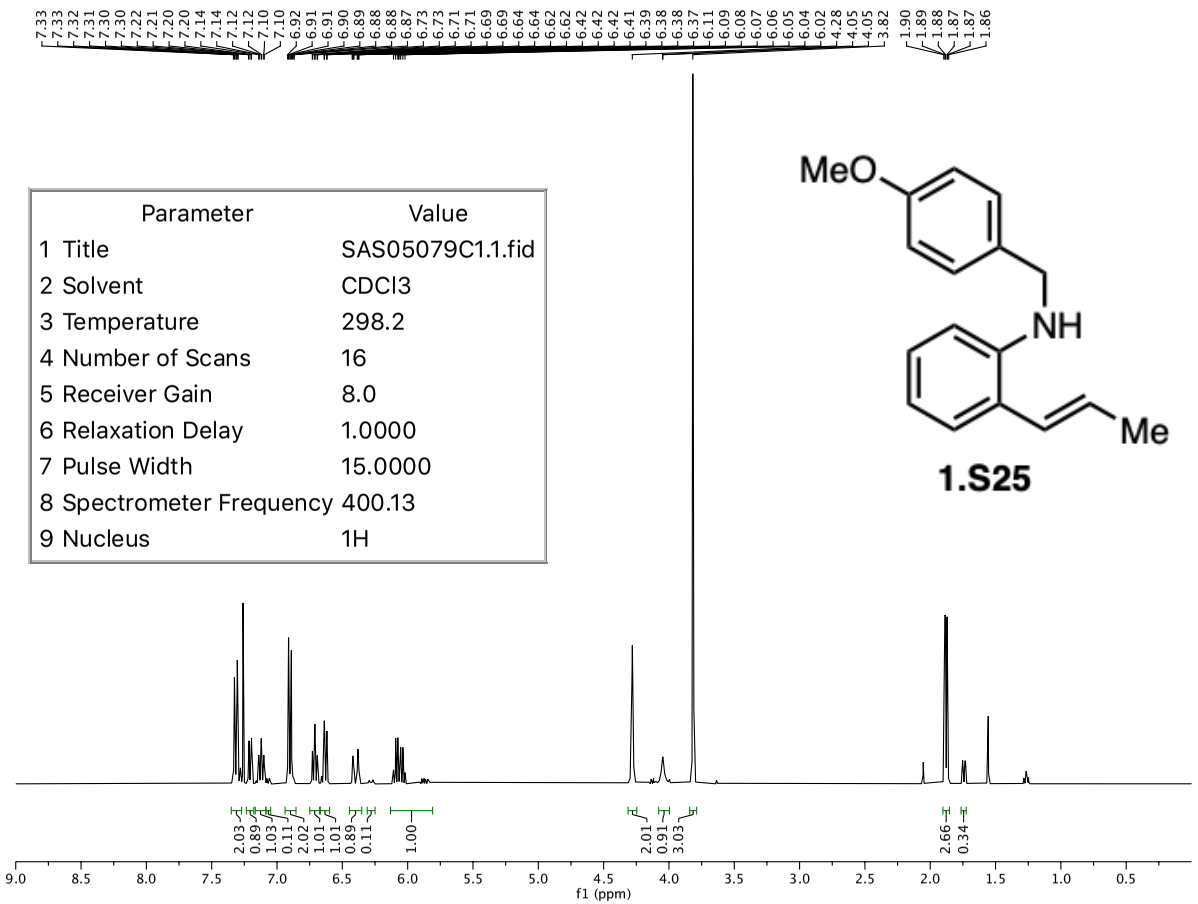
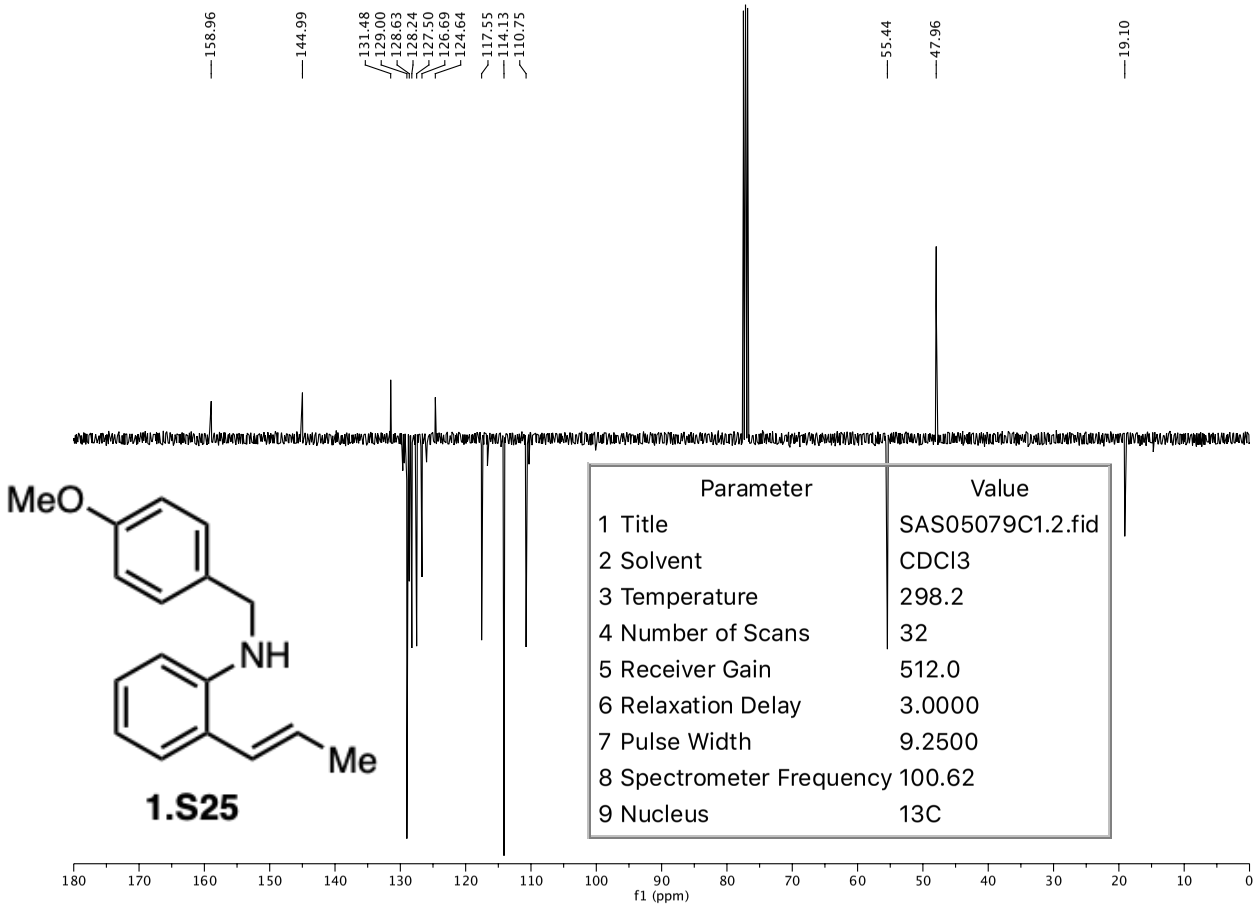
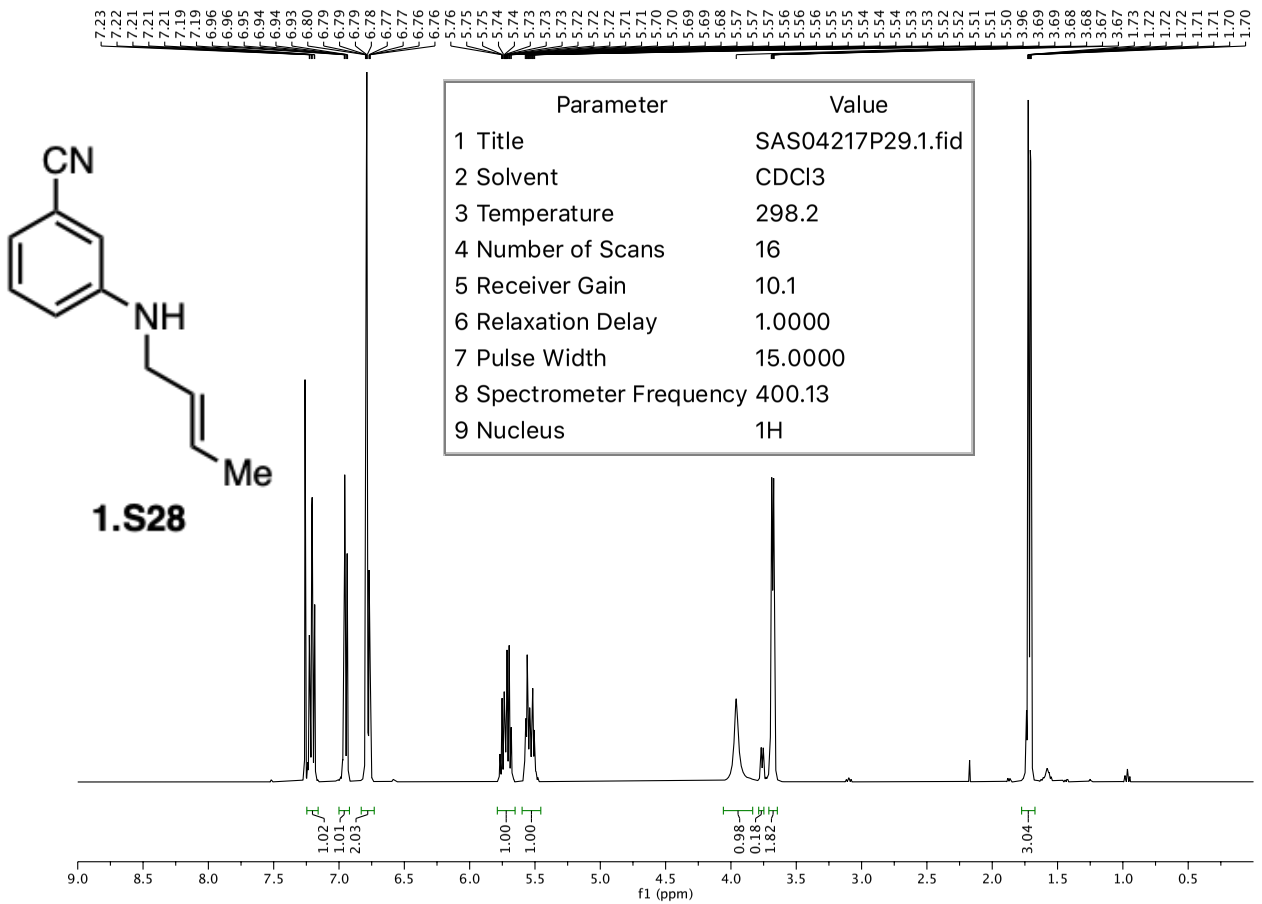
NH
O
19.74
24.91
28.76
42.91
51.59
106.42
110.28
127.87
130.47
141.65
154.83
Parameter
Value
1 Title
XUF02180DMSO.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
32
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)


7.33 7.33 7.32 7.31 7.30 7.30 7.22 7.21 7.20 7.20 7.14 7.14 7.12 7.12 7.10 7.10 6.92 6.91 6.91 6.90 6.89 6.88 6.88 6.87 6.73 6.73 6.71 6.71 6.69 6.69 6.64 6.64 6.62 6.62 6.42 6.42 6.41 6.39 6.38 6.38 6.37 6.11 6.09 6.08 6.07 6.06 6.05 6.04 6.02 4.28 4.05 4.05 3.82 1.90 1.89 1.88 1.87 1.87 1.86
Parameter Value
1 Title SAS05079C1.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
NH
Me
1.S25
2.03 0.89 1.03 0.11 2.02 1.01 0.89 0.11 1.00 2.01 0.91 3.03 2.66 0.34
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


158.96
144.99
131.48
129.00
128.63
128.24
127.50
126.69
124.64
117.55
114.13
110.75
55.44
47.96
19.10
MeO
NH
Me
1.S25
Parameter | Value
1 Title | SAS05079C1.2.fid
2 Solvent | CDCl3
3 Temperature | 298.2
4 Number of Scans | 32
5 Receiver Gain | 512.0
6 Relaxation Delay | 3.0000
7 Pulse Width | 9.2500
8 Spectrometer Frequency | 100.62
9 Nucleus | 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


CN
NH
Me
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4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
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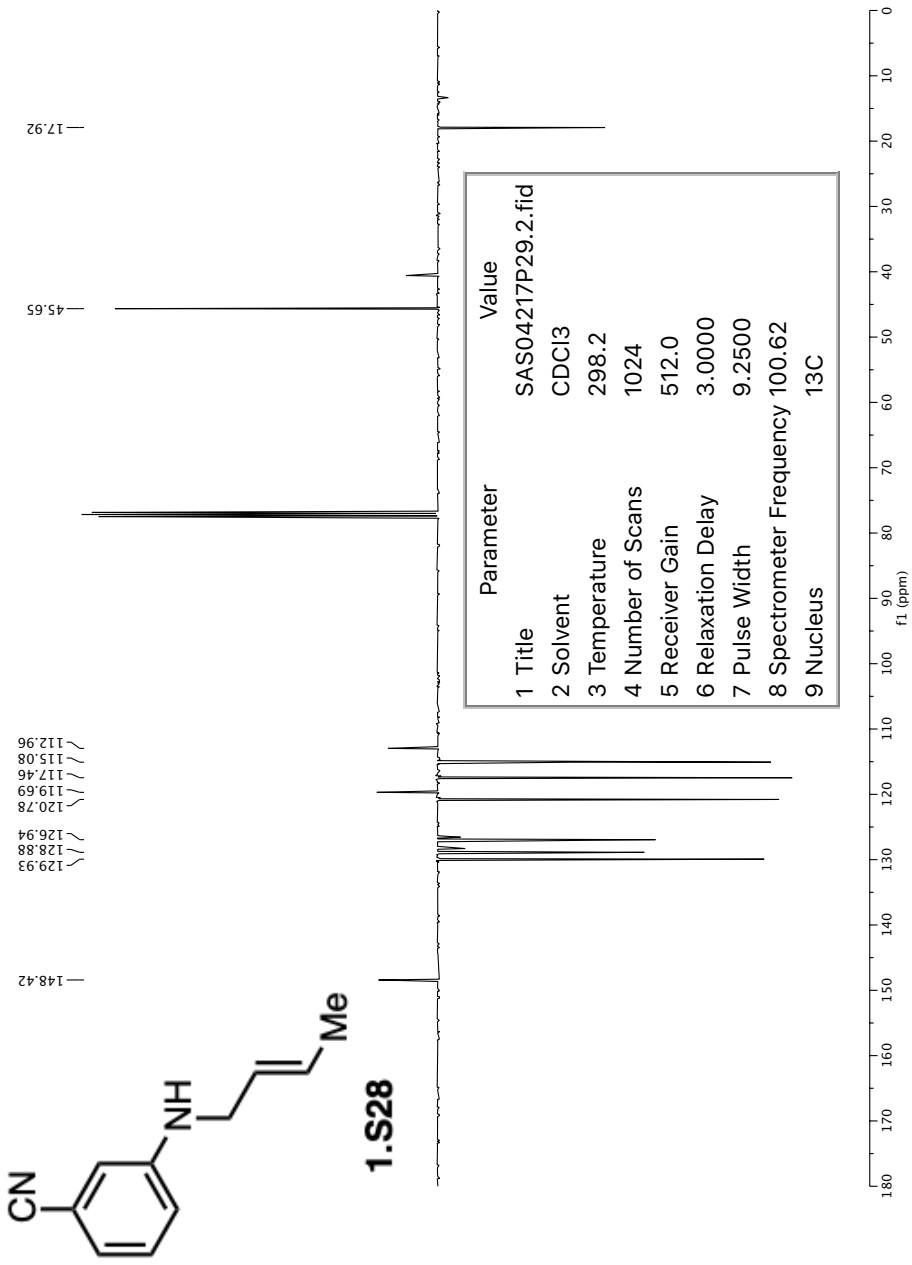
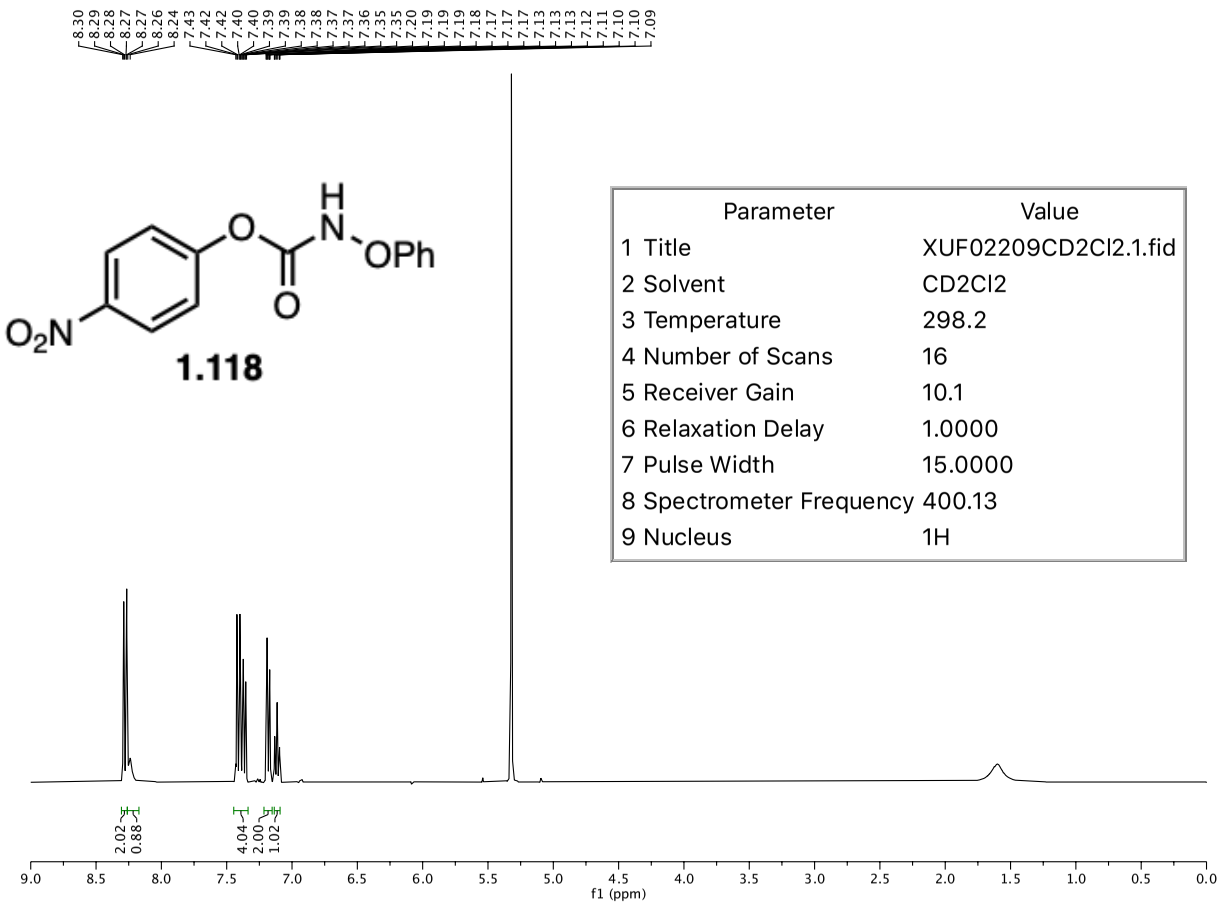
1.01
2.03
1.00
1.00
0.98
0.18
1.82
3.04
f1 (ppm)


CN
NH
Me
1.S28
148.42
129.93
128.88
126.94
120.78
119.69
117.46
115.08
112.96
45.65
17.92
Parameter Value
1 Title SAS04217P29.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)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8.28
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8.27
8.26
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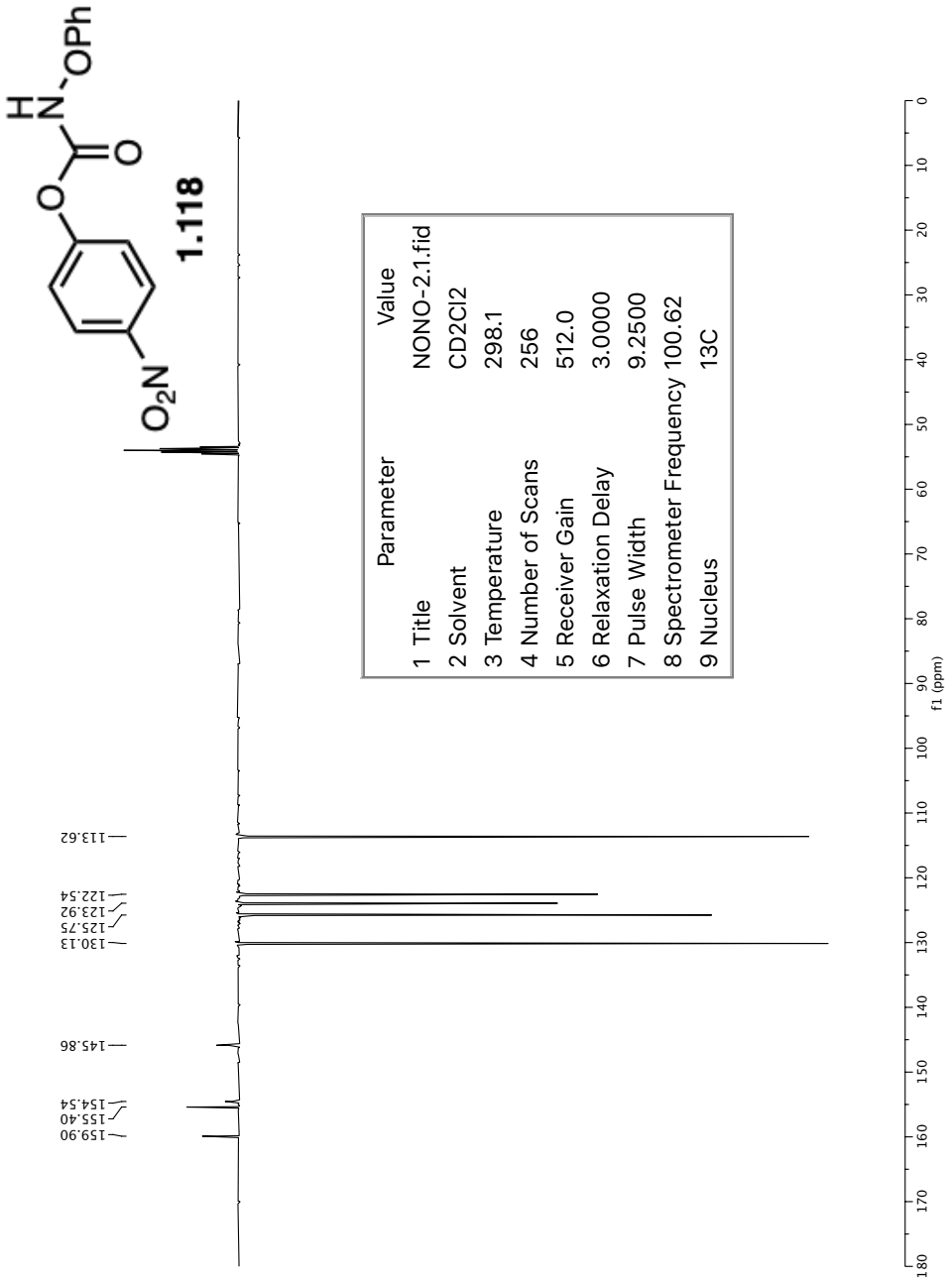
7.43
7.42
7.42
7.40
7.40
7.39
7.39
7.38
7.38
7.37
7.37
7.36
7.35
7.35
7.20
7.19
7.19
7.19
7.18
7.17
7.17
7.17
7.13
7.13
7.13
7.12
7.11
7.10
7.10
7.09
O
H
N
OPh
O
O2N
1.118
Parameter Value
1 Title XUF02209CD2Cl2.1.fid
2 Solvent CD2Cl2
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
2.02
0.88
4.04
2.00
1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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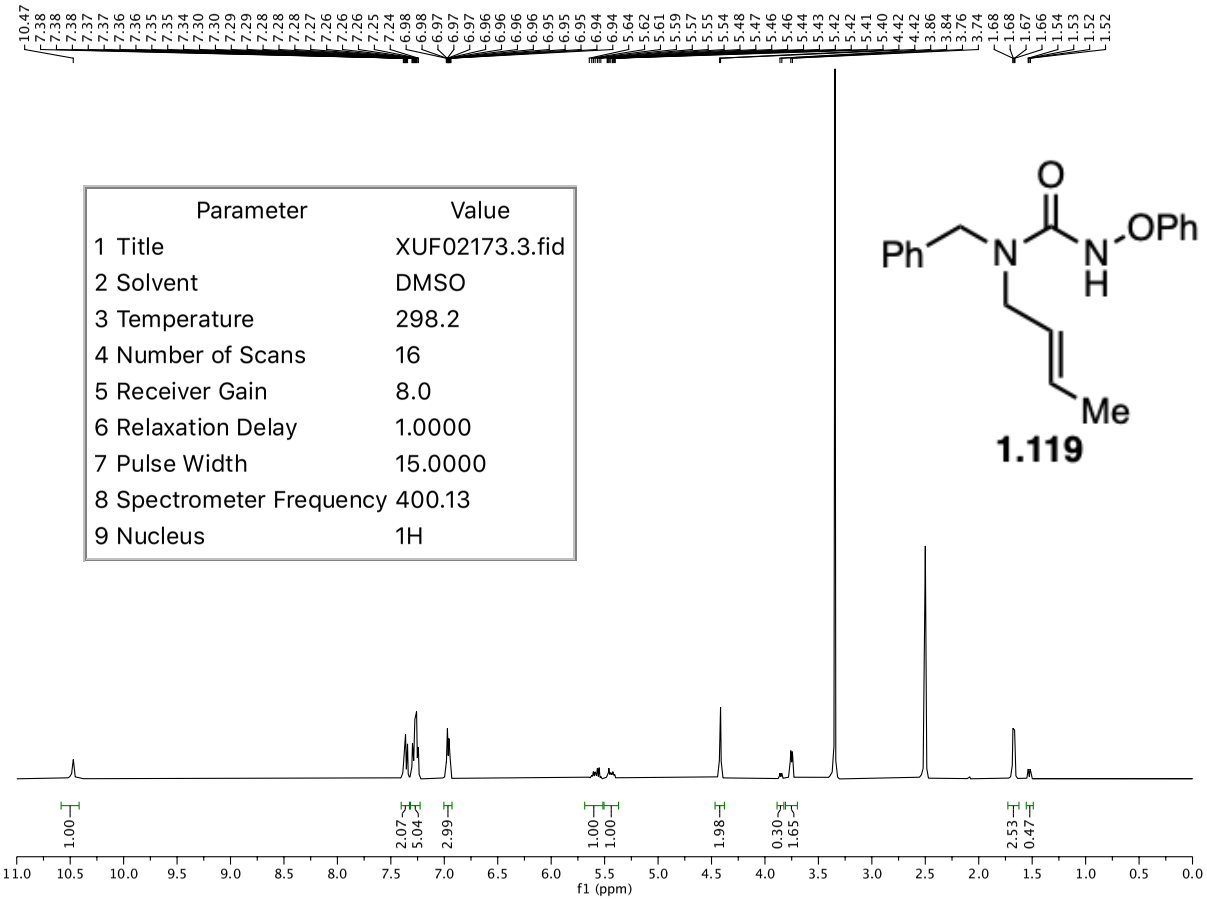
H
N
OPh
O
O
Parameter Value
1 Title NONO-2.1.fid
2 Solvent CD2Cl2
3 Temperature 298.1
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
113.62
122.54
123.92
125.75
130.13
145.86
154.54
155.40
159.90
f1 (ppm)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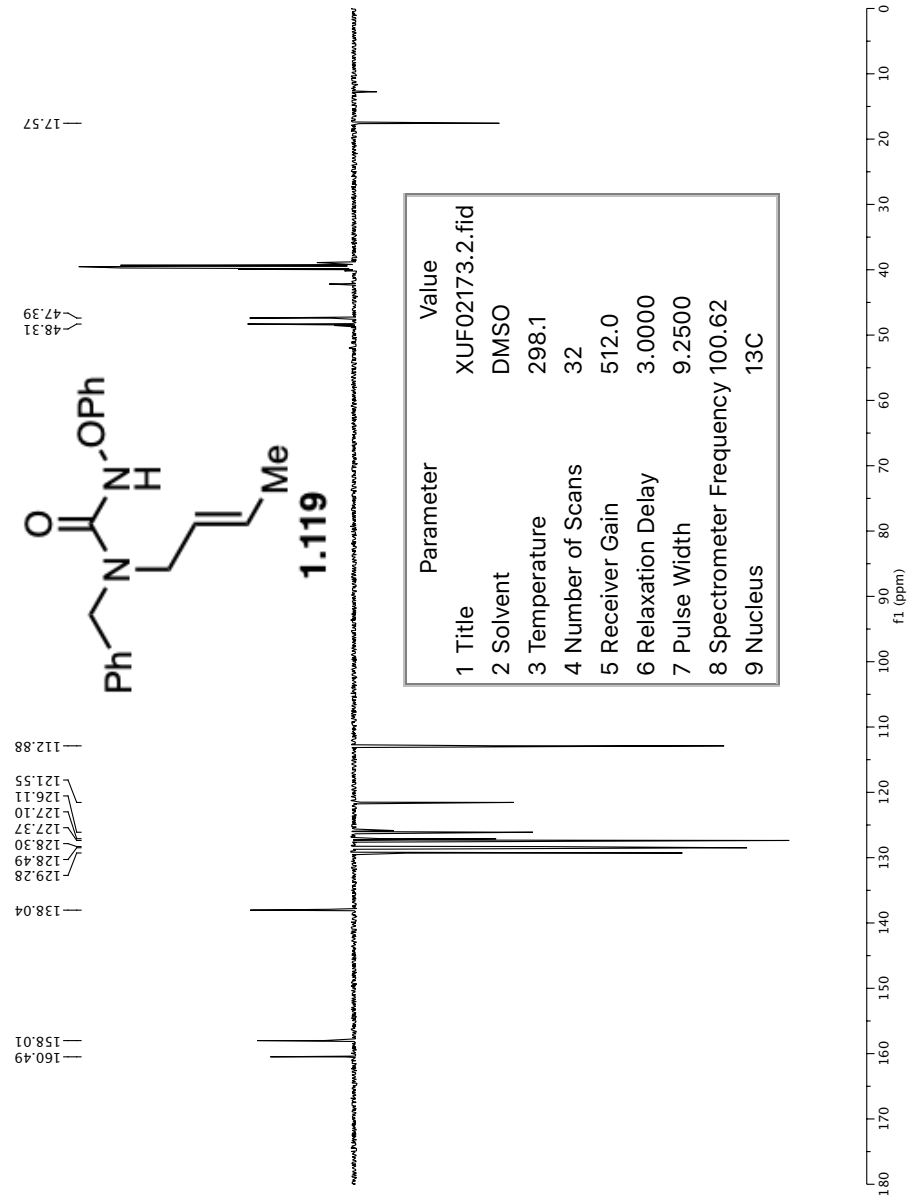
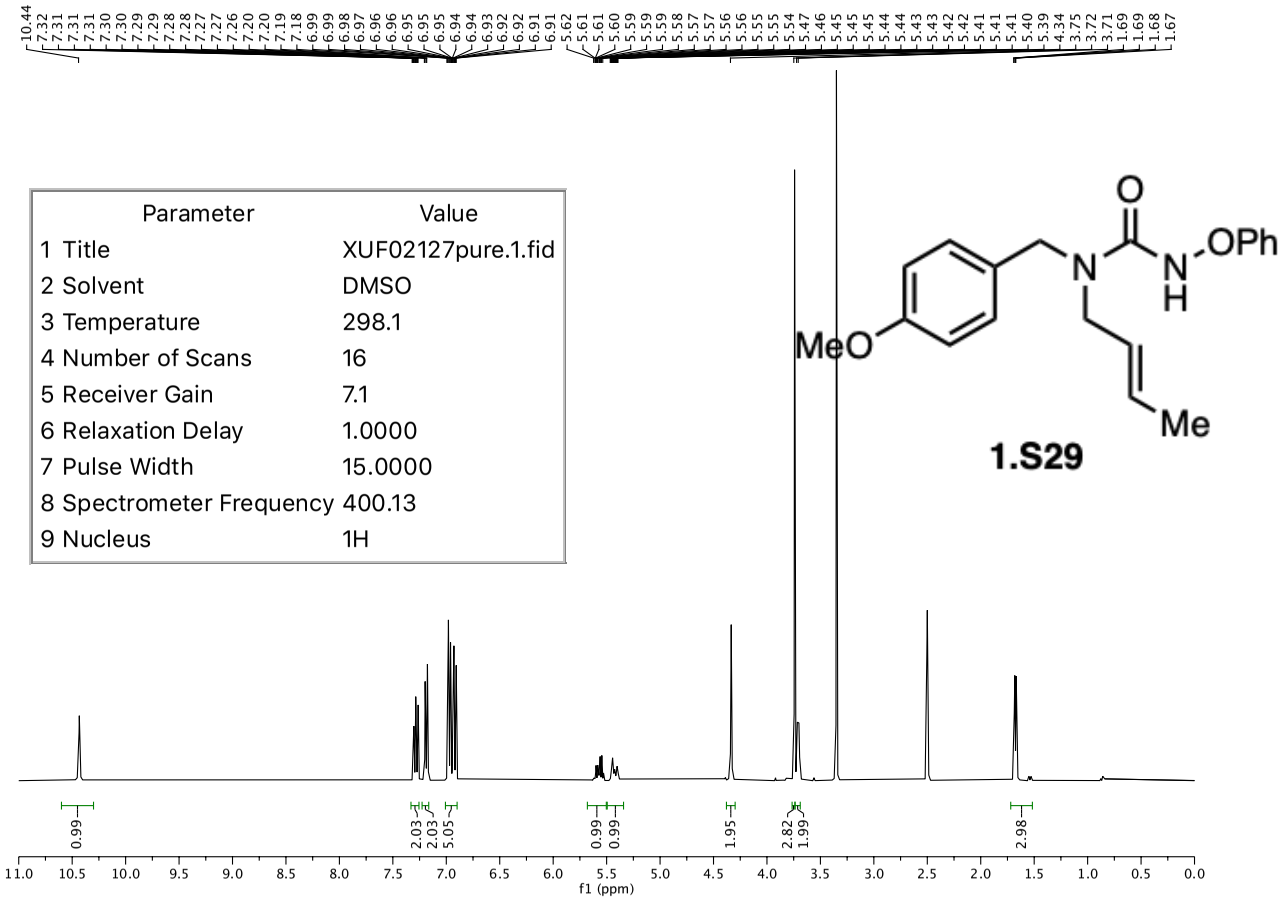
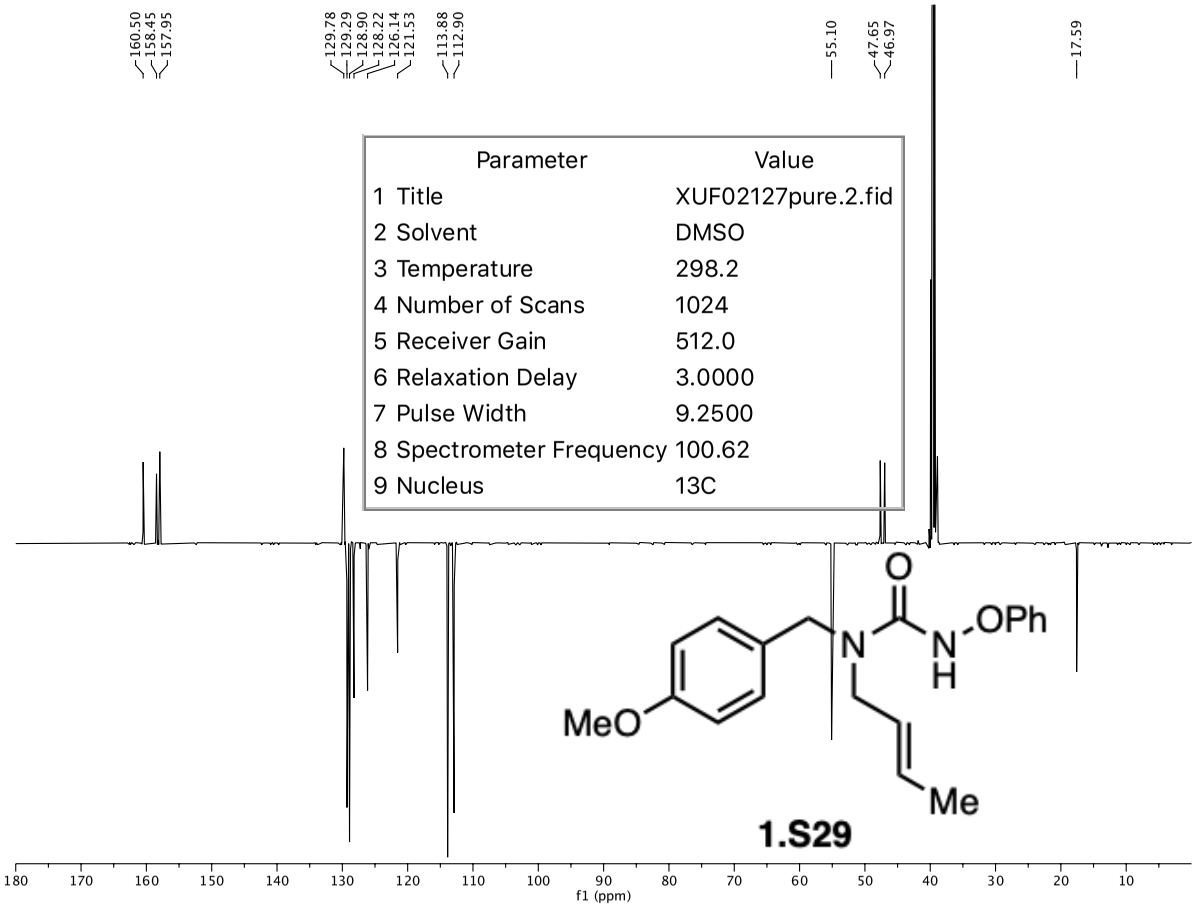
7.38
7.37
7.37
7.36
7.36
7.35
7.35
7.34
7.30
7.30
7.29
7.29
7.28
7.28
7.28
7.27
7.26
7.26
7.26
7.25
7.24
6.98
6.98
6.97
6.97
6.97
6.96
6.96
6.96
6.96
6.95
6.95
6.95
6.94
6.94
5.64
5.62
5.61
5.59
5.57
5.55
5.54
5.48
5.47
5.46
5.46
5.44
5.43
5.42
5.42
5.41
5.40
4.42
4.42
3.86
3.84
3.76
3.74
1.68
1.68
1.67
1.66
1.54
1.53
1.52
1.52
Parameter
Value
1 Title
XUF02173.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
8.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
Ph
N
N
H
OPh
Me
1.119
1.00
2.07
5.04
2.99
1.00
1.00
1.98
0.30
1.65
2.53
0.47
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


17.57
47.39
48.31
112.88
121.55
126.11
127.10
127.37
128.30
128.49
129.28
138.04
158.01
160.49
Ph
N
O
N
H
OPh
Me
1.119
Parameter Value
1 Title XUF02173.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)


10.44 7.32 7.31 7.31 7.31 7.30 7.30 7.29 7.29 7.28 7.28 7.27 7.27 7.26 7.20 7.20 7.19 7.18 6.99 6.99 6.98 6.97 6.96 6.96 6.95 6.95 6.95 6.94 6.94 6.93 6.92 6.92 6.91 6.91 5.62 5.61 5.61 5.60 5.59 5.59 5.59 5.58 5.57 5.57 5.56 5.56 5.55 5.55 5.54 5.47 5.46 5.45 5.45 5.45 5.44 5.44 5.43 5.43 5.42 5.42 5.41 5.41 5.41 5.40 5.39 4.34 3.75 3.72 3.71 1.69 1.69 1.68 1.67
Parameter Value
1 Title XUF02127pure.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
N
H
OPh
MeO
Me
1.S29
0.99 2.03 2.03 5.05 0.99 0.99 1.95 2.82 1.99 2.98
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


160.50
158.45
157.95
129.78
129.29
128.90
128.22
126.14
121.53
113.88
112.90
55.10
47.65
46.97
17.59
Parameter Value
1 Title XUF02127pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
N
H
OPh
MeO
Me
1.S29
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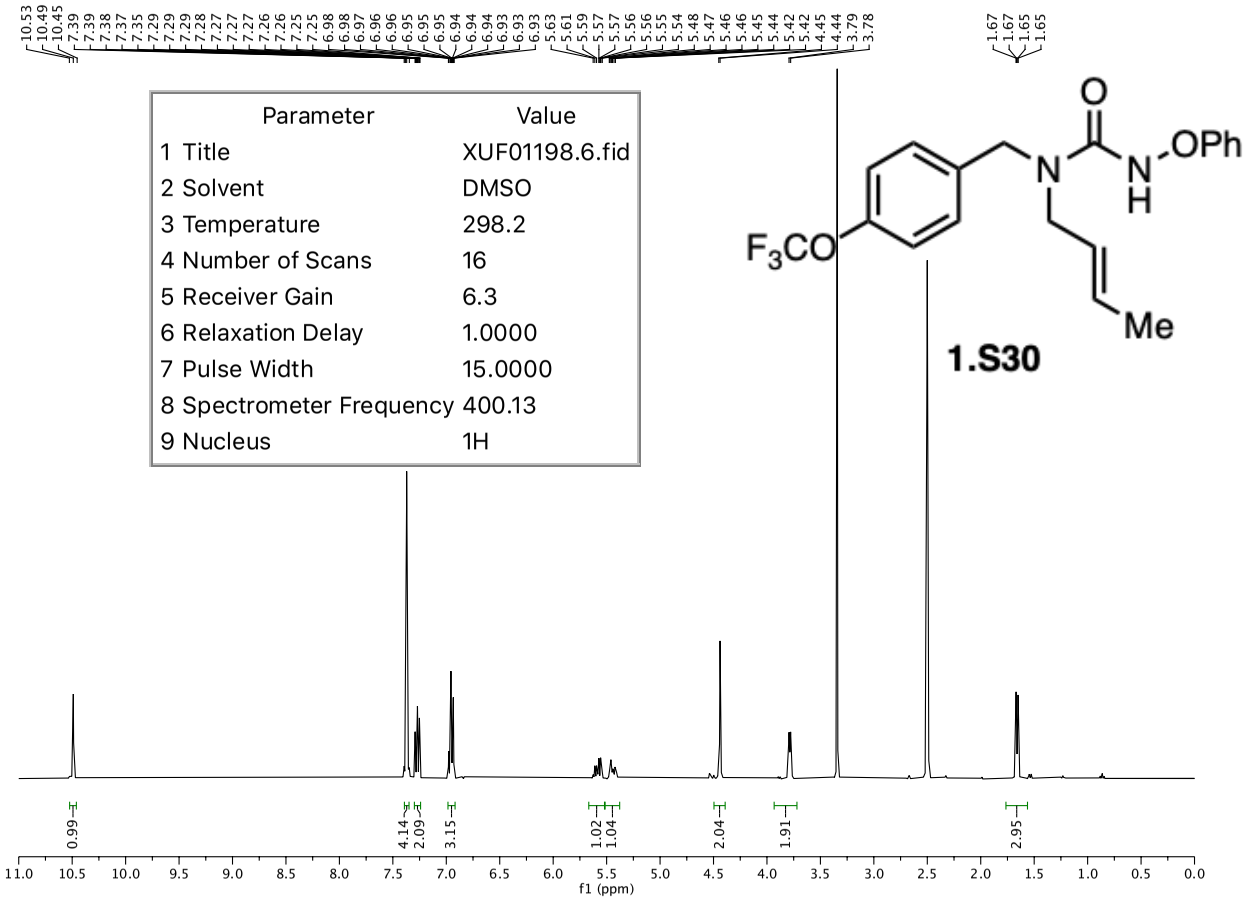
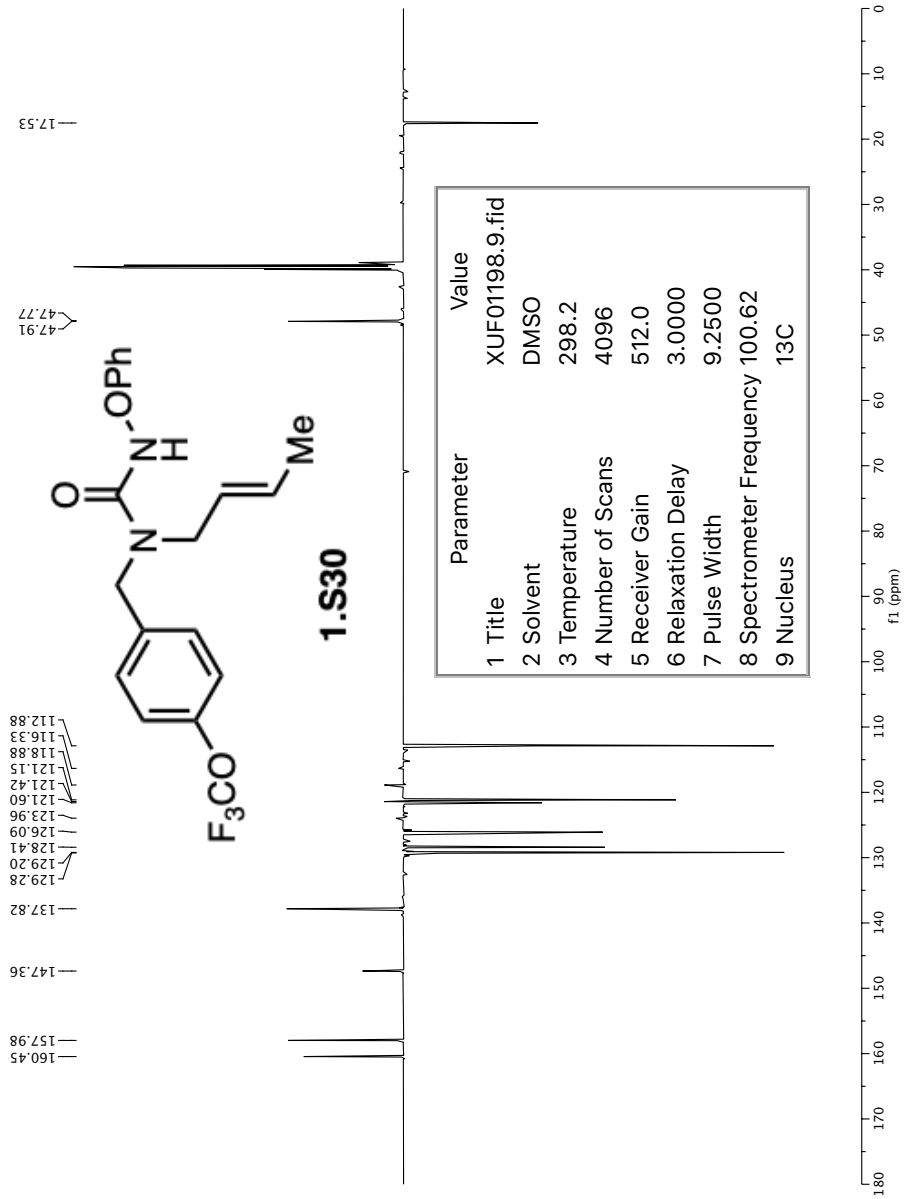
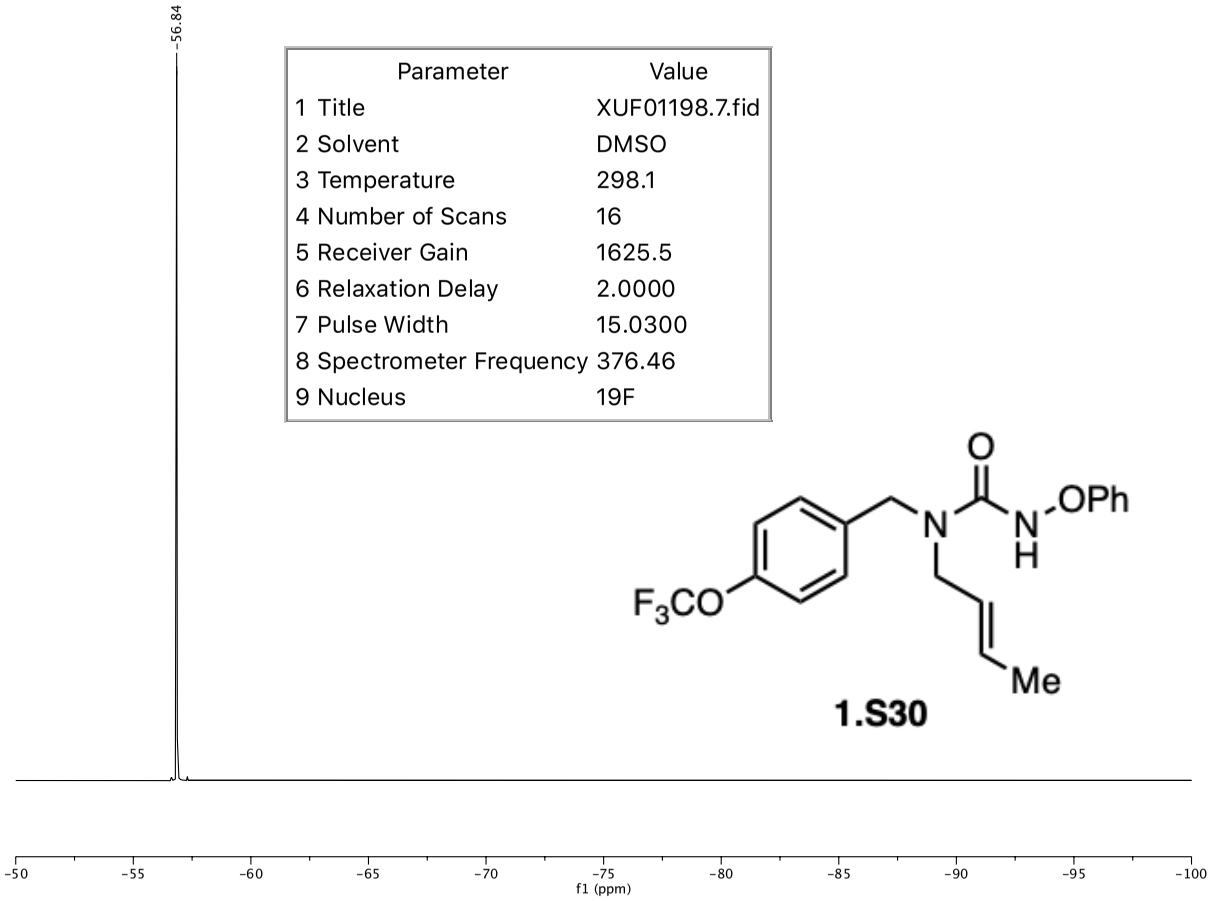
f1 (ppm)


10.53 10.49 10.45 7.39 7.39 7.38 7.37 7.35 7.29 7.29 7.29 7.28 7.27 7.27 7.27 7.26 7.26 7.25 7.25 6.98 6.98 6.97 6.96 6.96 6.95 6.95 6.95 6.94 6.94 6.94 6.93 6.93 5.63 5.61 5.59 5.57 5.57 5.56 5.56 5.55 5.54 5.48 5.47 5.46 5.46 5.45 5.44 5.42 5.42 4.45 4.44 3.79 3.78 1.67 1.67 1.65 1.65
Parameter Value
1 Title XUF01198.6.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OPh
N
H
N
F3CO
Me
1.S30
0.99 4.14 2.09 3.15 1.02 1.04 2.04 1.91 2.95
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


17.53
47.91
47.77
160.45
157.98
147.36
137.82
129.28
129.20
128.41
126.09
123.96
121.60
121.42
121.15
118.88
116.33
112.88
OPh
N
H
O
N
Me
F3CO
1.S30
Parameter Value
1 Title XUF01198.9.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)



Parameter	Value
1 Title	XUF01198.7.fid
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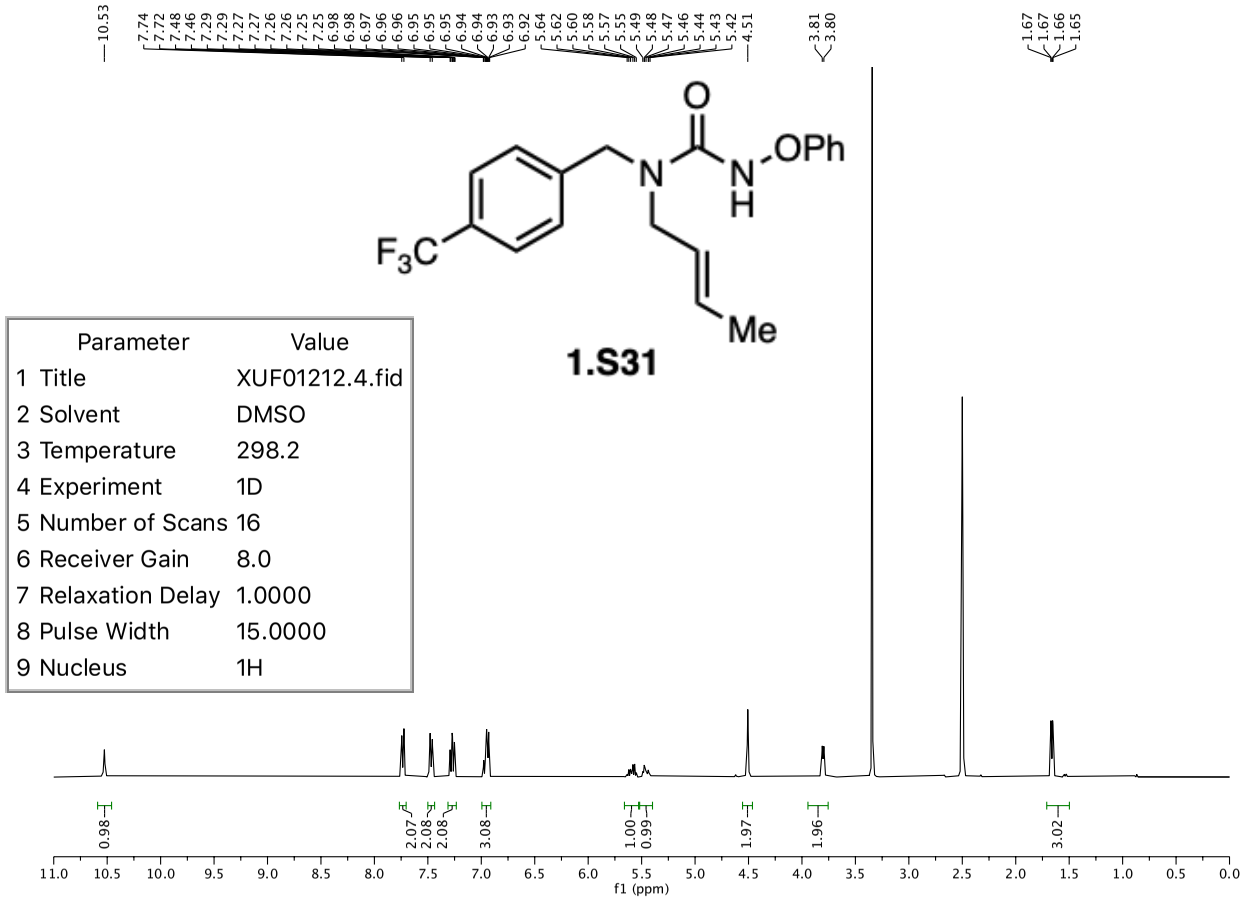
3 Temperature	298.1
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

1.S30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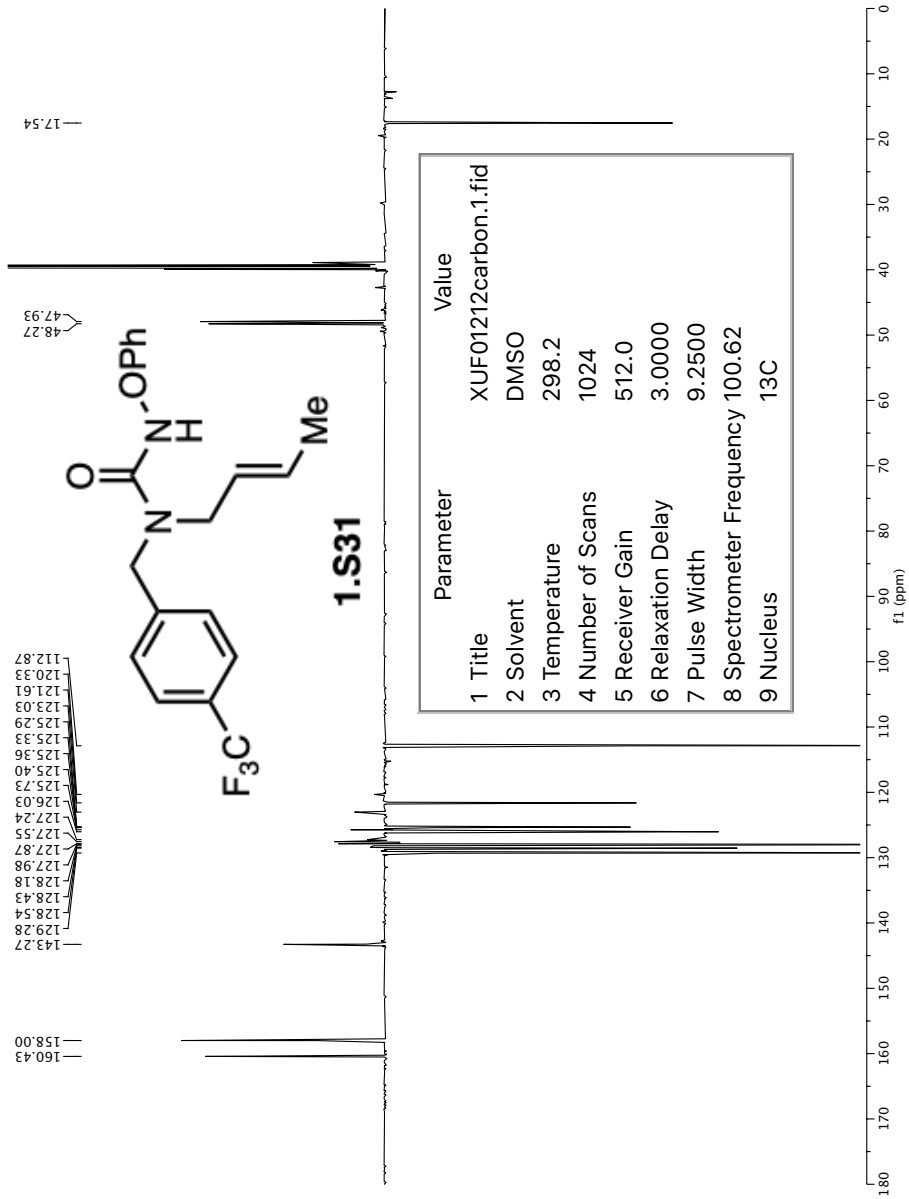
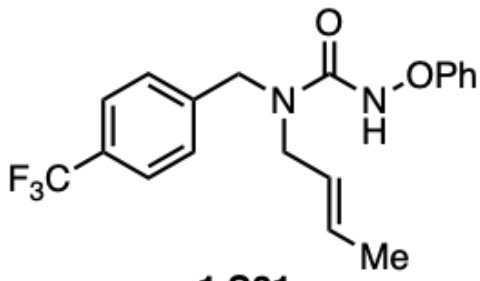
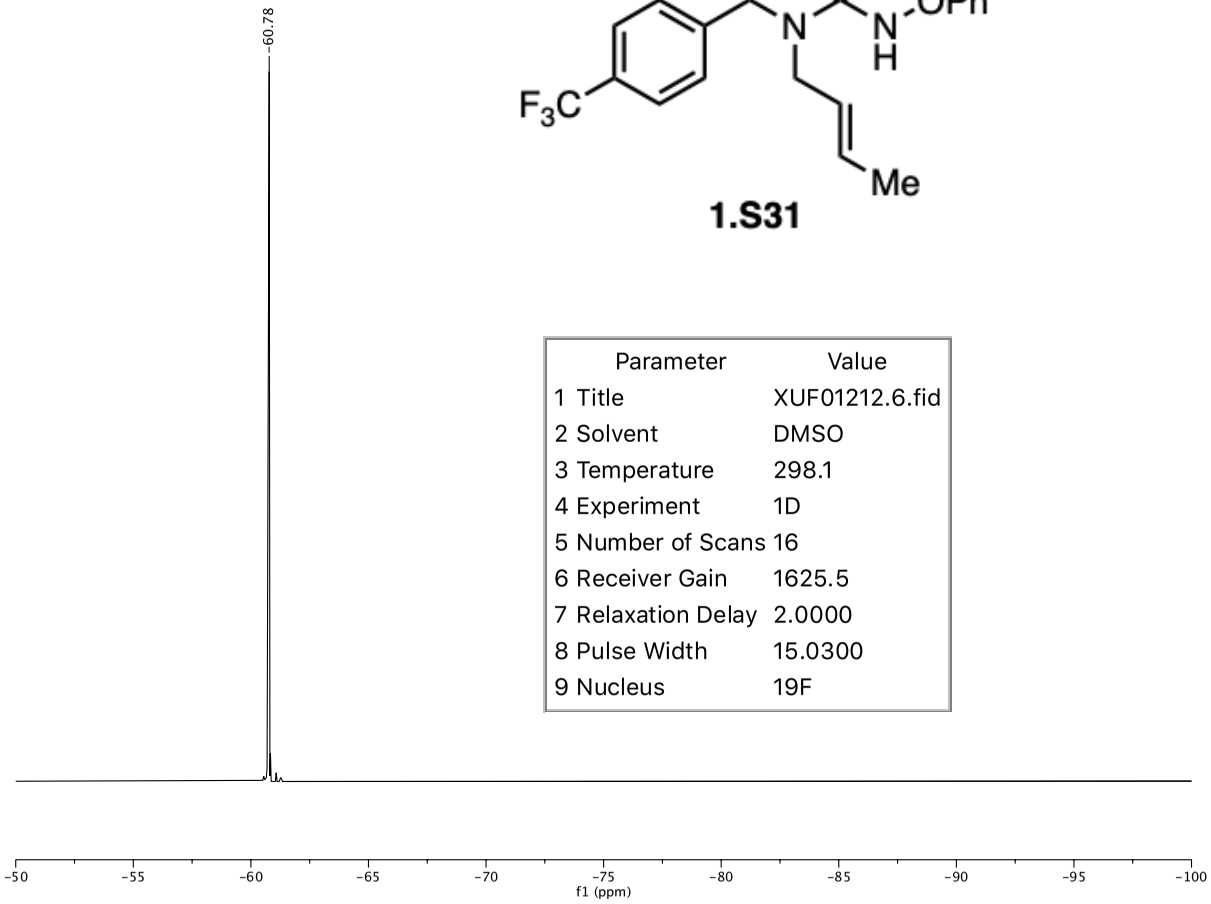
7.74
7.72
7.48
7.46
7.29
7.29
7.27
7.27
7.26
7.26
7.25
7.25
6.98
6.98
6.97
6.96
6.96
6.95
6.95
6.94
6.94
6.93
6.92
5.64
5.62
5.60
5.58
5.57
5.55
5.49
5.48
5.47
5.46
5.44
5.43
5.42
4.51
3.81
3.80
1.67
1.67
1.66
1.65
O
N
N
H
OPh
F3C
Me
1.S31
Parameter Value
1 Title XUF01212.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Experiment 1D
5 Number of Scans 16
6 Receiver Gain 8.0
7 Relaxation Delay 1.0000
8 Pulse Width 15.0000
9 Nucleus 1H
0.98
2.07
2.08
2.08
3.08
1.00
0.99
1.97
1.96
3.02
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

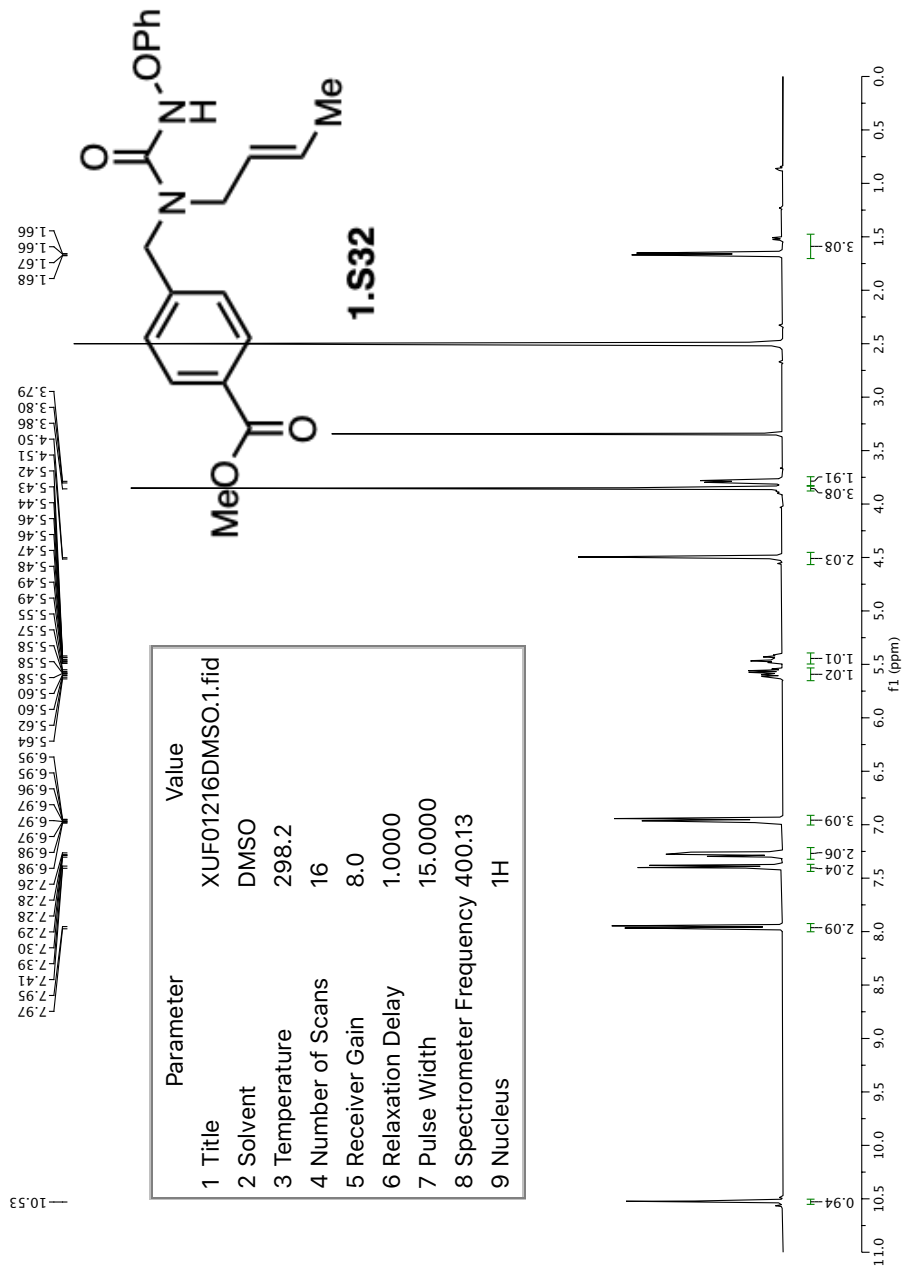

160.43
158.00
143.27
129.28
128.54
128.43
128.18
127.98
127.87
127.55
127.24
126.03
125.73
125.40
125.36
125.33
125.29
123.03
121.61
120.33
112.87
48.27
47.93
17.54
1.S31
Me
OPh
F3C
Parameter
Value
1 Title
XUF01212carbon.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

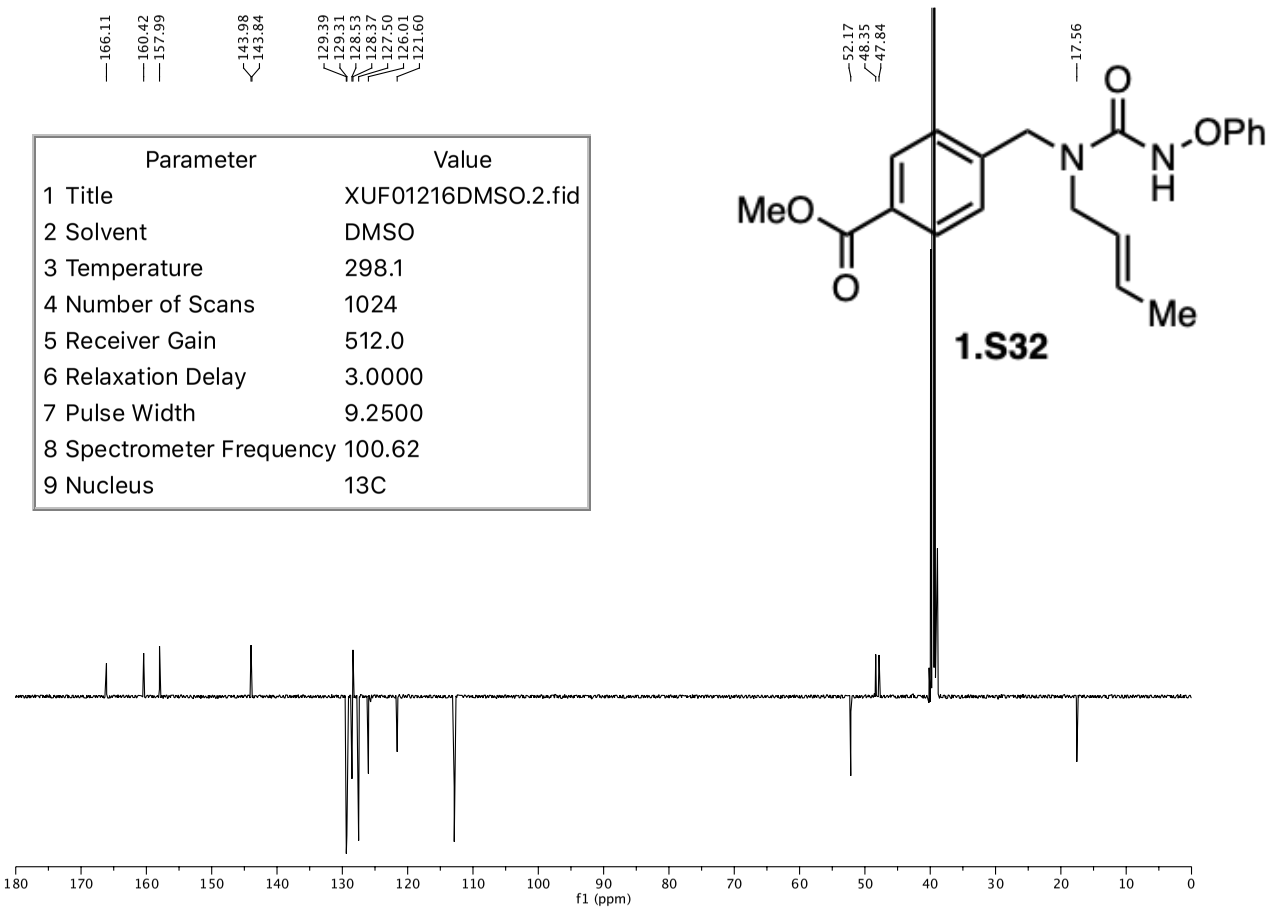


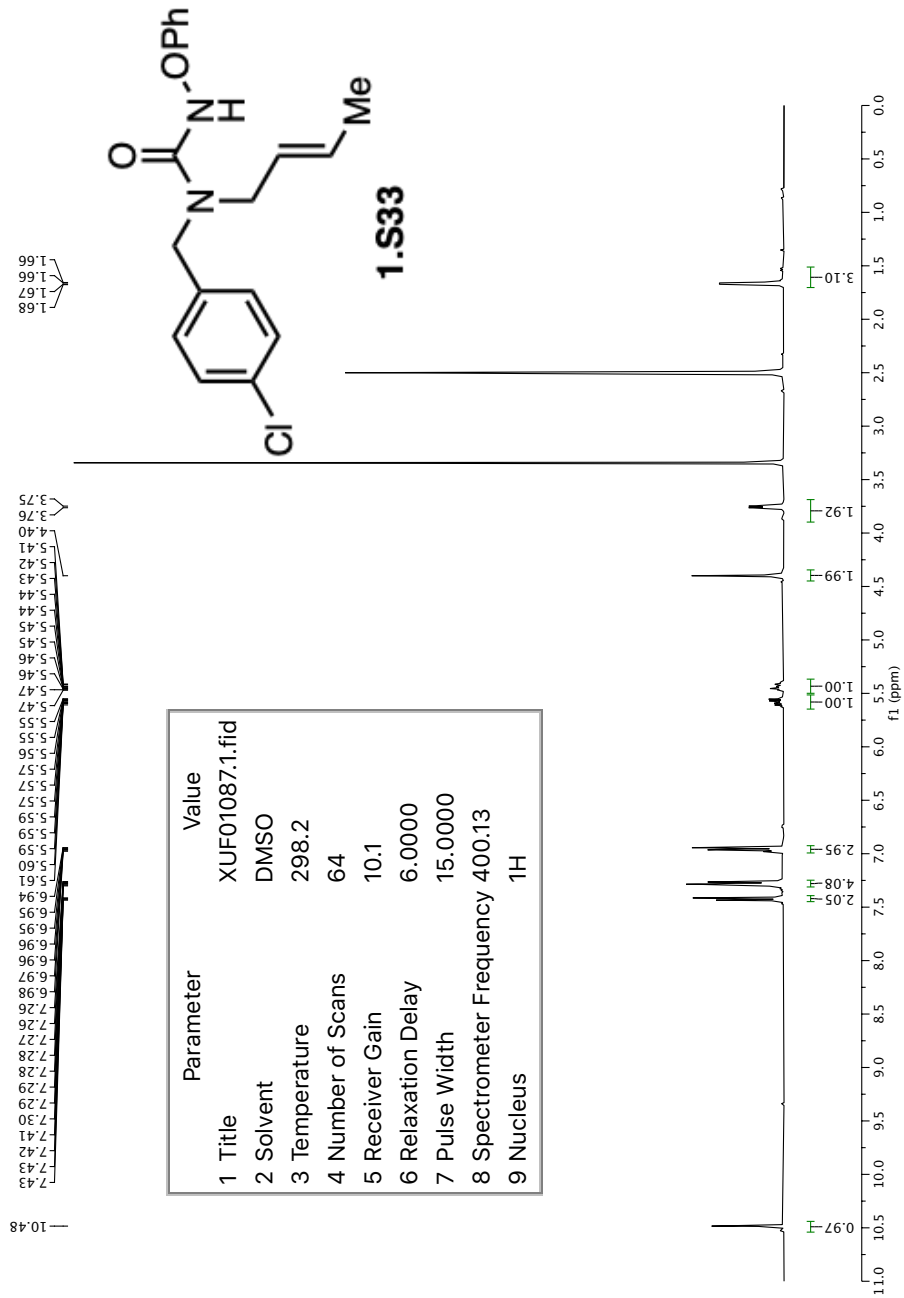
1.S31

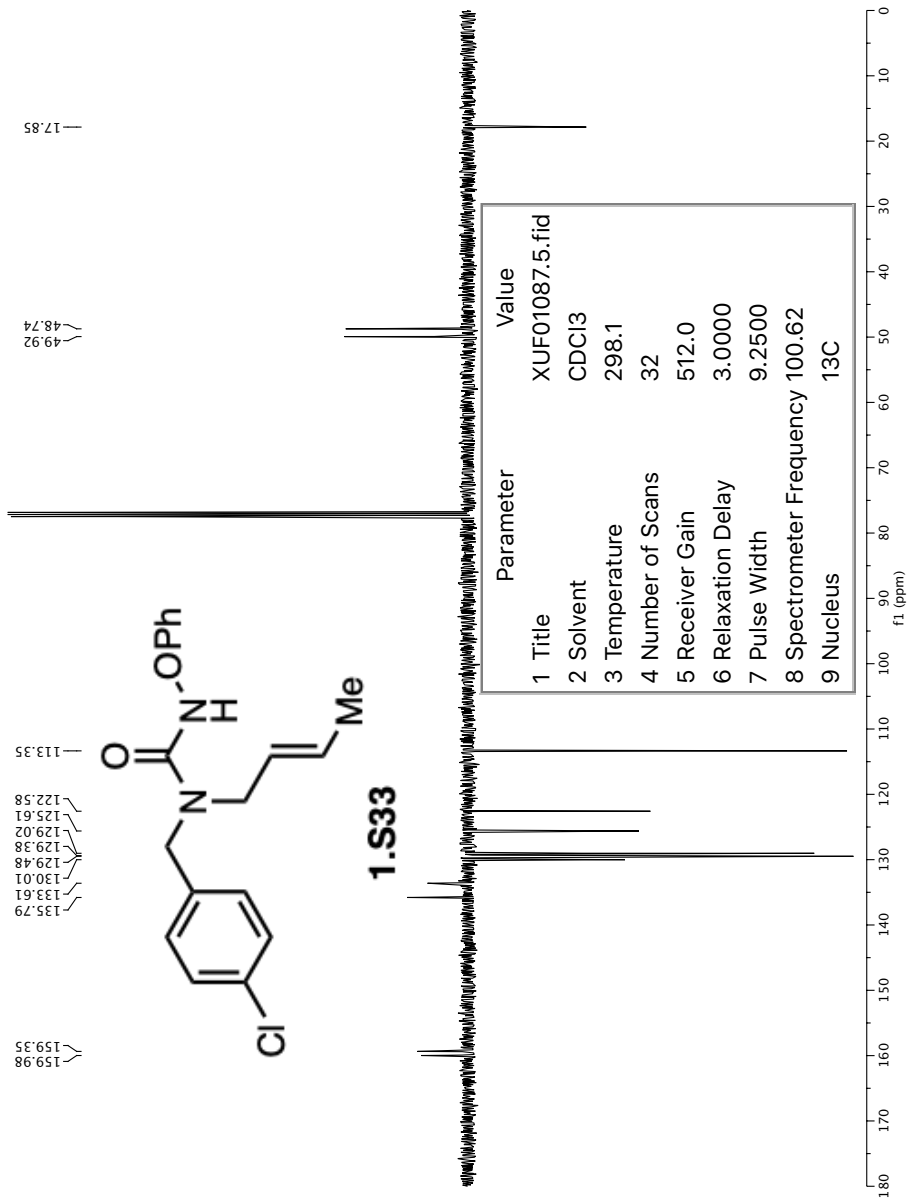
Parameter	Value
1 Title	XUF01212.6.fid
2 Solvent	DMSO
3 Temperature	298.1
4 Experiment	1D
5 Number of Scans	16
6 Receiver Gain	1625.5
7 Relaxation Delay	2.0000
8 Pulse Width	15.0300
9 Nucleus	19F

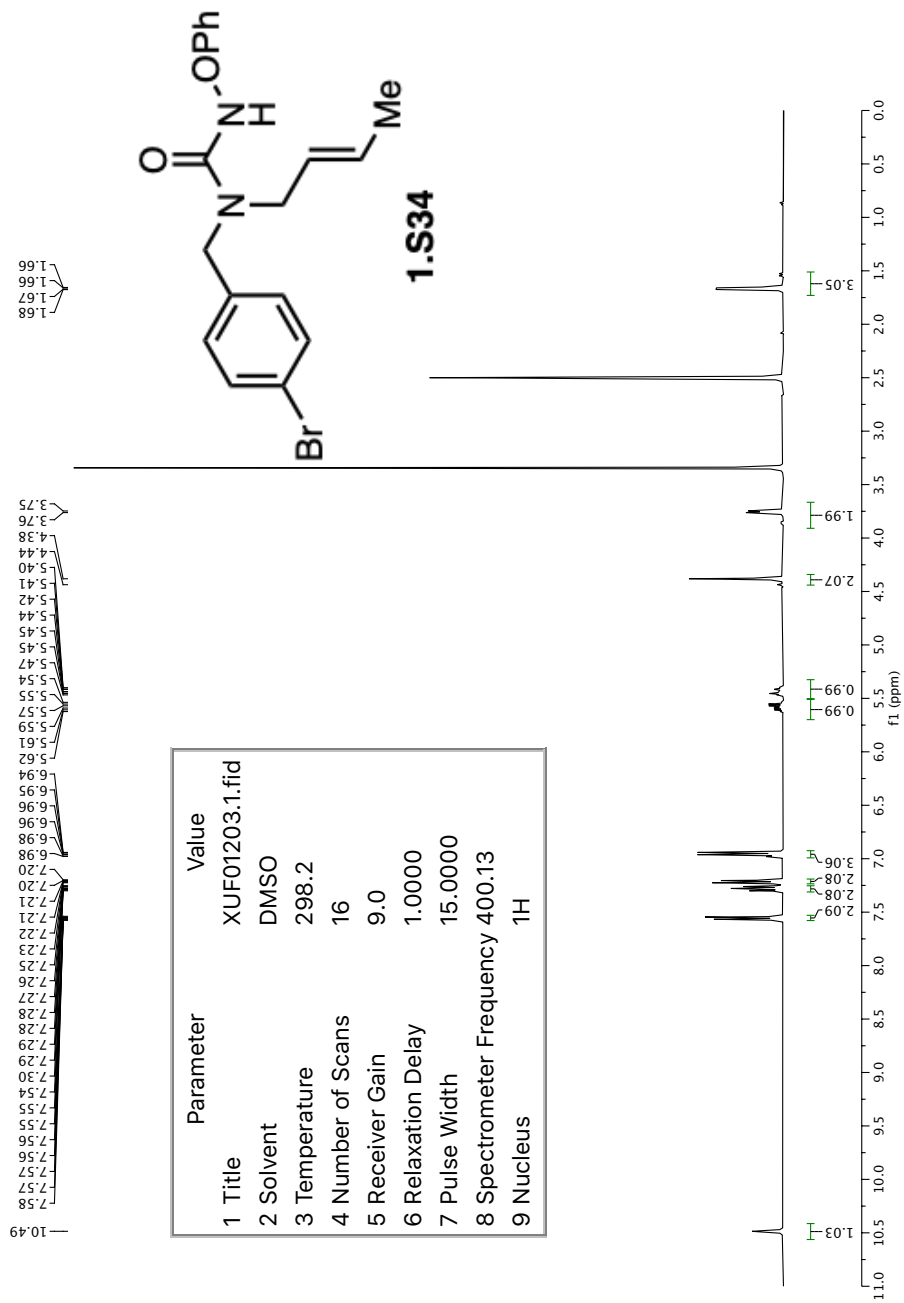


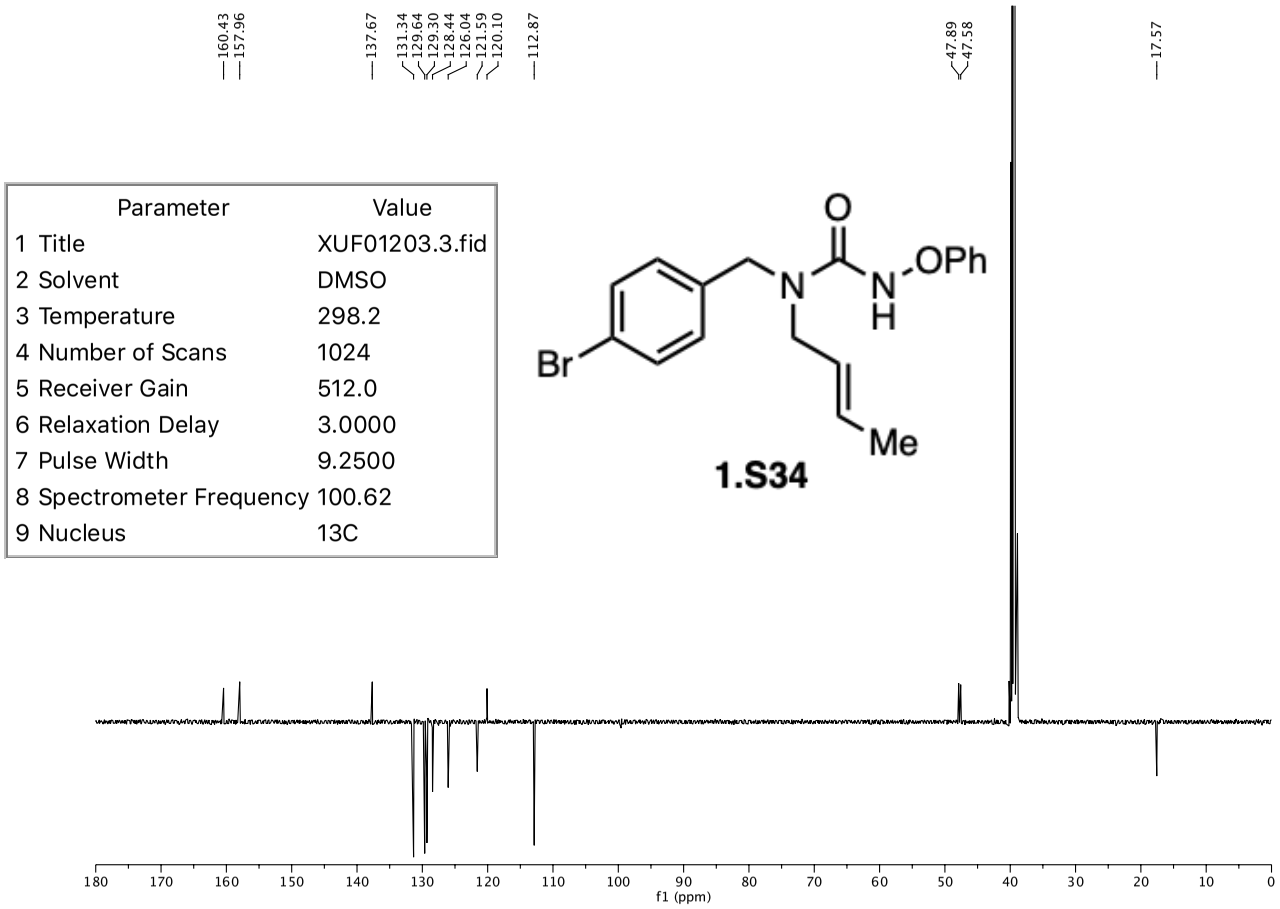

1.S32
MeO
O
N
O
N
H
OPh
Me
Parameter Value
1 Title XUF01216DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

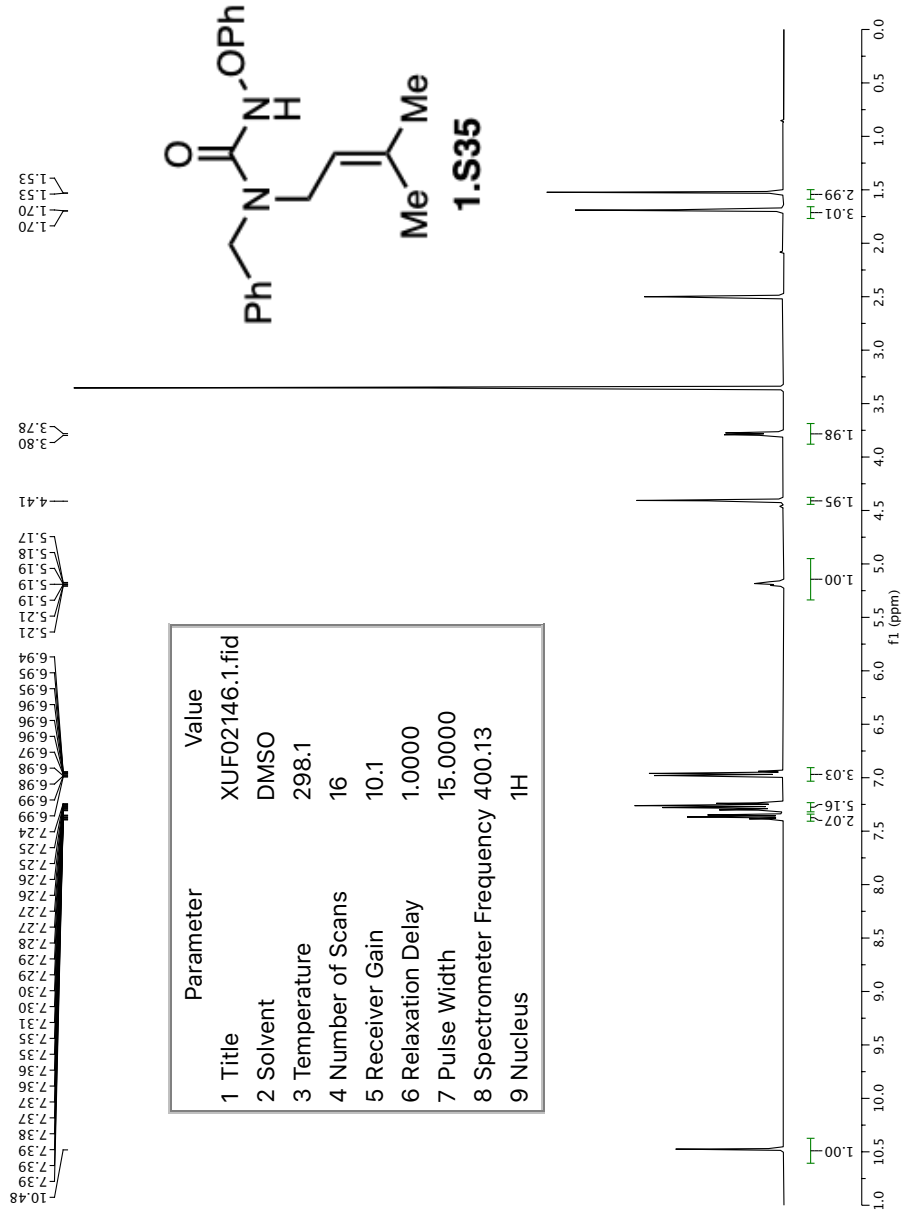

166.11
160.42
157.99
143.98
143.84
129.39
129.31
128.53
128.37
127.50
126.01
121.60
52.17
48.35
47.84
17.56
Parameter Value
1 Title XUF01216DMSO.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
O
N
N
H
OPh
Me
1.S32
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

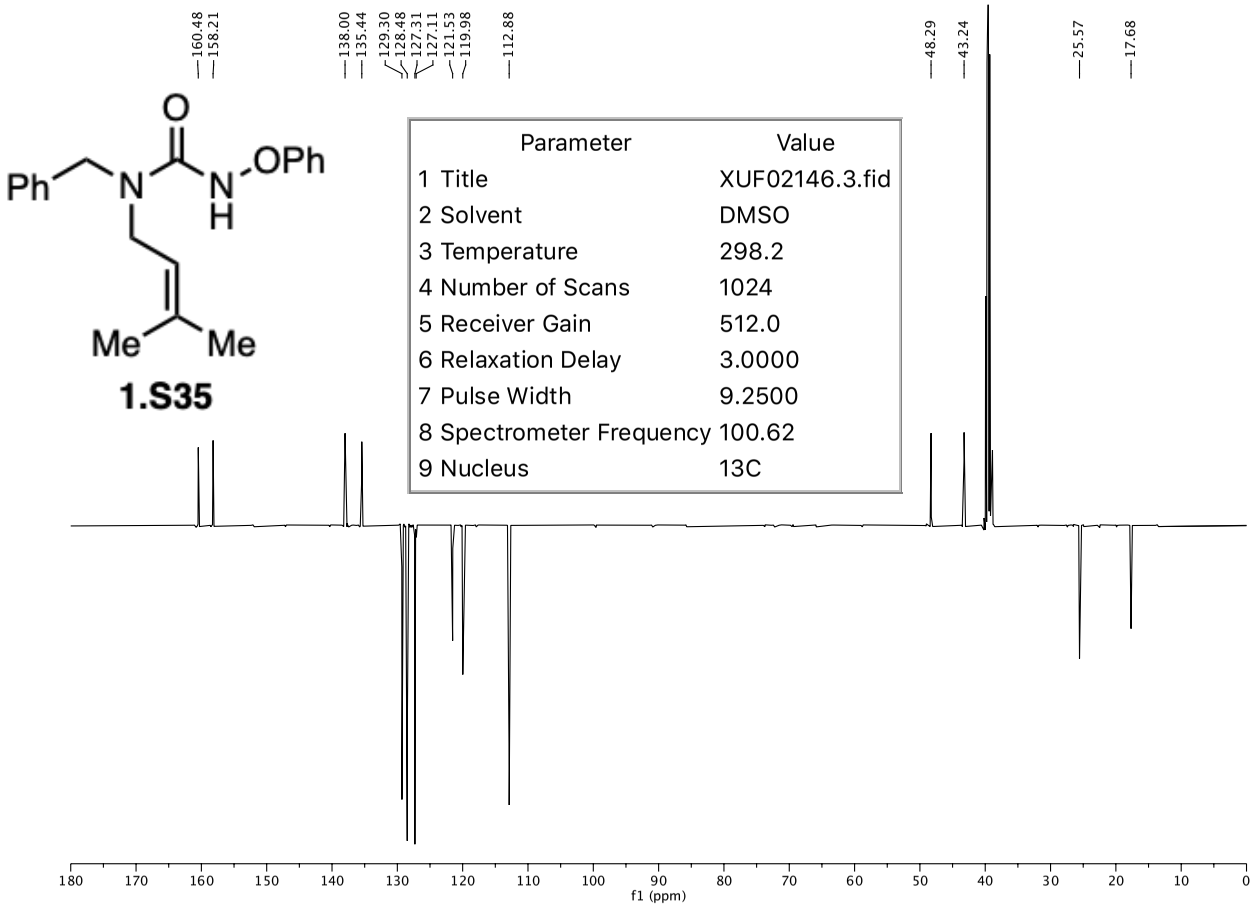

1.S33
Cl
N
H
O
OPh
Me
Parameter Value
1 Title XUF01087.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 64
5 Receiver Gain 10.1
6 Relaxation Delay 6.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

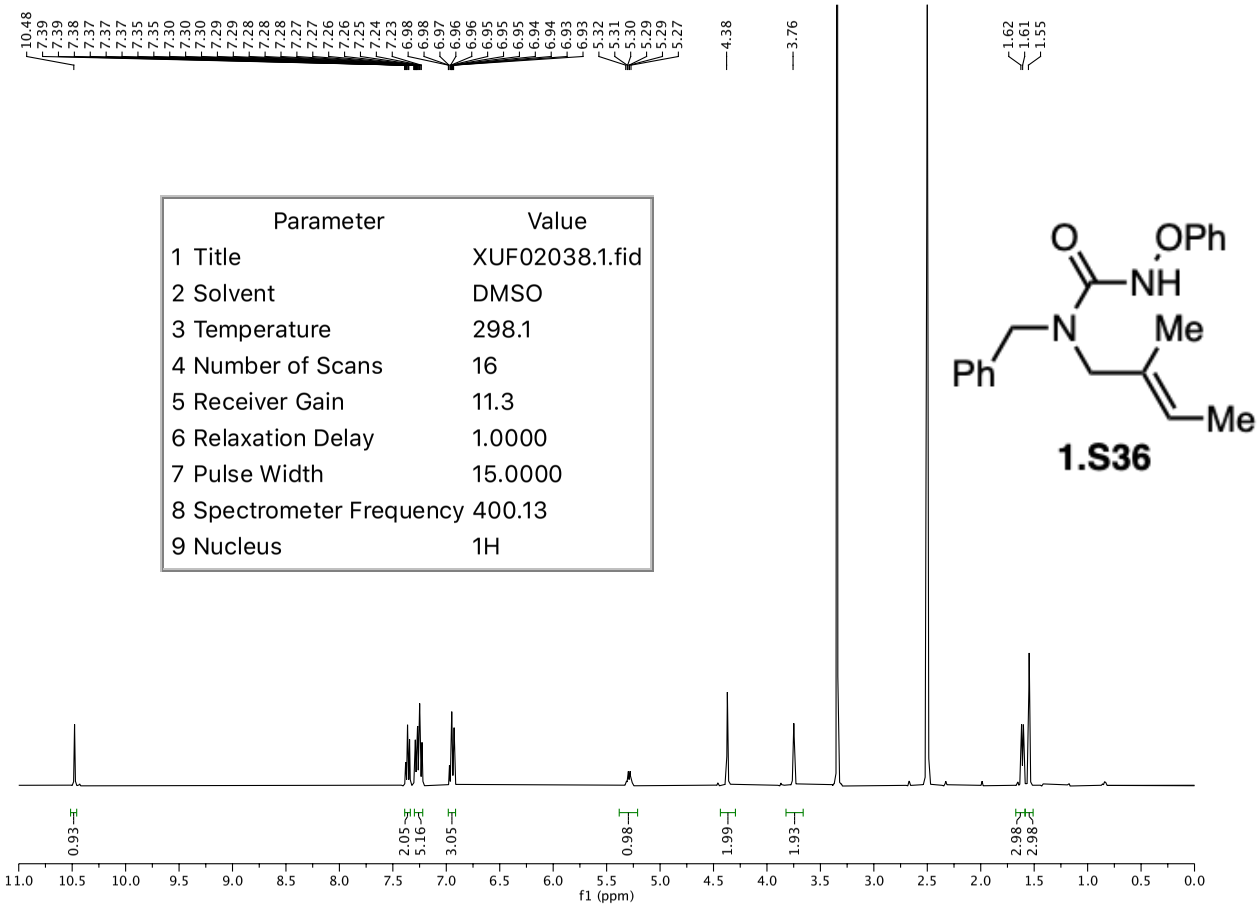

159.98
159.35
135.79
133.61
130.01
129.48
129.38
129.02
125.61
122.58
113.35
49.92
48.74
17.85
Cl
N
O
N
H
OPh
Me
1.S33
Parameter Value
1 Title XUF01087.5.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

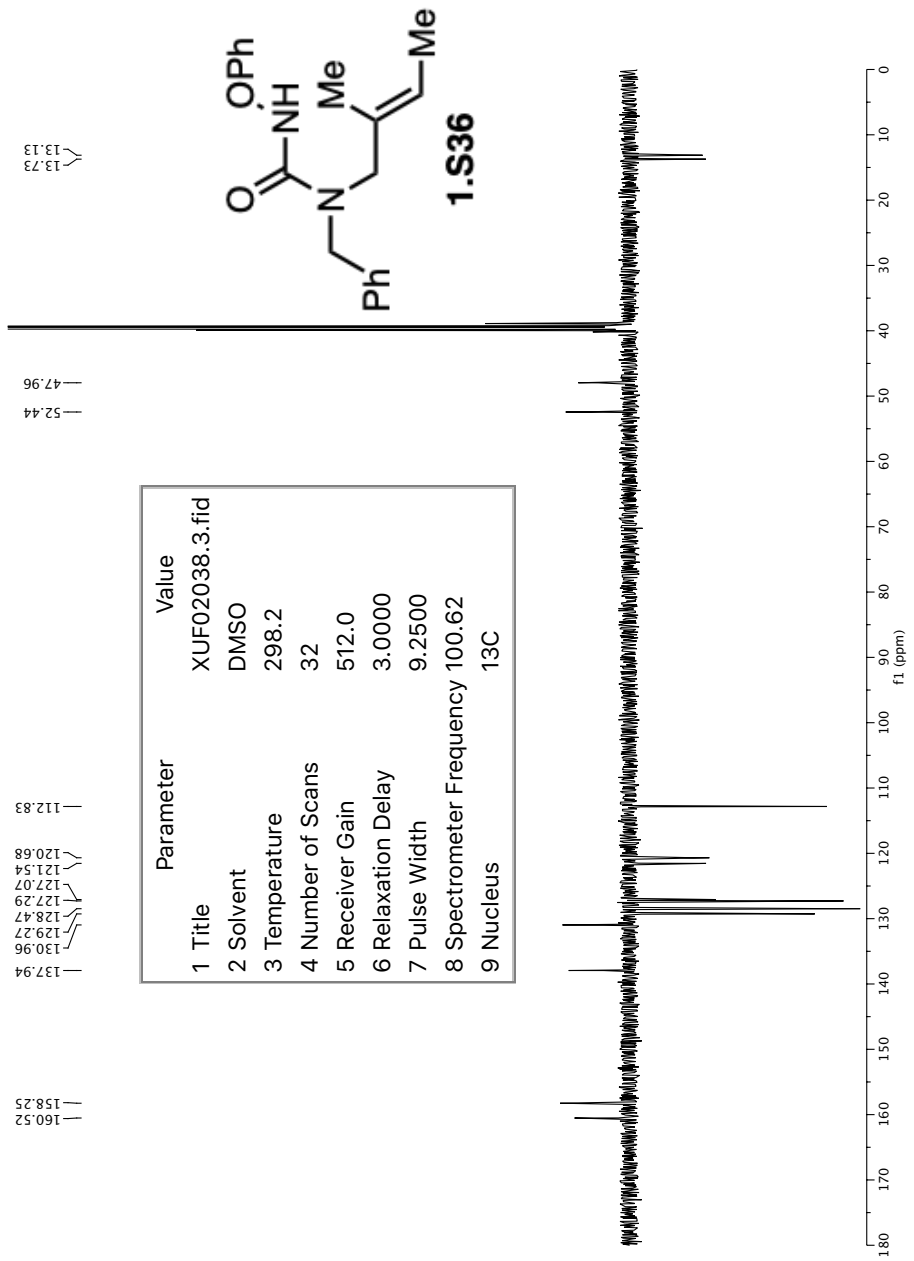

1.S34
Br
Me
OPh
O
N
H
Parameter Value
1 Title XUF01203.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

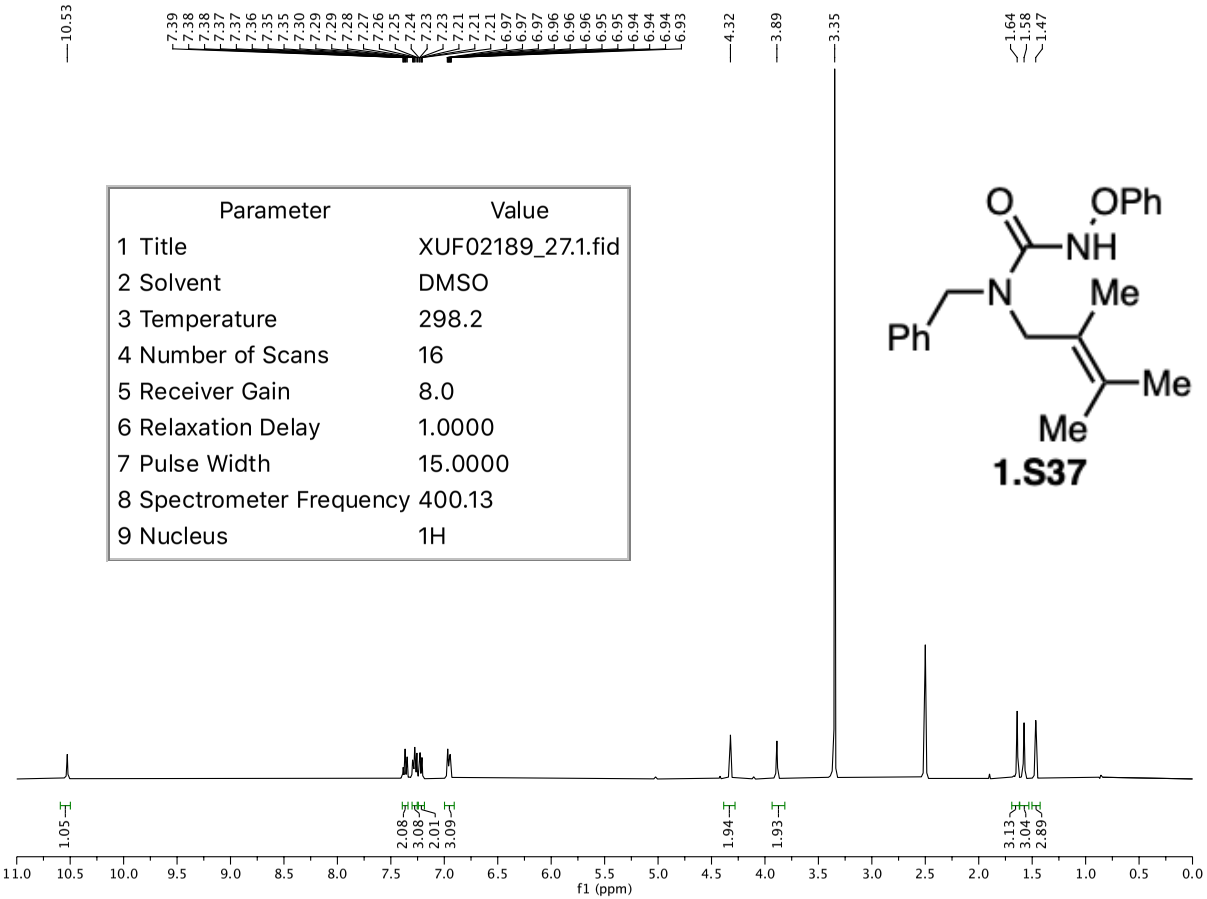

160.43
157.96
137.67
131.34
129.64
129.30
128.44
126.04
121.59
120.10
112.87
47.89
47.58
17.57
Parameter Value
1 Title XUF01203.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
N
H
OPh
Br
Me
1.S34
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

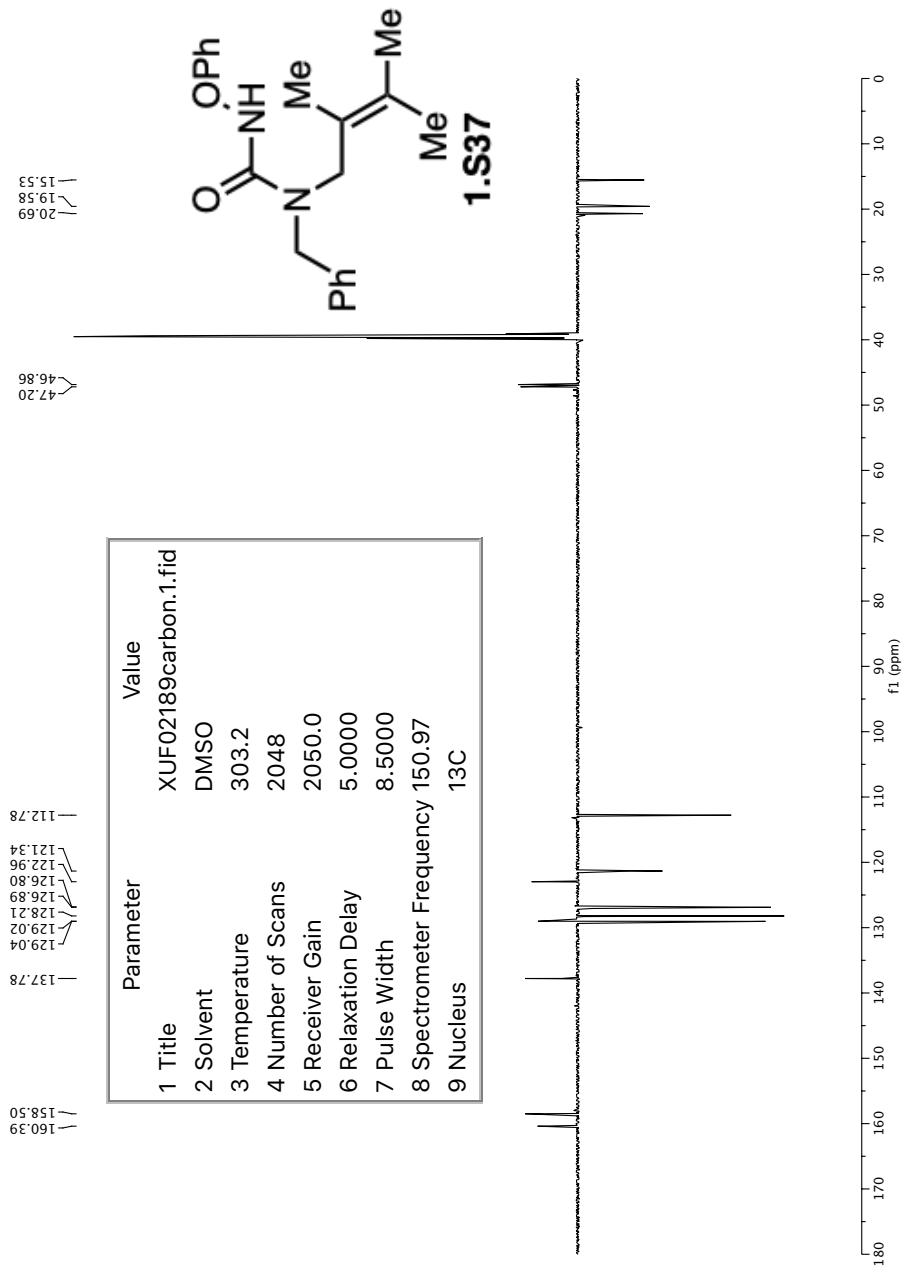

Parameter Value
1 Title XUF02146.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.S35
f1 (ppm)

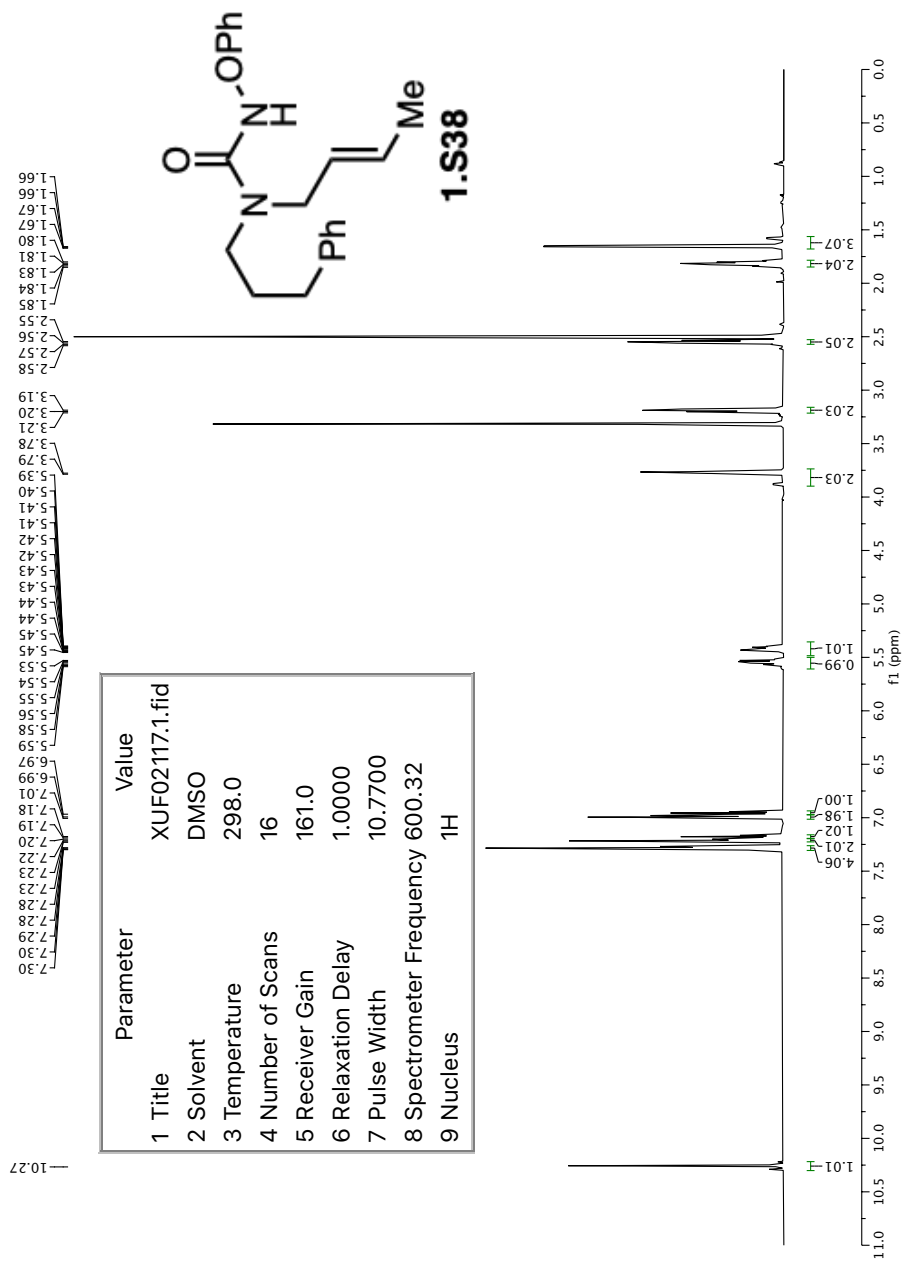

160.48
158.21
138.00
135.44
129.30
128.48
127.31
127.11
121.53
119.98
112.88
48.29
43.24
25.57
17.68
O
Ph
N
N
H
OPh
Me
Me
1.S35
Parameter Value
1 Title XUF02146.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


10.48
7.39
7.39
7.38
7.37
7.37
7.37
7.35
7.35
7.30
7.30
7.29
7.29
7.28
7.28
7.28
7.27
7.27
7.26
7.26
7.25
7.24
7.23
6.98
6.98
6.97
6.96
6.96
6.95
6.95
6.94
6.94
6.93
6.93
5.32
5.31
5.30
5.29
5.29
5.27
4.38
3.76
1.62
1.61
1.55
Parameter Value
1 Title XUF02038.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OPh
NH
N
Me
Ph
Me
1.S36
0.93
2.05
5.16
3.05
0.98
1.99
1.93
2.98
2.98
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


OPh
NH
O
N
Me
Me
Ph
1.S36
Parameter Value
1 Title XUF02038.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
160.52
158.25
137.94
130.96
129.27
128.47
127.29
127.07
121.54
120.68
112.83
52.44
47.96
13.73
13.13
f1 (ppm)


10.53
7.39
7.38
7.38
7.37
7.37
7.36
7.35
7.35
7.30
7.29
7.29
7.28
7.27
7.26
7.25
7.24
7.23
7.23
7.21
7.21
6.97
6.97
6.97
6.96
6.96
6.95
6.95
6.94
6.94
6.94
6.93
4.32
3.89
3.35
1.64
1.58
1.47
Parameter Value
1 Title XUF02189_27.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OPh
NH
N
Me
Ph
Me
Me
1.S37
1.05
2.08
3.08
2.01
3.09
1.94
1.93
3.13
3.04
2.89
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


OPh
NH
O
N
Ph
Me
Me
1.S37
160.39
158.50
137.78
129.04
129.02
128.21
126.89
126.80
122.96
121.34
112.78
47.20
46.86
20.69
19.58
15.53
Parameter
Value
1 Title
XUF02189carbon.1.fid
2 Solvent
DMSO
3 Temperature
303.2
4 Number of Scans
2048
5 Receiver Gain
2050.0
6 Relaxation Delay
5.0000
7 Pulse Width
8.5000
8 Spectrometer Frequency
150.97
9 Nucleus
13C
f1 (ppm)


OPh
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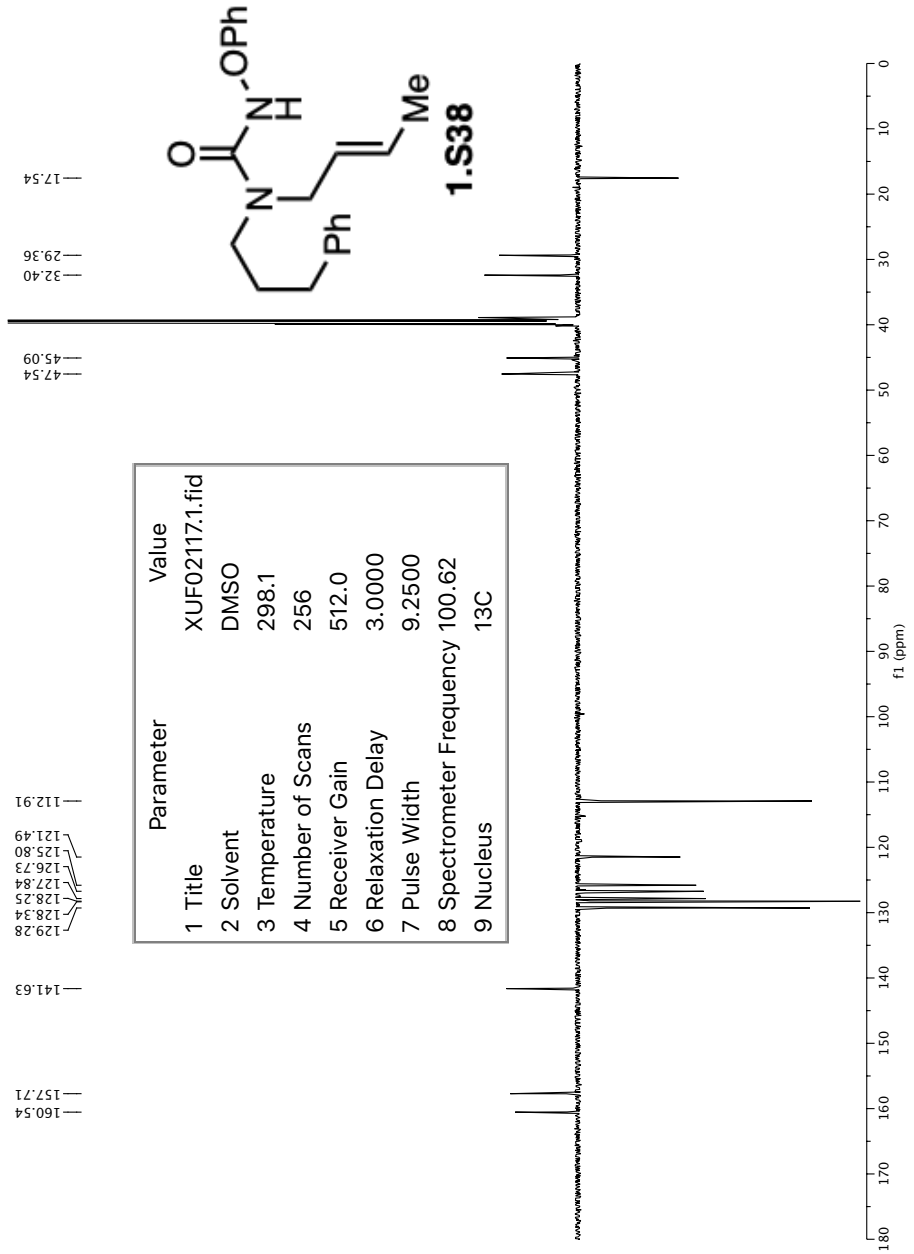
H
O
N
Ph
Me
1.S38
Parameter Value
1 Title XUF02117.1.fid
2 Solvent DMSO
3 Temperature 298.0
4 Number of Scans 16
5 Receiver Gain 161.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.7700
8 Spectrometer Frequency 600.32
9 Nucleus 1H
f1 (ppm)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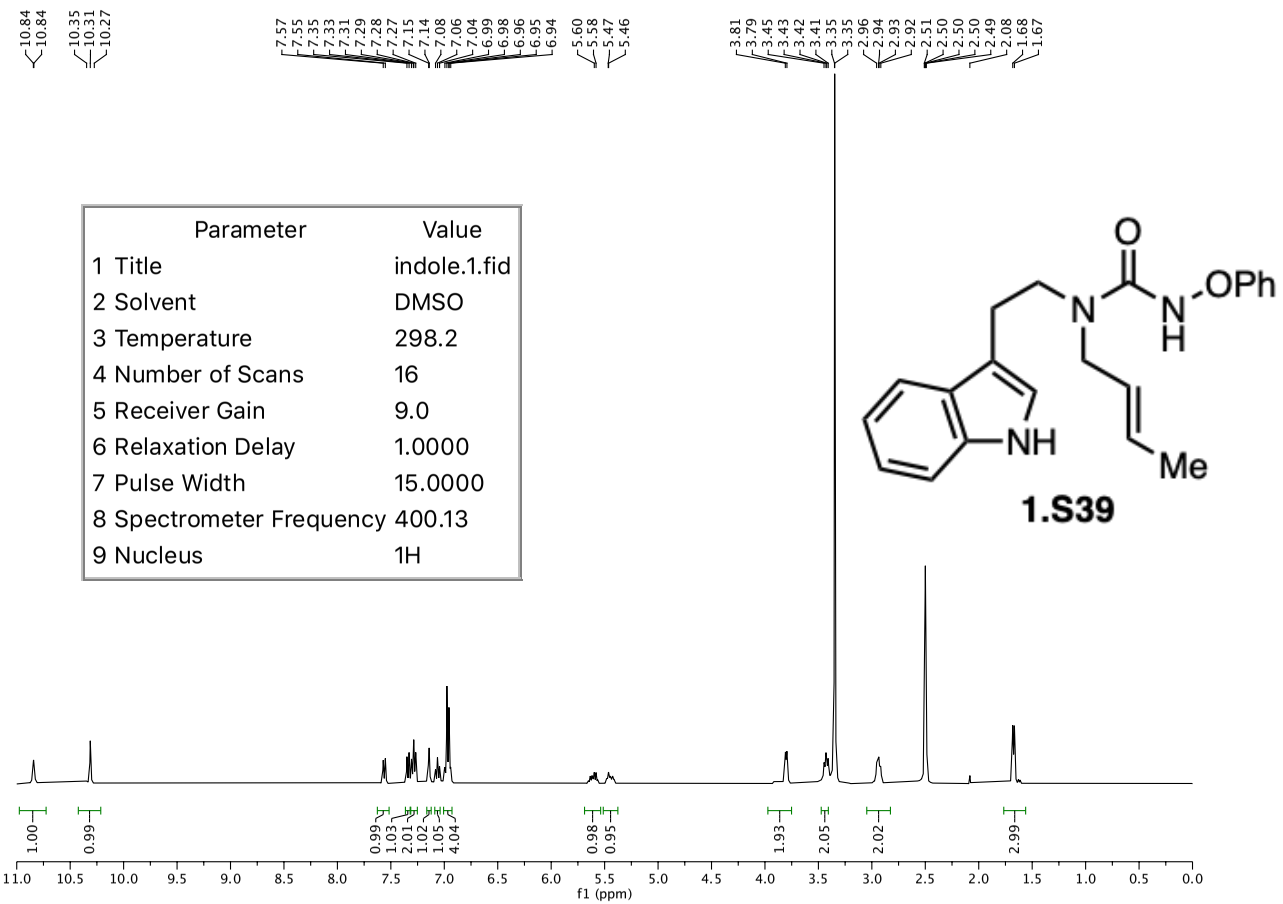
Parameter Value
1 Title XUF02117.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
160.54
157.71
141.63
129.28
128.34
128.25
127.84
126.73
125.80
121.49
112.91
47.54
45.09
32.40
29.36
17.54
f1 (ppm)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10.84
10.35
10.31
10.27
7.57
7.55
7.35
7.33
7.31
7.29
7.28
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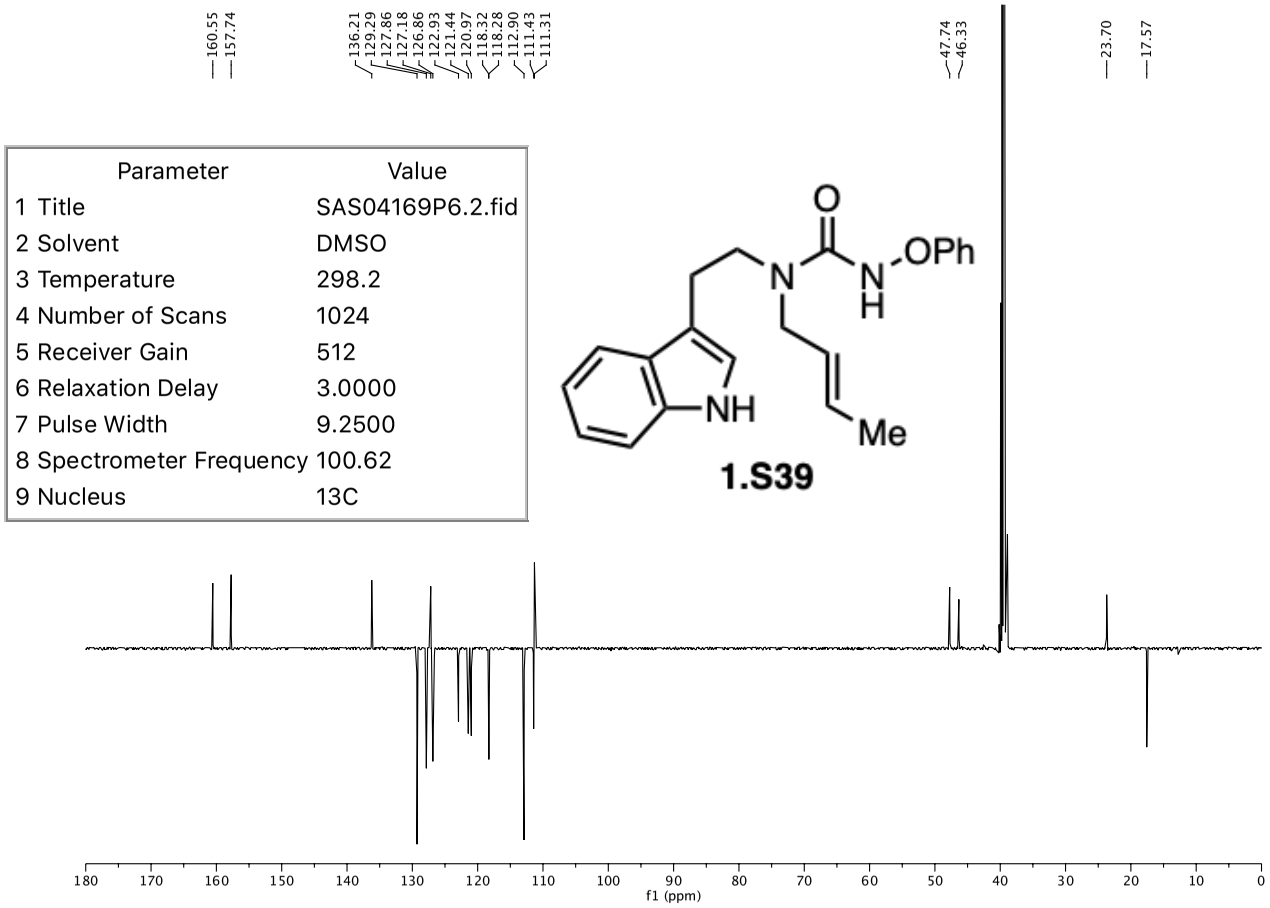
7.15
7.14
7.08
7.06
7.04
6.99
6.98
6.96
6.95
6.94
5.60
5.58
5.47
5.46
3.81
3.79
3.45
3.43
3.42
3.41
3.35
3.35
2.96
2.94
2.93
2.92
2.51
2.50
2.50
2.50
2.49
2.08
1.68
1.67
Parameter Value
1 Title indole.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
N
H
OPh
NH
Me
1.S39
1.00
0.99
0.99
1.03
2.01
1.02
1.05
4.04
0.98
0.95
1.93
2.05
2.02
2.99
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


160.55
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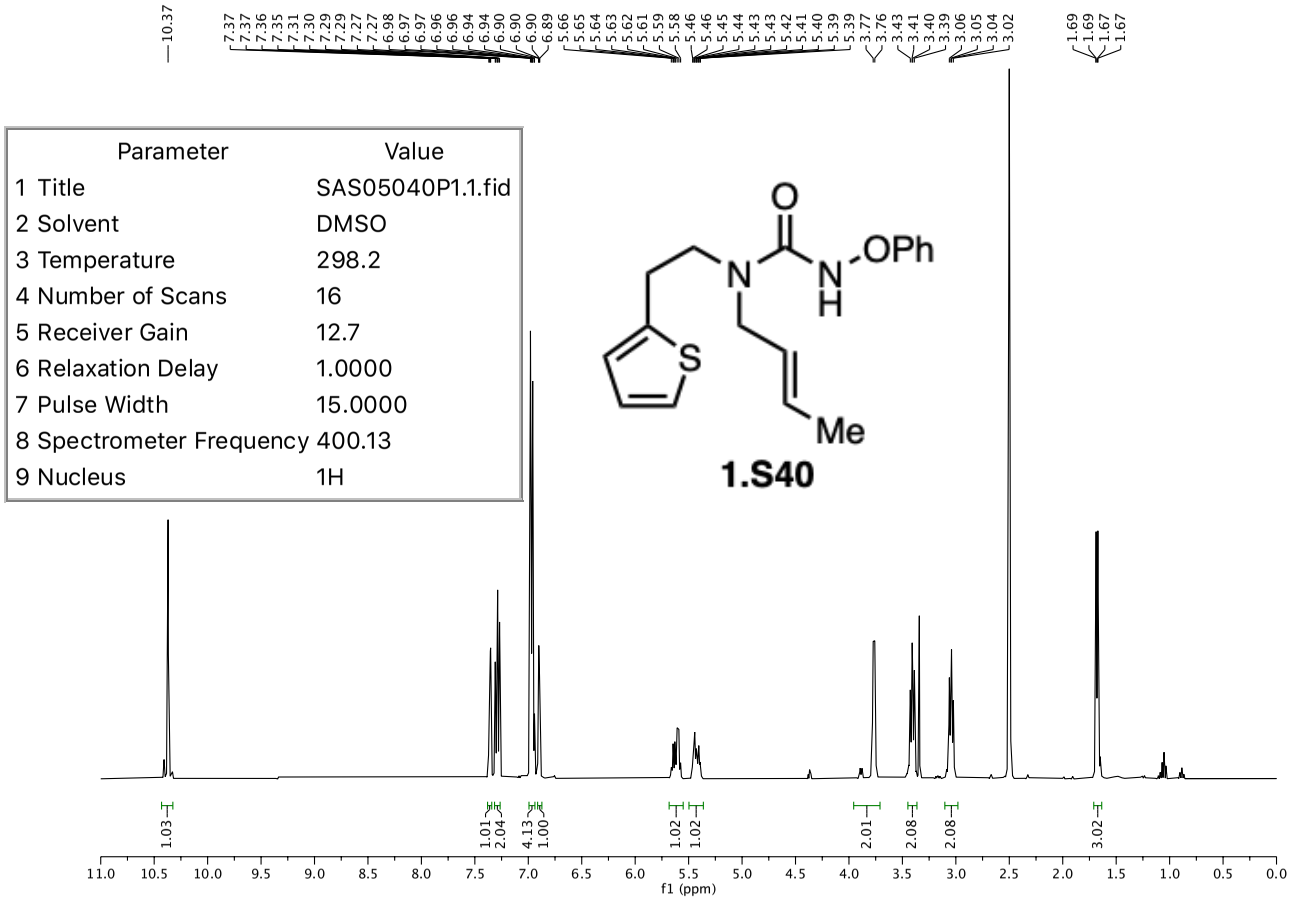
136.21
129.29
127.86
127.18
126.86
122.93
121.44
120.97
118.32
118.28
112.90
111.43
111.31
47.74
46.33
23.70
17.57
Parameter Value
1 Title SAS04169P6.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
N
H
OPh
NH
Me
1.S39
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


10.37
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7.37
7.36
7.35
7.31
7.30
7.29
7.29
7.27
7.27
6.98
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6.97
6.96
6.96
6.94
6.94
6.90
6.90
6.90
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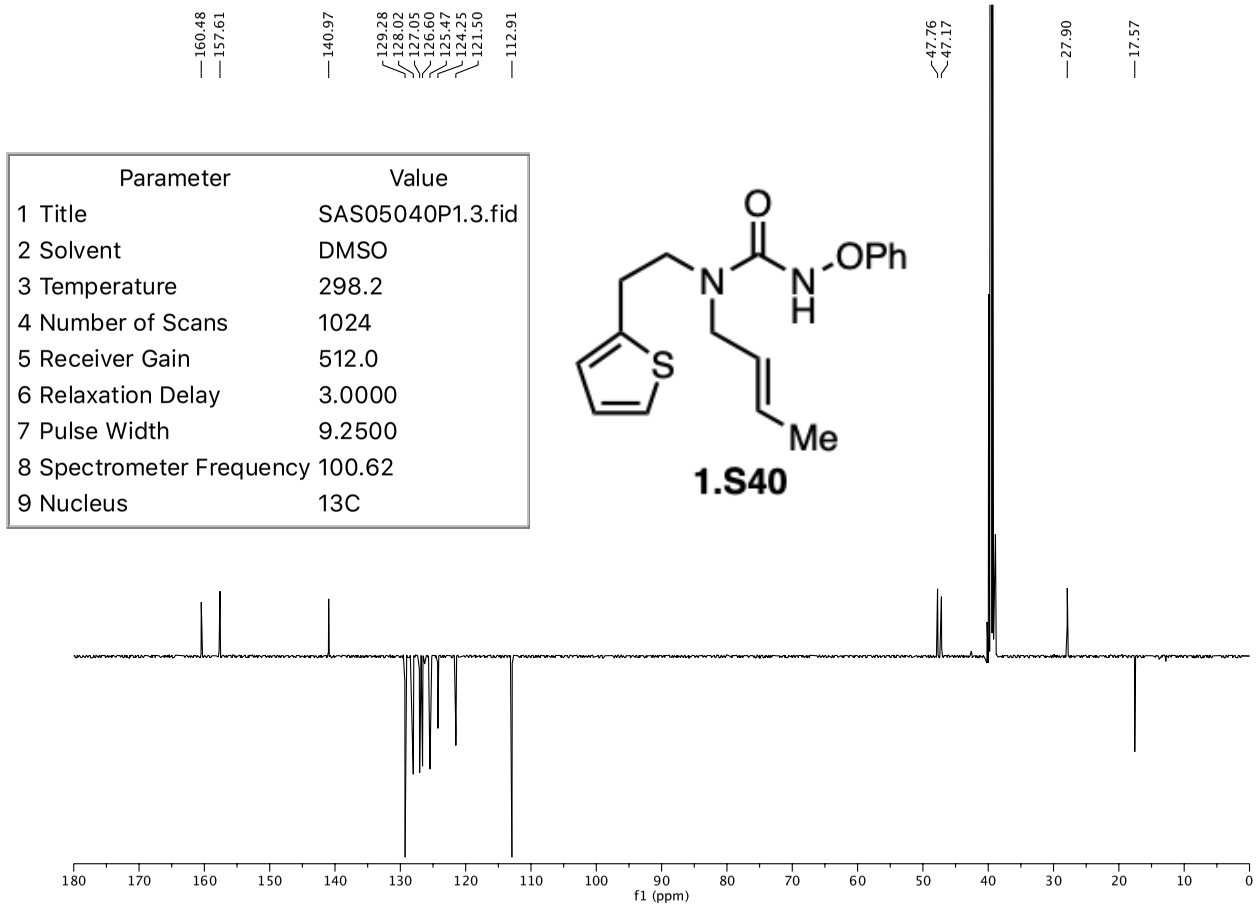
5.65
5.64
5.63
5.62
5.61
5.59
5.58
5.46
5.46
5.45
5.44
5.43
5.43
5.42
5.41
5.40
5.39
5.39
3.77
3.76
3.43
3.41
3.40
3.39
3.06
3.05
3.04
3.02
1.69
1.69
1.67
1.67
Parameter Value
1 Title SAS05040P1.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
N
H
OPh
S
Me
1.S40
1.03
1.01
2.04
4.13
1.00
1.02
1.02
2.01
2.08
2.08
3.02
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


160.48
157.61
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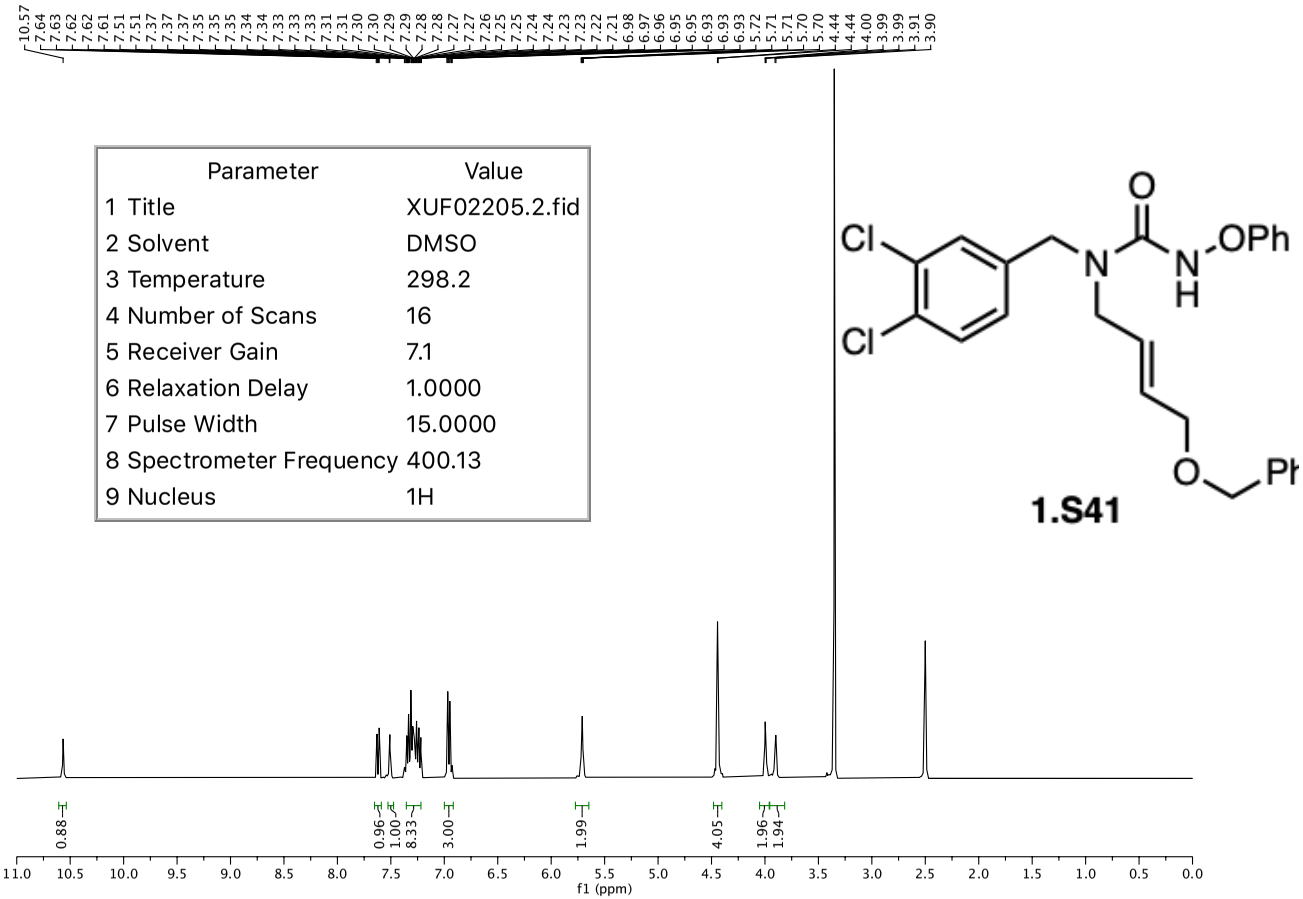
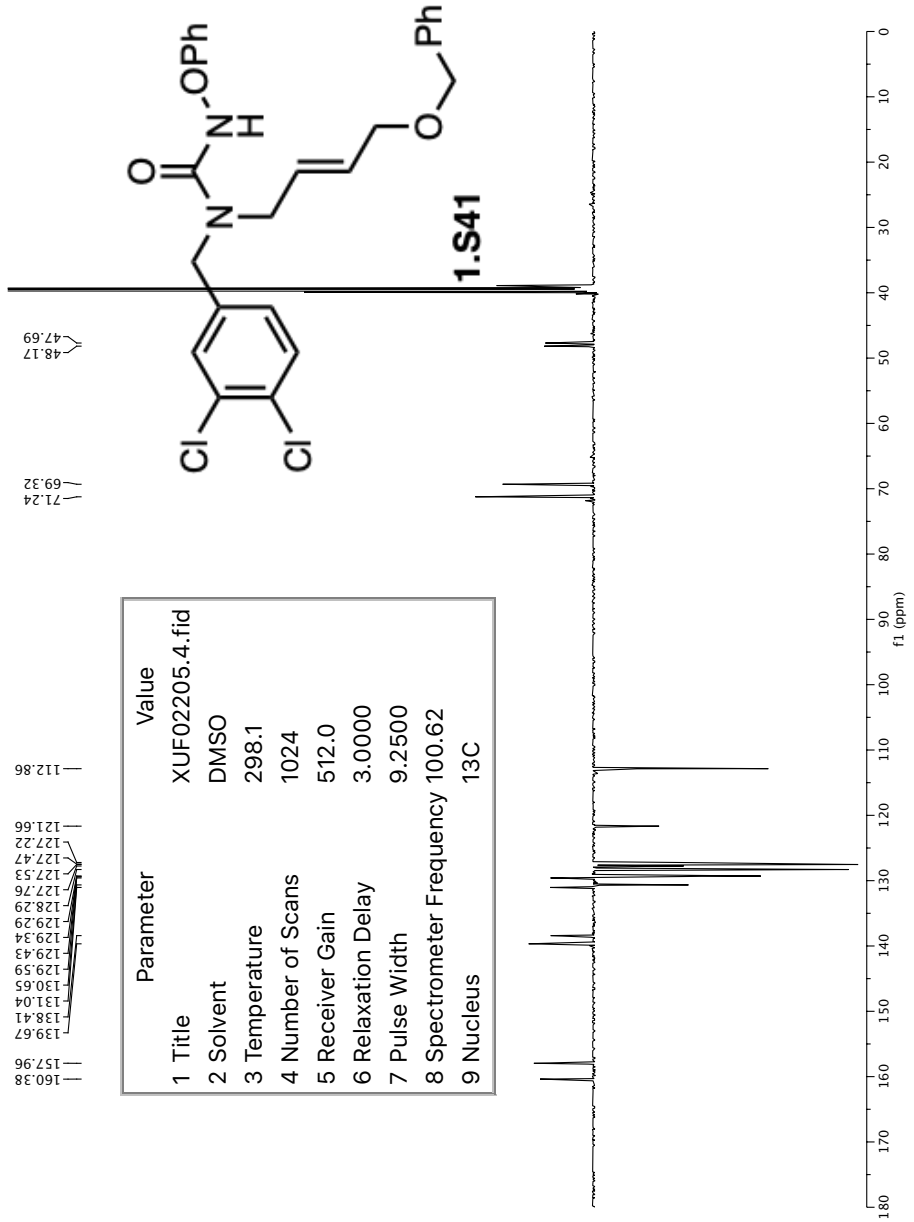
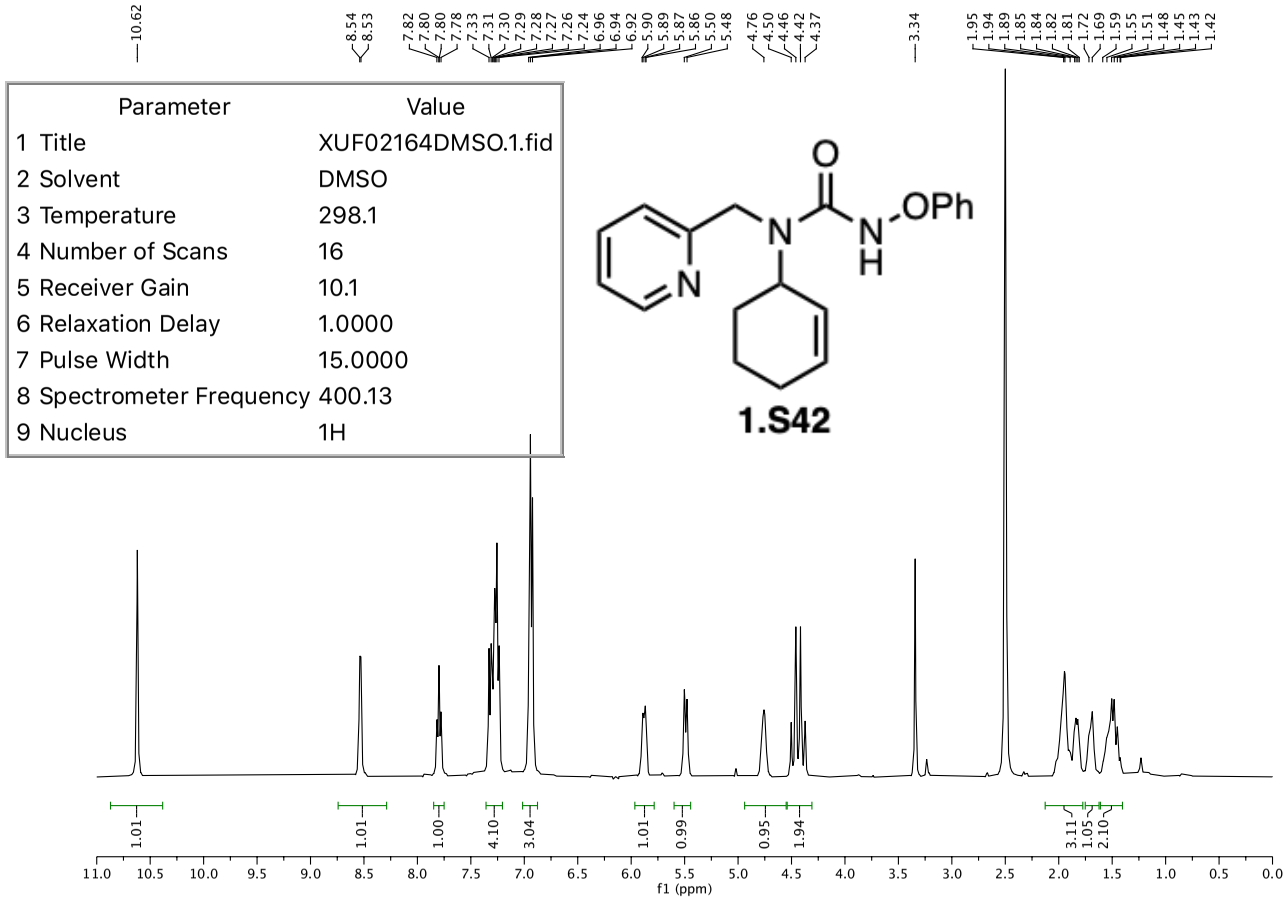
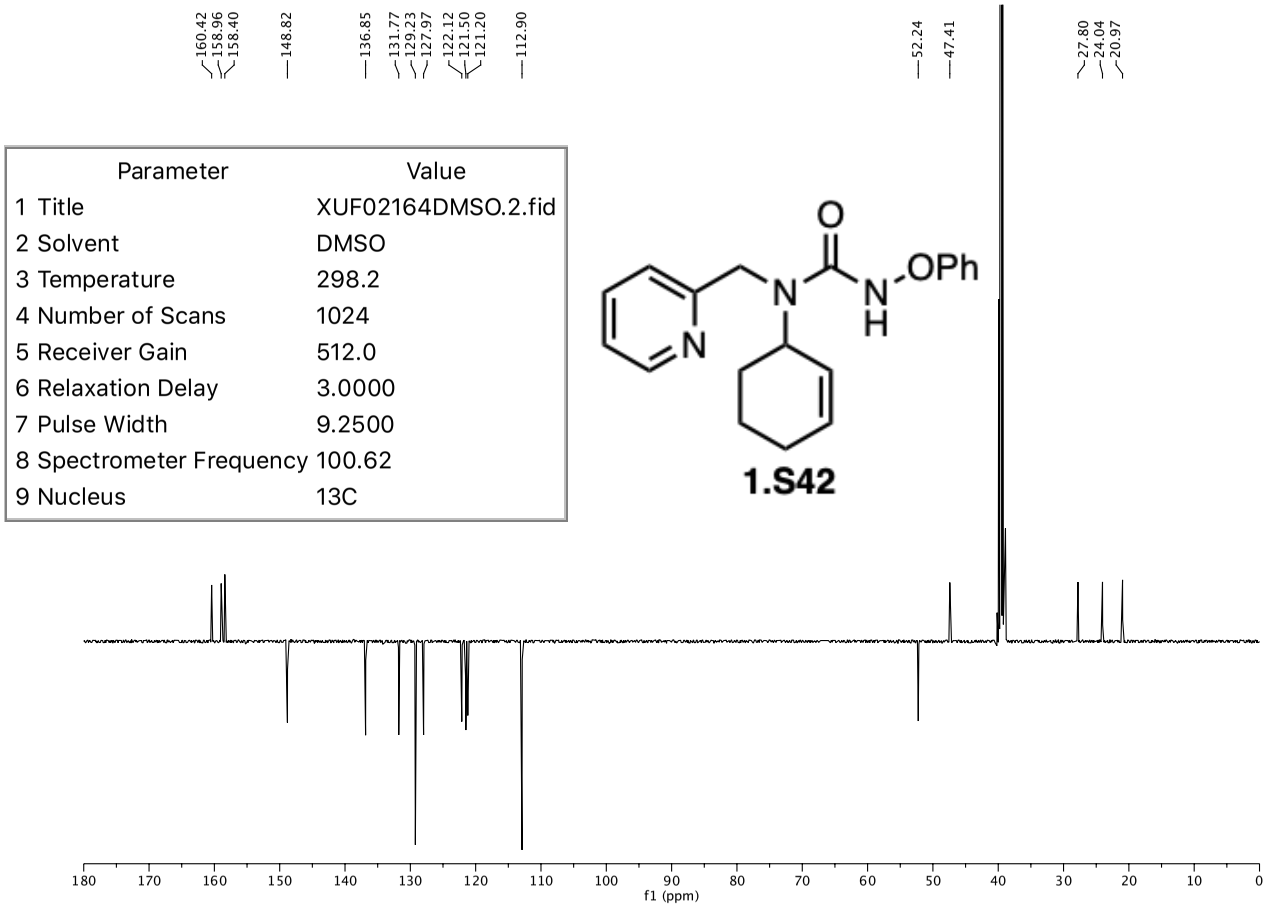
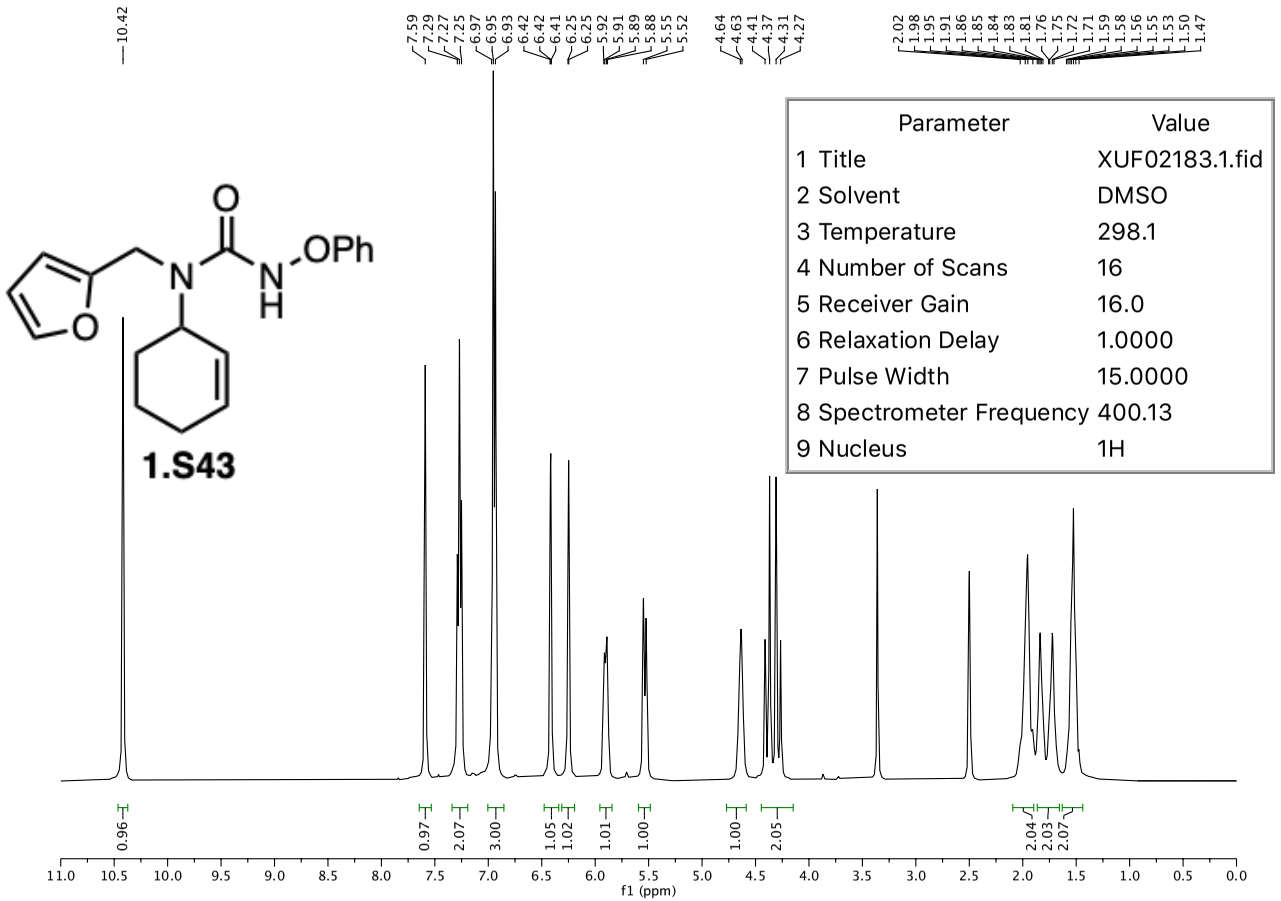
129.28
128.02
127.05
126.60
125.47
124.25
121.50
112.91
47.76
47.17
27.90
17.57
Parameter Value
1 Title SAS05040P1.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
N
H
OPh
S
Me
1.S40
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

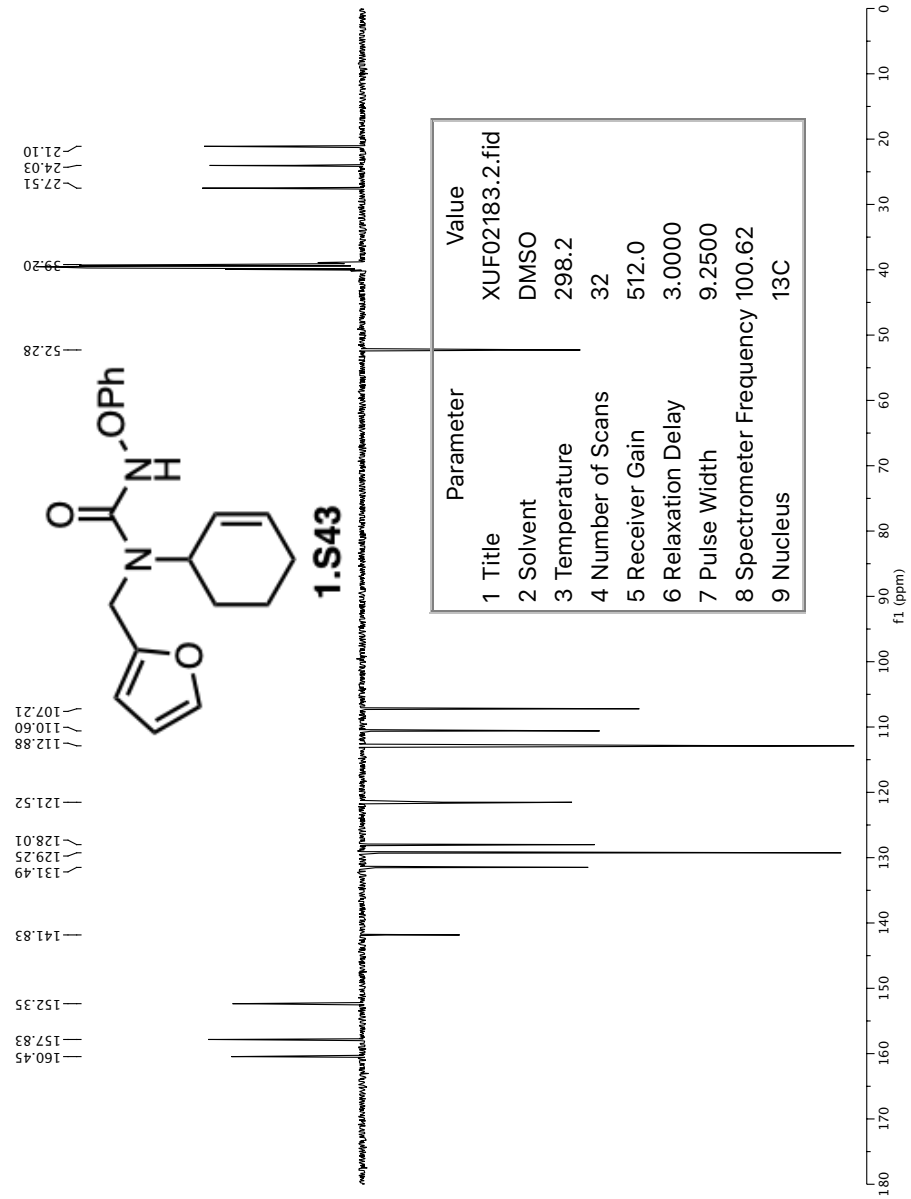

10.57
7.64
7.63
7.62
7.61
7.51
7.51
7.37
7.37
7.35
7.35
7.35
7.34
7.34
7.33
7.33
7.31
7.31
7.30
7.30
7.29
7.29
7.28
7.28
7.27
7.27
7.26
7.25
7.25
7.24
7.24
7.23
7.23
7.22
7.21
6.98
6.97
6.96
6.95
6.95
6.93
6.93
5.72
5.71
5.71
5.70
5.70
4.44
4.44
4.00
3.99
3.99
3.91
3.90
Parameter
Value
1 Title
XUF02205.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
7.1
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
Cl
Cl
N
O
N
H
OPh
O
Ph
1.S41
0.88
0.96
1.00
8.33
3.00
1.99
4.05
1.96
1.94
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

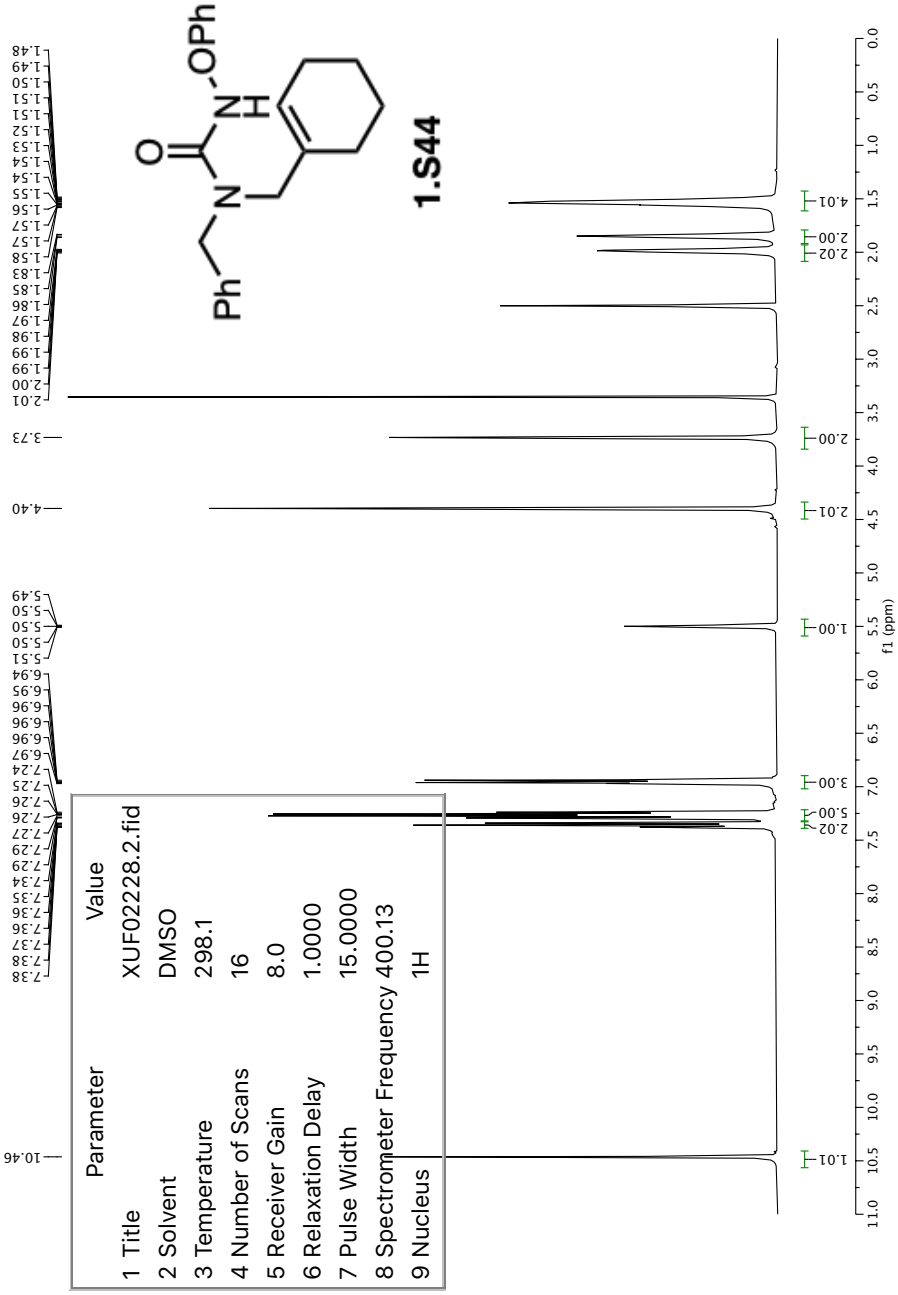

1.S41
Cl
Cl
O
N
H
OPh
N
O
Ph
47.69
48.17
69.32
71.24
112.86
121.66
127.22
127.47
127.53
127.76
128.29
129.29
129.34
129.43
129.59
130.65
131.04
138.41
139.67
157.96
160.38
Parameter Value
1 Title XUF02205.4.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

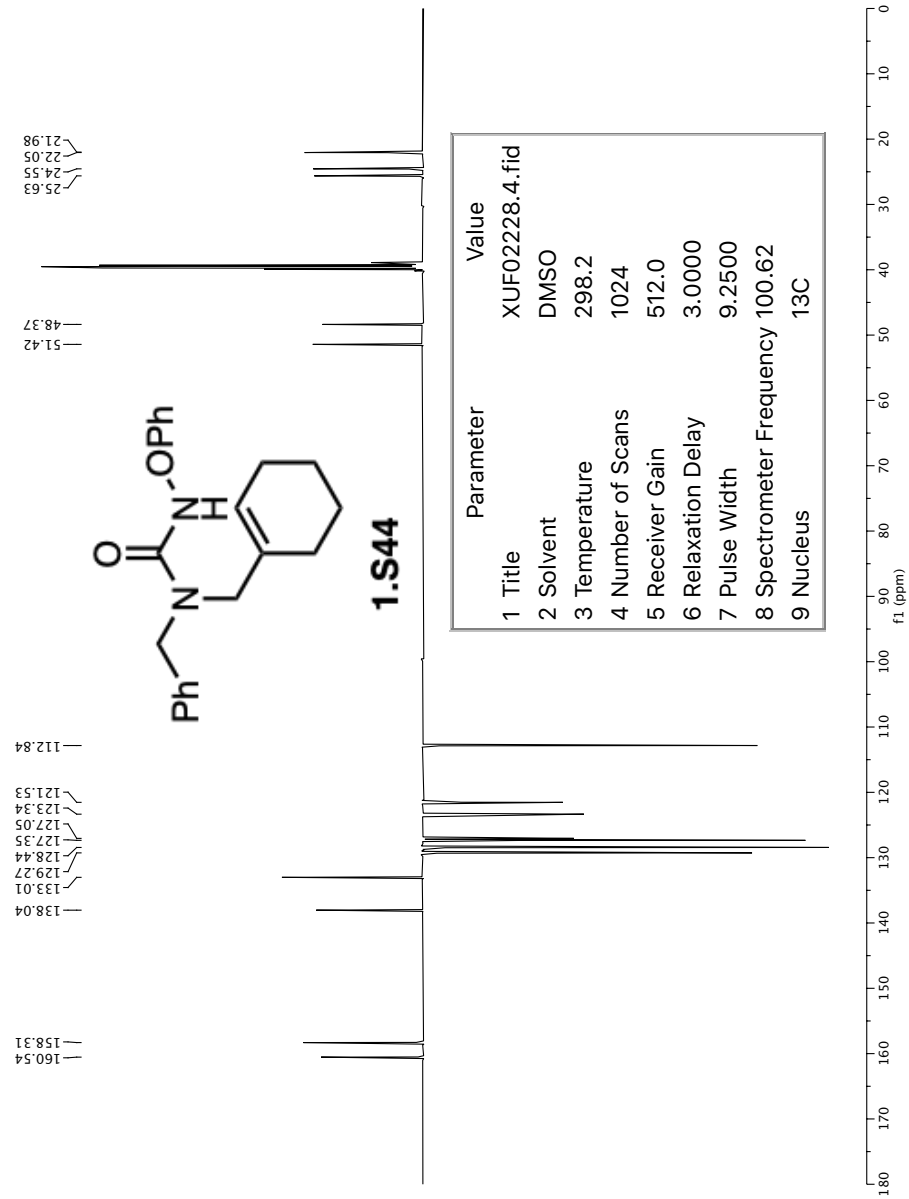

10.62
8.54
8.53
7.82
7.80
7.80
7.78
7.33
7.31
7.30
7.29
7.28
7.27
7.26
7.24
6.96
6.92
5.90
5.89
5.87
5.86
5.50
5.48
4.76
4.50
4.46
4.42
4.37
3.34
1.95
1.94
1.89
1.85
1.84
1.82
1.81
1.72
1.69
1.59
1.55
1.51
1.48
1.45
1.43
1.42
Parameter Value
1 Title XUF02164DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
N
H
OPh
1.S42
1.01
1.01
1.00
4.10
3.04
1.01
0.99
0.95
1.94
3.11
1.05
2.10
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

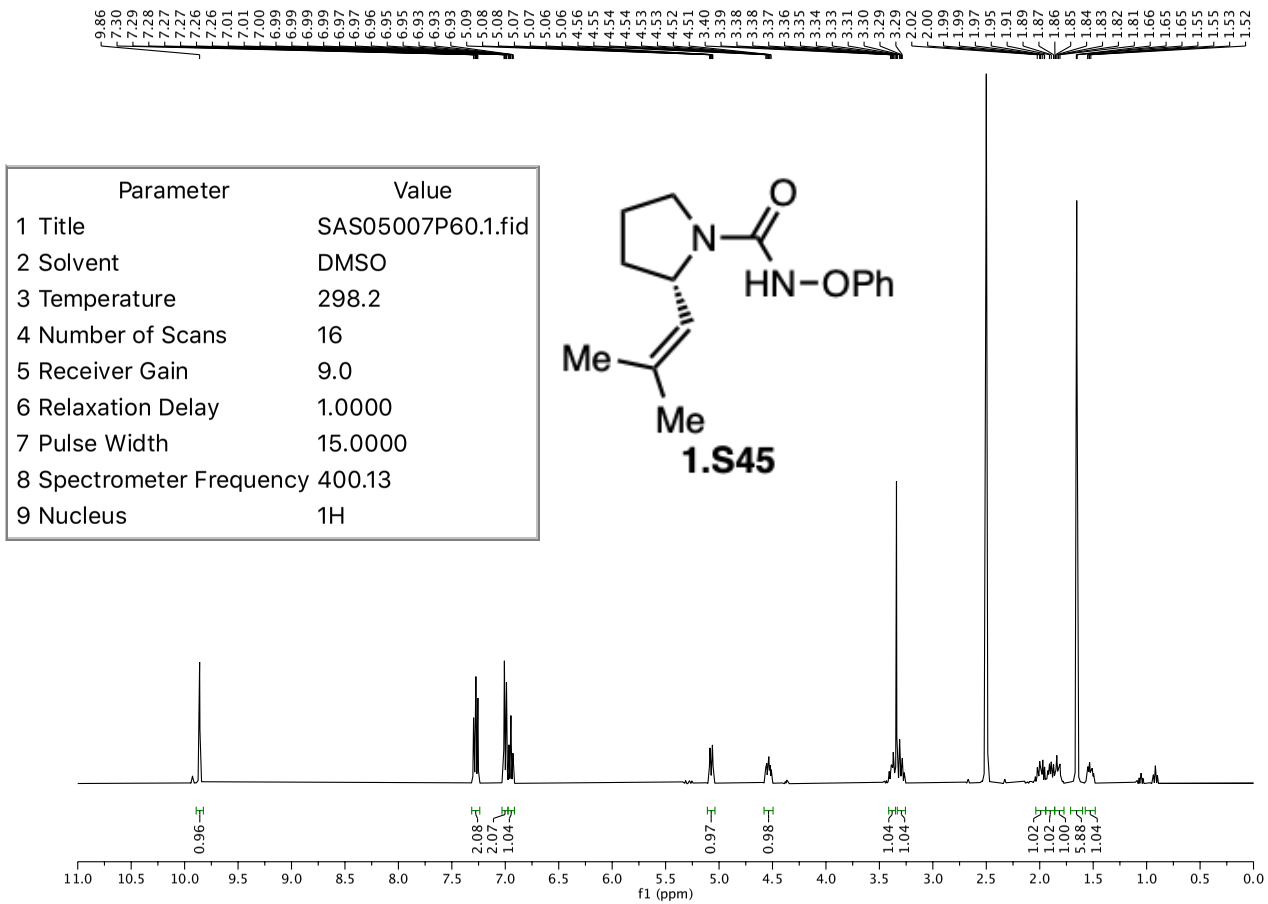

160.42
158.96
158.40
148.82
136.85
131.77
129.23
127.97
122.12
121.50
121.20
112.90
52.24
47.41
27.80
24.04
20.97
Parameter Value
1 Title XUF02164DMSO.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
N
H
OPh
N
1.S42
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

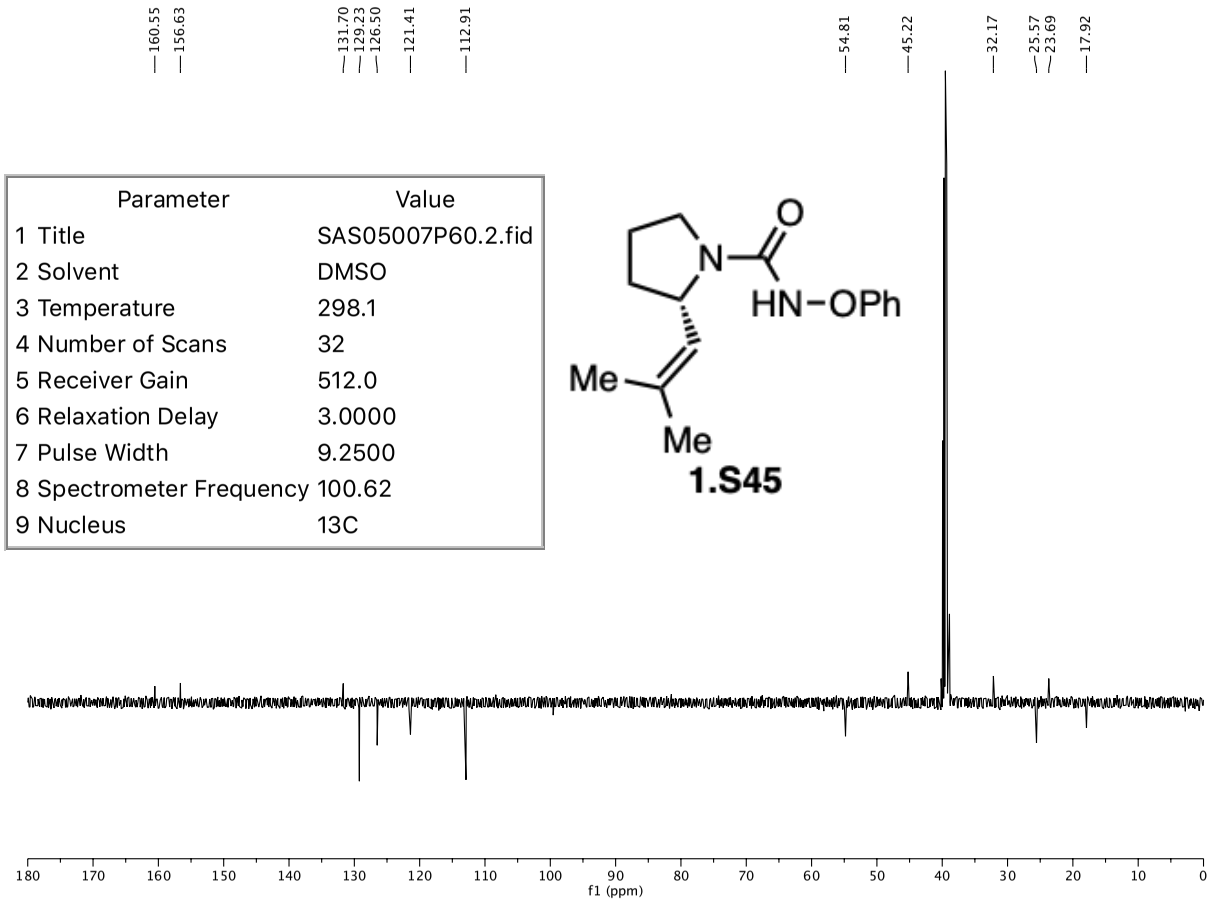

10.42
7.59
7.29
7.27
7.25
6.97
6.95
6.93
6.42
6.42
6.41
6.25
6.25
5.92
5.91
5.89
5.88
5.55
5.52
4.64
4.63
4.41
4.37
4.31
4.27
2.02
1.98
1.95
1.91
1.86
1.85
1.84
1.83
1.81
1.76
1.75
1.72
1.71
1.59
1.58
1.56
1.55
1.53
1.50
1.47
O
N
O
N
H
OPh
1.S43
Parameter Value
1 Title XUF02183.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 16.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
0.96
0.97
2.07
3.00
1.05
1.02
1.01
1.00
1.00
2.05
2.04
2.03
2.07
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

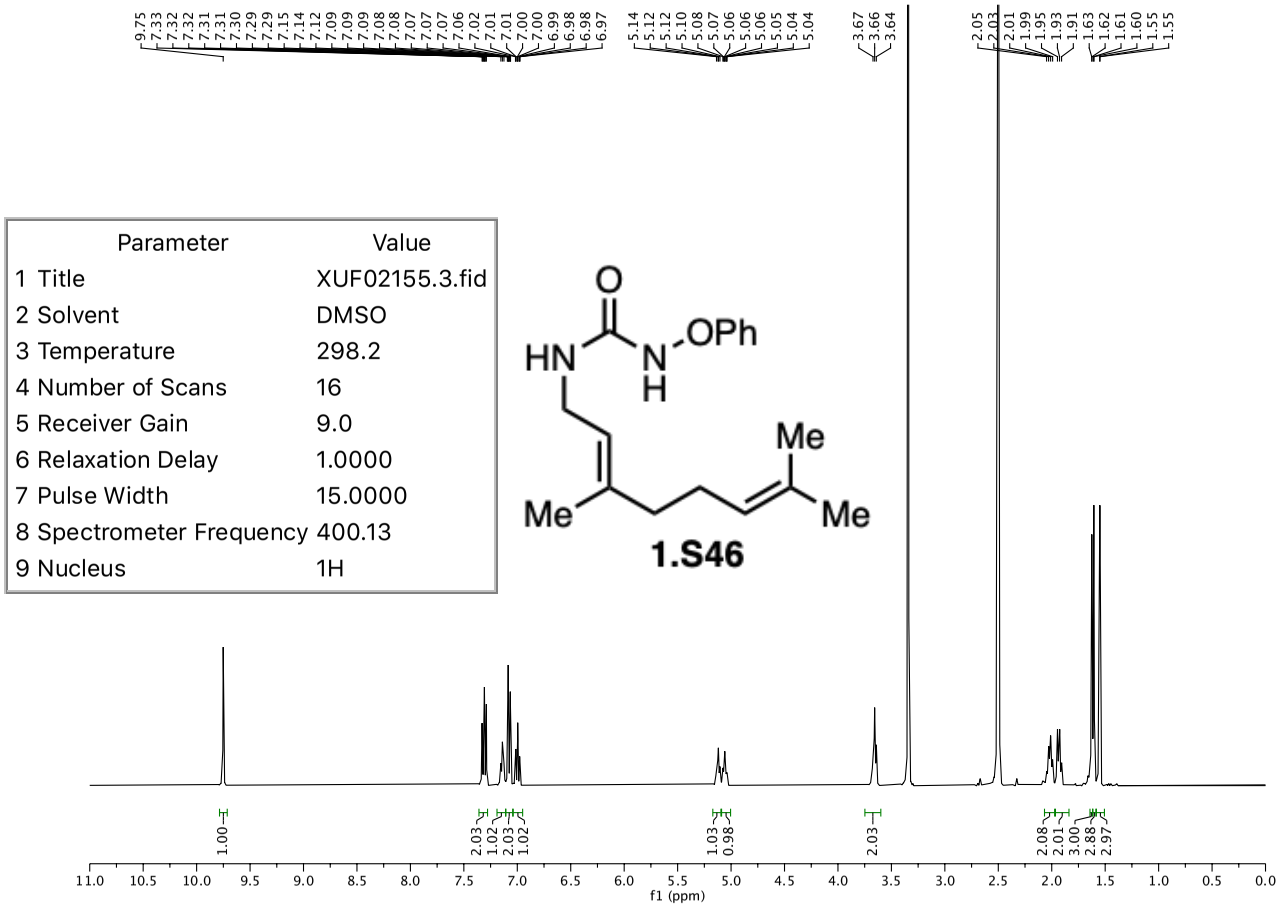

1.S43
Parameter
Value
1 Title
XUF02183.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
32
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
160.45
157.83
152.35
141.83
131.49
129.25
128.01
121.52
112.88
110.60
107.21
52.28
39.20
27.51
24.03
21.10
f1 (ppm)

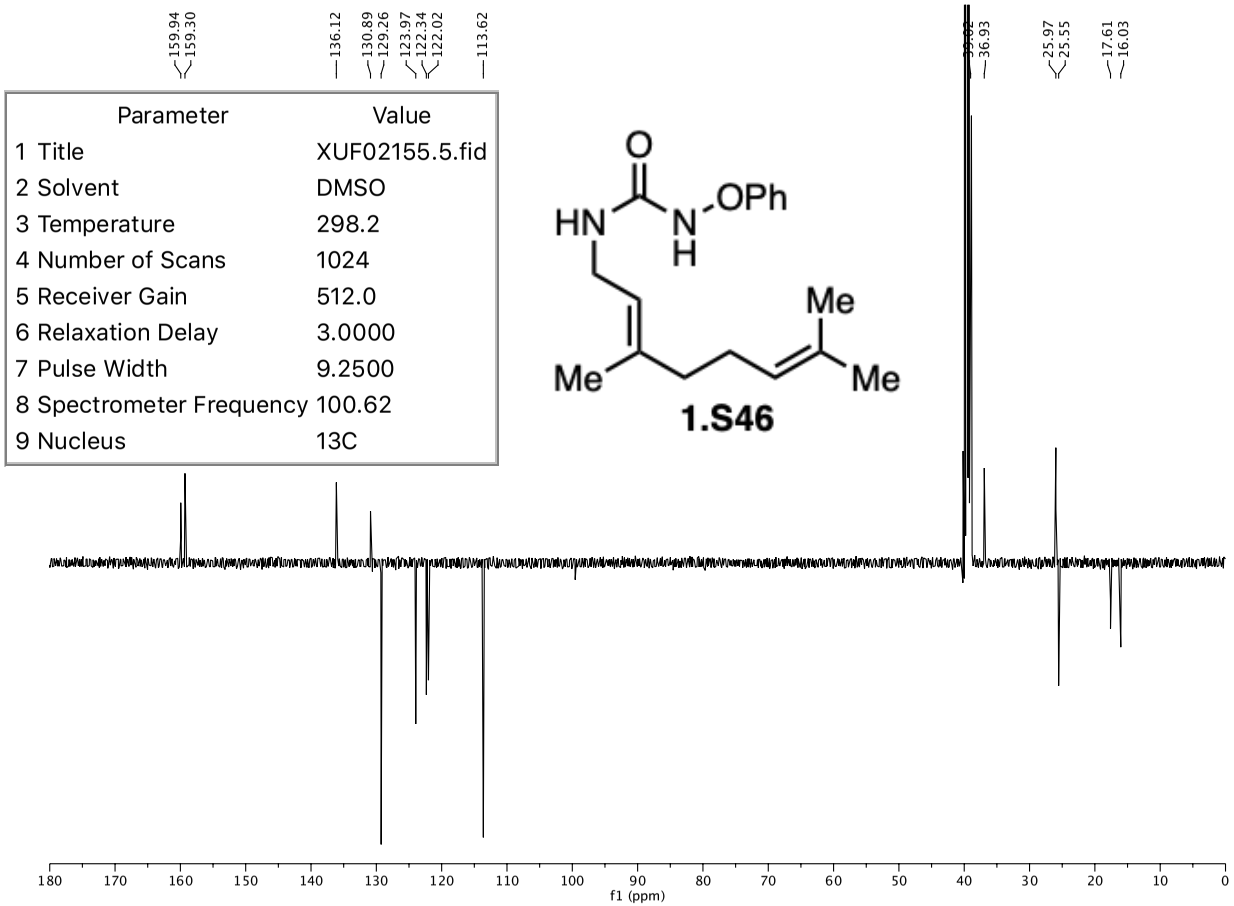

Parameter Value
1 Title XUF02228.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
H
OPh
N
Ph
1.S44
f1 (ppm)

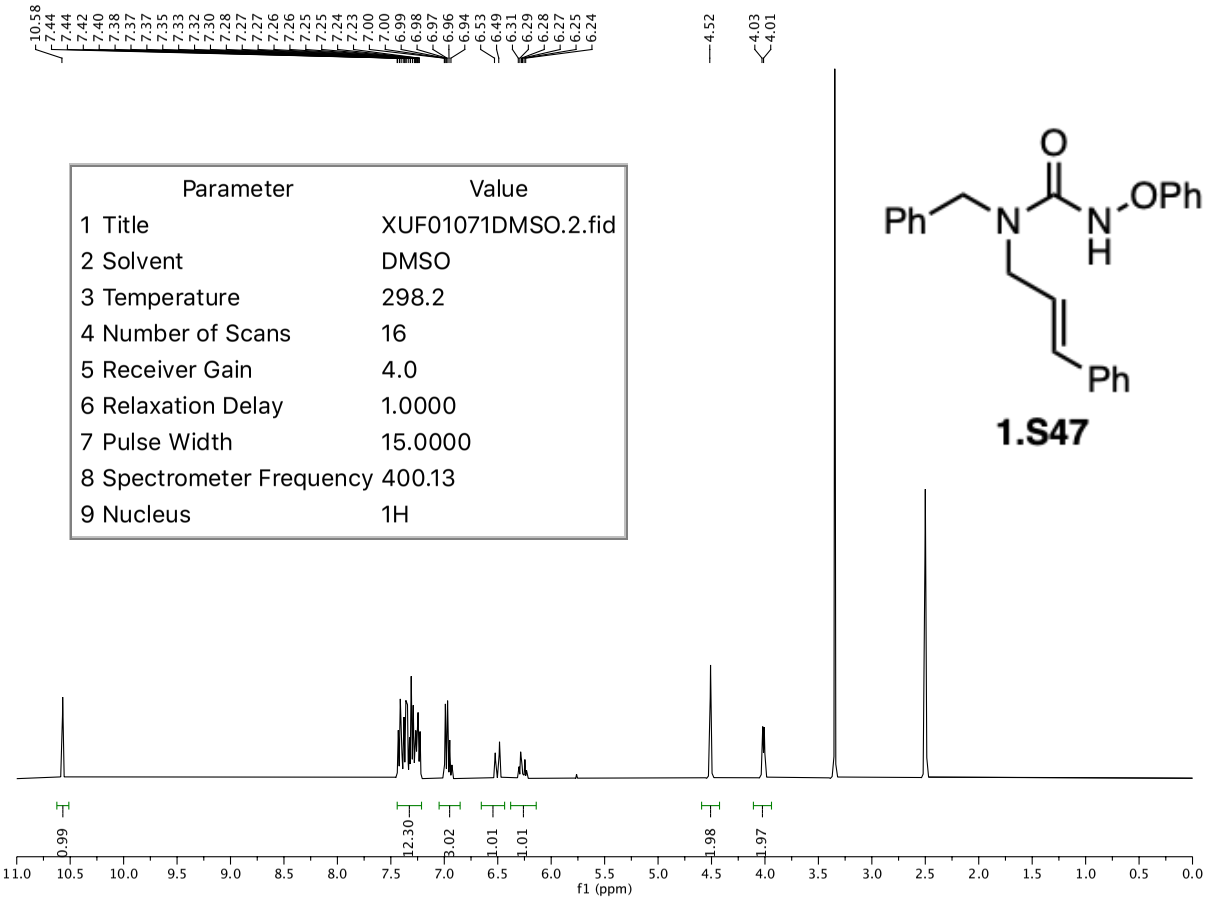

160.54
158.31
138.04
133.01
129.27
128.84
127.35
127.05
123.34
121.53
112.84
51.42
48.37
25.63
24.55
22.05
21.98
1.S44
Ph
N
H
N
O
OPh
Parameter
Value
1 Title
XUF02228.4.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

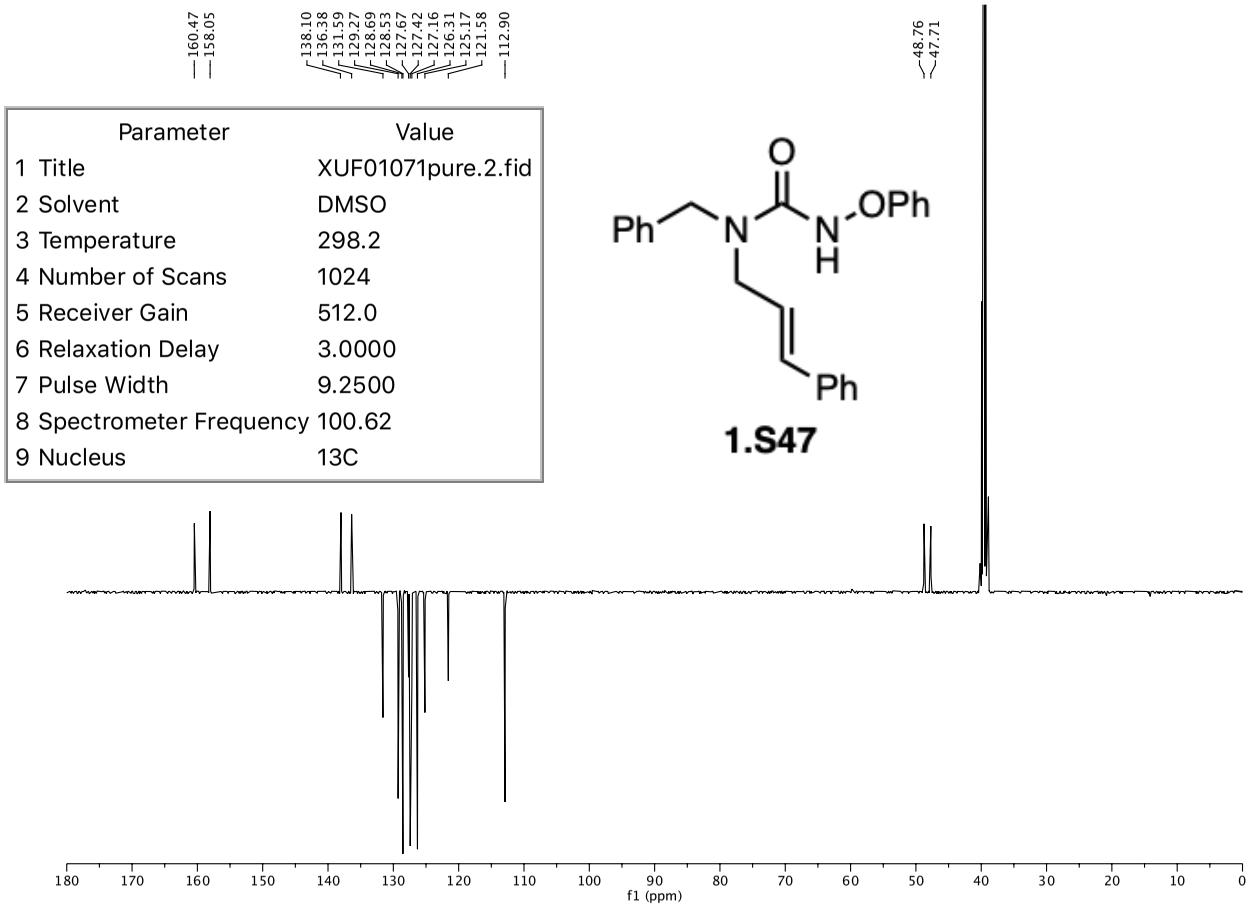

9.86 7.30 7.29 7.28 7.27 7.27 7.26 7.26 7.01 7.01 7.00 6.99 6.99 6.99 6.99 6.97 6.97 6.96 6.95 6.95 6.93 6.93 6.93 5.09 5.08 5.08 5.07 5.07 5.06 5.06 4.56 4.55 4.54 4.54 4.53 4.53 4.52 4.51 3.40 3.39 3.38 3.38 3.37 3.36 3.35 3.34 3.33 3.31 3.30 3.29 3.29 2.02 2.00 1.99 1.99 1.97 1.95 1.91 1.89 1.87 1.86 1.85 1.84 1.83 1.82 1.81 1.66 1.65 1.55 1.55 1.53 1.52
Parameter Value
1 Title SAS05007P60.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
HN−OPh
Me
Me
1.S45
0.96 2.08 2.07 1.04 0.97 0.98 1.04 1.04 1.02 1.02 1.00 5.88 1.04
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

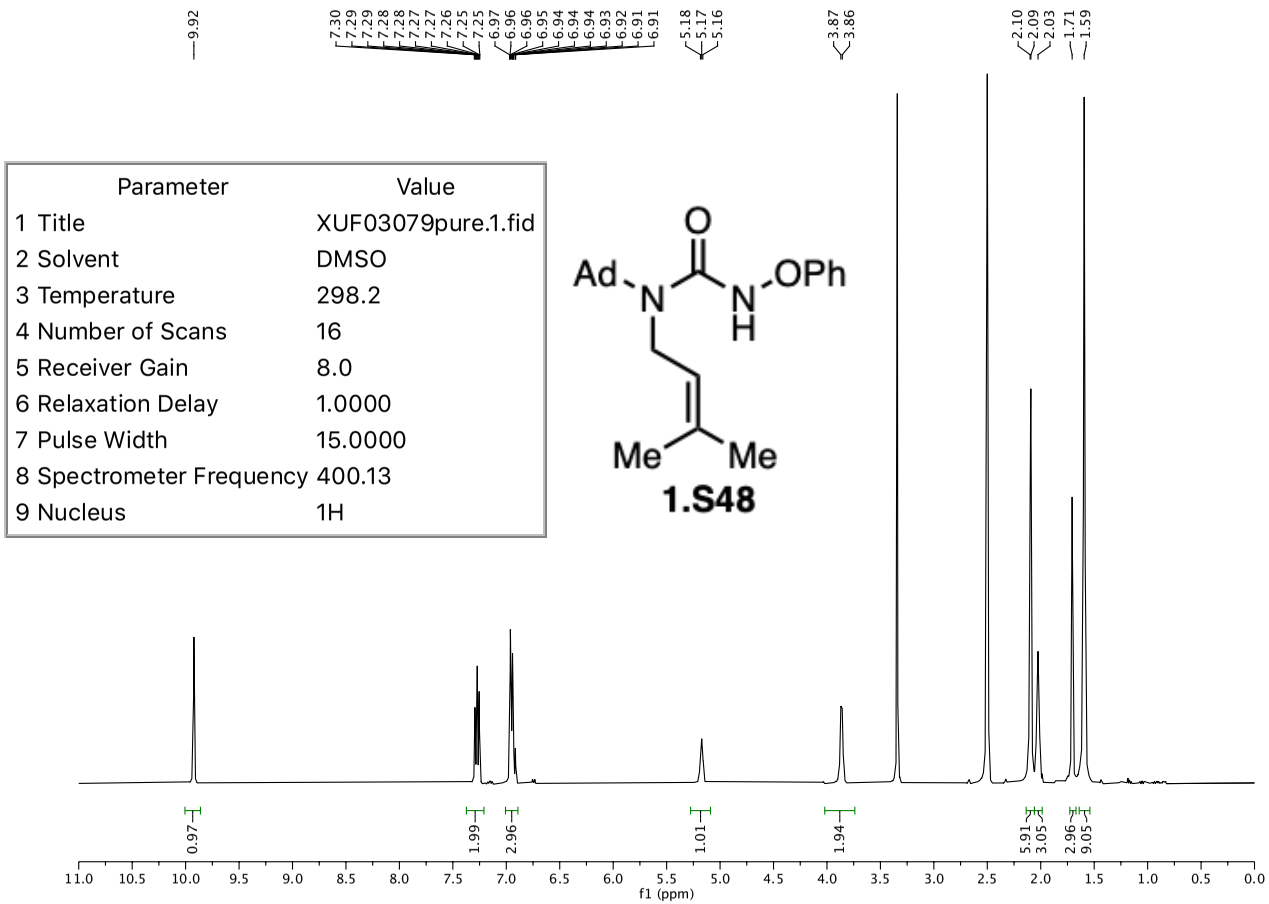

160.55
156.63
131.70
129.23
126.50
121.41
112.91
54.81
45.22
32.17
25.57
23.69
17.92
Parameter Value
1 Title SAS05007P60.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
N
O
HN−OPh
Me
Me
1.S45
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

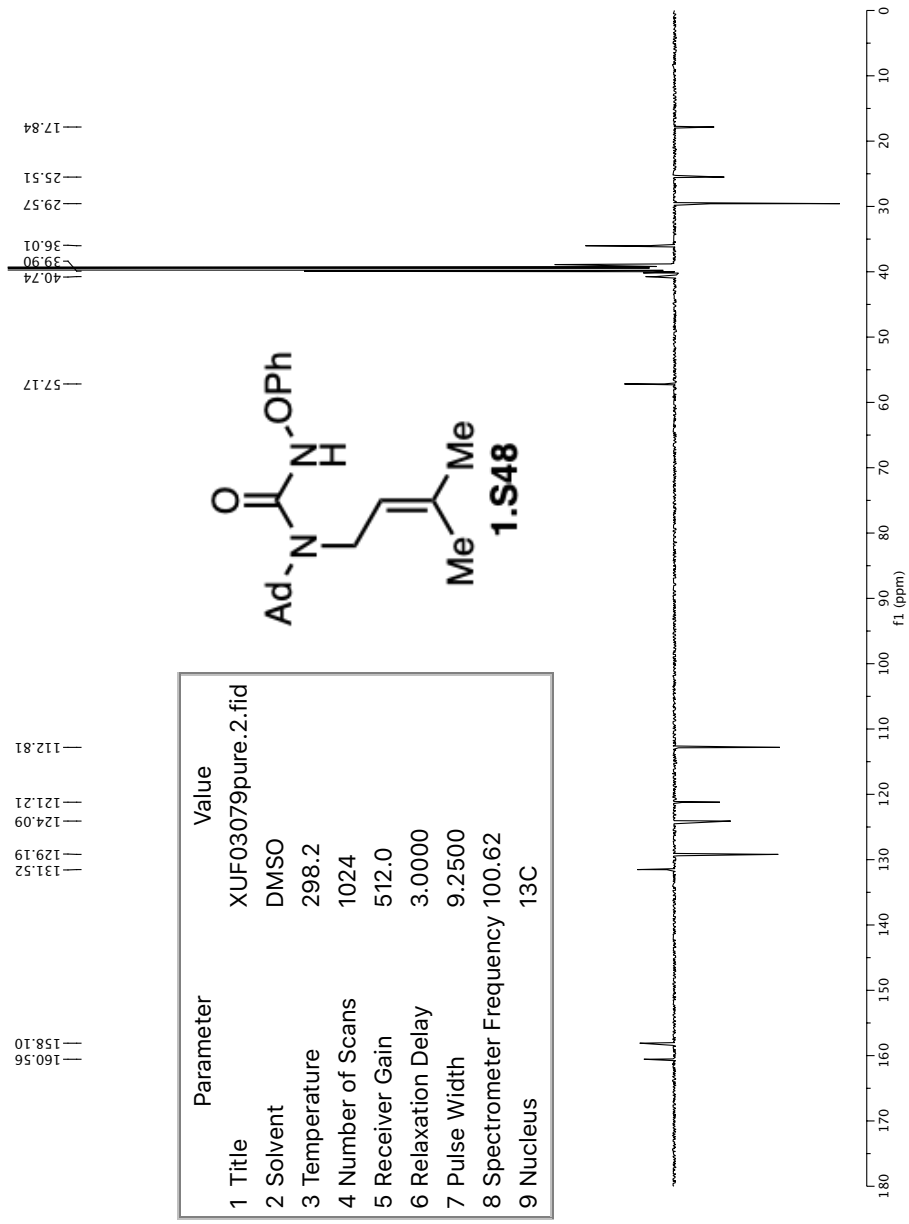

9.75 7.33 7.32 7.32 7.31 7.31 7.30 7.29 7.29 7.15 7.14 7.12 7.09 7.09 7.09 7.08 7.08 7.07 7.07 7.07 7.06 7.02 7.01 7.01 7.00 7.00 6.99 6.98 6.98 6.97
5.14 5.12 5.12 5.10 5.08 5.07 5.06 5.06 5.06 5.05 5.04 5.04
3.67 3.66 3.64
2.05 2.03 2.01 1.99 1.95 1.93 1.91 1.63 1.62 1.61 1.60 1.55 1.55
Parameter Value
1 Title XUF02155.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
HN
N
H
OPh
Me
Me
Me
1.S46
1.00 2.03 1.02 2.03 1.02 1.03 0.98 2.03 2.08 2.01 3.00 2.88 2.97
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


159.94
159.30
136.12
130.89
129.26
123.97
122.34
122.02
113.62
36.93
25.97
25.55
17.61
16.03
Parameter Value
1 Title XUF02155.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
HN
N
H
OPh
Me
Me
Me
1.S46
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

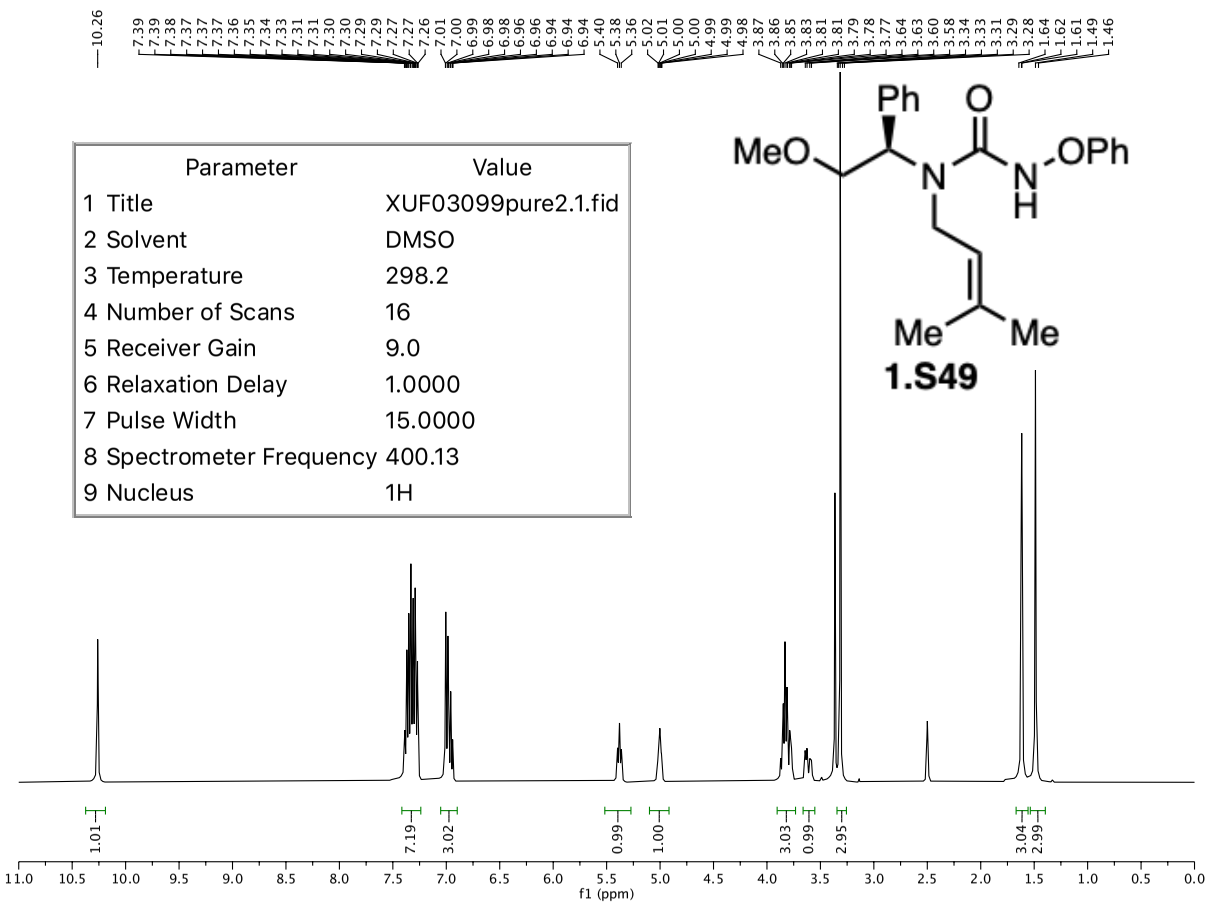

10.58
7.44
7.44
7.42
7.40
7.38
7.37
7.37
7.35
7.33
7.32
7.30
7.28
7.27
7.27
7.26
7.26
7.25
7.25
7.24
7.23
7.00
7.00
6.99
6.98
6.97
6.96
6.94
6.53
6.49
6.31
6.29
6.28
6.27
6.25
6.24
4.52
4.03
4.01
Parameter Value
1 Title XUF01071DMSO.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Ph
N
N
H
OPh
Ph
1.S47
0.99
12.30
3.02
1.01
1.01
1.98
1.97
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

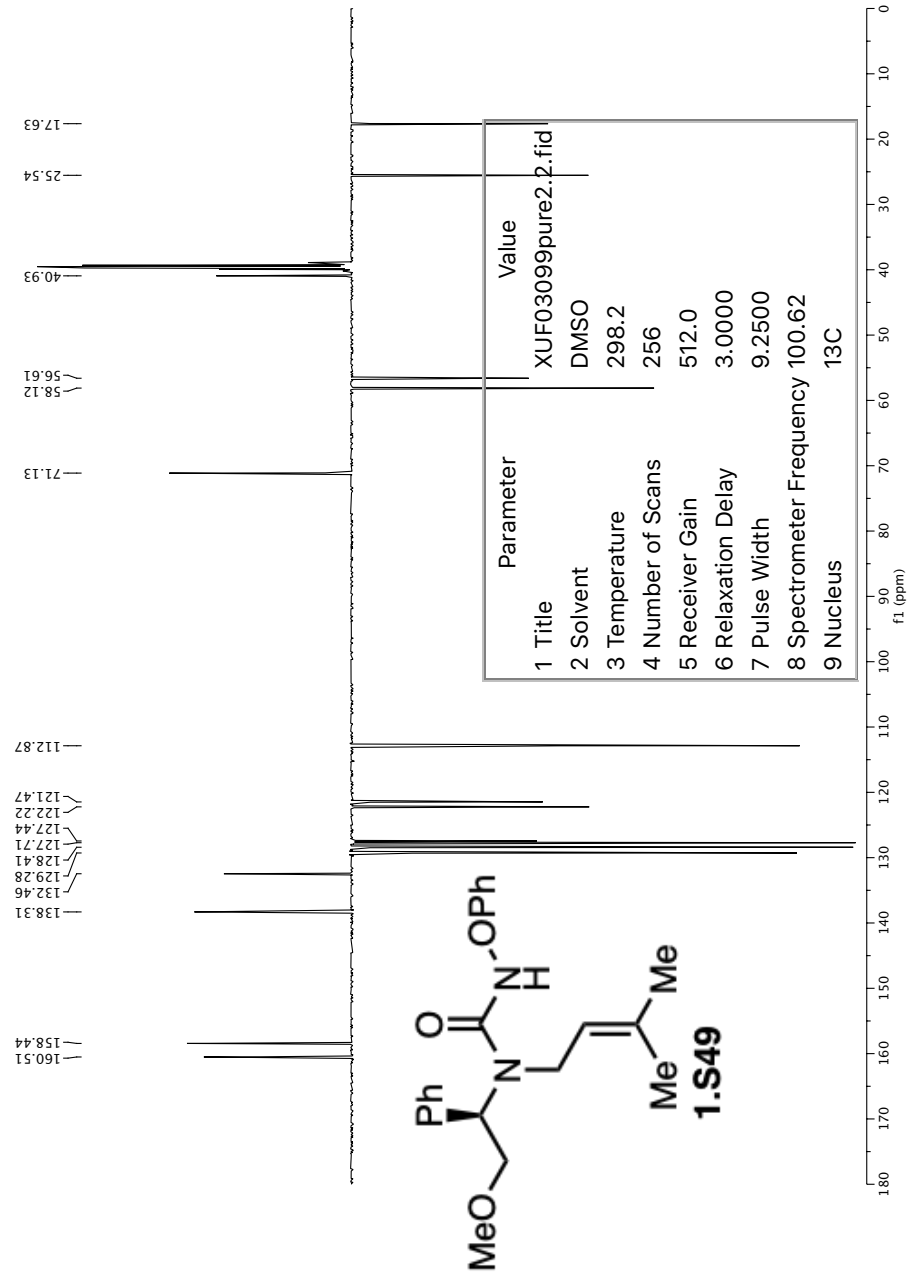

160.47
158.05
138.10
136.38
131.59
129.27
128.69
128.53
127.67
127.42
127.16
126.31
125.17
121.58
112.90
48.76
47.71
Parameter Value
1 Title XUF01071pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
Ph
N
N
H
OPh
Ph
1.S47
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

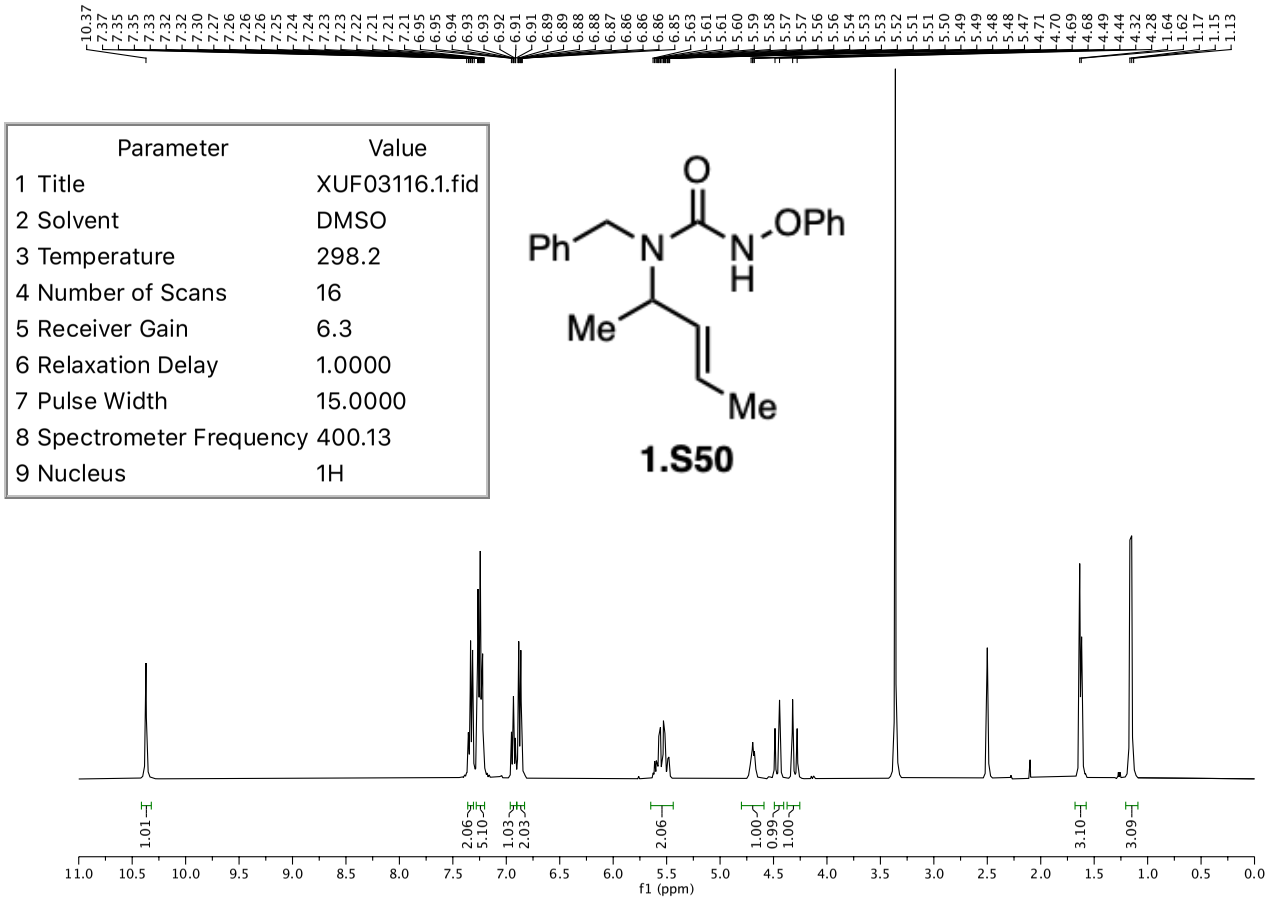

9.92
7.30
7.29
7.29
7.28
7.28
7.27
7.27
7.26
7.25
7.25
6.97
6.96
6.96
6.95
6.94
6.94
6.94
6.93
6.92
6.91
6.91
5.18
5.17
5.16
3.87
3.86
2.10
2.09
2.03
1.71
1.59
Parameter Value
1 Title XUF03079pure.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Ad
N
N
H
OPh
Me
Me
1.S48
0.97
1.99
2.96
1.01
1.94
5.91
3.05
2.96
9.05
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

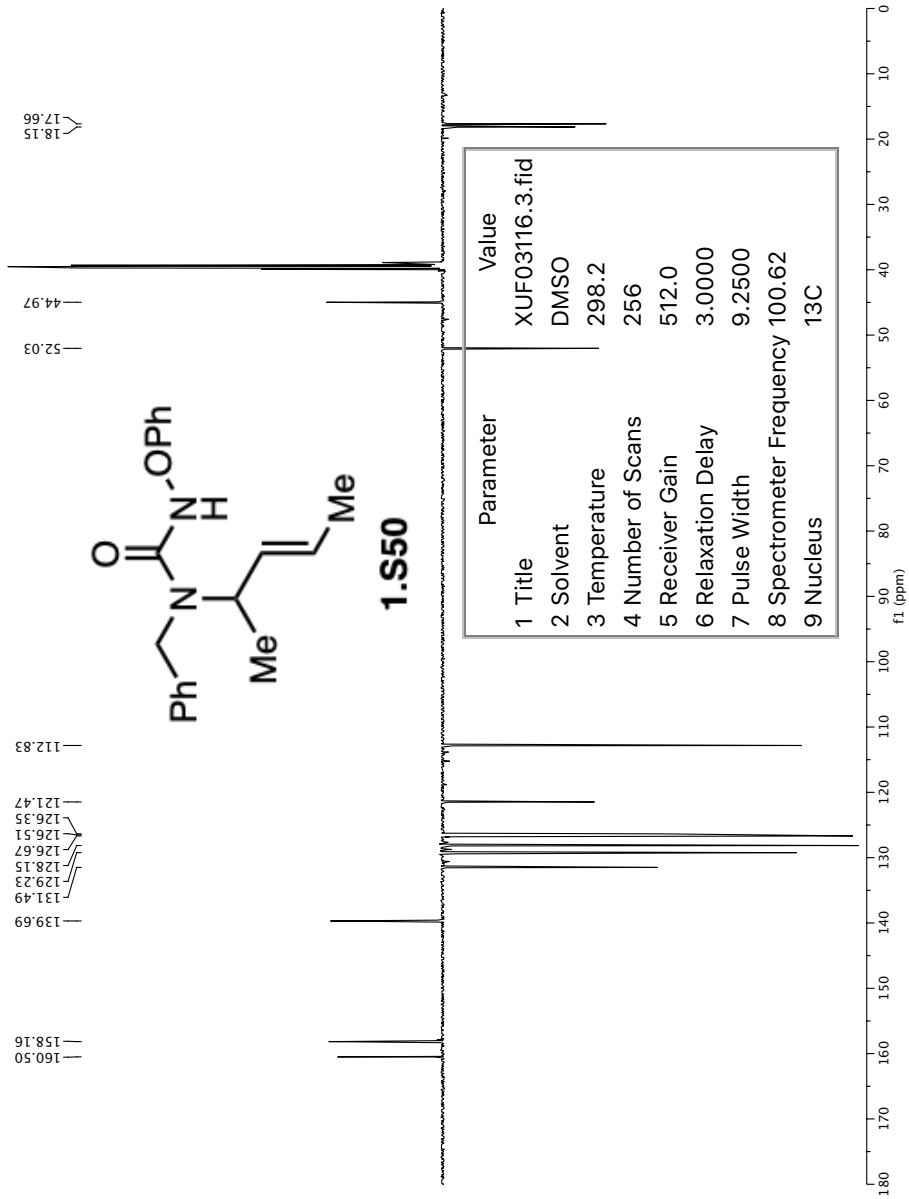


Parameter	Value
1 Title	XUF03079pure.2.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	9.2500
8 Spectrometer Frequency	100.62
9 Nucleus	13C


10.26
7.39 7.39 7.38 7.37 7.37 7.37 7.36 7.35 7.34 7.33 7.31 7.31 7.30 7.30 7.29 7.29 7.27 7.27 7.26 7.01 7.00 6.99 6.98 6.98 6.96 6.96 6.94 6.94 6.94 5.40 5.38 5.36 5.02 5.01 5.00 5.00 4.99 4.99 4.98 3.87 3.86 3.85 3.83 3.81 3.81 3.79 3.78 3.77 3.64 3.63 3.60 3.58 3.34 3.33 3.31 3.29 3.28 1.64 1.62 1.61 1.49 1.46
Parameter Value
1 Title XUF03099pure2.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
O
MeO
N
N
H
OPh
Me
Me
1.S49
1.01
7.19
3.02
0.99
1.00
3.03
0.99
2.95
3.04
2.99
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

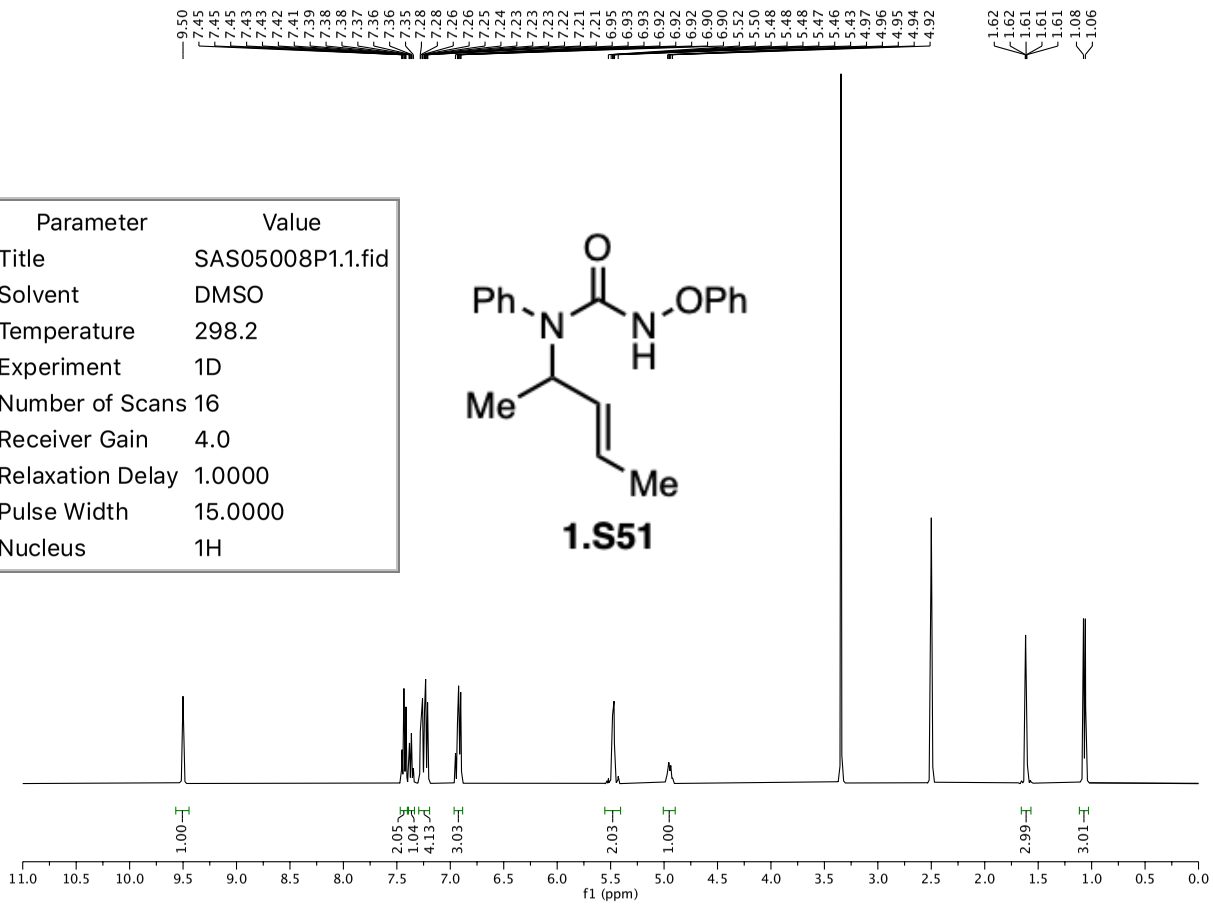

160.51
158.44
138.31
132.46
129.28
128.41
127.71
127.44
122.22
121.47
112.87
71.13
58.12
56.61
40.93
25.54
17.63
Parameter
Value
1 Title
XUF03099pure2.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
256
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)
MeO
Ph
O
N
H
OPh
Me
Me
1.S49

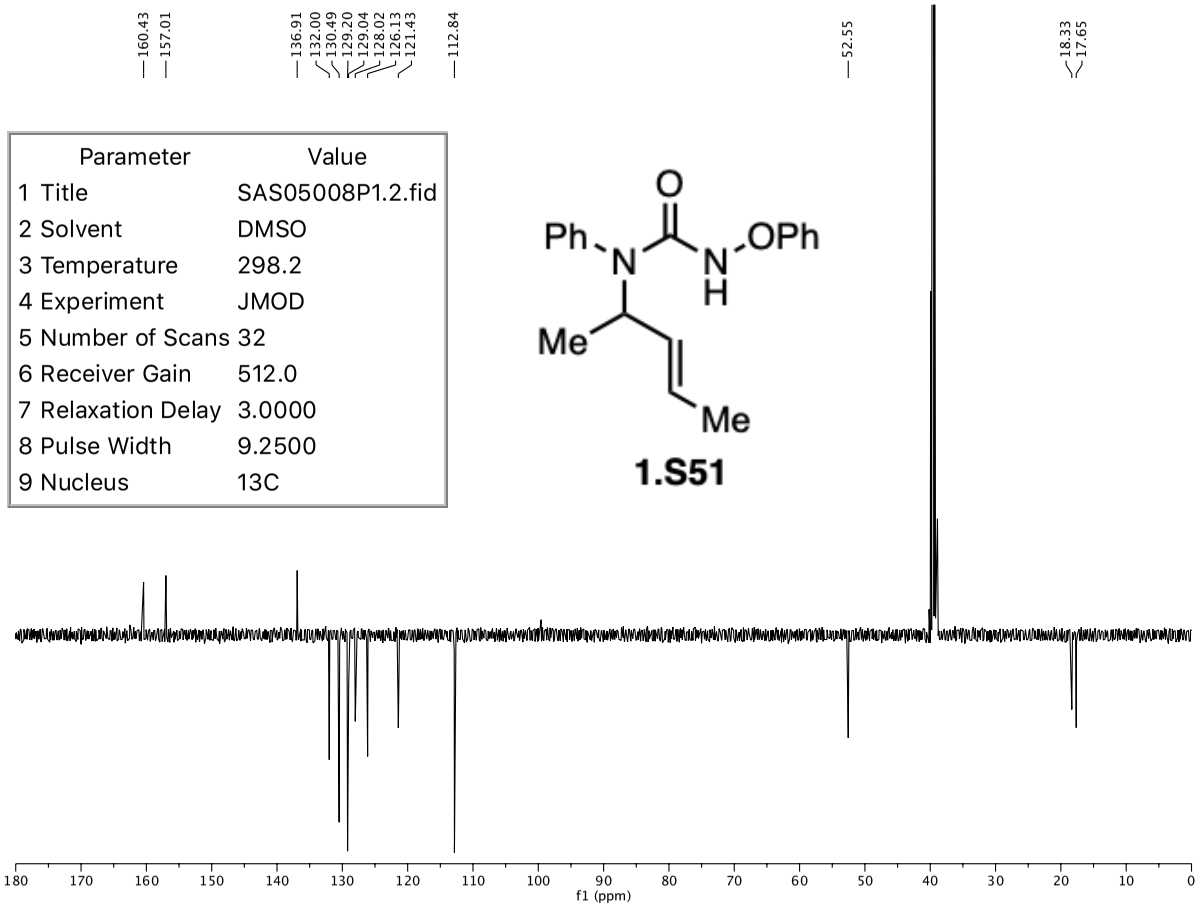

10.37
7.37
7.35
7.35
7.33
7.32
7.32
7.30
7.27
7.26
7.26
7.26
7.25
7.24
7.24
7.23
7.23
7.22
7.21
7.21
7.21
6.95
6.95
6.94
6.93
6.92
6.91
6.91
6.89
6.89
6.88
6.88
6.87
6.86
6.86
6.86
6.85
5.63
5.61
5.61
5.60
5.59
5.58
5.57
5.57
5.56
5.56
5.54
5.53
5.53
5.52
5.51
5.51
5.50
5.49
5.49
5.48
5.48
5.47
4.71
4.70
4.69
4.68
4.49
4.44
4.32
4.28
1.64
1.62
1.17
1.15
1.13
Parameter
Value
1 Title
XUF03116.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
6.3
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
Ph
N
N
H
OPh
Me
Me
1.S50
1.01
2.06
5.10
1.03
2.03
2.06
1.00
0.99
1.00
3.10
3.09
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

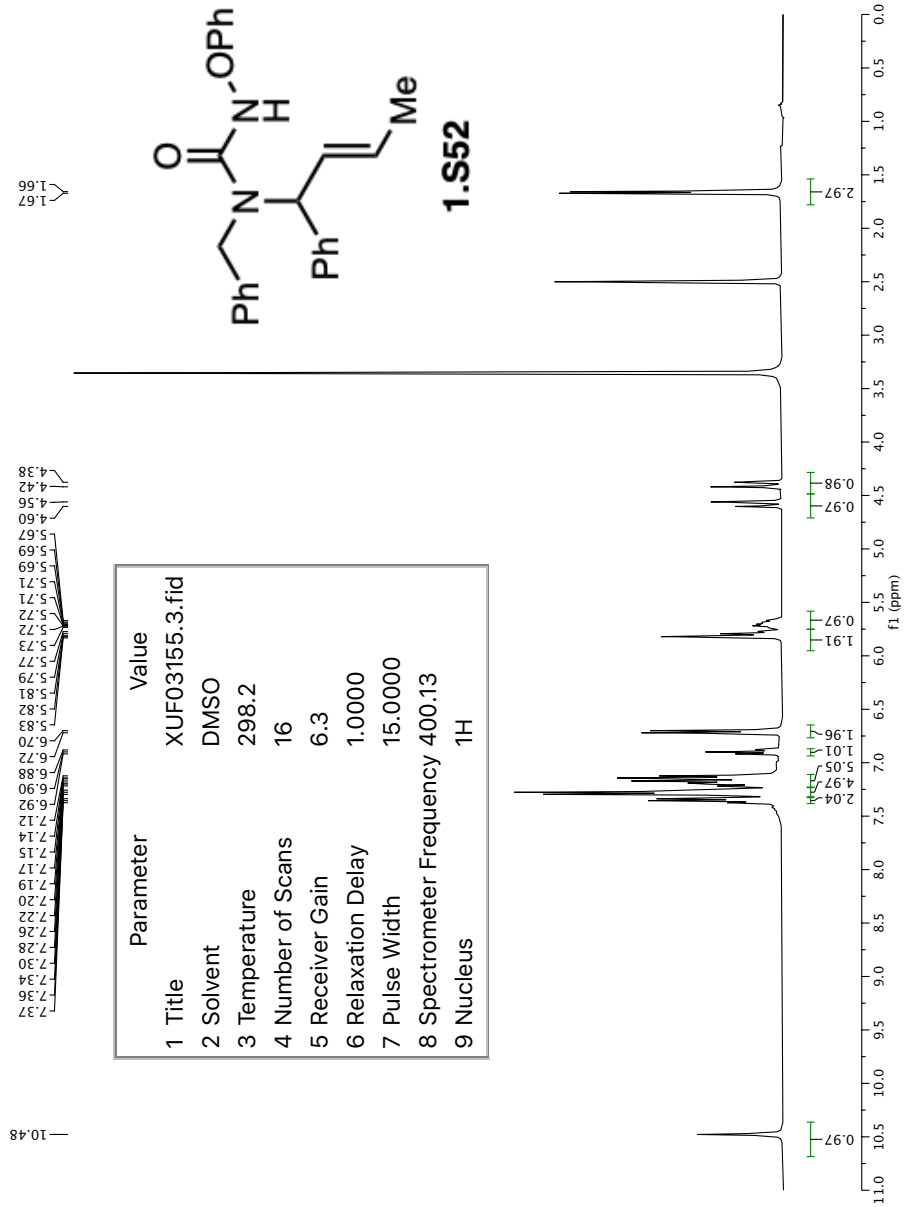

1.S50
Ph
Me
Me
O
N
H
OPh
Parameter
Value
1 Title
XUF03116.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
256
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

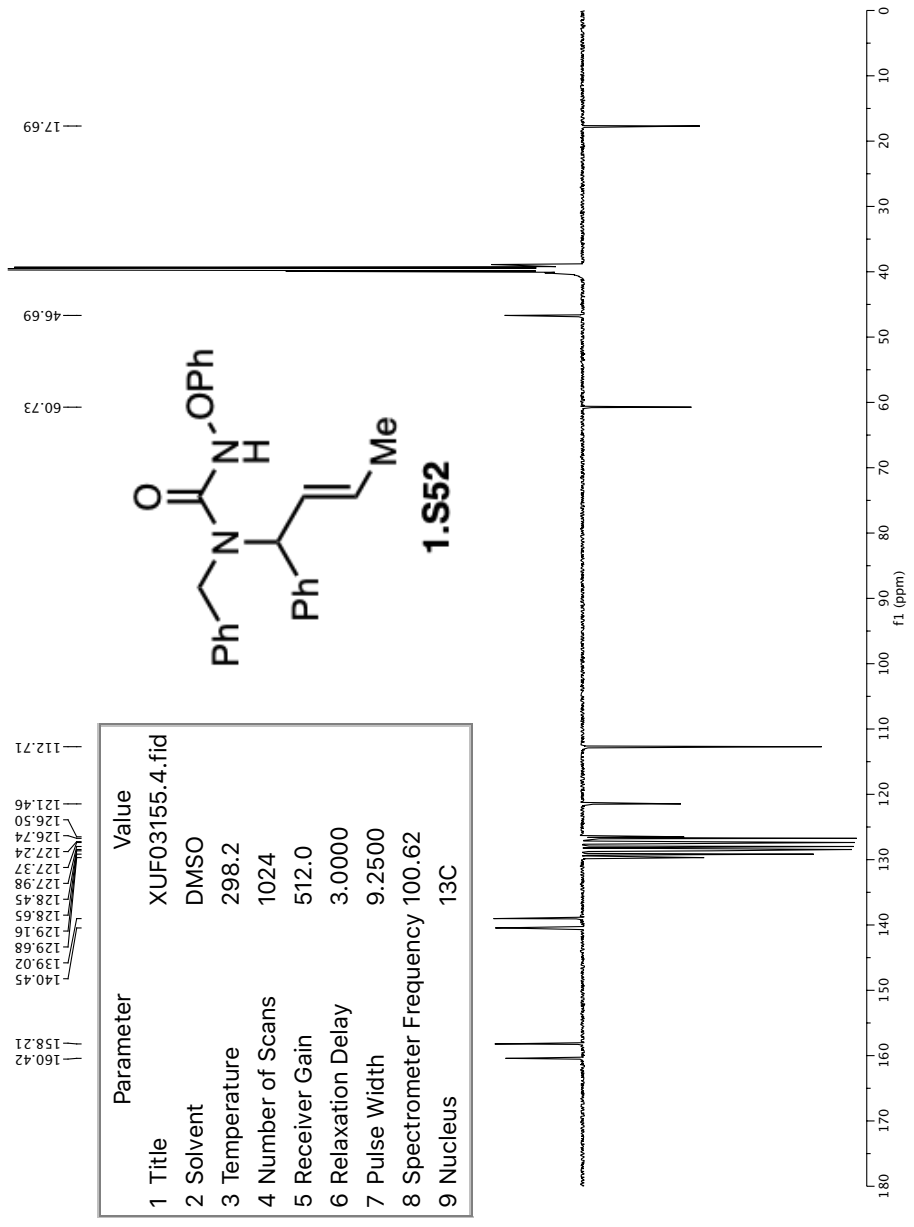
Parameter	Value
1 Title	SAS05008P1.1.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Experiment	1D
5 Number of Scans	16
6 Receiver Gain	4.0
7 Relaxation Delay	1.0000
8 Pulse Width	15.0000
9 Nucleus	1H

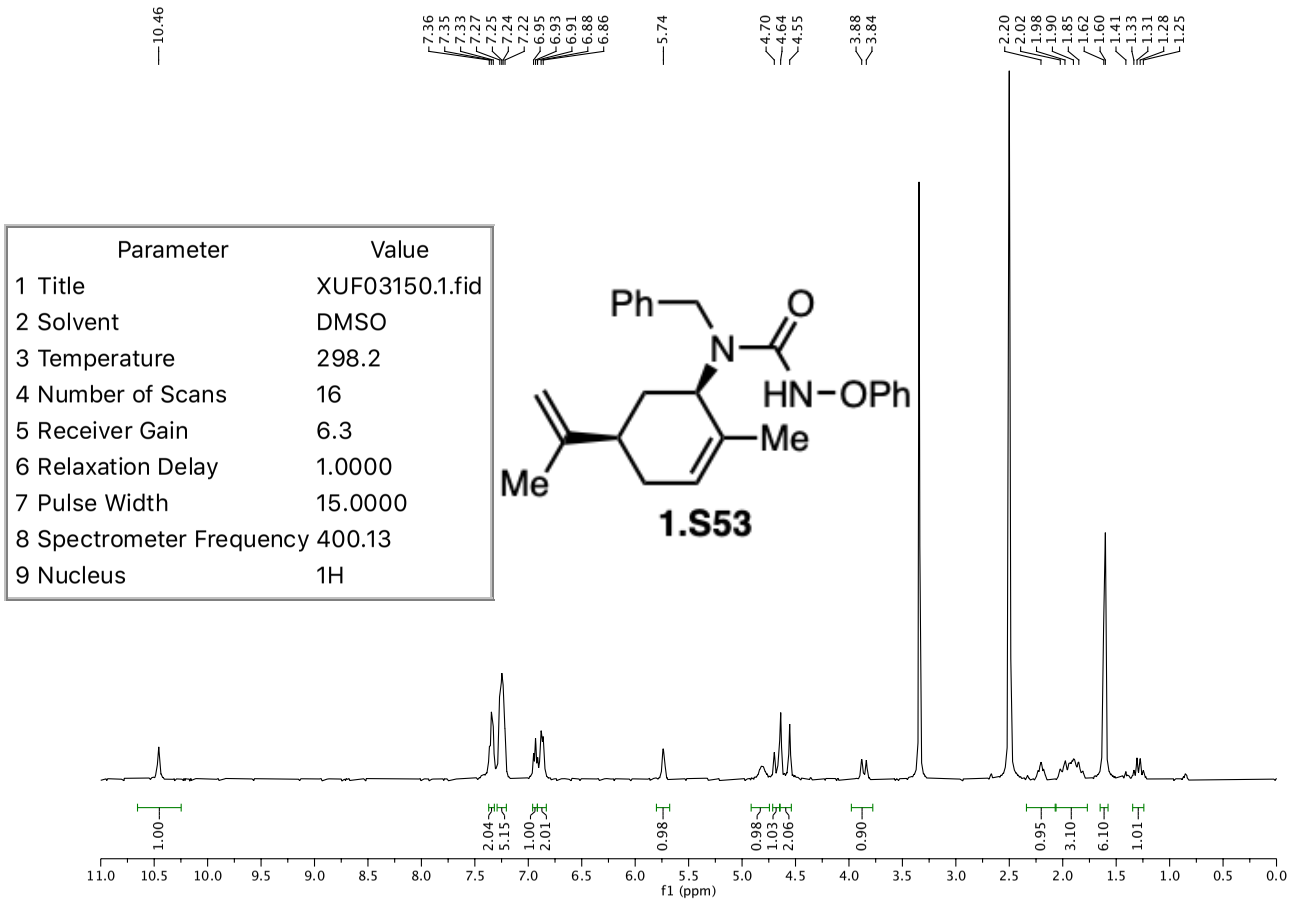
1.S51

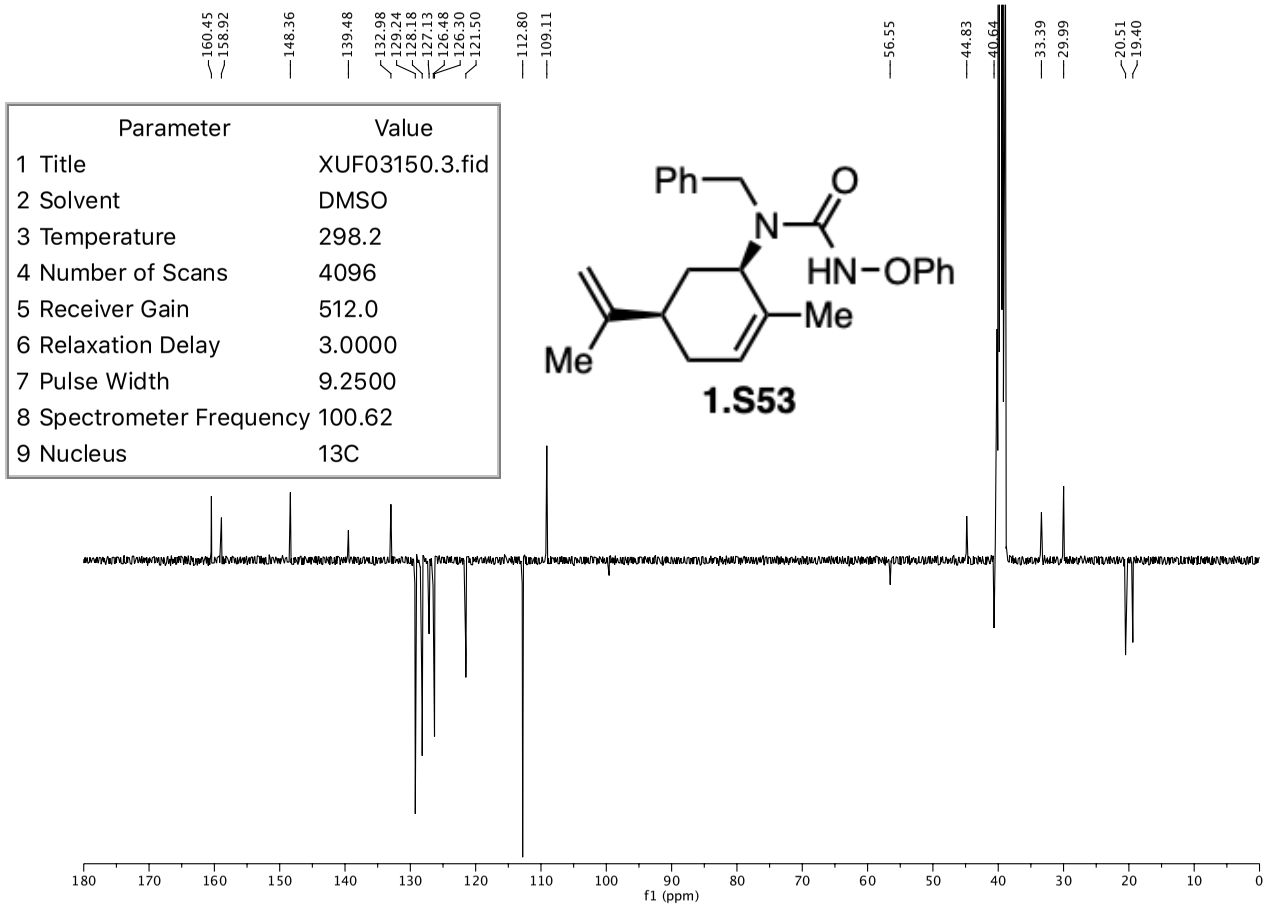


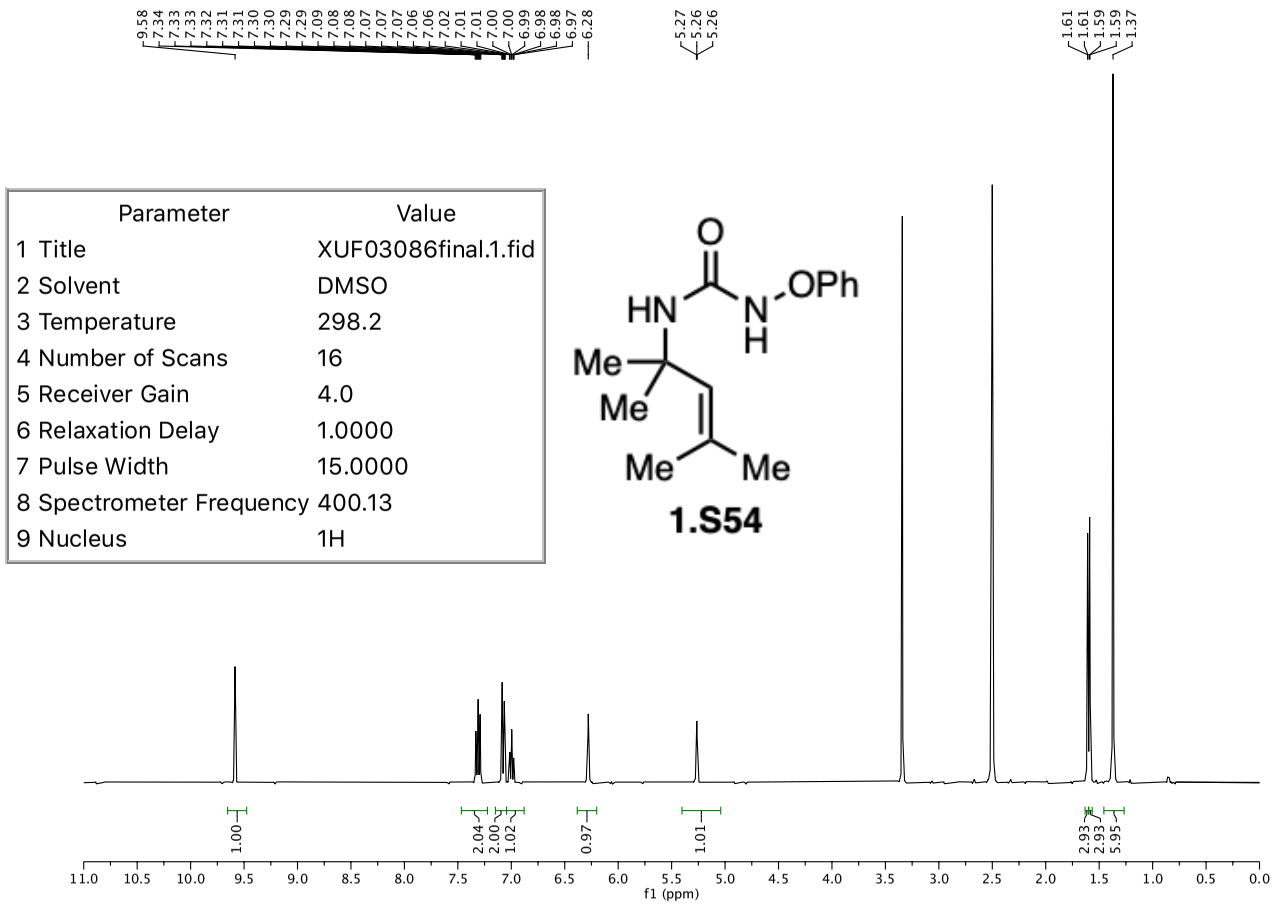

160.43
157.01
136.91
132.00
130.49
129.20
129.04
128.02
126.13
121.43
112.84
52.55
18.33
17.65
Parameter Value
1 Title SAS05008P1.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Experiment JMOD
5 Number of Scans 32
6 Receiver Gain 512.0
7 Relaxation Delay 3.0000
8 Pulse Width 9.2500
9 Nucleus 13C
Ph
N
O
N
H
OPh
Me
Me
1.S51
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

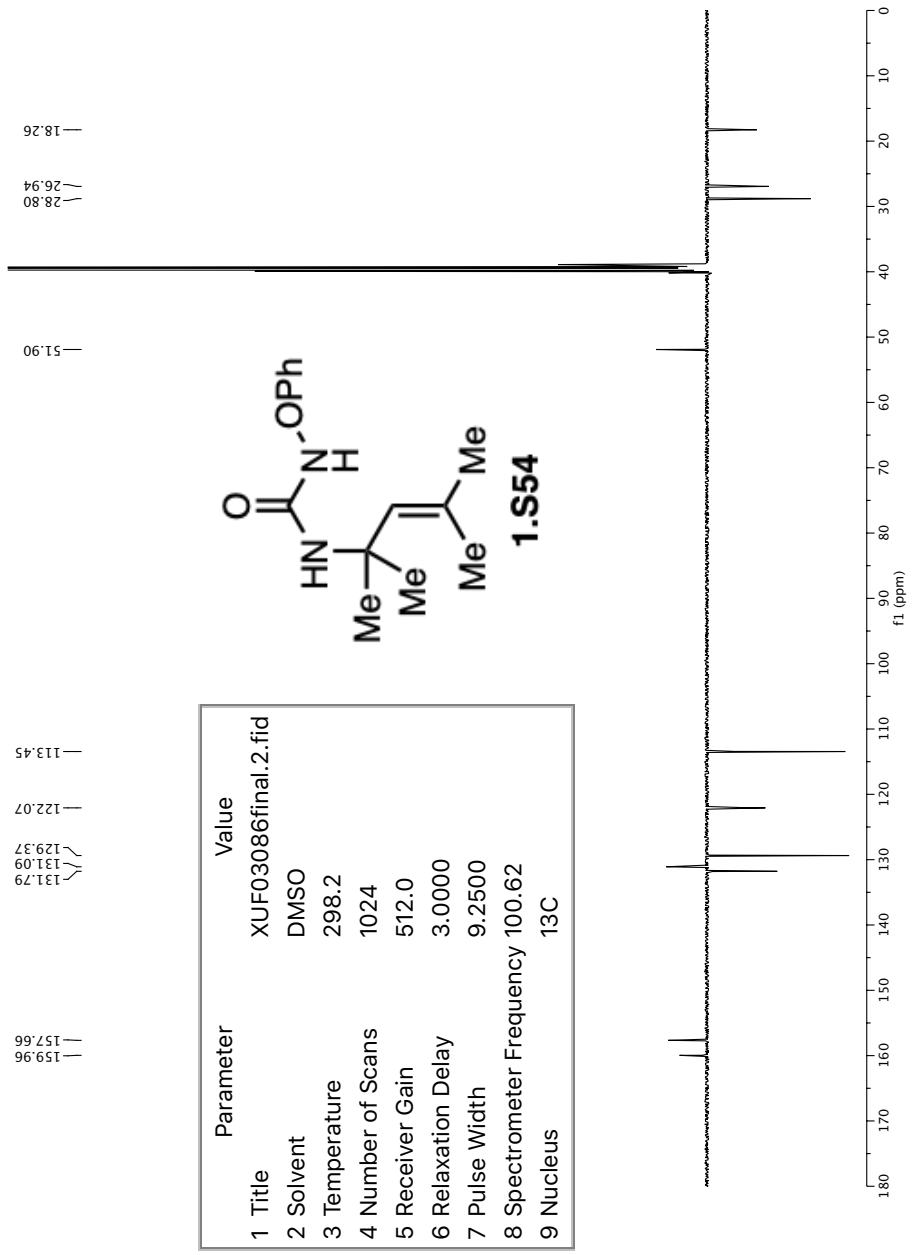

1.S52
Ph
N
O
N
H
OPh
Ph
Me
Parameter Value
1 Title XUF03155.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)


160.42
158.21
140.45
139.02
129.68
129.16
128.65
128.45
127.98
127.37
127.24
126.74
126.50
121.46
112.71
60.73
46.69
17.69
Parameter Value
1 Title XUF03155.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
H
OPh
N
Ph
Ph
Me
1.S52
f1 (ppm)

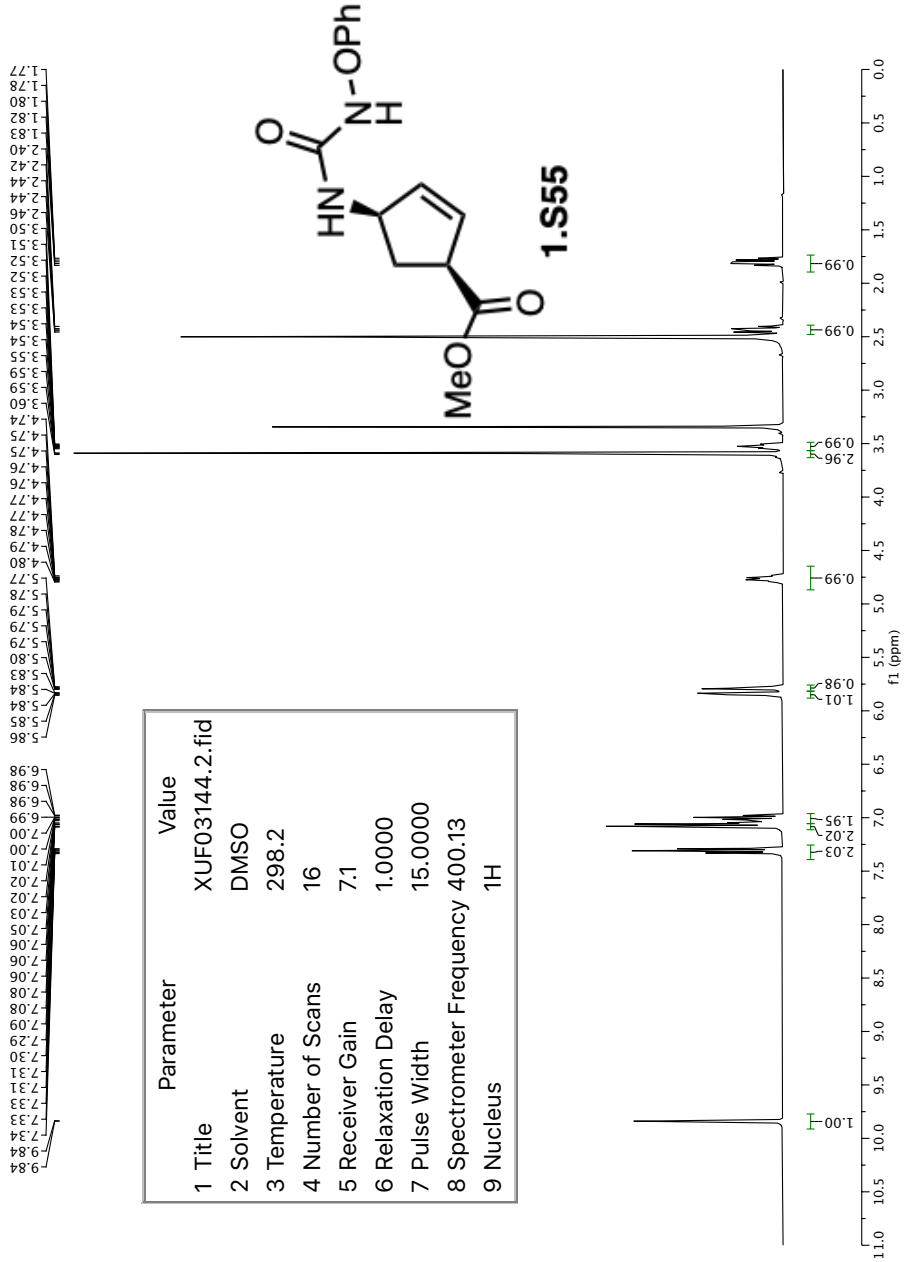

10.46
7.36
7.35
7.33
7.27
7.25
7.24
7.22
6.95
6.93
6.91
6.88
6.86
5.74
4.70
4.64
4.55
3.88
3.84
2.20
2.02
1.98
1.90
1.85
1.62
1.60
1.41
1.33
1.31
1.28
1.25
Parameter Value
1 Title XUF03150.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
HN−OPh
Me
Me
1.S53
1.00
2.04
5.15
1.00
2.01
0.98
0.98
1.03
2.06
0.90
0.95
3.10
6.10
1.01
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

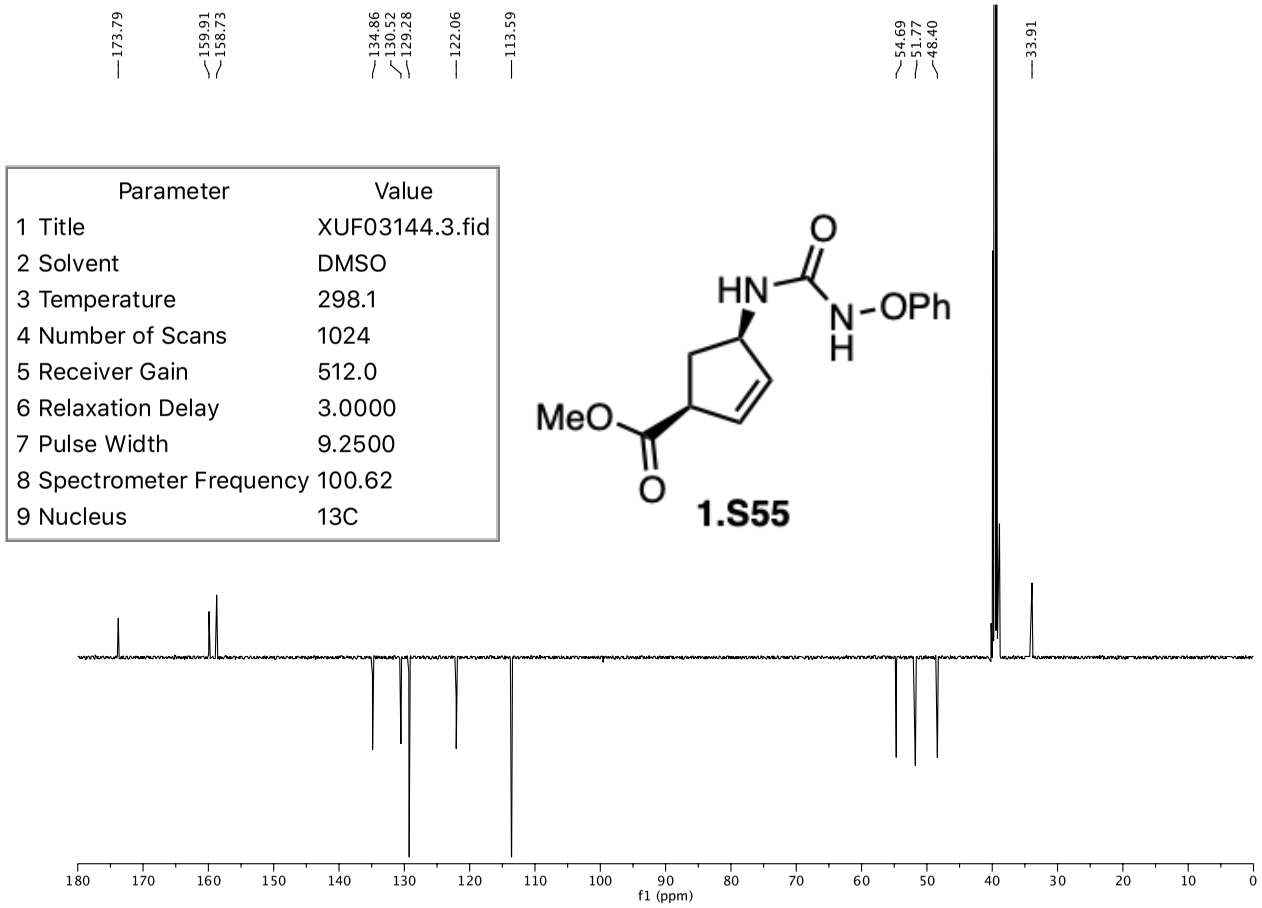

160.45
158.92
148.36
139.48
132.98
129.24
128.18
127.13
126.48
126.30
121.50
112.80
109.11
56.55
44.83
40.64
33.39
29.99
20.51
19.40
Parameter Value
1 Title XUF03150.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
HN−OPh
Me
Me
1.S53
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

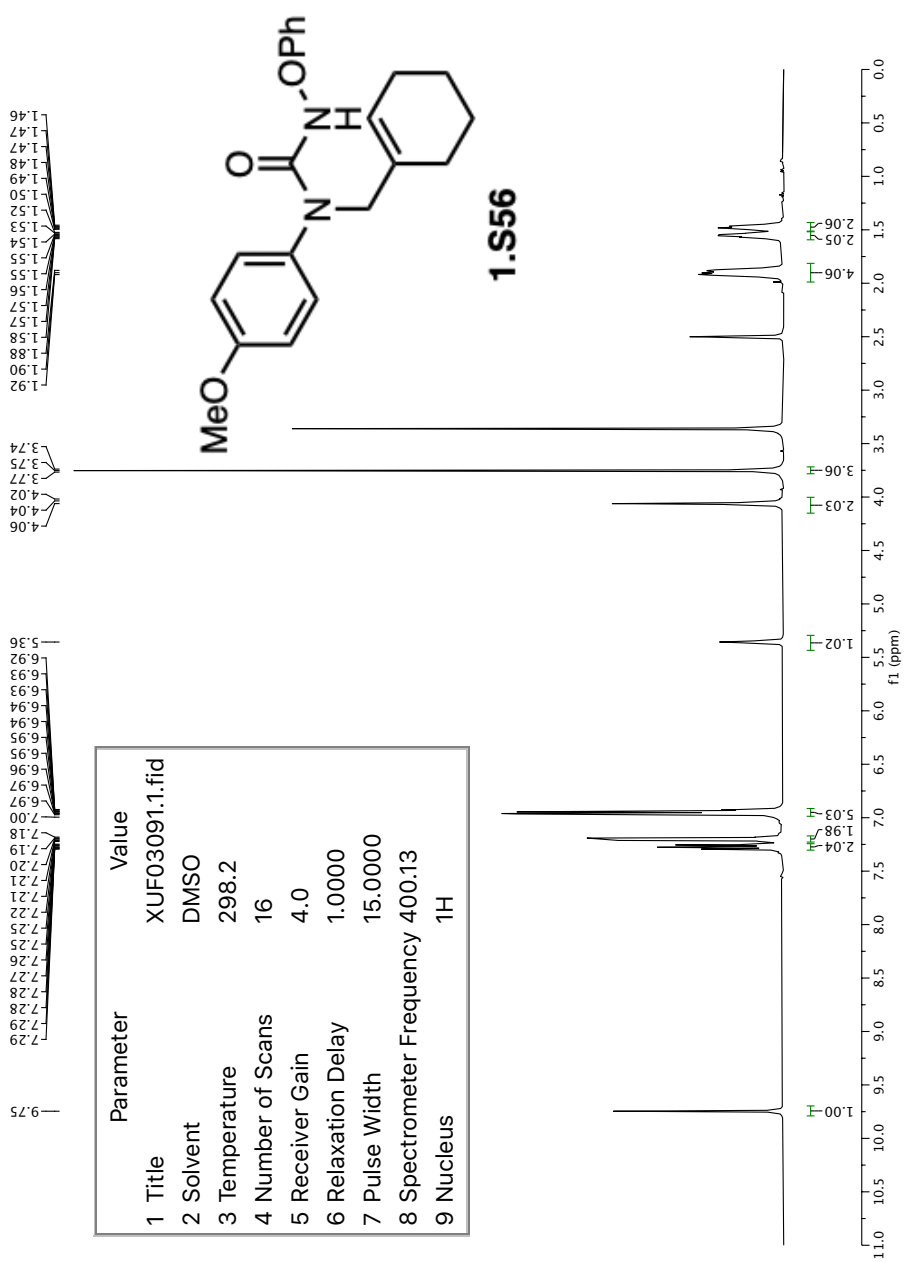

9.58
7.34
7.33
7.33
7.32
7.31
7.31
7.30
7.30
7.29
7.29
7.09
7.08
7.08
7.07
7.07
7.07
7.06
7.06
7.02
7.01
7.01
7.00
7.00
6.99
6.98
6.98
6.97
6.28
5.27
5.26
5.26
1.61
1.61
1.59
1.59
1.37
Parameter
Value
1 Title
XUF03086final.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
4.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
HN
N
H
OPh
Me
Me
Me
Me
1.S54
1.00
2.04
2.00
1.02
0.97
1.01
2.93
2.93
5.95
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

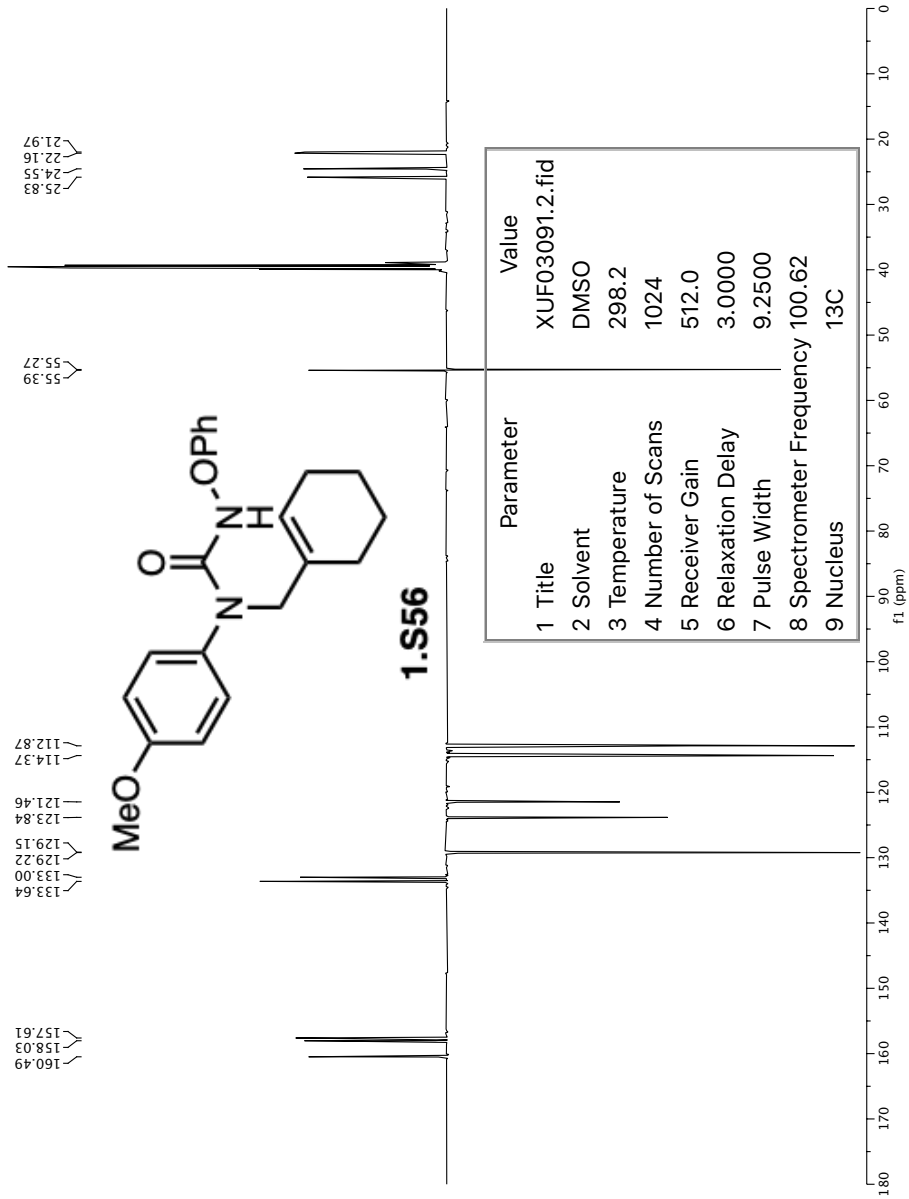


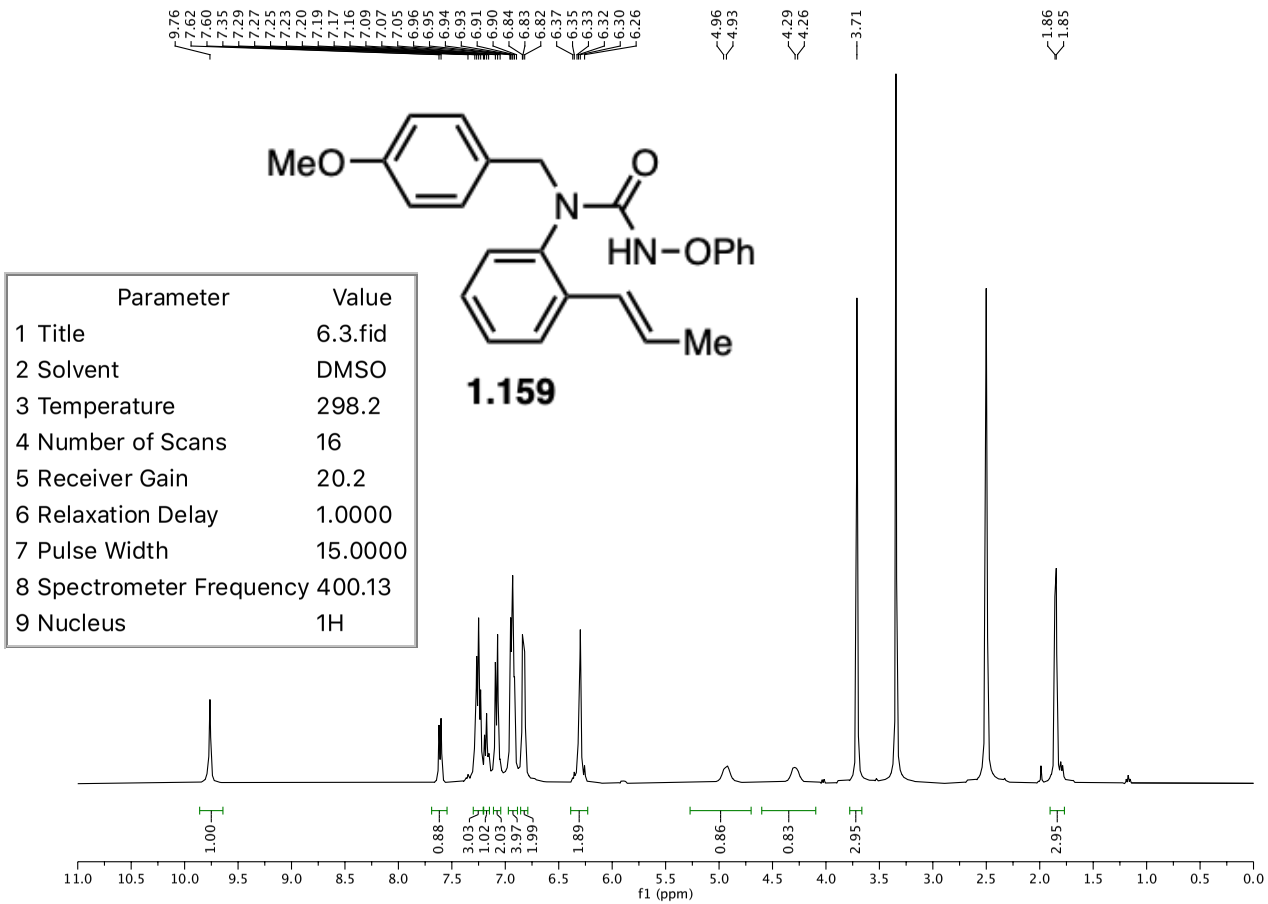
Parameter	Value
1 Title	XUF03086final.2.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	9.2500
8 Spectrometer Frequency	100.62
9 Nucleus	13C

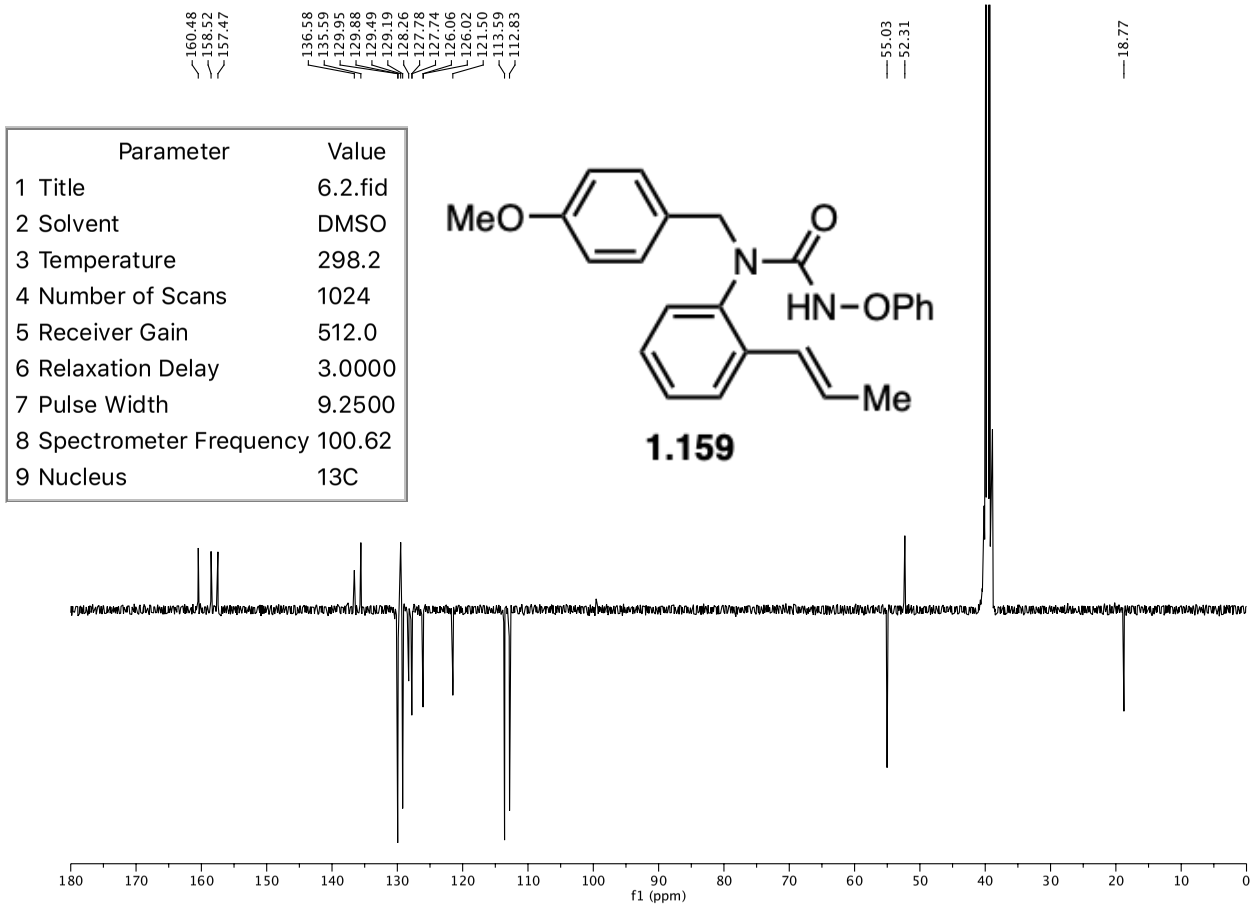

Parameter Value
1 Title XUF03144.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
HN
N
H
O
O
O
1.S55
f1 (ppm)


173.79
159.91
158.73
134.86
130.52
129.28
122.06
113.59
54.69
51.77
48.40
33.91
Parameter Value
1 Title XUF03144.3.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
HN
O
N
H
OPh
MeO
O
1.S55
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


MeO
O
N
H
N
OPh
1.S56
Parameter Value
1 Title XUF03091.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

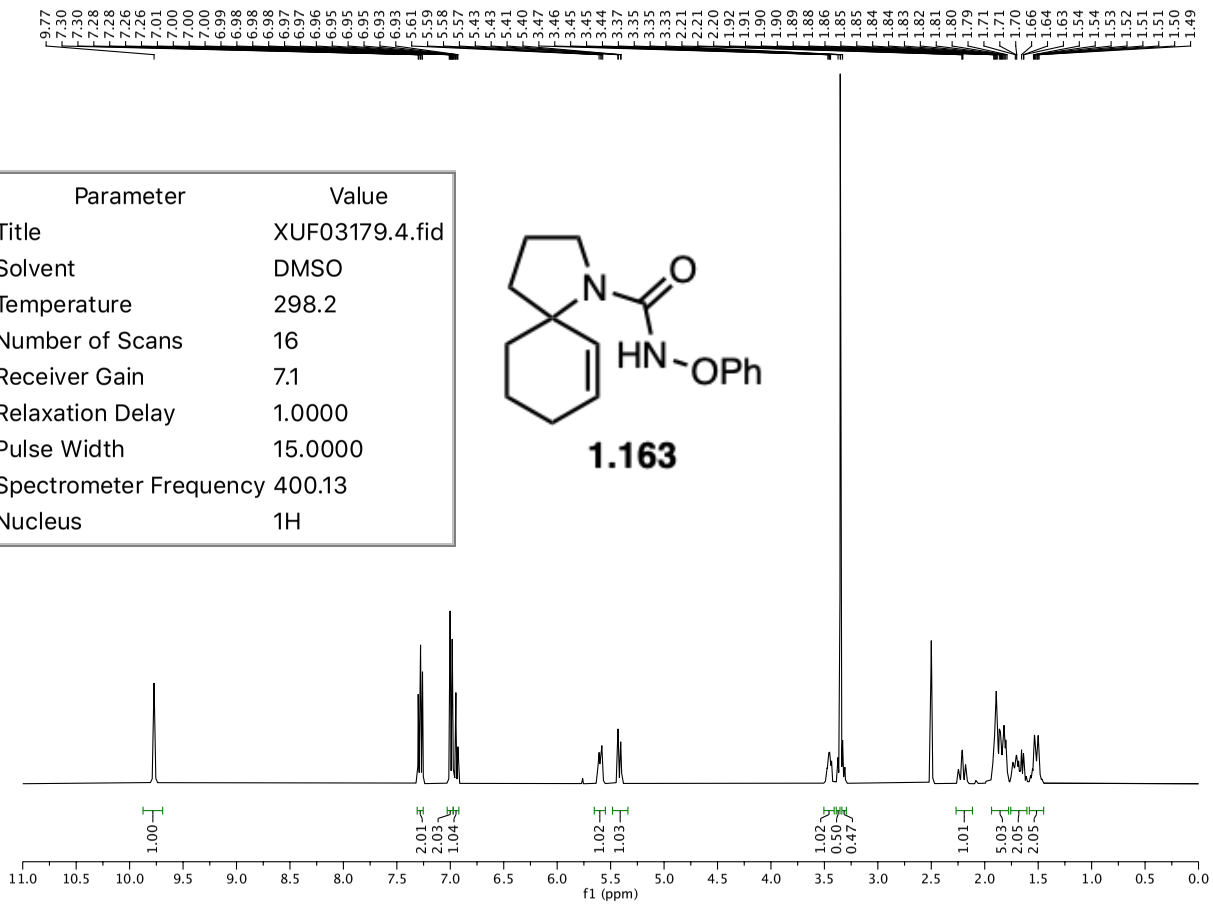

160.49
158.03
157.61
133.64
133.00
129.22
129.15
123.84
121.46
114.37
112.87
55.39
55.27
25.83
24.55
22.16
21.97
MeO
OPh
N
H
O
N
1.S56
Parameter
Value
1 Title
XUF03091.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)


9.76
7.62
7.60
7.35
7.29
7.27
7.25
7.23
7.20
7.19
7.17
7.16
7.09
7.07
7.05
6.96
6.95
6.94
6.93
6.91
6.90
6.84
6.83
6.82
6.37
6.35
6.33
6.32
6.30
6.26
4.96
4.93
4.29
4.26
3.71
1.86
1.85
MeO
O
N
HN−OPh
Me
1.159
Parameter Value
1 Title 6.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 20.2
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.00
0.88
3.03
1.02
2.03
3.97
1.99
1.89
0.86
0.83
2.95
2.95
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

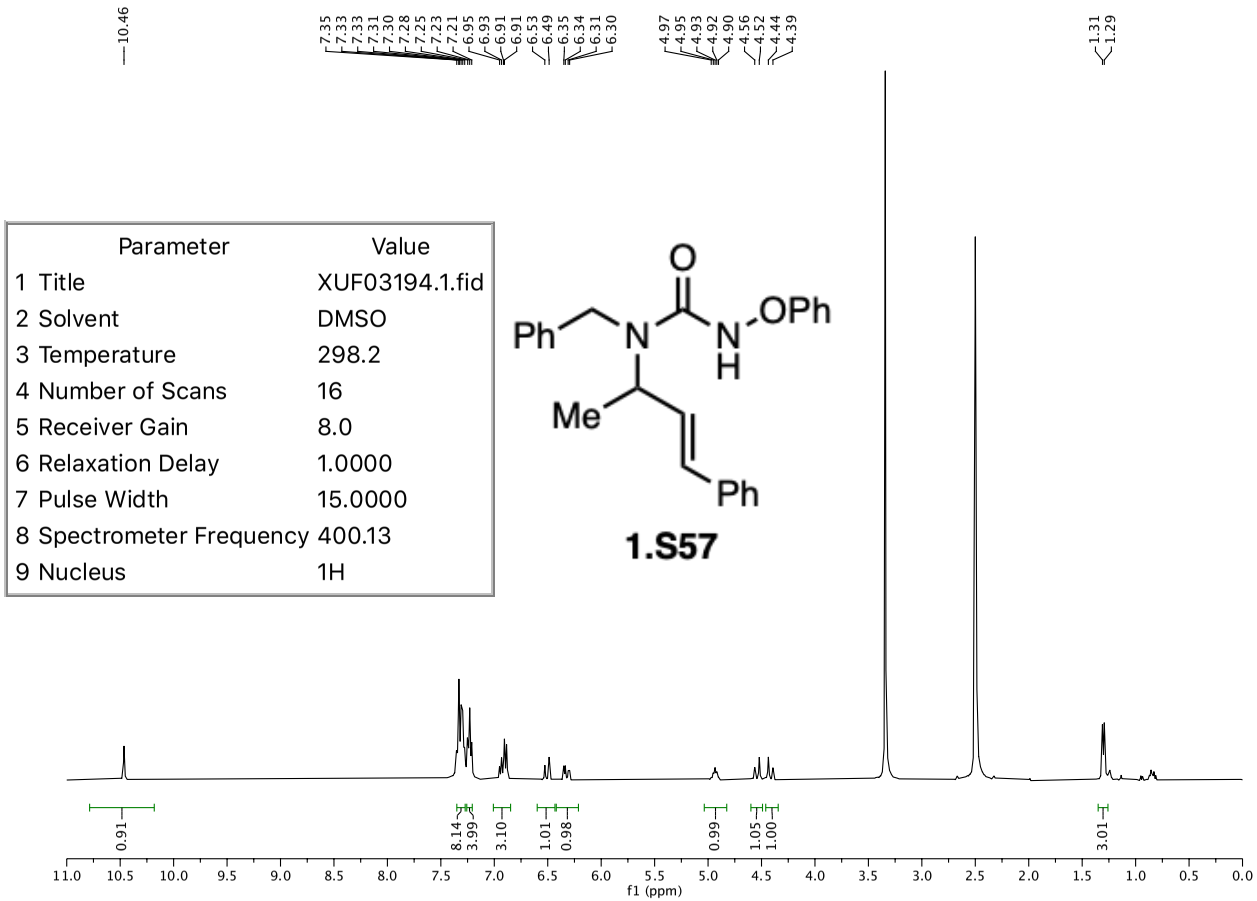

160.48
158.52
157.47
136.58
135.59
129.95
129.88
129.49
129.19
128.26
127.78
127.74
126.06
126.02
121.50
113.59
112.83
55.03
52.31
18.77
Parameter Value
1 Title 6.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
HN−OPh
Me
1.159
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

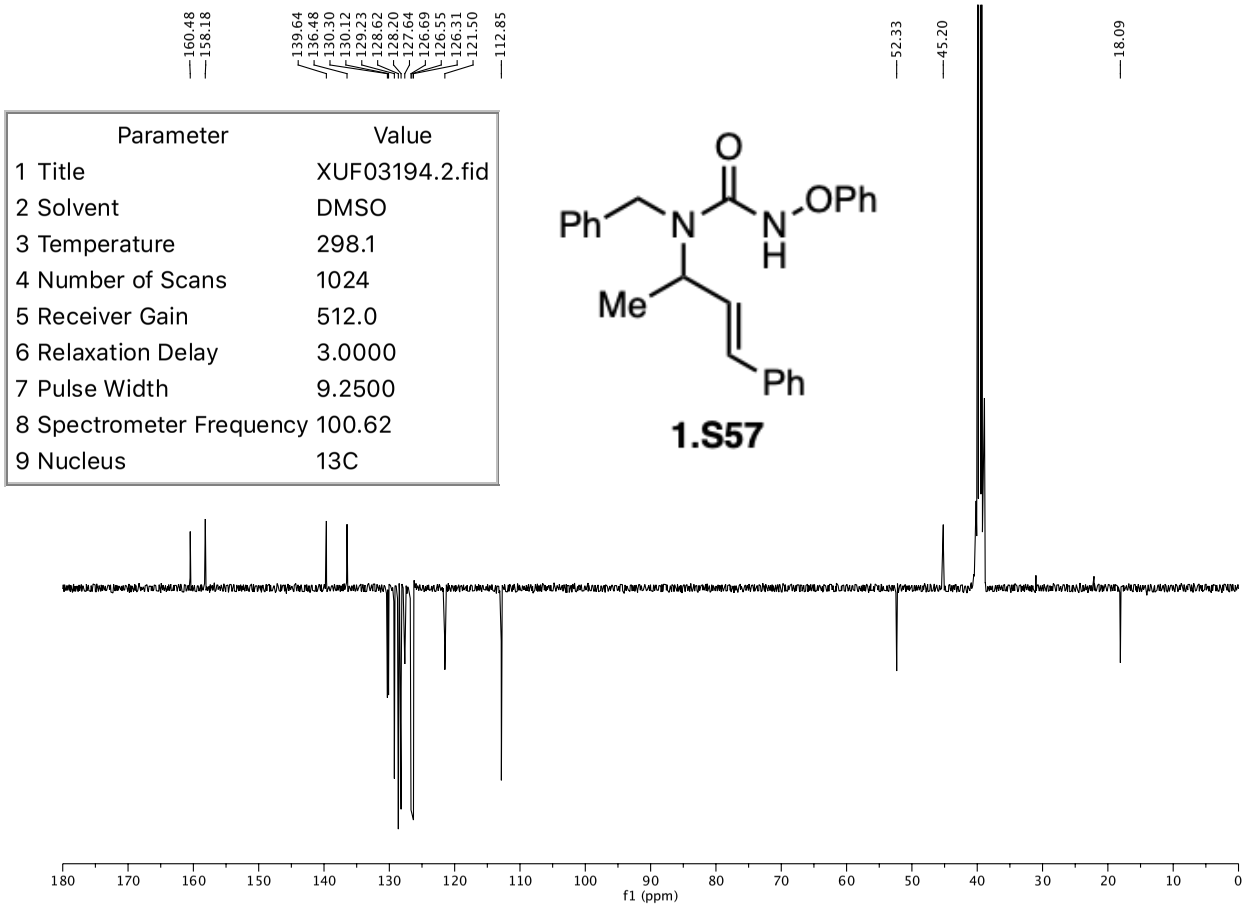
Parameter	Value
1 Title	XUF03179.4.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	7.1
6 Relaxation Delay	1.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

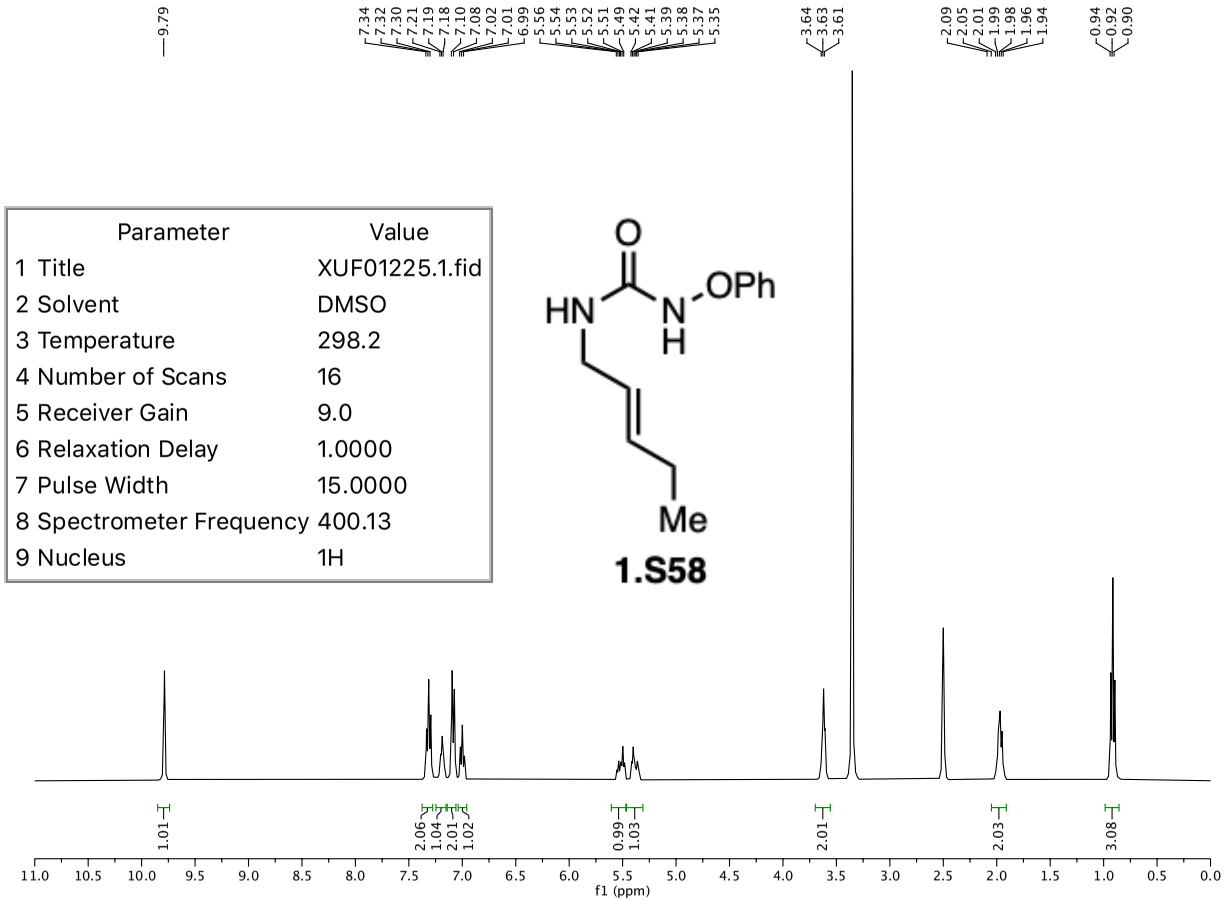
1.163

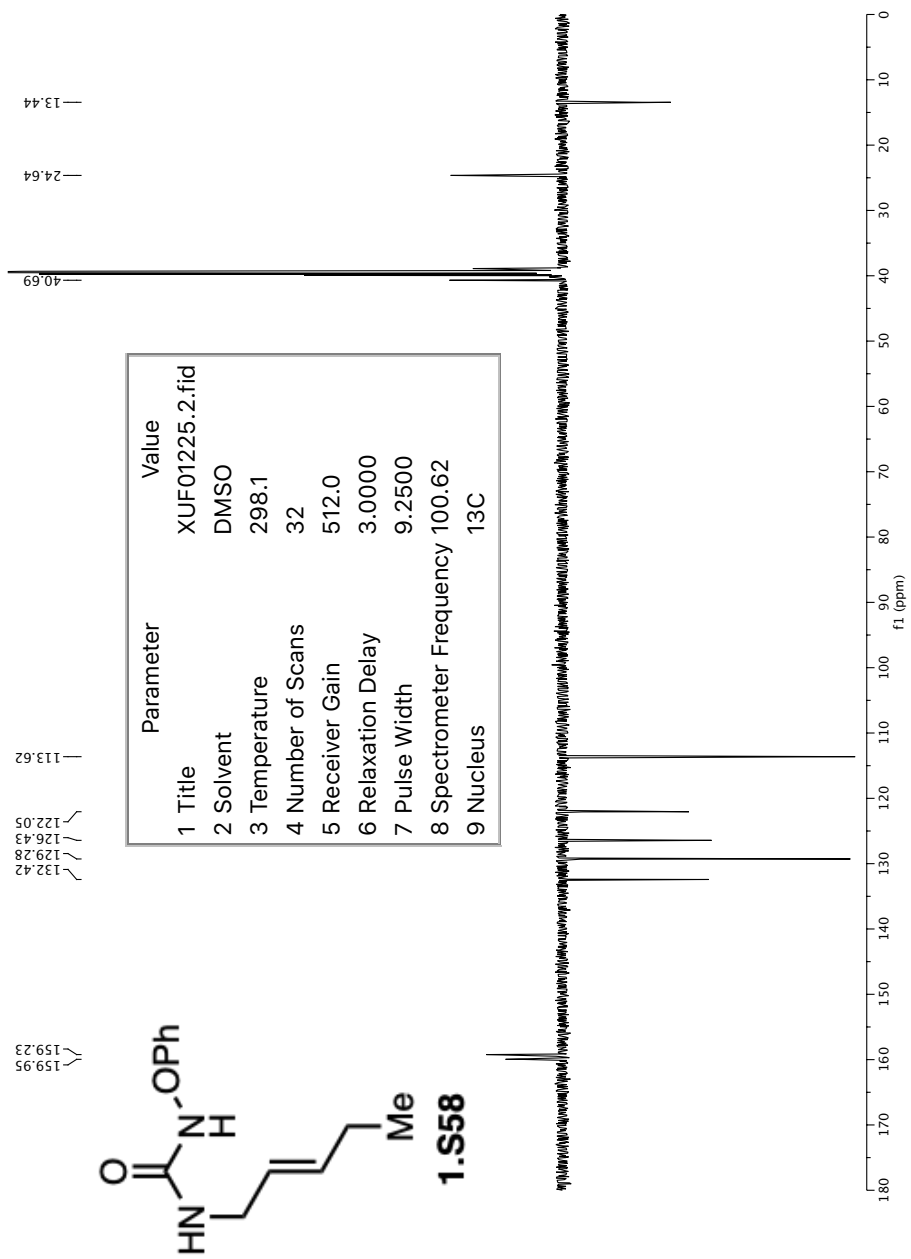


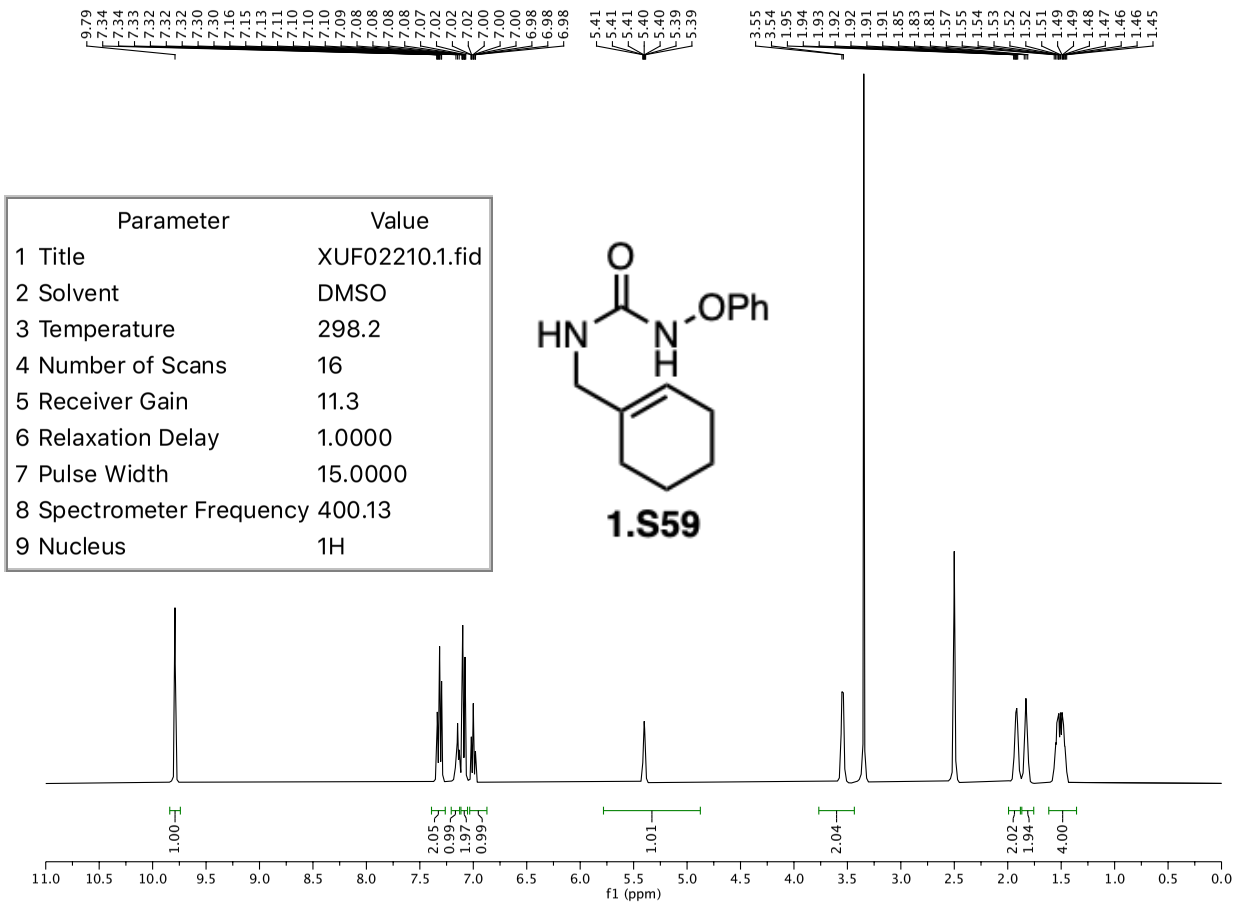
160.60
155.53
133.92
129.21
126.12
121.37
112.98
63.19
45.89
38.28
30.48
23.84
22.37
21.17
Parameter Value
1 Title XUF03179.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
HN-OPh
1.163
f1 (ppm)

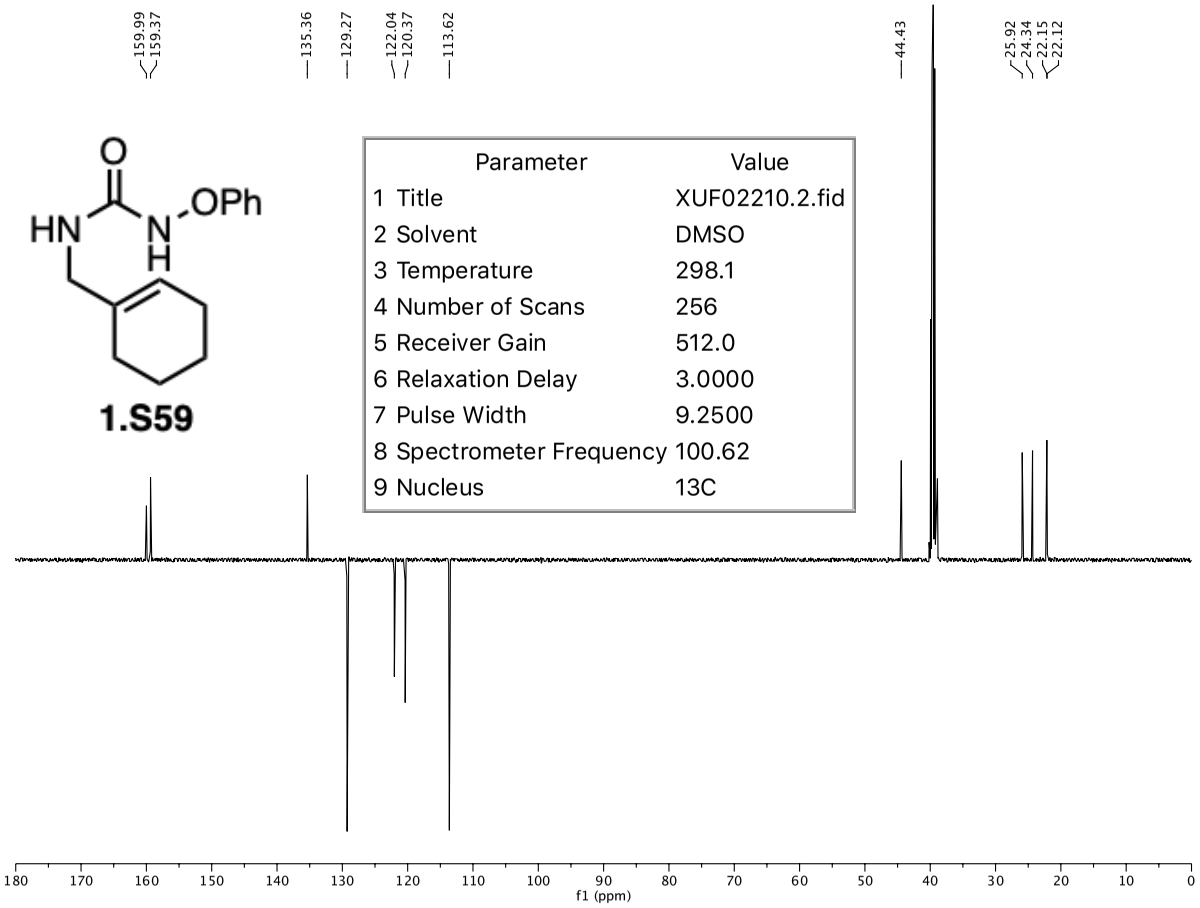

10.46
7.35
7.33
7.33
7.31
7.30
7.28
7.25
7.23
7.21
6.95
6.93
6.91
6.91
6.53
6.49
6.35
6.34
6.31
6.30
4.97
4.95
4.93
4.92
4.90
4.56
4.52
4.44
4.39
1.31
1.29
Parameter Value
1 Title XUF03194.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Ph
N
N
H
OPh
Me
Ph
1.S57
0.91
8.14
3.99
3.10
1.01
0.98
0.99
1.05
1.00
3.01
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

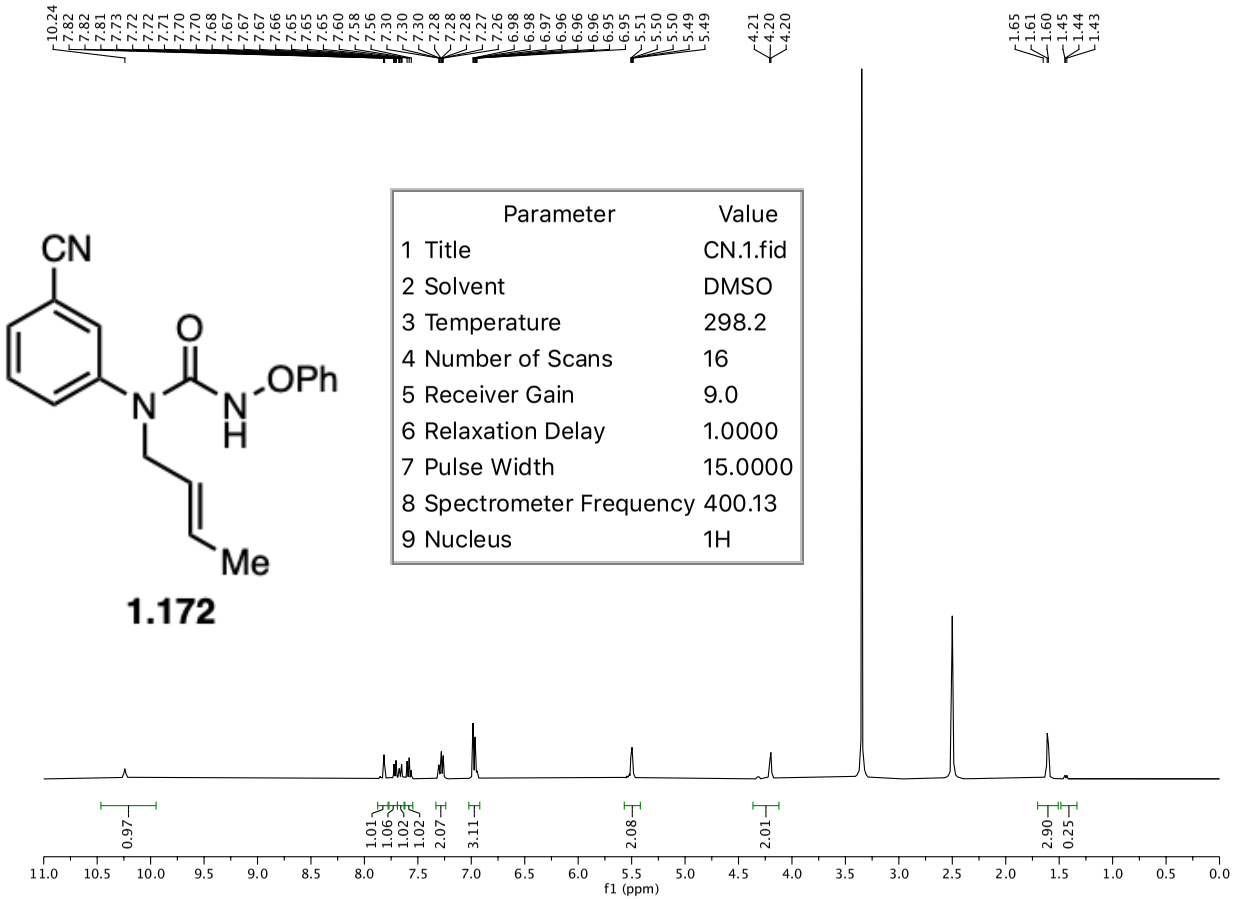

160.48
158.18
139.64
136.48
130.30
130.12
129.23
128.62
128.20
127.64
126.69
126.55
126.31
121.50
112.85
52.33
45.20
18.09
Parameter Value
1 Title XUF03194.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
Ph
N
N
H
OPh
Me
Ph
1.S57
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

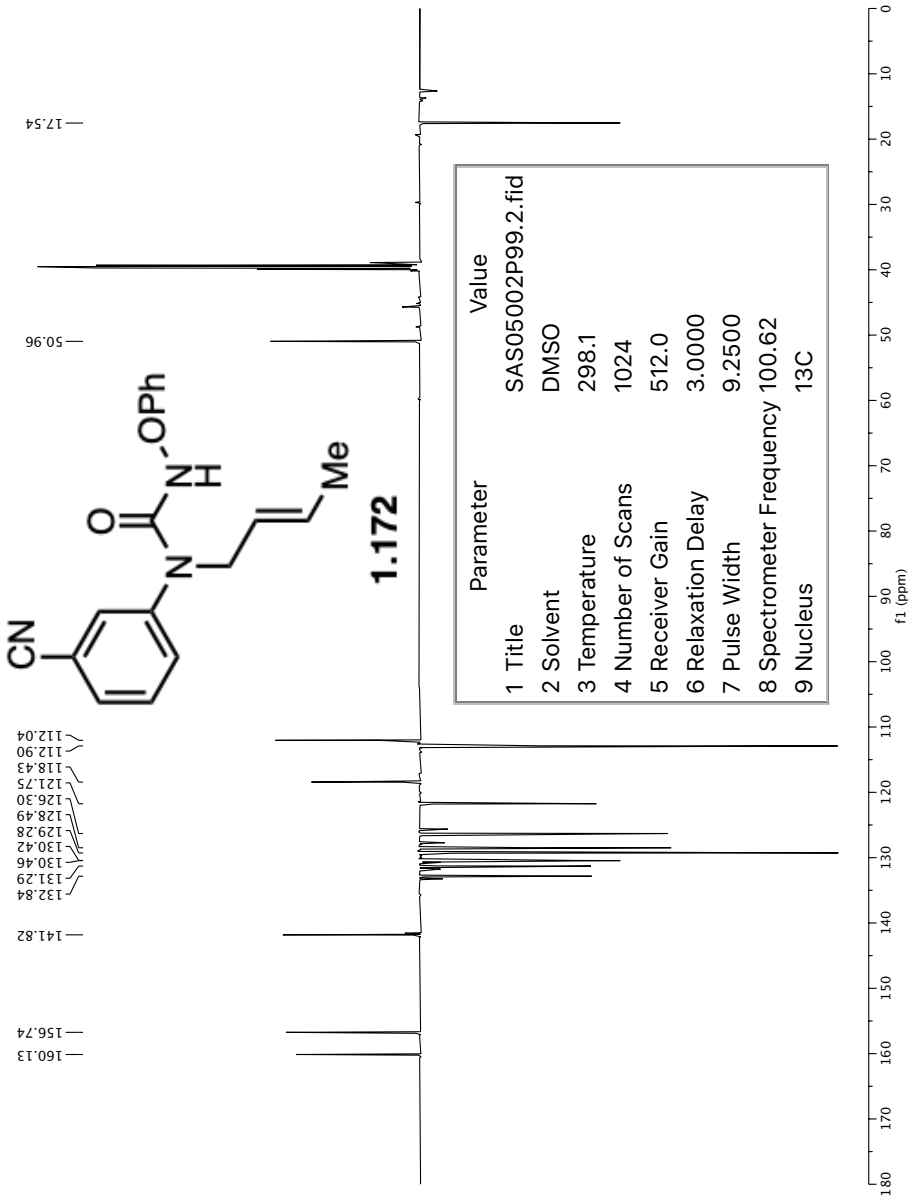

9.79
7.34
7.32
7.30
7.21
7.19
7.18
7.10
7.08
7.02
7.01
6.99
5.56
5.54
5.53
5.52
5.51
5.49
5.42
5.41
5.39
5.38
5.37
5.35
3.64
3.63
3.61
2.09
2.05
2.01
1.99
1.98
1.96
1.94
0.94
0.92
0.90
Parameter Value
1 Title XUF01225.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
HN
N
H
OPh
Me
1.S58
1.01
2.06
1.04
2.01
1.02
0.99
1.03
2.01
2.03
3.08
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

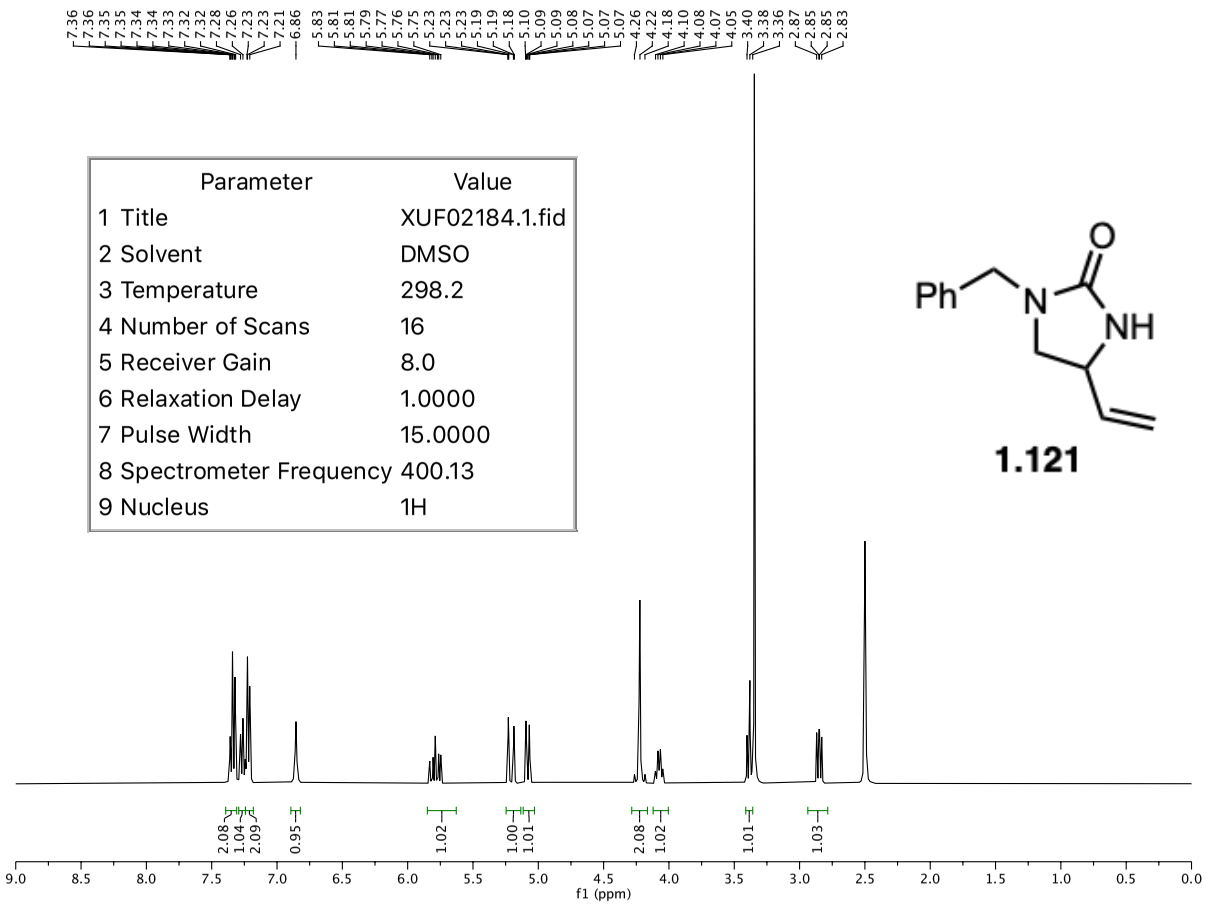

Parameter Value
1 Title XUF01225.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
159.95
159.23
132.42
129.28
126.43
122.05
113.62
40.69
24.64
13.44
HN
O
N
H
OPh
Me
1.S58
f1 (ppm)

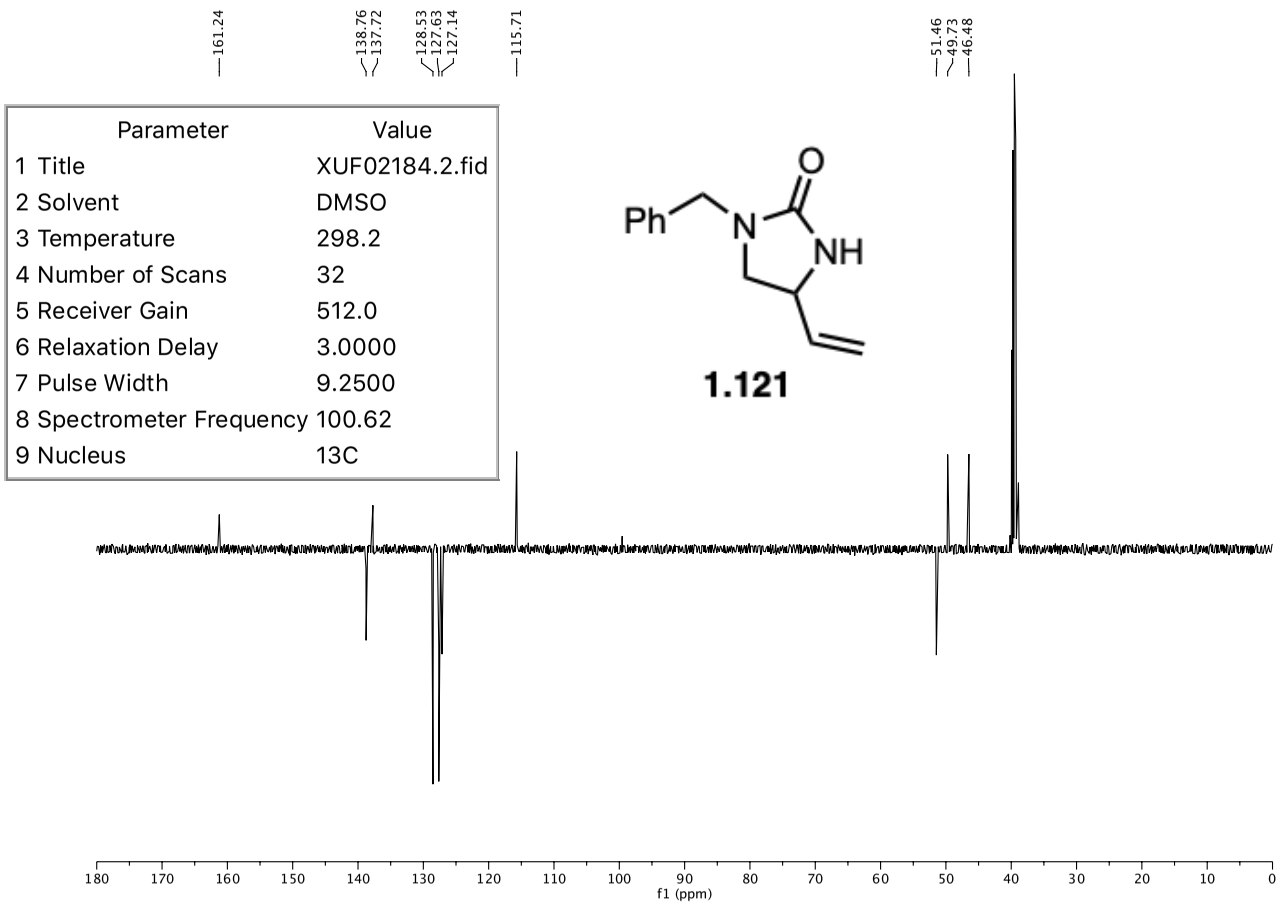

9.79 7.34 7.34 7.33 7.32 7.32 7.32 7.30 7.30 7.16 7.15 7.13 7.11 7.10 7.10 7.10 7.09 7.08 7.08 7.08 7.08 7.07 7.02 7.02 7.02 7.00 7.00 7.00 6.98 6.98 6.98
5.41 5.41 5.41 5.40 5.40 5.39 5.39
3.55 3.54 1.95 1.94 1.93 1.92 1.92 1.91 1.91 1.85 1.83 1.81 1.57 1.55 1.54 1.53 1.52 1.52 1.51 1.49 1.49 1.48 1.47 1.46 1.46 1.45
Parameter Value
1 Title XUF02210.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
HN
N
H
OPh
1.S59
1.00
2.05
0.99
1.97
0.99
1.01
2.04
2.02
1.94
4.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

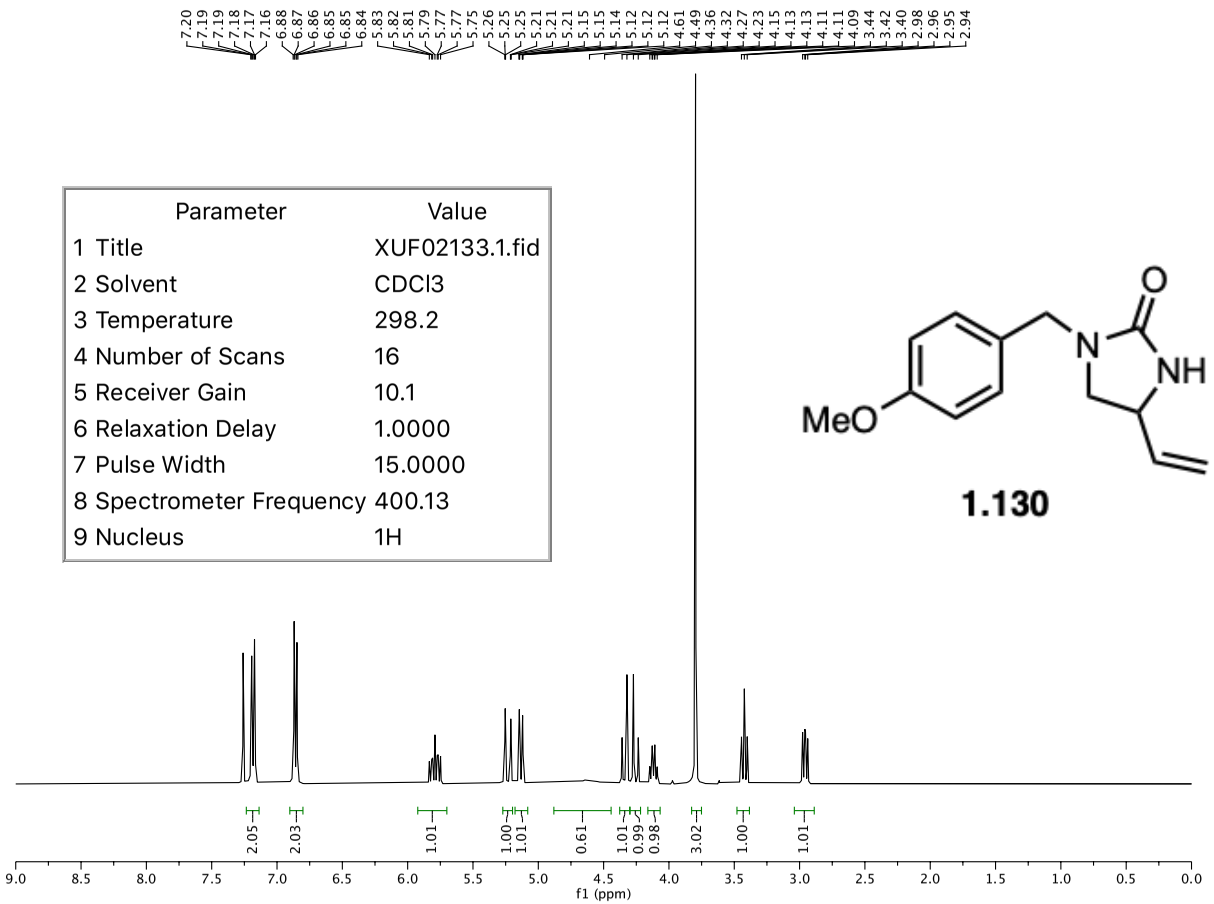

159.99
159.37
135.36
129.27
122.04
120.37
113.62
44.43
25.92
24.34
22.15
22.12
O
HN
N
H
OPh
1.S59
Parameter Value
1 Title XUF02210.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


10.24
7.82
7.81
7.73
7.72
7.72
7.71
7.70
7.68
7.67
7.67
7.67
7.66
7.65
7.65
7.65
7.60
7.58
7.56
7.30
7.30
7.28
7.28
7.28
7.27
7.26
6.98
6.98
6.97
6.96
6.96
6.96
6.95
6.95
5.51
5.50
5.50
5.49
5.49
4.21
4.20
4.20
1.65
1.61
1.60
1.45
1.44
1.43
CN
O
OPh
N
N
H
Me
1.172
Parameter Value
1 Title CN.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
0.97
1.01
1.06
1.02
2.07
3.11
2.08
2.01
2.90
0.25
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

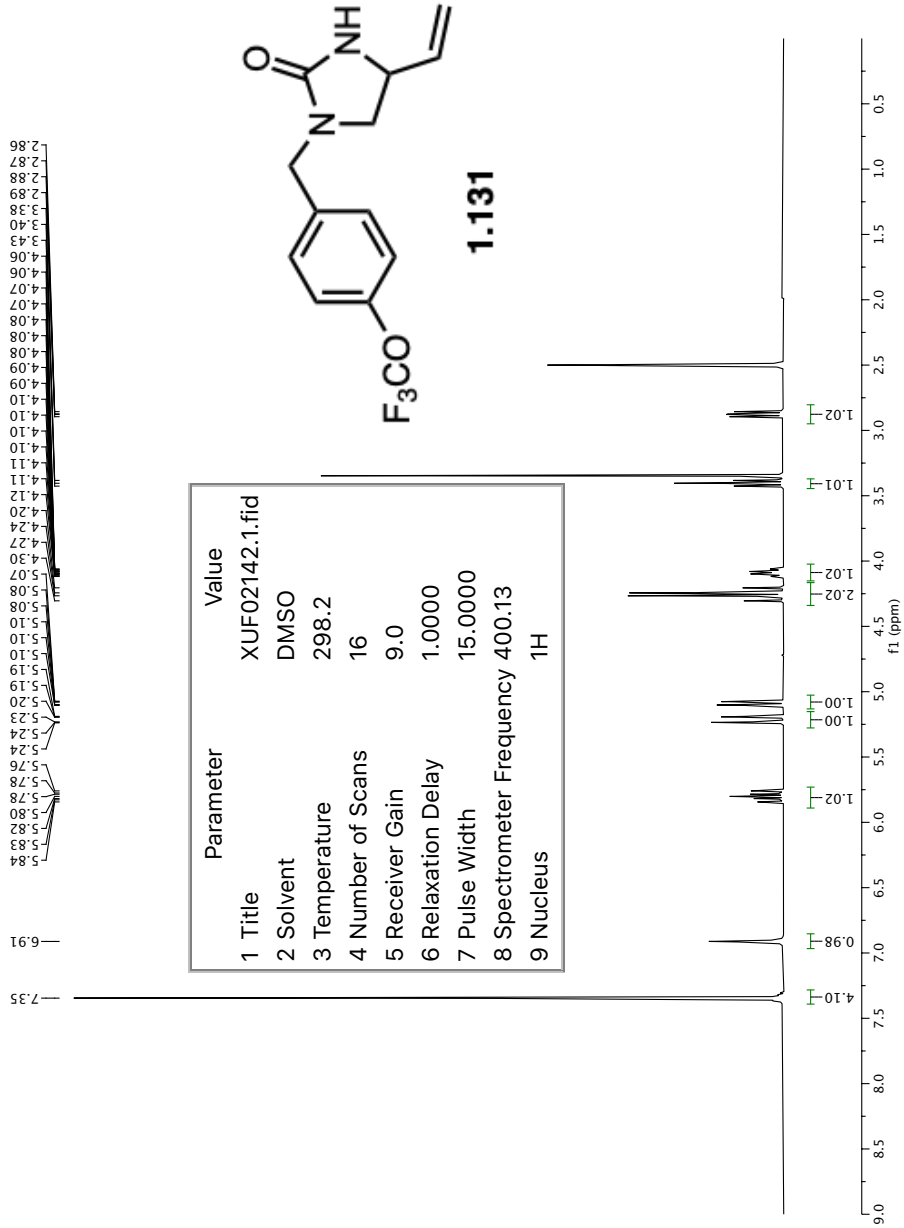

CN
N
O
N
H
OPh
Me
1.172
17.54
50.96
112.04
112.90
118.43
121.75
126.30
128.49
129.28
130.42
130.46
131.29
132.84
141.82
156.74
160.13
Parameter
Value
1 Title
SAS05002P99.2.fid
2 Solvent
DMSO
3 Temperature
298.1
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

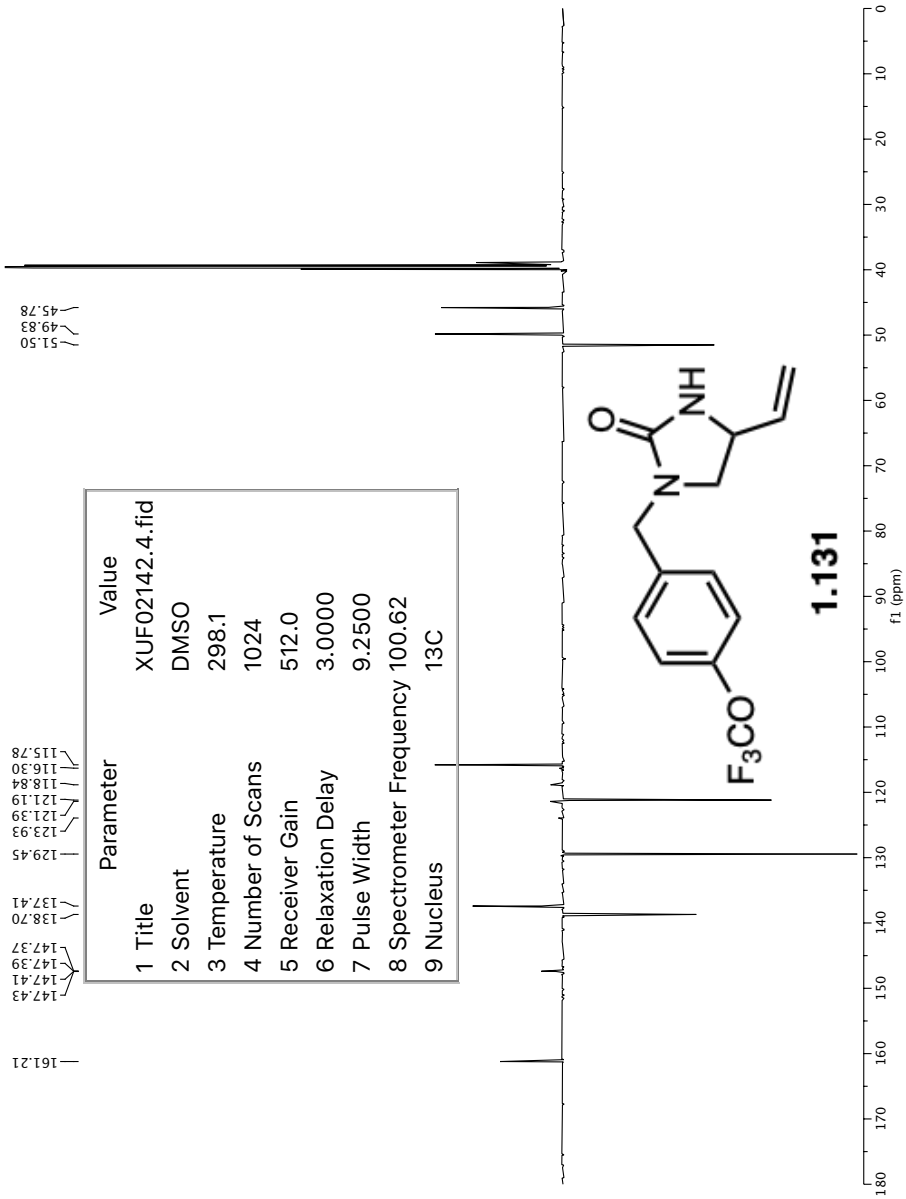

7.36
7.36
7.35
7.35
7.34
7.34
7.33
7.32
7.32
7.28
7.26
7.23
7.23
7.21
6.86
5.83
5.81
5.81
5.79
5.77
5.76
5.75
5.23
5.23
5.23
5.19
5.19
5.18
5.10
5.09
5.09
5.08
5.07
5.07
5.07
4.26
4.22
4.18
4.10
4.08
4.07
4.05
3.40
3.38
3.36
2.87
2.85
2.85
2.83
Parameter Value
1 Title XUF02184.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
1.121
2.08
1.04
2.09
0.95
1.02
1.00
1.01
2.08
1.02
1.01
1.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

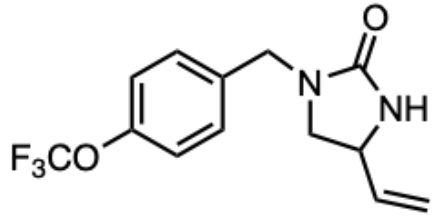

161.24
138.76
137.72
128.53
127.63
127.14
115.71
51.46
49.73
46.48
Parameter Value
1 Title XUF02184.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
NH
1.121
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.20
7.19
7.19
7.18
7.17
7.16
6.88
6.87
6.86
6.85
6.85
6.84
5.83
5.82
5.81
5.79
5.77
5.77
5.75
5.26
5.25
5.25
5.21
5.21
5.21
5.15
5.15
5.14
5.12
5.12
5.12
4.61
4.49
4.36
4.32
4.27
4.23
4.15
4.13
4.11
4.11
4.09
3.44
3.42
3.40
2.98
2.96
2.95
2.94
Parameter Value
1 Title XUF02133.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
MeO
1.130
2.05
2.03
1.01
1.00
1.01
0.61
1.01
0.99
0.98
3.02
1.00
1.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

161.63
159.11
137.61
129.51
129.01
117.15
114.09
55.41
52.78
50.27
46.99
Parameter
Value
1 Title
XUF02133.2.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
MeO
1.130
f1 (ppm)

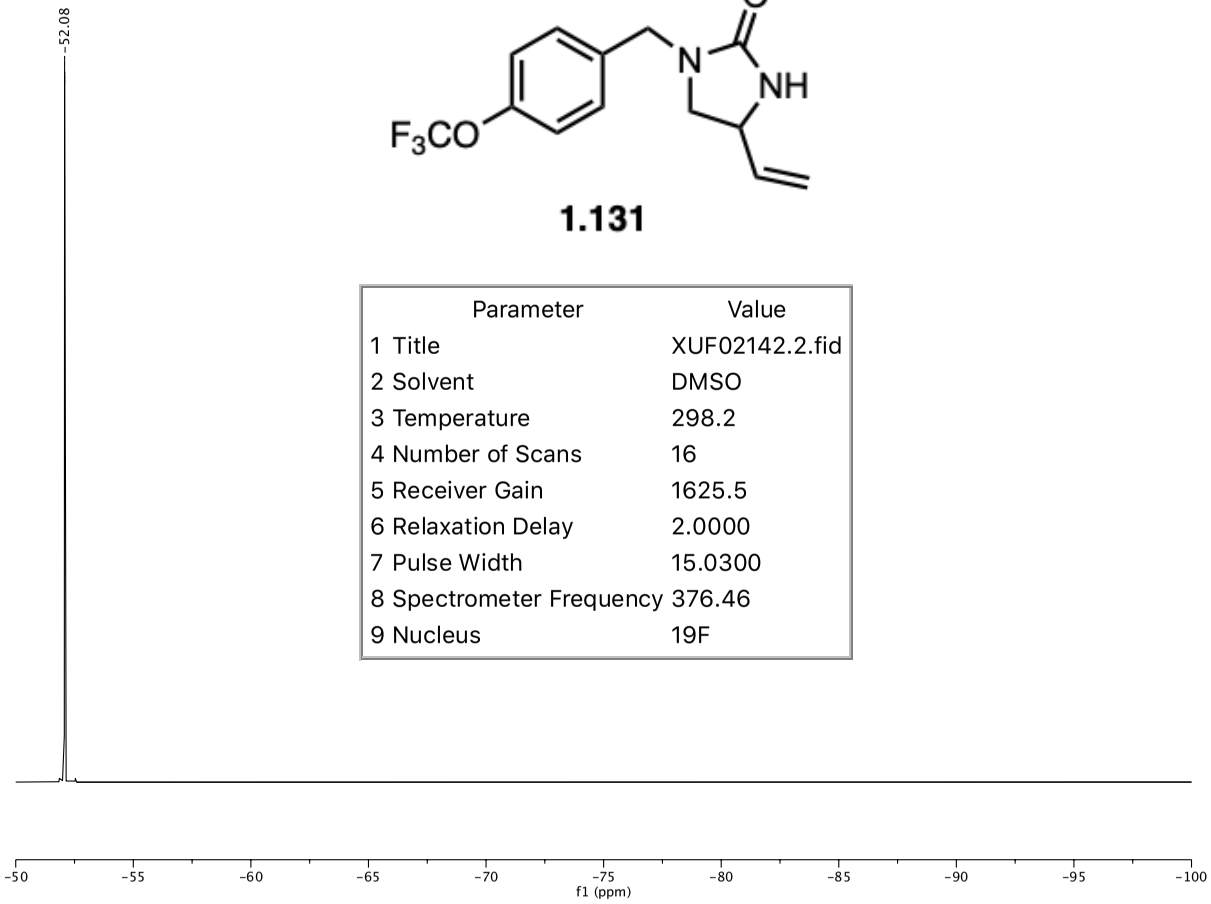

Parameter Value
1 Title XUF02142.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.131
f1 (ppm)

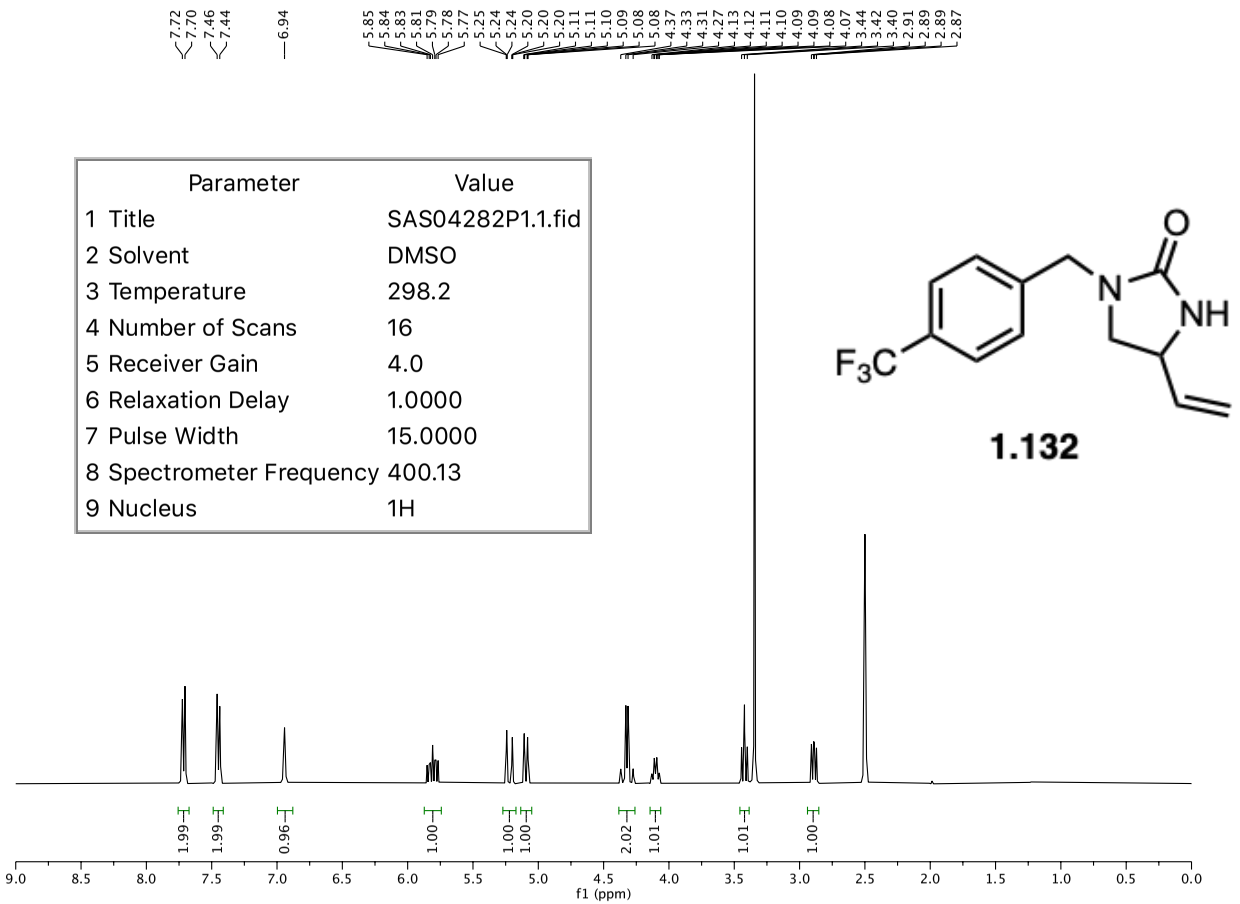

Parameter Value
1 Title XUF02142.4.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
161.21
147.43
147.41
147.39
147.37
138.70
137.41
129.45
123.93
121.39
121.19
118.84
116.30
115.78
51.50
49.83
45.78
F3CO
1.131
f1 (ppm)

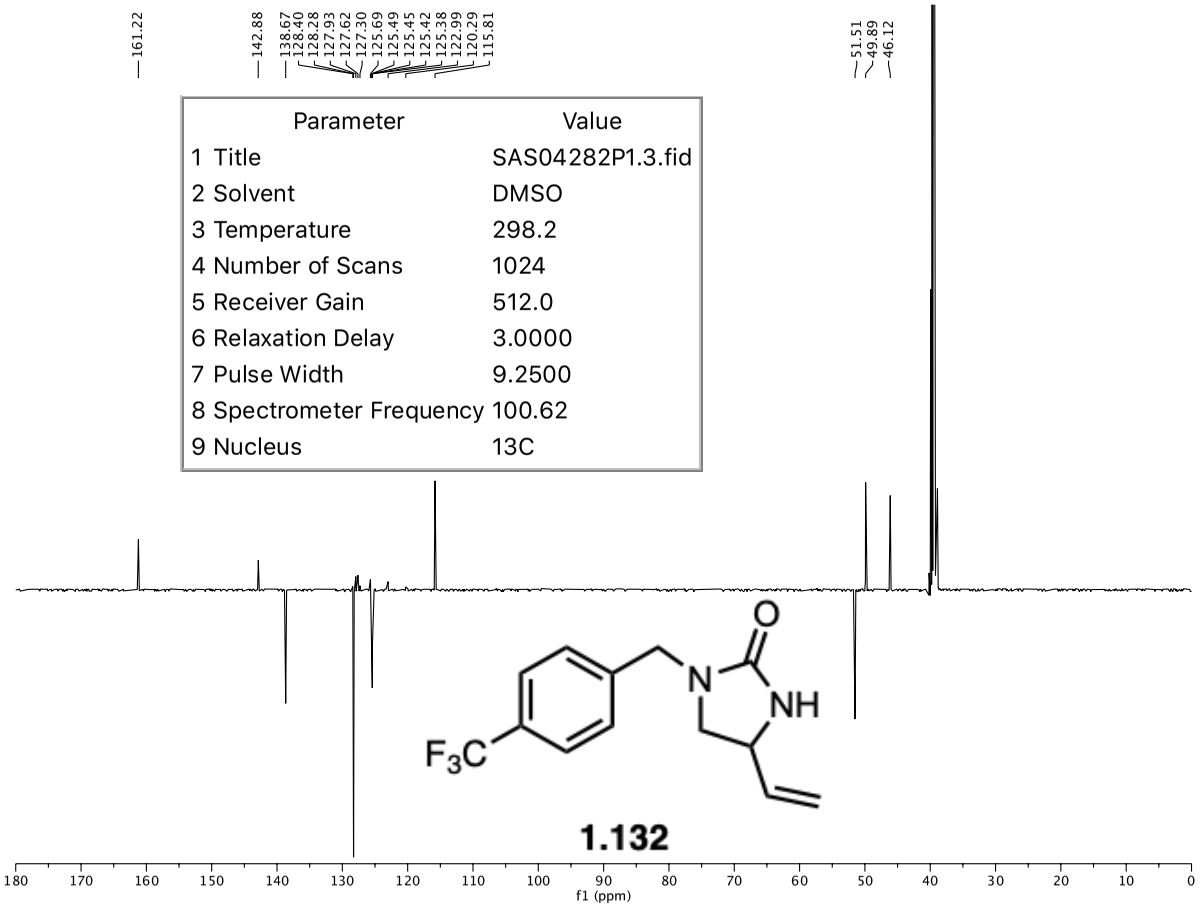


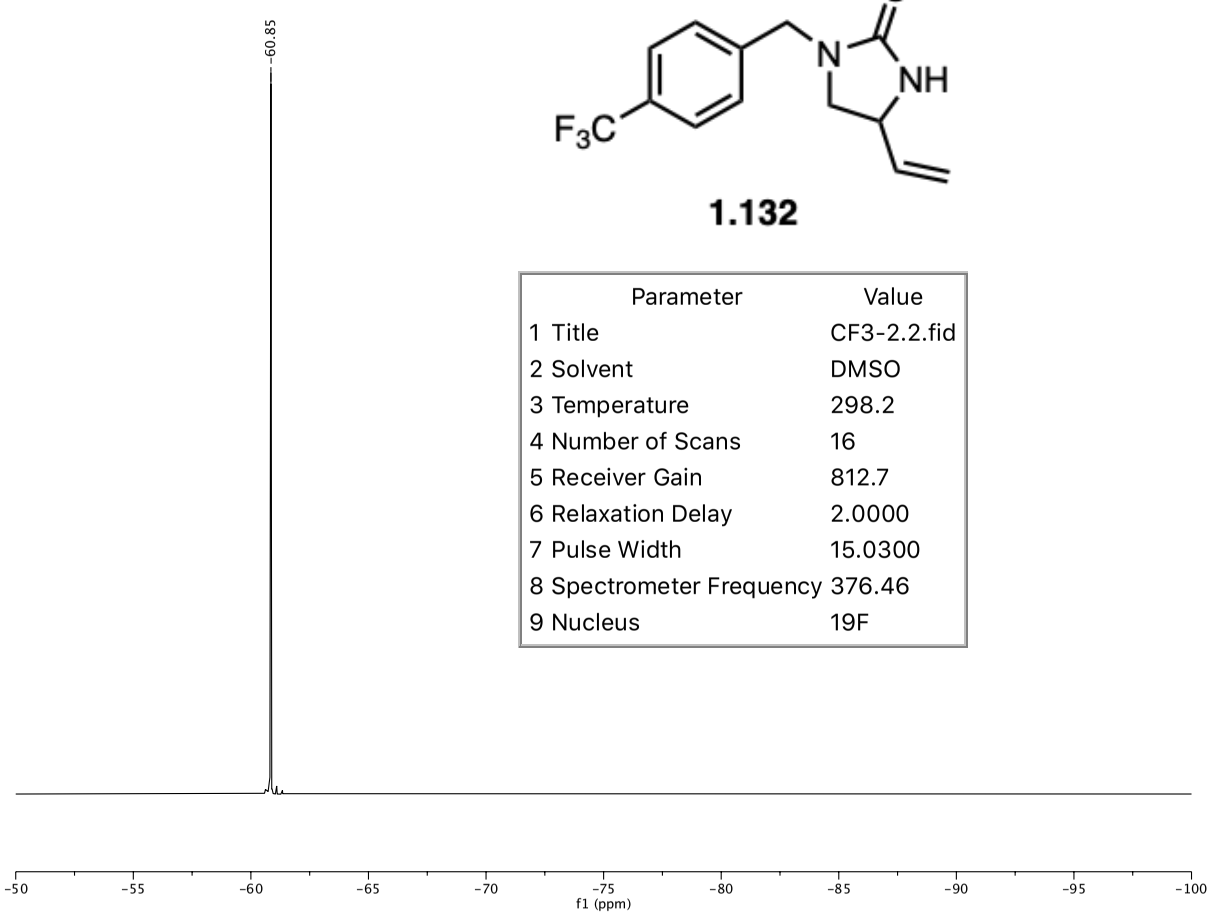
1.131

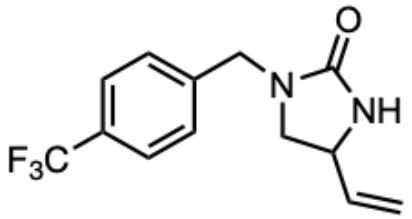
Parameter	Value
1 Title	XUF02142.2.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F




7.72
7.70
7.46
7.44
6.94
5.85
5.84
5.83
5.81
5.79
5.78
5.77
5.25
5.24
5.24
5.20
5.20
5.20
5.11
5.11
5.10
5.09
5.08
5.08
4.37
4.33
4.31
4.27
4.13
4.12
4.11
4.10
4.09
4.09
4.08
4.07
3.44
3.42
3.40
2.91
2.89
2.89
2.87
Parameter Value
1 Title SAS04282P1.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
F3C
1.132
1.99
1.99
0.96
1.00
1.00
1.00
2.02
1.01
1.01
1.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

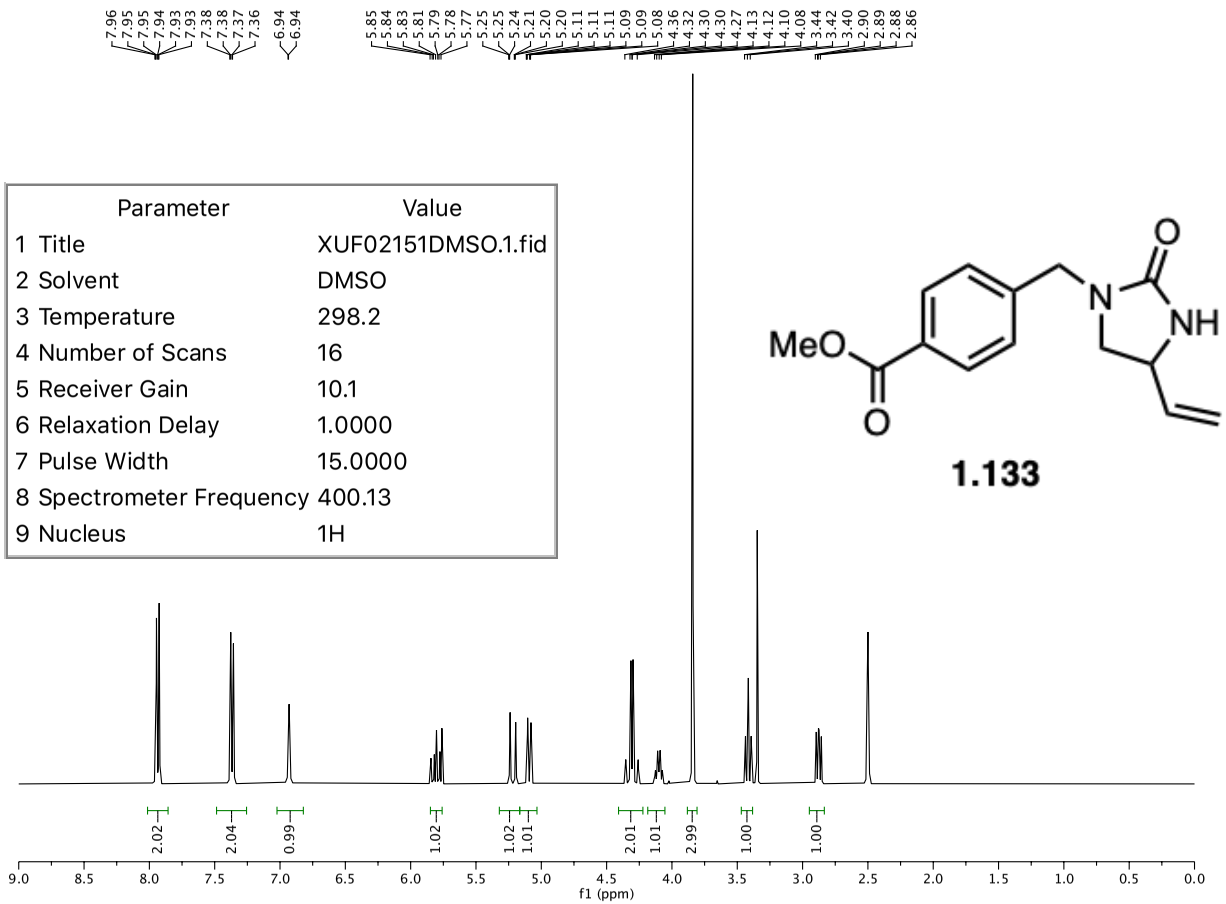

161.22
142.88
138.67
128.40
128.28
127.93
127.62
127.30
125.69
125.49
125.45
125.42
125.38
122.99
120.29
115.81
51.51
49.89
46.12
Parameter Value
1 Title SAS04282P1.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
F3C
1.132
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

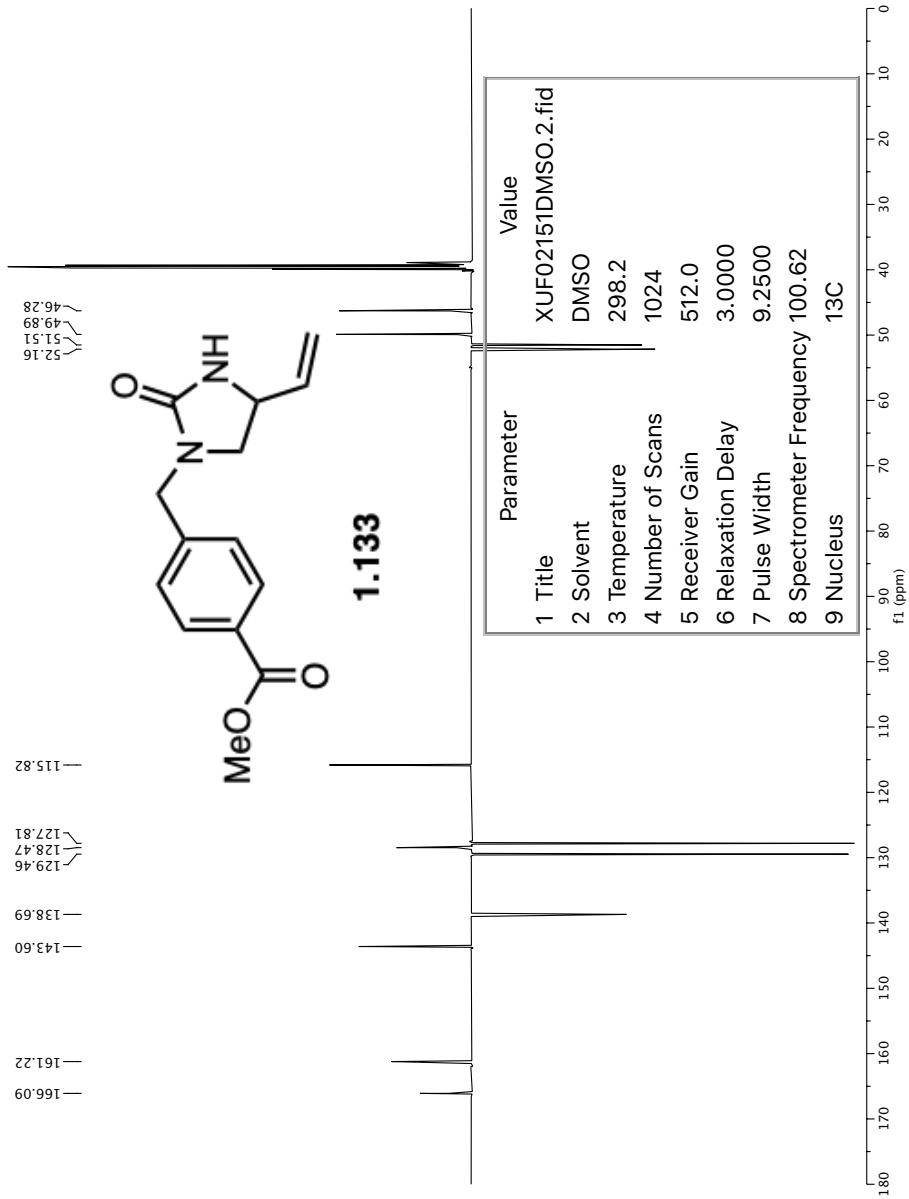


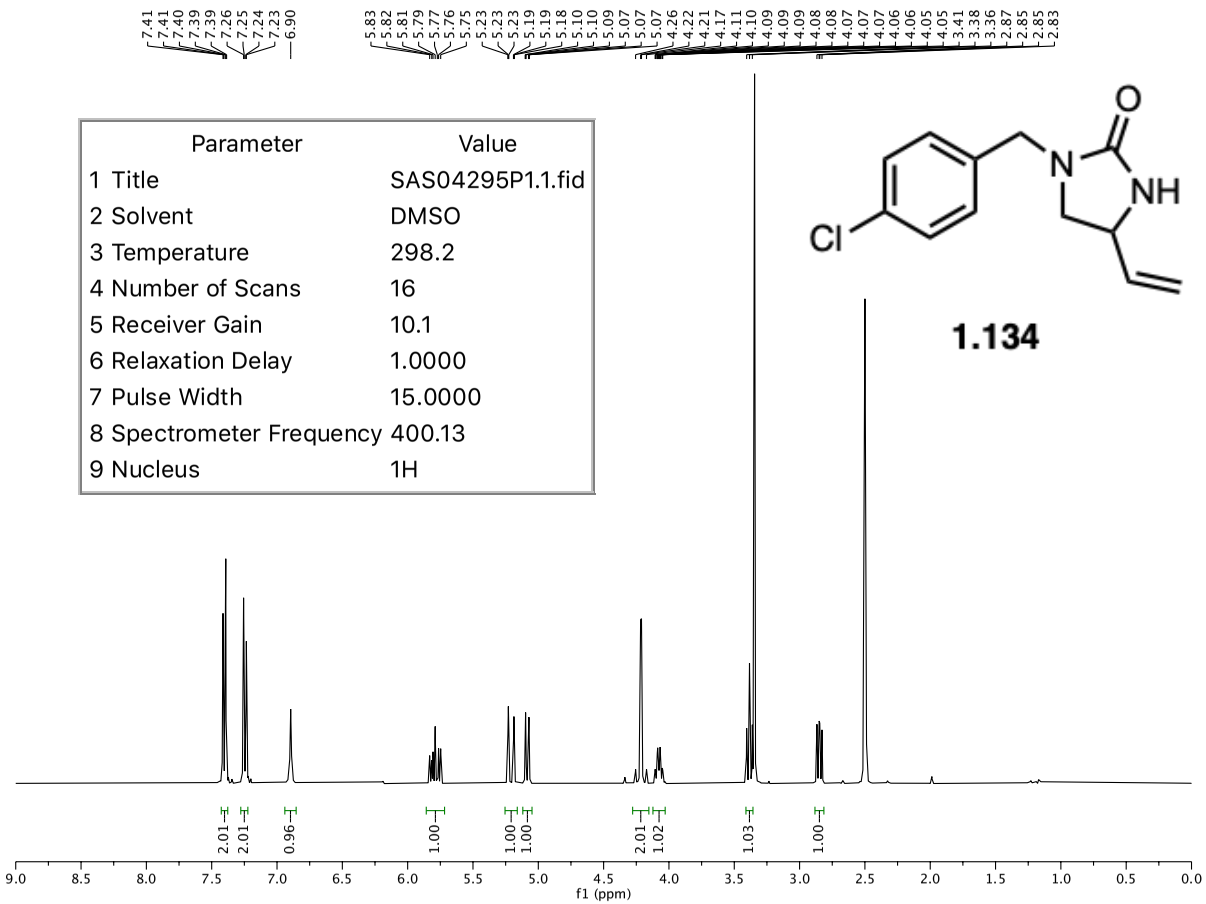


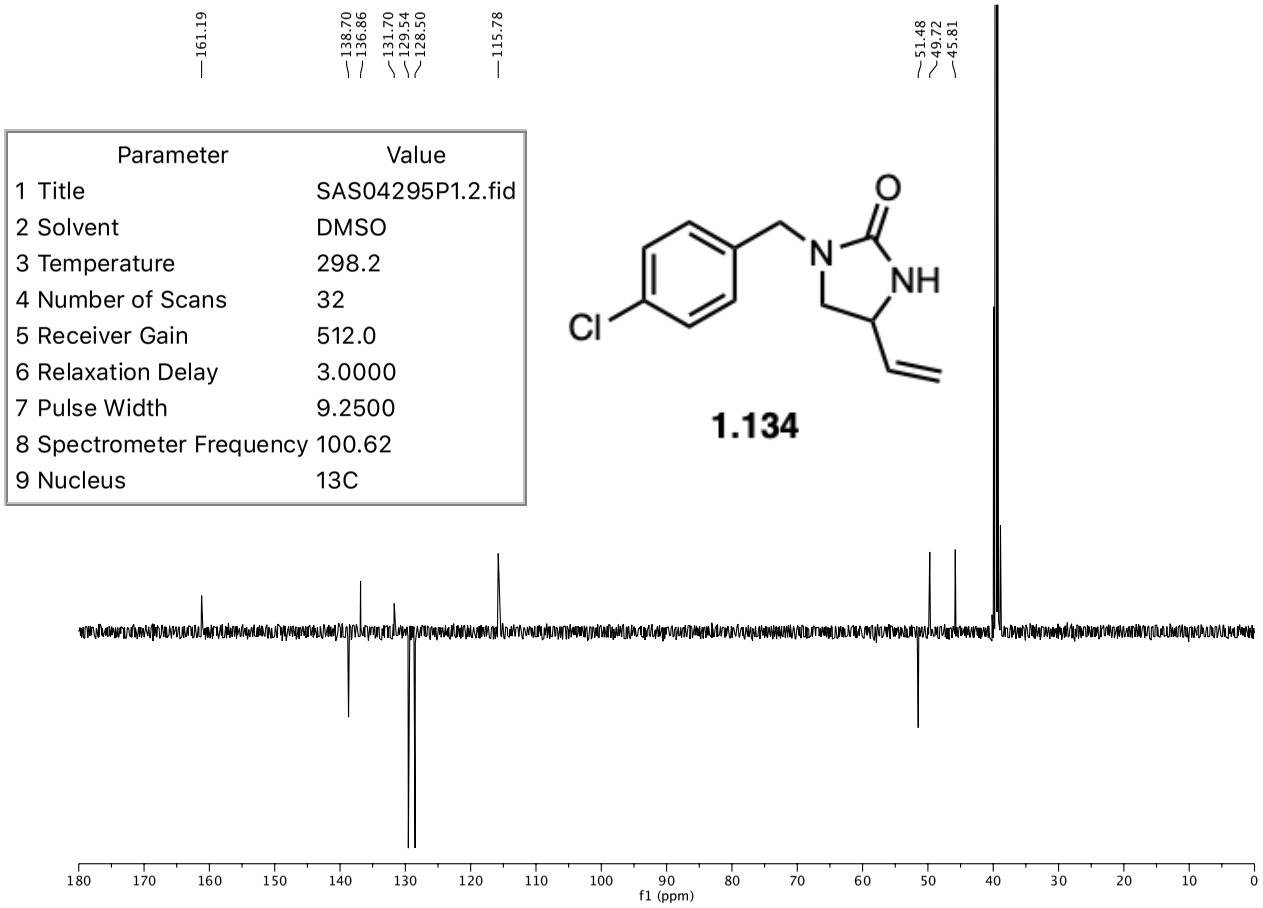
1.132

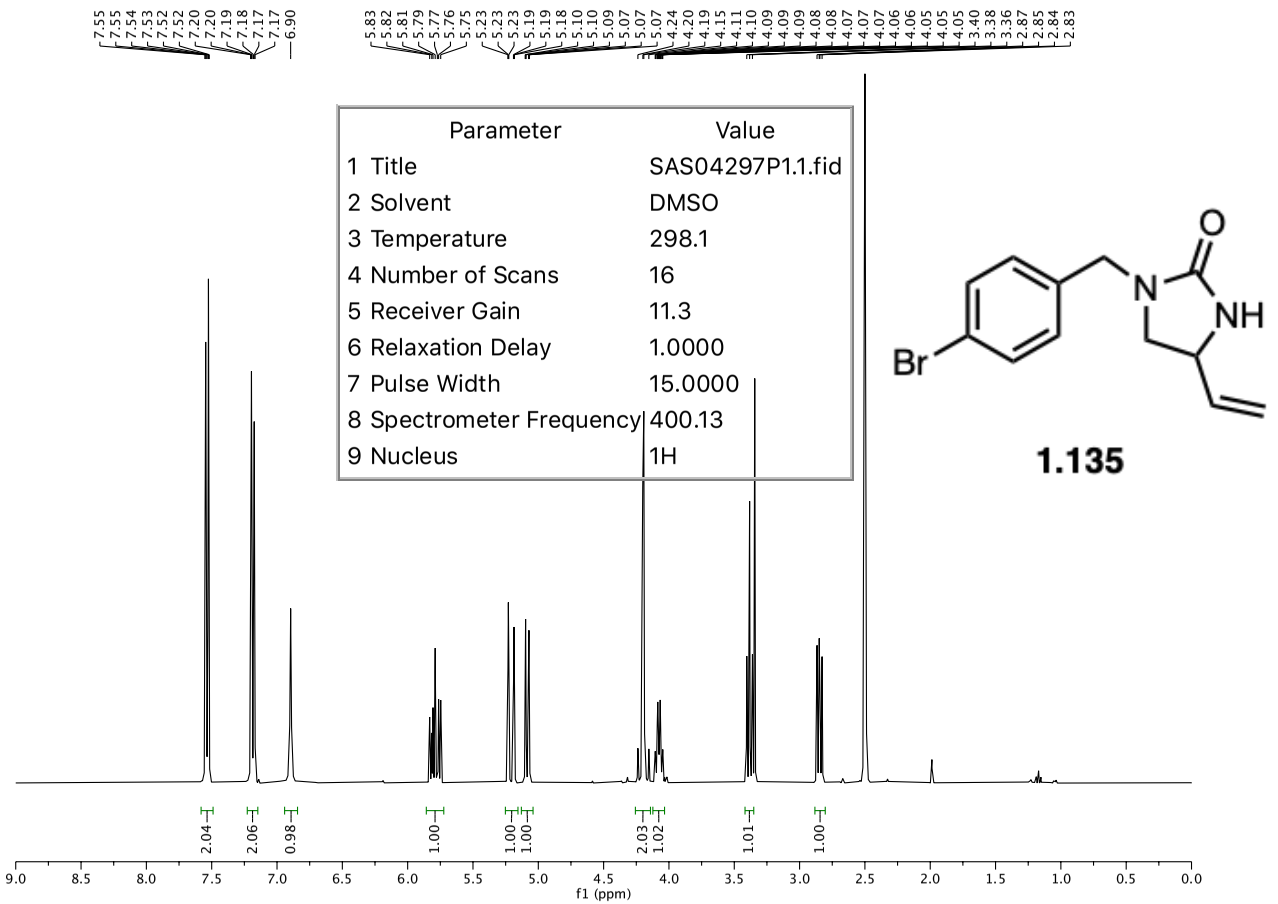
Parameter	Value
1 Title	CF3-2.2.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	812.7
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

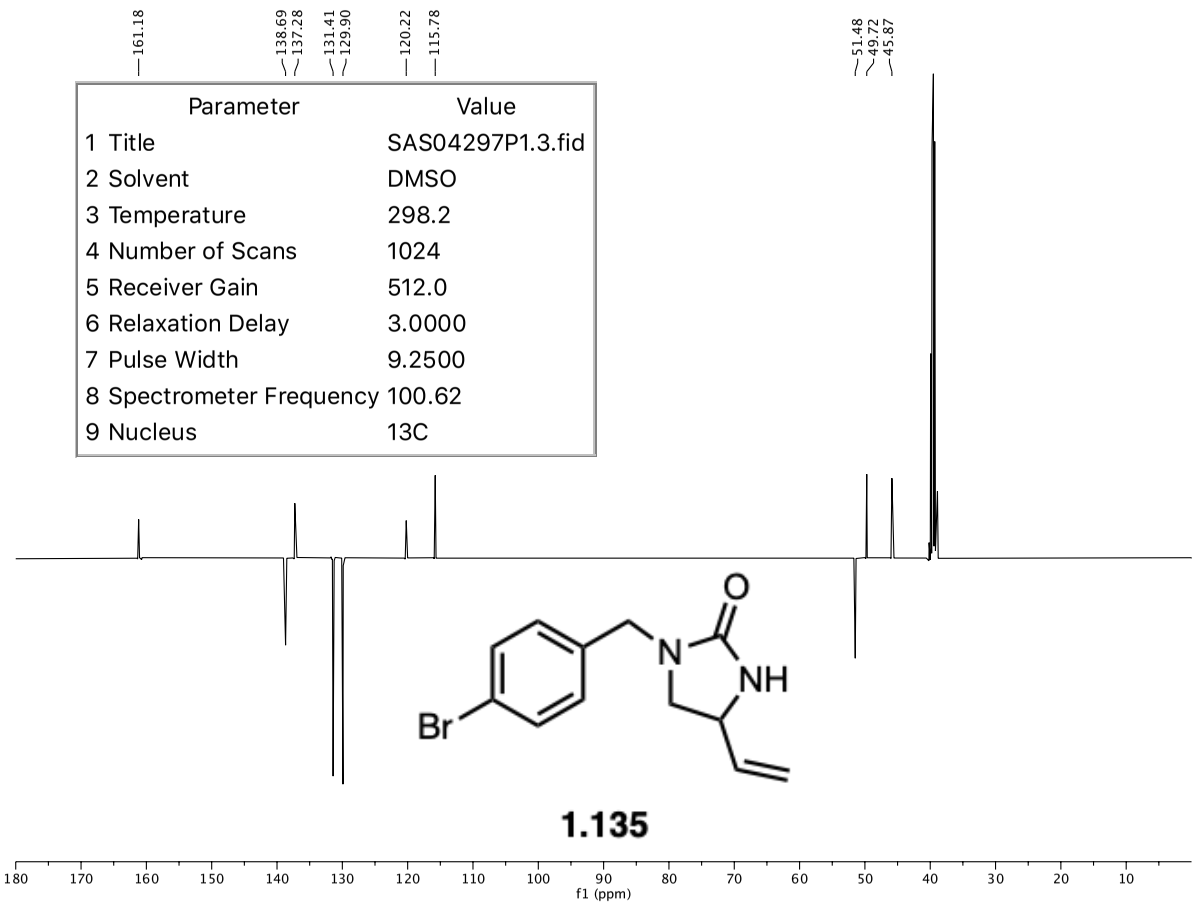

7.96
7.95
7.95
7.94
7.93
7.93
7.38
7.38
7.37
7.36
6.94
6.94
5.85
5.84
5.83
5.81
5.79
5.78
5.77
5.25
5.25
5.24
5.21
5.20
5.20
5.11
5.11
5.11
5.09
5.09
5.08
4.36
4.32
4.30
4.30
4.27
4.13
4.12
4.10
4.08
3.44
3.42
3.40
2.90
2.89
2.88
2.86
Parameter Value
1 Title XUF02151DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
NH
1.133
2.02
2.04
0.99
1.02
1.02
1.01
2.01
1.01
2.99
1.00
1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

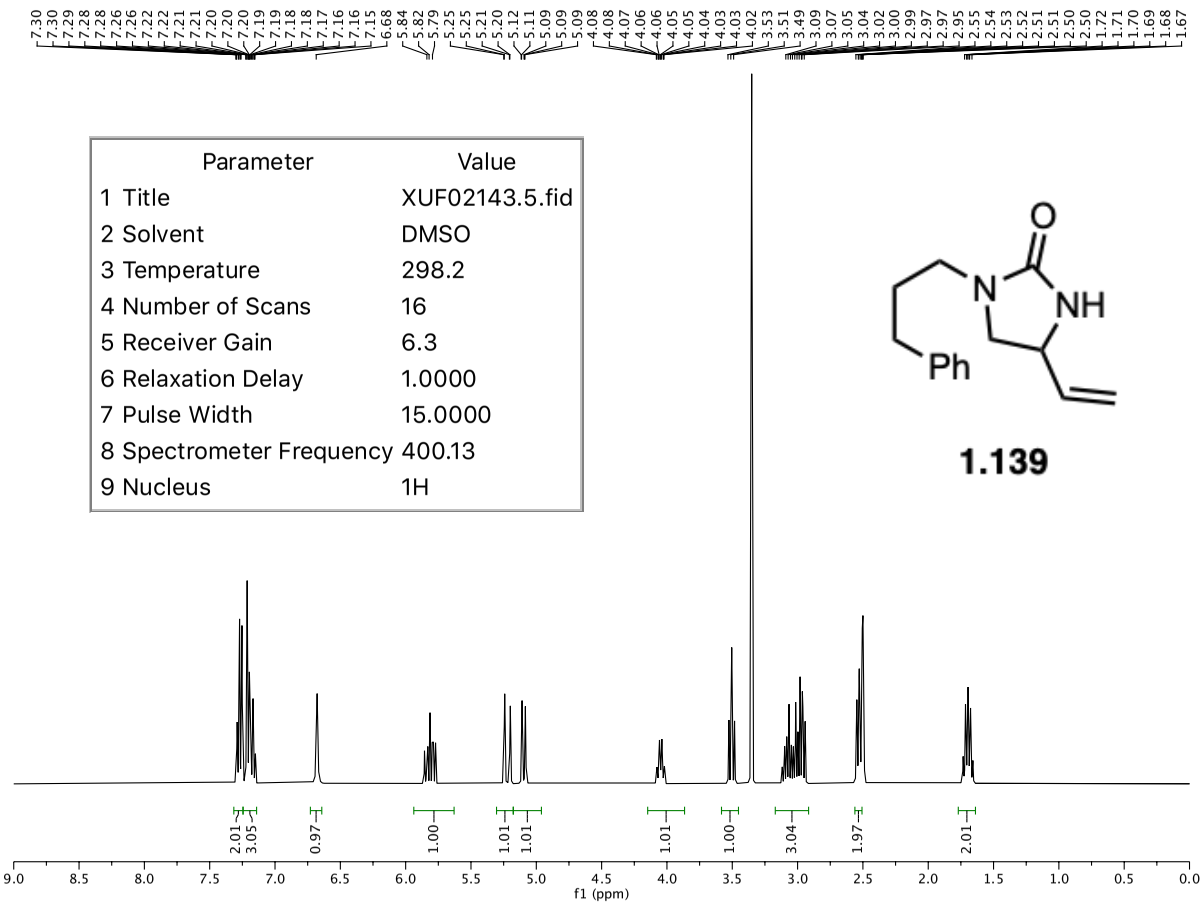

52.16
51.51
49.89
46.28
115.82
127.81
128.47
129.46
138.69
143.60
161.22
166.09
MeO
O
O
NH
N
1.133
Parameter
Value
1 Title
XUF02151DMSO.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

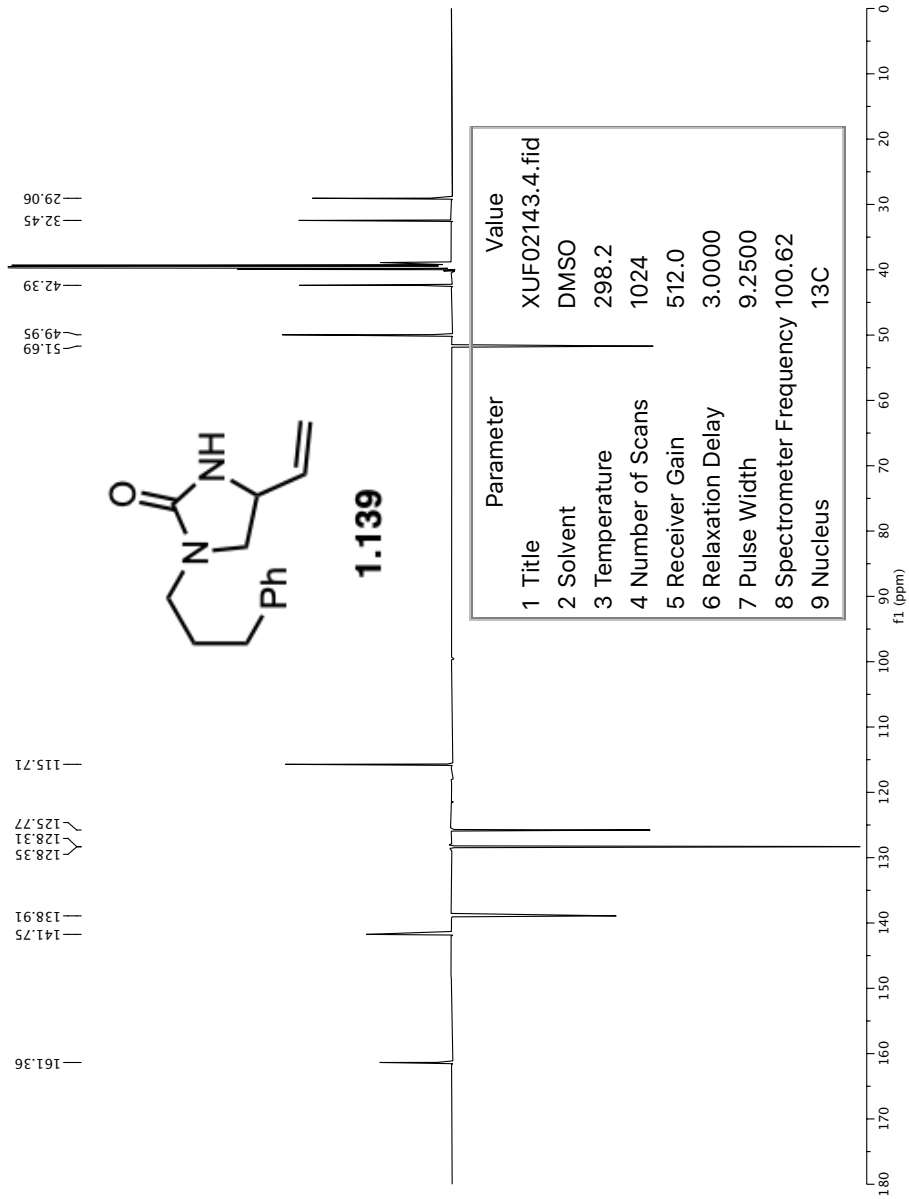

7.41
7.41
7.40
7.39
7.39
7.26
7.25
7.24
7.23
6.90
5.83
5.82
5.81
5.79
5.77
5.76
5.75
5.23
5.23
5.23
5.19
5.19
5.18
5.10
5.10
5.09
5.07
5.07
5.07
4.26
4.22
4.21
4.17
4.11
4.10
4.09
4.09
4.09
4.08
4.08
4.07
4.07
4.07
4.06
4.06
4.06
4.05
4.05
3.41
3.38
3.36
2.87
2.85
2.85
2.83
Parameter Value
1 Title SAS04295P1.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
Cl
1.134
2.01
2.01
0.96
1.00
1.00
1.00
2.01
1.02
1.03
1.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

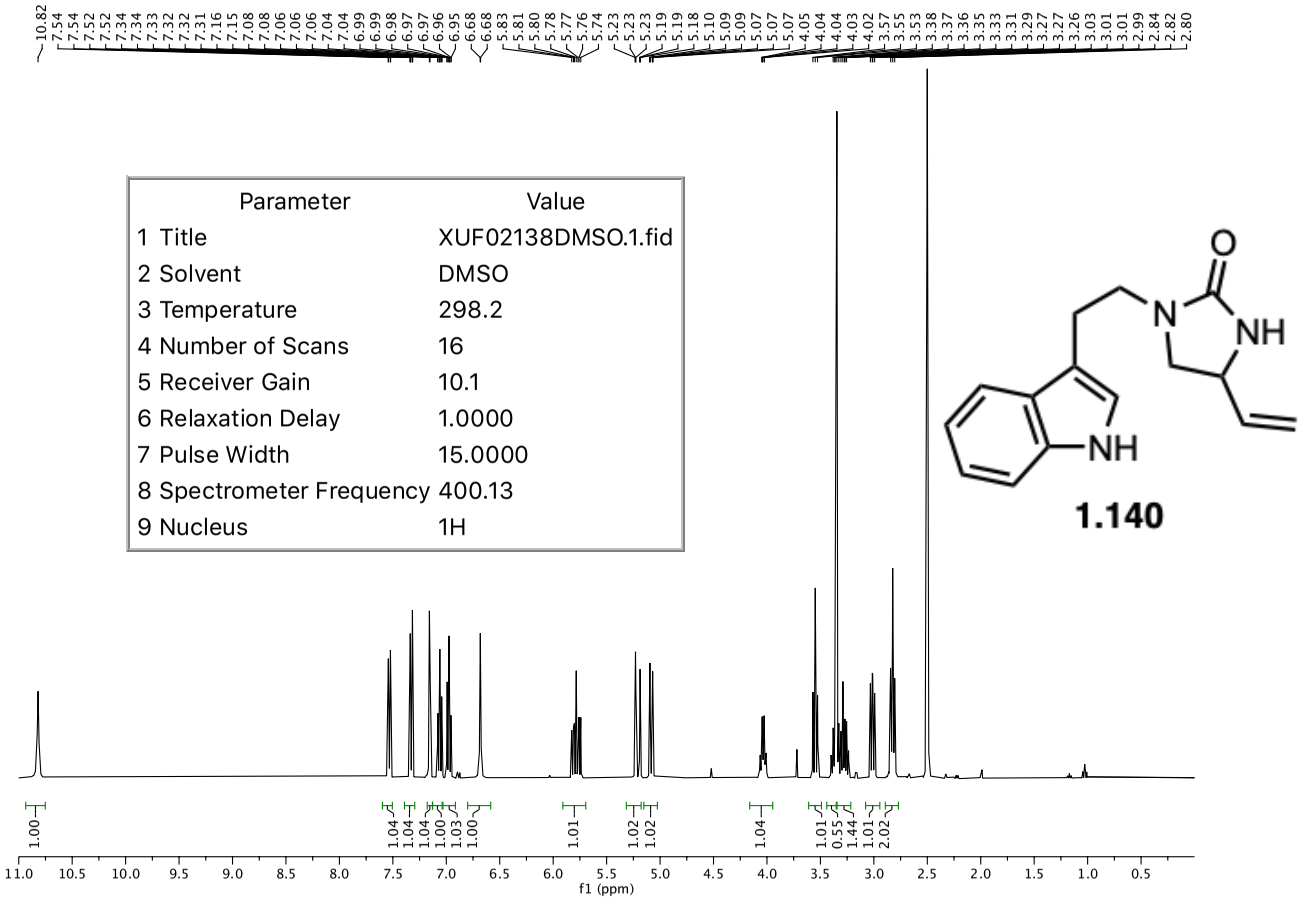

161.19
138.70
136.86
131.70
129.54
128.50
115.78
51.48
49.72
45.81
Parameter Value
1 Title SAS04295P1.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
Cl
1.134
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

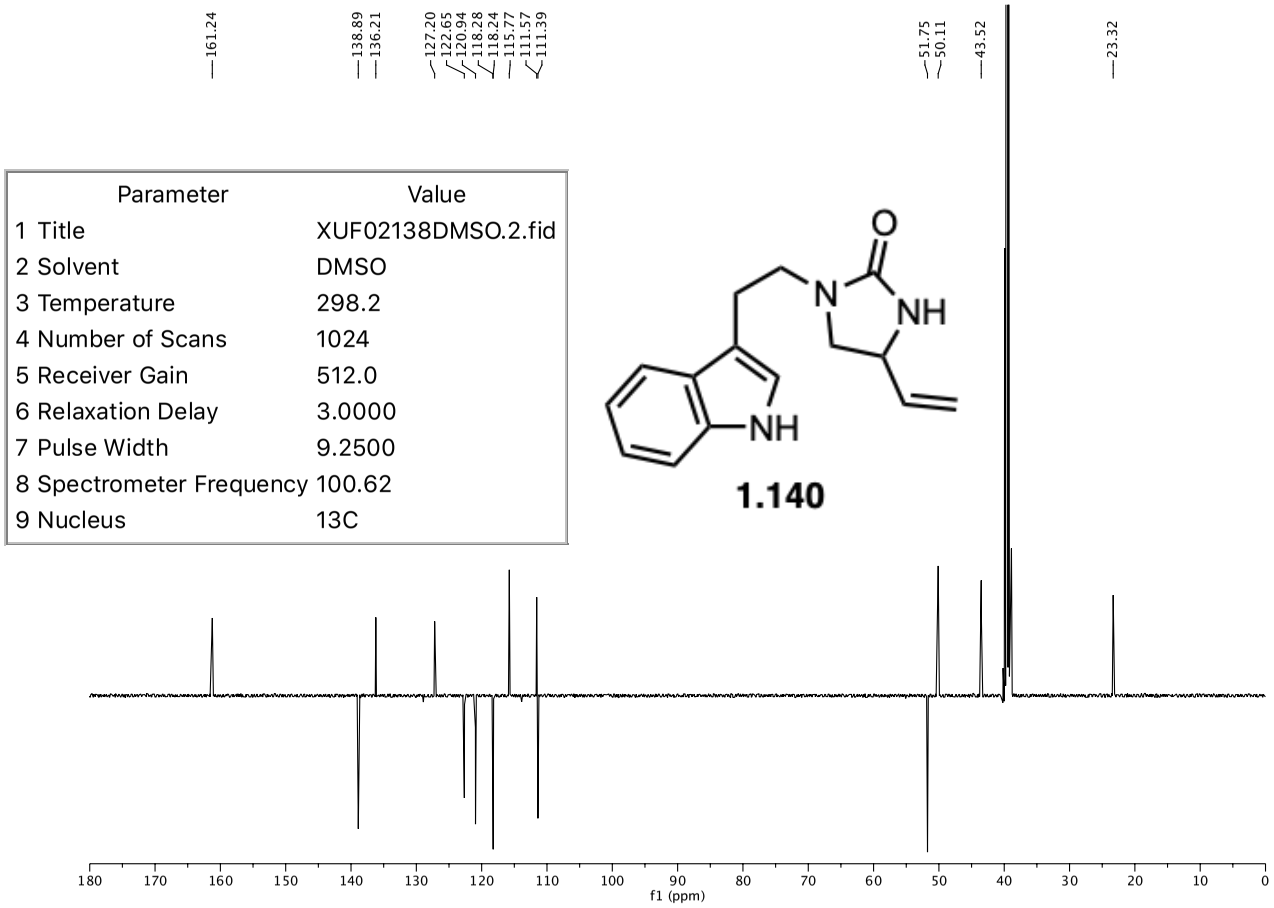

7.55 7.55 7.54 7.53 7.52 7.52 7.20 7.20 7.19 7.18 7.17 7.17 6.90
5.83 5.82 5.81 5.79 5.77 5.76 5.75 5.23 5.23 5.23 5.19 5.19 5.18 5.10 5.10 5.09 5.07 5.07 5.07 4.24 4.20 4.19 4.15 4.11 4.10 4.09 4.09 4.09 4.08 4.08 4.07 4.07 4.07 4.06 4.06 4.05 4.05 4.05 3.40 3.38 3.36 2.87 2.85 2.84 2.83
Parameter Value
1 Title SAS04297P1.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
Br
1.135
2.04 2.06 0.98 1.00 1.00 1.00 2.03 1.02 1.01 1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

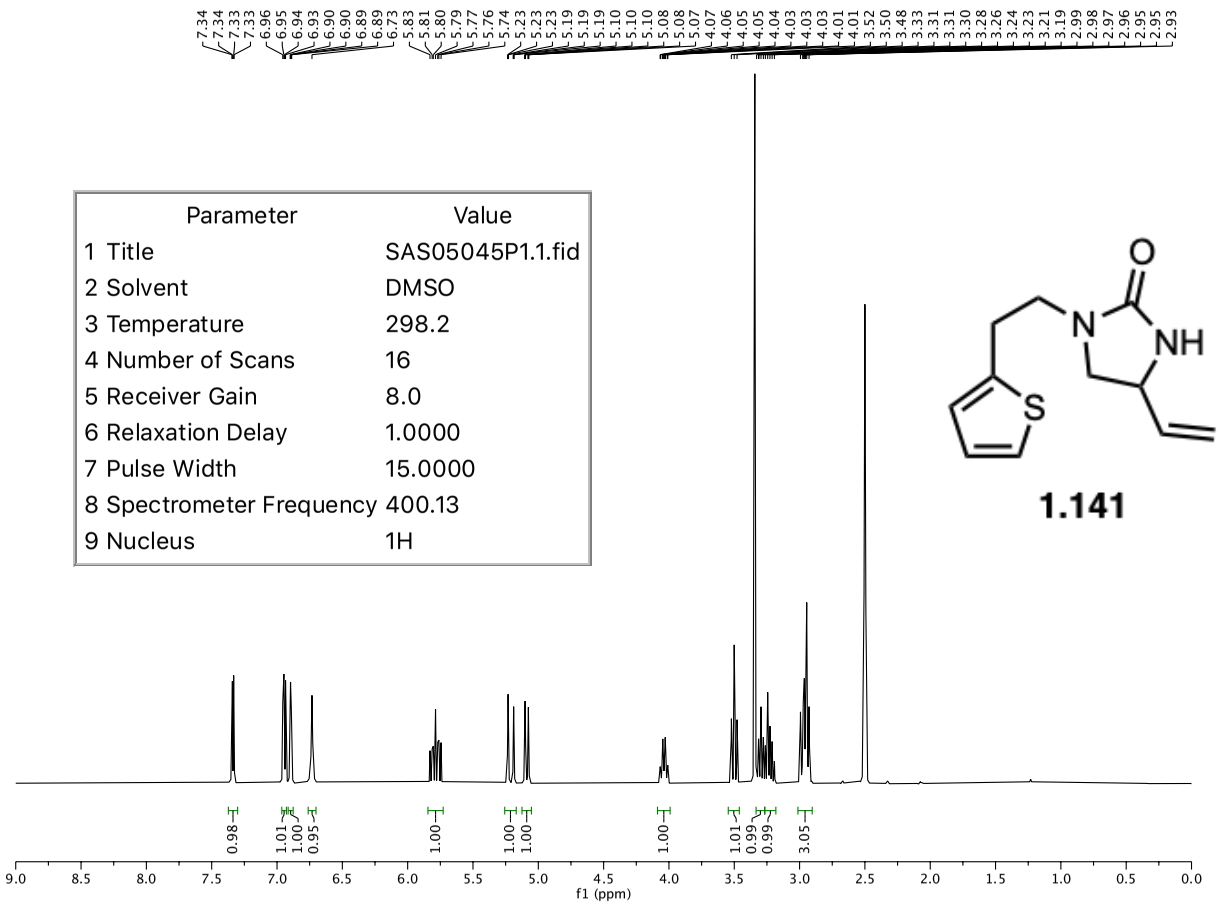

161.18
138.69
137.28
131.41
129.90
120.22
115.78
51.48
49.72
45.87
Parameter Value
1 Title SAS04297P1.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
Br
1.135
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

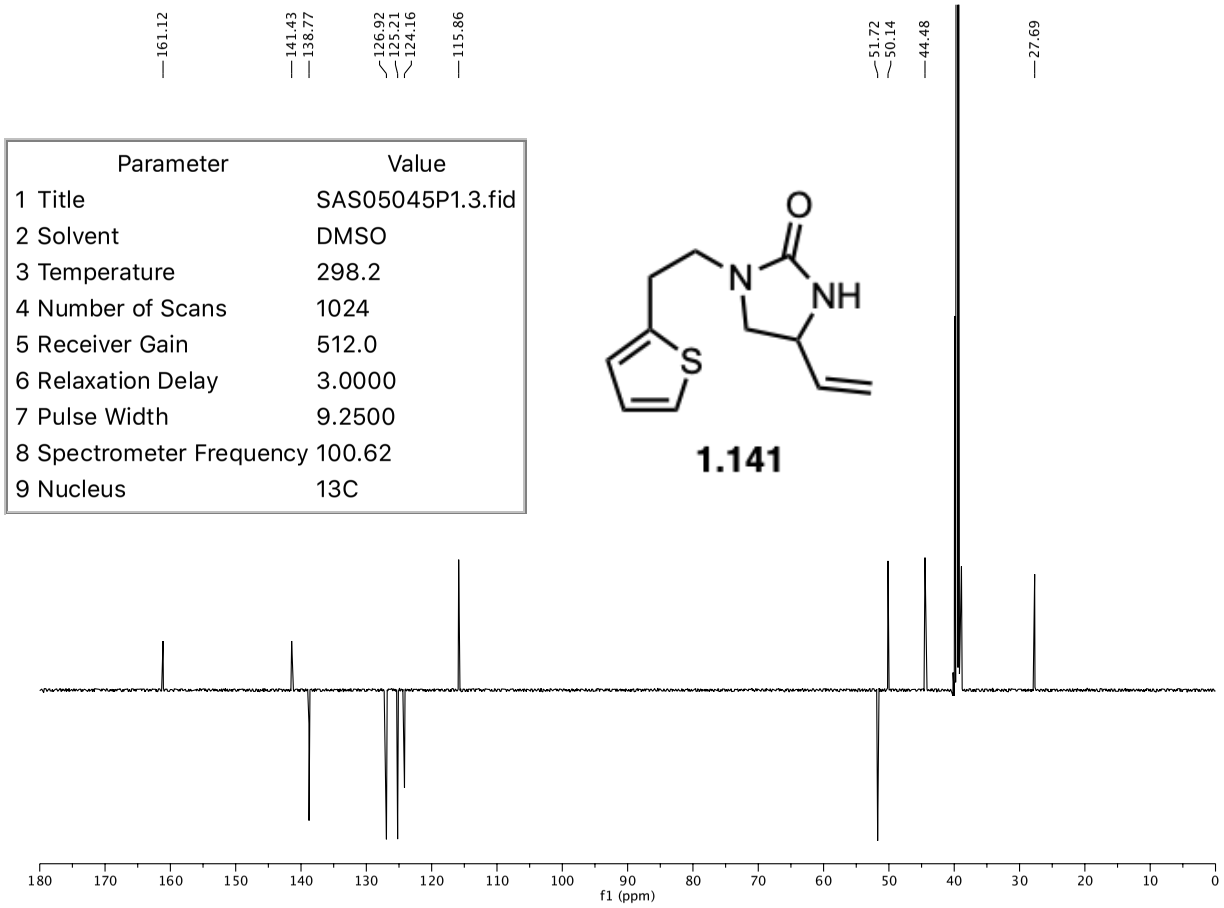

7.30 7.30 7.29 7.28 7.28 7.26 7.26 7.22 7.22 7.21 7.21 7.20 7.20 7.20 7.19 7.19 7.18 7.18 7.17 7.16 7.16 7.15 6.68
5.84 5.82 5.79 5.25 5.25 5.21 5.20 5.12 5.11 5.09 5.09 5.09
4.08 4.08 4.07 4.06 4.06 4.05 4.05 4.04 4.03 4.03 4.02 3.53 3.51 3.49 3.09 3.07 3.05 3.04 3.02 3.00 2.99 2.97 2.97 2.95 2.55 2.54 2.53 2.52 2.51 2.51 2.50 2.50 1.72 1.71 1.70 1.69 1.68 1.67
Parameter Value
1 Title XUF02143.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
Ph
1.139
2.01 3.05 0.97 1.00 1.01 1.01 1.01 1.00 3.04 1.97 2.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

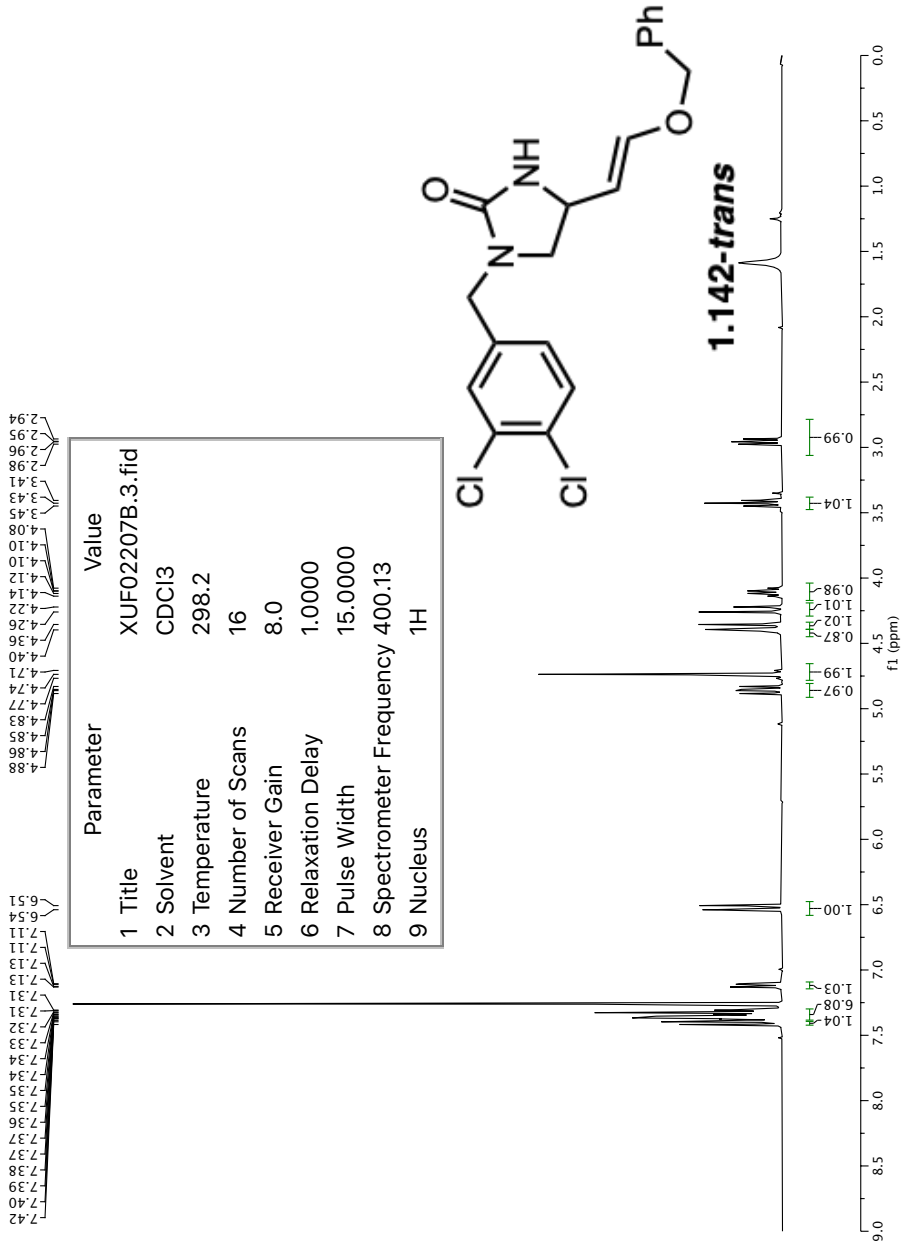

29.06
32.45
42.39
49.95
51.69
115.71
125.77
128.31
128.35
138.91
141.75
161.36
1.139
Ph
NH
O
N
Parameter
Value
1 Title
XUF02143.4.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

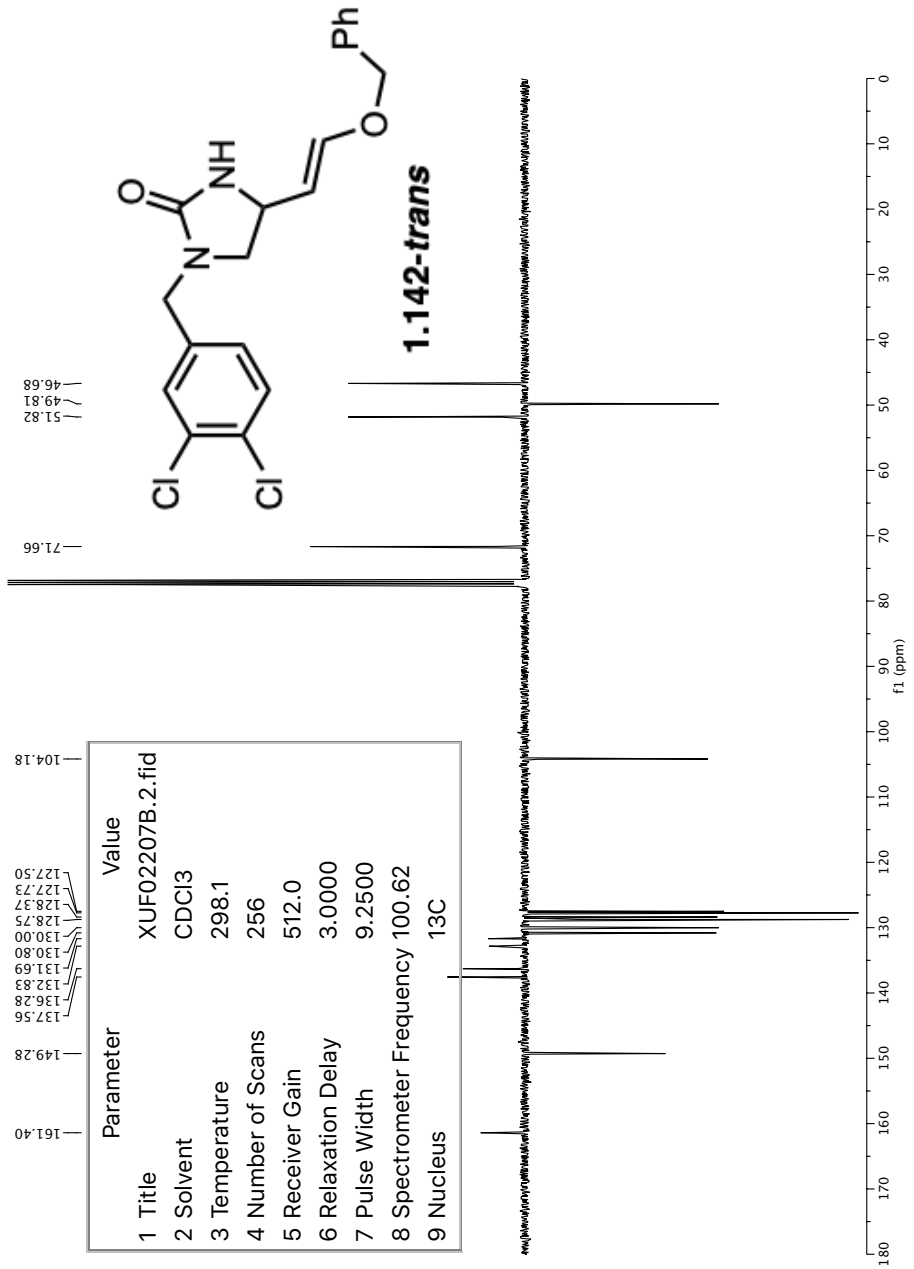

10.82
7.54
7.54
7.52
7.52
7.34
7.34
7.33
7.32
7.32
7.31
7.16
7.15
7.08
7.08
7.06
7.06
7.06
7.04
7.04
6.99
6.99
6.98
6.97
6.97
6.96
6.95
6.68
6.68
5.83
5.81
5.80
5.78
5.77
5.76
5.74
5.23
5.23
5.23
5.19
5.19
5.18
5.10
5.09
5.09
5.07
5.07
5.07
4.05
4.04
4.04
4.03
4.02
3.57
3.55
3.53
3.38
3.37
3.36
3.35
3.33
3.31
3.29
3.27
3.27
3.26
3.03
3.01
3.01
2.99
2.84
2.82
2.80
Parameter Value
1 Title XUF02138DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
NH
1.140
1.00
1.04
1.04
1.04
1.00
1.03
1.00
1.01
1.02
1.02
1.04
1.01
0.55
1.44
1.01
2.02
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

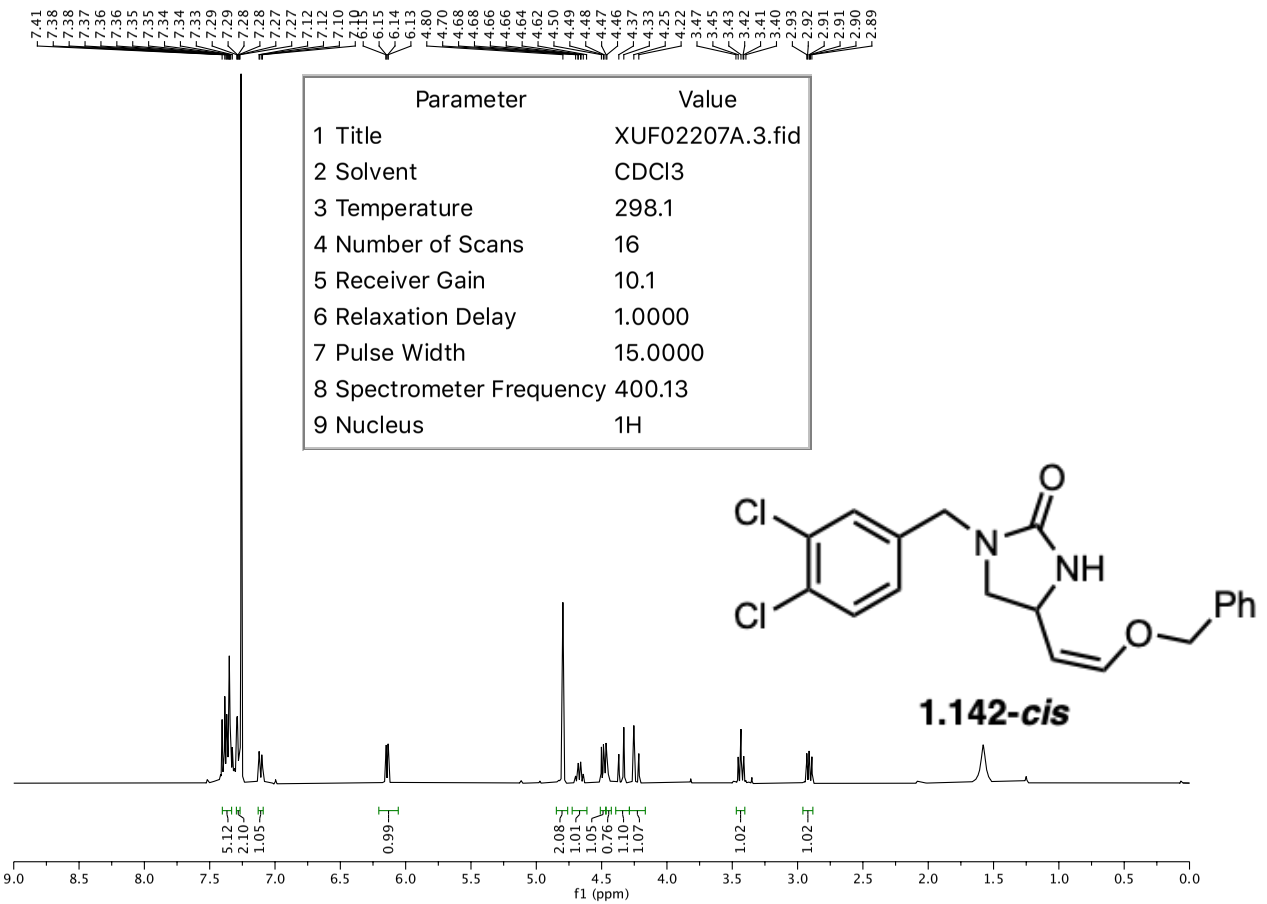

161.24
138.89
136.21
127.20
122.65
120.94
118.28
118.24
115.77
111.57
111.39
51.75
50.11
43.52
23.32
Parameter Value
1 Title XUF02138DMSO.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
NH
1.140
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

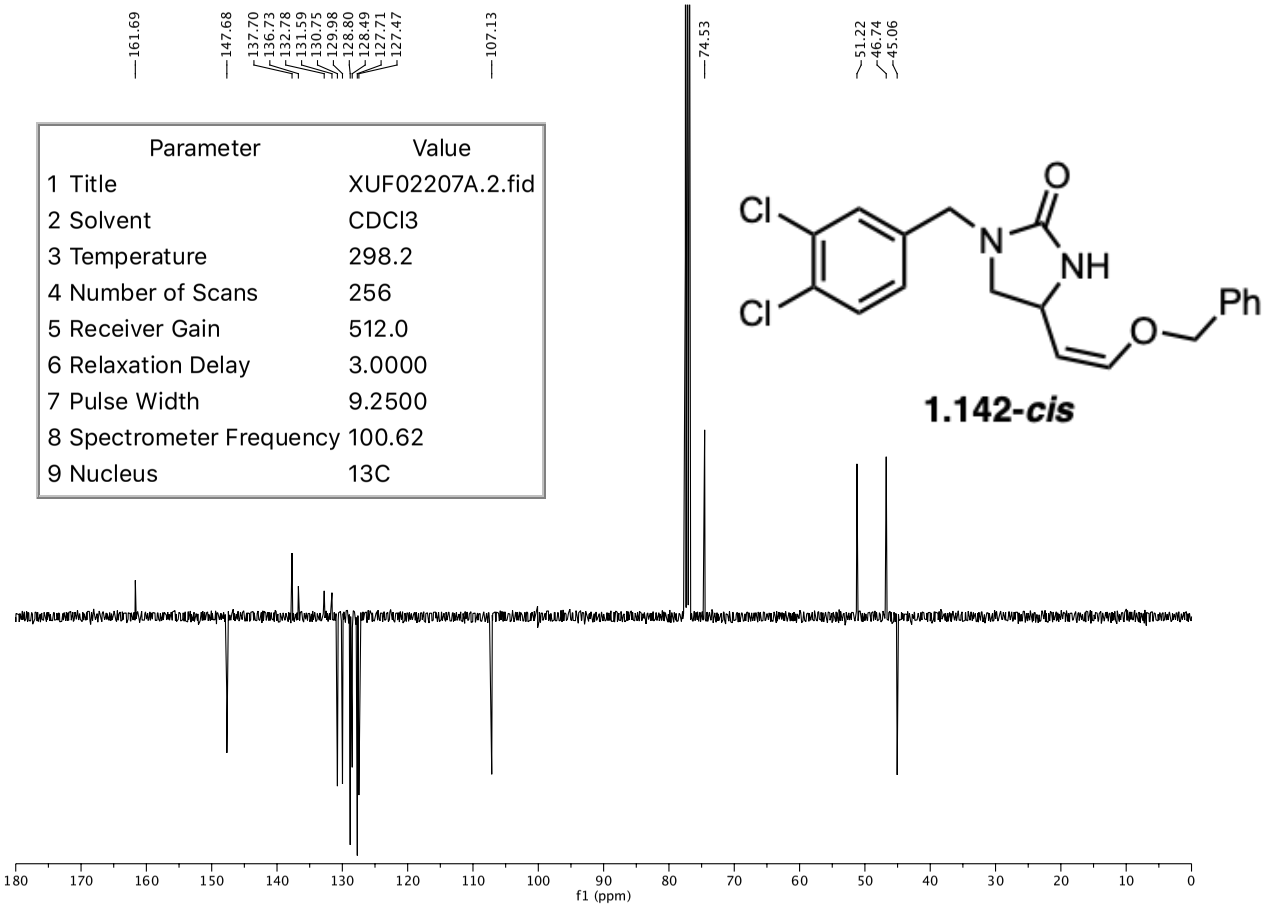

7.34 7.34 7.33 7.33 6.96 6.95 6.94 6.93 6.90 6.90 6.89 6.89 6.73 5.83 5.81 5.80 5.79 5.77 5.76 5.74 5.23 5.23 5.23 5.19 5.19 5.19 5.10 5.10 5.10 5.08 5.08 5.07 4.07 4.06 4.05 4.05 4.04 4.03 4.03 4.03 4.01 4.01 3.52 3.50 3.48 3.33 3.31 3.31 3.30 3.28 3.26 3.24 3.23 3.21 3.19 2.99 2.98 2.97 2.96 2.95 2.95 2.93
Parameter Value
1 Title SAS05045P1.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
S
1.141
0.98 1.01 1.00 0.95 1.00 1.00 1.00 1.00 1.01 0.99 0.99 3.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

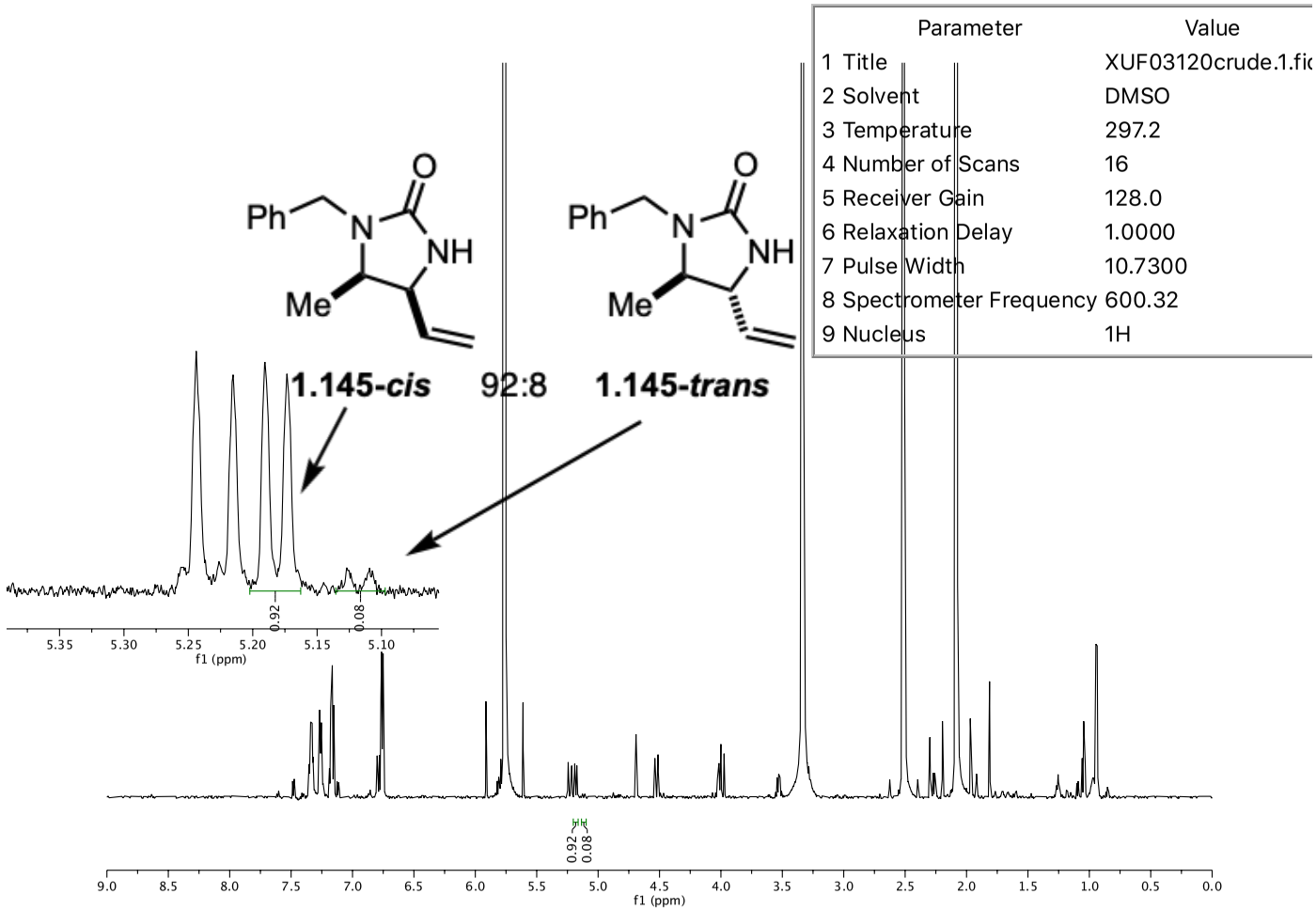

161.12
141.43
138.77
126.92
125.21
124.16
115.86
51.72
50.14
44.48
27.69
Parameter Value
1 Title SAS05045P1.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
S
1.141
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

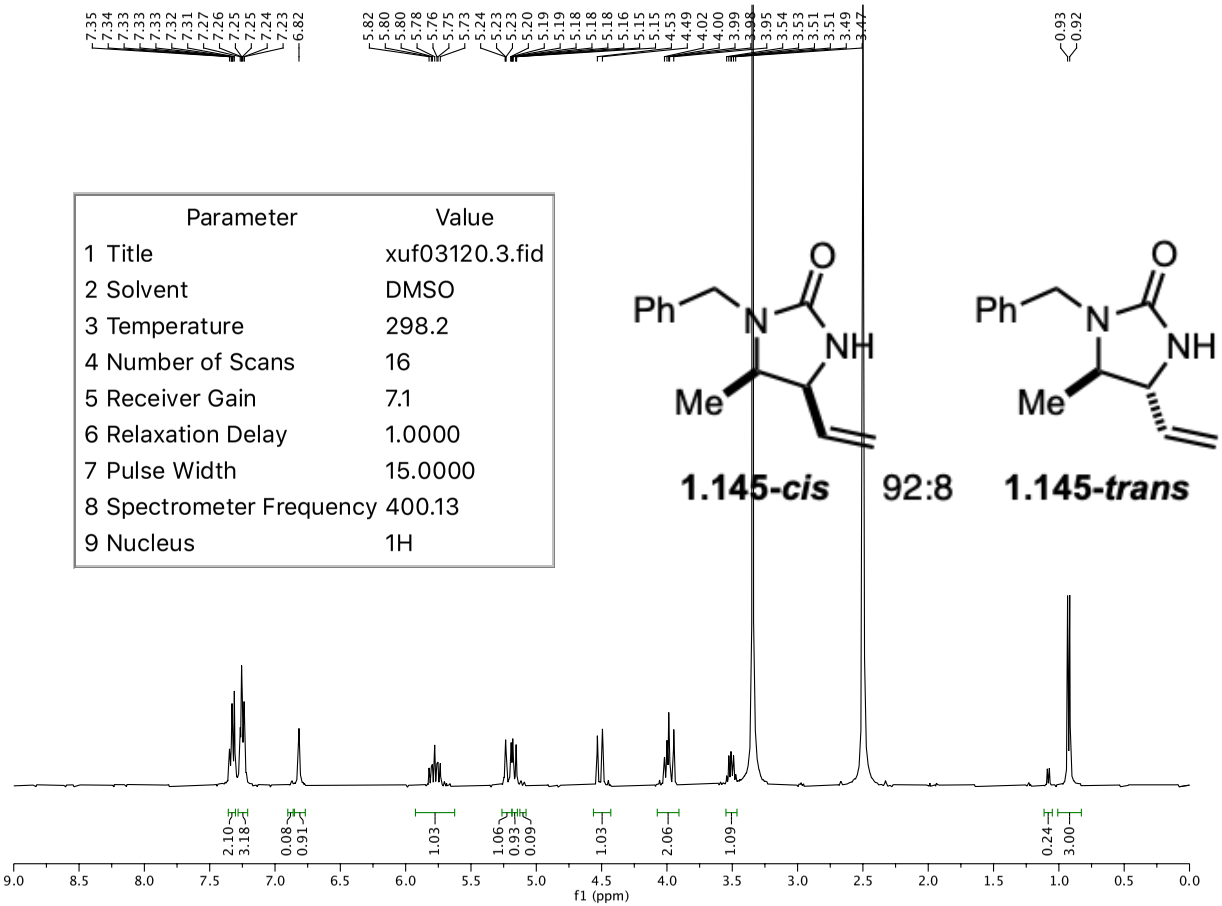

Parameter Value
1 Title XUF02207B.3.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.142-trans
f1 (ppm)

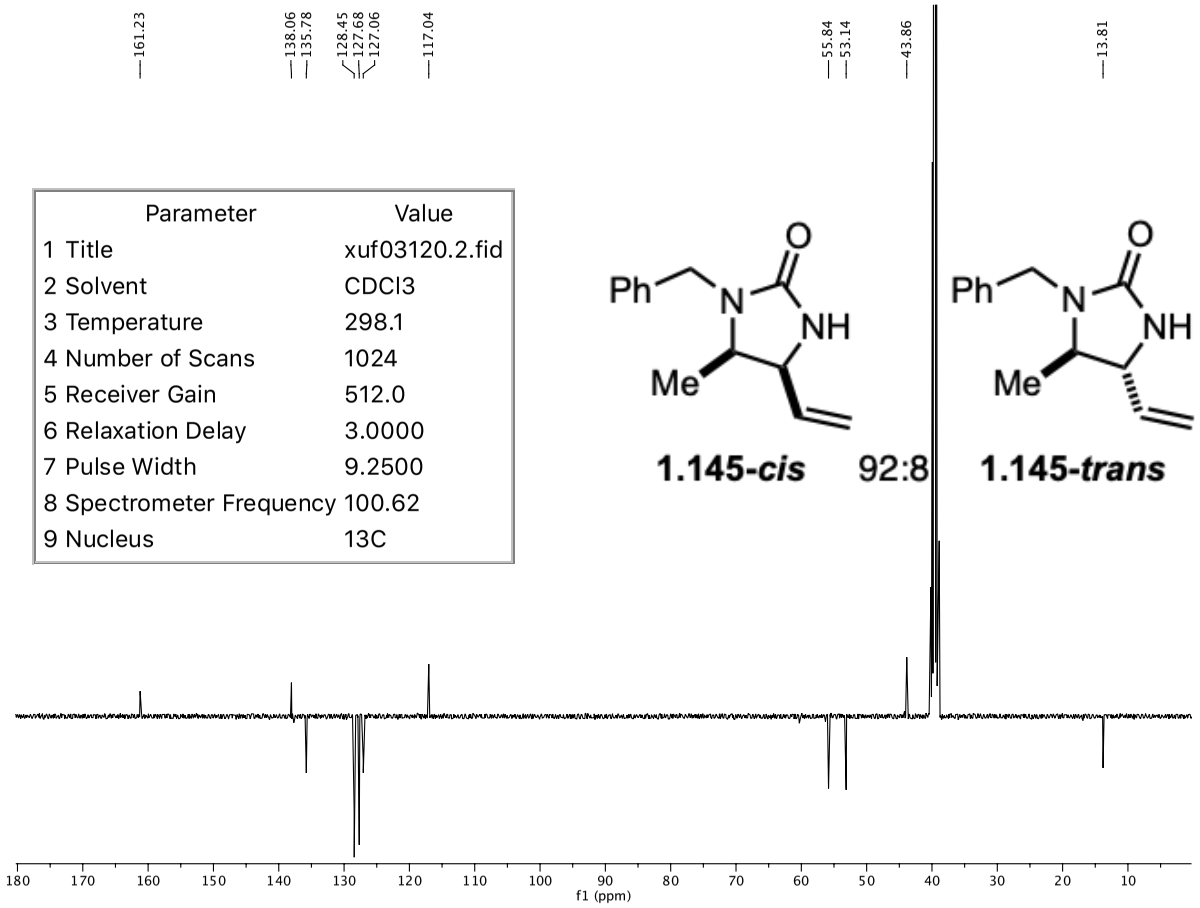

1.142-trans
Parameter Value
1 Title XUF02207B.2.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
161.40
149.28
137.56
136.28
132.83
131.69
130.80
130.00
128.75
128.37
127.73
127.50
104.18
71.66
51.82
49.81
46.68
f1 (ppm)

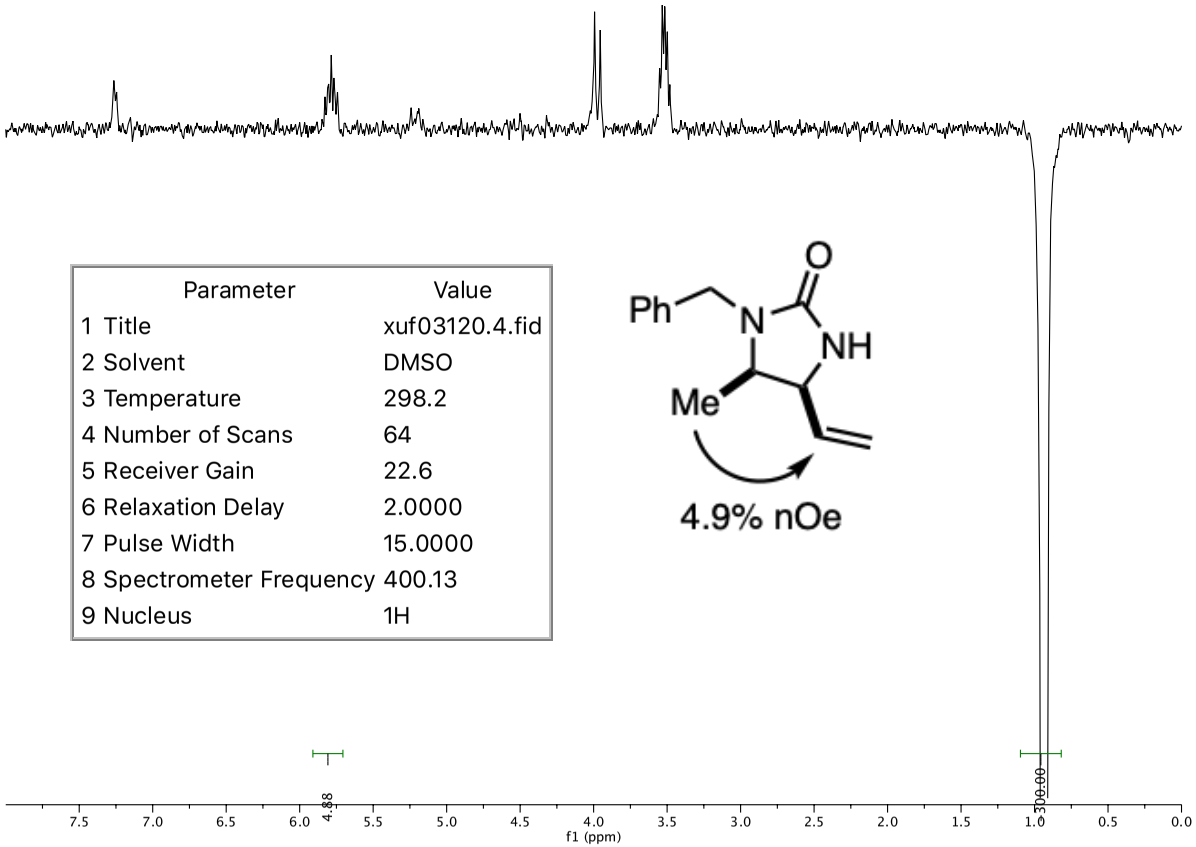

7.41 7.38 7.38 7.37 7.36 7.36 7.35 7.35 7.34 7.34 7.33 7.29 7.29 7.28 7.28 7.27 7.27 7.12 7.12 7.10 7.10 6.15 6.15 6.14 6.13 4.80 4.70 4.68 4.68 4.66 4.66 4.64 4.62 4.50 4.49 4.48 4.47 4.46 4.37 4.33 4.25 4.22 3.47 3.45 3.43 3.42 3.41 3.40 2.93 2.92 2.91 2.91 2.90 2.89
Parameter Value
1 Title XUF02207A.3.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Cl
Cl
N
O
NH
O
Ph
1.142-cis
5.12 2.10 1.05 0.99 2.08 1.01 1.05 0.76 1.10 1.07 1.02 1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


161.69
147.68
137.70
136.73
132.78
131.59
130.75
129.98
128.80
128.49
127.71
127.47
107.13
74.53
51.22
46.74
45.06
Parameter Value
1 Title XUF02207A.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Cl
Cl
N
O
NH
O
Ph
1.142-cis
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

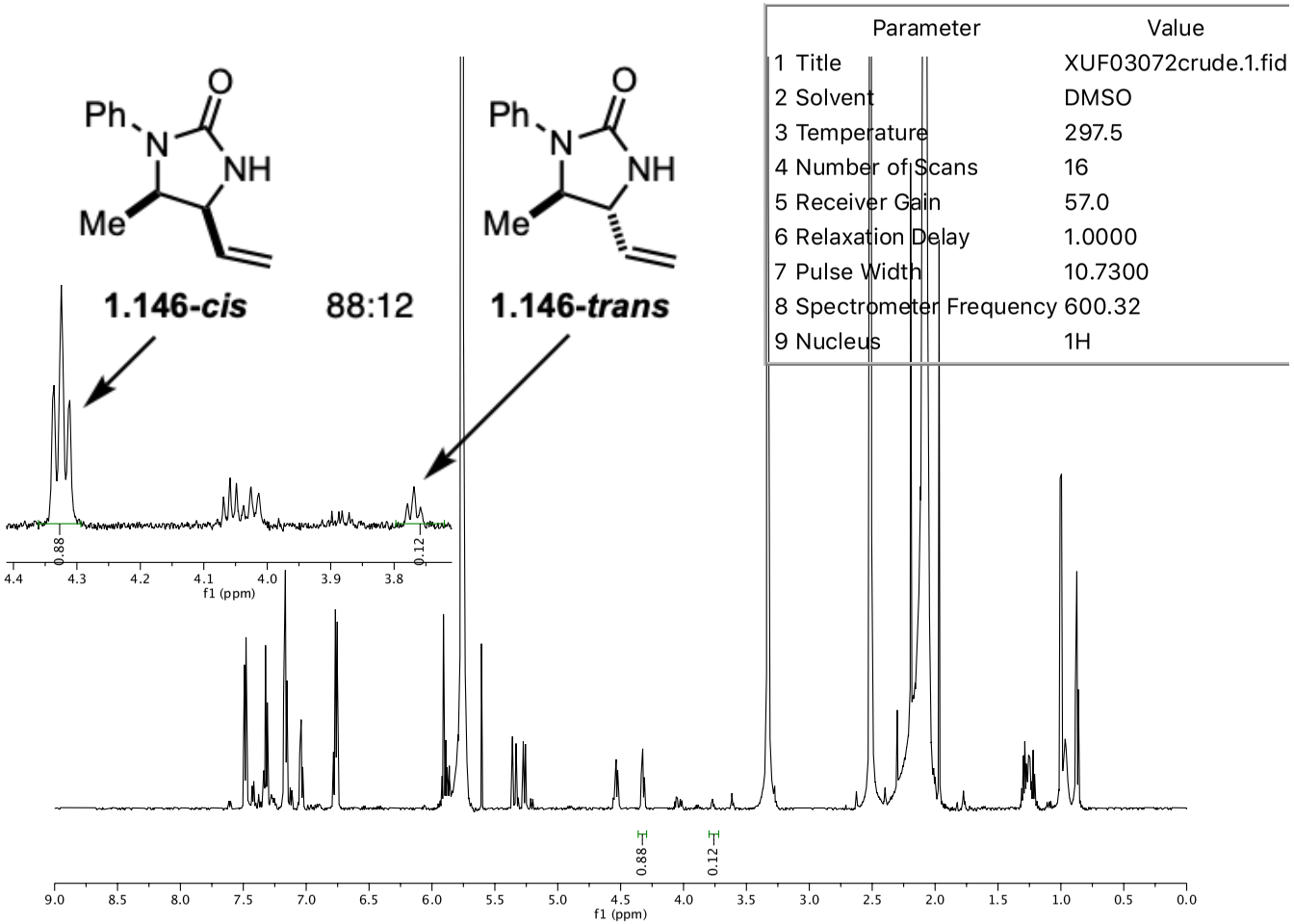

Parameter
Value
1 Title
XUF03120crude.1.fi
2 Solvent
DMSO
3 Temperature
297.2
4 Number of Scans
16
5 Receiver Gain
128.0
6 Relaxation Delay
1.0000
7 Pulse Width
10.7300
8 Spectrometer Frequency
600.32
9 Nucleus
1H
Ph
N
O
NH
Me
1.145-cis
92:8
1.145-trans
0.92
0.08
f1 (ppm)

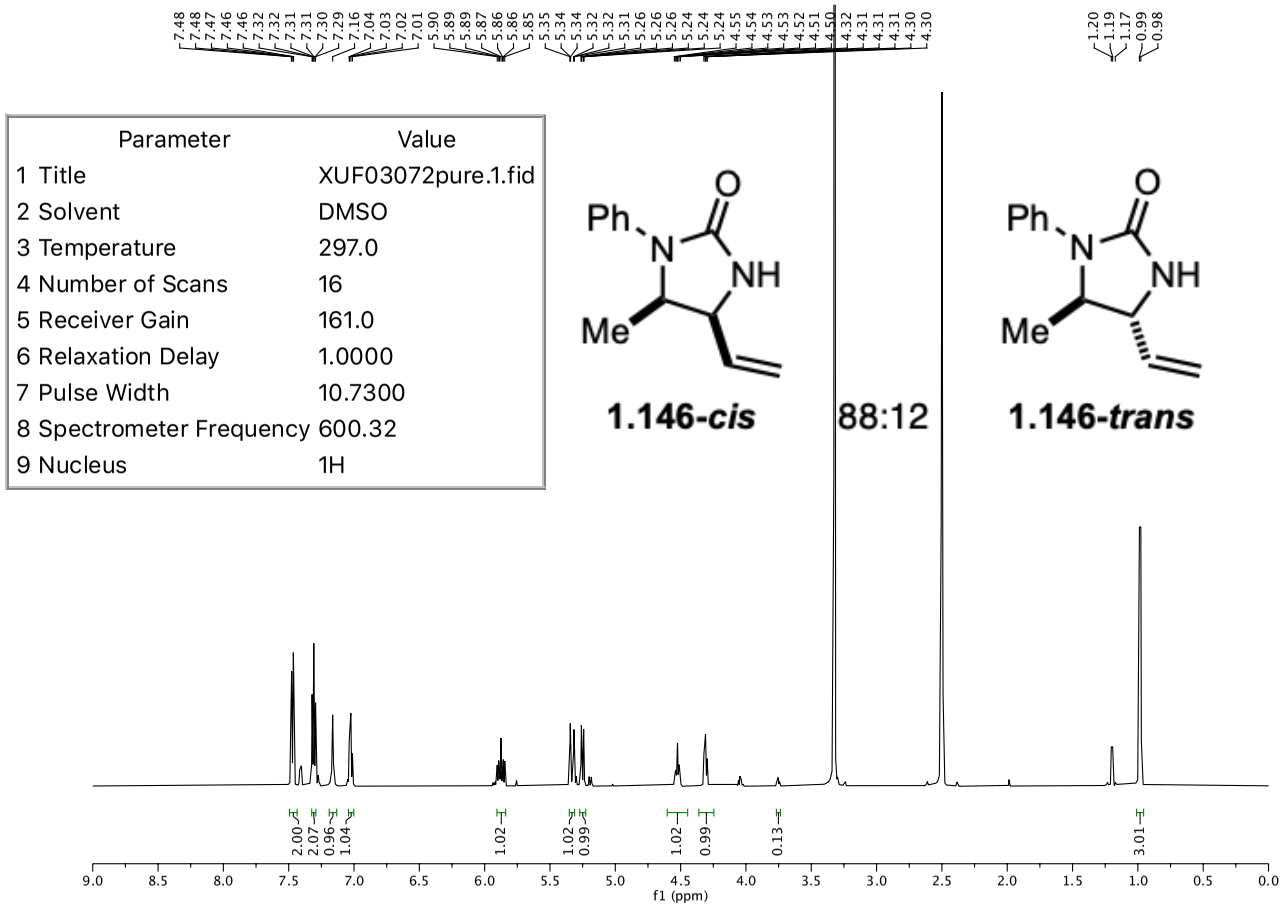

7.35 7.34 7.33 7.33 7.33 7.32 7.31 7.27 7.26 7.25 7.25 7.24 7.23 6.82
5.82 5.80 5.80 5.78 5.76 5.75 5.73 5.24 5.23 5.23 5.20 5.19 5.19 5.18 5.18 5.18 5.16 5.15 5.15 4.53 4.49 4.02 4.00 3.99 3.98 3.95 3.54 3.53 3.51 3.51 3.49 3.47
0.93 0.92
Parameter Value
1 Title xuf03120.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph N O NH Me
1.145-cis 92:8 1.145-trans
2.10 3.18 0.08 0.91 1.03 1.06 0.93 0.09 1.03 2.06 1.09 0.24 3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


161.23
138.06
135.78
128.45
127.68
127.06
117.04
55.84
53.14
43.86
13.81
Parameter Value
1 Title xuf03120.2.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
NH
Me
1.145-cis
92:8
1.145-trans
f1 (ppm)

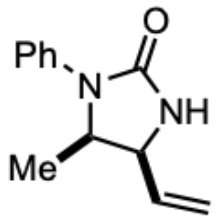


Parameter	Value
1 Title	xuf03120.4.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	64
5 Receiver Gain	22.6
6 Relaxation Delay	2.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

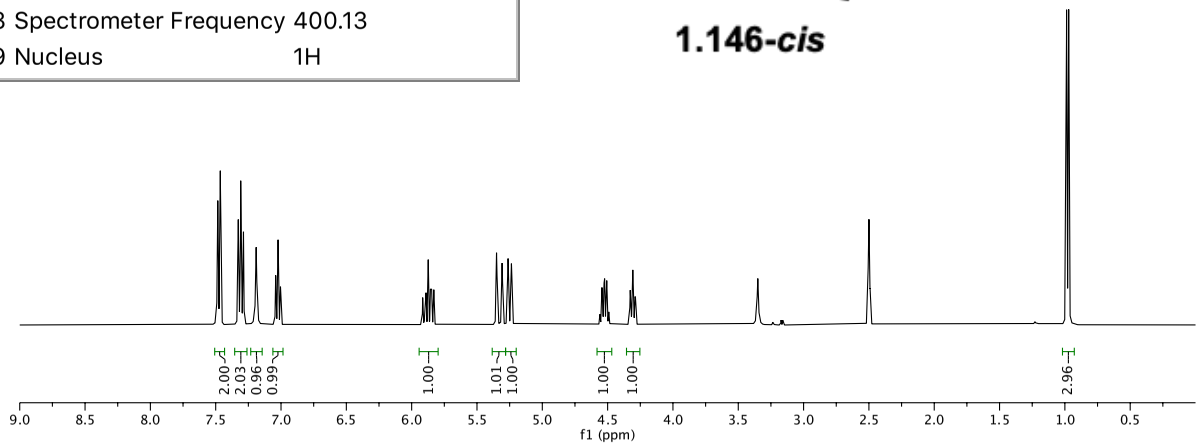

Ph
N
O
NH
Me
1.146-*cis*
88:12
1.146-*trans*
0.88
0.12
f1 (ppm)
Parameter
Value
1 Title
XUF03072crude.1.fid
2 Solvent
DMSO
3 Temperature
297.5
4 Number of Scans
16
5 Receiver Gain
57.0
6 Relaxation Delay
1.0000
7 Pulse Width
10.7300
8 Spectrometer Frequency
600.32
9 Nucleus
1H


Parameter Value
1 Title XUF03072pure.1.fid
2 Solvent DMSO
3 Temperature 297.0
4 Number of Scans 16
5 Receiver Gain 161.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.7300
8 Spectrometer Frequency 600.32
9 Nucleus 1H
Ph
N
O
NH
Me
1.146-cis
88:12
1.146-trans
f1 (ppm)

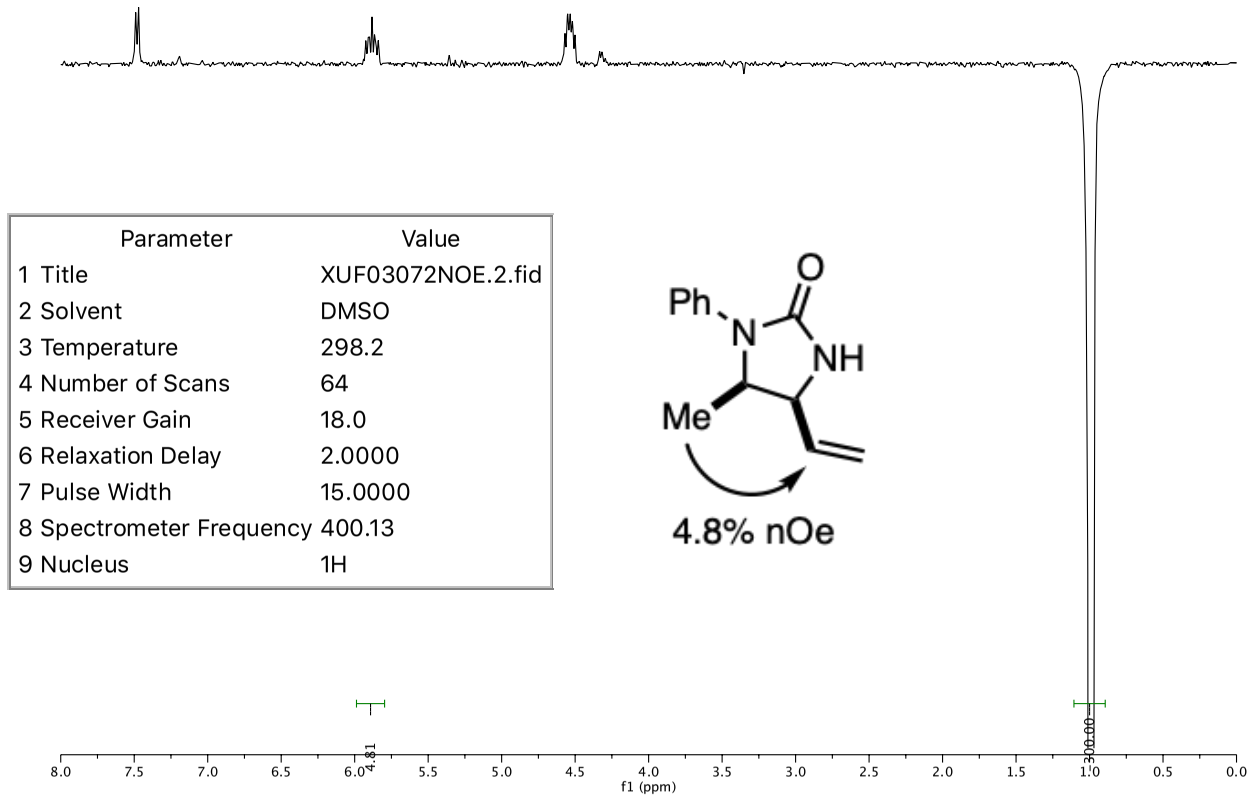
Parameter	Value
1 Title	SAS05013-PK1.1.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	10.1
6 Relaxation Delay	1.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

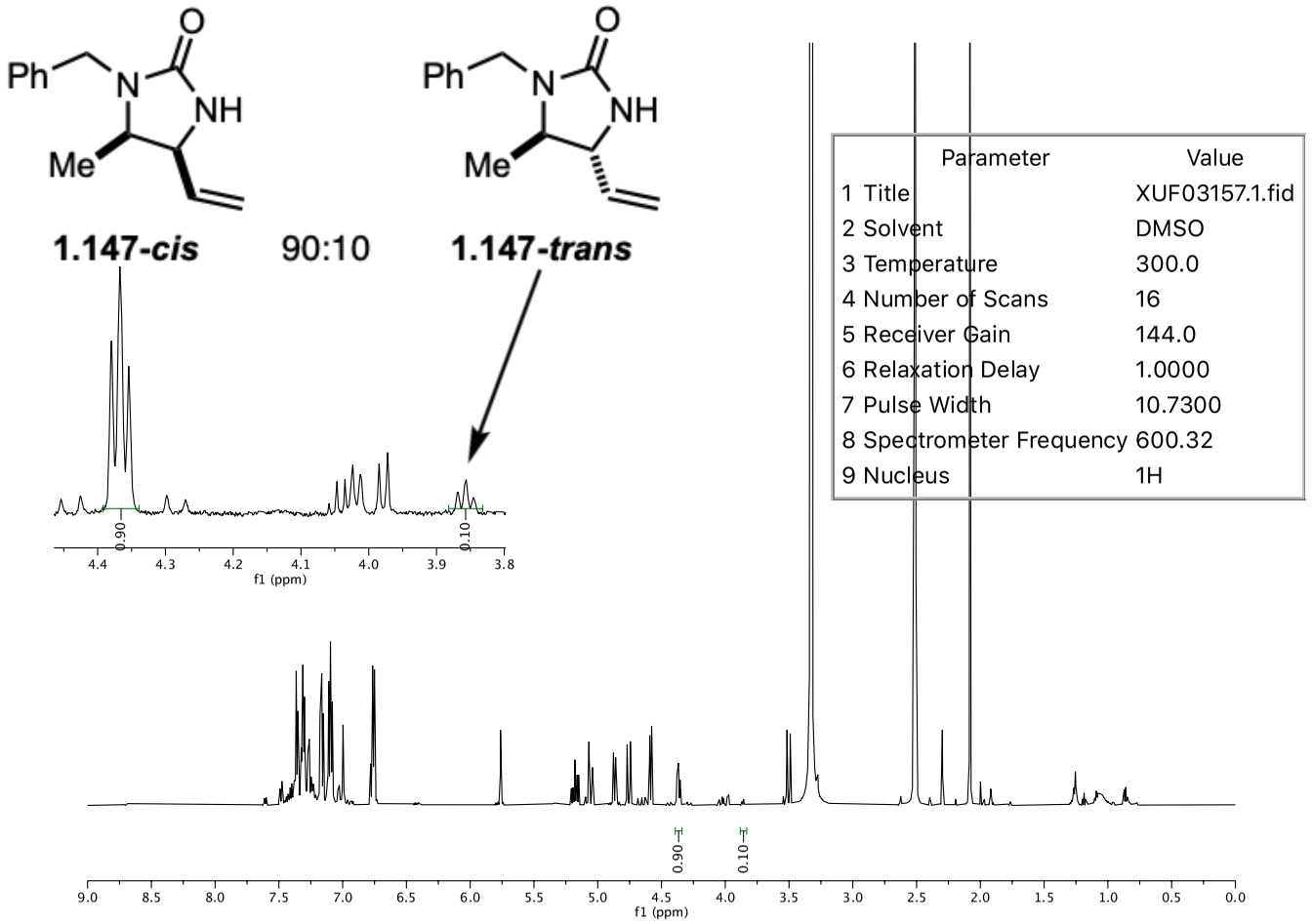


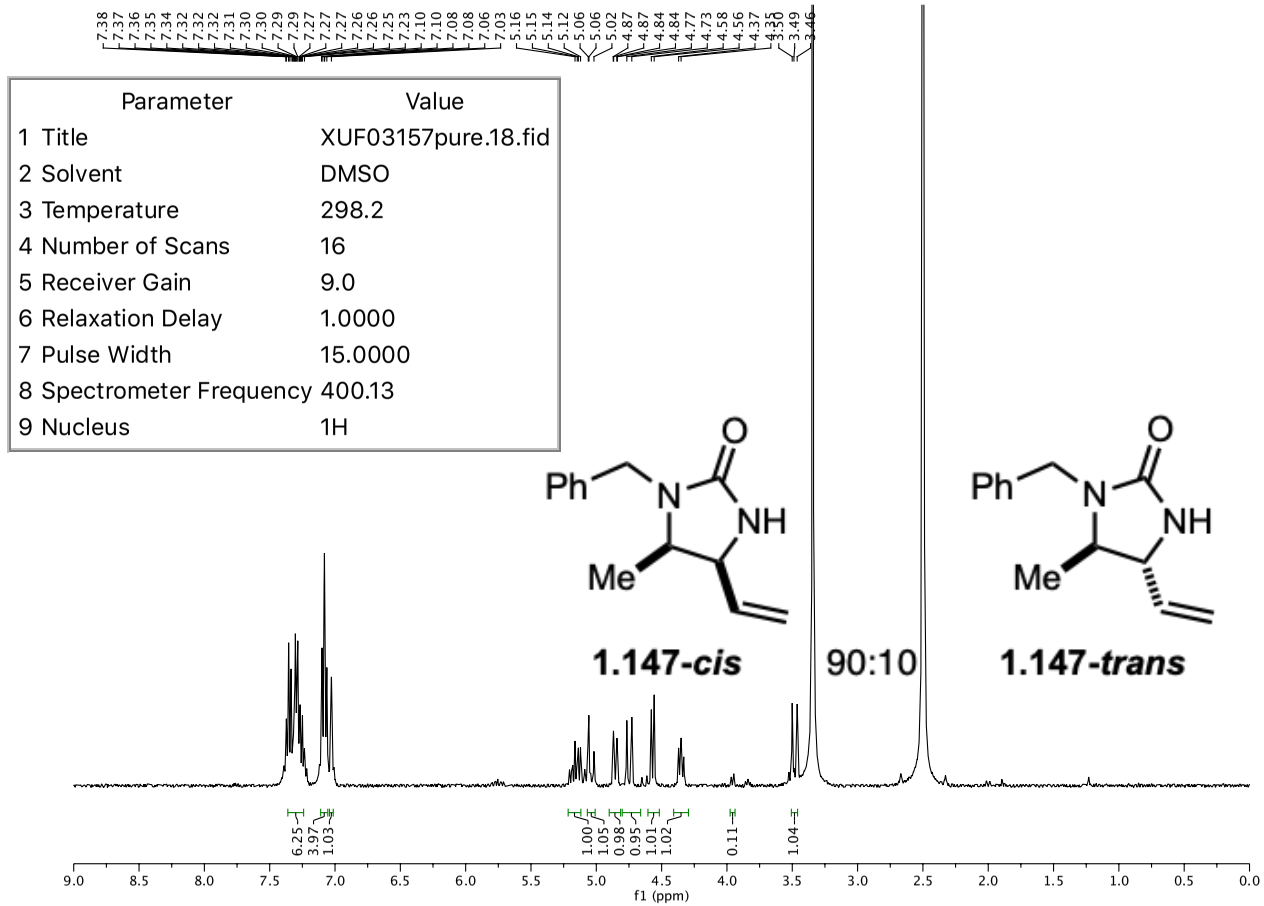
1.146-*cis*

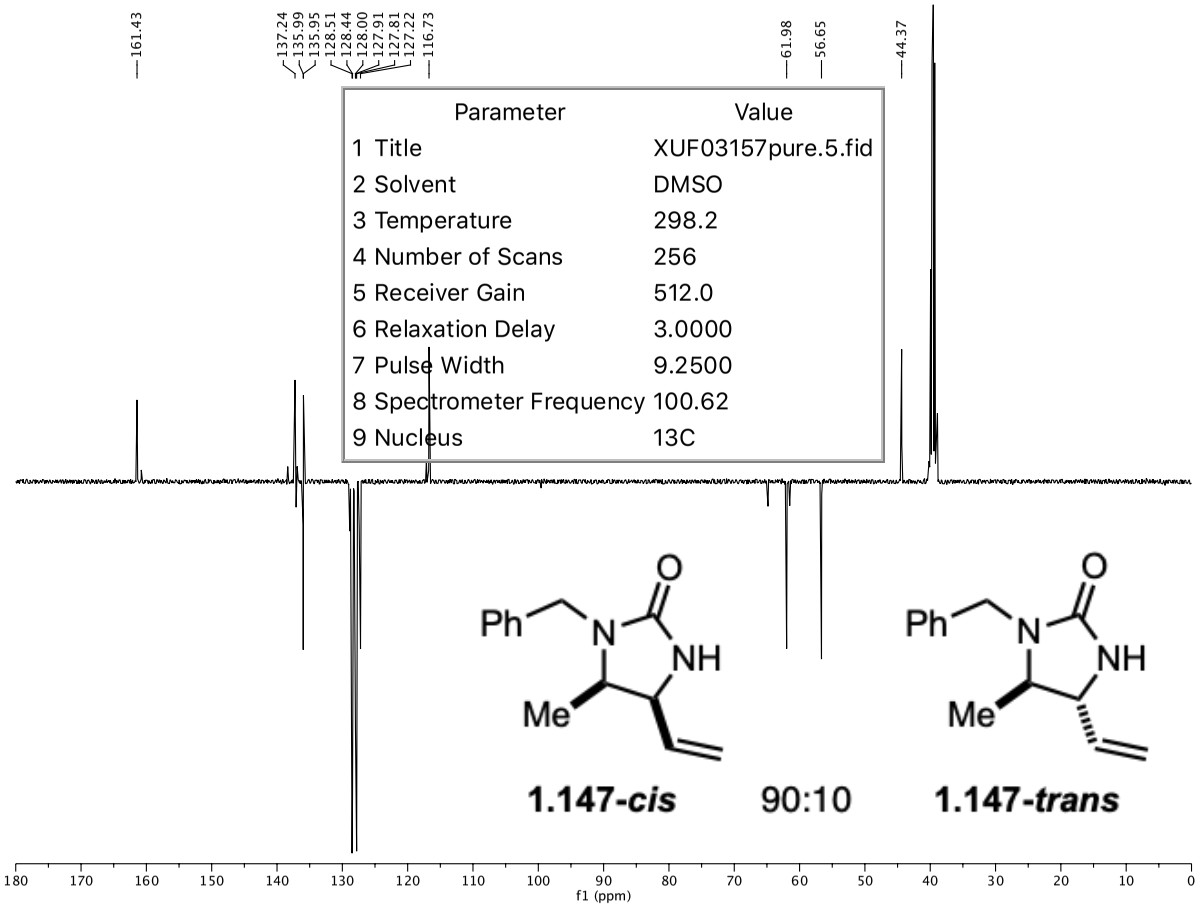


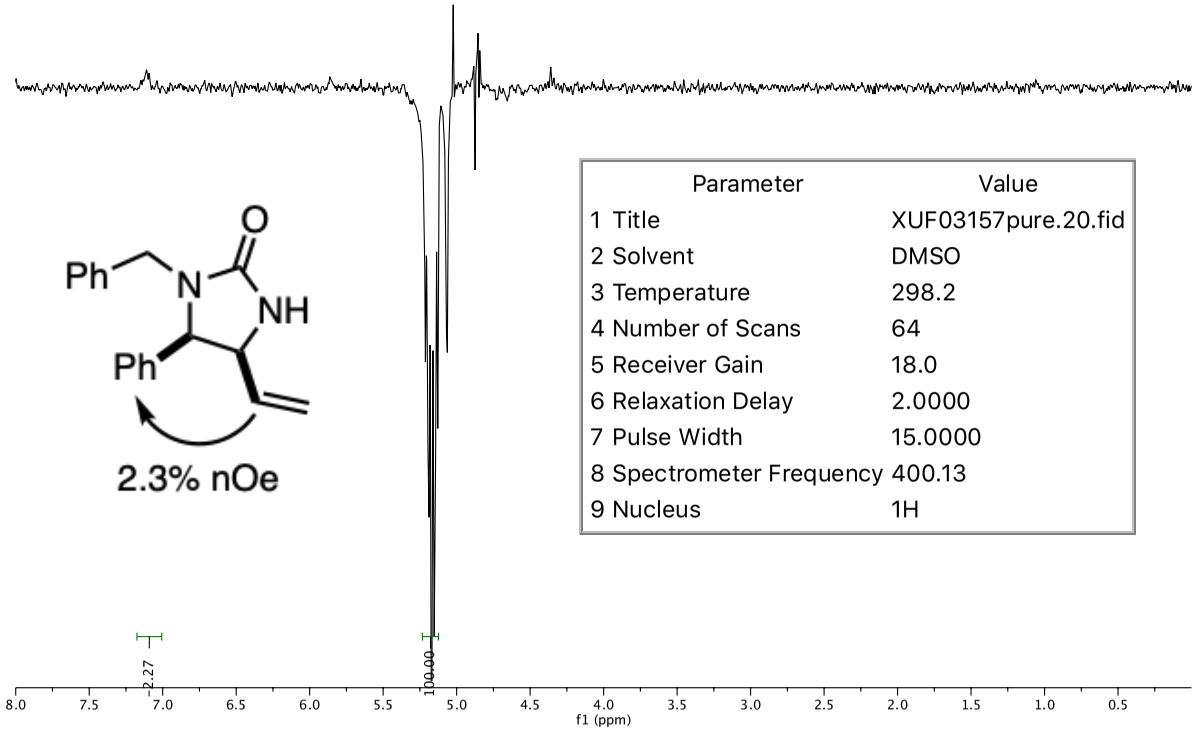
13.74
55.24
53.95
117.64
120.34
122.60
128.61
135.03
138.98
158.39
Ph
N
O
NH
Me
1.146-cis
Parameter
Value
1 Title
SAS05013-PK1.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
32
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)


Parameter Value
1 Title XUF03072NOE.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 64
5 Receiver Gain 18.0
6 Relaxation Delay 2.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
Me
4.8% nOe
4.81
300.00
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

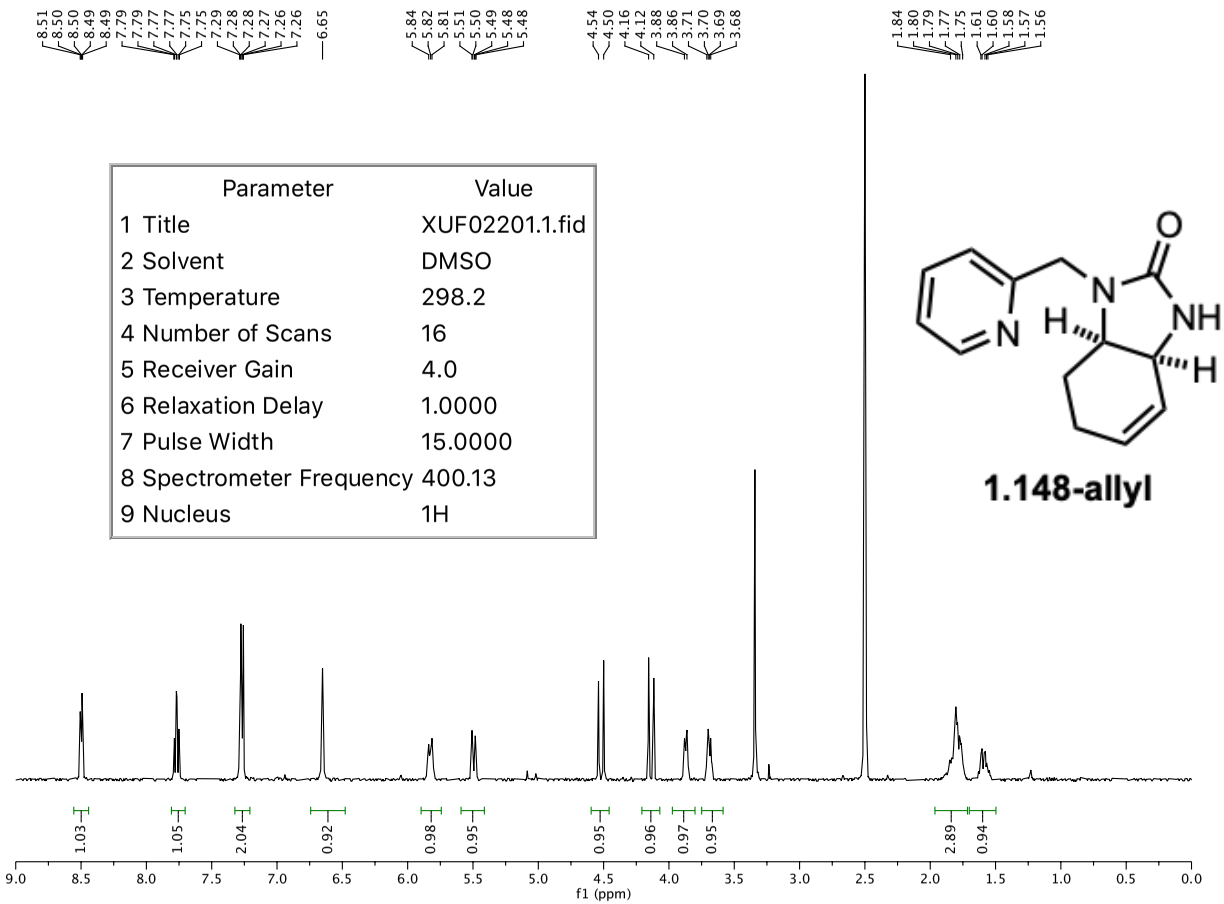

Ph
N
O
NH
Me
1.147-cis
90:10
1.147-trans
Parameter
Value
1 Title
XUF03157.1.fid
2 Solvent
DMSO
3 Temperature
300.0
4 Number of Scans
16
5 Receiver Gain
144.0
6 Relaxation Delay
1.0000
7 Pulse Width
10.7300
8 Spectrometer Frequency
600.32
9 Nucleus
1H
0.90
0.10
f1 (ppm)

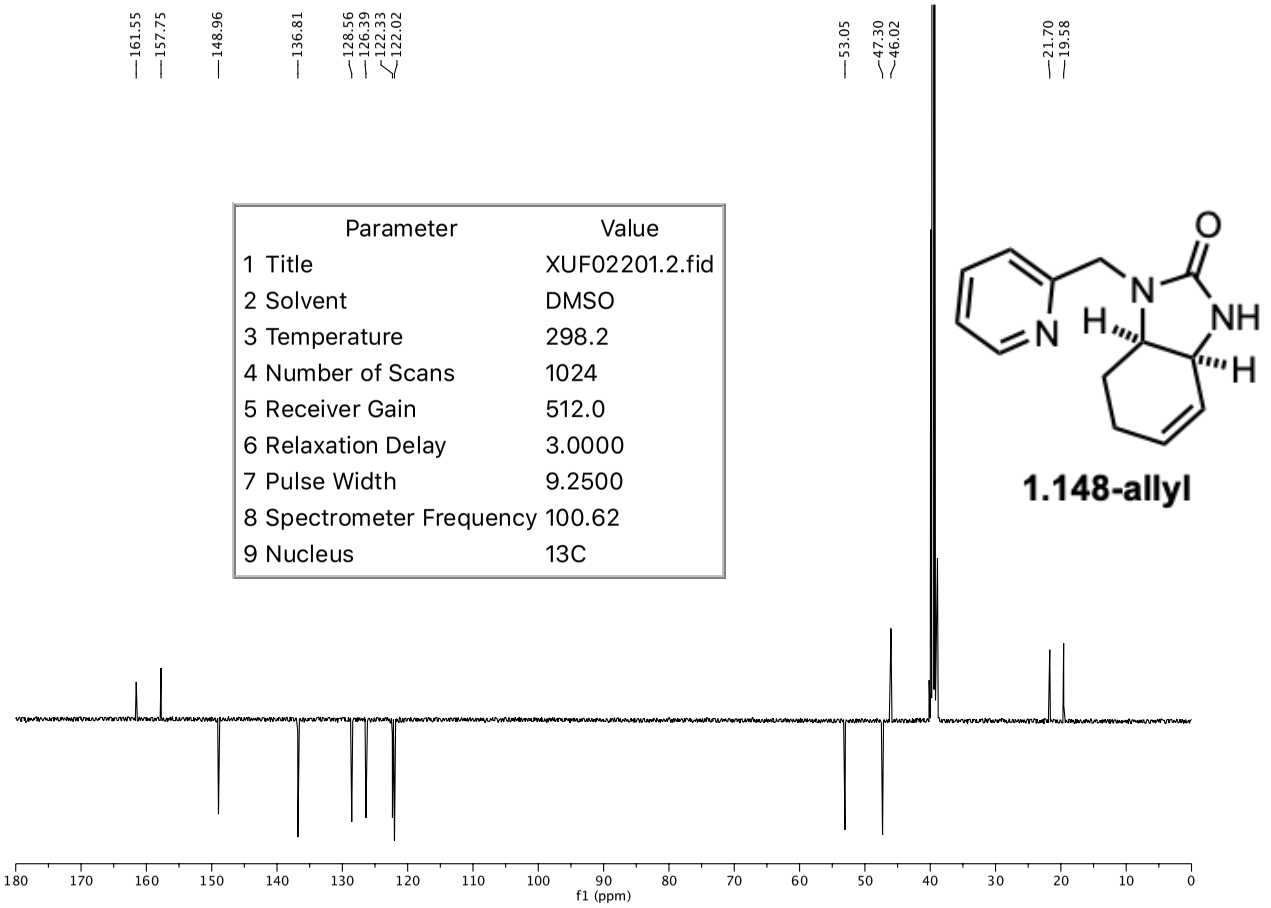

7.38 7.37 7.36 7.35 7.34 7.32 7.32 7.32 7.31 7.30 7.30 7.29 7.29 7.27 7.27 7.27 7.26 7.26 7.25 7.23 7.10 7.10 7.08 7.08 7.06 7.03 5.16 5.15 5.14 5.12 5.06 5.06 5.02 4.87 4.87 4.84 4.84 4.77 4.73 4.58 4.56 4.37 4.35 3.50 3.49 3.46
Parameter Value
1 Title XUF03157pure.18.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
Me
1.147-cis
90:10
1.147-trans
6.25 3.97 1.03 1.00 1.05 0.98 0.95 1.01 1.02 0.11 1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

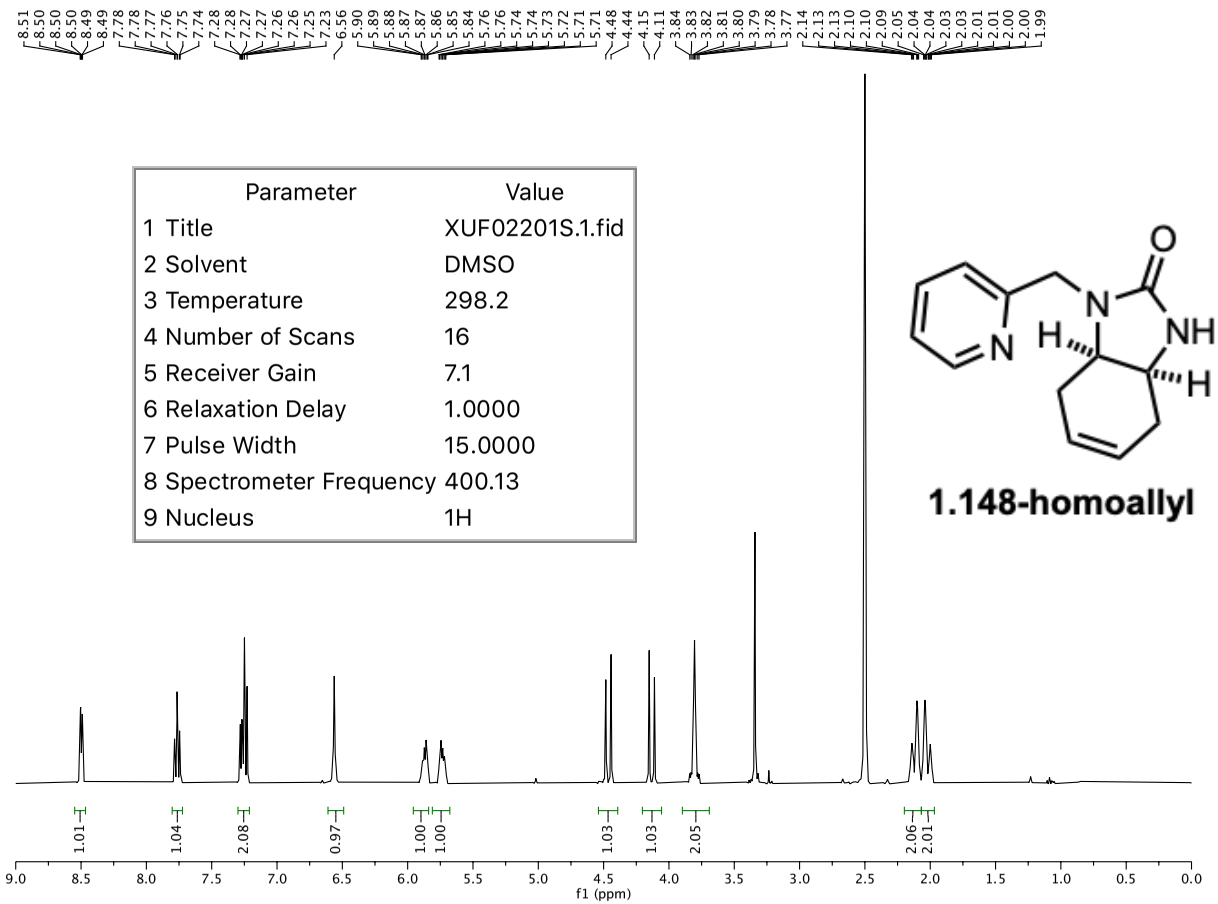

161.43
137.24
135.99
135.95
128.51
128.44
128.00
127.91
127.81
127.22
116.73
61.98
56.65
44.37
Parameter Value
1 Title XUF03157pure.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
NH
Me
1.147-cis
90:10
1.147-trans
f1 (ppm)

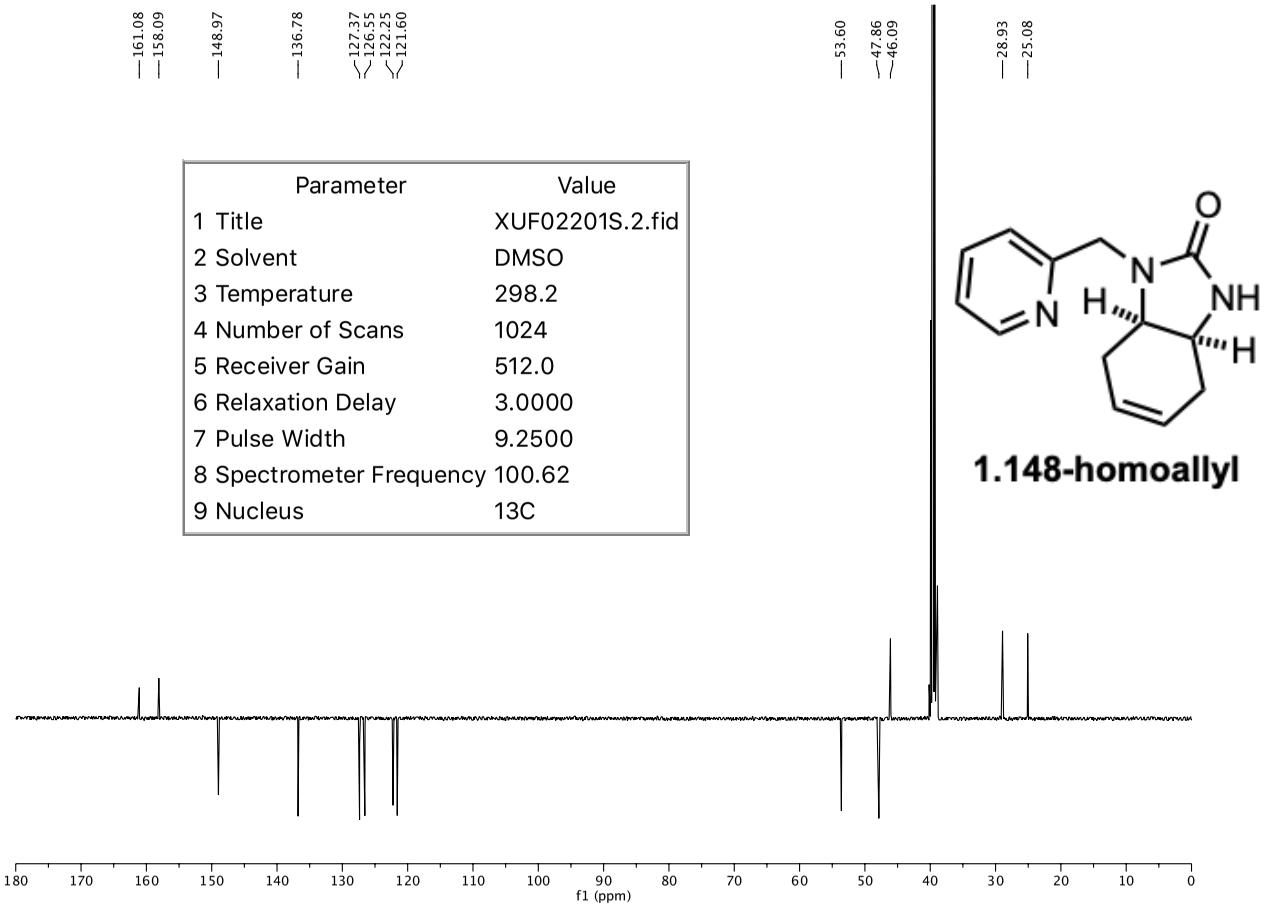


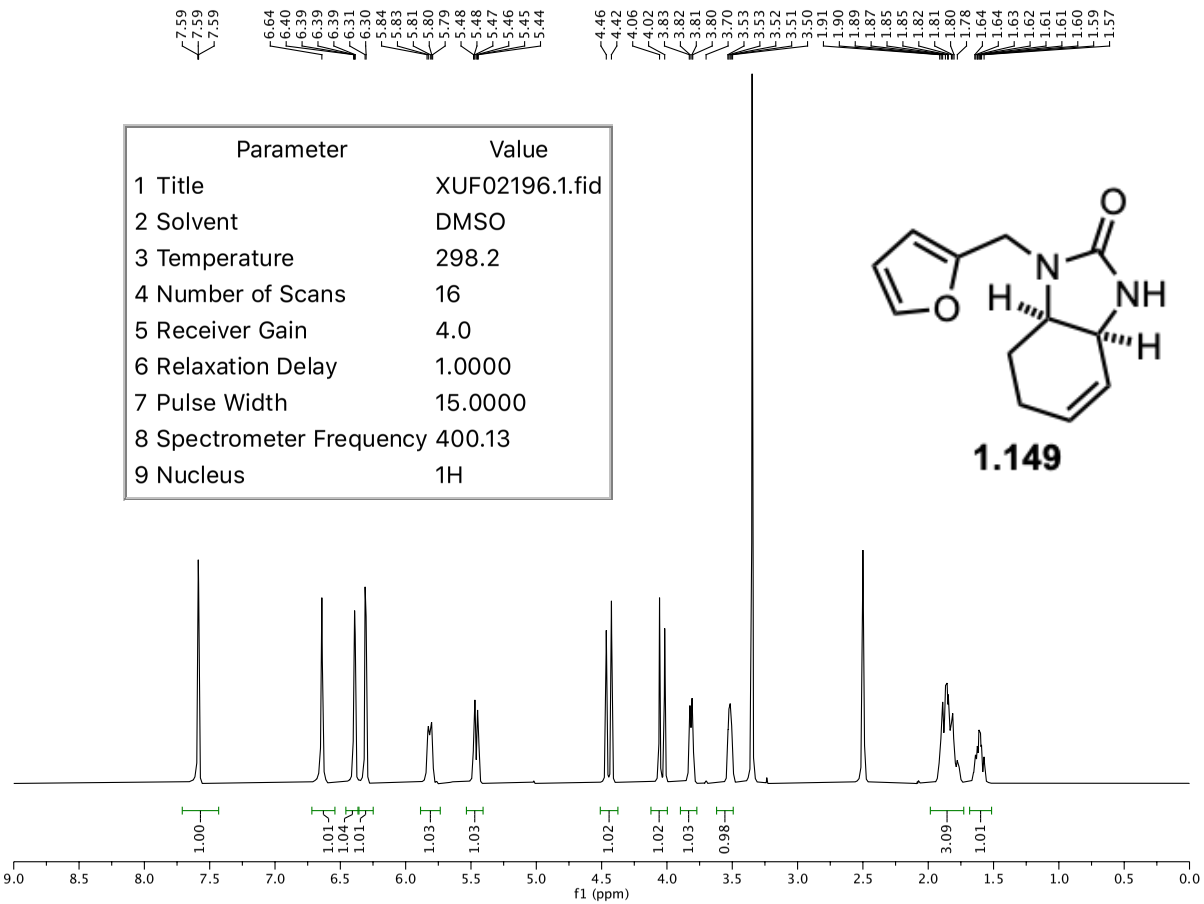
Parameter	Value
1 Title	XUF03157pure.20.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	64
5 Receiver Gain	18.0
6 Relaxation Delay	2.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

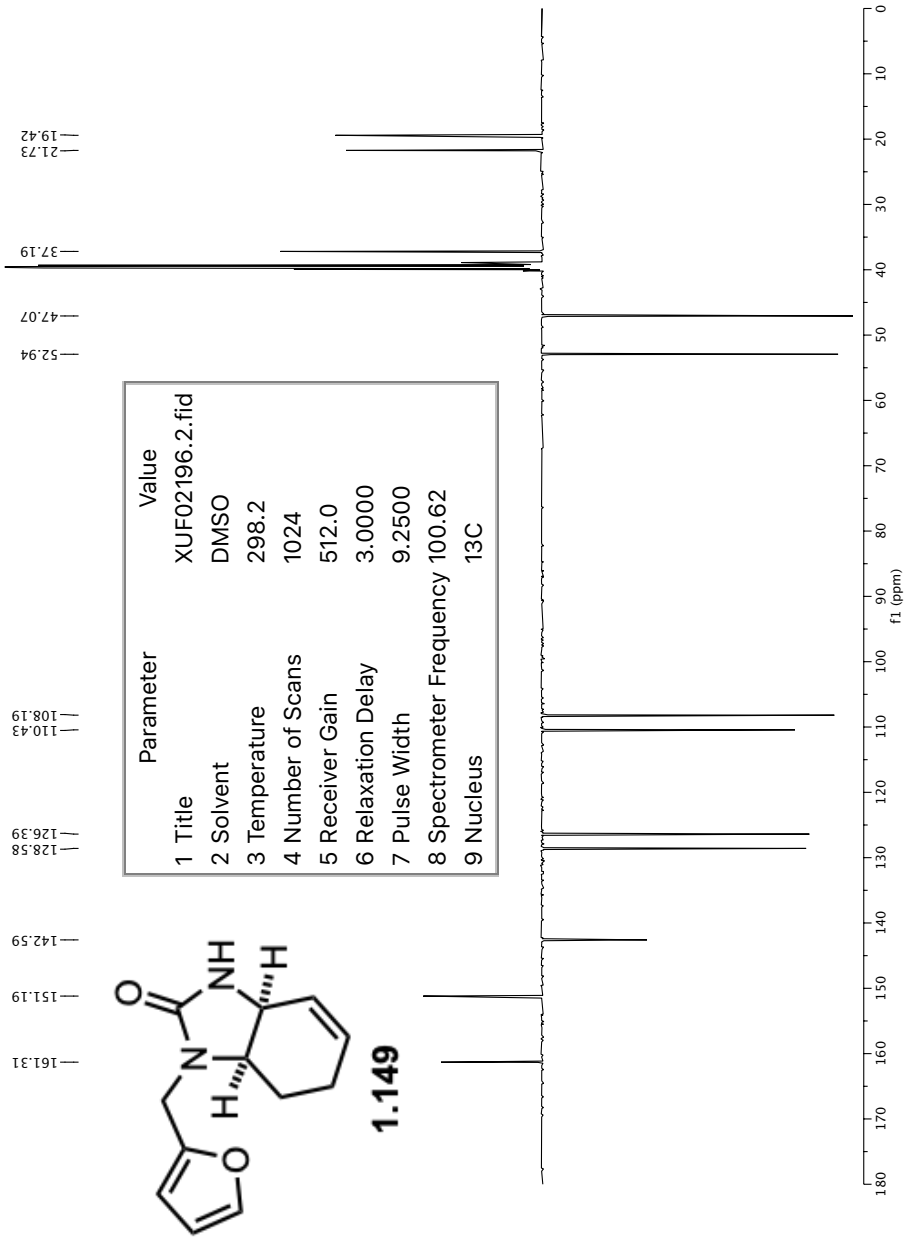

8.51
8.50
8.50
8.49
8.49
7.79
7.79
7.77
7.77
7.75
7.75
7.29
7.28
7.28
7.27
7.26
7.26
6.65
5.84
5.82
5.81
5.51
5.50
5.49
5.48
5.48
4.54
4.50
4.16
4.12
3.88
3.86
3.71
3.70
3.69
3.68
1.84
1.80
1.79
1.77
1.75
1.61
1.60
1.58
1.57
1.56
Parameter Value
1 Title XUF02201.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
H
H
N
1.148-allyl
1.03
1.05
2.04
0.92
0.98
0.95
0.95
0.96
0.97
0.95
2.89
0.94
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

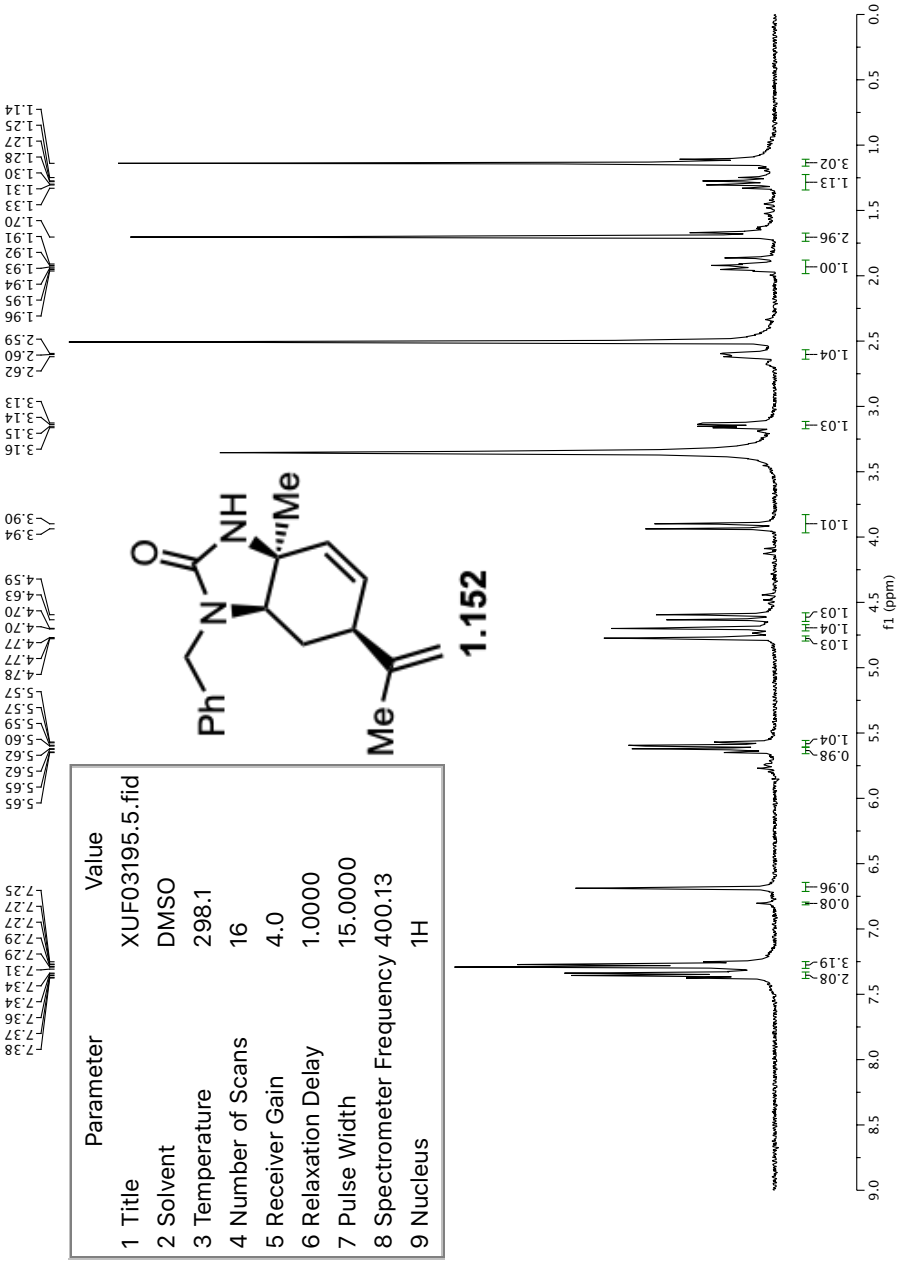

161.55
157.75
148.96
136.81
128.56
126.39
122.33
122.02
53.05
47.30
46.02
21.70
19.58
Parameter Value
1 Title XUF02201.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
N
H
H
1.148-allyl
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

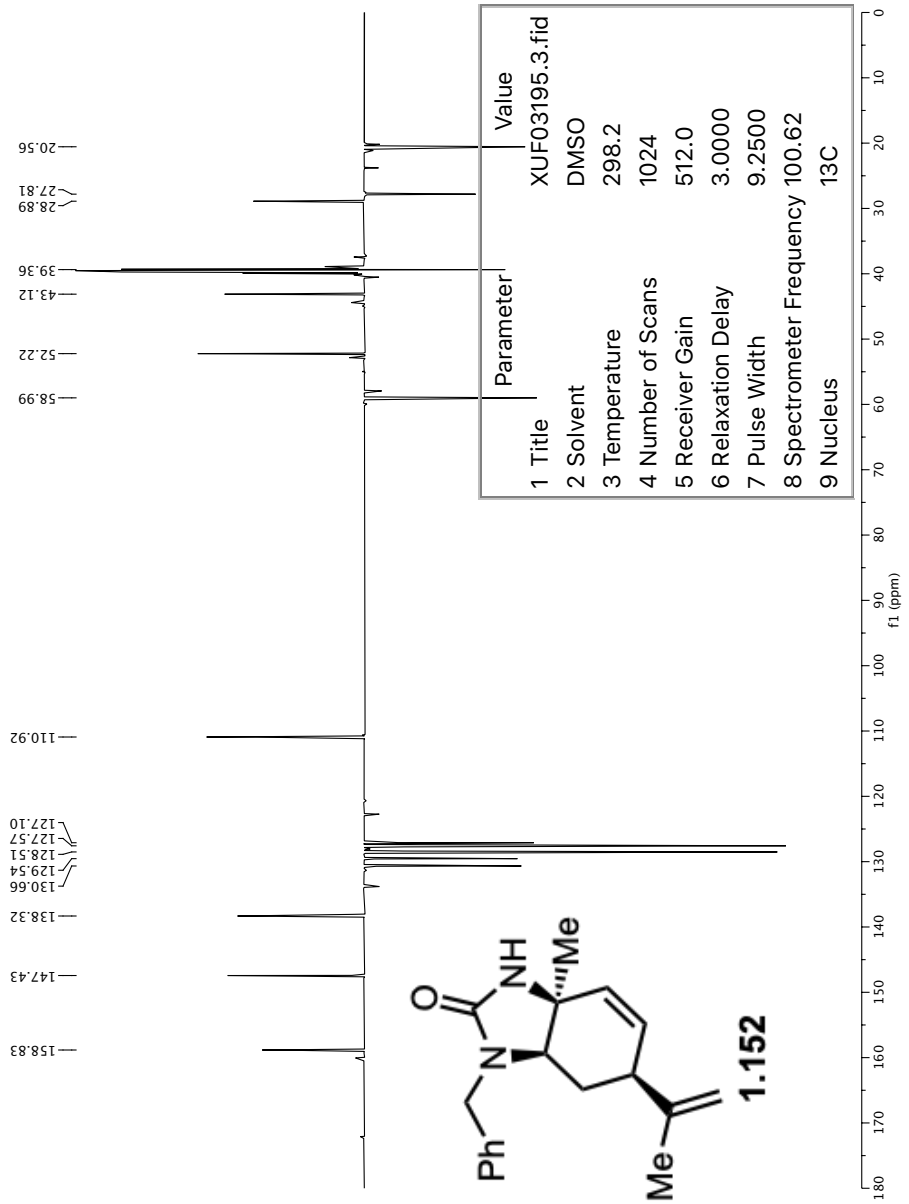

8.51 8.50 8.50 8.50 8.49 8.49 7.78 7.78 7.77 7.76 7.75 7.74 7.28 7.28 7.27 7.27 7.26 7.26 7.25 7.23 6.56 5.90 5.89 5.88 5.87 5.87 5.86 5.85 5.84 5.76 5.76 5.74 5.74 5.73 5.72 5.71 5.71 4.48 4.44 4.15 4.11 3.84 3.83 3.82 3.81 3.80 3.79 3.78 3.77 2.14 2.13 2.13 2.10 2.10 2.09 2.05 2.04 2.04 2.03 2.03 2.01 2.01 2.00 2.00 1.99
Parameter Value
1 Title XUF02201S.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
H
NH
H
N
1.148-homoallyl
1.01 1.04 2.08 0.97 1.00 1.00 1.03 1.03 2.05 2.06 2.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

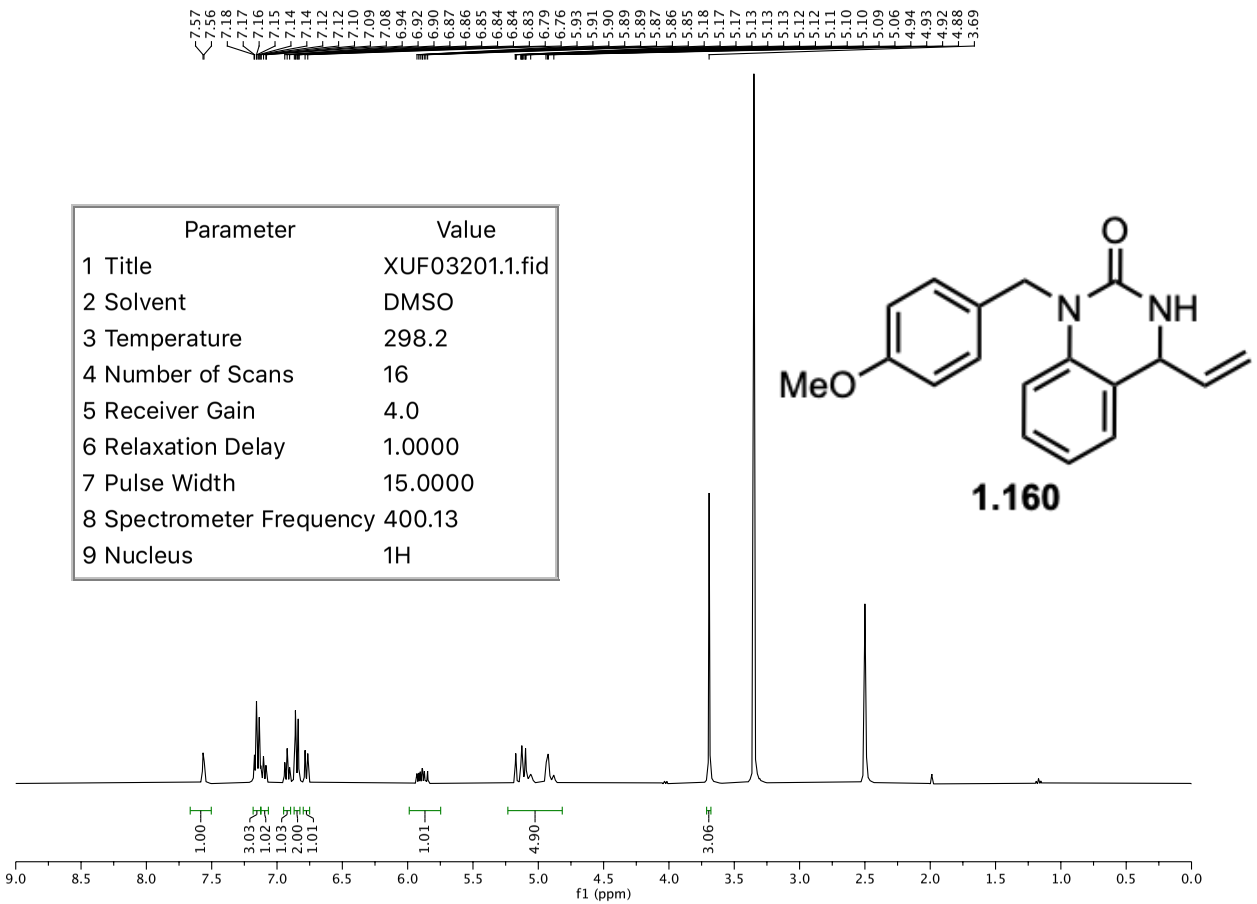

161.08
158.09
148.97
136.78
127.37
126.55
122.25
121.60
53.60
47.86
46.09
28.93
25.08
Parameter Value
1 Title XUF02201S.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
H
NH
N
H
1.148-homoallyl
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

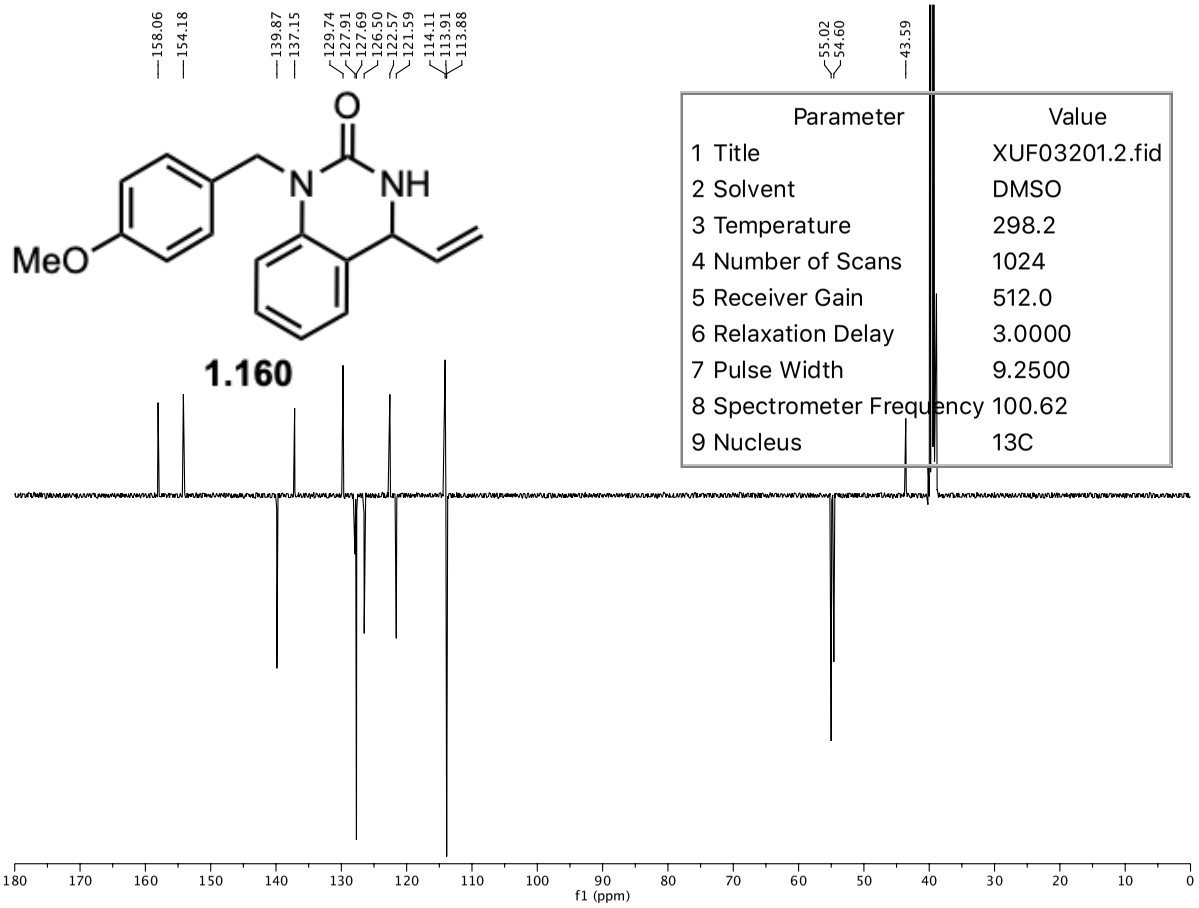

7.59
7.59
7.59
6.64
6.40
6.39
6.39
6.39
6.31
6.30
5.84
5.83
5.81
5.80
5.79
5.48
5.48
5.47
5.46
5.45
5.44
4.46
4.42
4.06
4.02
3.83
3.82
3.81
3.80
3.70
3.53
3.53
3.52
3.51
3.50
1.91
1.90
1.89
1.87
1.85
1.85
1.82
1.81
1.80
1.78
1.64
1.64
1.63
1.62
1.61
1.61
1.60
1.59
1.57
Parameter
Value
1 Title
XUF02196.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
4.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
N
NH
H
H
O
1.149
1.00
1.01
1.04
1.01
1.03
1.03
1.02
1.02
1.03
0.98
3.09
1.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

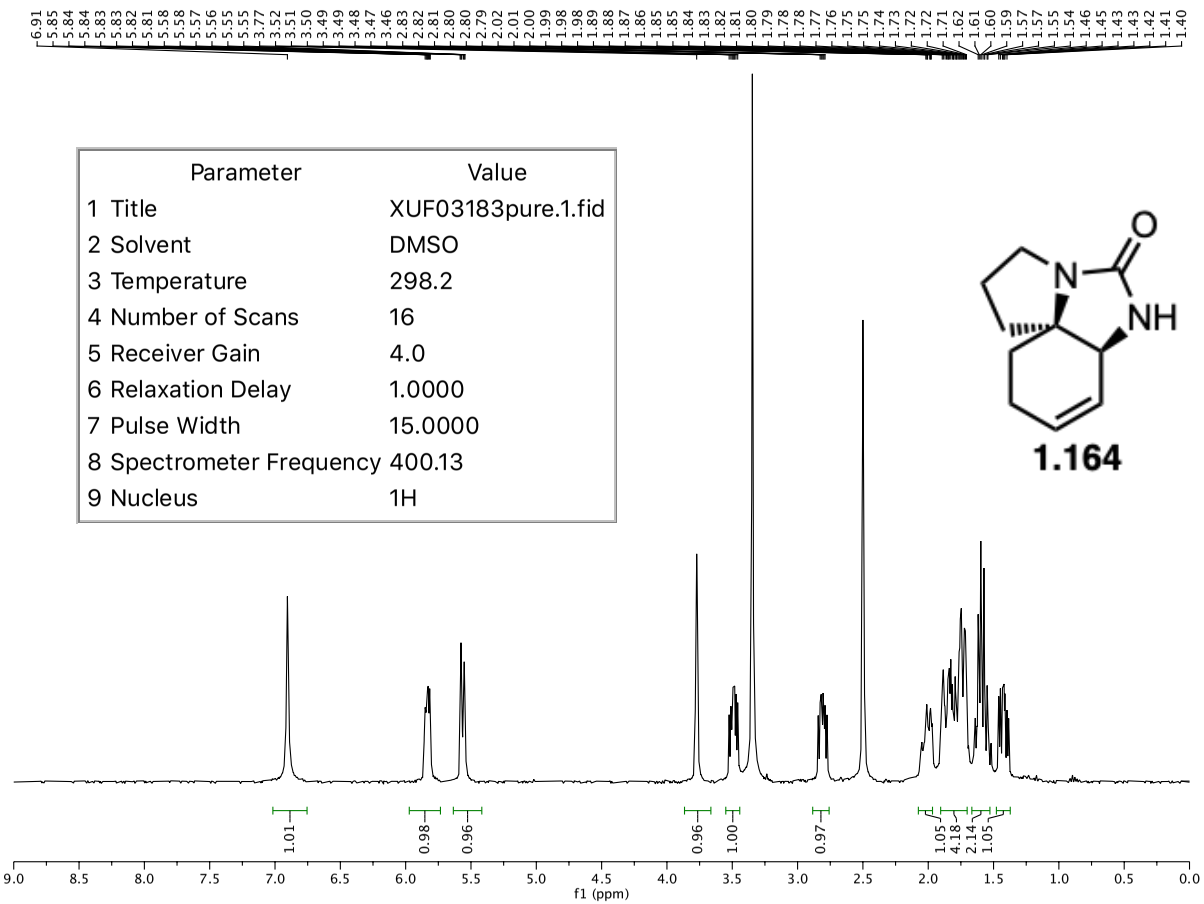

19.42
21.73
37.19
47.07
52.94
108.19
110.43
126.39
128.58
142.59
151.19
161.31
Parameter Value
1 Title XUF02196.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
NH
H
N
H
O
1.149
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
f1 (ppm)

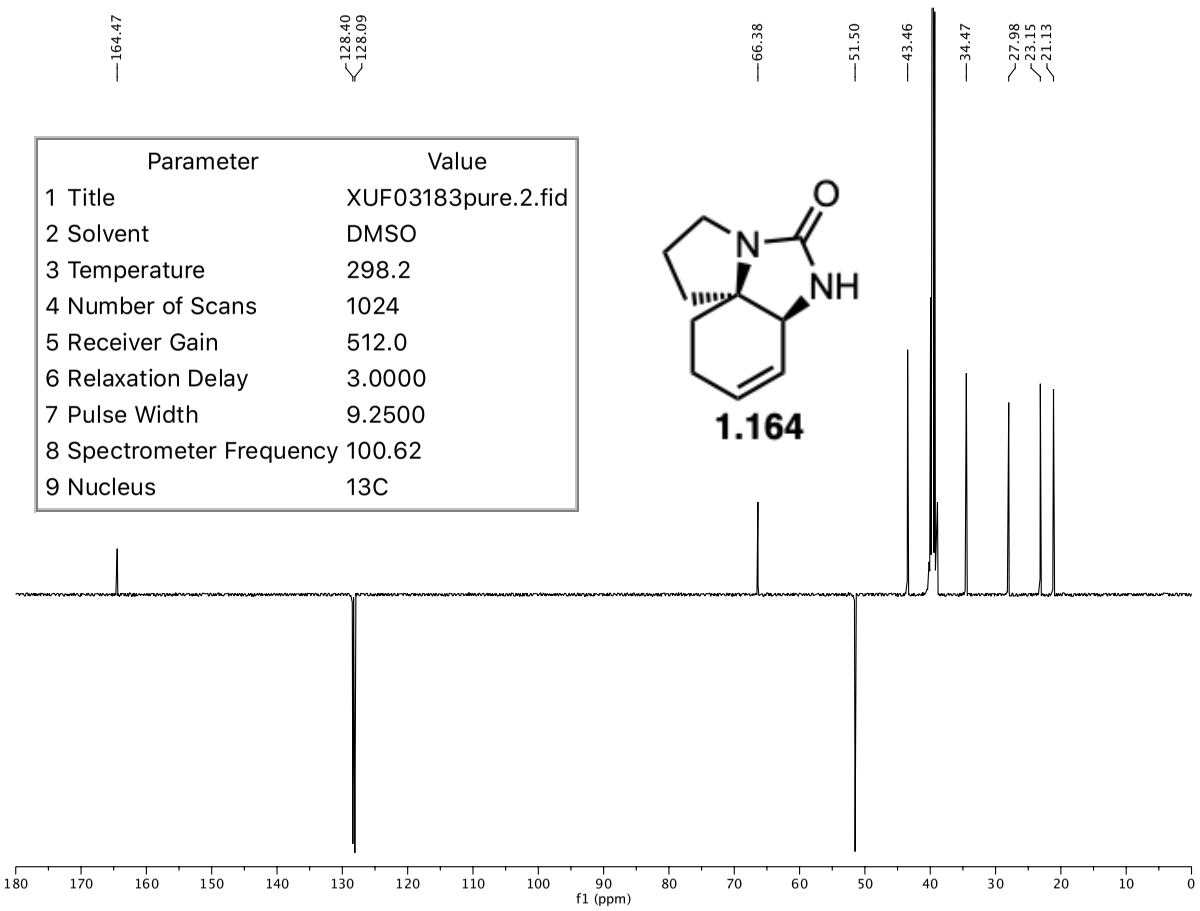

Parameter Value
1 Title XUF03195.5.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
Me
Me
1.152
f1 (ppm)

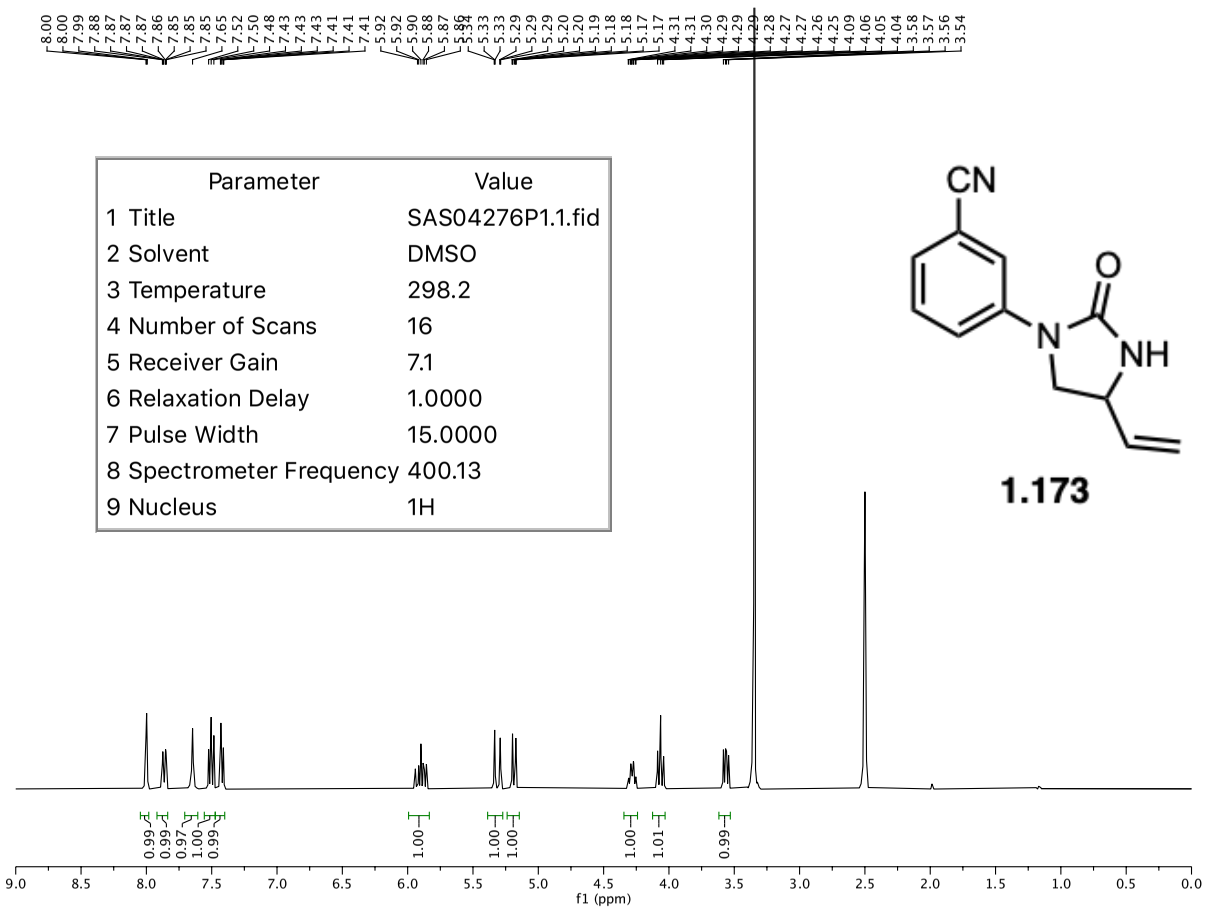

Parameter Value
1 Title XUF03195.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
20.56
27.81
28.89
39.36
43.12
52.22
58.99
110.92
127.10
127.57
128.51
129.54
130.66
138.32
147.43
158.83
f1 (ppm)
1.152

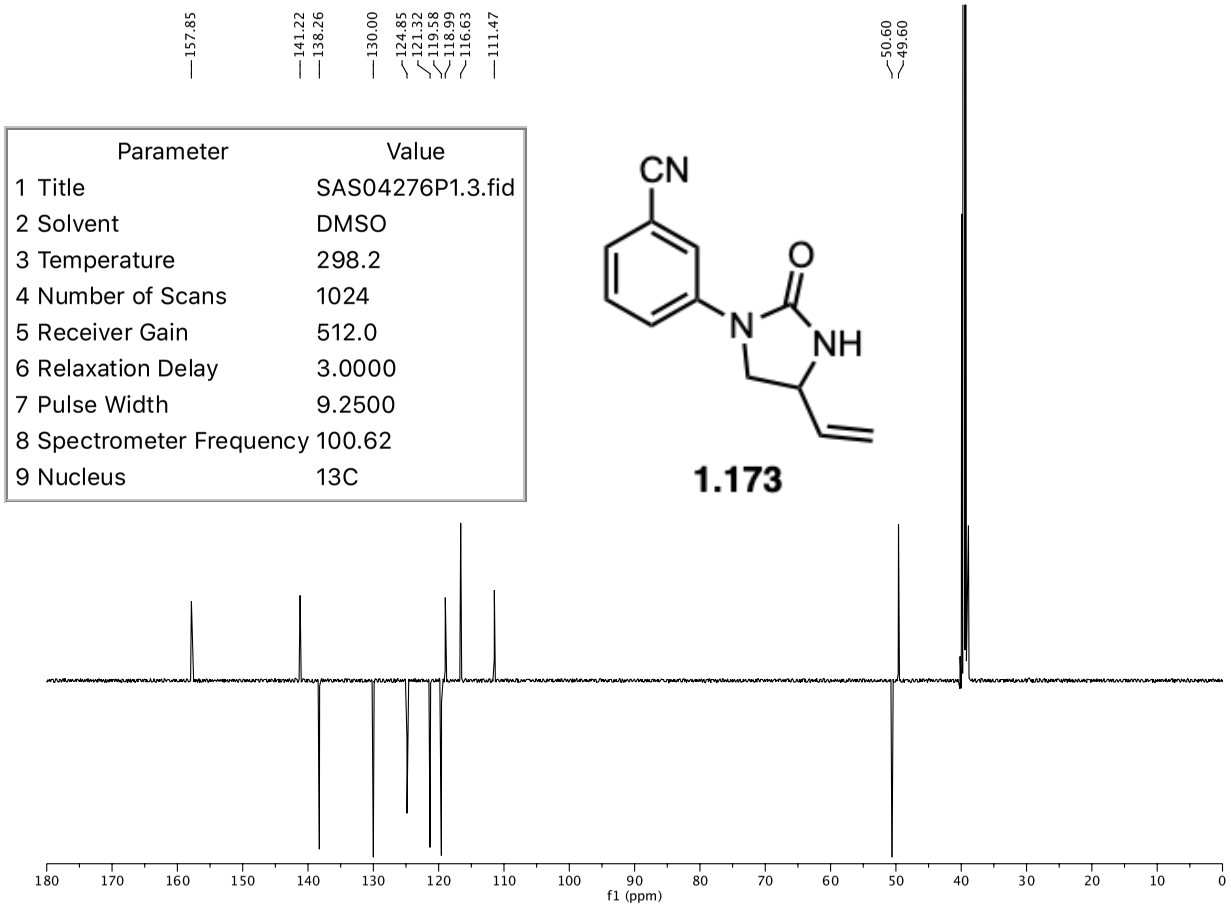

7.57
7.56
7.18
7.17
7.16
7.15
7.14
7.14
7.12
7.12
7.12
7.10
7.09
7.08
6.94
6.92
6.90
6.87
6.86
6.85
6.84
6.84
6.83
6.79
6.76
5.93
5.91
5.90
5.89
5.89
5.87
5.86
5.85
5.18
5.17
5.17
5.13
5.13
5.13
5.12
5.12
5.11
5.10
5.10
5.09
5.06
4.94
4.93
4.92
4.88
3.69
Parameter
Value
1 Title
XUF03201.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
4.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
N
NH
MeO
1.160
1.00
3.03
1.02
1.03
2.00
1.01
1.01
4.90
3.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

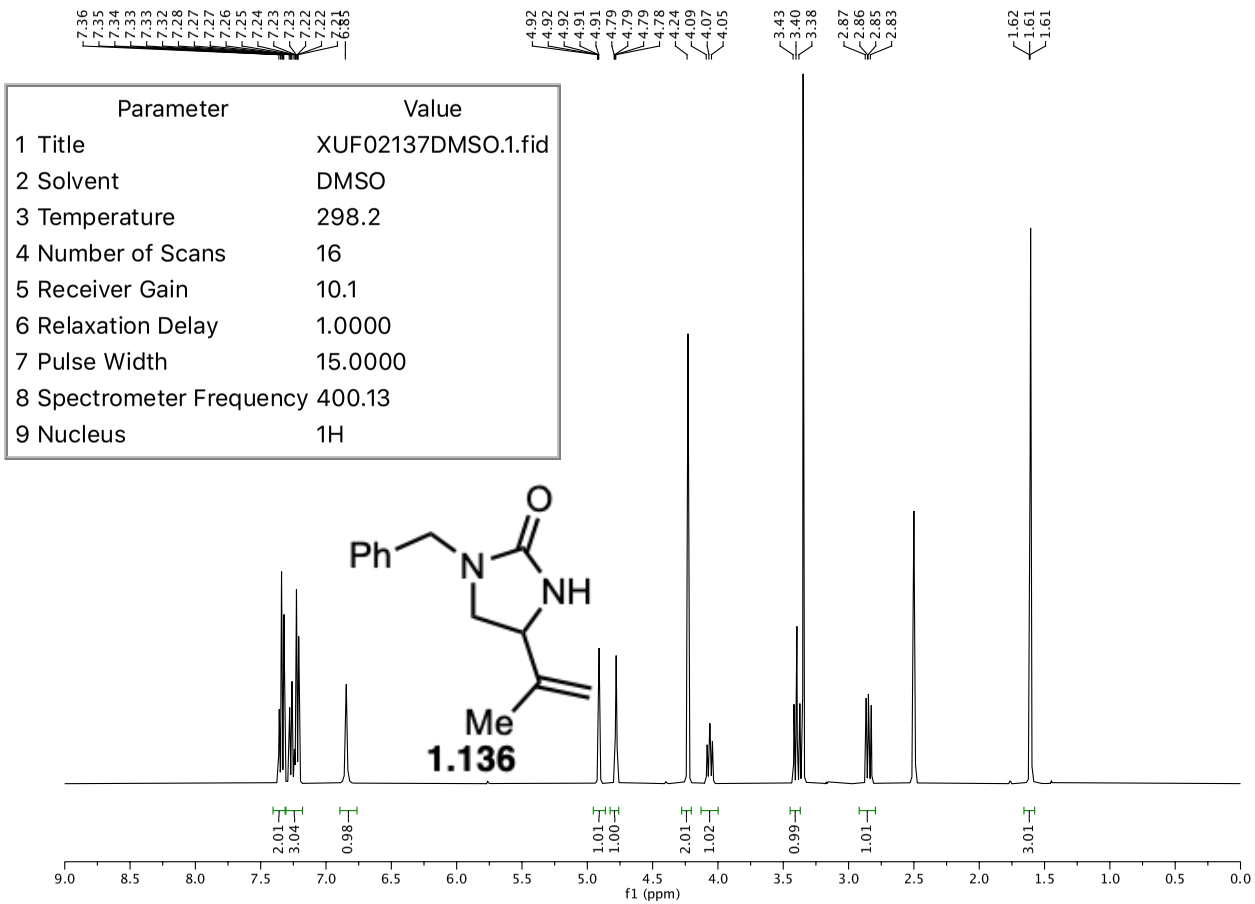

158.06
154.18
139.87
137.15
129.74
127.91
127.69
126.50
122.57
121.59
114.11
113.91
113.88
55.02
54.60
43.59
O
N
NH
MeO
1.160
Parameter
Value
1 Title
XUF03201.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


6.91 5.85 5.84 5.84 5.83 5.83 5.82 5.81 5.58 5.58 5.57 5.56 5.55 5.55 3.77 3.52 3.51 3.50 3.49 3.49 3.48 3.47 3.46 2.83 2.82 2.81 2.80 2.80 2.79 2.02 2.01 2.00 1.99 1.98 1.89 1.88 1.87 1.86 1.85 1.85 1.84 1.83 1.82 1.81 1.80 1.79 1.78 1.78 1.77 1.76 1.75 1.75 1.74 1.73 1.72 1.72 1.71 1.62 1.61 1.60 1.59 1.57 1.57 1.55 1.54 1.46 1.45 1.43 1.43 1.42 1.41 1.40
Parameter Value
1 Title XUF03183pure.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
1.164
1.01 0.98 0.96 0.96 1.00 0.97 1.05 4.18 2.14 1.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


164.47
128.40
128.09
66.38
51.50
43.46
34.47
27.98
23.15
21.13
Parameter Value
1 Title XUF03183pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
1.164
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.00
8.00
7.99
7.88
7.87
7.87
7.87
7.86
7.85
7.85
7.85
7.65
7.52
7.50
7.48
7.43
7.43
7.43
7.41
7.41
7.41
5.92
5.92
5.90
5.88
5.87
5.33
5.33
5.29
5.29
5.29
5.20
5.20
5.19
5.18
5.18
5.17
5.17
5.17
4.31
4.31
4.30
4.29
4.29
4.29
4.28
4.27
4.27
4.26
4.25
4.09
4.06
4.05
4.04
3.58
3.57
3.56
3.54
Parameter
Value
1 Title
SAS04276P1.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
7.1
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
CN
O
N
NH
1.173
0.99
0.99
0.97
1.00
0.99
1.00
1.00
1.00
1.00
1.01
0.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


157.85
141.22
138.26
130.00
124.85
121.32
119.58
118.99
116.63
111.47
50.60
49.60
Parameter Value
1 Title SAS04276P1.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
CN
O
N
NH
1.173
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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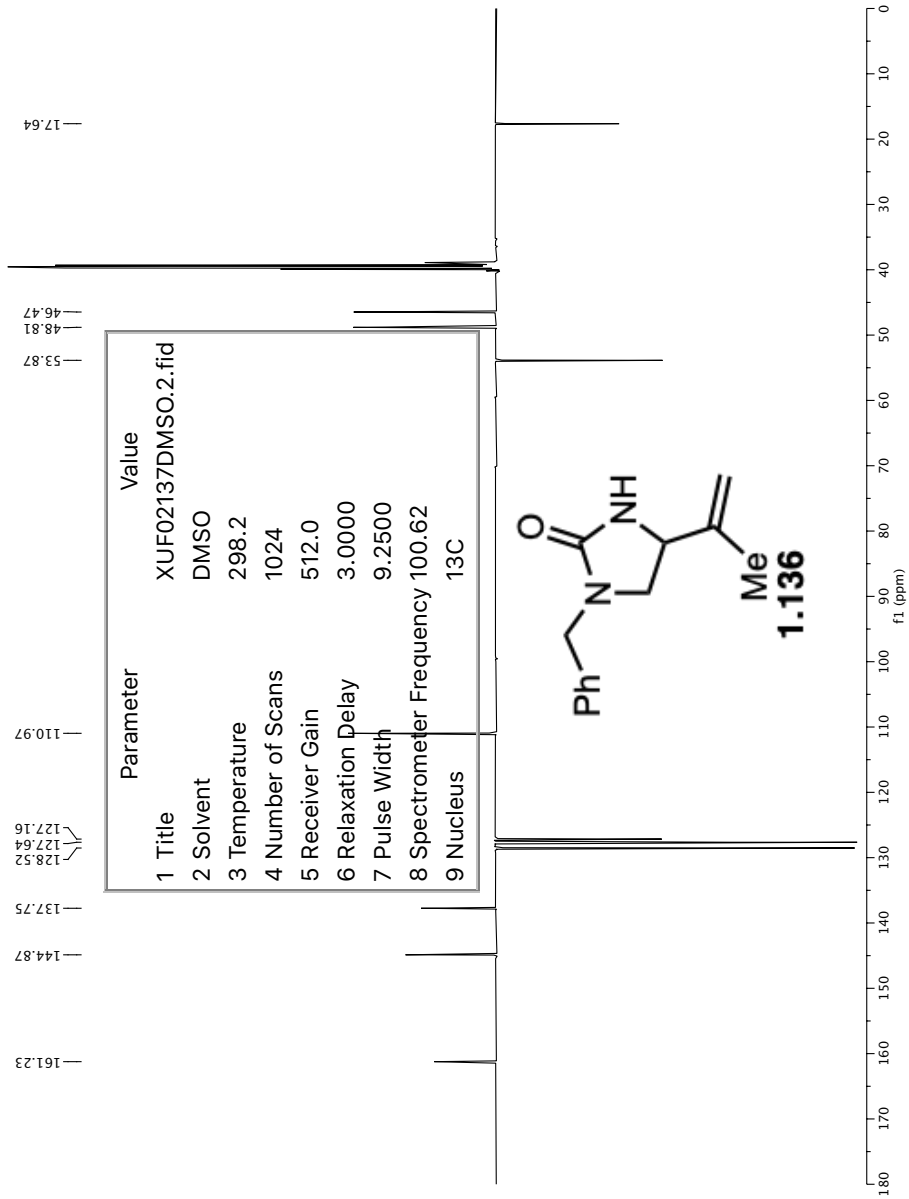
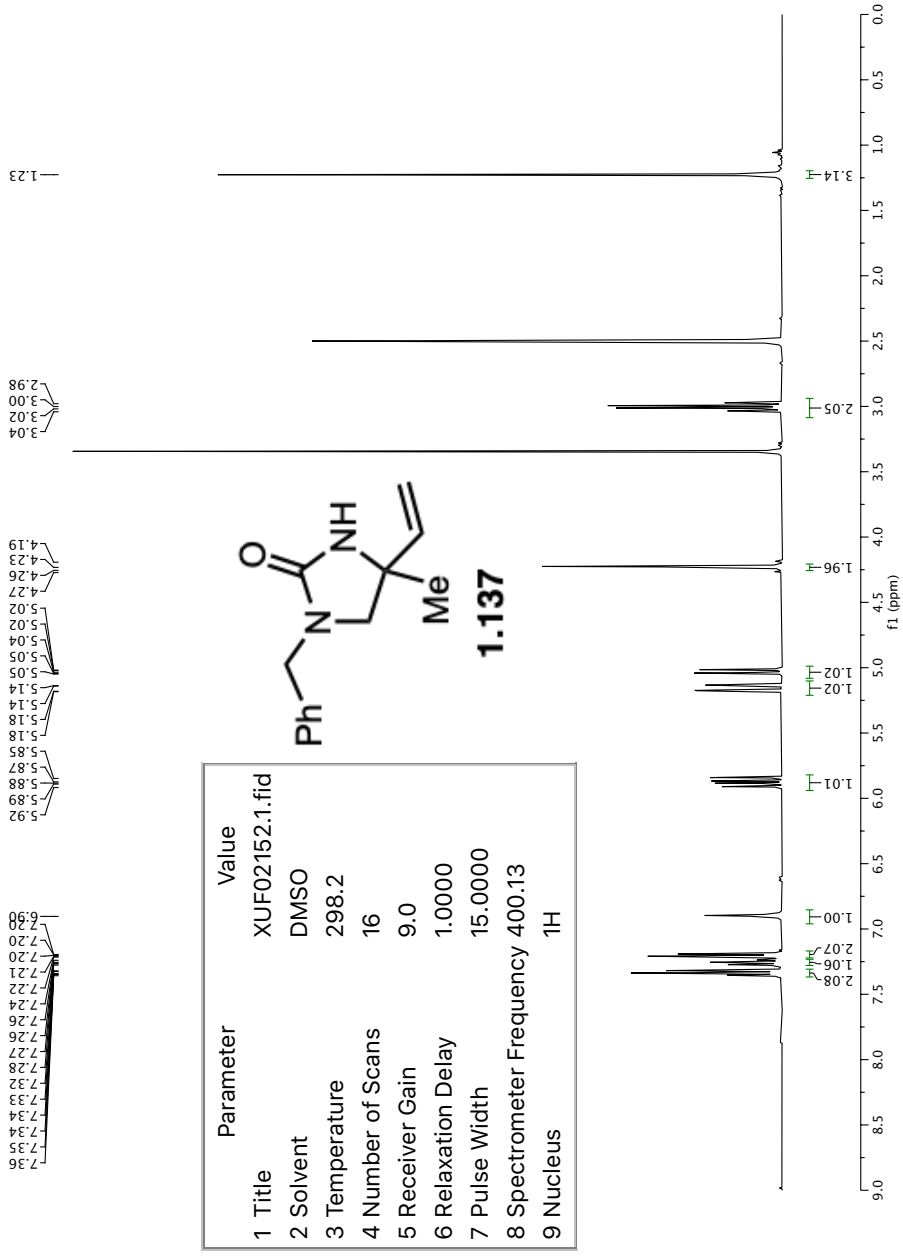
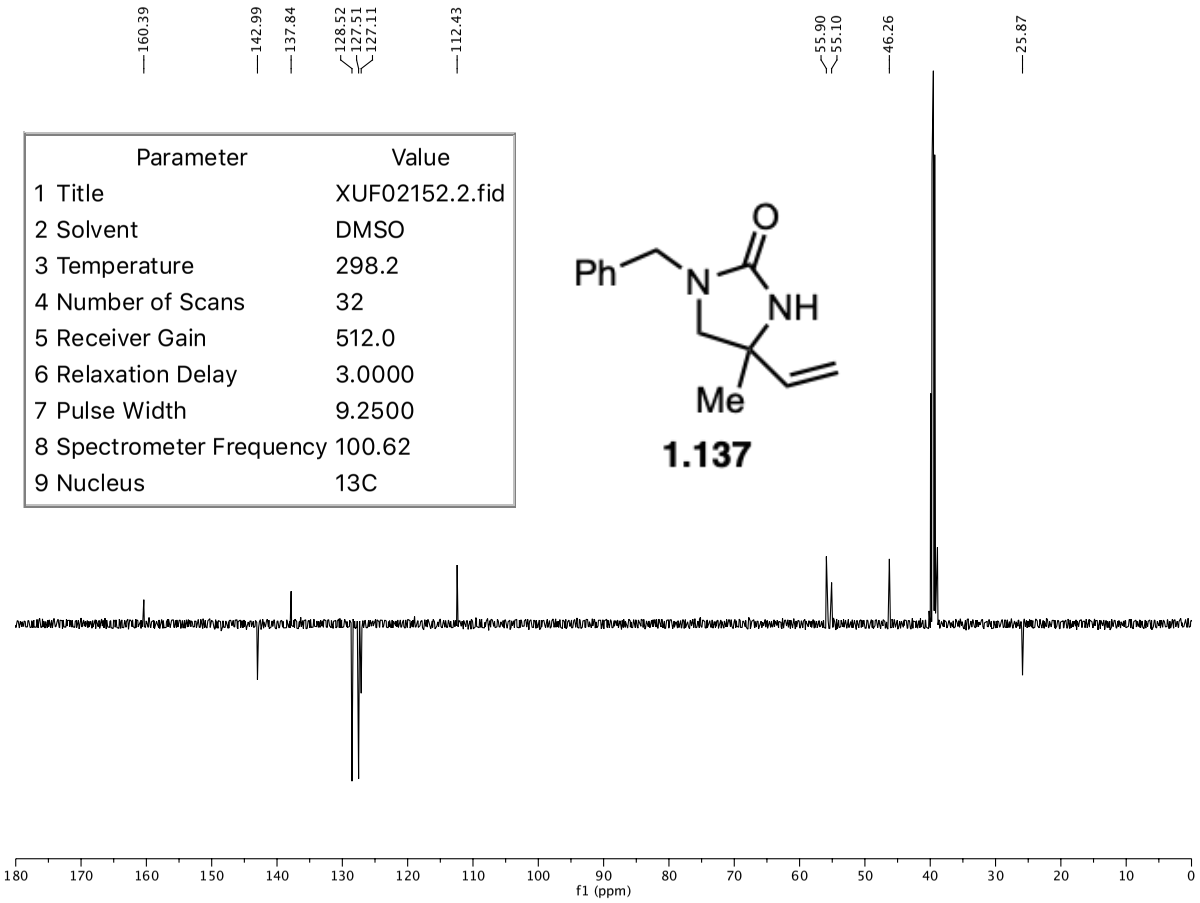
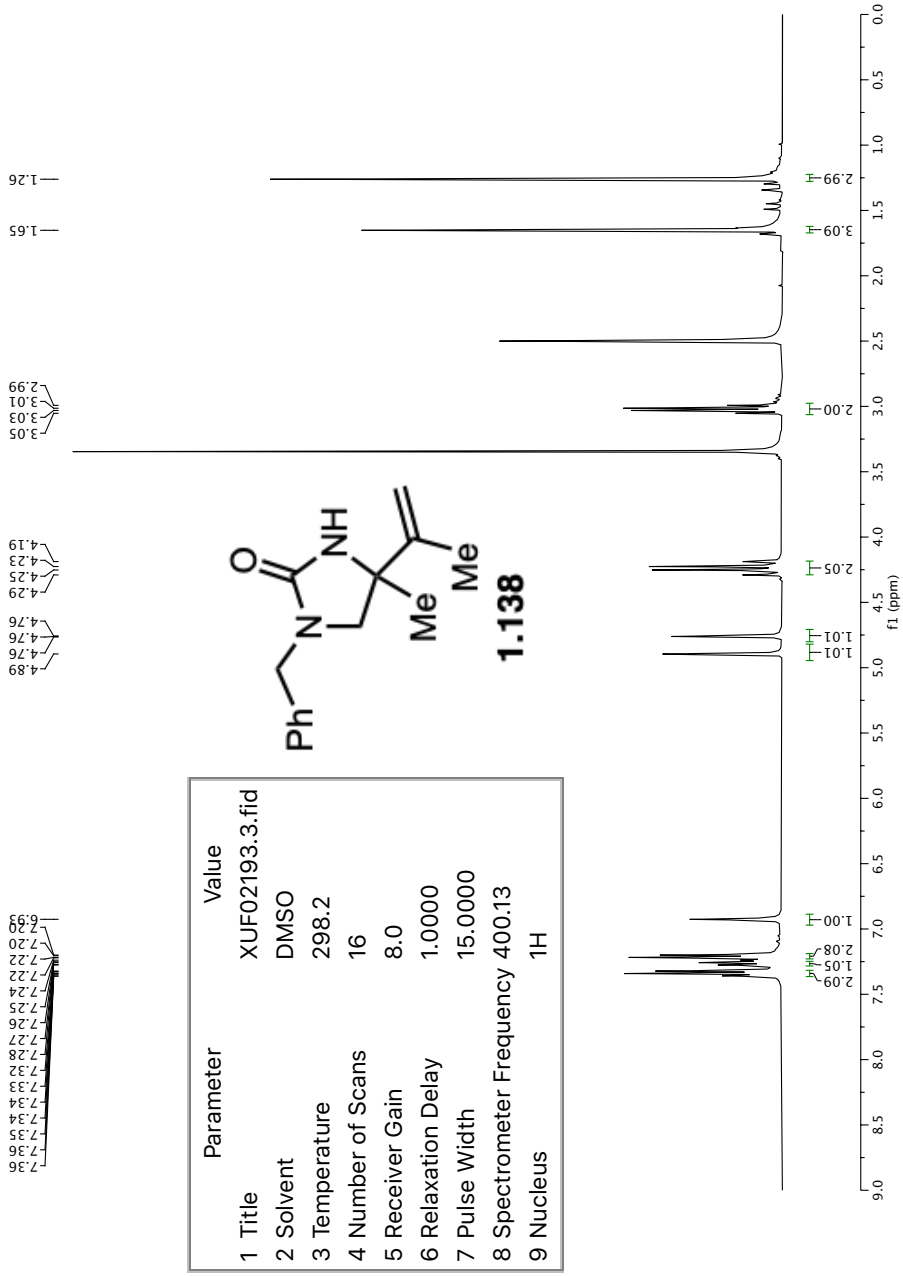
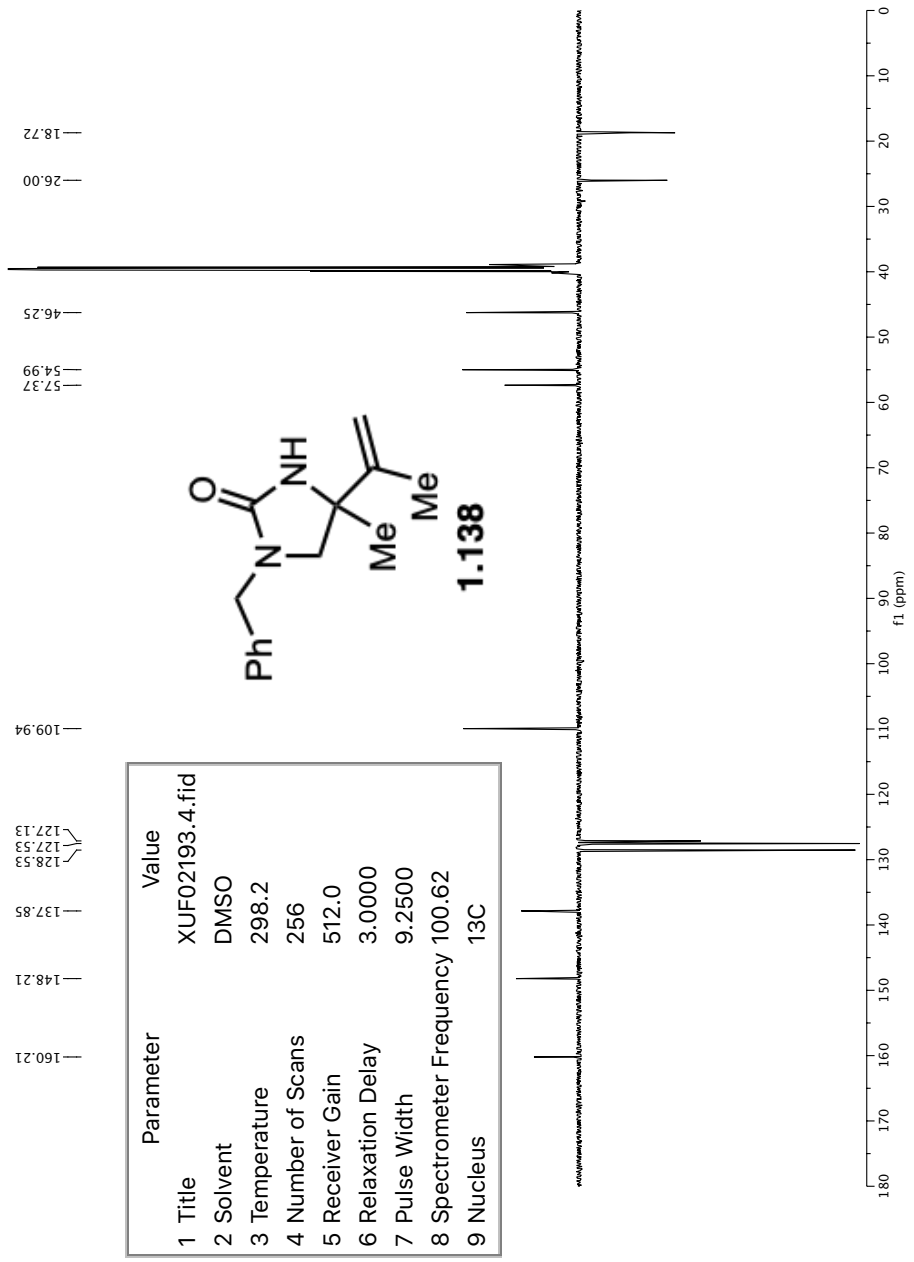
7.35
7.34
7.33
7.33
7.32
7.28
7.27
7.27
7.26
7.25
7.24
7.23
7.23
7.22
7.22
7.21
6.85
4.92
4.92
4.92
4.91
4.91
4.79
4.79
4.79
4.78
4.24
4.09
4.07
4.05
3.43
3.40
3.38
2.87
2.86
2.85
2.83
1.62
1.61
1.61
Parameter Value
1 Title XUF02137DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Ph
N
NH
Me
1.136
2.01
3.04
0.98
1.01
1.00
2.01
1.02
0.99
1.01
3.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

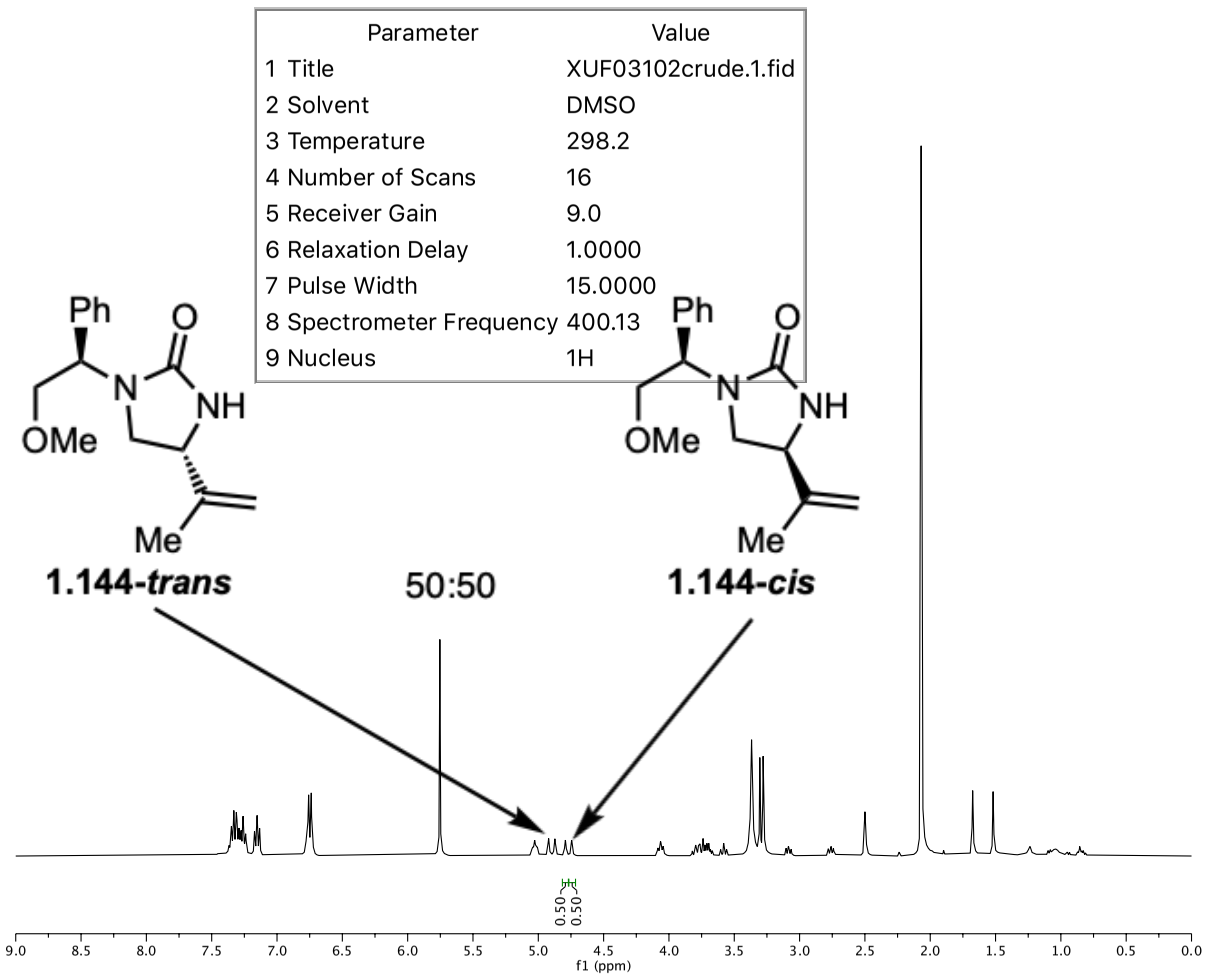

17.64
46.47
48.81
53.87
110.97
127.16
127.64
128.52
137.75
144.87
161.23
Parameter Value
1 Title XUF02137DMSO.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
NH
N
Ph
Me
1.136
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
f1 (ppm)

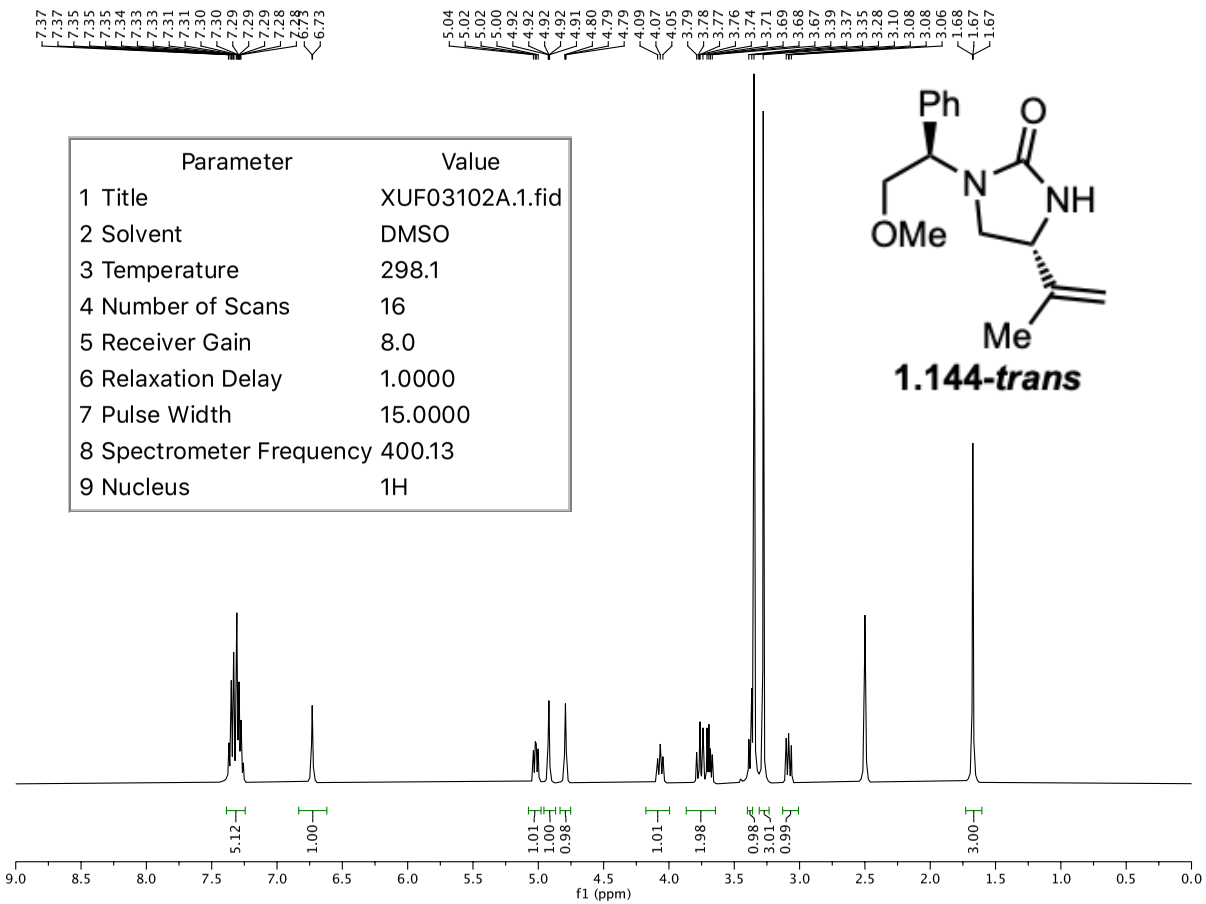

Parameter Value
1 Title XUF02152.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
Me
1.137
f1 (ppm)

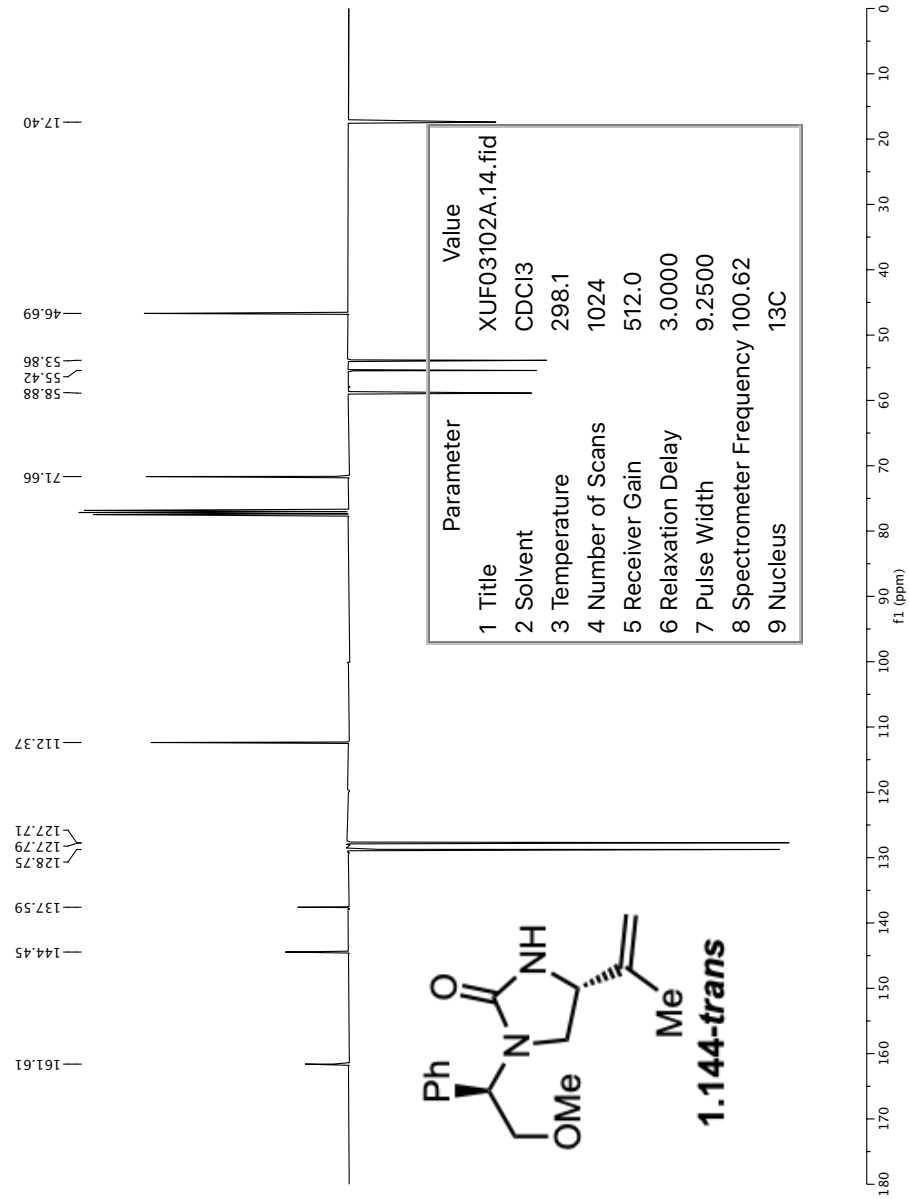

160.39
142.99
137.84
128.52
127.51
127.11
112.43
55.90
55.10
46.26
25.87
Parameter Value
1 Title XUF02152.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
NH
Me
1.137
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

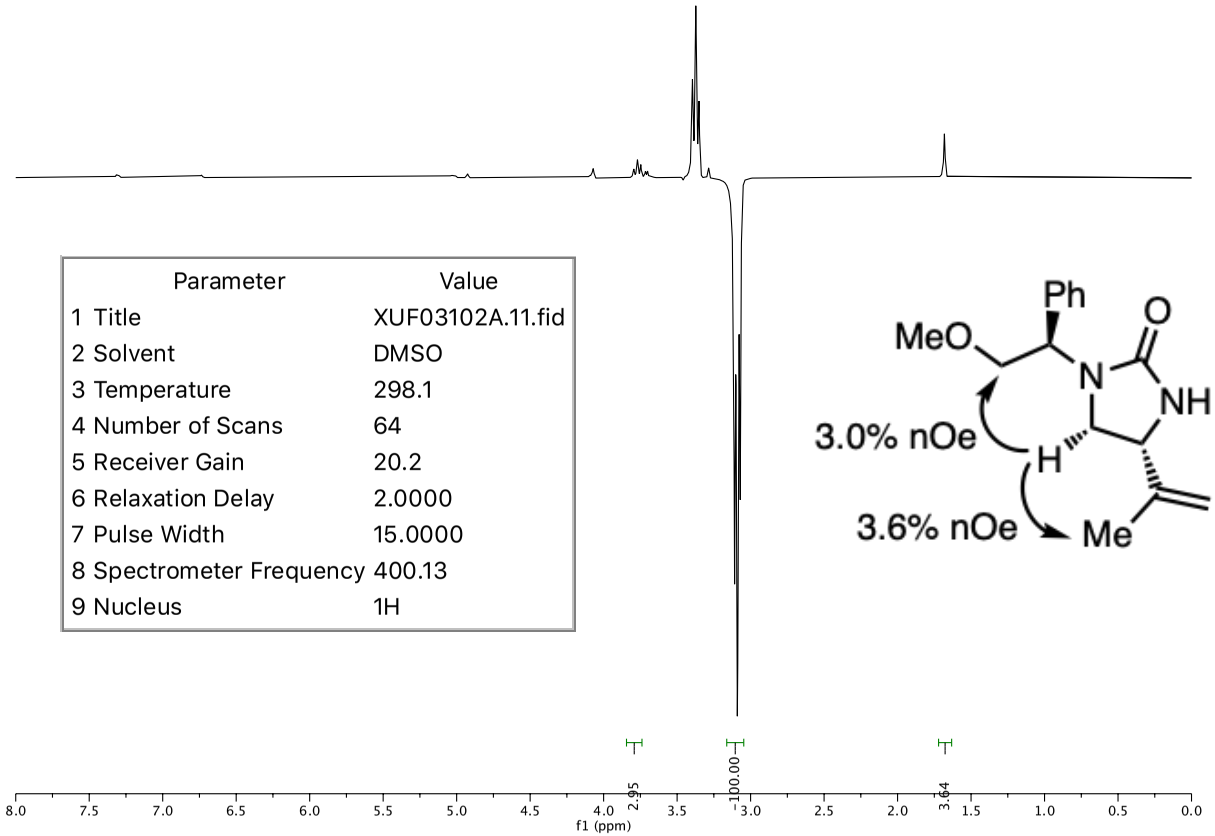

Parameter Value
1 Title XUF02193.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
Me
Me
1.138
f1 (ppm)

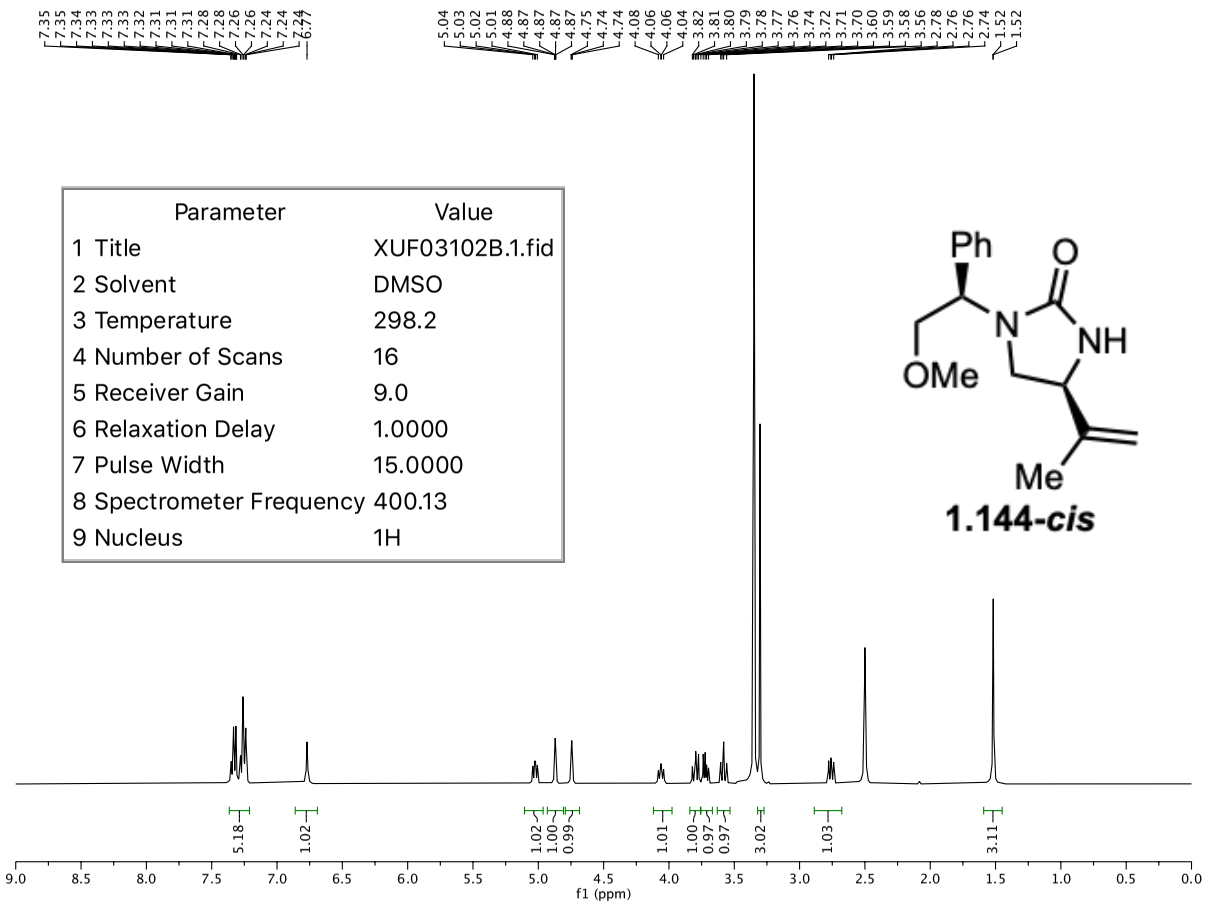

160.21
148.21
137.85
128.53
127.53
127.13
109.94
46.25
54.99
57.37
26.00
18.72
Ph
N
O
NH
Me
Me
1.138
f1 (ppm)
Parameter Value
1 Title XUF02193.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C

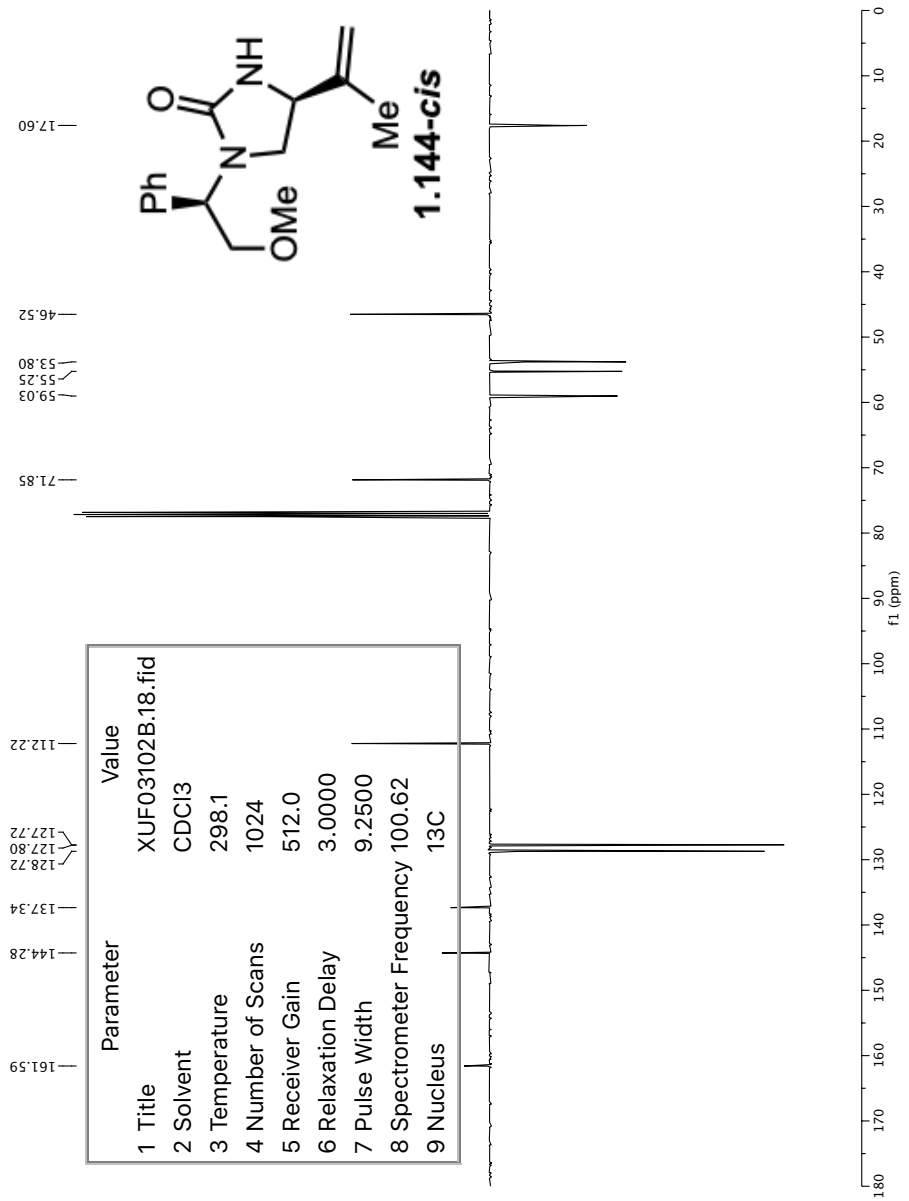

Parameter Value
1 Title XUF03102crude.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
O
N
NH
OMe
Me
1.144-trans
50:50
1.144-cis
0.50
0.50
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


7.37
7.37
7.35
7.35
7.35
7.34
7.33
7.33
7.31
7.31
7.30
7.30
7.29
7.29
7.29
7.28
7.28
6.73
6.73
5.04
5.02
5.02
5.00
4.92
4.92
4.92
4.92
4.91
4.80
4.79
4.79
4.09
4.07
4.05
3.79
3.78
3.77
3.76
3.74
3.71
3.69
3.68
3.67
3.39
3.37
3.35
3.28
3.10
3.08
3.08
3.06
1.68
1.67
1.67
Parameter Value
1 Title XUF03102A.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
O
N
NH
OMe
Me
1.144-trans
5.12
1.00
1.01
1.00
0.98
1.01
1.98
0.98
3.01
0.99
3.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

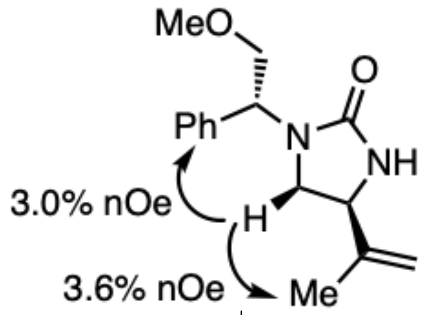

17.40
46.69
53.86
55.42
58.88
71.66
112.37
127.71
127.79
128.75
137.59
144.45
161.61
Parameter
Value
1 Title
XUF03102A.14.fid
2 Solvent
CDCl3
3 Temperature
298.1
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
Ph
OMe
O
N
NH
Me
1.144-trans
f1 (ppm)

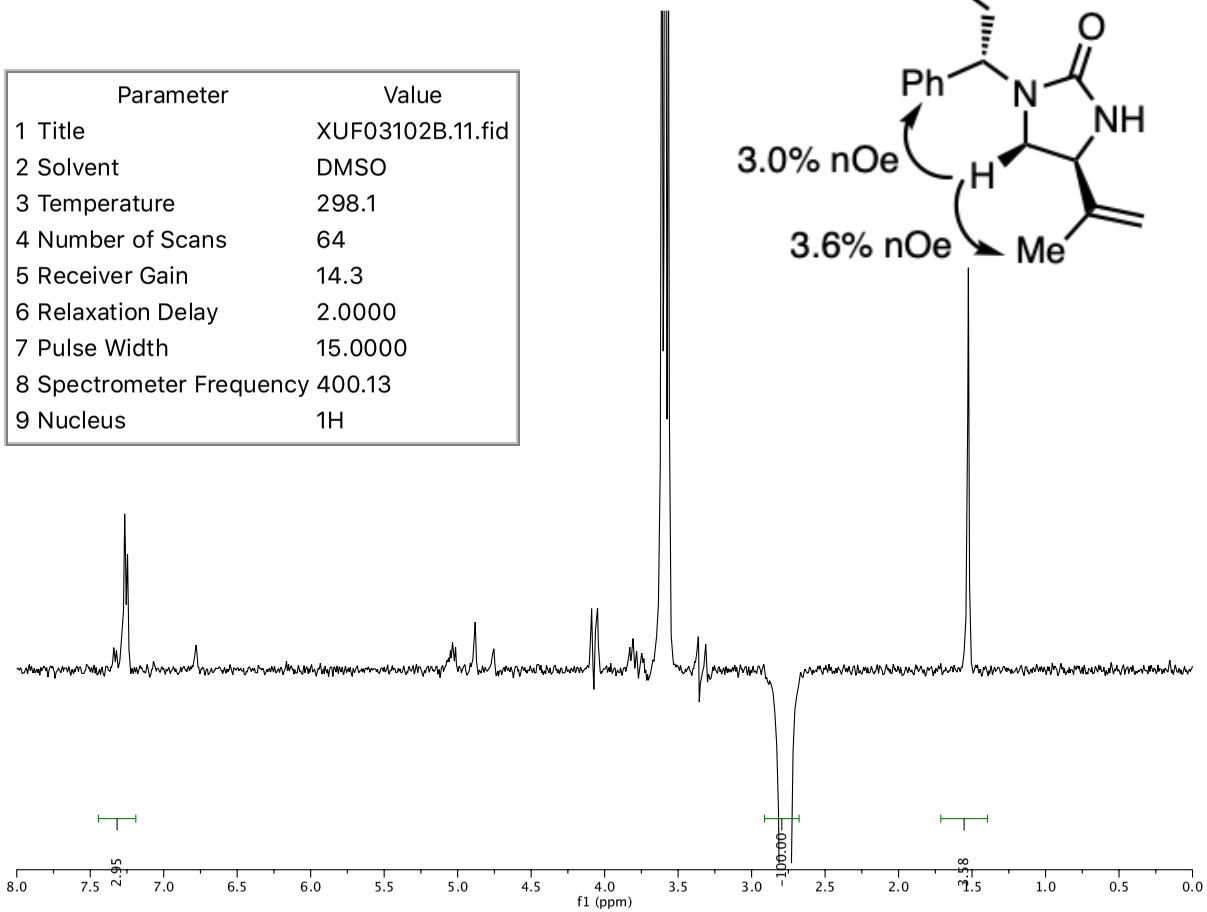

Parameter Value
1 Title XUF03102A.11.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 64
5 Receiver Gain 20.2
6 Relaxation Delay 2.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
O
MeO
N
NH
3.0% nOe
H
3.6% nOe
Me
2.95
100.00
3.64
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

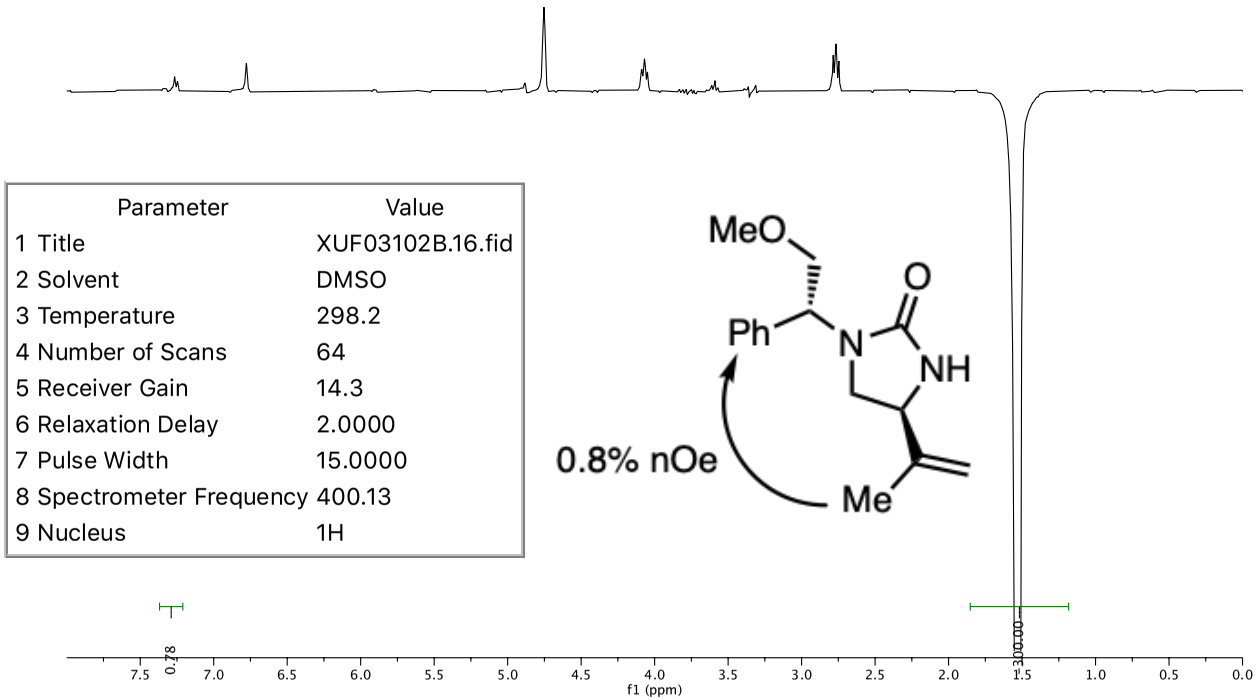

7.35
7.35
7.34
7.33
7.33
7.33
7.32
7.31
7.31
7.31
7.28
7.28
7.26
7.26
7.24
7.24
7.24
6.77
5.04
5.03
5.02
5.01
4.88
4.87
4.87
4.87
4.87
4.75
4.74
4.74
4.08
4.06
4.06
4.04
3.82
3.81
3.80
3.79
3.78
3.77
3.76
3.74
3.72
3.71
3.70
3.60
3.59
3.58
3.56
2.78
2.76
2.76
2.74
1.52
1.52
Parameter Value
1 Title XUF03102B.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
O
N
NH
OMe
Me
1.144-cis
5.18
1.02
1.02
1.00
0.99
1.01
1.00
0.97
0.97
3.02
1.03
3.11
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

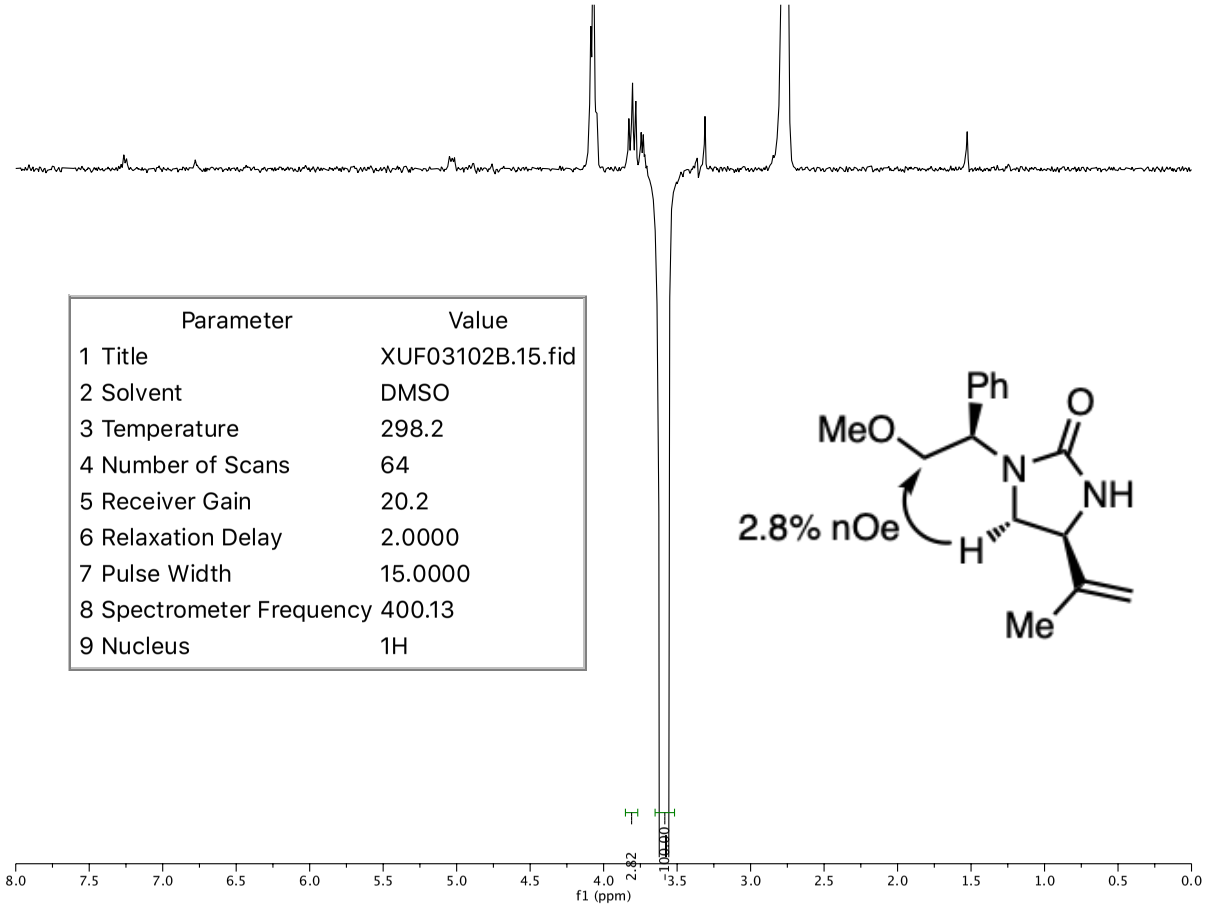

17.60
46.52
53.80
55.25
59.03
71.85
112.22
127.72
127.80
128.72
137.34
144.28
161.59
Parameter Value
1 Title XUF03102B.18.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
OMe
N
O
NH
Me
1.144-cis
f1 (ppm)

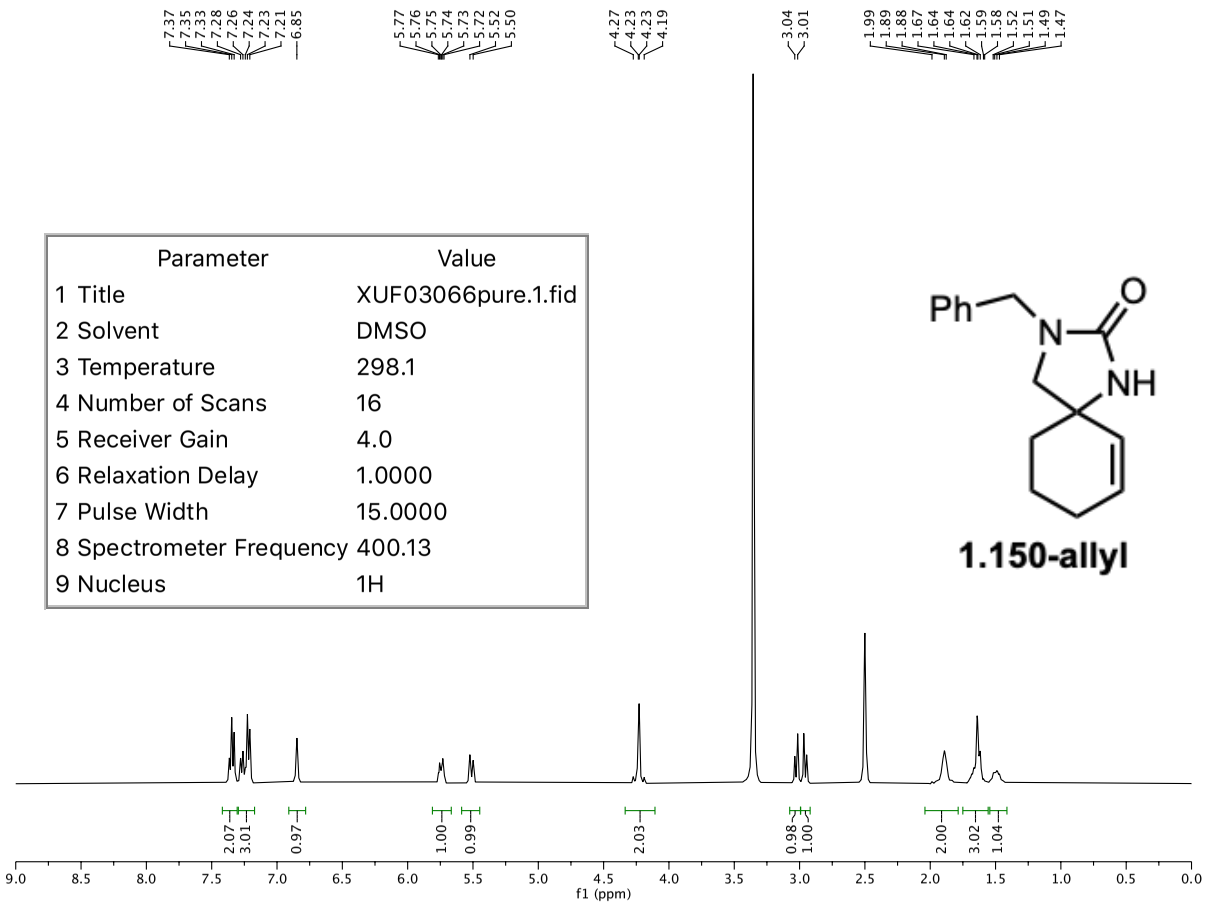
Parameter	Value
1 Title	XUF03102B.11.fid
2 Solvent	DMSO
3 Temperature	298.1
4 Number of Scans	64
5 Receiver Gain	14.3
6 Relaxation Delay	2.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

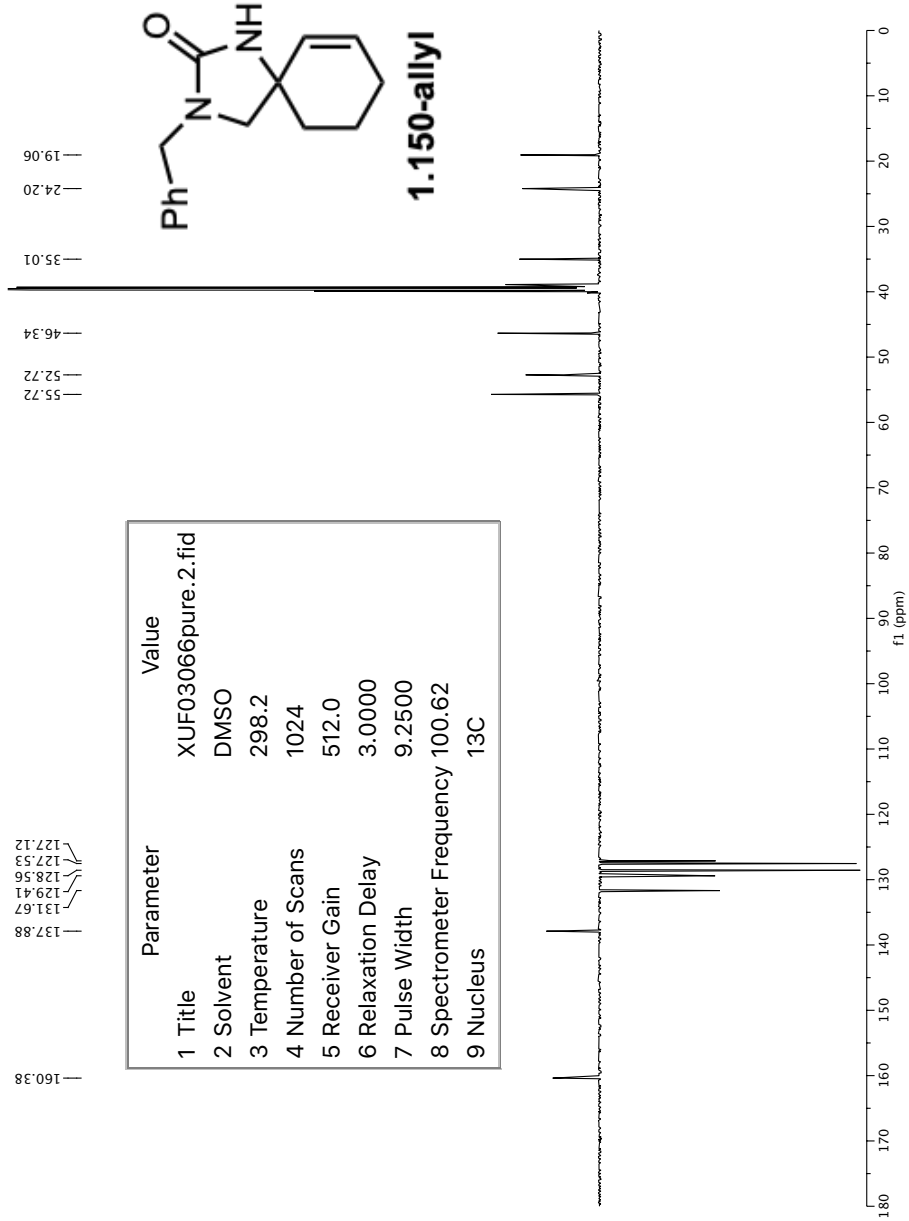


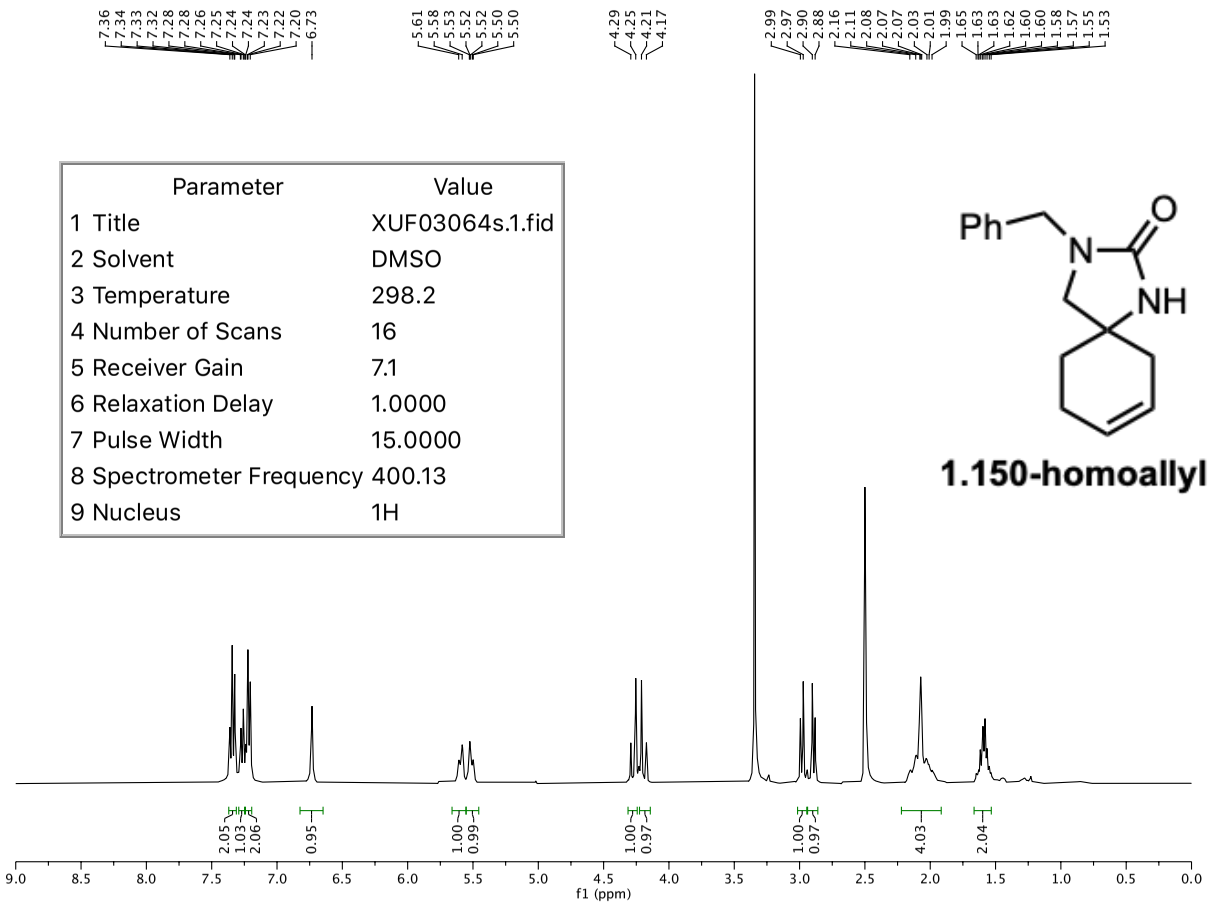


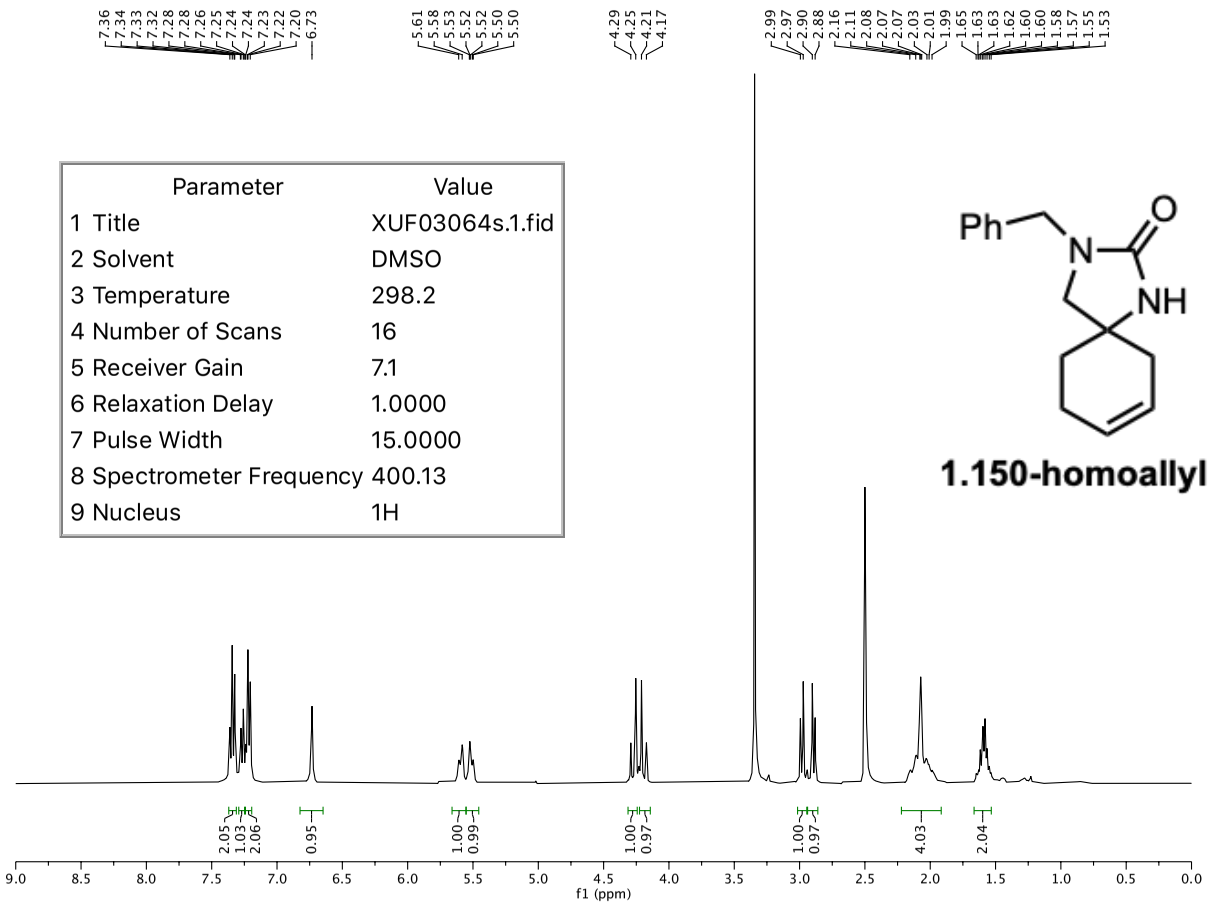

Parameter Value
1 Title XUF03102B.16.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 64
5 Receiver Gain 14.3
6 Relaxation Delay 2.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
Ph
N
O
NH
Me
0.8% nOe
0.78
300.00
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

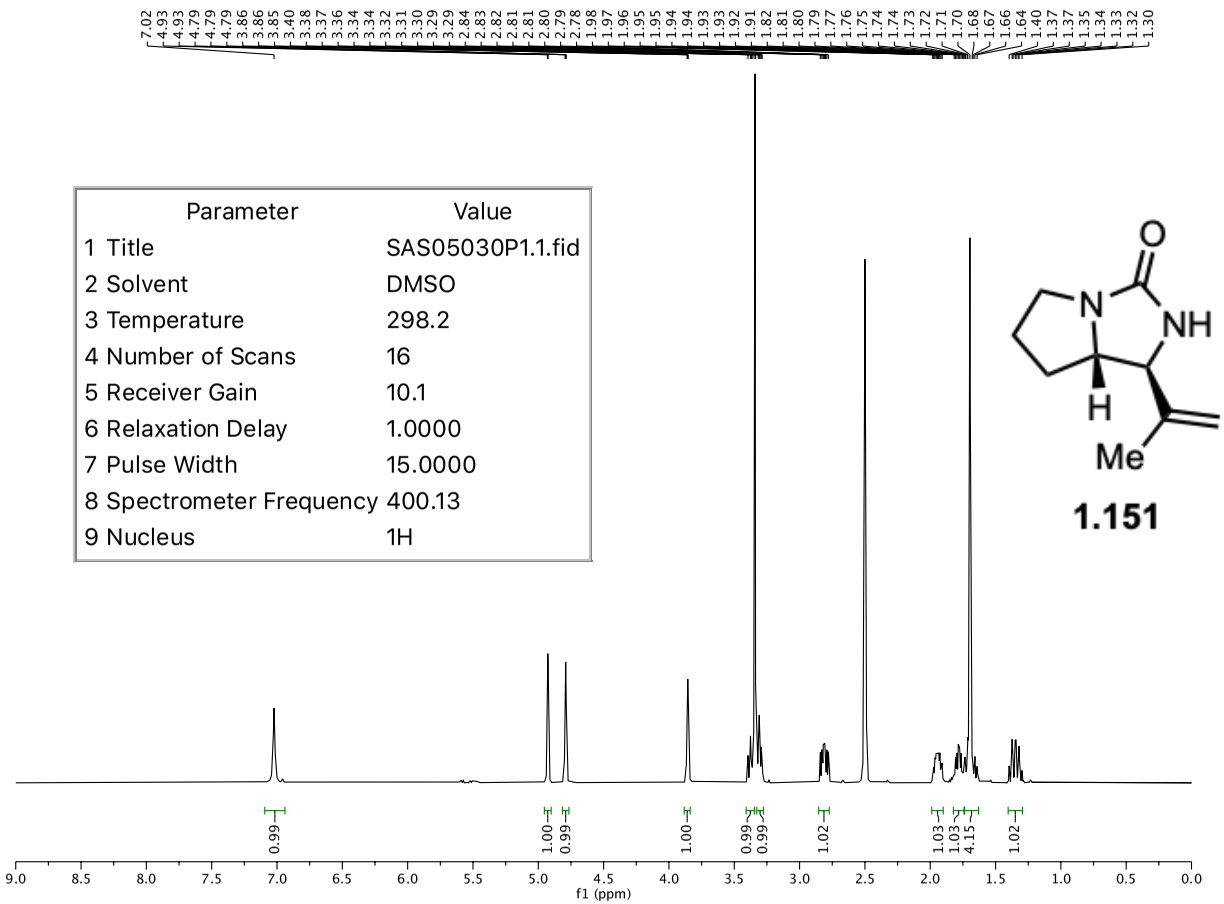

Parameter Value
1 Title XUF03102B.15.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 64
5 Receiver Gain 20.2
6 Relaxation Delay 2.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
MeO
O
N
NH
2.8% nOe
H
Me
2.82
1.00
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

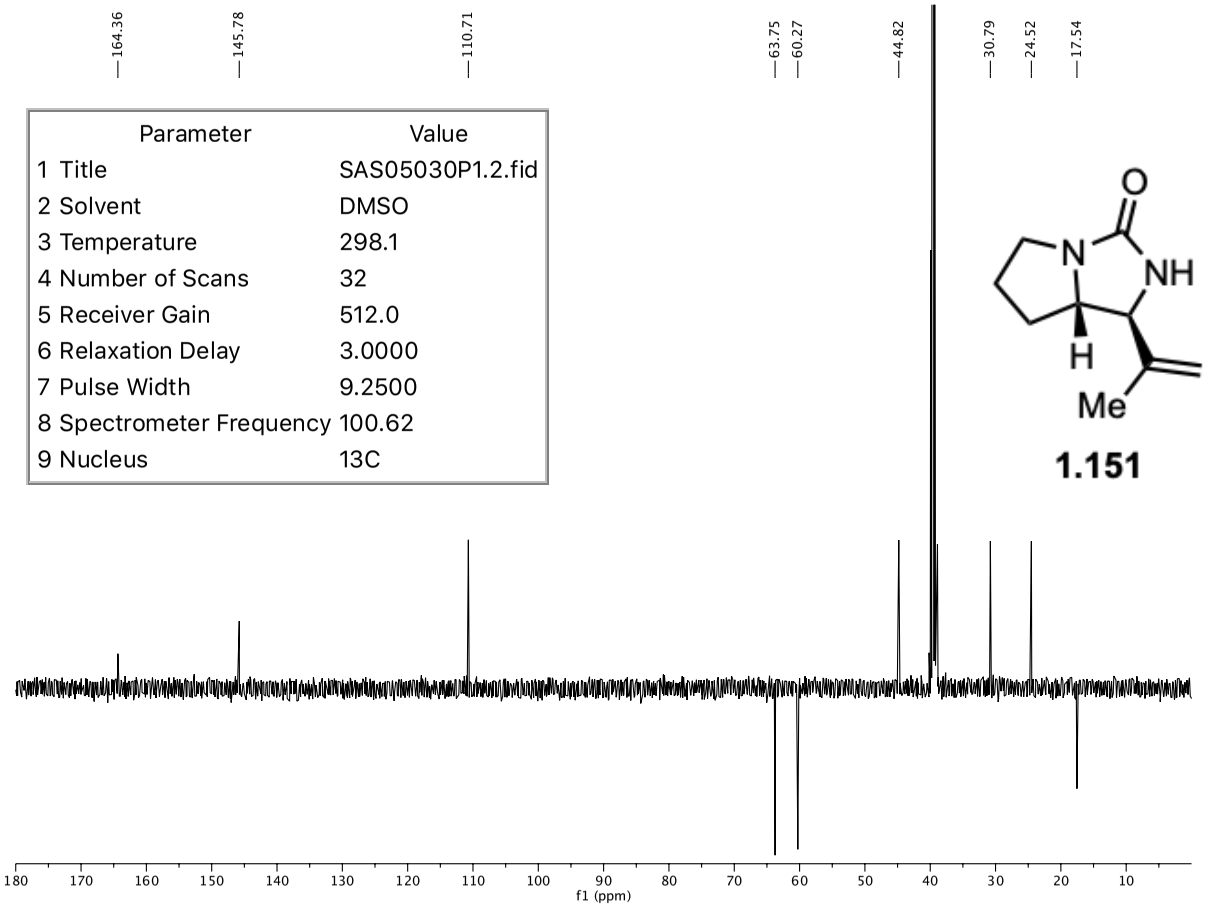

7.37
7.35
7.33
7.28
7.26
7.24
7.23
7.21
6.85
5.77
5.76
5.75
5.74
5.73
5.72
5.52
5.50
4.27
4.23
4.23
4.19
3.04
3.01
1.99
1.89
1.88
1.67
1.64
1.64
1.62
1.59
1.58
1.52
1.51
1.49
1.47
Parameter Value
1 Title XUF03066pure.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
1.150-allyl
2.07
3.01
0.97
1.00
0.99
2.03
0.98
1.00
2.00
3.02
1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

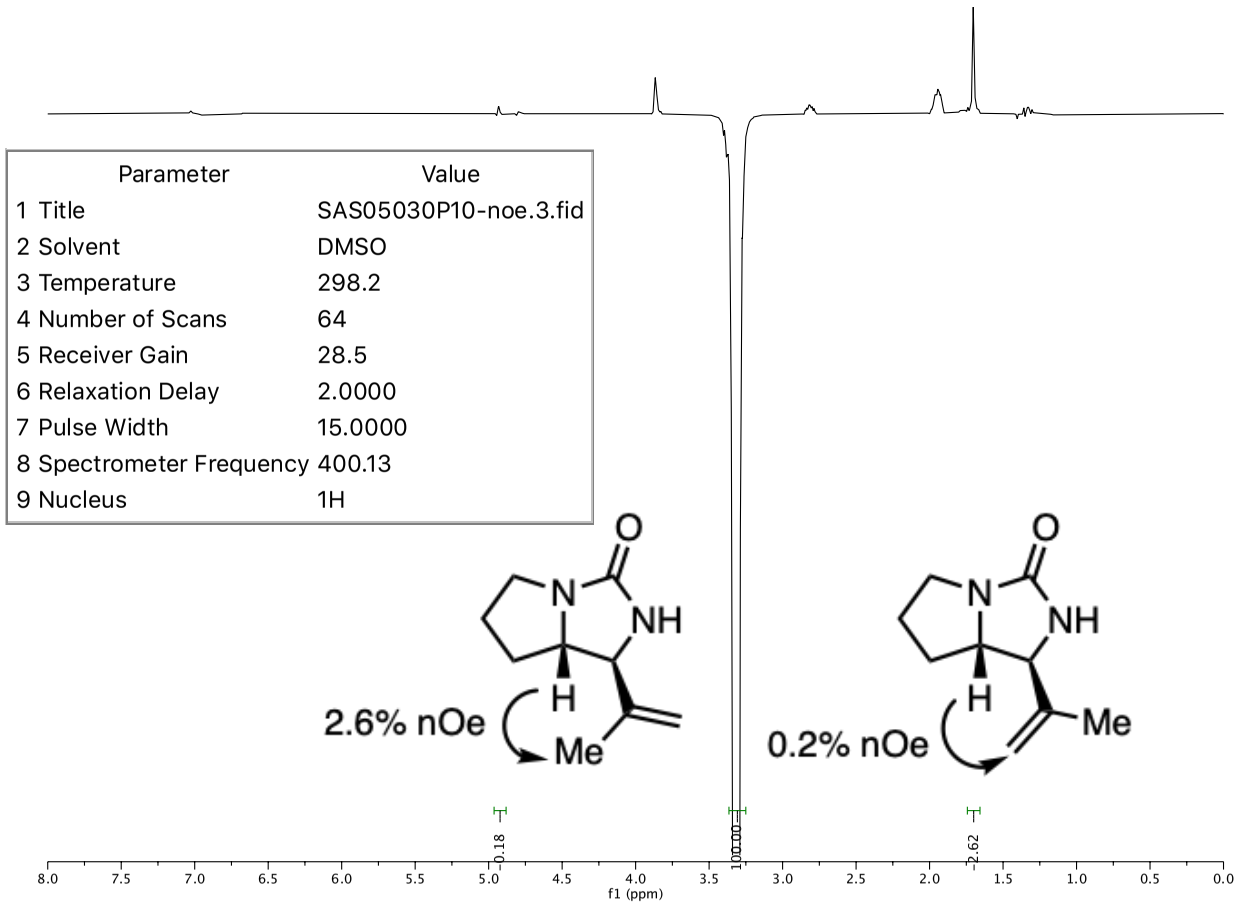

1.150-allyl
Ph
NH
O
N
19.06
24.20
35.01
46.34
52.72
55.72
137.88
160.38
127.12
127.53
128.56
129.41
131.67
Parameter Value
1 Title XUF03066pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

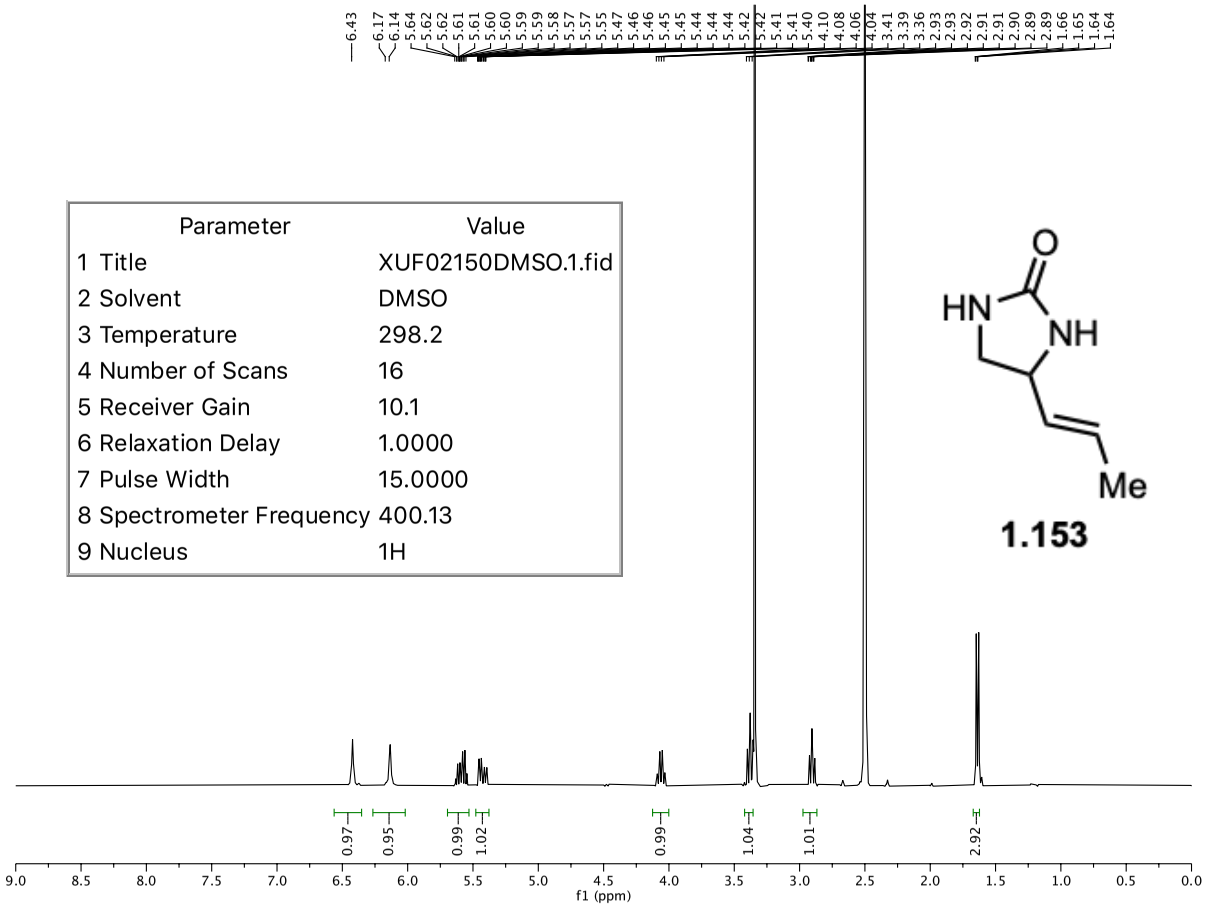

7.36
7.34
7.33
7.32
7.28
7.28
7.26
7.25
7.24
7.24
7.23
7.22
7.20
6.73
5.61
5.58
5.53
5.52
5.52
5.50
5.50
4.29
4.25
4.21
4.17
2.99
2.97
2.90
2.88
2.16
2.11
2.08
2.07
2.07
2.03
2.01
1.99
1.65
1.63
1.63
1.62
1.60
1.60
1.58
1.57
1.55
1.53
Parameter Value
1 Title XUF03064s.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
1.150-homoallyl
2.05
1.03
2.06
0.95
1.00
0.99
1.00
0.97
1.00
0.97
4.03
2.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

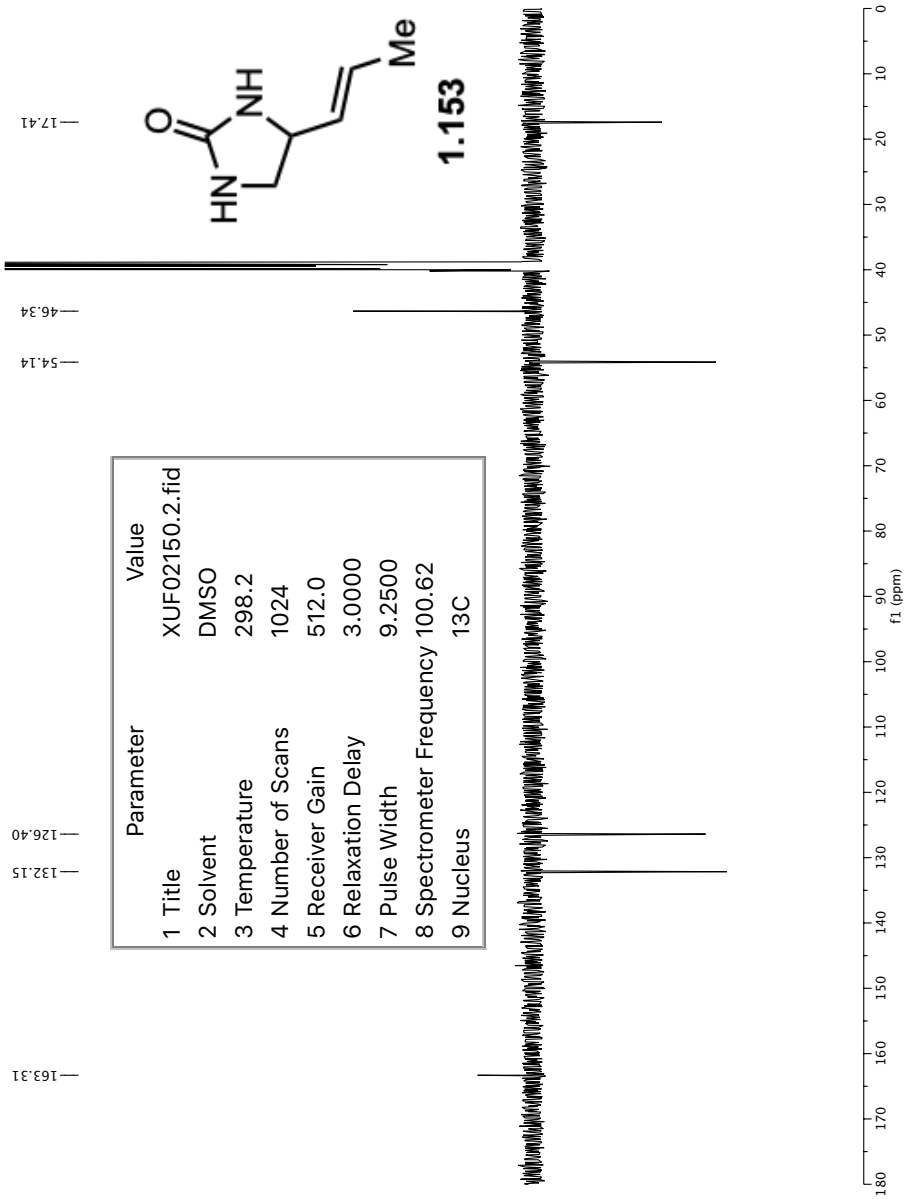

7.36
7.34
7.33
7.32
7.28
7.28
7.26
7.25
7.24
7.24
7.23
7.22
7.20
6.73
5.61
5.58
5.53
5.52
5.52
5.50
5.50
4.29
4.25
4.21
4.17
2.99
2.97
2.90
2.88
2.16
2.11
2.08
2.07
2.07
2.03
2.01
1.99
1.65
1.63
1.63
1.62
1.60
1.60
1.58
1.57
1.55
1.53
Parameter Value
1 Title XUF03064s.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Ph
N
O
NH
1.150-homoallyl
2.05
1.03
2.06
0.95
1.00
0.99
1.00
0.97
1.00
0.97
4.03
2.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


7.02 4.93 4.93 4.79 4.79 4.79 3.86 3.86 3.85 3.40 3.38 3.37 3.36 3.34 3.34 3.32 3.31 3.30 3.29 3.29 2.84 2.83 2.82 2.81 2.81 2.80 2.79 2.78 1.98 1.97 1.96 1.95 1.95 1.94 1.94 1.93 1.93 1.92 1.91 1.82 1.81 1.80 1.79 1.77 1.76 1.75 1.74 1.74 1.73 1.72 1.71 1.70 1.68 1.67 1.66 1.64 1.40 1.37 1.37 1.35 1.34 1.33 1.32 1.30
Parameter Value
1 Title SAS05030P1.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
H
Me
1.151
0.99 1.00 0.99 1.00 0.99 0.99 1.02 1.03 1.03 4.15 1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

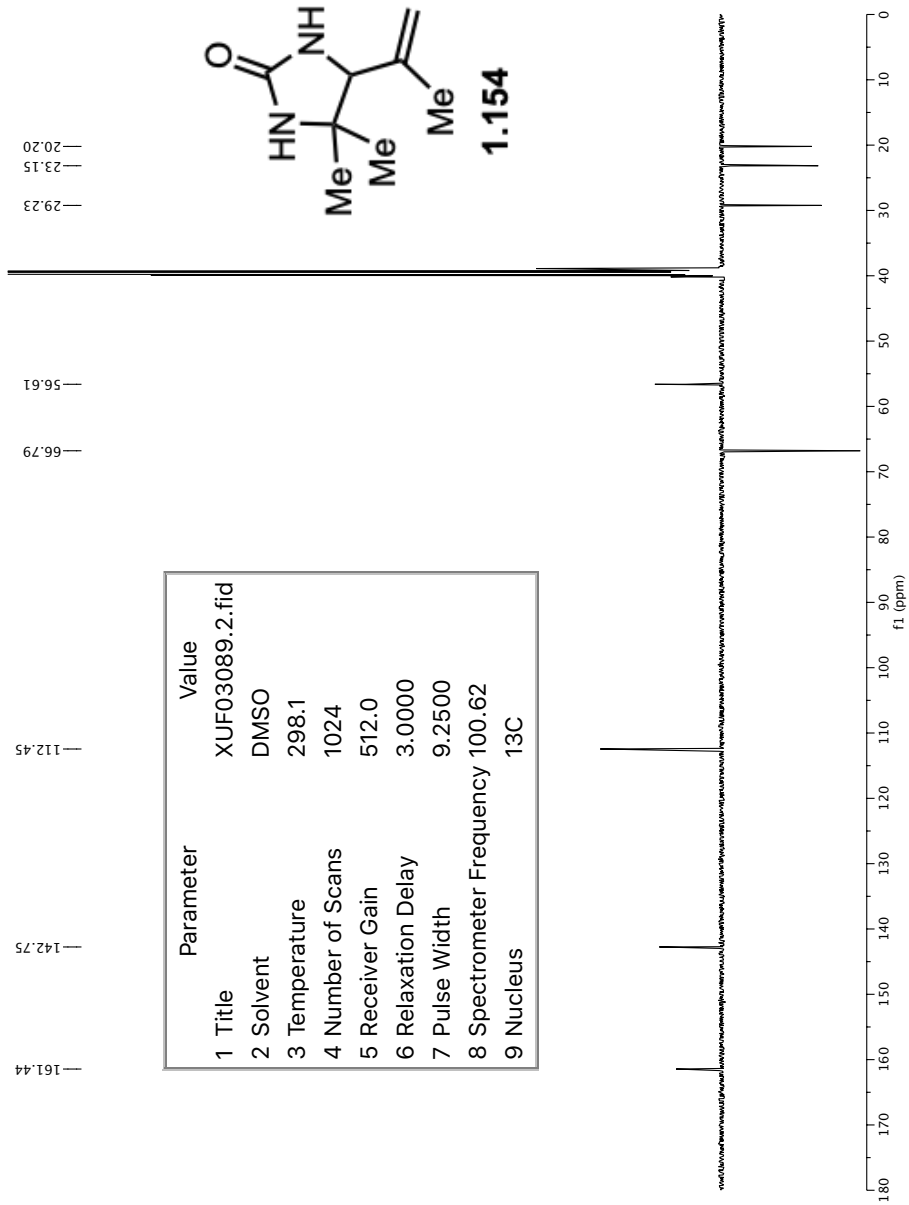

164.36
145.78
110.71
63.75
60.27
44.82
30.79
24.52
17.54
Parameter Value
1 Title SAS05030P1.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 32
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
N
NH
H
Me
1.151
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

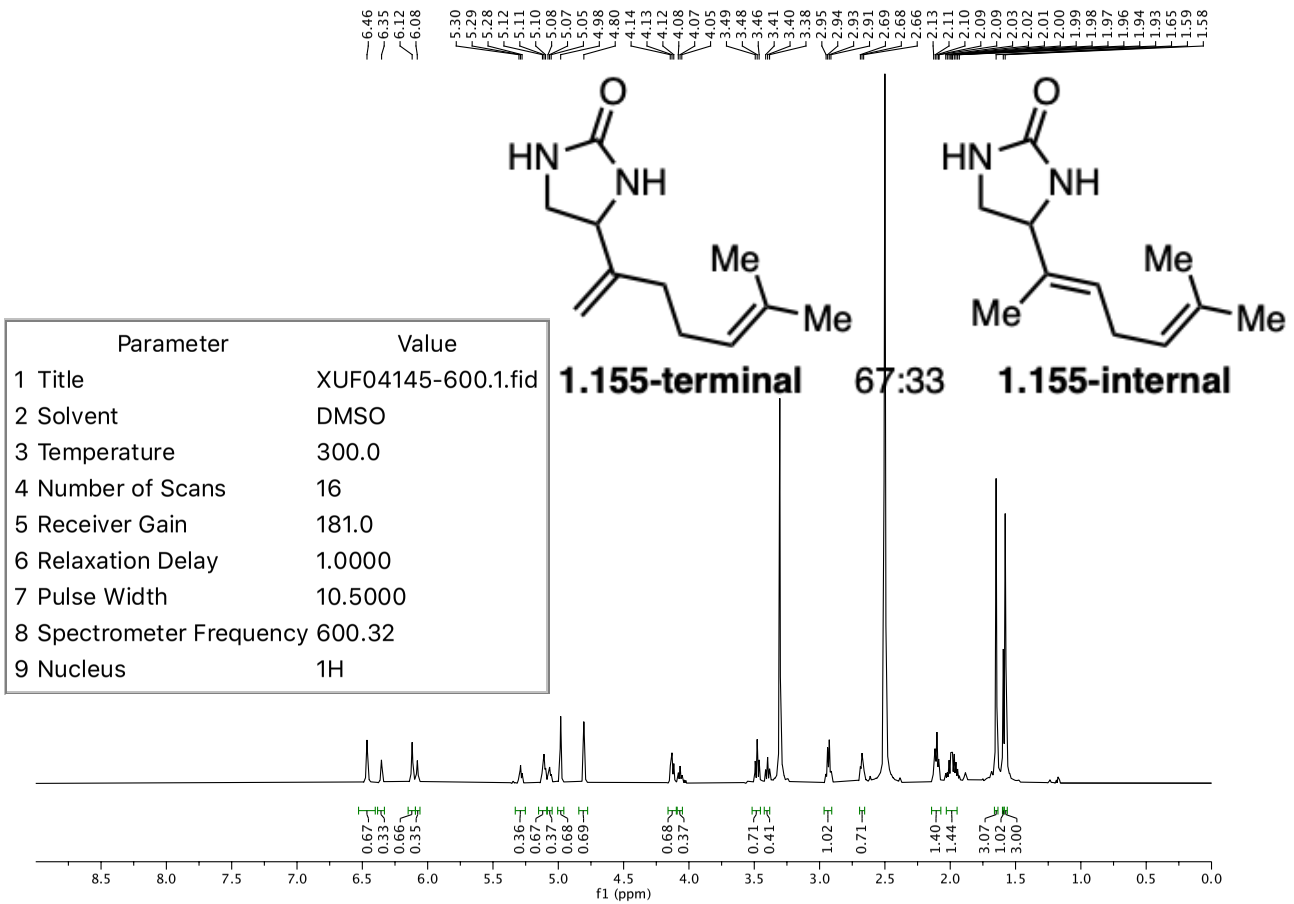

Parameter
Value
1 Title
SAS05030P10-noe.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
64
5 Receiver Gain
28.5
6 Relaxation Delay
2.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
N
NH
H
Me
2.6% nOe
0.2% nOe
0.18
100.00
2.62
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

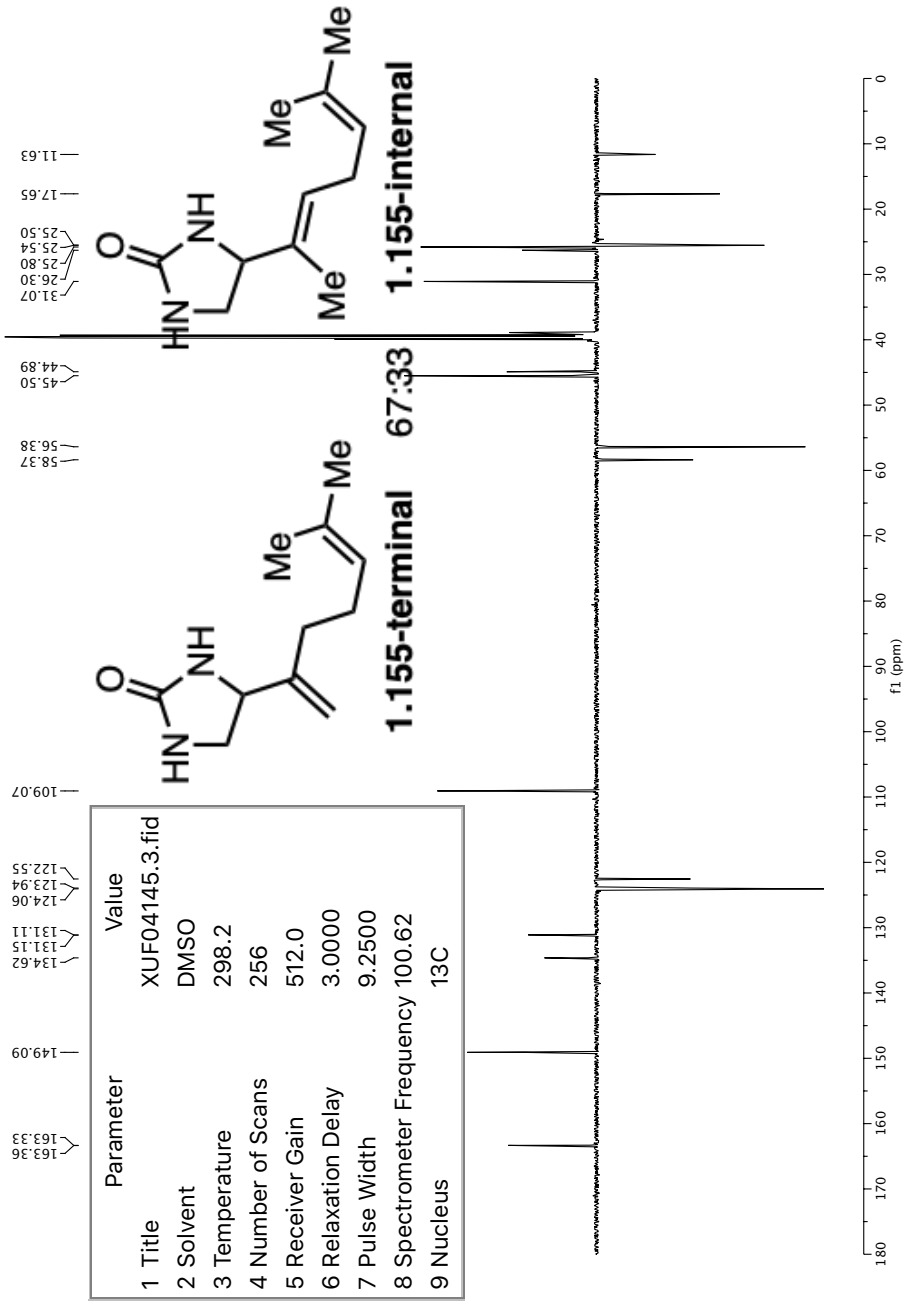

6.43
6.17
6.14
5.64
5.62
5.62
5.61
5.61
5.60
5.60
5.59
5.59
5.58
5.57
5.57
5.55
5.47
5.46
5.46
5.45
5.45
5.44
5.44
5.44
5.42
5.42
5.41
5.41
5.40
4.10
4.08
4.06
4.04
3.41
3.39
3.36
2.93
2.93
2.92
2.91
2.91
2.90
2.89
2.89
1.66
1.65
1.64
1.64
Parameter
Value
1 Title
XUF02150DMSO.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
10.1
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
HN
NH
Me
1.153
0.97
0.95
0.99
1.02
0.99
1.04
1.01
2.92
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

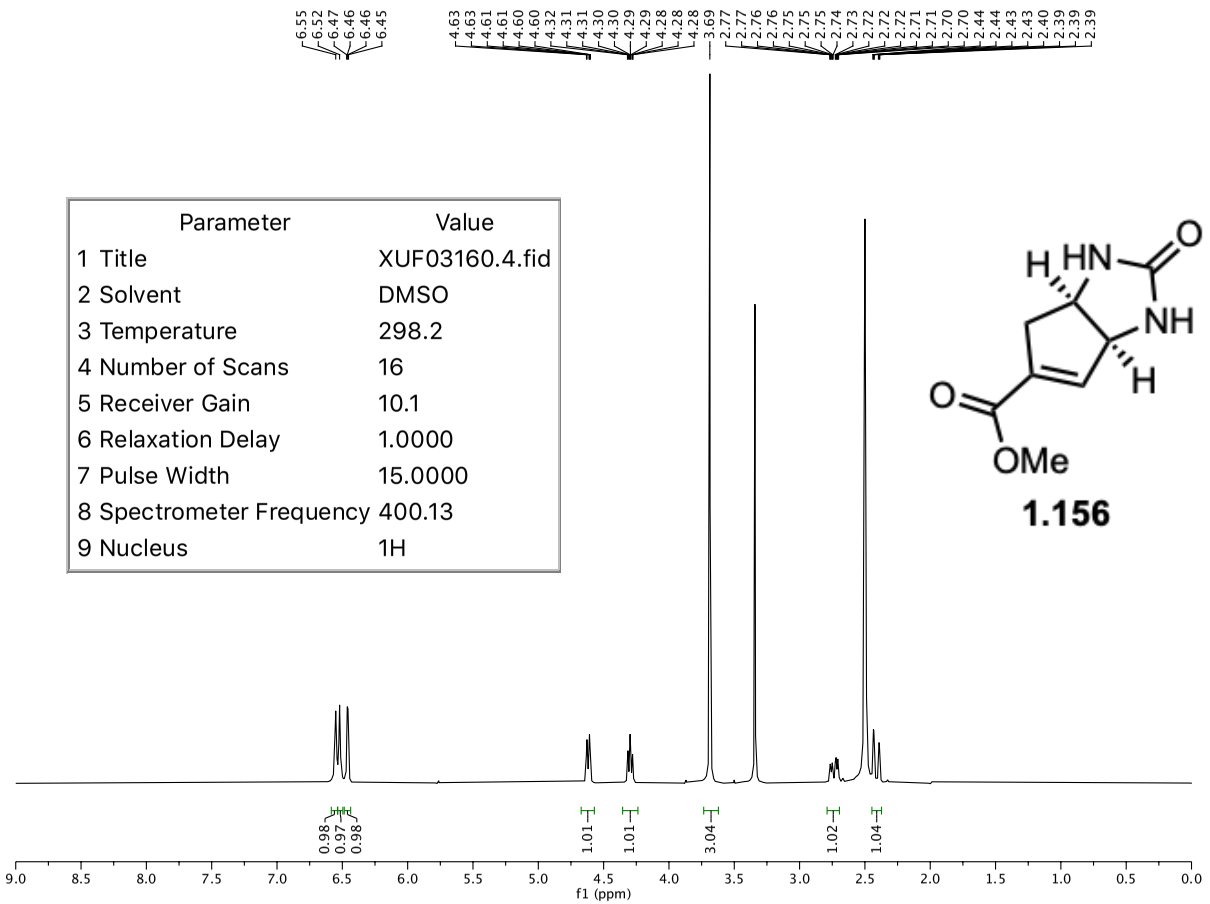

17.41
46.34
54.14
126.40
132.15
163.31
O
NH
HN
Me
1.153
Parameter Value
1 Title XUF02150.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

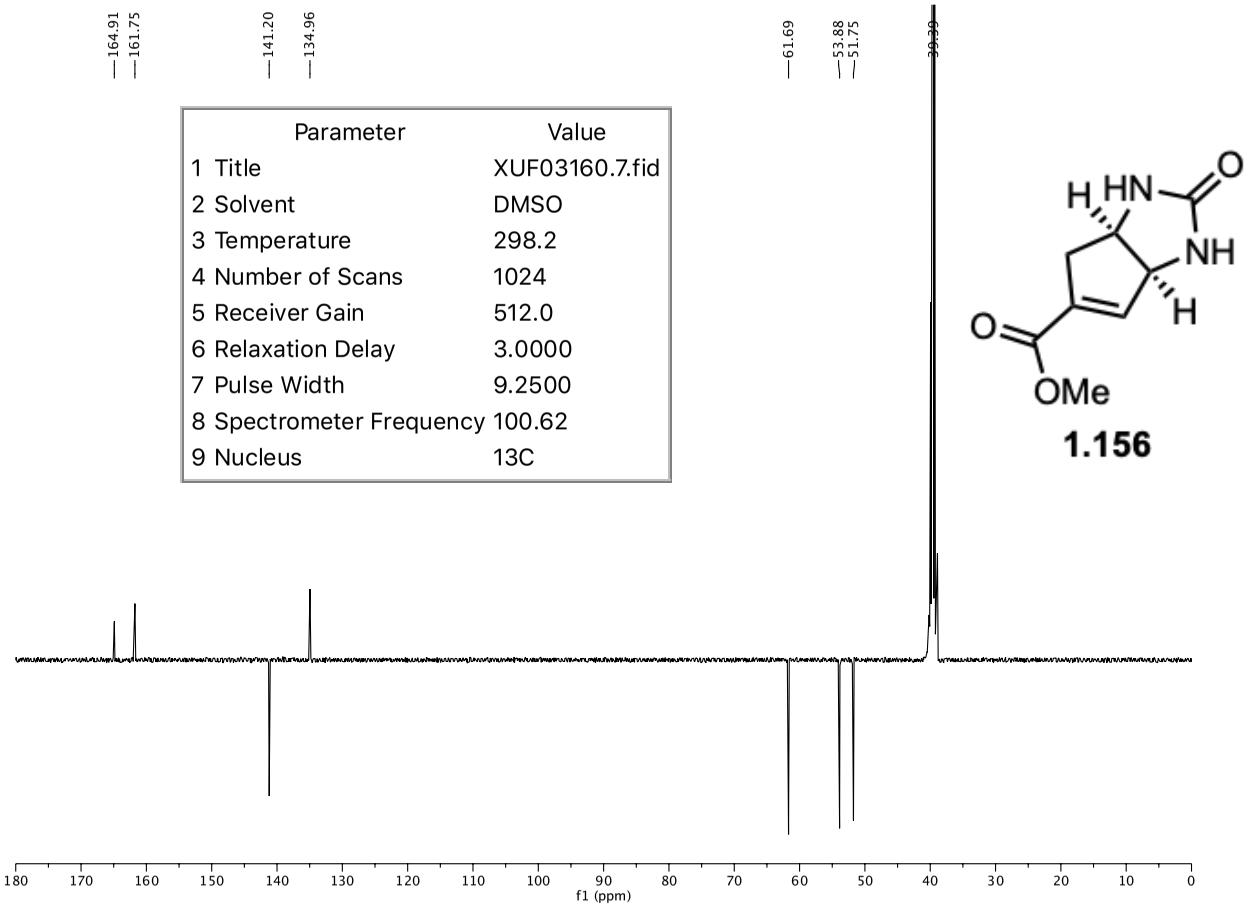
6.38
6.35
6.28
4.95
4.90
3.71
1.69
1.24
0.92
1.00
0.99
1.01
1.02
1.01
3.08
3.09
3.09
f1 (ppm)
Parameter Value
1 Title XUF03089.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 18.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
HN
NH
O
Me
Me
Me
1.154

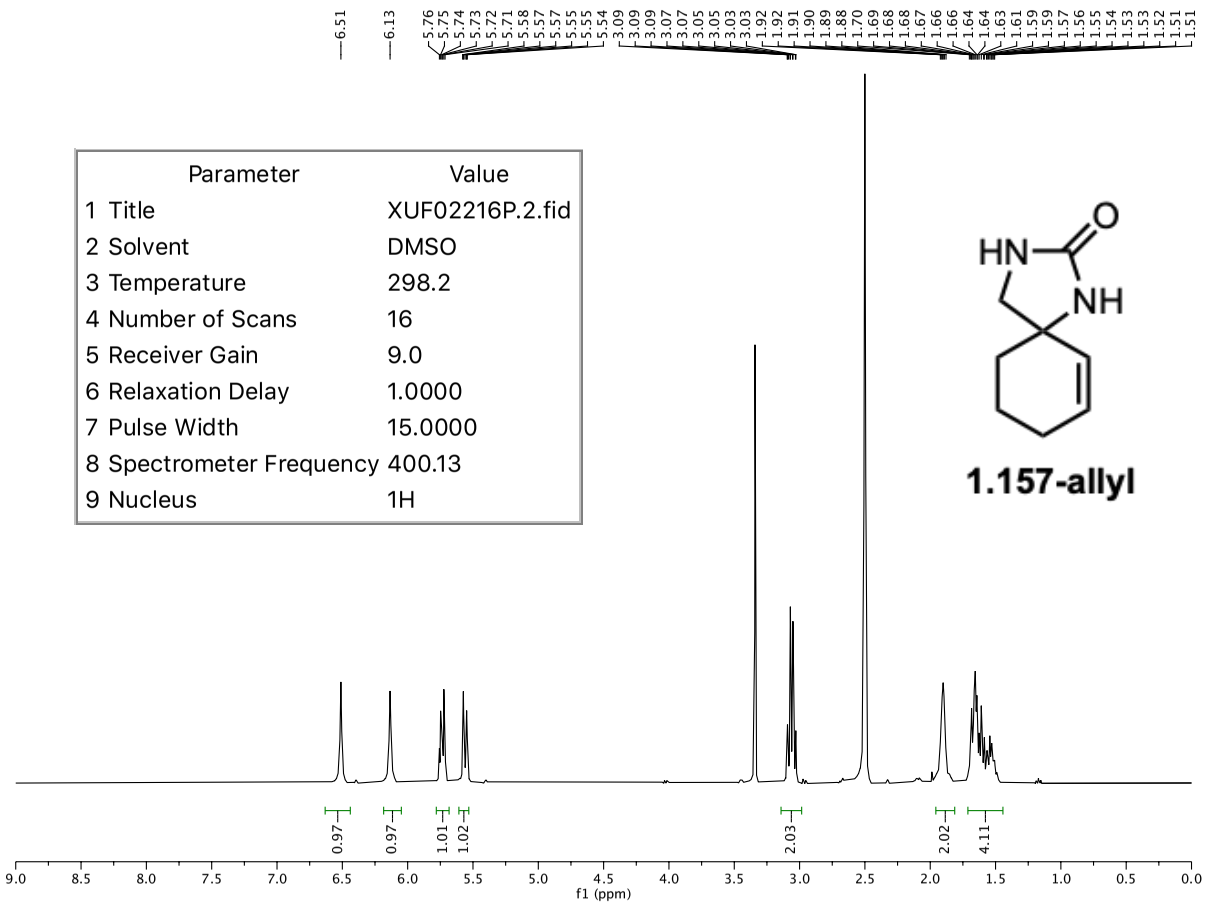

1.154
Me
Me
Me
HN
NH
O
20.20
23.15
29.23
56.61
66.79
112.45
142.75
161.44
f1 (ppm)
Parameter Value
1 Title XUF03089.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C

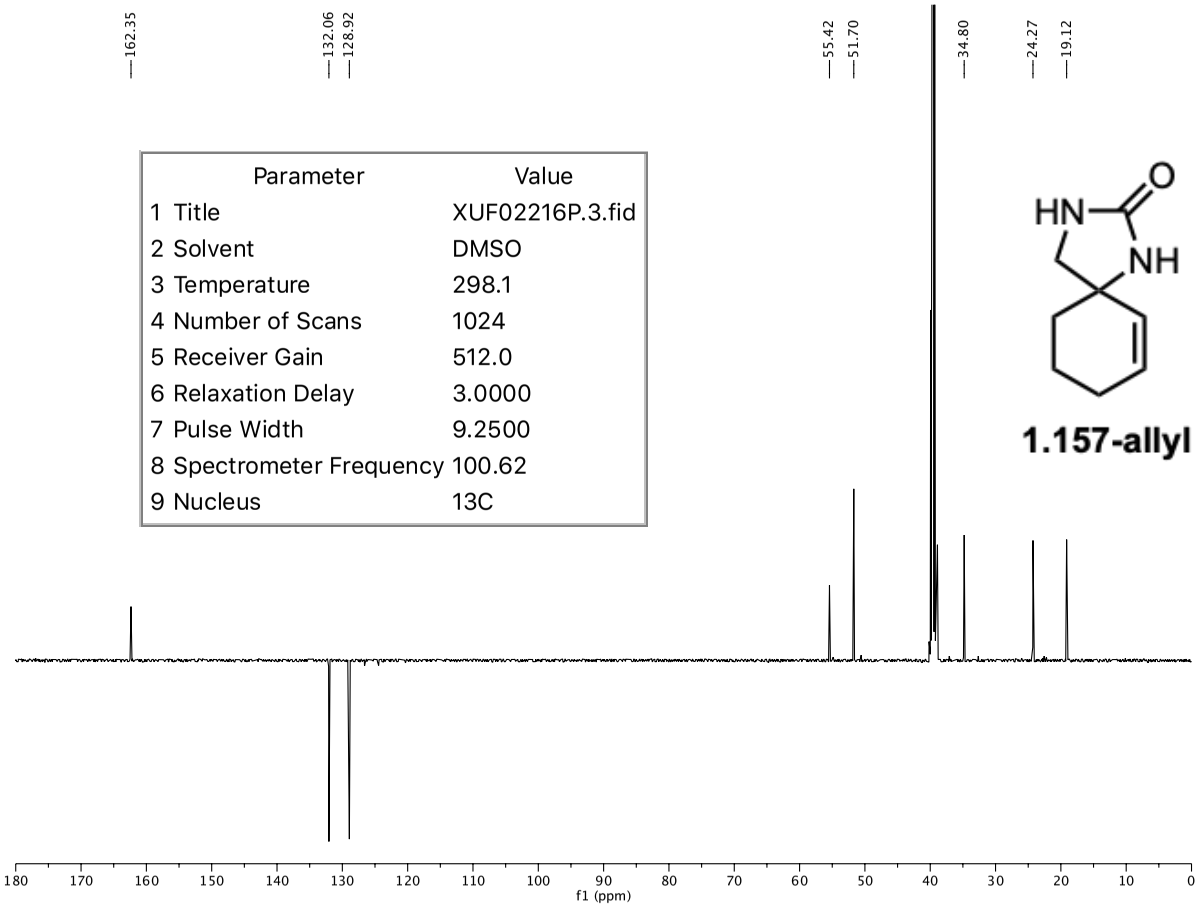

6.46 6.35 6.12 6.08
5.30 5.29 5.28 5.12 5.11 5.10 5.08 5.07 5.05 4.98 4.80 4.14 4.13 4.12 4.08 4.07 4.05 3.49 3.48 3.46 3.41 3.40 3.38 2.95 2.94 2.93 2.91 2.69 2.68 2.66 2.13 2.11 2.10 2.09 2.09 2.03 2.02 2.01 2.00 1.99 1.98 1.97 1.96 1.94 1.93 1.65 1.59 1.58
HN
NH
O
Me
Me
HN
NH
O
Me
Me
Me
1.155-terminal
67:33
1.155-internal
Parameter Value
1 Title XUF04145-600.1.fid
2 Solvent DMSO
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 181.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.5000
8 Spectrometer Frequency 600.32
9 Nucleus 1H
0.67 0.33 0.66 0.35 0.36 0.67 0.37 0.68 0.69 0.68 0.37 0.71 0.41 1.02 0.71 1.40 1.44 3.07 1.02 3.00
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

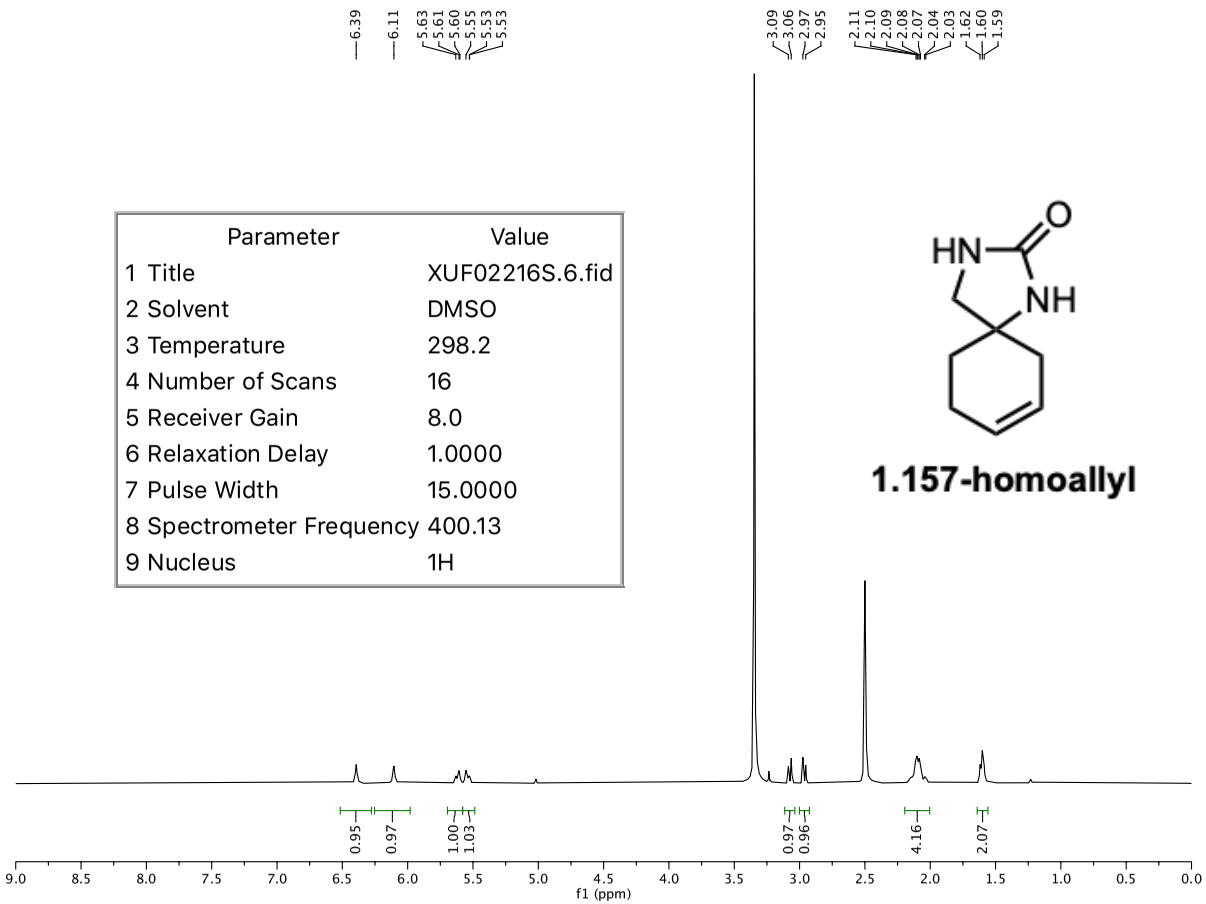

Parameter Value
1 Title XUF04145.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
1.155-terminal 67:33 1.155-internal
f1 (ppm)

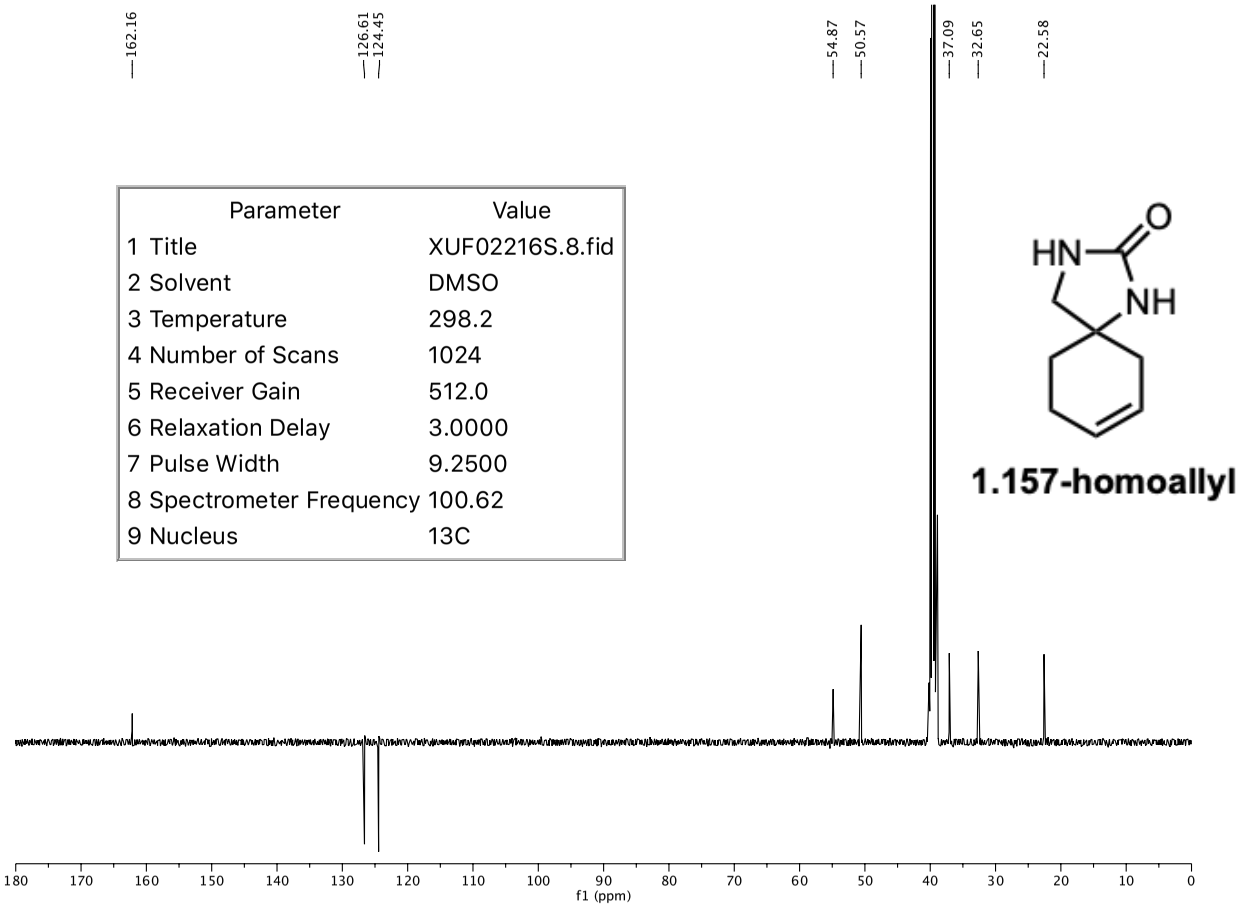

6.55
6.52
6.47
6.46
6.46
6.45
4.63
4.63
4.61
4.61
4.60
4.60
4.32
4.31
4.31
4.30
4.30
4.29
4.29
4.28
4.28
4.28
3.69
2.77
2.77
2.76
2.76
2.75
2.75
2.75
2.74
2.73
2.72
2.72
2.72
2.71
2.71
2.70
2.70
2.44
2.44
2.43
2.43
2.40
2.39
2.39
2.39
Parameter Value
1 Title XUF03160.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
H
HN
O
NH
H
O
OMe
1.156
0.98
0.97
0.98
1.01
1.01
3.04
1.02
1.04
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

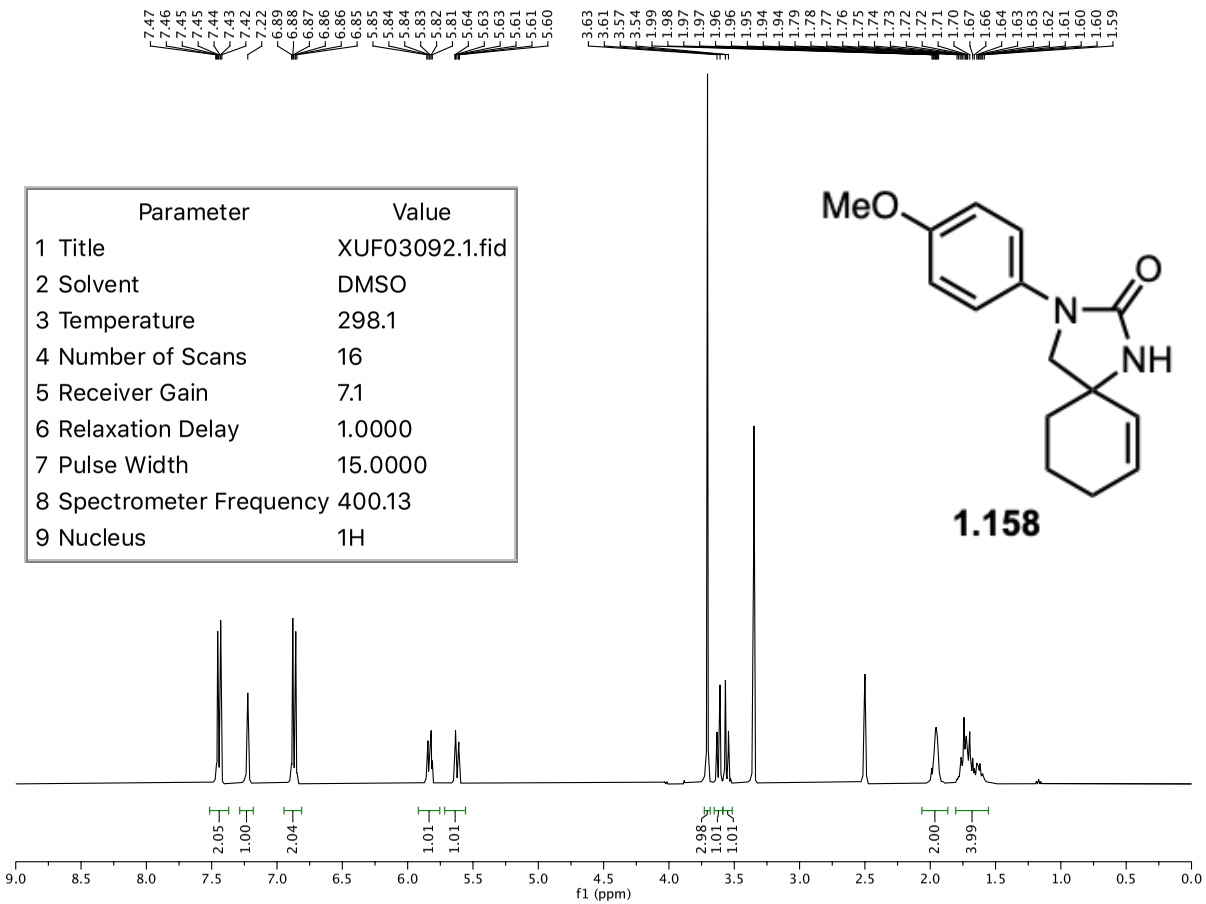

164.91
161.75
141.20
134.96
61.69
53.88
51.75
39.39
Parameter Value
1 Title XUF03160.7.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
H
HN
O
NH
H
O
OMe
1.156
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

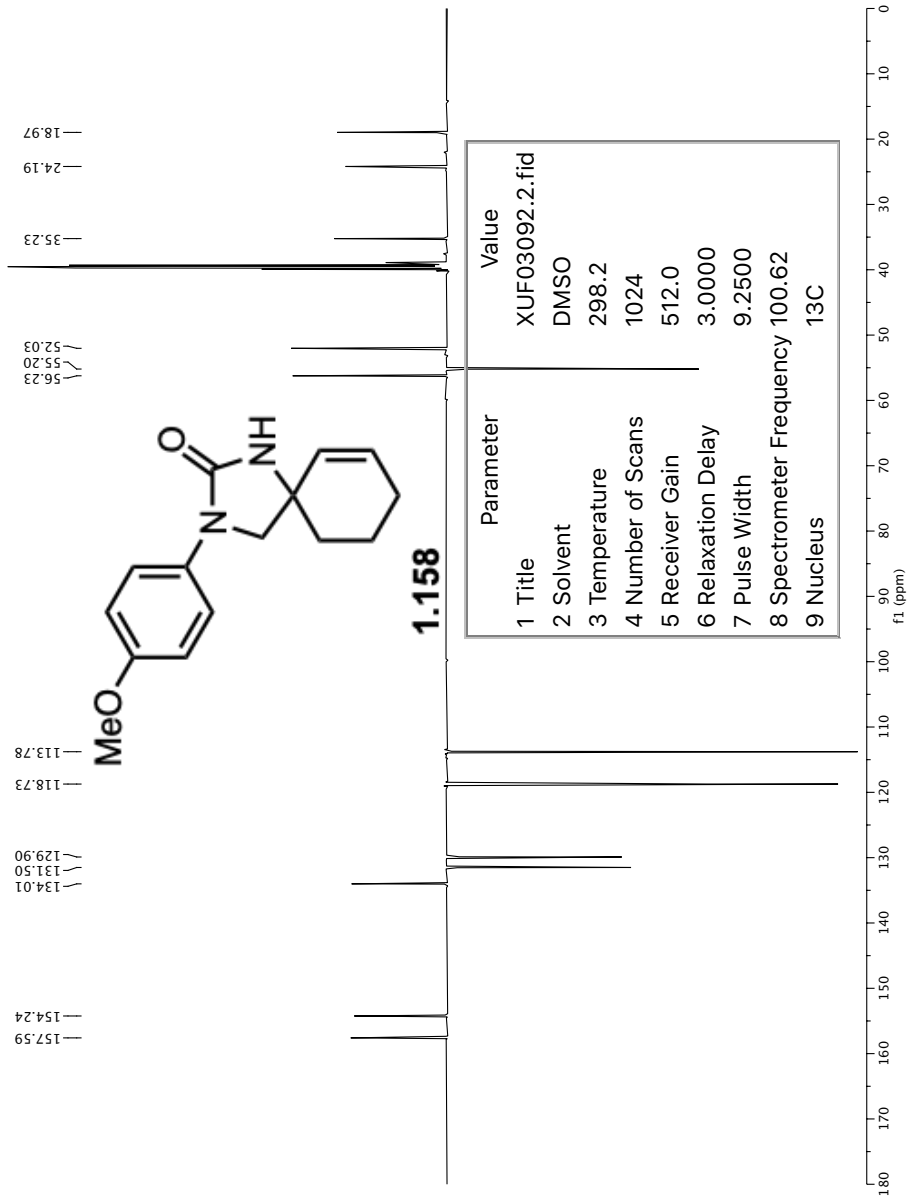

6.51
6.13
5.76 5.75 5.74 5.73 5.72 5.71 5.58 5.57 5.57 5.55 5.55 5.54
3.09 3.09 3.09 3.07 3.07 3.05 3.05 3.03 3.03 1.92 1.92 1.91 1.90 1.89 1.88 1.70 1.69 1.68 1.68 1.67 1.66 1.66 1.64 1.64 1.63 1.61 1.59 1.59 1.57 1.56 1.55 1.54 1.53 1.53 1.52 1.51 1.51
Parameter Value
1 Title XUF02216P.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
HN
O
NH
1.157-allyl
0.97
0.97
1.01
1.02
2.03
2.02
4.11
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

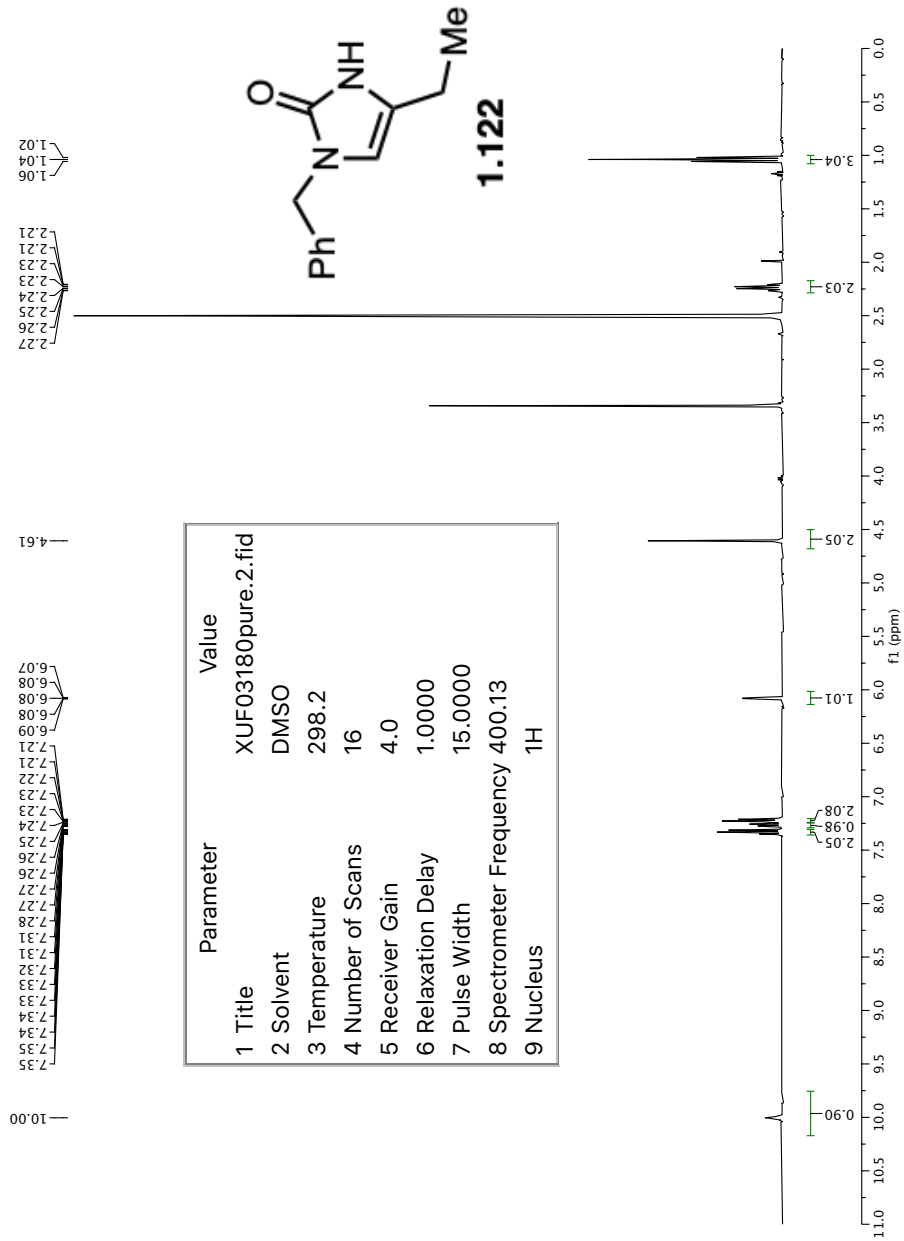

162.35
132.06
128.92
55.42
51.70
34.80
24.27
19.12
Parameter Value
1 Title XUF02216P.3.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
HN
O
NH
1.157-allyl
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

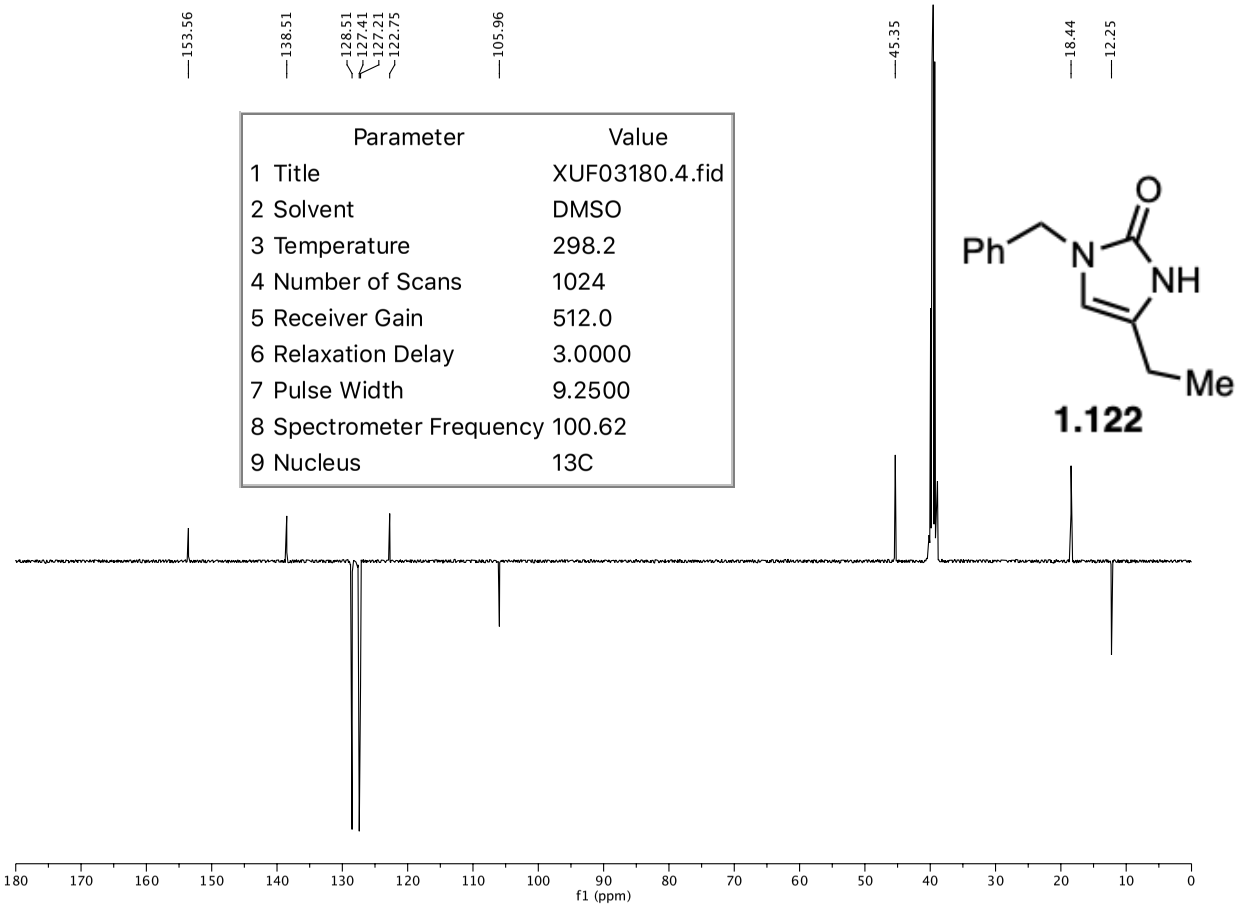

6.39
6.11
5.63
5.61
5.60
5.55
5.53
5.53
3.09
3.06
2.97
2.95
2.11
2.10
2.09
2.08
2.07
2.04
2.03
1.62
1.60
1.59
Parameter Value
1 Title XUF02216S.6.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
HN
O
NH
1.157-homoallyl
0.95
0.97
1.00
1.03
0.97
0.96
4.16
2.07
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

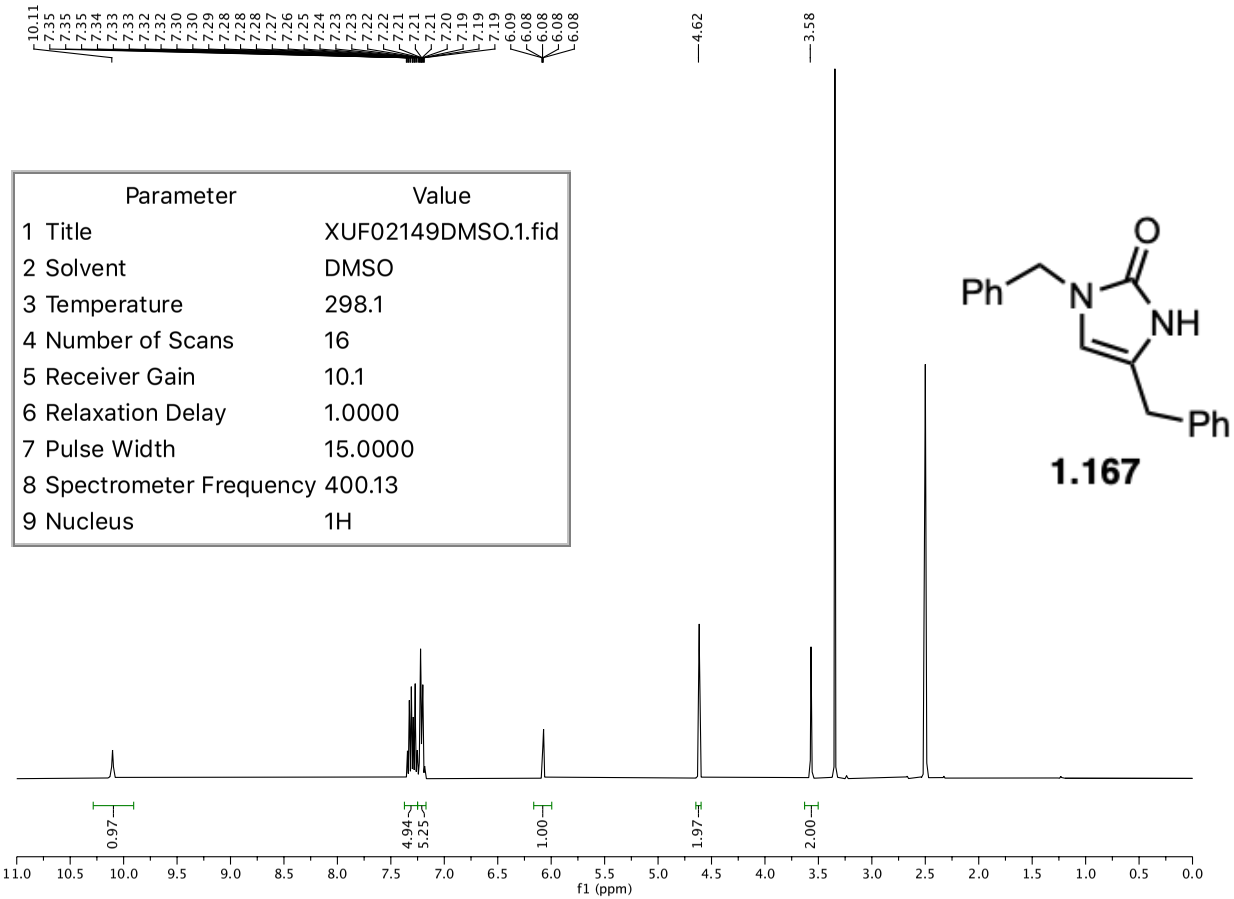

162.16
126.61
124.45
54.87
50.57
37.09
32.65
22.58
Parameter Value
1 Title XUF02216S.8.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
HN
O
NH
1.157-homoallyl
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

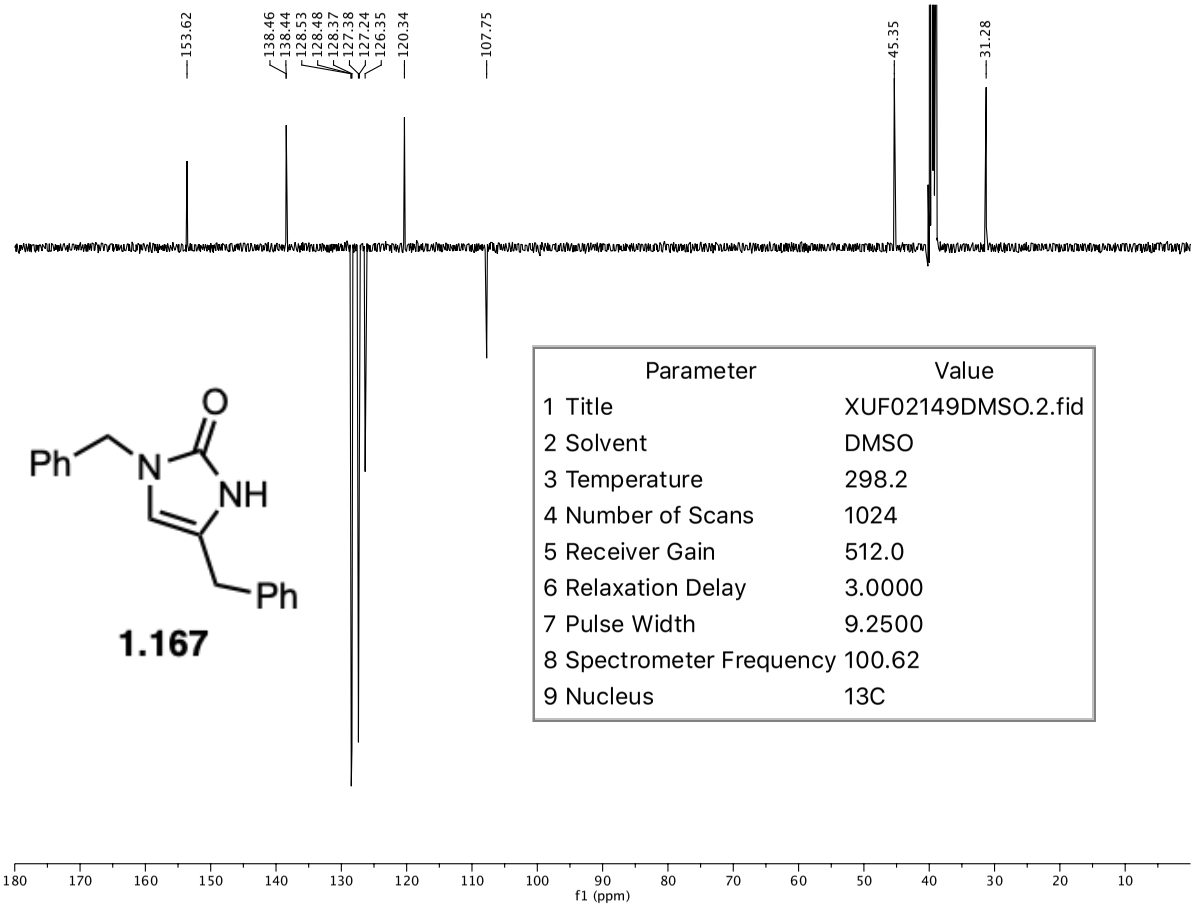

7.47 7.46 7.45 7.45 7.44 7.43 7.42 7.22 6.89 6.88 6.87 6.86 6.86 6.85 5.85 5.84 5.84 5.83 5.82 5.81 5.64 5.63 5.63 5.61 5.61 5.60
3.63 3.61 3.57 3.54 1.99 1.98 1.97 1.97 1.96 1.96 1.95 1.94 1.94 1.79 1.78 1.77 1.76 1.75 1.74 1.73 1.72 1.72 1.71 1.70 1.67 1.66 1.64 1.63 1.63 1.62 1.61 1.60 1.60 1.59
Parameter Value
1 Title XUF03092.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
N
O
NH
1.158
2.05 1.00 2.04 1.01 1.01 2.98 1.01 1.01 2.00 3.99
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


18.97
24.19
35.23
52.03
55.20
56.23
113.78
118.73
129.90
131.50
134.01
154.24
157.59
MeO
NH
O
N
1.158
Parameter
Value
1 Title
XUF03092.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

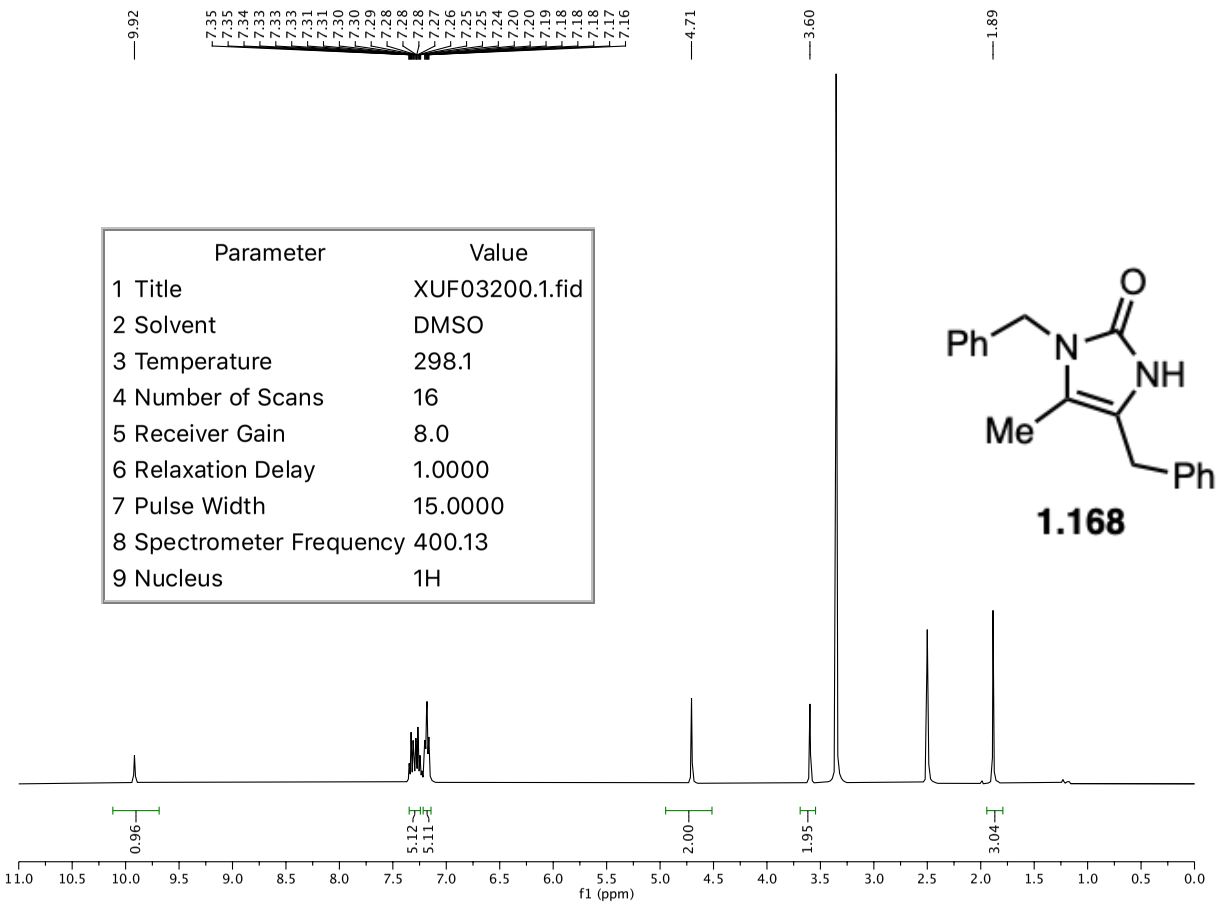

1.122
Ph
N
O
NH
Me
Parameter Value
1 Title XUF03180pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

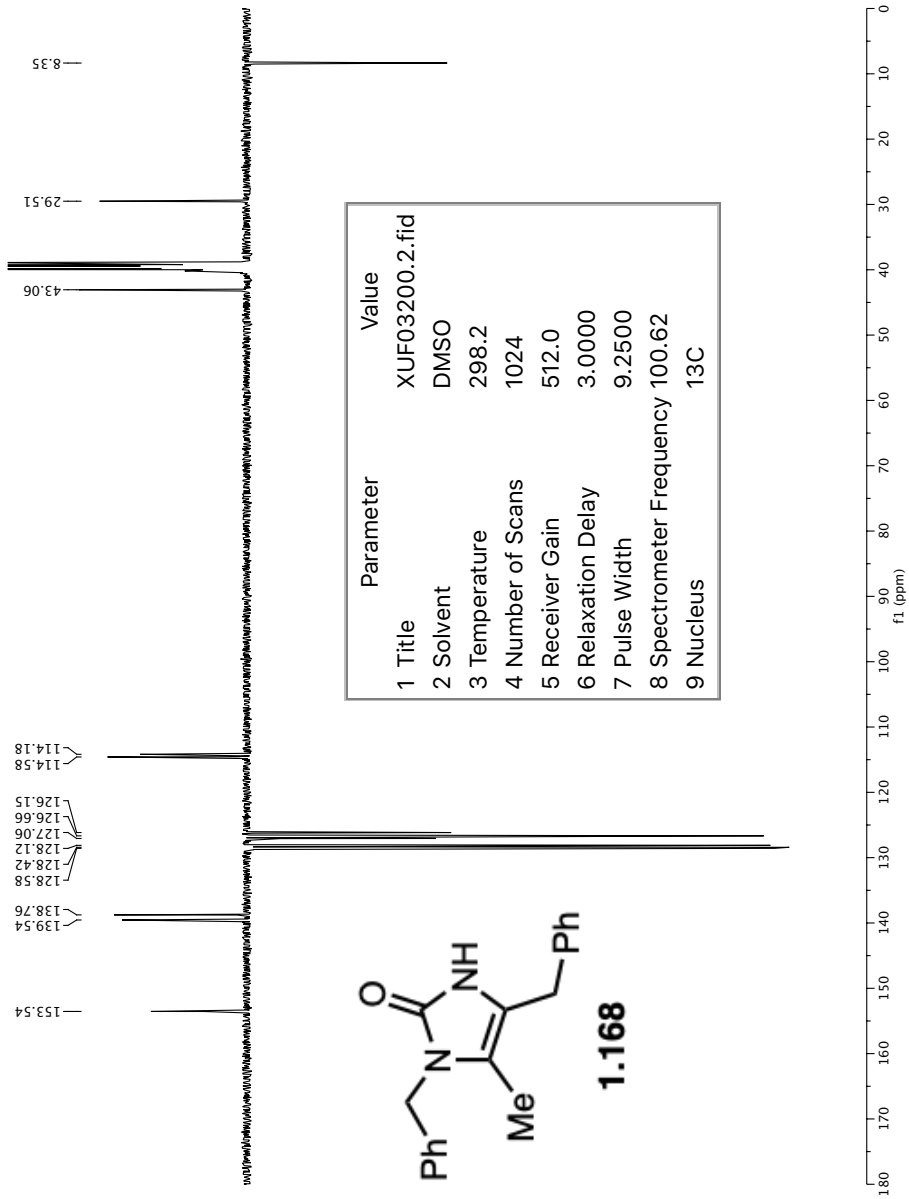

153.56
138.51
128.51
127.41
127.21
122.75
105.96
45.35
18.44
12.25
Parameter Value
1 Title XUF03180.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Ph
N
O
NH
Me
1.122
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

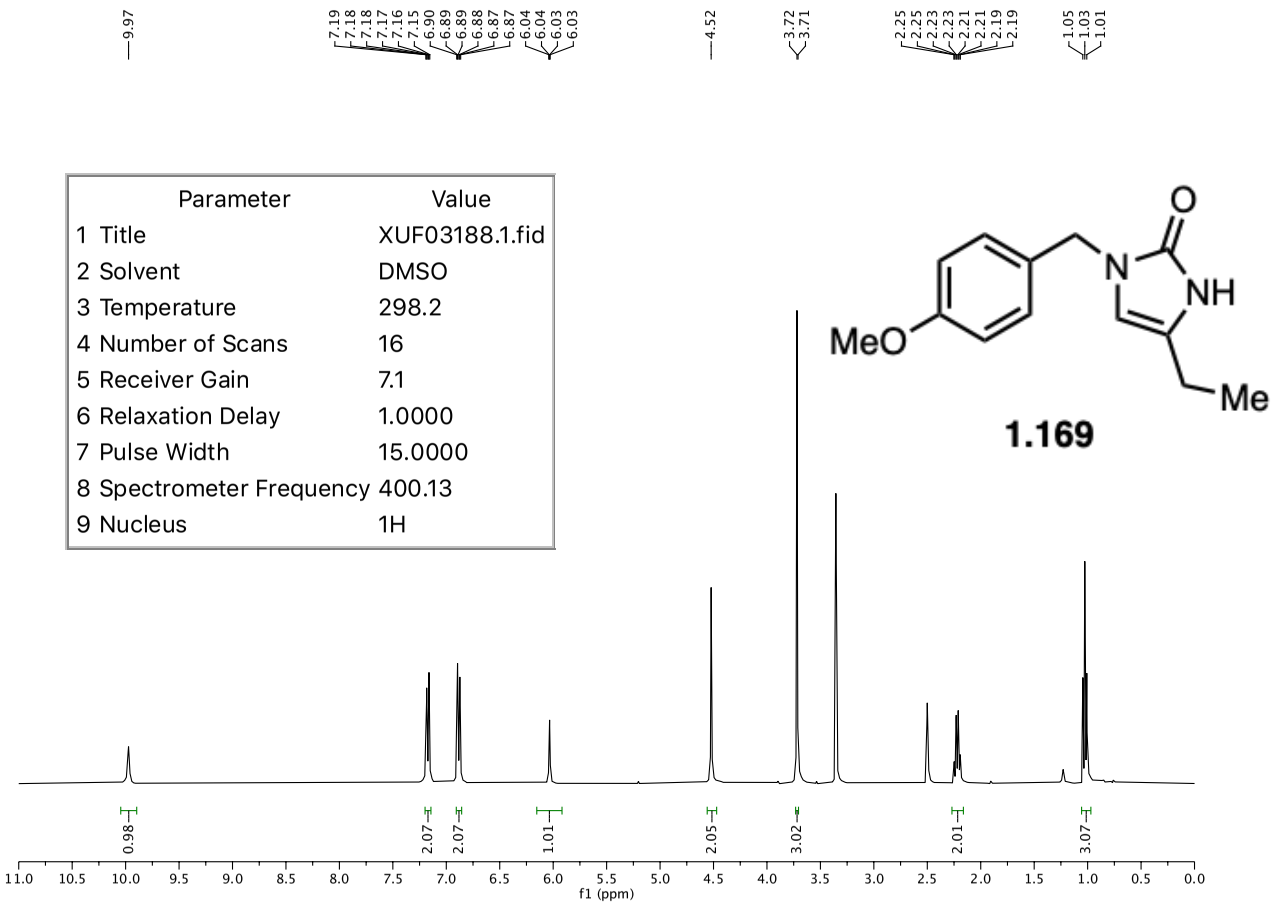

10.11
7.35
7.35
7.35
7.34
7.33
7.33
7.32
7.32
7.30
7.30
7.29
7.28
7.28
7.28
7.27
7.26
7.25
7.24
7.23
7.23
7.22
7.22
7.21
7.21
7.21
7.20
7.19
7.19
7.19
6.09
6.08
6.08
6.08
6.08
4.62
3.58
Parameter Value
1 Title XUF02149DMSO.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
0.97
4.94
5.25
1.00
1.97
2.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
O
Ph
N
NH
Ph
1.167

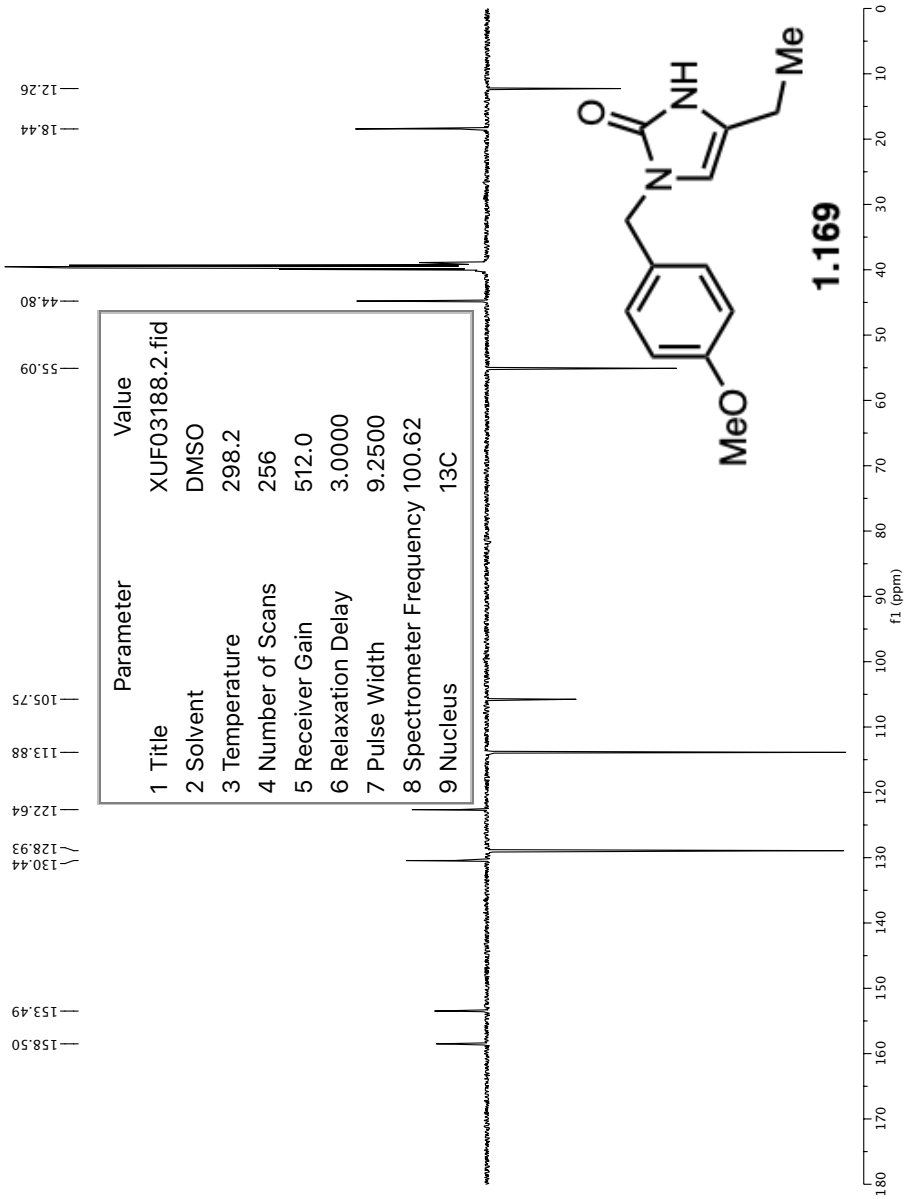


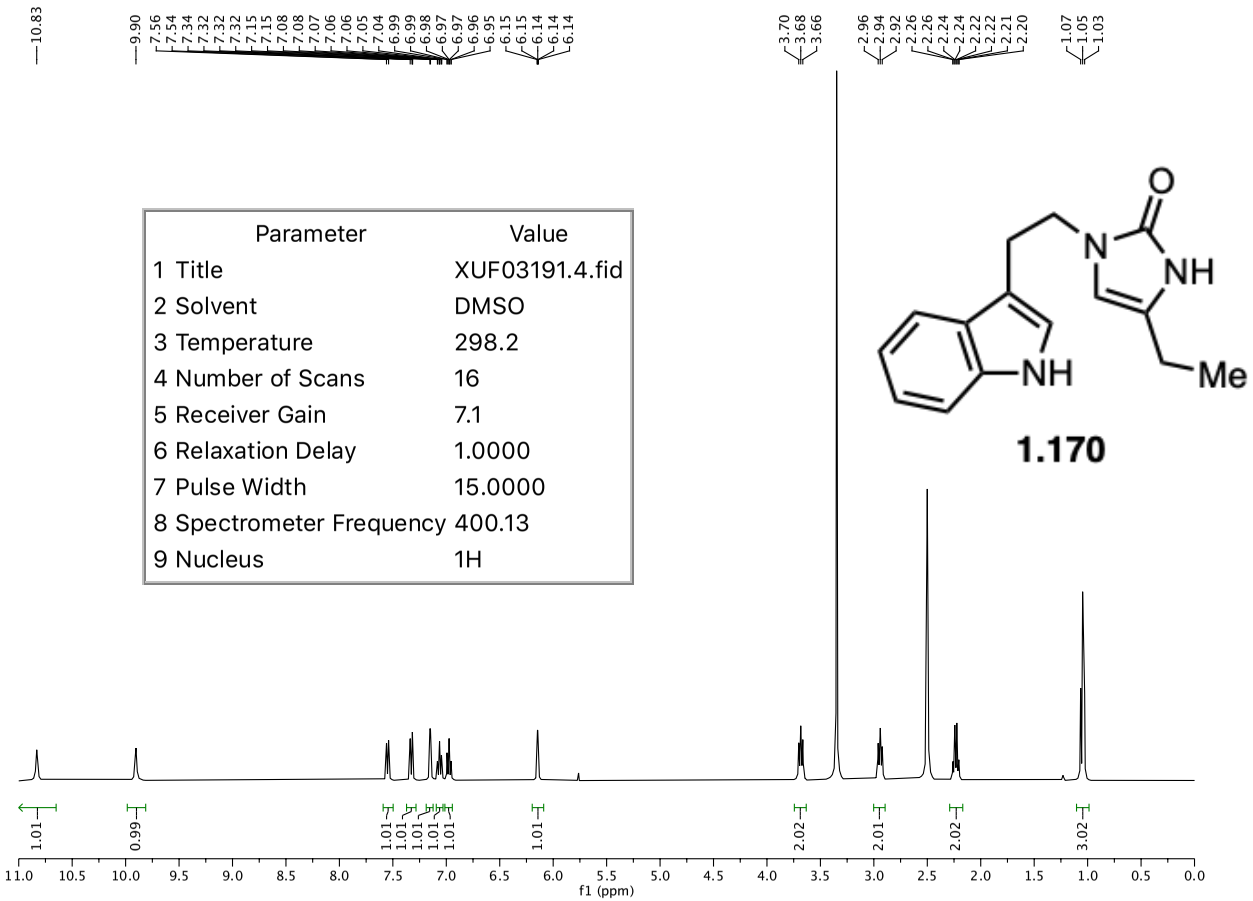
Parameter	Value
1 Title	XUF02149DMSO.2.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	9.2500
8 Spectrometer Frequency	100.62
9 Nucleus	13C

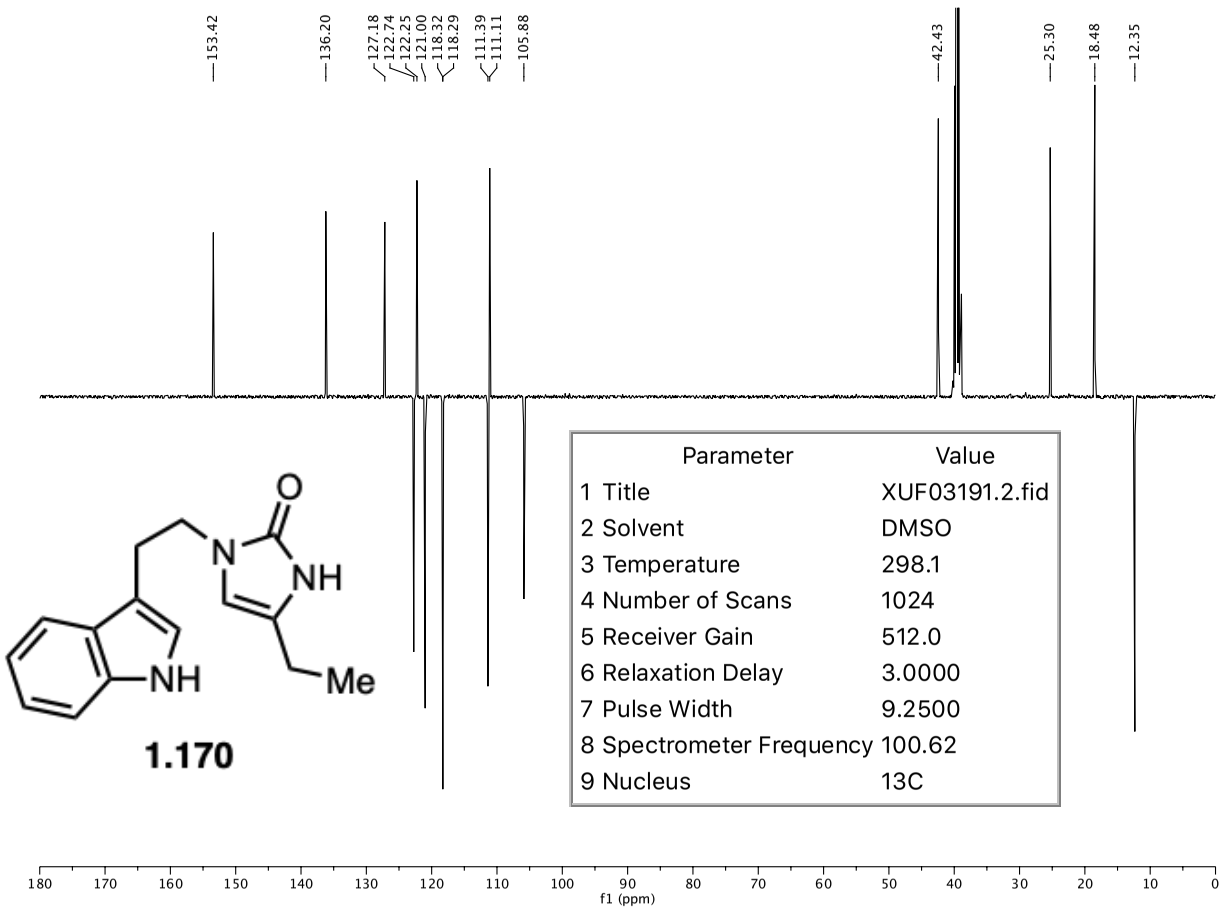

9.92
7.35
7.35
7.34
7.33
7.33
7.33
7.31
7.31
7.30
7.30
7.29
7.28
7.28
7.28
7.27
7.26
7.25
7.25
7.24
7.20
7.20
7.19
7.18
7.18
7.18
7.17
7.16
4.71
3.60
1.89
Parameter Value
1 Title XUF03200.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Ph
N
NH
Me
Ph
1.168
0.96
5.12
5.11
2.00
1.95
3.04
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

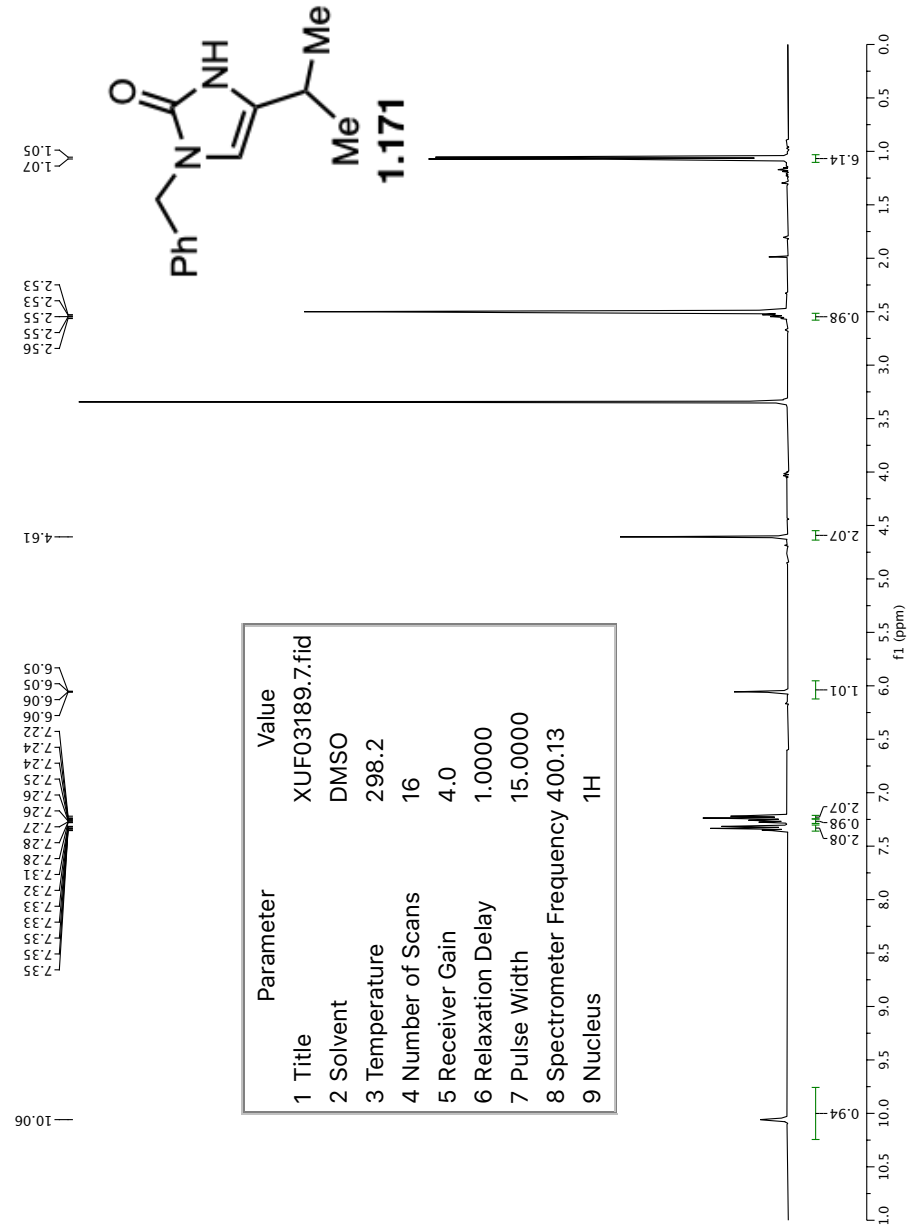

153.54
139.54
138.76
128.58
128.42
128.12
127.06
126.66
126.15
114.58
114.18
43.06
29.51
8.35
Parameter Value
1 Title XUF03200.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
NH
N
Ph
Me
Ph
1.168
f1 (ppm)

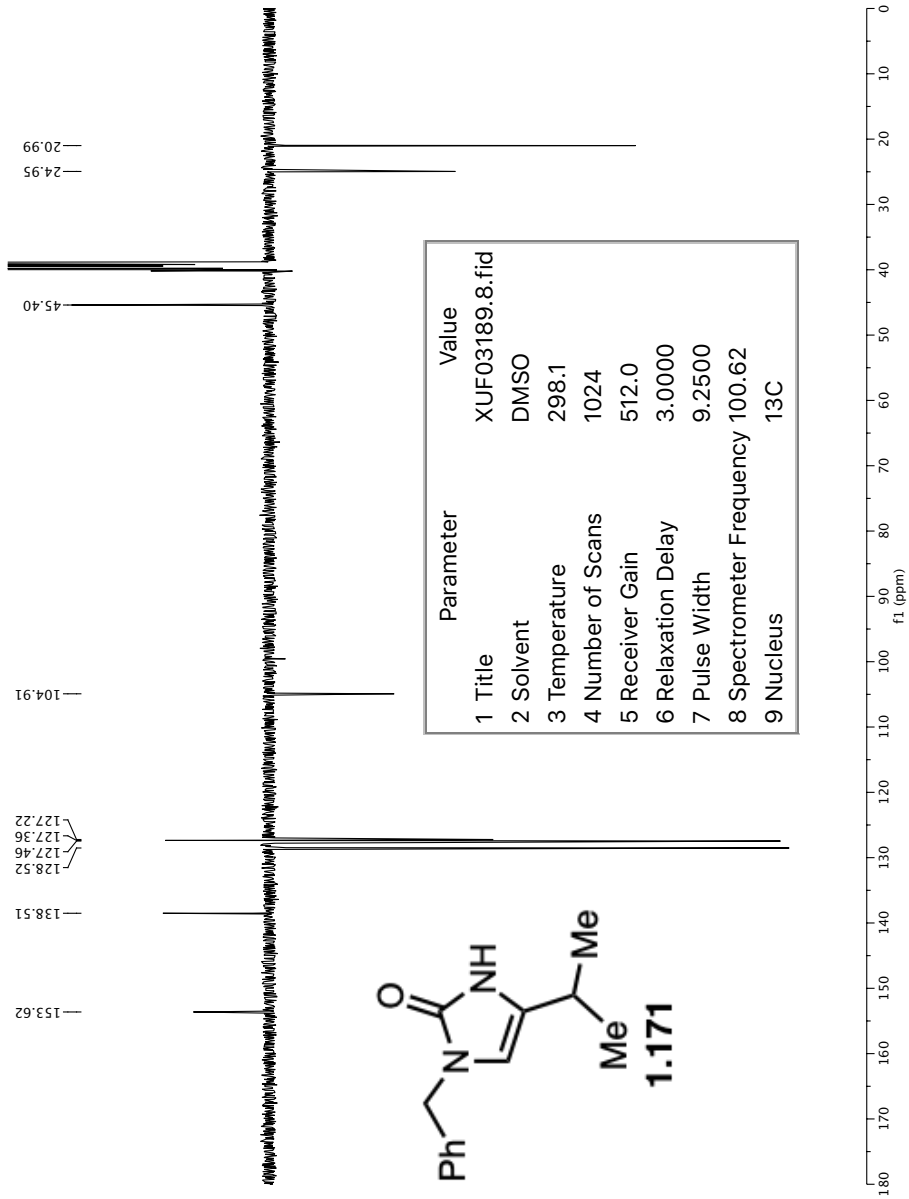

9.97
7.19
7.18
7.18
7.17
7.16
7.15
6.90
6.89
6.89
6.88
6.87
6.87
6.04
6.04
6.03
6.03
4.52
3.72
3.71
2.25
2.25
2.23
2.23
2.21
2.21
2.19
2.19
1.05
1.03
1.01
Parameter Value
1 Title XUF03188.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
MeO
Me
1.169
0.98
2.07
2.07
1.01
2.05
3.02
2.01
3.07
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

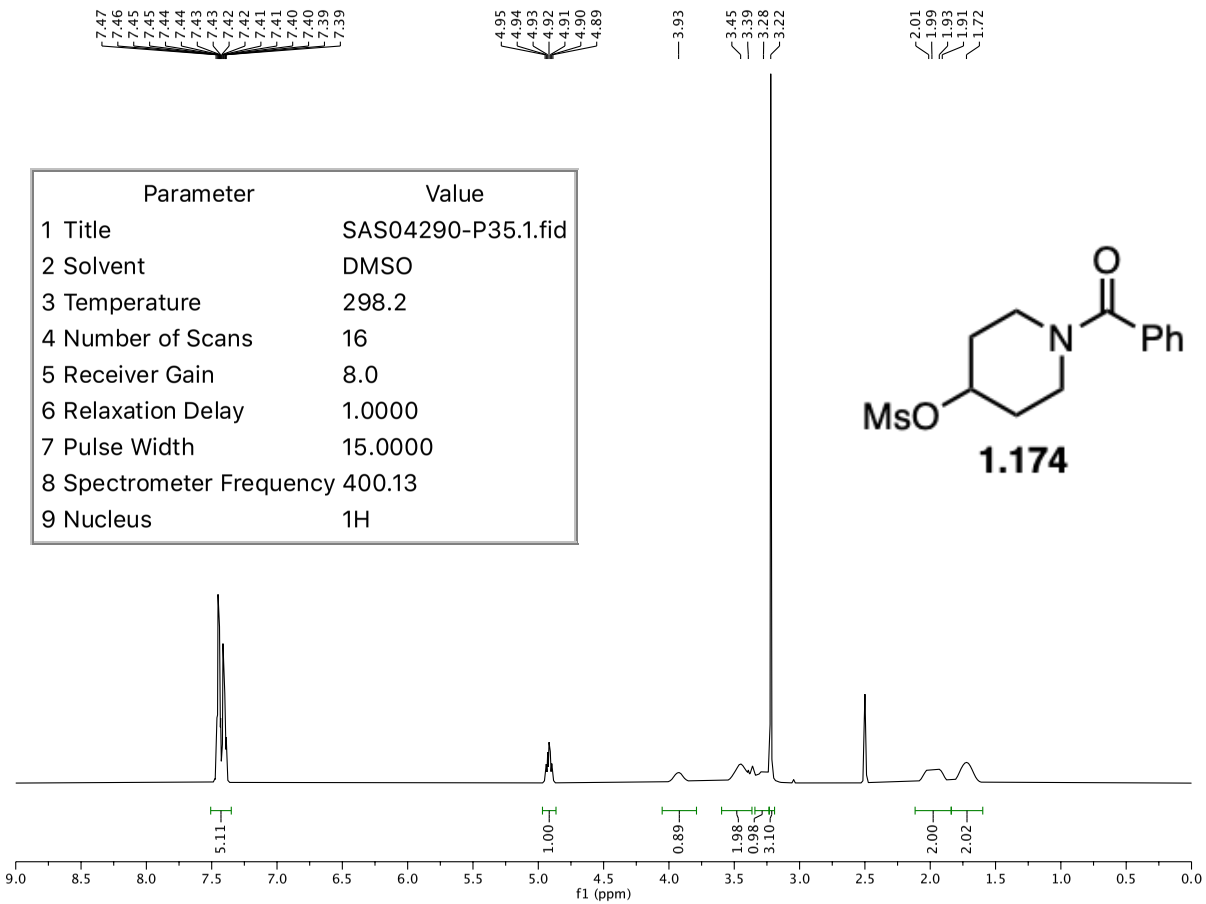

Parameter Value
1 Title XUF03188.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
12.26
18.44
44.80
55.09
105.75
113.88
122.64
128.93
130.44
153.49
158.50
MeO
NH
O
N
Me
1.169
f1 (ppm)

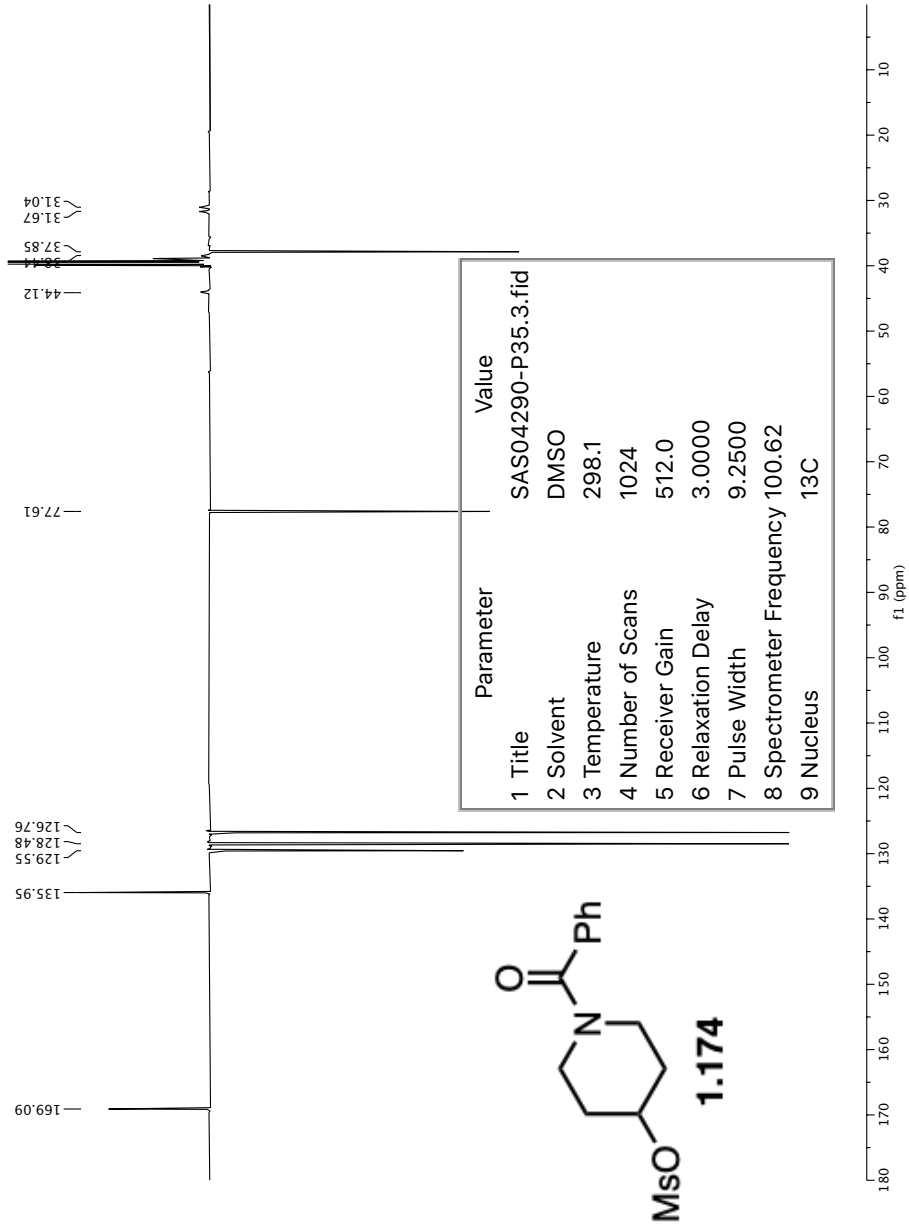

10.83
9.90
7.56
7.54
7.34
7.32
7.32
7.32
7.15
7.15
7.08
7.08
7.07
7.06
7.06
7.05
7.04
6.99
6.99
6.98
6.97
6.97
6.96
6.95
6.15
6.15
6.14
6.14
6.14
3.70
3.68
3.66
2.96
2.94
2.92
2.26
2.24
2.24
2.22
2.22
2.21
2.20
1.07
1.05
1.03
Parameter Value
1 Title XUF03191.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
NH
NH
Me
1.170
1.01
0.99
1.01
1.01
1.01
1.01
1.01
2.02
2.01
2.02
3.02
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

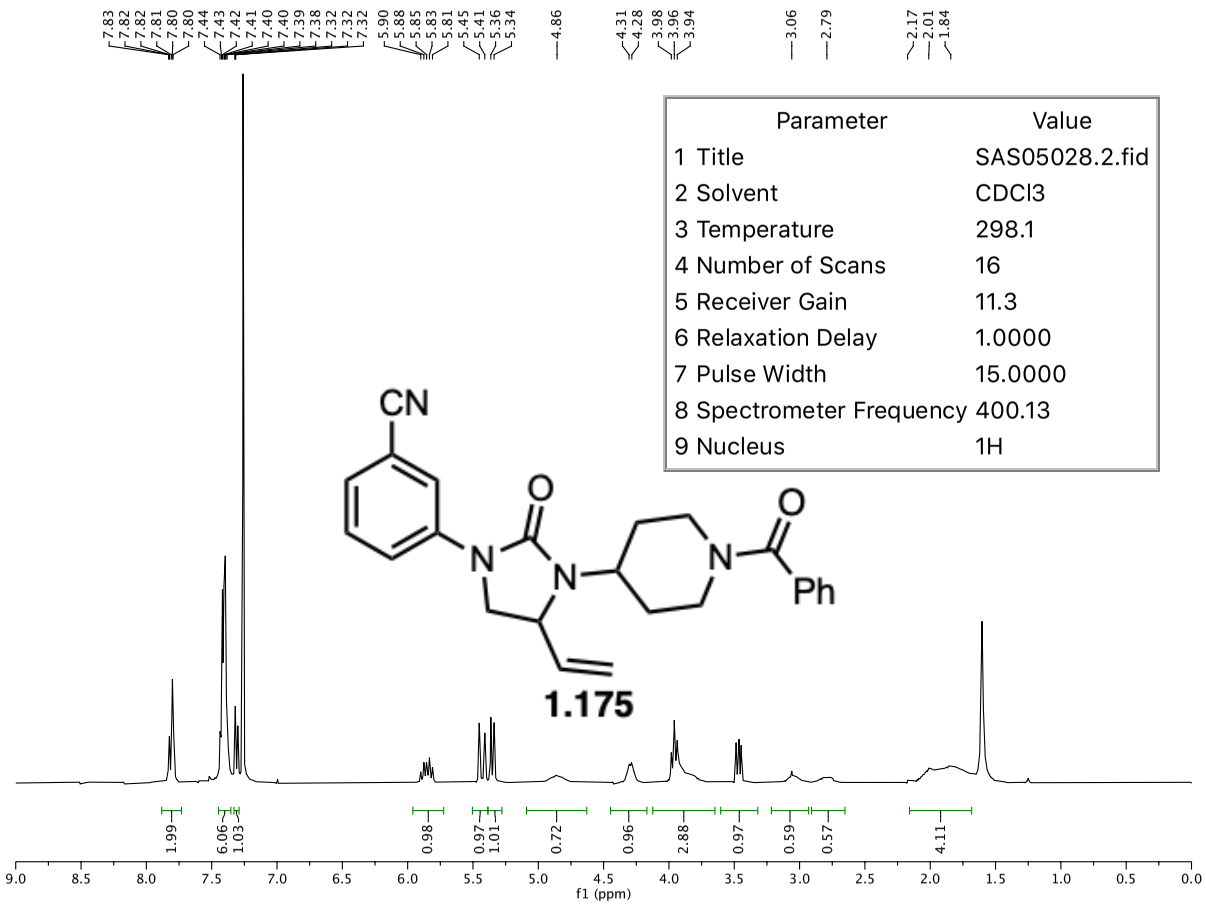

153.42
136.20
127.18
122.74
122.25
121.00
118.32
118.29
111.39
111.11
105.88
42.43
25.30
18.48
12.35
O
N
NH
NH
Me
1.170
Parameter Value
1 Title XUF03191.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

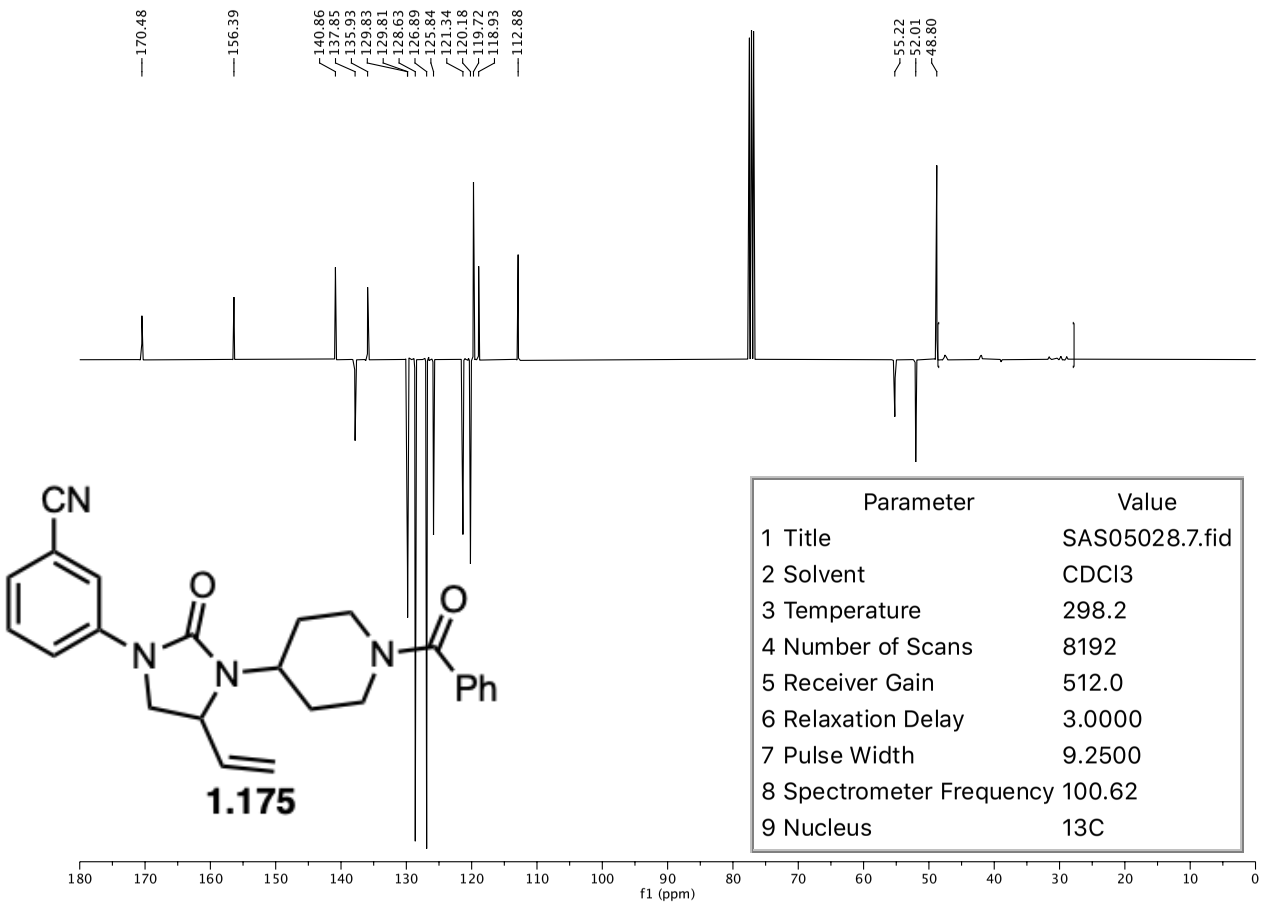

1.171
Parameter Value
1 Title XUF03189.7.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)


20.99
24.95
45.40
104.91
127.22
127.36
127.46
128.52
138.51
153.62
Parameter Value
1 Title XUF03189.8.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
NH
N
Ph
Me
Me
1.171
f1 (ppm)


7.47
7.46
7.45
7.45
7.44
7.44
7.43
7.43
7.42
7.42
7.41
7.41
7.40
7.40
7.39
7.39
4.95
4.94
4.93
4.92
4.91
4.90
4.89
3.93
3.45
3.39
3.28
3.22
2.01
1.99
1.93
1.91
1.72
Parameter Value
1 Title SAS04290-P35.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
N
Ph
MsO
1.174
5.11
1.00
0.89
1.98
0.98
3.10
2.00
2.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

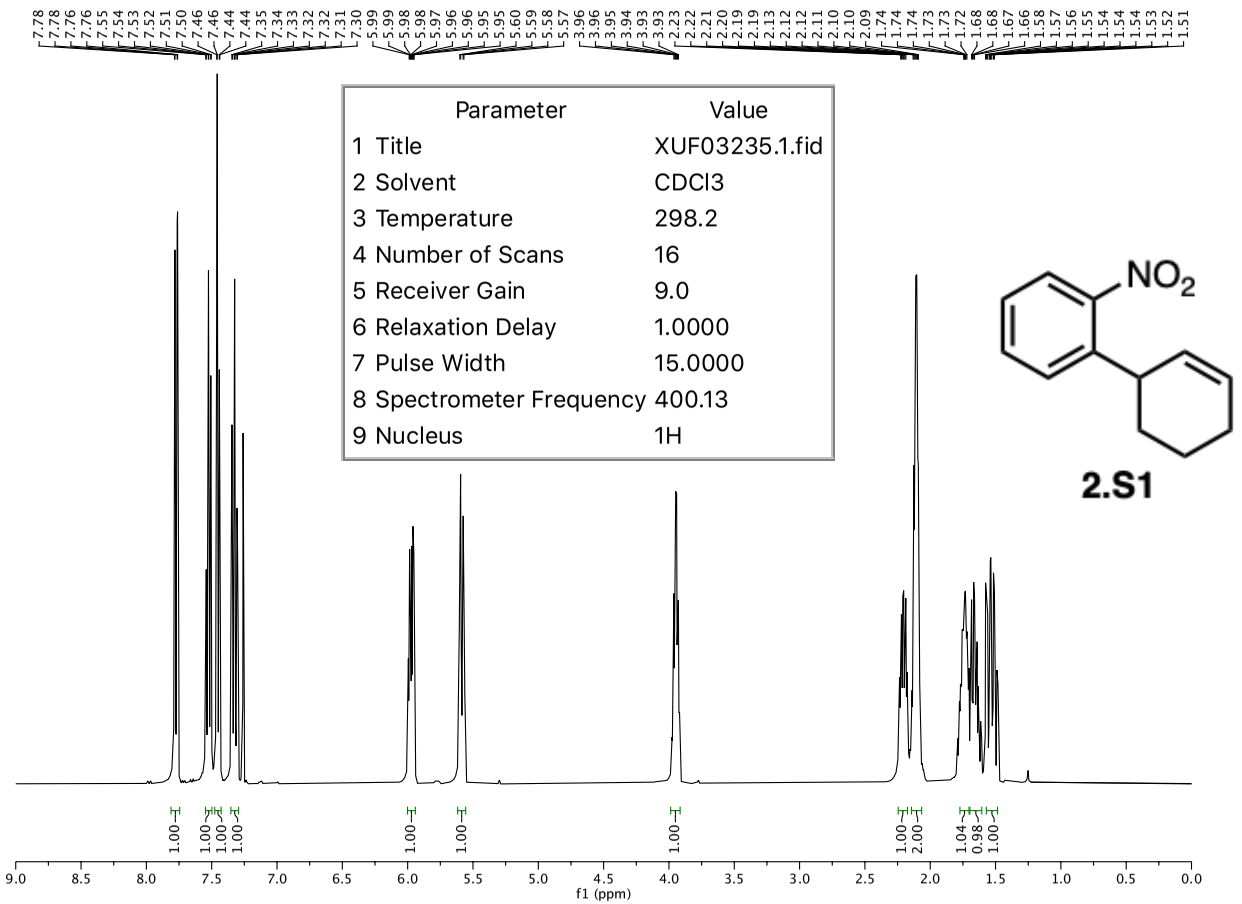

169.09
135.95
129.55
128.48
126.76
77.61
44.12
37.85
31.67
31.04
Parameter Value
1 Title SAS04290-P35.3.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
Ph
N
MsO
1.174
f1 (ppm)

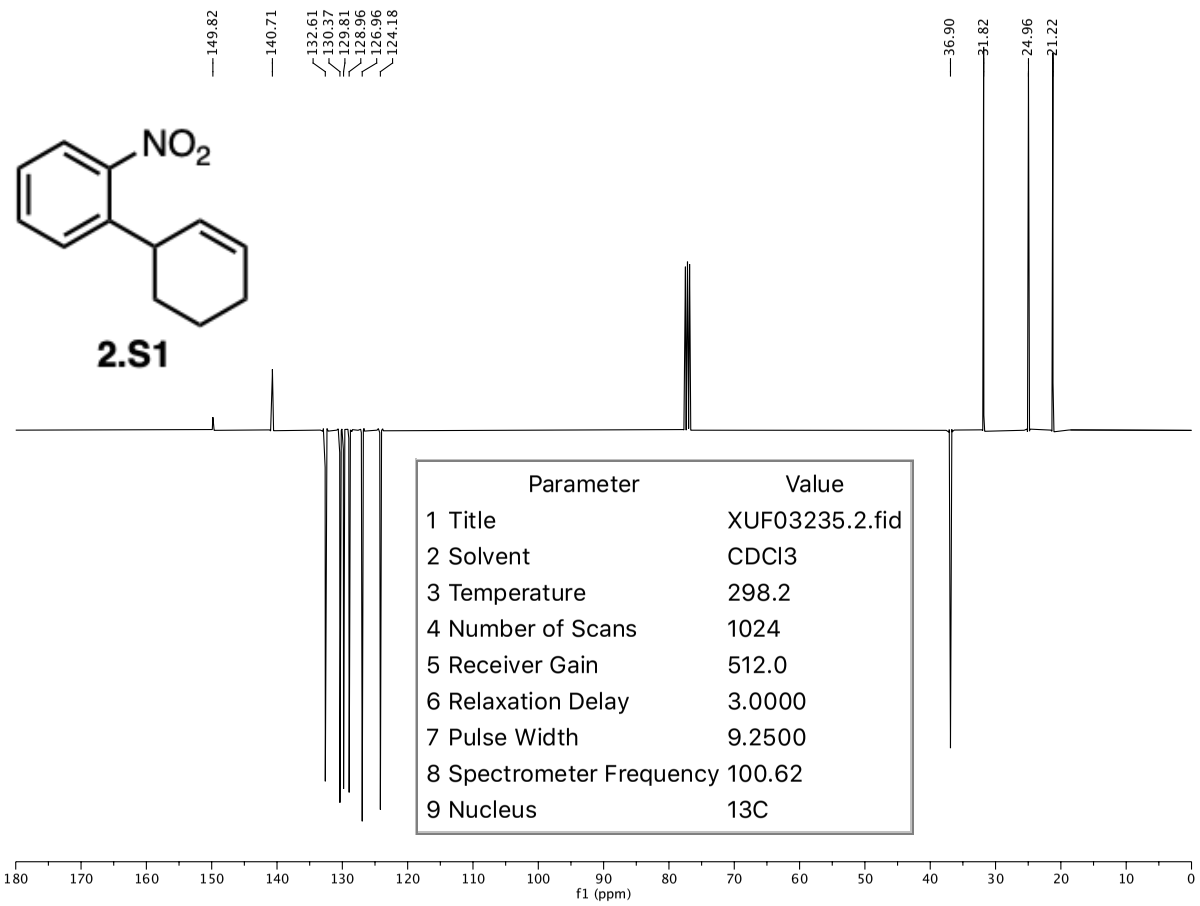

7.83
7.82
7.82
7.81
7.80
7.80
7.44
7.43
7.42
7.41
7.40
7.40
7.39
7.38
7.32
7.32
7.32
5.90
5.88
5.85
5.83
5.81
5.45
5.41
5.36
5.34
4.86
4.31
4.28
3.98
3.96
3.94
3.06
2.79
2.17
2.01
1.84
Parameter Value
1 Title SAS05028.2.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
CN
O
N
N
O
N
Ph
1.175
1.99
6.06
1.03
0.98
0.97
1.01
0.72
0.96
2.88
0.97
0.59
0.57
4.11
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

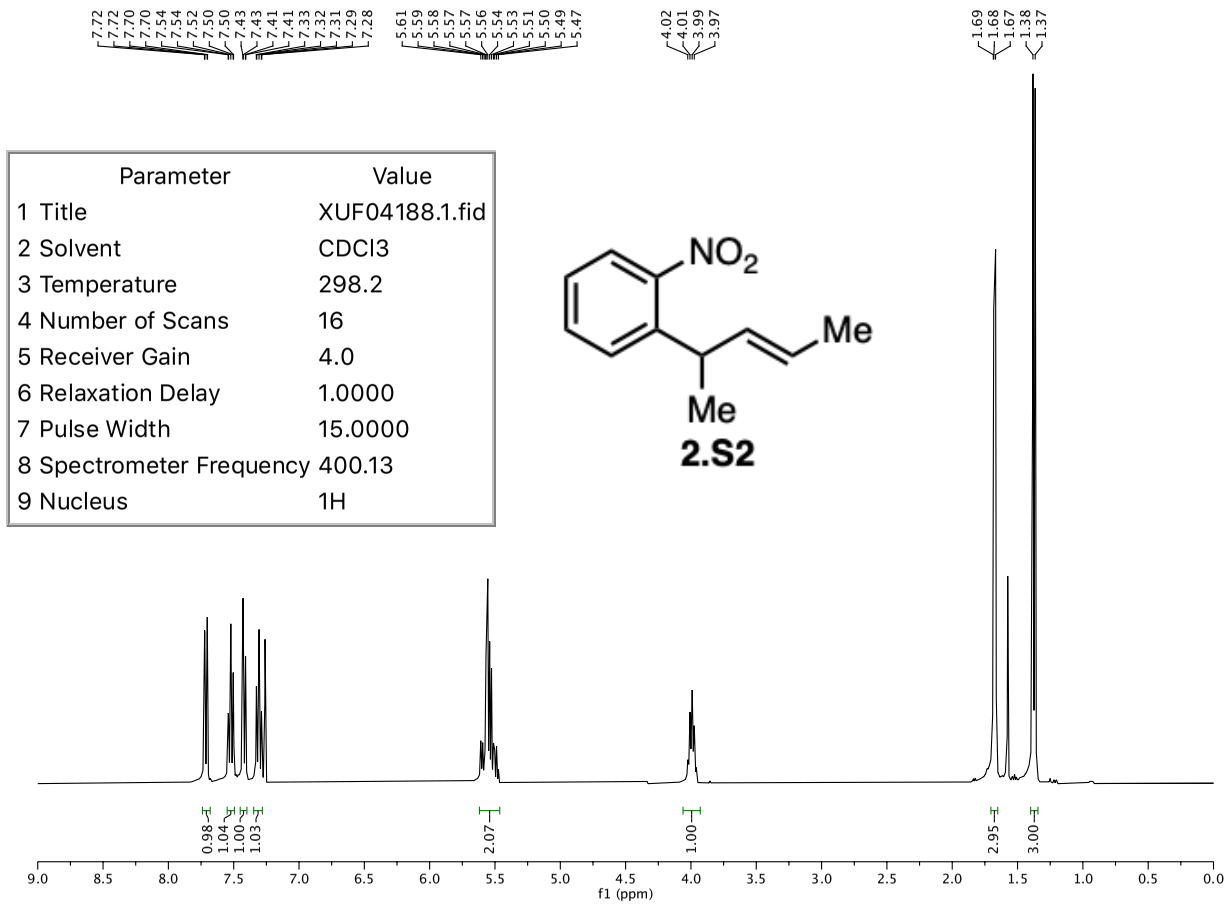

170.48
156.39
140.86
137.85
135.93
129.83
129.81
128.63
126.89
125.84
121.34
120.18
119.72
118.93
112.88
55.22
52.01
48.80
CN
O
N
N
N
O
Ph
1.175
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)
Parameter
Value
1 Title
SAS05028.7.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
8192
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C

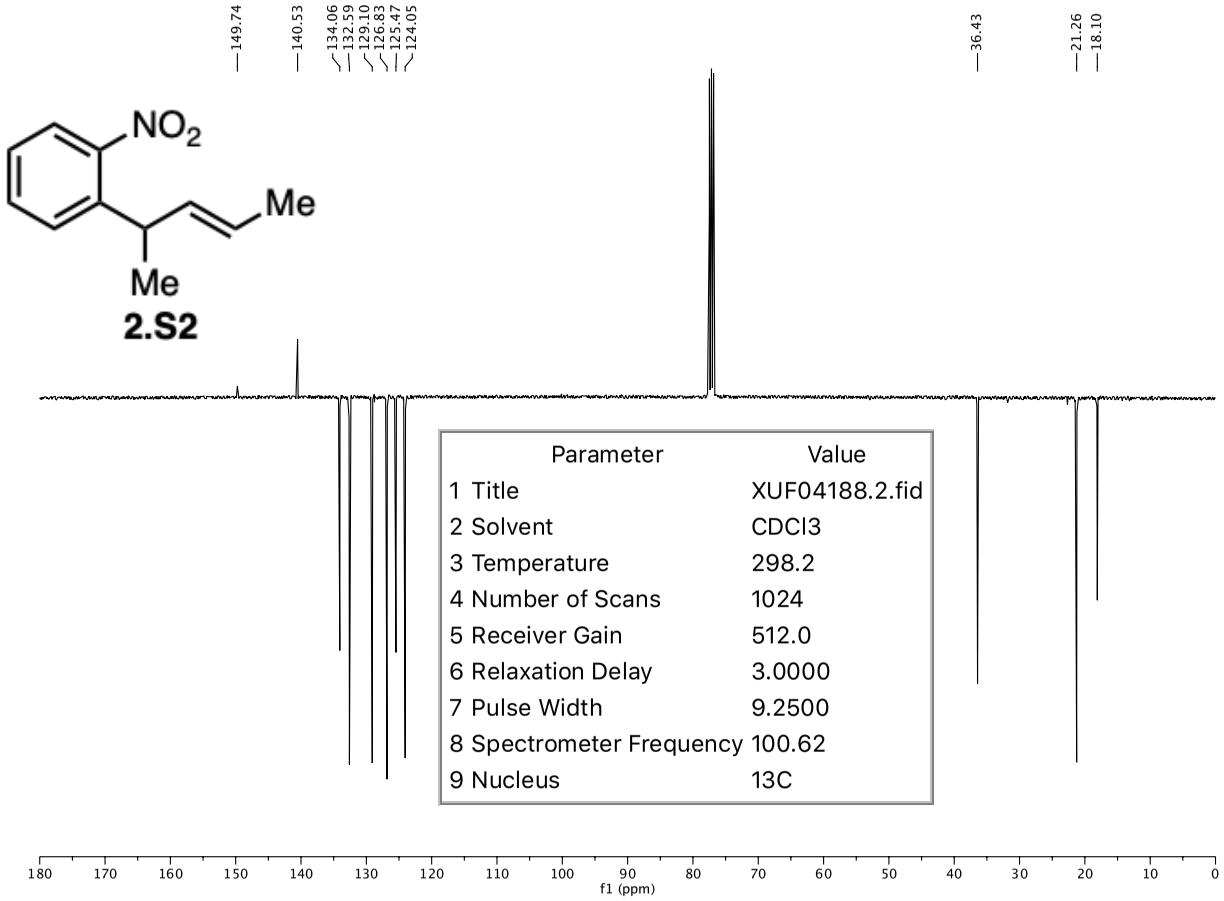
Appendix B

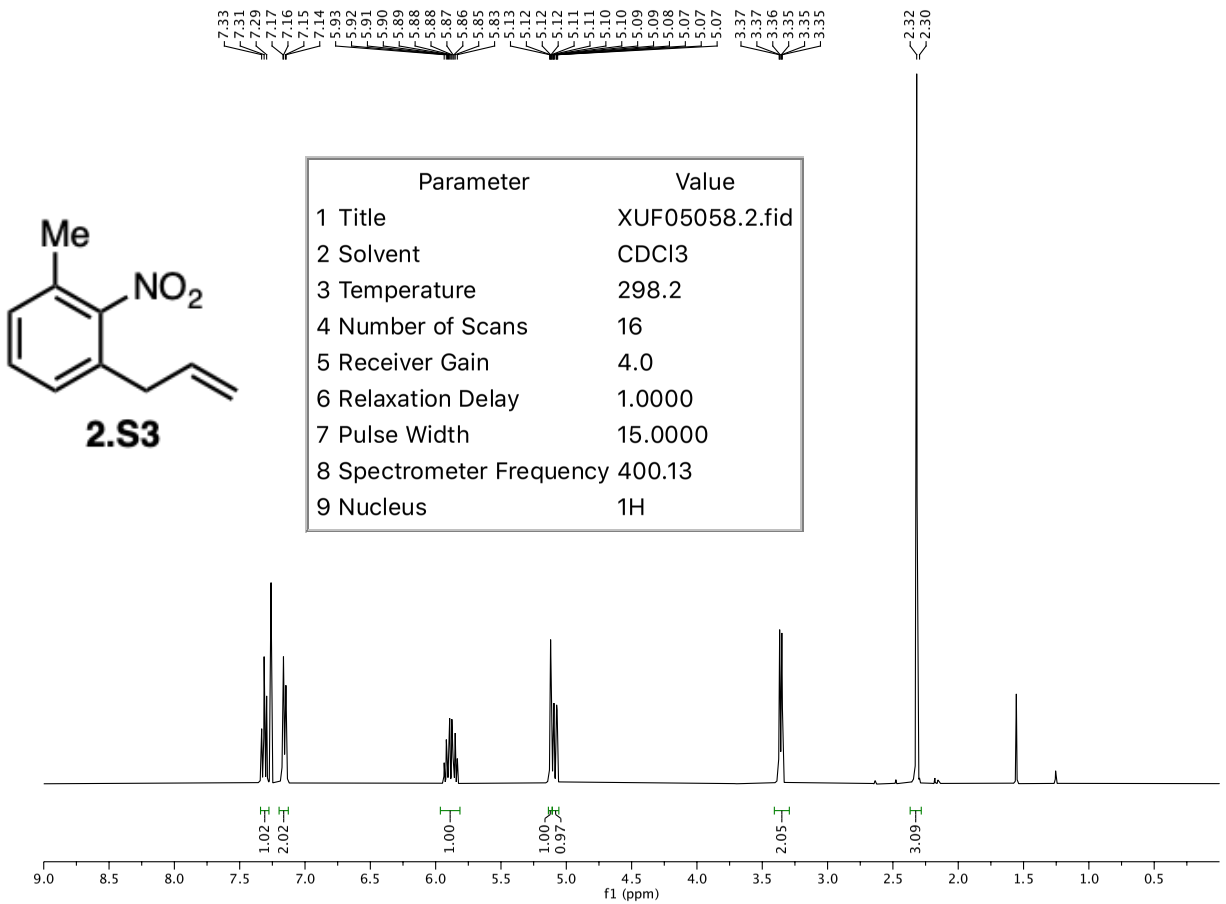
SPECTRAL DATA FOR CHAPTER 2

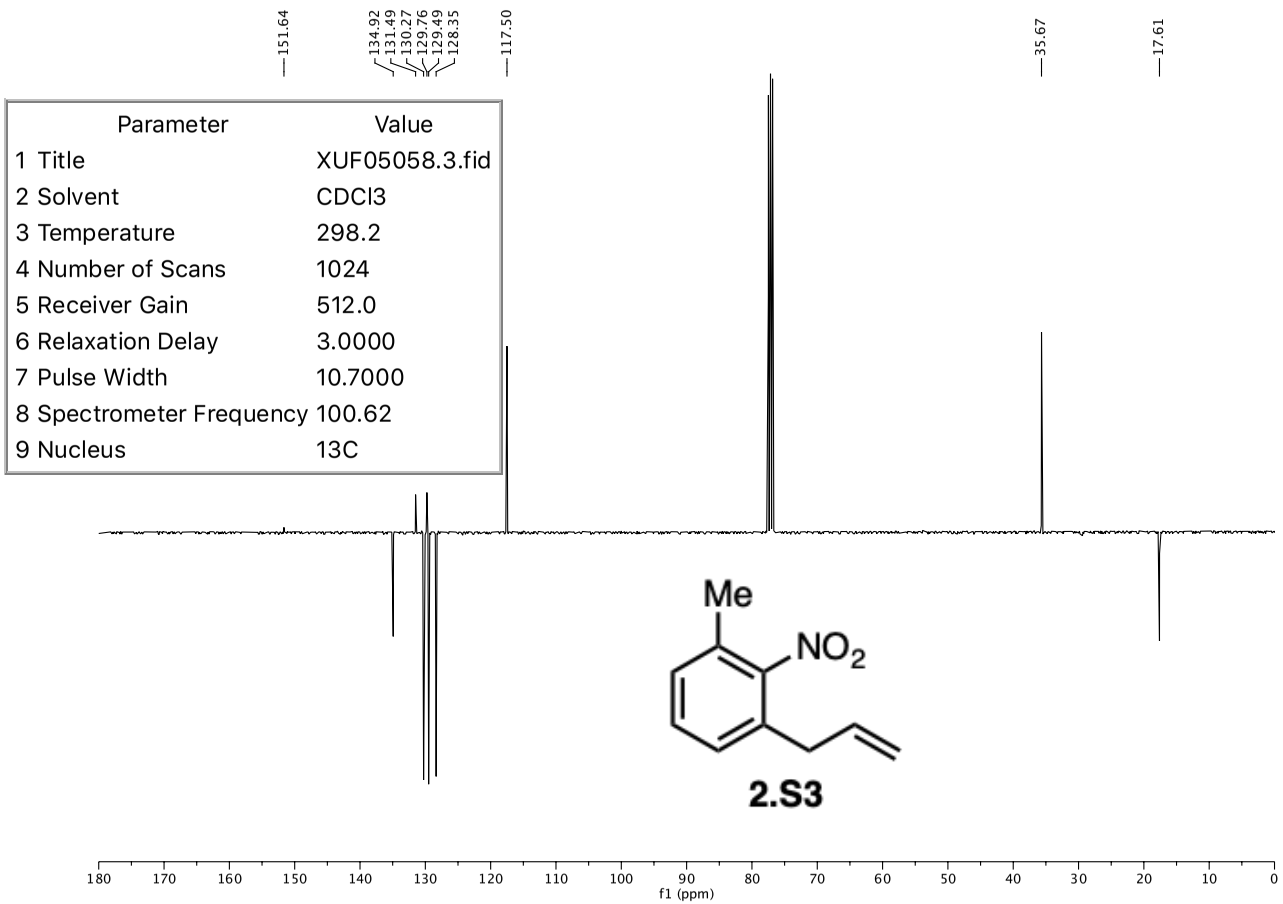

Parameter Value
1 Title XUF03235.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
2.S1
f1 (ppm)

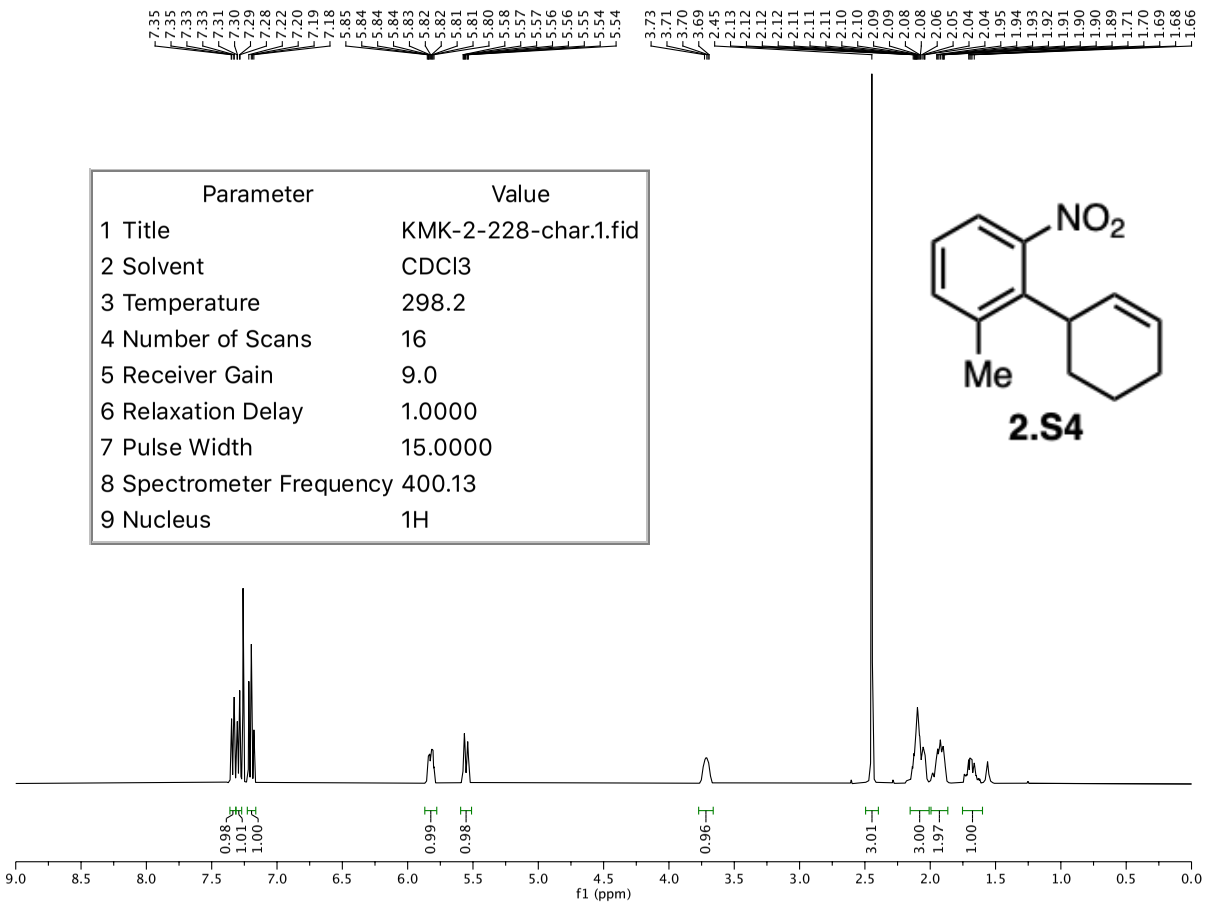

149.82
140.71
132.61
130.37
129.81
128.96
126.96
124.18
36.90
31.82
24.96
21.22
NO2
2.S1
Parameter Value
1 Title XUF03235.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

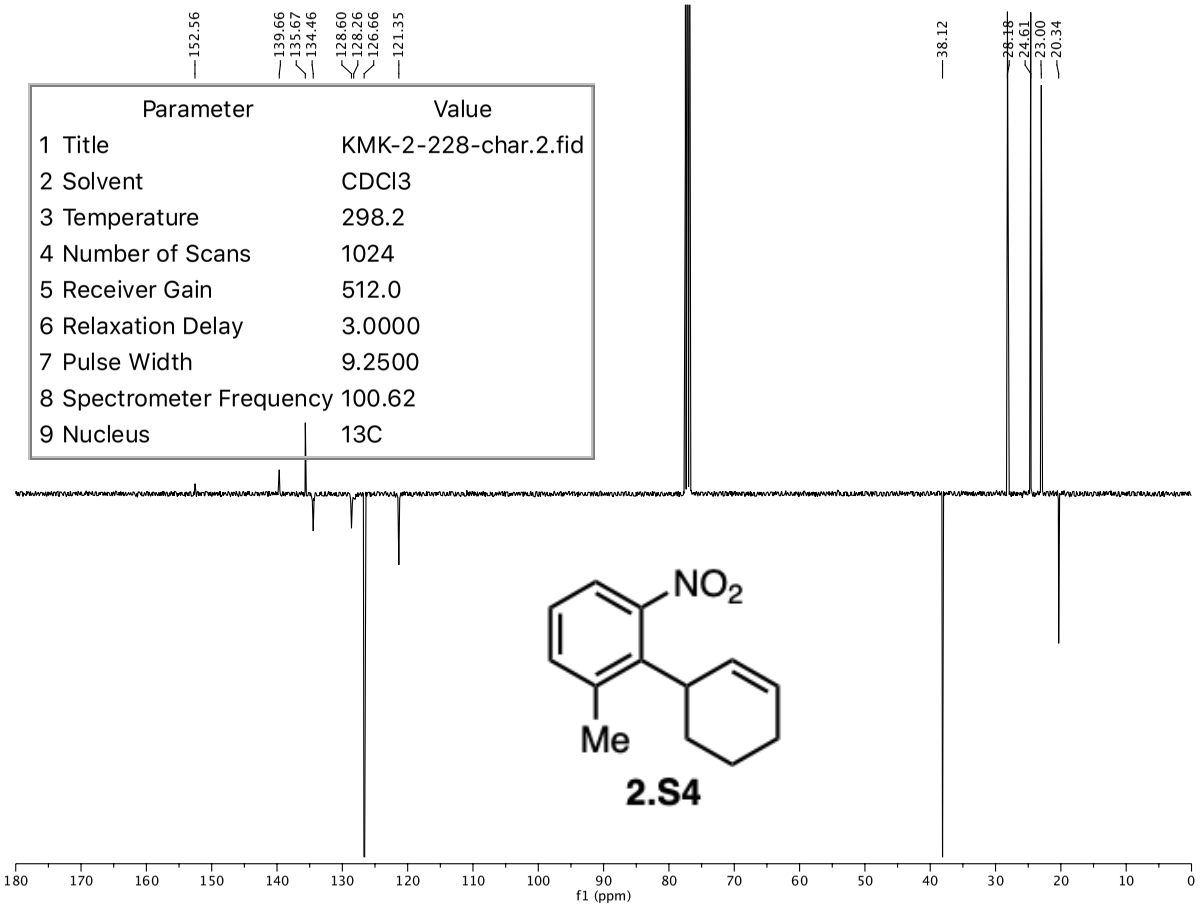

7.72
7.72
7.70
7.70
7.70
7.54
7.54
7.52
7.50
7.50
7.43
7.43
7.41
7.41
7.33
7.32
7.31
7.29
7.28
5.61
5.59
5.58
5.57
5.57
5.56
5.54
5.53
5.51
5.50
5.49
5.47
4.02
4.01
3.99
3.97
1.69
1.68
1.67
1.38
1.37
Parameter Value
1 Title XUF04188.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
Me
Me
2.S2
0.98
1.04
1.00
1.03
2.07
1.00
2.95
3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

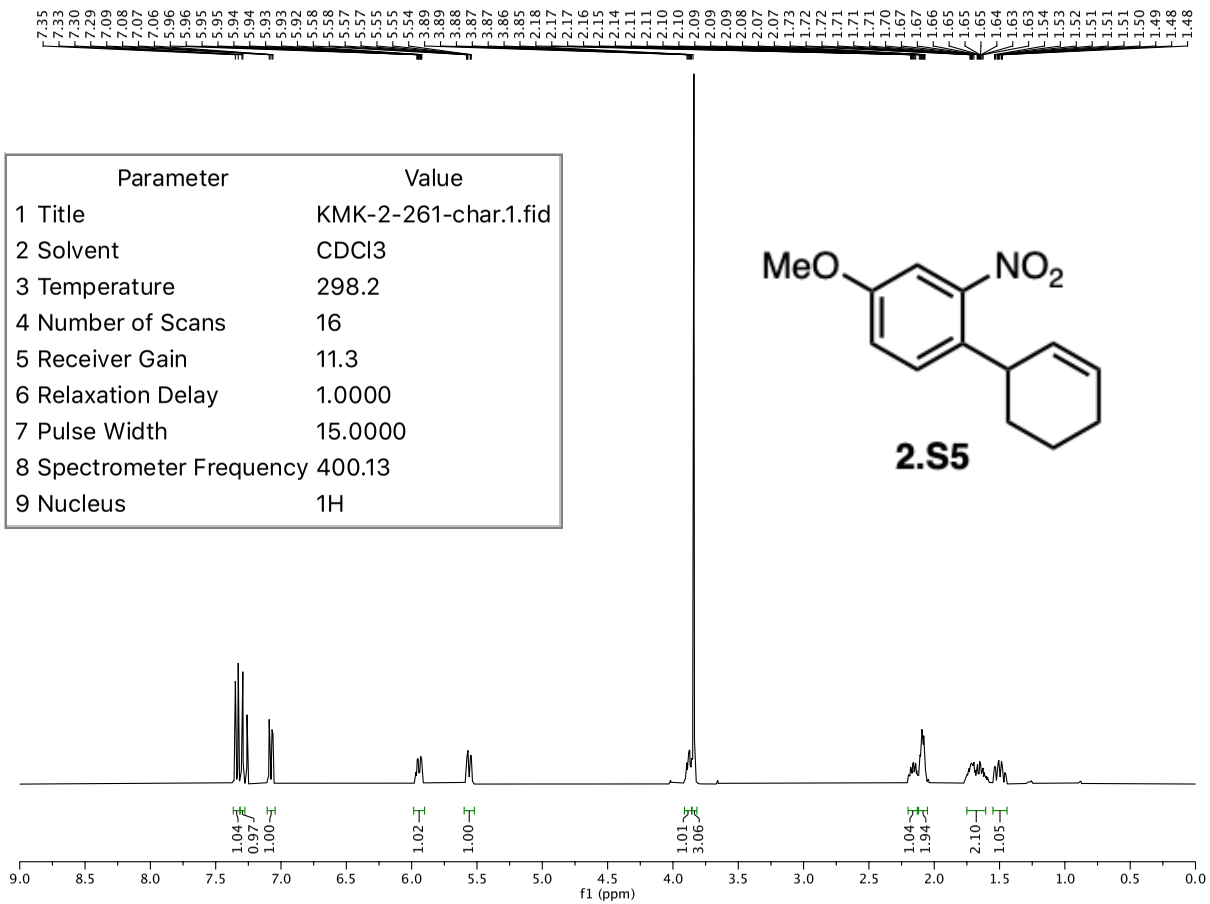

149.74
140.53
134.06
132.59
129.10
126.83
125.47
124.05
36.43
21.26
18.10
NO2
Me
Me
2.S2
Parameter Value
1 Title XUF04188.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

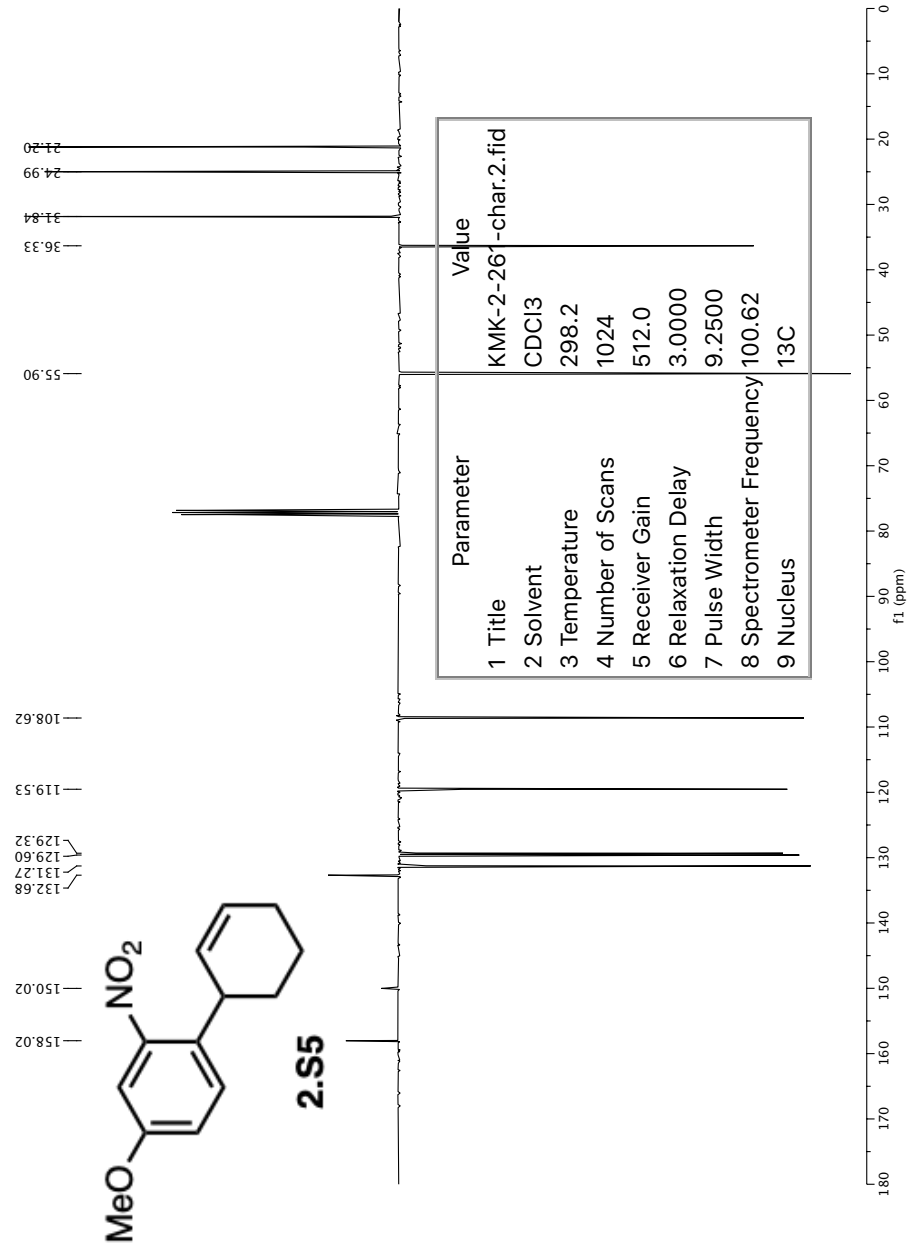

Me
NO2
2.S3
Parameter Value
1 Title XUF05058.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.02
2.02
1.00
1.00
0.97
2.05
3.09
f1 (ppm)

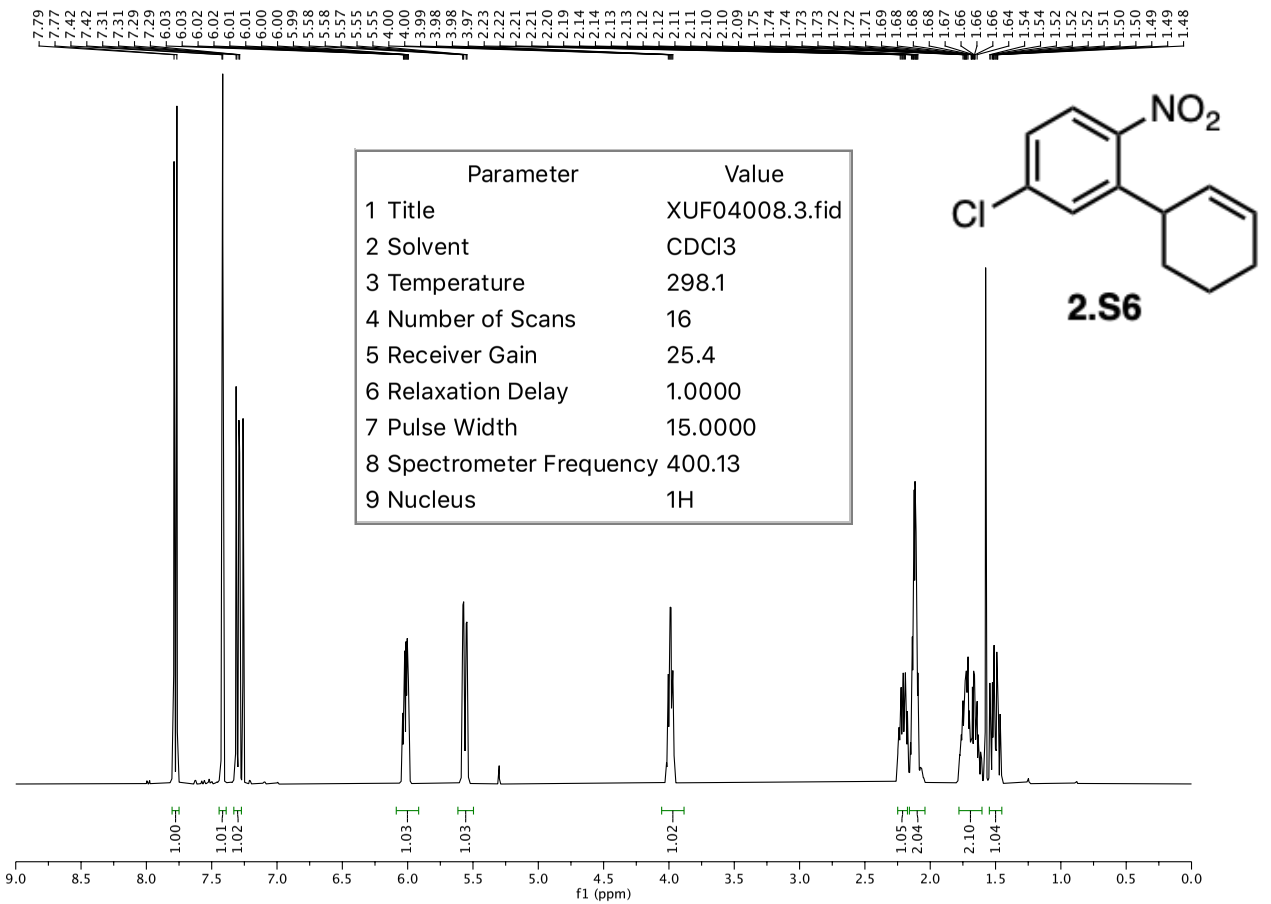

151.64
134.92
131.49
130.27
129.76
129.49
128.35
117.50
35.67
17.61
Parameter Value
1 Title XUF05058.3.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Me
NO2
2.S3
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

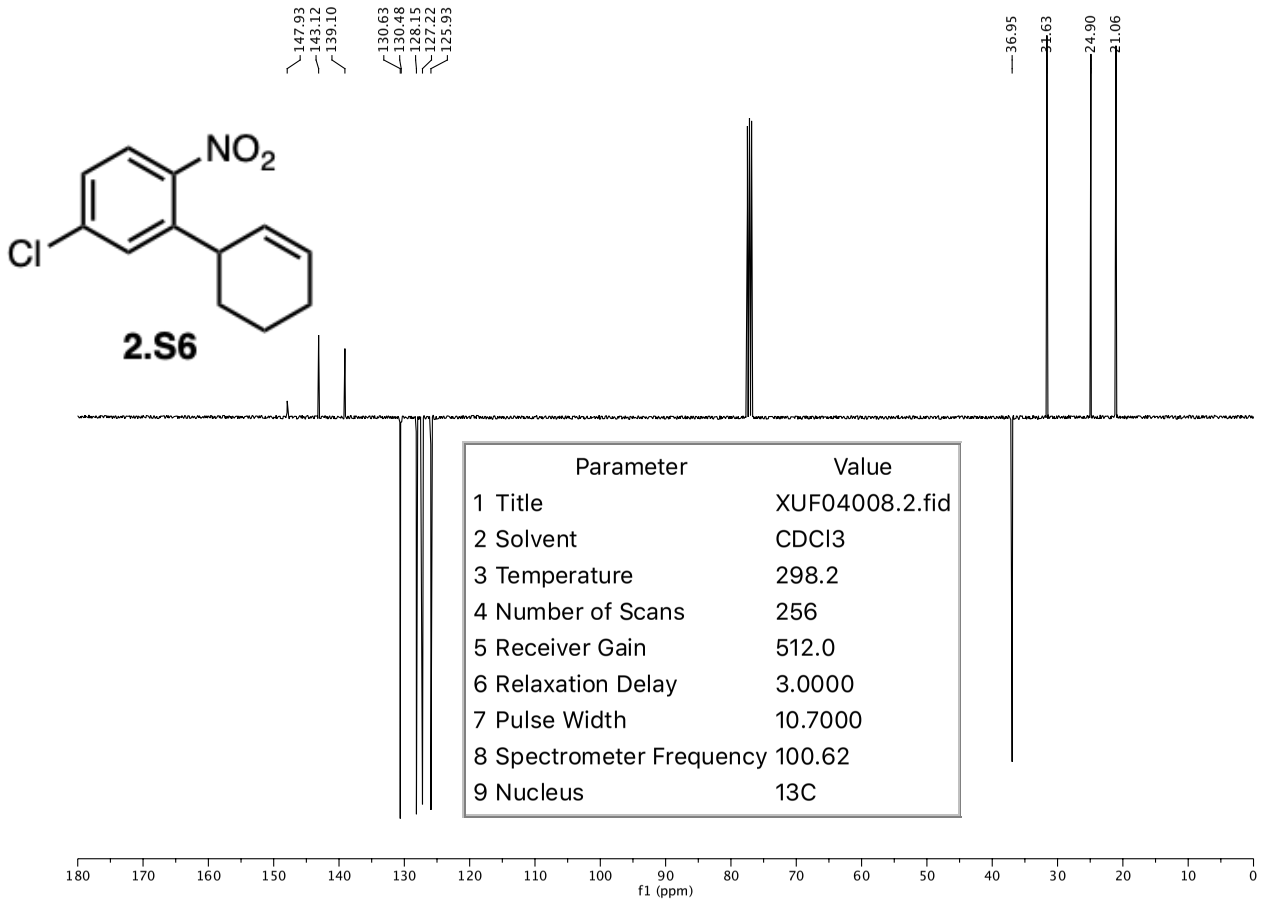

7.35 7.35 7.33 7.33 7.31 7.30 7.29 7.28 7.22 7.20 7.19 7.18
5.85 5.84 5.84 5.84 5.83 5.82 5.82 5.81 5.81 5.80 5.58 5.57 5.57 5.56 5.56 5.55 5.54 5.54
3.73 3.71 3.70 3.69 2.45 2.13 2.12 2.12 2.12 2.11 2.11 2.11 2.10 2.10 2.09 2.09 2.08 2.08 2.06 2.05 2.04 2.04 1.95 1.94 1.93 1.92 1.91 1.90 1.90 1.89 1.71 1.70 1.69 1.68 1.66
Parameter Value
1 Title KMK-2-228-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
Me
2.S4
0.98 1.01 1.00 0.99 0.98 0.96 3.01 3.00 1.97 1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

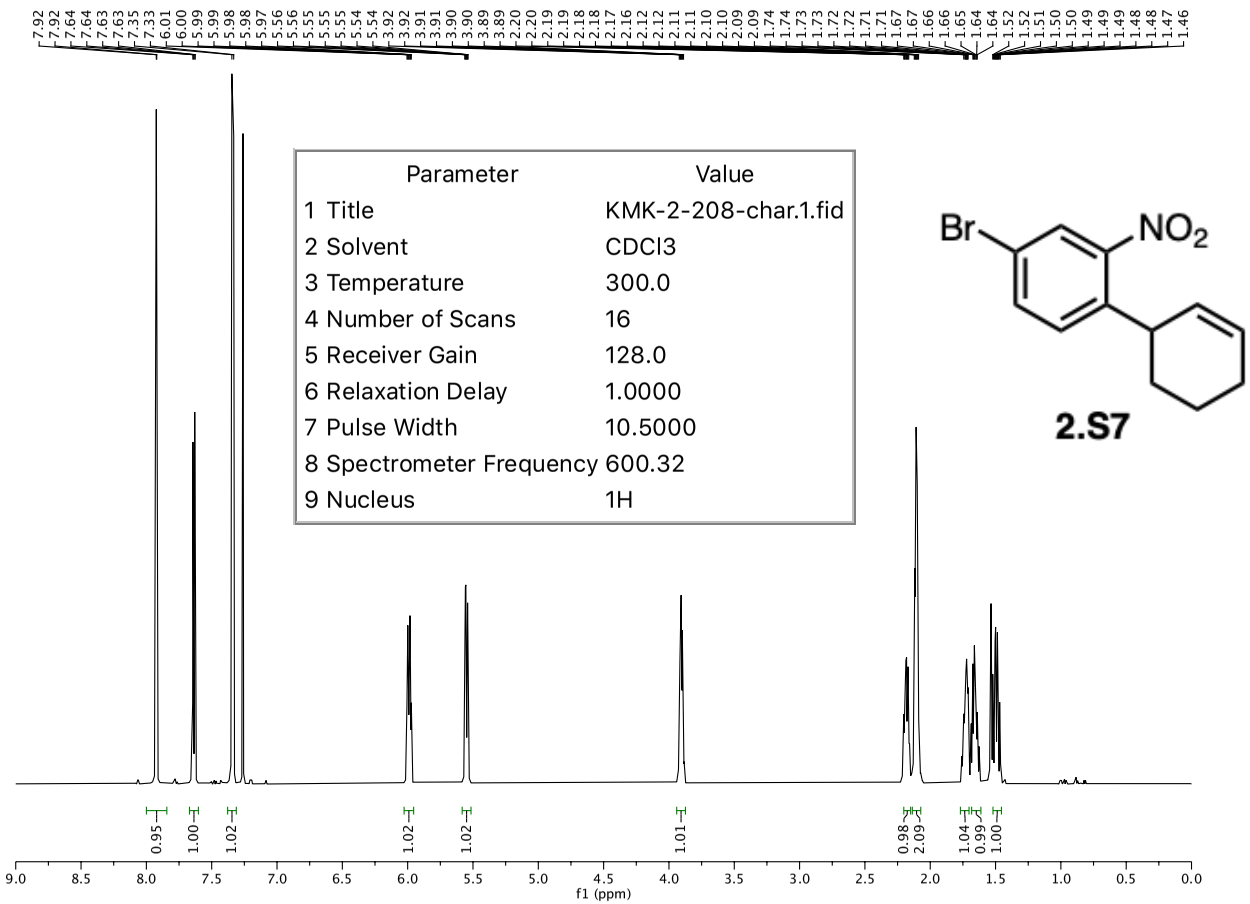

152.56
139.66
135.67
134.46
128.60
128.26
126.66
121.35
38.12
28.18
24.61
23.00
20.34
Parameter Value
1 Title KMK-2-228-char.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
NO2
Me
2.S4
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

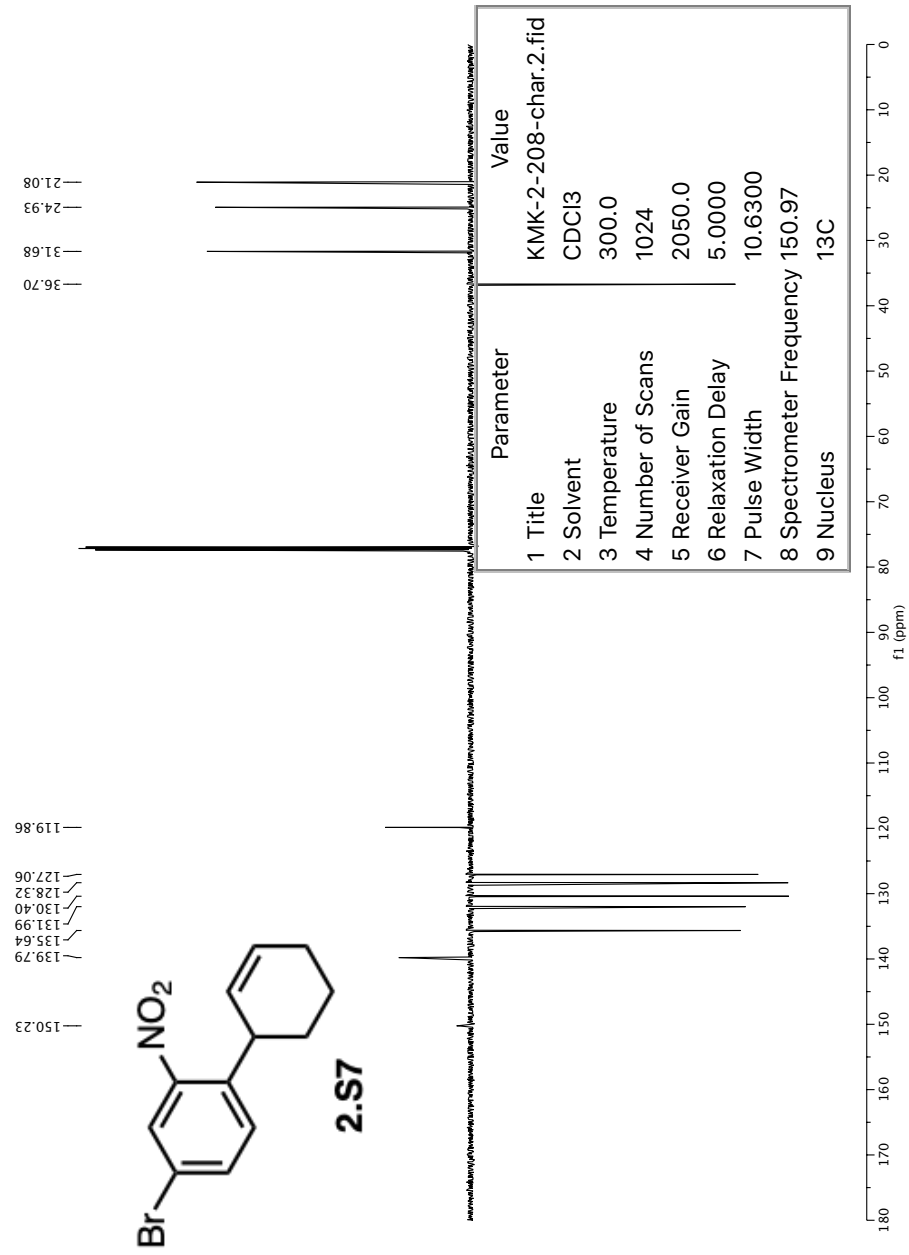

7.35 7.33 7.30 7.29 7.09 7.08 7.07 7.06 5.96 5.96 5.95 5.95 5.94 5.94 5.93 5.93 5.92 5.58 5.58 5.57 5.57 5.55 5.55 5.54 3.89 3.89 3.88 3.87 3.87 3.86 3.85 2.18 2.17 2.17 2.16 2.15 2.14 2.11 2.11 2.10 2.10 2.09 2.09 2.09 2.08 2.07 2.07 1.73 1.72 1.72 1.71 1.71 1.71 1.70 1.67 1.67 1.66 1.65 1.65 1.65 1.64 1.63 1.63 1.54 1.53 1.52 1.51 1.51 1.51 1.50 1.49 1.48 1.48
Parameter Value
1 Title KMK-2-261-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
NO2
2.S5
1.04 0.97 1.00 1.02 1.00 1.01 3.06 1.04 1.94 2.10 1.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

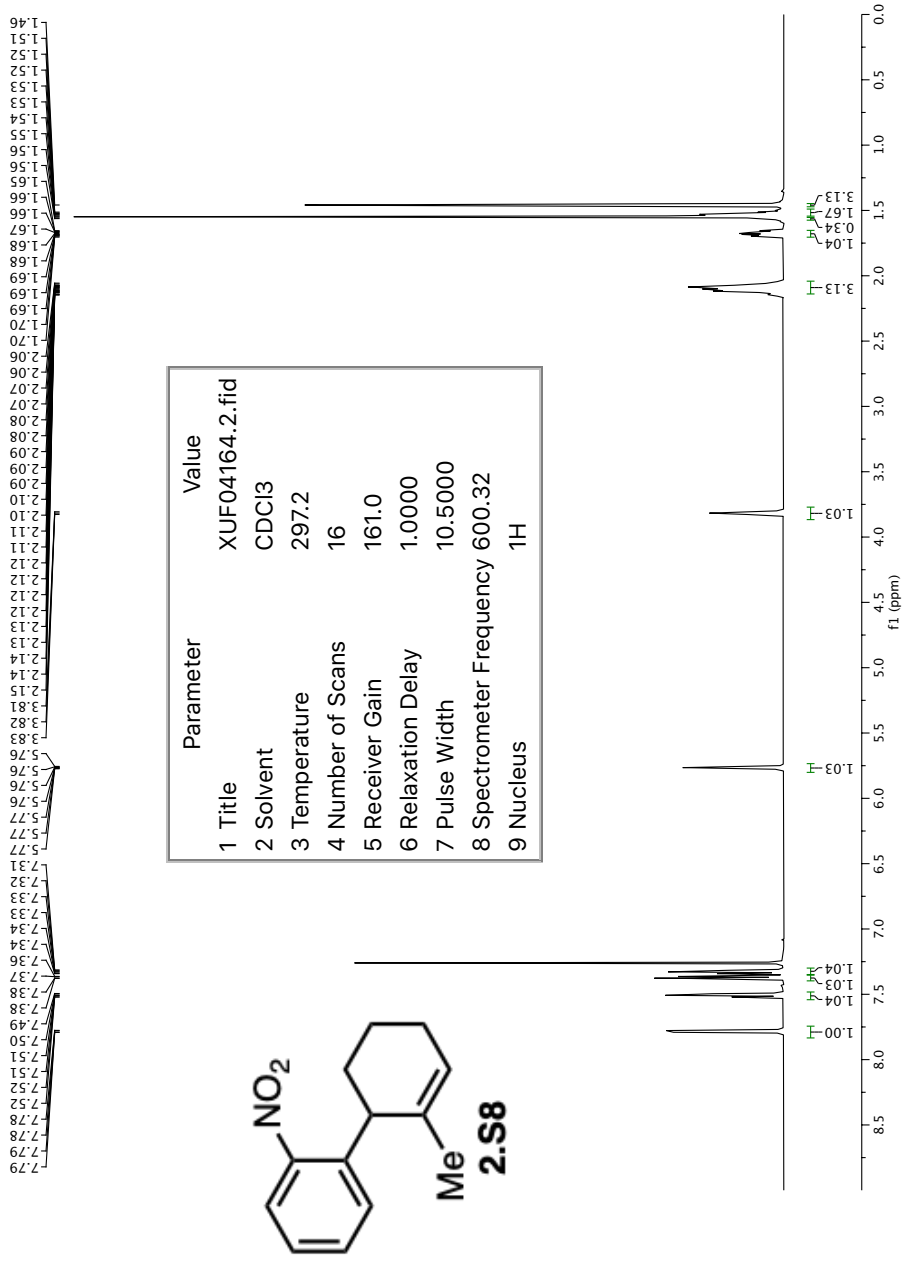

21.20
24.99
31.84
36.33
55.90
108.62
119.53
129.32
129.60
131.27
132.68
150.02
158.02
MeO
NO2
2.S5
Parameter
Value
1 Title
KMK-2-261-char.2.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

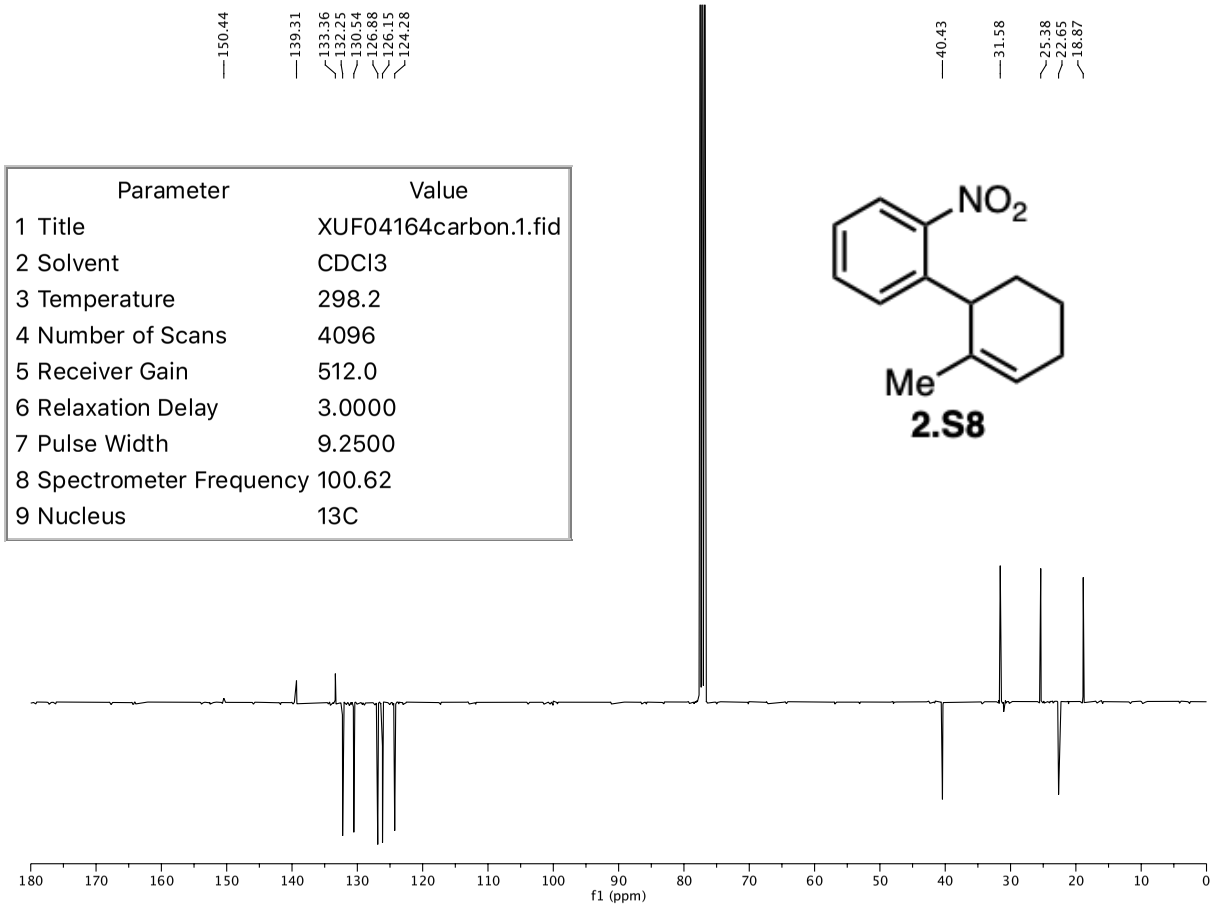

7.79 7.77 7.42 7.31 7.31 7.29 7.29 6.03 6.03 6.02 6.02 6.01 6.01 6.00 6.00 5.99 5.58 5.58 5.57 5.55 5.55 4.00 4.00 3.99 3.98 3.98 3.97 2.23 2.22 2.21 2.21 2.20 2.19 2.14 2.14 2.13 2.13 2.12 2.12 2.11 2.11 2.10 2.10 2.09 1.75 1.74 1.74 1.73 1.73 1.72 1.72 1.71 1.69 1.68 1.68 1.68 1.67 1.66 1.66 1.66 1.64 1.54 1.54 1.52 1.52 1.52 1.51 1.50 1.50 1.49 1.49 1.48
Parameter Value
1 Title XUF04008.3.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 25.4
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
Cl
2.S6
1.00 1.01 1.02 1.03 1.03 1.02 1.05 2.04 2.10 1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

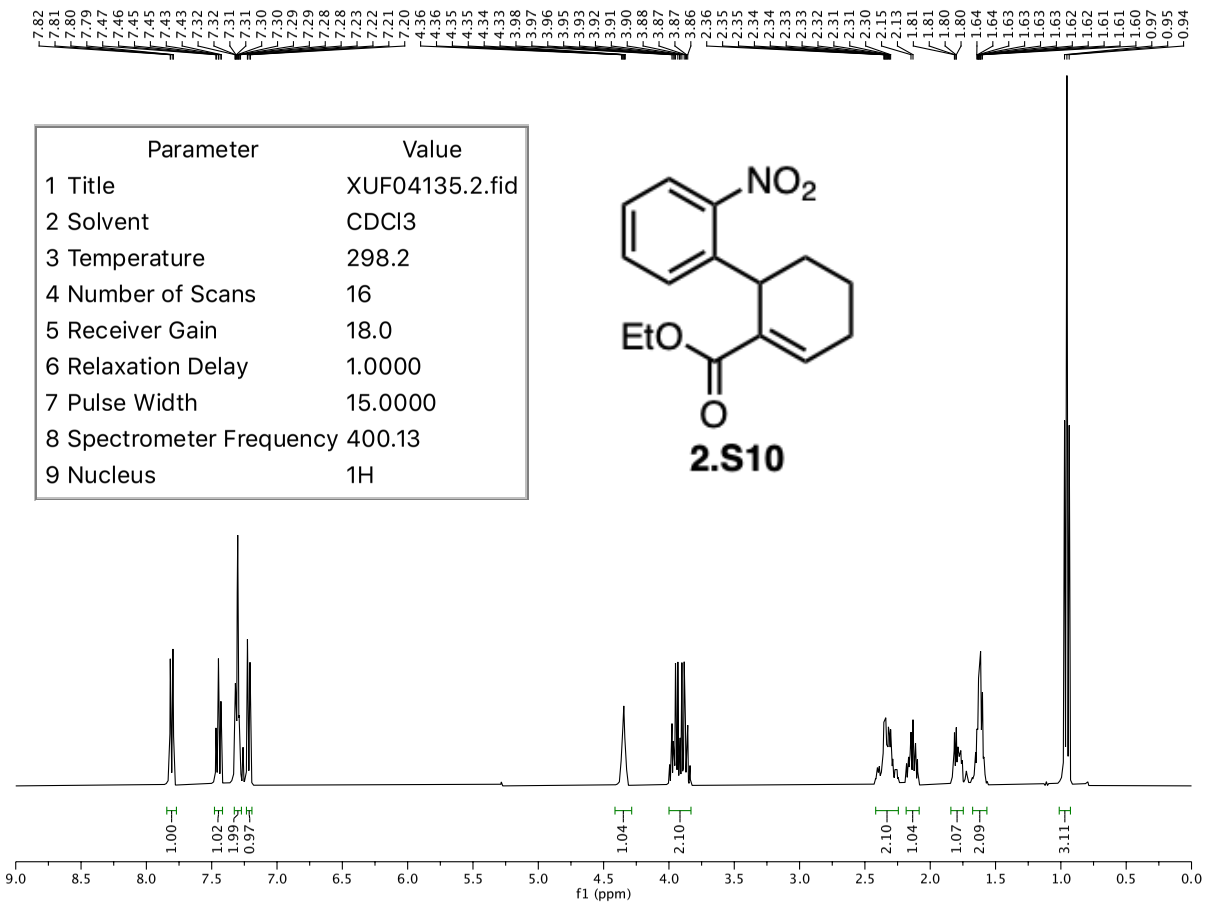

147.93
143.12
139.10
130.63
130.48
128.15
127.22
125.93
36.95
31.63
24.90
21.06
NO2
Cl
2.S6
Parameter Value
1 Title XUF04008.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.92 7.92 7.64 7.64 7.63 7.63 7.35 7.33 6.01 6.00 5.99 5.99 5.98 5.98 5.97 5.56 5.56 5.55 5.55 5.55 5.54 5.54 3.92 3.92 3.91 3.91 3.90 3.90 3.89 3.89 2.20 2.19 2.19 2.18 2.18 2.17 2.16 2.12 2.12 2.11 2.11 2.10 2.10 2.09 2.09 1.74 1.74 1.73 1.73 1.72 1.72 1.71 1.71 1.67 1.67 1.66 1.66 1.65 1.64 1.64 1.52 1.52 1.51 1.50 1.50 1.49 1.49 1.49 1.48 1.48 1.47 1.46
Parameter Value
1 Title KMK-2-208-char.1.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 128.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.5000
8 Spectrometer Frequency 600.32
9 Nucleus 1H
Br
NO2
2.S7
0.95 1.00 1.02 1.02 1.02 1.01 0.98 2.09 1.04 0.99 1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

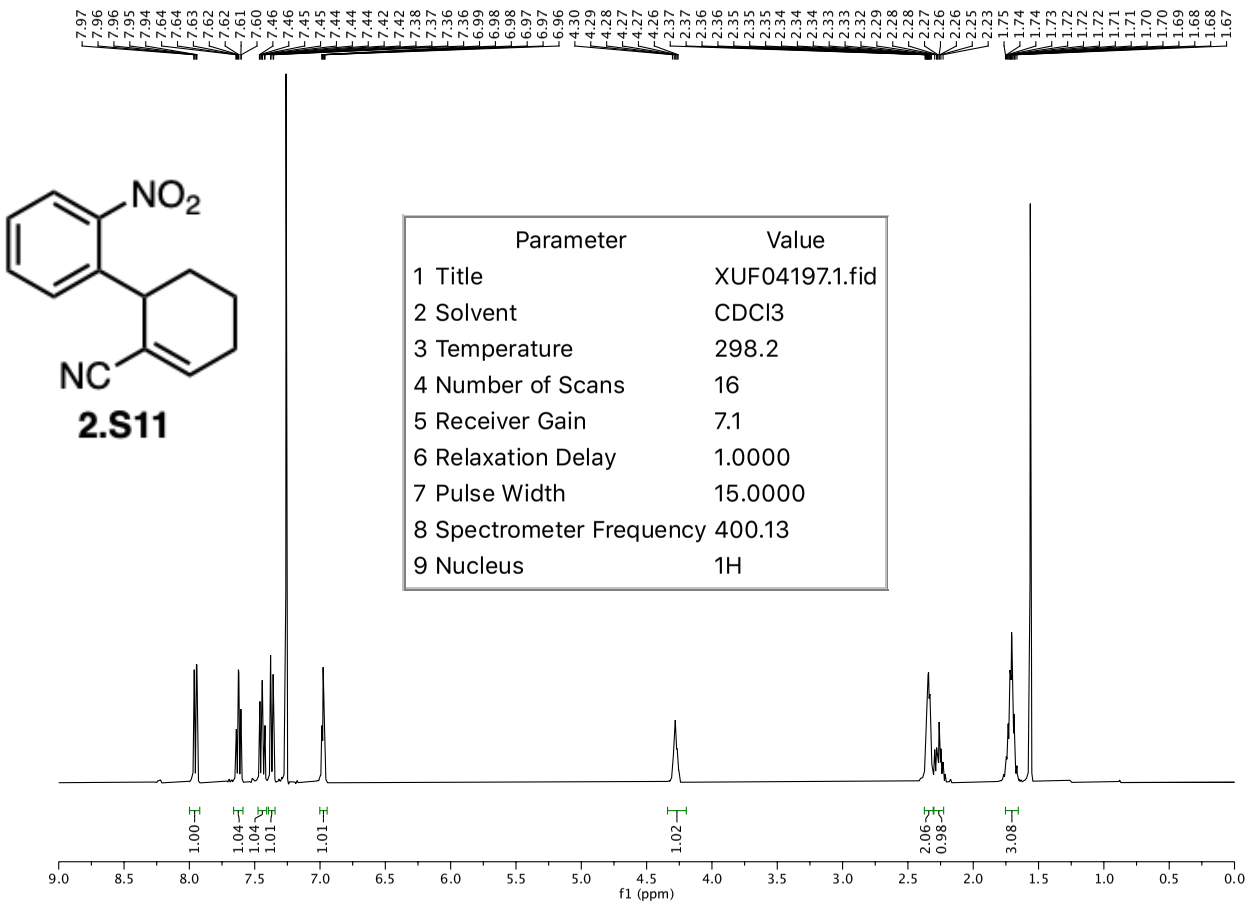

150.23
139.79
135.64
131.99
130.40
128.32
127.06
119.86
36.70
31.68
24.93
21.08
Br
NO2
2.S7
Parameter
Value
1 Title
KMK-2-208-char.2.fid
2 Solvent
CDCl3
3 Temperature
300.0
4 Number of Scans
1024
5 Receiver Gain
2050.0
6 Relaxation Delay
5.0000
7 Pulse Width
10.6300
8 Spectrometer Frequency
150.97
9 Nucleus
13C
f1 (ppm)

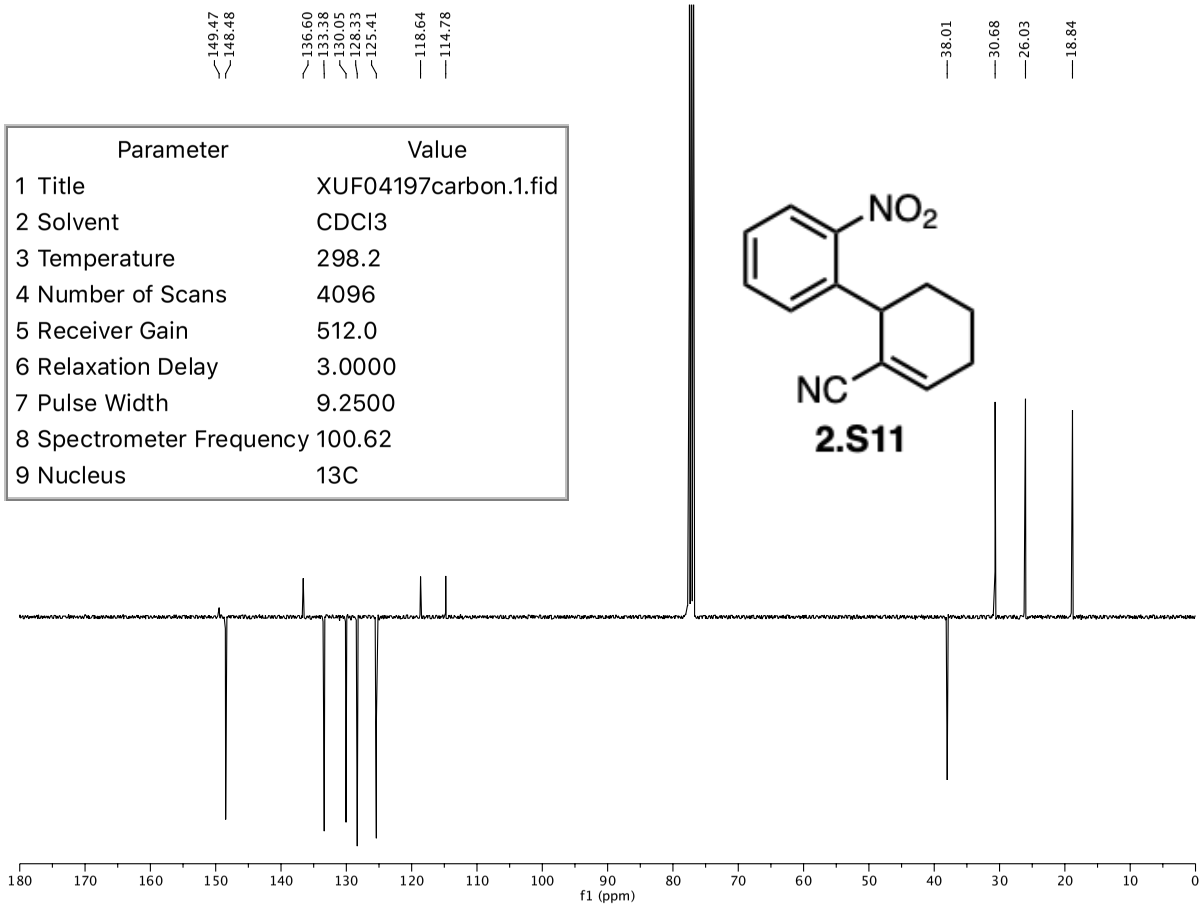

Parameter Value
1 Title XUF04164.2.fid
2 Solvent CDCl3
3 Temperature 297.2
4 Number of Scans 16
5 Receiver Gain 161.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.5000
8 Spectrometer Frequency 600.32
9 Nucleus 1H
NO2
Me
2.S8
f1 (ppm)

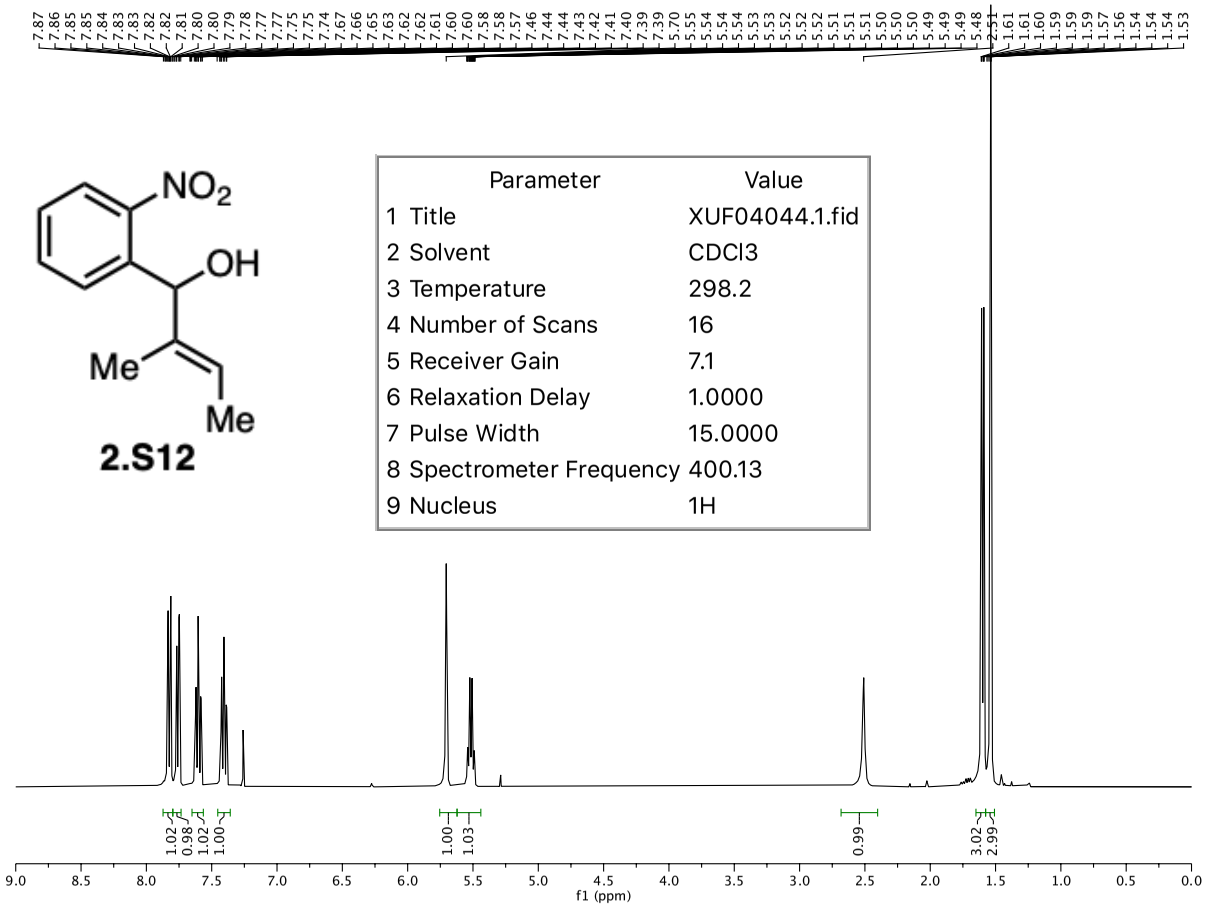

150.44
139.31
133.36
132.25
130.54
126.88
126.15
124.28
40.43
31.58
25.38
22.65
18.87
Parameter Value
1 Title XUF04164carbon.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
NO2
Me
2.S8
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

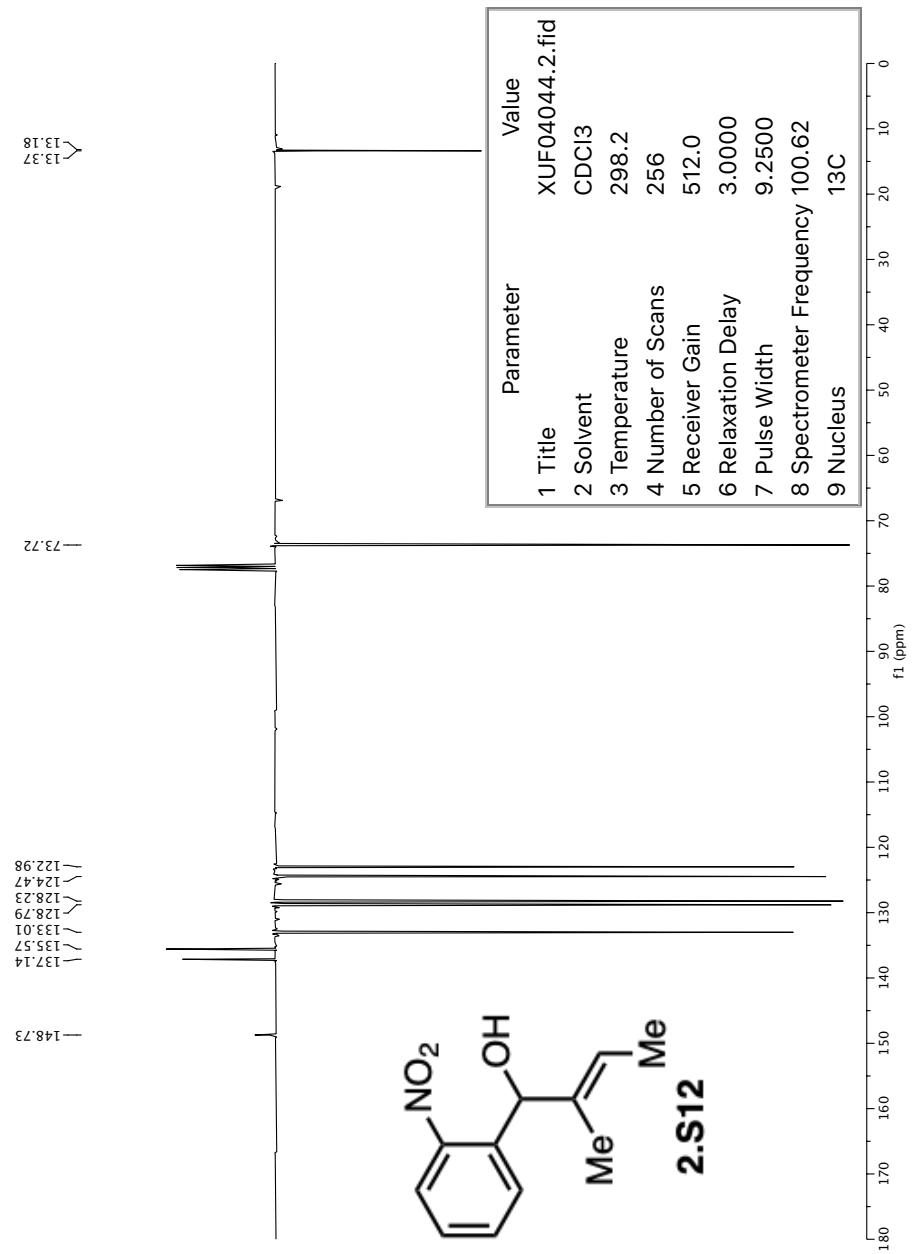

7.82 7.81 7.80 7.79 7.47 7.46 7.45 7.45 7.43 7.43 7.32 7.32 7.31 7.31 7.30 7.30 7.29 7.29 7.28 7.28 7.23 7.22 7.21 7.20
4.36 4.36 4.35 4.35 4.34 4.33 3.98 3.97 3.96 3.95 3.93 3.92 3.91 3.90 3.88 3.87 3.87 3.86
2.36 2.35 2.35 2.34 2.34 2.33 2.33 2.32 2.31 2.31 2.30 2.15 2.13 1.81 1.81 1.80 1.80 1.64 1.64 1.63 1.63 1.63 1.63 1.62 1.62 1.61 1.61 1.60 0.97 0.95 0.94
Parameter Value
1 Title XUF04135.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 18.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
EtO
O
2.S10
1.00 1.02 1.99 0.97 1.04 2.10 2.10 1.04 1.07 2.09 3.11
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

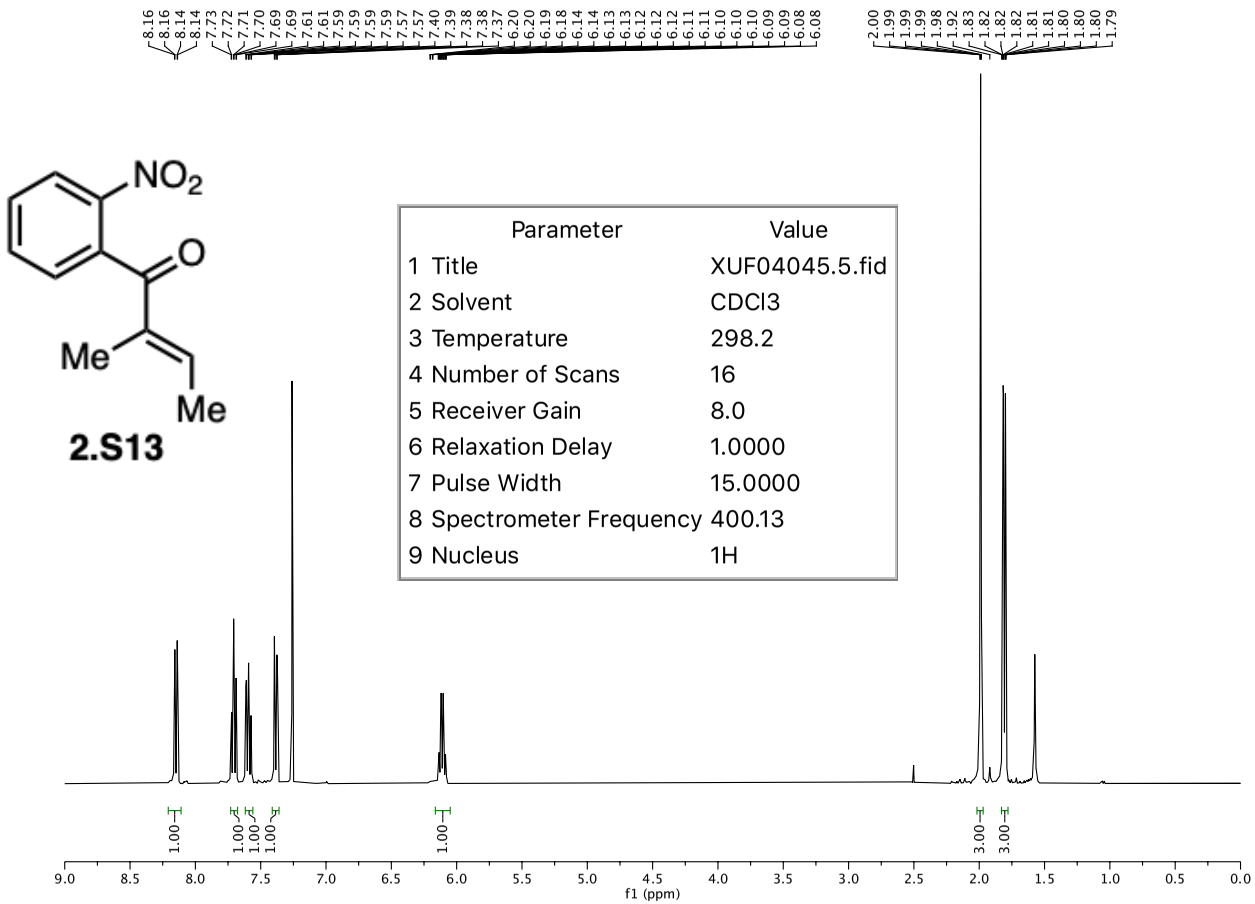
13.86
18.16
25.86
30.31
35.42
60.33
124.47
126.87
129.39
131.84
132.35
139.92
142.64
149.76
166.51
NO2
EtO
O
2.S10
Parameter Value
1 Title XUF04135.1.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

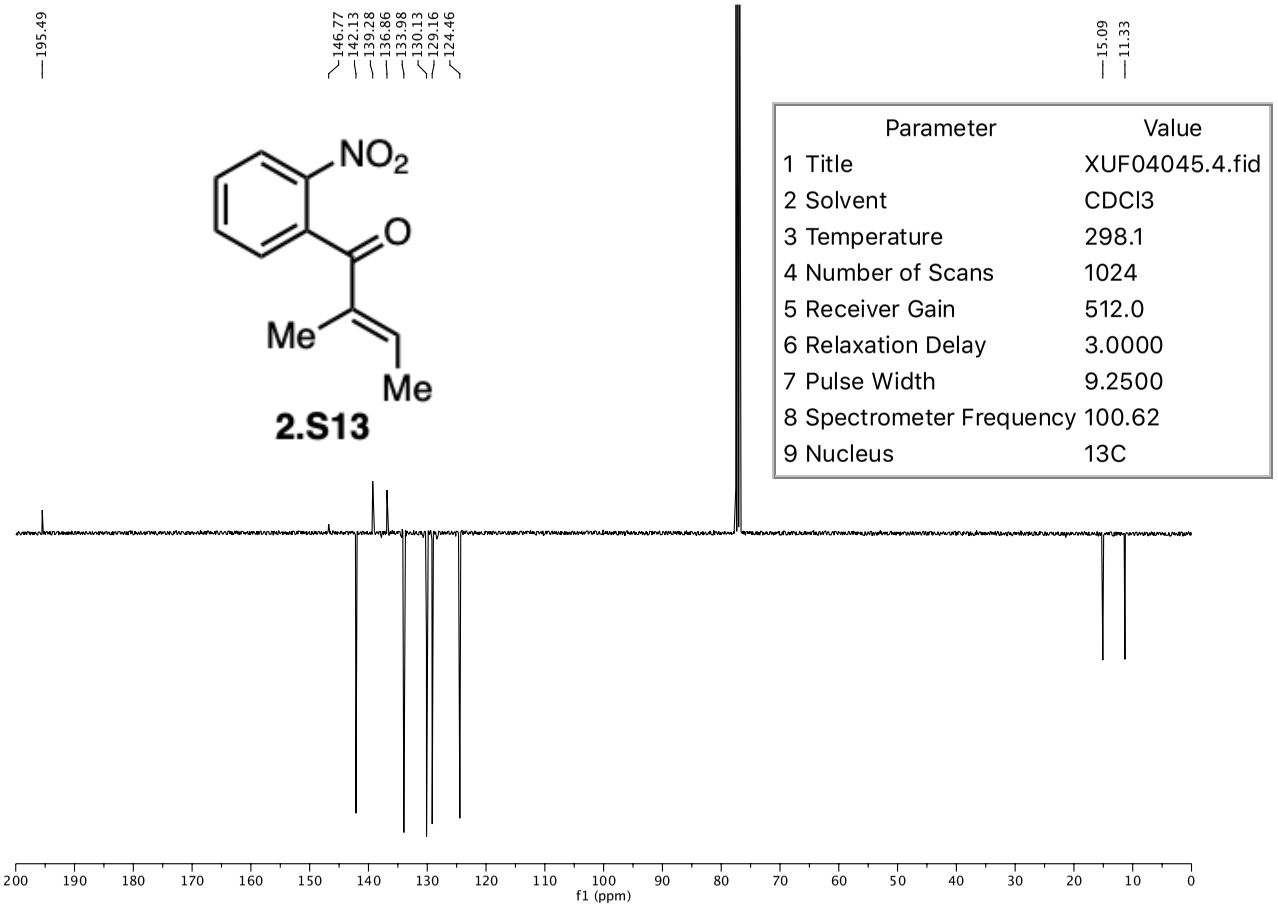

NO2
NC
2.S11
Parameter Value
1 Title XUF04197.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.00
1.04
1.04
1.01
1.01
1.02
2.06
0.98
3.08
f1 (ppm)

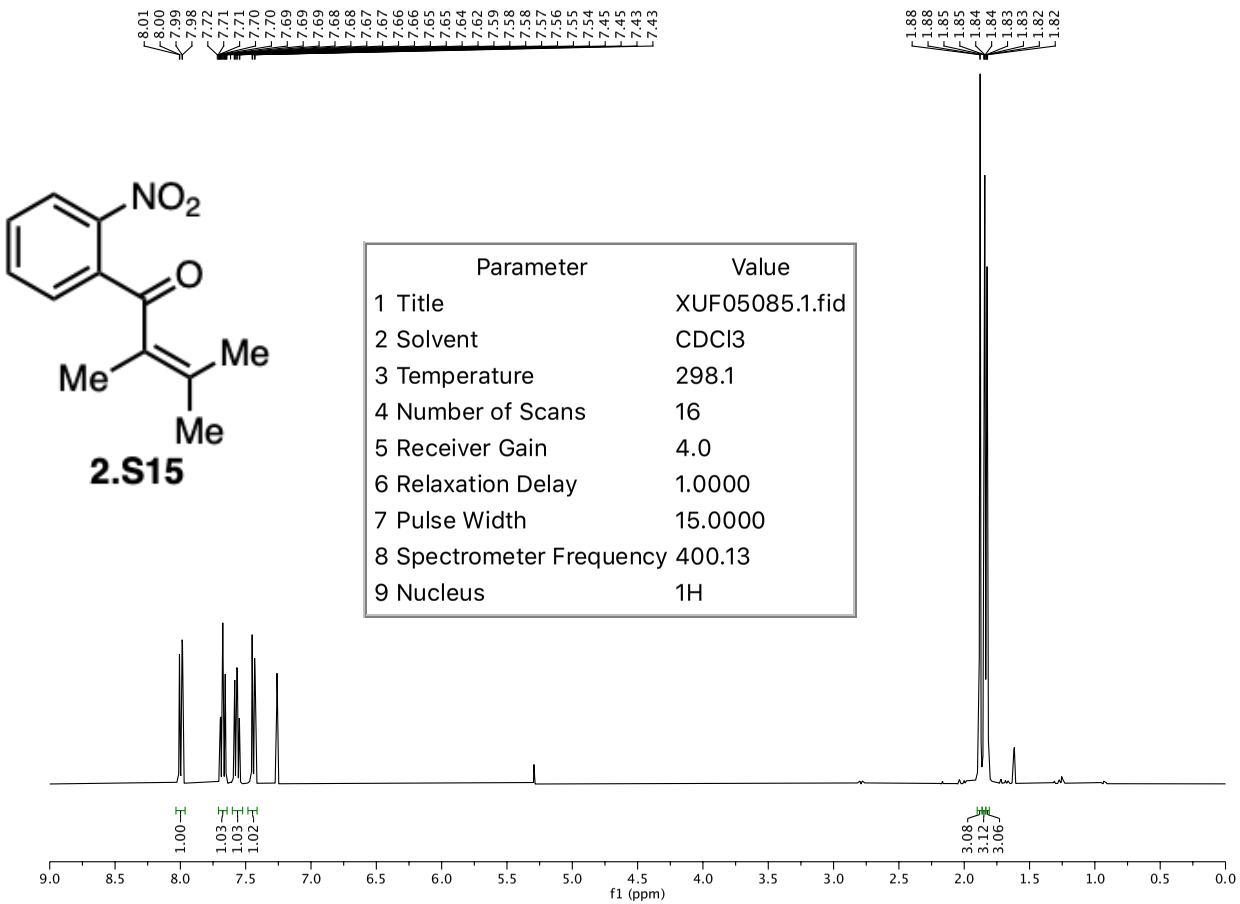

149.47
148.48
136.60
133.38
130.05
128.33
125.41
118.64
114.78
38.01
30.68
26.03
18.84
Parameter Value
1 Title XUF04197carbon.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
NO2
NC
2.S11
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

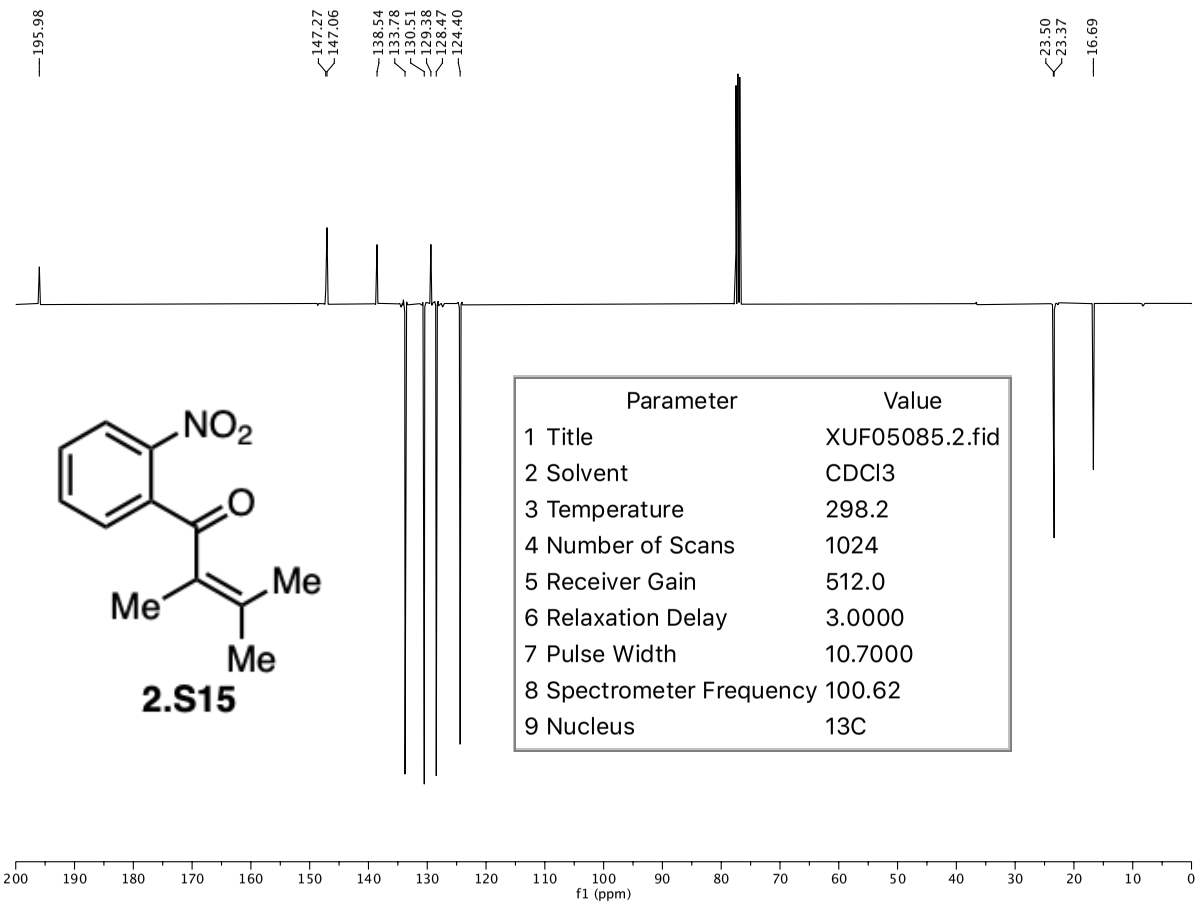

NO2
OH
Me
Me
2.S12
Parameter Value
1 Title XUF04044.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.02
0.98
1.02
1.00
1.00
1.03
0.99
3.02
2.99
f1 (ppm)

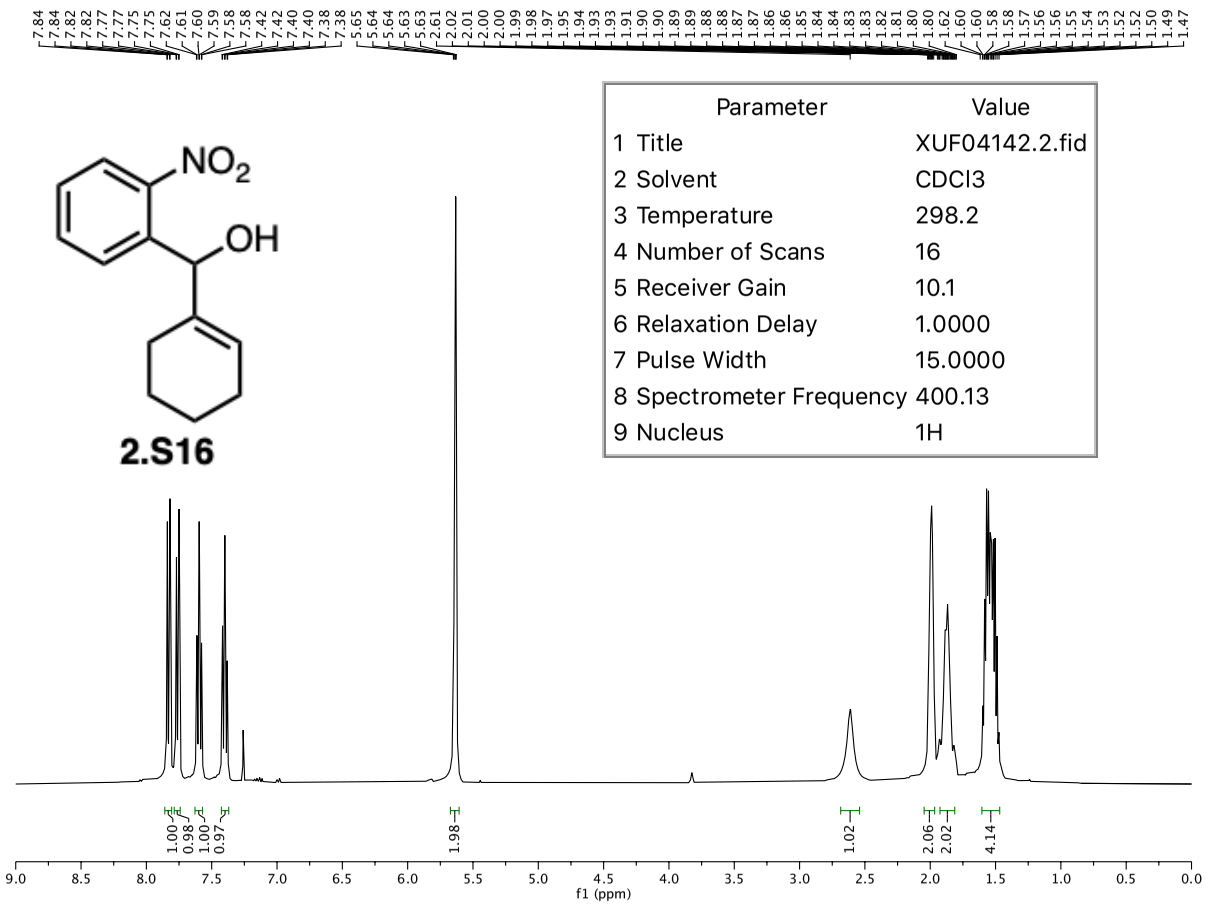

148.73
137.14
135.57
133.01
128.79
128.23
124.47
122.98
73.72
13.37
13.18
Parameter Value
1 Title XUF04044.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)
NO2
OH
Me
Me
2.S12

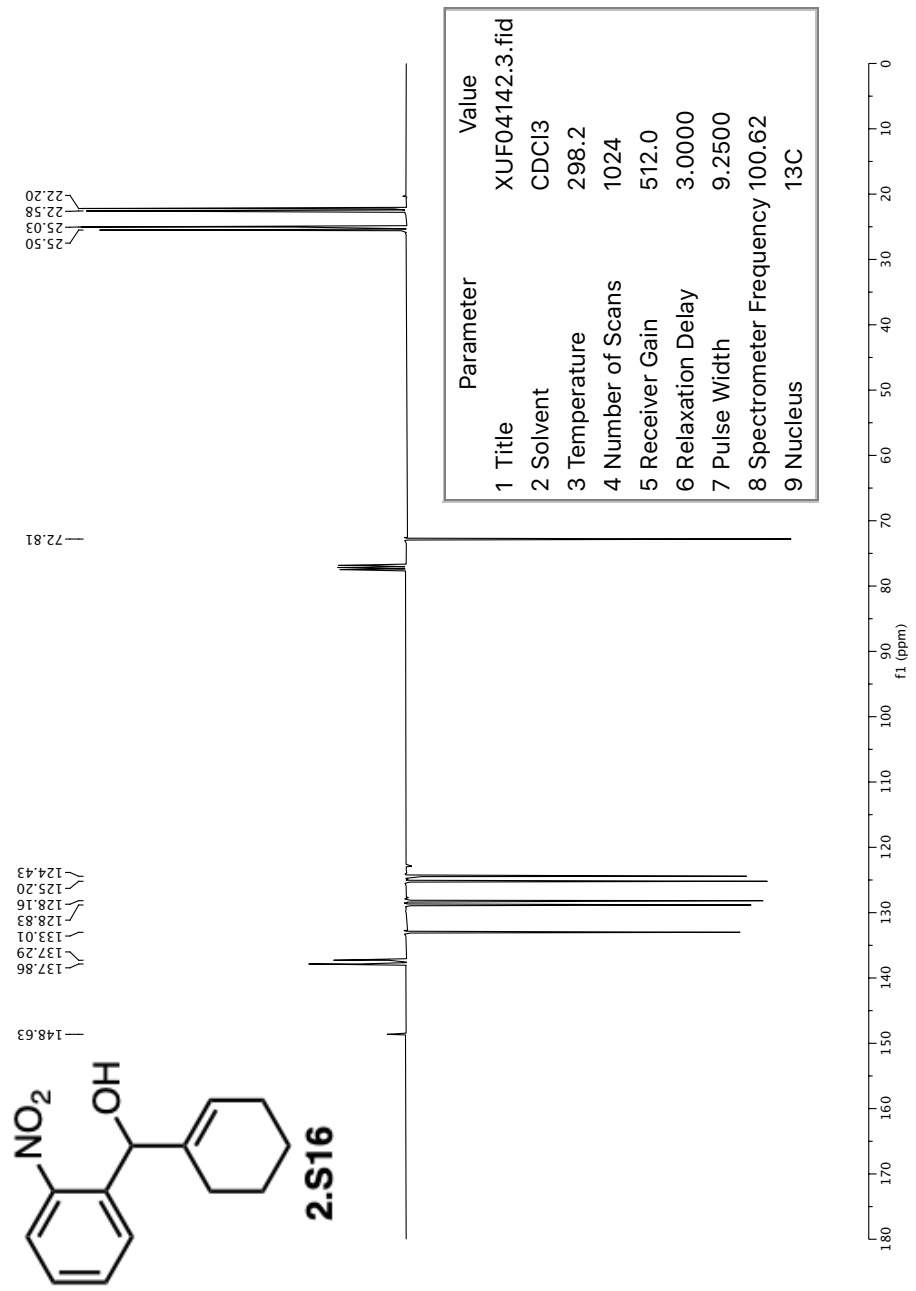

NO2
O
Me
Me
2.S13
Parameter Value
1 Title XUF04045.5.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

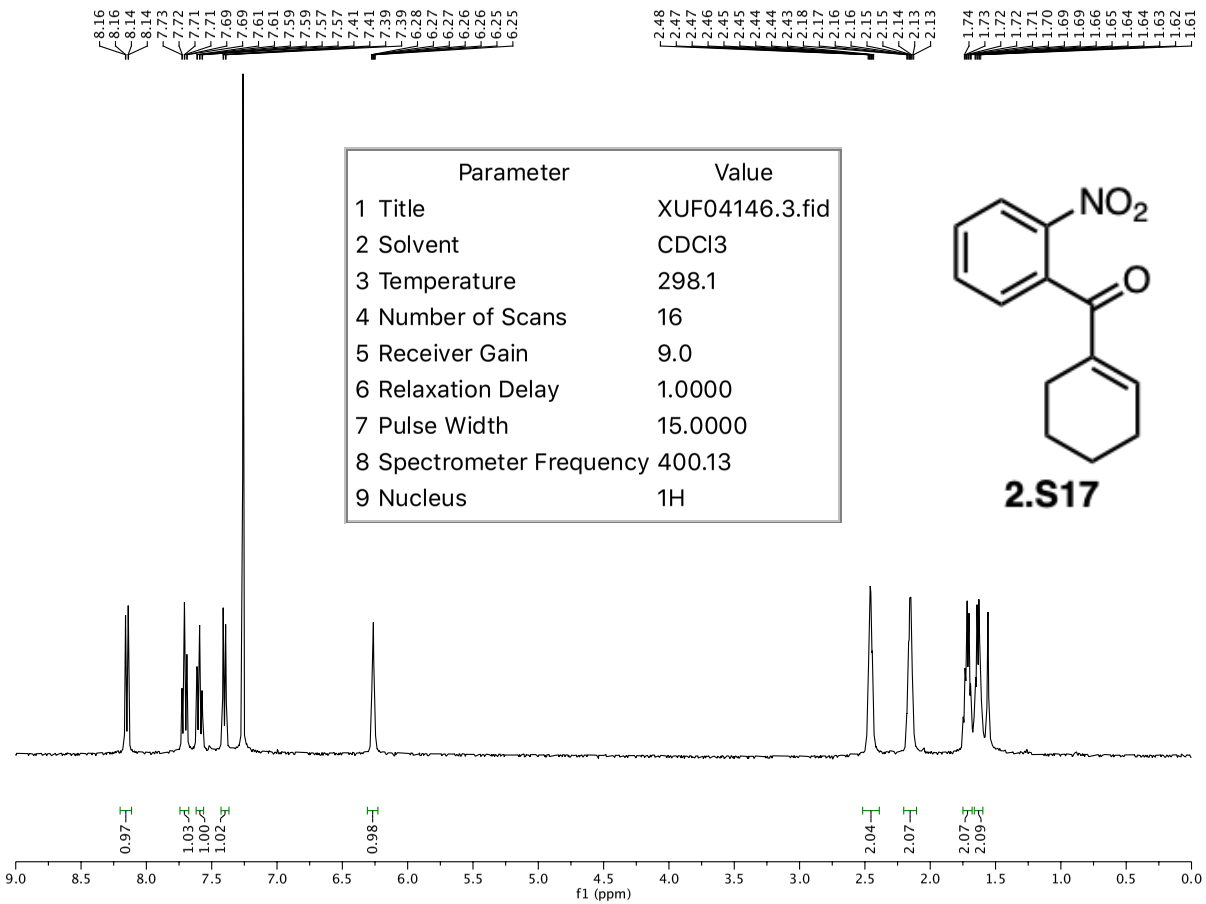

195.49
146.77
142.13
139.28
136.86
133.98
130.13
129.16
124.46
15.09
11.33
NO2
O
Me
Me
2.S13
Parameter Value
1 Title XUF04045.4.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

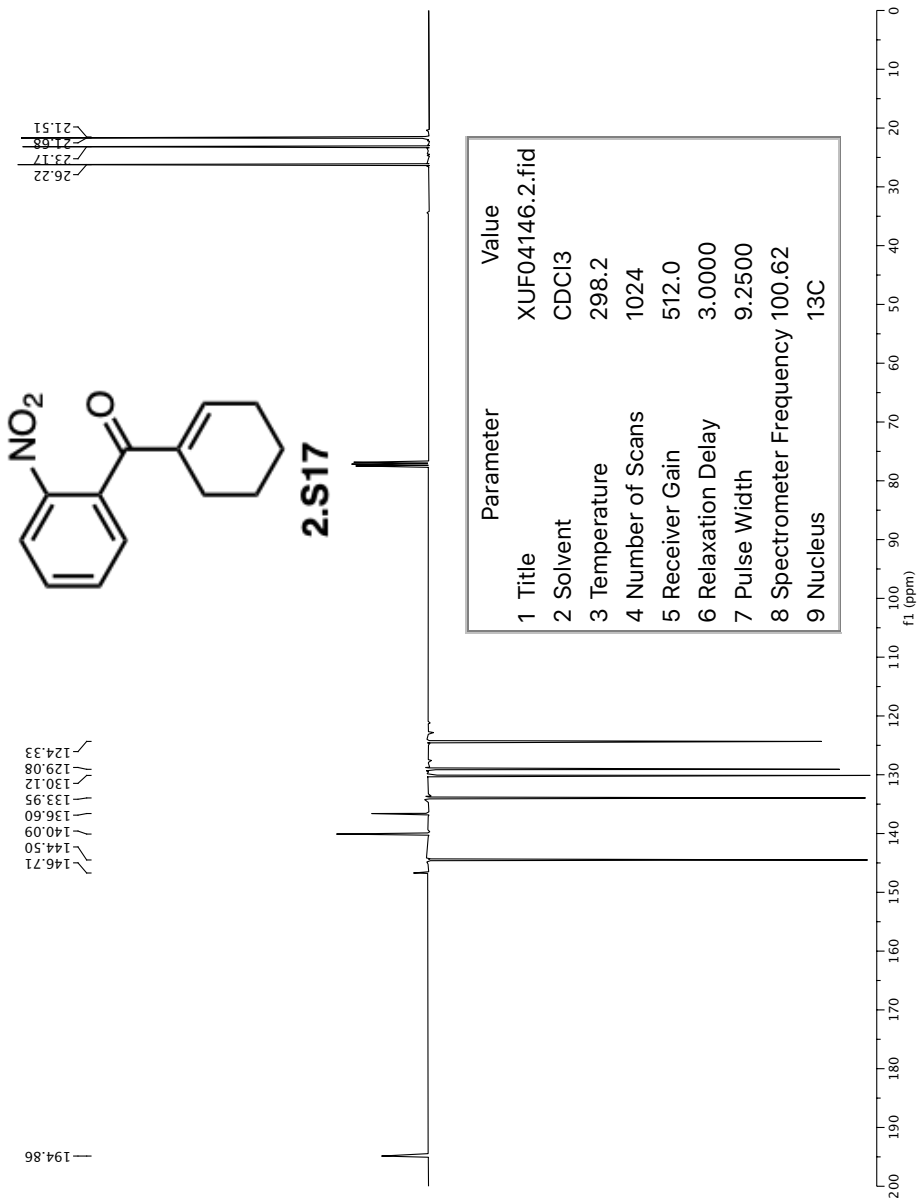

8.01
8.00
7.99
7.98
7.72
7.71
7.71
7.70
7.70
7.69
7.69
7.69
7.68
7.68
7.67
7.67
7.66
7.66
7.65
7.65
7.64
7.62
7.59
7.58
7.58
7.57
7.56
7.55
7.54
7.45
7.45
7.43
7.43
1.88
1.88
1.85
1.85
1.84
1.84
1.83
1.83
1.82
1.82
NO2
O
Me
Me
Me
2.S15
Parameter Value
1 Title XUF05085.1.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.00
1.03
1.03
1.02
3.08
3.12
3.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

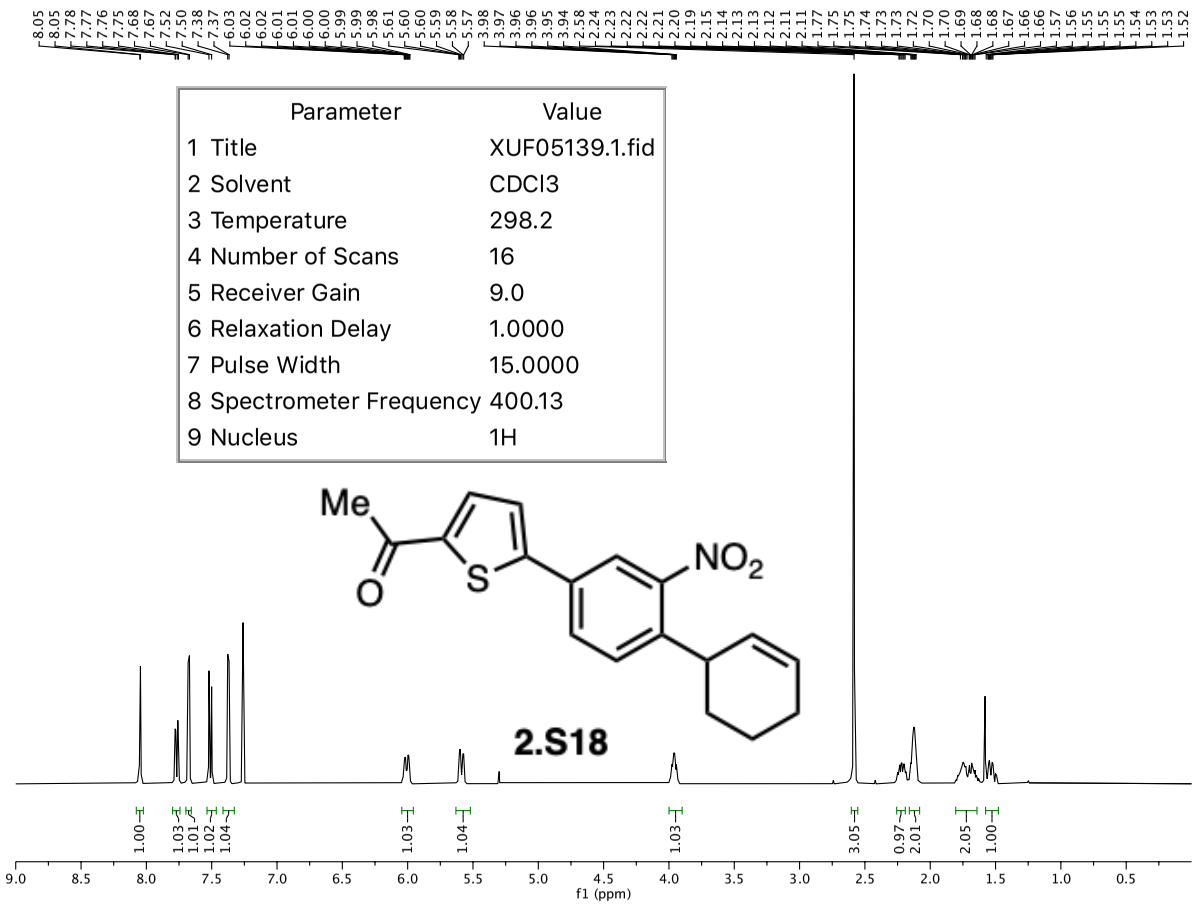

195.98
147.27
147.06
138.54
133.78
130.51
129.38
128.47
124.40
23.50
23.37
16.69
NO2
O
Me
Me
Me
2.S15
Parameter Value
1 Title XUF05085.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

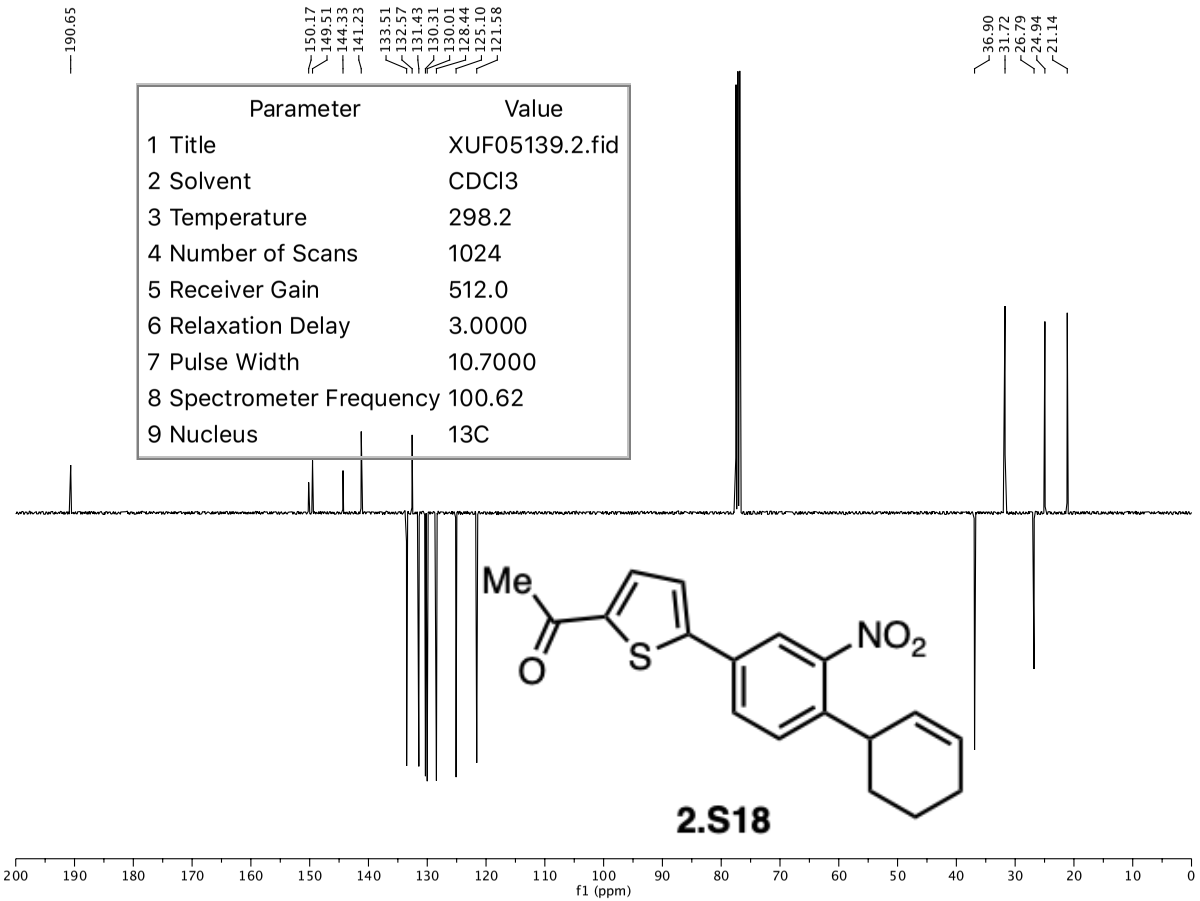

NO2
OH
2.S16
Parameter Value
1 Title XUF04142.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.00
0.98
1.00
0.97
1.98
1.02
2.06
2.02
4.14
f1 (ppm)

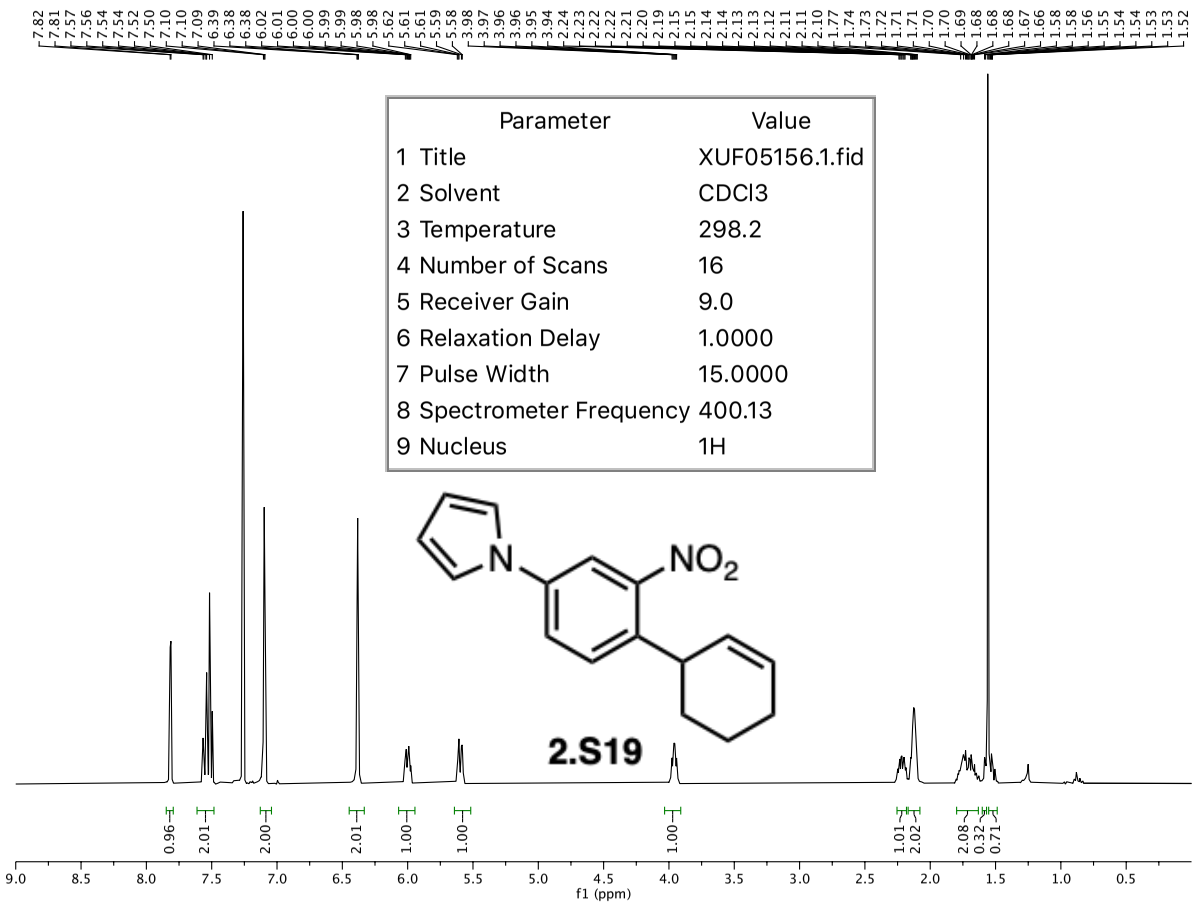

148.63
137.86
137.29
133.01
128.83
128.16
125.20
124.43
72.81
25.50
25.03
22.58
22.20
OH
NO2
2.S16
Parameter Value
1 Title XUF04142.3.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

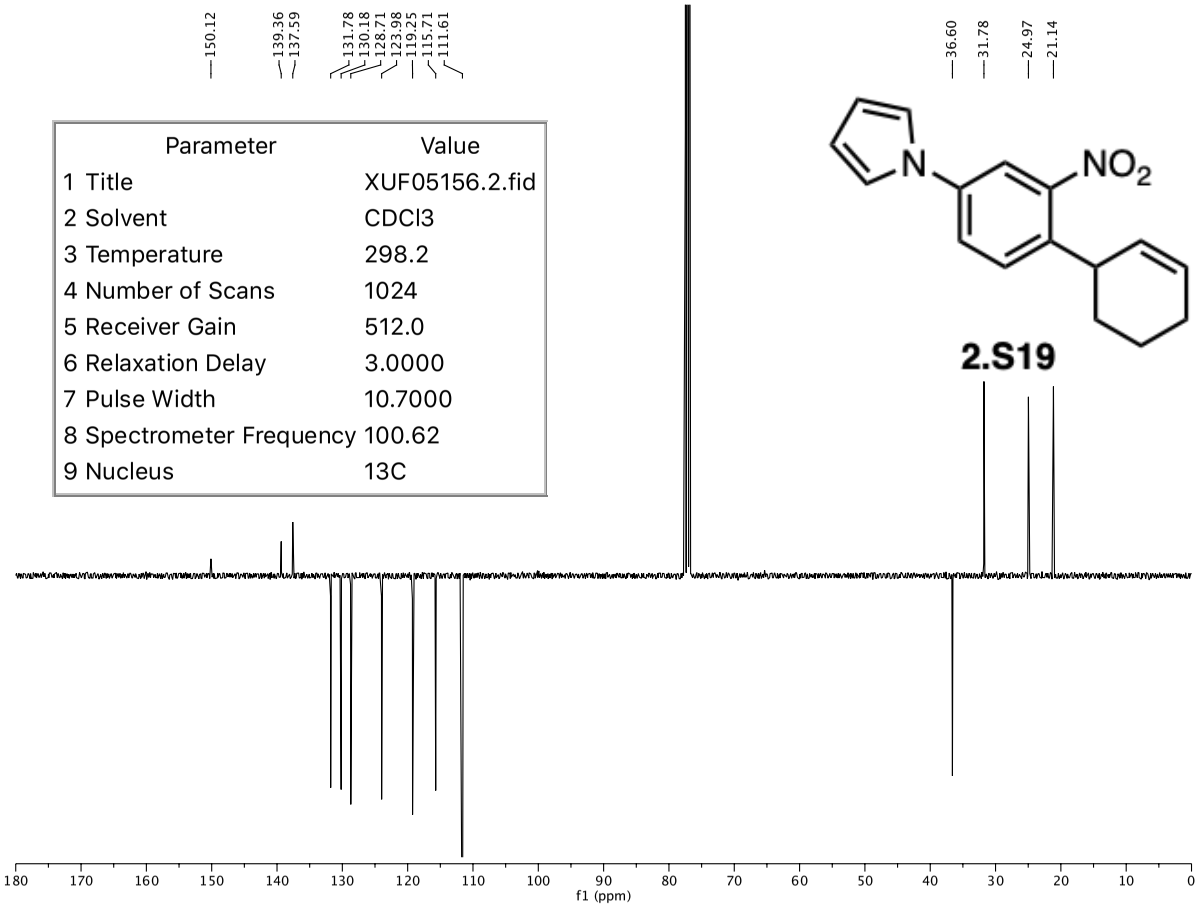

8.16 8.16 8.14 8.14 8.14 7.73 7.72 7.71 7.71 7.71 7.69 7.69 7.61 7.61 7.59 7.59 7.57 7.57 7.41 7.41 7.39 7.39 6.28 6.27 6.27 6.26 6.26 6.25 6.25
2.48 2.47 2.47 2.46 2.45 2.45 2.44 2.44 2.43 2.18 2.17 2.16 2.16 2.15 2.15 2.14 2.13 2.13
1.74 1.73 1.72 1.72 1.71 1.70 1.69 1.69 1.66 1.65 1.64 1.64 1.63 1.62 1.61
Parameter Value
1 Title XUF04146.3.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
O
2.S17
0.97 1.03 1.00 1.02 0.98 2.04 2.07 2.07 2.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

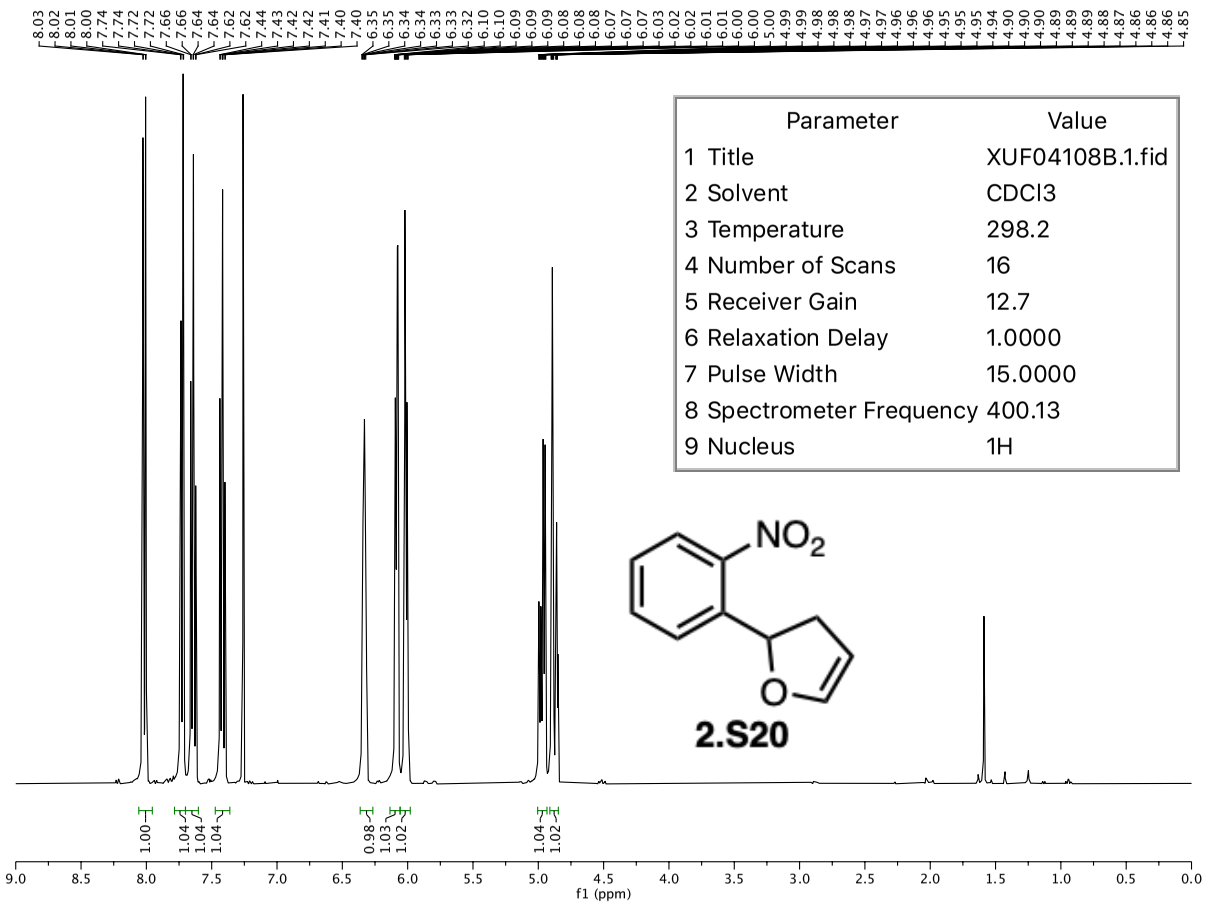

2.S17
NO2
O
Parameter Value
1 Title XUF04146.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
194.86
146.71
144.50
140.09
136.60
133.95
130.12
129.08
124.33
26.22
23.17
21.65
21.51
f1 (ppm)


Parameter Value
1 Title XUF05139.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Me
O
S
NO2
2.S18
f1 (ppm)


190.65
150.17
149.51
144.33
141.23
133.51
132.57
131.43
130.31
130.01
128.44
125.10
121.58
36.90
31.72
26.79
24.94
21.14
Parameter Value
1 Title XUF05139.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Me
O
S
NO2
2.S18
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

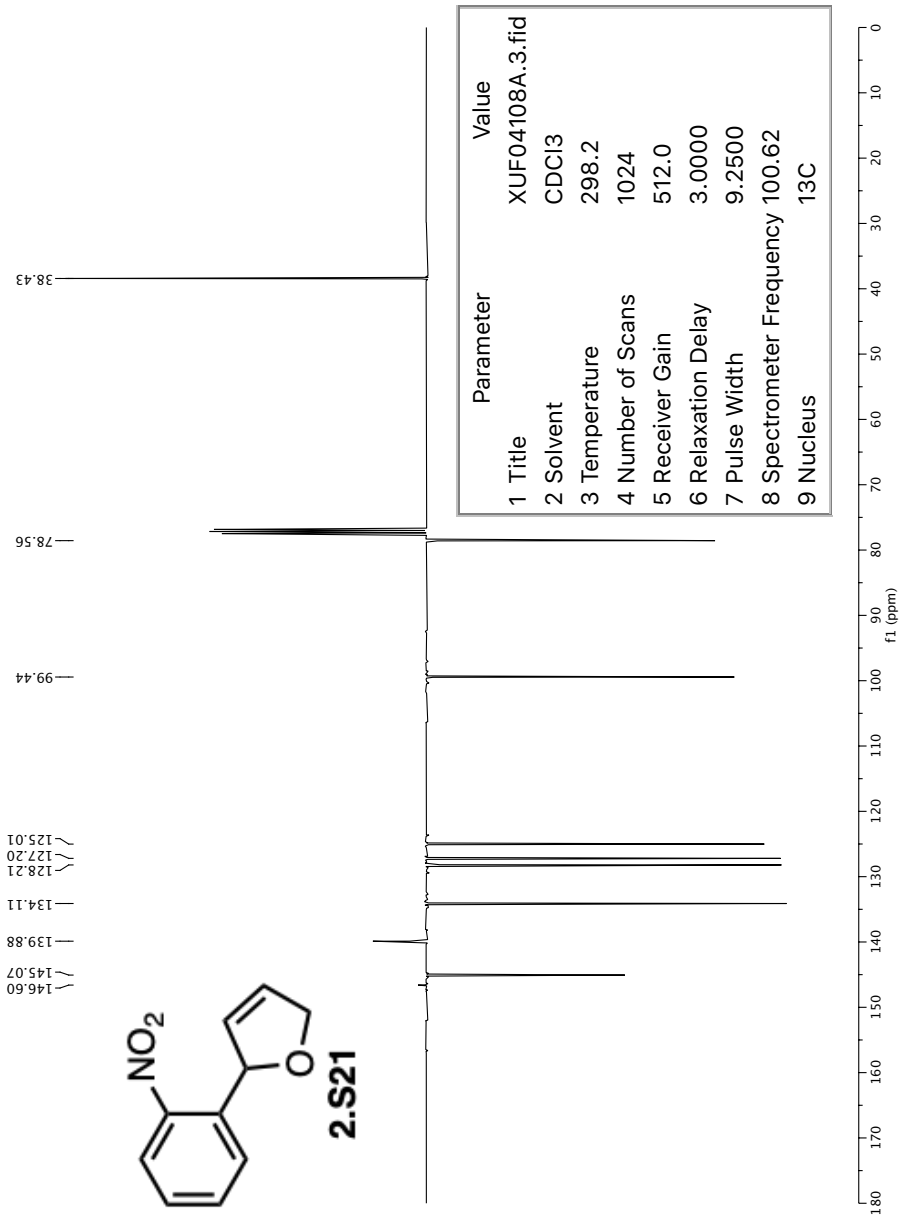

7.82 7.81 7.57 7.56 7.54 7.54 7.52 7.50 7.10 7.10 7.09 6.39 6.38 6.38 6.02 6.01 6.00 6.00 5.99 5.99 5.98 5.98 5.62 5.61 5.61 5.59 5.58 3.98 3.97 3.96 3.96 3.95 3.94 2.24 2.23 2.22 2.22 2.21 2.20 2.19 2.15 2.15 2.14 2.14 2.13 2.13 2.12 2.11 2.11 2.10 1.77 1.74 1.73 1.72 1.71 1.71 1.70 1.70 1.69 1.68 1.68 1.68 1.67 1.66 1.58 1.58 1.56 1.55 1.54 1.54 1.53 1.52
Parameter Value
1 Title XUF05156.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
N
NO2
2.S19
0.96 2.01 2.00 2.01 1.00 1.00 1.00 1.01 2.02 2.08 0.32 0.71
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

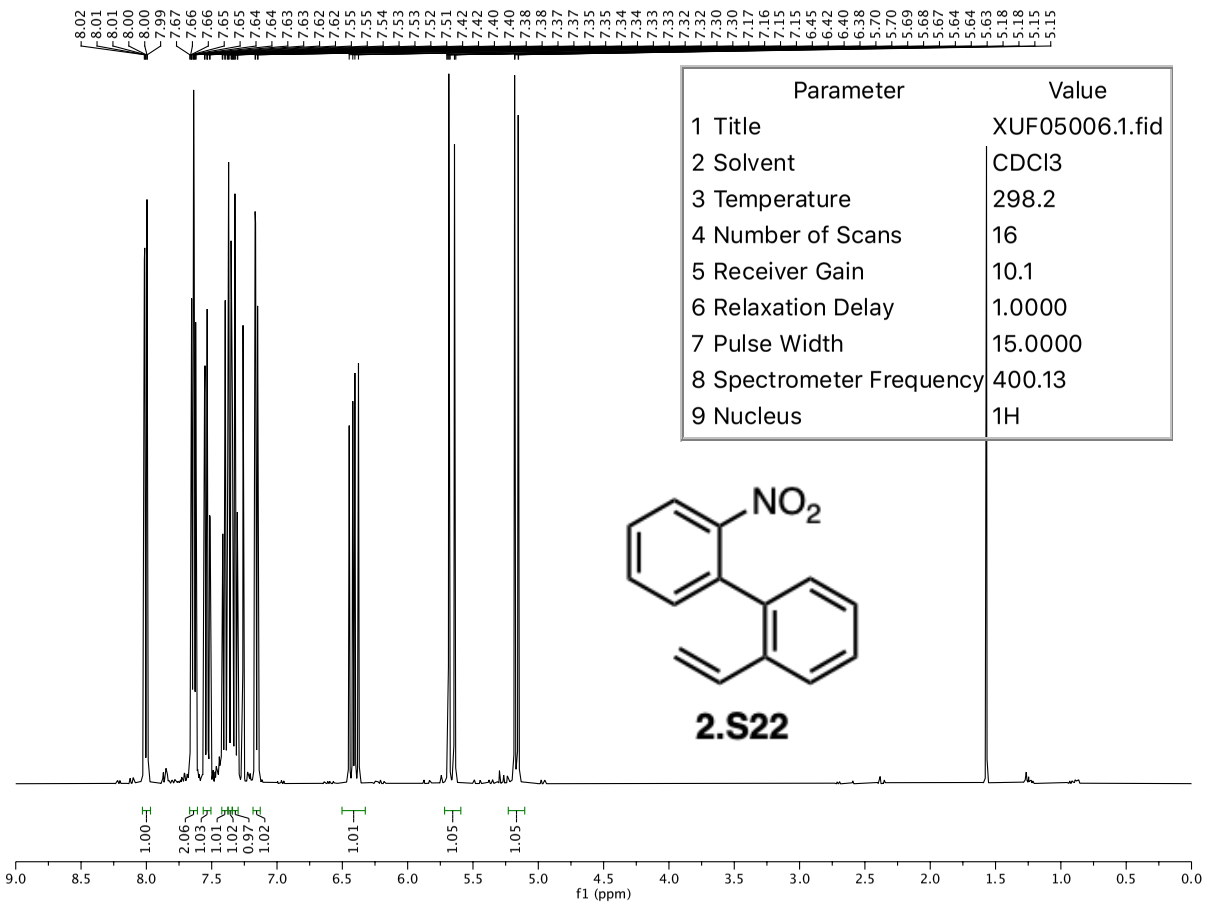

150.12
139.36
137.59
131.78
130.18
128.71
123.98
119.25
115.71
111.61
36.60
31.78
24.97
21.14
Parameter Value
1 Title XUF05156.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
N
NO2
2.S19
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

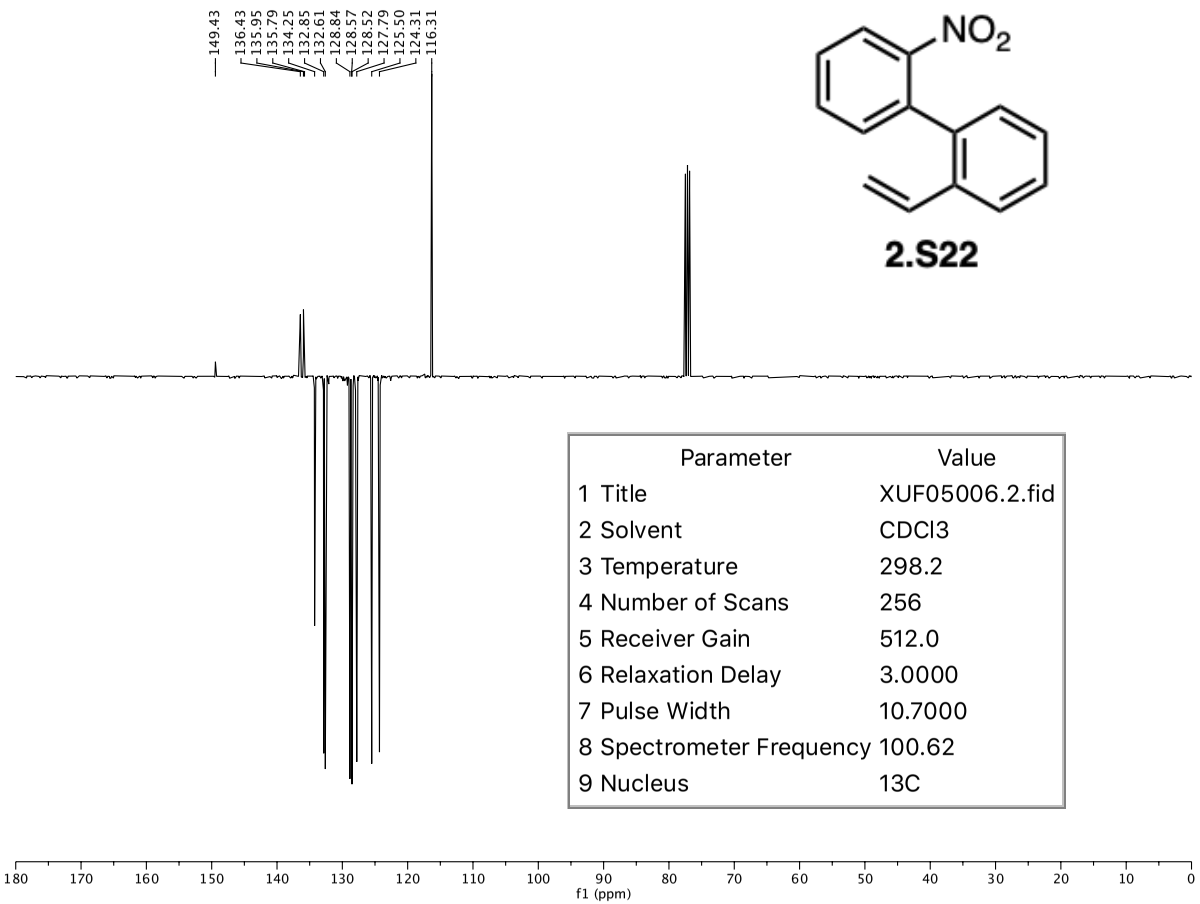

8.03 8.02 8.01 8.00 7.74 7.74 7.72 7.72 7.66 7.66 7.64 7.64 7.62 7.62 7.44 7.43 7.42 7.42 7.41 7.40 7.40 6.35 6.34 6.34 6.33 6.33 6.32 6.10 6.10 6.09 6.09 6.09 6.08 6.08 6.08 6.07 6.07 6.07 6.03 6.02 6.02 6.01 6.01 6.00 6.00 6.00 5.00 4.99 4.99 4.98 4.98 4.98 4.97 4.97 4.96 4.96 4.96 4.95 4.95 4.95 4.94 4.90 4.90 4.90 4.89 4.89 4.88 4.87 4.86 4.86 4.86 4.85
Parameter Value
1 Title XUF04108B.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
O
2.S20
1.00 1.04 1.04 1.04 0.98 1.03 1.02 1.04 1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

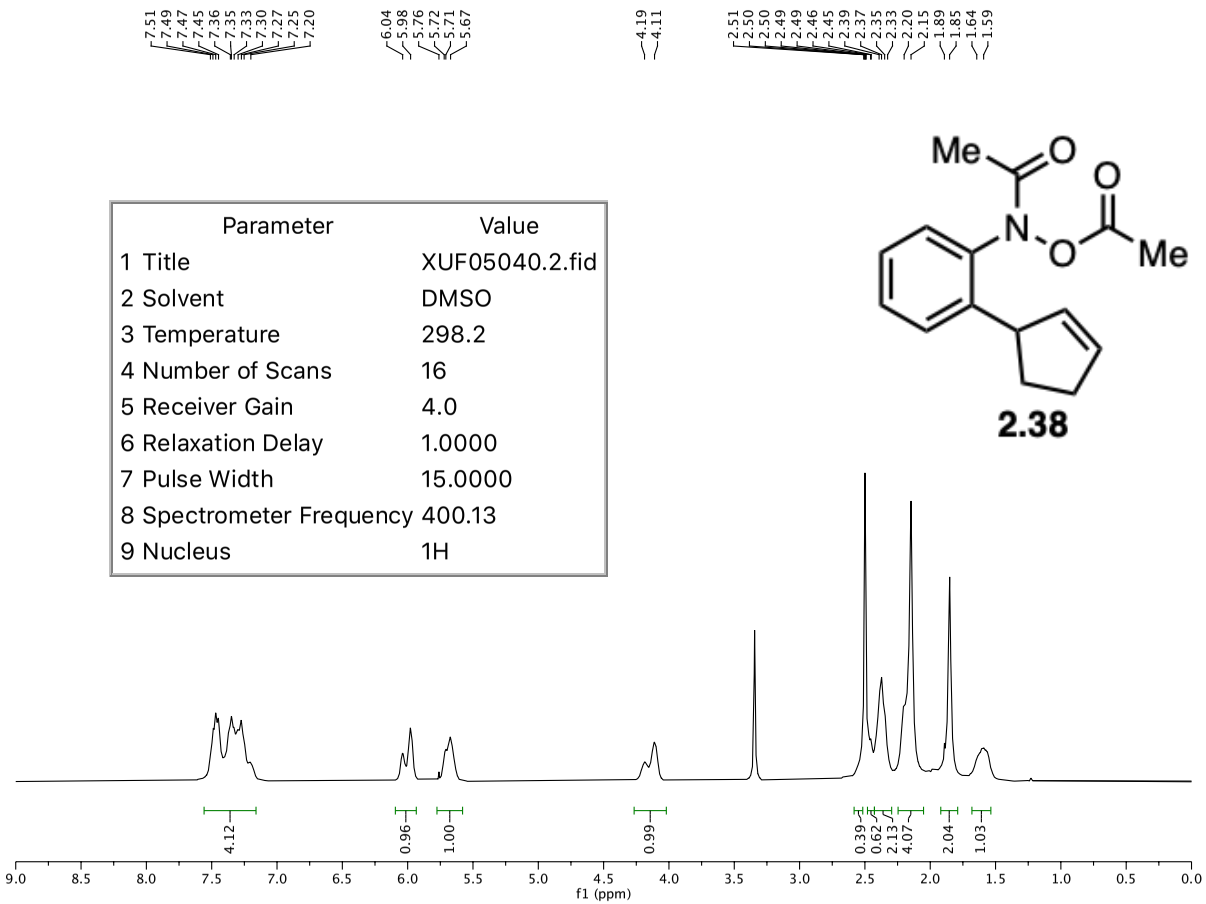
146.98
139.27
134.15
129.69
128.23
128.20
126.87
124.53
84.44
76.80
NO2
O
2.S20
Parameter Value
1 Title XUF04108B.5.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

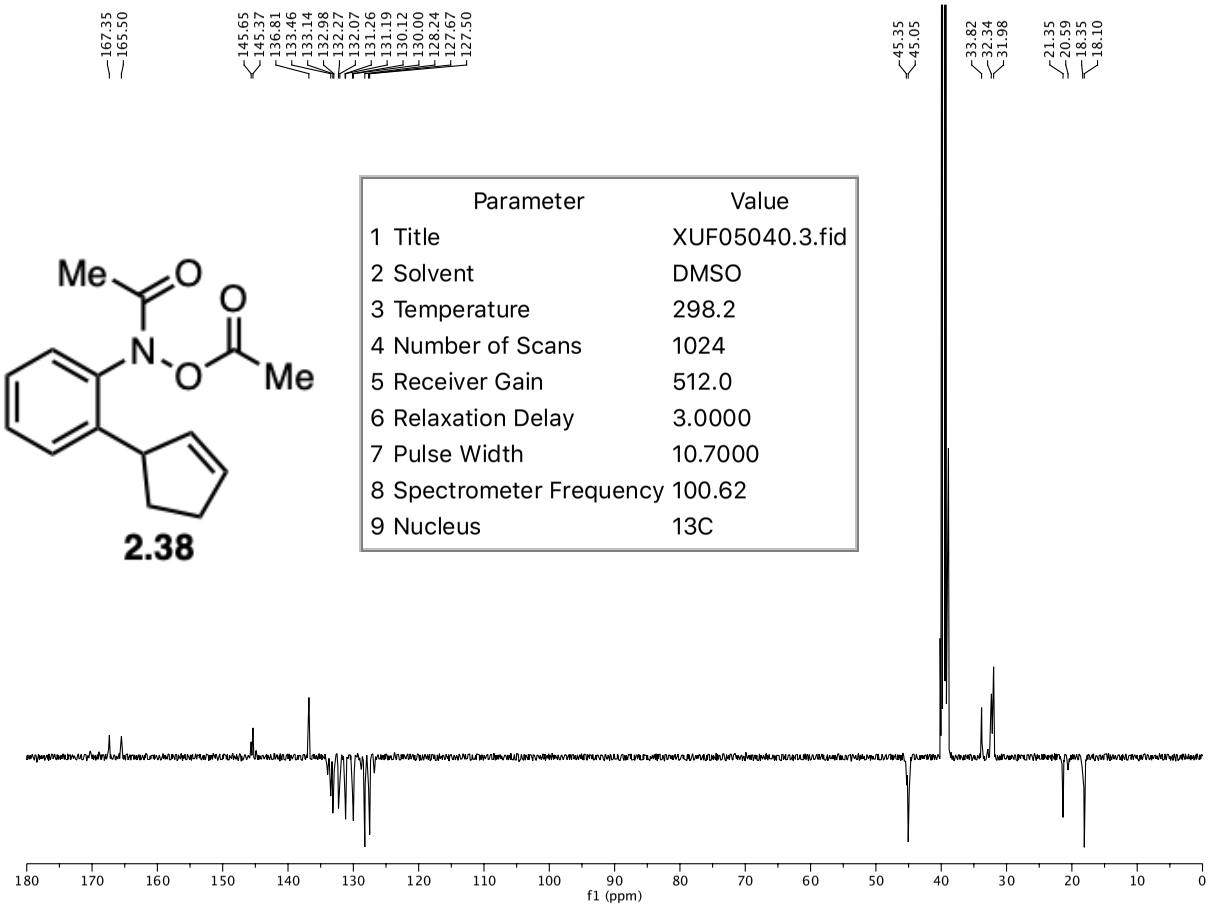
Parameter Value
1 Title XUF04108A.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
NO2
O
2.S21
f1 (ppm)

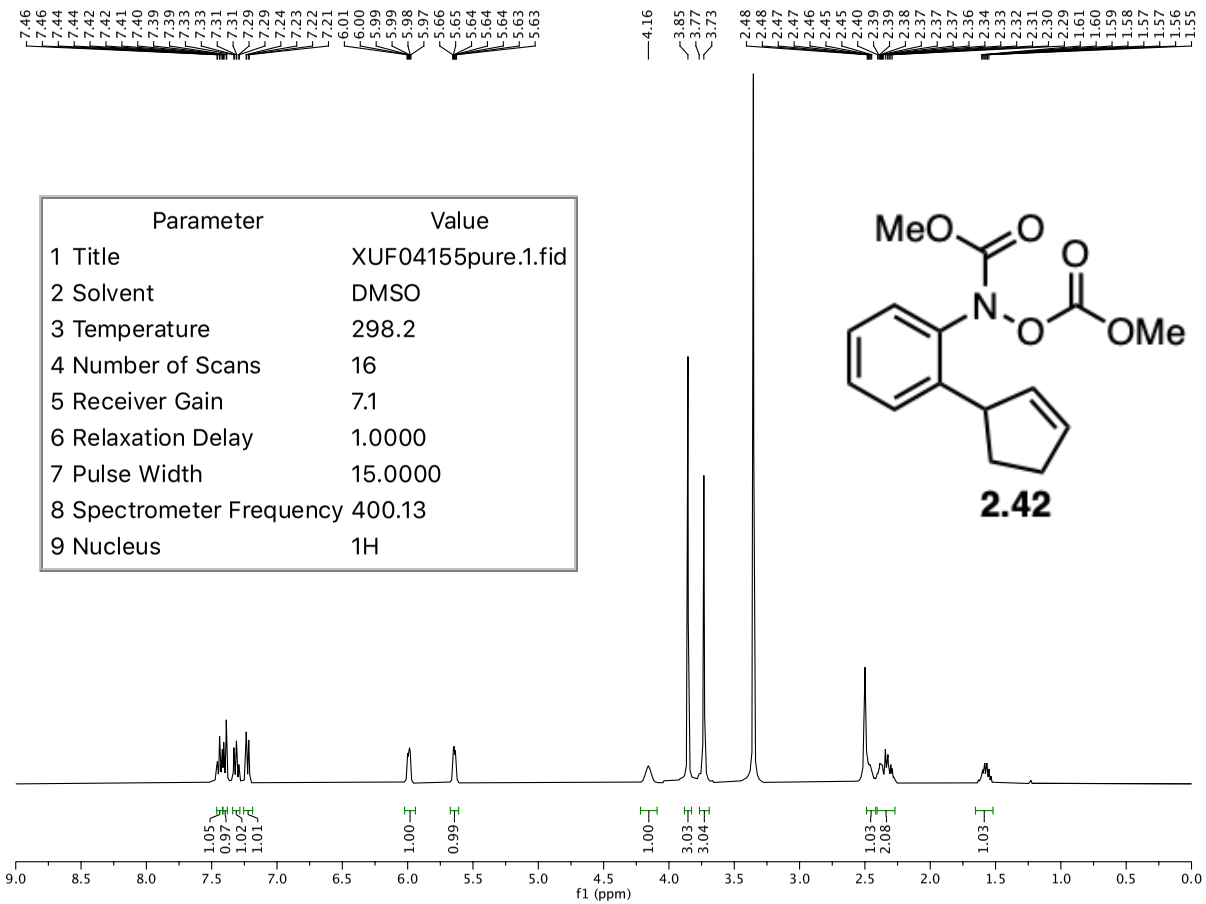

Parameter Value
1 Title XUF04108A.3.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
38.43
78.56
99.44
125.01
127.20
128.21
134.11
139.88
145.07
146.60
NO2
O
2.S21
f1 (ppm)

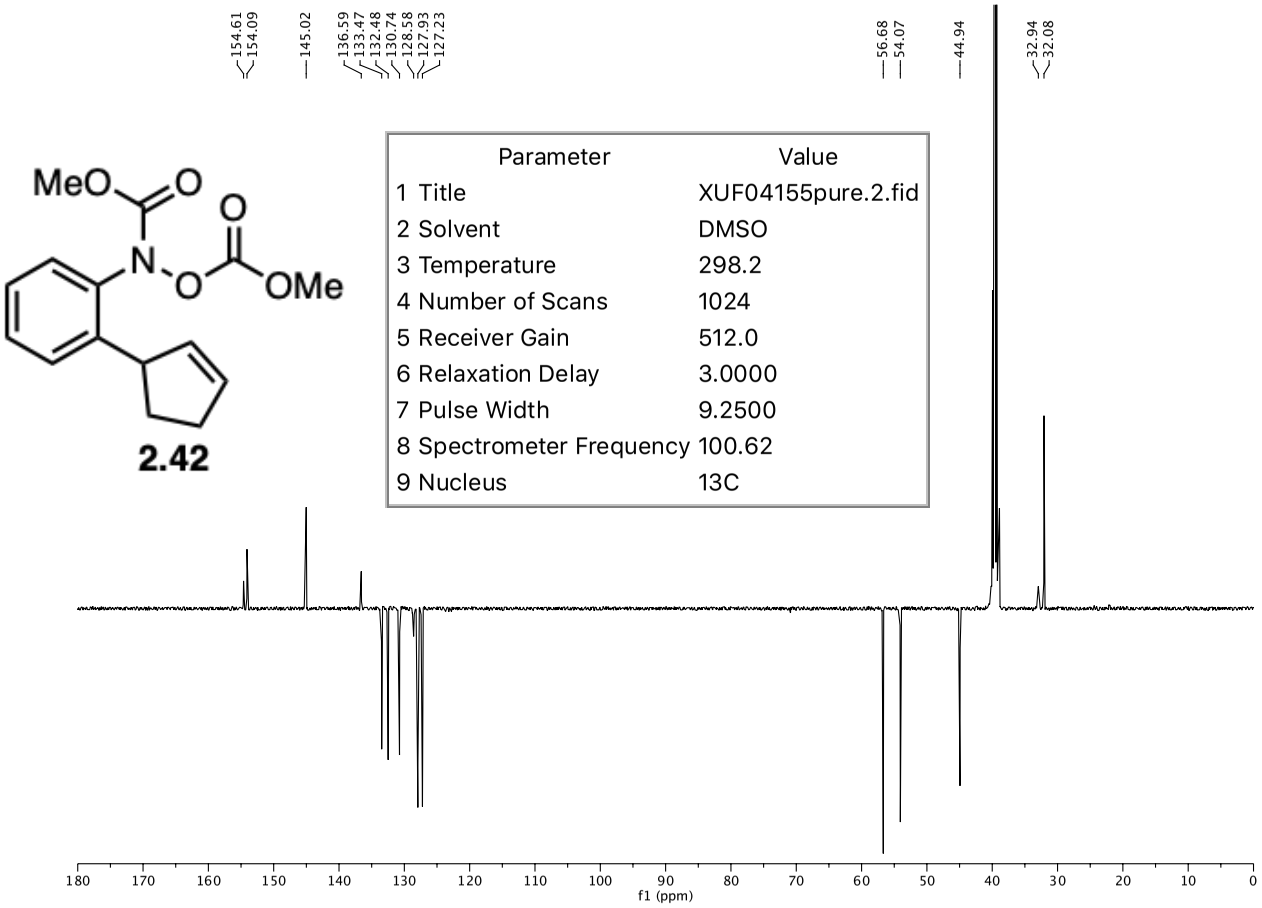

8.02 8.01 8.01 8.00 8.00 8.00 7.99 7.67 7.66 7.66 7.65 7.65 7.64 7.64 7.63 7.63 7.62 7.62 7.55 7.55 7.54 7.53 7.53 7.52 7.51 7.42 7.42 7.40 7.40 7.38 7.38 7.37 7.37 7.35 7.35 7.34 7.34 7.33 7.33 7.32 7.32 7.30 7.30 7.17 7.16 7.15 7.15 6.45 6.42 6.40 6.38 5.70 5.70 5.69 5.68 5.67 5.64 5.64 5.63 5.18 5.18 5.15 5.15
Parameter | Value
1 Title | XUF05006.1.fid
2 Solvent | CDCl3
3 Temperature | 298.2
4 Number of Scans | 16
5 Receiver Gain | 10.1
6 Relaxation Delay | 1.0000
7 Pulse Width | 15.0000
8 Spectrometer Frequency | 400.13
9 Nucleus | 1H
NO2
2.S22
1.00 2.06 1.03 1.01 1.02 0.97 1.02 1.01 1.05 1.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

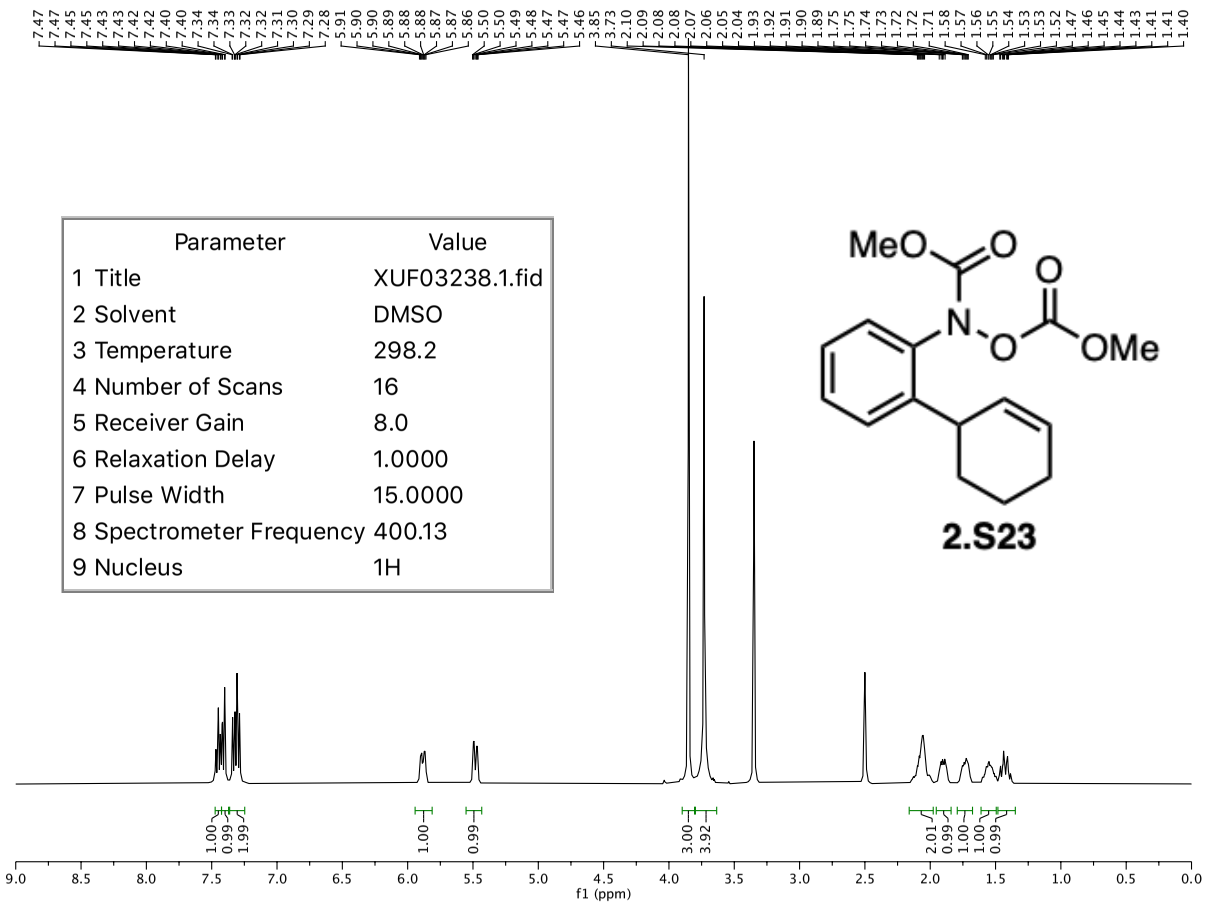

149.43
136.43
135.95
135.79
134.25
132.85
132.61
128.84
128.57
128.52
127.79
125.50
124.31
116.31
NO2
2.S22
Parameter Value
1 Title XUF05006.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 256
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

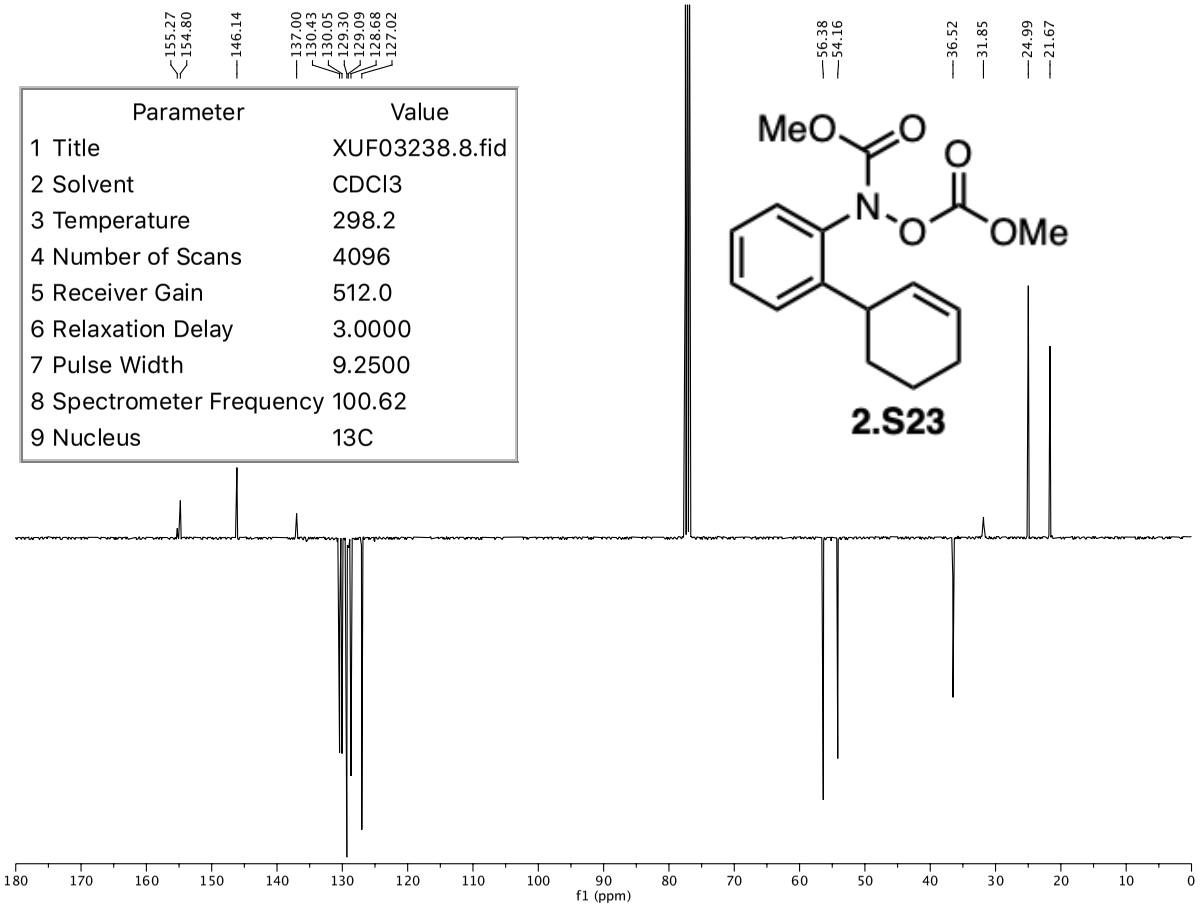

7.51
7.49
7.47
7.45
7.36
7.35
7.33
7.30
7.27
7.25
7.20
6.04
5.98
5.76
5.72
5.71
5.67
4.19
4.11
2.51
2.50
2.50
2.49
2.49
2.46
2.45
2.39
2.37
2.35
2.33
2.20
2.15
1.89
1.85
1.64
1.59
Parameter Value
1 Title XUF05040.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Me
O
O
N
O
Me
2.38
4.12
0.96
1.00
0.99
0.39
0.62
2.13
4.07
2.04
1.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

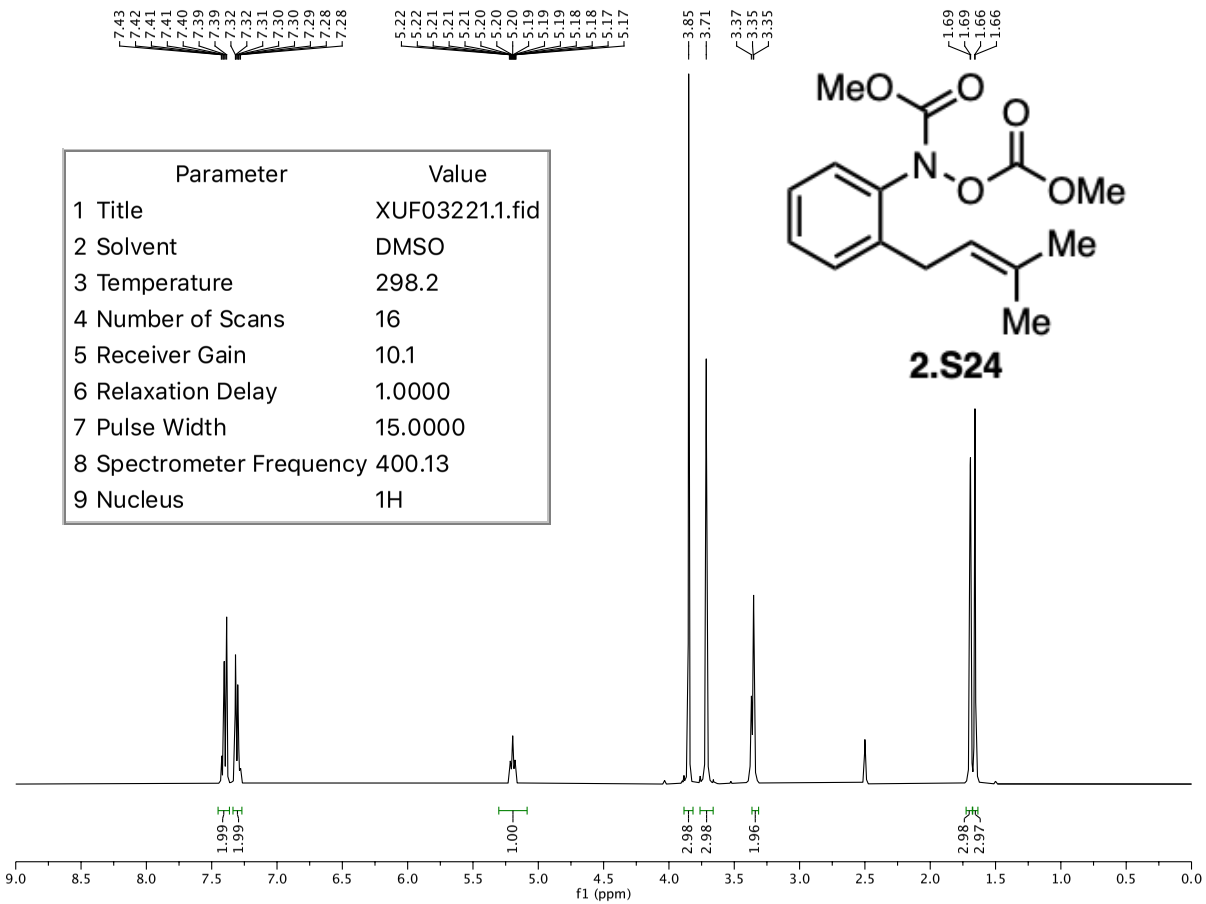

167.35
165.50
145.65
145.37
136.81
133.46
133.14
132.98
132.27
132.07
131.26
131.19
130.12
130.00
128.24
127.67
127.50
45.35
45.05
33.82
32.34
31.98
21.35
20.59
18.35
18.10
Me
O
O
N
O
Me
2.38
Parameter Value
1 Title XUF05040.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

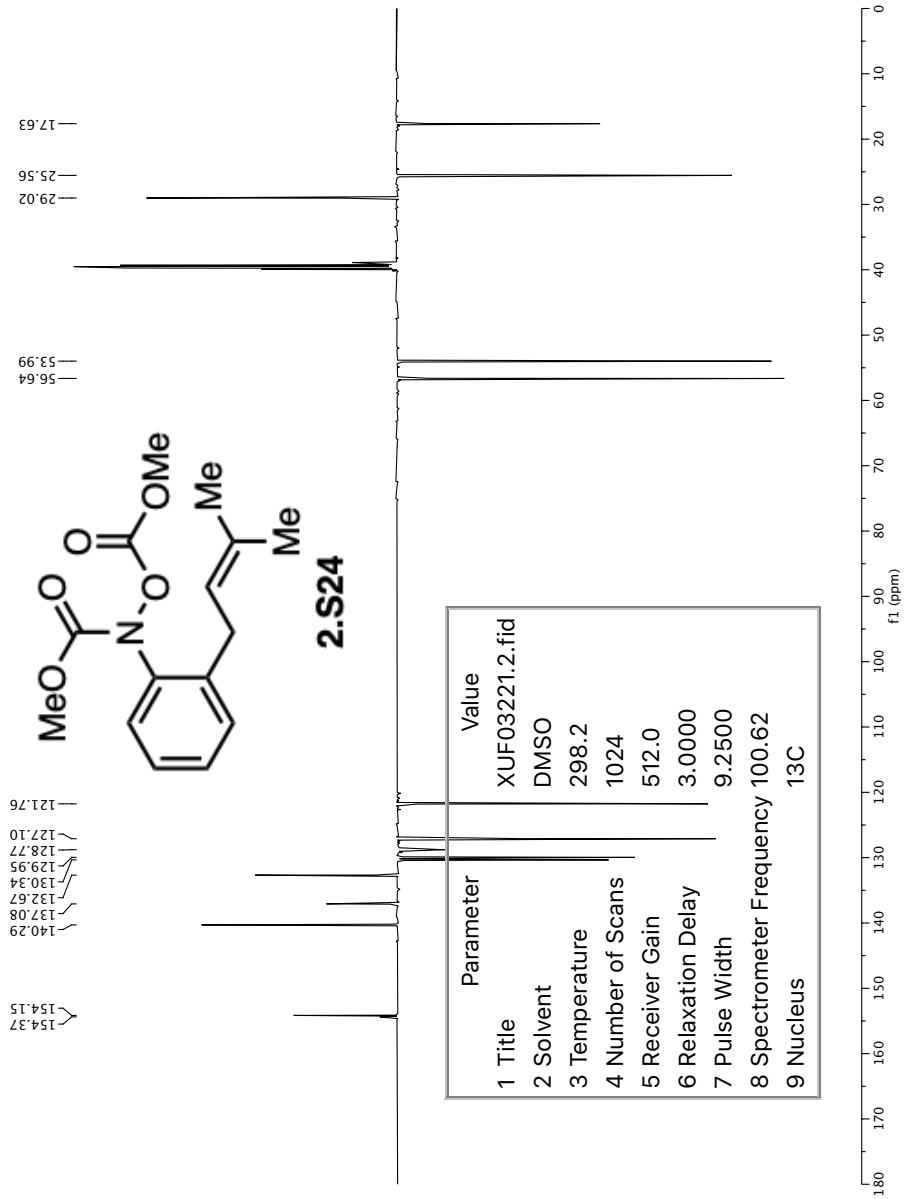

7.46 7.46 7.44 7.44 7.42 7.42 7.41 7.40 7.39 7.39 7.33 7.33 7.31 7.31 7.29 7.29 7.24 7.23 7.22 7.21 6.01 6.00 5.99 5.99 5.98 5.97 5.66 5.65 5.64 5.64 5.64 5.63 5.63
4.16 3.85 3.77 3.73
2.48 2.48 2.47 2.47 2.46 2.45 2.45 2.40 2.39 2.39 2.38 2.37 2.37 2.37 2.36 2.34 2.33 2.32 2.31 2.30 2.29 1.61 1.60 1.59 1.58 1.57 1.57 1.56 1.55
Parameter Value
1 Title XUF04155pure.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
O
OMe
2.42
1.05 0.97 1.02 1.01 1.00 0.99 1.00 3.03 3.04 1.03 2.08 1.03
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

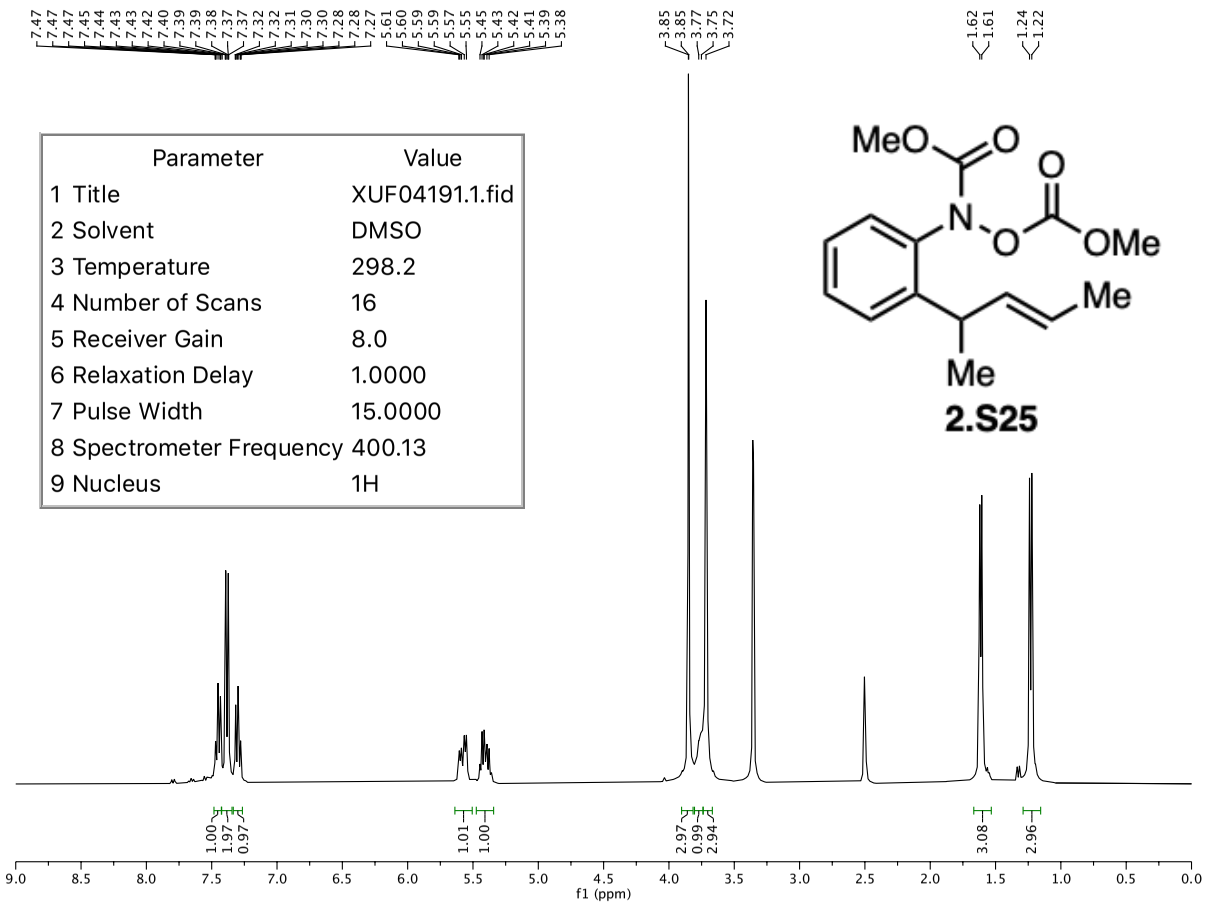

154.61
154.09
145.02
136.59
133.47
132.48
130.74
128.58
127.93
127.23
56.68
54.07
44.94
32.94
32.08
MeO
O
O
N
O
OMe
2.42
Parameter Value
1 Title XUF04155pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.47 7.47 7.45 7.45 7.43 7.43 7.42 7.42 7.40 7.40 7.34 7.34 7.33 7.32 7.32 7.31 7.30 7.29 7.28 5.91 5.90 5.90 5.89 5.88 5.88 5.87 5.87 5.86 5.50 5.50 5.49 5.48 5.47 5.47 5.46 3.85 3.73 3.73 2.10 2.09 2.08 2.08 2.07 2.06 2.05 2.04 1.93 1.92 1.91 1.90 1.89 1.75 1.75 1.74 1.73 1.72 1.72 1.71 1.58 1.57 1.56 1.55 1.54 1.53 1.53 1.52 1.47 1.46 1.45 1.44 1.43 1.41 1.41 1.40
Parameter Value
1 Title XUF03238.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
O
OMe
2.S23
1.00 0.99 1.99 1.00 0.99 3.00 3.92 2.01 0.99 1.00 0.99
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

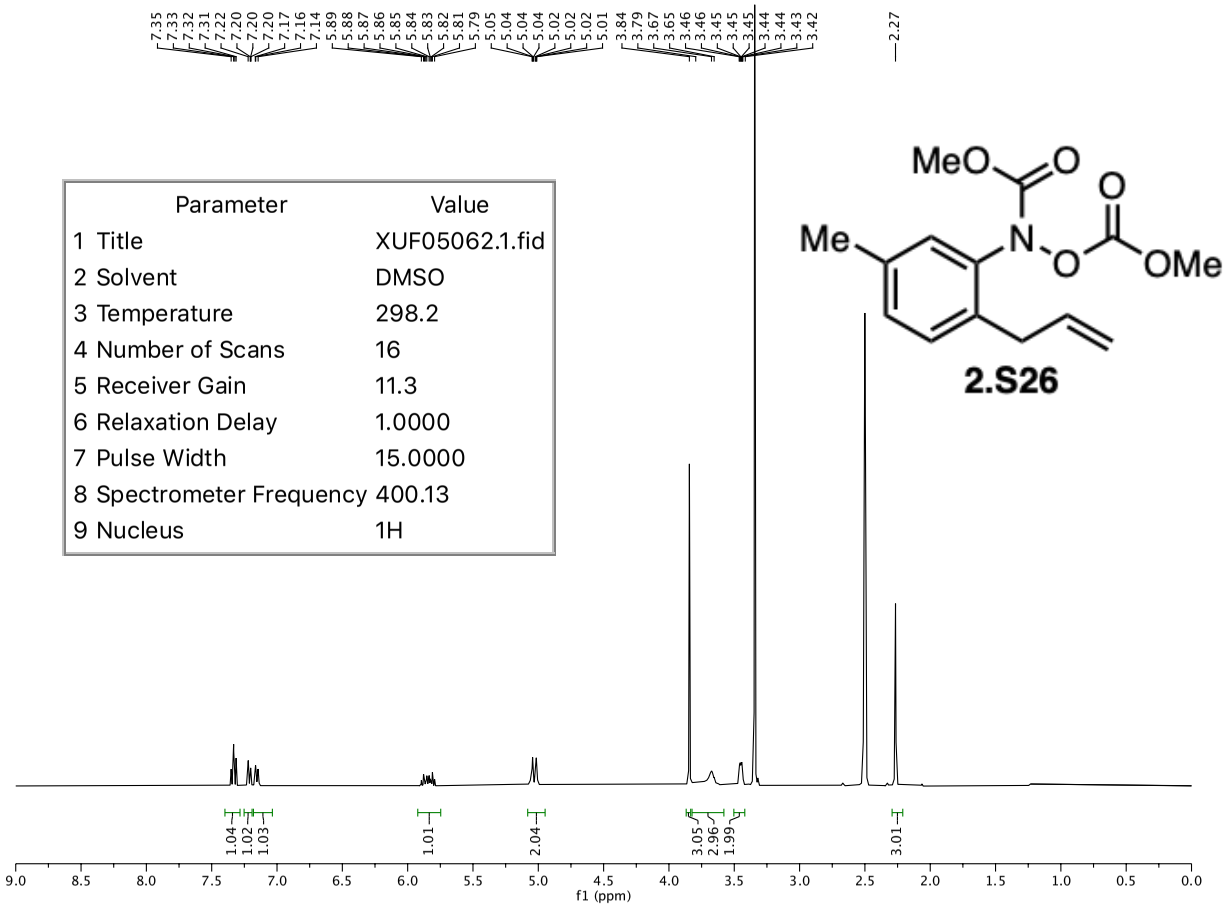

155.27
154.80
146.14
137.00
130.43
130.05
129.30
129.09
128.68
127.02
56.38
54.16
36.52
31.85
24.99
21.67
Parameter Value
1 Title XUF03238.8.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
O
O
OMe
2.S23
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

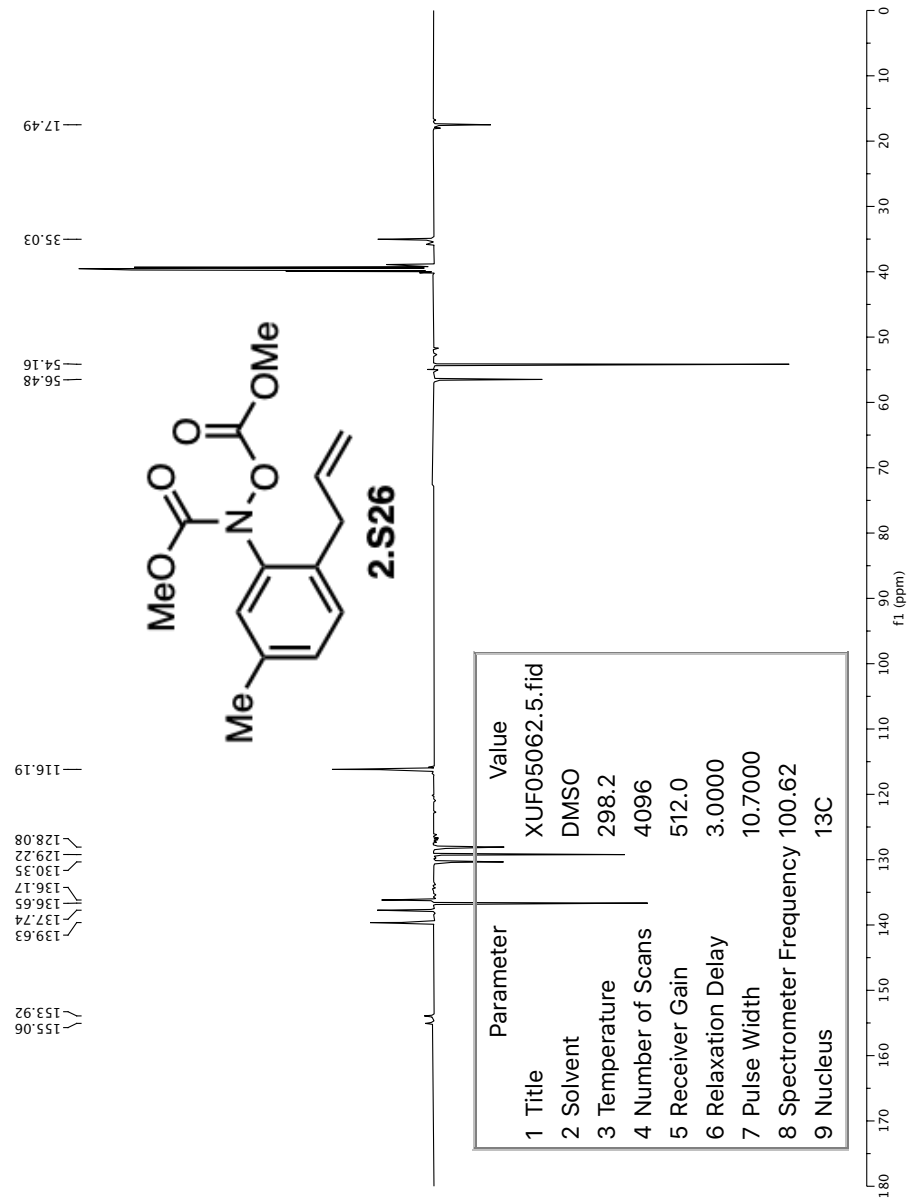

7.43
7.42
7.41
7.41
7.40
7.39
7.39
7.32
7.32
7.31
7.30
7.30
7.29
7.28
7.28
5.22
5.22
5.21
5.21
5.21
5.20
5.20
5.20
5.19
5.19
5.19
5.18
5.18
5.17
5.17
3.85
3.71
3.37
3.35
3.35
1.69
1.69
1.66
1.66
Parameter Value
1 Title XUF03221.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
Me
Me
2.S24
1.99
1.99
1.00
2.98
2.98
1.96
2.98
2.97
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

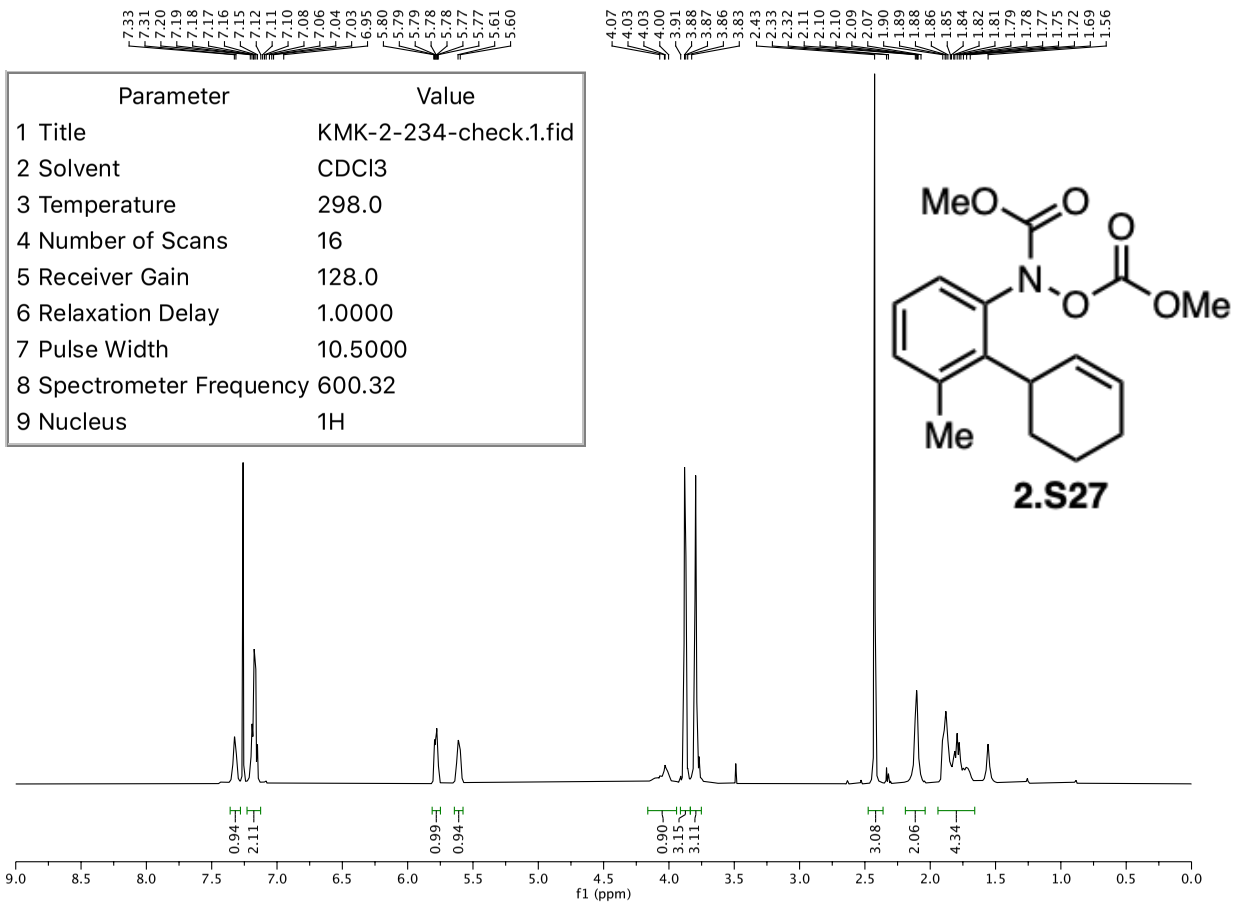

MeO
O
O
N
O
O
OMe
Me
Me
2.S24
154.37
154.15
140.29
137.08
132.67
130.34
129.95
128.77
127.10
121.76
56.64
53.99
29.02
25.56
17.63
Parameter
Value
1 Title
XUF03221.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

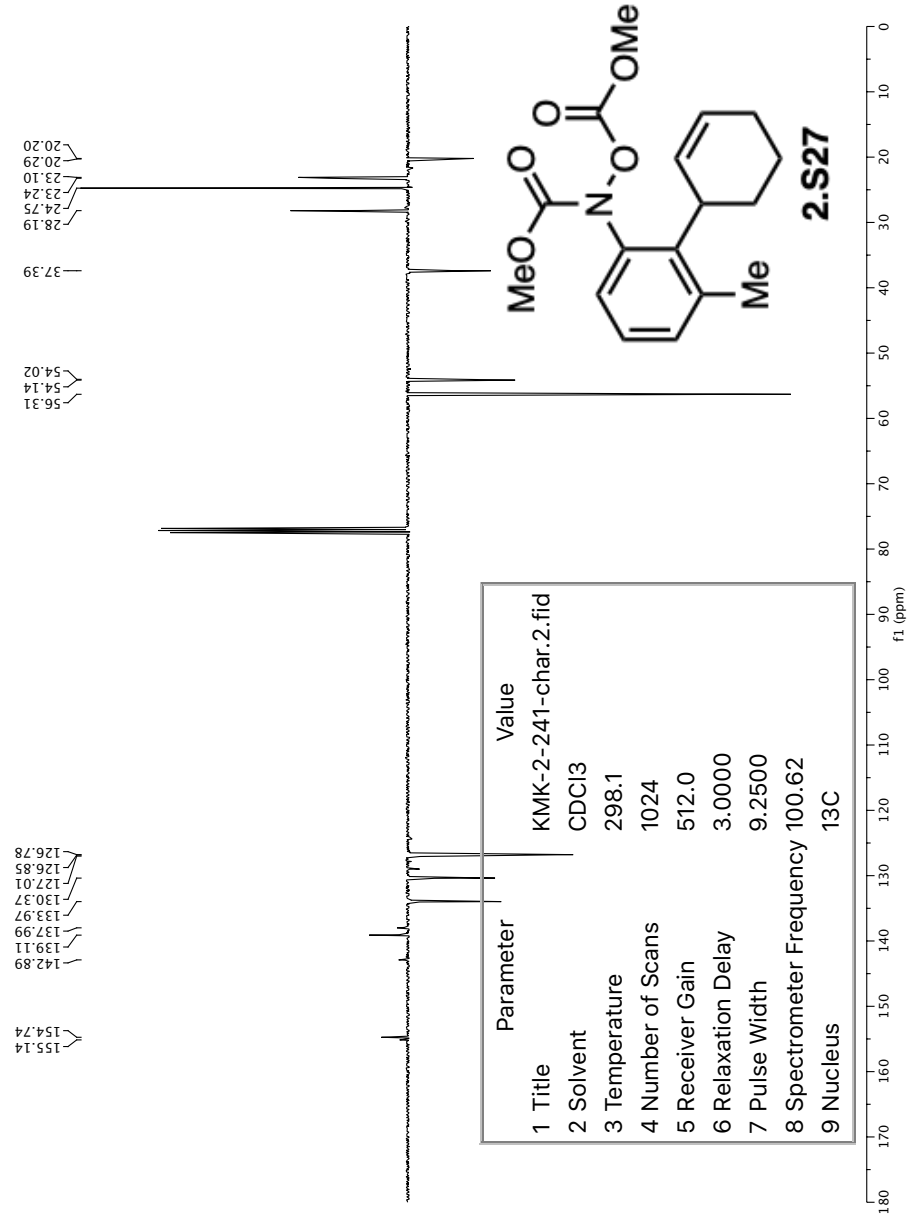

7.47 7.47 7.47 7.45 7.44 7.43 7.43 7.42 7.40 7.39 7.39 7.38 7.37 7.37 7.32 7.32 7.31 7.30 7.30 7.28 7.28 7.27
5.61 5.60 5.59 5.59 5.57 5.55 5.45 5.43 5.42 5.41 5.39 5.38
3.85 3.85 3.77 3.75 3.72
1.62 1.61
1.24 1.22
Parameter Value
1 Title XUF04191.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
Me
Me
2.S25
1.00 1.97 0.97 1.01 1.00 2.97 0.99 2.94 3.08 2.96
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

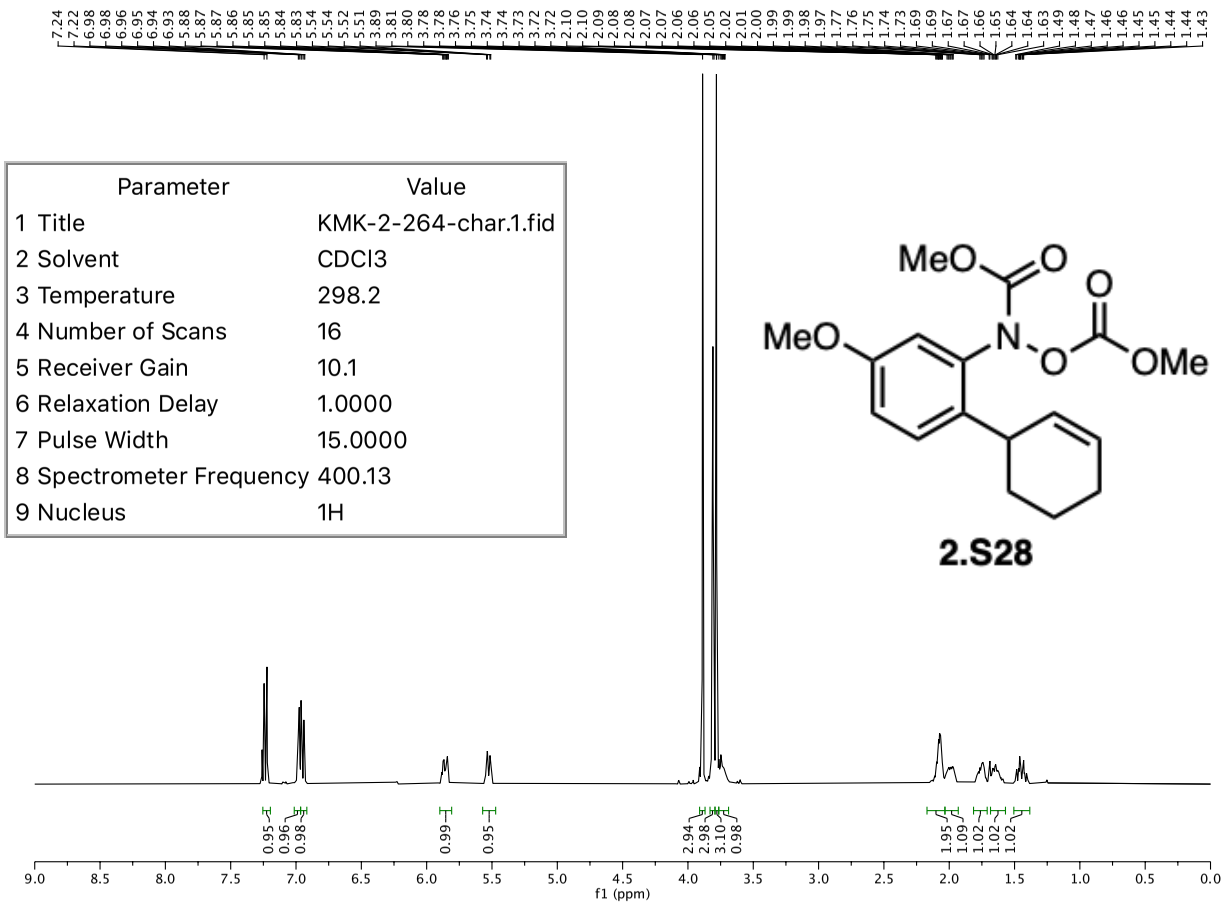
17.73
21.34
35.69
54.04
56.62
123.66
127.06
128.09
128.87
130.64
135.10
136.26
145.27
154.05
154.74
Parameter Value
1 Title XUF04191.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
O
N
O
O
OMe
Me
Me
2.S25
f1 (ppm)

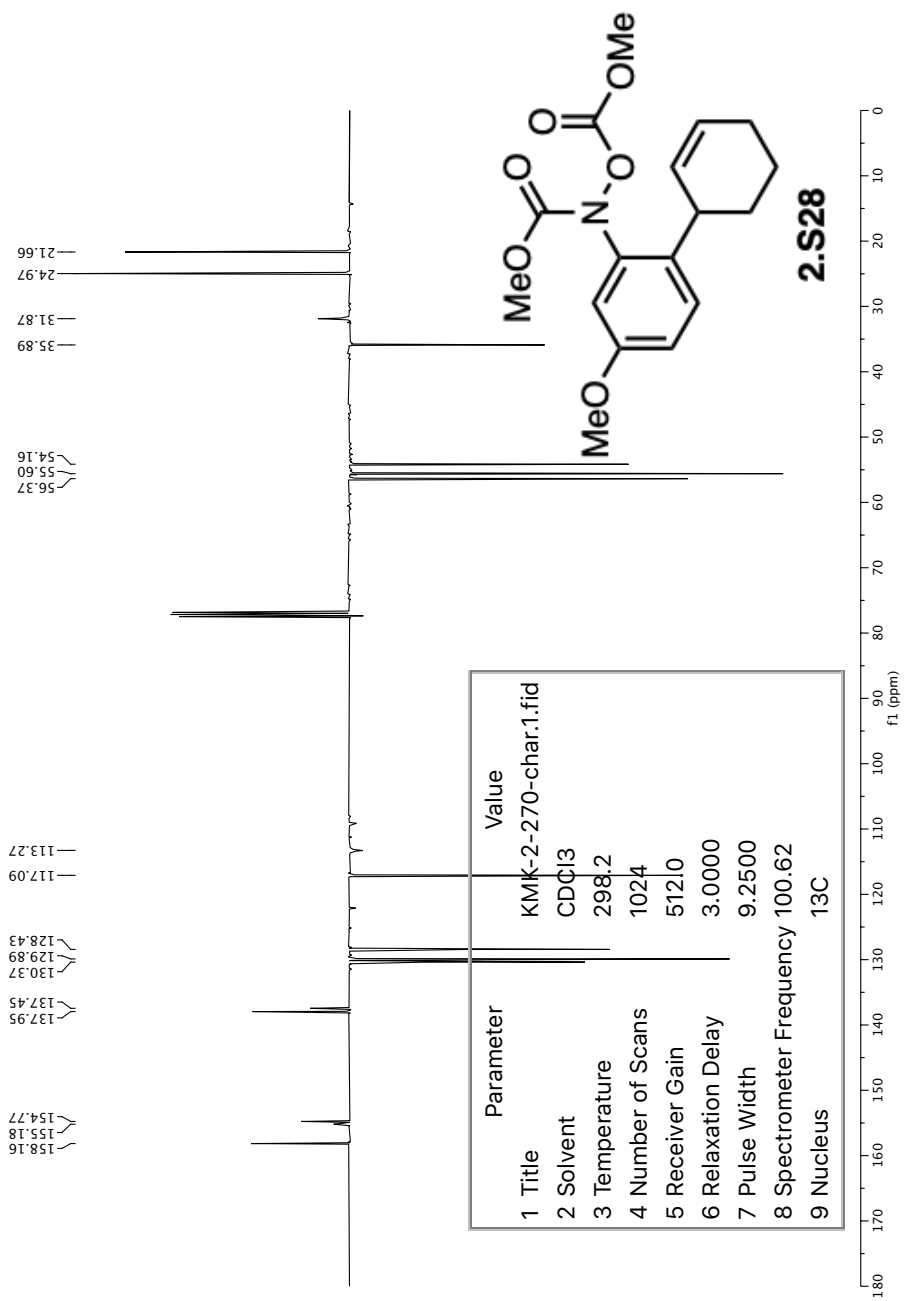

7.35 7.33 7.32 7.31 7.22 7.20 7.20 7.20 7.17 7.16 7.14 5.89 5.88 5.87 5.86 5.85 5.84 5.83 5.82 5.81 5.79 5.05 5.04 5.04 5.04 5.02 5.02 5.02 5.01 3.84 3.79 3.67 3.65 3.46 3.46 3.45 3.45 3.45 3.44 3.44 3.43 3.42 2.27
Parameter Value
1 Title XUF05062.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
Me
N
O
OMe
2.S26
1.04 1.02 1.03 1.01 2.04 3.05 2.96 1.99 3.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

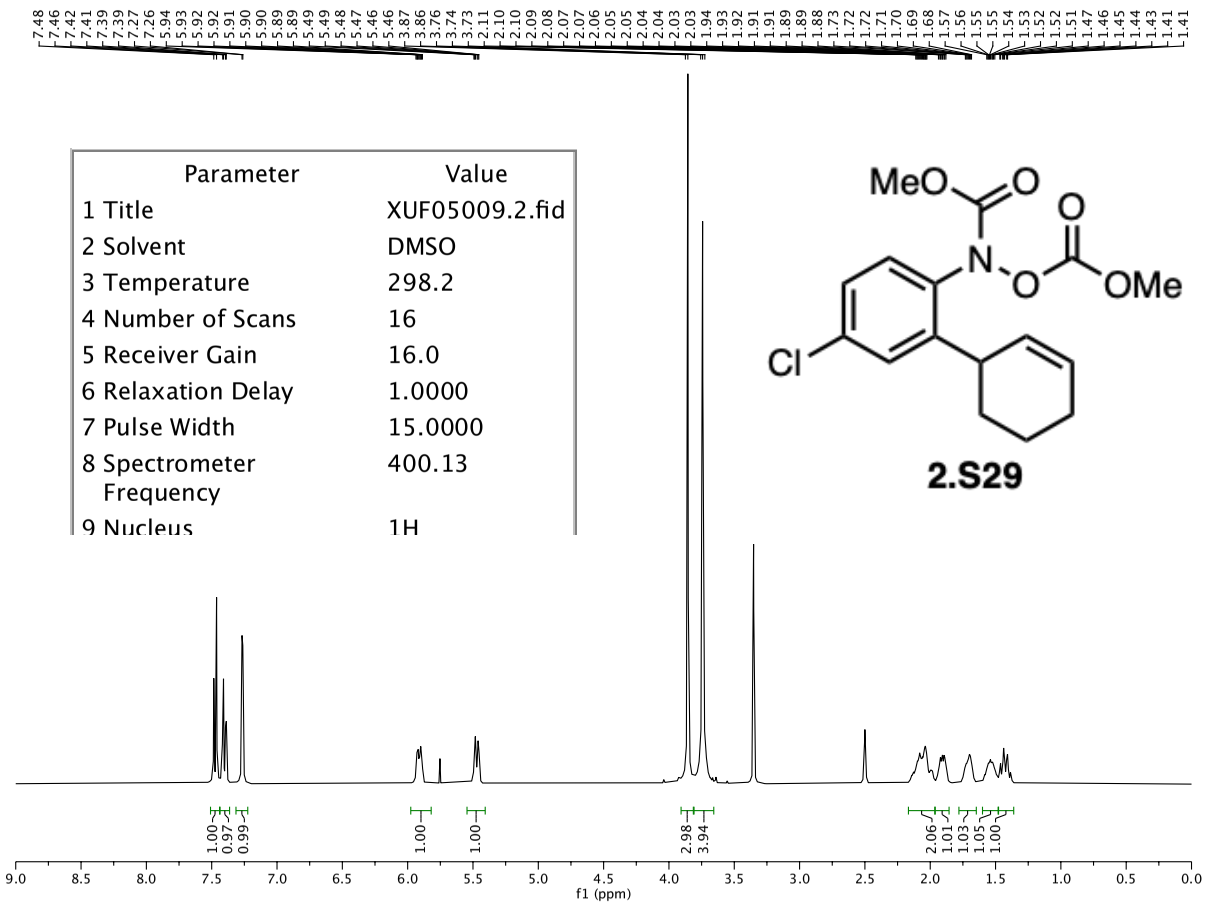

17.49
35.03
54.16
56.48
116.19
128.08
129.22
130.35
136.17
136.65
137.74
139.63
153.92
155.06
MeO
OMe
Me
2.S26
Parameter
Value
1 Title
XUF05062.5.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)


7.33
7.31
7.20
7.19
7.18
7.17
7.16
7.15
7.12
7.11
7.10
7.08
7.06
7.04
7.03
6.95
5.80
5.79
5.79
5.78
5.78
5.77
5.77
5.61
5.60
4.07
4.03
4.03
4.00
3.91
3.88
3.87
3.86
3.83
2.43
2.33
2.32
2.11
2.10
2.10
2.09
2.07
1.90
1.89
1.88
1.86
1.85
1.84
1.82
1.81
1.79
1.78
1.77
1.75
1.72
1.69
1.56
Parameter
Value
1 Title
KMK-2-234-check.1.fid
2 Solvent
CDCl3
3 Temperature
298.0
4 Number of Scans
16
5 Receiver Gain
128.0
6 Relaxation Delay
1.0000
7 Pulse Width
10.5000
8 Spectrometer Frequency
600.32
9 Nucleus
1H
MeO
O
O
N
O
OMe
Me
2.S27
0.94
2.11
0.99
0.94
0.90
3.15
3.11
3.08
2.06
4.34
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

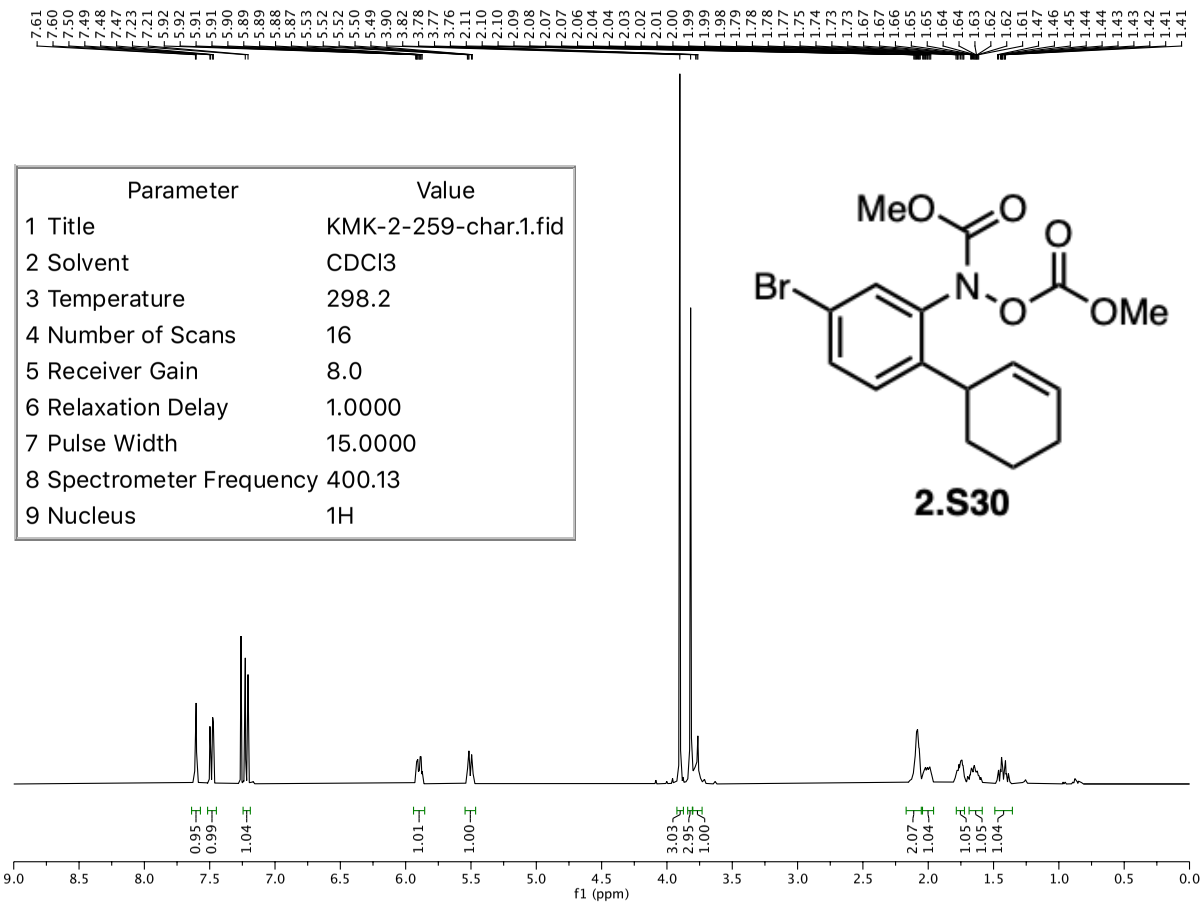

155.14
154.74
142.89
139.11
137.99
133.97
130.37
127.01
126.85
126.78
56.31
54.14
54.02
37.39
28.19
24.75
23.24
23.10
20.29
20.20
MeO
OMe
Me
2.S27
Parameter
Value
1 Title
KMK-2-241-char.2.fid
2 Solvent
CDCl3
3 Temperature
298.1
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

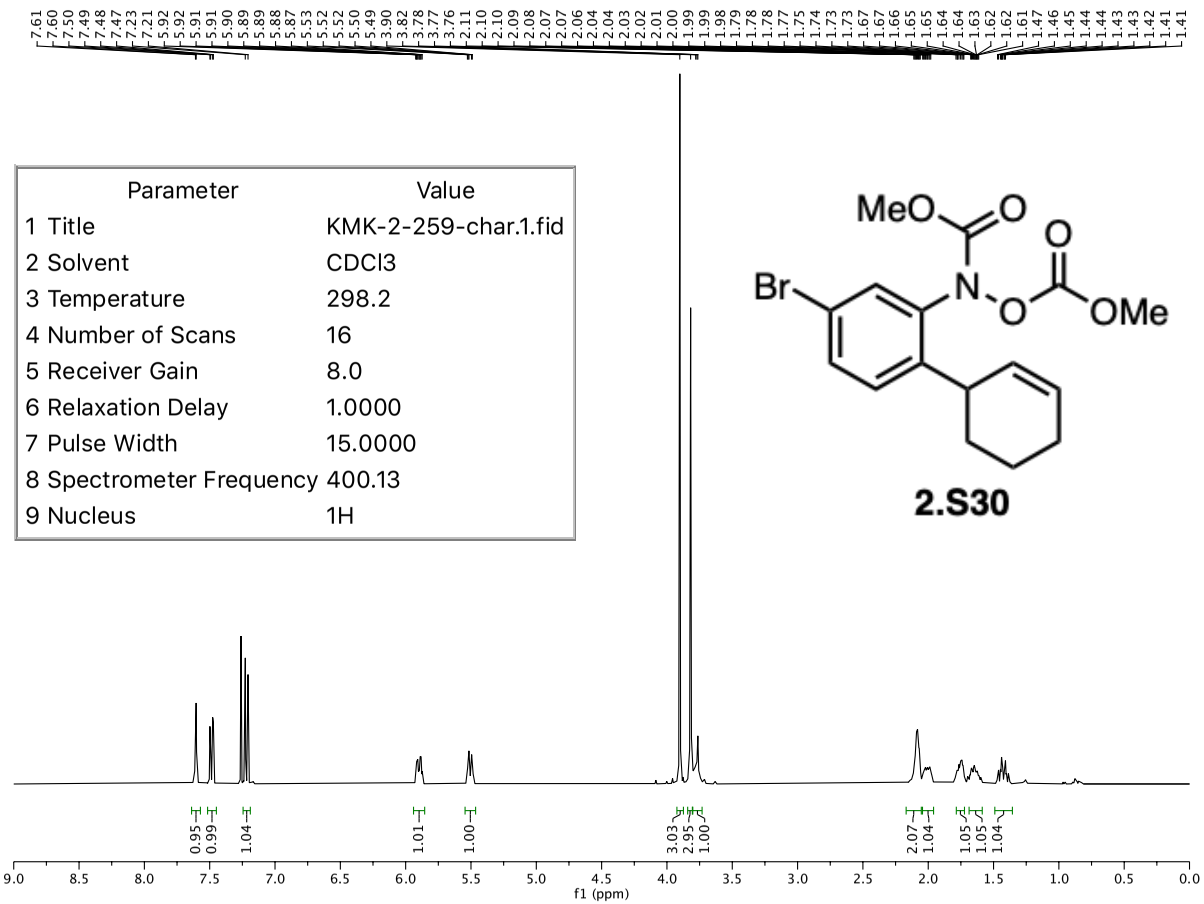

7.24 7.22 6.98 6.98 6.96 6.95 6.94 6.93 5.88 5.87 5.87 5.86 5.85 5.85 5.84 5.83 5.54 5.54 5.52 5.51 3.89 3.81 3.80 3.78 3.78 3.76 3.75 3.74 3.74 3.73 3.72 3.72 2.10 2.10 2.09 2.08 2.08 2.07 2.07 2.06 2.06 2.05 2.02 2.01 2.00 1.99 1.99 1.98 1.97 1.77 1.76 1.75 1.74 1.73 1.69 1.69 1.67 1.67 1.66 1.65 1.64 1.64 1.63 1.49 1.48 1.47 1.46 1.46 1.45 1.45 1.44 1.44 1.43
Parameter Value
1 Title KMK-2-264-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
MeO
N
O
OMe
2.S28
0.95 0.96 0.98 0.99 0.95 2.94 2.98 3.10 0.98 1.95 1.09 1.02 1.02 1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

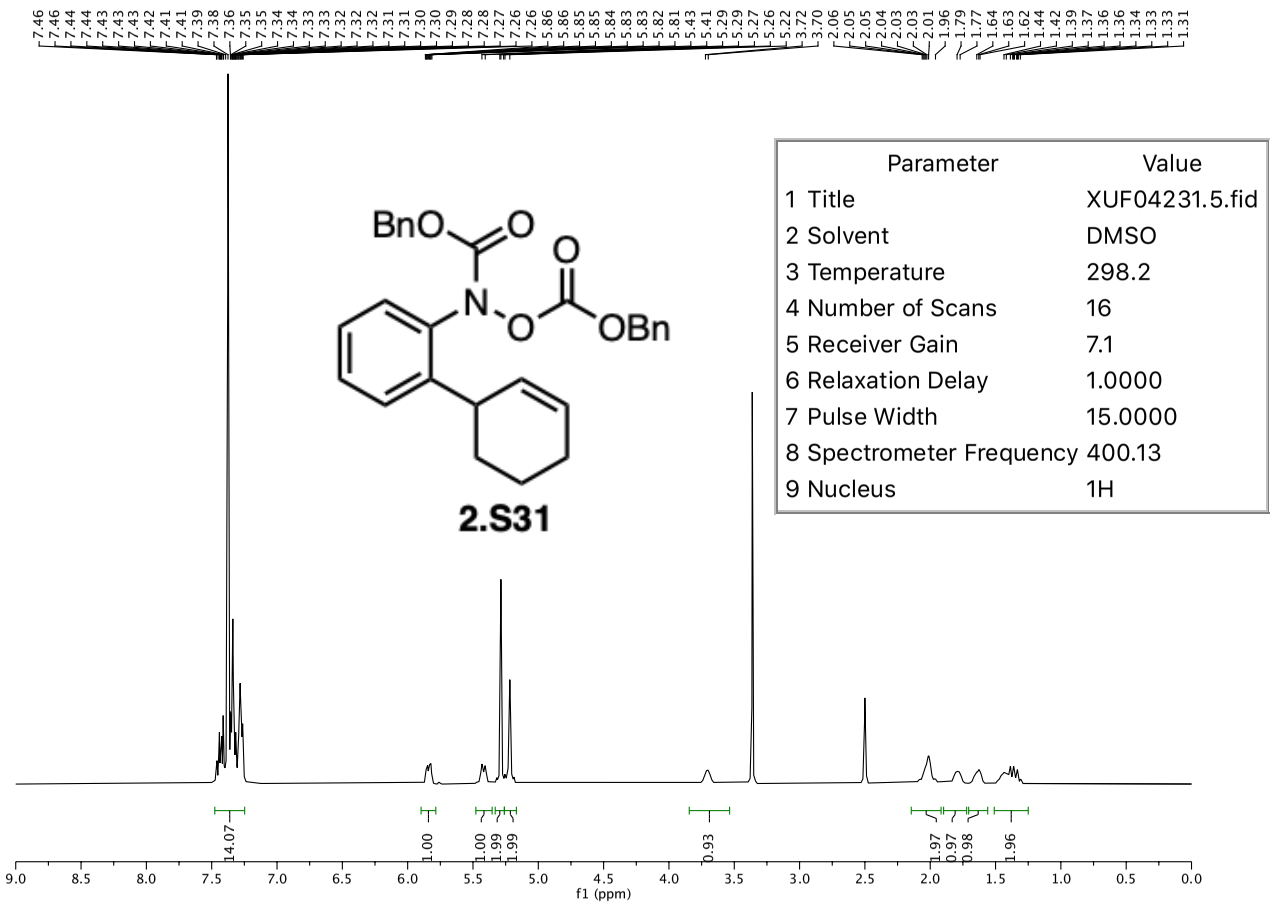

158.16
155.18
154.77
137.95
137.45
130.37
129.89
128.43
117.09
113.27
56.37
55.60
54.16
35.89
31.87
24.97
21.66
MeO
MeO
OMe
2.S28
Parameter Value
1 Title KMK-2-270-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

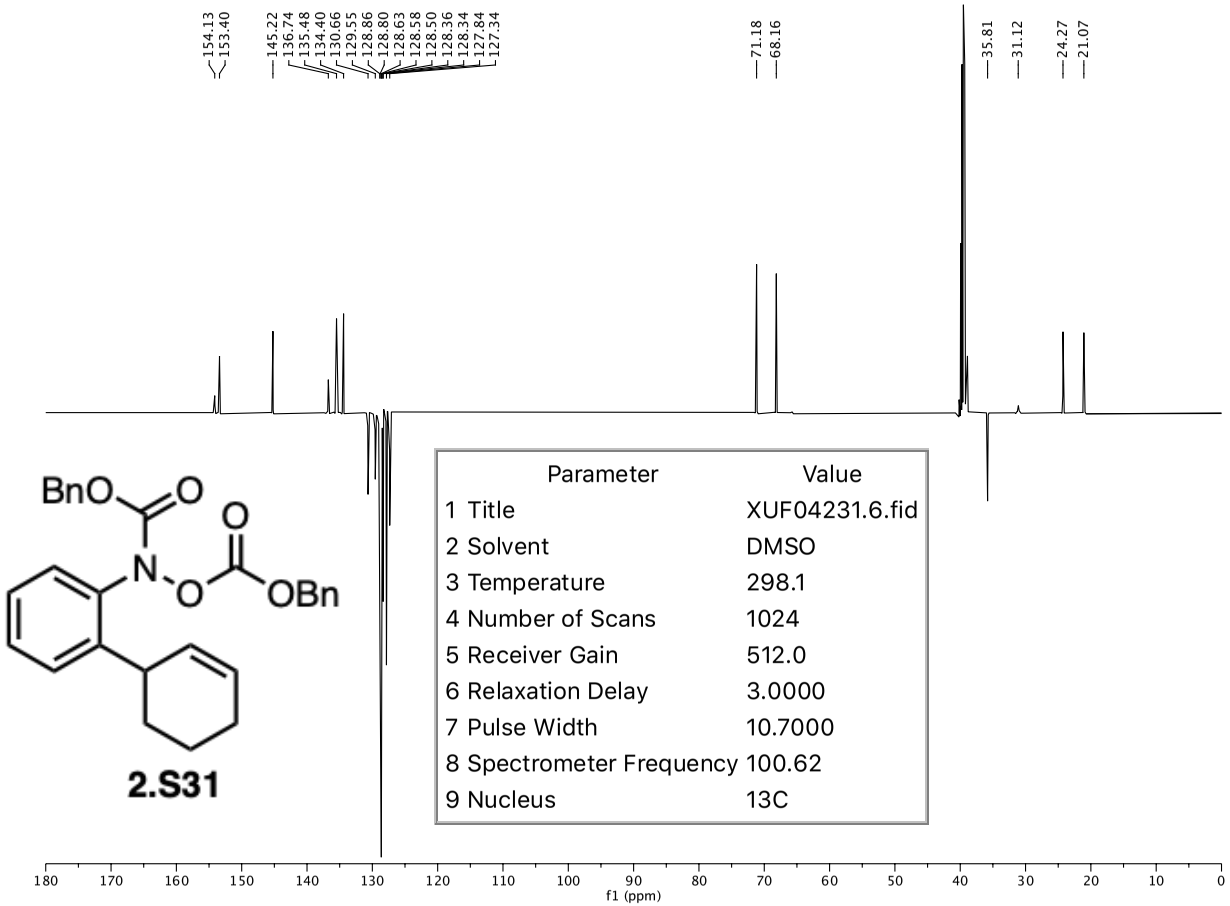

7.48 7.46 7.42 7.41 7.39 7.39 7.27 7.26 5.94 5.93 5.92 5.92 5.91 5.90 5.90 5.89 5.89 5.49 5.49 5.48 5.47 5.46 5.46 3.87 3.86 3.76 3.74 3.73 2.11 2.10 2.10 2.09 2.08 2.07 2.07 2.06 2.05 2.05 2.04 2.04 2.03 2.03 1.94 1.93 1.92 1.91 1.91 1.89 1.89 1.88 1.73 1.72 1.72 1.71 1.70 1.69 1.68 1.57 1.56 1.55 1.55 1.54 1.53 1.52 1.52 1.51 1.47 1.46 1.45 1.44 1.43 1.41 1.41
Parameter Value
1 Title XUF05009.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 16.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
Cl
2.S29
1.00 0.97 0.99 1.00 1.00 2.98 3.94 2.06 1.01 1.03 1.05 1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

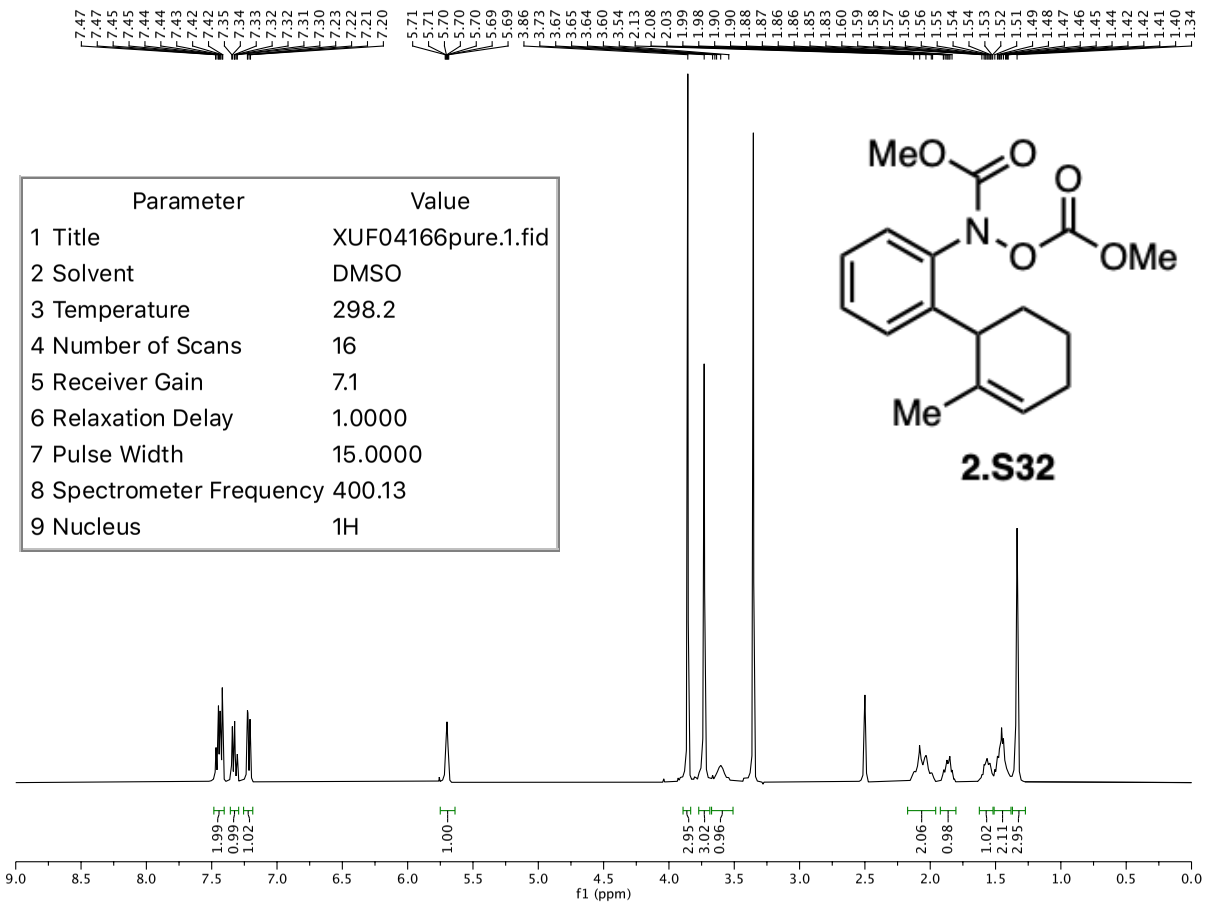
154.48
153.97
147.55
135.74
135.04
130.79
129.17
128.74
128.54
127.49
56.77
54.26
35.97
30.88
24.21
20.99
MeO
O
O
N
O
O
OMe
Cl
2.S29
Parameter
Value
1 Title
XUF05009.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

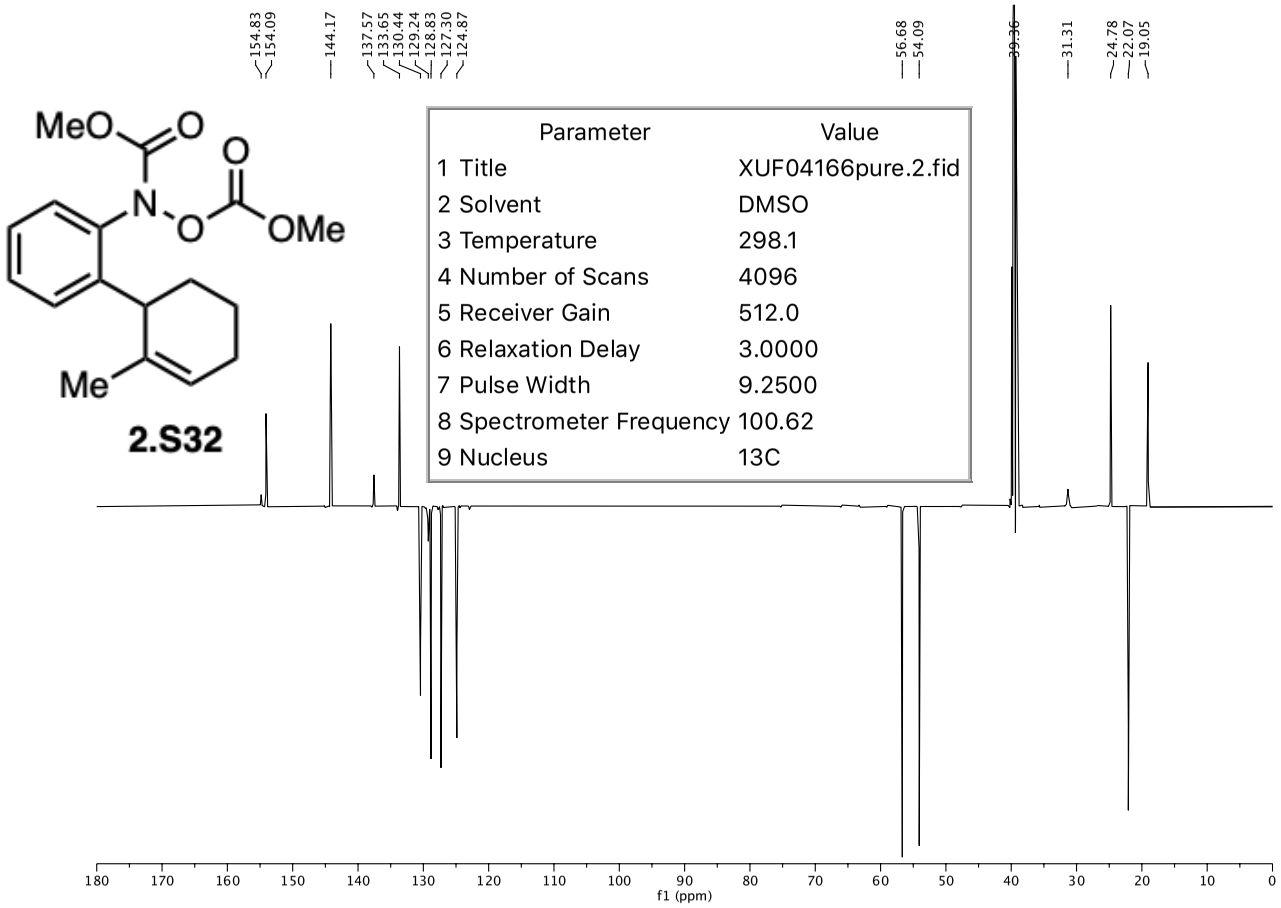

7.61 7.60 7.50 7.49 7.48 7.47 7.23 7.21 5.92 5.92 5.91 5.91 5.90 5.89 5.89 5.88 5.87 5.53 5.52 5.52 5.50 5.49 3.90 3.82 3.78 3.77 3.76 2.11 2.10 2.10 2.09 2.08 2.07 2.07 2.06 2.04 2.04 2.03 2.02 2.01 2.00 1.99 1.99 1.98 1.79 1.78 1.78 1.77 1.75 1.74 1.73 1.73 1.67 1.67 1.66 1.65 1.65 1.64 1.64 1.63 1.62 1.62 1.61 1.47 1.46 1.45 1.44 1.44 1.43 1.43 1.42 1.41 1.41
Parameter Value
1 Title KMK-2-259-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
Br
N
O
OMe
2.S30
0.95 0.99 1.04 1.01 1.00 3.03 2.95 1.00 2.07 1.04 1.05 1.05 1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

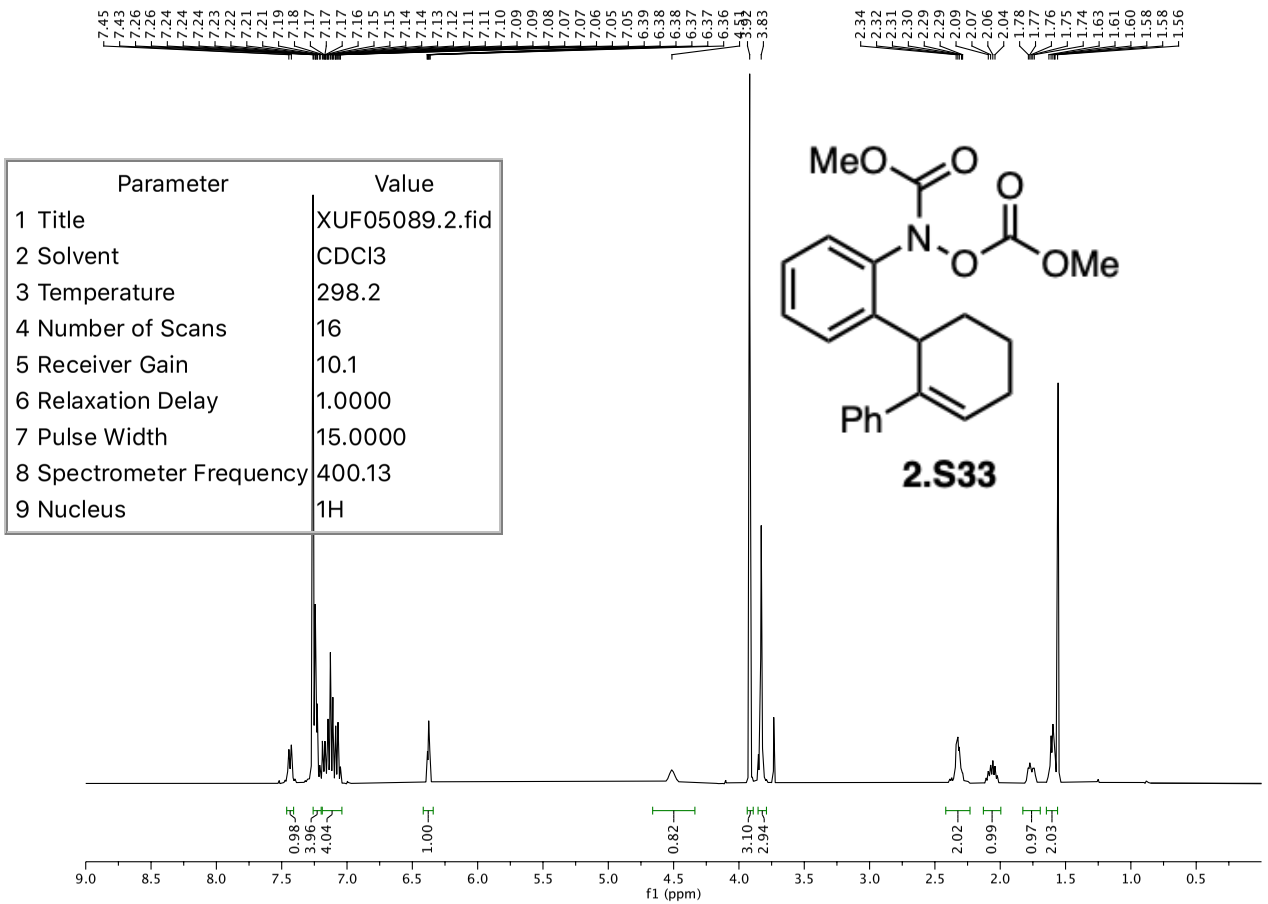

7.61 7.60 7.50 7.49 7.48 7.47 7.23 7.21 5.92 5.92 5.91 5.91 5.90 5.89 5.89 5.88 5.87 5.53 5.52 5.52 5.50 5.49 3.90 3.82 3.78 3.77 3.76 2.11 2.10 2.10 2.09 2.08 2.07 2.07 2.06 2.04 2.04 2.03 2.02 2.01 2.00 1.99 1.99 1.98 1.79 1.78 1.78 1.77 1.75 1.74 1.73 1.73 1.67 1.67 1.66 1.65 1.65 1.64 1.64 1.63 1.62 1.62 1.61 1.47 1.46 1.45 1.44 1.44 1.43 1.43 1.42 1.41 1.41
Parameter Value
1 Title KMK-2-259-char.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
Br
N
O
OMe
2.S30
0.95 0.99 1.04 1.01 1.00 3.03 2.95 1.00 2.07 1.04 1.05 1.05 1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

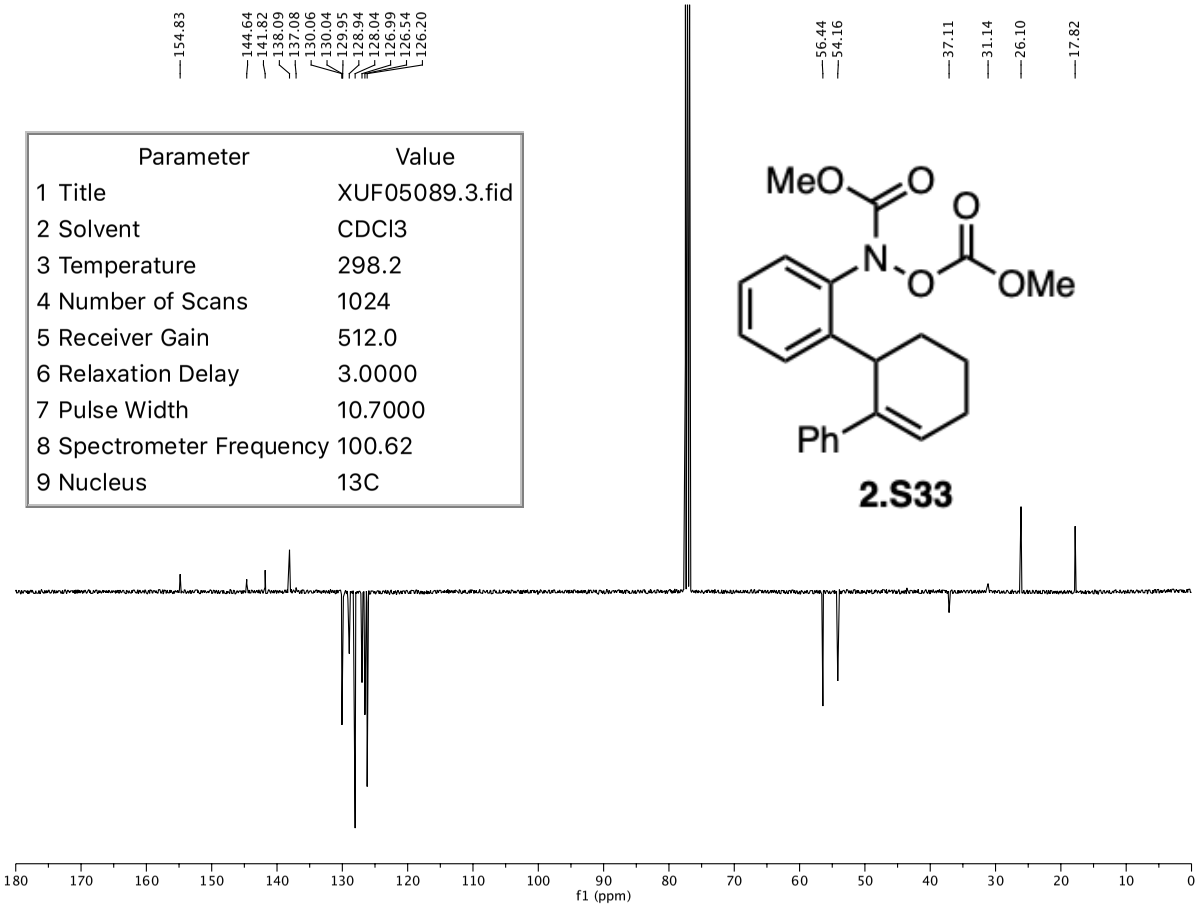

BnO
O
O
N
O
OBn
2.S31
Parameter
Value
1 Title
XUF04231.5.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
7.1
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
f1 (ppm)


154.13
153.40
145.22
136.74
135.48
134.40
130.66
129.55
128.86
128.80
128.63
128.58
128.50
128.36
128.34
127.84
127.34
71.18
68.16
35.81
31.12
24.27
21.07
BnO
O
N
O
O
OBn
2.S31
Parameter Value
1 Title XUF04231.6.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

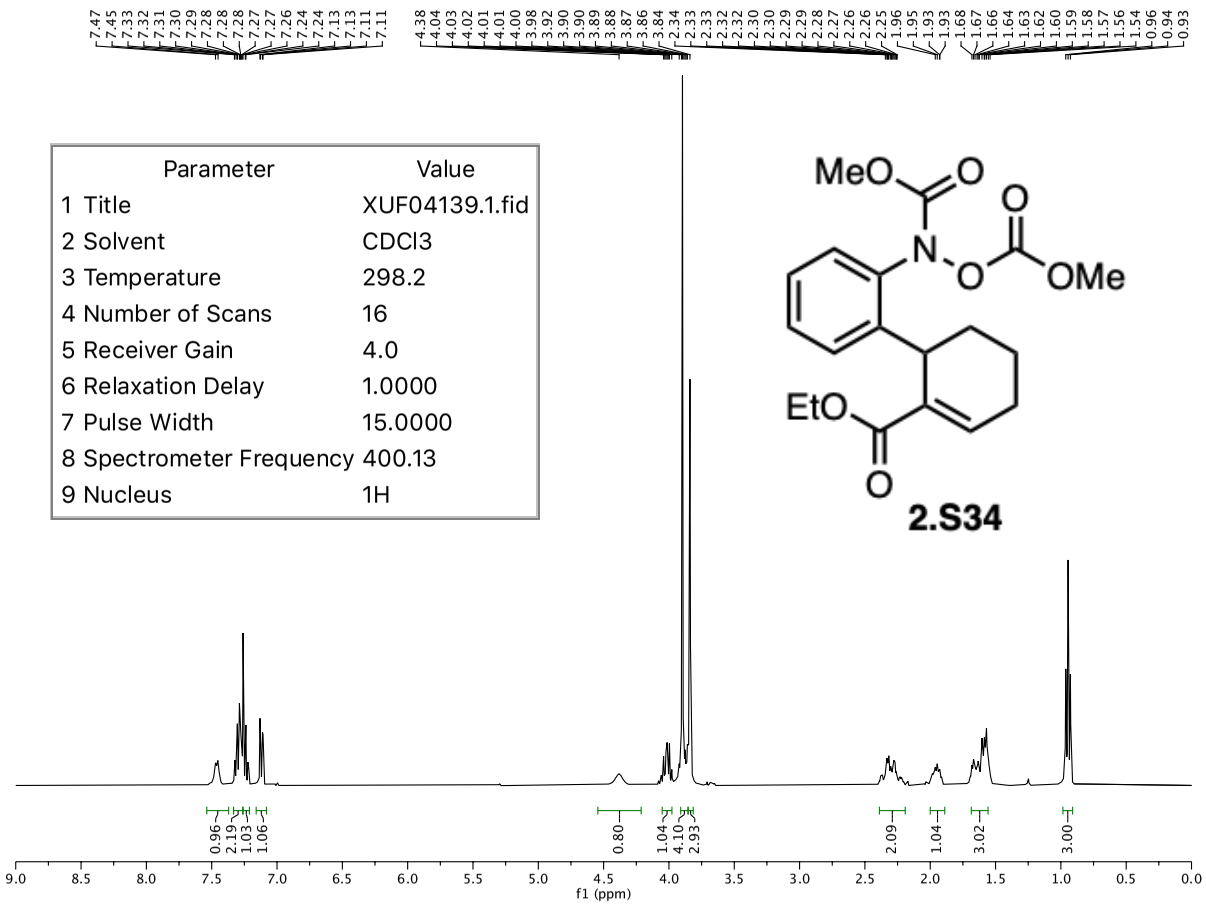

7.47 7.47 7.45 7.45 7.44 7.44 7.43 7.42 7.42 7.35 7.34 7.33 7.32 7.32 7.31 7.30 7.23 7.22 7.21 7.20
5.71 5.71 5.70 5.70 5.70 5.69 5.69
3.86 3.73 3.67 3.65 3.64 3.60 3.54 2.13 2.08 2.03 1.99 1.98 1.90 1.90 1.88 1.87 1.86 1.86 1.85 1.83 1.60 1.59 1.58 1.57 1.56 1.56 1.55 1.54 1.54 1.53 1.52 1.51 1.49 1.48 1.47 1.46 1.45 1.44 1.42 1.42 1.41 1.40 1.34
Parameter Value
1 Title XUF04166pure.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
Me
2.S32
1.99 0.99 1.02 1.00 2.95 3.02 0.96 2.06 0.98 1.02 2.11 2.95
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

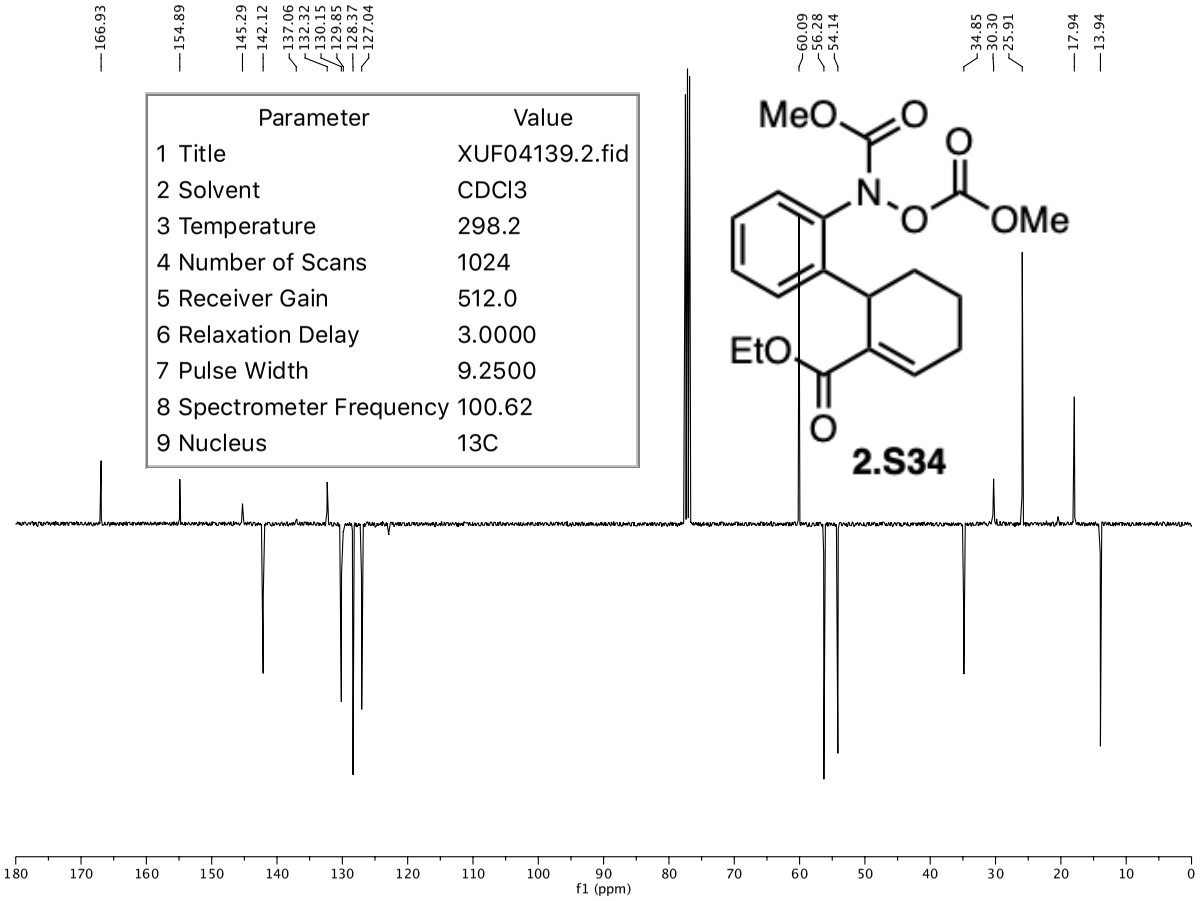

154.83
154.09
144.17
137.57
133.65
130.44
129.24
128.83
127.30
124.87
56.68
54.09
39.36
31.31
24.78
22.07
19.05
MeO
O
O
N
O
OMe
Me
2.S32
Parameter Value
1 Title XUF04166pure.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.45 7.43 7.26 7.26 7.24 7.24 7.24 7.23 7.22 7.21 7.21 7.19 7.18 7.17 7.17 7.17 7.16 7.15 7.15 7.14 7.14 7.13 7.12 7.11 7.11 7.10 7.09 7.09 7.08 7.07 7.07 7.06 7.05 7.05 6.39 6.38 6.38 6.37 6.37 6.36 3.83
2.34 2.32 2.31 2.30 2.29 2.29 2.09 2.07 2.06 2.04 1.78 1.77 1.76 1.75 1.74 1.63 1.61 1.60 1.58 1.58 1.56
Parameter | Value
1 Title | XUF05089.2.fid
2 Solvent | CDCl3
3 Temperature | 298.2
4 Number of Scans | 16
5 Receiver Gain | 10.1
6 Relaxation Delay | 1.0000
7 Pulse Width | 15.0000
8 Spectrometer Frequency | 400.13
9 Nucleus | 1H
MeO
O
O
N
O
OMe
Ph
2.S33
0.98 3.96 4.04 1.00 0.82 3.10 2.94 2.02 0.99 0.97 2.03
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

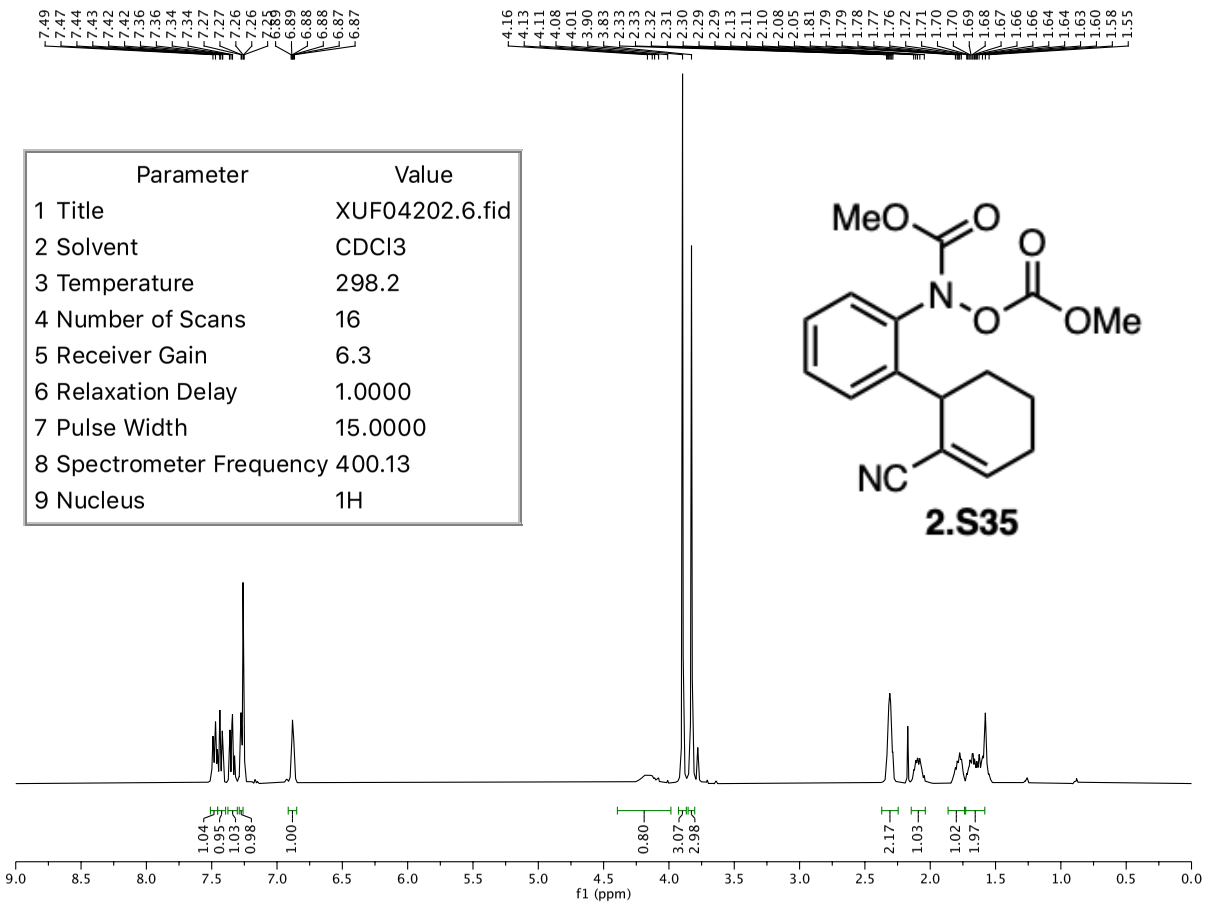

154.83
144.64
141.82
138.09
137.08
130.06
130.04
129.95
128.94
128.04
126.99
126.54
126.20
56.44
54.16
37.11
31.14
26.10
17.82
Parameter Value
1 Title XUF05089.3.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
O
O
OMe
Ph
2.S33
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

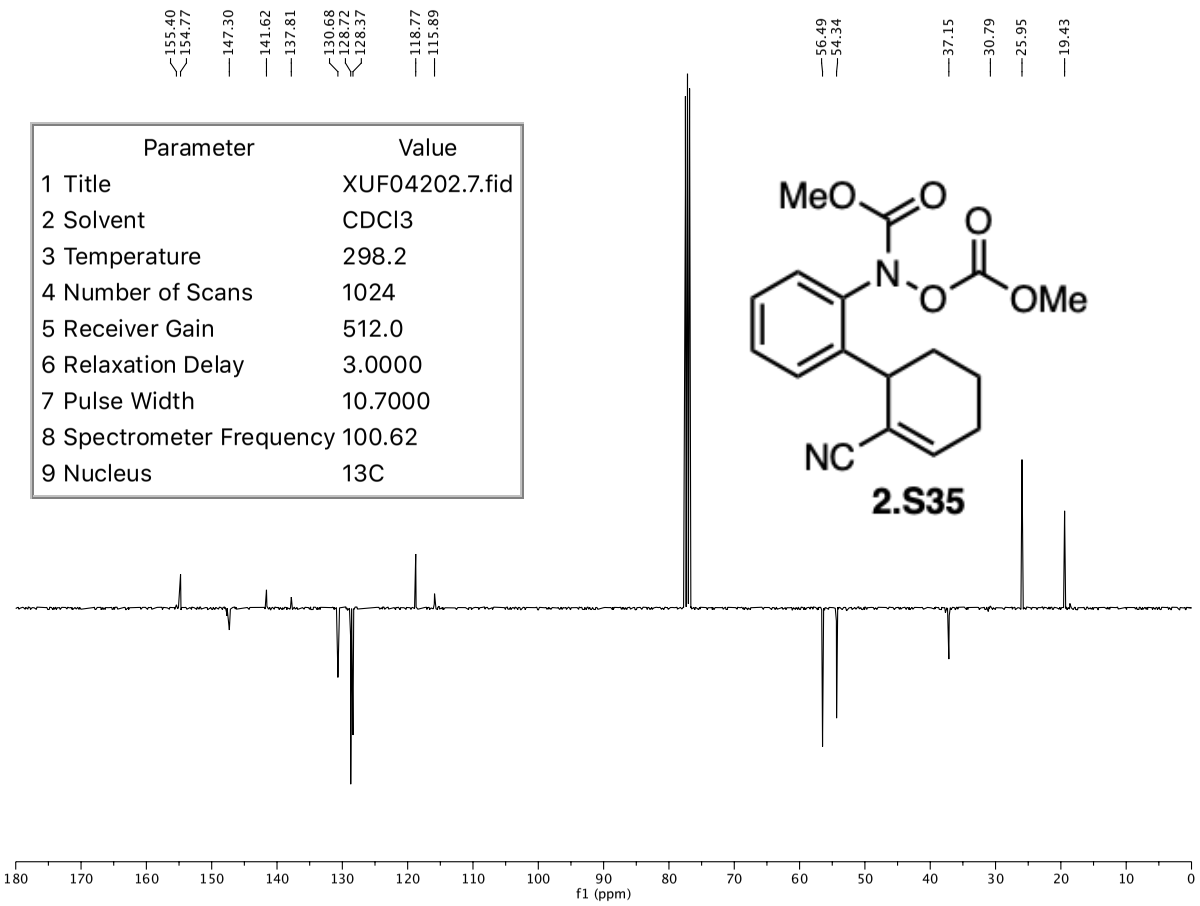
Parameter Value
1 Title XUF05089.7.ser
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 4
5 Receiver Gain 46341.0
6 Relaxation Delay 1.1805
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (2873.6, 22321.4)
10 Lowest Frequency (324.3, -1115.9)
11 Nucleus (1H, 13C)
12 Acquired Size (2048, 128)
13 Spectral Size (2048, 512)
two peaks overlaped
MeO
OMe
Ph
f2 (ppm)
f1 (ppm)


7.47 7.45 7.33 7.32 7.31 7.30 7.29 7.28 7.28 7.28 7.27 7.27 7.26 7.24 7.24 7.13 7.13 7.11 7.11
4.38 4.04 4.03 4.02 4.01 4.01 4.00 3.98 3.92 3.90 3.90 3.89 3.88 3.87 3.86 3.84 2.34 2.33 2.33 2.32 2.32 2.30 2.30 2.29 2.29 2.28 2.27 2.26 2.26 2.25 1.96 1.95 1.93 1.93 1.68 1.67 1.66 1.64 1.63 1.62 1.60 1.59 1.58 1.57 1.56 1.54 0.96 0.94 0.93
Parameter Value
1 Title XUF04139.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
EtO
O
2.S34
0.96 2.19 1.03 1.06 0.80 1.04 4.10 2.93 2.09 1.04 3.02 3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

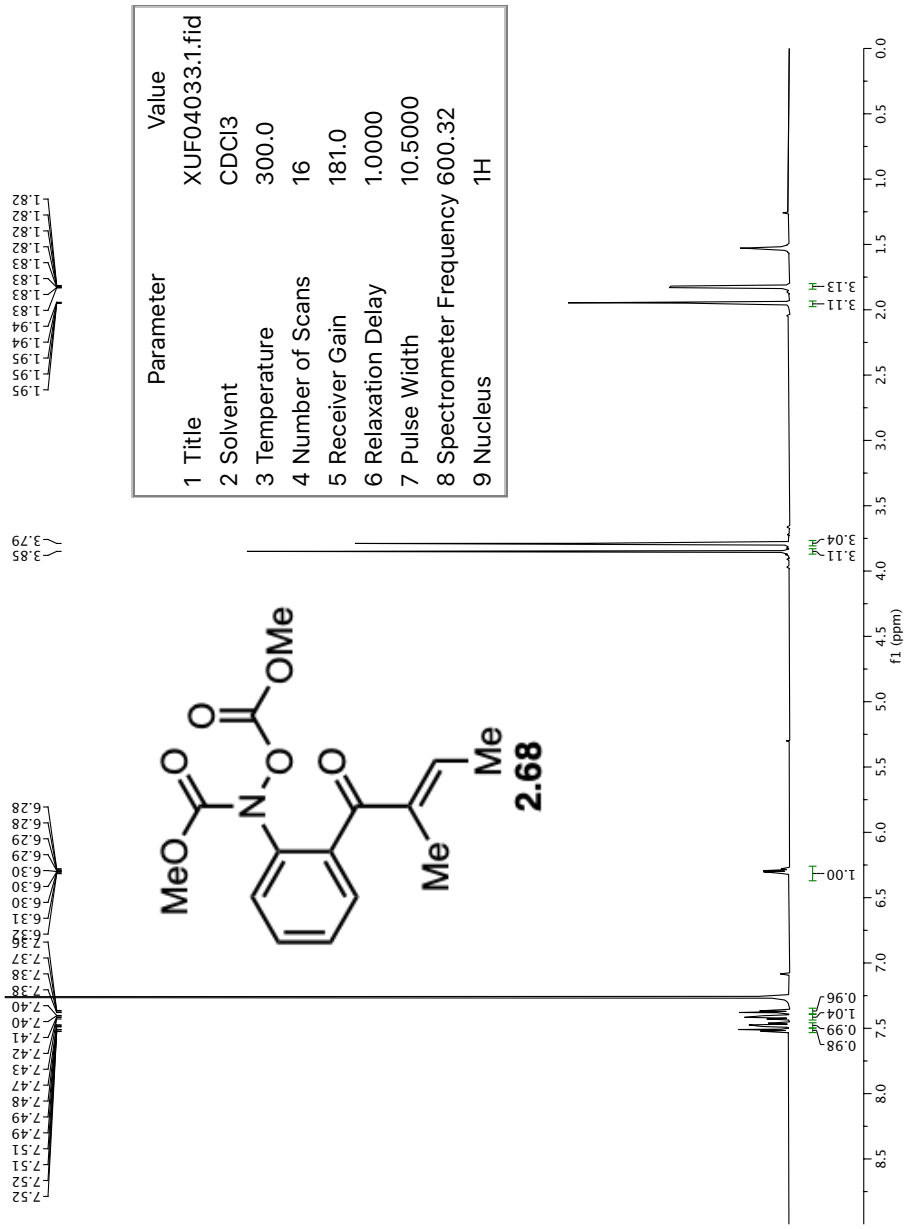

166.93
154.89
145.29
142.12
137.06
132.32
130.15
129.85
128.37
127.04
60.09
56.28
54.14
34.85
30.30
25.91
17.94
13.94
Parameter Value
1 Title XUF04139.2.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
O
O
OMe
EtO
O
2.S34
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

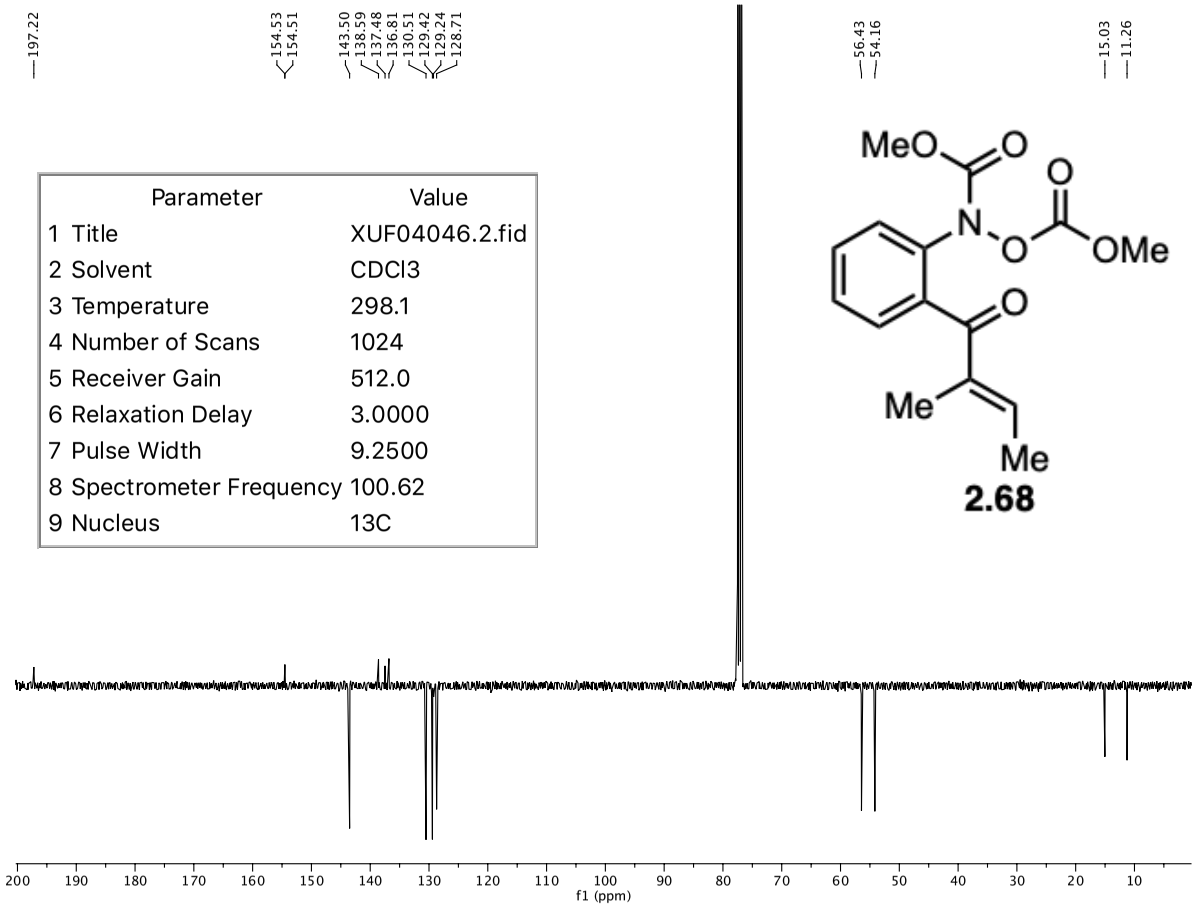
Parameter Value
1 Title XUF04139-2D.4.ser
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 4
5 Receiver Gain 46341.0
6 Relaxation Delay 1.2788
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (3324.5, 22321.4)
10 Lowest Frequency (98.7, -1115.9)
11 Nucleus (1H, 13C)
12 Acquired Size (2048, 128)
13 Spectral Size (2048, 512)
two peaks overlaped
MeO
OMe
EtO
f2 (ppm)
f1 (ppm)

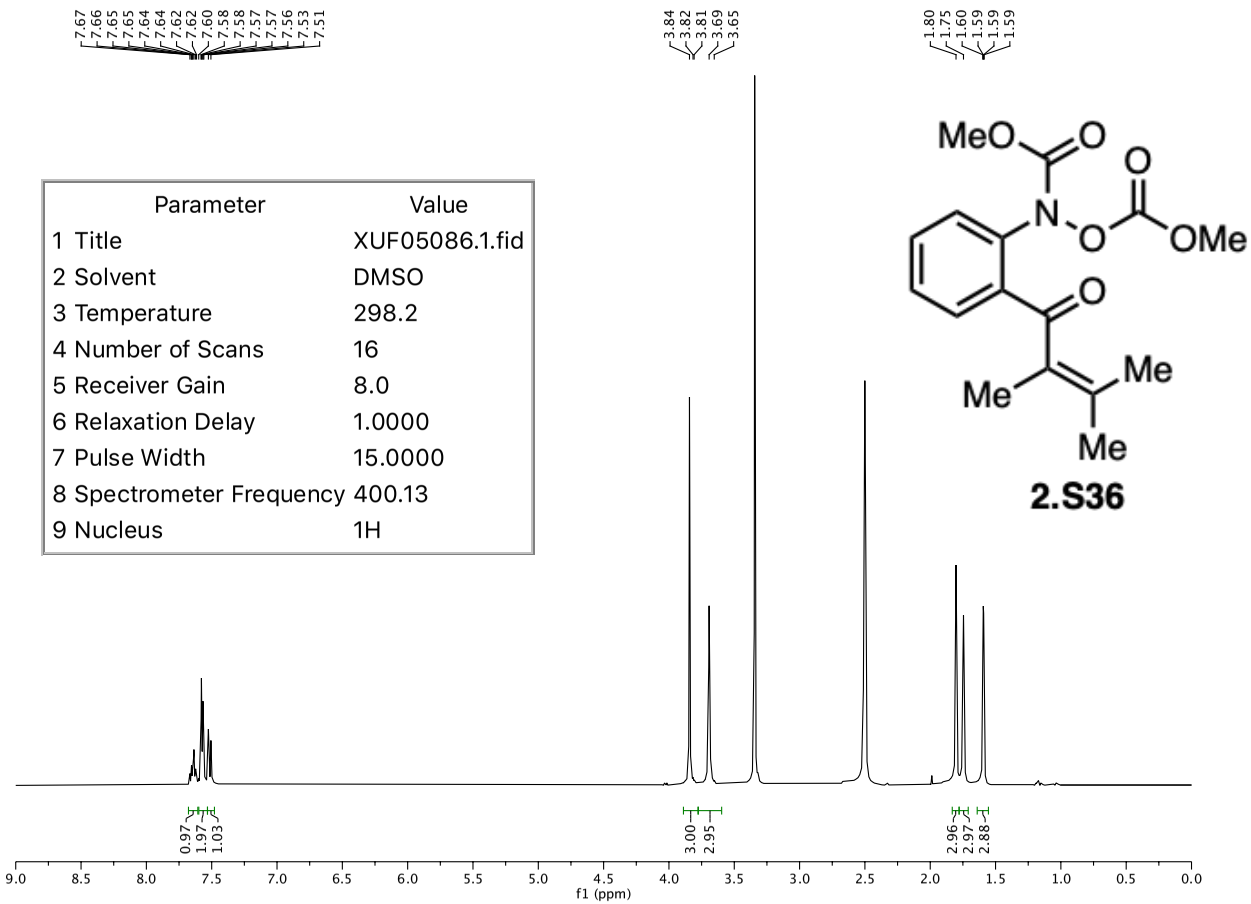

7.49
7.47
7.44
7.43
7.42
7.42
7.36
7.36
7.34
7.34
7.27
7.27
7.26
7.26
6.89
6.89
6.88
6.88
6.87
6.87
4.16
4.13
4.11
4.08
4.01
3.90
3.83
2.33
2.33
2.32
2.31
2.30
2.29
2.29
2.13
2.11
2.10
2.08
2.05
1.81
1.79
1.79
1.78
1.77
1.76
1.72
1.71
1.70
1.70
1.69
1.68
1.67
1.66
1.66
1.64
1.64
1.63
1.60
1.58
1.55
Parameter
Value
1 Title
XUF04202.6.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
6.3
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
MeO
O
O
N
O
OMe
NC
2.S35
1.04
0.95
1.03
0.98
1.00
0.80
3.07
2.98
2.17
1.03
1.02
1.97
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

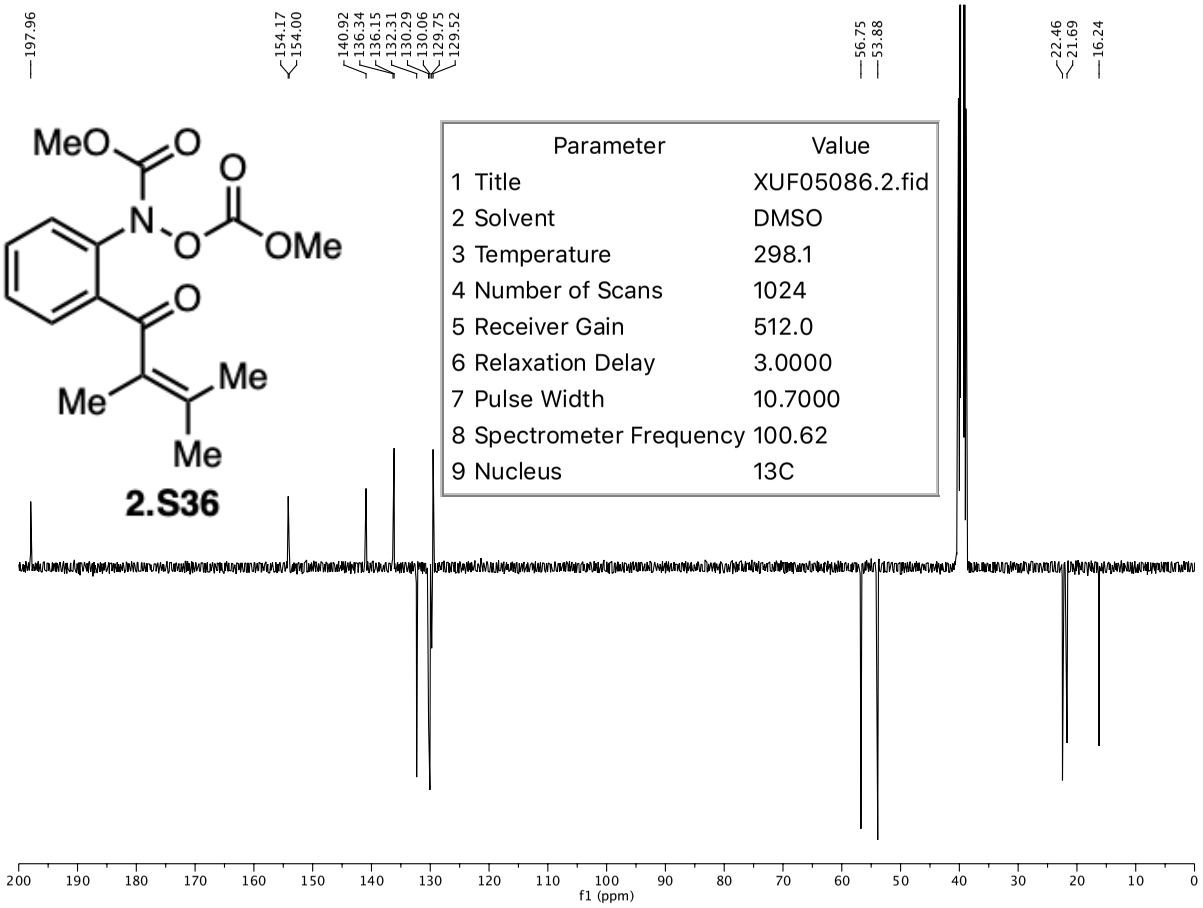

155.40
154.77
147.30
141.62
137.81
130.68
128.72
128.37
118.77
115.89
56.49
54.34
37.15
30.79
25.95
19.43
Parameter Value
1 Title XUF04202.7.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
O
O
OMe
NC
2.S35
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

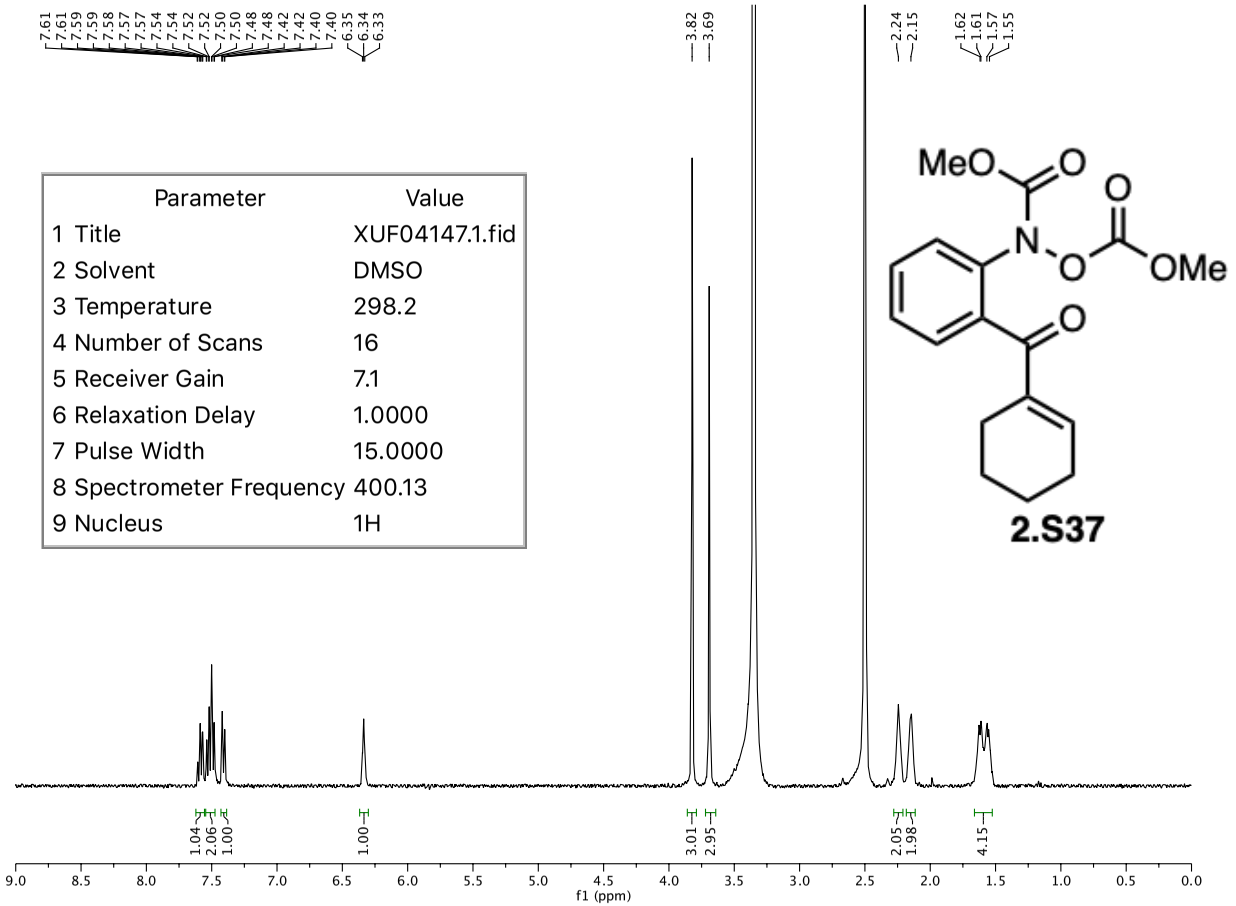
Parameter
Value
1 Title
XUF04202-2D.3.ser
2 Solvent
CDCl3
3 Temperature
298.1
4 Number of Scans
4
5 Receiver Gain
41285.1
6 Relaxation Delay
1.4611
7 Pulse Width
15.0000
8 Spectrometer Frequency
(400.13, 100.62)
9 Spectral Width
(3086.4, 16666.7)
10 Lowest Frequency
(284.1, -788.3)
11 Nucleus
(1H, 13C)
12 Acquired Size
(512, 128)
13 Spectral Size
(512, 512)
MeO
OMe
NC
two peaks
overlaped
f1 (ppm)
f2 (ppm)

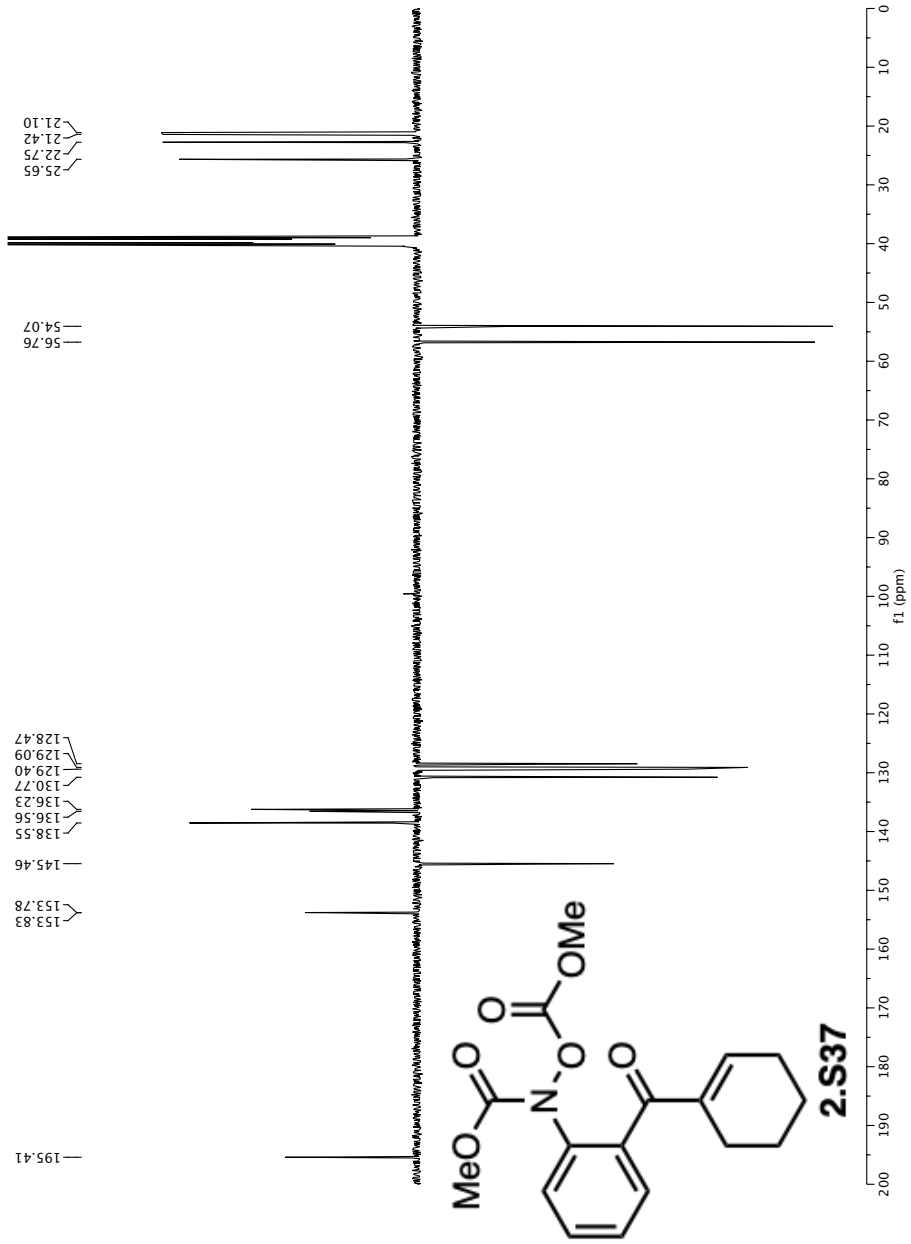

Parameter Value
1 Title XUF04033.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 181.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.5000
8 Spectrometer Frequency 600.32
9 Nucleus 1H
MeO
OMe
Me
Me
2.68
f1 (ppm)

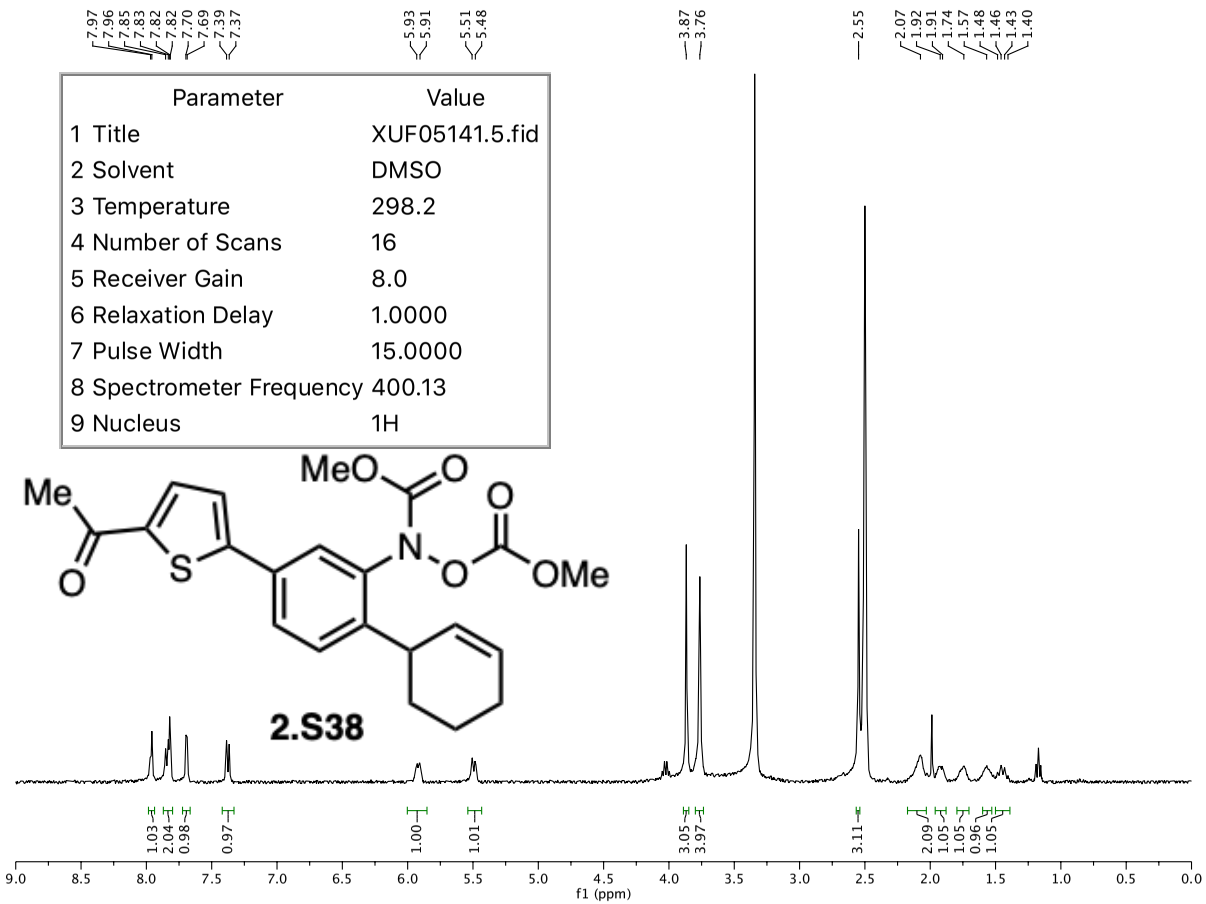

197.22
154.53
154.51
143.50
138.59
137.48
136.81
130.51
129.42
129.24
128.71
56.43
54.16
15.03
11.26
Parameter Value
1 Title XUF04046.2.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
O
N
O
OMe
O
Me
Me
2.68
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

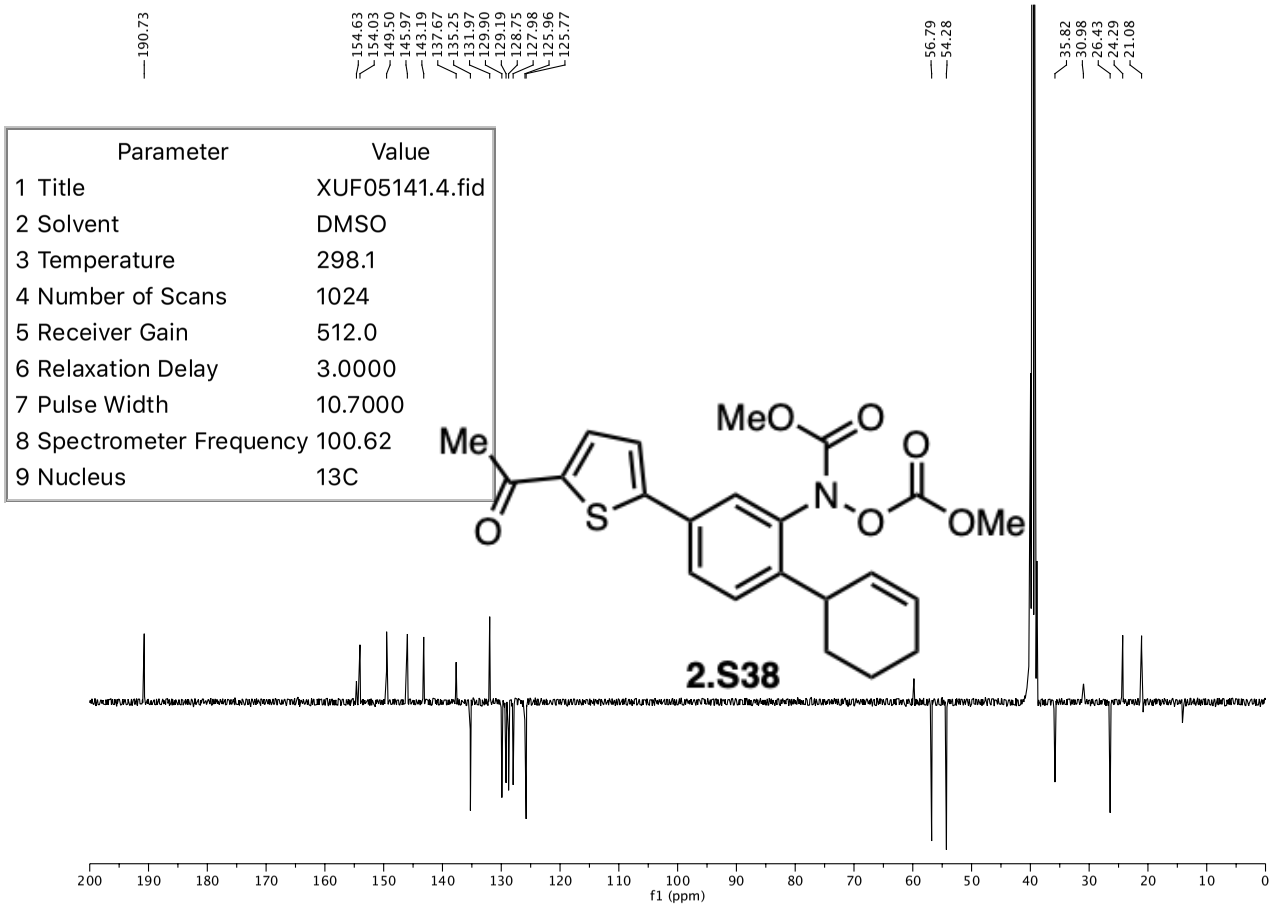

7.67
7.66
7.65
7.65
7.64
7.64
7.62
7.62
7.60
7.58
7.58
7.57
7.57
7.56
7.53
7.51
3.84
3.82
3.81
3.69
3.65
1.80
1.75
1.60
1.59
1.59
1.59
Parameter Value
1 Title XUF05086.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
O
Me
Me
Me
2.S36
0.97
1.97
1.03
3.00
2.95
2.96
2.97
2.88
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

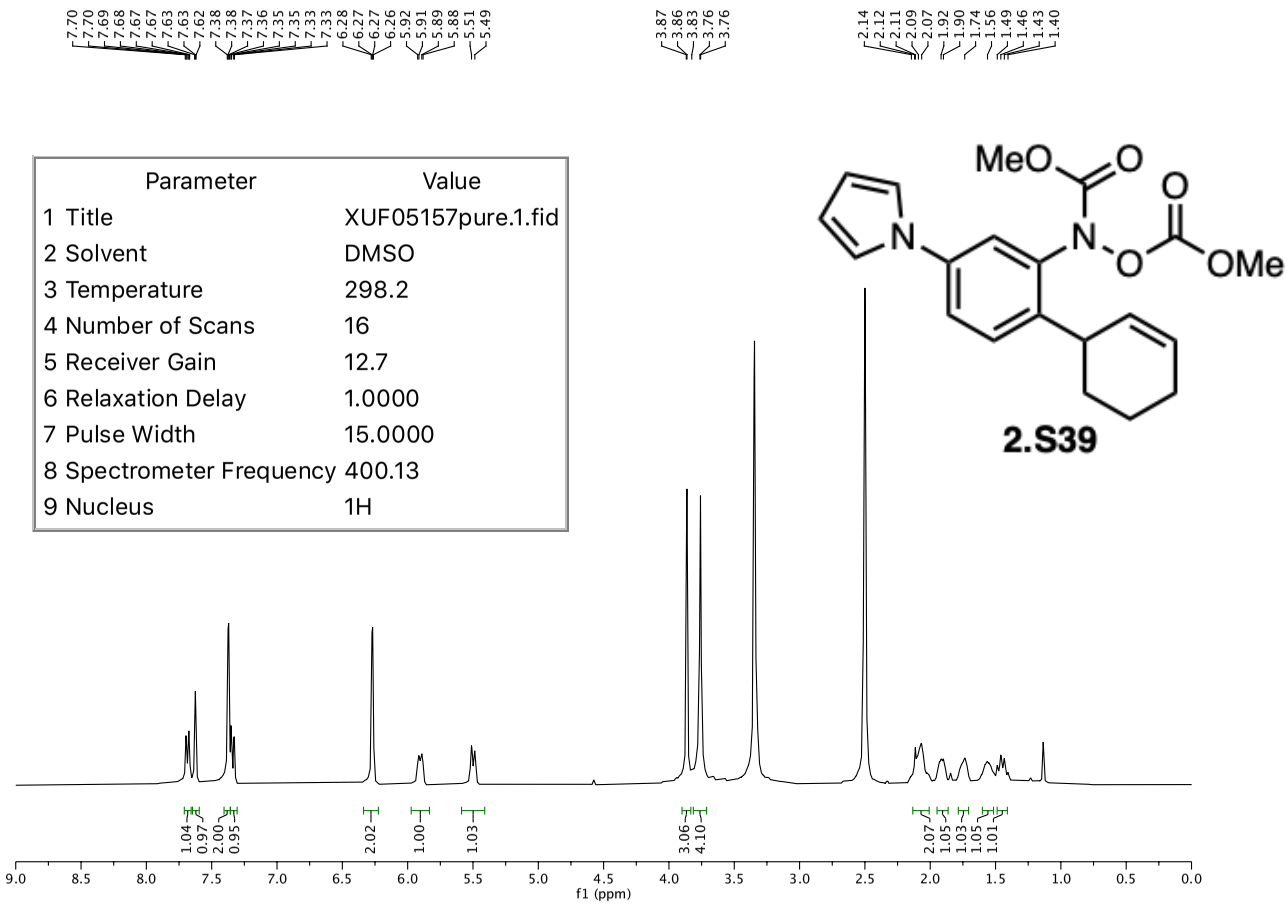

197.96
154.17
154.00
140.92
136.34
136.15
132.31
130.29
130.06
129.75
129.52
56.75
53.88
22.46
21.69
16.24
MeO
O
O
N
O
OMe
O
Me
Me
Me
2.S36
Parameter Value
1 Title XUF05086.2.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

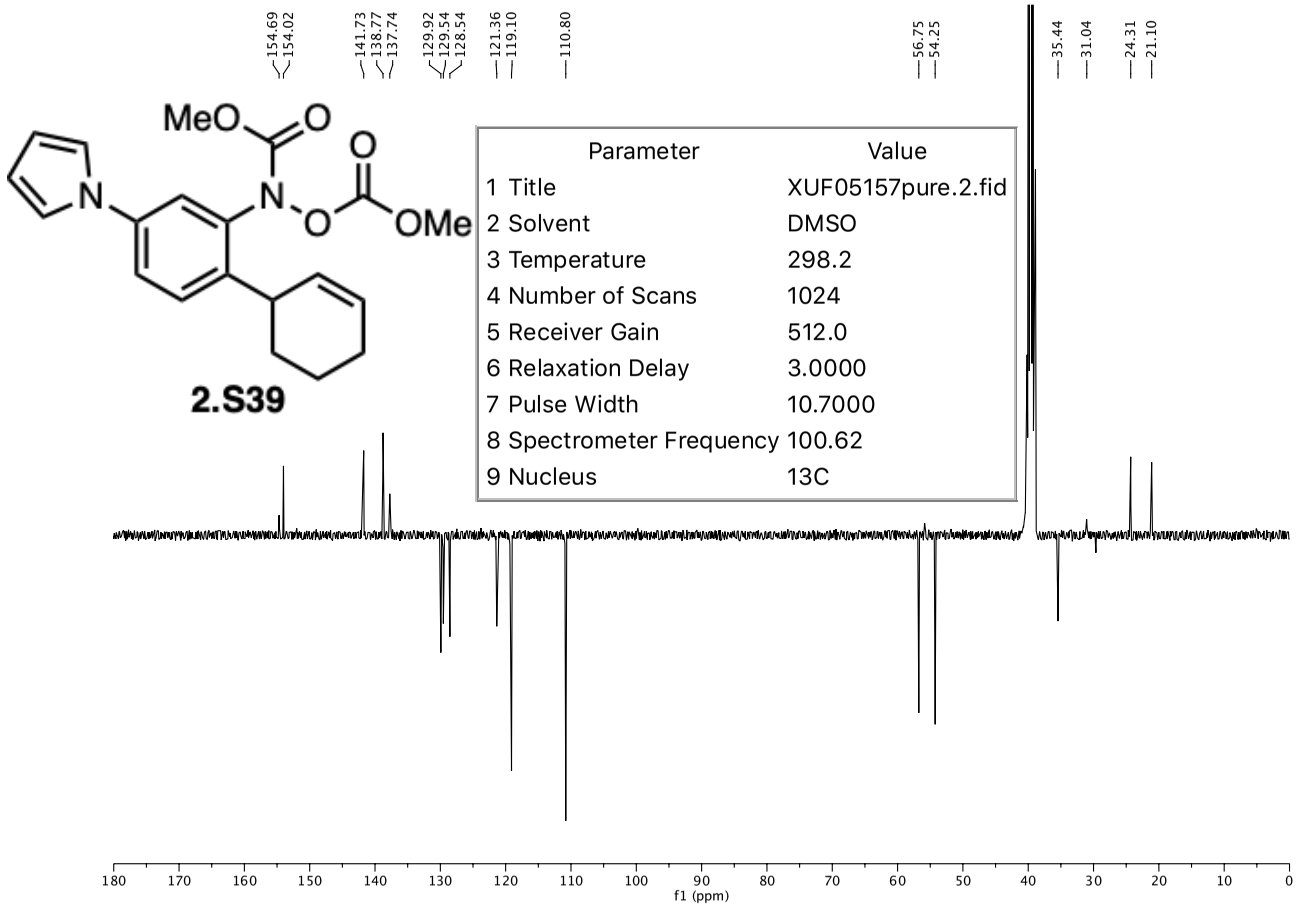

7.61
7.61
7.59
7.59
7.58
7.57
7.57
7.54
7.54
7.52
7.52
7.50
7.50
7.48
7.48
7.42
7.42
7.40
7.40
6.35
6.34
6.33
3.82
3.69
2.24
2.15
1.62
1.61
1.57
1.55
Parameter Value
1 Title XUF04147.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
N
O
O
O
OMe
O
2.S37
1.04
2.06
1.00
1.00
3.01
2.95
2.05
1.98
4.15
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

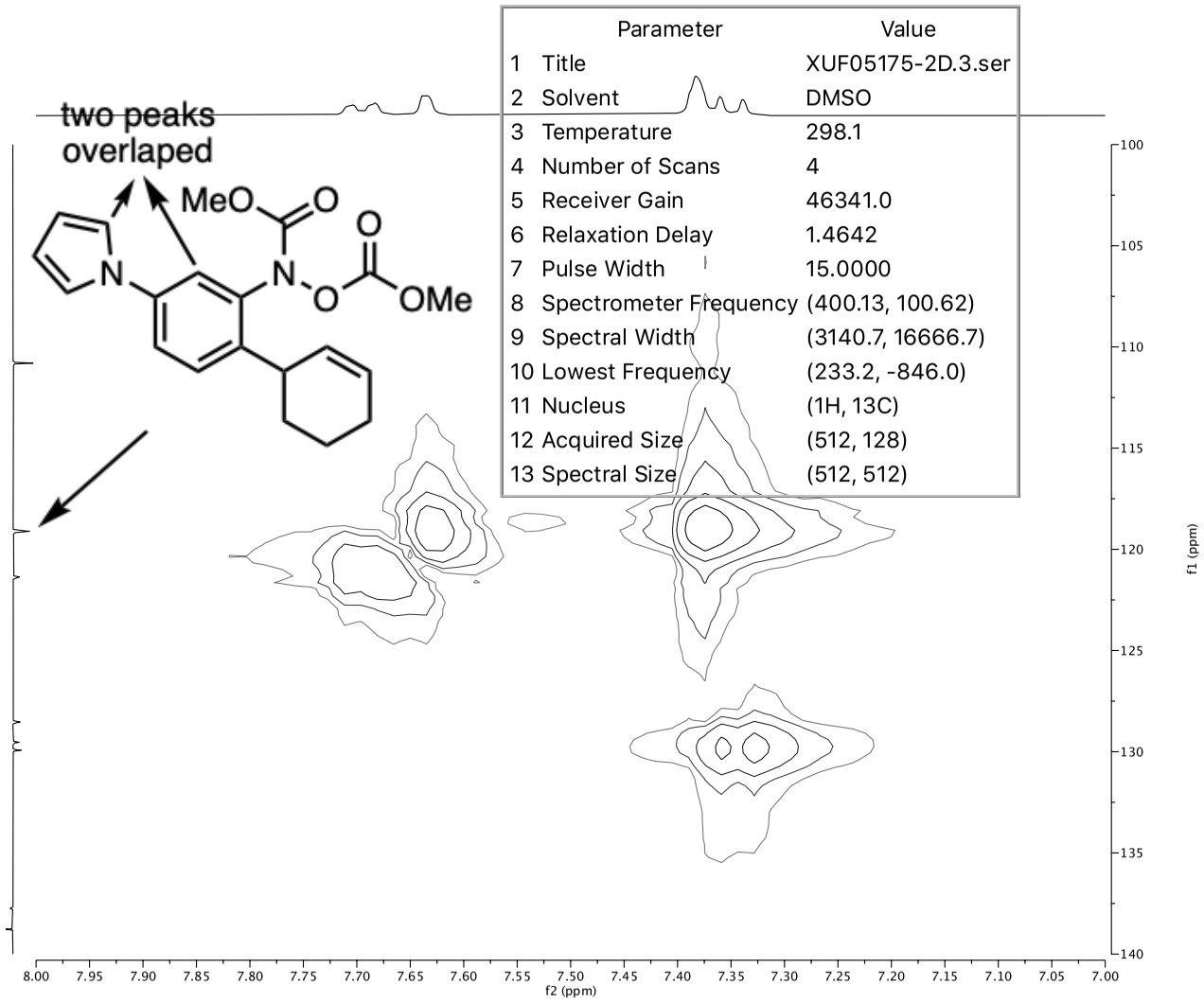

195.41
153.83
153.78
145.46
138.55
136.56
136.23
130.77
129.40
129.09
128.47
56.76
54.07
25.65
22.75
21.42
21.10
f1 (ppm)
MeO
OMe
2.S37

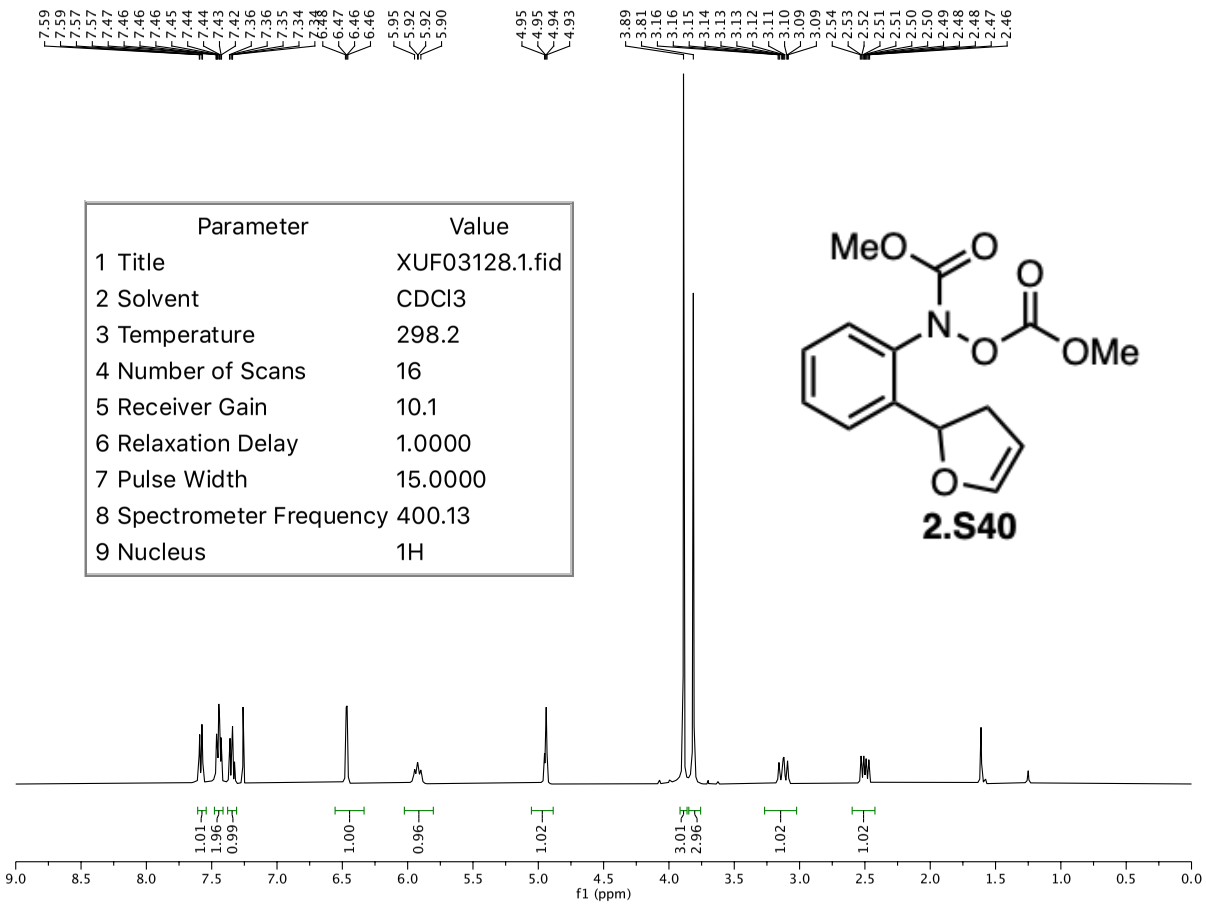

7.97
7.96
7.85
7.83
7.82
7.82
7.70
7.69
7.39
7.37
5.93
5.91
5.51
5.48
3.87
3.76
2.55
2.07
1.92
1.91
1.74
1.57
1.48
1.46
1.43
1.40
Parameter Value
1 Title XUF05141.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Me
O
S
MeO
O
N
O
O
OMe
2.S38
1.03
2.04
0.98
0.97
1.00
1.01
3.05
3.97
3.11
2.09
1.05
1.05
0.96
1.05
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


190.73
154.63
154.03
149.50
145.97
143.19
137.67
135.25
131.97
129.90
129.19
128.75
127.98
125.96
125.77
56.79
54.28
35.82
30.98
26.43
24.29
21.08
Parameter Value
1 Title XUF05141.4.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Me
O
S
MeO
O
N
O
O
OMe
2.S38
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

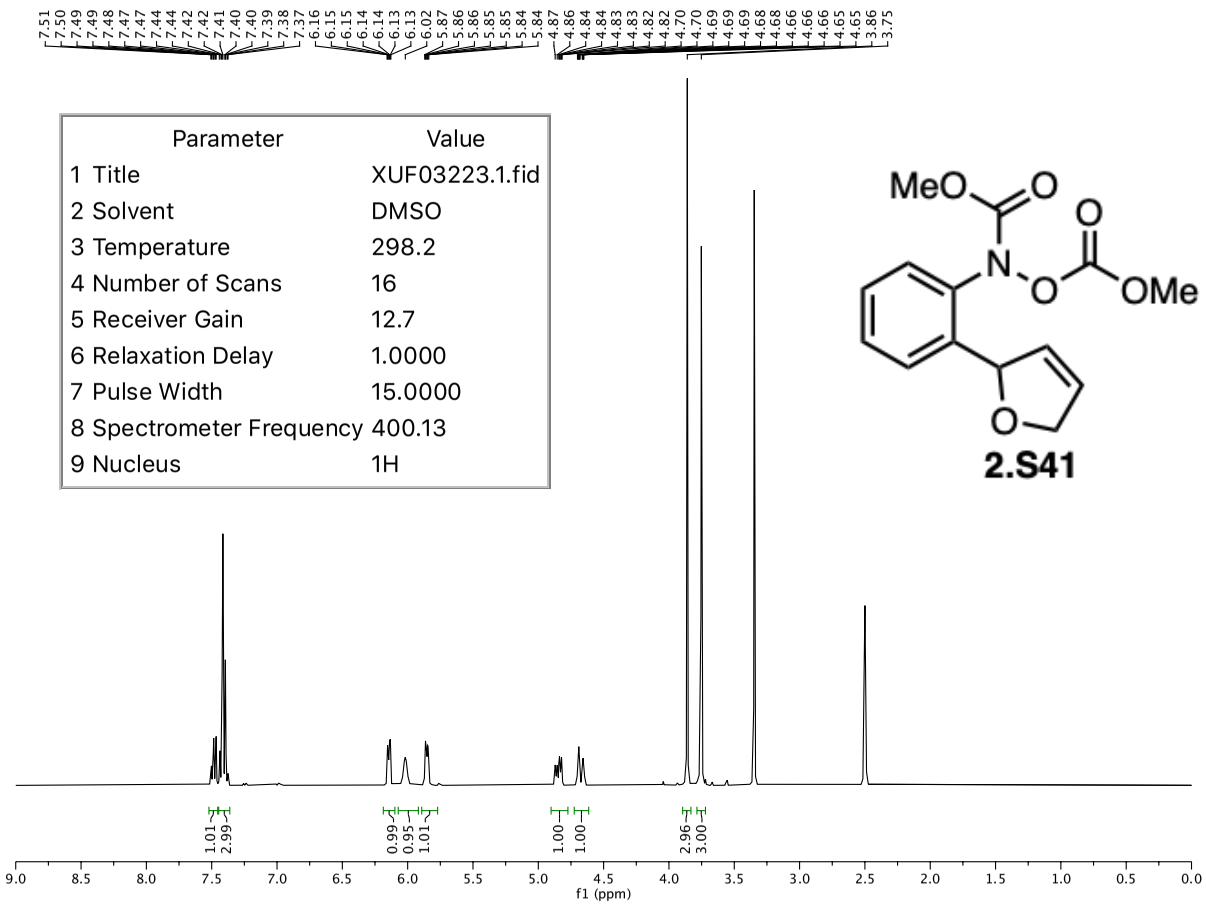

7.70
7.70
7.69
7.68
7.67
7.67
7.63
7.63
7.62
7.38
7.38
7.37
7.36
7.35
7.35
7.33
7.33
6.28
6.27
6.27
6.26
5.92
5.91
5.89
5.88
5.51
5.49
3.87
3.86
3.83
3.76
3.76
2.14
2.12
2.11
2.09
2.07
1.92
1.90
1.74
1.56
1.49
1.46
1.43
1.40
Parameter
Value
1 Title
XUF05157pure.1.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
12.7
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
MeO
O
O
N
N
O
OMe
2.S39
1.04
0.97
2.00
0.95
2.02
1.00
1.03
3.06
4.10
2.07
1.05
1.03
1.05
1.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

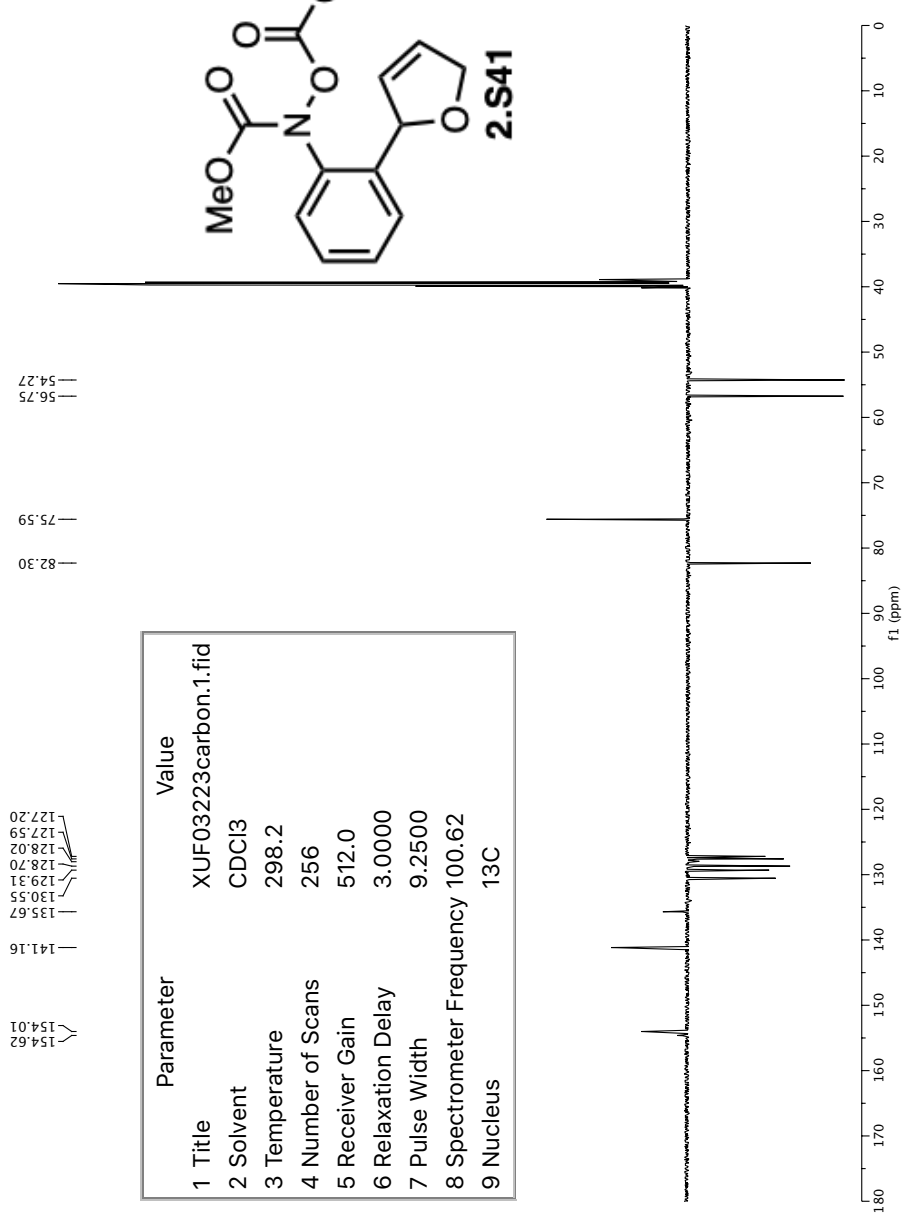

154.69
154.02
141.73
138.77
137.74
129.92
129.54
128.54
121.36
119.10
110.80
56.75
54.25
35.44
31.04
24.31
21.10
MeO
O
O
N
N
O
OMe
2.S39
Parameter Value
1 Title XUF05157pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

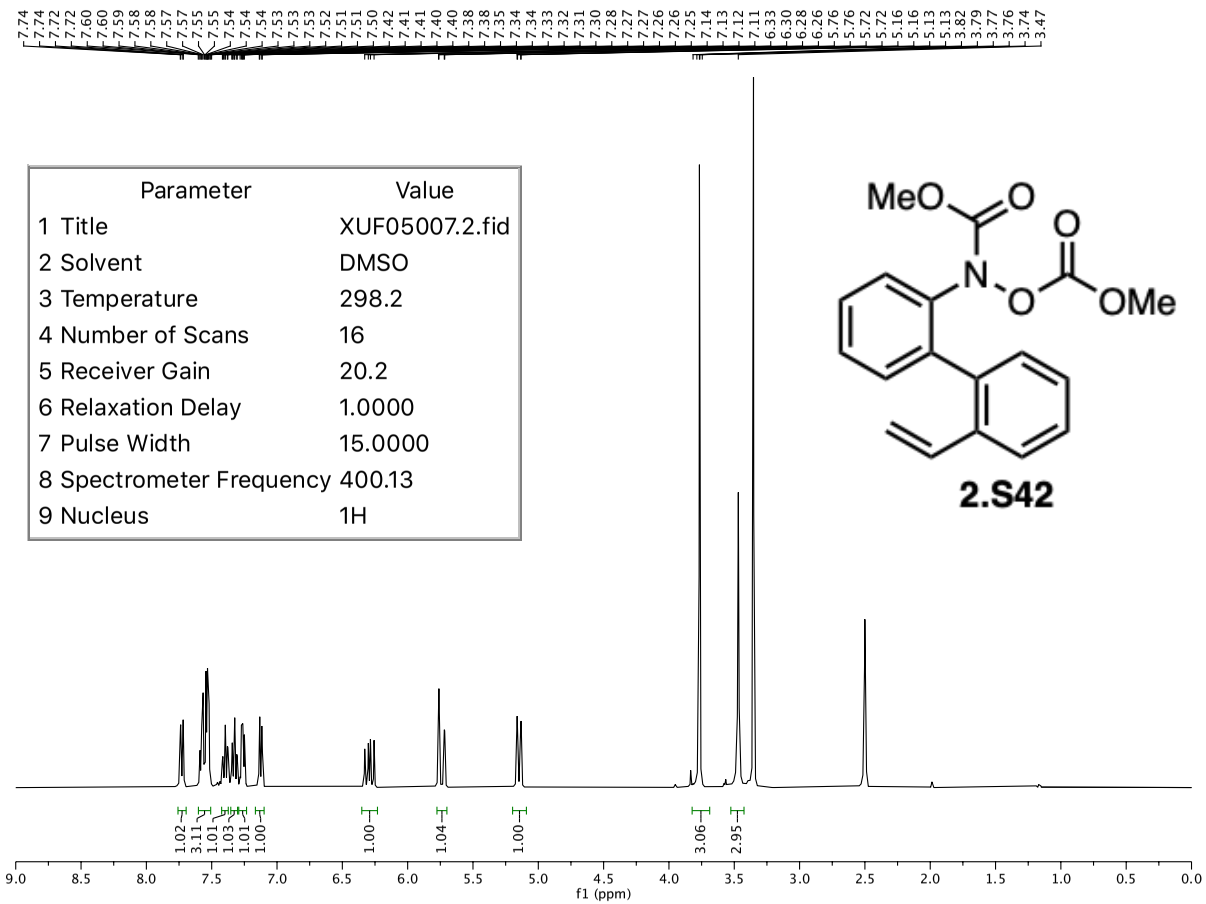

two peaks
overlaped
MeO
O
O
N
N
O
OMe
Parameter Value
1 Title XUF05175-2D.3.ser
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 4
5 Receiver Gain 46341.0
6 Relaxation Delay 1.4642
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (3140.7, 16666.7)
10 Lowest Frequency (233.2, -846.0)
11 Nucleus (1H, 13C)
12 Acquired Size (512, 128)
13 Spectral Size (512, 512)
8.00 7.95 7.90 7.85 7.80 7.75 7.70 7.65 7.60 7.55 7.50 7.45 7.40 7.35 7.30 7.25 7.20 7.15 7.10 7.05 7.00
f2 (ppm)
100 105 110 115 120 125 130 135 140
f1 (ppm)

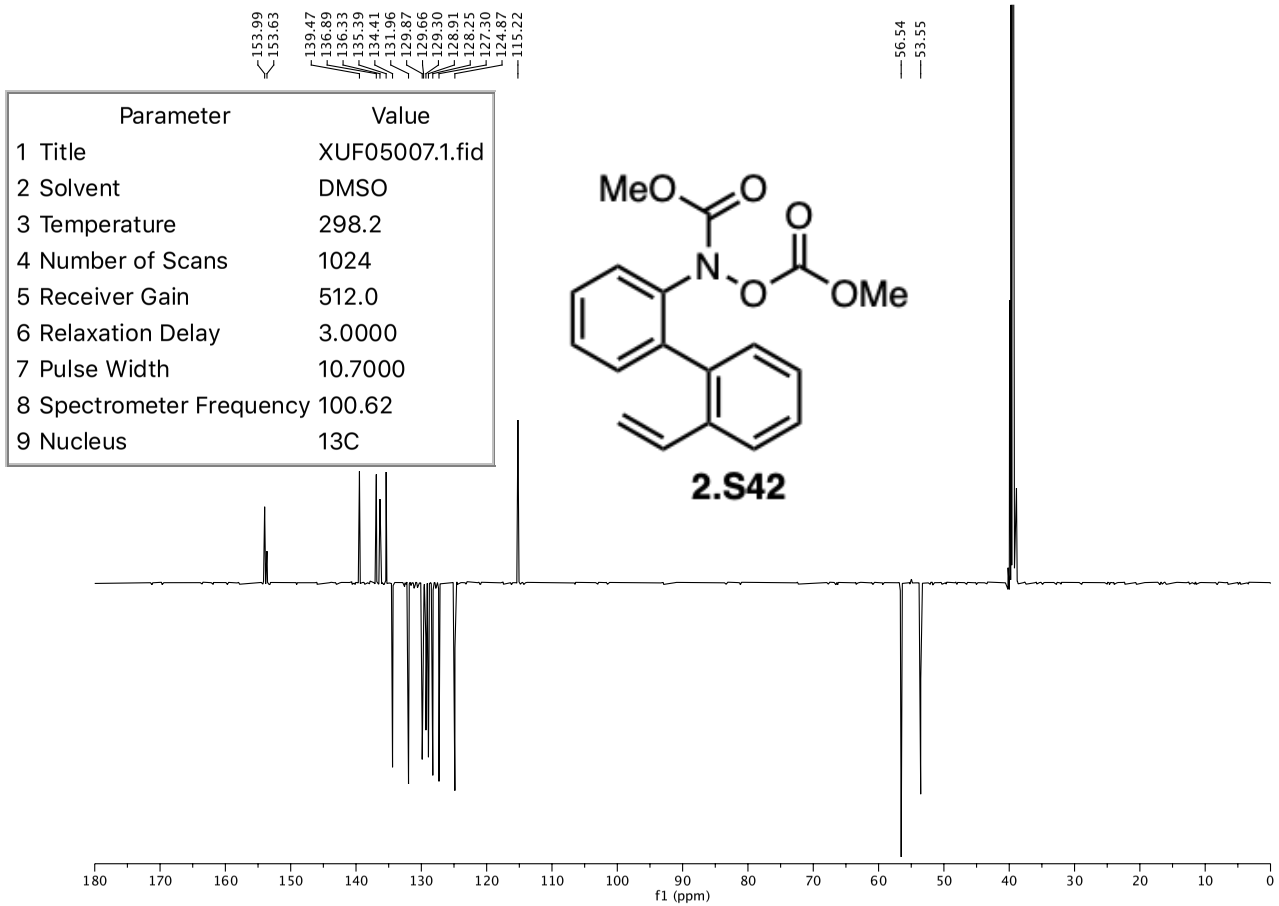

7.59
7.59
7.57
7.57
7.47
7.46
7.46
7.46
7.45
7.44
7.44
7.43
7.42
7.36
7.36
7.35
7.34
6.48
6.47
6.46
6.46
5.95
5.92
5.92
5.90
4.95
4.95
4.94
4.93
3.89
3.81
3.16
3.16
3.15
3.14
3.13
3.13
3.12
3.11
3.10
3.09
3.09
2.54
2.53
2.52
2.51
2.51
2.50
2.50
2.49
2.48
2.48
2.47
2.46
Parameter Value
1 Title XUF03128.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
O
2.S40
1.01
1.96
0.99
1.00
0.96
1.02
3.01
2.96
1.02
1.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

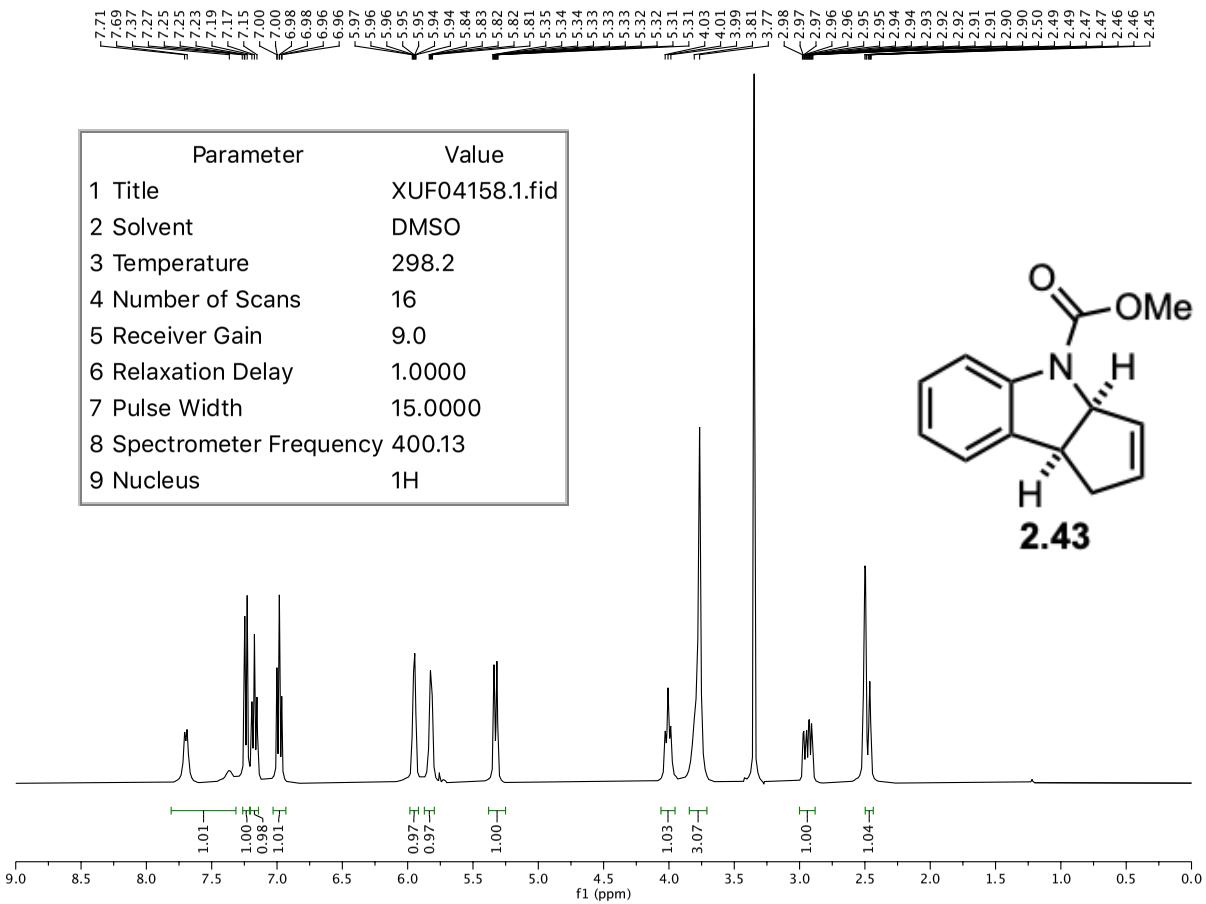
155.05
154.69
145.37
142.52
135.65
130.68
128.46
128.30
126.47
99.27
77.63
56.47
54.27
38.01
MeO
OMe
2.S40
Parameter
Value
1 Title
XUF03128.2.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

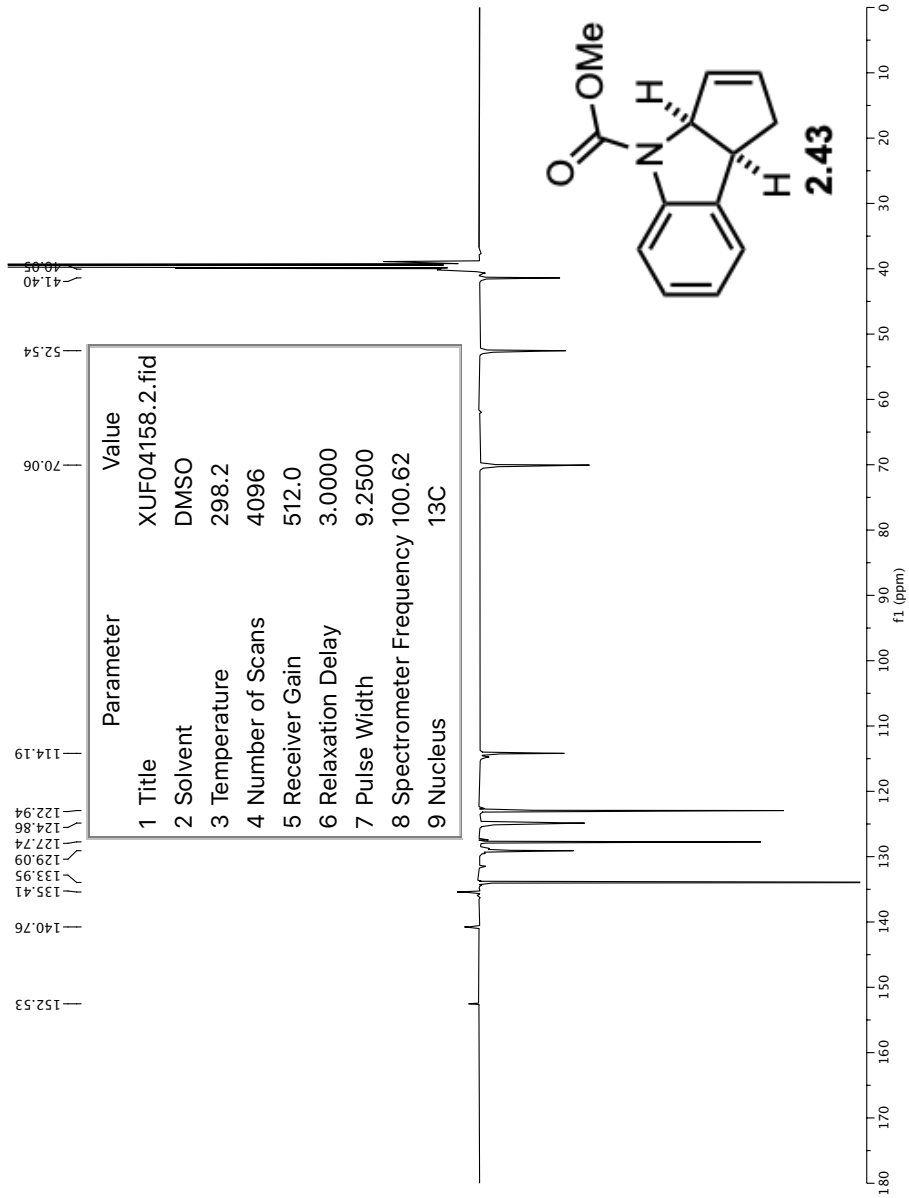

7.51 7.50 7.49 7.49 7.48 7.47 7.47 7.44 7.44 7.42 7.42 7.41 7.40 7.40 7.39 7.38 7.37 6.16 6.15 6.15 6.14 6.14 6.13 6.13 6.02 5.87 5.86 5.86 5.85 5.85 5.84 5.84 4.87 4.86 4.84 4.84 4.83 4.82 4.82 4.70 4.70 4.69 4.69 4.69 4.68 4.68 4.66 4.66 4.66 4.65 4.65 3.86 3.75
Parameter Value
1 Title XUF03223.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
N
O
O
OMe
O
2.S41
1.01 2.99 0.99 0.95 1.01 1.00 1.00 2.96 3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

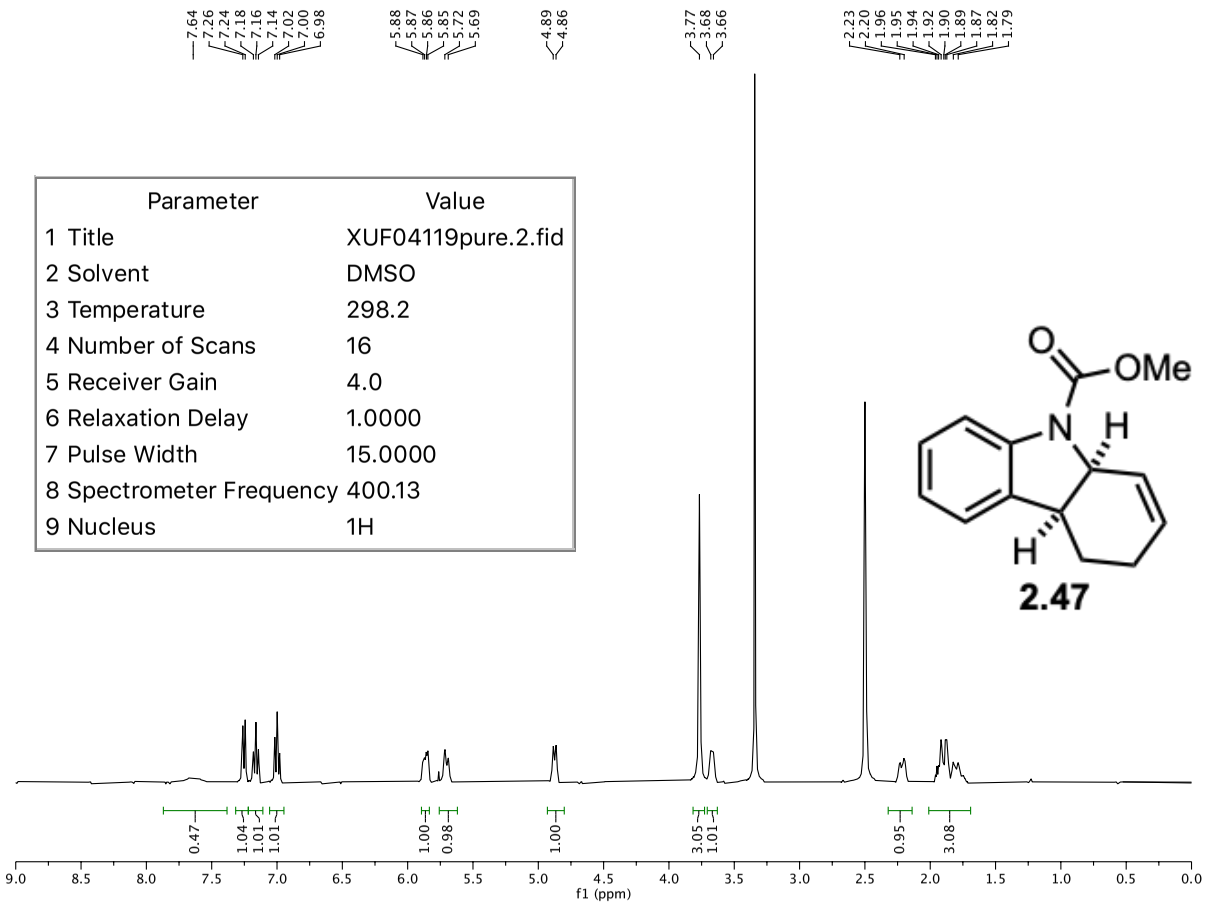

MeO
OMe
2.S41
154.62
154.01
141.16
135.67
130.55
129.31
128.70
128.02
127.59
127.20
82.30
75.59
56.75
54.27
Parameter
Value
1 Title
XUF03223carbon.1.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
256
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

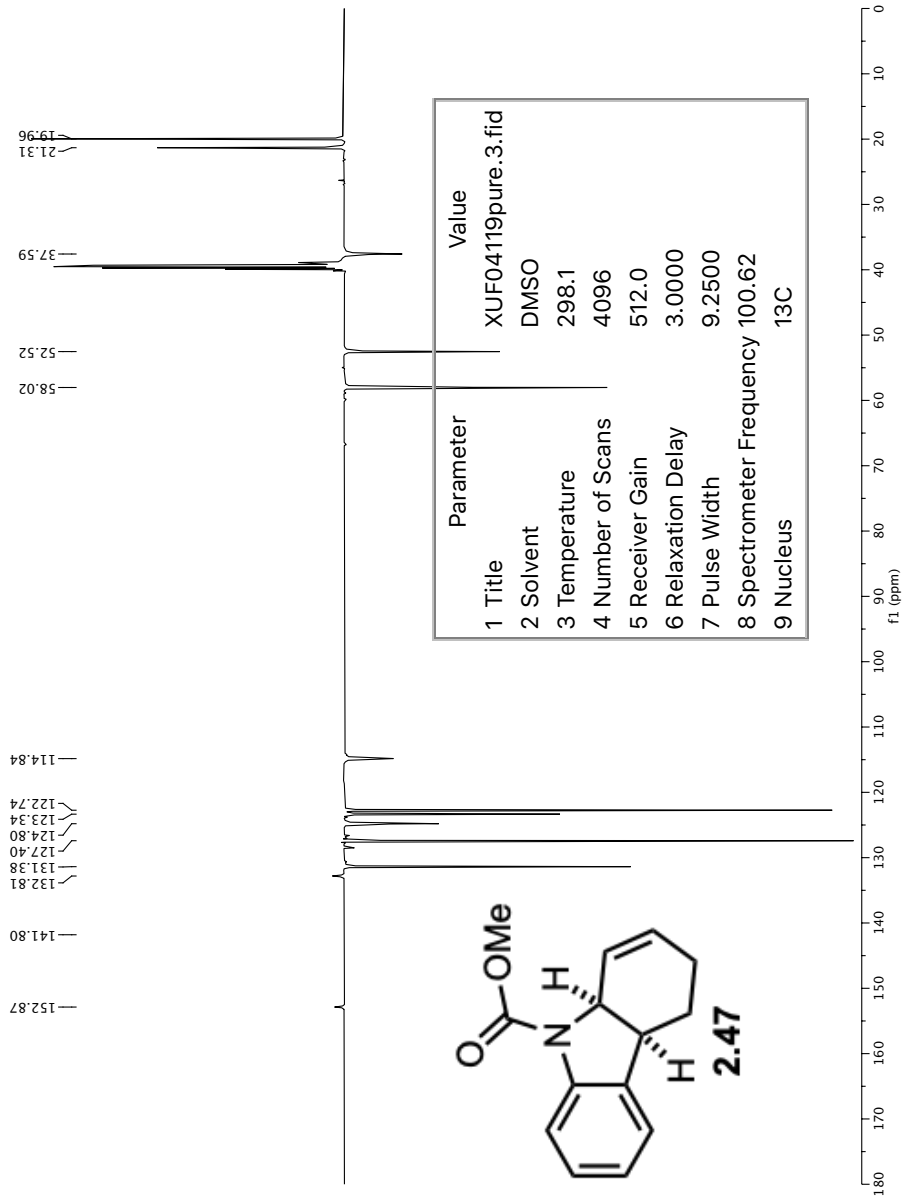

7.74 7.74 7.72 7.72 7.72 7.60 7.60 7.59 7.58 7.58 7.57 7.57 7.57 7.55 7.55 7.54 7.54 7.54 7.53 7.53 7.53 7.52 7.51 7.51 7.50 7.42 7.41 7.41 7.40 7.40 7.38 7.38 7.35 7.34 7.34 7.33 7.32 7.31 7.30 7.28 7.27 7.27 7.26 7.26 7.25 7.14 7.13 7.12 7.11 6.33 6.30 6.28 6.26 5.76 5.76 5.72 5.72 5.16 5.16 5.13 5.13 3.82 3.79 3.77 3.76 3.74 3.47
Parameter Value
1 Title XUF05007.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 20.2
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
MeO
O
O
N
O
OMe
2.S42
1.02 3.11 1.01 1.03 1.01 1.00 1.00 1.04 1.00 3.06 2.95
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

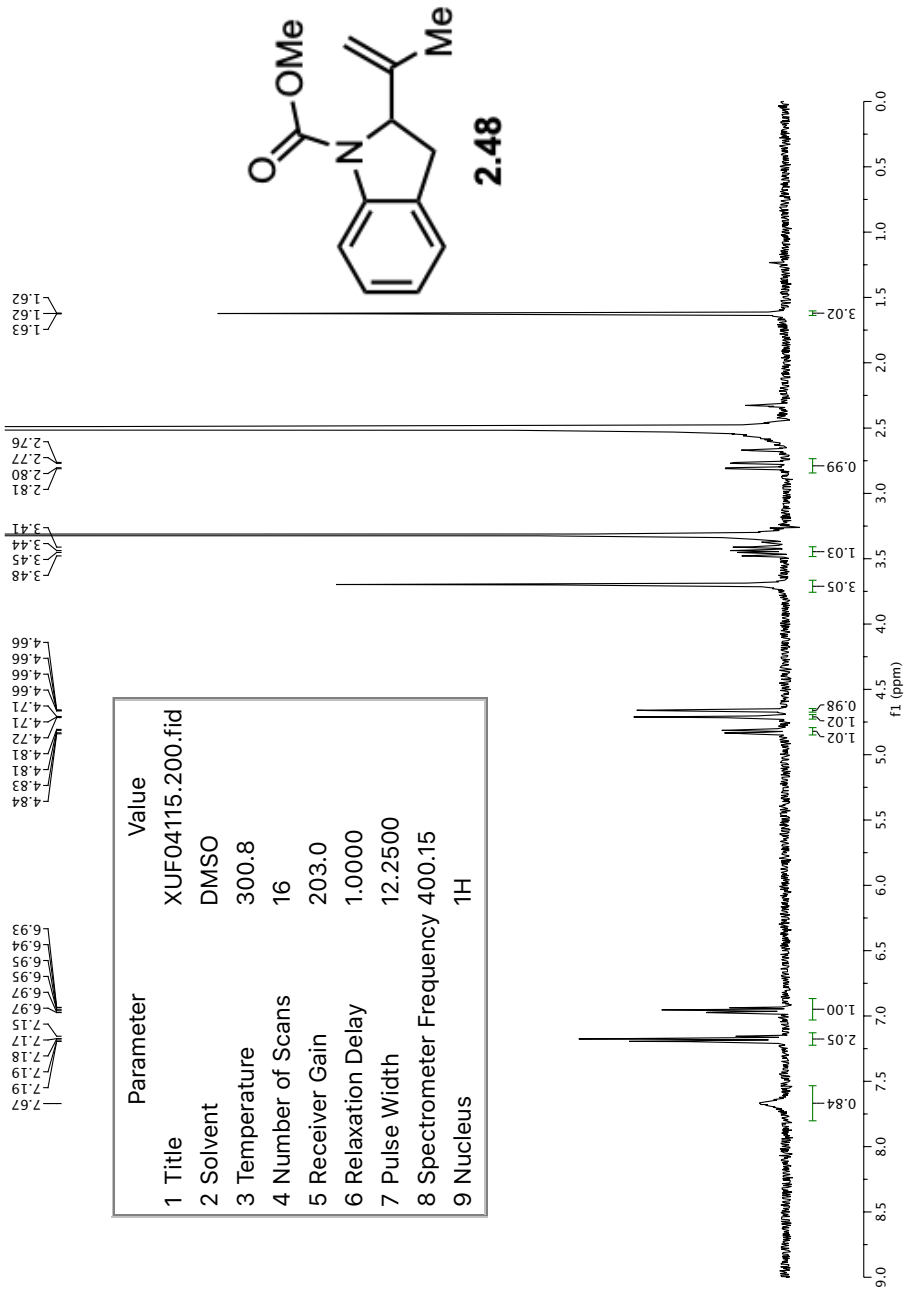

153.99
153.63
139.47
136.89
136.33
135.39
134.41
131.96
129.87
129.66
129.30
128.91
128.25
127.30
124.87
115.22
56.54
53.55
Parameter Value
1 Title XUF05007.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
MeO
O
N
O
O
OMe
2.S42
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

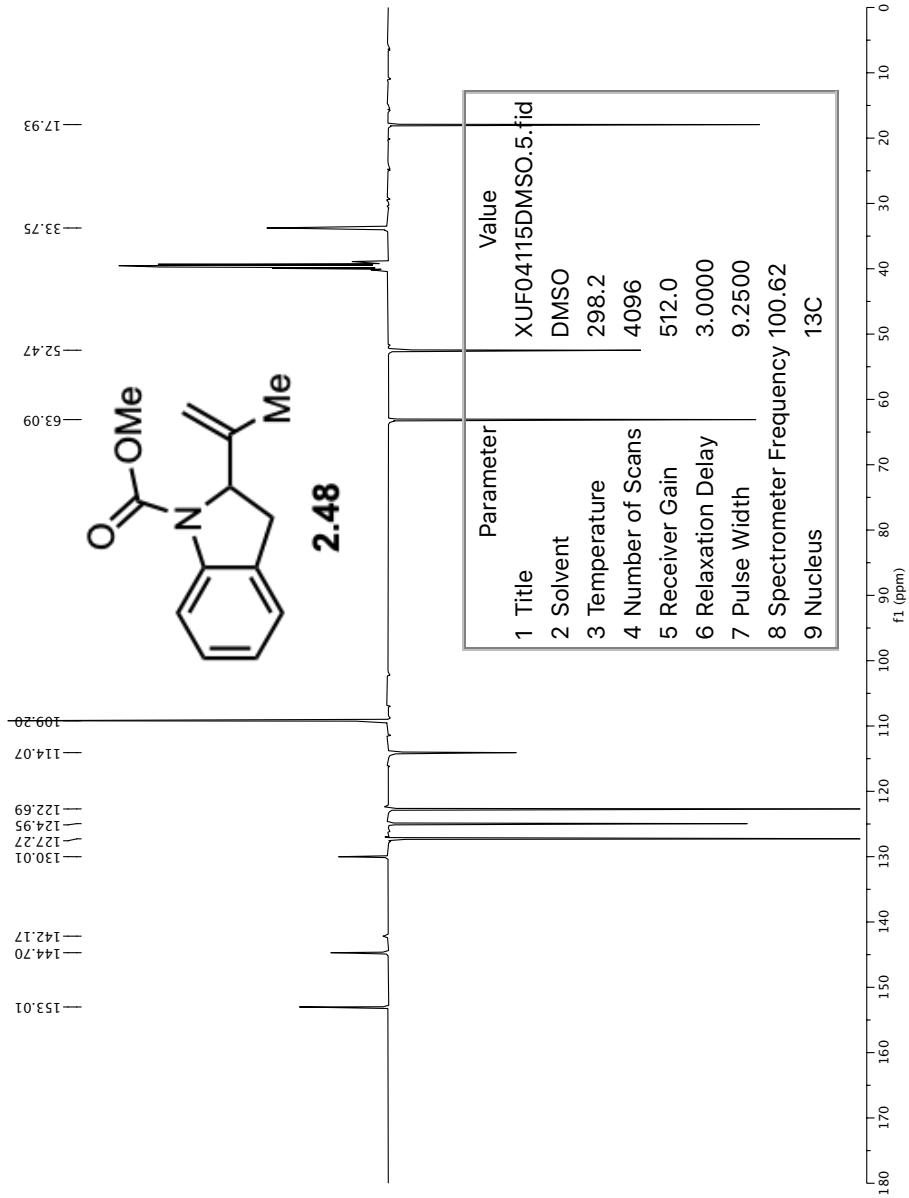

7.71 7.69 7.37 7.27 7.25 7.23 7.19 7.17 7.15 7.00 7.00 6.98 6.98 6.96 6.96 5.97 5.96 5.96 5.95 5.95 5.94 5.94 5.84 5.83 5.82 5.82 5.81 5.35 5.34 5.34 5.33 5.33 5.33 5.32 5.32 5.31 5.31 4.03 4.01 3.99 3.81 3.77 2.98 2.97 2.97 2.96 2.96 2.95 2.95 2.94 2.94 2.93 2.92 2.92 2.91 2.91 2.90 2.90 2.50 2.49 2.49 2.47 2.47 2.46 2.46 2.45
Parameter Value
1 Title XUF04158.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
H
H
2.43
1.01 1.00 0.98 1.01 0.97 0.97 1.00 1.03 3.07 1.00 1.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


Parameter Value
1 Title XUF04158.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
152.53
140.76
135.41
133.95
129.09
127.74
124.86
122.94
114.19
70.06
52.54
41.40
40.05
OMe
O
N
H
H
2.43
f1 (ppm)

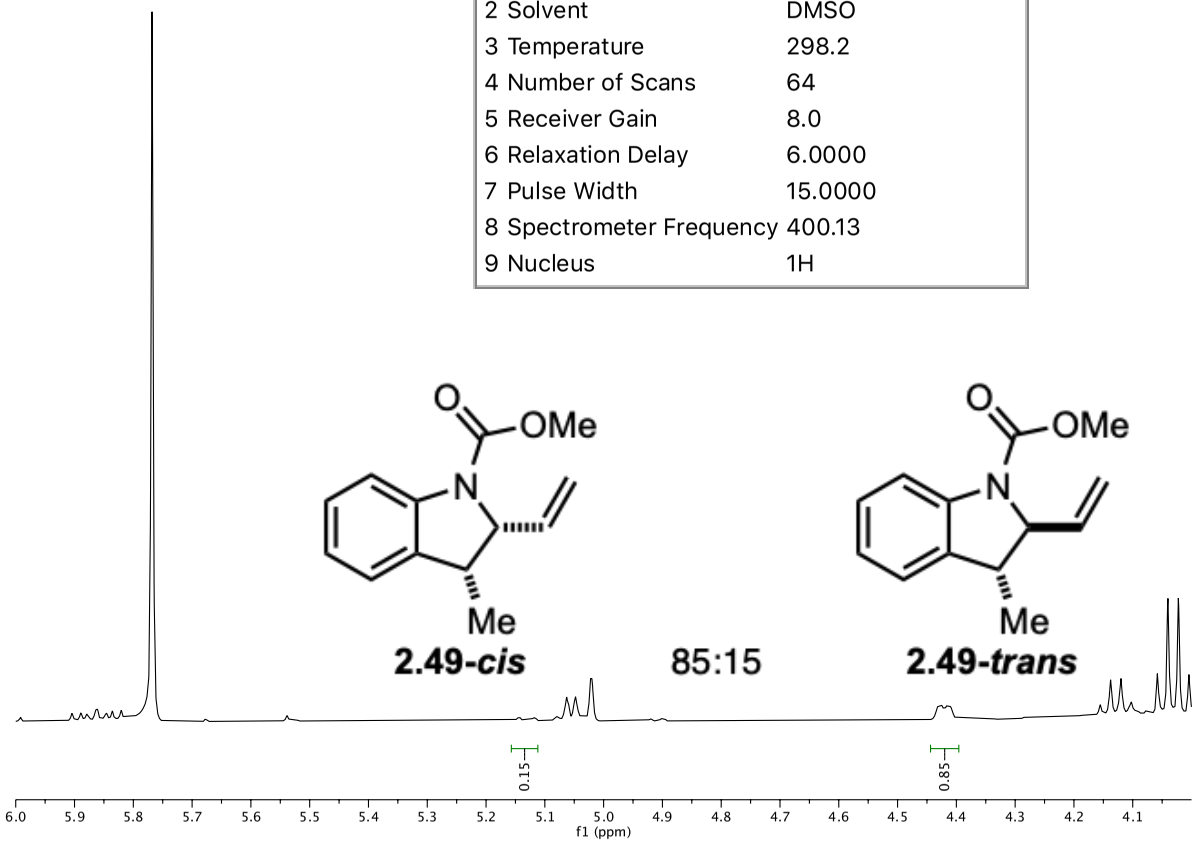

7.64
7.26
7.24
7.18
7.16
7.14
7.02
7.00
6.98
5.88
5.87
5.86
5.85
5.72
5.69
4.89
4.86
3.77
3.68
3.66
2.23
2.20
1.96
1.95
1.94
1.92
1.90
1.89
1.87
1.82
1.79
Parameter Value
1 Title XUF04119pure.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
H
H
2.47
0.47
1.04
1.01
1.01
1.00
0.98
1.00
3.05
1.01
0.95
3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

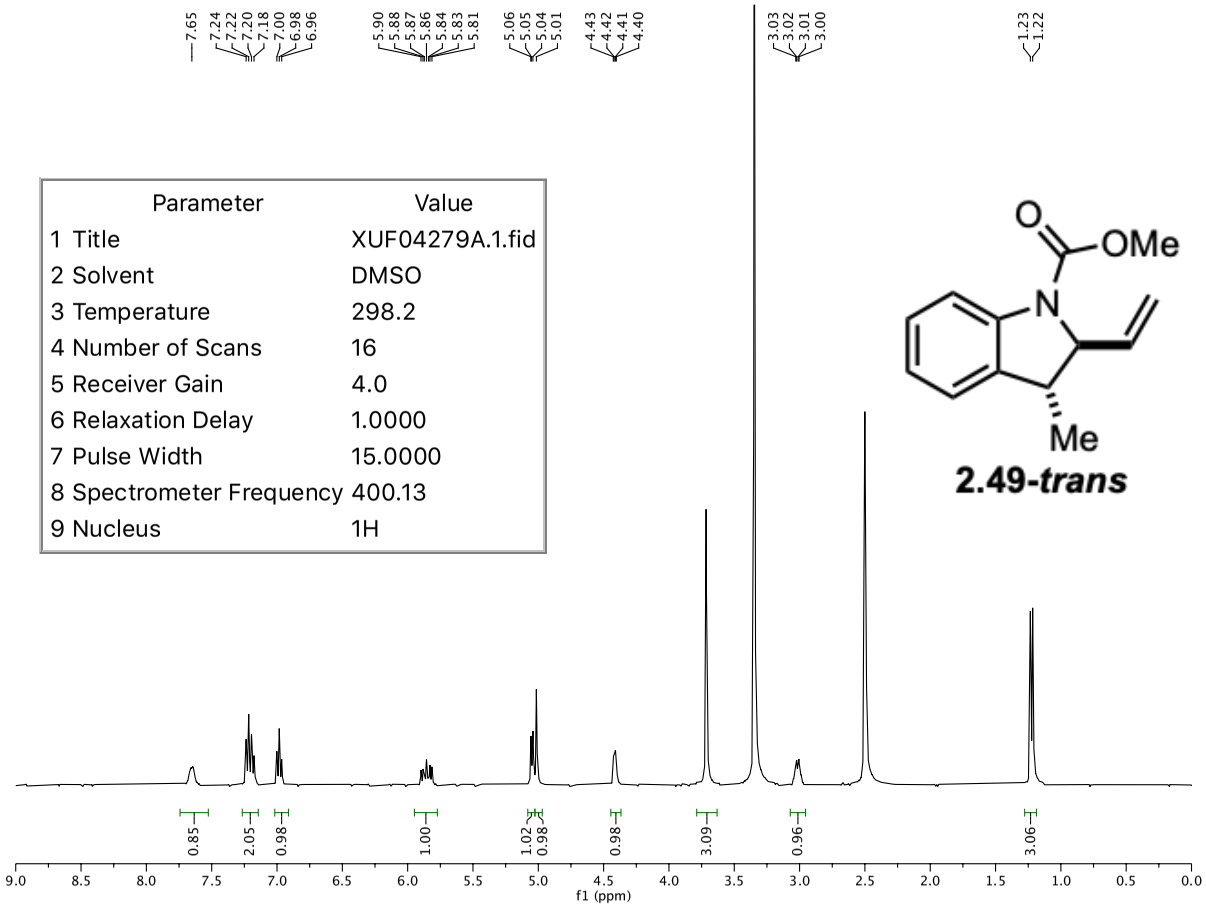

19.96
21.31
37.59
52.52
58.02
114.84
122.74
123.34
124.80
127.40
131.38
132.81
141.80
152.87
Parameter
Value
1 Title
XUF04119pure.3.fid
2 Solvent
DMSO
3 Temperature
298.1
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)
OMe
O
N
H
H
2.47

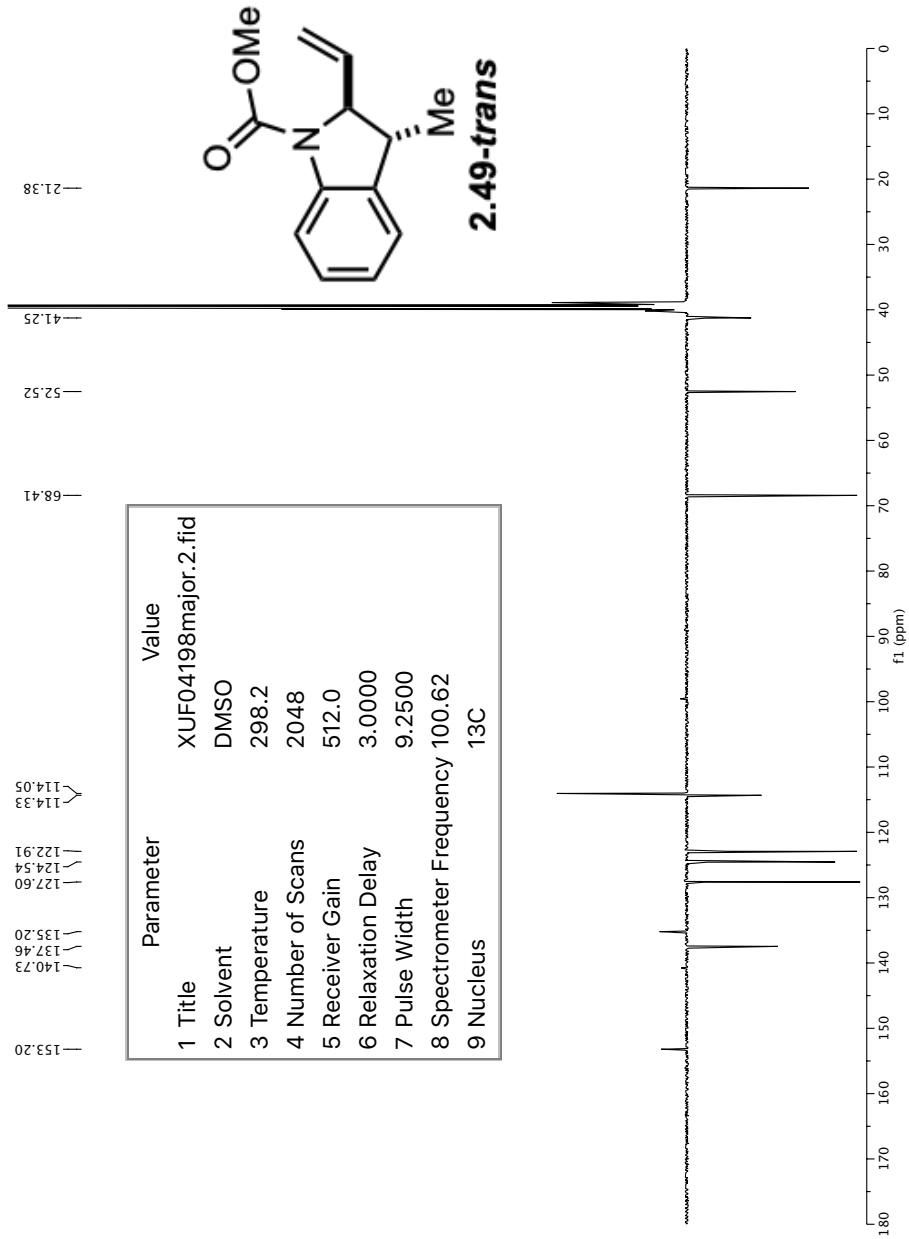

OMe
Me
2.48
Parameter Value
1 Title XUF04115.200.fid
2 Solvent DMSO
3 Temperature 300.8
4 Number of Scans 16
5 Receiver Gain 203.0
6 Relaxation Delay 1.0000
7 Pulse Width 12.2500
8 Spectrometer Frequency 400.15
9 Nucleus 1H
f1 (ppm)

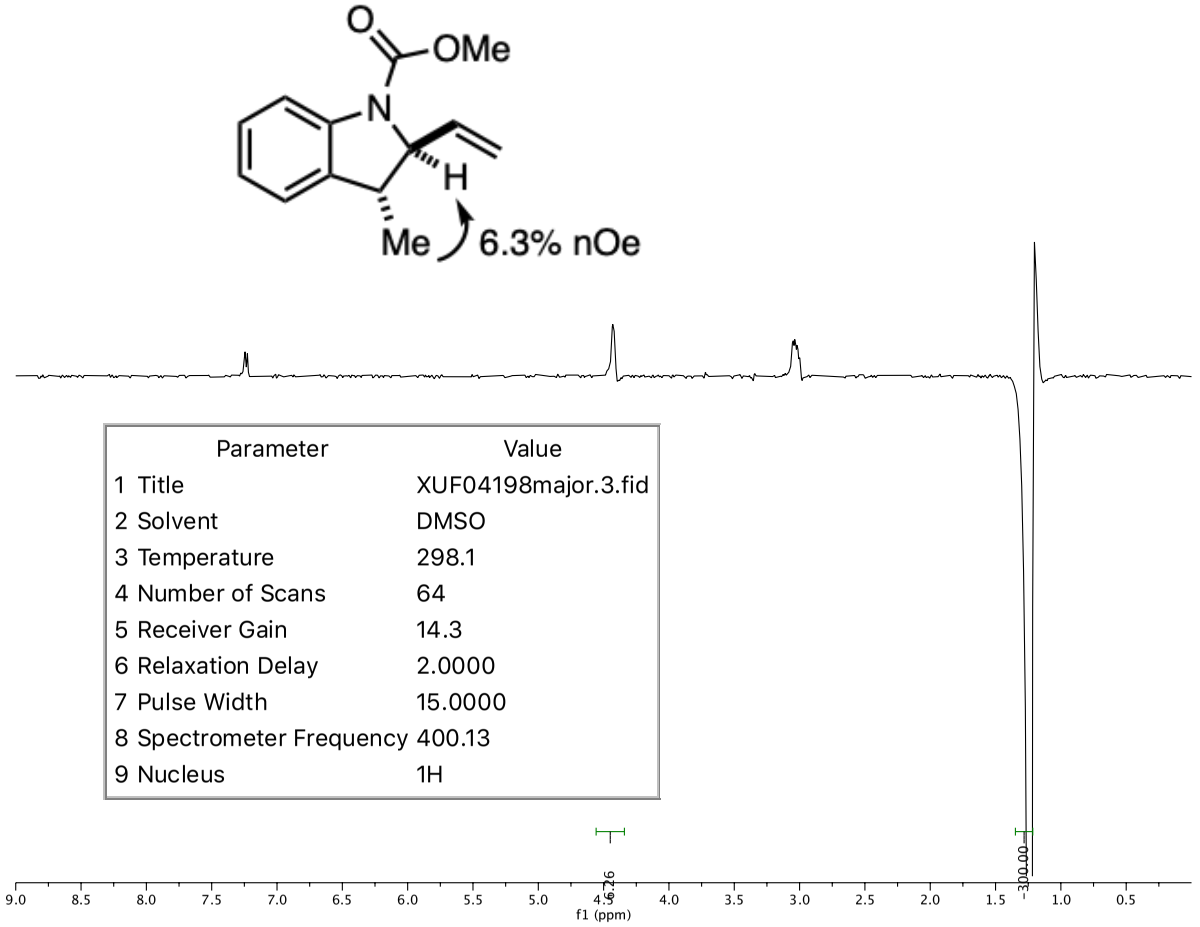

153.01
144.70
142.17
130.01
127.27
124.95
122.69
114.07
109.20
63.09
52.47
33.75
17.93
OMe
Me
N
O
2.48
Parameter Value
1 Title XUF04115DMSO.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

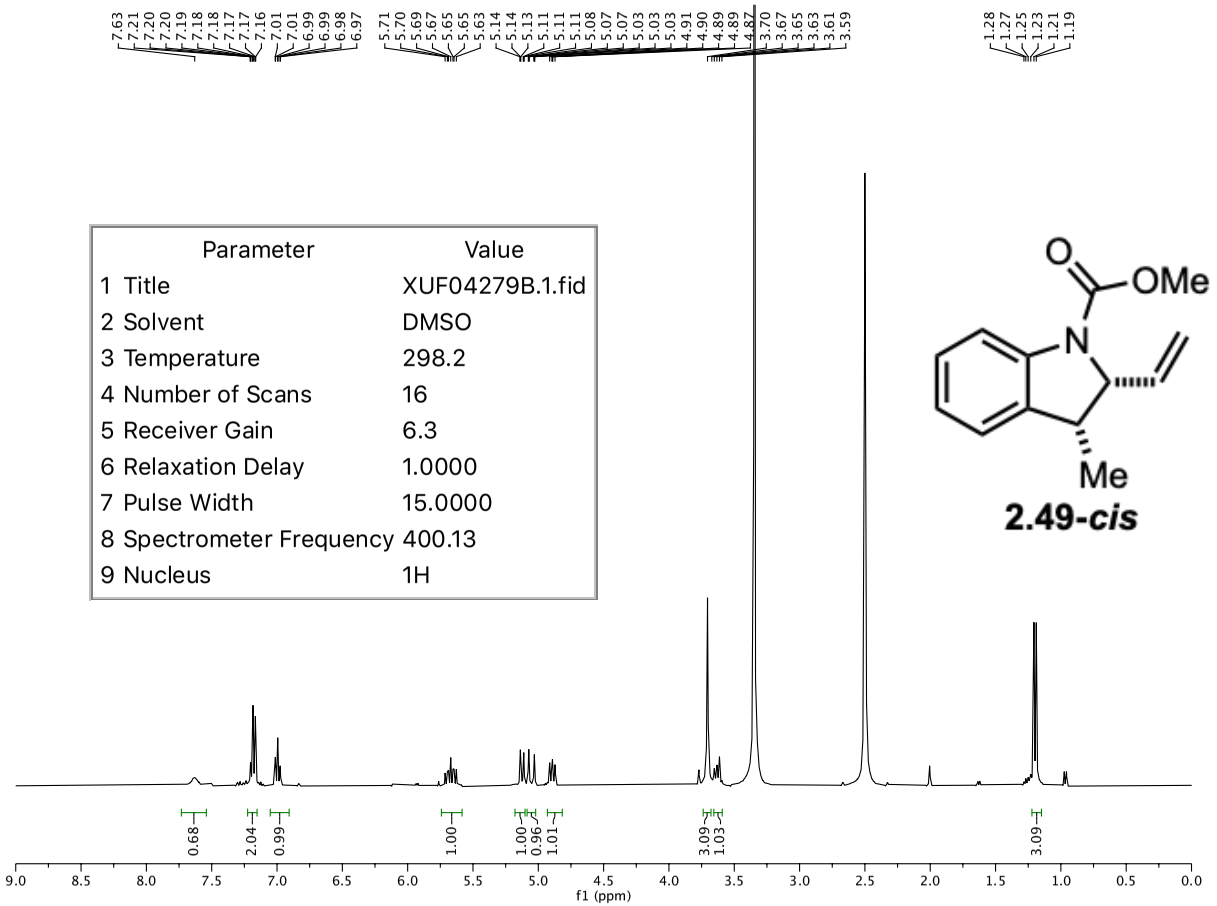
Parameter	Value
1 Title	XUF04279crude.1.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	64
5 Receiver Gain	8.0
6 Relaxation Delay	6.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

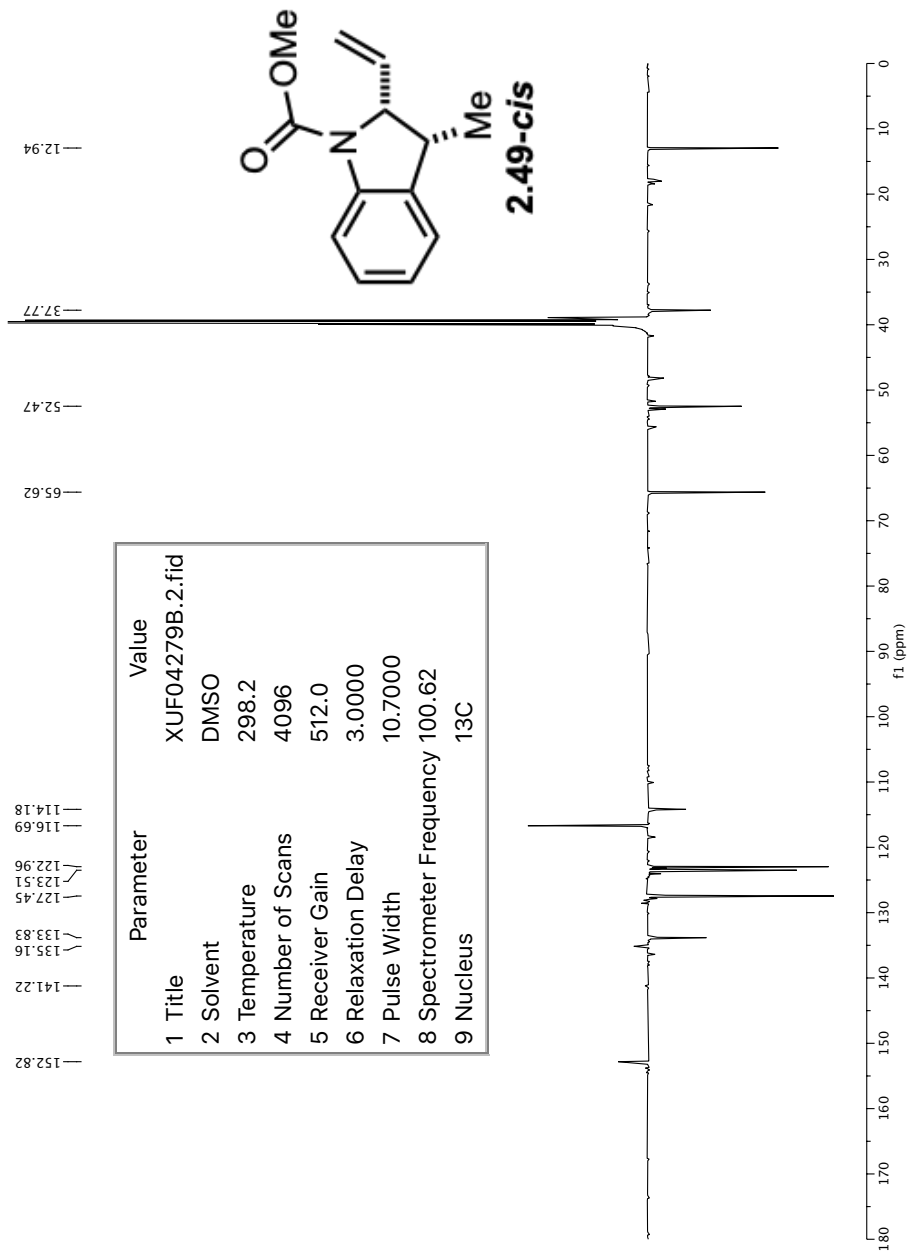


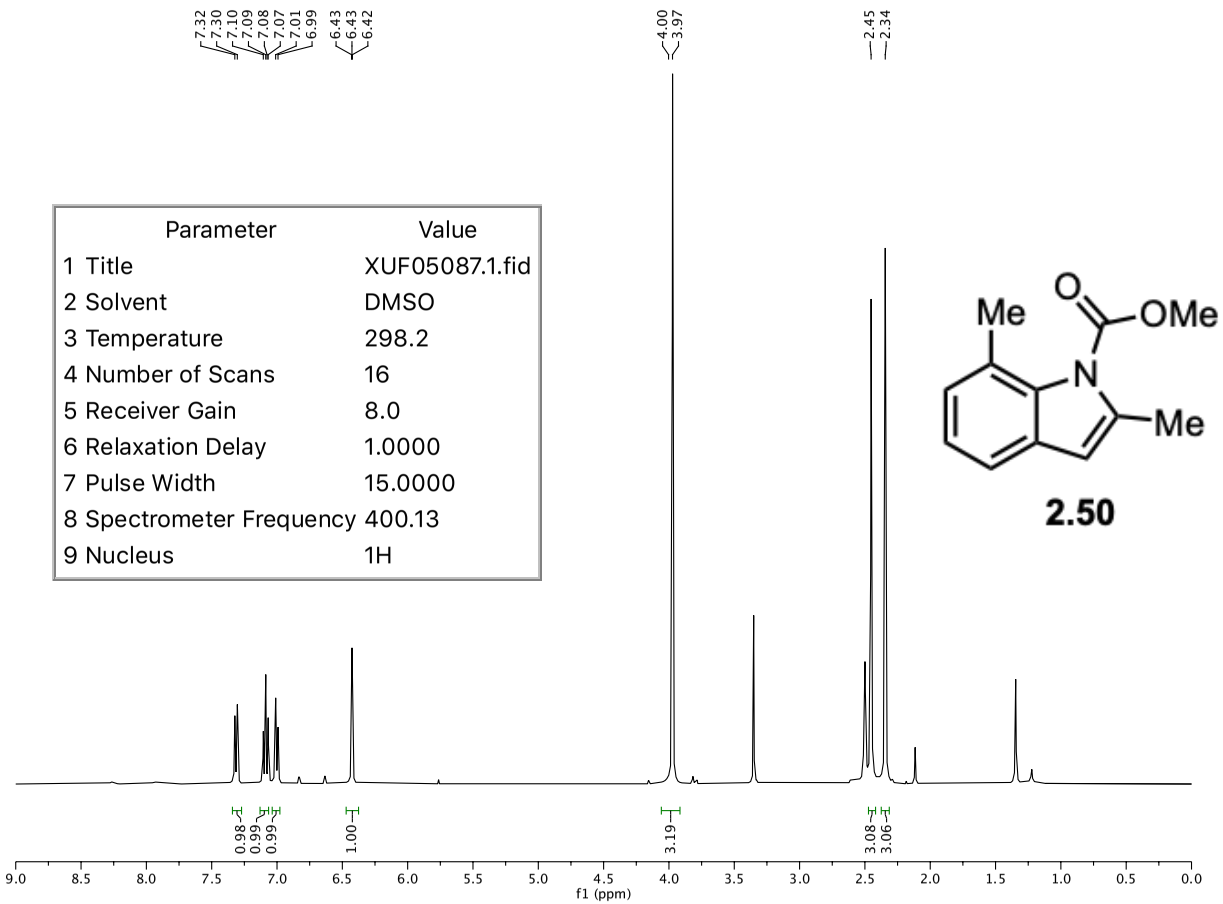

7.65
7.24
7.22
7.20
7.18
7.00
6.98
6.96
5.90
5.88
5.87
5.86
5.84
5.83
5.81
5.06
5.05
5.04
5.01
4.43
4.42
4.41
4.40
3.03
3.02
3.01
3.00
1.23
1.22
Parameter Value
1 Title XUF04279A.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
Me
2.49-trans
0.85
2.05
0.98
1.00
1.02
0.98
0.98
3.09
0.96
3.06
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


OMe
O
N
Me
2.49-trans
21.38
41.25
52.52
68.41
114.33
114.05
122.91
124.54
127.60
135.20
137.46
140.73
153.20
Parameter Value
1 Title XUF04198major.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 2048
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

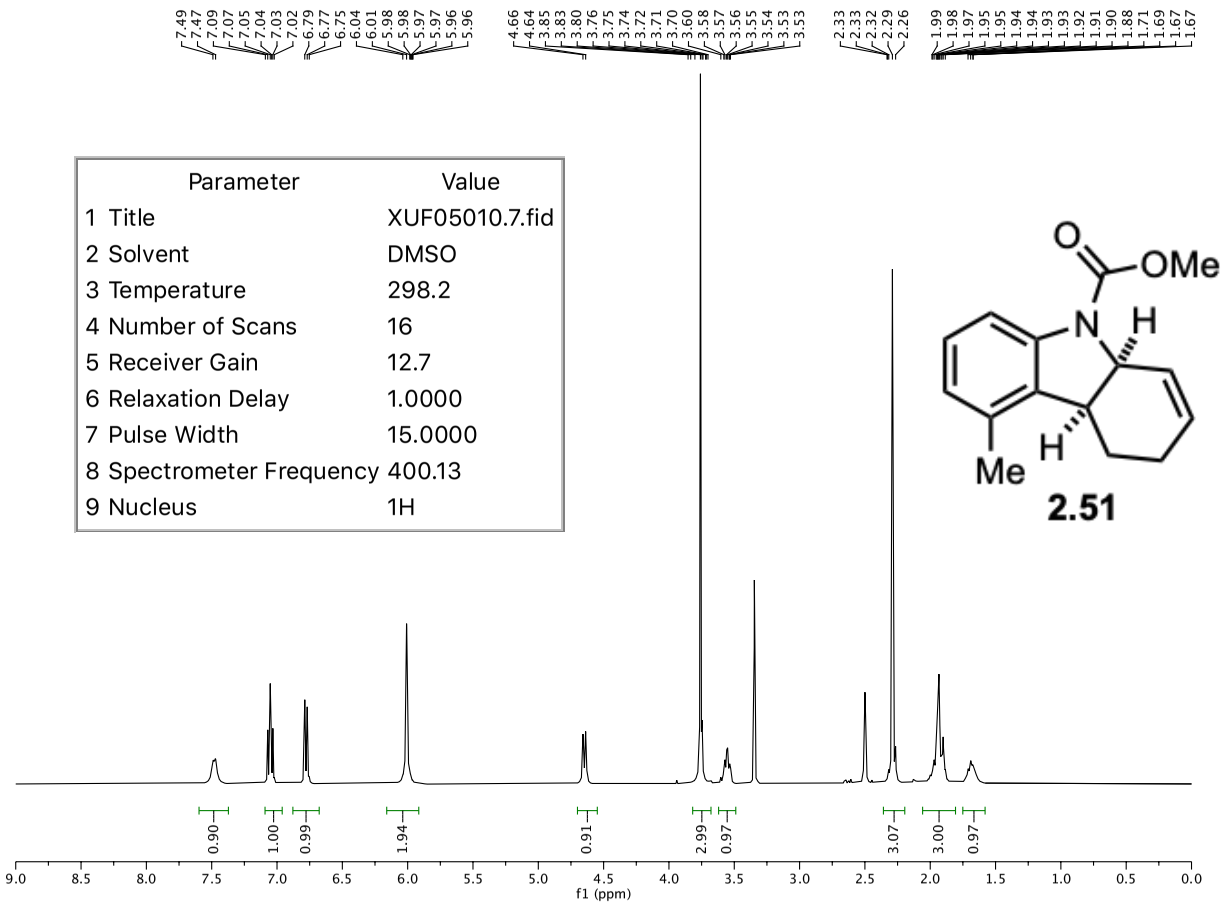

O
OMe
N
H
Me
6.3% nOe
Parameter Value
1 Title XUF04198major.3.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 64
5 Receiver Gain 14.3
6 Relaxation Delay 2.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
4.76
300.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

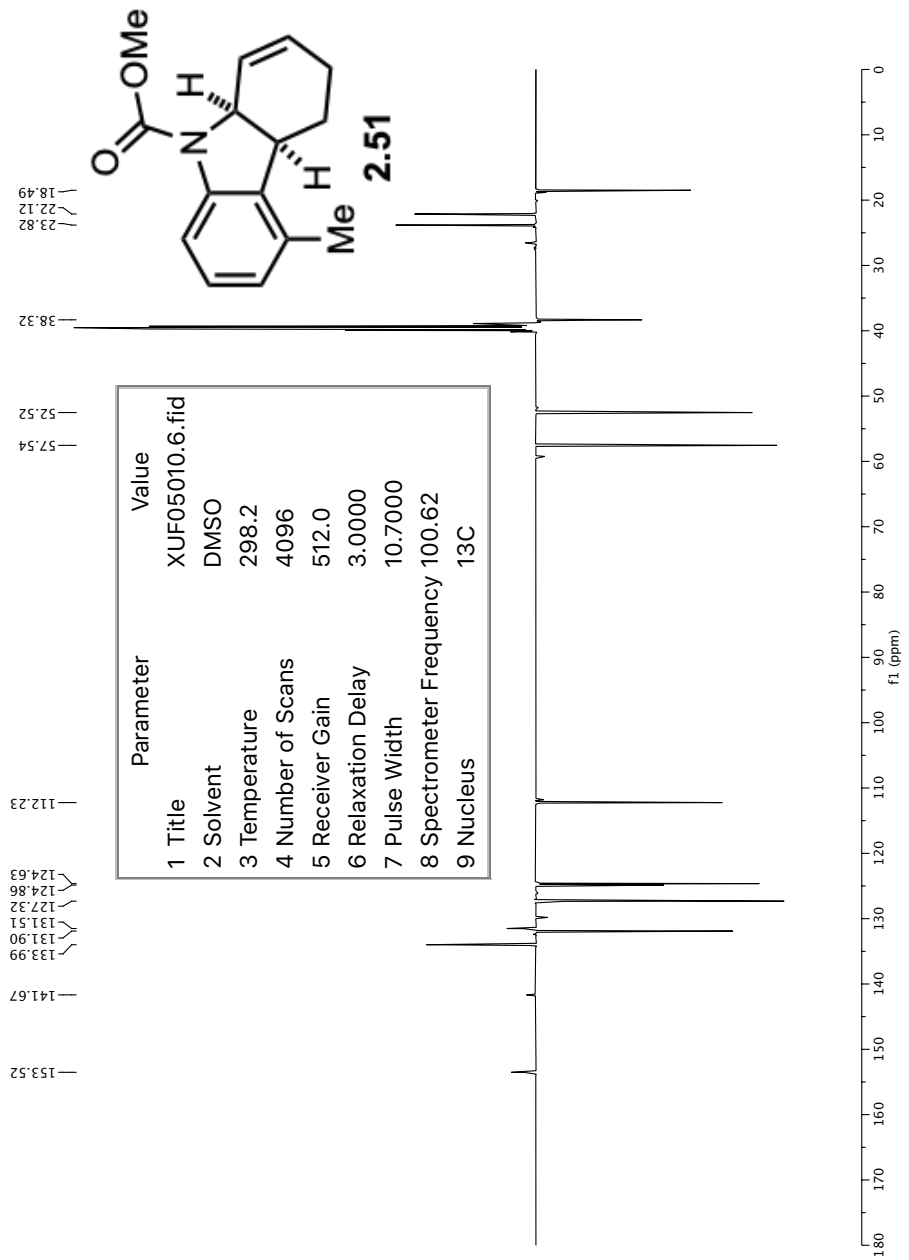

7.63 7.21 7.20 7.20 7.19 7.18 7.18 7.17 7.17 7.16 7.01 7.01 6.99 6.99 6.98 6.97
5.71 5.70 5.69 5.67 5.65 5.65 5.63 5.14 5.14 5.13 5.11 5.11 5.11 5.08 5.07 5.07 5.03 5.03 5.03 4.91 4.90 4.89 4.89 4.87
3.70 3.67 3.65 3.63 3.61 3.59
1.28 1.27 1.25 1.23 1.21 1.19
Parameter Value
1 Title XUF04279B.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
Me
2.49-cis
0.68 2.04 0.99 1.00 1.00 0.96 1.01 3.09 1.03 3.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

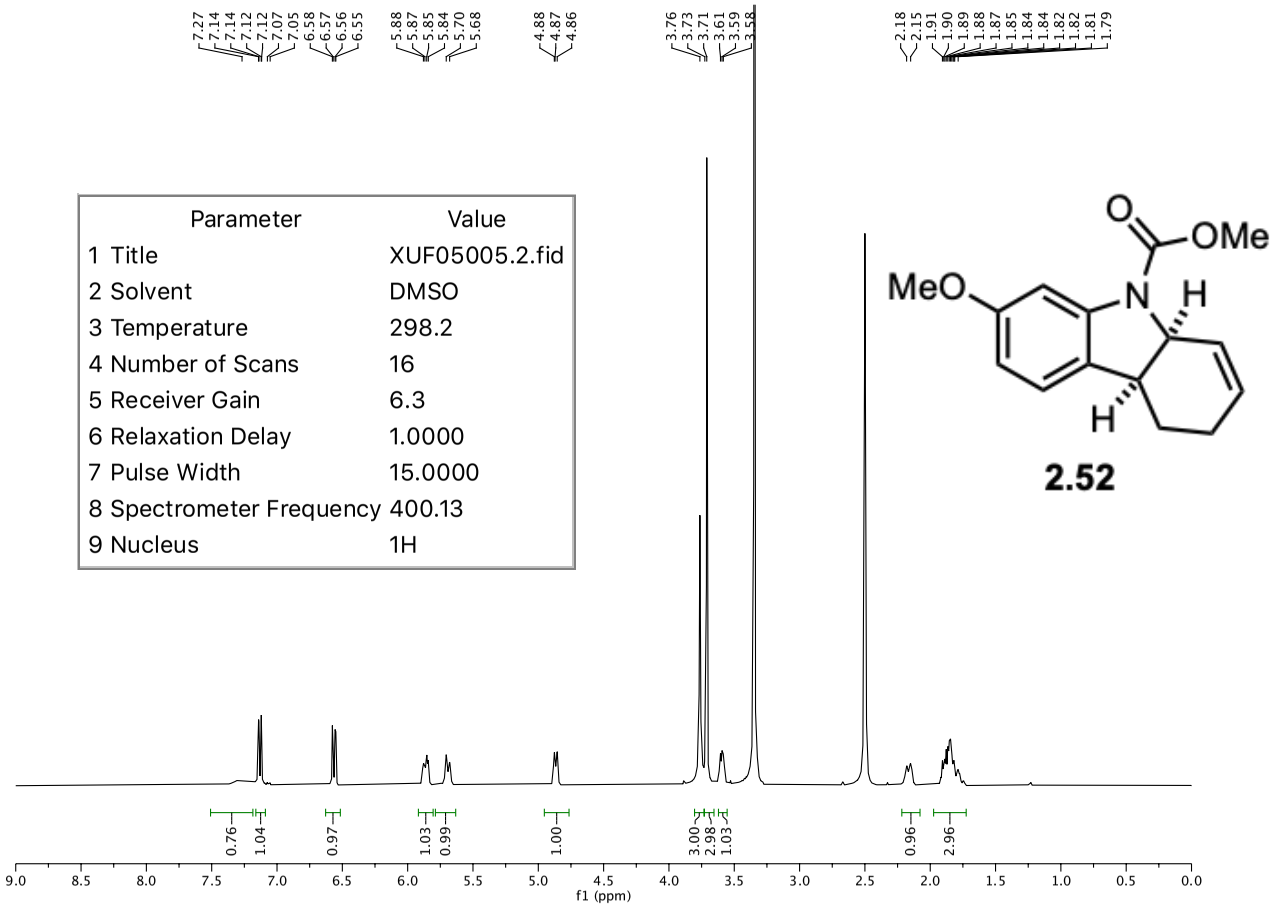

OMe
N
O
Me
2.49-cis
12.94
37.77
52.47
65.62
114.18
116.69
122.96
123.51
127.45
133.83
135.16
141.22
152.82
Parameter Value
1 Title XUF04279B.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

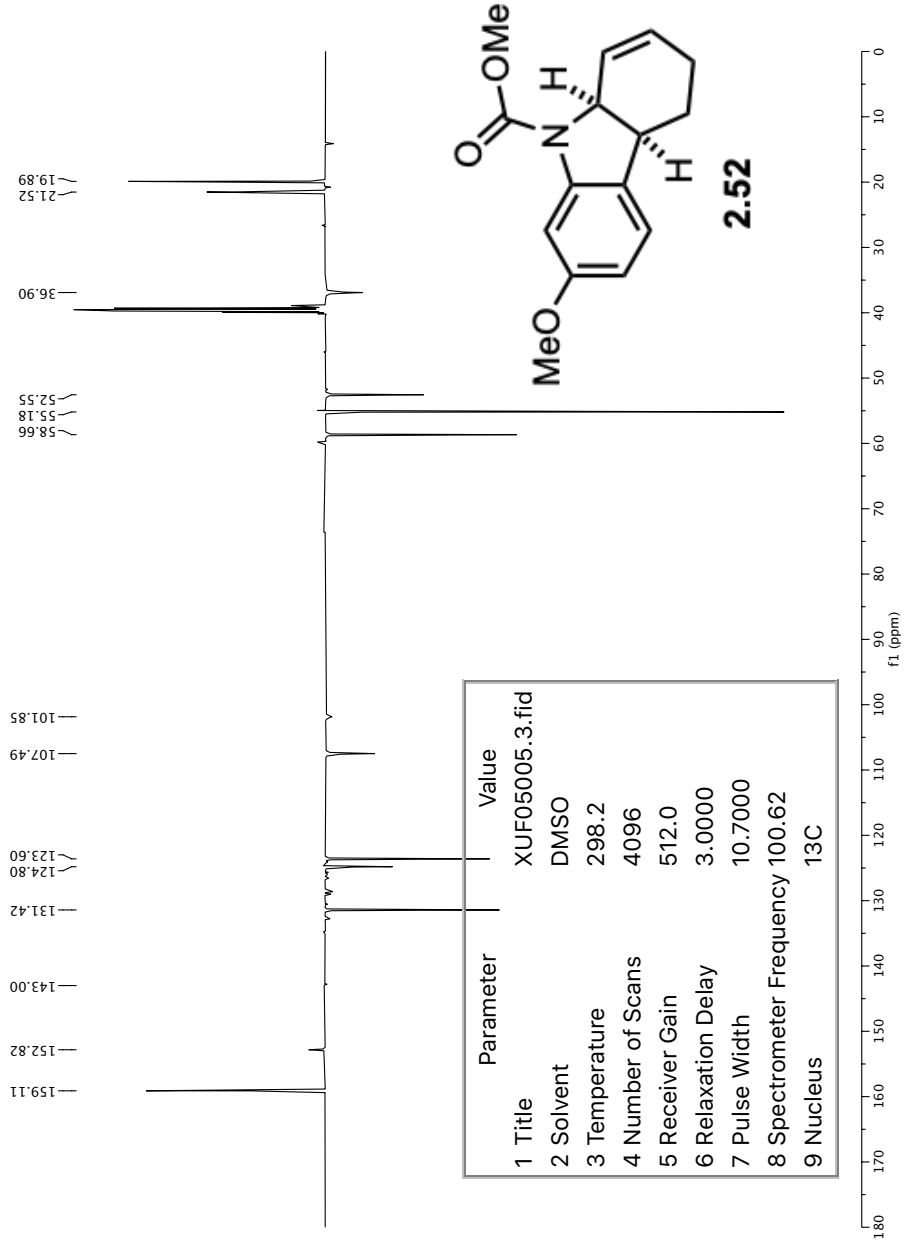

7.32
7.30
7.10
7.09
7.08
7.07
7.01
6.99
6.43
6.43
6.42
4.00
3.97
2.45
2.34
Parameter Value
1 Title XUF05087.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Me
O
OMe
N
Me
2.50
0.98
0.99
0.99
1.00
3.19
3.08
3.06
f1 (ppm)

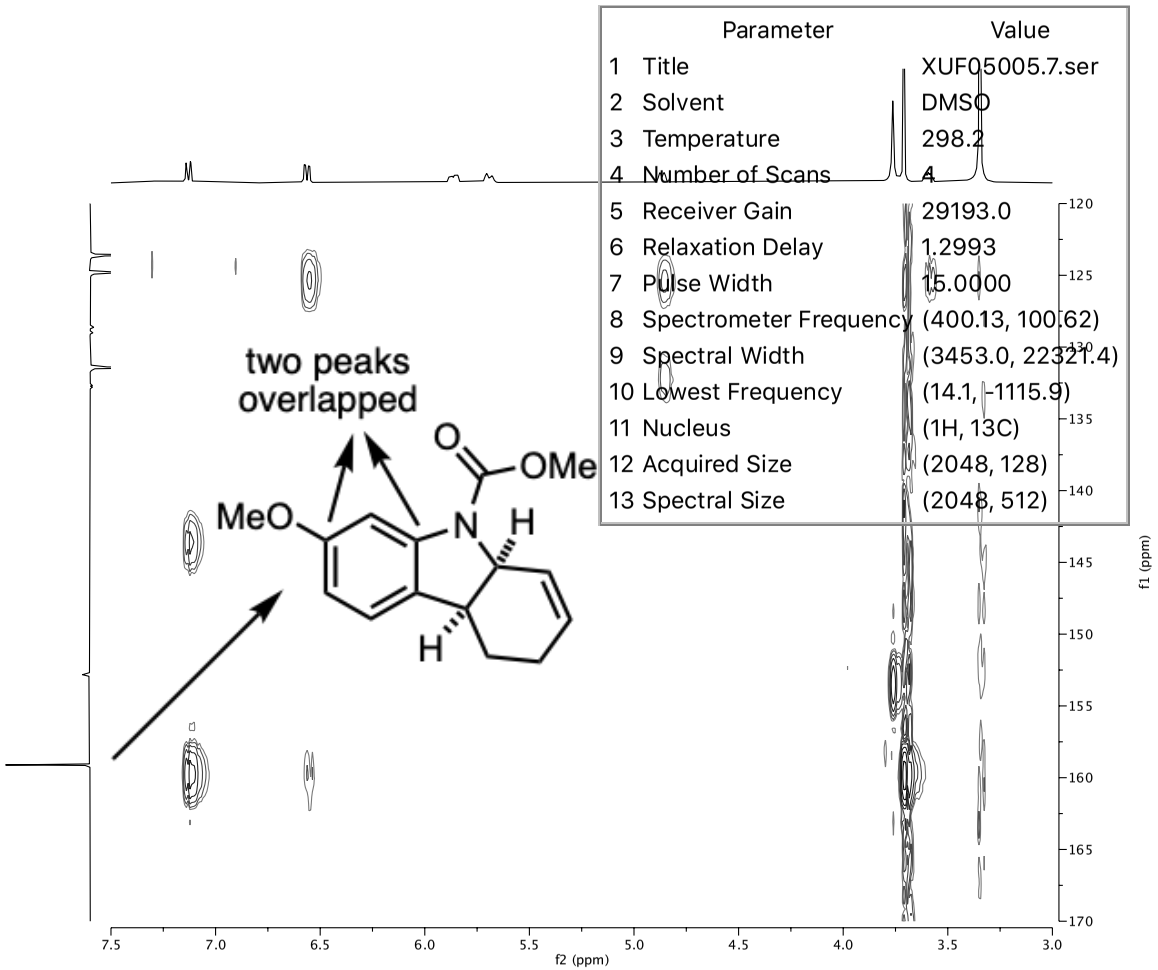
OMe
Me
Me
2.50
Parameter Value
1 Title XUF05087.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
15.10
20.25
54.18
106.76
117.61
122.80
123.58
125.98
130.07
135.16
137.30
152.15
f1 (ppm)

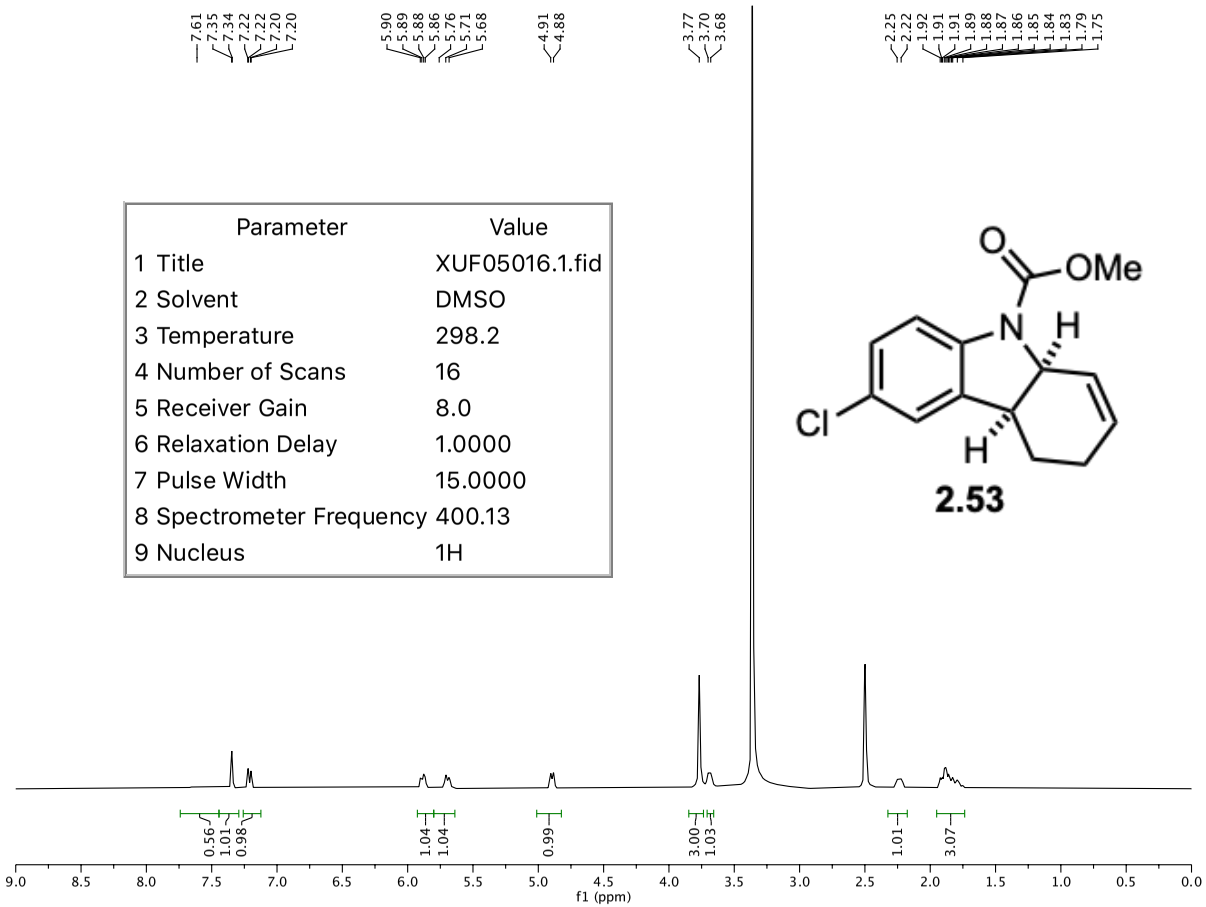

7.49 7.47 7.09 7.07 7.05 7.04 7.03 7.02 6.79 6.77 6.75 6.04 6.01 5.98 5.98 5.97 5.97 5.96 5.96
4.66 4.64 3.85 3.83 3.80 3.76 3.75 3.74 3.72 3.71 3.70 3.60 3.58 3.57 3.56 3.55 3.54 3.53 3.53
2.33 2.33 2.32 2.29 2.26
1.99 1.98 1.97 1.95 1.95 1.94 1.94 1.93 1.93 1.92 1.91 1.90 1.88 1.71 1.69 1.67 1.67
Parameter Value
1 Title XUF05010.7.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
H
H
Me
2.51
0.90 1.00 0.99 1.94 0.91 2.99 0.97 3.07 3.00 0.97
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

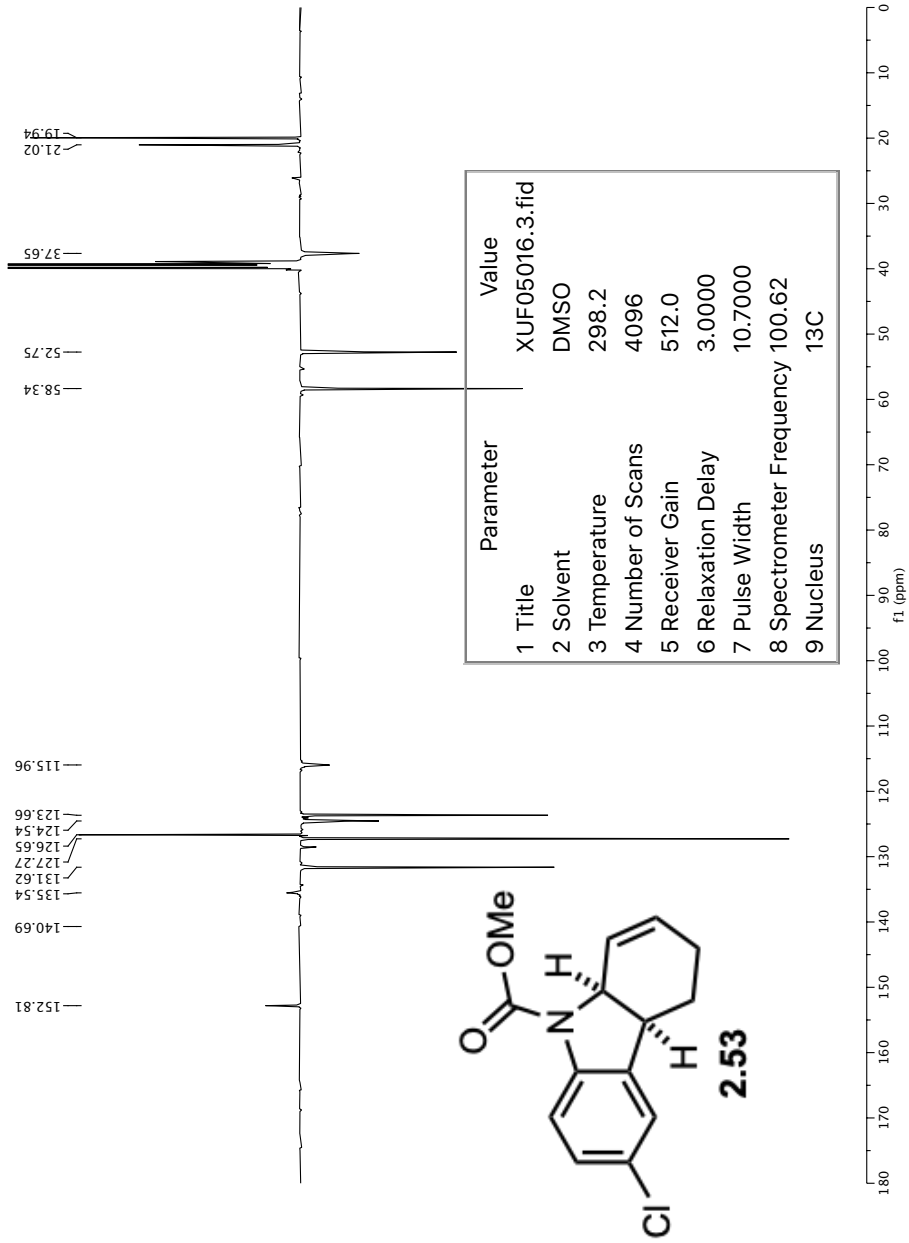

OMe
O
N
H
H
Me
2.51
18.49
22.12
23.82
38.32
52.52
57.54
112.23
124.63
124.86
127.32
131.51
131.90
133.99
141.67
153.52
Parameter Value
1 Title XUF05010.6.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

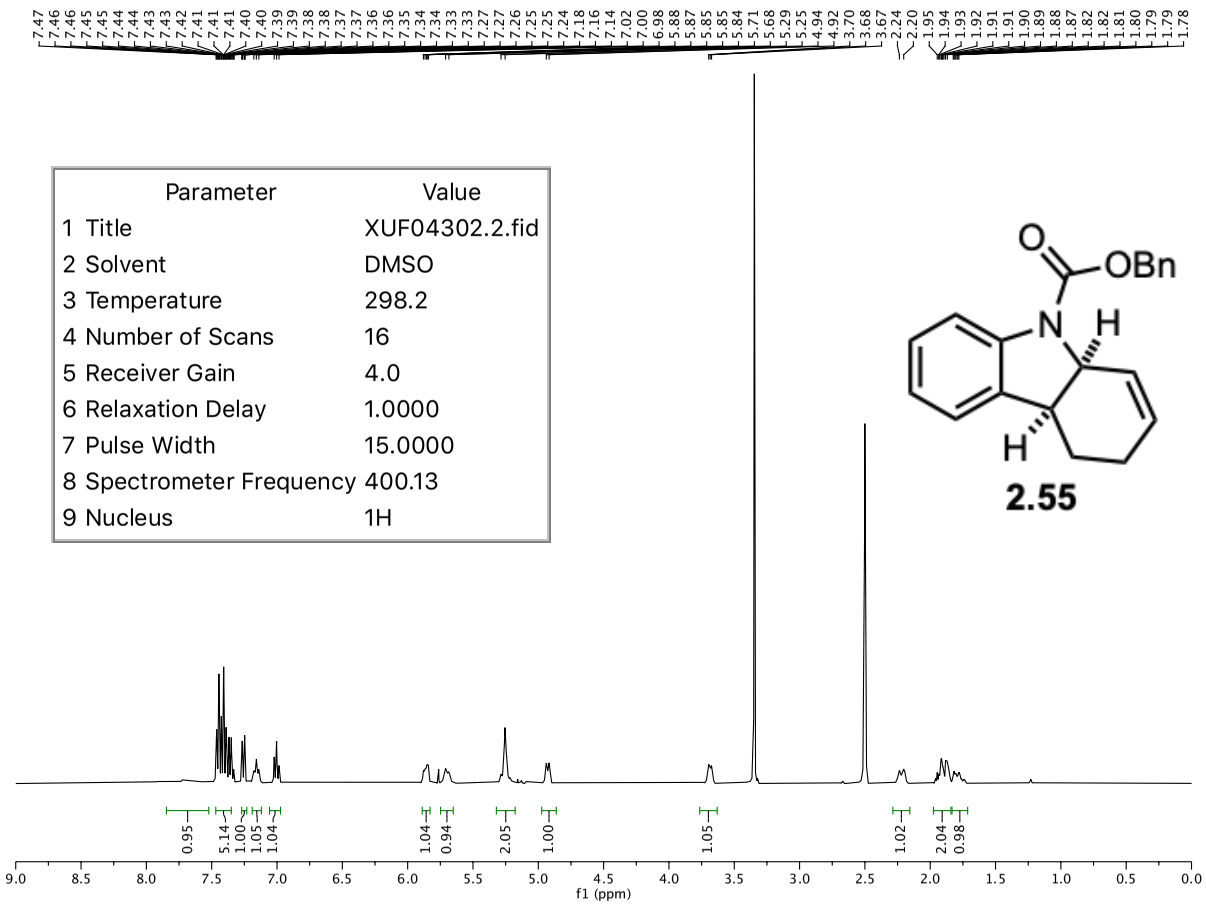

7.27
7.14
7.14
7.12
7.12
7.12
7.07
7.05
6.58
6.57
6.56
6.55
5.88
5.87
5.85
5.84
5.70
5.68
4.88
4.87
4.86
3.76
3.73
3.71
3.61
3.59
3.58
2.18
2.15
1.91
1.90
1.89
1.88
1.87
1.85
1.84
1.84
1.82
1.82
1.81
1.79
Parameter Value
1 Title XUF05005.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
MeO
N
H
H
2.52
0.76
1.04
0.97
1.03
0.99
1.00
3.00
2.98
1.03
0.96
2.96
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

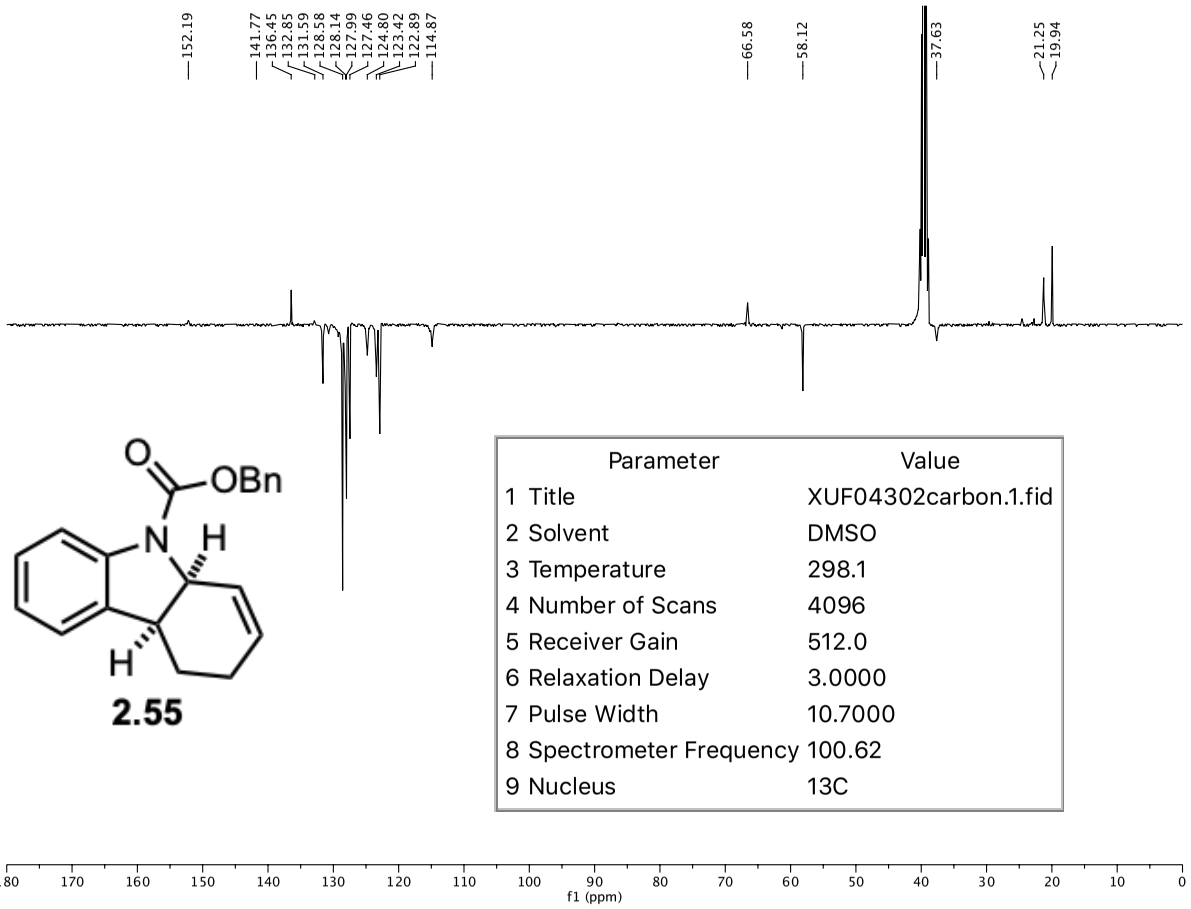

159.11
152.82
143.00
131.42
124.80
123.60
107.49
101.85
58.66
55.18
52.55
36.90
21.52
19.89
OMe
O
N
H
H
MeO
2.52
Parameter Value
1 Title XUF05005.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)


two peaks
overlapped
MeO
O
OMe
N
H
H
Parameter Value
1 Title XUF05005.7.ser
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4
5 Receiver Gain 29193.0
6 Relaxation Delay 1.2993
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (3453.0, 22321.4)
10 Lowest Frequency (14.1, -1115.9)
11 Nucleus (1H, 13C)
12 Acquired Size (2048, 128)
13 Spectral Size (2048, 512)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
f2 (ppm)
120
125
130
135
140
145
150
155
160
165
170
f1 (ppm)

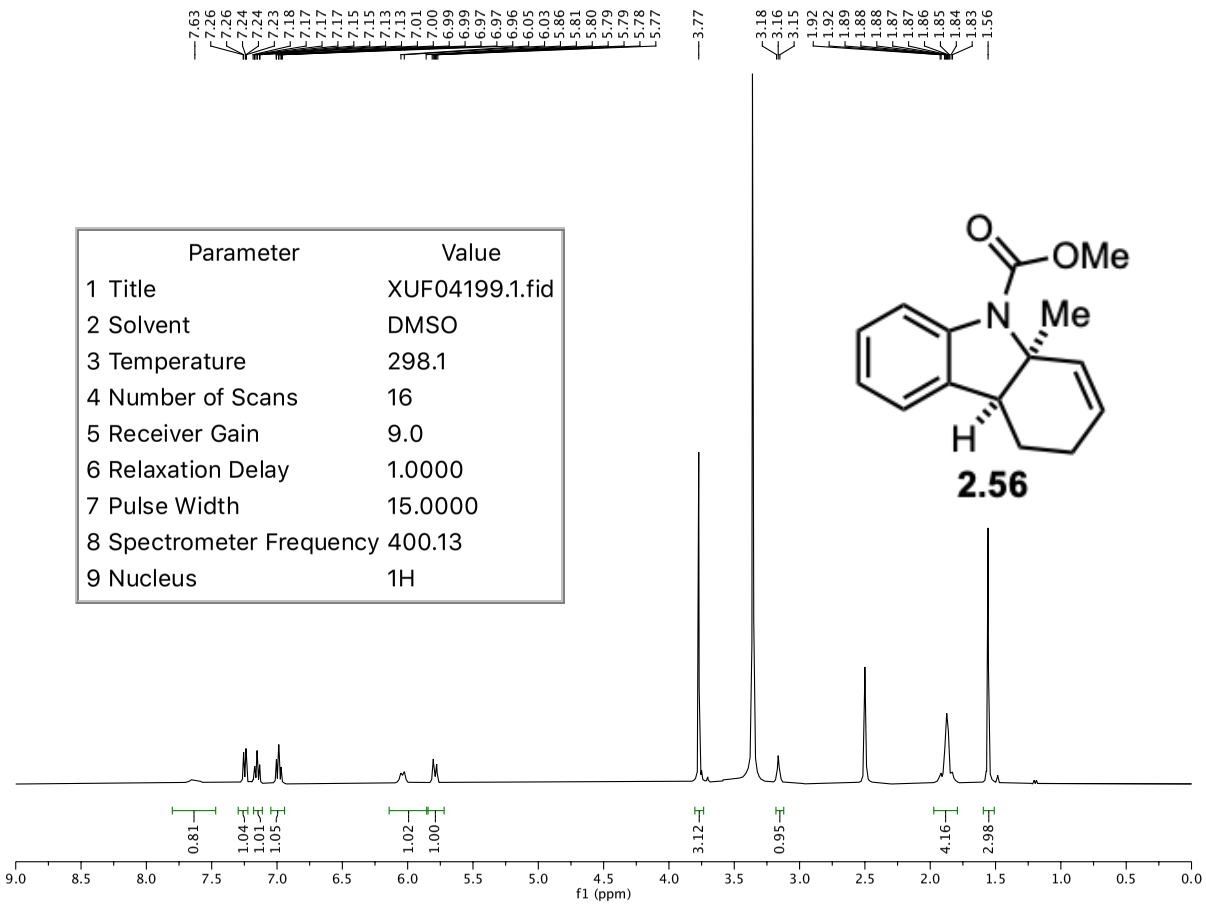

7.61
7.35
7.34
7.22
7.22
7.20
7.20
5.90
5.89
5.88
5.86
5.76
5.71
5.68
4.91
4.88
3.77
3.70
3.68
2.25
2.22
1.92
1.91
1.91
1.89
1.88
1.87
1.86
1.85
1.84
1.83
1.79
1.75
Parameter Value
1 Title XUF05016.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
H
Cl
H
2.53
0.56
1.01
0.98
1.04
1.04
0.99
3.00
1.03
1.01
3.07
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


19.94
21.02
37.65
52.75
58.34
115.96
123.66
124.54
126.65
127.27
131.62
135.54
140.69
152.81
Parameter
Value
1 Title
XUF05016.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)
OMe
O
N
H
H
Cl
2.53

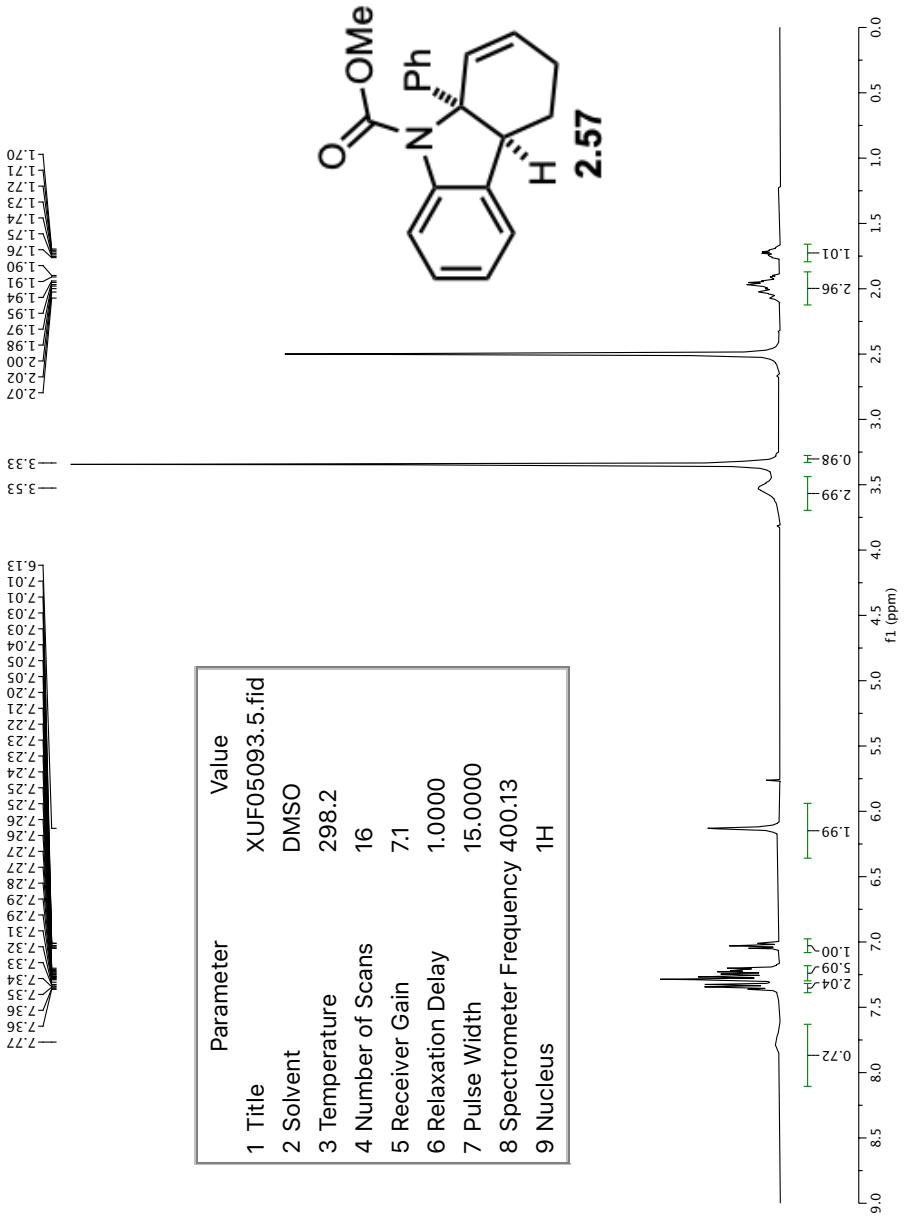

7.47 7.46 7.46 7.45 7.45 7.44 7.44 7.43 7.43 7.42 7.41 7.41 7.41 7.40 7.40 7.39 7.39 7.38 7.38 7.37 7.37 7.36 7.36 7.35 7.34 7.34 7.33 7.33 7.27 7.27 7.26 7.25 7.25 7.24 7.18 7.16 7.14 7.02 7.00 6.98 5.88 5.87 5.85 5.85 5.84 5.71 5.68 5.29 5.25 4.94 4.92 3.70 3.68 3.67 2.24 2.20 1.95 1.94 1.93 1.92 1.91 1.91 1.90 1.89 1.88 1.87 1.82 1.82 1.81 1.80 1.79 1.79 1.78
Parameter Value
1 Title XUF04302.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OBn
N
H
H
2.55
0.95 5.14 1.00 1.05 1.04 1.04 0.94 2.05 1.00 1.05 1.02 2.04 0.98
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

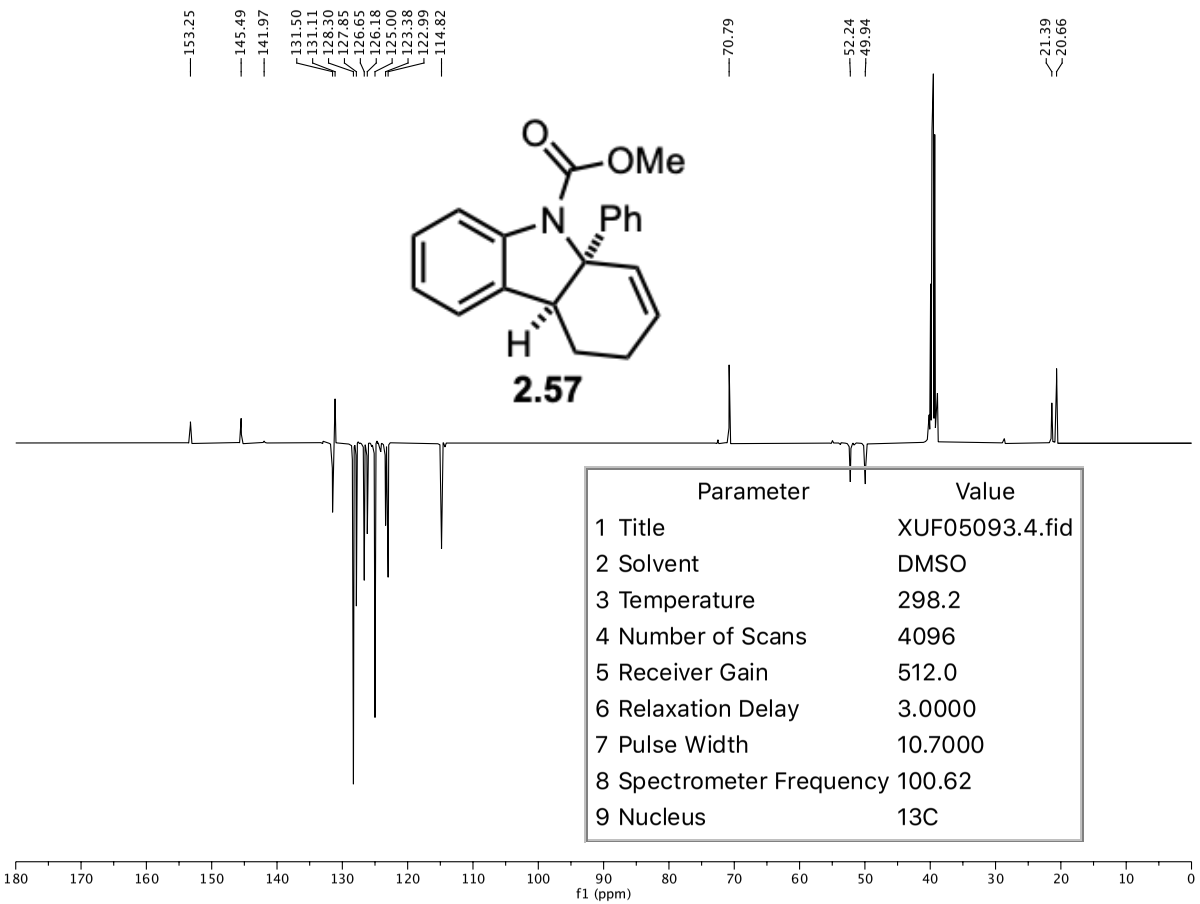


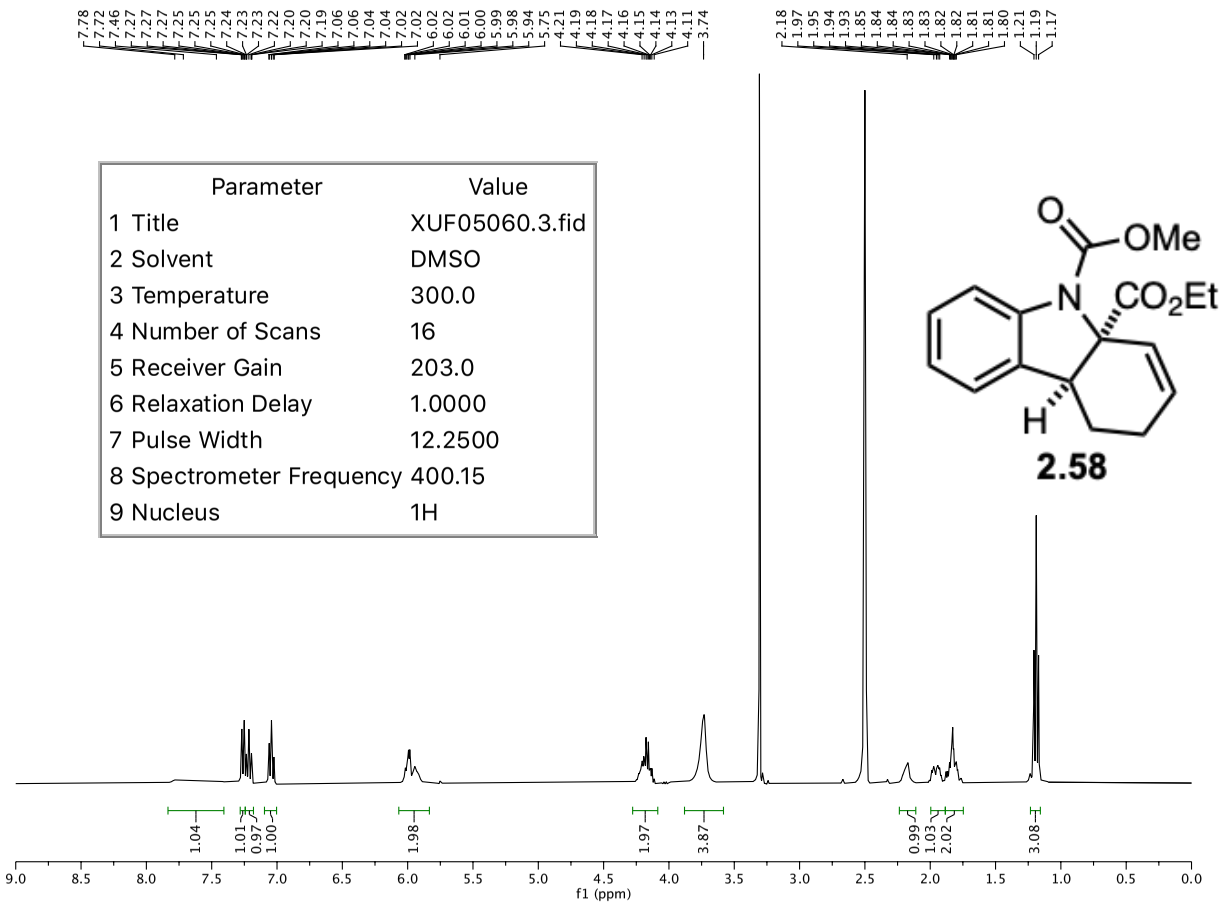
Parameter	Value
1 Title	XUF04302carbon.1.fid
2 Solvent	DMSO
3 Temperature	298.1
4 Number of Scans	4096
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C


7.63
7.26
7.26
7.24
7.24
7.23
7.18
7.17
7.17
7.17
7.17
7.15
7.15
7.13
7.13
7.01
7.00
6.99
6.99
6.99
6.97
6.97
6.96
6.05
6.03
5.86
5.81
5.80
5.79
5.79
5.78
5.77
3.77
3.18
3.16
3.15
1.92
1.92
1.89
1.88
1.88
1.87
1.87
1.87
1.86
1.85
1.84
1.83
1.56
Parameter Value
1 Title XUF04199.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
Me
H
2.56
0.81
1.04
1.01
1.05
1.02
1.00
3.12
0.95
4.16
2.98
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

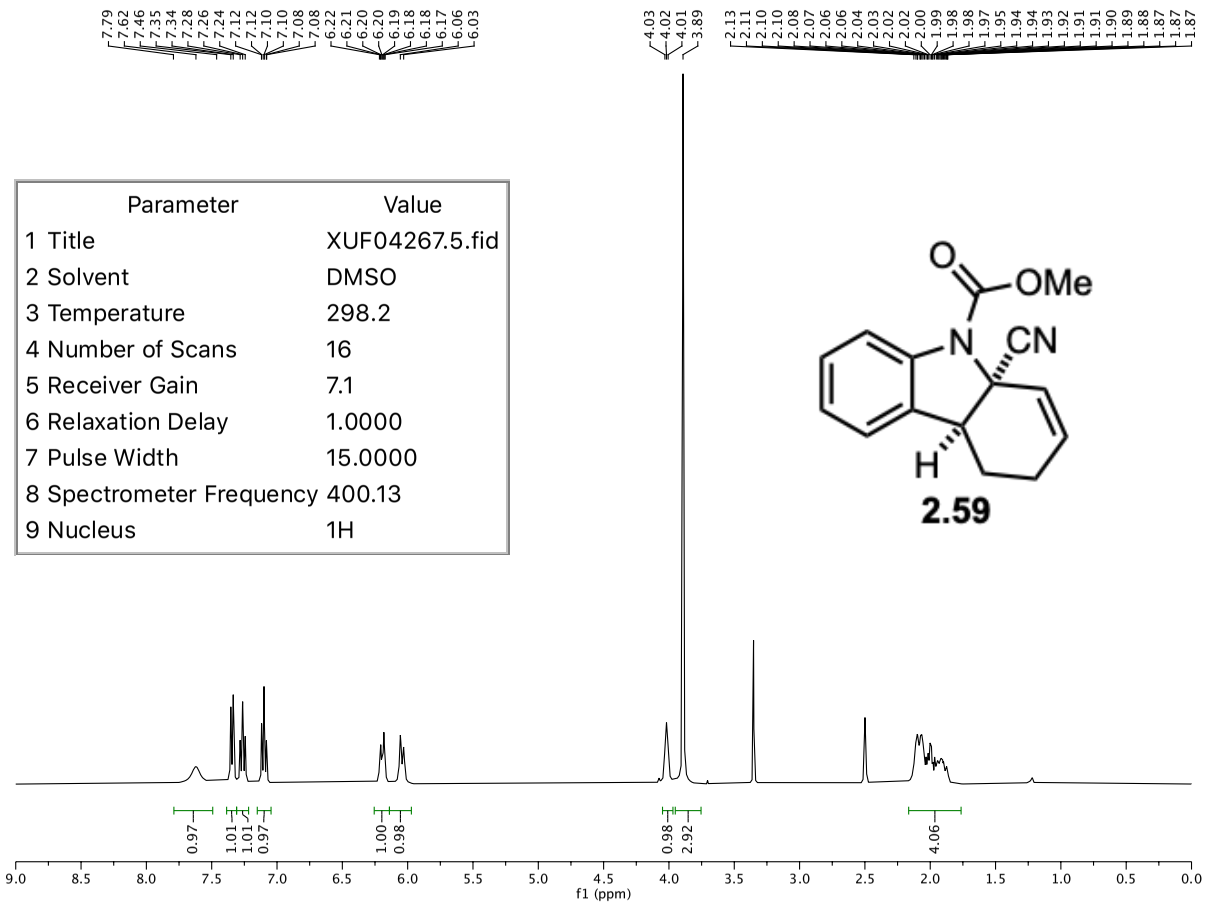
153.52
141.51
132.22
129.03
128.50
127.49
123.50
122.67
115.03
65.24
52.28
46.38
26.07
23.25
21.07
Parameter
Value
1 Title
XUF04199carbon.1.fid
2 Solvent
DMSO
3 Temperature
298.1
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)
OMe
Me
N
O
H
2.56

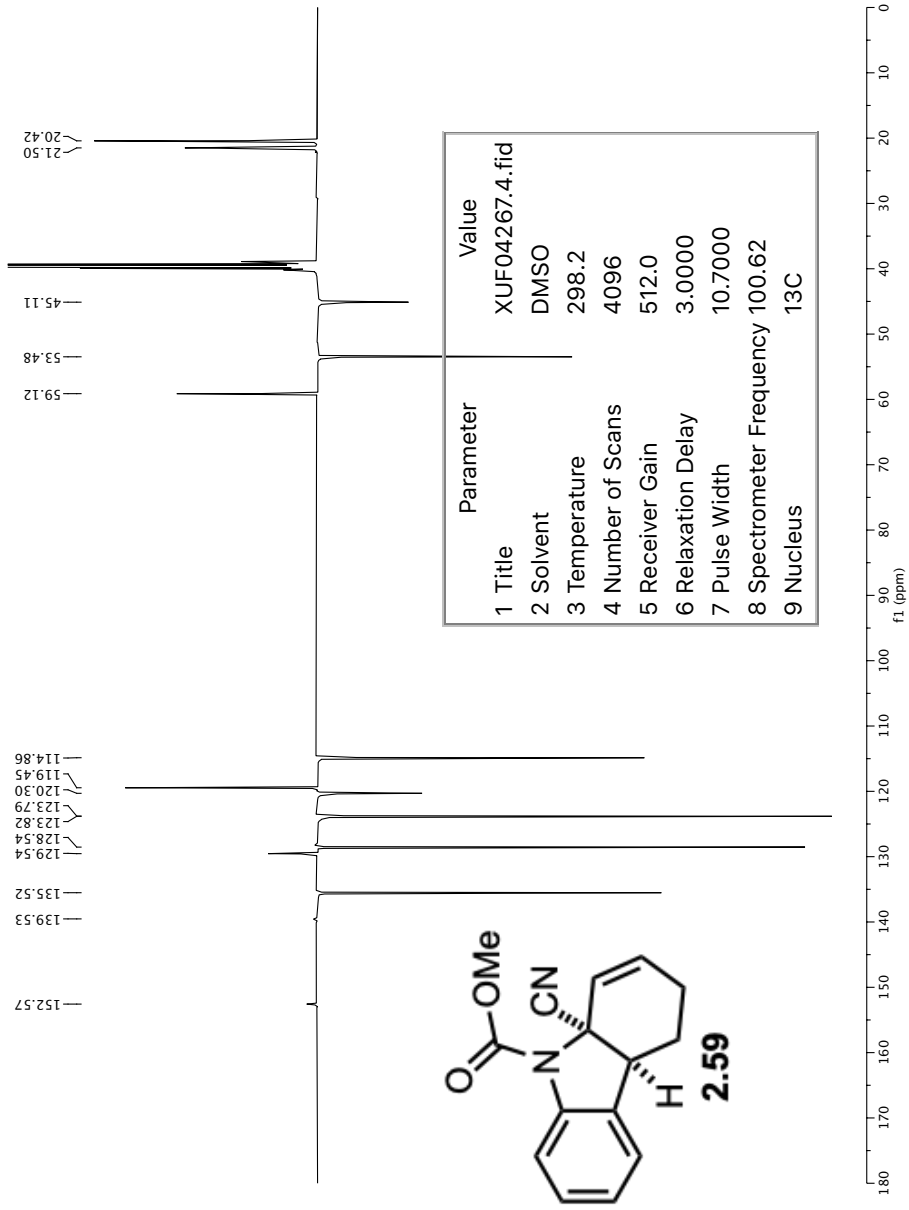

OMe
Ph
N
O
H
2.57
Parameter Value
1 Title XUF05093.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

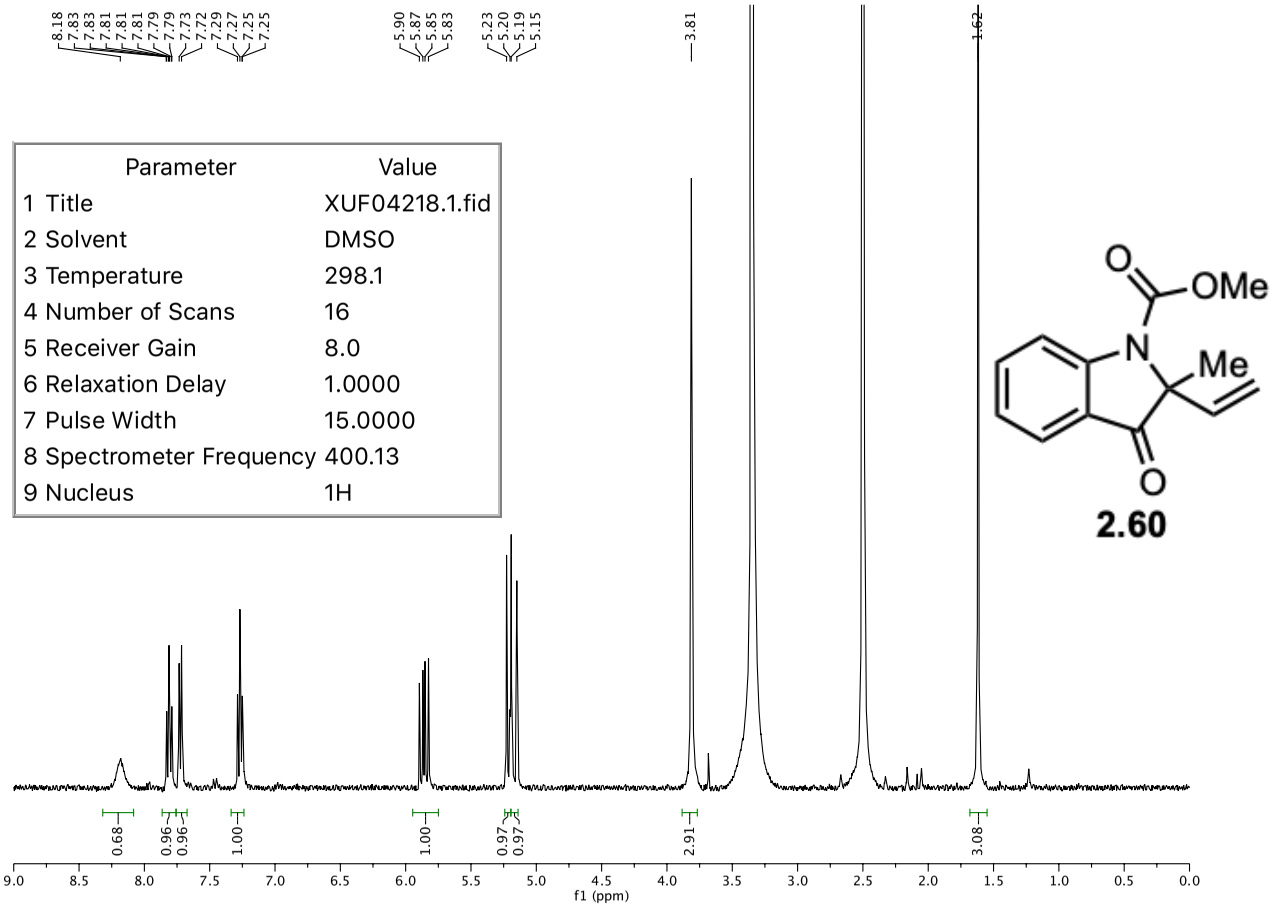

153.25
145.49
141.97
131.50
131.11
128.30
127.85
126.65
126.18
125.00
123.38
122.99
114.82
70.79
52.24
49.94
21.39
20.66
O
OMe
N
Ph
H
2.57
Parameter Value
1 Title XUF05093.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

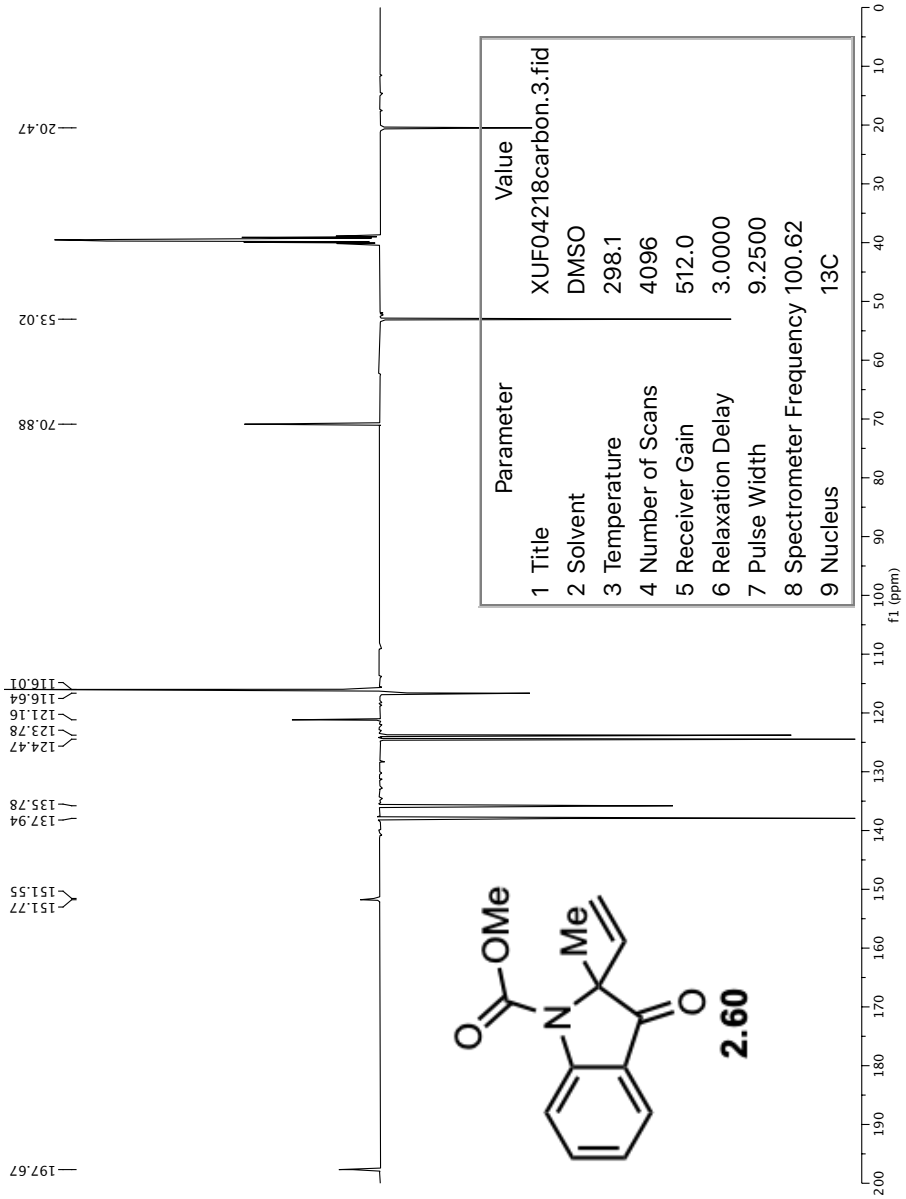

7.78 7.72 7.46 7.27 7.27 7.27 7.25 7.25 7.25 7.24 7.23 7.22 7.20 7.20 7.19 7.06 7.06 7.04 7.04 7.02 7.02 6.02 6.02 6.01 6.00 5.99 5.98 5.94 5.75 4.21 4.19 4.18 4.17 4.16 4.15 4.14 4.13 4.11 3.74
2.18 1.97 1.95 1.94 1.93 1.85 1.84 1.84 1.83 1.83 1.82 1.82 1.81 1.81 1.80 1.21 1.19 1.17
Parameter Value
1 Title XUF05060.3.fid
2 Solvent DMSO
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 203.0
6 Relaxation Delay 1.0000
7 Pulse Width 12.2500
8 Spectrometer Frequency 400.15
9 Nucleus 1H
O
OMe
N
CO2Et
H
2.58
1.04 1.01 0.97 1.00 1.98 1.97 3.87 0.99 1.03 2.02 3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

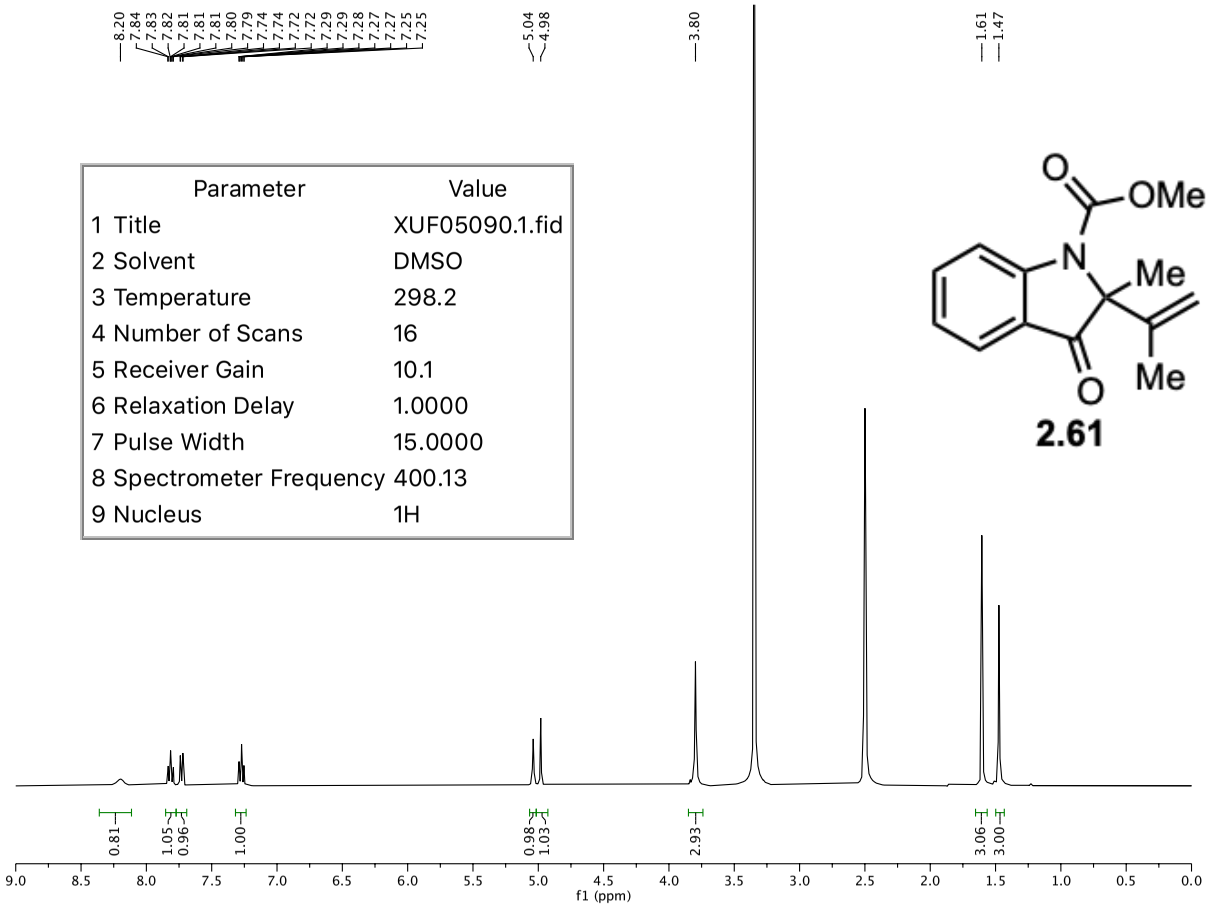
14.08
19.96
21.50
44.39
52.62
61.32
69.13
114.44
123.18
123.52
123.76
128.09
130.20
131.85
141.53
152.36
171.66
Parameter
Value
1 Title
XUF04269.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
OMe
CO2Et
N
O
H
2.58
f1 (ppm)

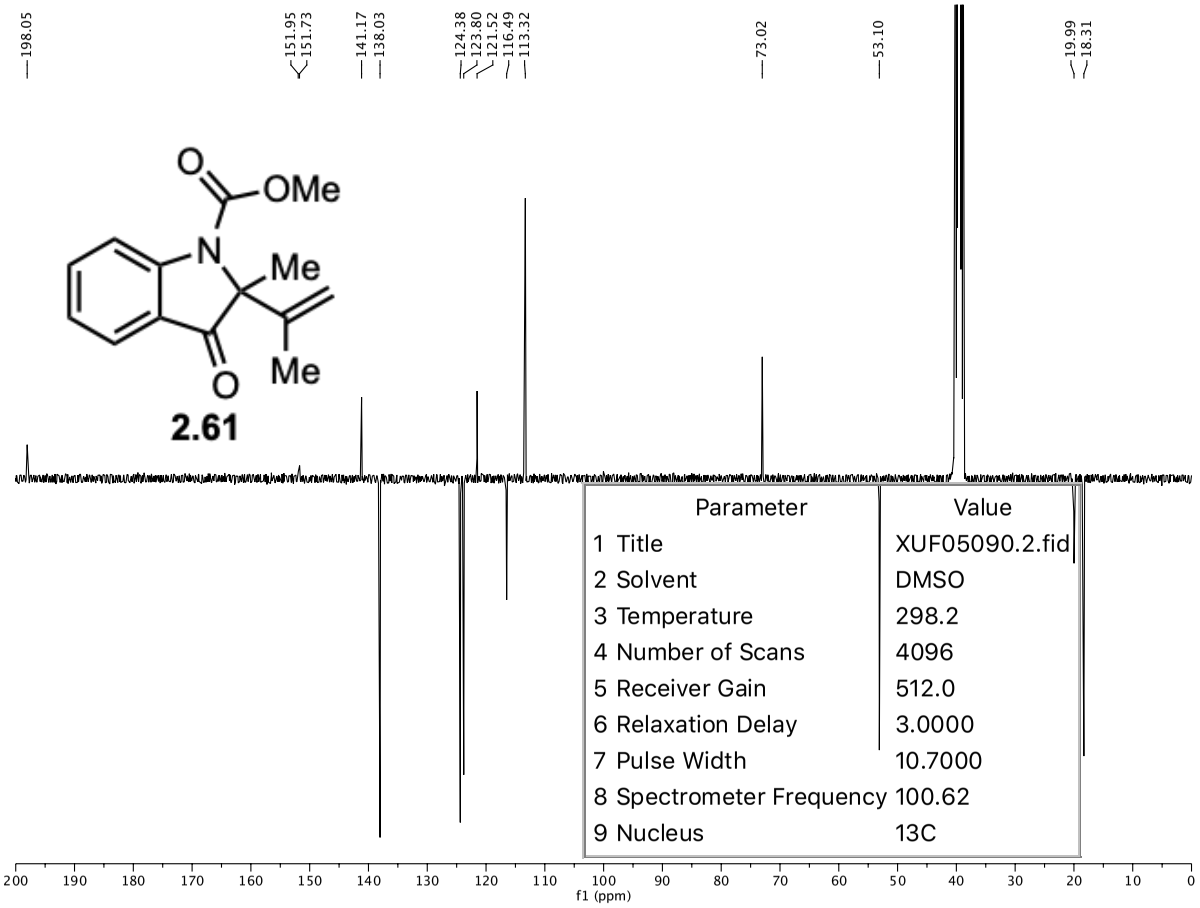

7.79
7.62
7.46
7.35
7.34
7.28
7.26
7.24
7.12
7.12
7.10
7.10
7.08
7.08
6.22
6.21
6.20
6.20
6.19
6.18
6.18
6.17
6.06
6.03
4.03
4.02
4.01
3.89
2.13
2.11
2.10
2.10
2.08
2.07
2.06
2.06
2.04
2.03
2.02
2.02
2.00
1.99
1.98
1.98
1.97
1.95
1.94
1.94
1.93
1.92
1.91
1.91
1.90
1.89
1.88
1.87
1.87
1.87
Parameter
Value
1 Title
XUF04267.5.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
16
5 Receiver Gain
7.1
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
O
OMe
N
CN
H
2.59
0.97
1.01
1.01
0.97
1.00
0.98
0.98
2.92
4.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

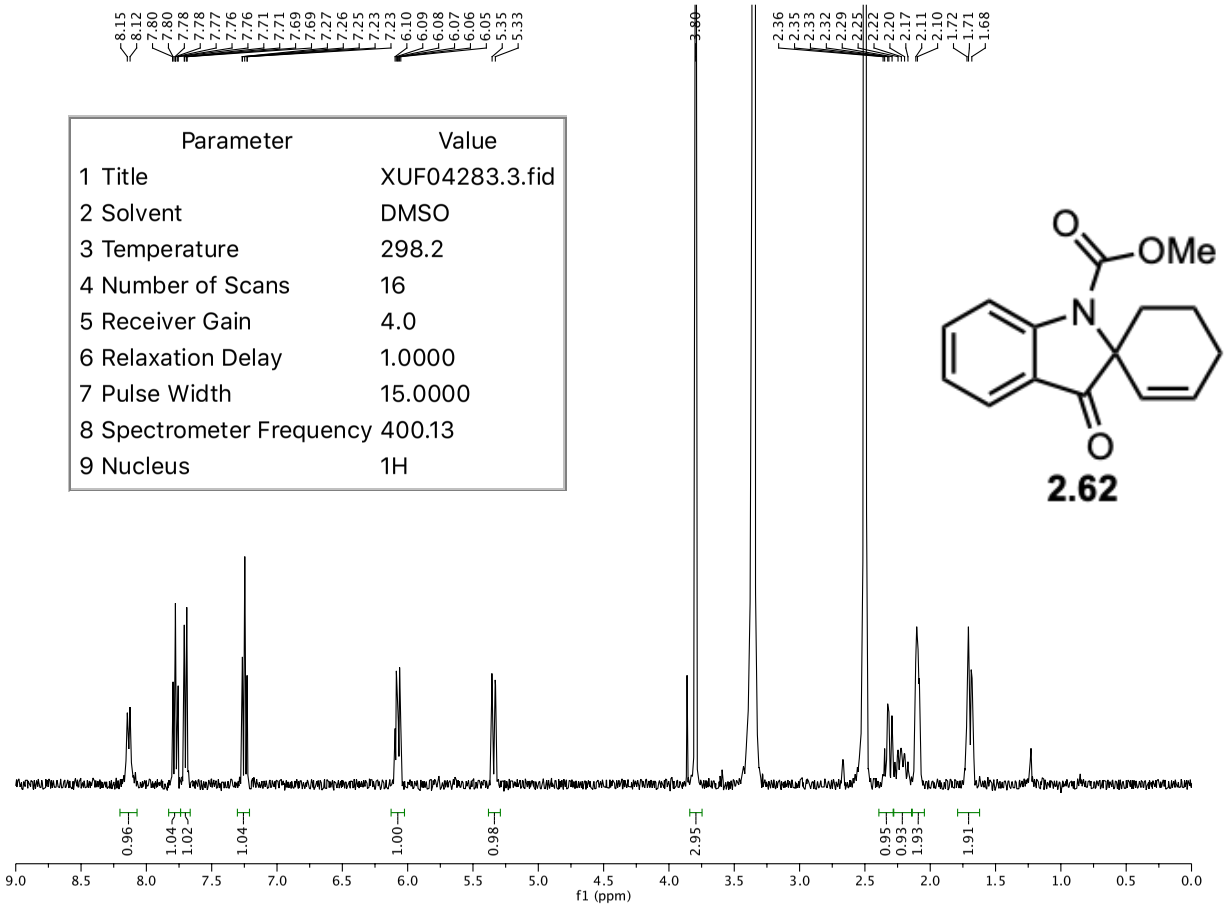

20.42
21.50
45.11
53.48
59.12
114.86
119.45
120.30
123.79
123.82
128.54
129.54
135.52
139.53
152.57
Parameter
Value
1 Title
XUF04267.4.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
OMe
O
N
CN
H
2.59
f1 (ppm)

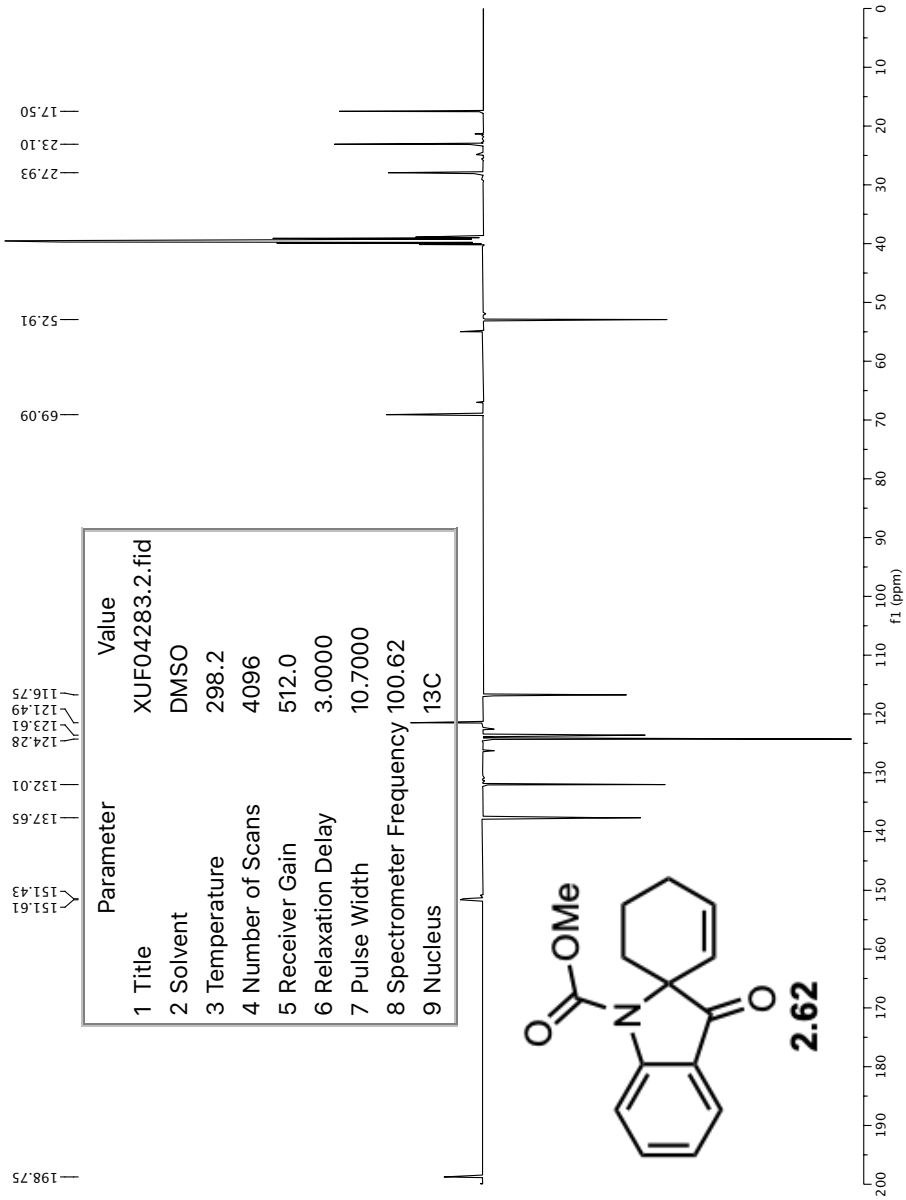

8.18
7.83
7.83
7.81
7.81
7.81
7.79
7.79
7.73
7.72
7.29
7.27
7.25
7.25
5.90
5.87
5.85
5.83
5.23
5.20
5.19
5.15
3.81
1.62
Parameter Value
1 Title XUF04218.1.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
Me
O
2.60
0.68
0.96
0.96
1.00
1.00
0.97
0.97
2.91
3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


Parameter
Value
1 Title
XUF04218carbon.3.fid
2 Solvent
DMSO
3 Temperature
298.1
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
9.2500
8 Spectrometer Frequency
100.62
9 Nucleus
13C
OMe
Me
O
N
O
2.60
f1 (ppm)

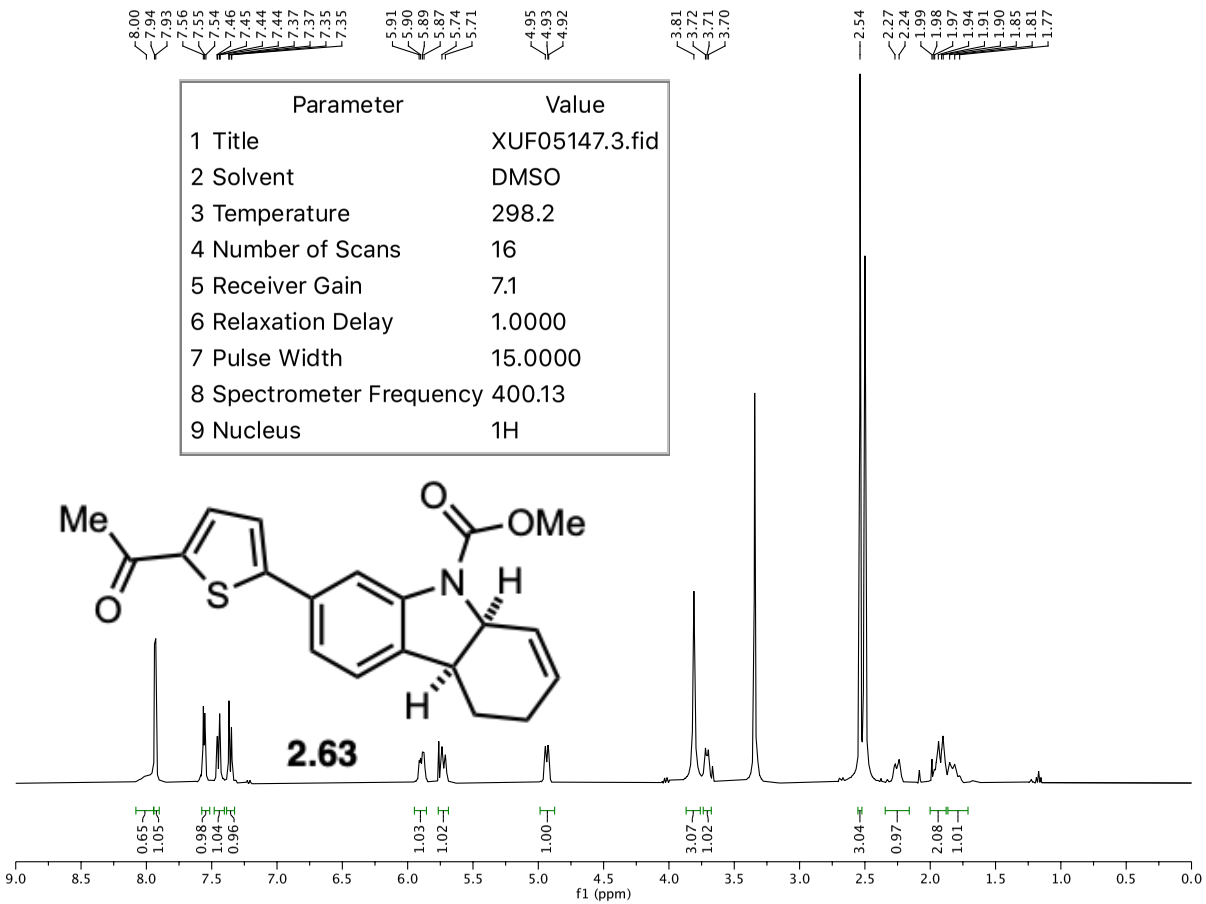

8.20
7.84
7.83
7.82
7.81
7.81
7.81
7.80
7.79
7.74
7.74
7.72
7.72
7.29
7.29
7.28
7.27
7.27
7.25
7.25
5.04
4.98
3.80
1.61
1.47
Parameter Value
1 Title XUF05090.1.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
Me
Me
O
2.61
0.81
1.05
0.96
1.00
0.98
1.03
2.93
3.06
3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

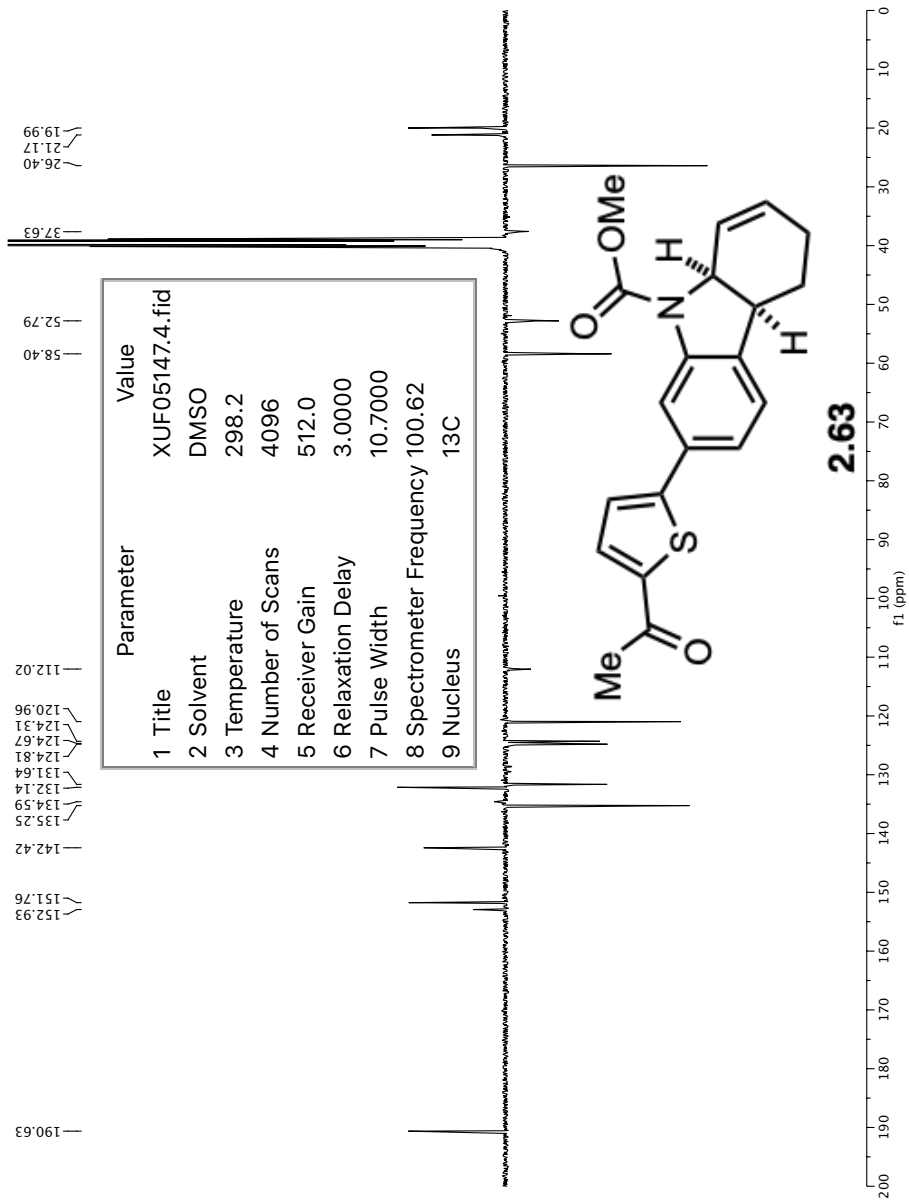

198.05
151.95
151.73
141.17
138.03
124.38
123.80
121.52
116.49
113.32
73.02
53.10
19.99
18.31
O
OMe
N
Me
Me
O
2.61
Parameter
Value
1 Title
XUF05090.2.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.15
8.12
7.80
7.80
7.78
7.78
7.77
7.76
7.76
7.71
7.71
7.69
7.69
7.27
7.26
7.25
7.23
7.23
6.10
6.09
6.08
6.07
6.06
6.05
5.35
5.33
3.80
2.36
2.35
2.33
2.32
2.29
2.25
2.22
2.20
2.17
2.11
2.10
1.72
1.71
1.68
Parameter Value
1 Title XUF04283.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
O
2.62
0.96
1.04
1.02
1.04
1.00
0.98
2.95
0.95
0.93
1.93
1.91
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

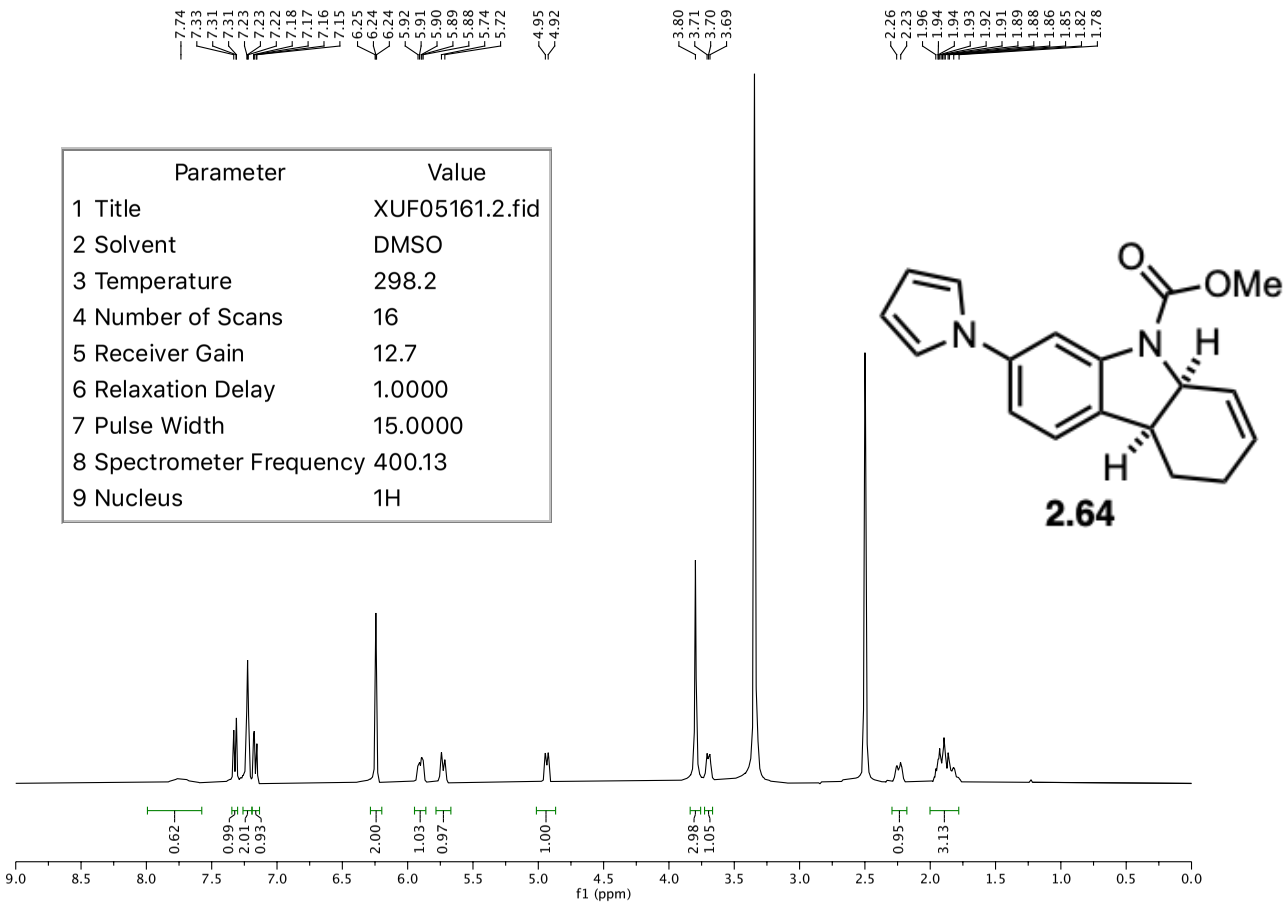

Parameter Value
1 Title XUF04283.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
198.75
151.61
151.43
137.65
132.01
124.28
123.61
121.49
116.75
69.09
52.91
27.93
23.10
17.50
OMe
O
O
N
O
2.62
f1 (ppm)

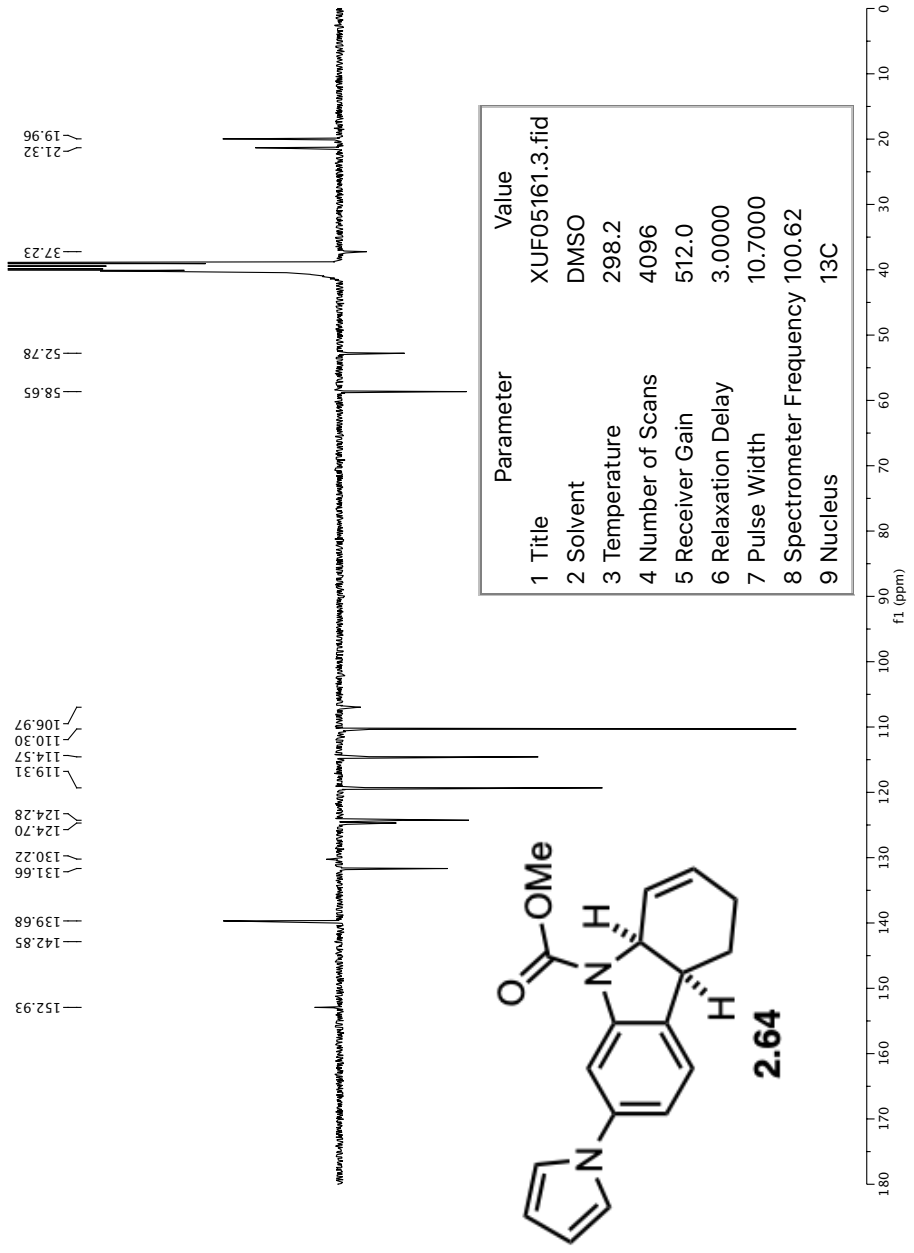
Parameter Value
1 Title XUF04283.5.ser
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4
5 Receiver Gain 36780.8
6 Relaxation Delay 1.4549
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (2976.2, 16666.7)
10 Lowest Frequency (482.1, -788.3)
11 Nucleus (1H, 13C)
12 Acquired Size (512, 128)
13 Spectral Size (512, 512)
OMe
O
N
O
two peaks
overlapped
f1 (ppm)
f2 (ppm)

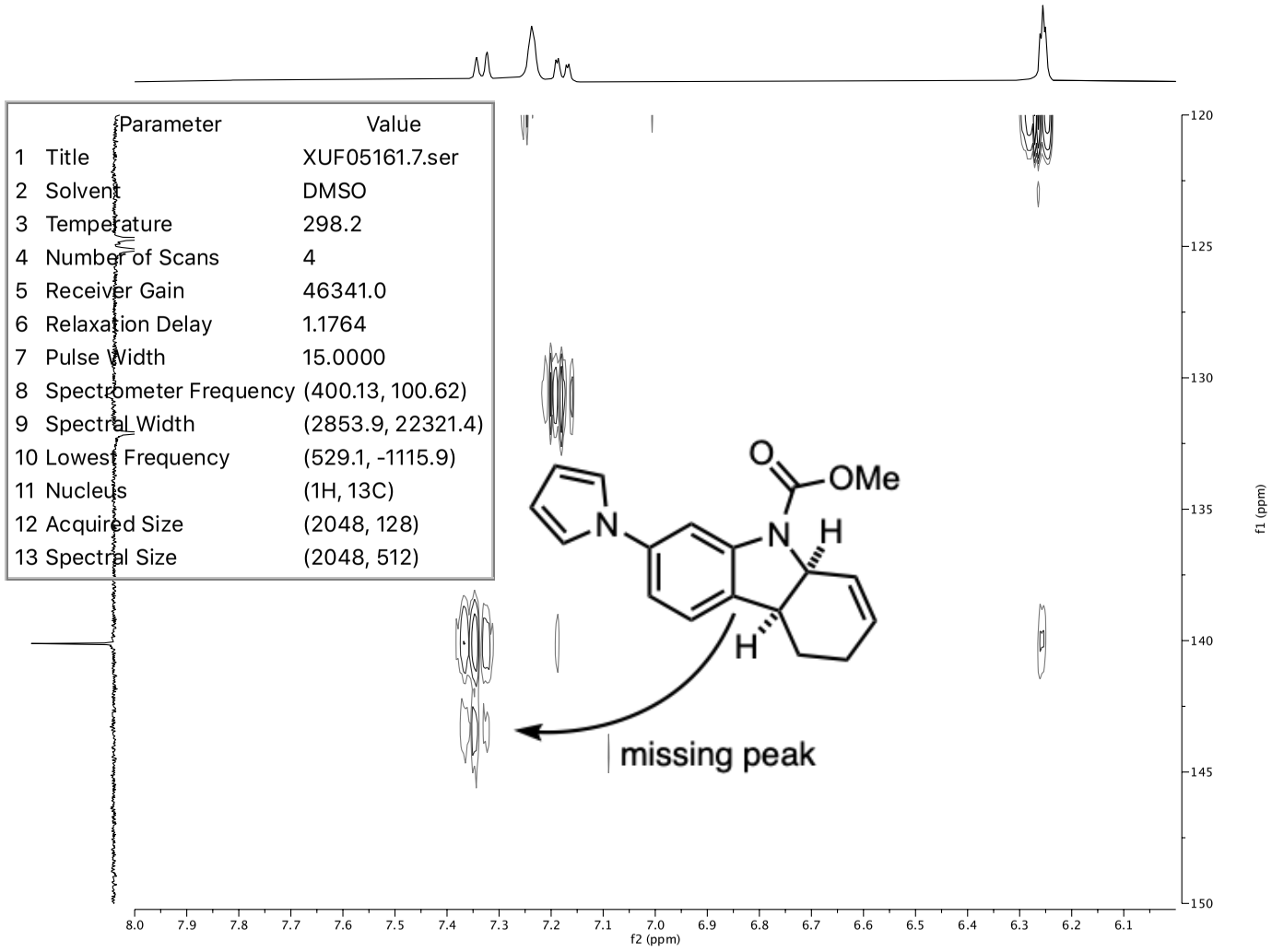

8.00
7.94
7.93
7.56
7.55
7.54
7.46
7.45
7.44
7.44
7.37
7.37
7.35
7.35
5.91
5.90
5.89
5.87
5.74
5.71
4.95
4.93
4.92
3.81
3.72
3.71
3.70
2.54
2.27
2.24
1.99
1.98
1.97
1.94
1.91
1.90
1.85
1.81
1.77
Parameter Value
1 Title XUF05147.3.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Me
O
S
O
OMe
N
H
H
2.63
0.65
1.05
0.98
1.04
0.96
1.03
1.02
1.00
3.07
1.02
3.04
0.97
2.08
1.01
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

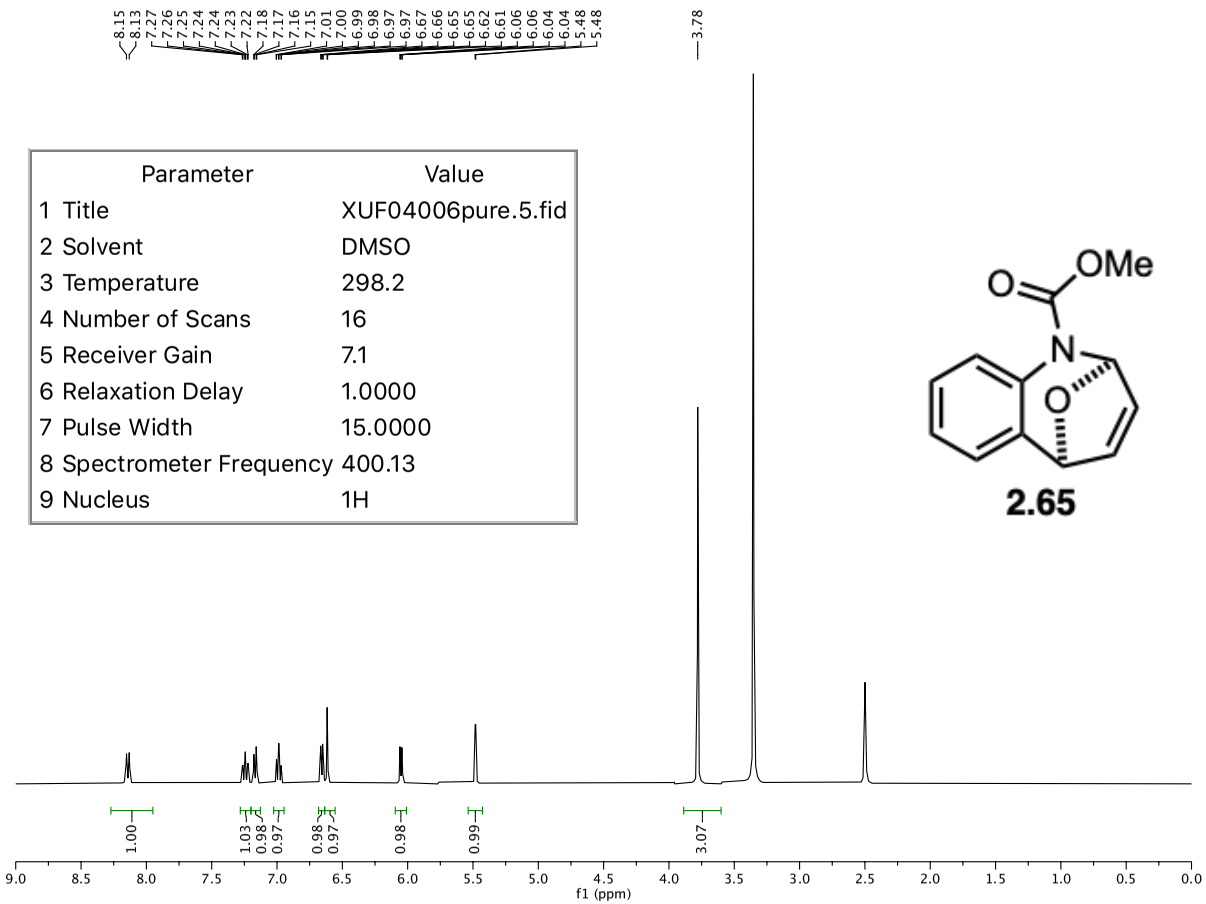

Parameter Value
1 Title XUF05147.4.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
190.63
152.93
151.76
142.42
135.25
134.59
132.14
131.64
124.81
124.67
124.31
120.96
112.02
58.40
52.79
37.63
26.40
21.17
19.99
Me
O
S
N
H
H
O
OMe
2.63
f1 (ppm)

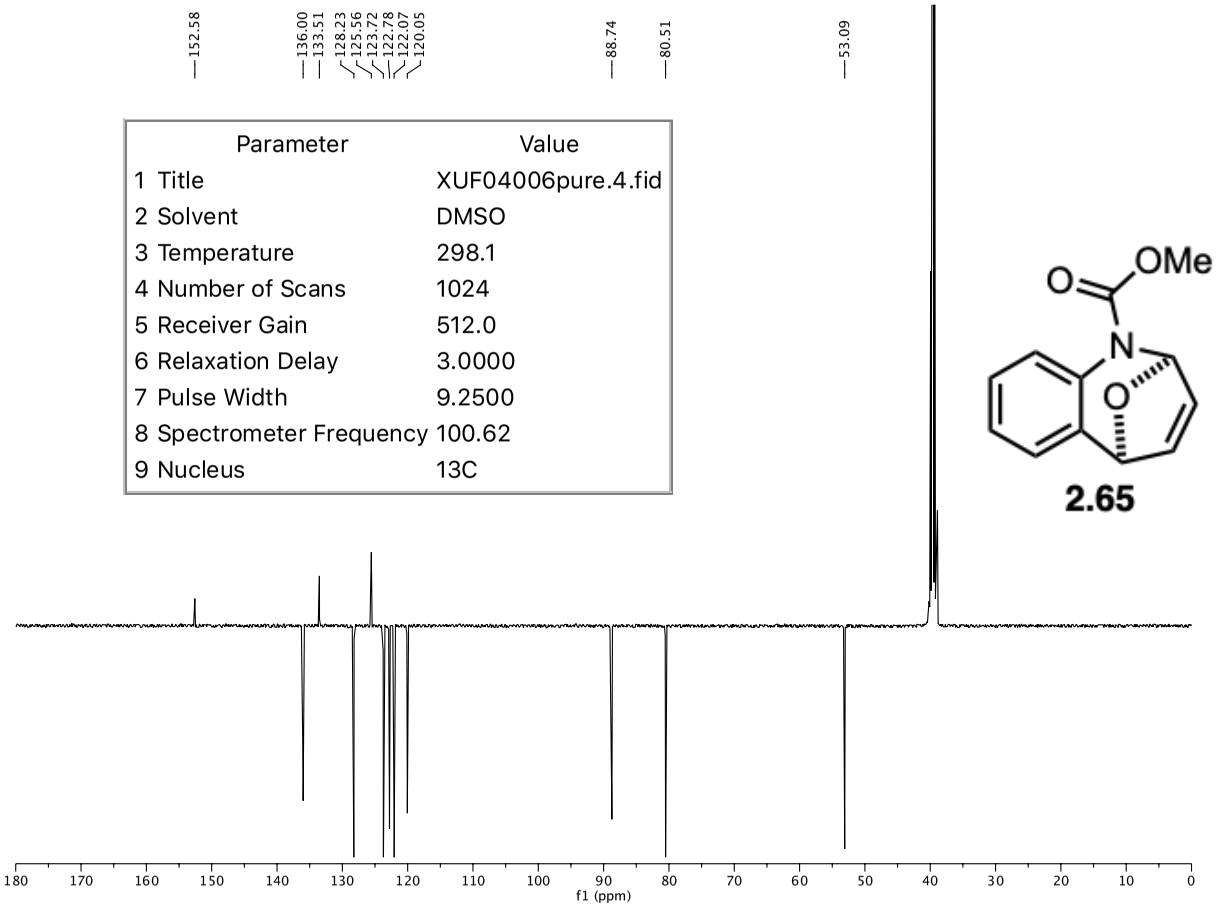
two peaks
overlapped
Me
O
OMe
N
H
S
Parameter Value
1 Title XUF05147.8.ser
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 4
5 Receiver Gain 46341.0
6 Relaxation Delay 1.2501
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (3188.8, 22321.4)
10 Lowest Frequency (267.6, -1115.9)
11 Nucleus (1H, 13C)
12 Acquired Size (2048, 128)
13 Spectral Size (2048, 512)
f2 (ppm)
f1 (ppm)

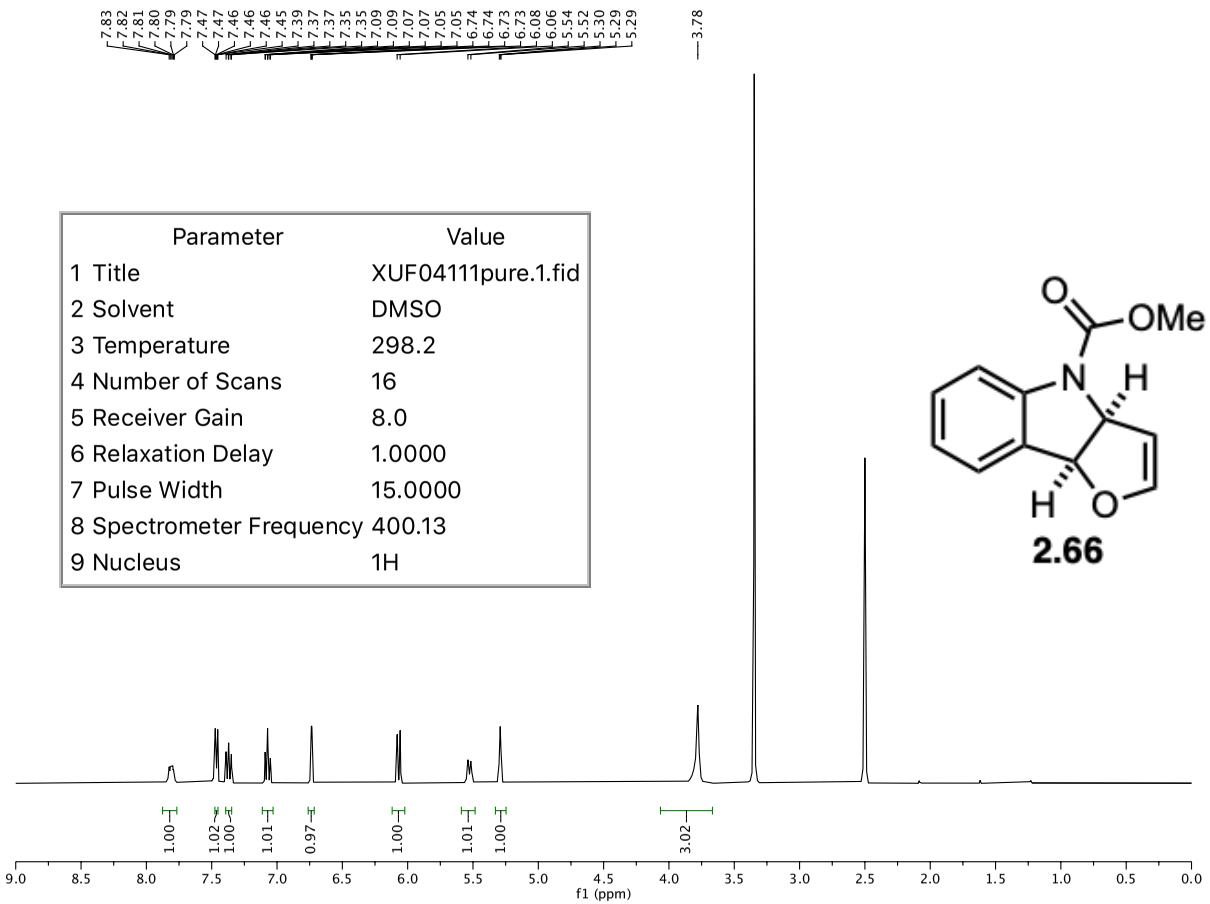

7.74
7.33
7.31
7.31
7.23
7.23
7.22
7.18
7.17
7.16
7.15
6.25
6.24
6.24
5.92
5.91
5.90
5.89
5.88
5.74
5.72
4.95
4.92
3.80
3.71
3.70
3.69
2.26
2.23
1.96
1.94
1.94
1.93
1.92
1.91
1.89
1.88
1.86
1.85
1.82
1.78
Parameter Value
1 Title XUF05161.2.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
N
H
H
2.64
0.62
0.99
2.01
0.93
2.00
1.03
0.97
1.00
2.98
1.05
0.95
3.13
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


21.32
19.96
37.23
52.78
58.65
106.97
110.30
114.57
119.31
124.70
124.28
131.66
130.22
139.68
142.85
152.93
Parameter
Value
1 Title
XUF05161.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
OMe
O
N
H
H
N
2.64
f1 (ppm)


Parameter Value
1 Title XUF05161.7.ser
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 4
5 Receiver Gain 46341.0
6 Relaxation Delay 1.1764
7 Pulse Width 15.0000
8 Spectrometer Frequency (400.13, 100.62)
9 Spectral Width (2853.9, 22321.4)
10 Lowest Frequency (529.1, -1115.9)
11 Nucleus (1H, 13C)
12 Acquired Size (2048, 128)
13 Spectral Size (2048, 512)
O
OMe
N
N
H
H
missing peak
8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6 6.5 6.4 6.3 6.2 6.1
f2 (ppm)
120 125 130 135 140 145 150
f1 (ppm)


8.15
8.13
7.27
7.26
7.25
7.24
7.24
7.23
7.22
7.18
7.17
7.16
7.15
7.01
7.00
6.99
6.98
6.97
6.97
6.67
6.66
6.65
6.65
6.62
6.61
6.06
6.06
6.04
6.04
5.48
5.48
3.78
Parameter Value
1 Title XUF04006pure.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
OMe
O
N
O
2.65
1.00
1.03
0.98
0.97
0.98
0.97
0.98
0.99
3.07
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

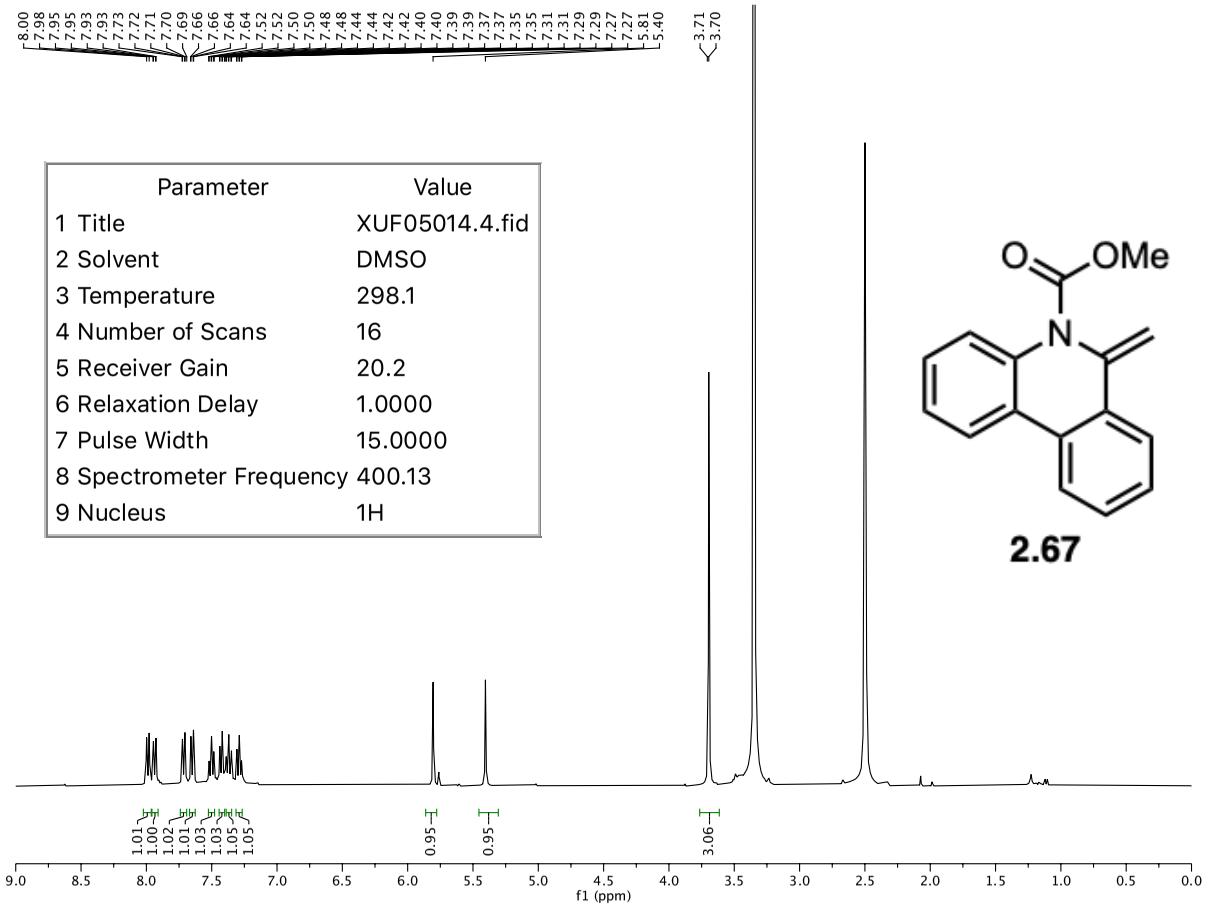

152.58
136.00
133.51
128.23
125.56
123.72
122.78
122.07
120.05
88.74
80.51
53.09
Parameter Value
1 Title XUF04006pure.4.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
OMe
N
O
2.65
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

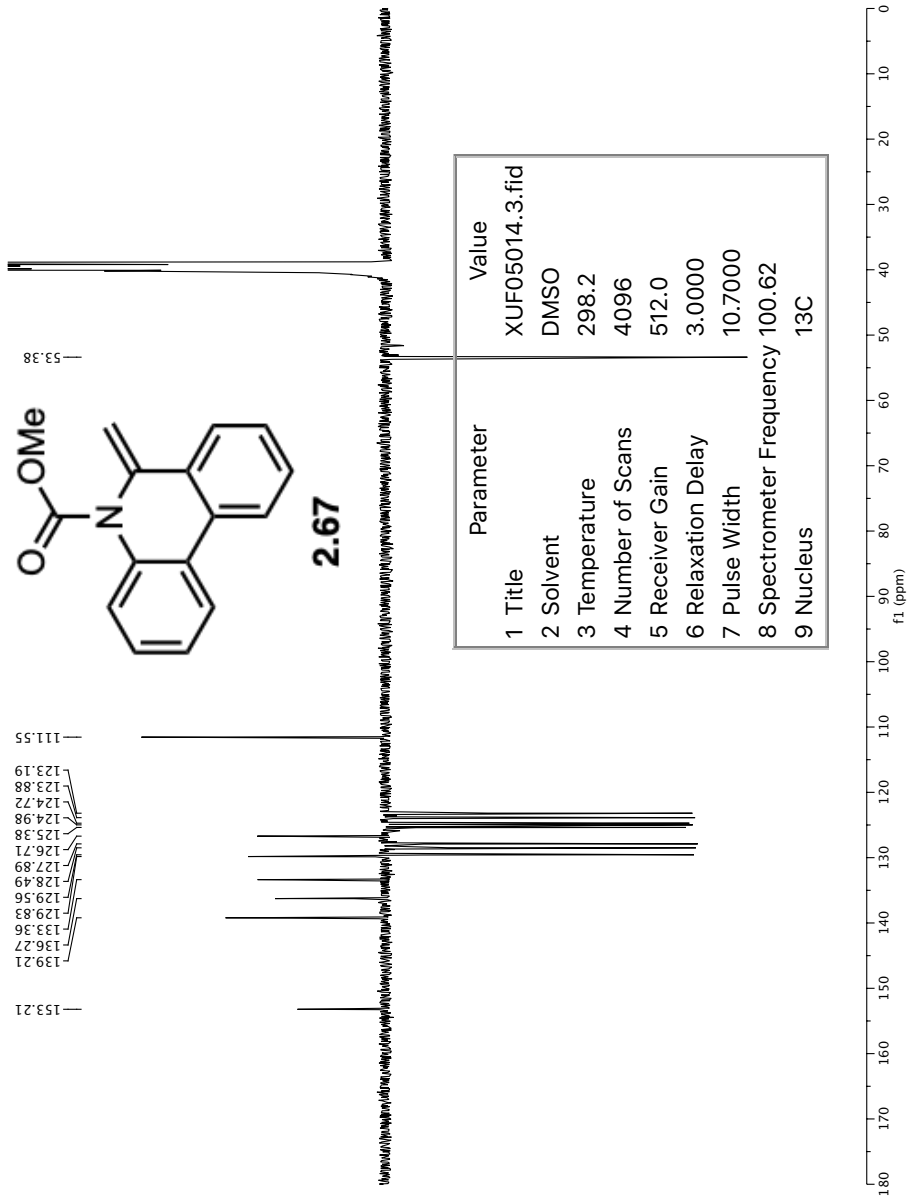


Parameter	Value
1 Title	XUF04111pure.1.fid
2 Solvent	DMSO
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	8.0
6 Relaxation Delay	1.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

2.66

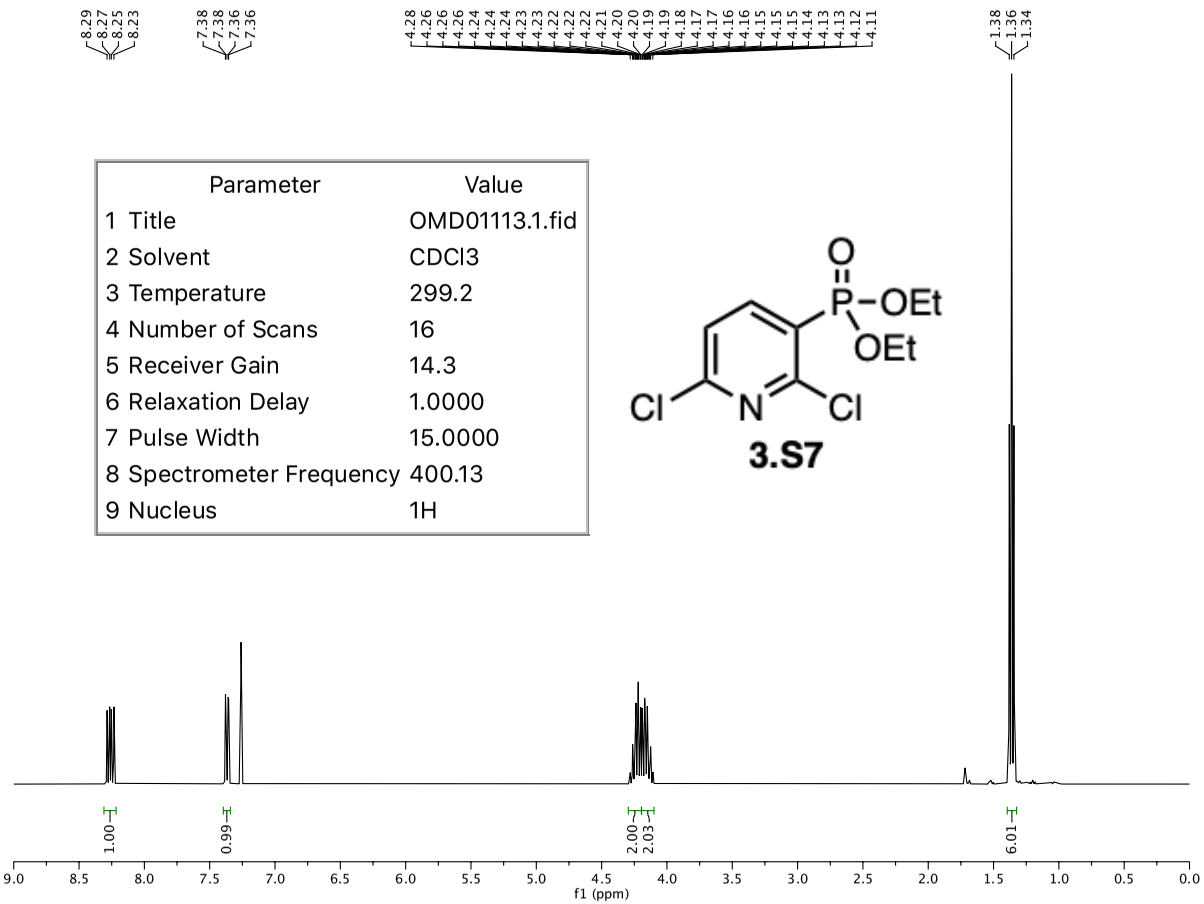
Parameter Value
1 Title XUF04111pure.5.fid
2 Solvent DMSO
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 9.2500
8 Spectrometer Frequency 100.62
9 Nucleus 13C
152.15
149.66
141.70
130.47
128.94
126.55
122.93
114.54
100.24
82.41
66.68
52.71
OMe
O
N
H
O
H
2.66
f1 (ppm)

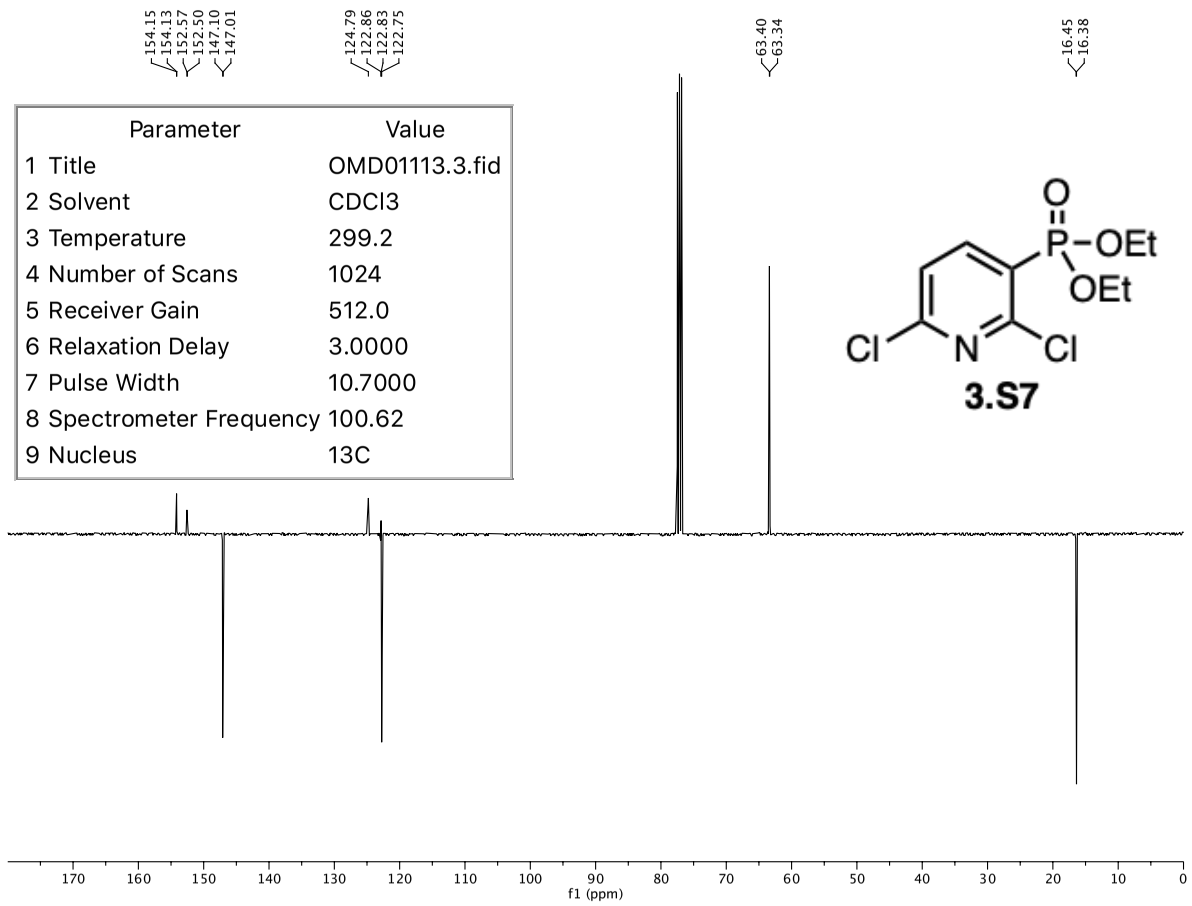

8.00
7.98
7.95
7.95
7.93
7.93
7.73
7.72
7.71
7.70
7.69
7.66
7.66
7.64
7.64
7.52
7.52
7.50
7.50
7.48
7.48
7.44
7.44
7.42
7.42
7.40
7.40
7.39
7.39
7.37
7.37
7.35
7.35
7.31
7.31
7.29
7.29
7.27
7.27
5.81
5.40
3.71
3.70
Parameter Value
1 Title XUF05014.4.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 20.2
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
OMe
N
2.67
1.01
1.00
1.02
1.01
1.03
1.03
1.05
1.05
0.95
0.95
3.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


153.21
139.21
136.27
133.36
129.83
129.56
128.49
127.89
126.71
125.38
124.98
124.72
123.88
123.19
111.55
53.38
OMe
O
N
2.67
Parameter
Value
1 Title
XUF05014.3.fid
2 Solvent
DMSO
3 Temperature
298.2
4 Number of Scans
4096
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

Appendix C

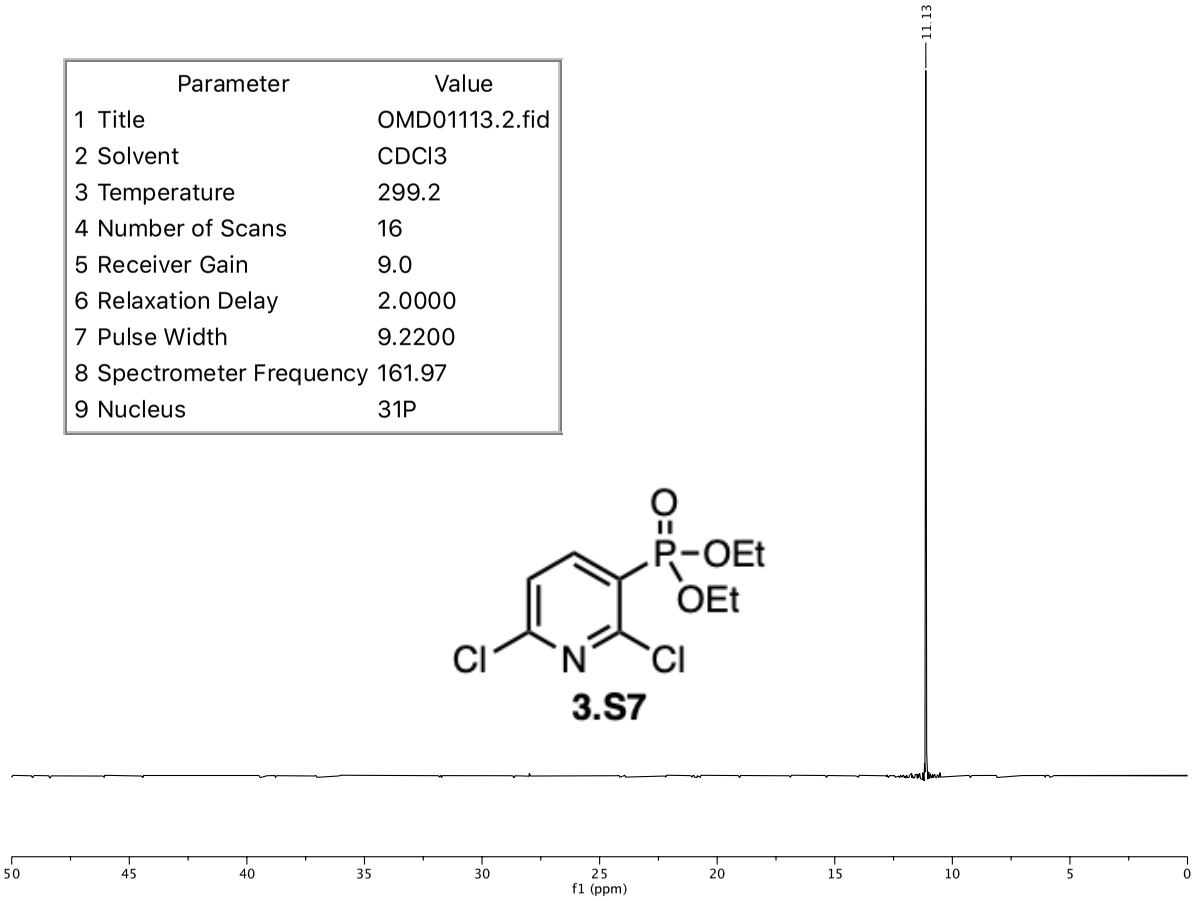
SPECTRAL DATA FOR CHAPTER 3


8.29
8.27
8.25
8.23
7.38
7.38
7.36
7.36
4.28
4.26
4.26
4.26
4.24
4.24
4.24
4.23
4.23
4.22
4.22
4.22
4.21
4.20
4.20
4.19
4.19
4.18
4.17
4.17
4.16
4.16
4.15
4.15
4.15
4.14
4.13
4.12
4.11
1.38
1.36
1.34
Parameter Value
1 Title OMD01113.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 14.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P–OEt
OEt
Cl
N
Cl
3.S7
1.00
0.99
2.00
2.03
6.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


154.15
154.13
152.57
152.50
147.10
147.01
124.79
122.86
122.83
122.75
63.40
63.34
16.45
16.38
Parameter Value
1 Title OMD01113.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
P
OEt
OEt
Cl
N
Cl
3.S7
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	OMD01113.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	9.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.S7

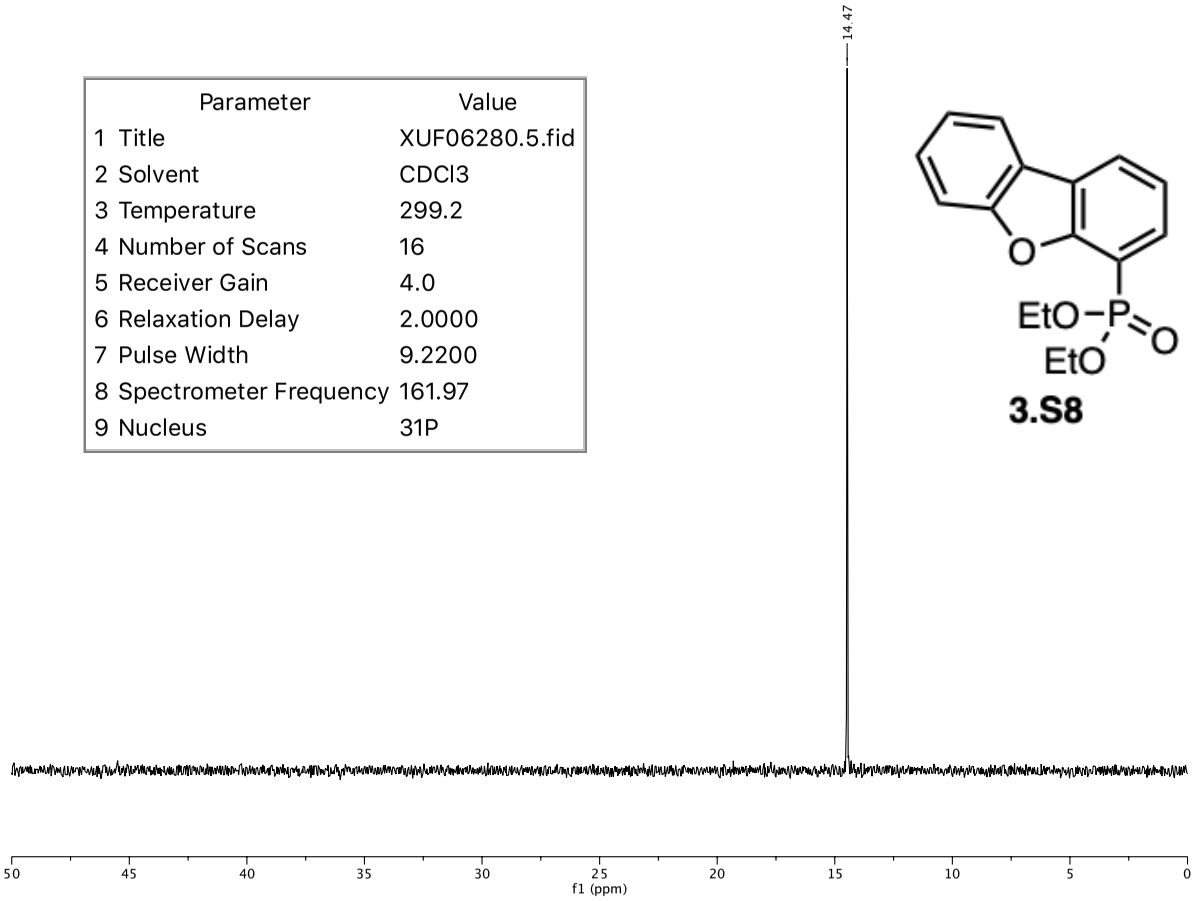


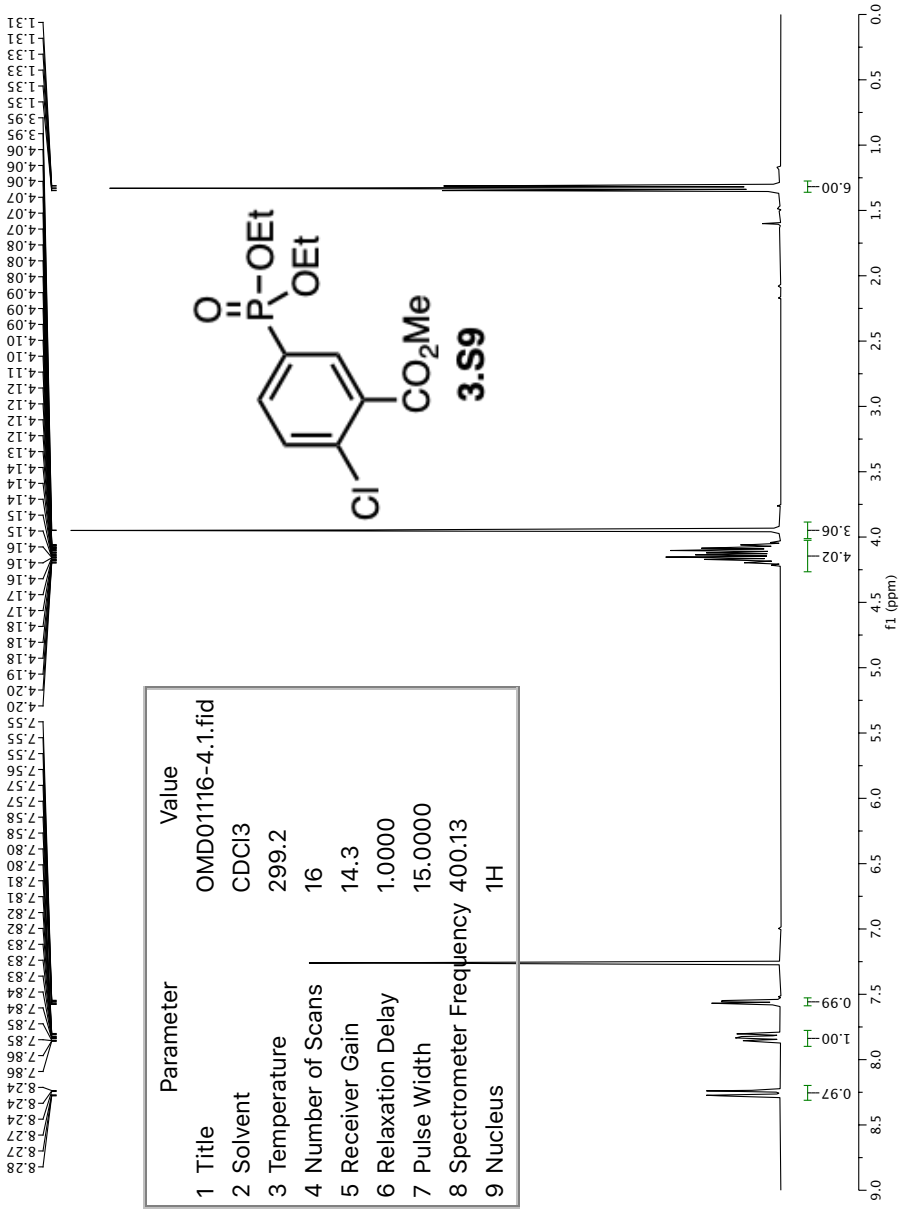
Parameter Value
1 Title XUF06280.3.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
EtO−P=O
EtO
3.S8
1.00
2.03
1.00
1.04
1.03
1.01
2.09
2.02
6.08
f1 (ppm)

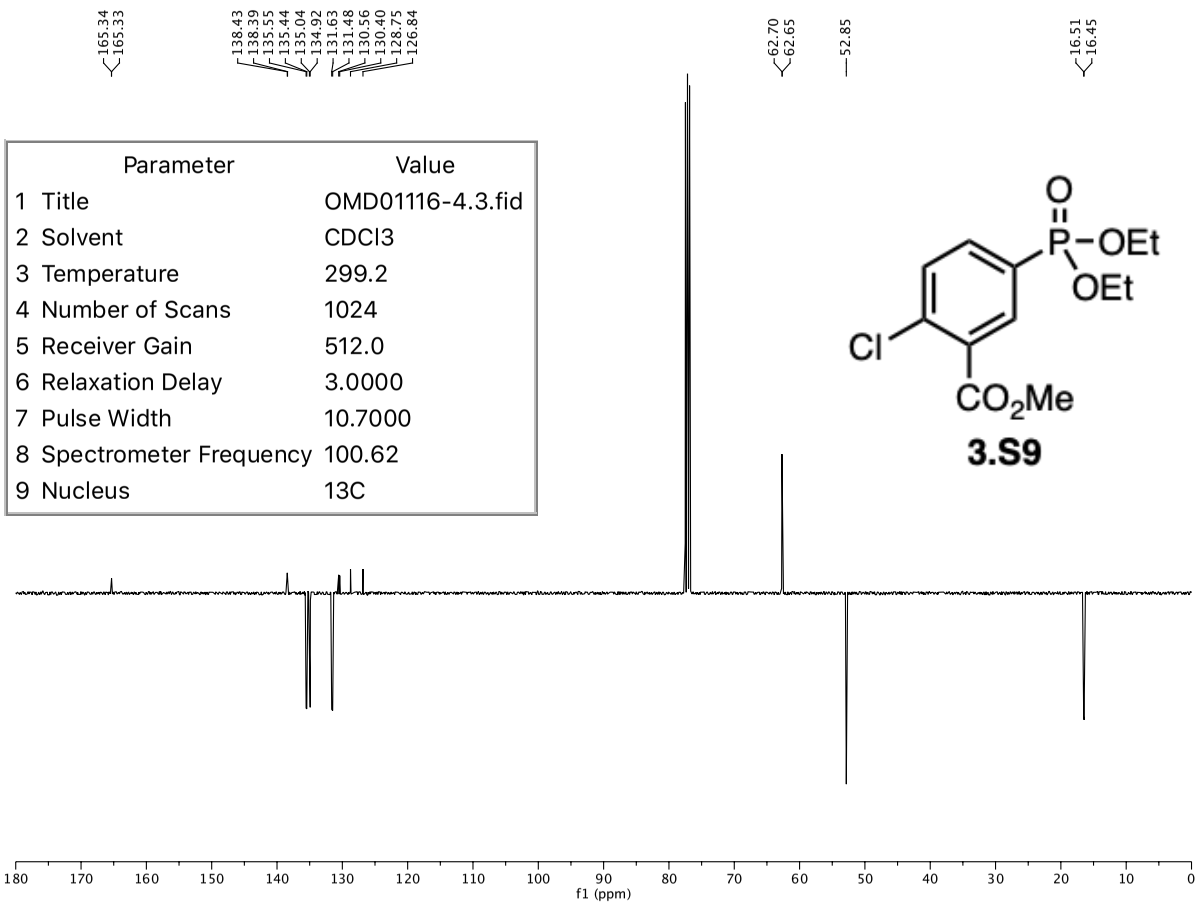
156.44
156.39
156.37
132.16
132.09
127.92
125.33
125.30
125.11
125.02
123.34
122.80
122.75
122.61
120.80
113.38
112.35
111.50
62.73
62.68
16.51
16.45
Parameter
Value
1 Title
XUF06280.6.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
EtO
EtO
P
O
O
3.S8
f1 (ppm)

Parameter	Value
1 Title	XUF06280.5.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	4.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

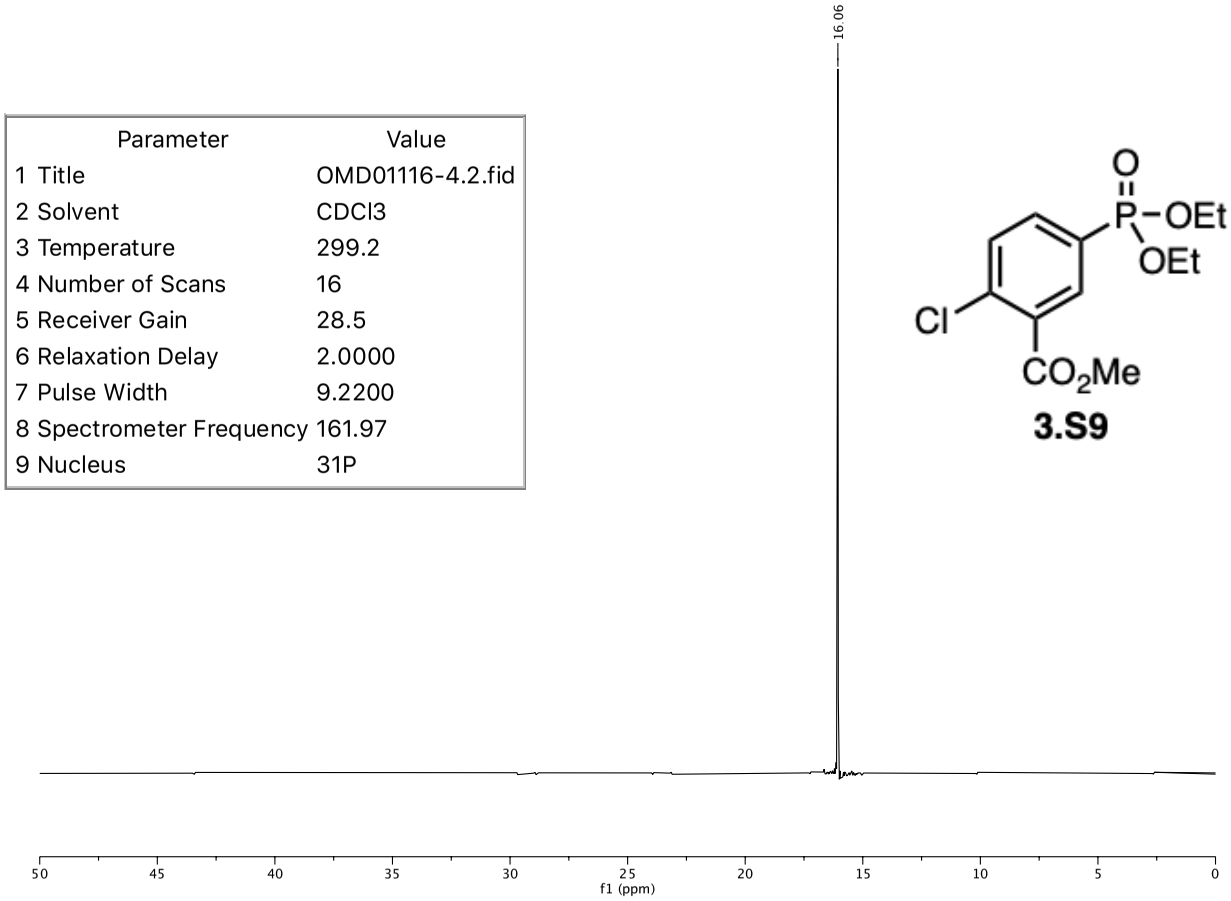
3.S8



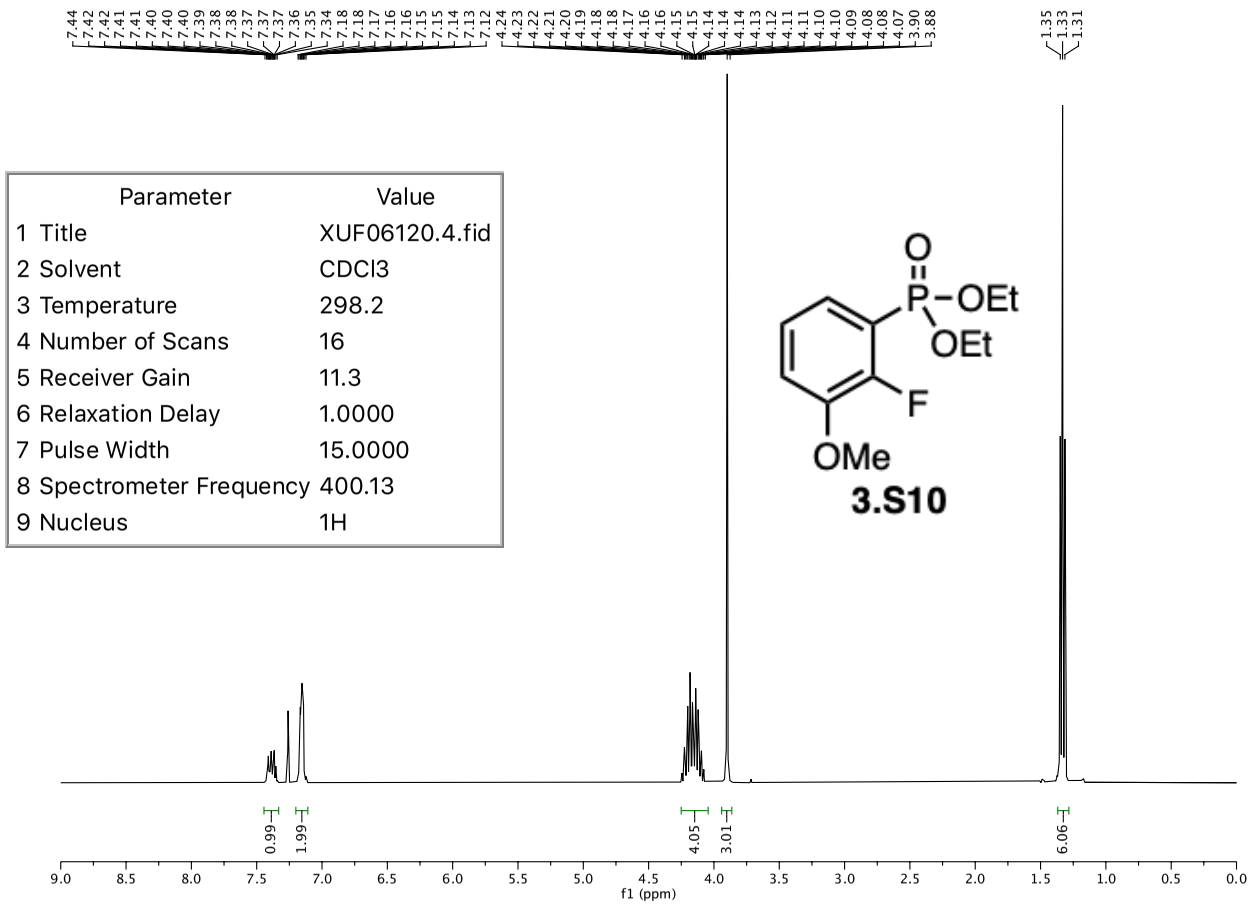

Parameter Value
1 Title OMD01116-4.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 14.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P
OEt
OEt
Cl
CO2Me
3.S9
0.97
1.00
0.99
3.06
4.02
6.00
f1 (ppm)

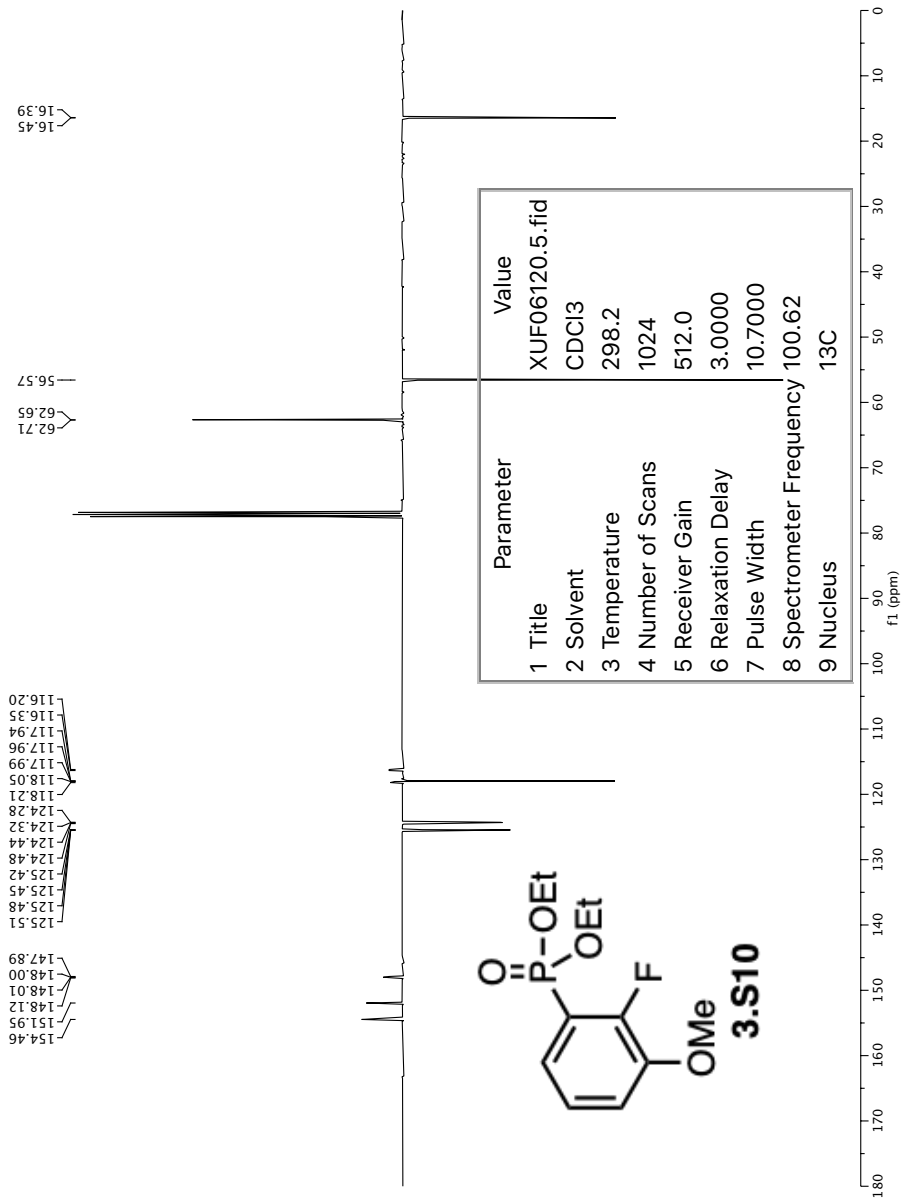

165.34
165.33
138.43
138.39
135.55
135.44
135.04
134.92
131.63
131.48
130.56
130.40
128.75
126.84
62.70
62.65
52.85
16.51
16.45
Parameter Value
1 Title OMD01116-4.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
P–OEt
OEt
Cl
CO2Me
3.S9
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	OMD01116-4.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	28.5
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P



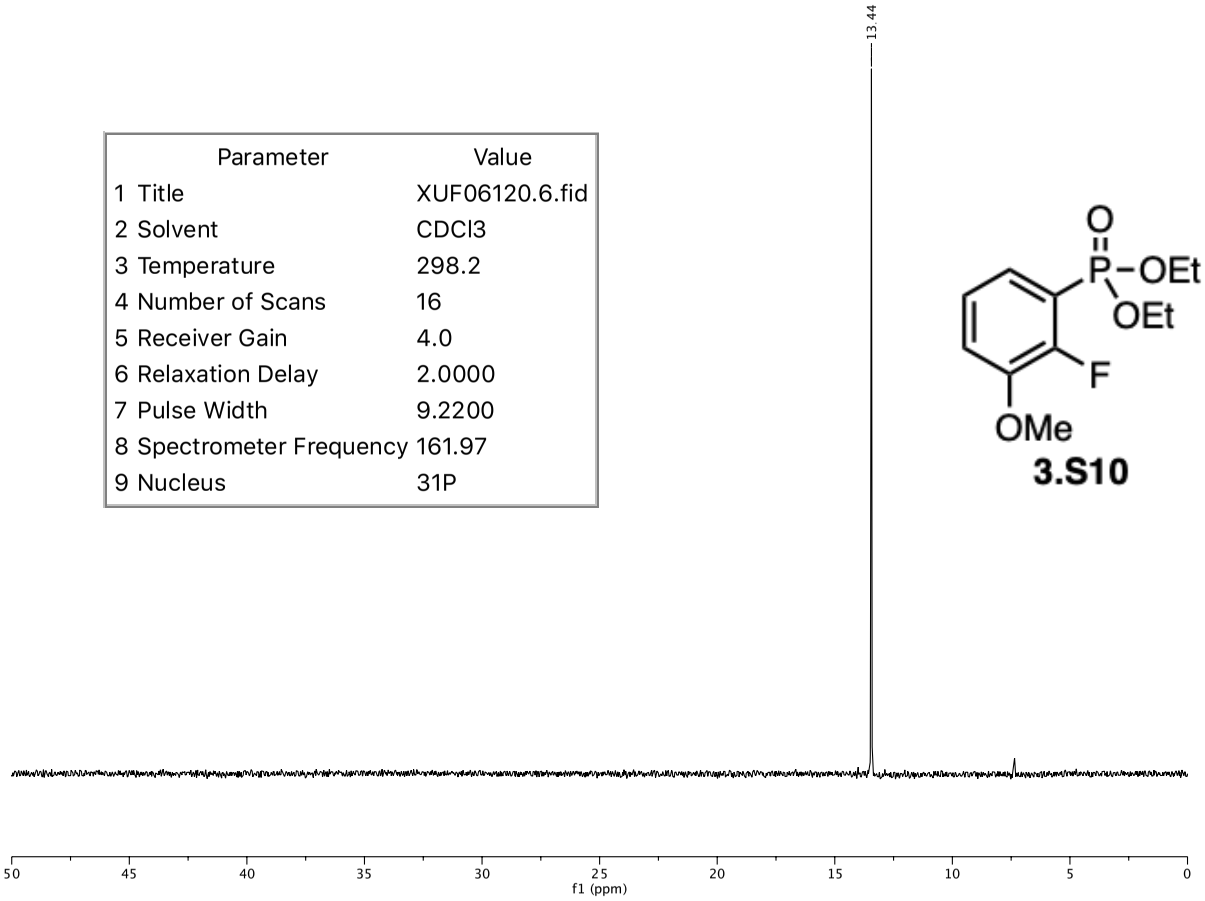
3.S9


7.44 7.42 7.42 7.41 7.41 7.40 7.40 7.40 7.39 7.38 7.38 7.37 7.37 7.37 7.36 7.35 7.34 7.18 7.18 7.17 7.16 7.16 7.15 7.15 7.14 7.13 7.12 4.24 4.23 4.22 4.21 4.20 4.19 4.18 4.18 4.17 4.16 4.16 4.15 4.15 4.14 4.14 4.13 4.12 4.11 4.11 4.10 4.10 4.09 4.08 4.08 4.07 3.90 3.88
1.35 1.33 1.31
Parameter Value
1 Title XUF06120.4.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P
OEt
OEt
F
OMe
3.S10
0.99
1.99
4.05
3.01
6.06
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

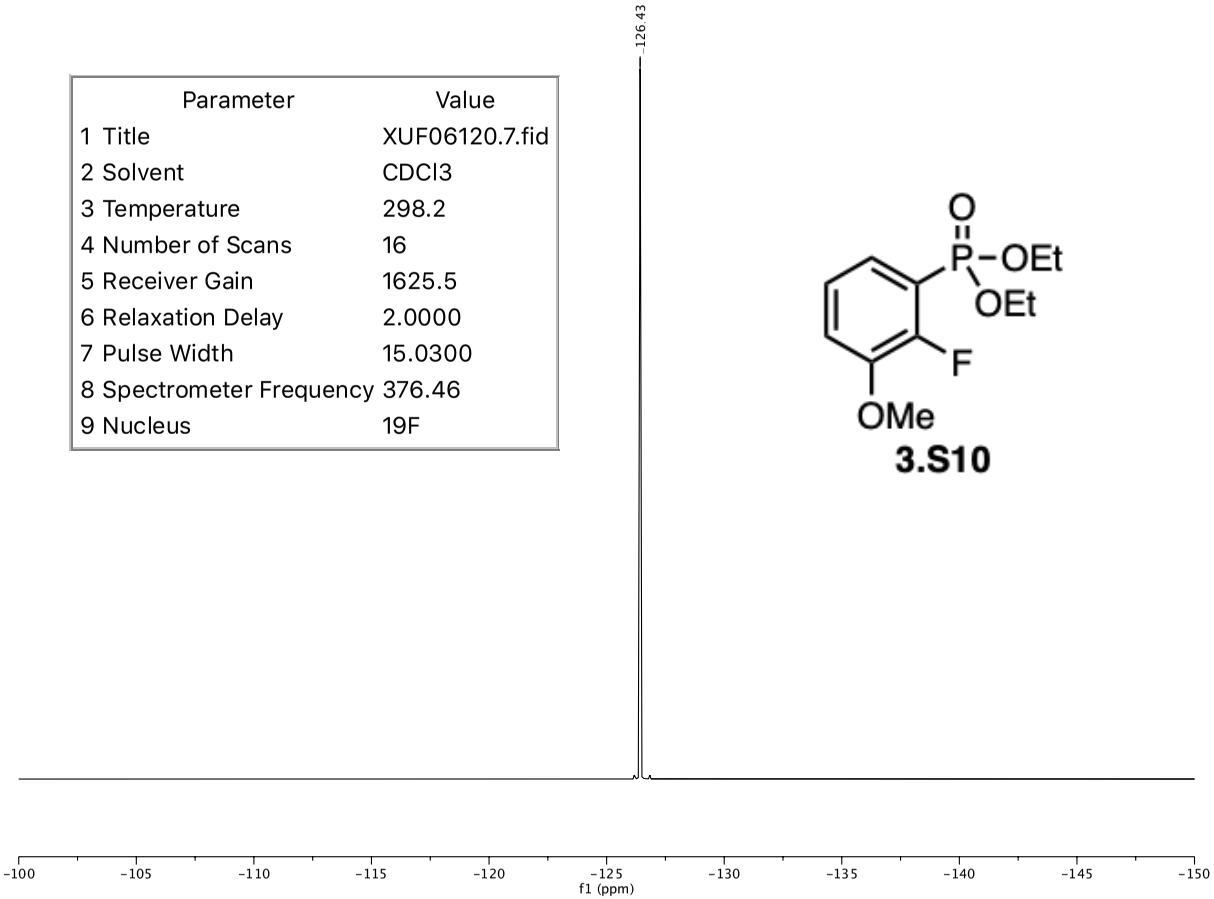

154.46
151.95
148.12
148.01
148.00
147.89
125.51
125.48
125.45
125.42
124.48
124.44
124.32
124.28
118.21
118.05
117.99
117.96
117.94
116.35
116.20
62.71
62.65
56.57
16.45
16.39
Parameter
Value
1 Title
XUF06120.5.fid
2 Solvent
CDCl3
3 Temperature
298.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
O
P
OEt
OEt
F
OMe
3.S10
f1 (ppm)

Parameter	Value
1 Title	XUF06120.6.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	4.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

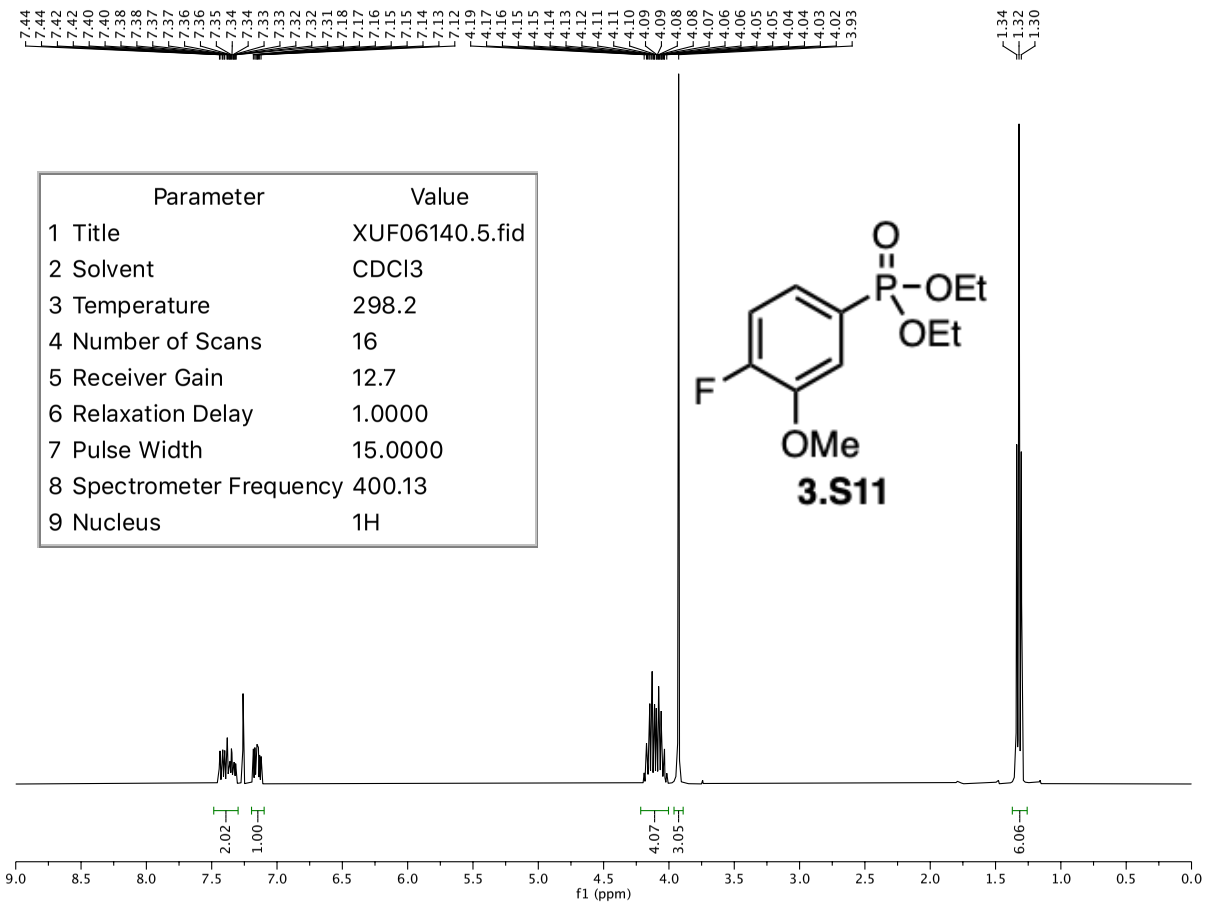
3.S10

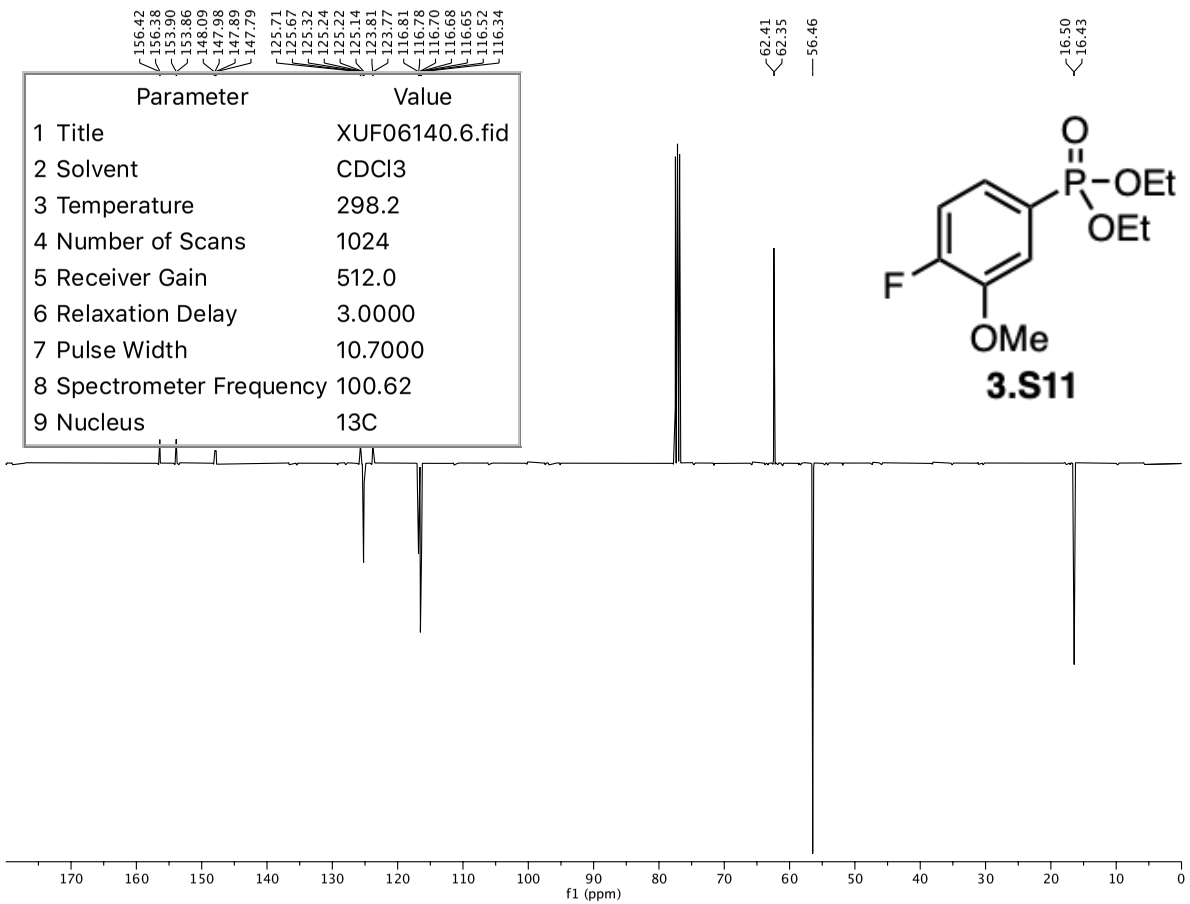


Parameter	Value
1 Title	XUF06120.7.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

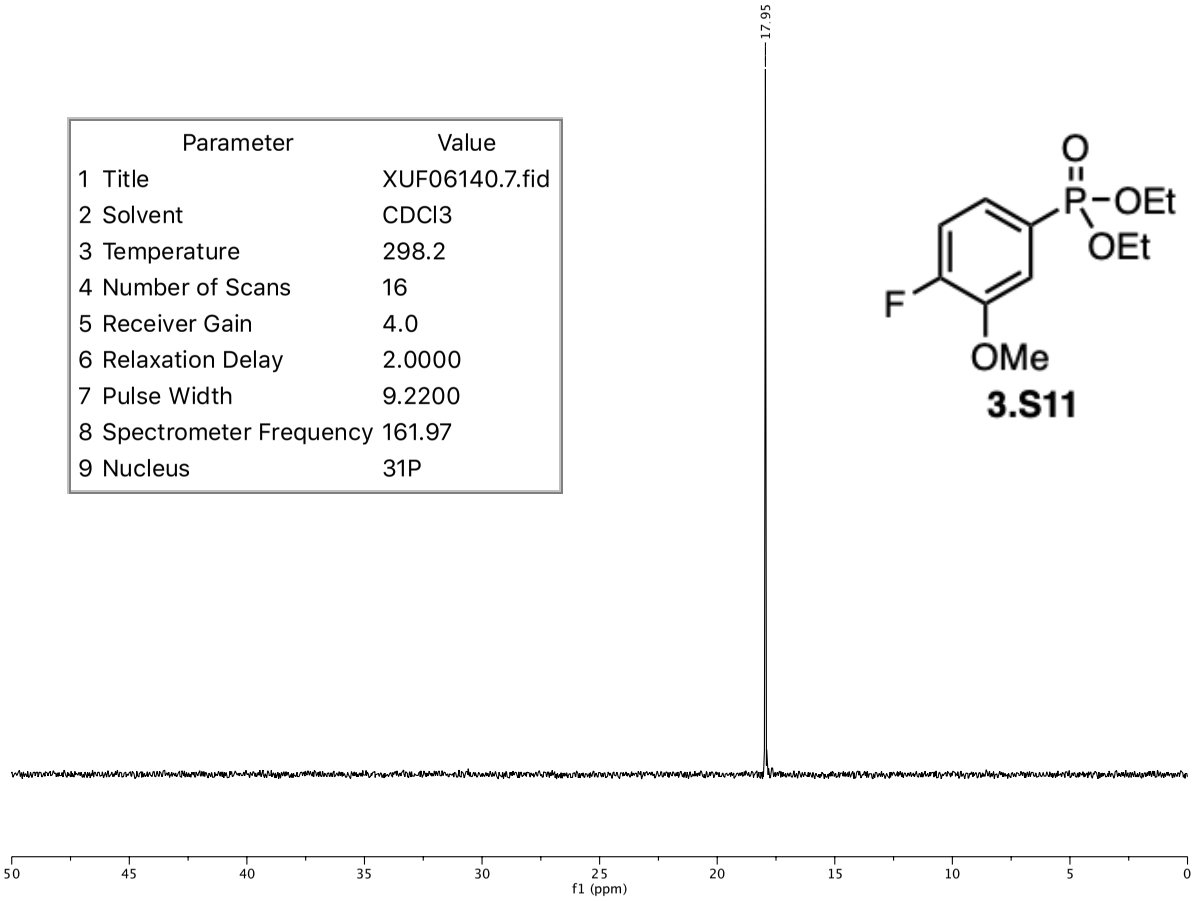


3.S10


7.44 7.44 7.42 7.42 7.40 7.40 7.38 7.38 7.37 7.37 7.36 7.36 7.35 7.34 7.34 7.33 7.33 7.32 7.32 7.31 7.18 7.17 7.16 7.15 7.15 7.14 7.13 7.12
4.19 4.17 4.16 4.15 4.15 4.14 4.13 4.12 4.11 4.11 4.10 4.09 4.09 4.08 4.08 4.07 4.06 4.06 4.05 4.05 4.04 4.04 4.03 4.02 3.93
1.34 1.32 1.30
Parameter Value
1 Title XUF06140.5.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P
OEt
OEt
F
OMe
3.S11
2.02
1.00
4.07
3.05
6.06
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


156.42
156.38
153.90
153.86
148.09
147.98
147.89
147.79
125.71
125.67
125.32
125.24
125.22
125.14
123.81
123.77
116.81
116.78
116.70
116.68
116.65
116.52
116.34
62.41
62.35
56.46
16.50
16.43
Parameter Value
1 Title XUF06140.6.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
P
OEt
OEt
F
OMe
3.S11
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

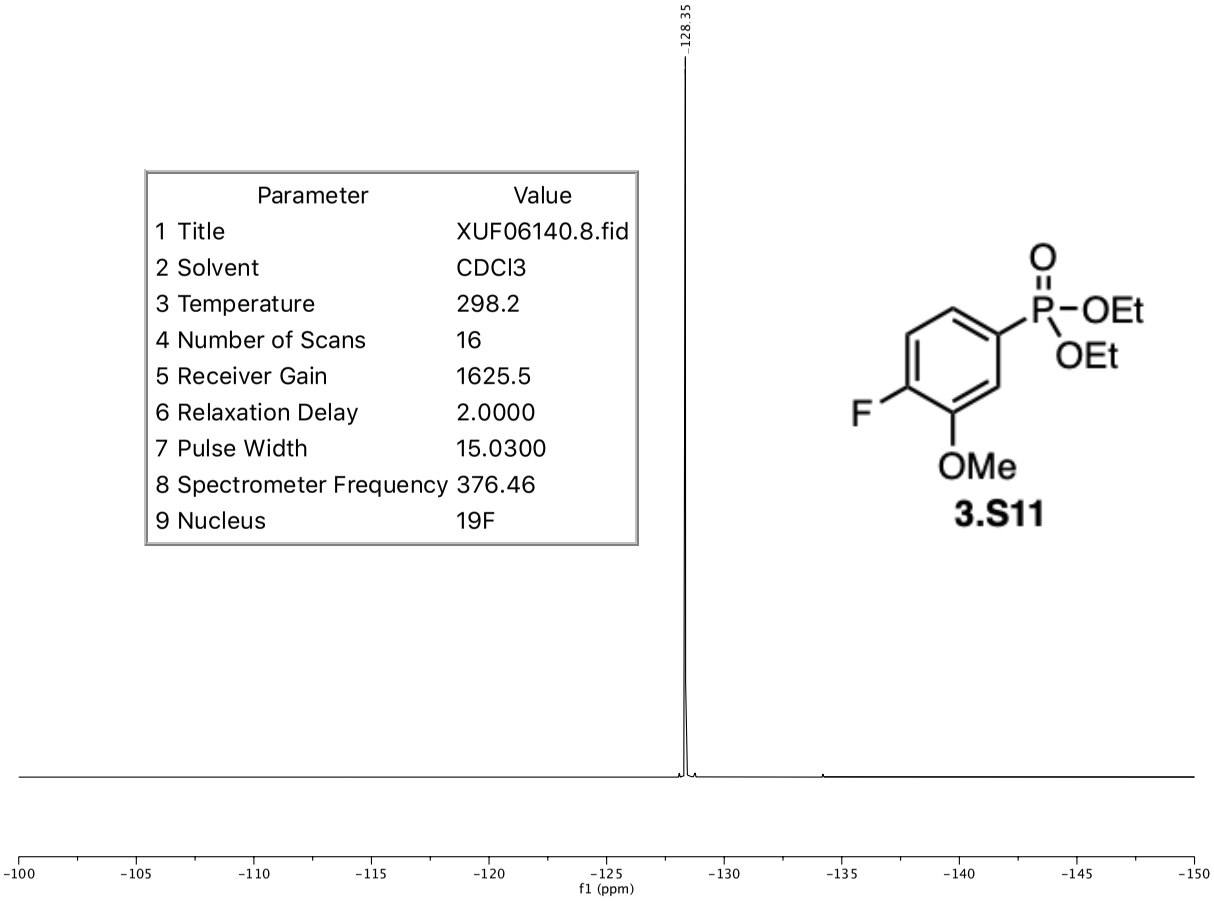
Parameter	Value
1 Title	XUF06140.7.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	4.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

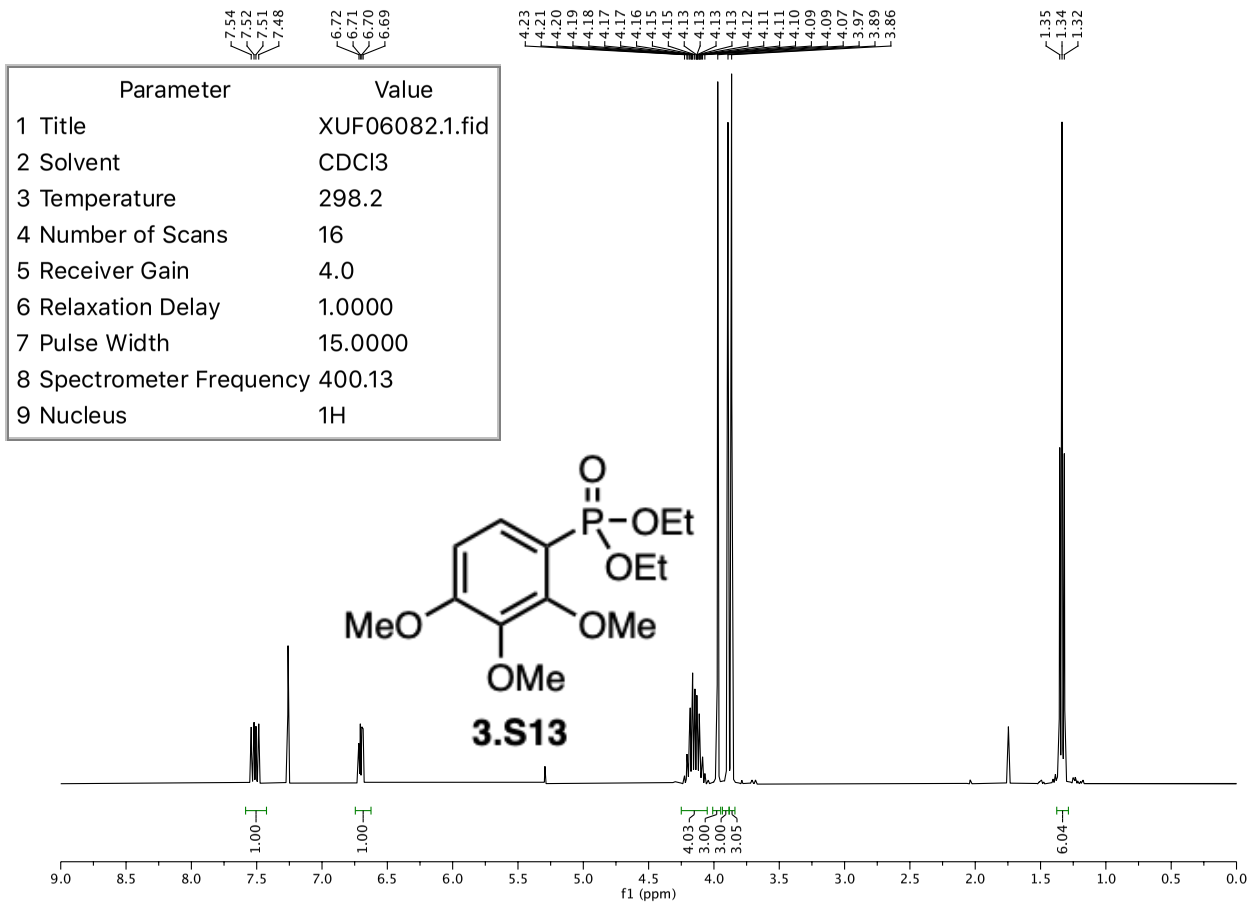


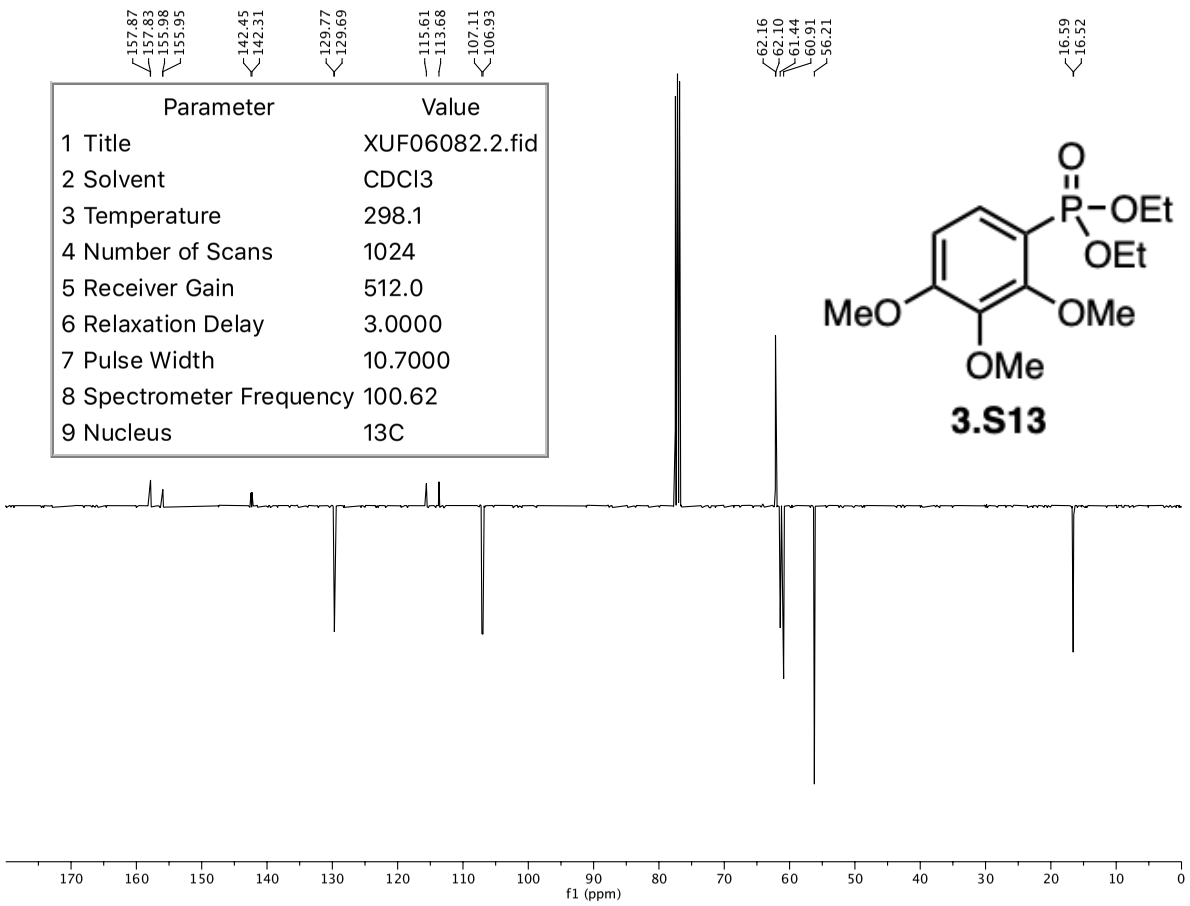
3.S11

Parameter	Value
1 Title	XUF06140.8.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

3.S11

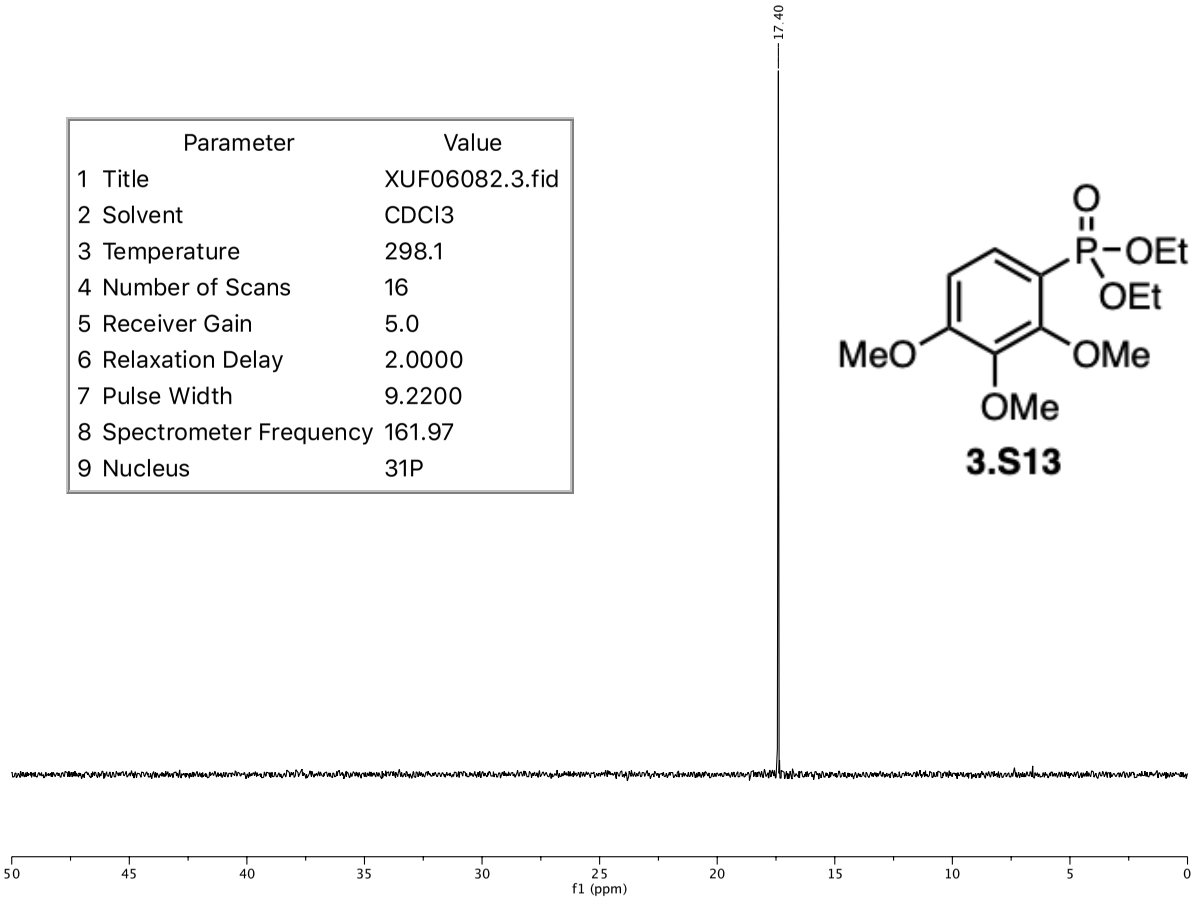



7.54
7.52
7.51
7.48
6.72
6.71
6.70
6.69
4.23
4.21
4.20
4.19
4.18
4.17
4.17
4.16
4.15
4.15
4.13
4.13
4.13
4.13
4.12
4.11
4.11
4.10
4.09
4.09
4.07
3.97
3.89
3.86
1.35
1.34
1.32
Parameter Value
1 Title XUF06082.1.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P
OEt
OEt
MeO
OMe
OMe
3.S13
1.00
1.00
4.03
3.00
3.00
3.05
6.04
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


157.87
157.83
155.98
155.95
142.45
142.31
129.77
129.69
115.61
113.68
107.11
106.93
62.16
62.10
61.44
60.91
56.21
16.59
16.52
Parameter Value
1 Title XUF06082.2.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
P–OEt
OEt
MeO
OMe
OMe
3.S13
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06082.3.fid
2 Solvent	CDCl3
3 Temperature	298.1
4 Number of Scans	16
5 Receiver Gain	5.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.S13

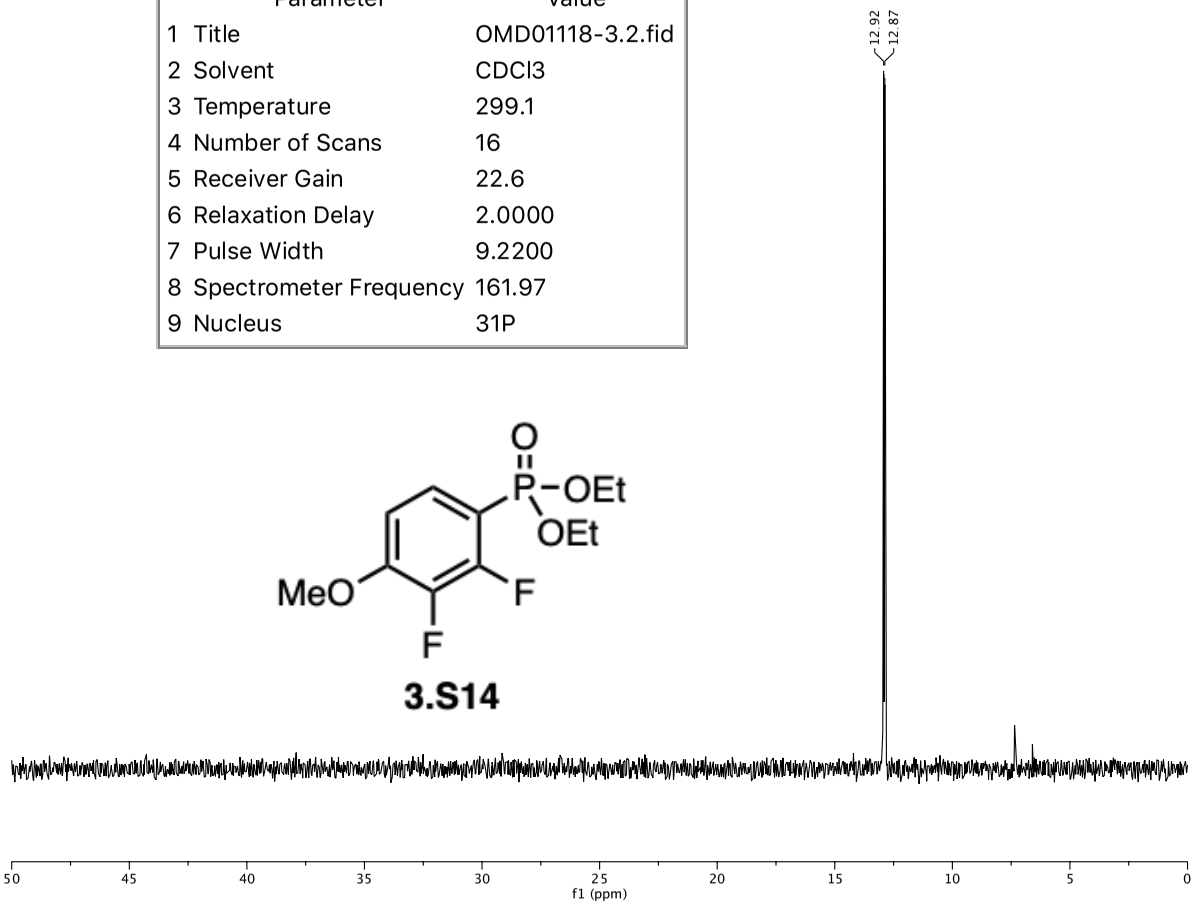


Parameter Value
1 Title OMD01118.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
3.S14
MeO
F
F
O
P
OEt
OEt
1.00
1.01
3.05
4.04
5.96
f1 (ppm)

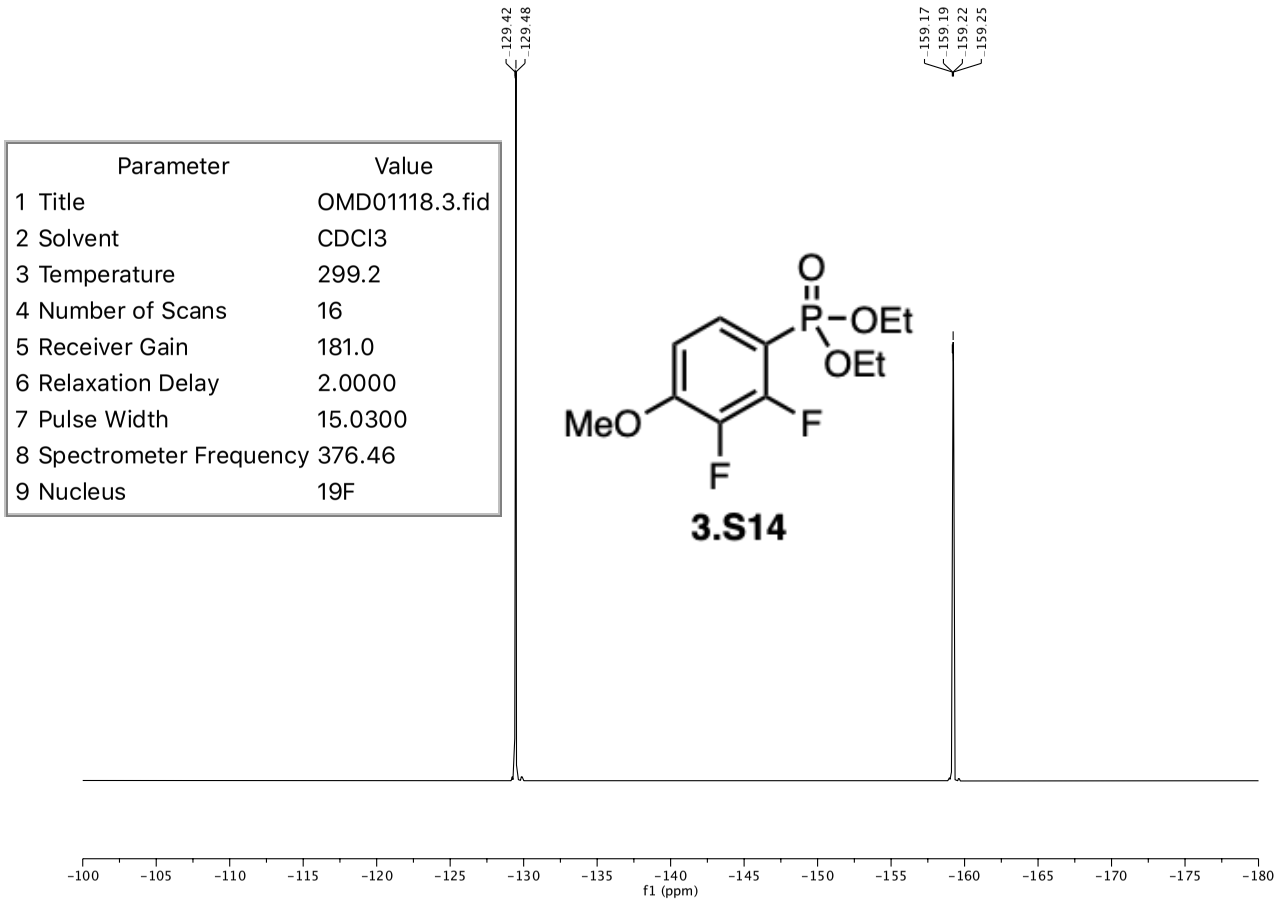
30.85
30.79
77.16
77.10
71.25
167.82
167.74
167.71
167.67
167.63
165.31
165.20
156.88
156.73
156.58
154.39
154.24
154.10
143.82
143.77
143.76
143.73
143.71
143.67
125.08
125.06
124.92
124.90
123.15
123.14
123.00
122.98
122.71
122.68
122.55
122.52
Parameter Value
1 Title OMD01118.4.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
P
OEt
OEt
F
F
MeO
3.S14
f1 (ppm)

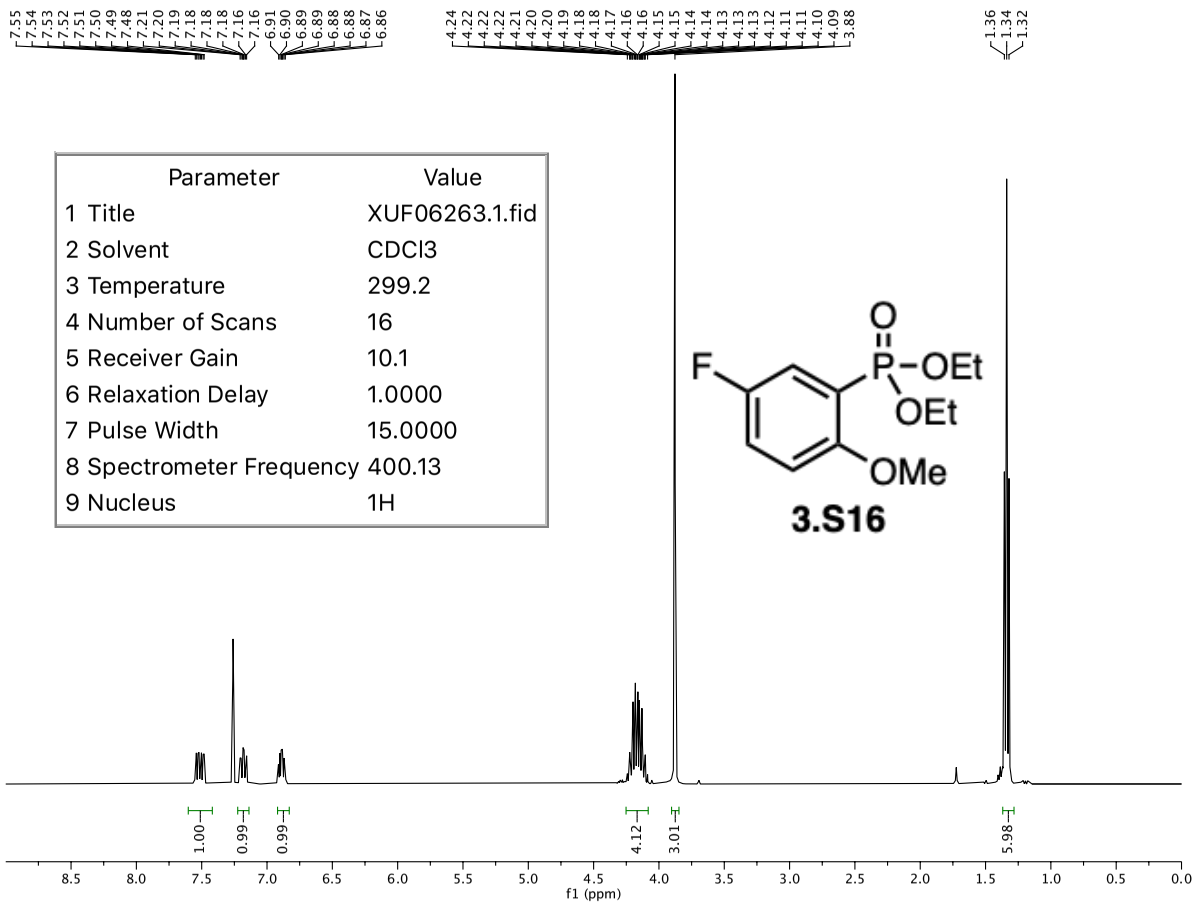
	Parameter	Value
1	Title	OMD01118-3.2.fid
2	Solvent	CDCl3
3	Temperature	299.1
4	Number of Scans	16
5	Receiver Gain	22.6
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P

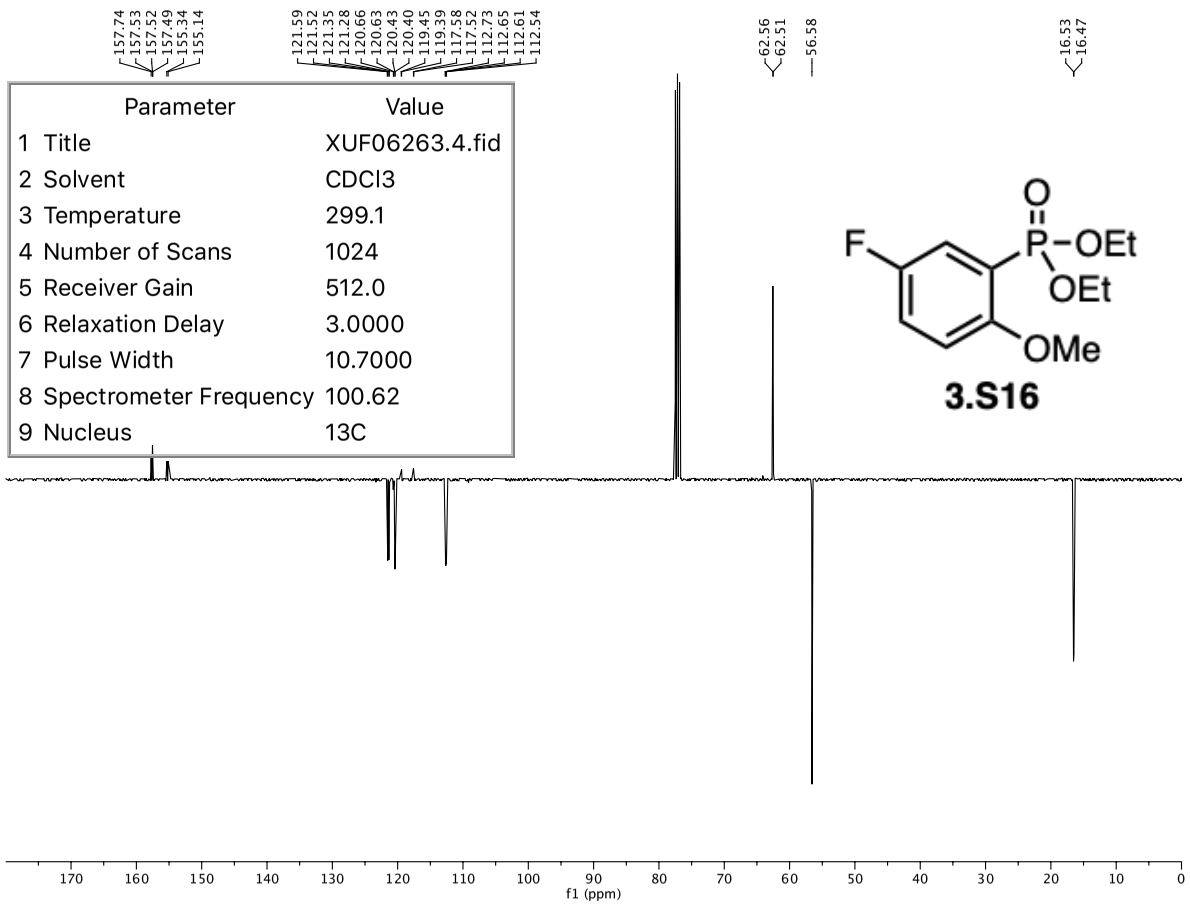
3.S14



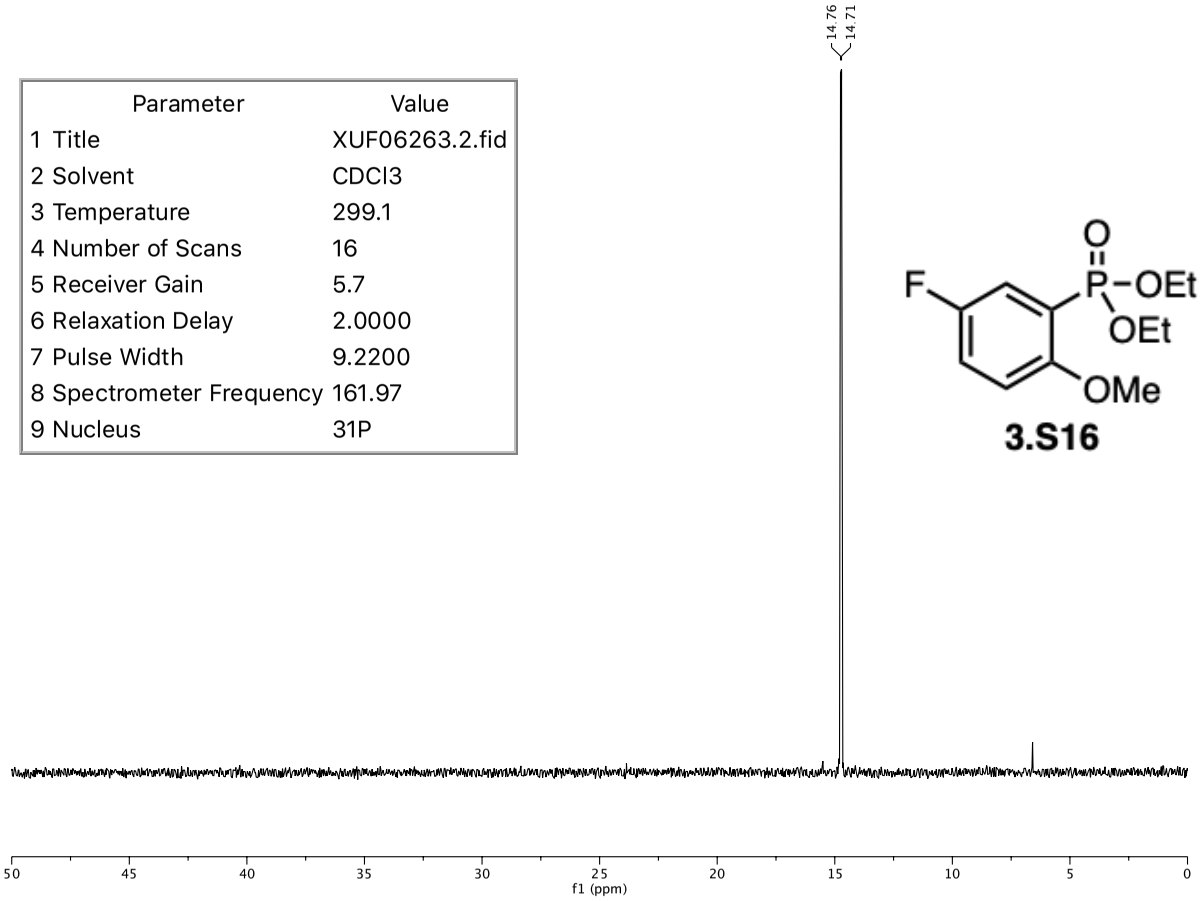
Parameter	Value
1 Title	OMD01118.3.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	181.0
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F




7.55 7.54 7.53 7.52 7.51 7.50 7.49 7.48 7.21 7.20 7.19 7.18 7.18 7.18 7.16 7.16 6.91 6.90 6.89 6.89 6.88 6.88 6.87 6.86
4.24 4.22 4.22 4.22 4.21 4.20 4.20 4.19 4.18 4.18 4.17 4.16 4.16 4.15 4.15 4.14 4.14 4.13 4.13 4.12 4.11 4.11 4.10 4.09 3.88
1.36 1.34 1.32
Parameter Value
1 Title XUF06263.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
F
O
P
OEt
OEt
OMe
3.S16
1.00 0.99 0.99 4.12 3.01 5.98
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

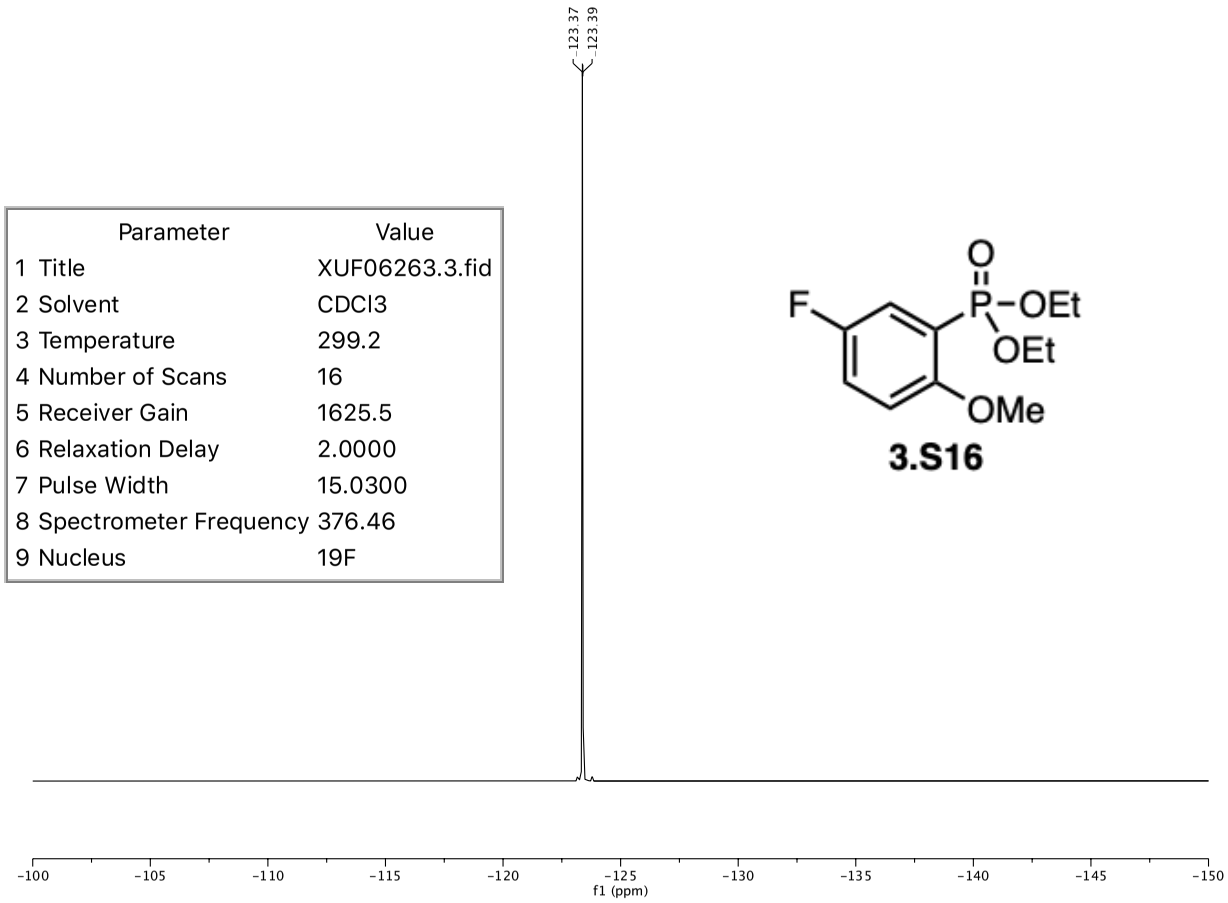

157.74
157.53
157.52
157.49
155.34
155.14
121.59
121.52
121.35
121.28
120.66
120.63
120.43
120.40
119.45
119.39
117.58
117.52
112.73
112.65
112.61
112.54
62.56
62.51
56.58
16.53
16.47
Parameter Value
1 Title XUF06263.4.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
O
F
P–OEt
OEt
OMe
3.S16
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06263.2.fid
2 Solvent	CDCl3
3 Temperature	299.1
4 Number of Scans	16
5 Receiver Gain	5.7
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

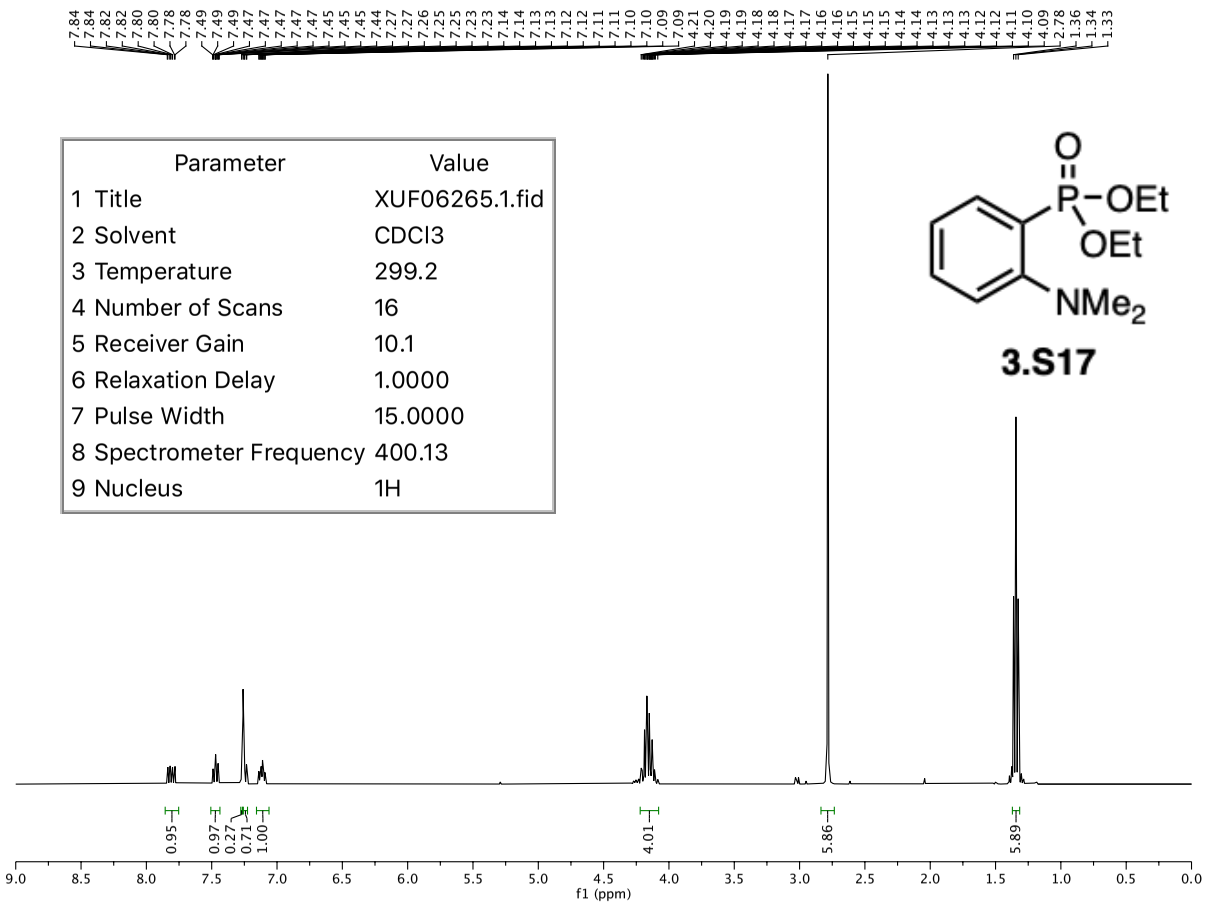


3.S16

Parameter	Value
1 Title	XUF06263.3.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F



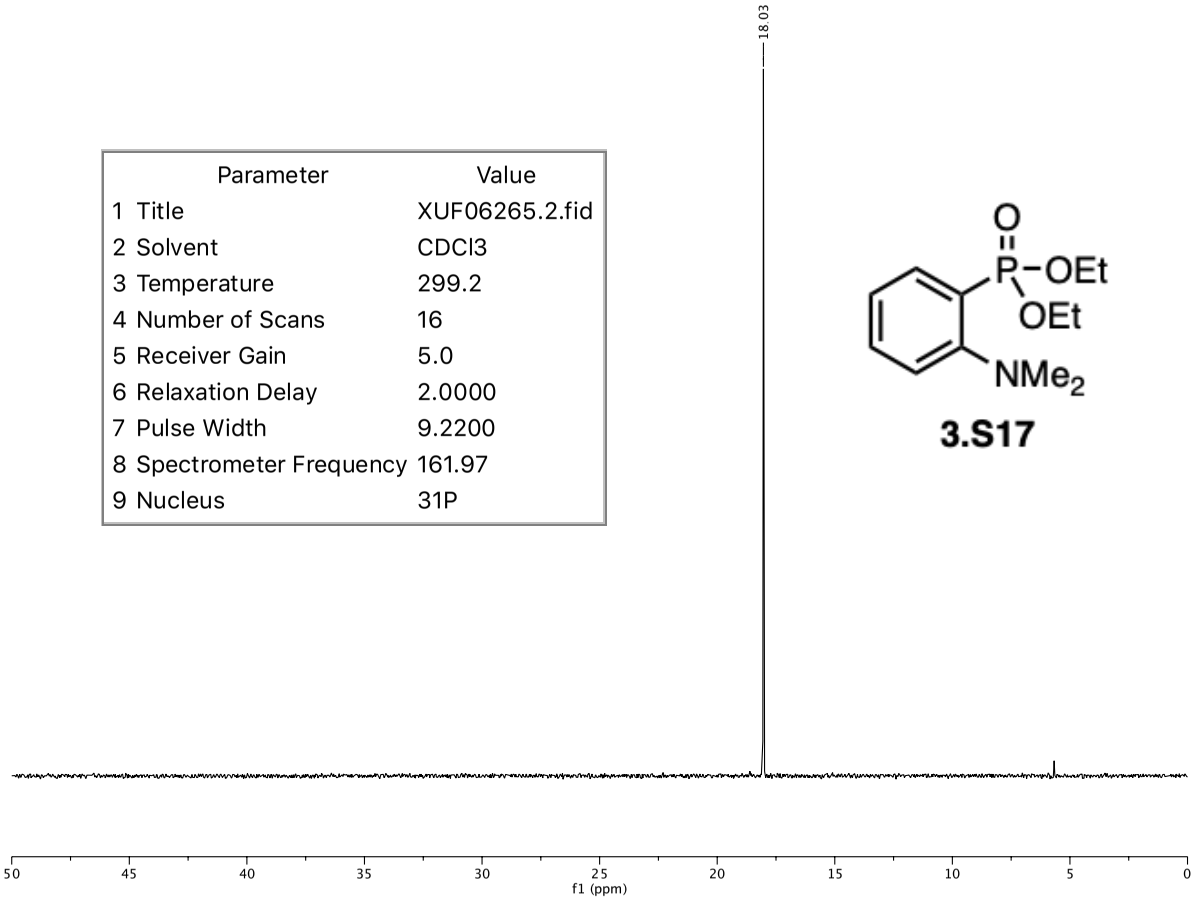
3.S16


7.84 7.84 7.82 7.82 7.80 7.80 7.78 7.78 7.49 7.49 7.47 7.47 7.47 7.47 7.47 7.45 7.45 7.44 7.27 7.27 7.26 7.25 7.25 7.23 7.23 7.14 7.14 7.13 7.13 7.12 7.12 7.11 7.11 7.10 7.10 7.09 7.09 4.21 4.20 4.19 4.19 4.18 4.18 4.17 4.17 4.16 4.16 4.15 4.15 4.15 4.14 4.14 4.13 4.13 4.12 4.12 4.11 4.10 4.09 2.78 1.36 1.34 1.33
Parameter Value
1 Title XUF06265.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P–OEt
OEt
NMe2
3.S17
0.95 0.97 0.27 0.71 1.00 4.01 5.86 5.89
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

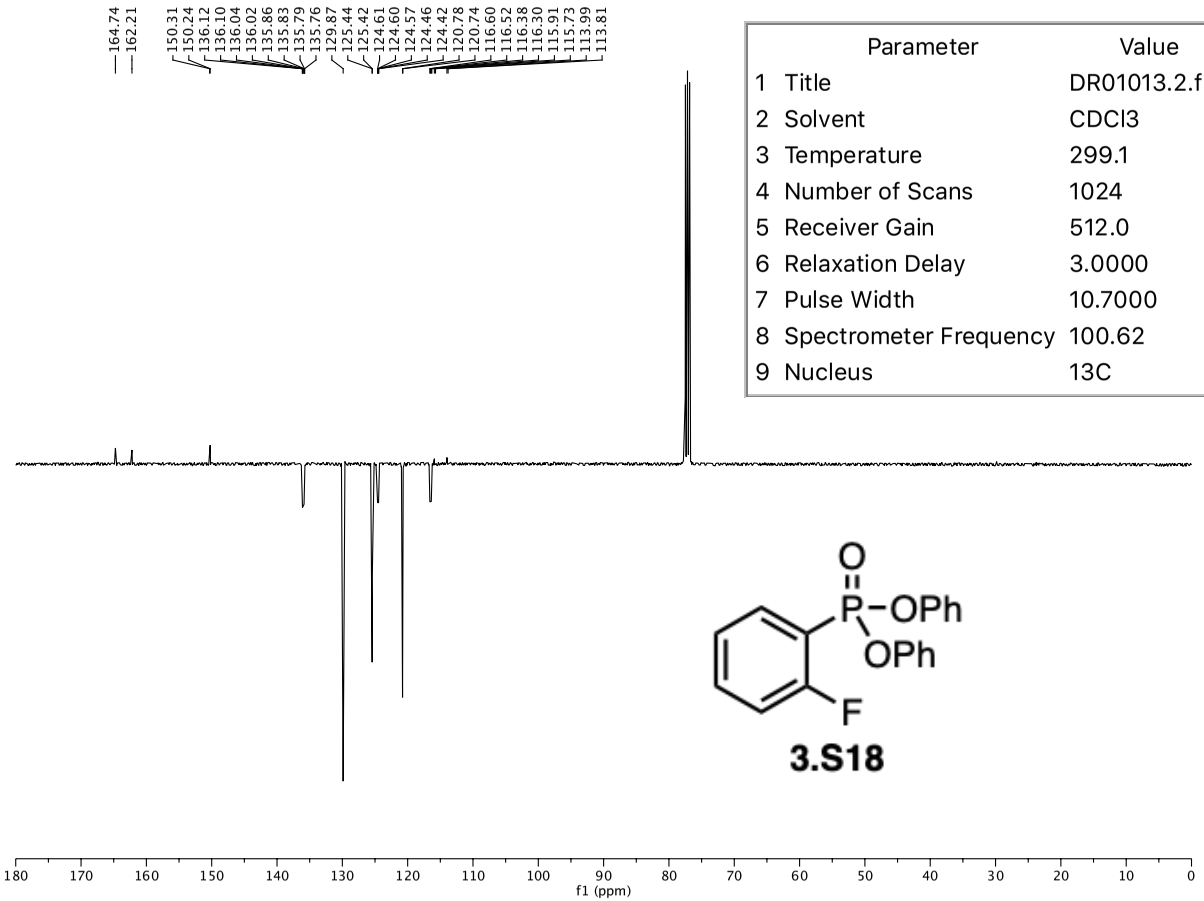
Parameter	Value
1 Title	XUF06265.3.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C

	Parameter	Value
1	Title	XUF06265.2.fid
2	Solvent	CDCl3
3	Temperature	299.2
4	Number of Scans	16
5	Receiver Gain	5.0
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P

3.S17



Parameter Value
1 Title DR01013.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
P
OPh
OPh
F
3.S18
1.00
1.00
4.23
7.94
f1 (ppm)

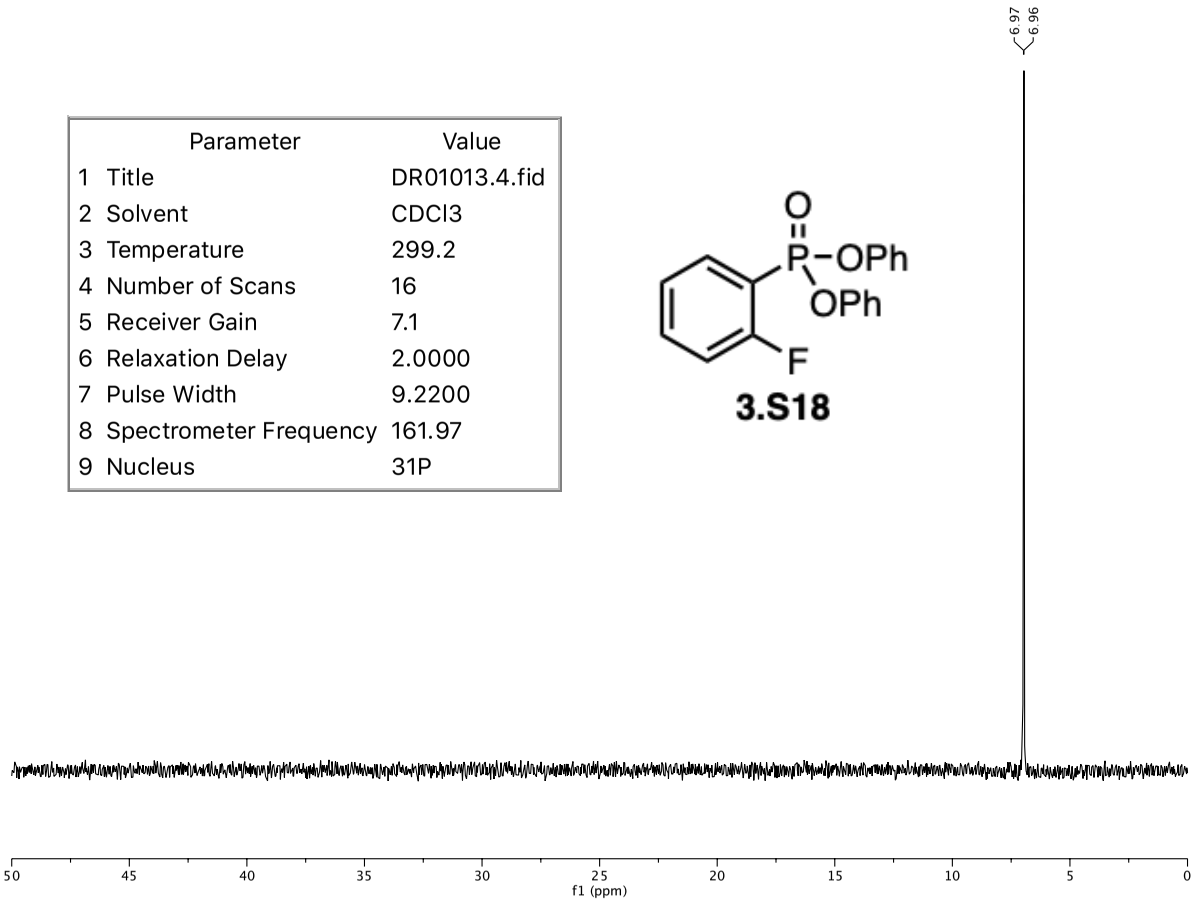


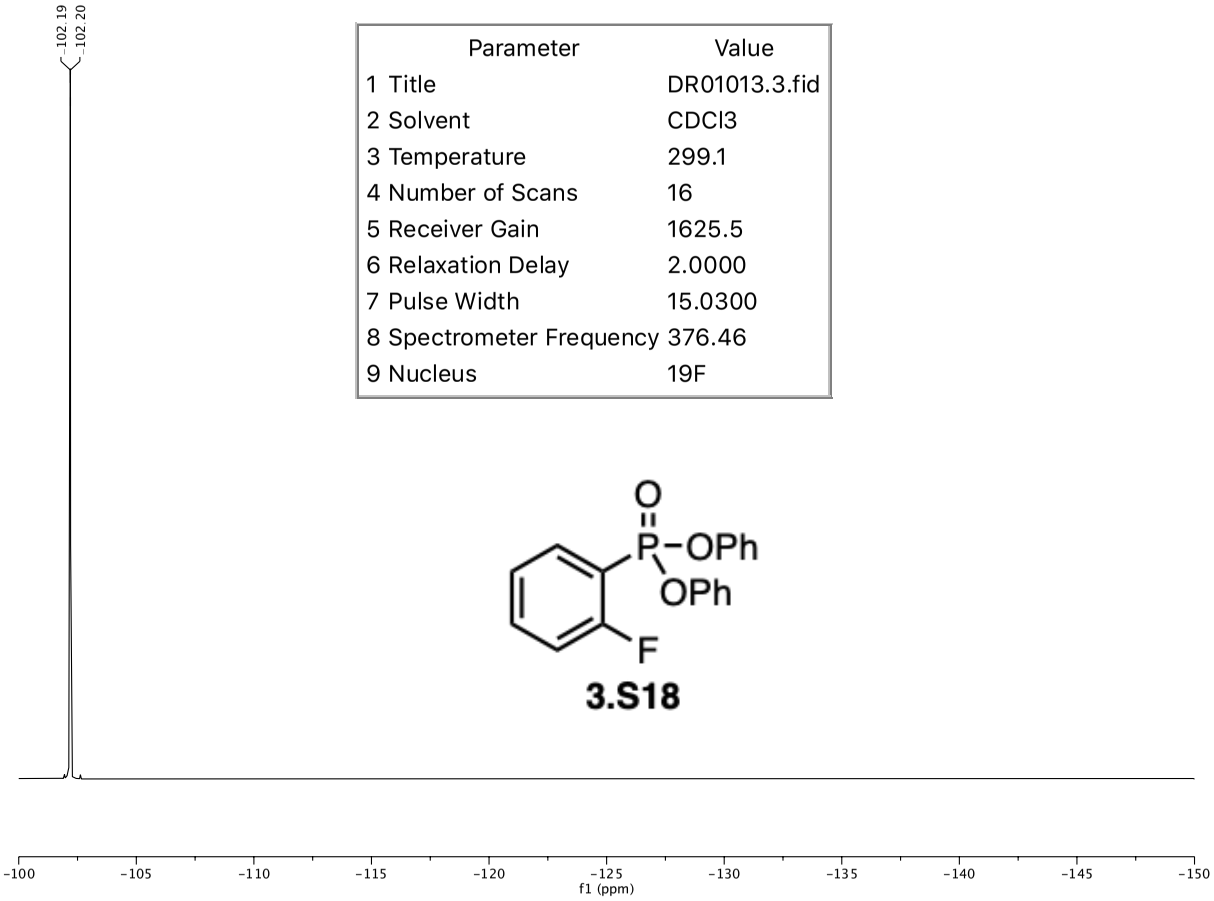
	Parameter	Value
1	Title	DR01013.2.fid
2	Solvent	CDCl3
3	Temperature	299.1
4	Number of Scans	1024
5	Receiver Gain	512.0
6	Relaxation Delay	3.0000
7	Pulse Width	10.7000
8	Spectrometer Frequency	100.62
9	Nucleus	13C

3.S18

	Parameter	Value
1	Title	DR01013.4.fid
2	Solvent	CDCl3
3	Temperature	299.2
4	Number of Scans	16
5	Receiver Gain	7.1
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P

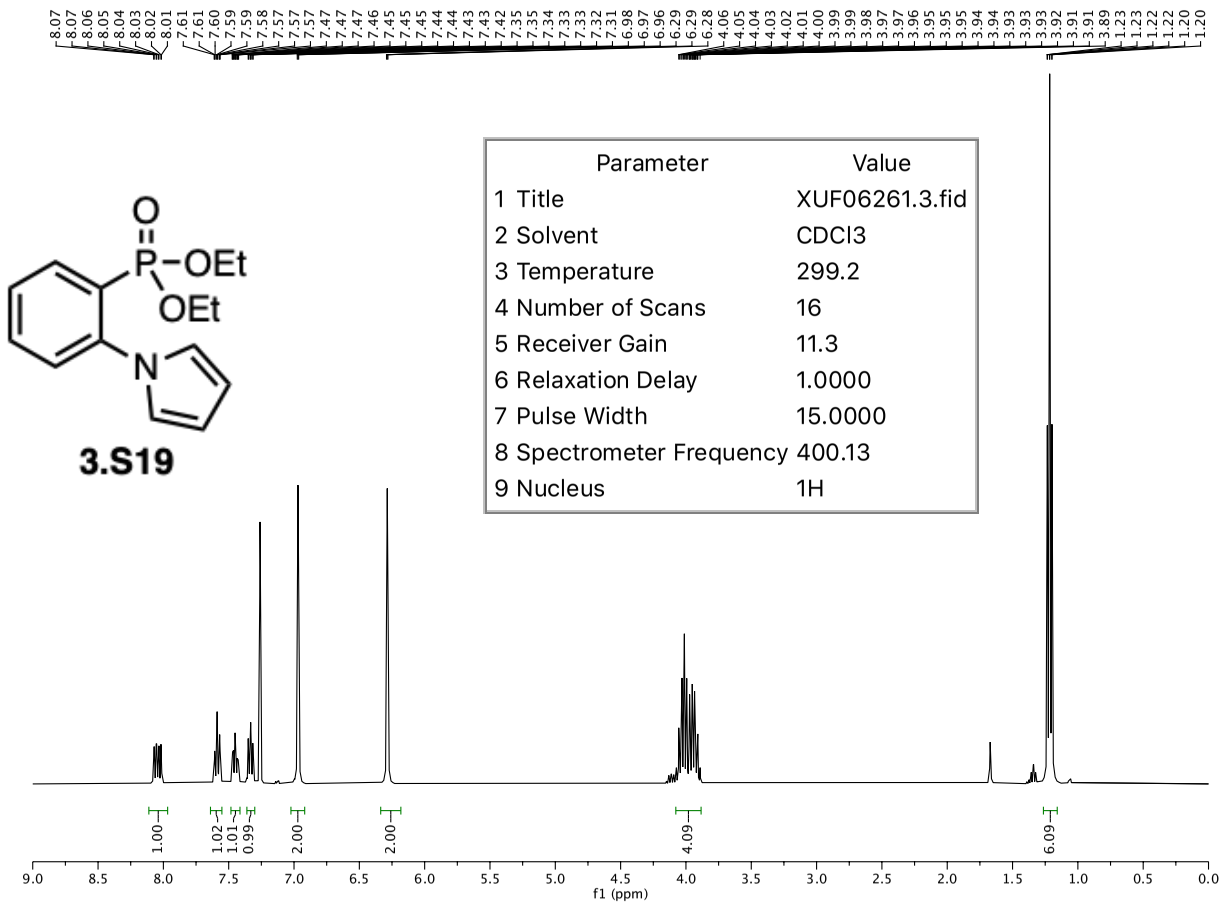
3.S18





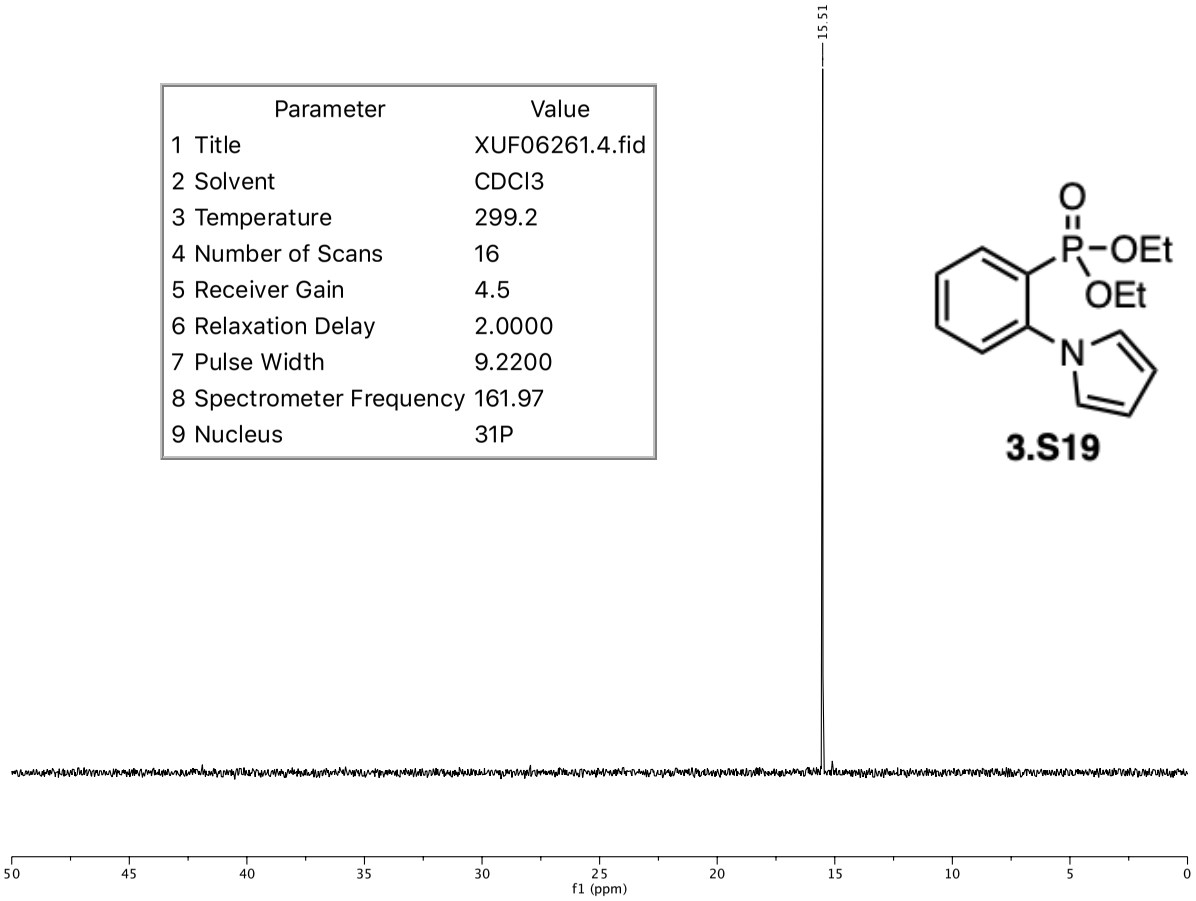
Parameter	Value
1 Title	DR01013.3.fid
2 Solvent	CDCl3
3 Temperature	299.1
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

3.S18

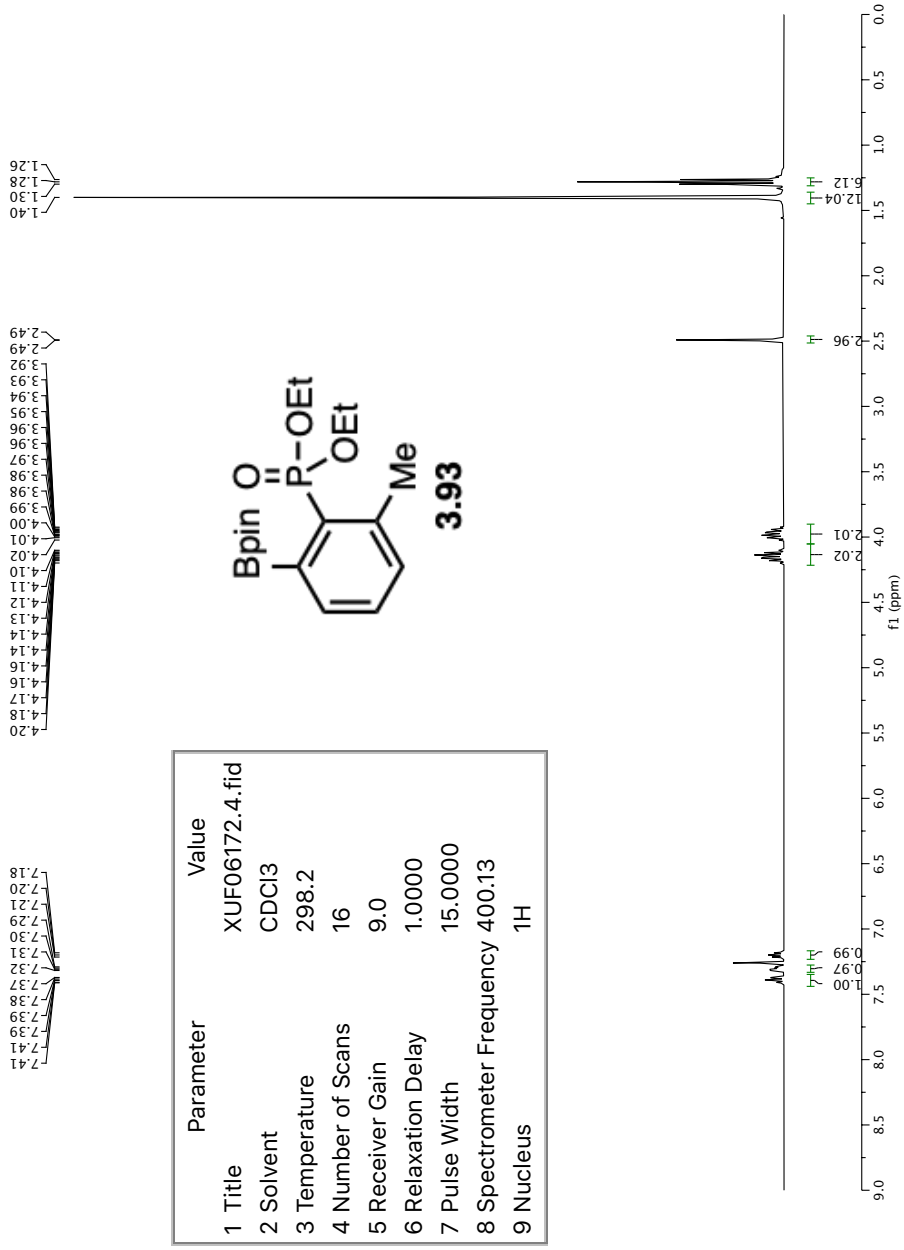

8.07 8.07 8.06 8.05 8.04 8.03 8.02 8.01 7.61 7.61 7.60 7.59 7.59 7.58 7.57 7.57 7.57 7.57 7.47 7.47 7.47 7.46 7.45 7.45 7.45 7.44 7.44 7.43 7.43 7.42 7.35 7.35 7.34 7.33 7.33 7.32 7.31 6.98 6.97 6.96 6.29 6.29 6.28 4.06 4.05 4.04 4.03 4.02 4.01 4.00 3.99 3.99 3.98 3.97 3.97 3.96 3.95 3.95 3.95 3.94 3.93 3.93 3.93 3.92 3.91 3.91 3.89 1.23 1.22 1.22 1.20 1.20
O
P–OEt
OEt
N
3.S19
Parameter Value
1 Title XUF06261.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
1.00 1.02 1.01 0.99 2.00 2.00 4.09 6.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

143.75
143.70
134.95
134.88
133.30
133.27
128.50
128.39
128.25
127.39
127.25
126.10
124.24
123.32
109.16
62.55
62.49
16.33
16.27
Parameter
Value
1 Title
XUF06261.5.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
O
P
OEt
OEt
N
3.S19
f1 (ppm)

Parameter	Value
1 Title	XUF06261.4.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	4.5
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

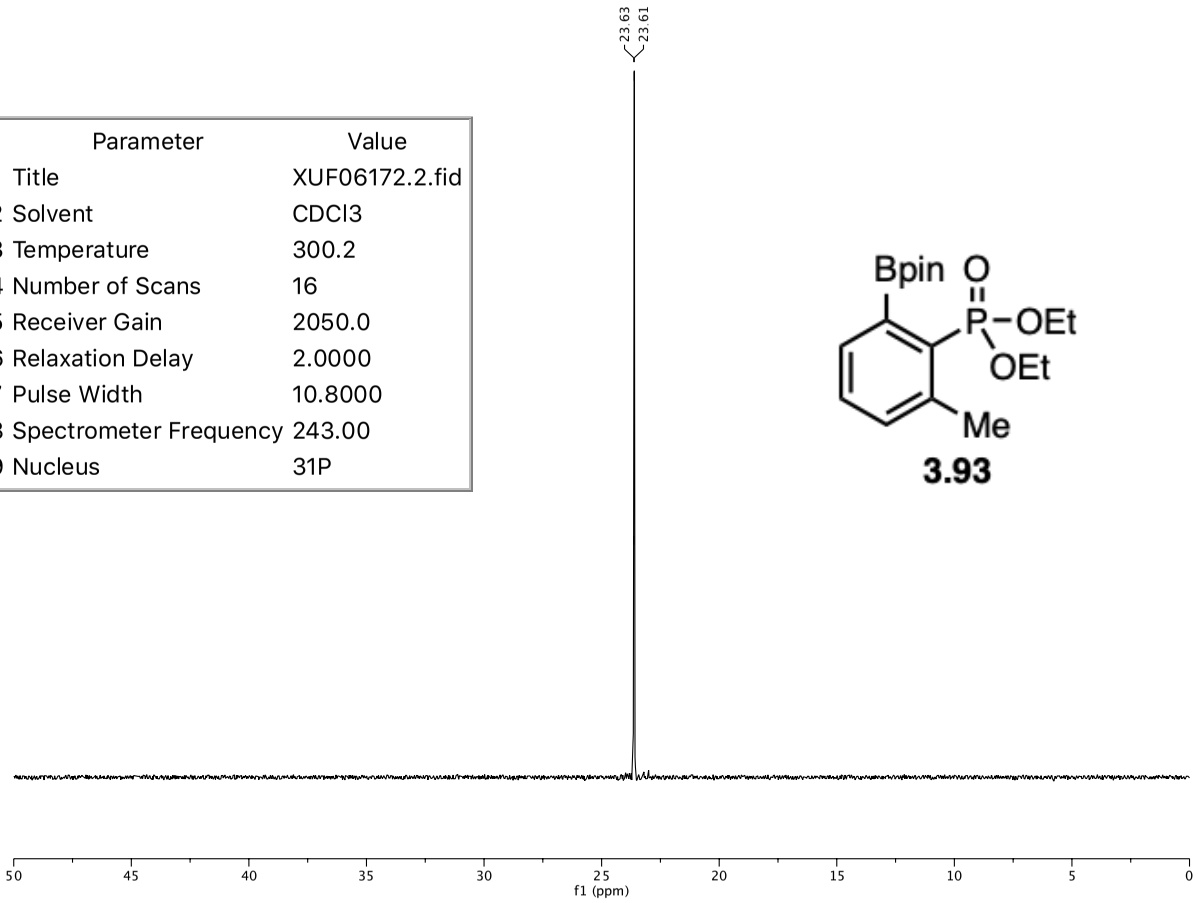


3.S19

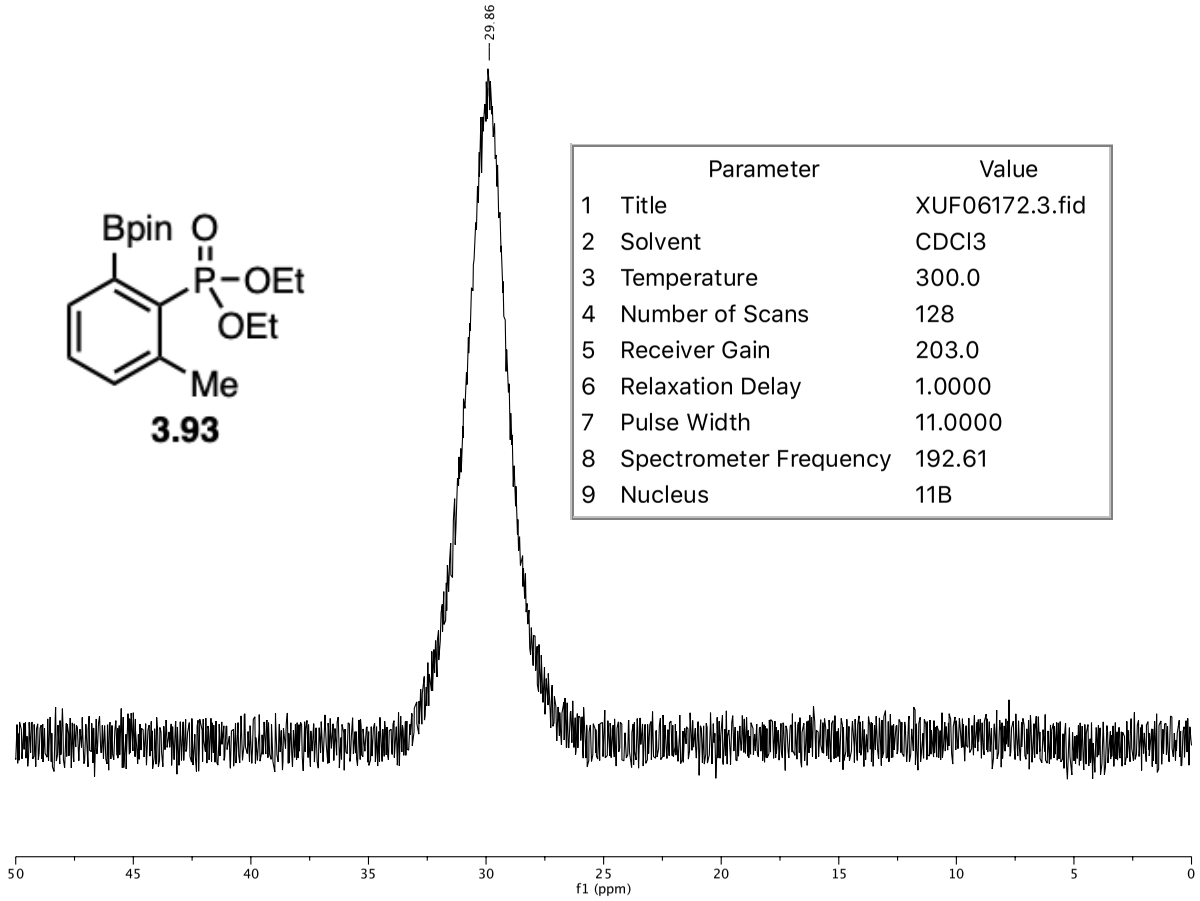

Bpin
O
P
OEt
OEt
Me
3.93
Parameter Value
1 Title XUF06172.4.fid
2 Solvent CDCl3
3 Temperature 298.2
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
f1 (ppm)

Parameter	Value
1 Title	XUF06172.5.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C

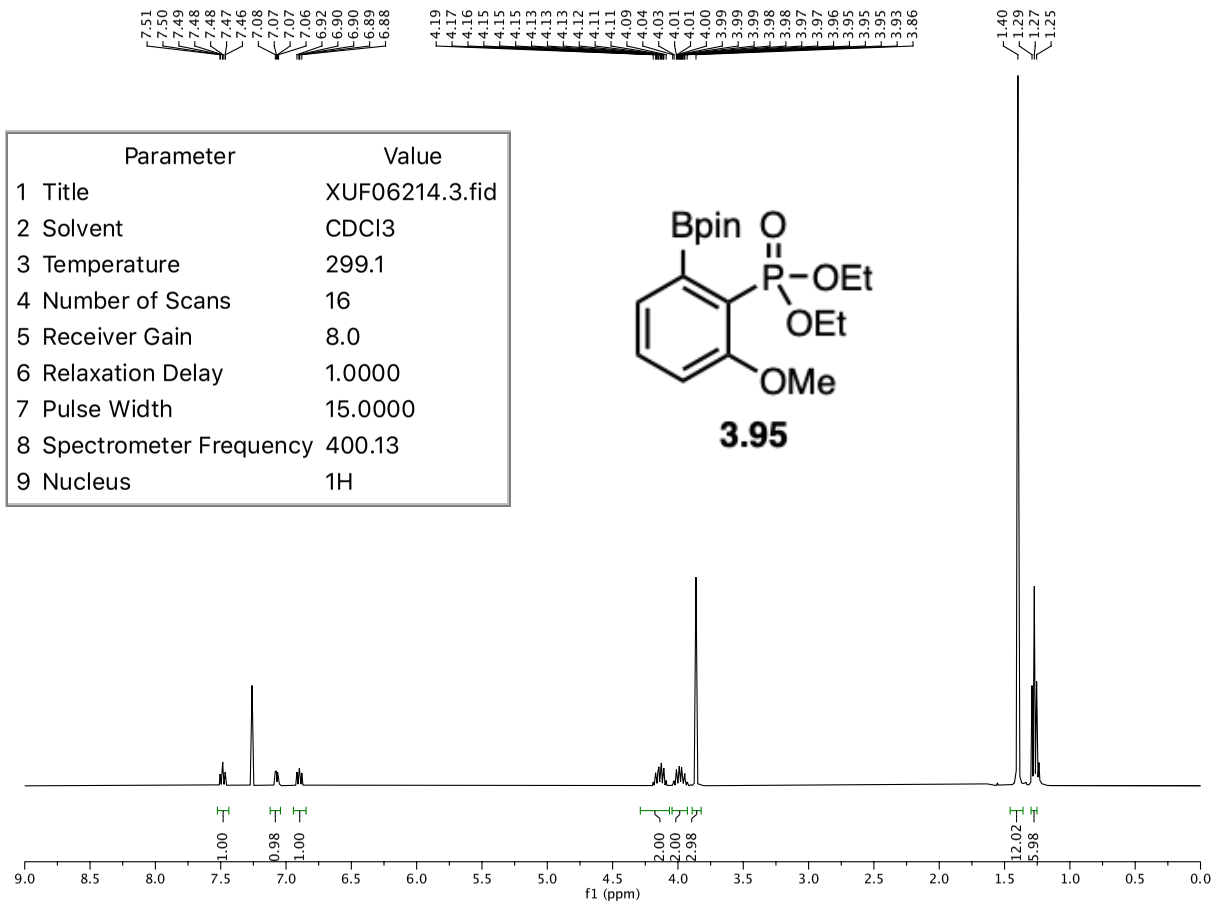
Parameter	Value
1 Title	XUF06172.2.fid
2 Solvent	CDCl3
3 Temperature	300.2
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P



3.93



	Parameter	Value
1	Title	XUF06172.3.fid
2	Solvent	CDCl3
3	Temperature	300.0
4	Number of Scans	128
5	Receiver Gain	203.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B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7.07
7.06
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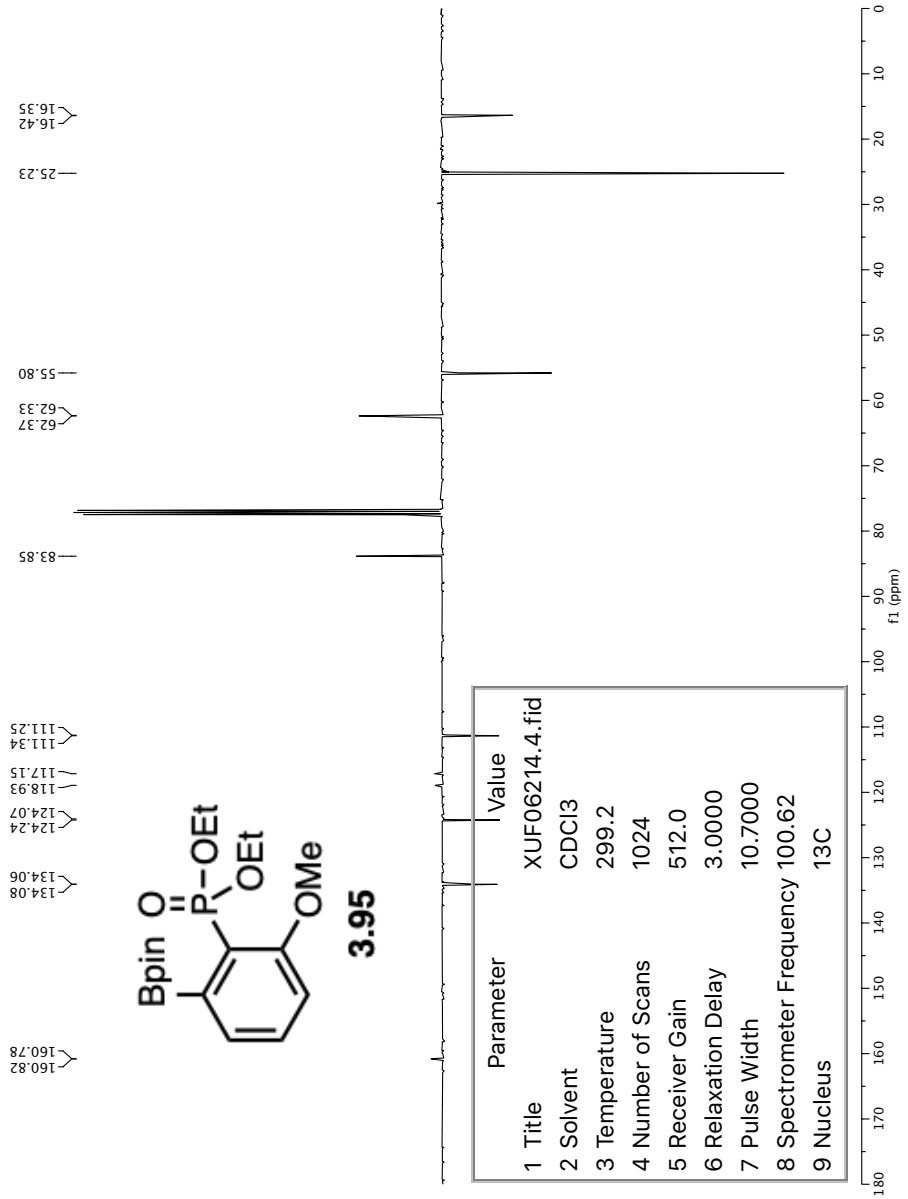
6.90
6.90
6.89
6.88
4.19
4.17
4.16
4.15
4.15
4.15
4.13
4.13
4.13
4.12
4.11
4.11
4.09
4.04
4.03
4.01
4.01
4.00
3.99
3.99
3.99
3.98
3.98
3.97
3.97
3.96
3.95
3.95
3.95
3.93
3.86
1.40
1.29
1.27
1.25
Parameter Value
1 Title XUF06214.3.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 8.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
OMe
3.95
1.00
0.98
1.00
2.00
2.00
2.98
12.02
5.98
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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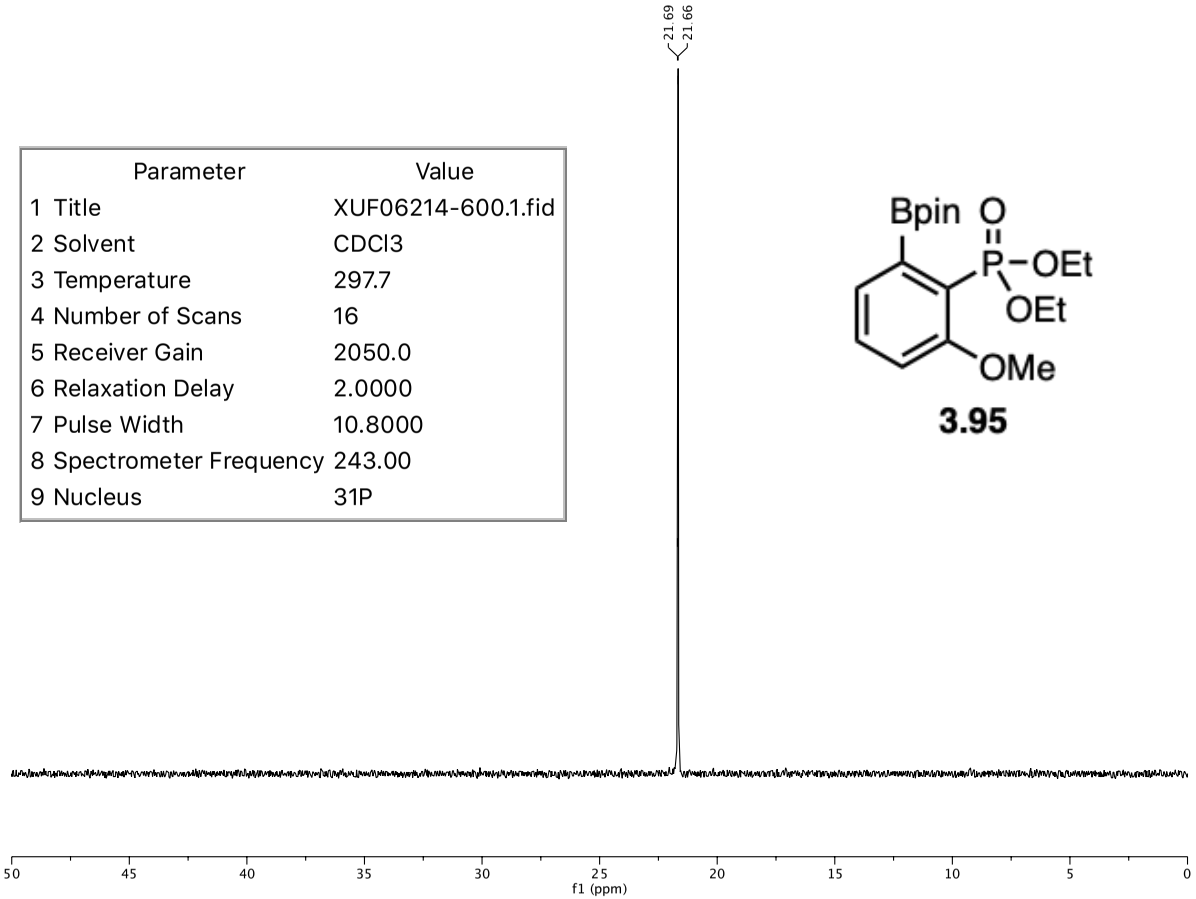
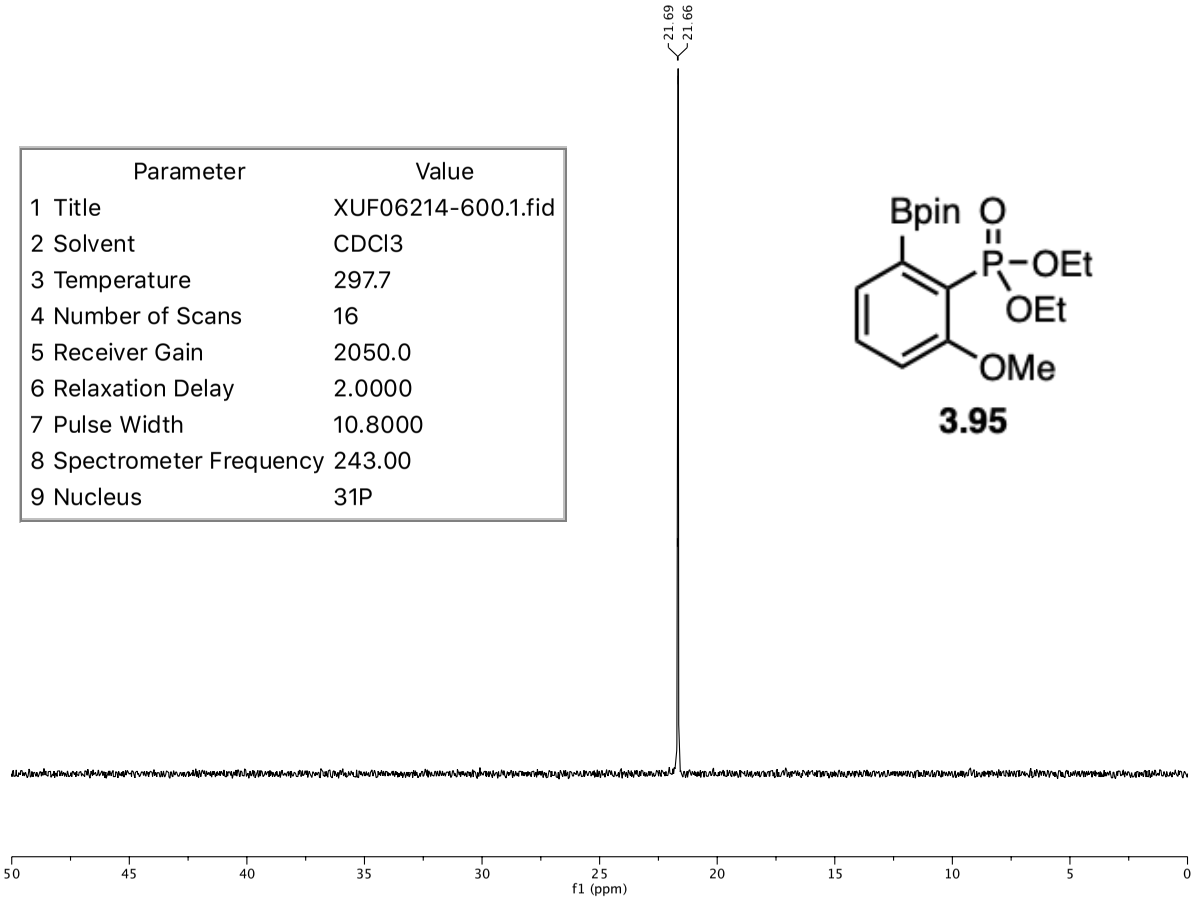
160.78
134.08
134.06
124.24
124.07
118.93
117.15
111.34
111.25
83.85
62.37
62.33
55.80
25.23
16.42
16.35
Bpin
O
P
OEt
OEt
OMe
3.95
Parameter
Value
1 Title
XUF06214.4.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

Parameter	Value
1 Title	XUF06214-600.1.fid
2 Solvent	CDCl3
3 Temperature	297.7
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P



3.95

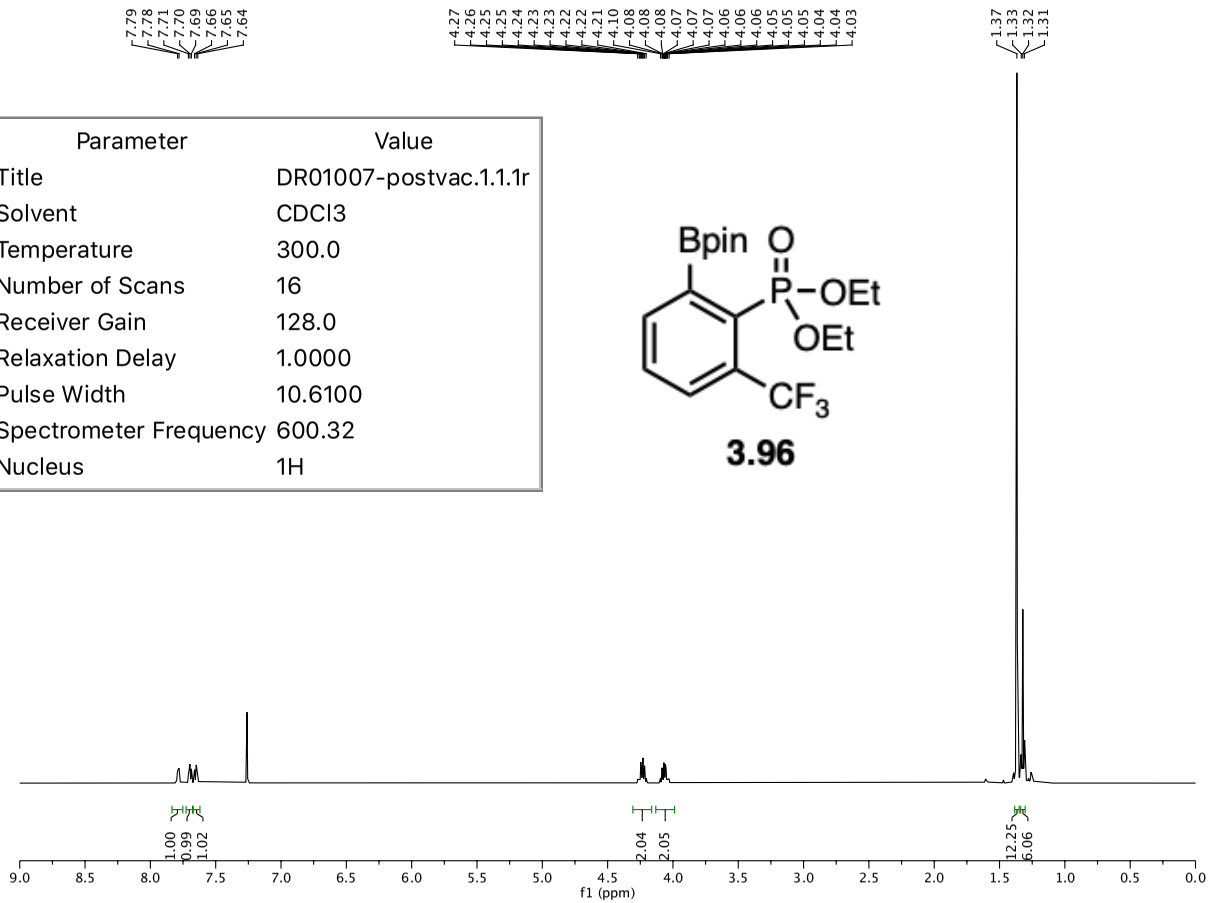
	Parameter	Value
1	Title	XUF06214-600.1.fid
2	Solvent	CDCl3
3	Temperature	297.7
4	Number of Scans	16
5	Receiver Gain	2050.0
6	Relaxation Delay	2.0000
7	Pulse Width	10.8000
8	Spectrometer Frequency	243.00
9	Nucleus	31P

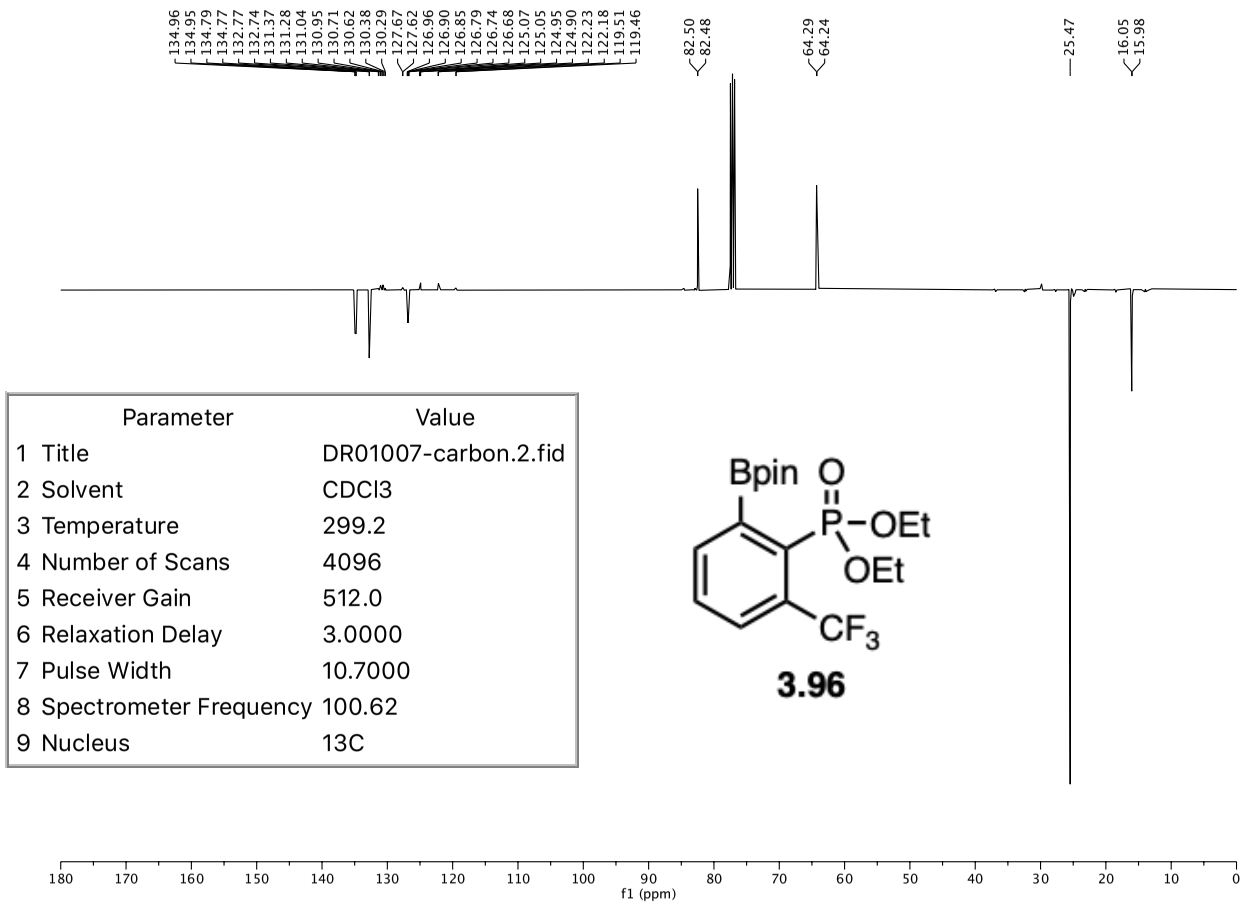


3.95

Parameter	Value
1 Title	DR01007-postvac.1.1.1r
2 Solvent	CDCl3
3 Temperature	300.0
4 Number of Scans	16
5 Receiver Gain	128.0
6 Relaxation Delay	1.0000
7 Pulse Width	10.6100
8 Spectrometer Frequency	600.32
9 Nucleus	1H

3.96

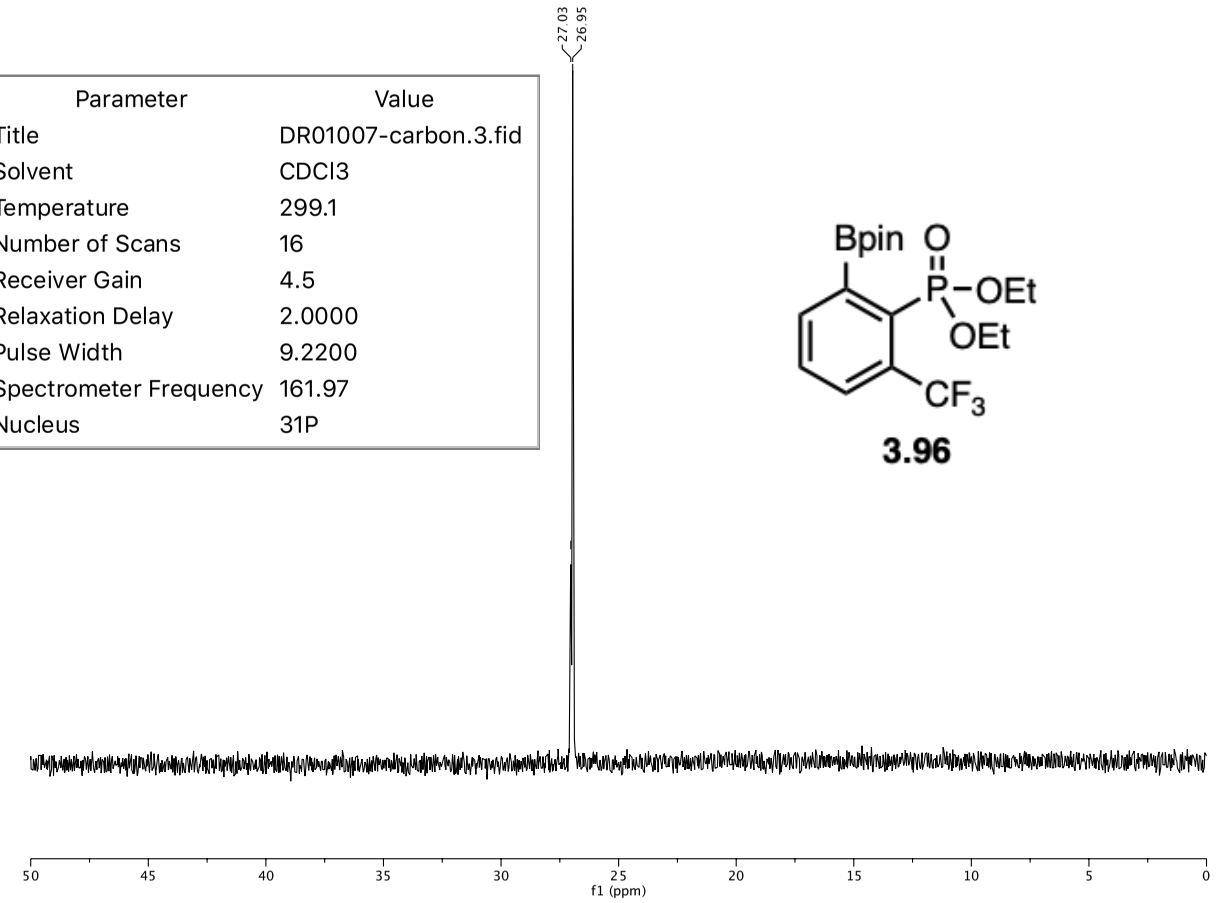




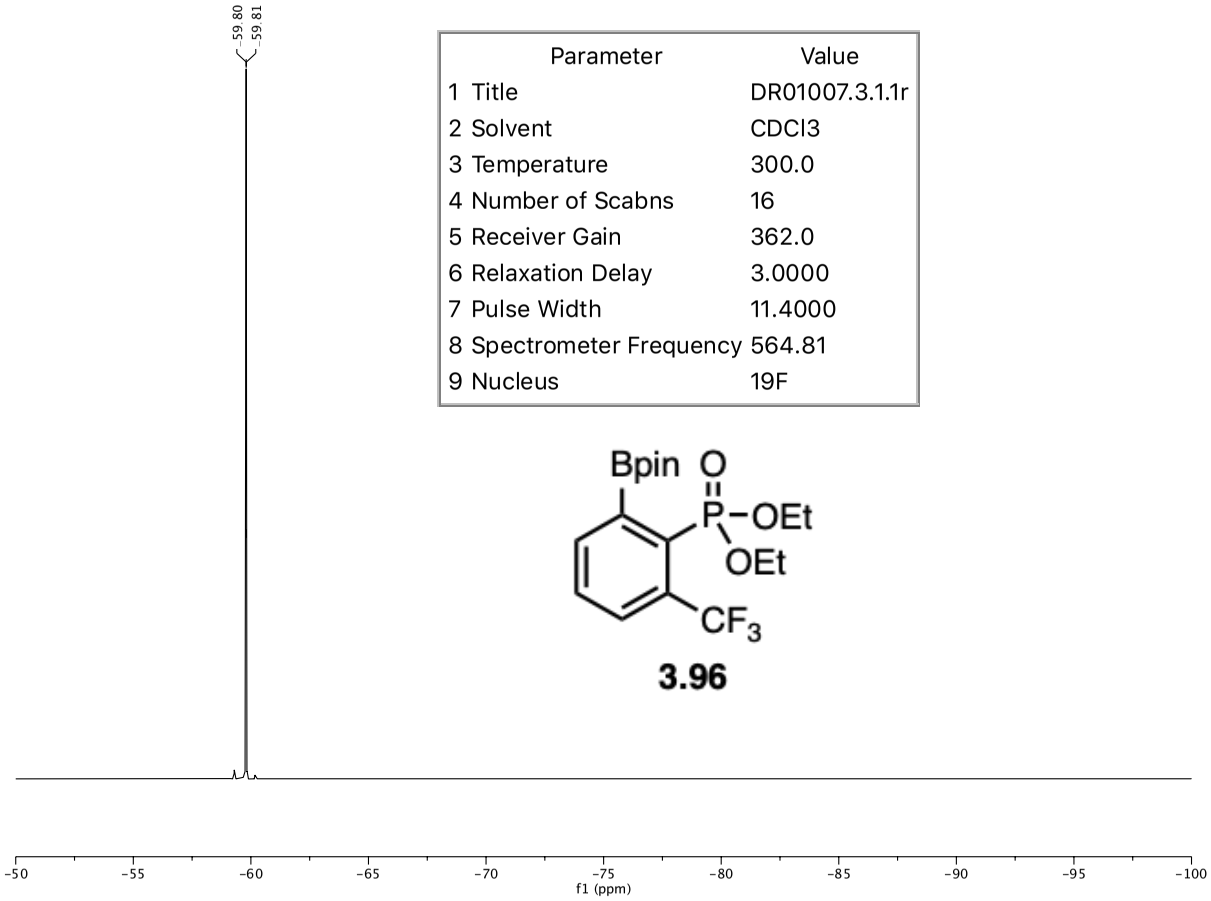
Parameter	Value
1 Title	DR01007-carbon.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	4096
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C

3.96

	Parameter	Value
1	Title	DR01007-carbon.3.fid
2	Solvent	CDCl3
3	Temperature	299.1
4	Number of Scans	16
5	Receiver Gain	4.5
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P



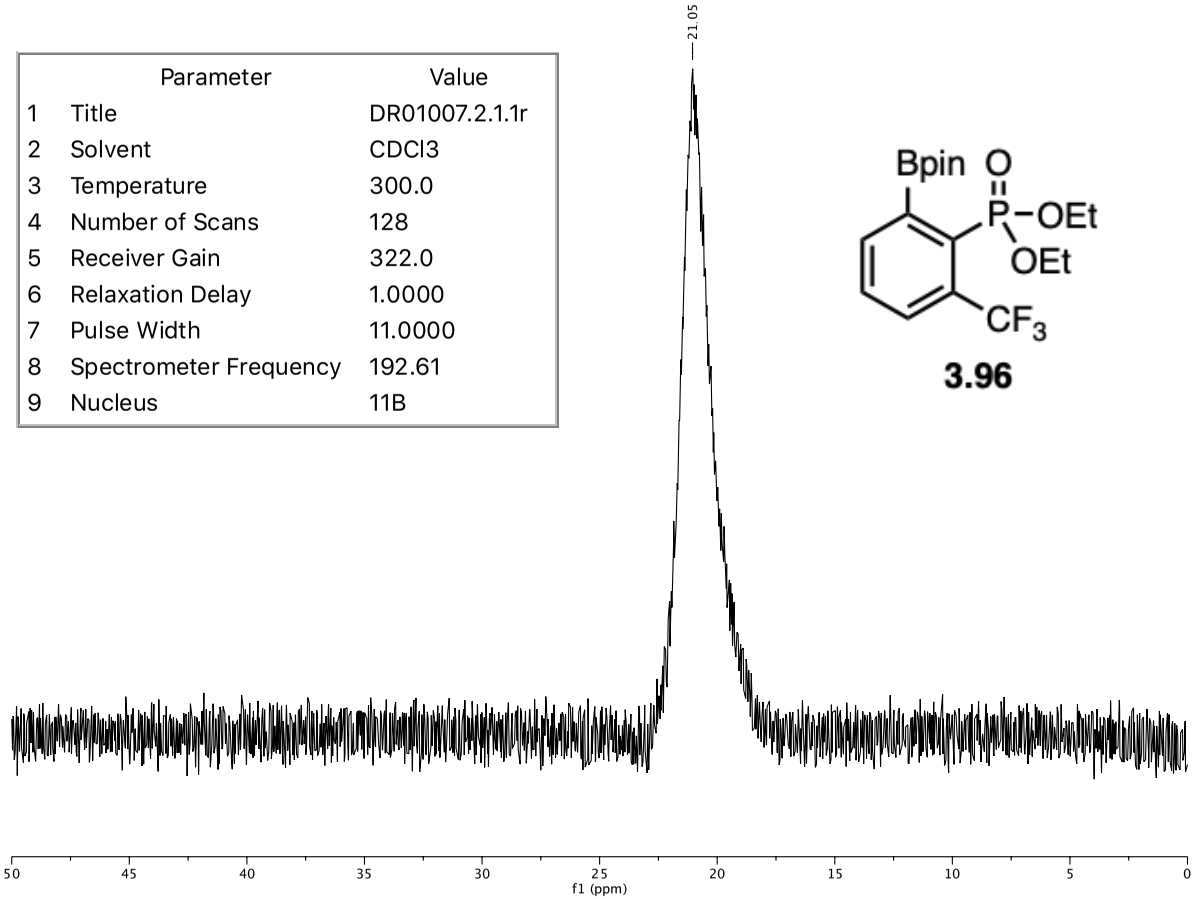
3.96



Parameter	Value
1 Title	DR01007.3.1.1r
2 Solvent	CDCl3
3 Temperature	300.0
4 Number of Scabns	16
5 Receiver Gain	362.0
6 Relaxation Delay	3.0000
7 Pulse Width	11.4000
8 Spectrometer Frequency	564.81
9 Nucleus	19F

3.96

	Parameter	Value
1	Title	DR01007.2.1.1r
2	Solvent	CDCl3
3	Temperature	300.0
4	Number of Scans	128
5	Receiver Gain	322.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B



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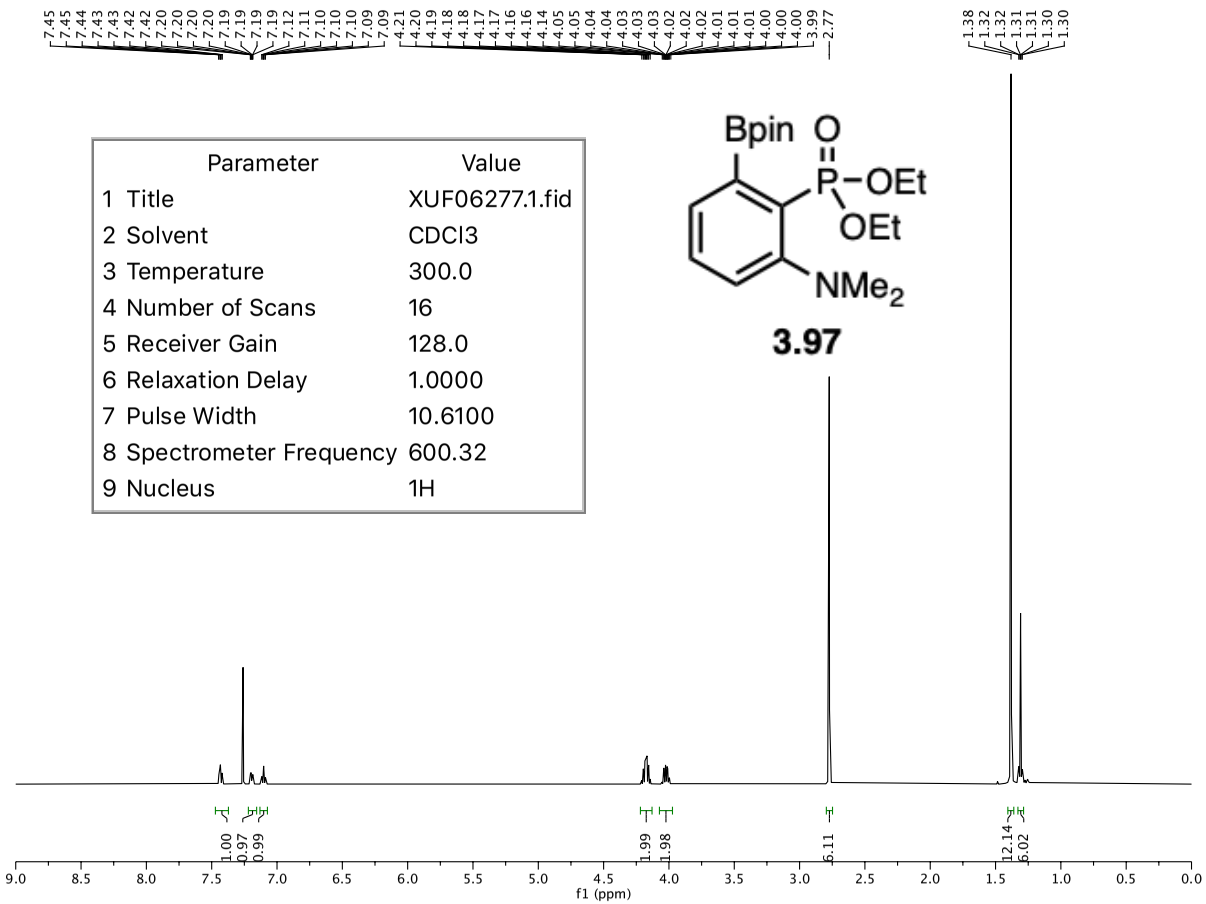
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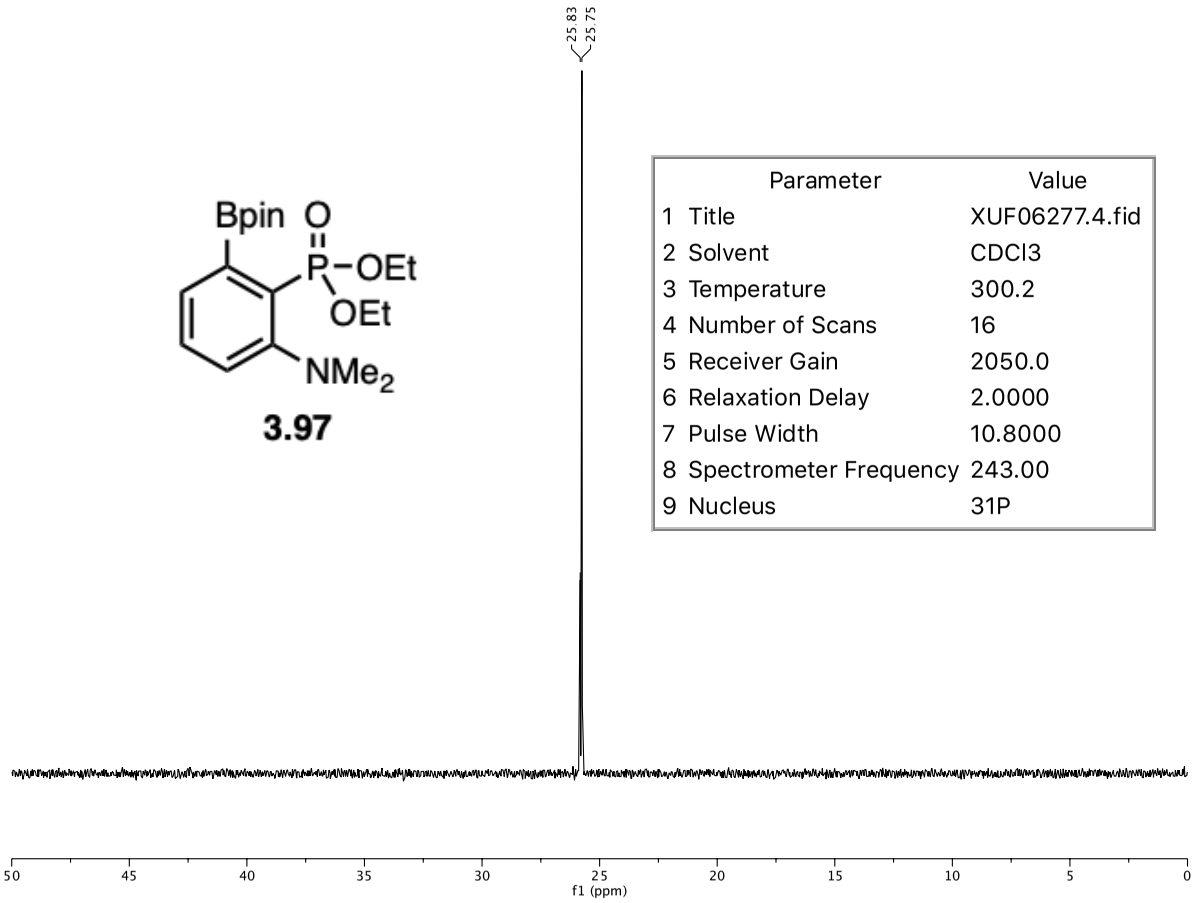
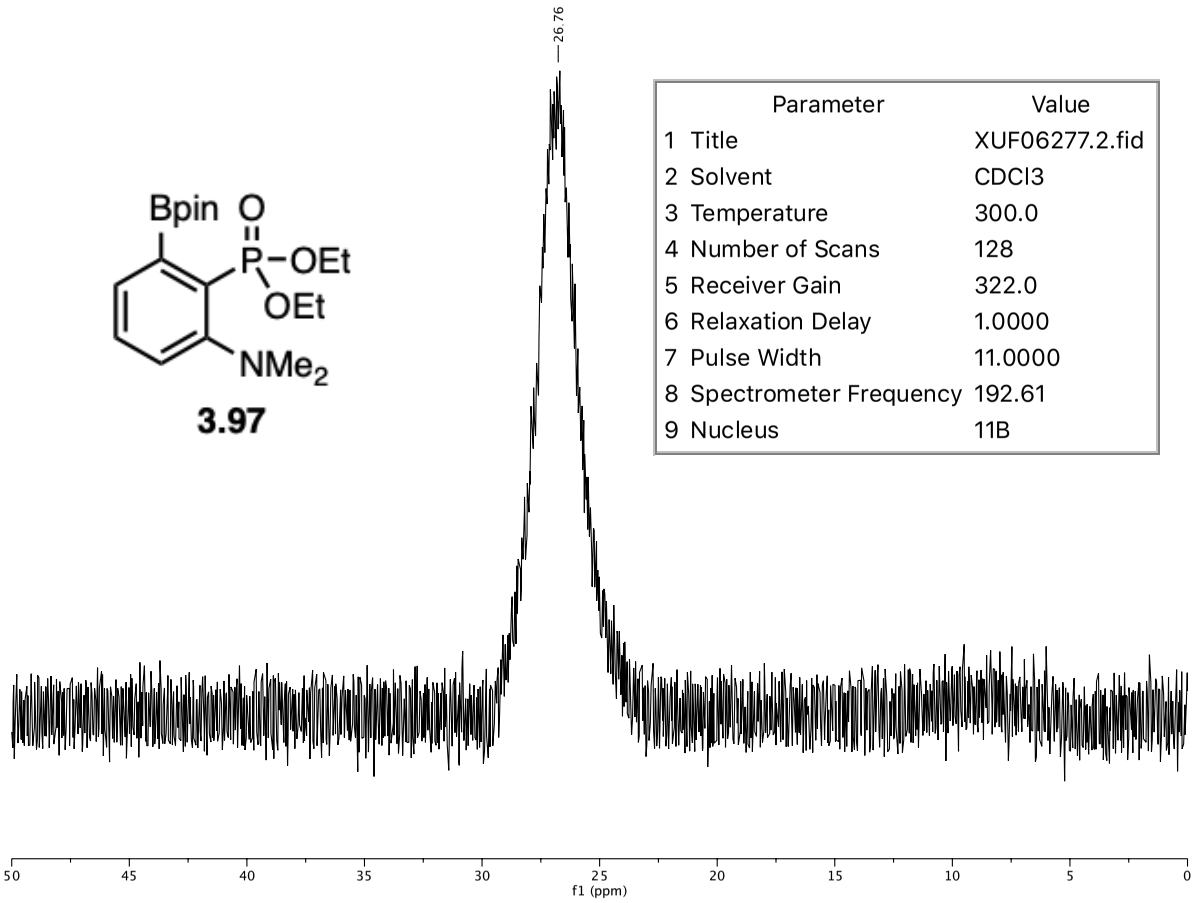
Parameter Value
1 Title XUF06277.1.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 128.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.6100
8 Spectrometer Frequency 600.32
9 Nucleus 1H
Bpin
O
P
OEt
OEt
NMe2
3.97
1.00 0.97 0.99 1.99 1.98 6.11 12.14 6.02
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

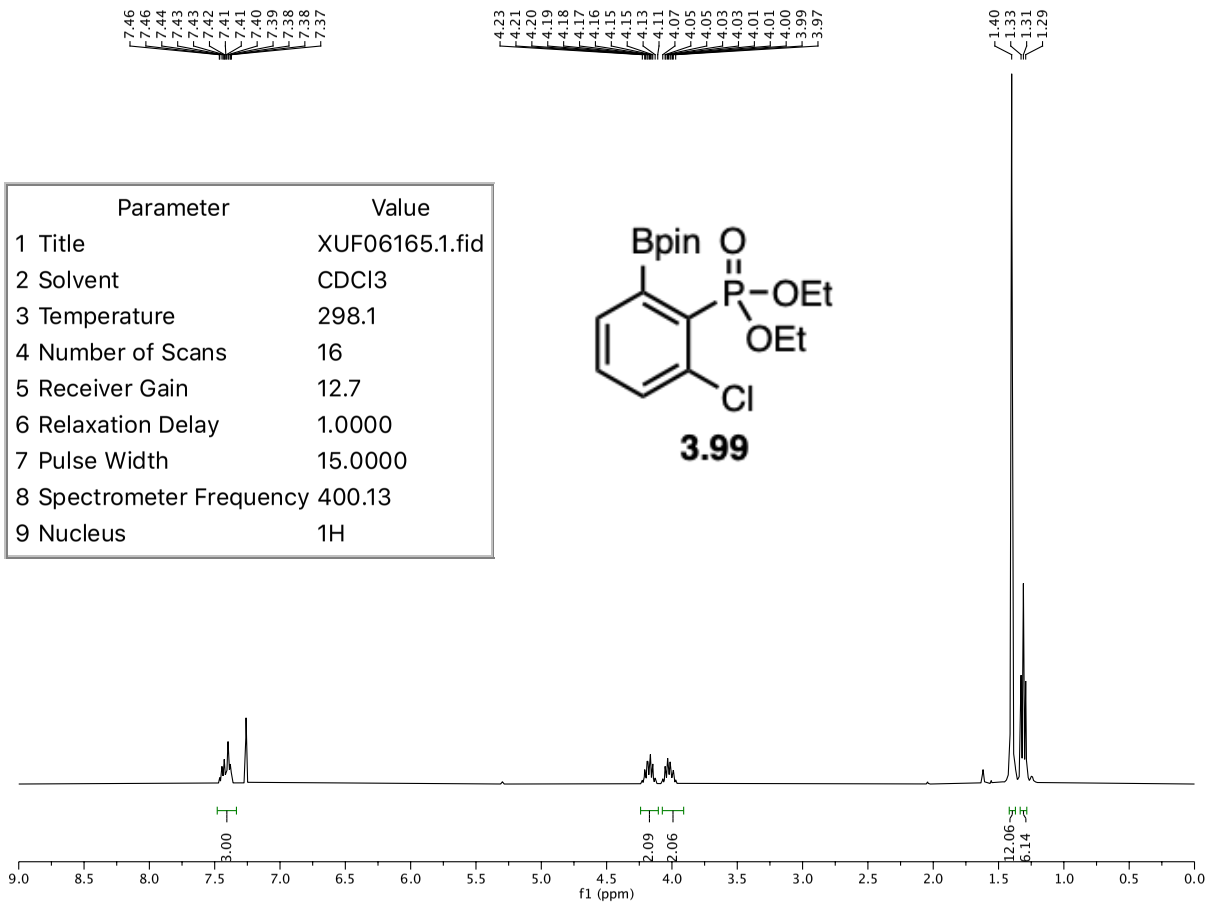
Parameter Value
1 Title XUF06277.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
156.83
156.76
133.39
133.36
126.50
126.32
124.34
122.57
120.32
120.21
83.28
62.68
62.63
45.54
25.29
16.38
16.31
Bpin
O
P
OEt
OEt
NMe2
3.97
f1 (ppm)

3.97



	Parameter	Value
1	Title	XUF06277.4.fid
2	Solvent	CDCl3
3	Temperature	300.2
4	Number of Scans	16
5	Receiver Gain	2050.0
6	Relaxation Delay	2.0000
7	Pulse Width	10.8000
8	Spectrometer Frequency	243.00
9	Nucleus	31P

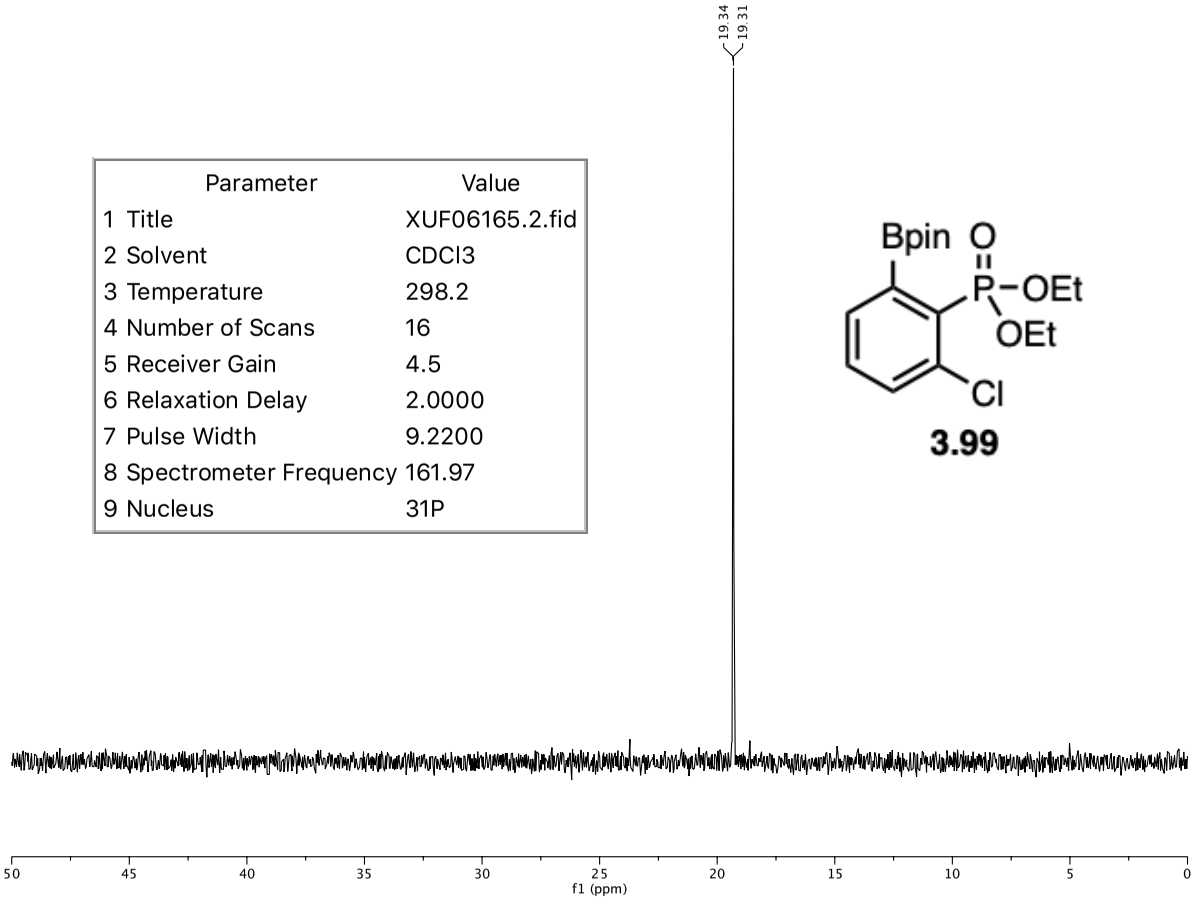

26.76
Bpin
O
P–OEt
OEt
NMe2
3.97
Parameter Value
1 Title XUF06277.2.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


7.46
7.46
7.44
7.43
7.43
7.42
7.41
7.41
7.40
7.39
7.38
7.38
7.37
4.23
4.21
4.20
4.19
4.18
4.17
4.16
4.15
4.15
4.13
4.11
4.07
4.05
4.05
4.03
4.03
4.01
4.01
4.00
3.99
3.97
1.40
1.33
1.31
1.29
Parameter Value
1 Title XUF06165.1.fid
2 Solvent CDCl3
3 Temperature 298.1
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
Cl
3.99
3.00
2.09
2.06
12.06
6.14
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

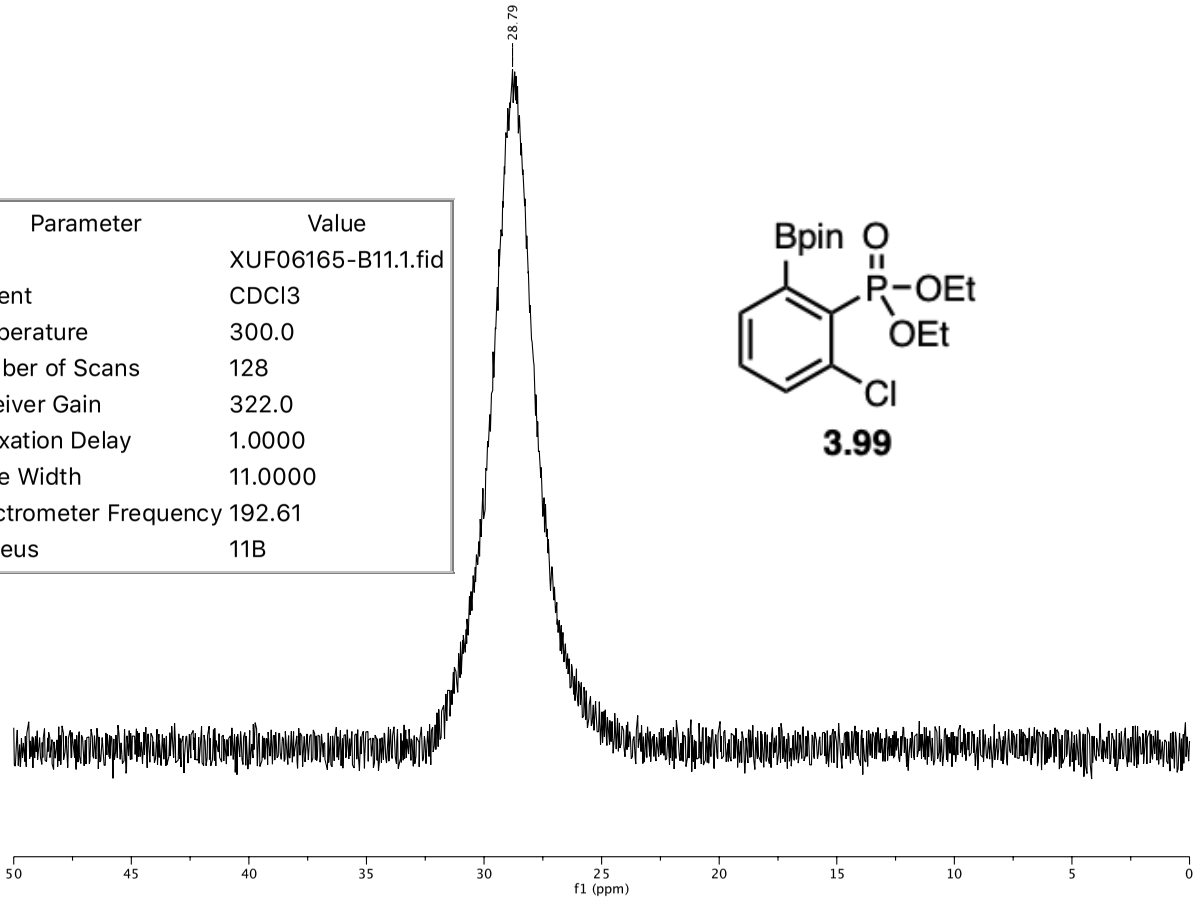
Parameter	Value
1 Title	XUF06165.4.fid
2 Solvent	CDCl3
3 Temperature	298.1
4 Number of Scans	1024
5 Receiver Gain	512.0
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C

Parameter	Value
1 Title	XUF06165.2.fid
2 Solvent	CDCl3
3 Temperature	298.2
4 Number of Scans	16
5 Receiver Gain	4.5
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.99



Parameter	Value
1 Title	XUF06165-B11.1.fid
2 Solvent	CDCl3
3 Temperature	300.0
4 Number of Scans	128
5 Receiver Gain	322.0
6 Relaxation Delay	1.0000
7 Pulse Width	11.0000
8 Spectrometer Frequency	192.61
9 Nucleus	11B



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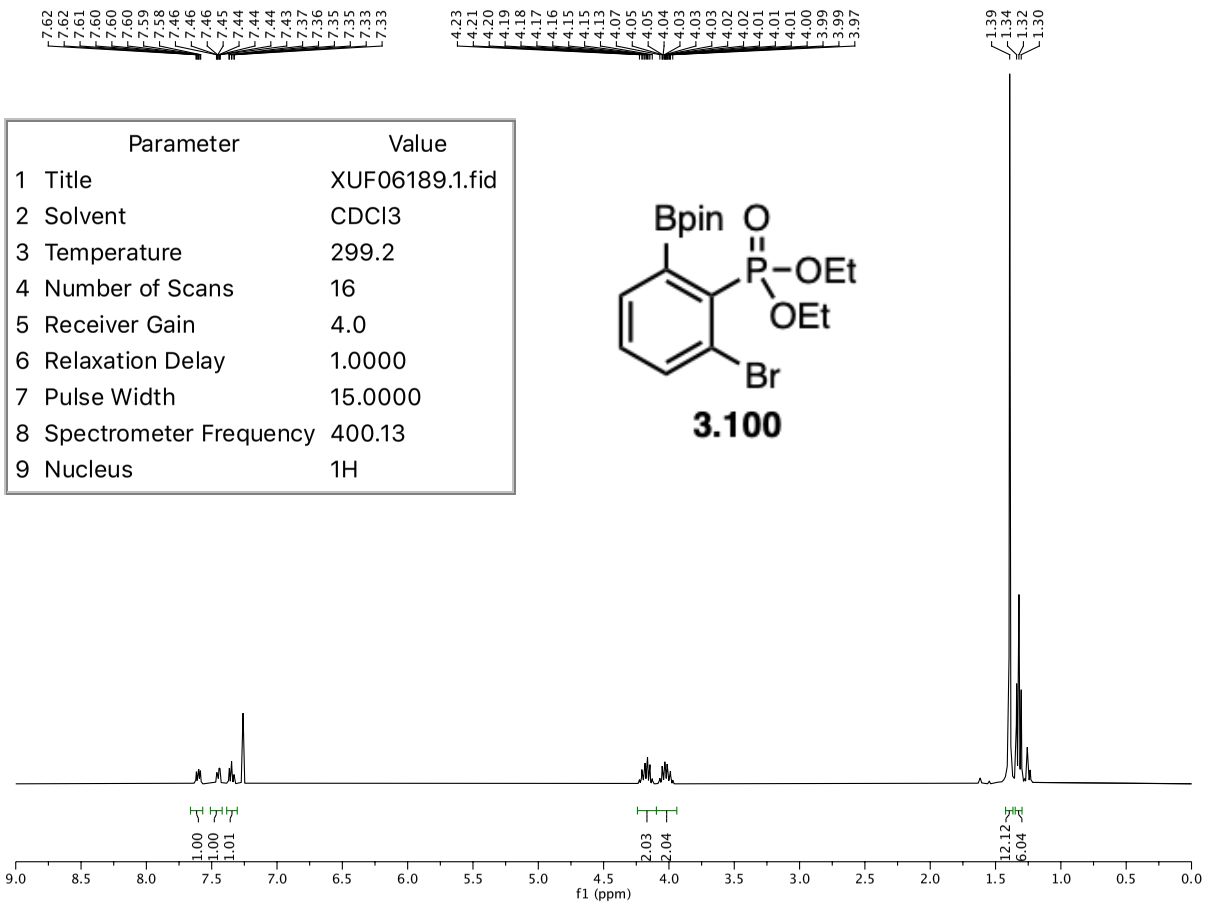
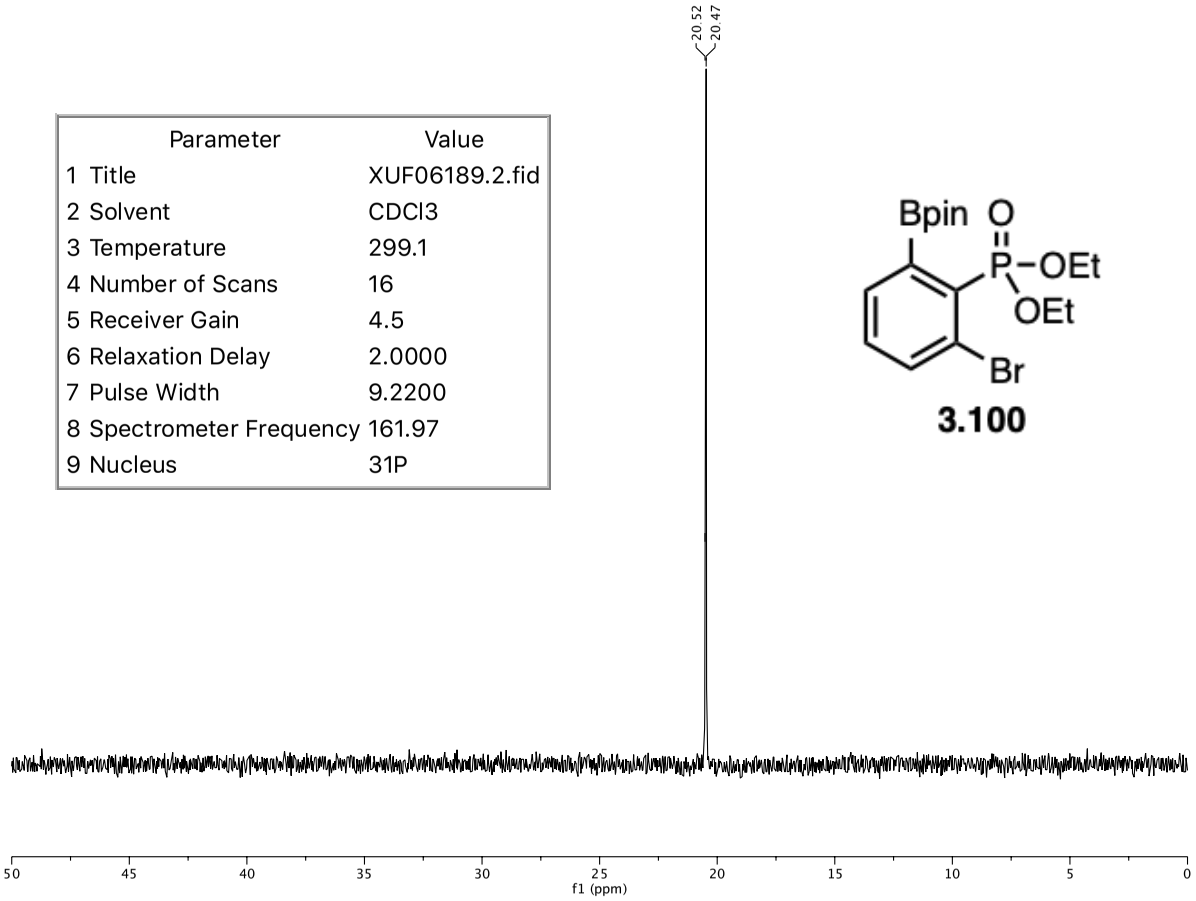

7.62 7.62 7.61 7.60 7.60 7.60 7.59 7.58 7.46 7.46 7.46 7.45 7.44 7.44 7.44 7.43 7.37 7.36 7.35 7.35 7.33 7.33
4.23 4.21 4.20 4.19 4.18 4.17 4.16 4.15 4.15 4.13 4.07 4.05 4.05 4.04 4.03 4.03 4.03 4.02 4.02 4.01 4.01 4.01 4.00 3.99 3.99 3.97
1.39 1.34 1.32 1.30
Parameter Value
1 Title XUF06189.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
Br
3.100
1.00 1.00 1.01 2.03 2.04 12.12 6.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

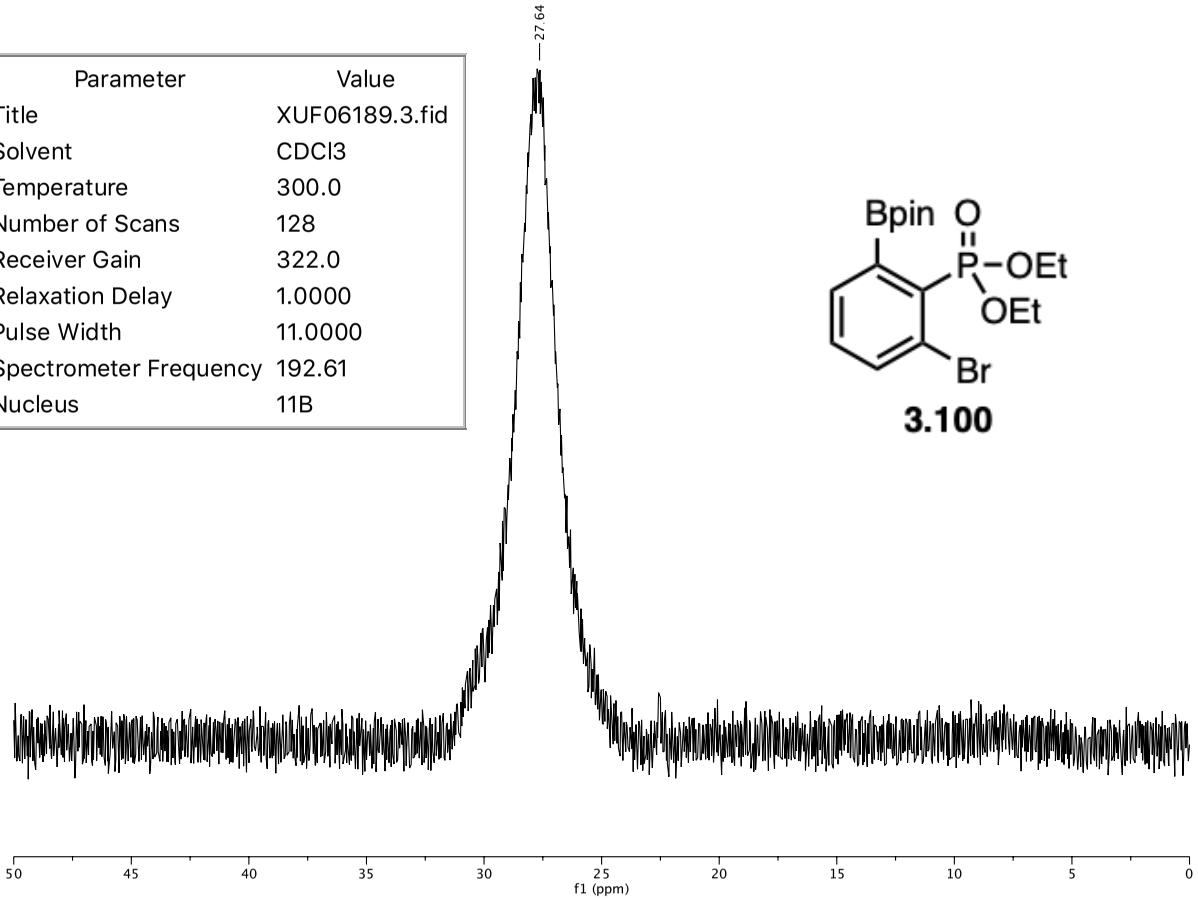
134.14
134.03
133.41
133.38
131.56
130.61
130.44
129.73
124.72
124.67
83.80
63.05
63.01
25.26
16.30
16.24
Bpin
O
P
OEt
OEt
Br
3.100
Parameter Value
1 Title XUF06189.4.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

Parameter	Value
1 Title	XUF06189.2.fid
2 Solvent	CDCl3
3 Temperature	299.1
4 Number of Scans	16
5 Receiver Gain	4.5
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

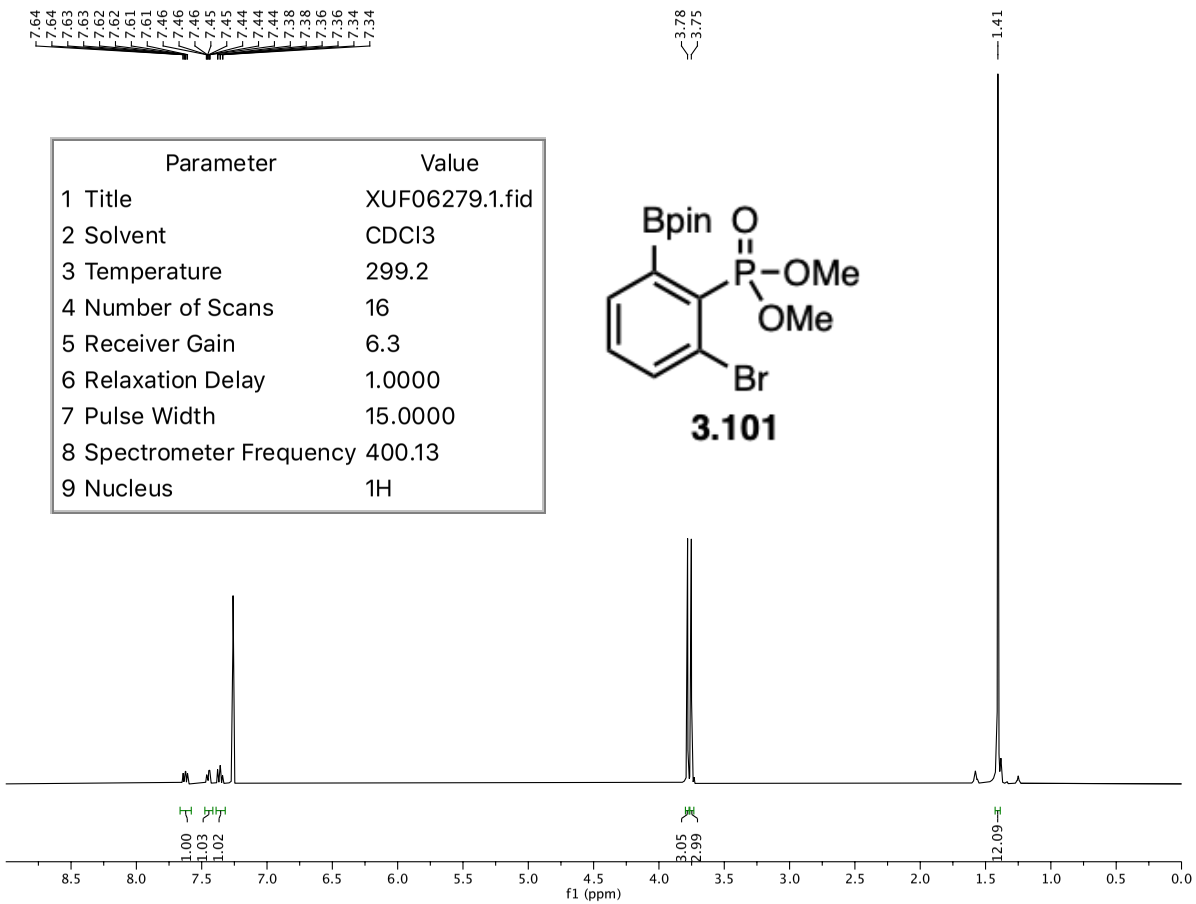
3.100



	Parameter	Value
1	Title	XUF06189.3.fid
2	Solvent	CDCl3
3	Temperature	300.0
4	Number of Scans	128
5	Receiver Gain	322.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B



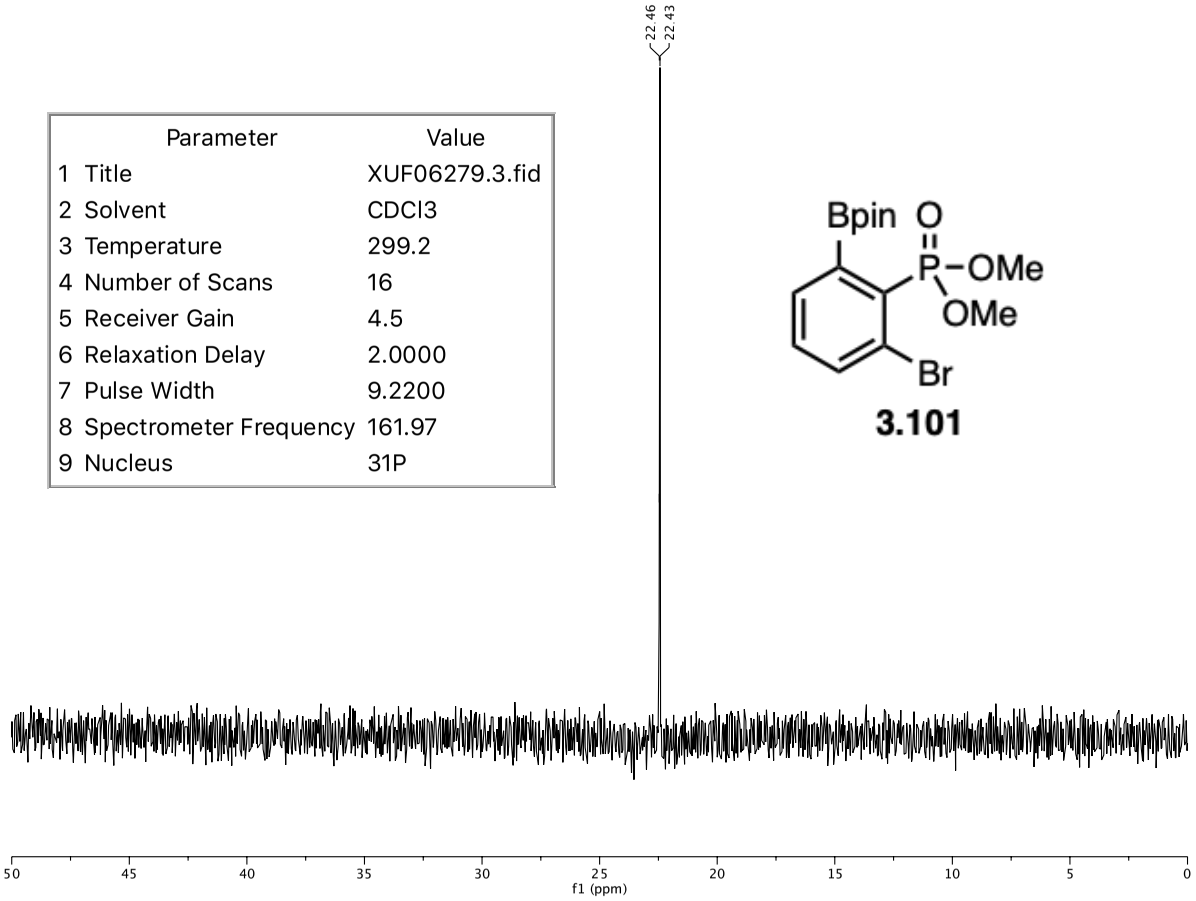
3.100

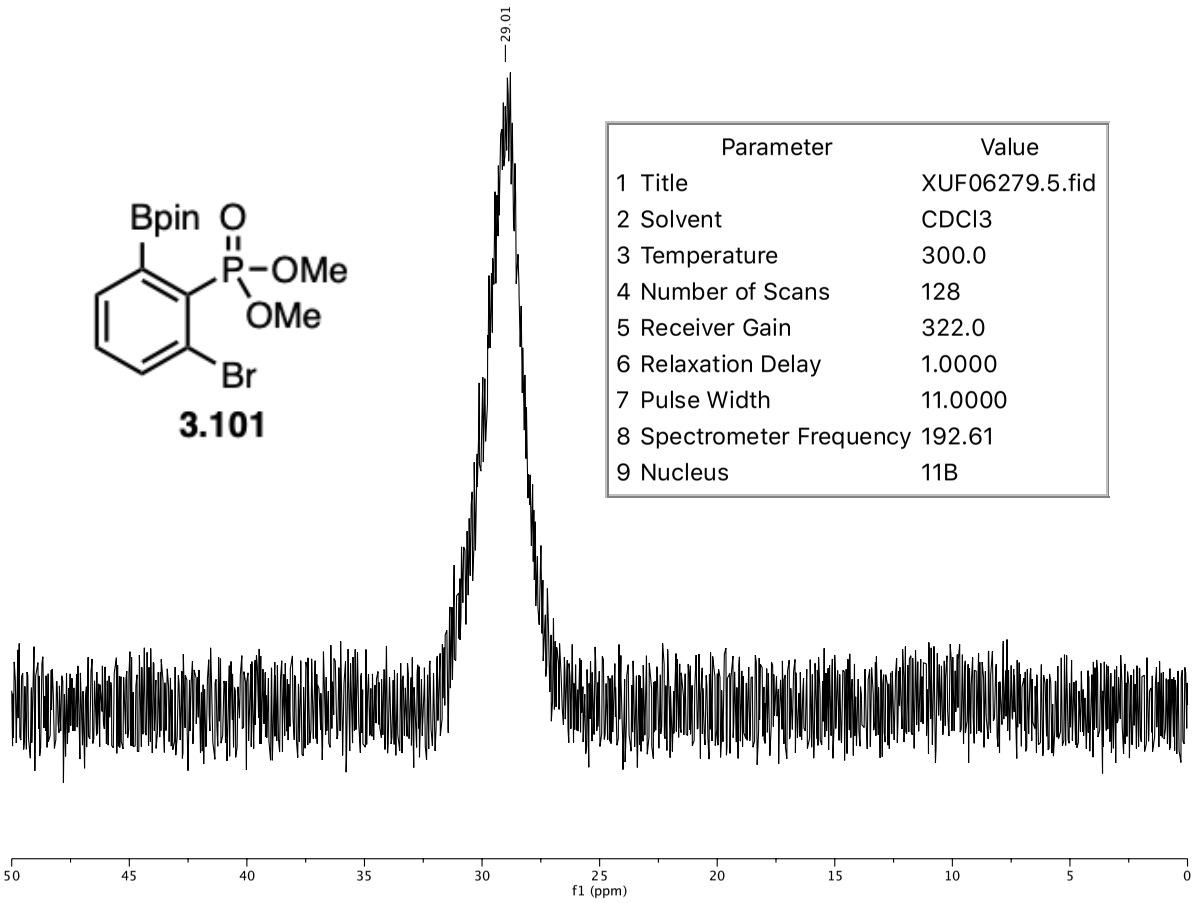

7.64
7.64
7.63
7.63
7.62
7.62
7.61
7.61
7.46
7.46
7.46
7.45
7.45
7.44
7.44
7.44
7.38
7.38
7.36
7.36
7.34
7.34
3.78
3.75
1.41
Parameter Value
1 Title XUF06279.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OMe
OMe
Br
3.101
1.00
1.03
1.02
3.05
2.99
12.09
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

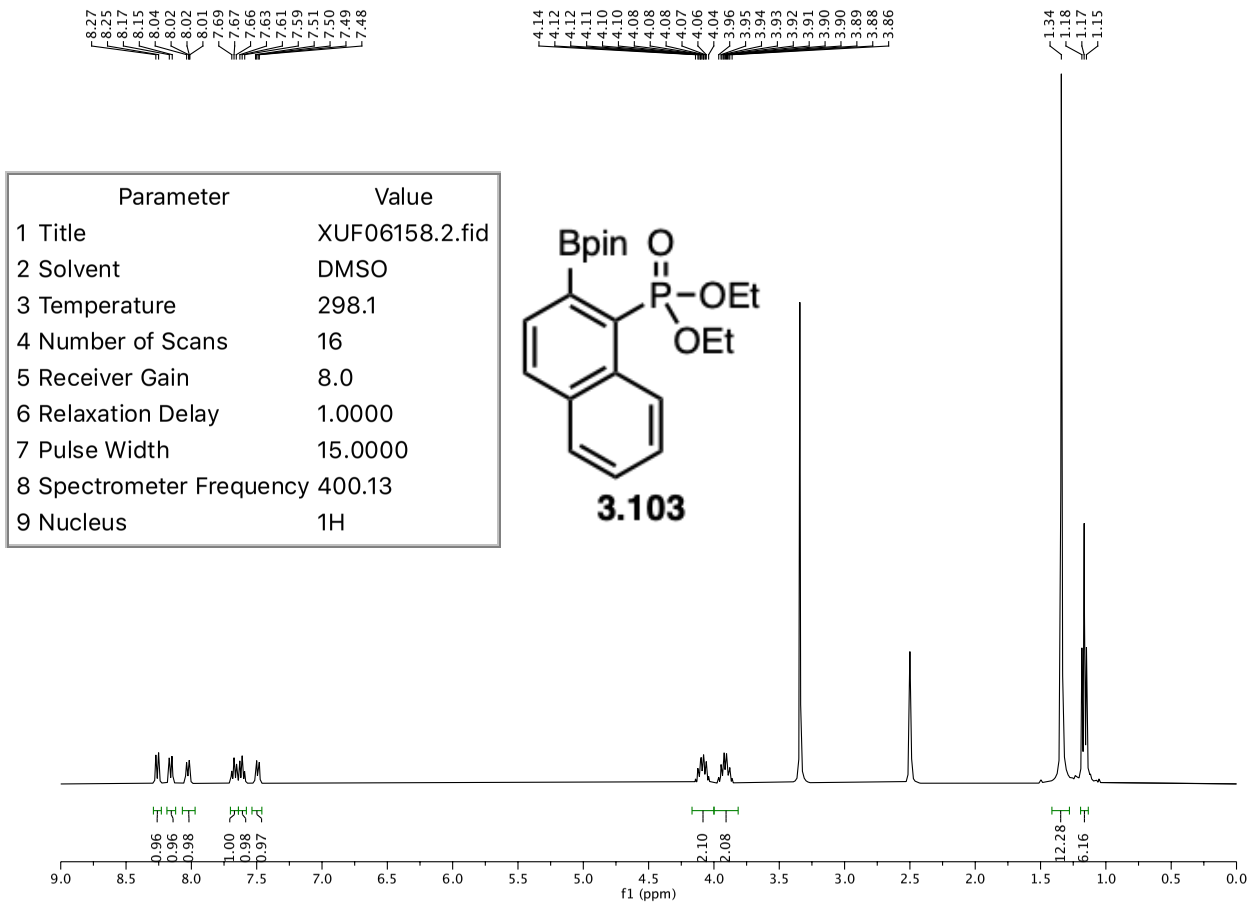
Parameter Value
1 Title XUF06279.2.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
84.15
53.22
53.17
25.21
134.39
134.28
133.42
133.39
130.77
130.68
130.61
128.82
124.99
124.94
Bpin
O
P
OMe
OMe
Br
3.101
f1 (ppm)

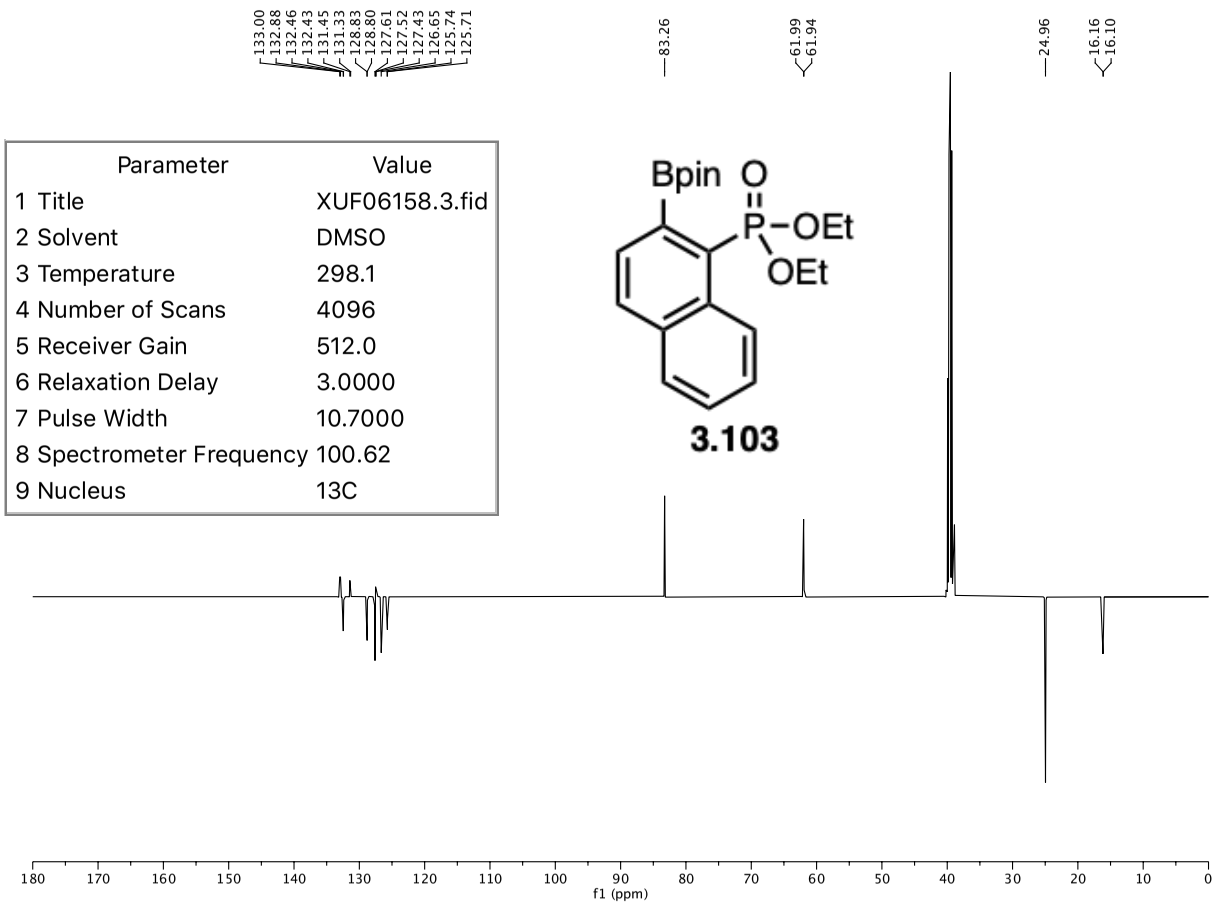
	Parameter	Value
1	Title	XUF06279.3.fid
2	Solvent	CDCl3
3	Temperature	299.2
4	Number of Scans	16
5	Receiver Gain	4.5
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P

3.101

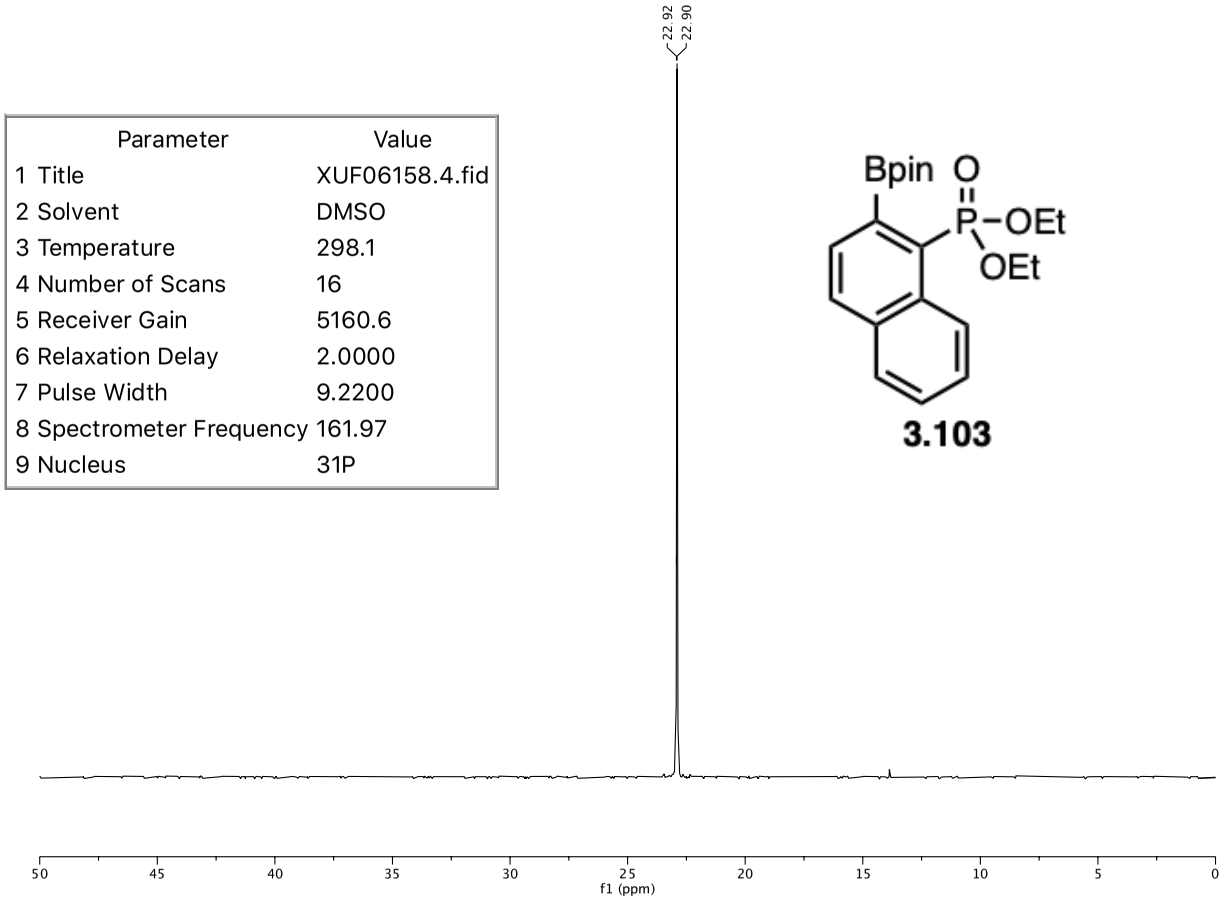



29.01
Bpin
O
P–OMe
OMe
Br
3.101
Parameter Value
1 Title XUF06279.5.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


8.27
8.25
8.17
8.15
8.04
8.02
8.02
8.01
7.69
7.67
7.66
7.63
7.61
7.59
7.51
7.50
7.49
7.48
4.14
4.12
4.12
4.11
4.10
4.10
4.08
4.08
4.08
4.07
4.06
4.04
3.96
3.95
3.94
3.93
3.92
3.91
3.90
3.90
3.89
3.88
3.86
1.34
1.18
1.17
1.15
Parameter
Value
1 Title
XUF06158.2.fid
2 Solvent
DMSO
3 Temperature
298.1
4 Number of Scans
16
5 Receiver Gain
8.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
Bpin
O
P
OEt
OEt
3.103
0.96
0.96
0.98
1.00
0.98
0.97
2.10
2.08
12.28
6.16
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

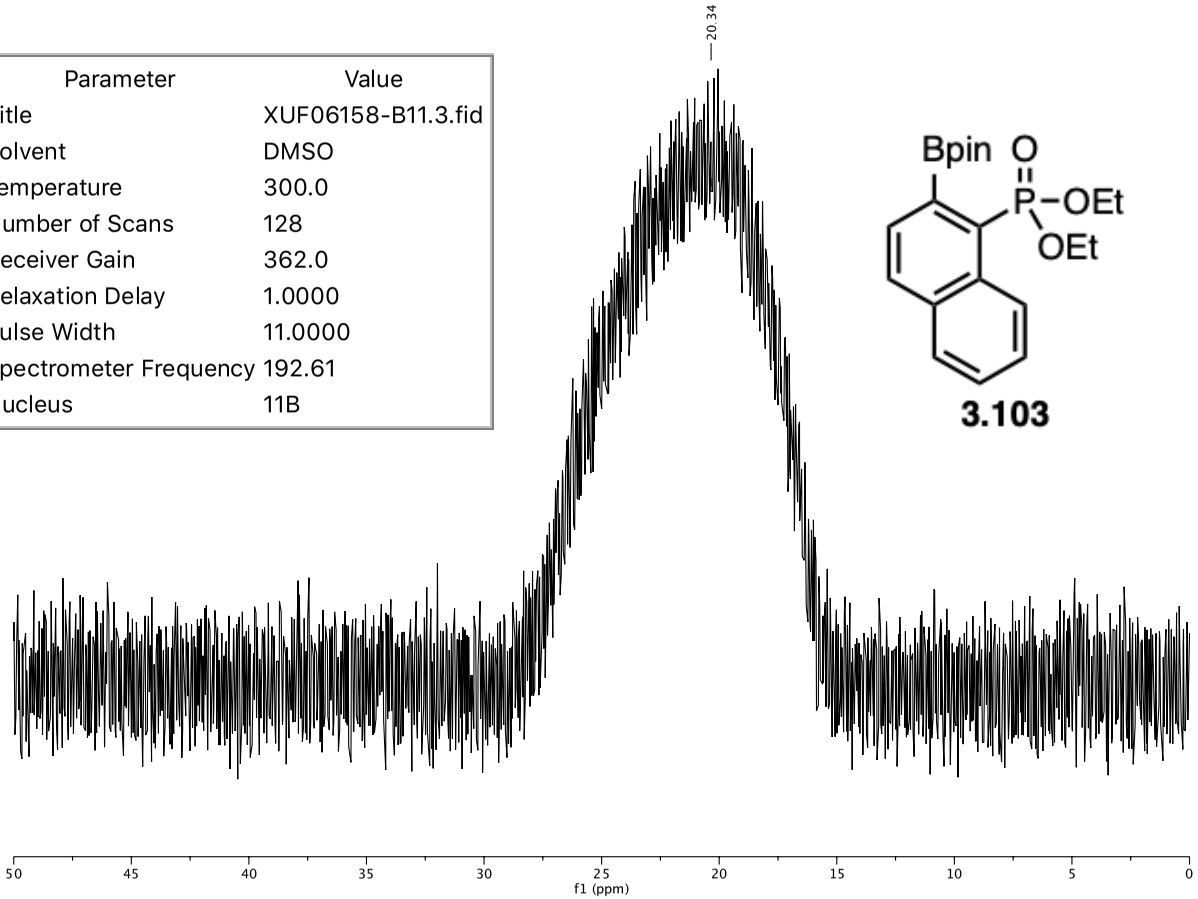

133.00
132.88
132.46
132.43
131.45
131.33
128.83
128.80
127.61
127.52
127.43
126.65
125.74
125.71
83.26
61.99
61.94
24.96
16.16
16.10
Parameter Value
1 Title XUF06158.3.fid
2 Solvent DMSO
3 Temperature 298.1
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P–OEt
OEt
3.103
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06158.4.fid
2 Solvent	DMSO
3 Temperature	298.1
4 Number of Scans	16
5 Receiver Gain	5160.6
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

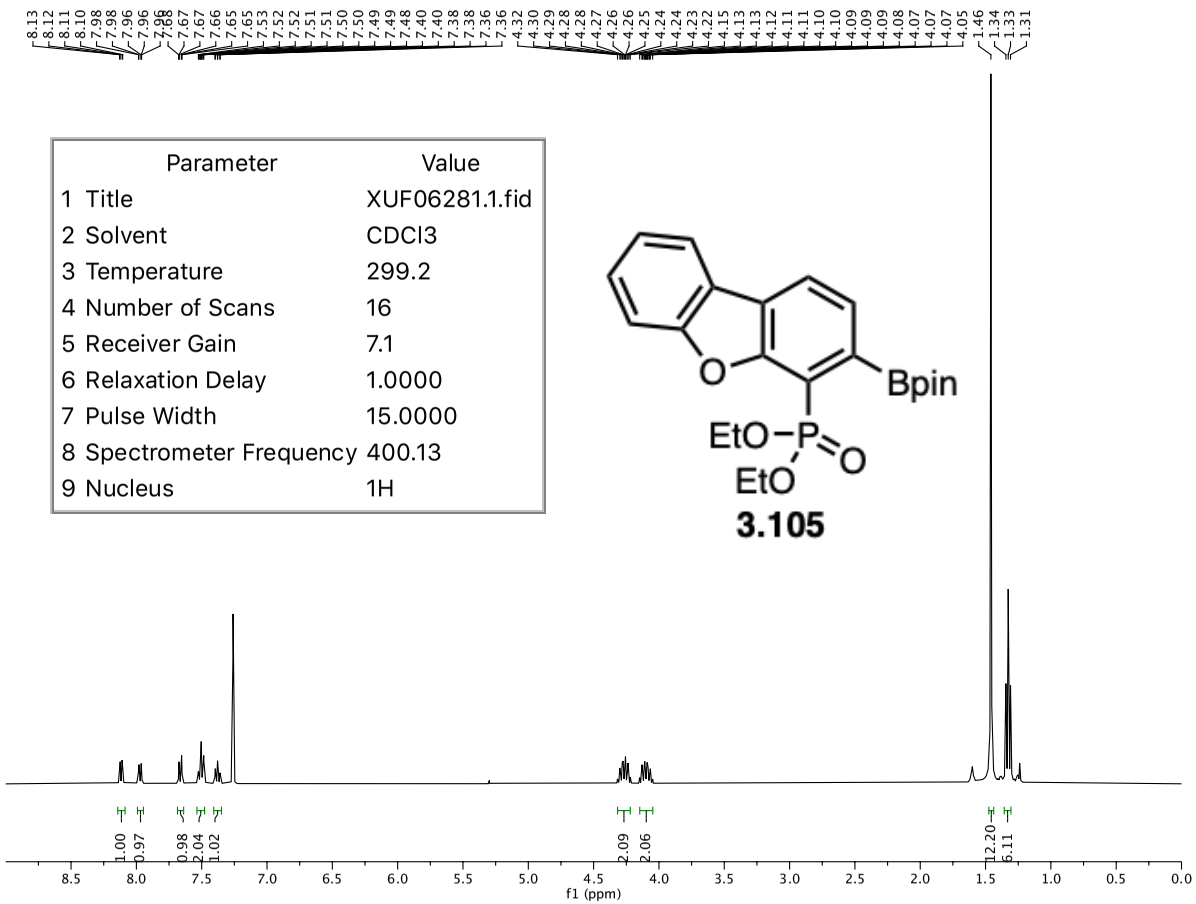


3.103

Parameter	Value
1 Title	XUF06158-B11.3.fid
2 Solvent	DMSO
3 Temperature	300.0
4 Number of Scans	128
5 Receiver Gain	362.0
6 Relaxation Delay	1.0000
7 Pulse Width	11.0000
8 Spectrometer Frequency	192.61
9 Nucleus	11B



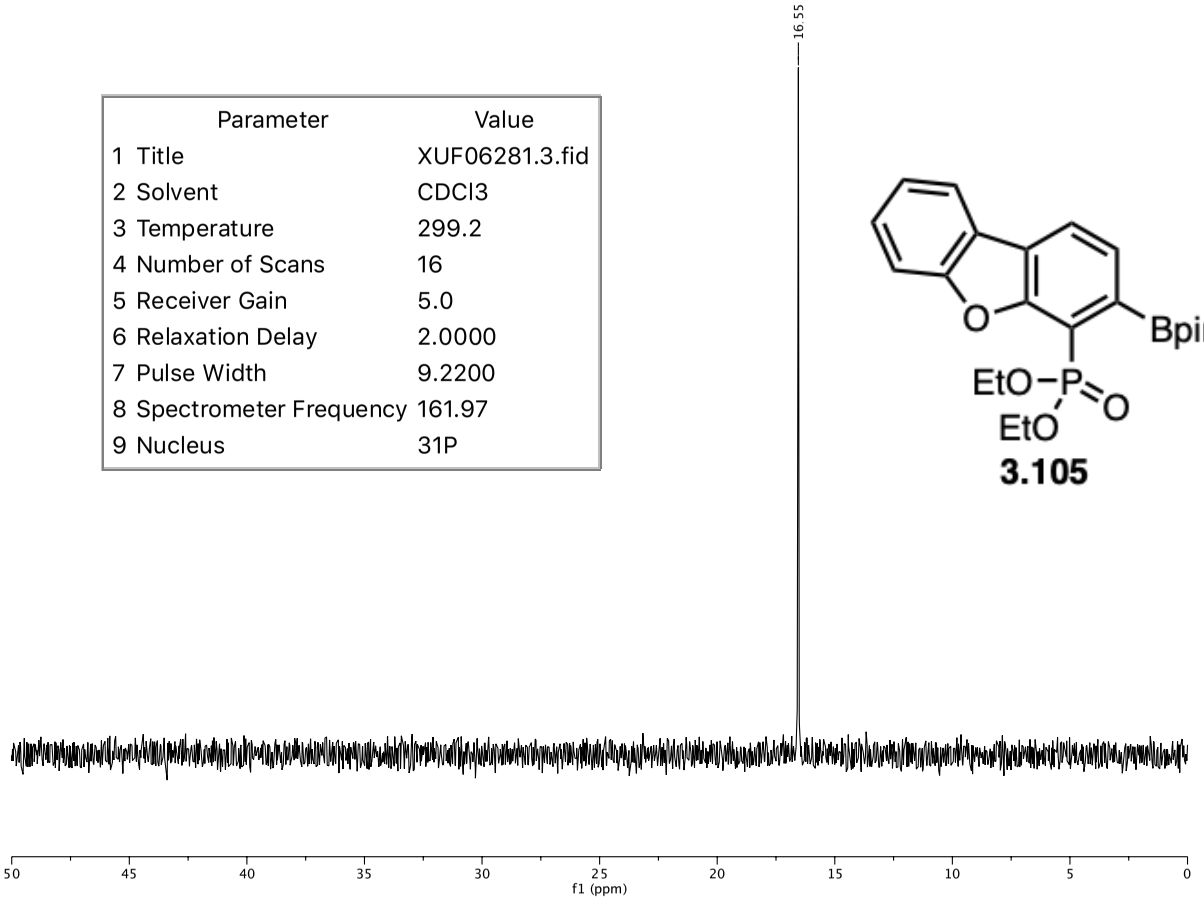
3.103

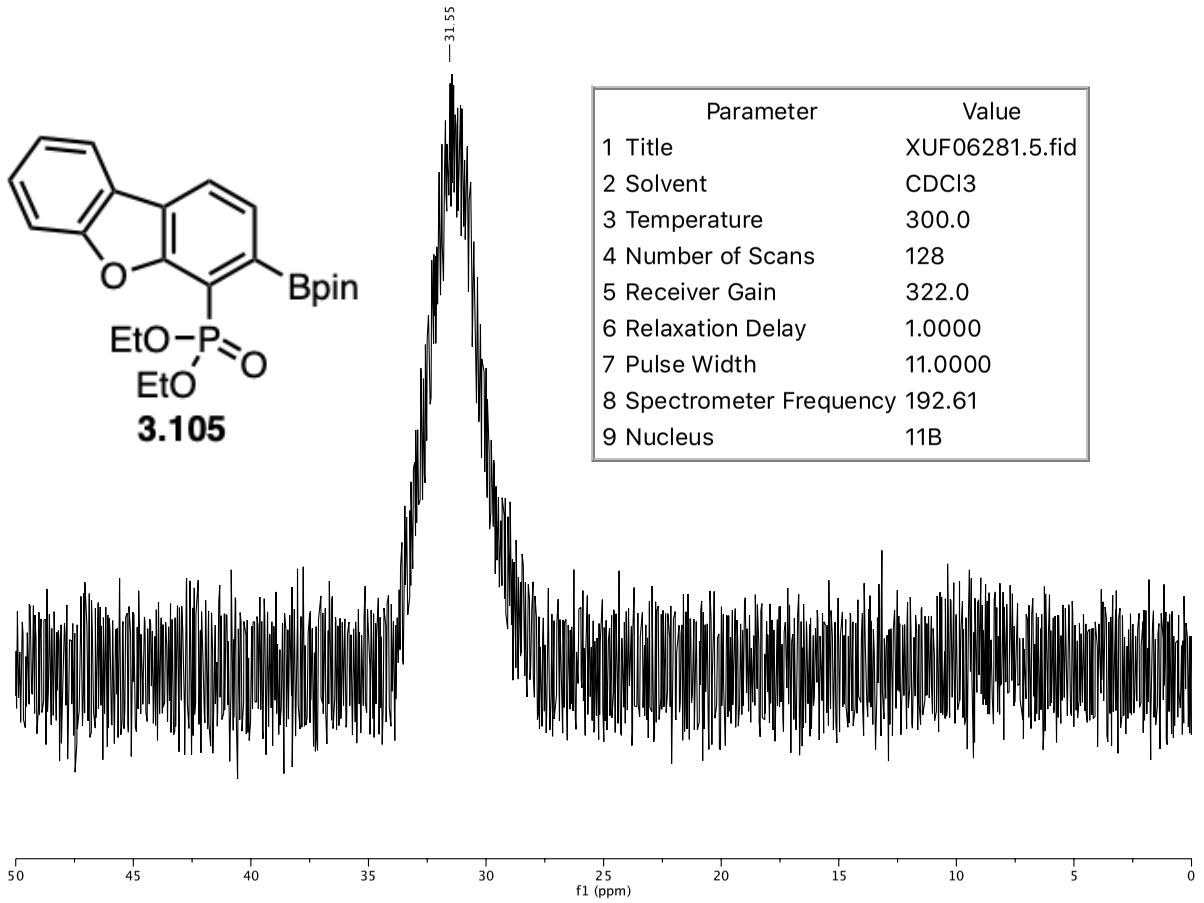

8.13 8.12 8.11 8.10 7.98 7.98 7.96 7.96 7.96 7.68 7.67 7.67 7.66 7.65 7.65 7.53 7.52 7.52 7.51 7.51 7.50 7.50 7.49 7.49 7.48 7.40 7.40 7.38 7.38 7.36 7.36 4.32 4.30 4.29 4.28 4.28 4.27 4.26 4.26 4.25 4.24 4.24 4.23 4.22 4.15 4.13 4.13 4.12 4.11 4.11 4.10 4.10 4.09 4.09 4.09 4.08 4.07 4.07 4.07 4.05 1.46 1.34 1.33 1.31
Parameter Value
1 Title XUF06281.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 7.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
O
Bpin
EtO−P=O
EtO
3.105
1.00 0.97 0.98 2.04 1.02 2.09 2.06 12.20 6.11
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

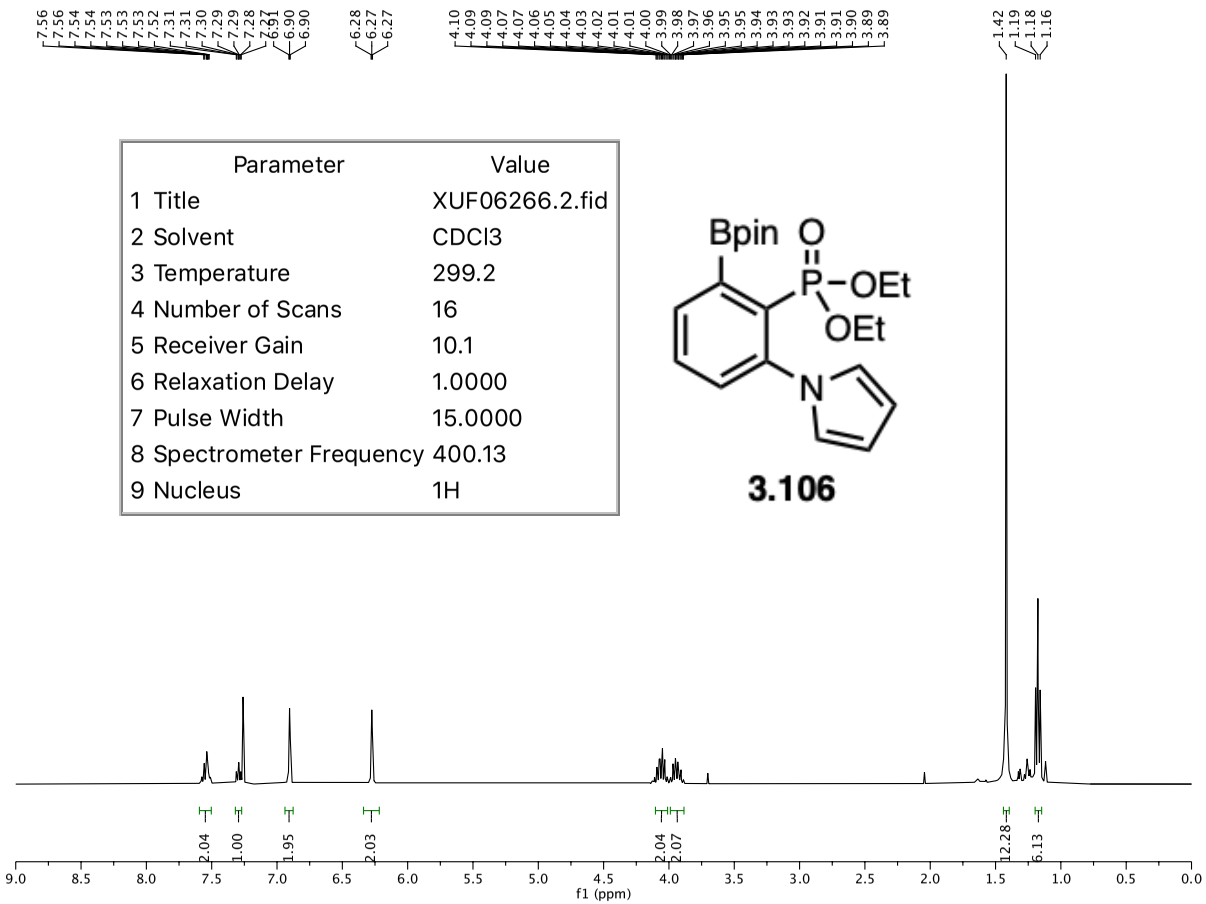
16.41
16.47
25.19
62.63
62.68
84.52
112.29
113.90
115.75
120.99
123.26
123.37
124.55
124.58
125.27
125.36
126.59
126.75
128.03
156.28
156.31
156.37
Parameter Value
1 Title XUF06281.4.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
EtO–P=O
EtO
3.105
f1 (ppm)

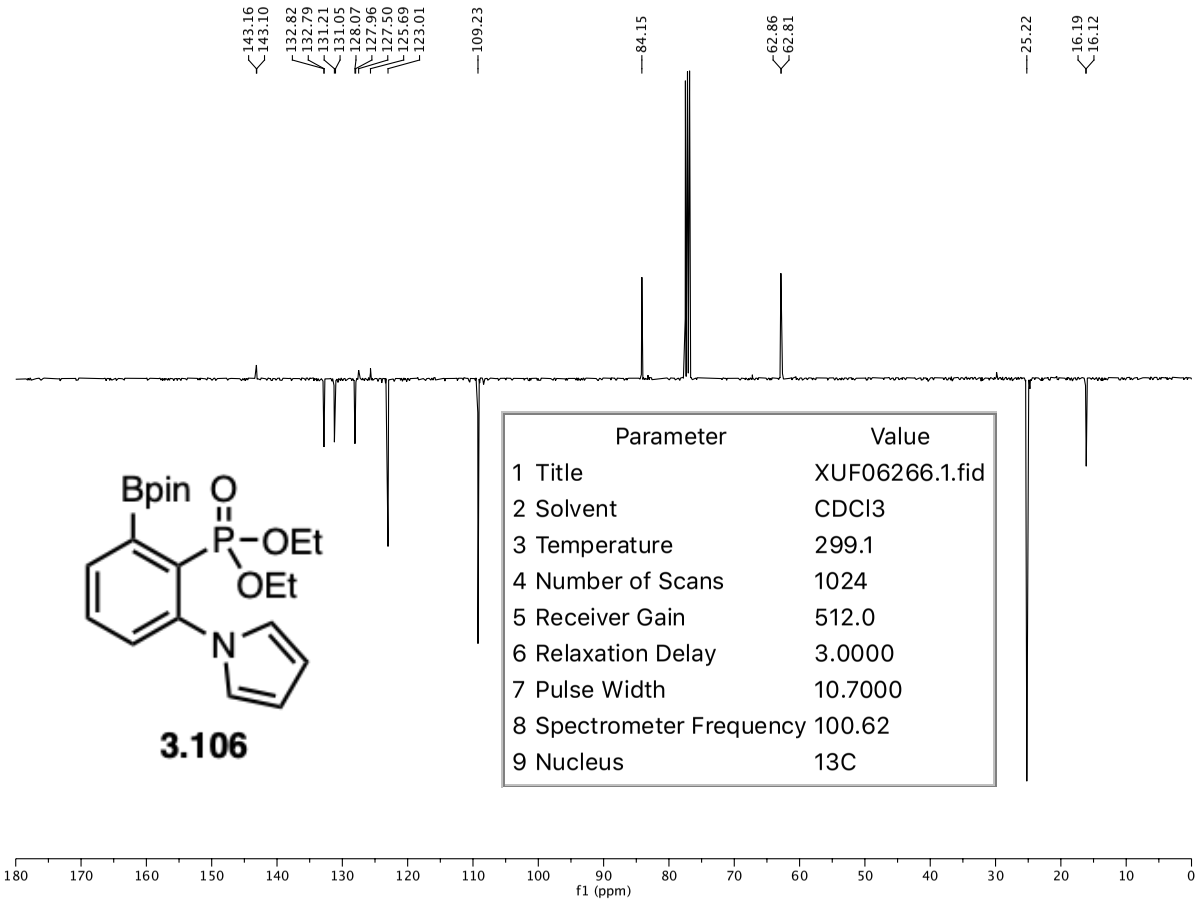
	Parameter	Value
1	Title	XUF06281.3.fid
2	Solvent	CDCl3
3	Temperature	299.2
4	Number of Scans	16
5	Receiver Gain	5.0
6	Relaxation Delay	2.0000
7	Pulse Width	9.2200
8	Spectrometer Frequency	161.97
9	Nucleus	31P

3.105

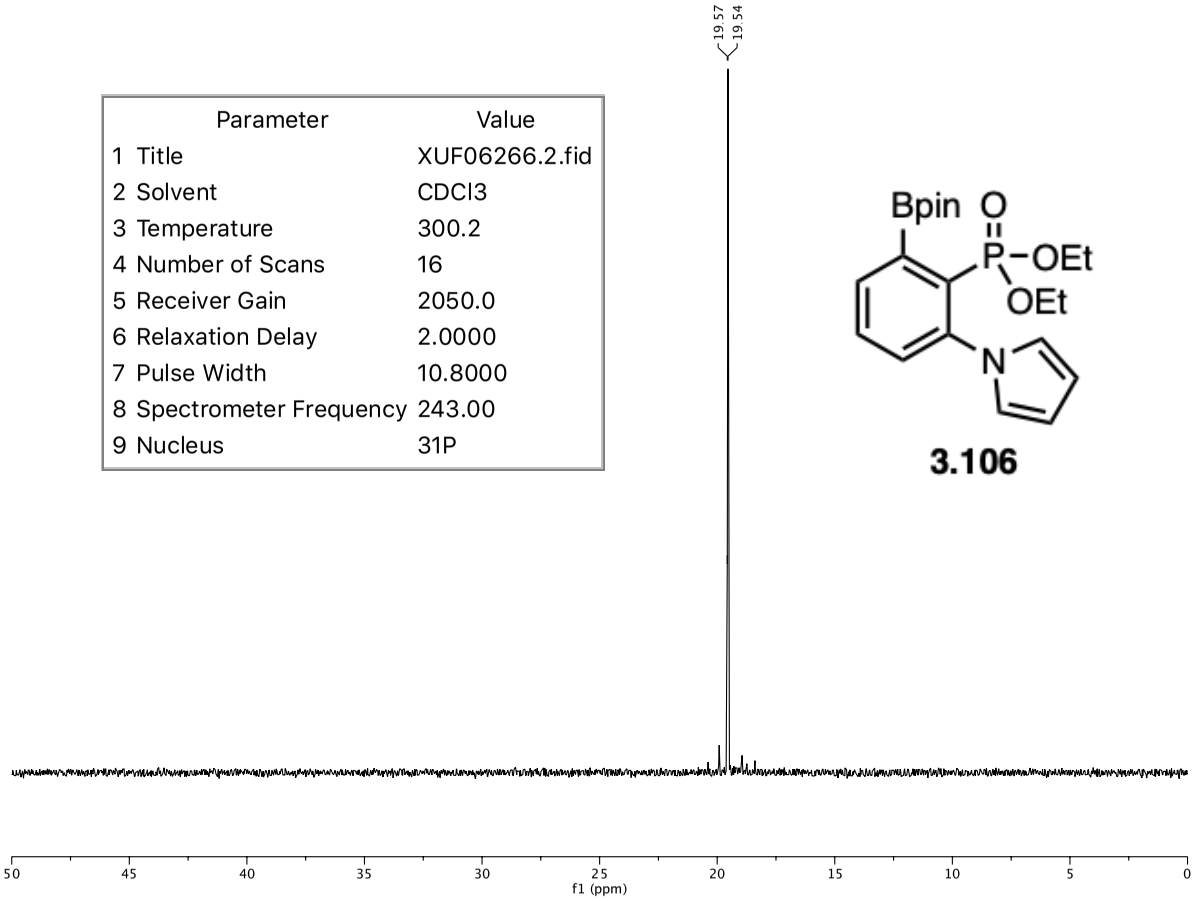



31.55
Bpin
EtO
EtO
3.105
Parameter Value
1 Title XUF06281.5.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)

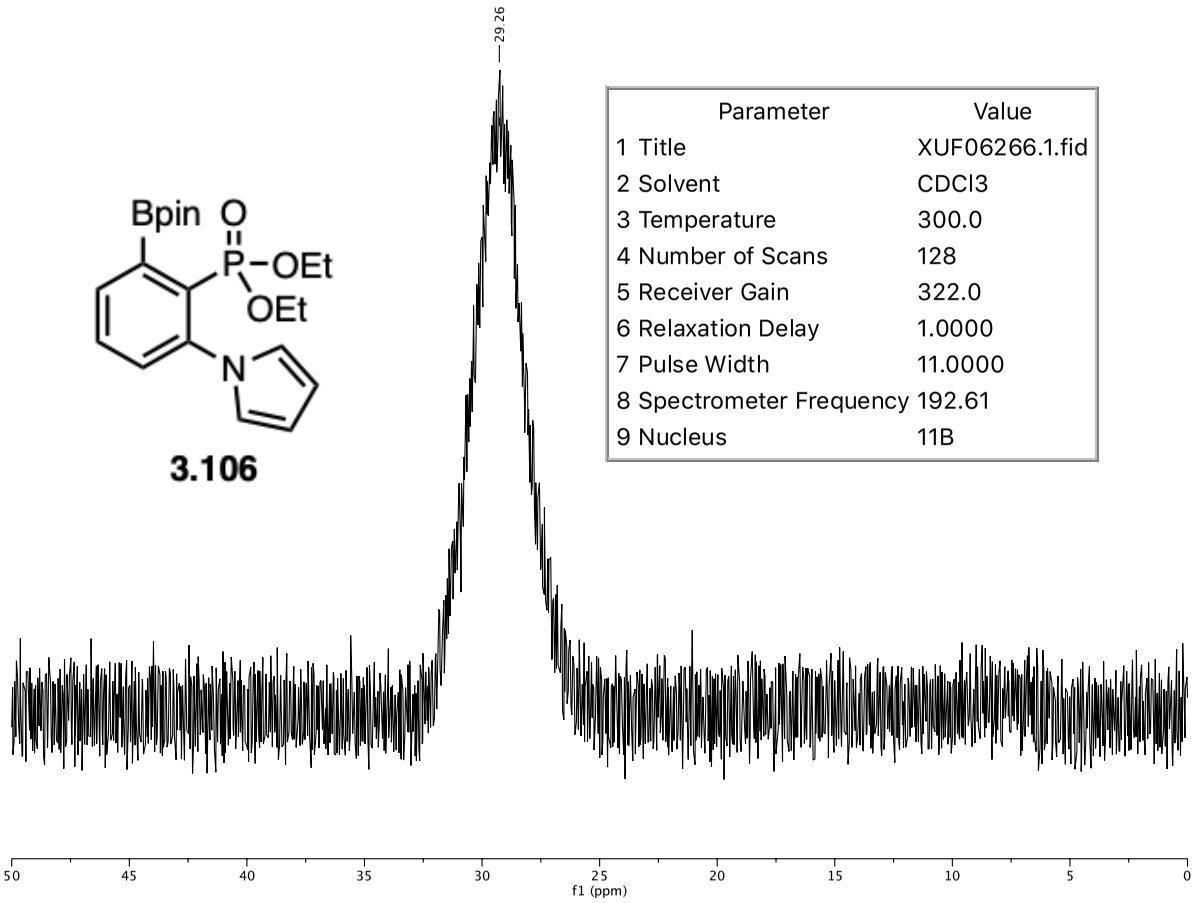

7.56 7.56 7.54 7.54 7.53 7.53 7.53 7.52 7.31 7.31 7.30 7.29 7.29 7.28 6.91 6.90 6.90
6.28 6.27 6.27
4.10 4.09 4.09 4.07 4.07 4.06 4.05 4.04 4.03 4.02 4.01 4.01 4.00 3.99 3.98 3.97 3.96 3.95 3.95 3.94 3.93 3.93 3.92 3.91 3.91 3.90 3.89 3.89
1.42 1.19 1.18 1.16
Parameter Value
1 Title XUF06266.2.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 10.1
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
N
3.106
2.04 1.00 1.95 2.03 2.04 2.07 12.28 6.13
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

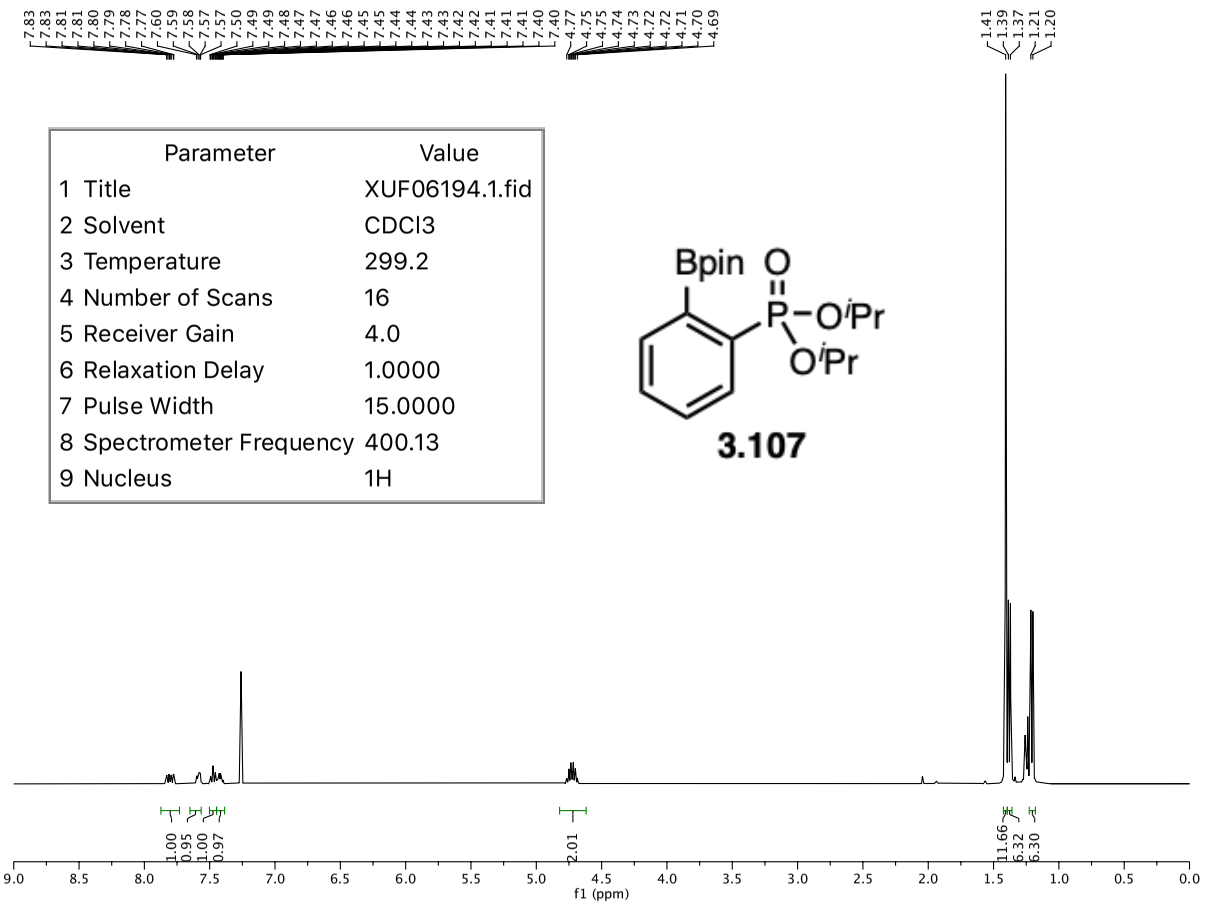

143.16
143.10
132.82
132.79
131.21
131.05
128.07
127.96
127.50
125.69
123.01
109.23
84.15
62.86
62.81
25.22
16.19
16.12
Bpin
O
P
OEt
OEt
N
3.106
Parameter Value
1 Title XUF06266.1.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

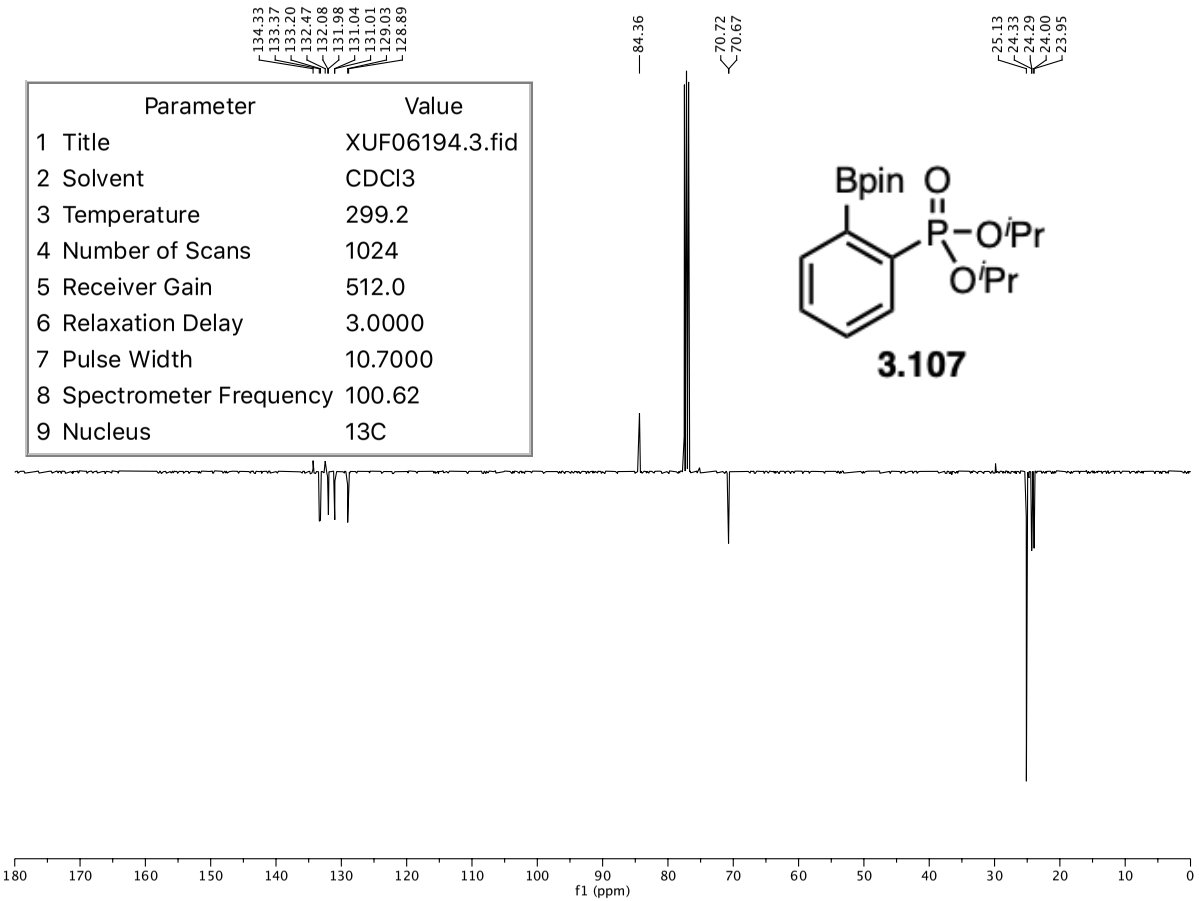
Parameter	Value
1 Title	XUF06266.2.fid
2 Solvent	CDCl3
3 Temperature	300.2
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P



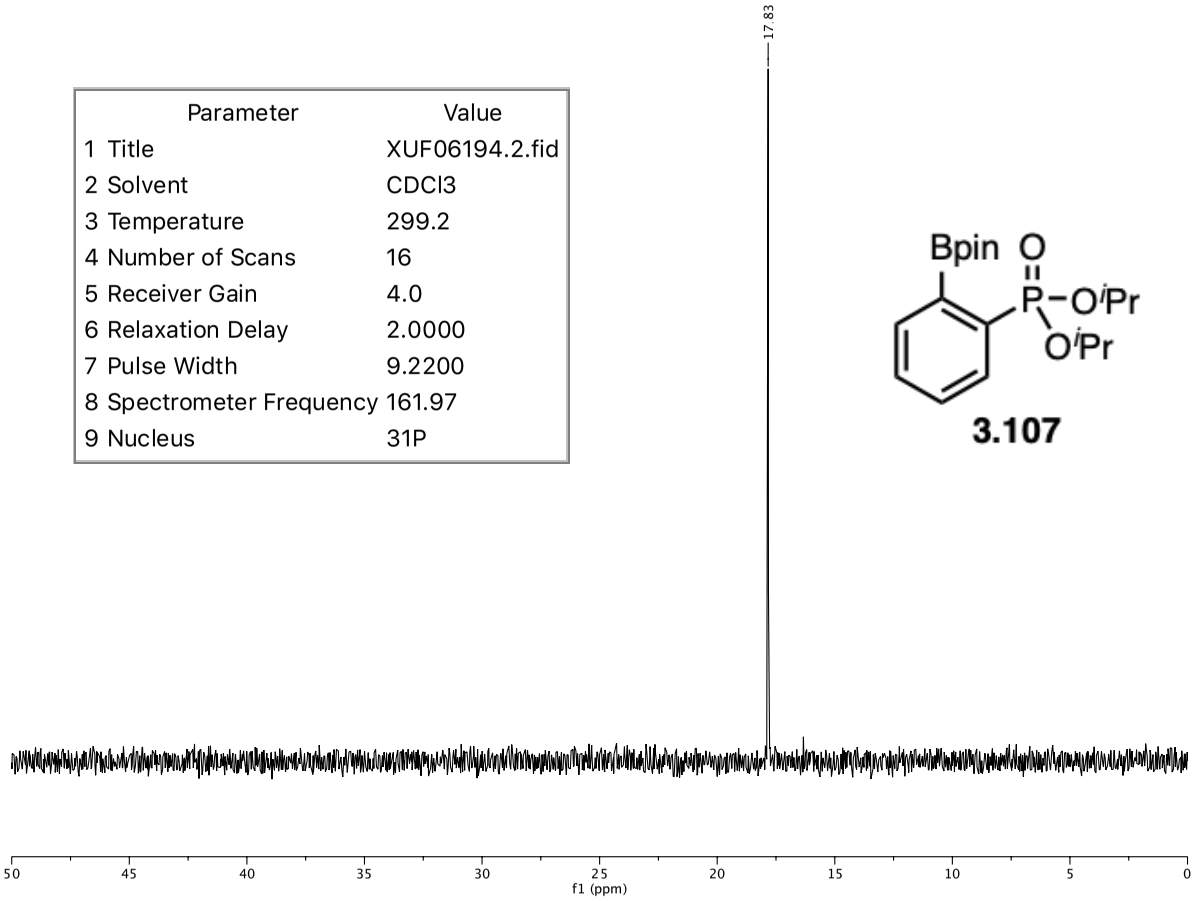
3.106


29.26
Bpin
O
P–OEt
OEt
N
3.106
Parameter Value
1 Title XUF06266.1.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)

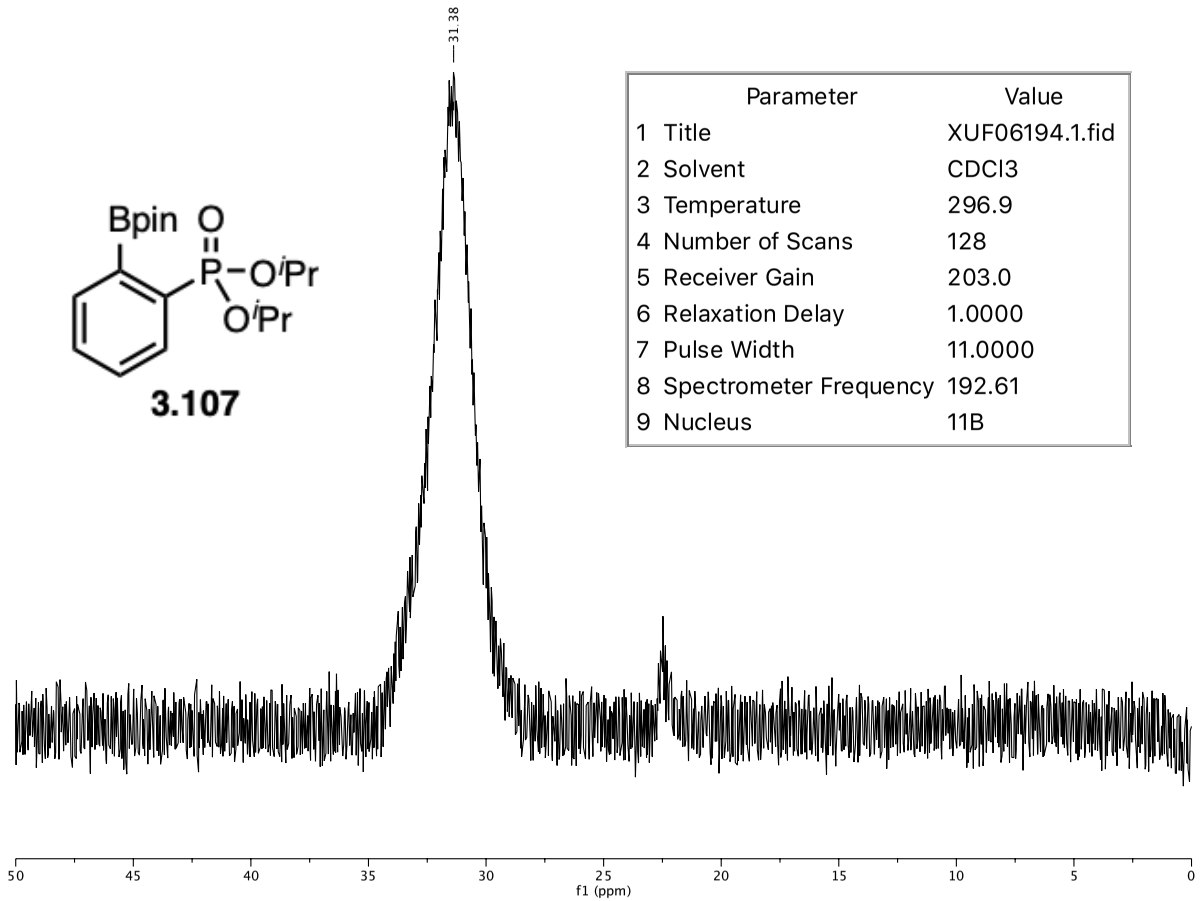

7.83 7.83 7.81 7.81 7.81 7.80 7.79 7.78 7.77 7.60 7.59 7.58 7.57 7.57 7.50 7.49 7.49 7.48 7.47 7.47 7.46 7.46 7.45 7.45 7.44 7.44 7.43 7.43 7.42 7.42 7.41 7.41 7.41 7.40 7.40
4.77 4.75 4.75 4.74 4.73 4.72 4.72 4.71 4.70 4.69
1.41 1.39 1.37 1.21 1.20
Parameter Value
1 Title XUF06194.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 4.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
O^{i}Pr
O^{i}Pr
3.107
1.00 0.95 1.00 0.97
2.01
11.66 6.32 6.30
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

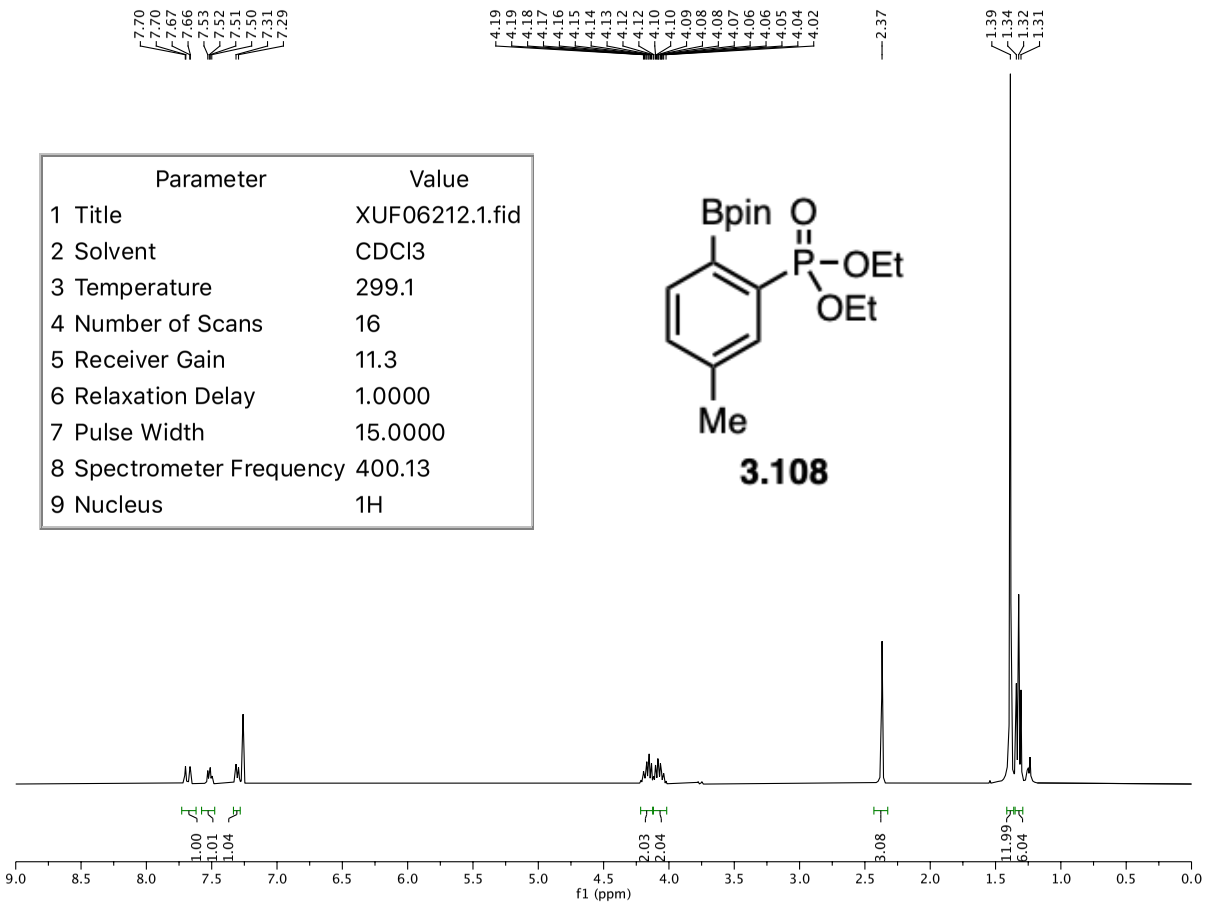

134.33
133.37
133.20
132.47
132.08
131.98
131.04
131.01
129.03
128.89
84.36
70.72
70.67
25.13
24.33
24.29
24.00
23.95
Parameter Value
1 Title XUF06194.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P
O^{i}Pr
O^{i}Pr
3.107
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

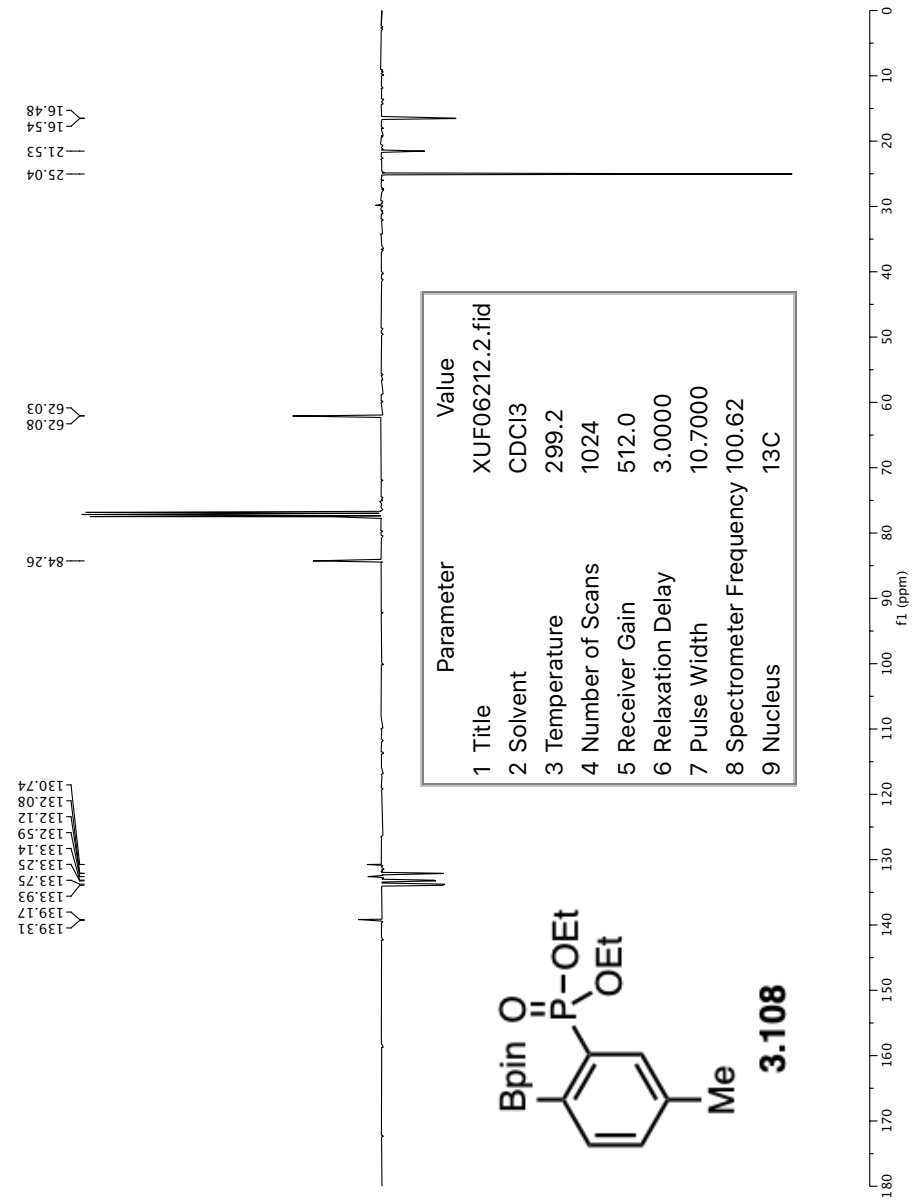
Parameter	Value
1 Title	XUF06194.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	4.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P



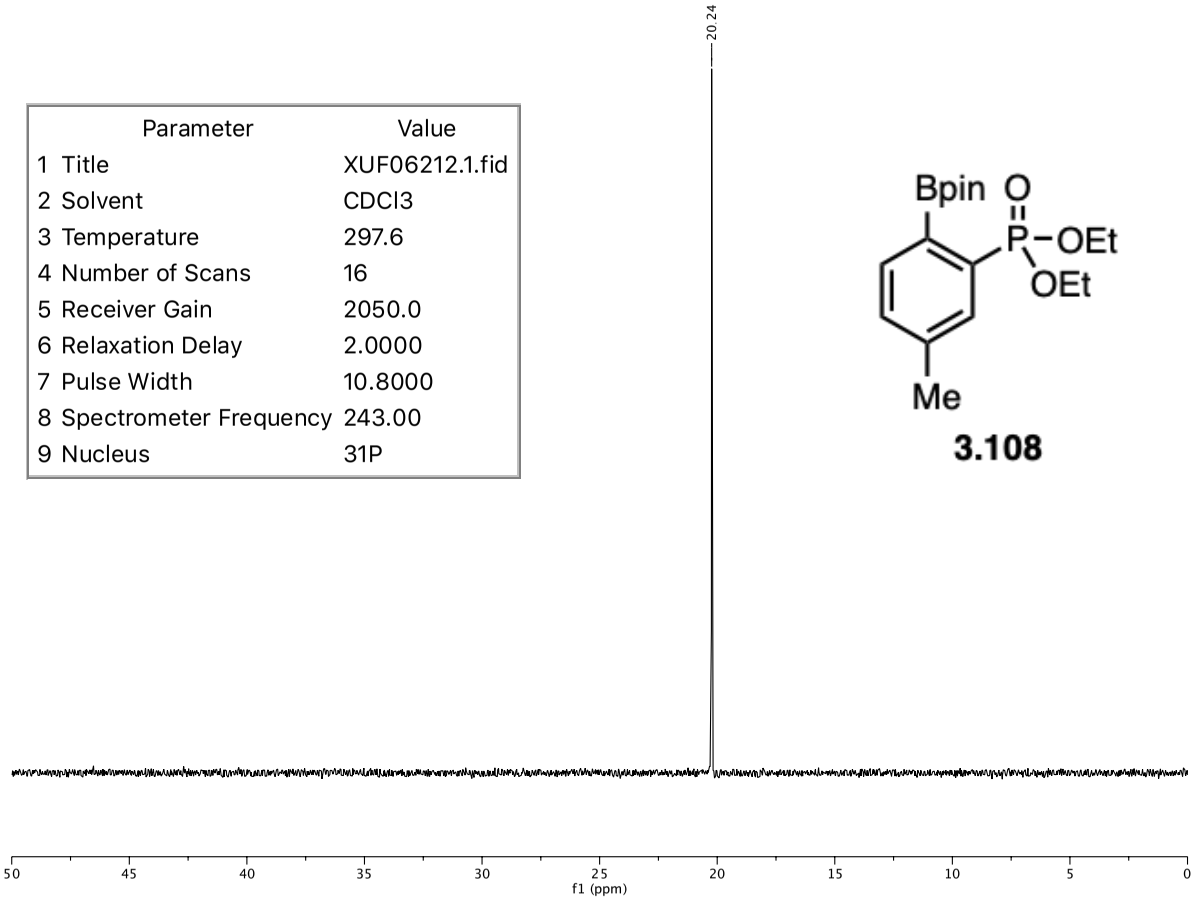
3.107


31.38
Bpin
O
P
O^{i}Pr
O^{i}Pr
3.107
Parameter Value
1 Title XUF06194.1.fid
2 Solvent CDCl3
3 Temperature 296.9
4 Number of Scans 128
5 Receiver Gain 203.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)

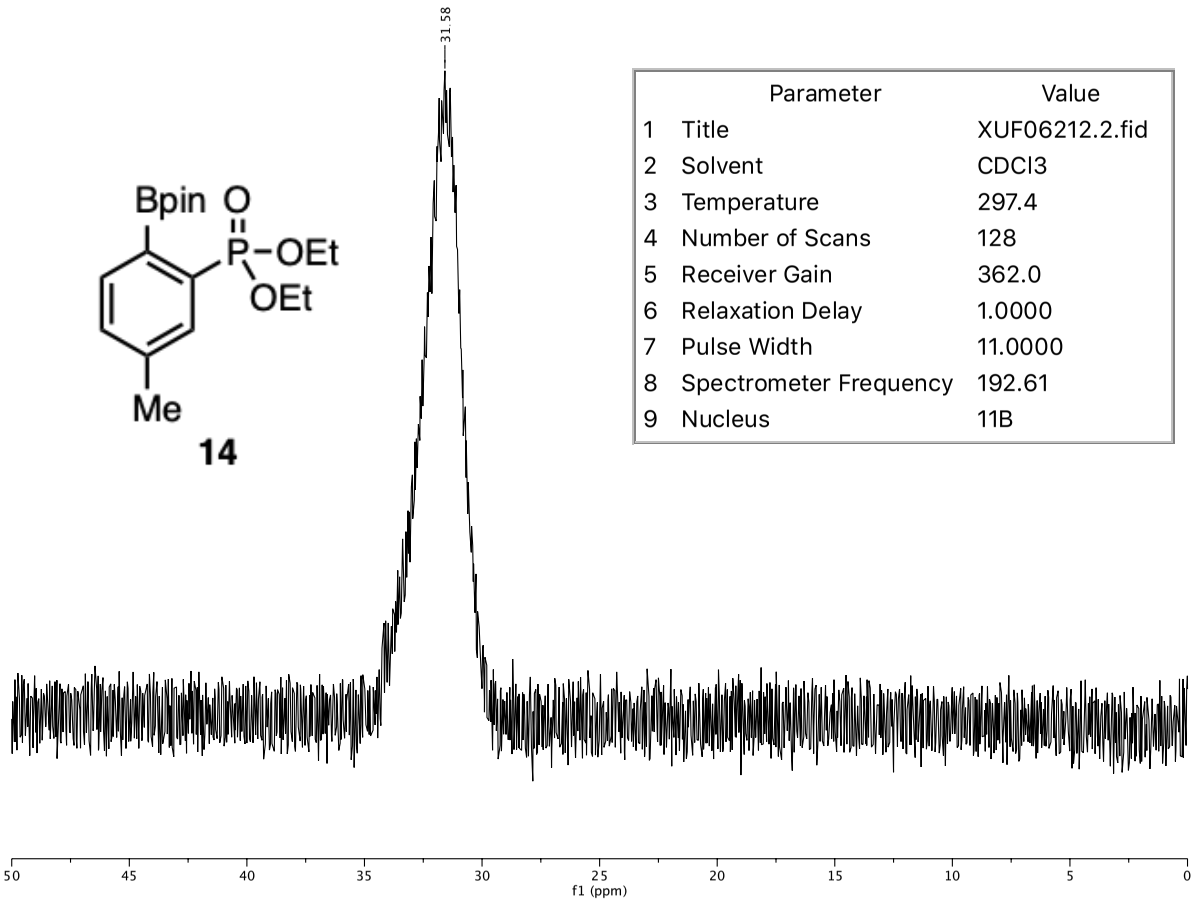

7.70
7.70
7.67
7.66
7.53
7.52
7.51
7.50
7.31
7.29
4.19
4.19
4.18
4.17
4.16
4.15
4.14
4.13
4.12
4.12
4.10
4.10
4.09
4.08
4.08
4.07
4.06
4.06
4.05
4.04
4.02
2.37
1.39
1.34
1.32
1.31
Parameter Value
1 Title XUF06212.1.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
Me
3.108
1.00
1.01
1.04
2.03
2.04
3.08
11.99
6.04
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


139.31
139.17
133.93
133.75
133.25
133.14
132.59
132.12
132.08
130.74
84.26
62.08
62.03
25.04
21.53
16.54
16.48
Parameter Value
1 Title XUF06212.2.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P
OEt
OEt
Me
3.108
f1 (ppm)

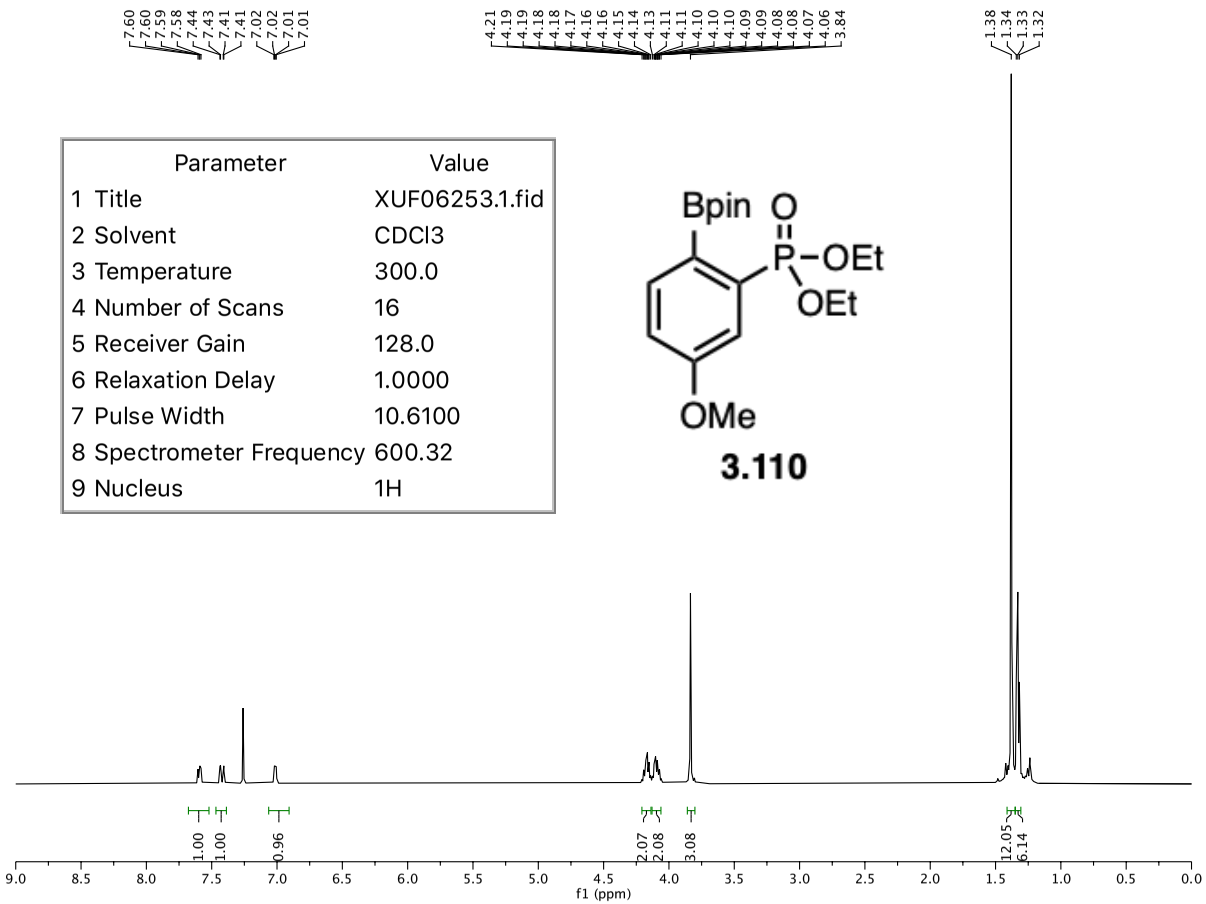
Parameter	Value
1 Title	XUF06212.1.fid
2 Solvent	CDCl3
3 Temperature	297.6
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P

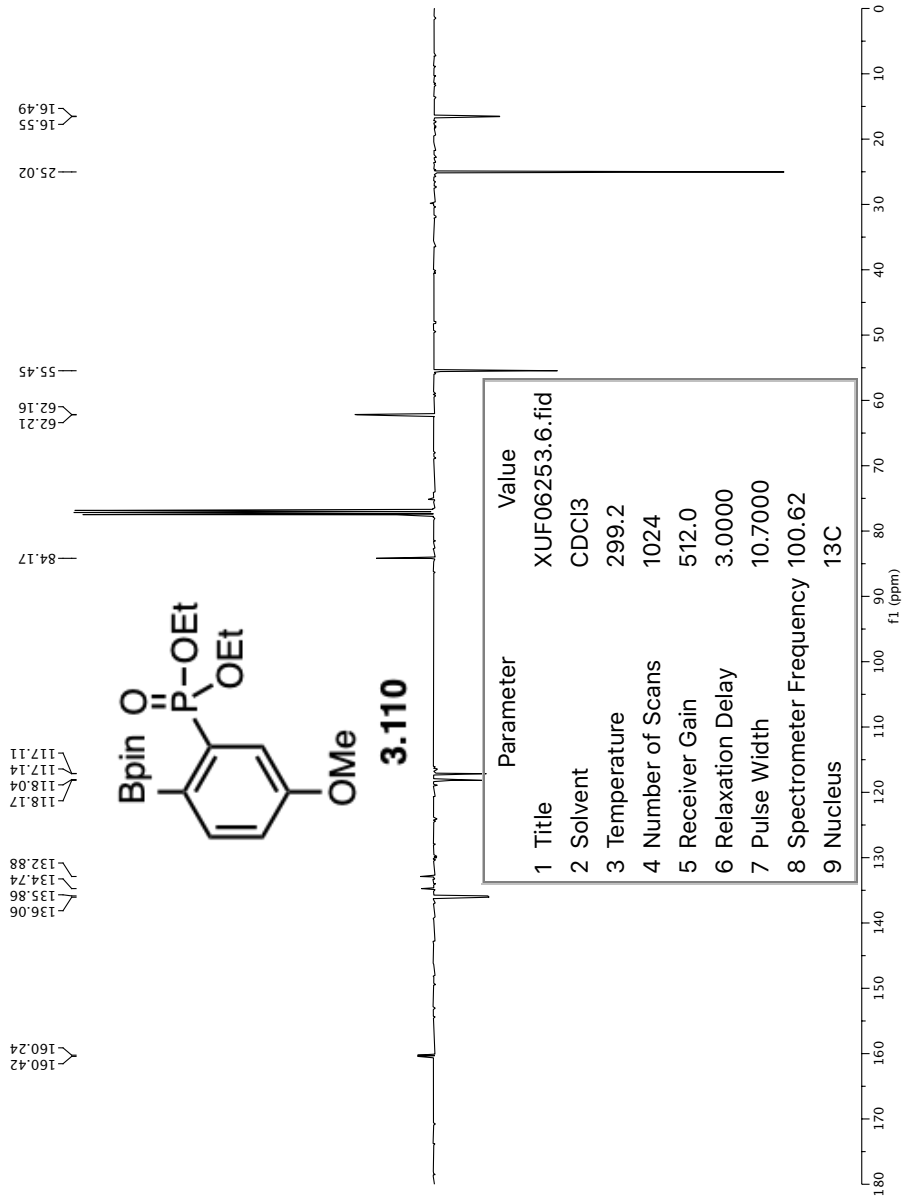


3.108

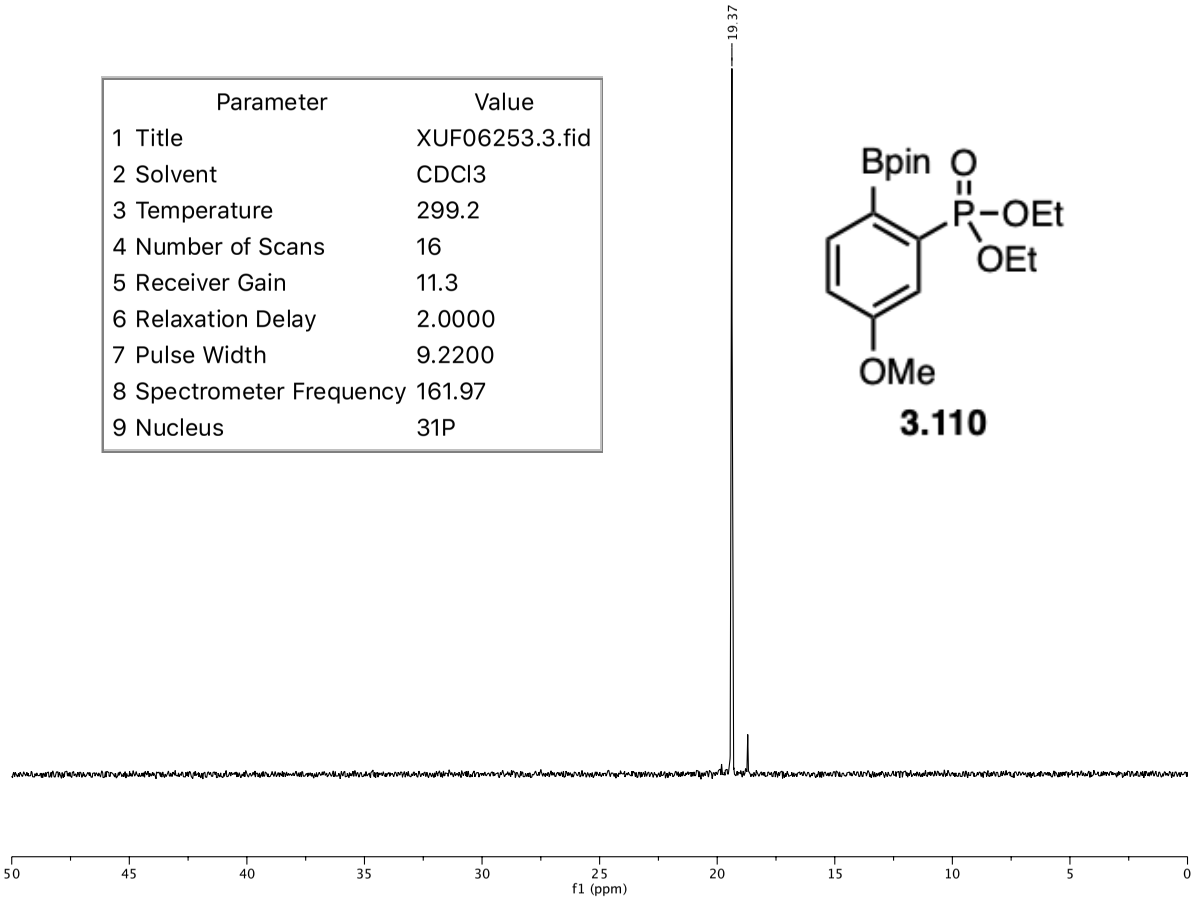


	Parameter	Value
1	Title	XUF06212.2.fid
2	Solvent	CDCl3
3	Temperature	297.4
4	Number of Scans	128
5	Receiver Gain	362.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B

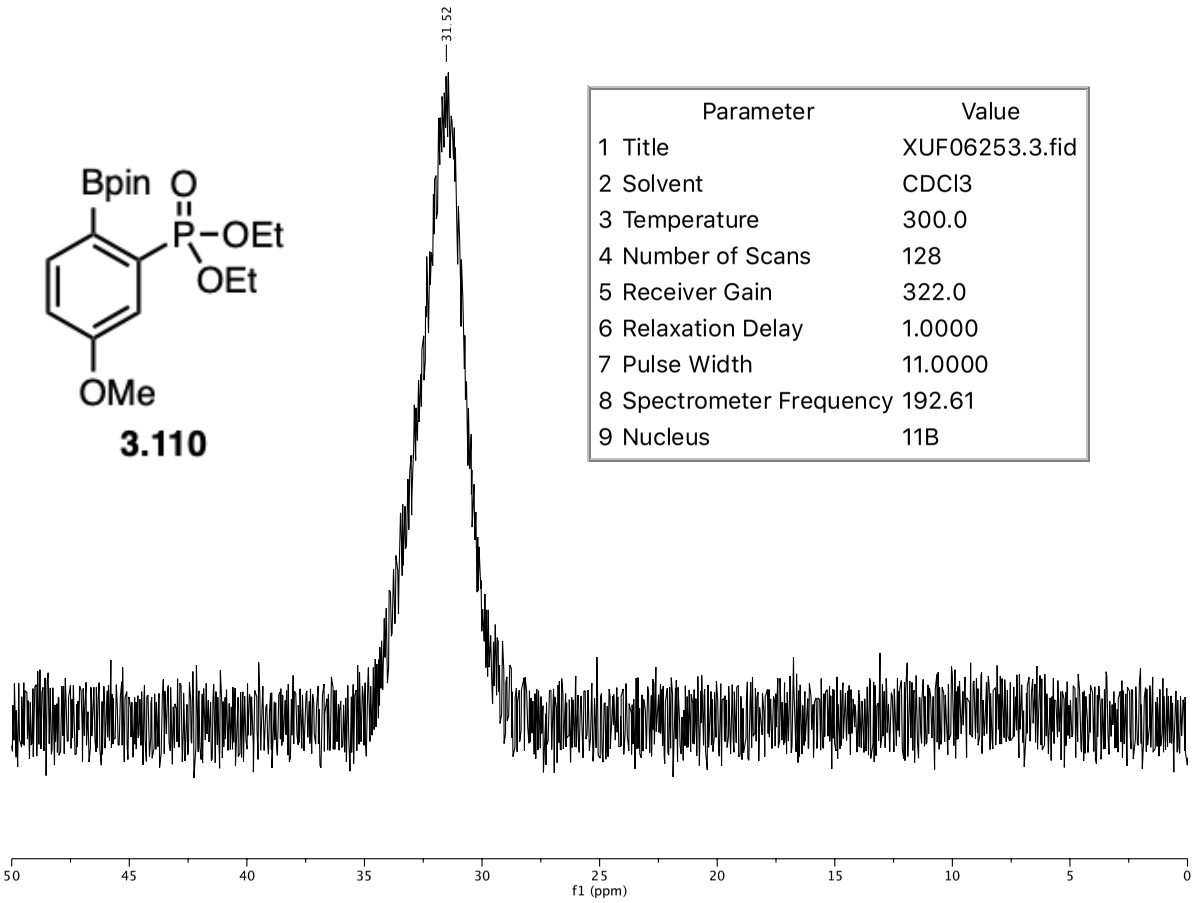

7.60
7.60
7.59
7.58
7.44
7.43
7.41
7.41
7.02
7.02
7.01
7.01
4.21
4.19
4.19
4.18
4.18
4.17
4.16
4.16
4.15
4.14
4.13
4.11
4.11
4.10
4.10
4.10
4.09
4.09
4.08
4.08
4.07
4.06
3.84
1.38
1.34
1.33
1.32
Parameter Value
1 Title XUF06253.1.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 128.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.6100
8 Spectrometer Frequency 600.32
9 Nucleus 1H
Bpin
O
P
OEt
OEt
OMe
3.110
1.00
1.00
0.96
2.07
2.08
3.08
12.05
6.14
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

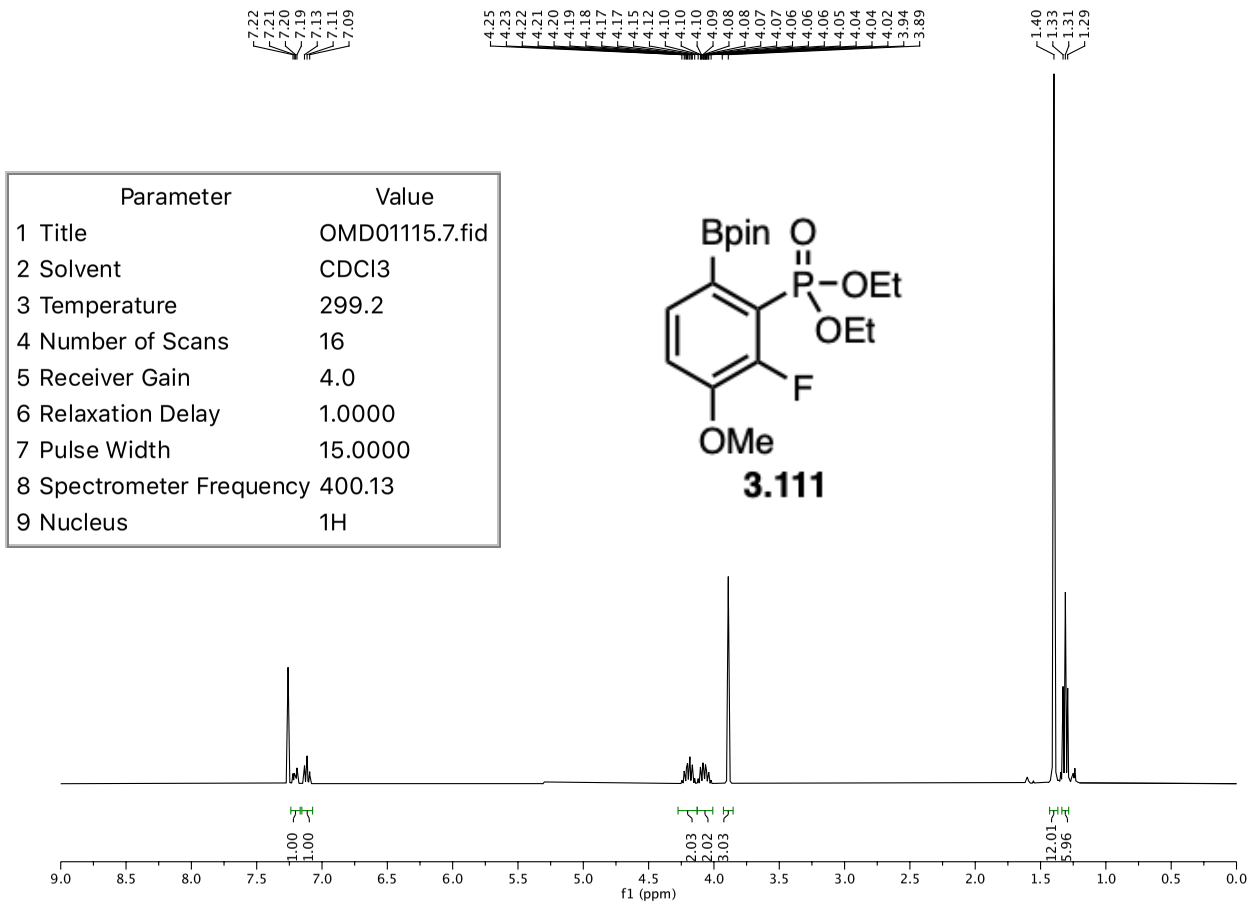

3.110
Bpin
O
P
OEt
OEt
OMe
160.42
160.24
136.06
135.86
134.74
132.88
118.17
118.04
117.14
117.11
84.17
62.21
62.16
55.45
25.02
16.55
16.49
Parameter
Value
1 Title
XUF06253.6.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
1024
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

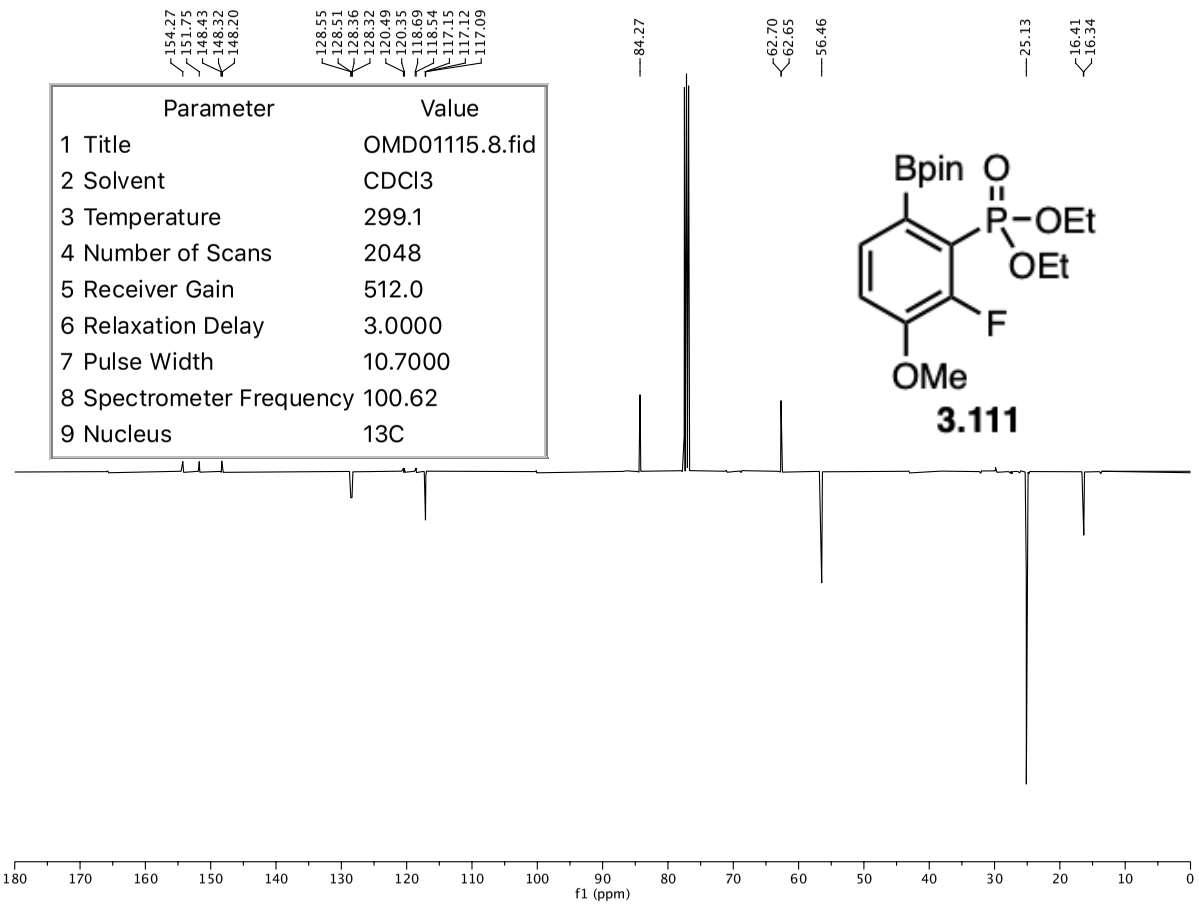
Parameter	Value
1 Title	XUF06253.3.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	11.3
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P



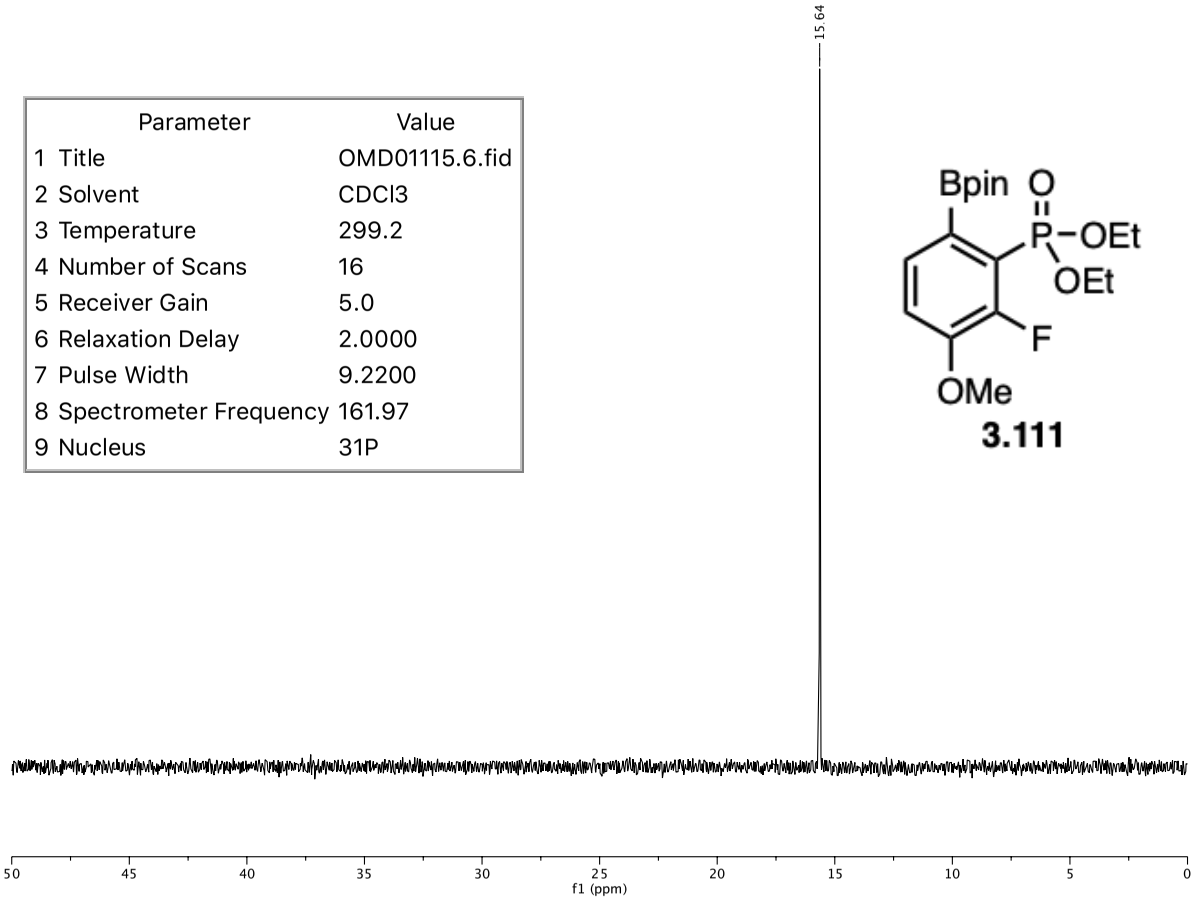
3.110


31.52
Bpin
O
P–OEt
OEt
OMe
3.110
Parameter Value
1 Title XUF06253.3.fid
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


7.22
7.21
7.20
7.19
7.13
7.11
7.09
4.25
4.23
4.22
4.21
4.20
4.19
4.18
4.17
4.17
4.15
4.12
4.10
4.10
4.10
4.09
4.08
4.08
4.07
4.07
4.06
4.06
4.06
4.05
4.04
4.04
4.02
3.94
3.89
1.40
1.33
1.31
1.29
Parameter
Value
1 Title
OMD01115.7.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
16
5 Receiver Gain
4.0
6 Relaxation Delay
1.0000
7 Pulse Width
15.0000
8 Spectrometer Frequency
400.13
9 Nucleus
1H
Bpin
O
P
OEt
OEt
F
OMe
3.111
1.00
1.00
2.03
2.02
3.03
12.01
5.96
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

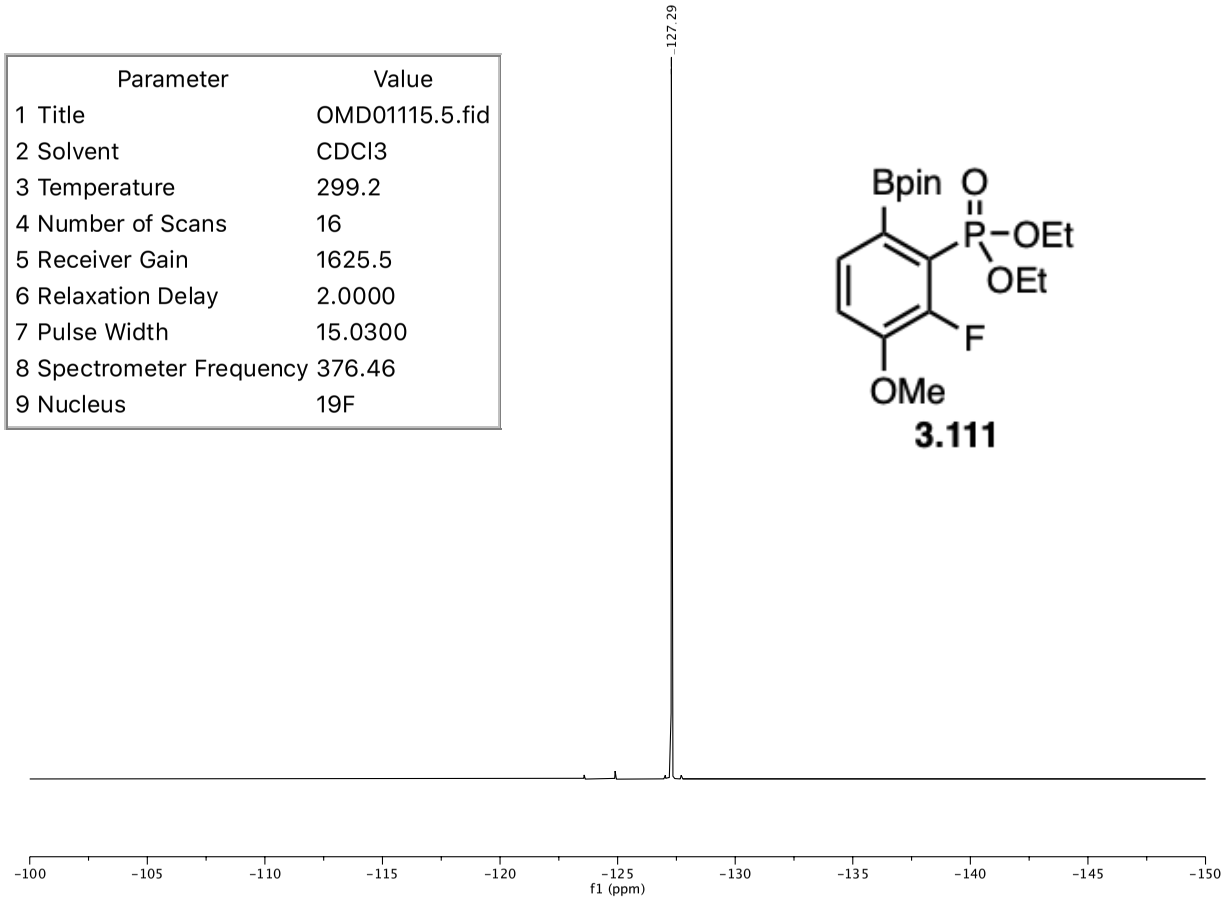

154.27
151.75
148.43
148.32
148.20
128.55
128.51
128.36
128.32
120.49
120.35
118.69
118.54
117.15
117.12
117.09
84.27
62.70
62.65
56.46
25.13
16.41
16.34
Parameter Value
1 Title OMD01115.8.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 2048
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P
OEt
OEt
F
OMe
3.111
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	OMD01115.6.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	5.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

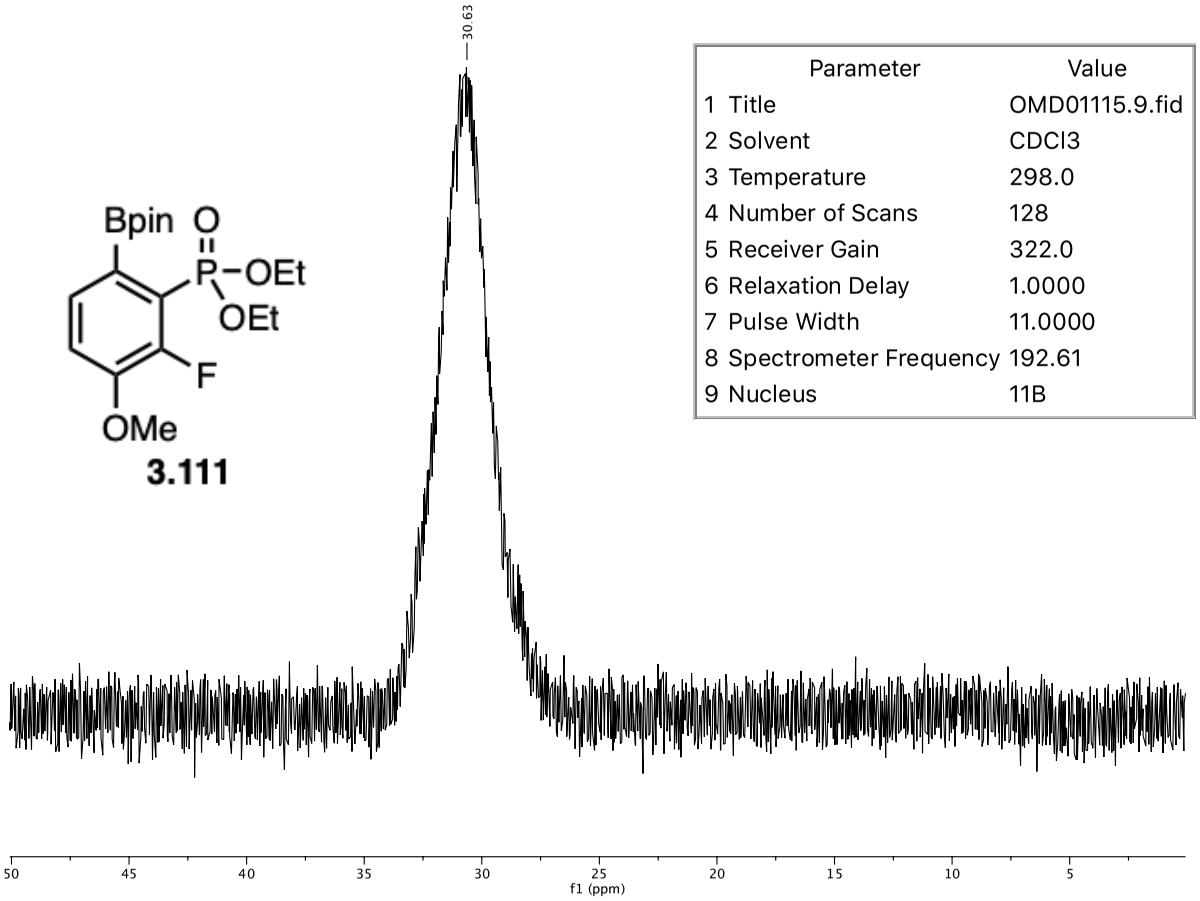


3.111

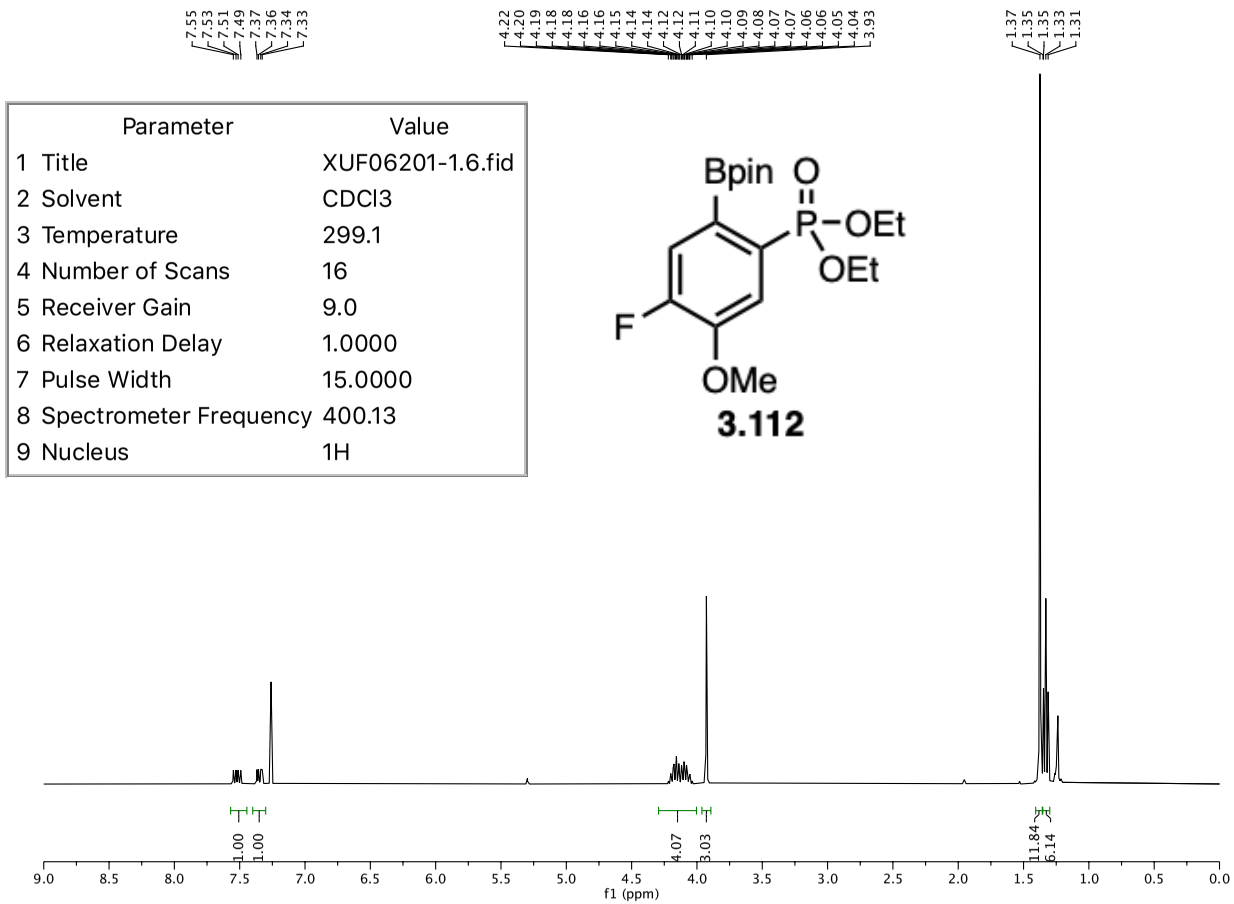
Parameter	Value
1 Title	OMD01115.5.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	1625.5
6 Relaxation Delay	2.0000
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F

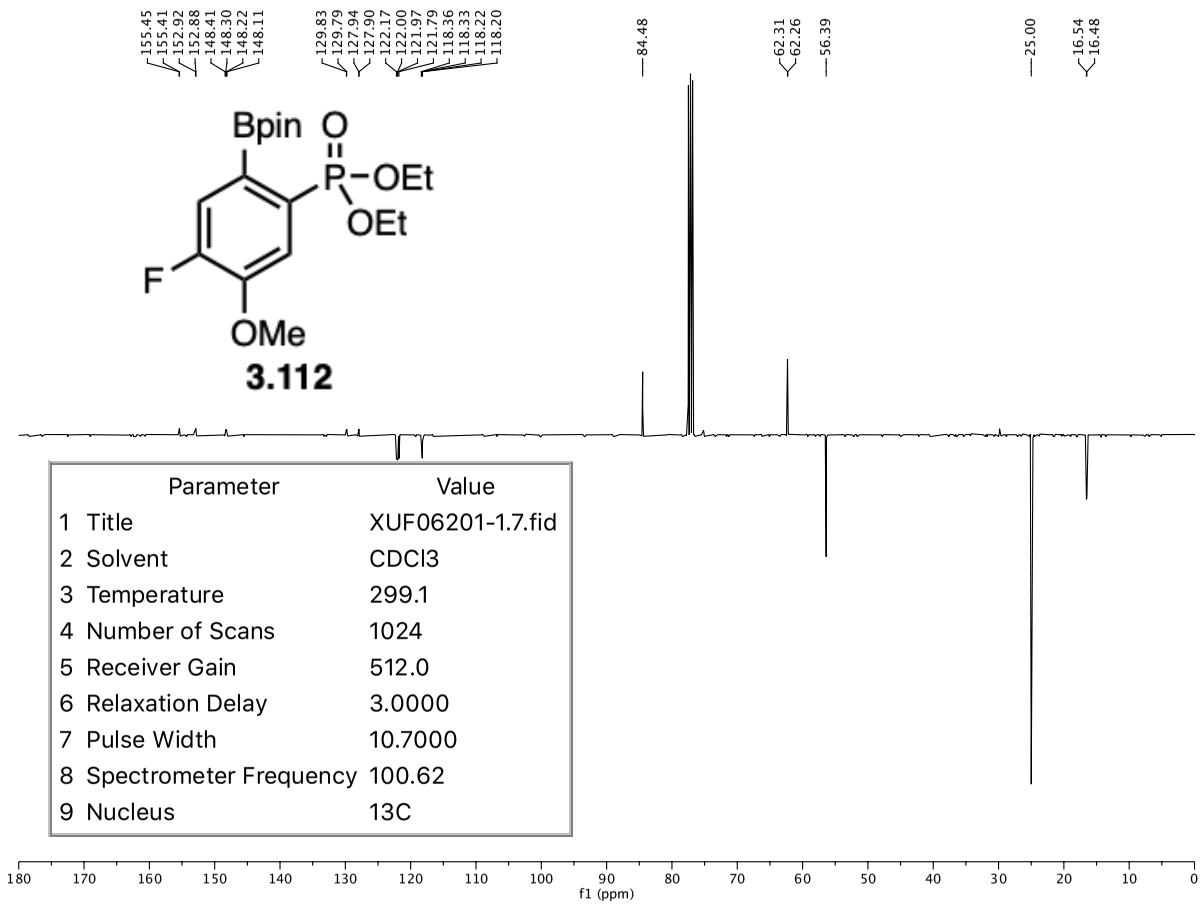


3.111

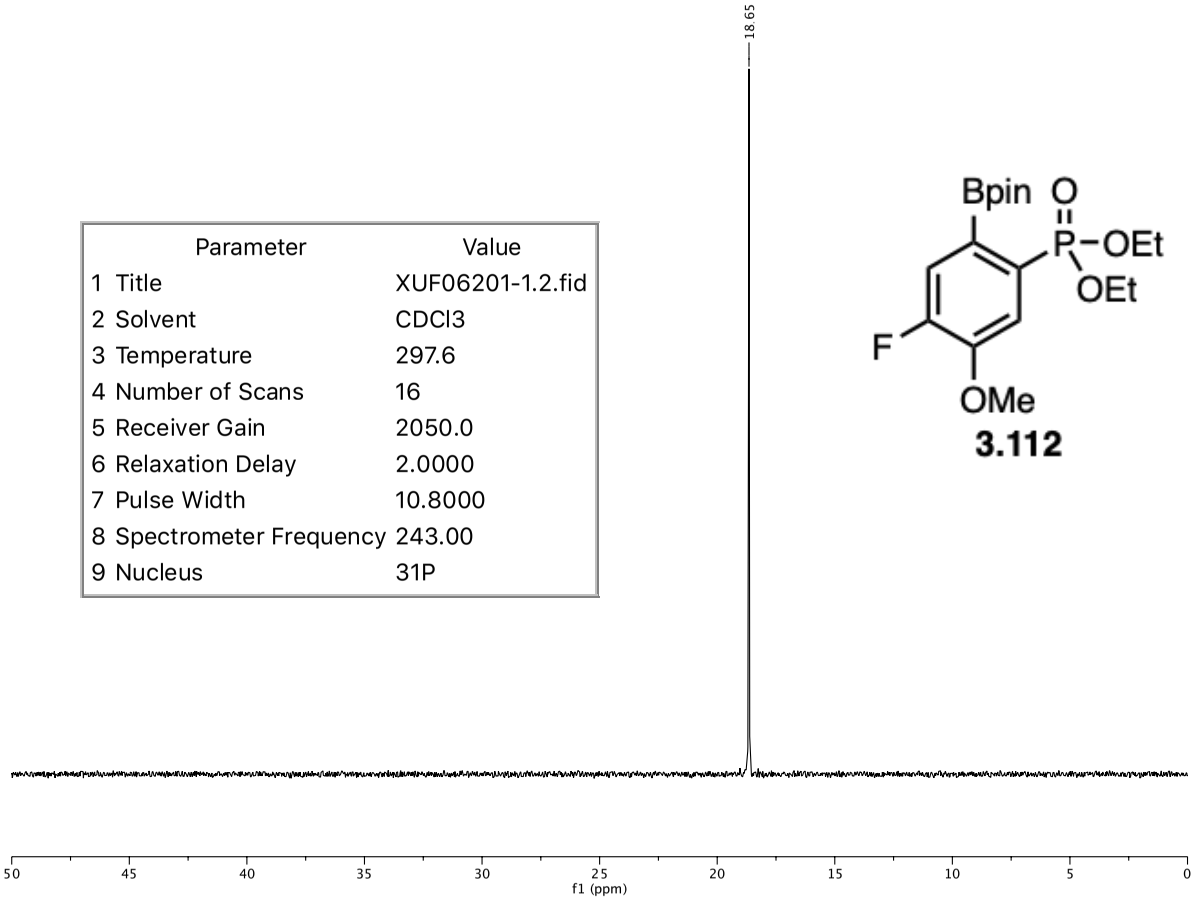


	Parameter	Value
1	Title	OMD01115.9.fid
2	Solvent	CDCl3
3	Temperature	298.0
4	Number of Scans	128
5	Receiver Gain	322.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B


7.55
7.53
7.51
7.49
7.37
7.36
7.34
7.33
4.22
4.20
4.19
4.18
4.18
4.16
4.16
4.15
4.14
4.14
4.12
4.12
4.11
4.10
4.10
4.09
4.08
4.07
4.07
4.06
4.06
4.05
4.04
3.93
1.37
1.35
1.35
1.33
1.31
Parameter Value
1 Title XUF06201-1.6.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 9.0
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
F
OMe
3.112
1.00
1.00
4.07
3.03
11.84
6.14
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

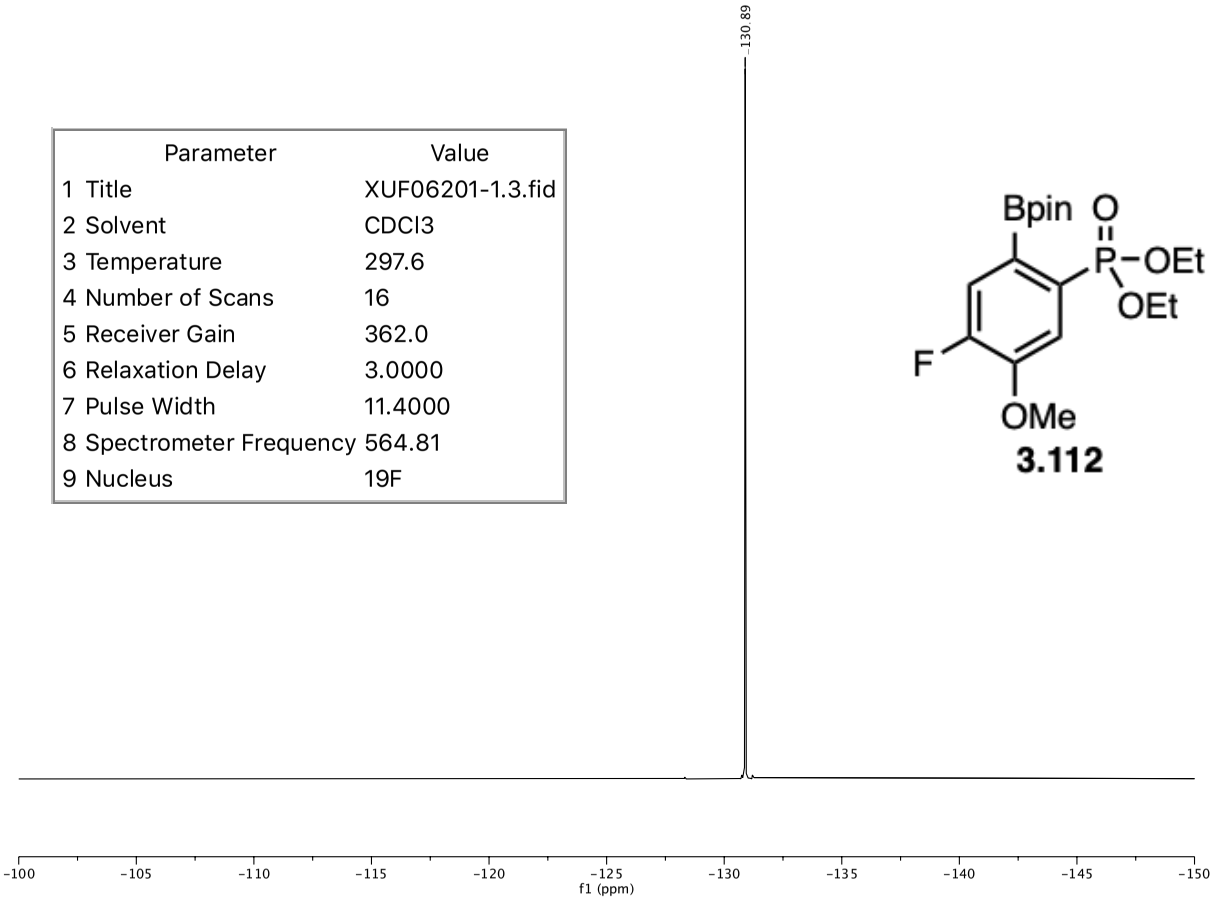

155.45
155.41
152.92
152.88
148.41
148.30
148.22
148.11
129.83
129.79
127.94
127.90
122.17
122.00
121.97
121.79
118.36
118.33
118.22
118.20
84.48
62.31
62.26
56.39
25.00
16.54
16.48
Bpin
O
P
OEt
OEt
F
OMe
3.112
Parameter Value
1 Title XUF06201-1.7.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06201-1.2.fid
2 Solvent	CDCl3
3 Temperature	297.6
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P

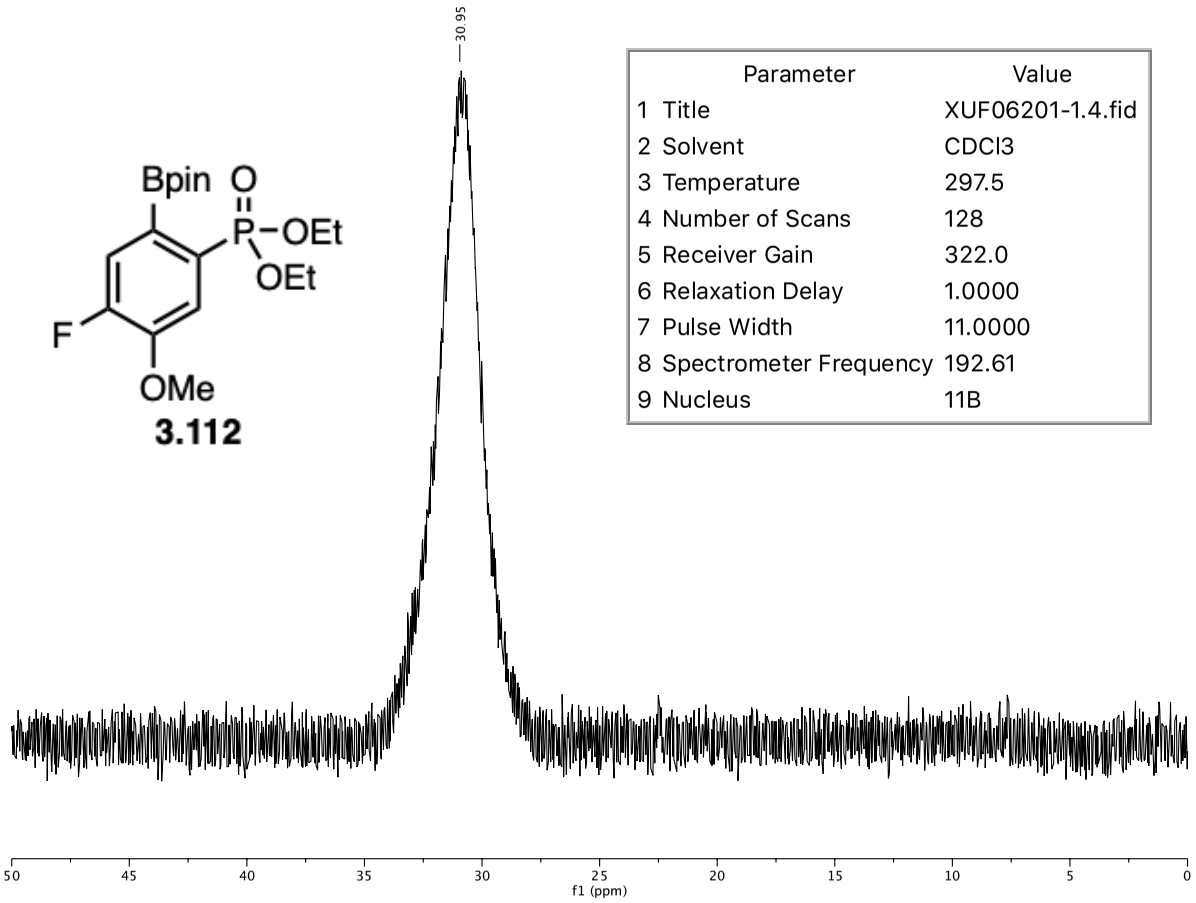


3.112

Parameter	Value
1 Title	XUF06201-1.3.fid
2 Solvent	CDCl3
3 Temperature	297.6
4 Number of Scans	16
5 Receiver Gain	362.0
6 Relaxation Delay	3.0000
7 Pulse Width	11.4000
8 Spectrometer Frequency	564.81
9 Nucleus	19F



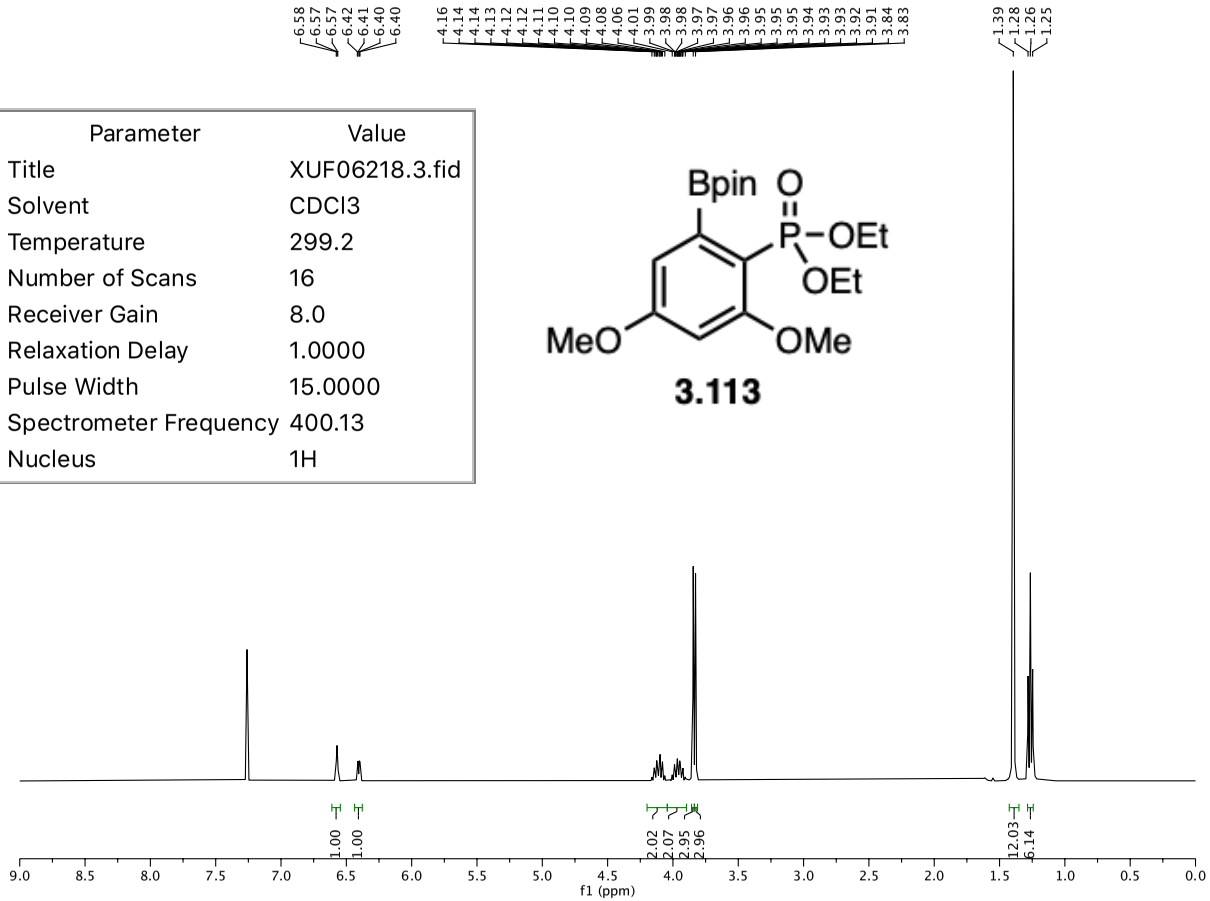
3.112



	Parameter	Value
1	Title	XUF06201-1.4.fid
2	Solvent	CDCl3
3	Temperature	297.5
4	Number of Scans	128
5	Receiver Gain	322.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B

Parameter	Value
1 Title	XUF06218.3.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	8.0
6 Relaxation Delay	1.0000
7 Pulse Width	15.0000
8 Spectrometer Frequency	400.13
9 Nucleus	1H

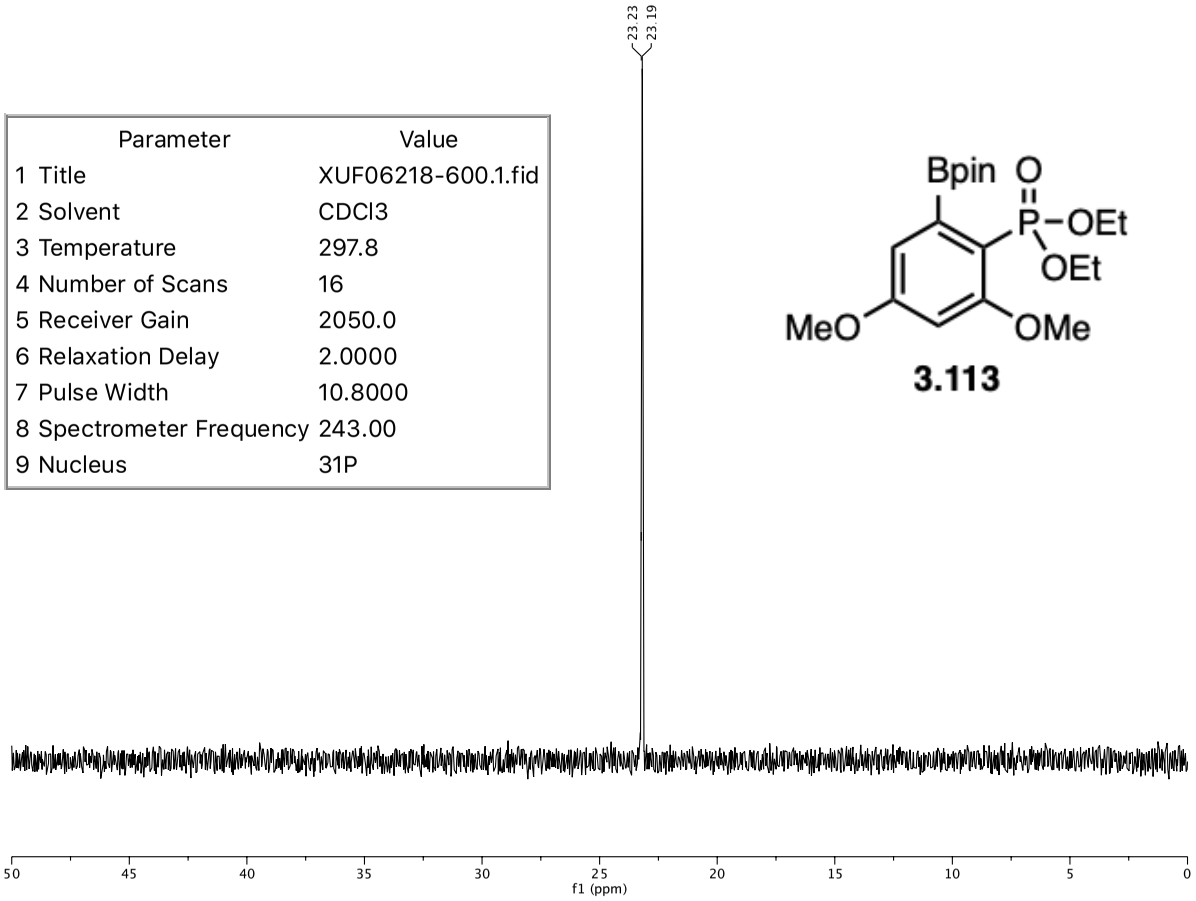
3.113



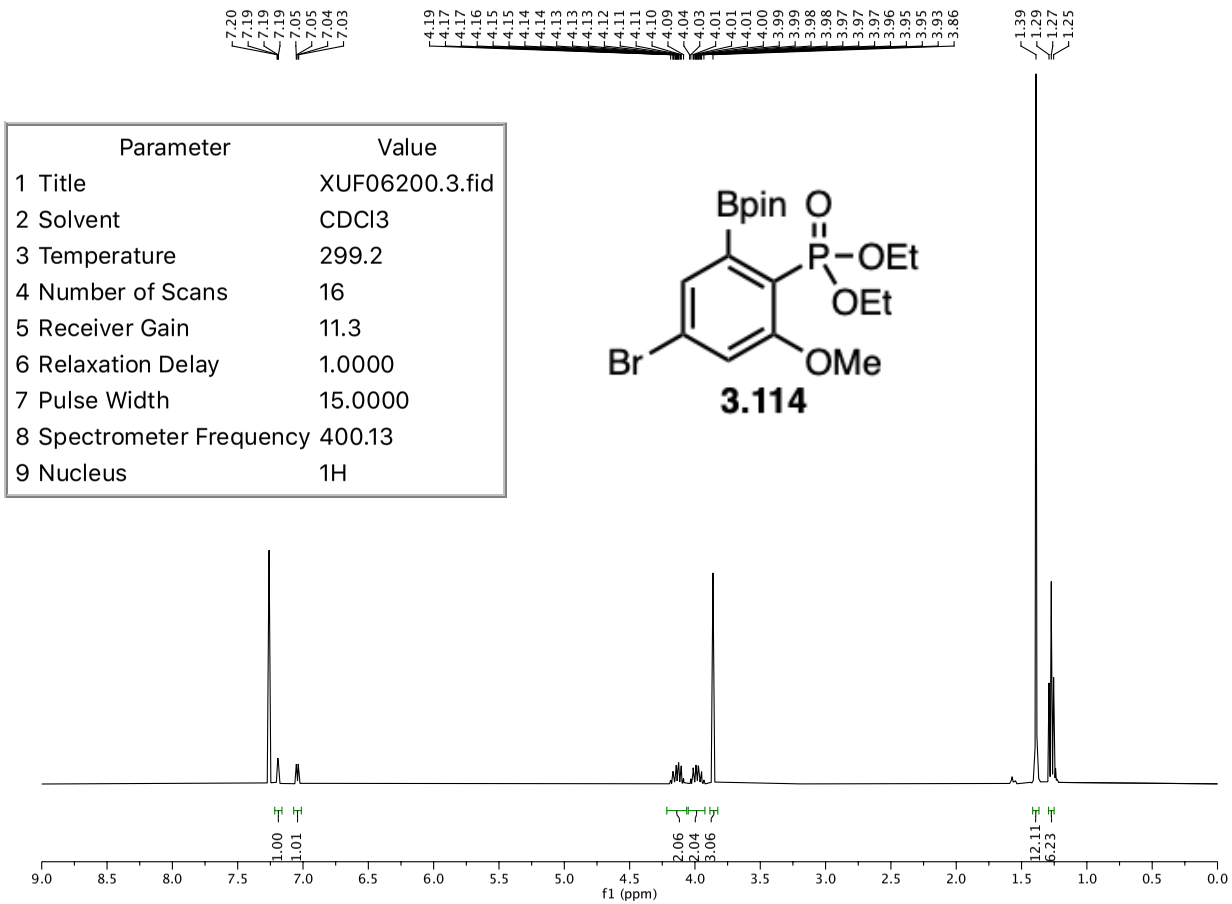
16.32
16.39
25.00
25.29
55.56
55.75
62.27
62.31
83.72
98.92
99.02
107.66
107.84
108.60
110.45
162.35
162.40
164.81
164.83
Bpin
O
P
OEt
OEt
OMe
MeO
3.113
Parameter Value
1 Title XUF06218.5.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

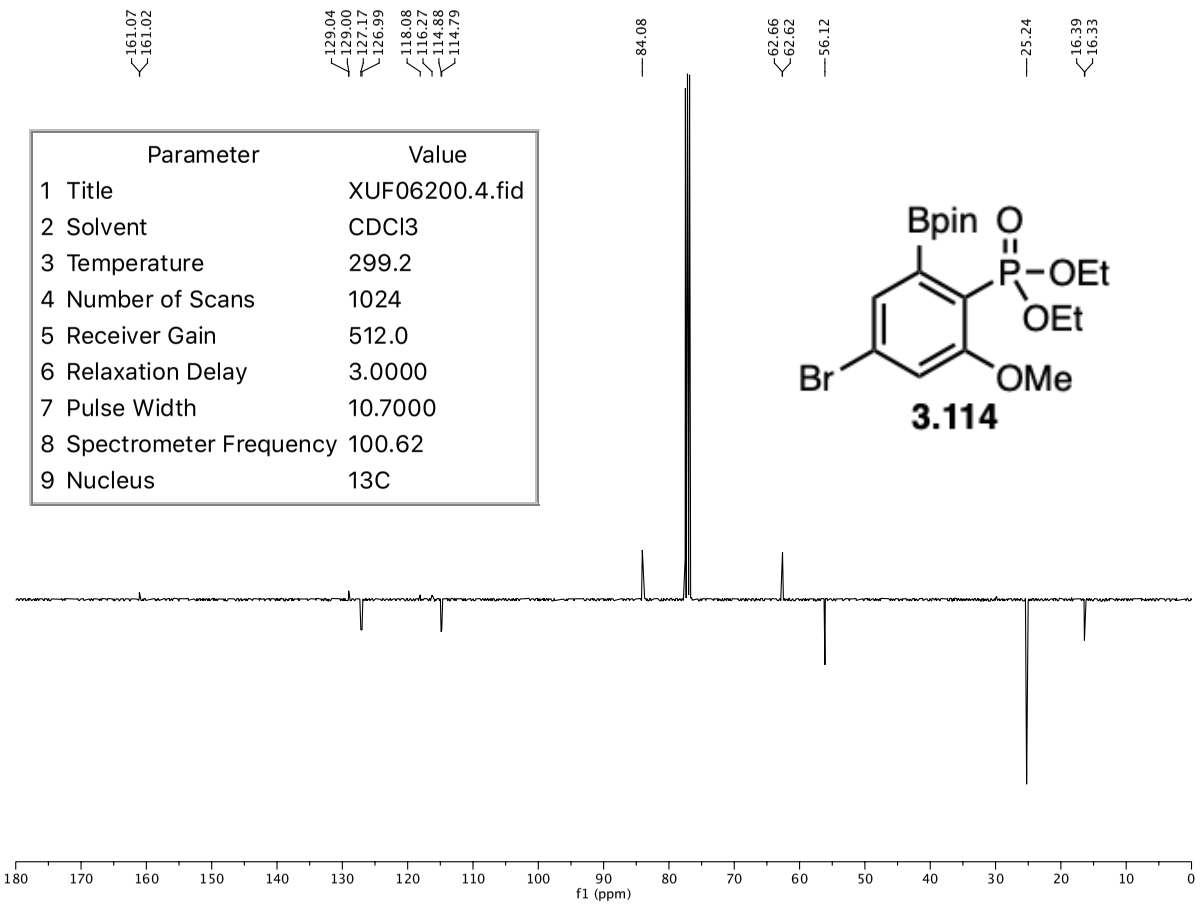
Parameter	Value
1 Title	XUF06218-600.1.fid
2 Solvent	CDCl3
3 Temperature	297.8
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P

3.113

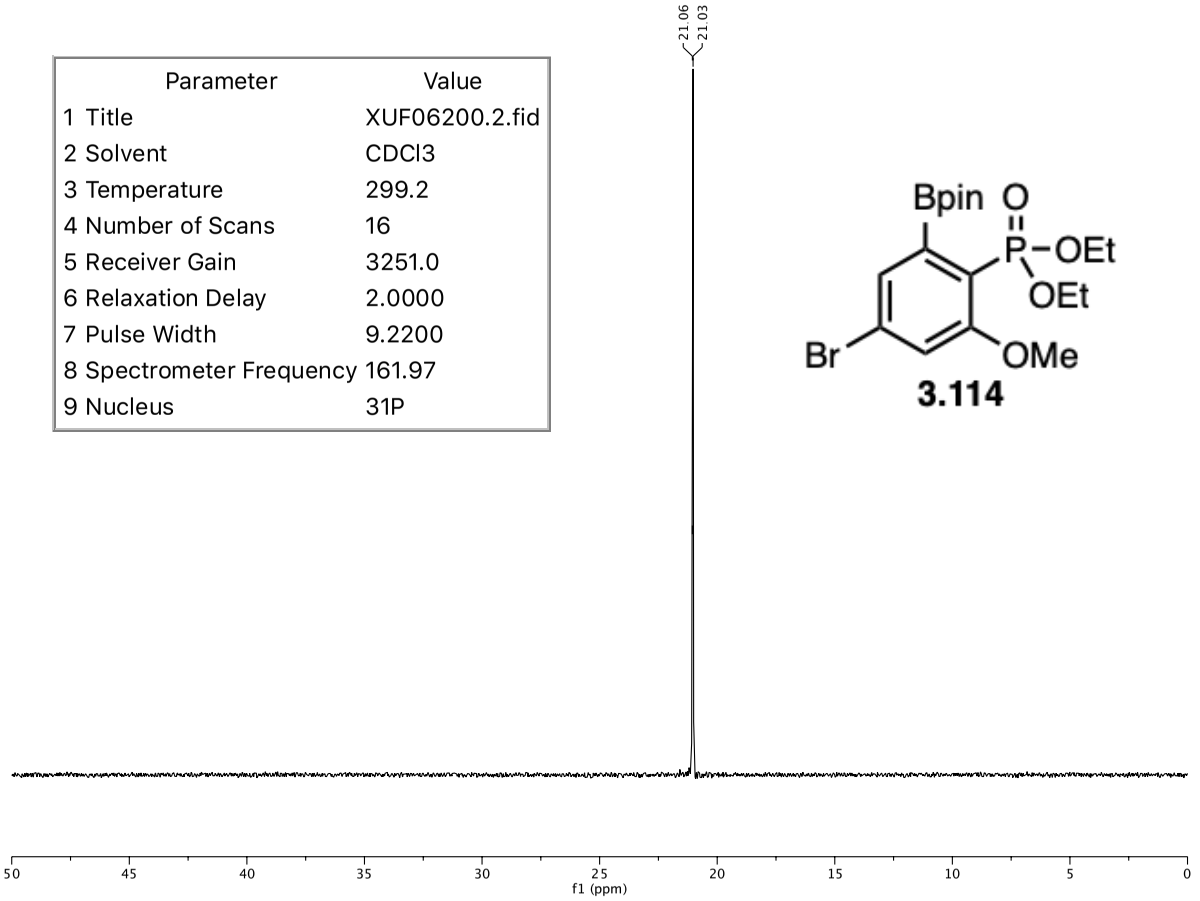


Parameter
Value
1 Title
XUF06218-600.2.fid
2 Solvent
CDCl3
3 Temperature
297.6
4 Number of Scans
128
5 Receiver Gain
322.0
6 Relaxation Delay
1.0000
7 Pulse Width
11.0000
8 Spectrometer Frequency
192.61
9 Nucleus
11B
28.12
Bpin
O
P
OEt
OEt
OMe
MeO
3.113
f1 (ppm)


7.20
7.19
7.19
7.19
7.05
7.05
7.04
7.03
4.19
4.17
4.17
4.16
4.15
4.15
4.14
4.14
4.13
4.13
4.13
4.12
4.11
4.11
4.10
4.09
4.04
4.03
4.01
4.01
4.00
3.99
3.99
3.98
3.98
3.97
3.97
3.97
3.96
3.95
3.95
3.93
3.86
1.39
1.29
1.27
1.25
Parameter Value
1 Title XUF06200.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 11.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
Br
OMe
3.114
1.00
1.01
2.06
2.04
3.06
12.11
6.23
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

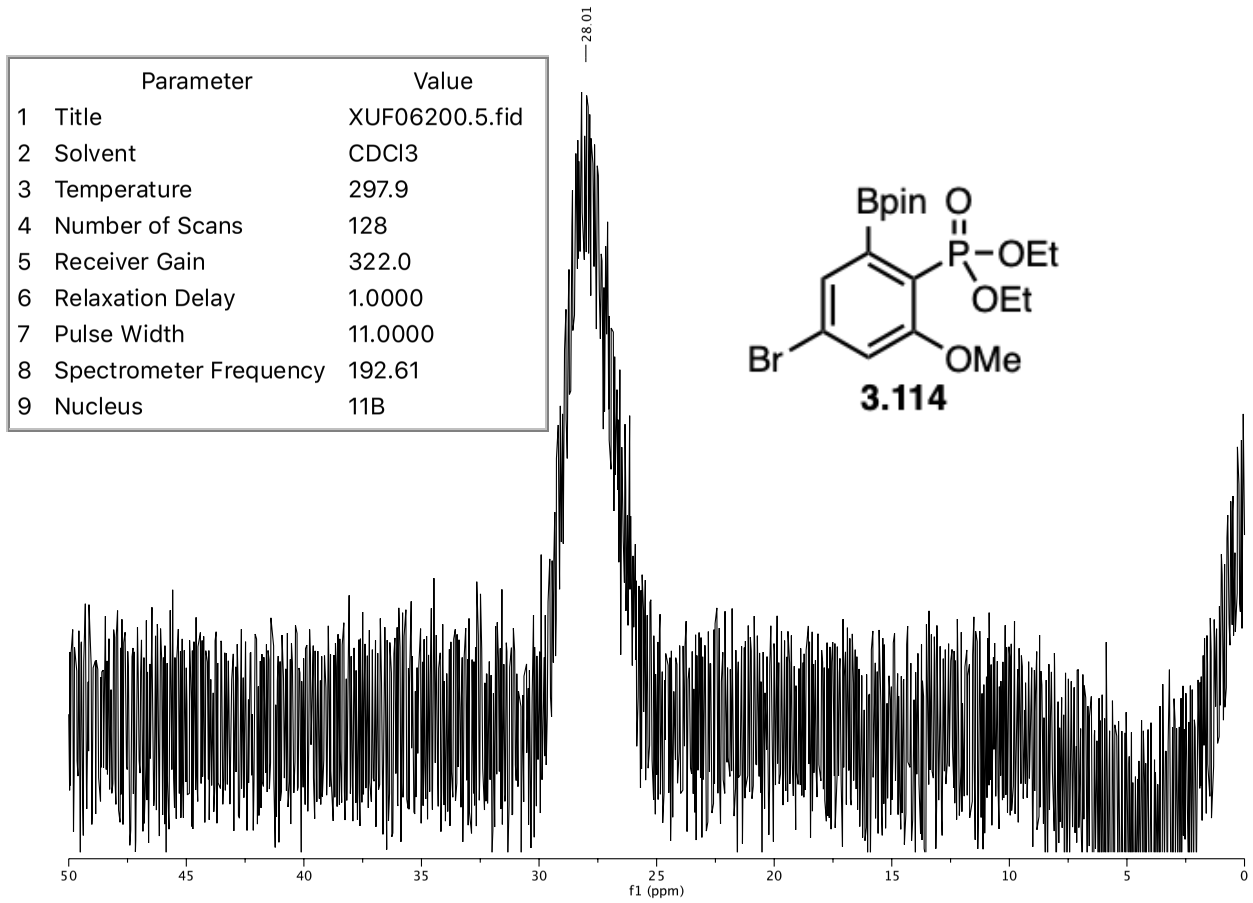

161.07
161.02
129.04
129.00
127.17
126.99
118.08
116.27
114.88
114.79
84.08
62.66
62.62
56.12
25.24
16.39
16.33
Parameter Value
1 Title XUF06200.4.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P
OEt
OEt
Br
OMe
3.114
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

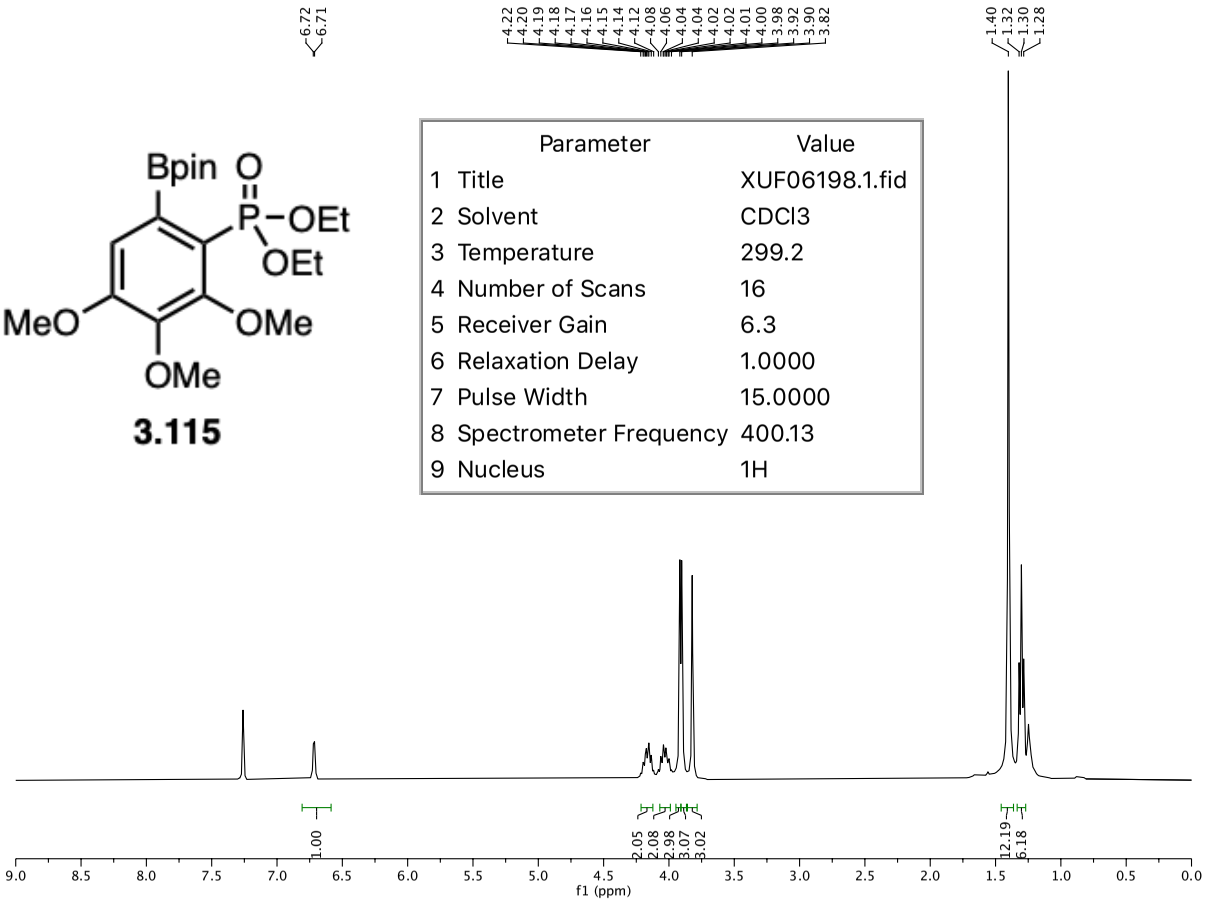
Parameter	Value
1 Title	XUF06200.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	3251.0
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

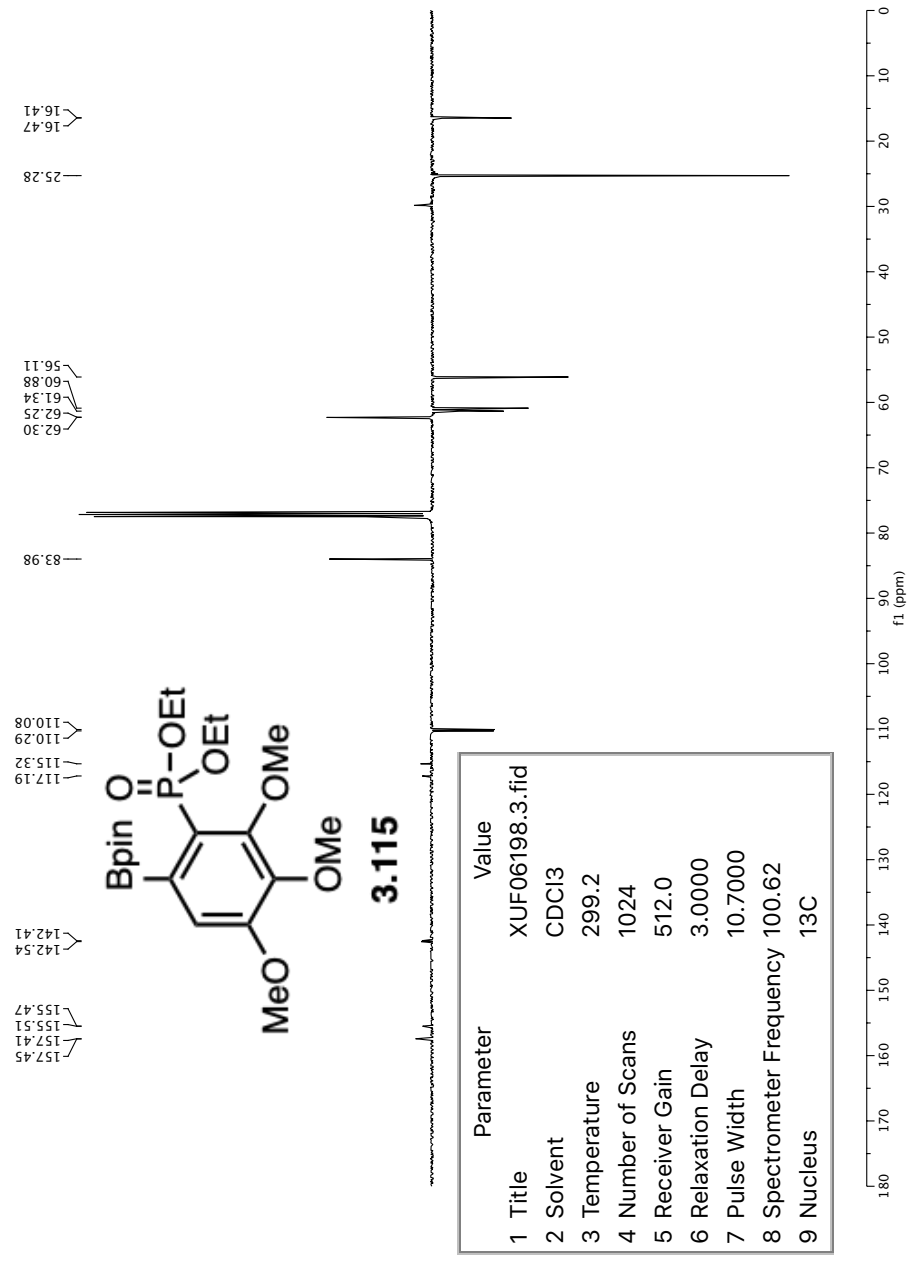


3.114

	Parameter	Value
1	Title	XUF06200.5.fid
2	Solvent	CDCl3
3	Temperature	297.9
4	Number of Scans	128
5	Receiver Gain	322.0
6	Relaxation Delay	1.0000
7	Pulse Width	11.0000
8	Spectrometer Frequency	192.61
9	Nucleus	11B

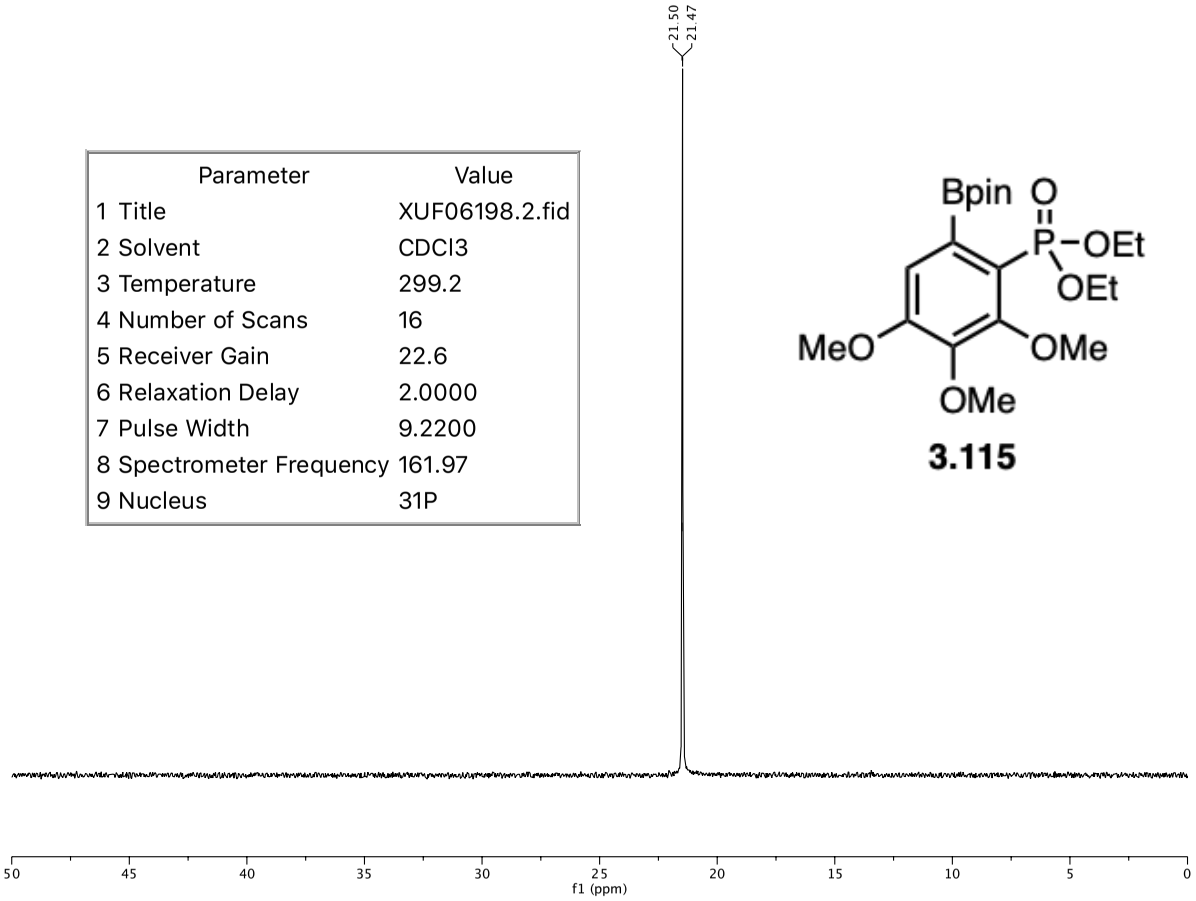


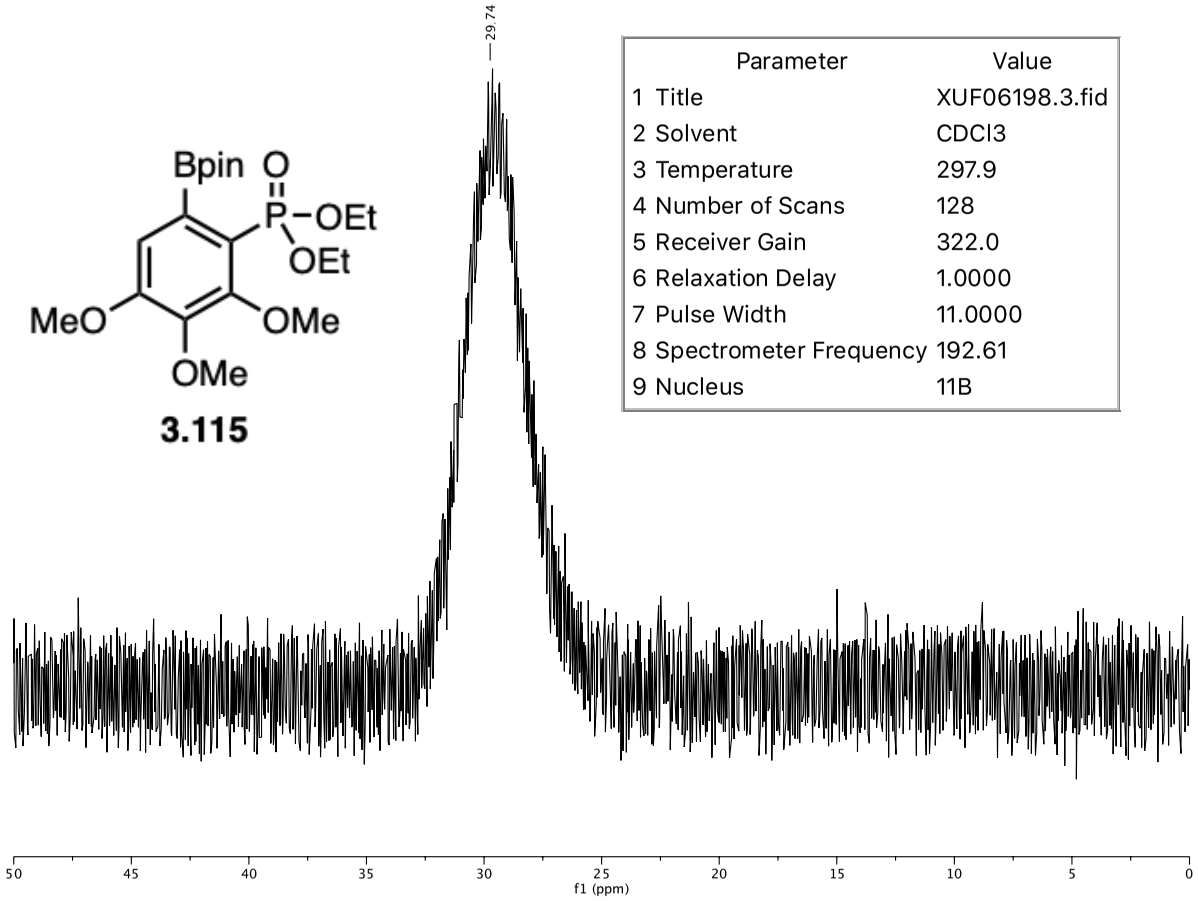

Bpin
O
P
OEt
OEt
MeO
OMe
OMe
3.115
Parameter Value
1 Title XUF06198.1.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 6.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
6.72
6.71
4.22
4.20
4.19
4.18
4.17
4.16
4.15
4.14
4.12
4.08
4.06
4.04
4.04
4.02
4.02
4.01
4.00
3.98
3.92
3.90
3.82
1.40
1.32
1.30
1.28
1.00
2.05
2.08
2.98
3.07
3.02
12.19
6.18
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

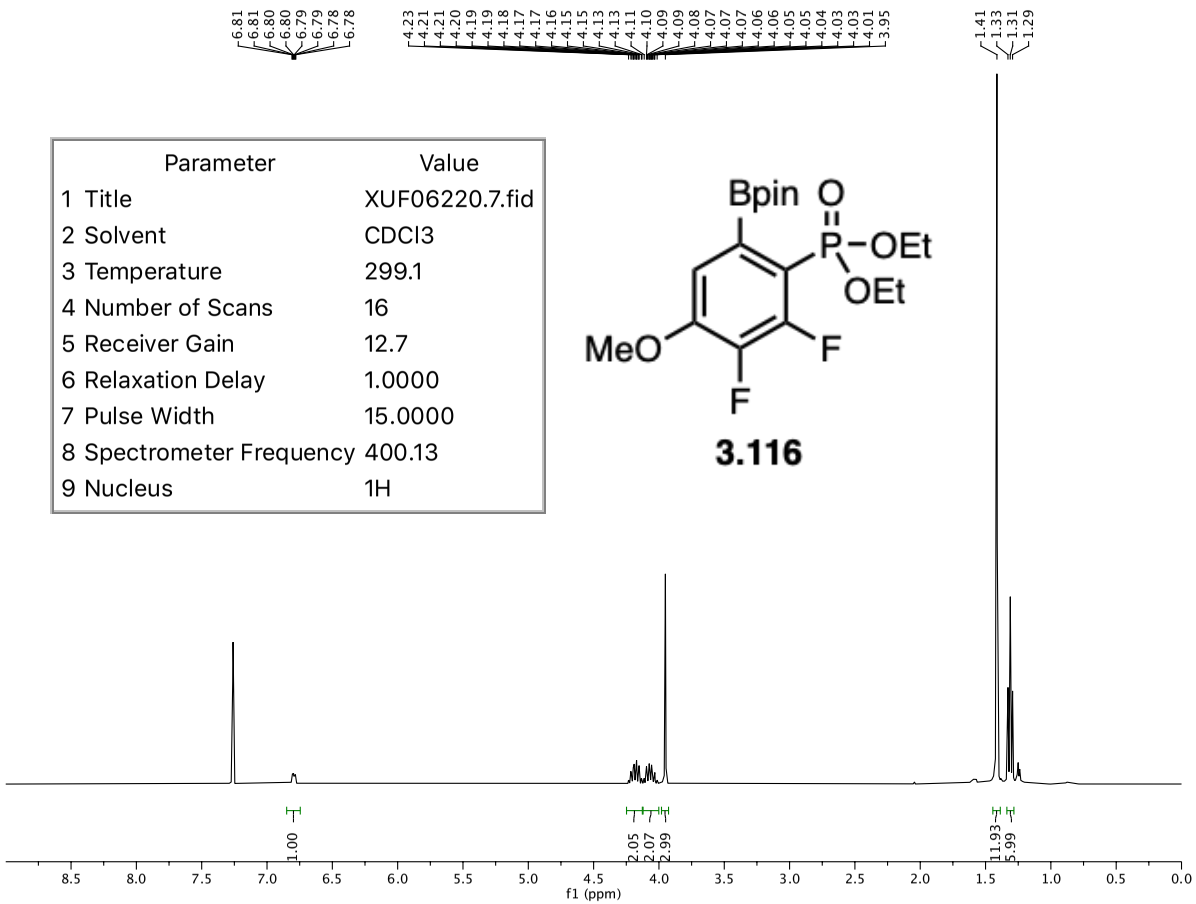

Bpin
O
P
OEt
OEt
OMe
OMe
MeO
3.115
157.45
157.41
155.51
155.47
142.54
142.41
117.19
115.32
110.29
110.08
83.98
62.30
62.25
61.34
60.88
56.11
25.28
16.47
16.41
Parameter Value
1 Title XUF06198.3.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
f1 (ppm)

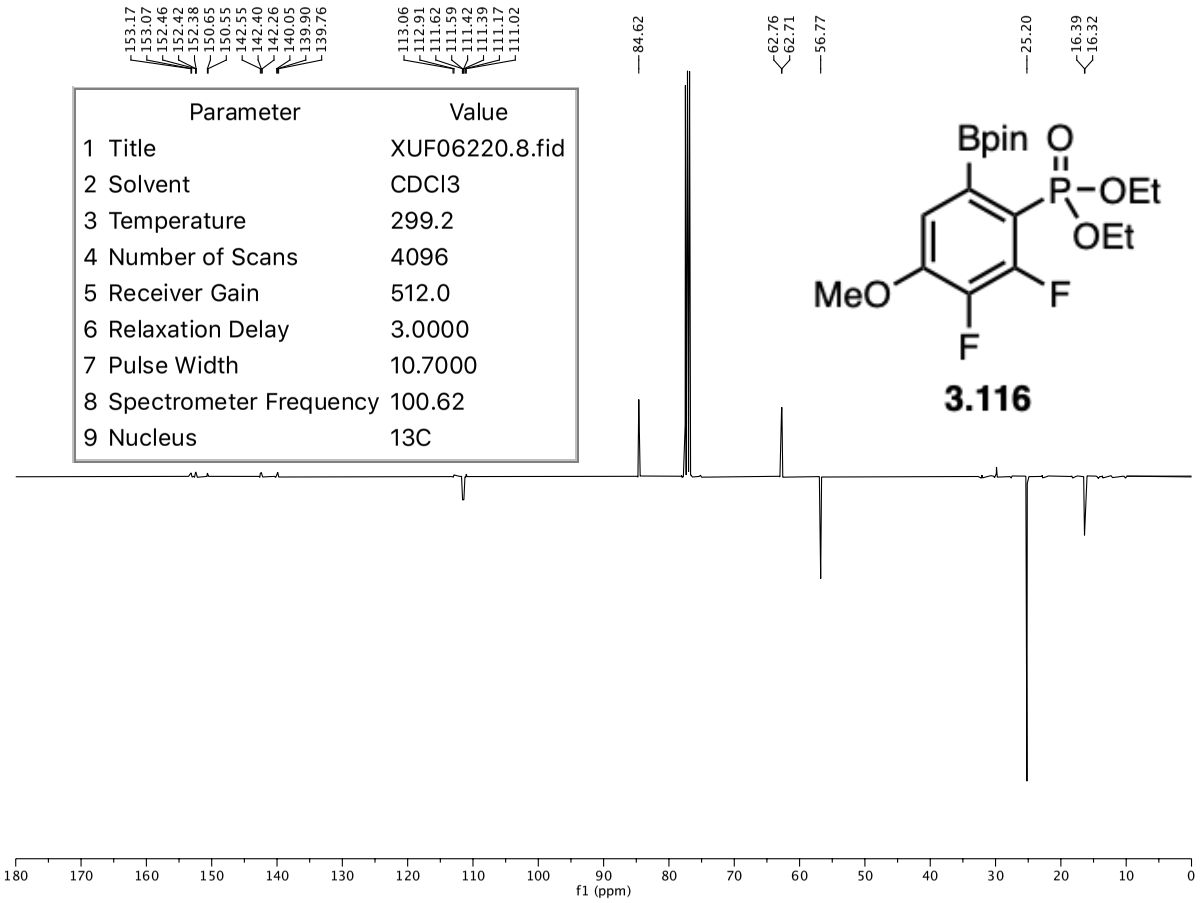
Parameter	Value
1 Title	XUF06198.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	22.6
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.115

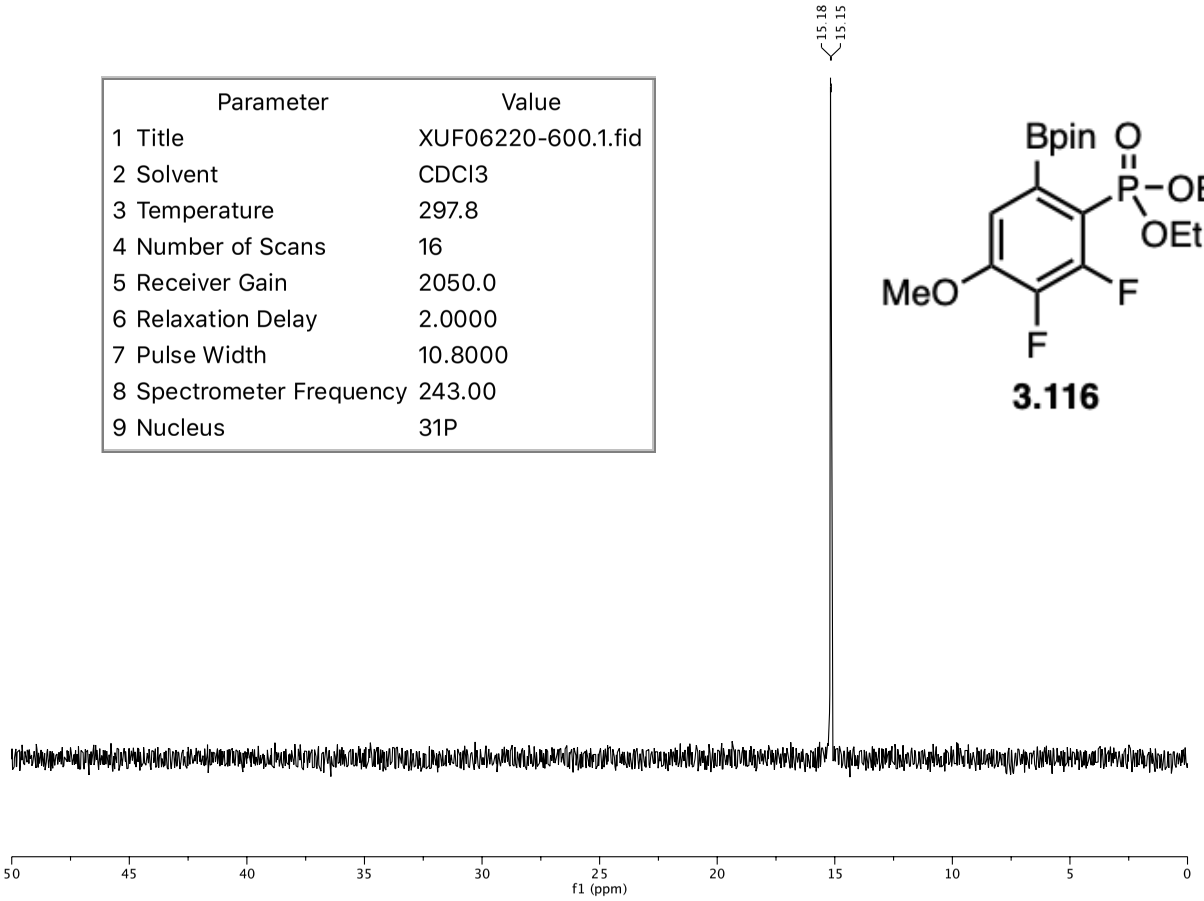



29.74
Bpin
O
P
OEt
OEt
MeO
OMe
OMe
3.115
Parameter Value
1 Title XUF06198.3.fid
2 Solvent CDCl3
3 Temperature 297.9
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


6.81
6.81
6.80
6.80
6.79
6.79
6.78
6.78
4.23
4.21
4.21
4.20
4.19
4.19
4.18
4.17
4.17
4.16
4.15
4.15
4.13
4.13
4.11
4.10
4.09
4.09
4.08
4.07
4.07
4.07
4.06
4.06
4.05
4.05
4.04
4.03
4.03
4.01
3.95
1.41
1.33
1.31
1.29
Parameter Value
1 Title XUF06220.7.fid
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Bpin
O
P
OEt
OEt
MeO
F
F
3.116
1.00
2.05
2.07
2.99
11.93
5.99
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


153.17
153.07
152.46
152.42
152.38
150.65
150.55
142.55
142.40
142.26
140.05
139.90
139.76
113.06
112.91
111.62
111.59
111.42
111.39
111.17
111.02
84.62
62.76
62.71
56.77
25.20
16.39
16.32
Parameter Value
1 Title XUF06220.8.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 4096
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Bpin
O
P
OEt
OEt
MeO
F
F
3.116
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06220-600.1.fid
2 Solvent	CDCl3
3 Temperature	297.8
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P



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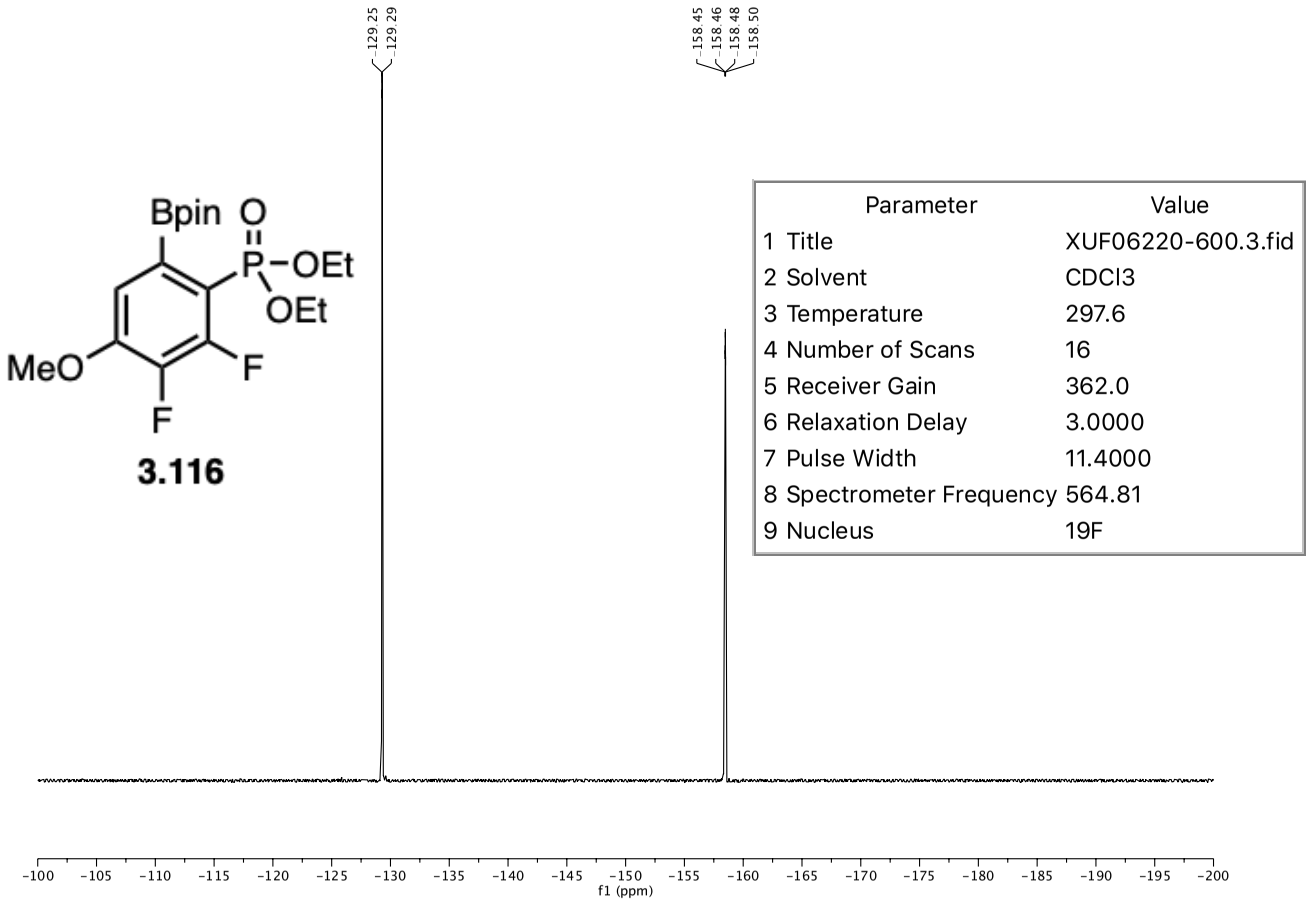

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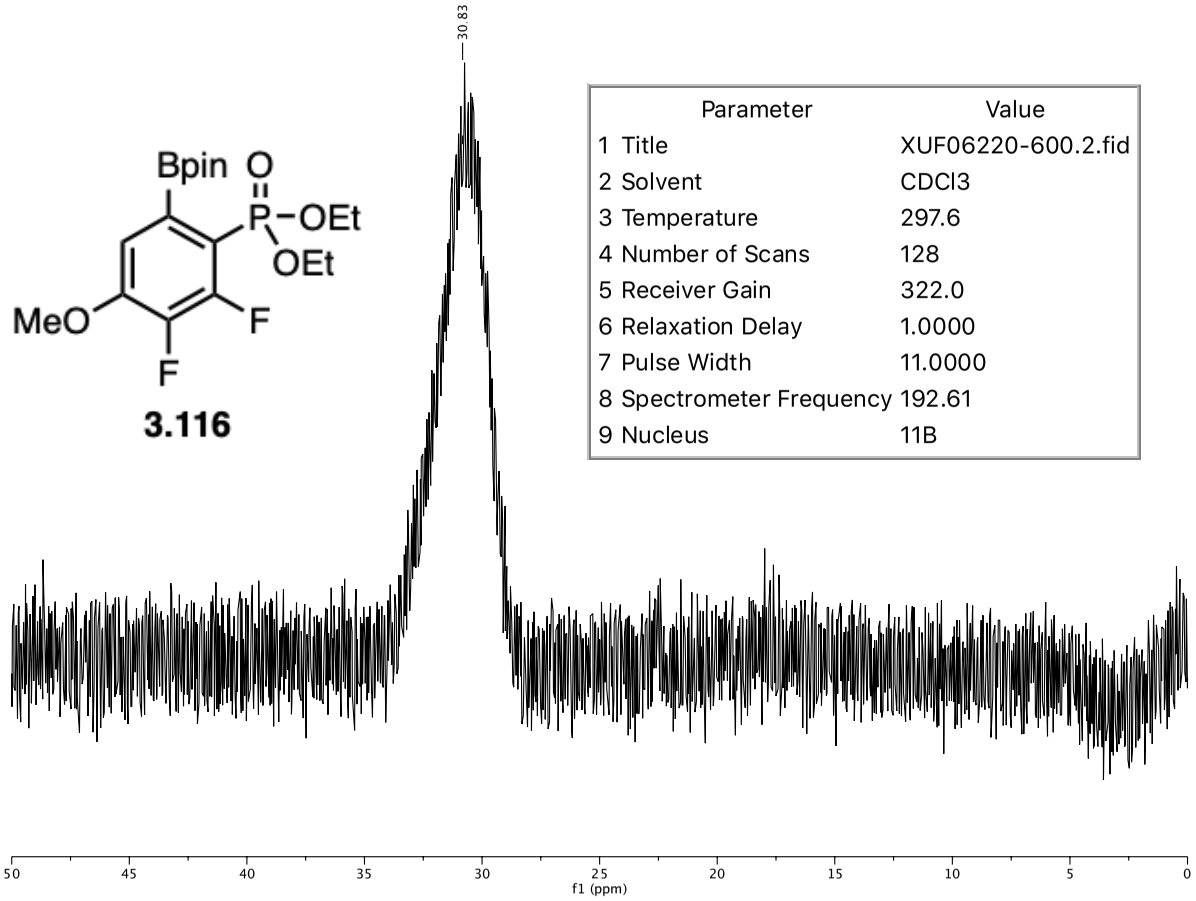
9 Nucleus	19F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O
P–OEt
OEt
MeO
F
F
3.116
30.83
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2 Solvent CDCl3
3 Temperature 297.6
4 Number of Scans 128
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7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
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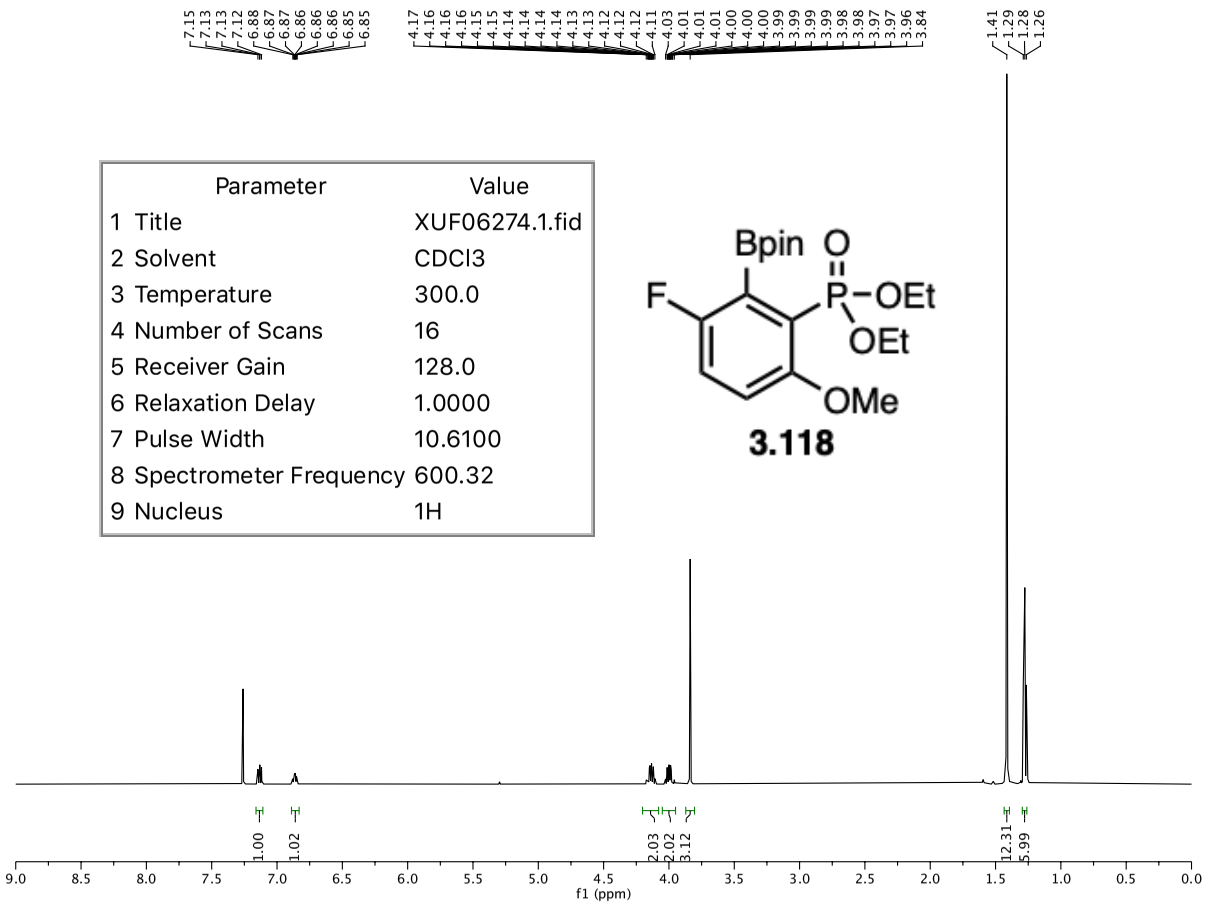
f1 (ppm)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4.16
4.16
4.16
4.15
4.15
4.14
4.14
4.14
4.14
4.13
4.13
4.12
4.12
4.12
4.11
4.03
4.01
4.01
4.01
4.00
4.00
4.00
4.00
3.99
3.99
3.99
3.99
3.98
3.98
3.97
3.97
3.96
3.84
1.41
1.29
1.28
1.26
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4 Number of Scans 16
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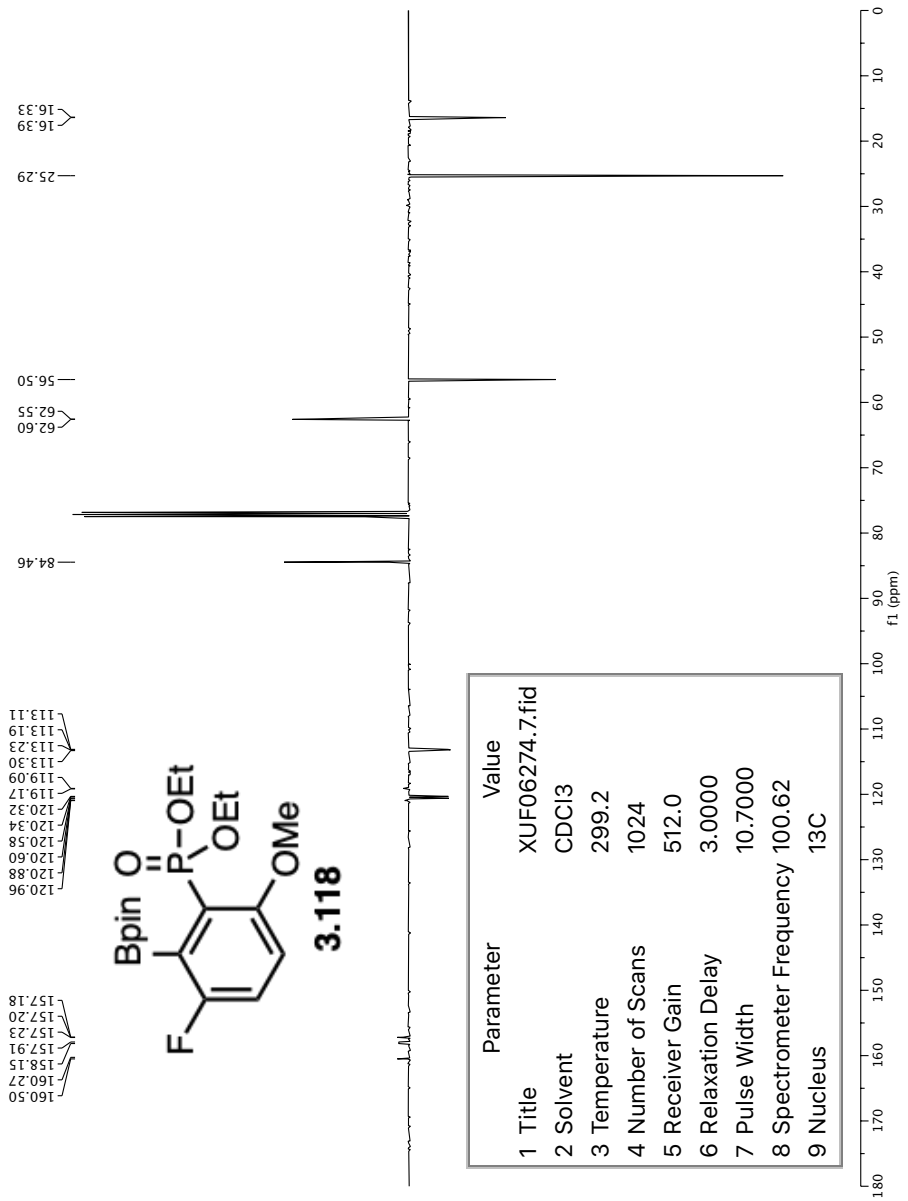
6 Relaxation Delay 1.0000
7 Pulse Width 10.6100
8 Spectrometer Frequency 600.32
9 Nucleus 1H
Bpin
O
F
P
OEt
OEt
OMe
3.118
1.00
1.02
2.03
2.02
3.12
12.31
5.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)



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4 Number of Scans	1024
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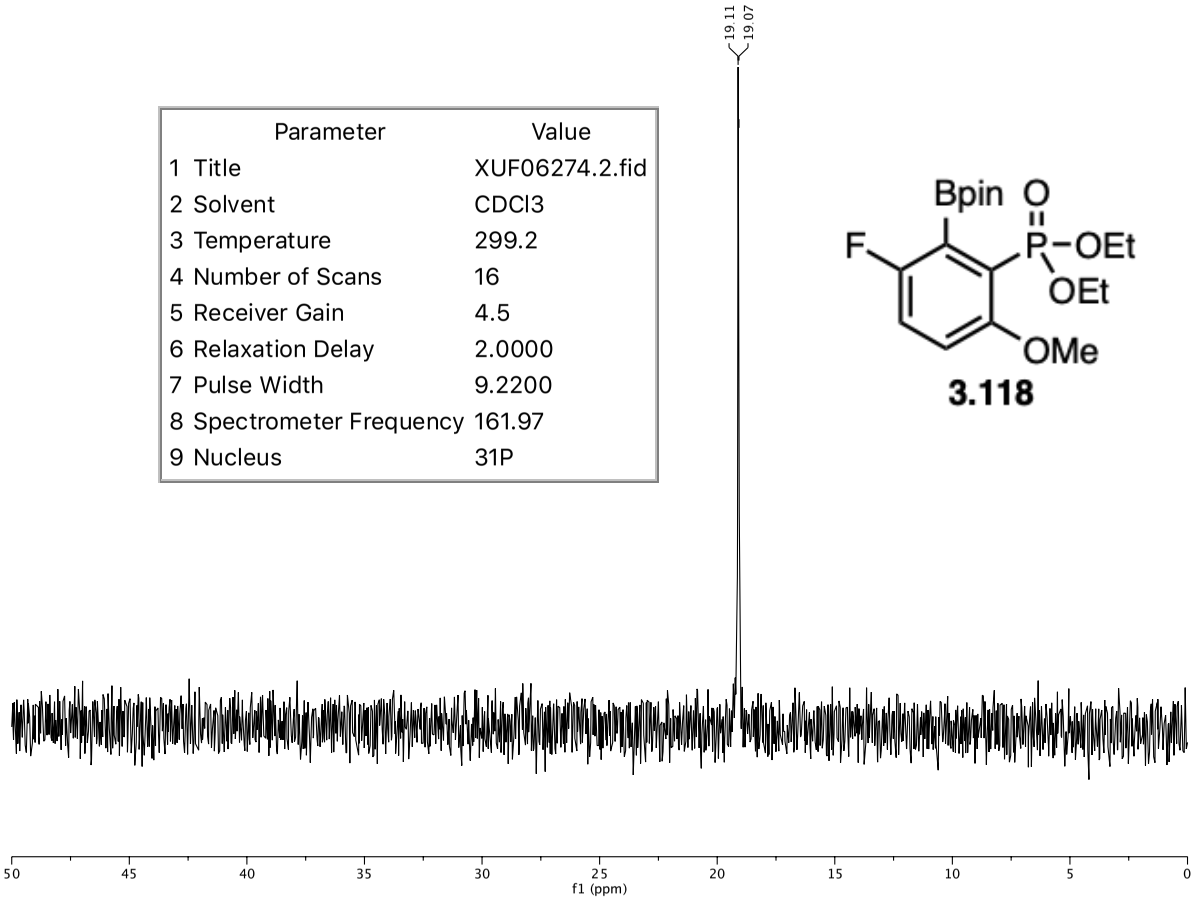
6 Relaxation Delay	3.0000
7 Pulse Width	10.7000
8 Spectrometer Frequency	100.62
9 Nucleus	13C

Parameter	Value
1 Title	XUF06274.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
5 Receiver Gain	4.5
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.118



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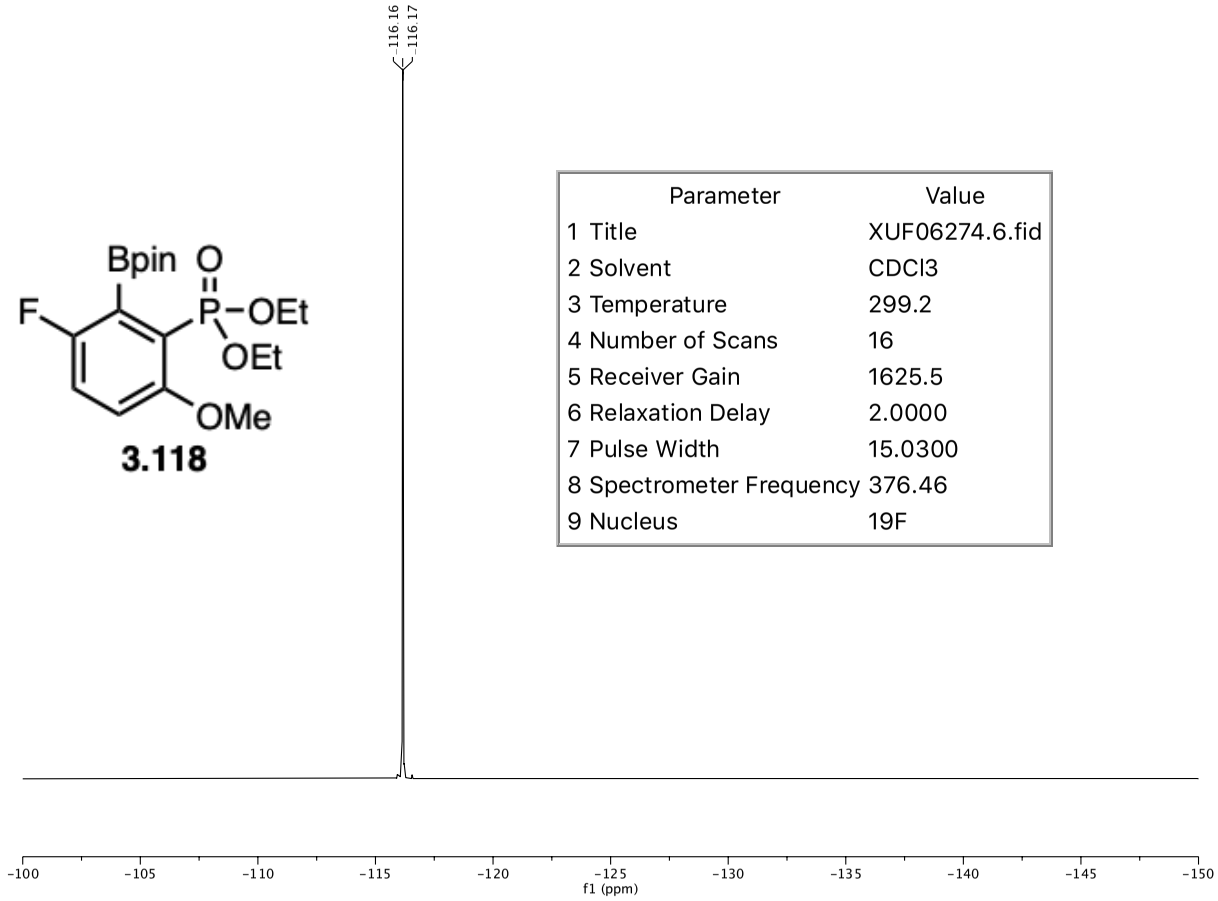

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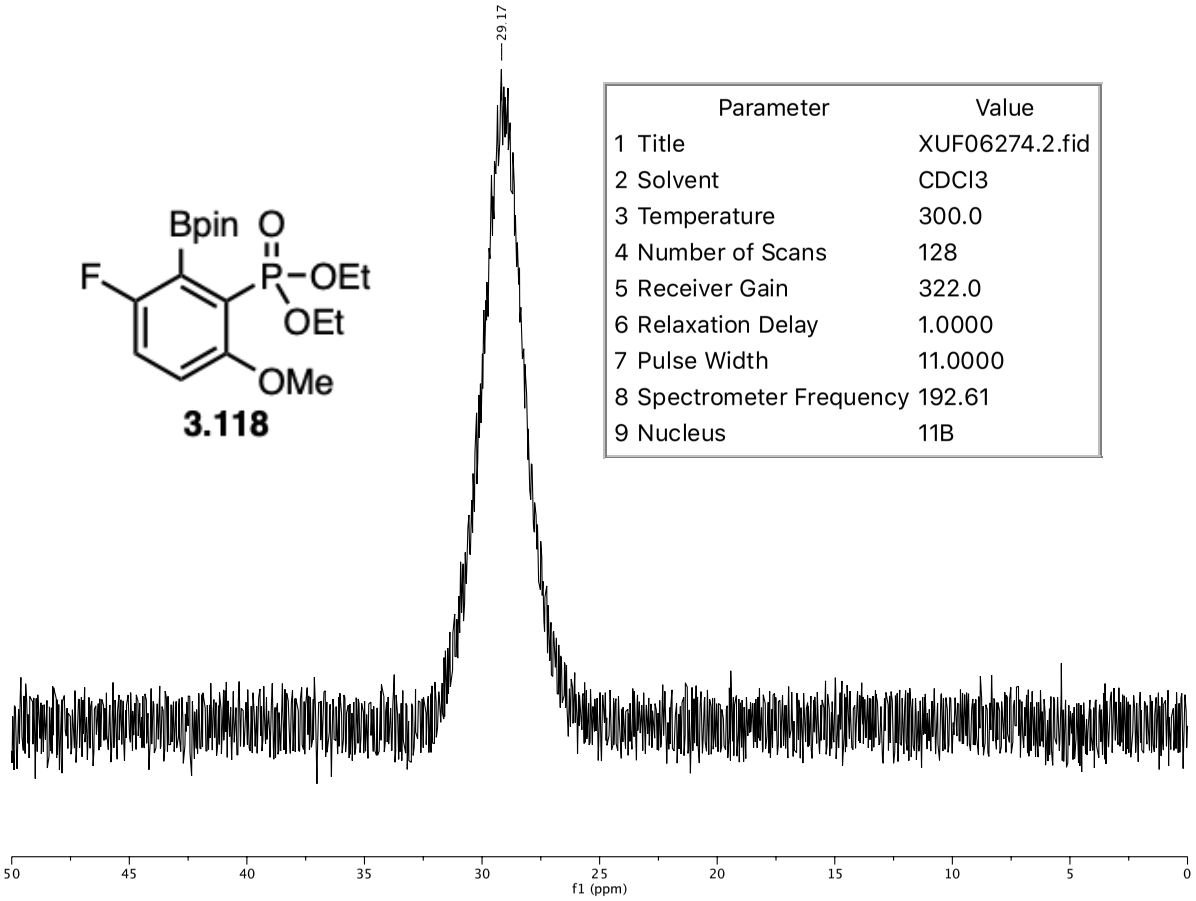
7 Pulse Width	15.0300
8 Spectrometer Frequency	376.46
9 Nucleus	19F


29.17
Bpin
O
F
P
OEt
OEt
OMe
3.118
Parameter Value
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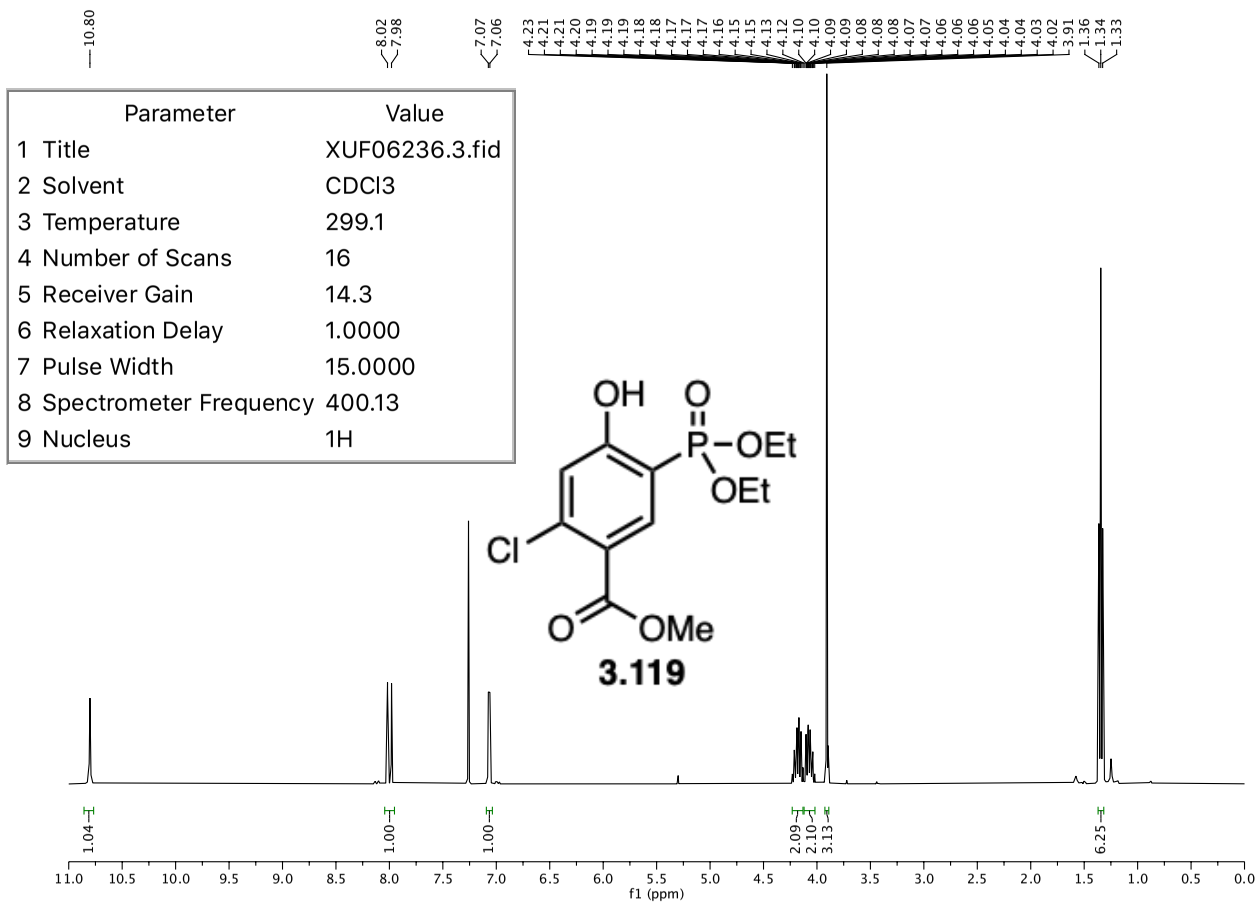
2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 128
5 Receiver Gain 322.0
6 Relaxation Delay 1.0000
7 Pulse Width 11.0000
8 Spectrometer Frequency 192.61
9 Nucleus 11B
50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


10.80
8.02
7.98
7.07
7.06
4.23 4.21 4.21 4.20 4.19 4.19 4.19 4.18 4.18 4.17 4.17 4.17 4.16 4.15 4.15 4.13 4.12 4.10 4.10 4.09 4.09 4.08 4.08 4.08 4.07 4.07 4.06 4.06 4.06 4.05 4.04 4.04 4.03 4.02
3.91
1.36
1.34
1.33
Parameter Value
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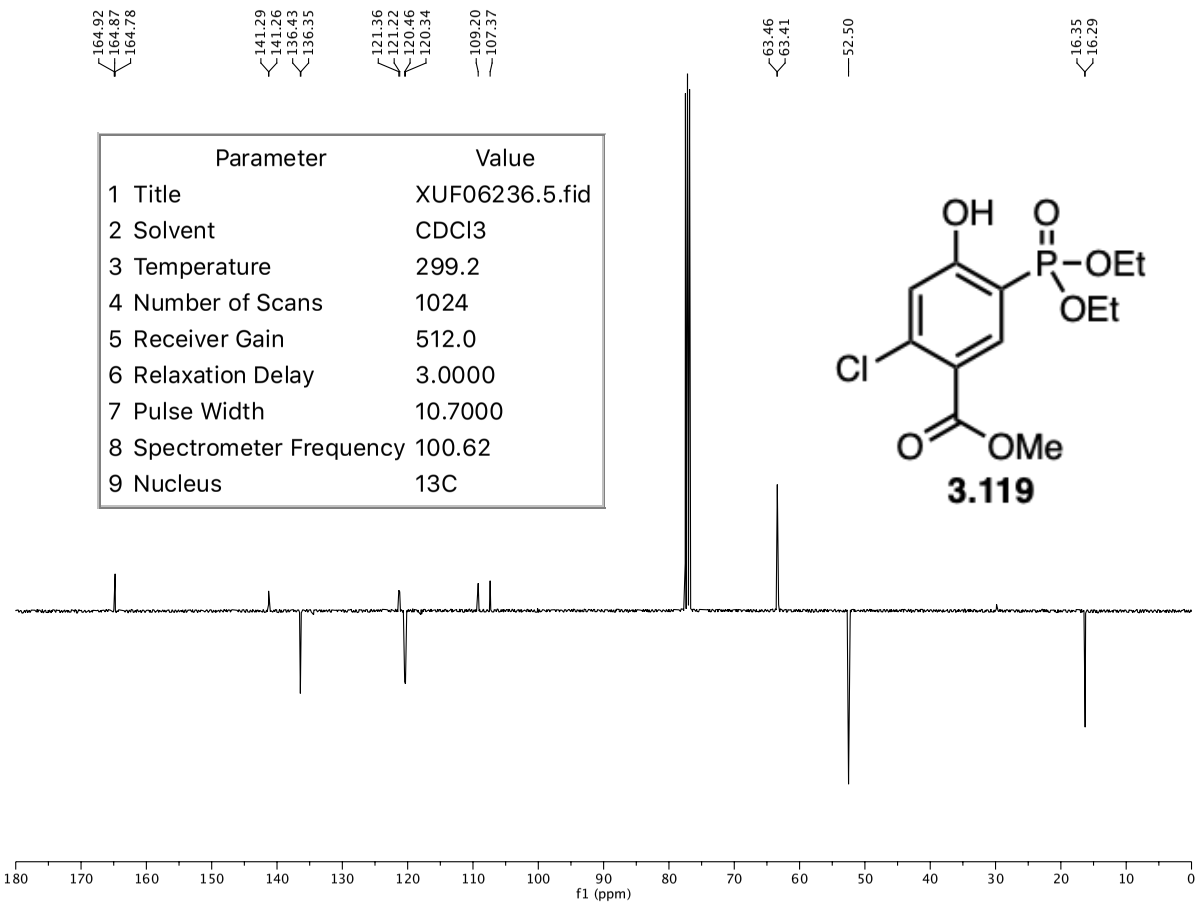
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 16
5 Receiver Gain 14.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
OH
O
P
OEt
OEt
Cl
O
OMe
3.119
1.04
1.00
1.00
2.09
2.10
3.13
6.25
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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164.87
164.78
141.29
141.26
136.43
136.35
121.36
121.22
120.46
120.34
109.20
107.37
63.46
63.41
52.50
16.35
16.29
Parameter Value
1 Title XUF06236.5.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
OH
O
P–OEt
OEt
Cl
O
OMe
3.119
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
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2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
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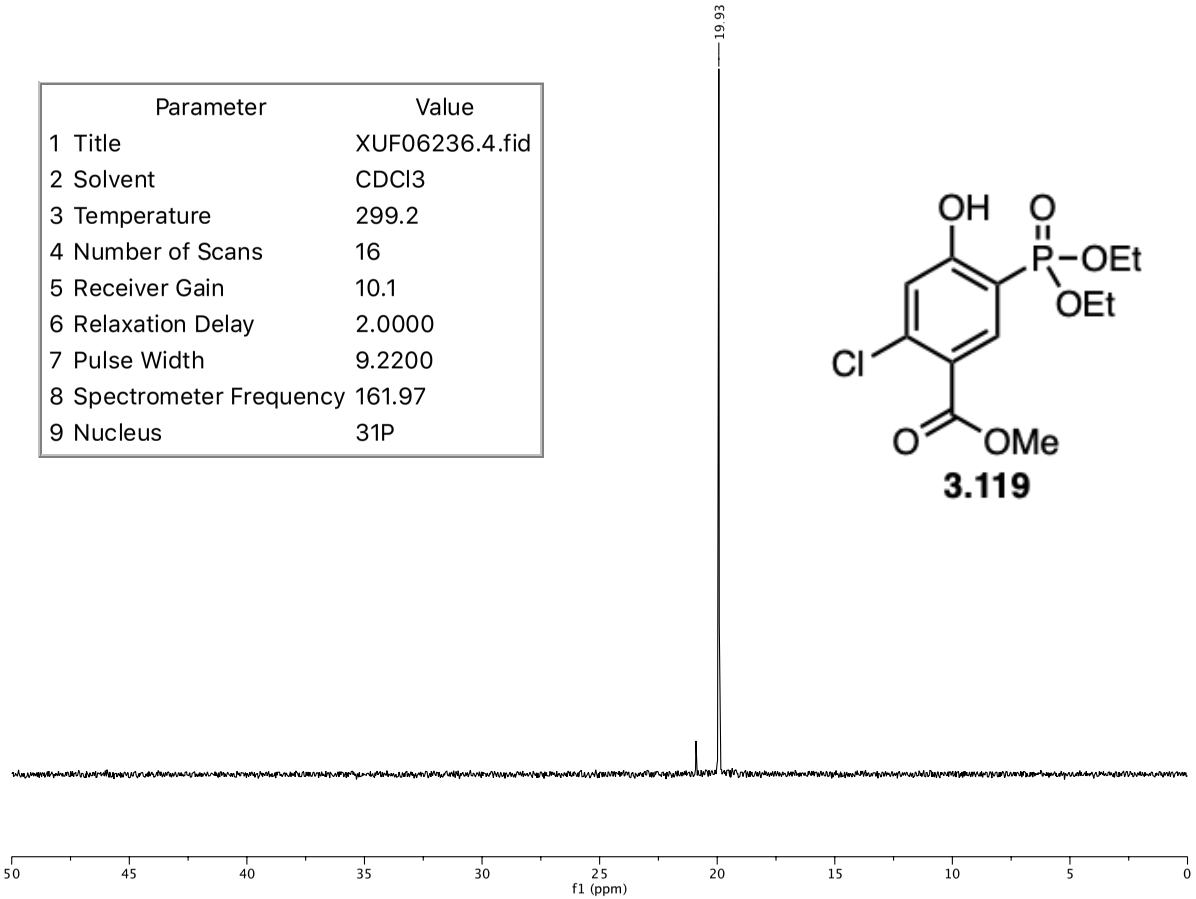
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P



3.119

6.88
6.87
6.86
6.86
6.85
6.85
6.84
4.29
4.27
4.26
4.25
4.25
4.25
4.23
4.23
4.23
4.22
4.21
4.20
4.19
4.19
4.18
4.18
4.17
4.17
4.17
4.16
4.15
4.15
4.15
4.15
4.13
3.93
1.38
1.36
1.34
Parameter Value
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2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 14.3
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
Cl
O
P
OEt
OEt
F
F
MeO
3.120
6.00
3.00
4.01
0.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

154.52
154.40
151.97
151.86
151.82
151.80
151.77
151.74
151.71
151.68
151.66
141.49
141.36
141.32
141.20
139.00
138.87
138.83
138.70
133.12
133.07
133.06
133.00
111.62
111.59
111.51
111.48
110.60
110.58
110.45
110.42
108.68
108.65
108.52
108.50
56.99
63.04
62.98
16.41
16.34
3.120
Cl
O
P
OEt
OEt
F
F
MeO
Parameter
Value
1 Title
XUF06234.3.fid
2 Solvent
CDCl3
3 Temperature
299.2
4 Number of Scans
2048
5 Receiver Gain
512.0
6 Relaxation Delay
3.0000
7 Pulse Width
10.7000
8 Spectrometer Frequency
100.62
9 Nucleus
13C
f1 (ppm)

Parameter	Value
1 Title	XUF06234.2.fid
2 Solvent	CDCl3
3 Temperature	299.2
4 Number of Scans	16
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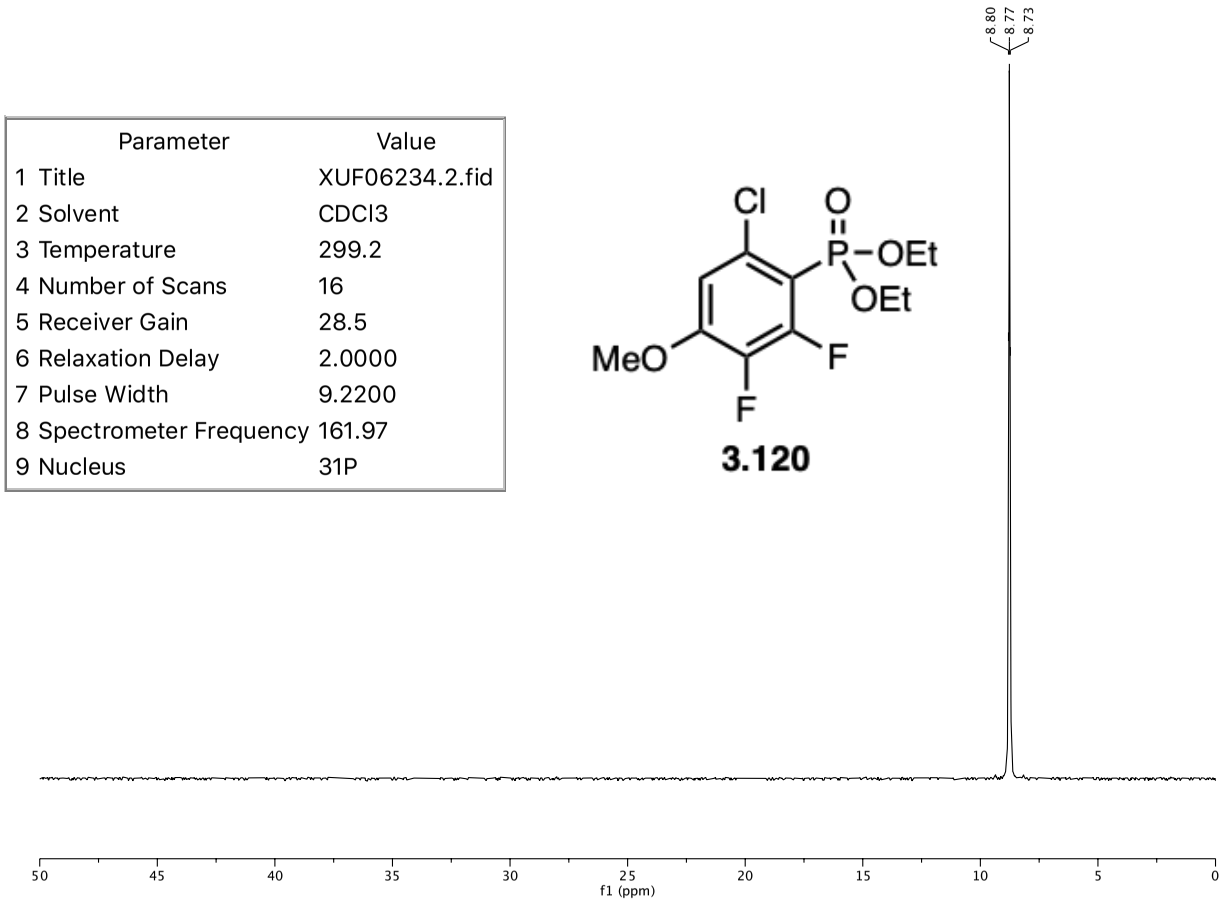
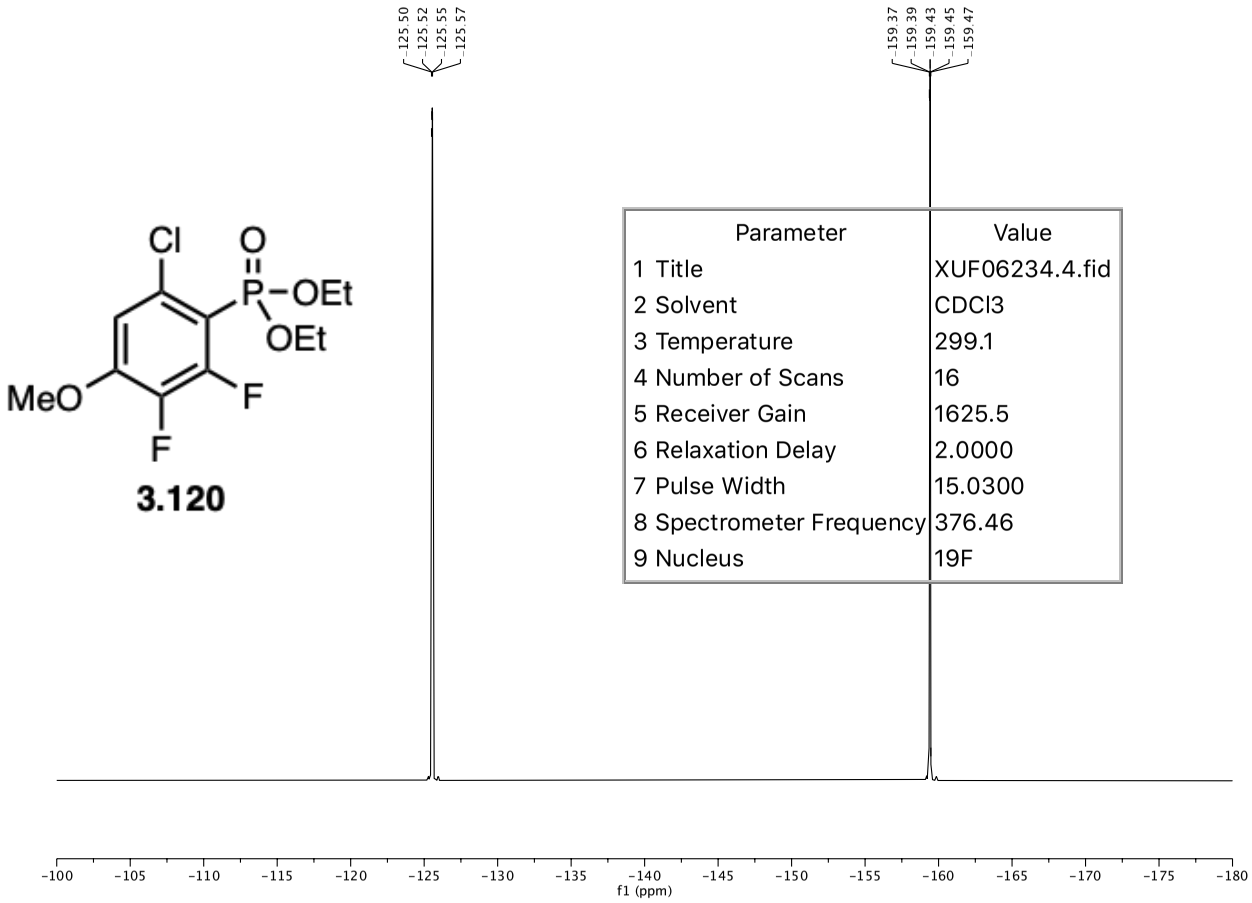
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.120




-125.50
-125.52
-125.55
-125.57
-159.37
-159.39
-159.43
-159.45
-159.47
Cl
O
P–OEt
OEt
MeO
F
F
3.120
Parameter
Value
1 Title
XUF06234.4.fid
2 Solvent
CDCl3
3 Temperature
299.1
4 Number of Scans
16
5 Receiver Gain
1625.5
6 Relaxation Delay
2.0000
7 Pulse Width
15.0300
8 Spectrometer Frequency
376.46
9 Nucleus
19F
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
-155
-160
-165
-170
-175
-180
f1 (ppm)

Parameter Value
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2 Solvent CDCl3
3 Temperature 300.0
4 Number of Scans 16
5 Receiver Gain 114.0
6 Relaxation Delay 1.0000
7 Pulse Width 10.6100
8 Spectrometer Frequency 600.32
9 Nucleus 1H
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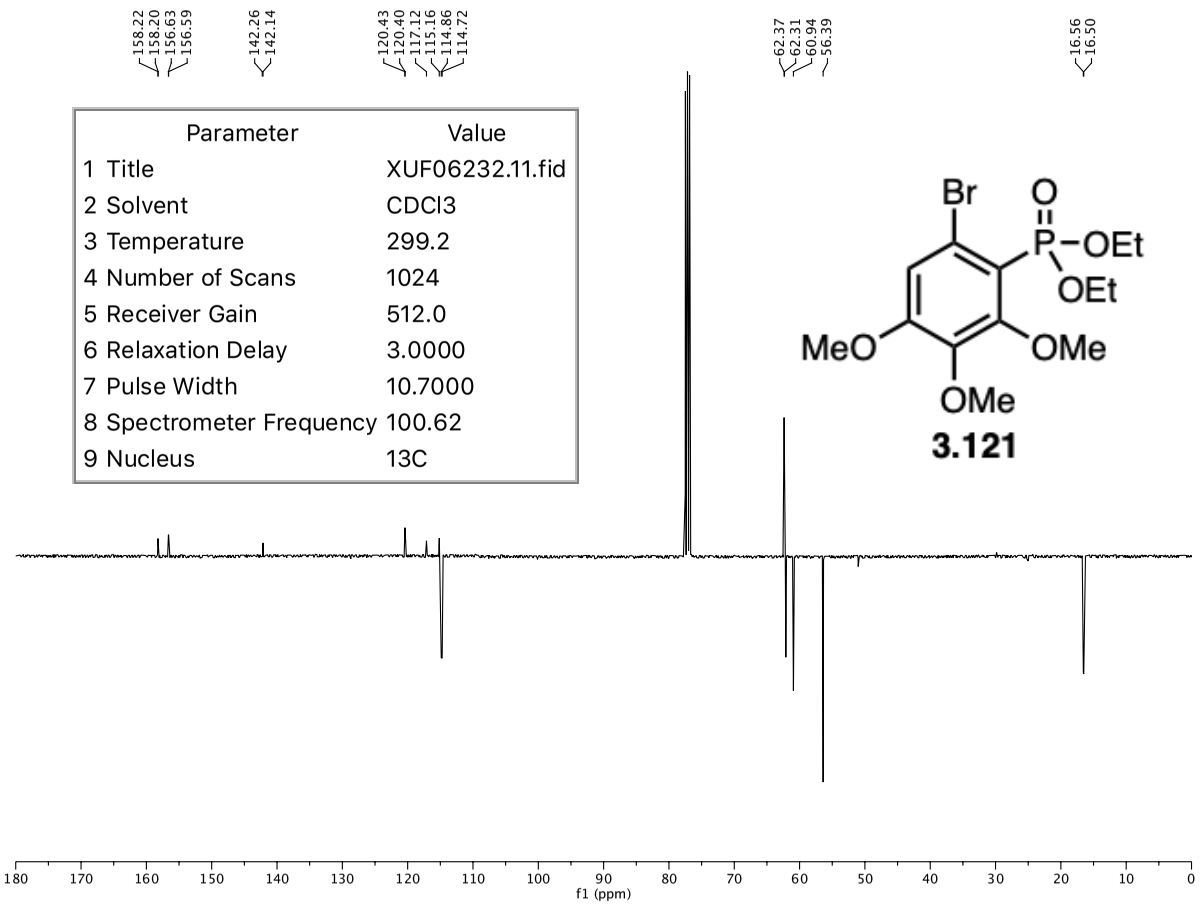
O
P
OEt
OEt
OMe
OMe
MeO
3.121
f1 (ppm)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156.59
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142.14
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114.72
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62.31
60.94
56.39
16.56
16.50
Parameter Value
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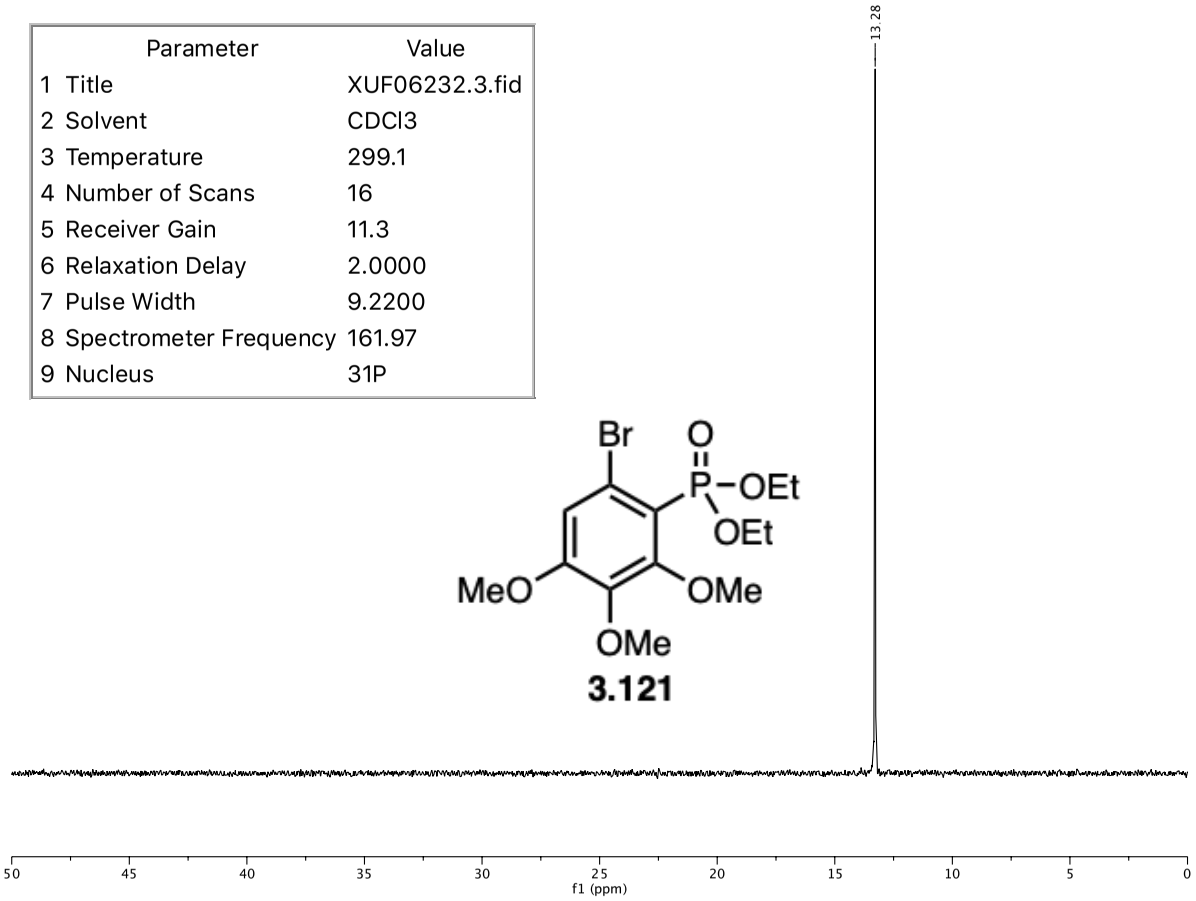
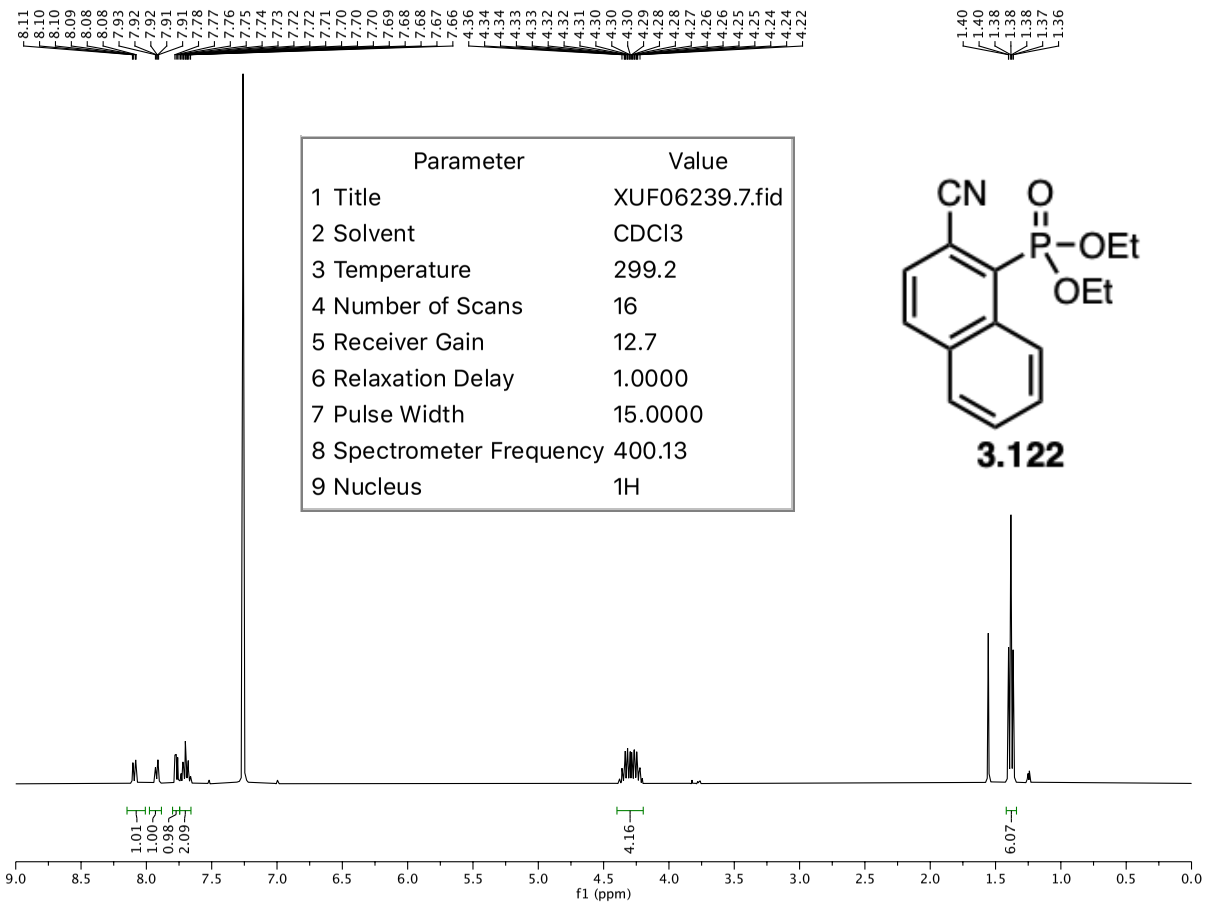
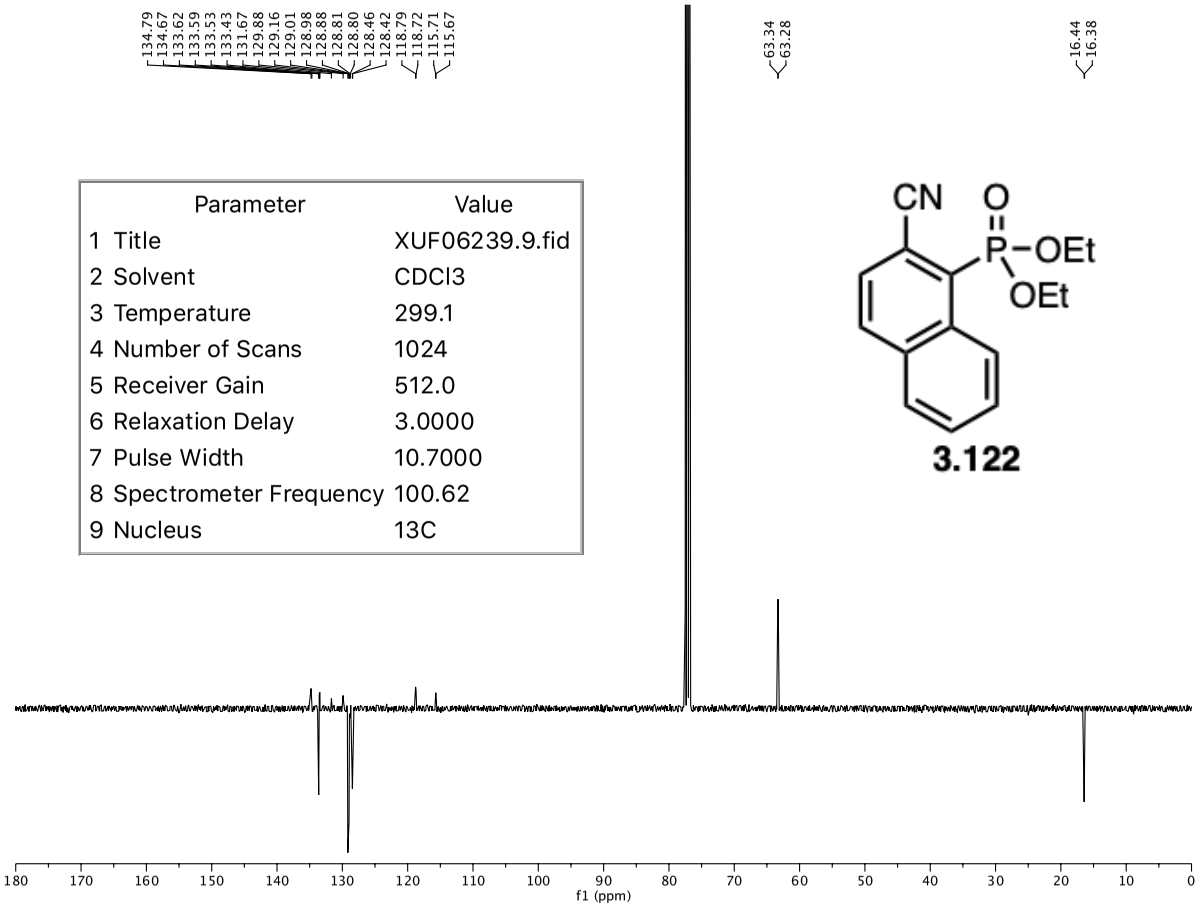
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
Br
O
P–OEt
OEt
MeO
OMe
OMe
3.121
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06232.3.fid
2 Solvent	CDCl3
3 Temperature	299.1
4 Number of Scans	16
5 Receiver Gain	11.3
6 Relaxation Delay	2.0000
7 Pulse Width	9.2200
8 Spectrometer Frequency	161.97
9 Nucleus	31P

3.121




8.11 8.10 8.10 8.09 8.08 8.08 7.93 7.92 7.92 7.91 7.91 7.78 7.77 7.76 7.75 7.74 7.73 7.72 7.72 7.71 7.70 7.70 7.70 7.69 7.68 7.68 7.67 7.66 4.36 4.34 4.34 4.33 4.32 4.32 4.31 4.30 4.30 4.29 4.28 4.28 4.27 4.26 4.26 4.25 4.25 4.24 4.24 4.22 1.40 1.40 1.38 1.38 1.38 1.37 1.36
Parameter Value
1 Title XUF06239.7.fid
2 Solvent CDCl3
3 Temperature 299.2
4 Number of Scans 16
5 Receiver Gain 12.7
6 Relaxation Delay 1.0000
7 Pulse Width 15.0000
8 Spectrometer Frequency 400.13
9 Nucleus 1H
CN
O
P–OEt
OEt
3.122
1.01 1.00 0.98 2.09 4.16 6.07
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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133.59
133.53
133.43
131.67
129.88
129.16
129.01
128.98
128.88
128.81
128.80
128.46
128.42
118.79
118.72
115.71
115.67
63.34
63.28
16.44
16.38
Parameter Value
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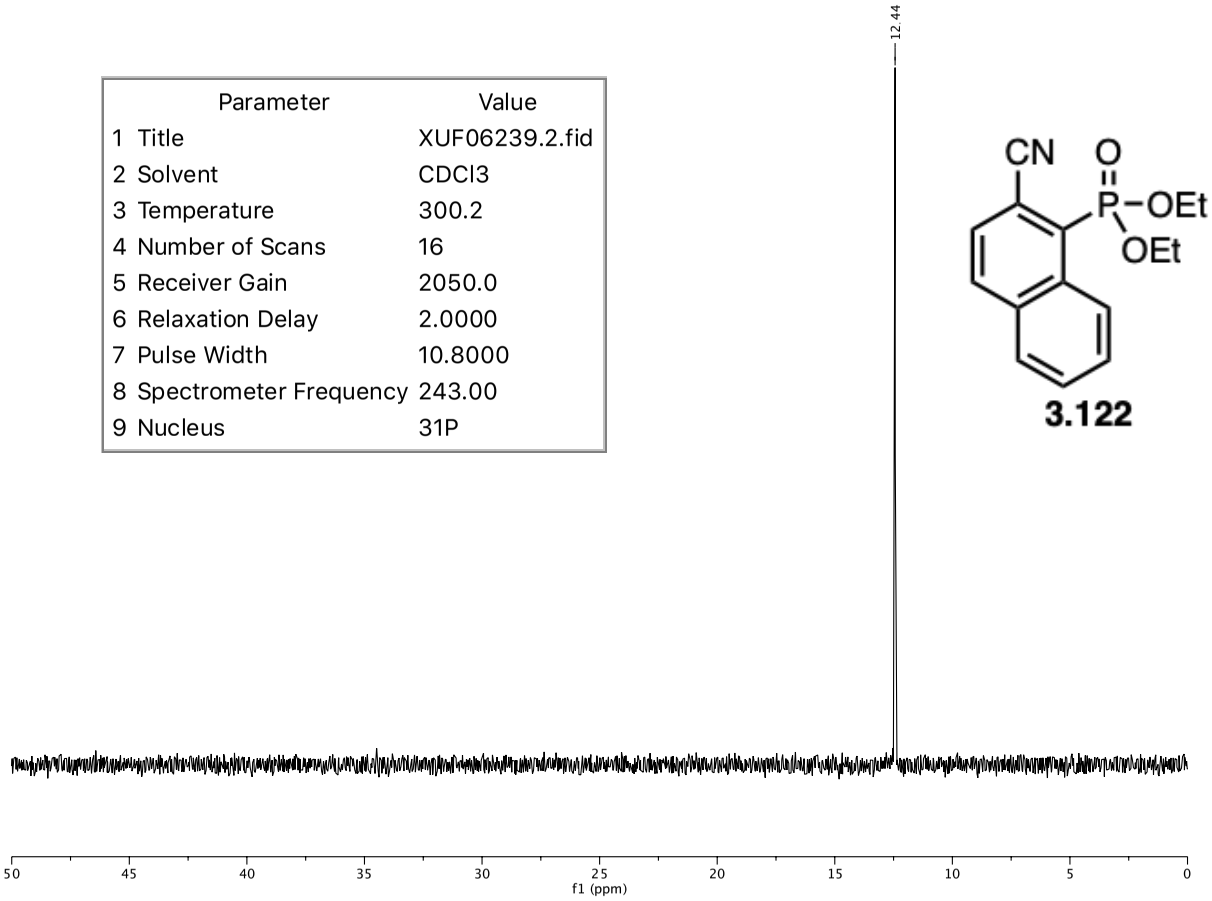
2 Solvent CDCl3
3 Temperature 299.1
4 Number of Scans 1024
5 Receiver Gain 512.0
6 Relaxation Delay 3.0000
7 Pulse Width 10.7000
8 Spectrometer Frequency 100.62
9 Nucleus 13C
CN
O
P
OEt
OEt
3.122
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Parameter	Value
1 Title	XUF06239.2.fid
2 Solvent	CDCl3
3 Temperature	300.2
4 Number of Scans	16
5 Receiver Gain	2050.0
6 Relaxation Delay	2.0000
7 Pulse Width	10.8000
8 Spectrometer Frequency	243.00
9 Nucleus	31P

3.122

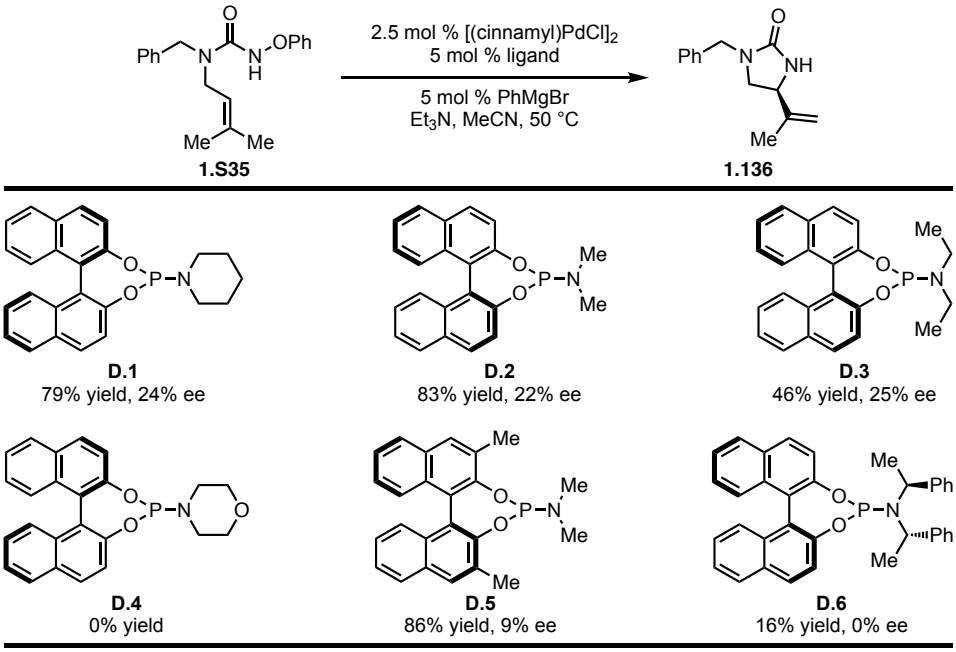


Appendix D

PRELIMINARY RESULTS

D.1 Preliminary Result of Enantioselective Imidazolidinone-Forming Aza-Heck Cyclization

Due to the broad substrate scope and complex ring topologies observed in the imidazolidinone-forming aza-Heck cyclization, we would like to develop an asymmetric version of this method to prepare enantioenriched imidazolidinones. The preliminary examination of chiral ligands revealed that many binol-based chiral phosphoramidite ligands could be used to deliver products in good yields with appreciate level of enantioselectivity (Figure D.1). Using (*S*)-MonoPhos (**D.2**), for example, the cyclization of **1.S35** provided 83% yield of imidazolidinone **1.136** with 22% ee. This is one future direction for this project.



[a] Yields calculated by ^{1}H NMR analysis with 1,3,5-trimethoxybenzene as internal standard.

Figure D.1: Preliminary Asymmetric Imidazolidinone-Forming Aza-Heck Cyclization

D.1.1 General Procedure of Figure D.1

In a N_2-refilled glovebox, $[(cinnamyl)PdCl]_2$ (2.6 mg, 5.0 umol, 0.025 equiv), ligand (10 umol, 0.050 equiv), and **1.S35** (62.1 mg, 200 umol, 1.00 equiv) were added to a 1-dram reaction vial. Anhydrous MeCN (4 mL), anhydrous Et_3N (56.0 uL, 200 umol, 2.00 equiv), and PhMgBr (6.9 uL, 1.44 M in THF, 10 umol, 0.050 equiv) were added sequentially to the vial via micropipette. The reaction vial was then capped with a Teflon-sealed cap and placed in a pre-heated 50 °C heating block to stir for 24 h. Upon completion, the reaction was cooled to rt, opened to air, and then diluted with EtOAc (2 mL). 1,3,5-trimethoxybenzene (11.2 mg, 66.7 umol, 0.333 equiv) was added into the reaction vial as internal standard. The crude reaction yield was then determined by ^{1}H NMR analysis, and the enantiomeric excess was determined by chiral SFC analysis.

D.2 Preliminary Result of Enantioselective Indoline-Forming Aza-Heck Cyclization

Due to the wide range of topologically complex products observed above, we are motivated to develop an asymmetric version of this chemistry. Currently, asymmetric cyclizations are still very challenging in this field. Even though there are a few asymmetric indoline-forming aza-Wacker cyclizations reported, the enantioselectivties of those methods are limited (up to 74% ee with only one substrate). In this chemistry, however, with only limited optimization, I observed the formation of **2.60** with appreciable enantioselectivity using the classic chiral ligand (*R*)-BINAP (Figure D.2). This result provides the evidence for the feasibility of asymmetric indoline-forming aza-Heck cyclization.

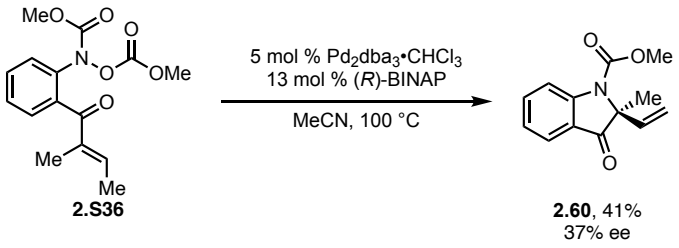


Figure D.2: Preliminary Asymmetric Indoline-Forming Aza-Heck Cyclization

With further optimization, I identified the use of an electron-deficient PHOX ligand in this reaction, which provides decent yield of cyclized product with very promising enantioselectivity (Figure D.3). This is one future direction for this project, and currently being discovered by other group members.

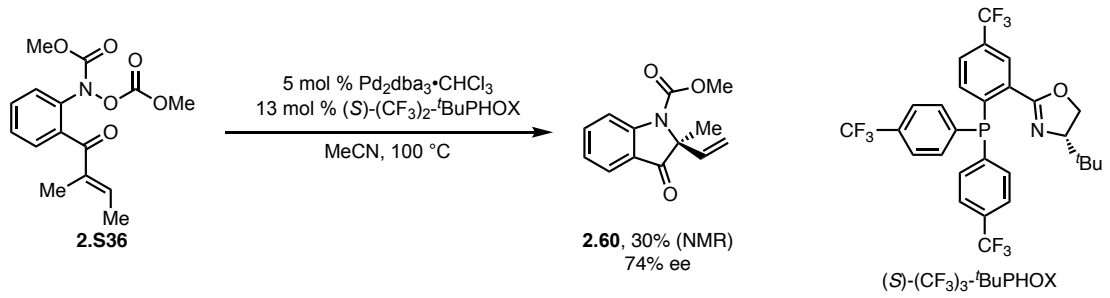
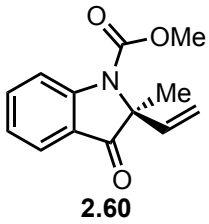


Figure D.3: Promising Enantioselectivity with the Use of PHOX Ligand

D.2.1 General Procedure of Figure D.2



(**2.60**) A 25 mL flame-dried Schlenk flask equipped with a magnetic stir bar and rubber septum was attached to a double manifold and cooled under vacuum. The flask was backfilled with N_2, the septum was removed. Pd_2dba_3•$CHCl_3$ (51.8 mg, 50 umol, 0.050 equiv), (*R*)-BINAP (77.8 mg, 0.13 mmol, 0.13 equiv), and *N*-aryl-*N*-hydroxy carbamate **2.S36** (307.5 mg, 1.00 mmol, 1.00 equiv) were added to the flask. The septum was replaced, and the flask was evacuated and backfilled with N_2 four times. Anhydrous MeCN (20 mL) was added to the flask via syringe. The resulting solution was allowed to stir at rt for 1 h, and then placed in a pre-heated oil bath and stirred at 100 °C for 24 h under sealed environment. Upon completion, the reaction was cooled to rt, then added *L*-Cysteine ethyl ester hydrochloride (139.3 mg, 750 umol, 15.0 equiv to Pd_2dba_3•$CHCl_3$) and Et_3N (0.66 mL, 5.0 mmol, 100 equiv to Pd_2dba_3•$CHCl_3$). The reaction mixture was stirred at rt for 1 h, then opened to air and diluted with CH_2Cl_2 (10 mL). The suspension was transferred to a round bottom flask and adsorbed onto Celite via rotary evaporation. The resulting powder was directly chromatographed (linear gradient, 1:99 EtOAc:hexanes to 5:95 EtOAc:hexanes) on silica gel (5-20 μm particle size) to afford

indoline **2.60** (94.2 mg, 41%, 37% ee) as yellow oil. The enantiomeric excess was determined to be 37% ee by chiral HPLC analysis (CHIRALPAK OD-H, 0.2 mL/min, 2.0% ^{i}PrOH/hexanes, λ = 254 nm); t_R(major) = 35.542 min, t_R(minor) = 37.331 min.

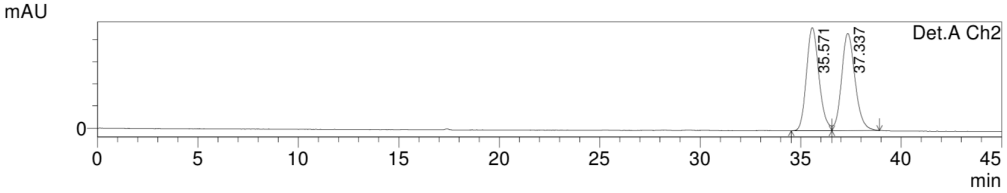
^{1}H NMR (400 MHz, DMSO-d_6) δ 8.18 (bs, 1H), 7.81 (ddd, J = 8.6, 7.2, 1.5 Hz, 1H), 7.72 (d, J = 7.3 Hz, 1H), 7.27 (t, J = 7.4 Hz, 1H), 5.86 (dd, J = 17.3, 10.6 Hz, 1H), 5.21 (d, J = 10.6 Hz, 1H), 5.17 (d, J = 17.3 Hz, 1H), 3.81 (s, 3H), 1.62 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 197.7, 151.8, 151.6, 137.9, 135.8, 124.5, 123.8, 121.2, 116.6, 116.0, 70.9, 53.0, 20.5.

FTIR (cm^{-1}): 1713, 1608, 1468, 1359, 1256.

HRMS (ESI) m/z, calculated for $[C_{13}H_{14}NO_3]^+$: 232.0974; found: 232.0963.

Racemic **2.60**

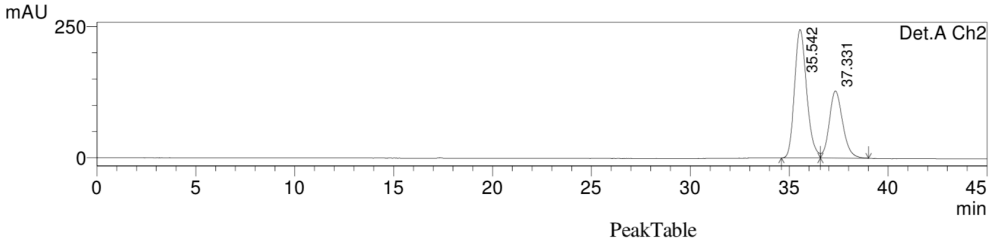


PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	35.571	4044907	93311	49.701	51.482
2	37.337	4093503	87939	50.299	48.518
Total		8138410	181250	100.000	100.000

Enantioenriched **2.60**, 37% ee



PeakTable

Detector A Ch2 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	35.542	10422621	244493	63.341	65.690
2	37.331	6032154	127701	36.659	34.310
Total		16454775	372195	100.000	100.000

D.3 Preliminary Result of Intermolecular C-H Amination

Besides the intramolecular aza-Heck cyclizations, I have also discovered reaction condition for intermolecular C-H amination using electron-rich nitrogen electrophiles (Figure D.4). This transformation allows the direct synthesis of electron-rich allylic amines from terminal olefins. With only limited optimization, I have already observed good reactivity. Future efforts are directed to further optimize this reaction and evaluate the reaction scope.

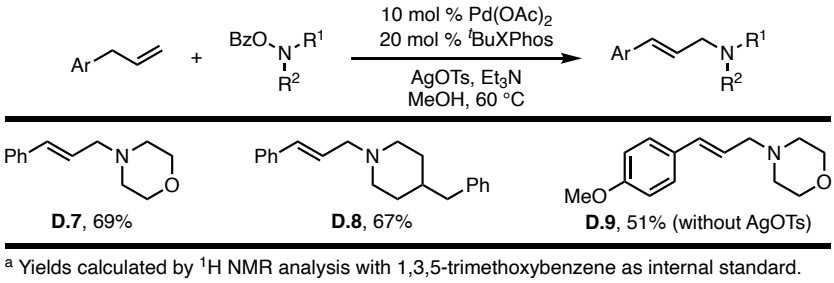


Figure D.4: Preliminary Intermolecular C–H Amination of Terminal Olefines

D.3.1 General Procedure of Figure D.4

In a N_2-refilled glovebox, $Pd(OAc)_2$ (11.2 mg, 50.0 umol, 0.010 equiv), ^{t}BuXPhos (42.5 mg, 100 umol, 0.020 equiv), hydroxylamine ester (1 mmol, 2 equiv), AgOTs (209.3 mg, 0.750 mmol, 1.50 equiv), anhydrous MeOH (1 mL), alkene (0.5 mmol, 1 equiv), and anhydrous Et_3N (0.35 mL, 2.5 mmol, 5.0 equiv) were added sequentially to 1-dram reaction vial. The reaction vial was then capped with a Teflon-sealed cap and placed in a pre-heated 60 °C heating block to stir for 24 h. Upon completion, the reaction was cooled to rt, opened to air, and then diluted with EtOAc (2 mL). 1,3,5-

trimethoxybenzene (28.0 mg, 167 umol, 0.333 equiv) was added into the reaction vial as internal standard. The crude reaction yield was then determined by ^{1}H NMR analysis.