ZINC-CATALYZED ALKYNYLATION OF ACETALS VIA OXOCARBENIUM ION INTERMEDIATES

by

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ABSTRACT

Reactions that allow the conversion of a simple achiral or racemic starting material into an enantiomerically pure product are of great importance. Such processes are particularly advantageous when they are combined with the formation of a carbon–carbon bond. In the large majority of such reactions, stereoselectivity is controlled by enzymes, chiral auxiliaries, organocatalysts, or transition metal catalysts. In particular, enantioselective transition metal catalysis is a powerful tool in the synthesis of enantioenriched products. The M. Watson group has recently demonstrated a new enantioselective metal-catalyzed strategy for the addition of terminal alkynes to racemic isochroman and chromene acetals. This thesis describes my progress towards establishing this alkynylation strategy for a much broader class of cyclic acetal substrates.

The first chapter reviews developments in enantioselective additions of carbon nucleophiles to prochiral cyclic oxocarbenium ions using both organocatalysis and transition metal catalysis. The chapter briefly discusses the addition of carbon nucleophiles to aldehydes and ketones catalyzed by transition metals, as well as enantioselective alkynylation of iminium ions.

The second chapter of this thesis describes my work on alkynylation of chroman acetals through cyclic oxocarbenium ions, specifically optimization of reaction conditions and my progress towards an asymmetric version of this reaction.

The third chapter discusses diastereoselective alkynylation reactions. In addition to the routes for substrate synthesis for these studies, the alkynylation of

several nonbenzopyranyl substrates through aliphatic oxocarbenium ion intermediates has been achieved.

This work establishes that the alkynylation strategy previously used for the addition of terminal alkynes to racemic isochroman and chromene acetals can be applied to a much broader class of cyclic acetal substrates, in particular chroman, tetrahydrofuran, and tetrahydropyran acetals.

Chapter 1

ENANTIOSELECTIVE ADDITIONS OF CARBON NUCLEOPHILES TO OXOCARBENIUM IONS

α-Substituted oxygen heterocycles constitute the framework of many biologically active molecules, as well as synthetic and semisynthetic compounds of interest (Figure 1.1).[1-12] The development of highly efficient methods for the enantioselective synthesis of such compounds would contribute greatly to the fields of medicinal, agricultural, and material sciences.

Multiple routes for the enantioselective preparation of α-substituted cyclic ethers have been reported. In many of these methods, the formation of the stereogenic center occurs before cyclization.[13-22] Other strategies, such as hetero-Diels−Alder reactions, Wacker-type cyclizations, and intramolecular conjugate additions rely on simultaneous formation of the stereocenter with the cyclization.[23-31] In addition to the above-mentioned strategies, several enantioselective substitution reactions of oxygen heterocycles have been described.[32-36] Most notably, in 2005, Hoveyda reported examples of enantioselective copper-catalyzed conjugate addition of dialkylzinc reagents to unsaturated furanones and pyranones. α-Substituted cyclic ether **1-3** was formed enantioselectively from chromenone **1-1** (Scheme 1.1). However, the application of this methodology to other substrates to make α-substituted oxygen heterocycles was not investigated.

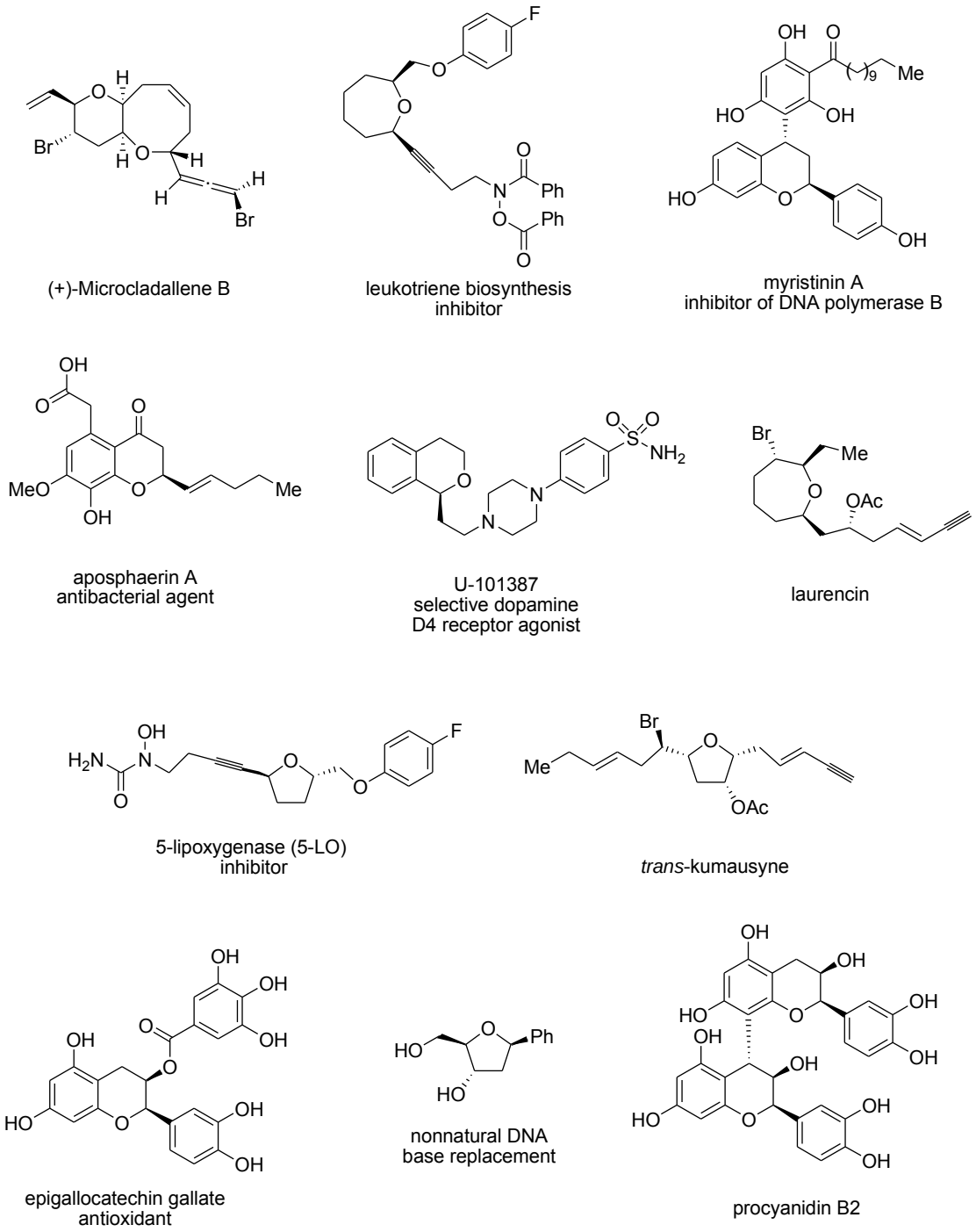
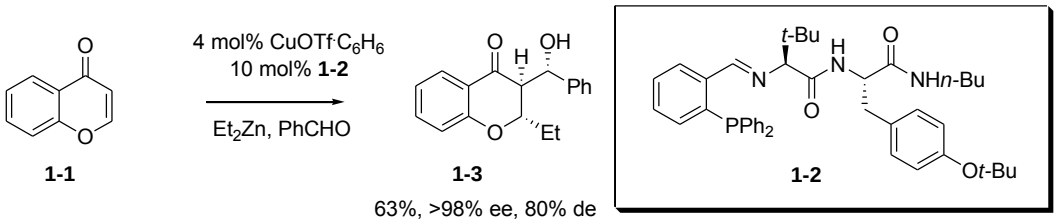


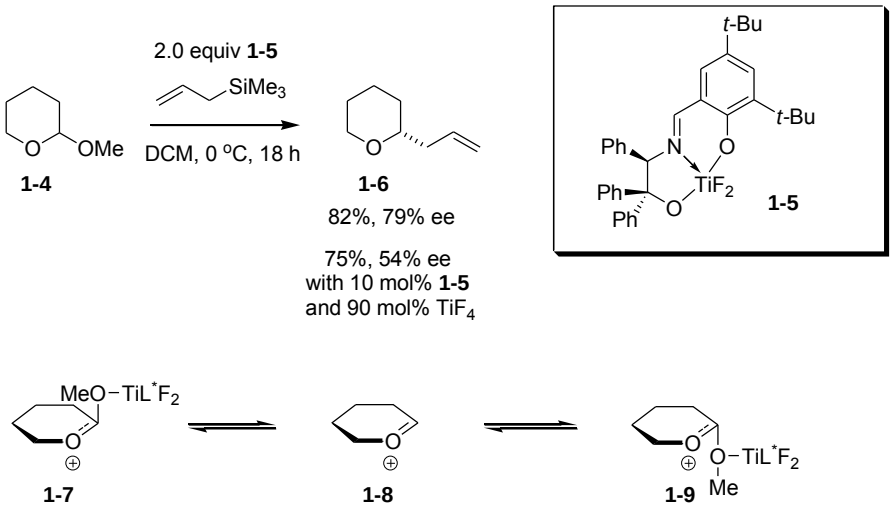
Figure 1.1. Biologically Active and Natural Oxygen Heterocycles with α-Stereocenters



Scheme 1.1. Hoveyda's Copper-Catalyzed Conjugate Addition

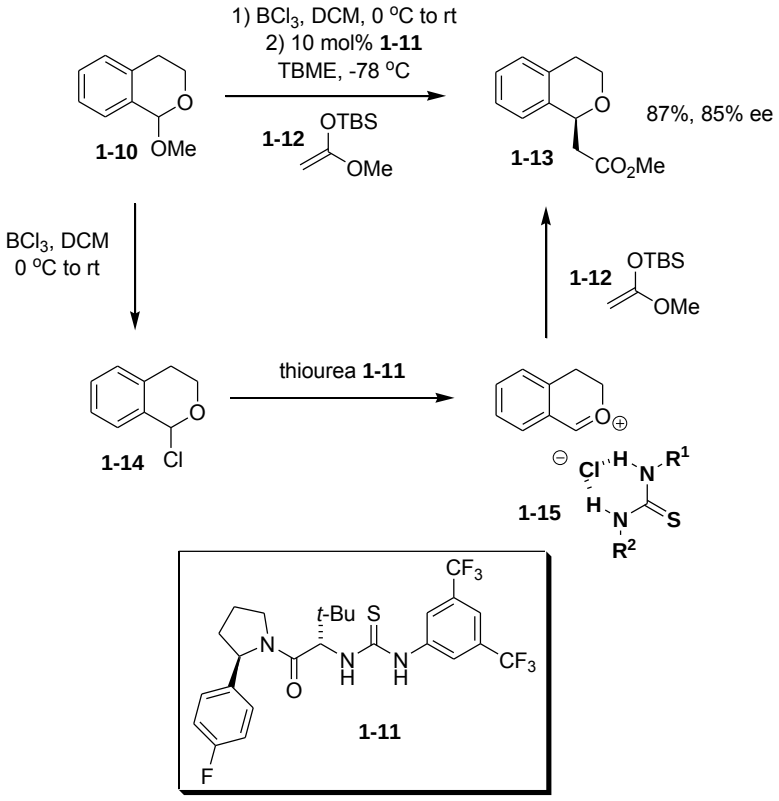
Nucleophilic additions to oxocarbenium ion intermediates would provide a powerful method for the synthesis of α-substituted cyclic ethers. However, controlling enantioselectivity of these additions is not trivial. The high reactivity of oxocarbenium ions as well as the E1 elimination pathway make the uncatalyzed addition reaction problematic. The enantioselective addition to oxocarbenium ion intermediates is vastly under-developed, and only a few examples of enantioselective catalytic additions to prochiral cyclic oxocarbenium ions have been reported to date.[37-40]

Braun reported the first example of enantioselective additions to cyclic oxocarbenium ions in 2004. In his report, Braun described a titanium(IV)-catalyzed asymmetric allylation of alcohols, silyl ethers, and acetals.[38] The majority of reactions did not utilize cyclic acetal substrates. However, Braun showed that a single example of cyclic acetal **1-4** underwent allylation (Scheme 1.2). This allylation is proposed to proceed via dynamic kinetic resolution of the diastereomeric acetal-catalyst complexes **1-7** and **1-9**, which interconvert via prochiral oxocarbenium ion **1-8**. Notably, a stoichiometric amount of chiral Lewis acid was required to achieve good enantioselectivity in this transformation.



Scheme 1.2. Braun's Allylation of Dihydropyranyl Acetal

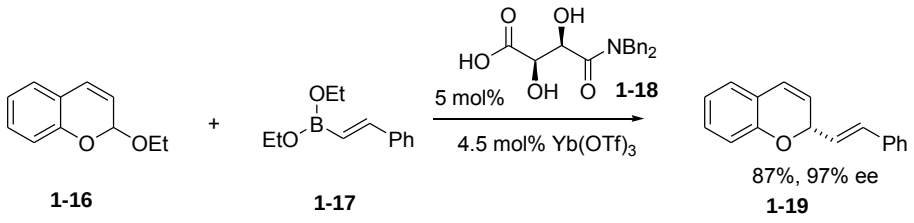
In 2008, Jacobsen reported the thiourea-catalyzed addition of silyl ketene acetals to 1-chloroisochromans to give esters (Scheme 1.3).[37] 1-Chloroisochroman **1-14** was prepared in situ from methyl acetal **1-10** by treatment with BCl_3. The catalyst **1-11** promoted the substitution to generate ester **1-13**. The chiral thiourea catalyst was used to control stereochemistry by inducing chloride dissociation to generate a reactive oxocarbenium-chloride-thiourea complex **1-15**.[41] A wide variety of substituted isochromans were prepared using this method. Jacobsen's work proved that prochiral oxocarbenium ions were viable substrates for asymmetric catalysis.



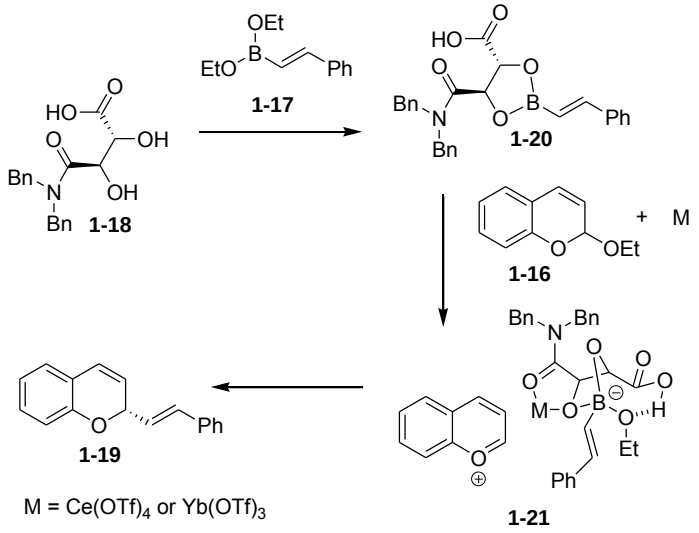
Scheme 1.3. Thiourea-Catalyzed Addition of Silyl Ketene Acetals to 1-Chloroisochromans by Jacobsen

In 2010, Schaus described the enantioselective addition of boronic esters such as **1-17** to chromene acetals **1-16** catalyzed by a chiral Brønsted acid/Lewis acid system to generate chiral chromene products **1-19** (Scheme 1.4).[39,42-43] A wide variety of vinyl boronic esters was tolerated under optimized reaction conditions, but aryl boronates proved to be less reactive and required electron-donating substituents on the aromatic ring, such as methoxy groups. The proposed mechanism is presented in Scheme 1.5. The boronic ester **1-17** and tartaramide acid **1-18** first form dioxoborolane **1-20**. With the addition of metal Lewis acid (M) and chromene acetal

1-16, boronate complex **1-21** is generated. The addition of the chiral nucleophile to the oxocarbenium ion furnished product **1-19** in 87% yield and 97% ee. According to the authors, Lewis acid alone provided none of the desired product, while chiral Brønsted acids gave only moderate yields and enantioselectivites. A combination of the two afforded a chiral Brønsted acid/metal triflate Lewis acid/vinyl boronate catalytic complex **1-21** that led to the products in high yields and enantioselectivities.

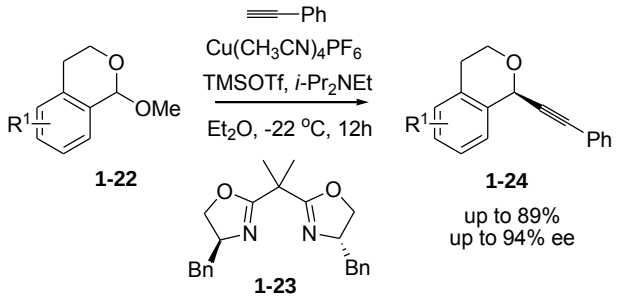


Scheme 1.4. Addition of Vinyl- and Aryl-Based Nucleophiles to Oxocarbenium Ions by Schaus



Scheme 1.5. Proposed Mechanism of Schaus' Reaction

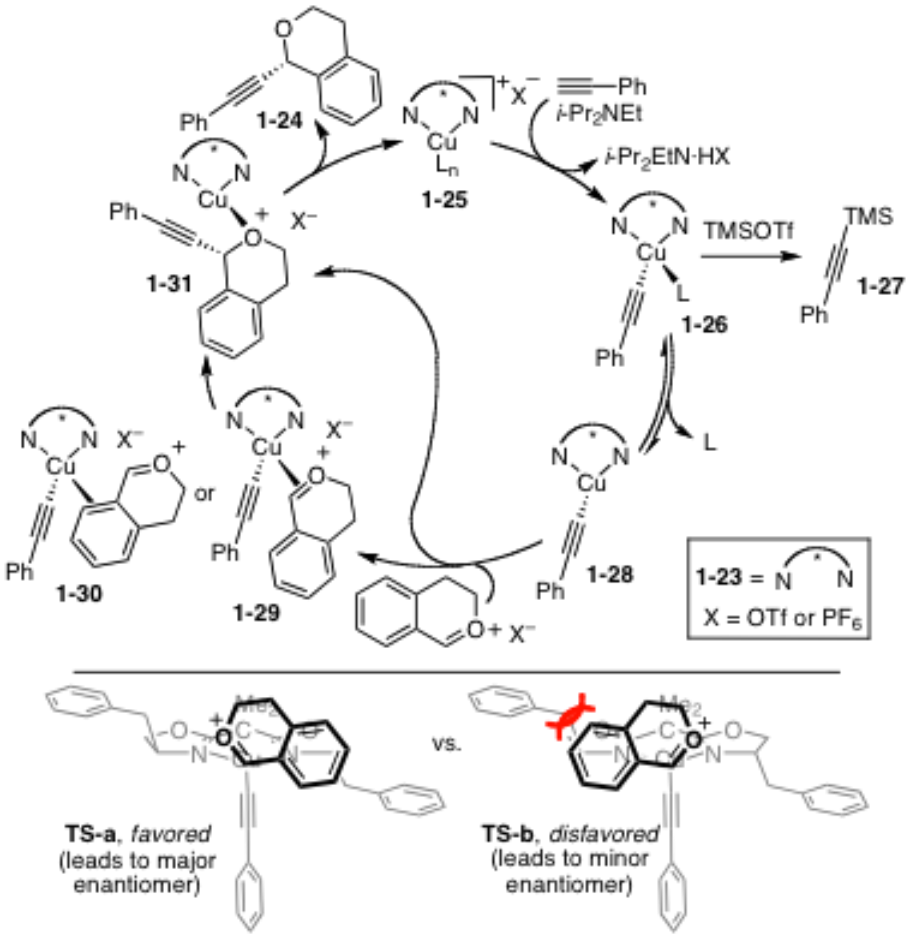
Most recently, Watson et al. developed an enantioselective, copper(I)-catalyzed alkynylation of racemic isochroman acetals **1-22** (Scheme 1.6)**.**[40] Use of a chiral catalyst derived from copper (I) and bis(oxazoline) ligand **1-23** gave 1-alkynyl isochromans **1-24** in good yields and high enantioselectivities.



Scheme 1.6. Enantioselective Alkynylation of Isochroman Acetals

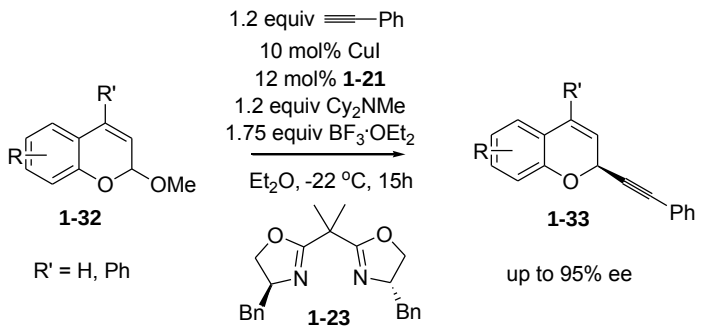
The proposed catalytic cycle is shown in Scheme 1.7. Chiral copper acetylide **1-26** is formed by combination of $[Cu(MeCN)_4]PF_6$, chiral ligand **1-23,** phenyl acetylene, and diisopropylethylamine. In the presence of TMSOTf, isochroman acetal **1-22** is converted in situ to the corresponding oxocarbenium ion. A minor byproduct, silylacetylene **1-27**, is generated from the reaction of TMSOTf and copper acetylide. However, use of 1.2 equiv of alkyne enables high yields of desired product. Ligand dissociation from the 18-electron copper acetylide complex likely occurs to enable the interaction with the oxocarbenium ion intermediate. The authors propose that formation of the carbon-carbon bond occurs either directly from trivalent **1-28** or via π-complexation of the oxocarbenium ion to copper forming intermediate **1-29** or **1-30**. The authors proposed a preliminary model for enantioselectivity based on analysis of molecular models. They suggest that steric interactions between the benzyl group of

the chiral copper acetylide and oxocarbenium ion disfavors transition state **TS-b**.[40] However, several experimental details suggest that the factors that control enantioselectivity are more complicated than this simple model depicts. Certainly, extending the asymmetric alkynylation to other classes of oxocarbenium ions will test this stereochemical model.



Scheme 1.7. Proposed Catalytic Cycle

The authors also reported the alkynylation of chromene acetals such as **1-32** to afford chromene products such as **1-33** in good yields and high enantioselectivities under modified conditions (Scheme 1.8).[40]

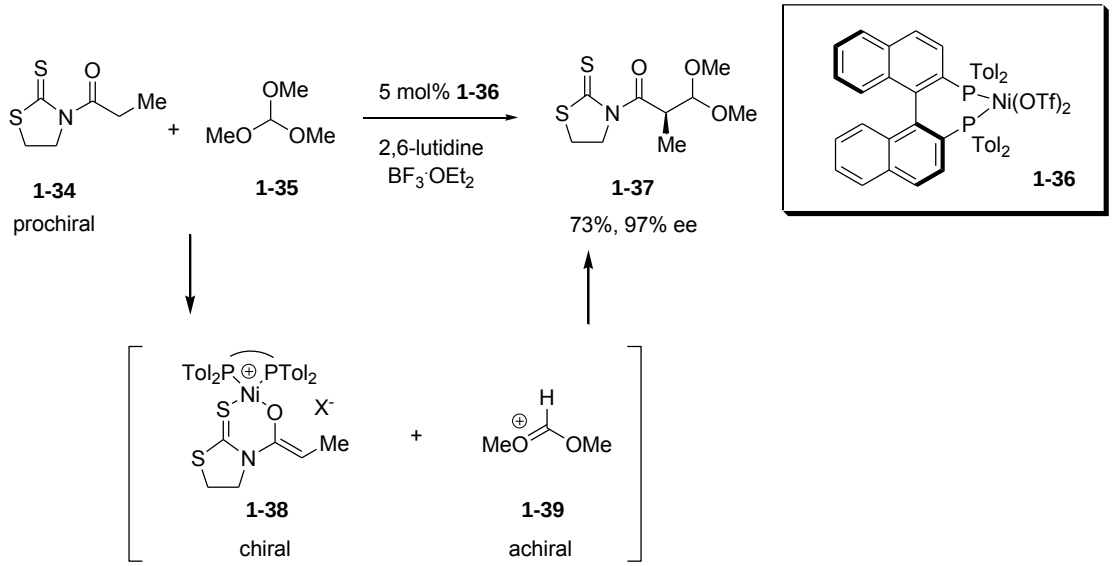


Scheme 1.8. Enantioselective Alkynylation of Chromene Acetals

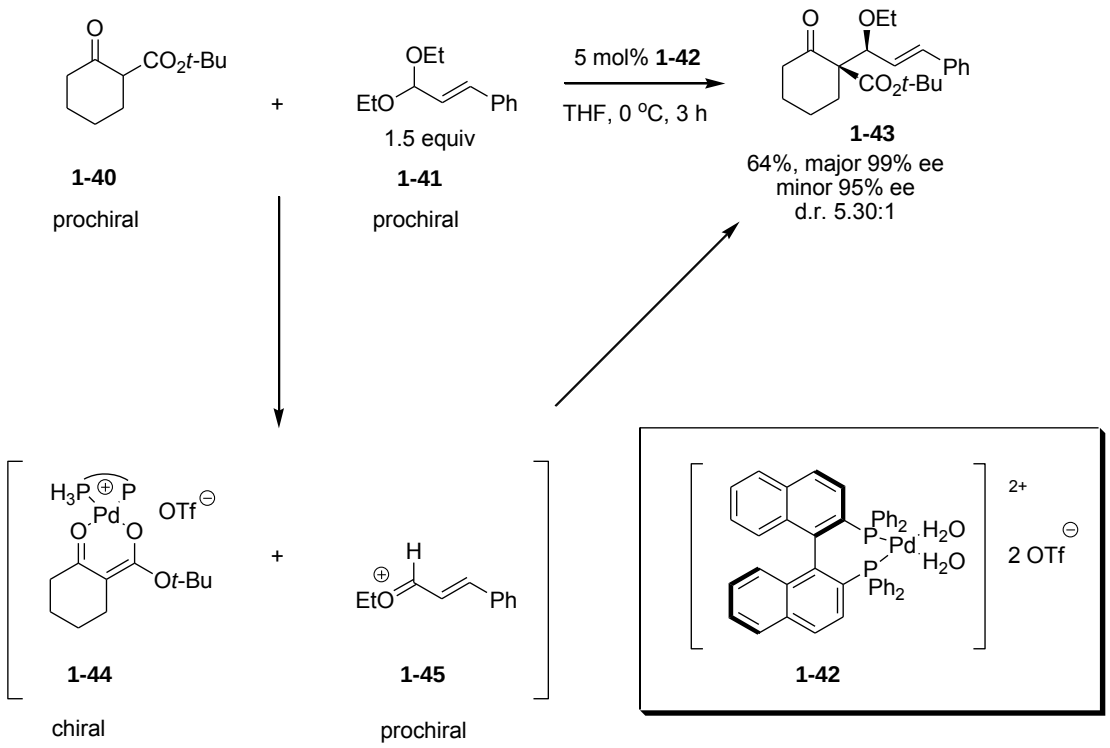
Compared to the organocatalytic enantioselective additions of carbon nucleophiles to prochiral oxocarbenium ions reported by Jacobsen and Schaus, this method was the first approach that uses a transition metal catalyst and proceeds through organometallic intermediates. This work demonstrated that transition metals can be used for the enantioselective addition of carbon nucleophiles to cyclic oxocarbenium ions.

All above-mentioned methodologies to prepare enantioenriched α-substituted cyclic ethers involve nucleophilic additions to prochiral cyclic oxocarbenium ion intermediates. However, enantioselective reactions of prochiral nucleophiles and achiral oxocarbenium ions have also been disclosed. In 2005, Evans reported a nickel-catalyzed enantioselective orthoester alkylation of *N*-acylthiazolidinethiones (Scheme 1.9).[44] According to Evans, the high observed enantioselectivity can be explained by

the formation of Ni-enolate **1-38**, which then reacts with achiral oxocarbenium ion **1-39**. In this reaction, the stereocenter emerges from the prochiral nucleophile, instead of a prochiral oxocarbenium ion.



Scheme 1.9. Enantioselective Orthoester Alkylation of N-Acylthiazolidinethiones by Evans



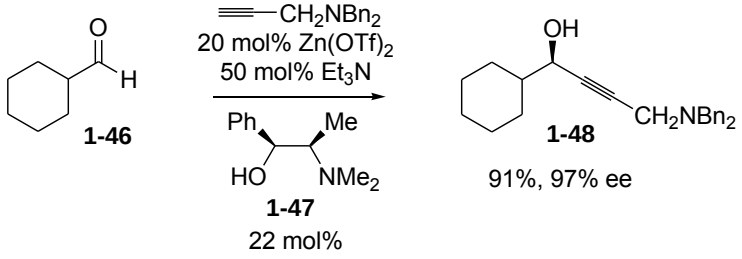
Scheme 1.10. Enantioselective Aldol-Type Reaction with Acetals by Sodeoka

In 2008, Sodeoka reported an enantioselective catalytic aldol-type reaction of β-ketoesters such as **1-40**, with acetals **1-41** (Scheme 1.10).[45] In this reaction Pd complex **1-42** acts as an acid/base catalyst, simultaneously activating both the nucleophile and the electrophile. The Pd catalyst assists the formation of enolate **1-44** while in situ generated proton activates the acetal to give oxocarbenium ion intermediate **1-45**. This reaction employs a prochiral nucleophile and a prochiral electrophile; strereocenters emerge on both the β-ketoester and acetal.[46-47]

The only example of an enantioselective transition metal-catalyzed addition to cyclic oxocarbenium intermediates has been reported by Watson et. al.[40] However, multiple cases of transition metal-catalyzed additions of carbon nucleophiles to similar systems – aldehydes and ketones – have been described. In this thesis, I will limit my

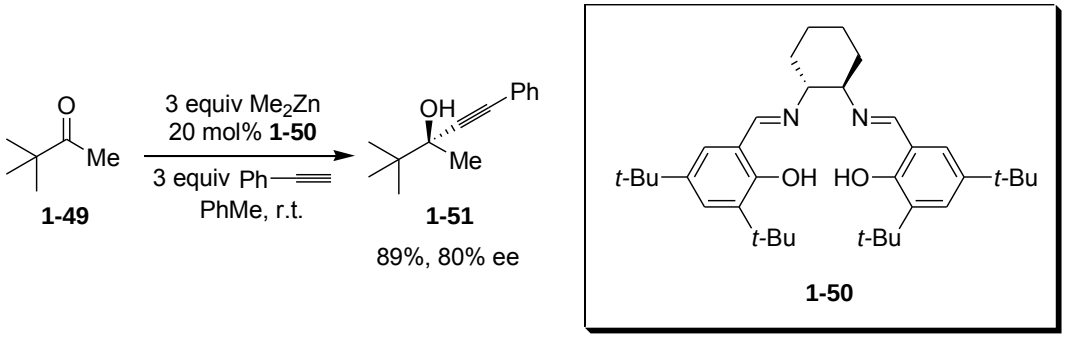
discussion to enantioselective transition metal-catalyzed alkynylation for the synthesis of chiral propargylic alcohols.[48-66]

In 2001, Carreira described a zinc-catalyzed enantioselective addition of terminal alkynes to aldehydes (Scheme 1.11).[67] These additions proceed through chiral zinc-acetylide intermediates, which add to aldehydes to give chiral alcohols in high enantioselectivities. Both the Zn(II) salts and ligands are commercially available. Further, the reaction can tolerate air and moisture and can be conducted at temperatures as high as 100 °C, affording products in excellent yields and high enantioselectivities.



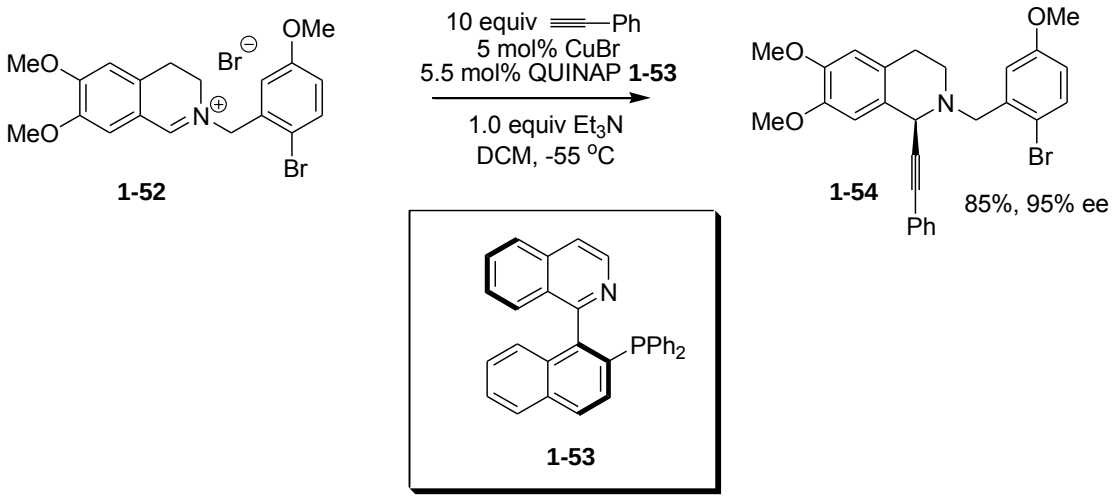
Scheme 1.11. Carreira's Enantioselective Alkynylation of Aldehydes

The first general method that allowed the enantioselective addition of acetylenes to ketones was described by Cozzi in 2003 and utilized zinc/salen catalysis (Scheme 1.12).[48] Since 2003, many articles have been published in the field of enantioselective alkynylation of aldehydes and ketones.[49-67]



Scheme 1.12. Cozzi's Enantioselective Alkynylation of Ketones

Alkynylation of oxocarbenium ions is also similar to alkynylation of iminium ions. Enantioselective copper-catalyzed coupling reactions of alkynes with iminium ions are well known.[68-71] In 2006 Schreiber published the asymmetric alkynylation of alkylisoquinolinium and alkyldihydroisoquinolinium ions, such as **1-52** in the presence of triethylamine, catalytic copper bromide, and QUINAP (**1-53**) (Scheme 1.13). These conditions tolerated a variety of alkynes and furnished propargylic amines in high yields and enantioselectivities. Ma and Arndtsen later demonstrated that Cu catalysts also enable enantioselective alkynylation of pyridinium ions.[70,72]



Scheme 1.13. Schreiber's Alkynylation of Isolated Isoquinolinium Ions

Despite the recent advances in many areas of asymmetric catalysis, the development of new methodologies for enantioselective nucleophilic additions to oxocarbenium intermediates is still in demand. The new methods for enantioselective synthesis of α-substituted oxygen heterocycles are indispensable. α-Substituted oxygen heterocycles represent a promising class of biologically active compounds, and highly efficient strategies for the synthesis of these compounds would make a great contribution to the development of new medicines.

The successful enantioselective additions of carbon nucleophiles to benzylic and vinylogous oxocarbenium ions create a platform for further exploration of asymmetric additions to oxocarbenium ions. Enantioselective addition to aliphatic oxocarbenium ions still represents a major synthetic challenge. My preliminary results towards alkynylation of aliphatic oxocarbenium ions will be discussed in the following chapters. This work is significant as it will change the way chiral ethers are prepared.

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Chapter 2

ALKYNYLATION OF CHROMAN ACETALS[1]

As discussed in chapter 1, there are only four methods for the enantioselective addition to cyclic oxocarbenium ion intermediates.[2-5] Three of these (Jacobsen,[2] Schaus,[3] Watson[4]) are limited to fairly stable benzylic or aromatic oxocarbenium ions **2-1** or **2-2** (Figure 2-1). Braun's allylation of a single dihydropyranyl acetal[5] represents the only example to date of enantioselective nucleophilic addition to a less stable aliphatic cyclic oxocarbenium ion **2-4**.

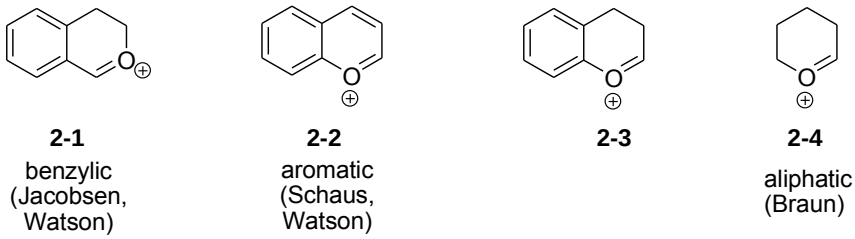
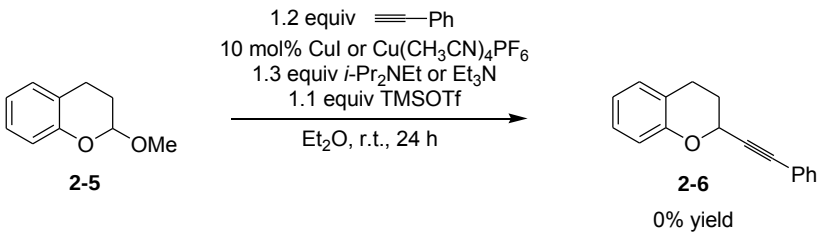


Figure 2.1. Oxocarbenium Ions for Enantioselective Additions

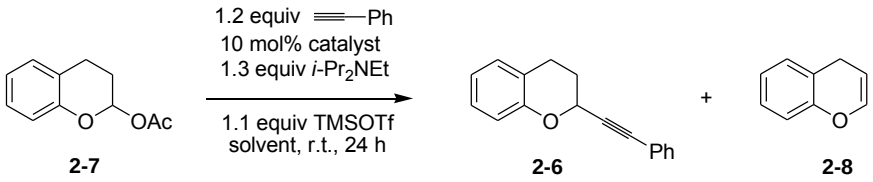
In an effort to extend the enantioselective Cu-catalyzed alkynylation to less stable oxocarbenium ions such as **2-3**, I investigated the alkynylation of chroman acetal **2-5**[6] (Scheme 2-1), which was easily prepared from 2-hydroxychroman using methanol and trifluoroacetic acid.[3] The application of the optimized reaction conditions for the chromene and isochroman acetals failed to give any product with substrate **2-5.** Catalyst screening was required to identify an effective catalyst for alkynylation.



Scheme 2.1. Alkynylation of 2-Methoxychroman

I initiated a catalyst screen and investigated the ability of various copper and zinc salts to perform the addition of terminal alkynes to chroman **2-7**[7] (Table 2-1). I hypothesized that a better leaving group was required for alkynylation, as it would assist the oxocarbenium ion formation. 2-Acetoxychroman **2-7** was chosen as a model substrate. Diethyl ether and dichloromethane were tested as solvents for the reaction. I discovered that copper(I) and copper(II) salts were ineffective catalysts for the alkynylation, and the formation of the desired product was not observed in diethyl ether or dichloromethane (entries 1-2, 5-8, 11-12). In comparison, zinc salts provided promising results (entries 3-4, 9-10). Zinc bromide furnished the product in higher yields than zinc triflate. Zinc bromide furnished the product in 59% yield in diethyl ether. Alkene by-product **2-8**[7-8] formed through an E1-elimination pathway was observed in entries 2-4 and 11. Starting material was present in all cases except entries 6 and 12.

Table 2.1. Catalyst Screen for Alkynylation of 2-Acetoxychroman

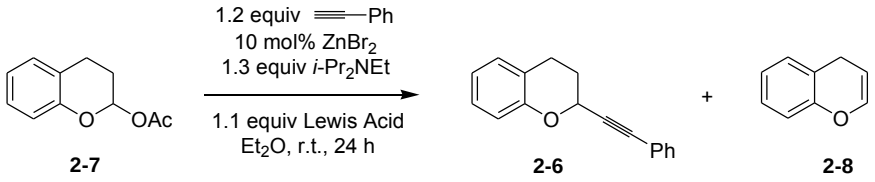


Entry	Catalyst	Solvent	Yield (%)[a]	
			2-6	**2-8**
1	CuI	Et_2O	0	0
2	$Cu(MeCN)_4PF_6$	Et_2O	0	4
3	$Zn(OTf)_2$	Et_2O	11	28
4	$ZnBr_2$	Et_2O	59	8
5	$CuSO_4$	Et_2O	0	0
6	$Cu(OTf)_2$	Et_2O	0	0
7	CuI	DCM	0	0
8	$Cu(MeCN)_4PF_6$	DCM	0	0
9	$Zn(OTf)_2$	DCM	36	0
10	$ZnBr_2$	DCM	53	0
11	$CuSO_4$	DCM	0	20
12	$Cu(OTf)_2$	DCM	0	0

a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard.

To determine the best Lewis acid for the transformation, I investigated various silyl triflates and $BF_3{\cdot}OEt_2$ (Table 2.2). $BF_3{\cdot}OEt_2$ provided significantly lower yield of the desired product compared to silyl triflates (entry 4). TESOTf was the best Lewis acid for the transformation, increasing the yield of the alkynylated product to 78% (entry 2).[9] No desired product was observed in the absence of Lewis acid.

Table 2.2. Lewis Acid Screen for Alkynylation of 2-Acetoxychroman

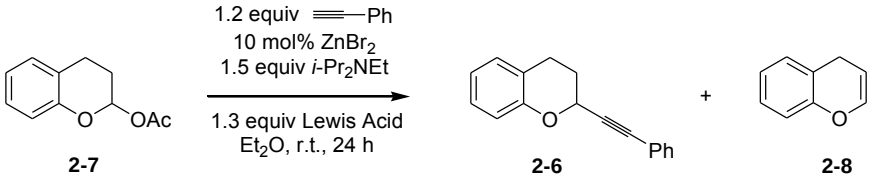


Entry	Lewis Acid	Yield (%)[a]		
		2-6	**2-8**	**2-7**
1	TMSOTf	64	10	30
2	TESOTf	78	2	20
3	TIPSOTf	71	Trace	15
4	$BF_3 \cdot OEt_2$	18	0	90

a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard.

The presence of unreacted starting material suggested that not all acetal was ionizing to the oxocarbenium ion. Based on this hypothesis, I increased the amounts of base and Lewis acid. The quantity of Lewis acid was increased from 1.1 to 1.3 equivalents. The amount of base was increased to 1.5 equivalents due to the possibility of triflic acid formation in the presence of trace amounts of water. I repeated the Lewis acid screen under these new conditions (Table 2.3). Silyl triflates, $AlCl_3$, and $FeCl_3$ were investigated as Lewis acids. $AlCl_3$ furnished the product in low yield (entry 5). $FeCl_3$ provided only trace amounts of desired product (entry 6), and silyl trilates (entries 1-3) gave comparable results with the yields of **2-6** close to 90%.

Table 2.3. Lewis Acid Screen for Alkynylation of 2-Acetoxychroman under Modified Conditions

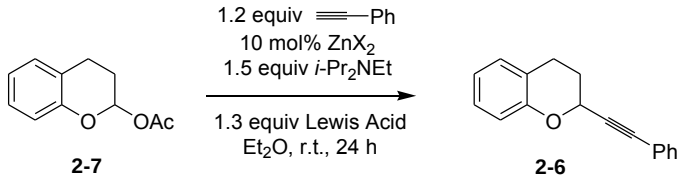


Entry	Lewis Acid	Yield (%)[a]		
		2-6	**2-8**	**2-7**
1	TMSOTf	89	8	2
2	TESOTf	88	12	0
3	TIPSOTf	90	0	12
4	TBSOTf	16	18	27
5	$AlCl_3$	14	2	0
6	$FeCl_3$	Trace	n.d.[b]	n.d.[b]

a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) n.d. = not determined.

As the final step of optimization, different zinc salts were investigated with TMSOTf, TESOTf, and TIPSOTf (Table 2.4). From the results of the screening, I concluded that $ZnBr_2$ was the most efficient catalyst and TESOTf was the best Lewis acid for the transformation. With freshly distilled TESOTf and $ZnBr_2$ as catalyst, quantitative conversion of the starting material to the desired product was observed (entry 6).

Table 2.4. Comparison of Zinc Salts

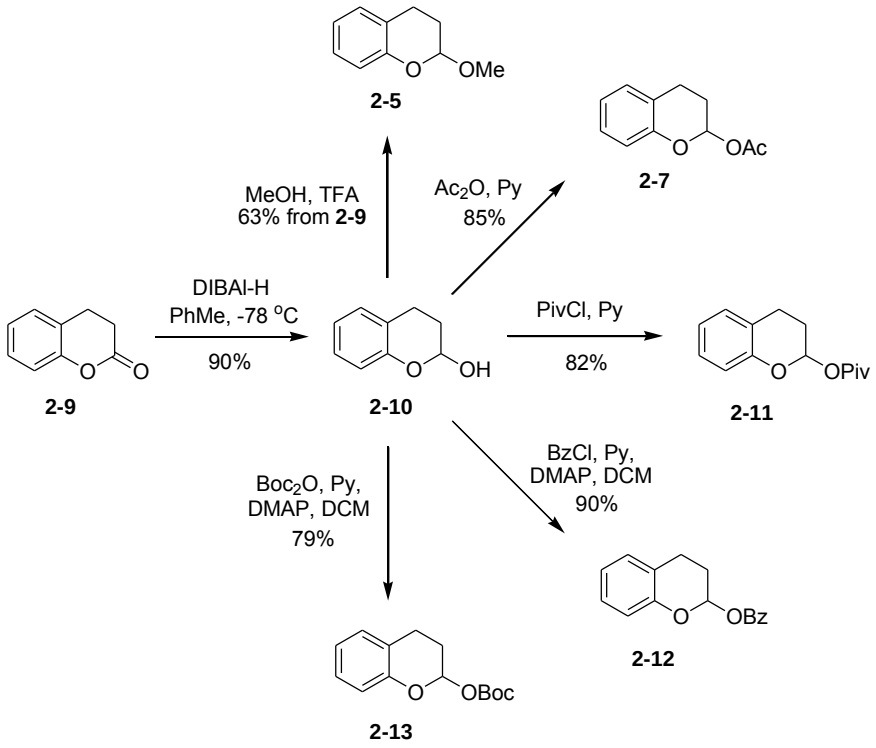


Entry	Catalyst	Lewis Acid	Yield (%)[a]
1	$ZnCl_2$	TMSOTf	47
2	$ZnBr_2$	TMSOTf	60-90
3	$Zn(OTf)_2$	TMSOTf	14
4	ZnI_2	TMSOTf	37
5	$ZnCl_2$	TESOTf	94
6	$ZnBr_2$	TESOTf	99
7	$Zn(OTf)_2$	TESOTf	31
8	ZnI_2	TESOTf	51
9	$ZnCl_2$	TIPSOTf	92
10	$ZnBr_2$	TIPSOTf	81
11	$Zn(OTf)_2$	TIPSOTf	48
12	ZnI_2	TIPSOTf	57

a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard.

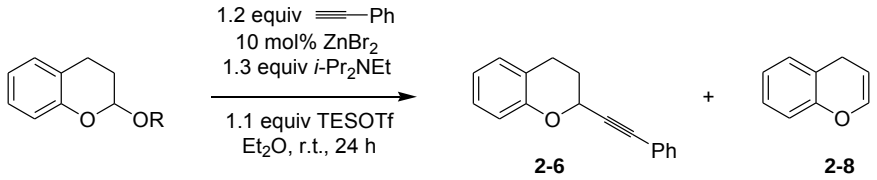
I also investigated the effect of the leaving group on reactivity. A variety of chroman acetals were prepared from dihydrocoumarin and tested under the alkynylation conditions. The synthesis of chroman acetals is presented in Scheme 2.2. Dihydrocoumarin **2-9** was reduced to lactol **2-10** with DIBAl-H.[7,10] Lactol **2-10** was then converted to the acetals **2-5**, **2-7**, **2-11**, **2-12** and **2-13**. The results of the screening are presented in Table 2.5. The hydroxy and methoxy groups (entries 1-2) were not

suitable leaving groups for the transformation. The bulky OPiv, OBoc, and OBz groups furnished the product in low yields (entries 4-6). Acetate was the optimal leaving group for the reaction (entry 3).



Scheme 2.2. Synthesis of Chroman Acetals

Table 2.5. Effect of Leaving Group on Reactivity

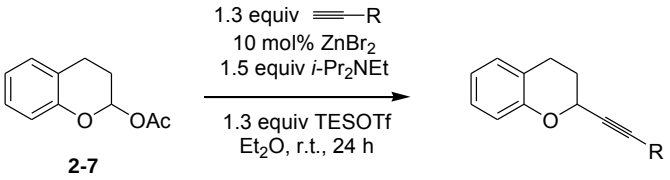


Entry	R	Yield (%)[a]	
		2-6	**2-8**
1[b]	H	2	0
2	Me	0	0
3	Ac	78	2
4	Piv	21	Trace
5	Boc	20	18
6	Bz	3	0

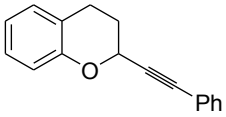
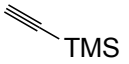
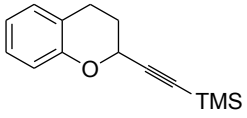
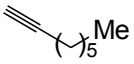
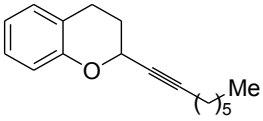
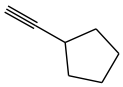
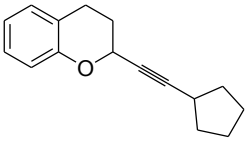
a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) 2.5 equiv of *i*-Pr_2NEt and 2.5 equiv of TESOTf were used.

With optimized reaction conditions in hand, I determined the preliminary alkyne scope. I discovered that aromatic, aliphatic, and silyl alkynes are viable in the alkynylation, providing excellent yields of the desired products (Table 2.6).

Table 2.6. Scope of Alkyne[a]



2-7

Entry	Alkyne	Product	Yield (%)[b]
1	 **2-14**	 **2-6**	95
2	 **2-15**	 **2-16**	88
3	 **2-17**	 **2-18**	91
4	 **2-19**	 **2-20**	82

a) Conditions: Acetal **2-7** (0.30 mmol, 1.0 equiv), $ZnBr_2$ (0.030 mmol, 10 mol %), alkyne (0.39 mmol, 1.3 equiv), i-Pr_2NEt (0.45 mmol, 1.5 equiv), TESOTf (0.39 mmol, 1.3 equiv), Et_2O, r.t., 24 h. b) Isolated yields.

Having determined optimized reaction conditions for the nonasymmetric reaction, I tested various chiral ligands for an asymmetric version of this reaction. Initial screening was performed with chiral amino alcohols, diols, and diamine ligands and zinc bromide or zinc triflate (Figure 2.2). No enantiomeric enrichment was observed in all cases. The same results were obtained with stoichiometric quantities of diethyl zinc and chiral ligands. I then investigated bis(oxazoline) ligands. I noticed that $Zn(OTf)_2$ provided higher ee compared to other zinc sources. Enantiomeric enrichment was detected with ligands **2-32, 2-34**, **2-35**, **2-36**, and **2-37** (Figure 2.3). The highest ee of 42% was observed with ligand **2-35**. However, significant reduction in yield of the desired product was observed with only 10-20% of **2-6** formed. Attempts to further increase ee by reducing temperature to -27 ^{o}C were unsuccessful and no product formation occurred. Chiral NHC, phosphine, and phosphoramidite ligands were also investigated (Figure 2.4). All these ligands furnished products in low to no enantioselectivity. These results indicate that the development of enantioselective alkynylation of chroman acetals is workable and further screening of chiral ligands will be required to improve the yield and enantioselectivity.

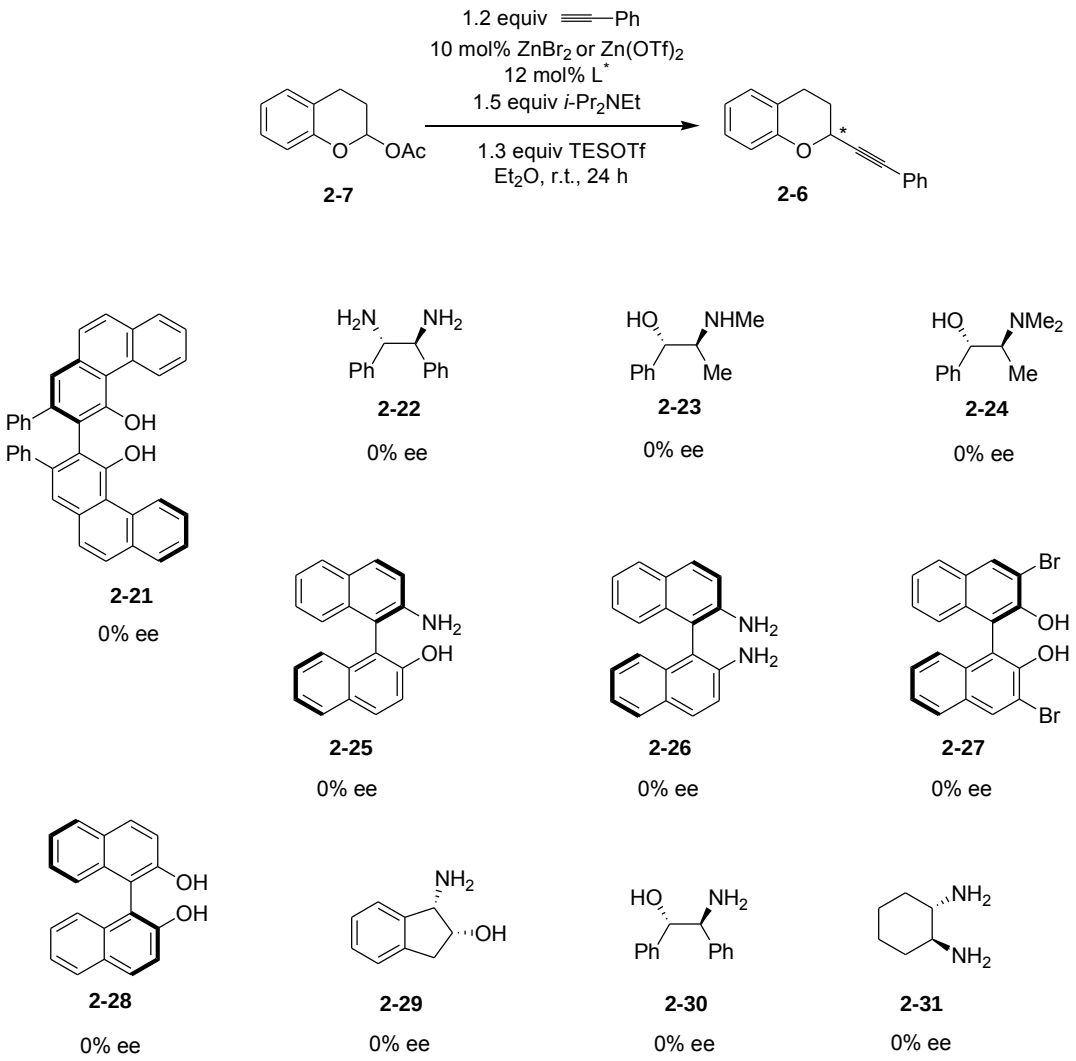


Figure 2.2. Representative Results with Chiral Amino Alcohol, Diol, and Diamine Ligands

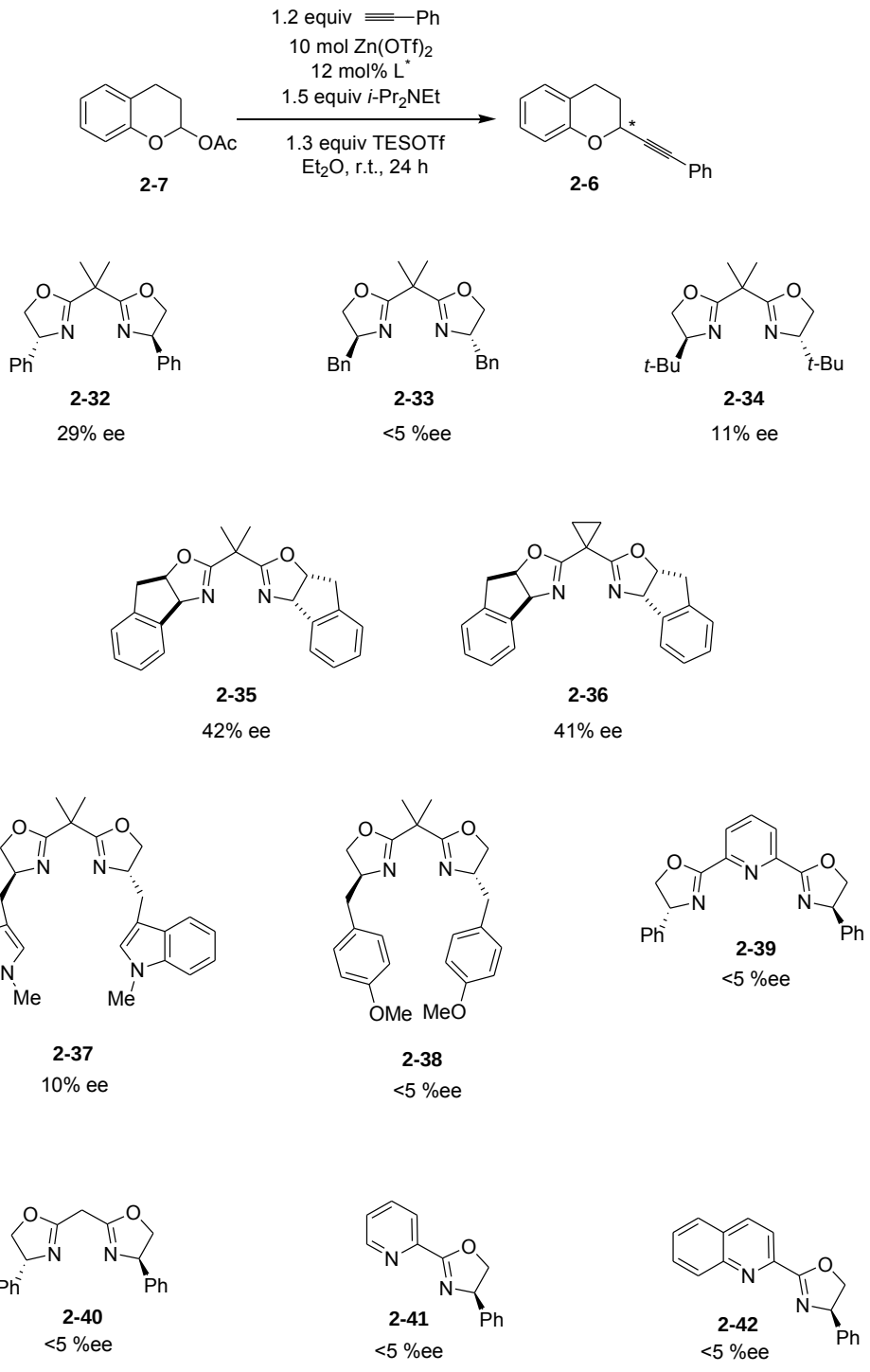


Figure 2.3. Bis(Oxazoline) Ligands Screen

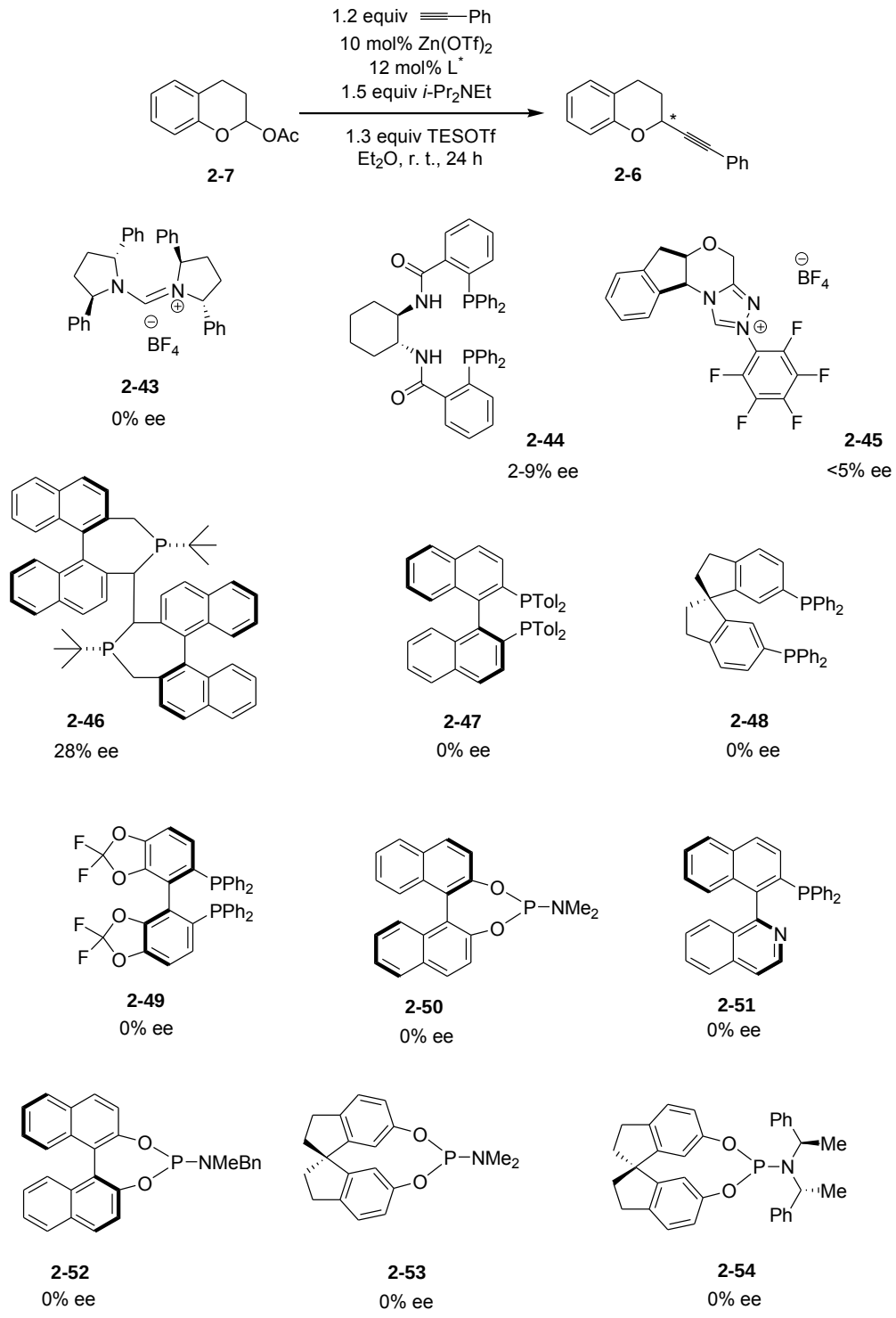


Figure 2.4. Chiral Ligands Screen

In conclusion, we have developed a zinc-catalyzed alkynylation of chroman acetals through oxocarbenium ion intermediates. Key to achieving high yields in this reaction were (1) identification of acetate as the best leaving group; (2) identification of $ZnBr_2$ as catalyst; and (3) using increased equivalents of Lewis acid and base. Aromatic, aliphatic, and silyl acetylenes were viable partners in the reaction and produced alkynylated products in excellent yields. From the preliminary screening of chiral ligands, promising enantioselectivities have been achieved; my best result to date is 42% ee, which was observed with bis(oxazoline) ligand **2-35.** This promising result shows the potential of developing an asymmetric variant of this reaction. Further screening of chiral ligands will be necessary to identify a catalyst able to furnish the product in excellent yield and high enantioselectivity.

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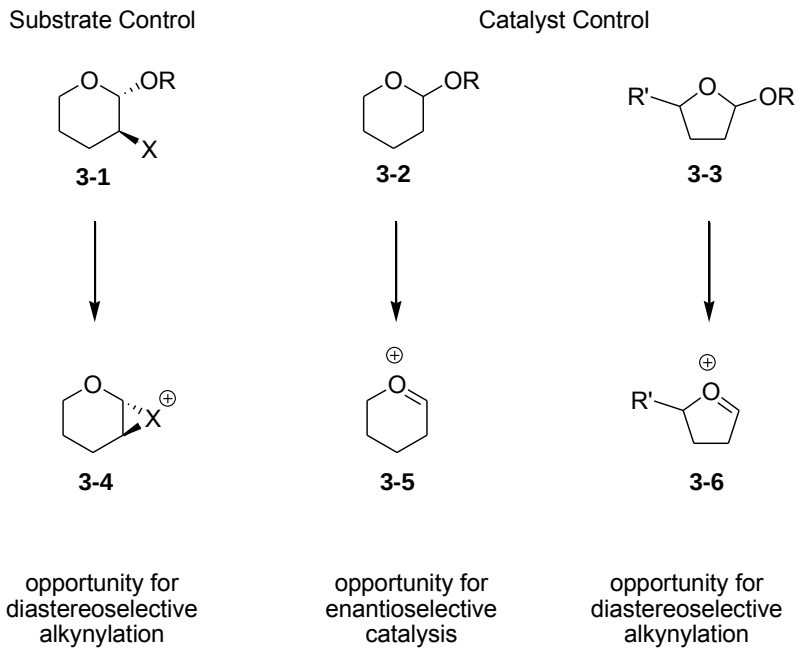
Chapter 3

ALKYNYLATION OF NONBENZOPYRANYL SUBSTRATES

The reactions of oxocarbenium ion intermediates play a significant role in the synthesis of various complex natural products and in the chemistry of carbohydrates.[1] Tetrahydrofuran and tetrahydropyran structural motifs are present in many bioactive molecules and other synthetic targets.[2] Given the importance of α-substituted tetrahydropyrans and tetrahydrofurans, the development of metal-catalyzed alkynylation of their oxocarbenium ion precursors would be of great advantage. We have begun to extend our metal-catalyzed alkynylation strategy[3] to aliphatic oxocarbenium ions such as **3-4**, **3-5**, and **3-6** derived from acetals **3-1**, **3-2**, and **3-3** respectively (Scheme 3.1). For oxocarbenium ions with stereocenters such as **3-4**, we envisioned the opportunity for diastereoselective alkynylation via a substrate-controlled reaction. For oxocarbenium ions **3-5** with no stereocenters, we envisioned the opportunity for enantioselective catalysis to control the stereoselectivity of nucleophilic addition. We proposed that oxocarbenium ions **3-6** would have little stereochemical bias in the addition of terminal alkynes. In this case, we envisioned catalyst control of diastereoselectivity. In this chapter, I present the development of zinc-catalyzed alkynylations of each of these types of oxocarbenium ions.

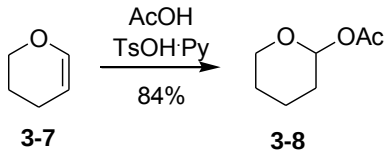


Scheme 3.1. Cyclic Aliphatic Oxocarbenium Ions as Intermediates for Enantioselective and Diastereoselective Alkynylation of Acetals

3.1 Alkynylation of 2-Acetoxytetrahydropyran

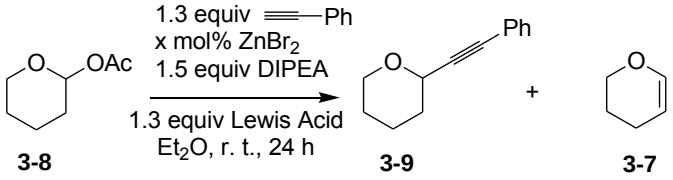
2-Acetoxytetrahydropyran **3-8** was selected as a model substrate for my initial investigations of the alkynylation of non-benzopyranyl acetals. Pyran **3-8** was prepared from dihydropyran **3-7** in 84% yield using acetic acid and pyridinium *p*-toluenesulfonate[4] (Scheme 3.2). The application of the optimized reaction conditions for benzopyranyl substrates (Chapter 2) furnished the product in only 7% yield (Table 3-1, entry 1). Increasing the catalyst loading did not improve the yield of the alkynylation product (entry 2). With stoichiometric quantities of $ZnBr_2$, still only 17% yield of the product was observed (entry 3). With $BF_3{\cdot}OEt_2$ as Lewis acid, the yield was 19% (entry 4). With no Lewis acid present, only trace amount of the product **3-9** was detected. In all these reactions, no starting material was recovered, suggesting a

competitive decomposition pathway for acetal **3-8**. Because no byproducts were observed by NMR, I propose that the mass balance is likely due to competitive E1 elimination of the acetal, leading to volatile pyran **3-7**. With this hypothesis in mind, I analyzed the reaction parameters in an effort to optimize the yield of ether **3-9**.



Scheme 3.2. Synthesis of 2-Acetoxytetrahydropyran Model Substrate

Table 3.1. Initial Screening for Alkynylation of 2-Acetoxytetrahydropyran

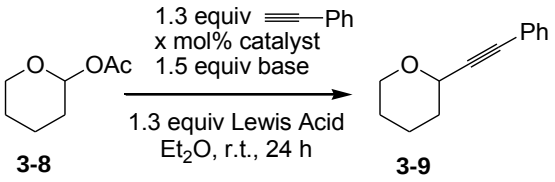


Entry	X mol % of $ZnBr_2$	Lewis Acid	Yield of **3-9** (%)[a]
1	10	TESOTf	7
2	20	TESOTf	8
3	100	TESOTf	17
4	10	$BF_3 \cdot OEt_2$	19
5	10	-	trace

a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard.

Catalyst screening was performed to identify an effective catalytic system for the alkynylation (Table 3.2). Copper (I) and zinc (II) salts were investigated with Lewis acids $BF_3 \cdot OEt_2$ and TMSOTf. Et_3N and *i*-Pr_2NEt were evaluated as bases for the reaction. Supporting ligands were evaluated for both copper and zinc (enries 2, 4, 9). No product formation or very low yield of the desired product was observed in all cases. With stoichiometric quantities of $ZnEt_2$ and TMSOTf, the yield of the desired product was 30% (entry 7).

Table 3.2. Catalyst Screen for Alkynylation of 2-Acetoxytetrahydropyran



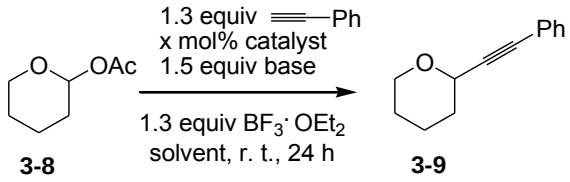
Entry	Catalyst	Mol% of Catalyst	Lewis Acid	Base	Yield (%)[a]
1	CuI	20	$BF_3{\cdot}OEt_2$	Et_3N	4
2	CuI + L[b]	20	$BF_3{\cdot}OEt_2$	Et_3N	1
3	$[Cu(MeCN)_4PF_6]$	20	$BF_3{\cdot}OEt_2$	DIPEA	0
4	$[Cu(MeCN)_4PF_6]$ + L[b]	20	$BF_3{\cdot}OEt_2$	DIPEA	0
5	CuOTf·PhMe	20	TMSOTf	Et_3N	0
6	CuO*t*-Bu	20	TMSOTf	Et_3N	Trace
7	$ZnEt_2$	100	TMSOTf	DIPEA	30
8	$ZnEt_2$	20	TMSOTf	DIPEA	7
9	$ZnEt_2$ + L_1[c]	20	TMSOTf	-	0
10	$Zn(OTf)_2$	20	TMSOTf	DIPEA	1
11	$ZnBr_2$	20	TMSOTf	DIPEA	1

a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) L = 1,10-phenanthroline (24 mol %). c) L_1 = N-methylephedrine (24 mol %).

A solvent screen was conducted with both copper(I) and zinc(II) catalysts (Table 3.3). Under all conditions examined, copper(I) salts were ineffective catalysts for alkynylation (entries 2, 4, 6, and 8). In comparison, $ZnBr_2$ provided promising results in polar solvents – dichloromethane, tetrahydrofuran, and dioxane (entries 1, 7,

9-11). In these solvents, decreasing catalyst loading to 10 mol% did not reduce the yield of the cross-coupling product. The highest yield of 50% was observed with $ZnBr_2$ in dioxane (entry 10).

Table 3.3. Solvent Screen for Alkynylation of 2-Acetoxytetrahydropyran

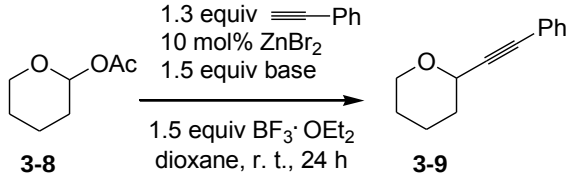


Entry	Catalyst	X mol % of catalyst	Base	Solvent	Yield (%)[a]
1	$ZnBr_2$	20	DIPEA	DCM	33
2	CuI +L[b]	20	Et_3N	DCM	0
3	$ZnBr_2$	20	DIPEA	PhMe	8
4	CuI +L[b]	20	Et_3N	PhMe	3
5	$ZnBr_2$	20	DIPEA	MeCN	5
6	CuI +L[b]	20	Et_3N	MeCN	0
7	$ZnBr_2$	20	DIPEA	dioxane	45
8	CuI +L[b]	20	Et_3N	dioxane	0
9	$ZnBr_2$	10	DIPEA	DCM	28
10	$ZnBr_2$	10	DIPEA	dioxane	50
11	$ZnBr_2$	10	DIPEA	THF	39

a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) L = 1,10-phenanthroline (24 mol %).

Next, I screened a variety of soluble organic bases (Table 3.4). From the results of the screening, I concluded that a non-nucleophilic, hindered base proved to be optimal for the reaction (entries 1, 3, and 4). Less hindered Et_3N and DBU prevented product formation (entries 2 and 5). Our hypothesis that the addition of pyridine in the reaction mixture could increase yield by stabilization of the oxocarbenium ion intermediate was disproved. With the addition of pyridine, the yield of the desired cross-coupling product decreased to 4% (entry 6).

Table 3.4. Base Screen for Alkynylation of 2-Acetoxytetrahydropyran



3-8 **3-9**

Entry	Base	Yield (%)[a]
1	DIPEA	50
2	Et_3N	0
3	PMP	48
4	Cy_2NEt	40
5	DBU	0
6	DIPEA + Pyridine[b]	4

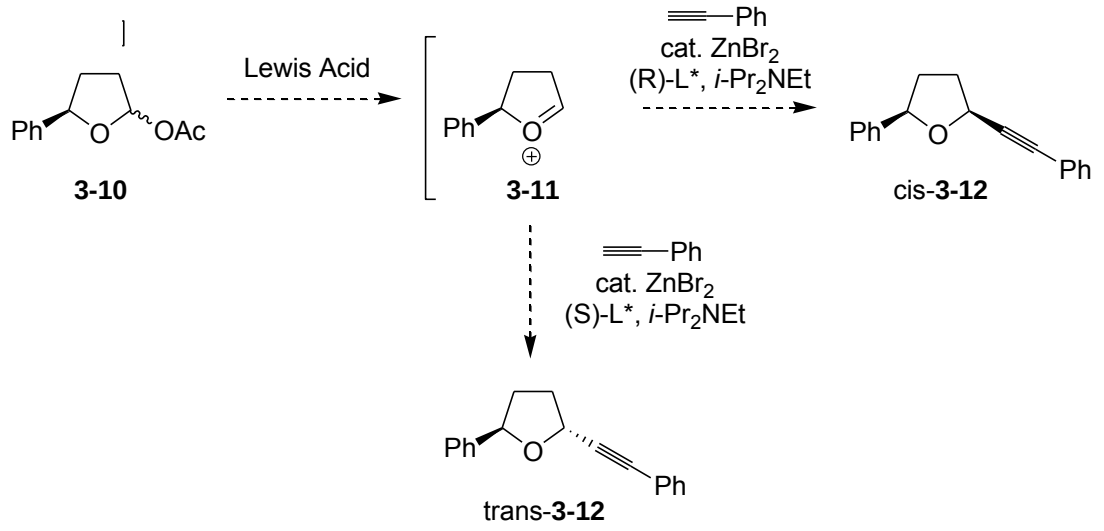
a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) 1.0 equiv of pyridine was used.

In conclusion, using 2-acetoxytetrahydropyran as the model substrate, I obtained useful data about the conditions required for alkynylation of aliphatic cyclic acetals. I discovered that $ZnBr_2$ was an efficient catalyst for alkynylation, while

copper(I) catalysts provided no product or gave very low yields of the desired product. I concluded that $BF_3 \cdot OEt_2$ was an optimal Lewis acid for the reaction, and a non-nucleophilic base such as DIPEA was required for the alkynylation. The choice of solvent was of great importance. Polar solvents such as dioxane, tetrahydrofuran, and dichloromethane provided the product in higher yields. These requirements were considered in the development of the alkynylation of other cyclic acetals.

3.2 Diastereoselective Alkynylation of Tetrahydrofuranyl Acetals

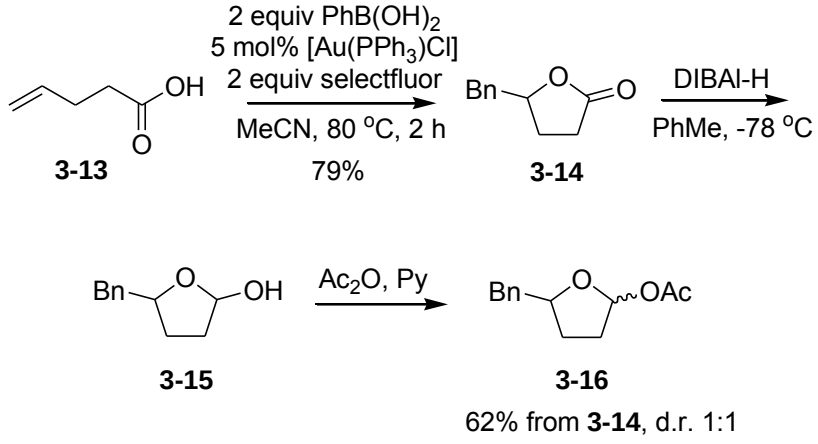
In addition to enantioselective catalysis, catalyst control of diastereoselectivity in the addition of carbon nucleophiles to racemic oxocarbenium ions remains challenging. We proposed to examine cyclic acetals that have little stereochemical bias towards the incoming nucleophile and identify a catalyst that is capable of controlling the stereochemistry of the addition. The precedent in the literature suggested that five-membered cyclic acetals would be stereochemically unbiased towards the incoming nucleophile.[2,5-6] Thus, catalyst-controlled stereoselective additions may be possible, and the cis or trans products could be formed selectively (Scheme 3.3).



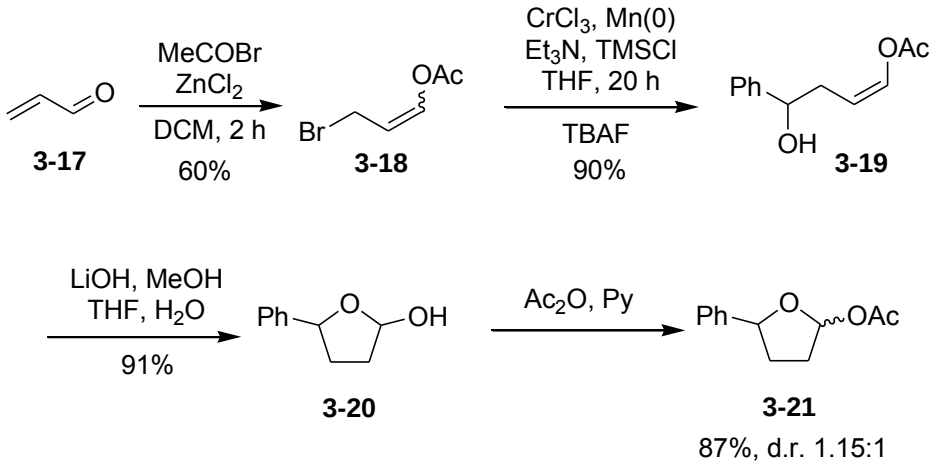
Scheme 3.3. Proposed Diastereoselective Alkynylation of Tetrahydropyranyl Acetals

I decided to examine the racemic five-membered oxocarbenium ions first to confirm that the tetrahydrofuranyl acetals were stereochemically unbiased towards the addition of terminal alkynes. Three different routes for the substrate synthesis were proposed, and the desired acetal was prepared using these methods. The first route involved gold-catalyzed homogeneous oxidative carboheterofunctionalization of 4-pentenoic acid **3-13** with phenylboronic acid to give lactone **3-14**[7] (Scheme 3.4). The subsequent reduction of the lactone with DIBAl-H and the acylation of the lactol **3-15** produced acetal **3-16** in 90% yield as a 1:1 ratio of diastereomers. Route B started with zinc-catalyzed coupling of acrolein **3-17** with acetyl bromide to give alkene **3-18** as a mixture of *E*- and *Z*-isomers (Scheme 3.5).[8] Alkene **3-18** underwent chromium-catalyzed homoaldol coupling (Nozaki-Hiyama-Kishi reaction) with benzaldehyde to give vinyl acetate **3-19**.[9] After the basic hydrolysis of intermediate **3-19**, lactol **3-20** was formed. Subsequent acylation produced desired acetal **3-21** as a 1.15:1 ratio of diastereomers. Route C started with 4-bromo-1-butene **3-22**, which was converted to

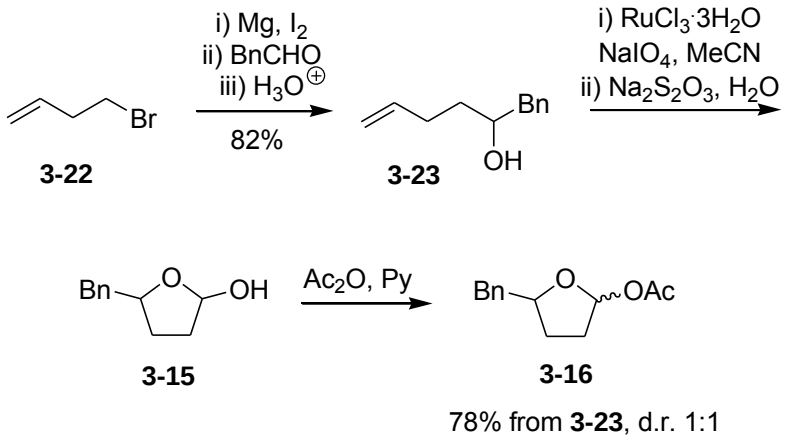
the Grignard reagent and phenylacetaldehyde was added to provide secondary alcohol **3-23** (Scheme 3.6).[10] Ruthenium-catalyzed oxidative cleavage of **3-23** gave lactol **3-15**.[11] Subsequent acylation provided desired acetal **3-16** in a 1:1 ratio of diastereomers. Via these three routes, both phenyl- and benzyl acetals **3-16** and **3-21** were prepared efficiently.



Scheme 3.4. Substrate Synthesis. Route A.



Scheme 3.5. Substrate Synthesis. Route B.

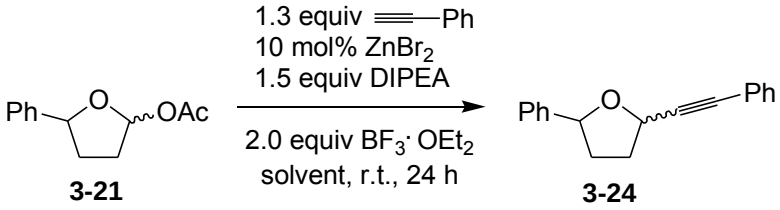


Scheme 3.6. Substrate Synthesis. Route C

With the substrates in hand, I investigated the use of polar solvents under the previously optimized alkynylation conditions for model substrate **3-8** and determined the diastereomeric ratio of products. For acetal **3-21**, product formation was observed in good yields in dioxane, dichloromethane, and tetrahydrofuran in a 2:1 ratio of diastereomers (Table 3.5).

When the best conditions for acetal **3-21** were applied to acetal **3-16**, the desired product was formed in 81% yield in a 3:2 ratio of diasteremers (Scheme 3.7). Using 1D NOE experiments, I determined that the major diastereomer was the trans-product. Substrates **3-16** and **3-21** are slightly biased towards the addition of a terminal alkyne. However, we are optimistic that this slight stereochemical bias may be overcome by identification of the proper chiral catalyst.

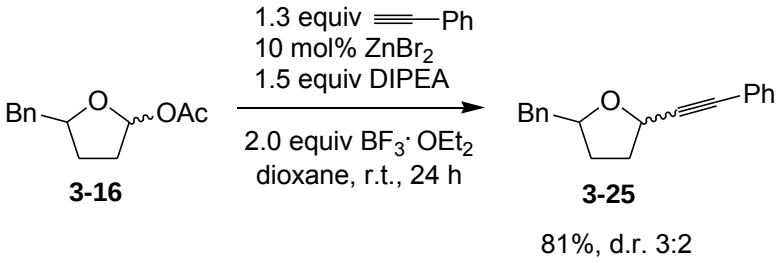
Table 3.5. Solvent Screen for Alkynylation of Tetrahydropyranyl Acetal **3-21**



3-21 **3-24**

Entry	Solvent	Yield, (%)[a]	d. r.[b]
1	DCM	69	2:1
2	dioxane	84 (68)[c]	2:1
3	THF	76	2:1

a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) The diastereomeric ratio was determined by ^{1}H NMR analysis of the crude reaction mixture. c) Isolated yield in parenthesis.



3-16 **3-25**

81%, d.r. 3:2

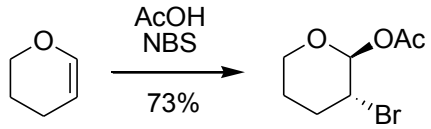
Scheme 3.7. Alkynylation of Tetrahydropyranyl Acetal **3-16**

Within this project, I have developed efficient routes for the preparation of racemic acetal starting materials and demonstrated that zinc-catalyzed alkynylation occurs with little stereochemical bias. The future work on this project will include identification of a chiral catalyst capable of controlling the stereochemistry of the alkyne addition. This effort will require preparation of enantiopure tetrahydrofuranyl acetals. By using opposite enantiomers of the chiral catalyst, we anticipate that both

cis and trans products can be prepared in high enantioselectivity. Methoxy will also be investigated as a leaving group in addition to acetate.

3.3 Diastereoselective Alkynylation of 2-Acetoxy-3-Bromotetrahydropyran

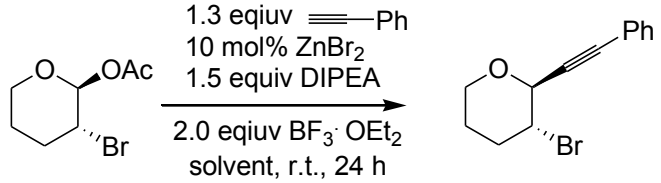
To investigate six-membered cyclic acetals in the zinc-catalyzed alkynylation, I prepared 2-acetoxy-3-bromotetrahydropyran **3-26** from dihydropyran **3-7** using acetic acid and *N*-bromosuccinamide (Scheme 3.8).[12] I conducted a solvent screen with this substrate under previously optimized conditions (Table 3.6). Dichloromethane was the optimal solvent providing 75% yield of desired product **3-27** (entry 1). A single diastereomer formed in the reaction under all conditions examined. The anti diastereoselectivity can be explained by neighboring group participation of the bromine substituent, which ensures delivery of the alkyne nucleophile from the opposite face of the bromine (Scheme 3.9). Neighboring group participation of bromine is well precedented.[13-25] However, the only reported alkynylations of a bromonium ion derived from enol ether were described with 2,3-dibromotetrahydropyran and trimethylsilyl lithium acetylide or ethynyl magnesium bromide.[26] Our route is more synthetically attractive, as the metal acetylide is catalytically formed in situ. This difference will enable greater functional group tolerance in our alkynylation.



3-7 (*rac*)-**3-26**

Scheme 3.8. Synthesis of 2-Acetoxy-3-Bromotetrahydropyran

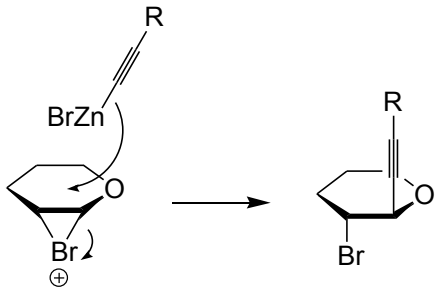
Table 3.6. Solvent Screen for Alkynylation of 2-Acetoxy-3-Bromotetrahydropyran



(rac)-**3-26** *(rac)*-**3-27**

Entry	Solvent	Yield (%)[a]	d.r.[b]
1	DCM	75	1:0
2	Et_2O	31	1:0
3	dioxane	38	1:0
4	THF	12	1:0

a) Yields determined by ^{1}H NMR analysis using 1,3,5-trimethoxybenzene as internal standard. b) The diastereomeric ratio was determined by ^{1}H NMR analysis of the crude reaction mixture.

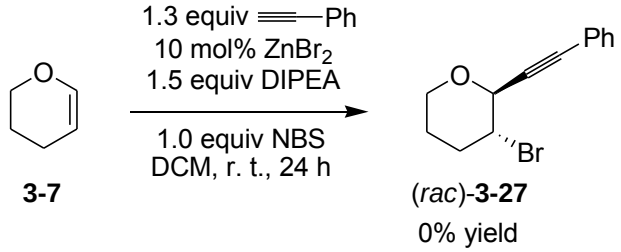


3-28 **3-29**

Scheme 3.9. Neighboring Group Participation in Alkynylation of 2-Acetoxy-3-Bromotetrahydropyran

I also investigated the possibility of a one-pot bromination/alkynylation sequence (Scheme 3.10). However, the one-pot bromoalkynylation of dihydropyran **3-7** did not provide desired product. The lack of desired reaction may be due to the

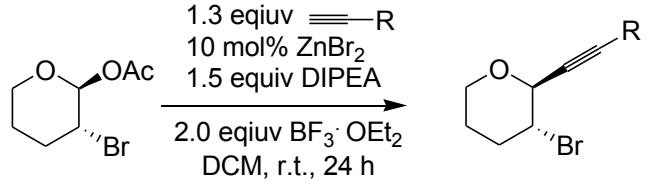
reaction of *N*-bromosuccinimide with the alkyne or zinc acetylide. A possible solution for this problem would be to premix **3-7** and *N*-bromosuccinamide to form the bromonium ion before the addition of the alkyne.

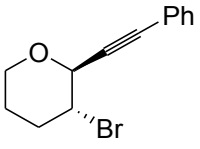


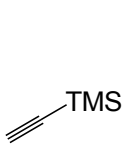
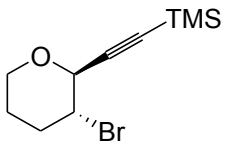
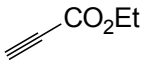
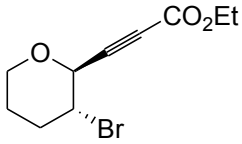
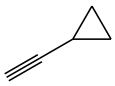
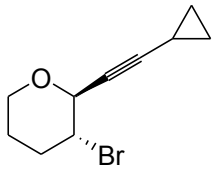
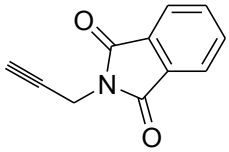
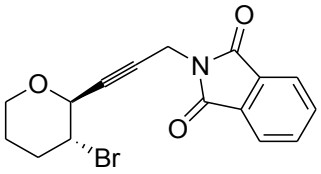
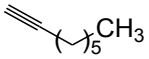
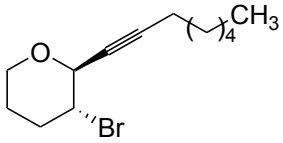
Scheme 3.10. Alkynylation of Dihydropyran via Bromonium Ion

Preliminary investigation of alkyne scope of this reaction suggests that a wide variety of alkynes can be used. Aromatic, aliphatic, and silyl acetylenes underwent the alkynylation in moderate to good yields (Table 3.7). The reaction can tolerate ester and amide functional groups (entries 3 and 5). A single trans diastereomer was formed in all cases.

Table 3.7. Preliminary Alkyne Scope[a]



Entry	Alkyne	Product	Yield (%)[b]	Ratio of Diatereomers[c]
1			54	1:0
	3-30	(*rac*)-**3-31**		

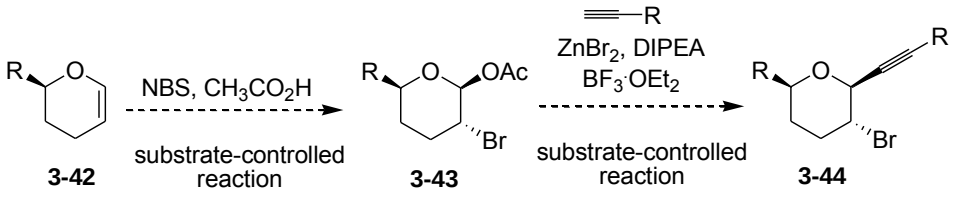
2			59	1:0
	3-32	(*rac*)-**3-33**		
3[d]			56	1:0
	3-34	(*rac*)-**3-35**		
4			81	1:0
	3-36	(*rac*)-**3-37**		
5[e]			33	1:0
	3-38	(*rac*)-**3-39**		
6			42	1:0
	3-40	(*rac*)-**3-41**		

a) Conditions: Acetal **3-26** (0.30 mmol, 1.0 equiv), $ZnBr_2$ (0.030 mmol, 10 mol %), alkyne (0.39 mmol, 1.3 equiv), i-Pr_2NEt (0.45 mmol, 1.5 equiv), $BF_3{\cdot}OEt_2$ (0.60 mmol, 2.0 equiv), DCM, r.t., 24 h. b) Isolated yields. c) The diastereomeric ratio was determined ^1H NMR analysis of the crude reaction mixture. d) 3.0 equiv of $BF_3{\cdot}OEt_2$ was used. e) 4.0 equiv of $BF_3{\cdot}OEt_2$ was used.

The products shown in Table 3.6 are useful intermediates in organic synthesis, as they contain both an alkyne and bromide for further functionalization.[16]

Halogenosugars serve as starting materials in the synthesis of other carbohydrate derivatives, including naturally occurring and synthetic deoxysugars, since the halogen can be easily removed by reducing agents[27] and photolysis.[28] Secondary bromide can also be functionalized using cross-coupling reactions.[29-37] Halogenosugars also represent valuable precursors in synthesis of non-sugar natural products.[16] For example, the products in Table 3.6 can react with *n*-BuLi to give cis and trans enynes.[26] This motif is present in natural products such as histrionicotoxin,[38] Laurencin,[39] and (-)-laurenine.[40]

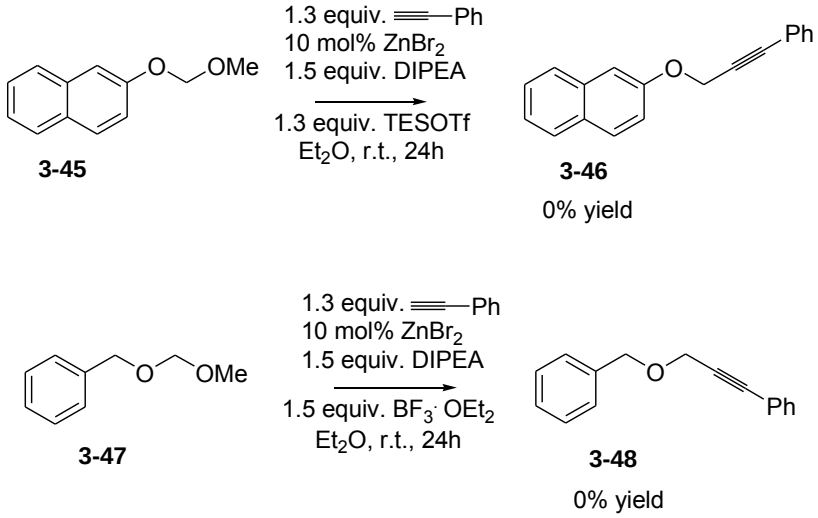
The future work on this project will include further optimization of reaction conditions to increase the reaction yields. The alkynylation of 2-acetoxy-3-chlorotetrahydropyran and 2-acetoxy-3-iodotetrahydropyran in a similar diastereoselective manner will be investigated. This methodology will be applied to functionalize glucals such as **3-42** using substrate-controlled stereoselective formation of bromoacetate **3-43** and then substrate-controlled alkynylation to give pyran **3-44** in high diastereoselectivity (Scheme 3.11). This strategy will constitute a powerful procedure for the construction of multi-substituted pyrans.



Scheme 3.11. Proposed Functionalization of Glucals

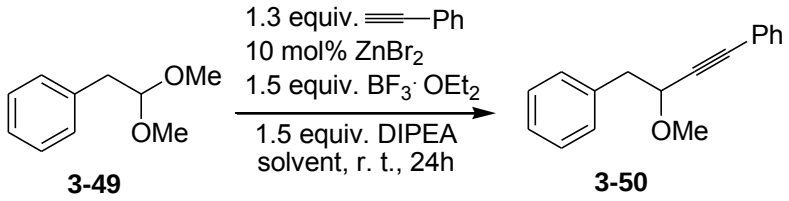
3.4 Preliminary Results for Alkynylation of Acyclic Acetals

To confirm that our alkynylation methodology can be applied to aliphatic acyclic oxocarbenium ions in the same manner, primary and secondary acetals were tested in the alkynylation reaction. The application of the optimized conditions for alkynylation did not produce desired product with primary acetals **3-45** and **3-47** (Scheme 3.12). In comparison, alkynylation of secondary acetal **3-49** furnished desired product **3-50** in 79% yield in Et_2O (Table 3.8). Thus, secondary acyclic acetals were good substrates for the alkynylation, affording products in good yields, while primary acetals did not react under the optimized reaction conditions. We hypothesize that this reactivity difference is due to the greater stability of the secondary oxocarbenium ion; with primary acetals **3-45** and **3-47**, the oxocarbenium ion may not form under these conditions.



Scheme 3.12. Alkynylation of Primary Acetals

Table 3.8. Solvent Screen Alkynylation of Secondary Acyclic Acetals



3-49 **3-50**

Entry	Solvent	Yield, (%)[a]
1	dioxane	53
2	Et_2O	79 (41)[b]
3	DCM	67
4	THF	65

a) Yields determined by ^1H NMR analysis using 1,3,5-trimethoxybenzene as internal standard (0.10 mmol scale). b) Isolated yield in parenthesis (0.30 mmol scale).

3.5 Conclusion and Future Work

I have developed efficient conditions for the zinc-catalyzed alkynylation of cyclic nonbenzopyranyl acetals. Studying 2-acetoxytetrahydropyran as a model substrate, I obtained useful data regarding the conditions required for alkynylation. I discovered that zinc bromide was an efficient catalyst for alkynylation and $BF_3{\cdot}OEt_2$ was a suitable Lewis acid for the reaction. I concluded that a hindered base such as DIPEA was required for alkynylation and that the choice of solvent had a major effect on the reaction. Acetate was chosen as the leaving group for the reaction based on previous results with chroman acetals. I also prepared tetrahydrofuranyl acetals which were tested under the optimized alkynylation conditions. Product formation was observed in good yields. I determined that substituted tetrahydrofuranyl acetals were

slightly stereochemically biased towards the addition of zinc acetylides. In the case of six-membered rings, the alkynylation of 3-bromo-2-acetoxypyran was performed in moderate to good yields, and a single diastereomer was formed in these reactions. The stereoselectivity can be explained by the participation of the neighboring bromine substituent via formation of a bromonium ion. The preliminary alkyne scope of this reaction is very promising.

Working with acyclic acetals, I discovered that secondary acyclic acetals underwent alkynylation in good yields, while primary acetals did not react under the optimized alkynylation conditions. This reactivity difference is likely due to the differing stabilities of their respective oxocarbenium ions.

These studies established several exciting directions for the future studies. For five-membered acetals, future work will include preparation of enantiomerically pure substrates and identification of a chiral catalyst that is capable of forming selectively a single cis or trans diastereomer. For six-membered acetals, the future work will include the functionalization of glucals using substrate-controlled stereoselective formation of bromoacetate and subsequent substrate-controlled alkynylation to give multisubstituted pyrans in high diastereoselectivity.

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Appendix A

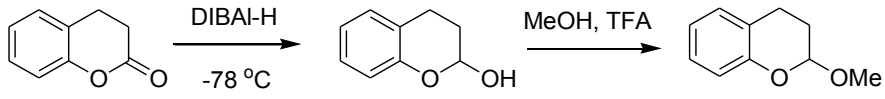
EXPERIMENTAL

Reactions were performed either in a N_2-atmosphere glovebox in oven-dried 1-dram vials with Teflon-lined caps or in oven-dried round-bottomed flasks unless otherwise noted. Flasks were fitted with rubber septa, and reactions were conducted under a positive pressure of N_2. Stainless steel syringes or cannulae were used to transfer air- and moisture-sensitive liquids. Flash chromatography was performed on silica gel 60 (40-63μm, 60Å). Thin layer chromatography (TLC) was performed on glass plates coated with silica gel 60 with F254 indicator. Commercial reagents were purchased from Sigma Aldrich, Acros, Fisher, Strem, or Cambridge Isotopes Laboratories and used as received with the following exceptions: toluene, dioxane, CH_2Cl_2, THF and Et_2O were dried by passing through drying columns.[1] Toluene and dioxane were then degassed by sparging with N_2. Toluene was stored over activated 4Å MS in a N_2-atmosphere glovebox. MeCN, Et_3N, (*i*-Pr)$_2$NEt, PMP, Cy_2NEt, pyridine, and DBU were distilled from CaH_2. TMSOTf, TESOTf, TIPSOTf, and TBSOTf were distilled before use and stored under N_2. $CDCl_3$ was stored over oven-dried potassium carbonate. Alkynes were degassed before use by either freeze-pump-thaw cycles or sparging with N_2. Proton nuclear magnetic resonance (^{1}H NMR) spectra and carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded on 400 MHz spectrometers. Chemical shifts for protons are reported in parts per million downfield from tetramethylsilane and are referenced to residual protium in the NMR solvent ($CHCl_3$ = δ 7.26). Chemical shifts for carbon are reported in parts per million downfield from tetramethylsilane and are referenced to the carbon resonances of the solvent ($CDCl_3$ = δ 77.16). Data are represented as follows: chemical shift, multiplicity (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in Hertz (Hz), integration. Infrared (IR) spectra were obtained using FTIR spectrophotometers with material loaded

onto a NaCl plate. The mass spectral data were obtained at the University of Delaware spectrometry facility. Known lactone **3-14**,[2] lactols **2-10**[3-4] and **3-20**,[5] and acetals **3-8**,[6] **3-26**,[7] and **3-49**[8] were prepared as described in the literature.

Preparation of Chroman Acetal Substrates

2-Methoxychroman[9]



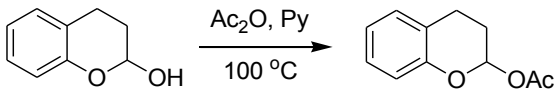
2-9 **2-10** **2-5**

This procedure was adopted from that reported in the literature.[10] The solution of **2-9** (5.0 g, 33.7 mmol, 1.0 equiv) in toluene (0.6 M, 60 mL) was cooled to -78 °C and DIBAl-H (1.2 M, 36.5 mL, 43.8 mmol, 1.3 equiv) was added slowly via syringe. The reaction mixture was stirred for 4 hours at -78 °C and then allowed to warm to 0 °C and stirred for 15 min. The reaction was diluted with EtOAc (150 mL) and quenched with H_2O (150 mL) and vigorously stirred and filtered through Celite. The layers were separated and the aqueous layer was extracted with EtOAc (2 x 150 mL). The organic layers were combined and washed with brine (100 mL) and then dried with $MgSO_4$, filtered, and concentrated. This material was taken forward without purification.

The crude **2-10** was redissolved in MeOH (60 mL, 0.6 M). Trifluoroacetic acid (77 μL, 1.0 mmol, 0.03 equiv) was added, and the reaction was stirred for 3 h at room temperature. The reaction was quenched with K_2CO_3 (233 mg, 1.7 mmol, 0.05 equiv), filtered and concentrated under reduced pressure. Crude product was purified by silica gel chromatography (2 - 5% EtOAc in hexanes) to give 2-methoxychroman **2-5** (2.50 g, 63%) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (t, *J*=7.6 Hz, 1 H), 7.03 (d, *J*=7.6 Hz, 1 H), H), 6.92 - 6.87 (m, 2 H), 5.15 (t, *J*=2.7 Hz, 1 H), 3.50 (s, 3 H), 3.02 - 2.90 (m, 1 H), 2.69 - 2.60, (m, 1 H), 2.11 - 1.90 (m, 2 H); ^{13}C NMR (101 MHz, $CDCl_3$)

δ 152.0, 129.4, 127.4, 122.7, 120.8, 117.1, 98.2, 55.8, 26.4, 20.4; FTIR (NaCl/thin film) 2936, 1583, 1488, 1458, 1374, 1275, 1213, 1184, 1106, 1060, 999, 910, 755cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{10}H_{12}O_2$: 164.0832, found: 164.

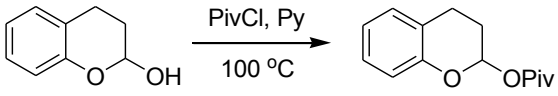
2-Acetoxychroman



2-10 **2-7**

This procedure was adopted from that reported in the literature.[11] Pyridine (1.2 mL, 14.9 mmol, 2.0 equiv) was added to a solution of 2-hydroxychroman (**2-10**, 1.12 g, 7.46 mmol, 1.0 equiv) in acetic anhydride (4.0 mL, 42.4 mmol, 5.7 equiv). The reaction mixture was stirred at 100 °C for 3 hours and then cooled to room temperature. H_2O (5 mL) was added to the reaction mixture. The layers were separated and the aqueous layer was extracted with Et_2O (5 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. The crude product was purified by silica gel chromatography (10% Et_2O/hexanes with 2% Et_3N) to give 2-acetoxychroman **2-7** (1.08 g, 75%) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14 (t, *J*=7.6 Hz, 1 H), 7.08 (d, *J*=7.6 Hz, 1 H), 6.96 - 6.85 (m, 2 H), 6.53 (t, *J*=2.3 Hz, 1 H), 2.99 (ddd, *J*=16.9, 12.6, 6.1 Hz, 1 H), 2.71 (ddd, *J*=15.8, 6.1, 2.9 Hz, 1 H), 2.17 – 1.97 (m, 5 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.1, 151.6, 129.4, 127.7, 121.8, 121.5, 117.2, 90.3, 25.1, 21.4, 19.7; FTIR (NaCl/thin film) 2939, 2853, 1751, 1491, 1458, 1244, 1207, 1174, 1119, 1049, 1004, 955, 916, 757 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{11}H_{12}O_3$: 192.0781, found 192.

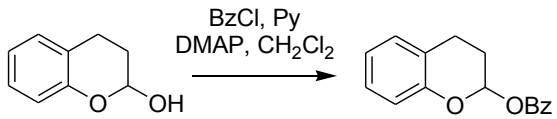
2-Pivaloyloxychroman



2-10 **2-11**

Pivaloyl chloride (2.5 mL, 20 mmol, 2.0 equiv) was added to a solution of 2-hydroxychroman (**2-10**, 1.5 g, 10 mmol, 1.0 equiv) in pyridine (3 mL, 3.3 M). The reaction mixture was stirred at 100 °C for 3 hours and then cooled to room temperature. H_2O (10 mL) was added. The layers were separated and the aqueous layer was extracted with Et_2O (10 mL×3). Combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Crude product was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give 2-pivaloyloxychroman **2-11** (1.21g, 52%) as a yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16 - 7.04 (m, 2 H), 6.95 - 6.83 (m, 2 H), 6.55 - 6.47 (t, *J*=0.6 Hz, 1 H), 2.98 (ddd, *J*=16.4, 12.9, 6.3 Hz, 1 H), 2.72 (ddd, *J*=16.4, 15.8, 2.5 Hz, 1 H), 2.18 - 1.97 (m, 2 H), 1.15 (s, 9 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 177.4, 151.7, 129.3, 127.7, 121.8, 121.4, 117.2, 90.2, 39.1, 27.1, 25.2, 19.9; FTIR (thin film) 2973, 2935, 1743, 1585, 1492, 1481, 1459, 1275, 1227, 1181, 113, 1114, 1048, 1033, 944, 914, 755 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{14}H_{18}O_3$: 234.1251, found: 234.

2-Benzoyloxychroman

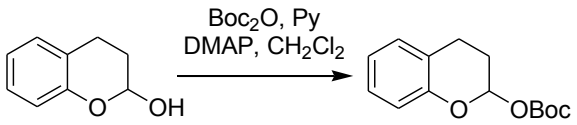


2-10 **2-12**

Pyridine (120 µL, 1.47 mmol, 2.0 equiv) and DMAP (8.9 mg, 0.073 mmol, 0.10 equiv) were added to a solution of 2-hydroxychroman (**2-10**, 110 mg, 0.733 mmol, 1.0

equiv) in CH_2Cl_2 (2 mL, 0.4 M). The reaction mixture was cooled to 0 ^oC in an ice-water bath and BzCl (102 µL, 0.88 mmol, 1.2 equiv) was added via syringe. The reaction was warmed to room temperature and stirred for 3 days. H_2O (7 mL) was added to the reaction mixture. The layers were separated and the aqueous layer was extracted with EtOAc (10 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Purification by silica gel chromatography gave 2-benzoyloxychroman **2-12** (167 mg, 90%)[12] as a white solid (m. p. 99-100 ^oC): ^1H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J*=7.3 Hz, 2 H), 7.63 - 7.50 (m, 1 H), 7.48 - 7.36 (m, 2 H), 7.14 (m, 2 H), 7.00 - 6.87 (m, 2 H), 6.80 (br s, 1 H), 3.25 - 3.07 (m, 1 H), 2.82 (dd, *J*=16.3, 3.4 Hz, 1 H), 2.38 - 2.24 (m, 1 H), 2.10 - 2.23 (m, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.4, 151.7, 133.5, 129.8, 129.4, 129.3, 128.5, 127.8, 121.8, 121.6, 117.3, 90.9, 24.3, 19.9; FTIR (NaCl/thin layer) 3736, 2923, 1729, 1488, 1262, 1220, 1084, 1008, 700. cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{16}H_{14}O_3$: 254.0938, found: 254.

2-*tert*-Butyloxycarbonyloxychroman

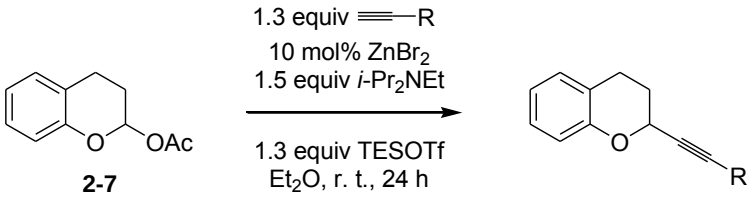


2-10 **2-13**

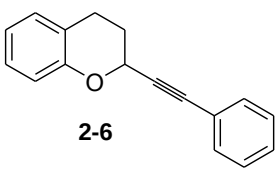
Pyridine (220 µL, 2.76 mmol, 2.0 equiv) and DMAP (16.9 mg, 0.138 mmol, 0.10 equiv) were added to a solution of 2-hydroxychroman (**2-10**, 207 mg, 1.38 mmol, 1.0 equiv) in CH_2Cl_2 (3 mL, 0.5 M). The reaction mixture was cooled to 0 ^oC in an ice-water bath, and Boc_2O (361 mg, 1.65 mmol, 1.2 equiv) was added. The reaction was then warmed to room temperature and stirred for 3 days. H_2O (5 mL) was added to the reaction mixture. The layers were separated and the aqueous layer was extracted with EtOAc (5 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Purification by silica gel chromatography (5% Et_2O/hexanes with 2%

Et_3N) gave chroman **2-13** (273mg, 80%) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.13 (t, *J*=7.6 Hz, 1 H), 7.07 (d, *J*=7.6 Hz, 1 H), 6.91 (t, *J*=7.6 Hz, 2 H), 6.36 (t, *J*=2.8 Hz, 1 H), 3.09 - 2.95 (m, 1 H), 2.76 - 2.63 (m, 1 H), 2.23 - 2.11 (m, 1 H), 2.10 - 1.97 (m, 1 H), 1.49 (s, 9 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 152.4, 151.5, 129.4, 127.7, 121.9, 121.5, 117.2, 92.7, 83.0, 27.9, 25.2, 19.7; FTIR (NaCl/thin film) 2980, 2935, 1751, 1585, 1491, 1458, 1369, 1286, 1215, 1160, 1105, 1050, 1013, 917, 891, 843, 755 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{14}H_{18}O_4$: 250.1200, found 250.

Alkynylation of Chroman Acetals

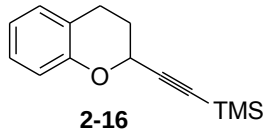


General Method. In a N_2-atmosphere glovebox, $ZnBr_2$ (6.8 mg, 0.030 mmol, 10 mol%) was weighed into a 1-dram vial, and then Et_2O (1.5 mL, 0.2 M), alkyne (0.39 mmol, 1.3 equiv), *i*-Pr_2NEt (75 μL, 0.45 mmol, 1.5 equiv) and 2-acetoxychroman (**2-7**, 57.6 mg 0.30 mmol, 1.0 equiv) were added. The vial was capped with a Teflon-lined septum cap and removed from the glovebox. TESOTf (90 μL, 0.39 mmol, 1.3 equiv) was added via syringe, and the reaction mixture was stirred for 24 h at room temperature. The mixture was then diluted with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was rinsed with Et_2O (10 mL). The filtrate was concentrated and purified by silica gel chromatography.



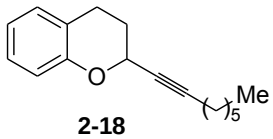
Chroman 2-6. Prepared via General Method described above. Crude material was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give compound **2-6** (67.1 mg, 95%) as a colorless oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 -

7.41 (m, 2 H), 7.37 - 7.27 (m, 3 H), 7.18 - 7.05 (m, 2 H), 6.94 - 6.86 (m, 2 H), 5.17 (dd, *J*=6.8, 3.3 Hz, 1 H), 3.05 (dt, *J*=16.5, 6.8 Hz, 1 H), 2.86 (dt, *J*=16.5, 6.8 Hz, 1 H), 2.18 - 2.35 (m, 2 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.6, 132.0, 129.7, 128.7, 128.4, 127.5, 122.4, 121.7, 120.8, 117.3, 87.1, 85.5, 66.2, 28.1, 23.4; FTIR (NaCl/thin layer) 3858, 3750, 3060, 2932, 2846, 2231, 1653, 1559, 1488, 1456, 1228, 1112, 990, 752, 690 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{17}H_{14}O$: 234.1040, found: 234.



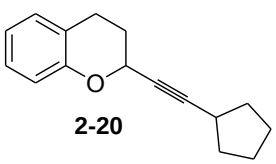
2-16

Chroman 2-16. Prepared via General Method described above. Crude material was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give compound **2-16** (61.1 mg, 88%) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.10 (t, *J*=7.6 Hz, 1 H), 7.05 (d, *J*=7.6 Hz, 1 H), 7.14 - 7.02 (m, 2 H), 6.90 - 6.83 (m, 2 H), 4.88 (dd, *J*=7.6, 3.0 Hz, 1 H), 2.99 - 2.89 (m, 1 H), 2.85 - 2.75 (m, 1 H), 2.25 - 2.04 (m, 2 H), 0.17 (s, 9 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.6, 129.6, 127.4, 121.6, 120.8, 117.3, 103.4, 90.5, 66.2, 28.2, 23.6, -0.1; FTIR (NaCl/thin film) 3853, 2959, 2900, 2181, 1583, 1488, 1457, 1250, 1229, 1114, 1059, 993, 958, 844, 756, 668 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{14}H_{18}OSi$: 230.1122, found: 230.



2-18

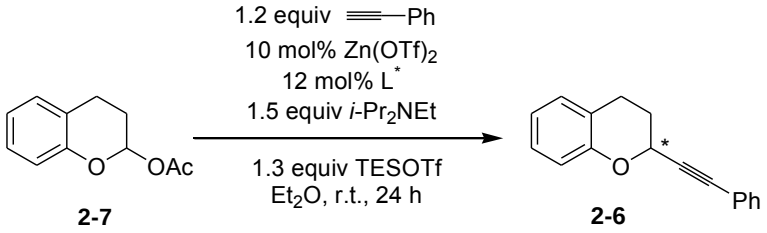
Chroman 2-18. Prepared via General Method described above. Crude material was purified by silica gel chromatography (2% Et_3N/hexanes) to give compound **2-18** (66.1 mg, 91%) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14 - 7.03 (m, 2 H), 6.90 - 6.82 (m, 2 H), 4.93 - 4.86 (m, 1 H), 2.95 (dt, *J*=16.4, 6.4 Hz, 1 H), 2.80 (dt, *J*=16.4, 6.4 Hz, 1 H), 2.26 - 2.12 (m, 3 H), 2.11 - 2.00 (m, 1 H), 1.54 - 1.44 (m, 2 H), 1.39 - 1.18 (m, 6 H), 0.87 (t, *J*=7.0 Hz, 3 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.7, 129.6, 127.4, 121.7, 120.7, 117.3, 86.6, 78.2, 66.1, 31.4, 28.62, 28.59, 28.4, 23.5, 22.7, 18.9, 14.2; FTIR (NaCl/thin film) 3853, 2955, 2931, 2857, 2265, 1488, 1457, 1230, 1066, 991, 752, 668 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{17}H_{22}O$: 242.1666, found: 242.



2-20

Chroman 2-20. Prepared via General Method described above. Crude material was purified by silica gel chromatography (2% Et_2O/hexanes with 2% Et_3N) to give compound **2-18** (55.6 mg, 82%)[13] as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.07 (t, *J*=8.0 Hz, 1 H), 7.03 (d, *J*=8.0 Hz, 1 H), 6.89 - 6.80 (m, 2 H), 4.93 - 4.83 (m, 1 H), 2.99 - 2.88 (m, 1 H), 2.84 - 2.73 (m, 1 H), 2.69 - 2.58 (m, 1 H), 2.22 - 2.12 (m, 1 H), 2.11 - 2.00 (m, 1 H), 1.96 - 1.84 (m, 2 H), 1.76 - 1.46 (m, 6 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.8, 129.6, 127.4, 121.7, 120.6, 117.3, 90.7, 77.7, 66.1, 33.8, 30.2, 28.5, 25.0, 23.6; FTIR (NaCl/thin film) 3853, 3750, 2958, 2869, 2237, 1653, 1559, 1506, 1488, 1457, 1229, 1065, 991, 753, 668 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{16}H_{18}O$: 226.1353, found: 226.

Asymmetric Alkynylation of Chroman Acetals

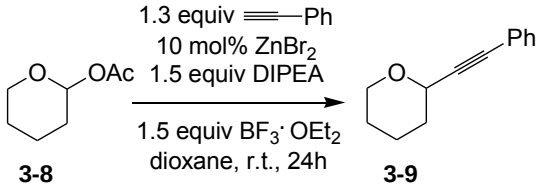


2-7 2-6

General Method. In a N_2-atmosphere glovebox, $ZnOTf_2$ (3.6 mg, 0.010 mmol, 10 mol%) was weighed into a 1-dram vial. Ligand (0.012 mmol, 12 mol%) and then Et_2O (0.5 mL) were added. The vial was capped with a Teflon-lined cap. The mixture was stirred for 1 h at room temperature in the glovebox. The vial was then opened, and phenylacetylene (13 µL, 0.13 mmol, 1.3 equiv), *i*-Pr_2NEt (25 µL, 0.15 mmol, 1.5 equiv), and 2-acetoxychroman (**2-7**, 19.2 mg 0.10 mmol, 1.0 equiv) were added. The vial was capped with a Teflon-lined septum cap and removed from the glovebox. TESOTf (30 µL, 0.13 mmol, 1.3 equiv) was added via syringe, and the reaction mixture was stirred for 24 h at room temperature. The mixture was then diluted with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was rinsed with Et_2O (10 mL). The filtrate

was concentrated, purified using preparatory TLC and submitted for analysis on chiral HPLC.

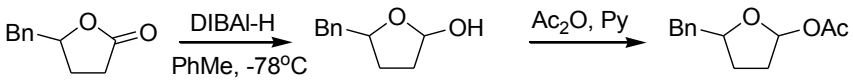
Alkynylation of 2-Acetoxytetrahydropyran



In a N_2-atmosphere glovebox, $ZnBr_2$ (7.9 mg, 0.035 mmol, 10 mol%) was weighed into a 1-dram vial, and then dioxane (1.7 mL, 0.2 M), phenylacetylene (49 µL, 0.45 mmol, 1.3 equiv), *i*-Pr_2NEt (86 µL, 0.52 mmol, 1.5 equiv), 2-acetoxytetrahydropyran **3-8** (50 mg, 0.35 mmol, 1.0 equiv) and $BF_3{\cdot}OEt_2$ (88 µL, 0.69 mmol, 2.0 equiv) were added. The vial was capped, and the reaction mixture was stirred for 24 h at room temperature in the glovebox. The vial was removed from the box, and the mixture was diluted with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was then rinsed with Et_2O (10 mL). The filtrate was concentrated and purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give pyran **3-9** (34 mg, 53%).[14] The spectral data for this compound match that reported in the literature.[15]

Preparation of Tetrahydropyranyl Acetals

2-Acetoxy-5-Benzyl-Tetrahydropyran

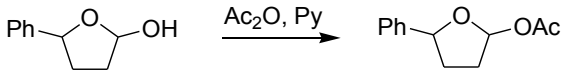


A solution of **3-14**[2] (67.4 mg, 0.38 mmol, 1.0 equiv) in toluene (1.9 mL, 0.2 M) was cooled to -78 °C and DIBAl-H (1.2 M, 414 µL, 0.497 mmol, 1.3 equiv) was added slowly via syringe. The reaction mixture was stirred for 4 hours at -78 °C. The reaction

was then quenched with methanol (500 µL) and stirred for 30 minutes at -78 ^{o}C. A saturated solution of Rochelle's salt (10 mL) was added, and the reaction mixture was warmed to room temperature and stirred overnight. The layers were separated and the aqueous layer was extracted with Et_2O (10 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. This material was taken forward without purification.

The crude **3-15** was redissolved in CH_2Cl_2 (2 mL, 0.2 M). Acetic anhydride (0.5 mL, 5.30 mmol, 13.9 equiv) and pyridine (0.5 mL, 6.20 mmol, 16.3 equiv) were added to the solution, and the reaction mixture was stirred at 60 ^{o}C overnight. The solution was cooled to room temperature and H_2O (5 mL) was added to the reaction mixture. The layers were separated and the aqueous layer was extracted with EtOAc (5 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Excess acetic anhydride and pyridine were removed under high vacuum. Crude product was purified by silica gel chromatography to give 2-acetoxy-5-benzyl-tetrahydropyran **3-16** (51.9 mg, 62 %) as a 1:1 mixture of diastereomers as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$, both diastereomers) δ 7.19 - 7.36 (m, 10 H), 6.36 - 6.31 (m, 1 H), 6.26 (d, *J*=2.8 Hz, 1 H), 4.52 (quin, *J*=6.3 Hz, 1 H), 4.35 (dq, *J*=9.1, 6.3 Hz, 1 H), 3.08 (dd, *J*=13.5, 6.0 Hz, 1 H), 2.99 (dd, *J*=13.5, 6.0 Hz, 1 H), 2.85 (dd, *J*=13.5, 7.0 Hz, 1 H), 2.77 (dd, *J*=13.5, 7.0 Hz, 1 H), 2.10 - 1.62 (m, 14 H); ^{13}C NMR (101 MHz, $CDCl_3$, both diastereomers) δ 170.74, 170.68, 138.1, 137.9, 129.54, 129.53, 128.46, 126.6, 126.5, 99.3, 99.0, 82.7, 80.9, 42.9, 41.5, 32.9, 31.7, 28.4, 27.7, 21.6, 21.5; FTIR (NaCl/thin film) 3062, 3028, 2941, 1743, 1604, 1497, 1454, 1375, 1240, 1101, 1009, 959, 854, 753, 701 cm^{-1}.

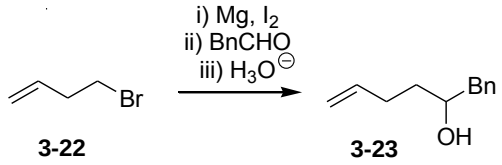
2-Acetoxy-5-Phenyl-Tetrahydropyran



3-20 **3-21**

Acetic anhydride (0.5 mL, 5.30 mmol, 7.9 equiv) and pyridine (0.5 mL, 6.20 mmol, 9.3 equiv) were added to a solution of 2-hydroxy-5-phenyl-tetrahydropyran[5] (**3-20**, 110 mg, 0.67 mmol, 1.0 equiv) in CH_2Cl_2 (3.4 mL, 0.2 M), and the reaction mixture was stirred at 60 ^oC overnight. The solution was cooled to room temperature and H_2O (10 mL) was added to the reaction mixture. The layers were separated and the aqueous layer was extracted with EtOAc (10 mL×3). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Excess acetic anhydride and pyridine were removed under high vacuum. Crude product was purified by silica gel chromatography (10% Et_2O/hexanes with 2% Et_3N) to give 2-acetoxy-5-benzyl-tetrahydropyran **3-21**(124.2 mg, 90%) as a 1.15:1 mixture of diastereomers as a light yellow oil: ^1H NMR (400 MHz, $CDCl_3$, both diastereomers) δ 7.39 - 7.32 (m, 10 H), 6.54 (d, *J*=4.8 Hz, 1 H), 6.42 (br. s., 1 H), 5.27 (t, *J*=7.0 Hz, 1 H), 5.10 (dd, *J*=10.1, 6.3 Hz, 1 H), 2.49 (dq, *J*=12.2, 7.9 Hz, 1 H), 2.24 - 2.42 (m, 2 H), 2.16 - 2.23 (m, 2 H), 1.94 - 2.14 (m, 8 H), 1.88 (dq, *J*=15.47, 5.79 Hz, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$, both diastereomers) δ 170.7, 170.6, 142.3, 141.8, 128.6, 128.5, 127.74, 127.69, 126.1, 125.7, 99.3, 99.1, 83.8, 81.4, 33.7, 32.4, 32.1, 31.8, 21.7, 21.6; FTIR (NaCl/thin film) 3031, 2990, 2951, 1744, 1375, 1237, 1165, 1097, 1010, 962, 883, 849, 760, 701 cm^{-1}.

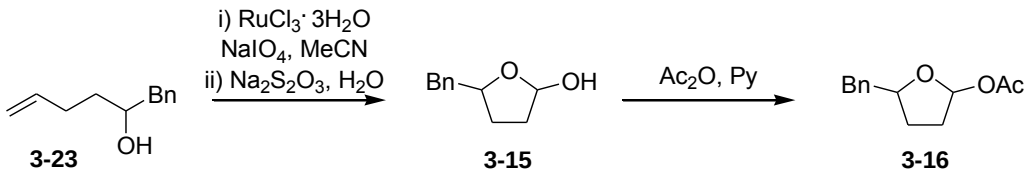
1-Phenyl-5-Hexene-2-ol



3-22 **3-23**

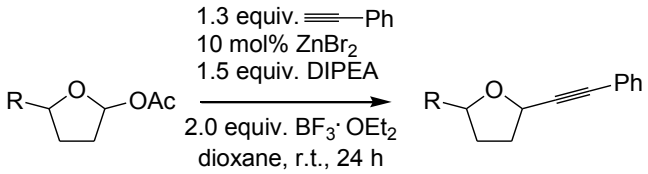
This procedure was adopted from that reported in the literature.[16-17] Magnesium turnings (196 mg, 8.05 mmol, 1.2 equiv) were placed in a 50-mL three-neck round-bottomed flask and dried with a heat gun under vacuum. The flask was cooled to room temperature, and dry Et_2O (6.7 mL, 1.0 M), 1,2-dibromoethane (9 µL, 0.10 mmol, 0.015 equiv), and a small crystal of iodine were added to the flask. The mixture was stirred for 30 minutes and 4-bromo-1-butene (**3-22**, 680µL, 6.71 mmol, 1.0 equiv) was added slowly via syringe. The reaction mixture turned green and started to boil. The mixture was stirred at 45 ^oC for 3 hours, and the green color disappeared. The reaction mixture was then cooled to 0 ^oC in an ice-water bath and phenylacetaldehyde (780 µL, 6.71 mmol, 1.0 equiv) was added slowly via syringe. The reaction mixture was stirred for 2 hours at room temperature and then quenched with H_2O (10 mL) and then 1.0 M HCl (5 mL). The magnesium salts dissolved. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (15 mL×3). The organic layers were washed with sat. Na_2CO_3 (40 mL) and then water (40 mL) . The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Crude product was purified by silica gel chromatography (20% Et_2O/hexanes) to give **3-23** (970 mg, 82%) as a light yellow oil. The spectral data for this compound match that reported in the literature.[16-17]

2-Acetoxy-5-Benzyl-Tetrahydropyran



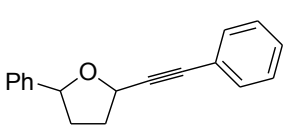
$RuCl_3 \cdot 3H_2O$ (8.5 mg, 0.040 mmol, 0.035 equiv) was added to a solution of **3-23** (200 mg, 1.14 mmol, 1.0 equiv) in MeCN (5.7 mL, 0.2 M). Then H_2O (1.0 mL) and $NaIO_4$ (485.5 mg, 2.27 mmol, 2.0 equiv) were added. The reaction mixture was stirred for 1 hour at room temperature. Sat. $Na_2S_2O_3$ (5 mL) and then H_2O (5 mL) were added to dissolve all precipitates. The layers were separated and the aqueous layer was extracted with Et_2O (15 mL×3) and washed with brine (40 mL). The combined organic layers were dried with $MgSO_4$, filtered, and concentrated. Crude product was taken forward without purification. The procedure for acylation of **3-15** is the same as described above.

Alkynylation of Tetrahydrofuran Acetals



General Method. In a N_2-atmosphere glovebox, $ZnBr_2$ (6.8 mg, 0.030 mmol, 10 mol%) was weighed into a 1-dram vial, and then dioxane (1.5 mL, 0.2 M), phenylacetylene (43 µL, 0.39 mmol, 1.3 equiv), *i*-Pr_2NEt (75 µL, 0.45 mmol, 1.5 equiv), acetal (0.30 mmol, 1.0 equiv) and $BF_3 \cdot OEt_2$ (76 µL, 0.60 mmol, 2.0 equiv) were added. The vial was capped, and the reaction mixture was stirred for 24 h at room temperature in the glovebox. The vial was removed from the glovebox, and the mixture was diluted

with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was rinsed with Et_2O (10 mL). The filtrate was concentrated and purified by silica gel chromatography.



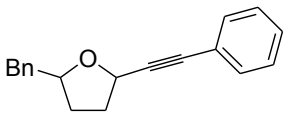
3-24

Tetrahydropyran 3-24. Prepared via General Method described above. ^{1}H NMR analysis of the crude material showed that the ratio of diastereomers was 2:1.[18] Crude material was purified by silica gel chromatography (2% Et_3N/hexanes) to give compound **3-24** (Total: 50.7 mg, 68%; *Trans*-**3-24**: 16.3 mg, 22 %; *Cis*-**3-24**: 7.2 mg, 10 %; mixture of *cis*- and *trans*-**3-24**: 27.2 mg, 36%).

T*rans*-**3-24**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (dd, *J*=6.4, 2.9 Hz, 2 H), 7.40 - 7.25 (m, 8 H), 5.21 (t, *J*=7.2 Hz, 1 H), 5.14 (t, *J*=6.4 Hz, 1 H), 2.59 - 2.49 (m, 1 H), 2.43 (dtd, *J*=12.4, 7.5, 7.5, 5.1 Hz, 1 H), 2.30 - 2.19 (m, 1 H), 1.91 (dq, *J*=12.4, 7.5 Hz, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.6, 131.9, 128.48, 128.45, 128.37, 127.5, 125.9, 122.9, 89.3, 84.8, 80.6, 69.3, 34.6, 34.0; LCMS (CI+) $[M]^+$ calculated for $C_{18}H_{16}O$: 248.1196, found: 248.

Cis-**3-24**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 - 7.43 (m, 4 H), 7.39 - 7.27 (m, 6 H), 5.05 – 4.97 (m, 2 H), 2.46 - 2.31 (m, 2 H), 2.30 - 2.20 (m, 1 H), 2.14 - 2.03 (m, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.8, 131.7, 128.34, 128.33, 128.29, 127.4, 126.1, 122.9, 89.4, 85.0, 82.1, 69.5, 34.9, 34.0; LCMS (CI+) $[M]^+$ calculated for $C_{18}H_{16}O$: 248.1196, found: 248.

FTIR (NaCl/thin film, both diastereomers) 2948, 2871, 1598, 1490, 1443, 1335, 1079, 1045, 755, 691 cm^{-1}.



3-25

Tetrahydropyran 3-25. Prepared via General Method described above. The reaction was run on a 0.136 mmol scale. ^{1}H NMR analysis of the crude material showed that the ratio of

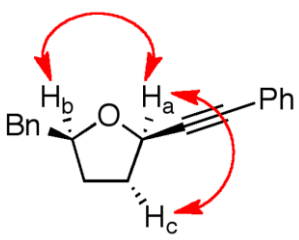
diastereomers was 3:2. Crude material was purified by silica gel chromatography (3% Et_2O/hexanes with 2% Et_3N) to give compound **3-25** (Total: 29.0 mg, 81%; *Trans*-**3-25**: 7.0 mg, 20 %; *Cis*-**3-25**: 5.1 mg, 14%; mixture of *cis*- and *trans*-**3-25**: 16.9 mg, 47%).

Trans-**3-25**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 - 7.38 (m, 2 H), 7.35 - 7.18 (m, 8 H), 4.96 - 4.88 (m, 1 H), 4.42 (quin, *J*=6.5 Hz, 1 H), 3.02 (dd, *J*=13.4, 5.6 Hz, 1 H), 2.78 (dd, *J*=13.6, 7.3 Hz, 1 H), 2.31 - 2.17 (m, 1 H), 2.15 - 2.01 (m, 2 H), 1.71 - 1.60 (m, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) 138.4, 131.9, 129.5, 128.5, 128.4, 128.3, 126.4, 122.9, 89.5, 84.6, 79.9, 68.7, 41.7, 33.7, 30.8; LCMS (CI+) $[M]^+$ calculated for $C_{19}H_{18}O$: 262.1353, found: 262.

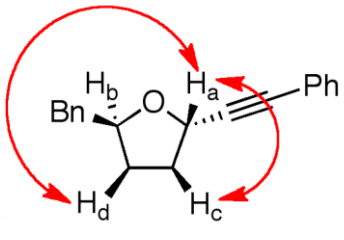
Cis-**3-25**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (dd, *J*=6.4, 2.9 Hz, 2 H), 7.38 - 7.18 (m, 8 H), 4.85 - 4.77 (m, 1 H), 4.18 (quin, *J*=6.9 Hz, 1 H), 3.13 (dd, *J*=13.5, 6.4 Hz, 1 H), 2.83 (dd, *J*=13.5, 6.9 Hz, 1 H), 2.29 - 2.16 (m, 1 H), 2.15 - 2.06 (m, 1 H), 2.00 (td, *J*=12.2, 7.2 Hz, 1 H), 1.92 - 1.81 (m, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 138.8, 131.9, 129.45, 128.50, 128.40, 128.38, 126.4, 123.0, 89.7, 84.6, 81.2, 68.8, 42.6, 33.6, 31.0; LCMS (CI+) $[M]^+$ calculated for $C_{19}H_{18}O$: 262.1353, found: 262.

FTIR (thin film, both diastereomers) 3027, 2925, 2867, 1490, 1455, 1333, 1044, 756, 692 cm^{-1}.

The stereochemistry of diastereomers was assigned using 1D NOE experiment. In this NMR experiment, H_a was irradiated. In case of *cis*-**3-25**, I observed the correlations with H_b and H_c. In case of *trans*-**3-25**, I observed the correlations with H_c and H_d.

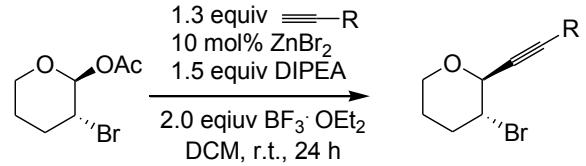


(*rac*)-*cis*-**3-25**
nOe experiment



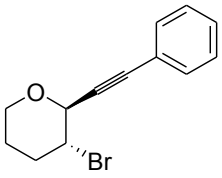
(*rac*)-*trans*-**3-25**
nOe experiment

Alkynylation of 2-Acetoxy-3-Bromotetrahydropyran



(rac)-**3-26**

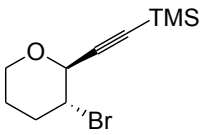
General Method. In a N_2-atmosphere glovebox, $ZnBr_2$ (6.8 mg, 0.030 mmol, 10 mol%) was weighed into a 1-dram vial, and then CH_2Cl_2 (1.5 mL, 0.2M), alkyne (0.39 mmol, 1.3 equiv), *i*-Pr_2NEt (75 µL, 0.45 mmol, 1.5 equiv), 2-acetoxy-3-bromotetrahydropyran[7] (**3-26**, 66.9 mg, 0.30 mmol, 1.0 equiv), and $BF_3{\cdot}OEt_2$ (76 µL, 0.60 mmol, 2.0 equiv) were added. The vial was capped, and the reaction mixture was stirred for 24 h at room temperature in the glovebox. The mixture was then removed from the glovebox, diluted with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was rinsed with Et_2O (10 mL). The filtrate was concentrated and purified by silica gel chromatography.



(*rac*)-**3-31**

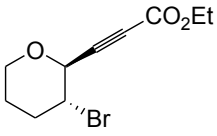
Tetrahydropyran 3-31. Prepared via General Method described above. Crude material was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give compound **3-31** (43.0 mg, 54 %) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 - 7.45 (m, 2 H), 7.39 - 7.30 (m, 3 H), 4.55 (d, *J*=7.6 Hz, 1 H), 4.24 - 4.06 (m, 2 H), 3.66 (ddd, *J*=11.6, 9.1, 3.0 Hz, 1 H), 2.53 (dt, *J*=13.6, 4.5 Hz, 1 H), 2.09 – 1.96 (m, 1 H), 1.93 - 1.84 (m, 1 H), 1.82 - 1.70 (m, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 132.0, 128.8, 128.4, 122.2, 86.7, 85.6, 73.0, 66.8, 50.7, 33.1, 25.8; FTIR (NaCl/thin film) 3411, 3027, 2241, 1777, 1497, 1454, 1069, 985, 745, 700 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{13}H_{13}BrO$: 264.010, found: 264.

Tetrahydropyran 3-33. Prepared via General Method described above. Crude material was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give



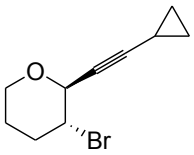
(*rac*)-**3-33**

compound **3-33** (46.5 mg, 59 %) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.29 (d, *J*=7.6 Hz, 1 H), 4.04 (ddt, *J*=12.2, 8.3, 4.2, 4.2 Hz, 2 H), 3.56 (ddd, *J*=11.6, 8.9, 3.0 Hz, 1 H), 2.50 - 2.38 (m, 1 H), 1.99 - 1.88 (m, 1 H), 1.82 (dd, *J*=9.2, 4.6 Hz, 1 H), 1.69 (dtd, *J*=13.7, 9.2, 9.2, 4.6 Hz, 1 H), 0.19 (s, 9 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 101.5, 92.0, 72.8, 66.6, 50.4, 32.9, 25.6, -0.2; FTIR (NaCl/thin film) 2959, 2927, 2852, 2169, 1250, 1115, 1102, 1079, 1044, 1022, 917, 844, 761 cm^{-1}.



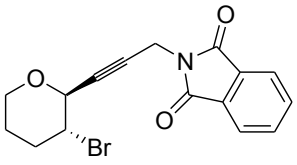
(*rac*)-**3-35**

Tetrahydropyran 3-35. Prepared via General Method described above. Crude material was purified by silica gel chromatography (10% Et_2O/hexanes) to give compound **3-35** (44.2 mg, 56 %) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.42 (d, *J*=7.3 Hz, 1 H), 4.24 (q, *J*=7.1 Hz, 2 H), 4.13 – 3.97 (m, 2 H), 3.59 (ddd, *J*=11.6, 8.9, 3.0 Hz, 1 H), 2.50 - 2.38 (m, 1 H), 2.02 – 1.80 (m, 2 H), 1.70 (dtd, *J*=13.7, 9.1, 8.9, 4.6 Hz, 1 H), 1.30 (t, *J*=7.1 Hz, 3 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.1, 82.6, 78.0, 72.0, 66.9, 62.5, 48.6, 32.7, 25.2, 14.1; FTIR (NaCl/thin film) 2963, 2853, 2250, 1712, 1366, 1260, 1169, 1101, 1067, 1025, 934, 800, 750 cm^{-1}.



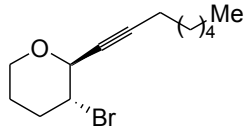
(*rac*)-**3-37**

Tetrahydropyran 3-37. Prepared via General Method described above. Crude material was purified by silica gel chromatography (2% Et_2O/hexanes) to give compound **3-37** (55.7 mg, 81 %) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.22 (d, *J*=7.1 Hz, 1 H), 4.09 – 3.92 (m, 2 H), 3.53 (ddd, *J*=11.7, 9.2, 2.9 Hz, 1 H), 2.43 (dq, *J*=13.6, 4.4 Hz, 1 H), 1.92 (dtd, *J*=13.6, 9.8, 9.8, 4.4 Hz, 1 H), 1.83 - 1.74 (m, 1 H), 1.73 - 1.62 (m, 1 H), 1.35 - 1.23 (m, 1 H), 0.82 – 0.69 (m, 4 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 90.7, 72.9, 72.0, 66.6, 51.2, 33.3, 31.1, 25.9, 8.5, 8.4; FTIR (NaCl/thin film) 2951, 2852, 2246, 1756, 1370, 1220, 1202, 1077, 1023, 934, 866, 720 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{10}H_{13}BrO$: 228.0150, found: 228.



(*rac*)-**3-39**

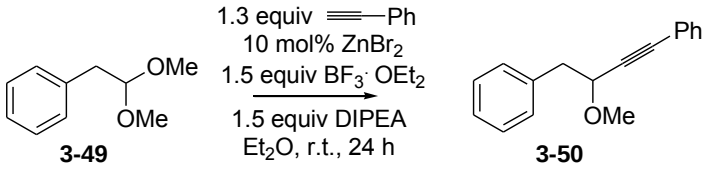
Tetrahydropyran 3-39. Prepared via General Method described above. Crude material was purified by silica gel chromatography (10-20% EtOAc/hexanes) to give compound **3-39** (34.0 mg, 33 %)[19] as a yellow solid (m. p. 129-130 ^{o}C): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (dd, *J*=5.3, 3.0 Hz, 2 H), 7.73 (dd, *J*=5.3, 3.0 Hz, 2 H), 4.51 (d, *J*=1.0 Hz, 2 H), 4.29 (d, *J*=7.1 Hz, 1 H), 4.07 – 3.92 (m, 2 H), 3.58 - 3.48 (m, 1 H), 2.47 - 2.33 (m, 1 H), 1.99 - 1.74 (m, 2 H), 1.64 (td, *J*=9.0, 4.6 Hz, 1 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.1, 134.3, 132.1, 123.7, 80.4, 79.7, 72.2, 66.4, 50.2, 32.6, 27.4, 25.3; FTIR (NaCl/thin layer) 2926, 2851, 1772, 1721, 1421, 1392, 1346, 1118, 1074, 940, 724, 711 cm^{-1}.



(*rac*)-**3-41**

Tetrahydropyran 3-41. Prepared via General Method described above. Crude material was purified by silica gel chromatography (5% Et_2O/hexanes with 2% Et_3N) to give compound **3-41** (34.8 mg, 42 %) as a light yellow oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.27 (d, *J*=7.6 Hz, 1 H), 4.03 (dt, *J*=12.2, 4.4 Hz, 2 H), 3.61 - 3.51 (m, 1 H), 2.50 - 2.38 (m, 1 H), 2.25 (td, *J*=7.0, 1.6 Hz, 2 H), 2.01 – 1.87 (m, 1 H), 1.79 (tt, *J*=8.8, 4.4 Hz, 1 H), 1.75 - 1.63 (m, 1 H), 1.53 (quin, *J*=7.0 Hz, 2 H), 1.42 - 1.35 (m, 2 H), 1.34 - 1.22 (m, 4 H), 0.89 (t, *J*=7.0 Hz, 3 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 87.8, 72.9, 66.6, 51.3, 33.2, 31.4, 30.3, 28.6, 28.5, 25.9, 22.7, 18.8, 14.2; FTIR (NaCl/thin film) 2930, 2857, 2243, 1458, 1434, 1360, 1168, 1114, 1103, 1076, 1024, 935, 866, 722 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{13}H_{21}BrO$: 272.0771, found: 272.

Alkynylation of Phenylacetaldehyde Dimethyl Acetal



3-49 **3-50**

In a N_2-atmosphere glovebox, $ZnBr_2$ (6.8 mg, 0.030 mmol, 10 mol%) was weighed into a 1-dram vial, and then Et_2O (1.5 mL, 0.2 M), phenylacetylene (43 µL, 0.39 mmol, 1.3 equiv), *i*-Pr_2NEt (75 µL, 0.45 mmol, 1.5 equiv), phenylacetaldehyde dimethyl acetal[8] (**3-49**, 50 mg, 0.30 mmol, 1.0 equiv) and $BF_3{\cdot}OEt_2$ (57 µL, 0.45 mmol, 1.5 equiv) were added. The vial was capped, and the reaction mixture was stirred for 24 h at room temperature in the glovebox. The vial was then removed from the glovebox, and the reaction mixture was diluted with Et_2O (1.5 mL) and filtered through a plug of silica gel, which was then rinsed with Et_2O (10 mL). The filtrate was concentrated and purified by silica gel chromatography (3% Et_2O/hexanes) to give compound **3-50** (29 mg, 41%) as a yellow oil: ^1H NMR (400 MHz, $CDCl_3$) δ 7.45 - 7.39 (m, 2 H), 7.36 - 7.24 (m, 8 H), 4.37 (t, *J*=6.7 Hz, 1 H), 3.49 (s, 3 H), 3.20 - 3.05 (m, 2 H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.4, 131.8, 129.8, 128.5, 128.4, 128.3, 126.8, 122.8, 87.6, 86.9, 72.8, 56.8, 42.2; FTIR (NaCl/thin layer) 3029.49, 2925.62, 2850.61, 2821.38, 2229, 1489.94, 1339.34, 1099.58, 1029.38, 755.80, 730.58, 691.53 cm^{-1}; LCMS (CI+) $[M]^+$ calculated for $C_{17}H_{16}O$: 236.1197, found: 236.

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(12) Slightly contaminated with hydrocarbon grease. See ^{1}H NMR spectrum.

(13) Slightly contaminated with ethyl acetate, dichlomethane, and hydrocarbon grease. See ^{1}H NMR spectrum.

(14) Slightly contaminated with diethyl ether, dichlomethane, and hydrocarbon grease. See ^{1}H NMR spectrum.

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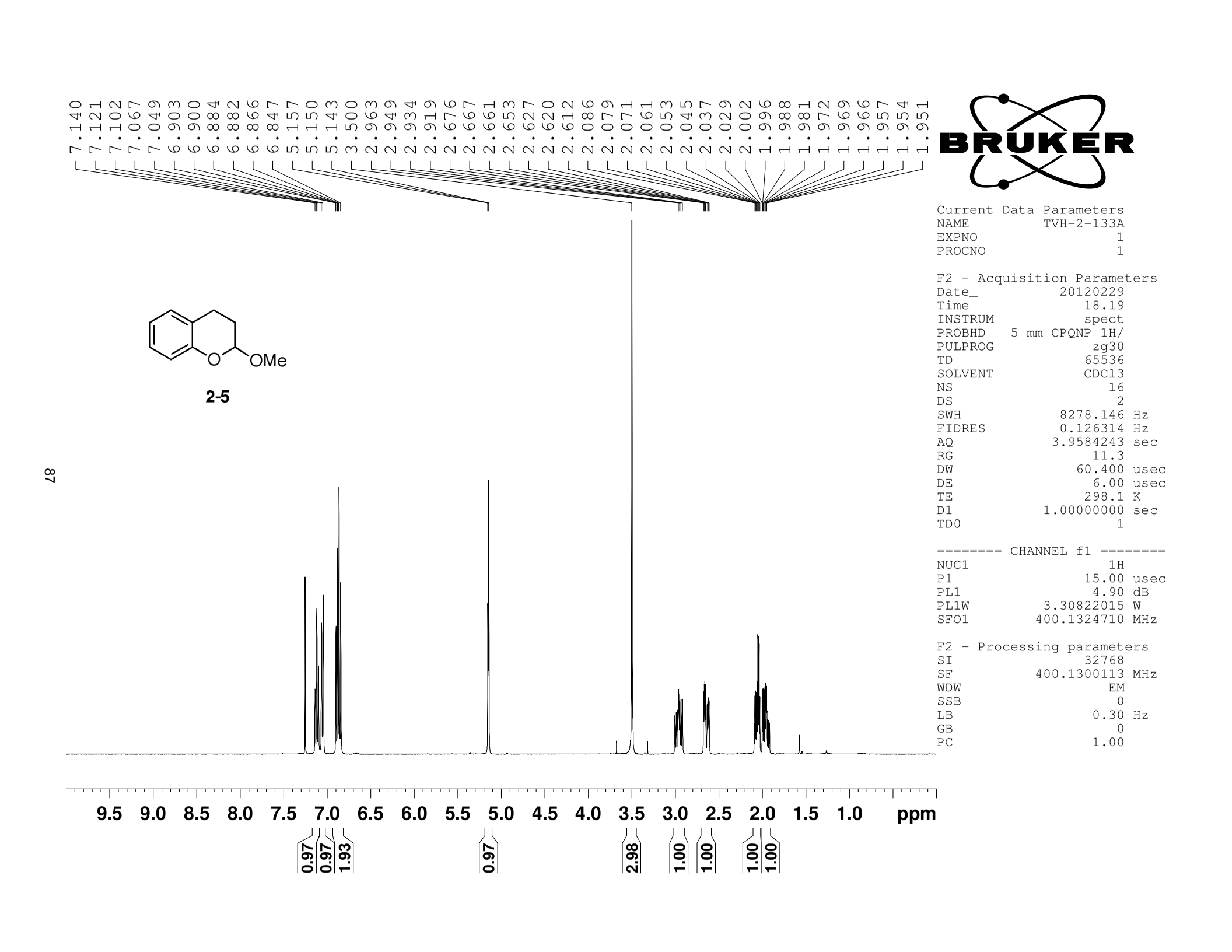
(18) Stereochemistry of diastereomers was assigned by analogy to **3-25**.

(19) Slightly contaminated with dichlomethane and hydrocarbon grease. See ^{1}H NMR spectrum.

Appendix B

SPECTRAL DATA



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PROCNO 1

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TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
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PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
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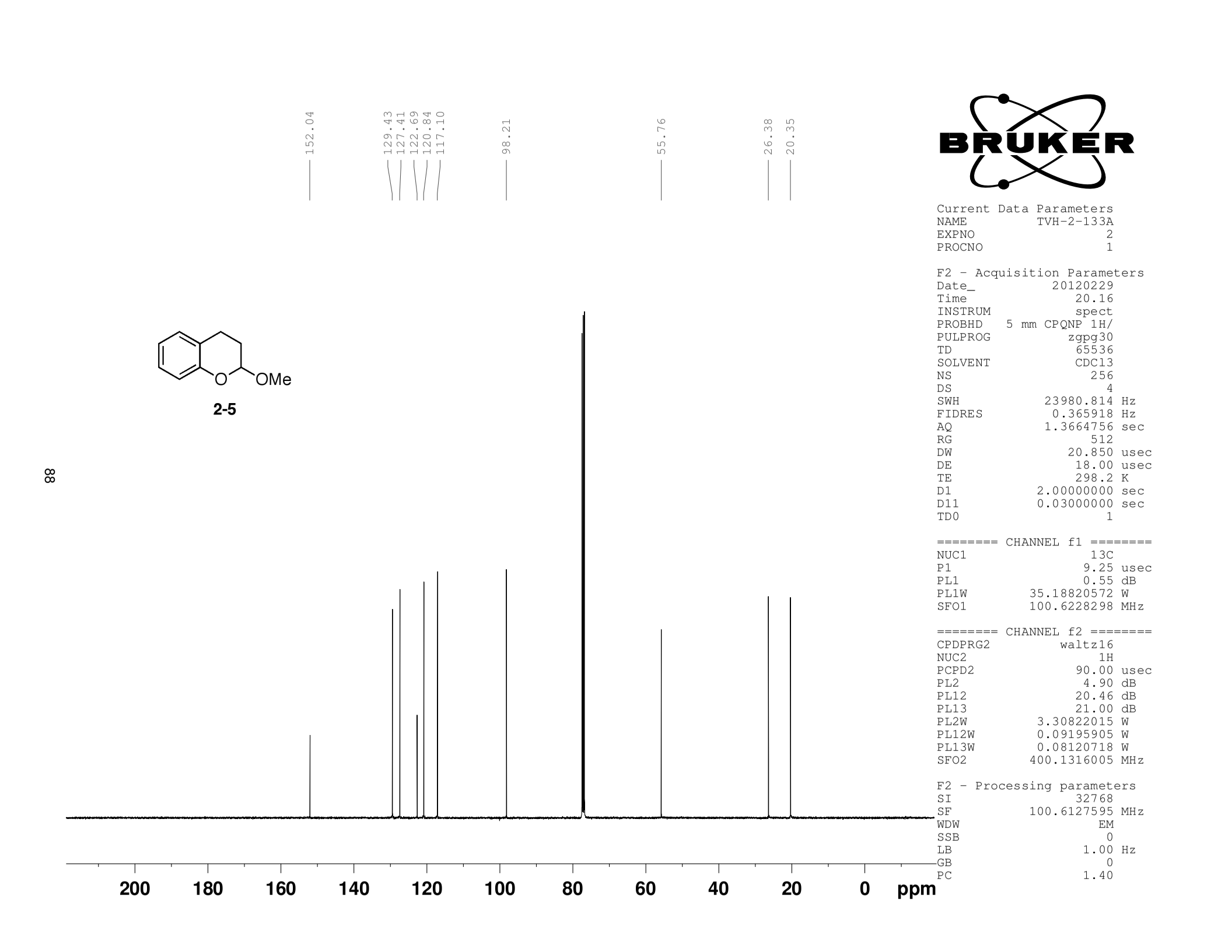
GB 0
PC 1.00



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SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
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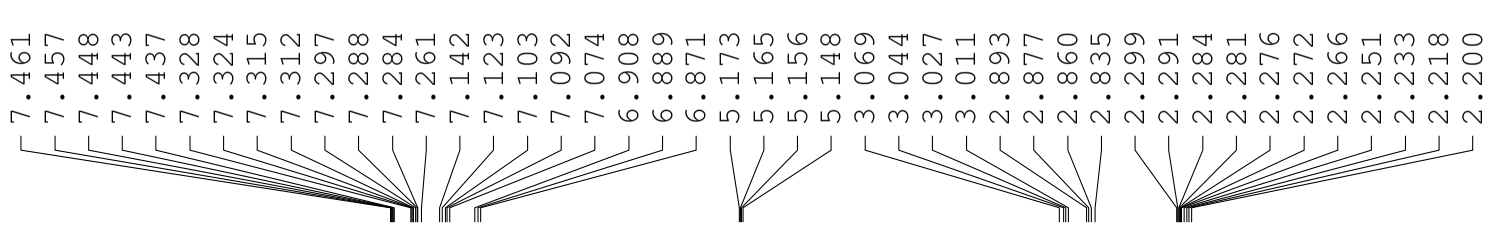

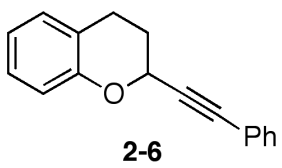

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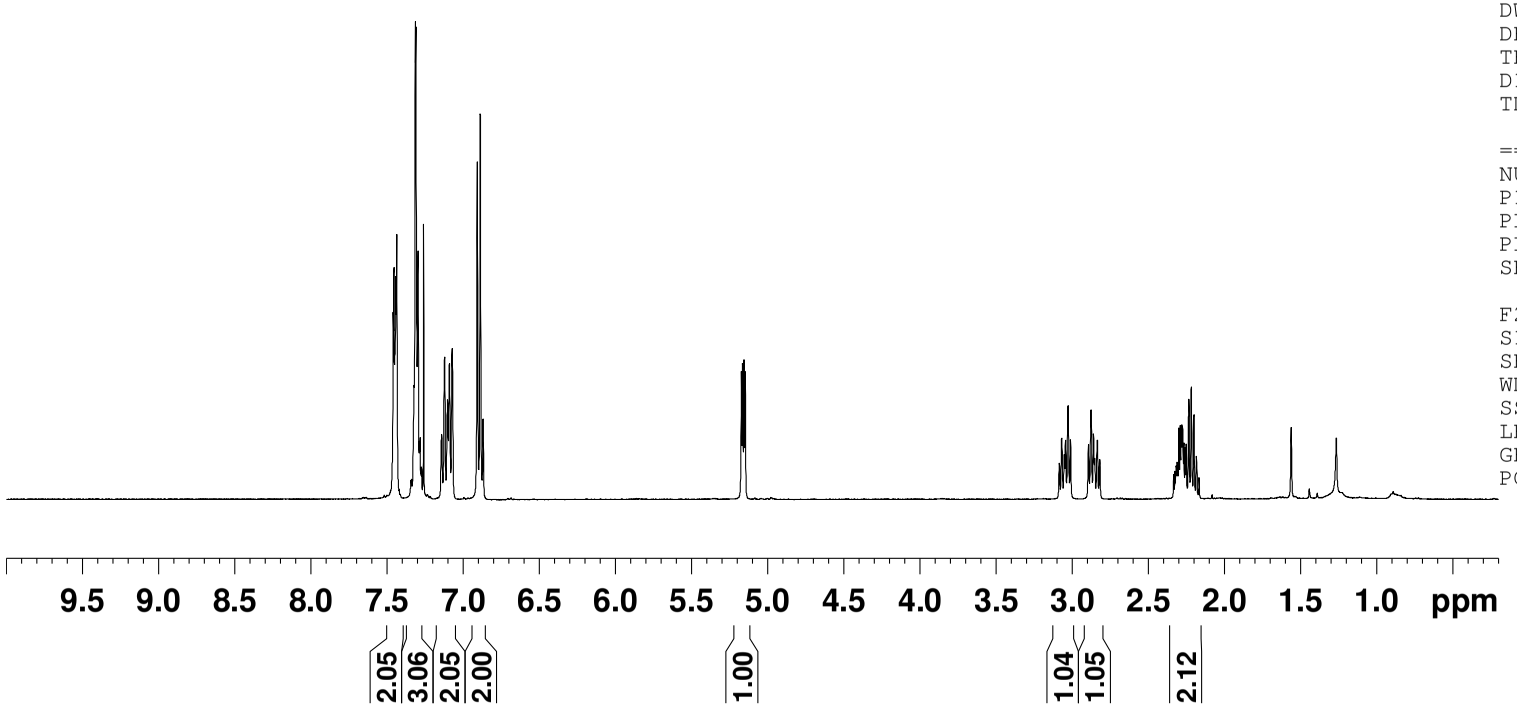

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PROCNO 1

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SOLVENT CDCl3
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DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 6.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
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P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
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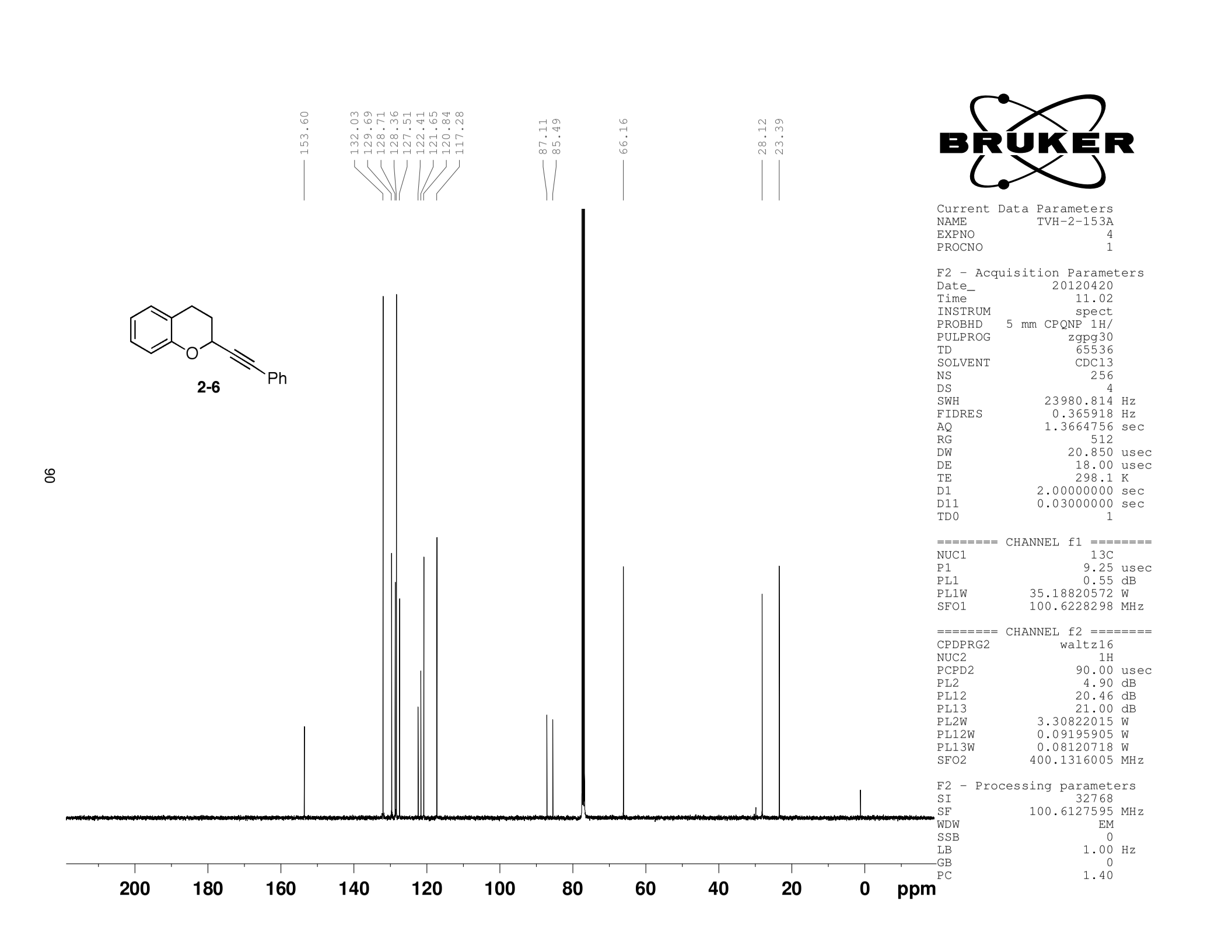

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PROCNO 1

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PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.1 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
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F2 - Processing parameters
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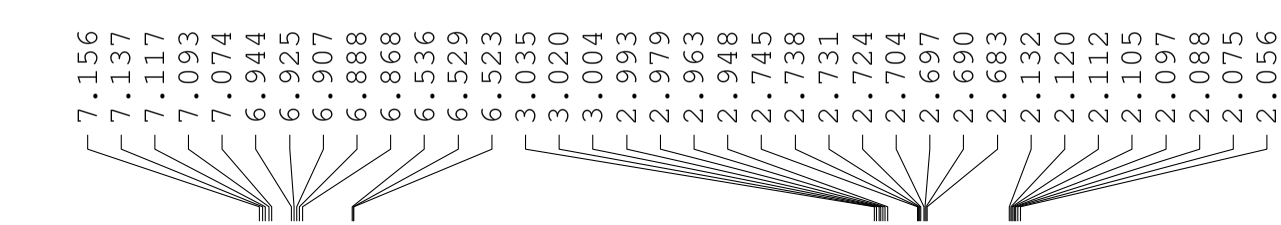

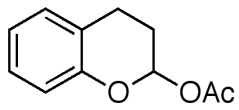

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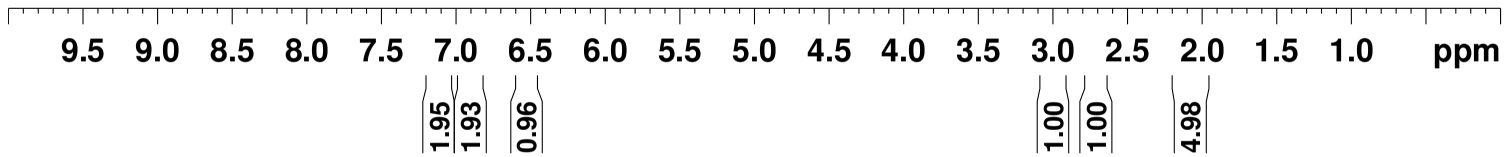

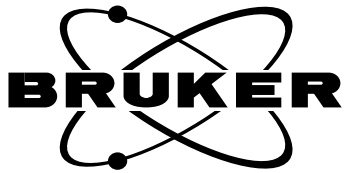


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DS                     2
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FIDRES          0.126314 Hz
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RG                  11.3
DW                60.400 usec
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TE                298.2 K
D1             1.00000000 sec
TD0                    1

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SFO1        400.1324710 MHz

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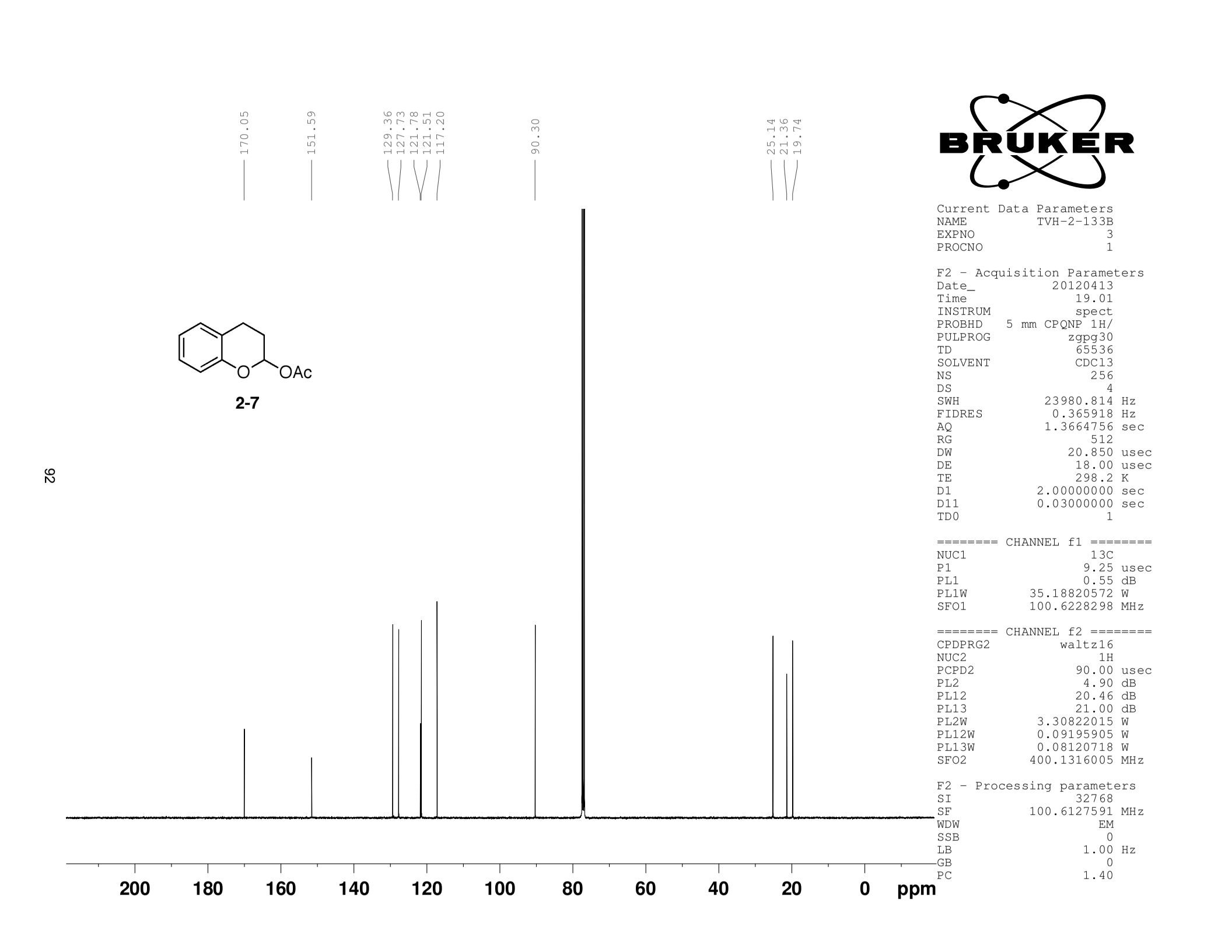

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FIDRES 0.365918 Hz
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D1 2.00000000 sec
D11 0.03000000 sec
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P1 9.25 usec
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PL1W 35.18820572 W
SFO1 100.6228298 MHz

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NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
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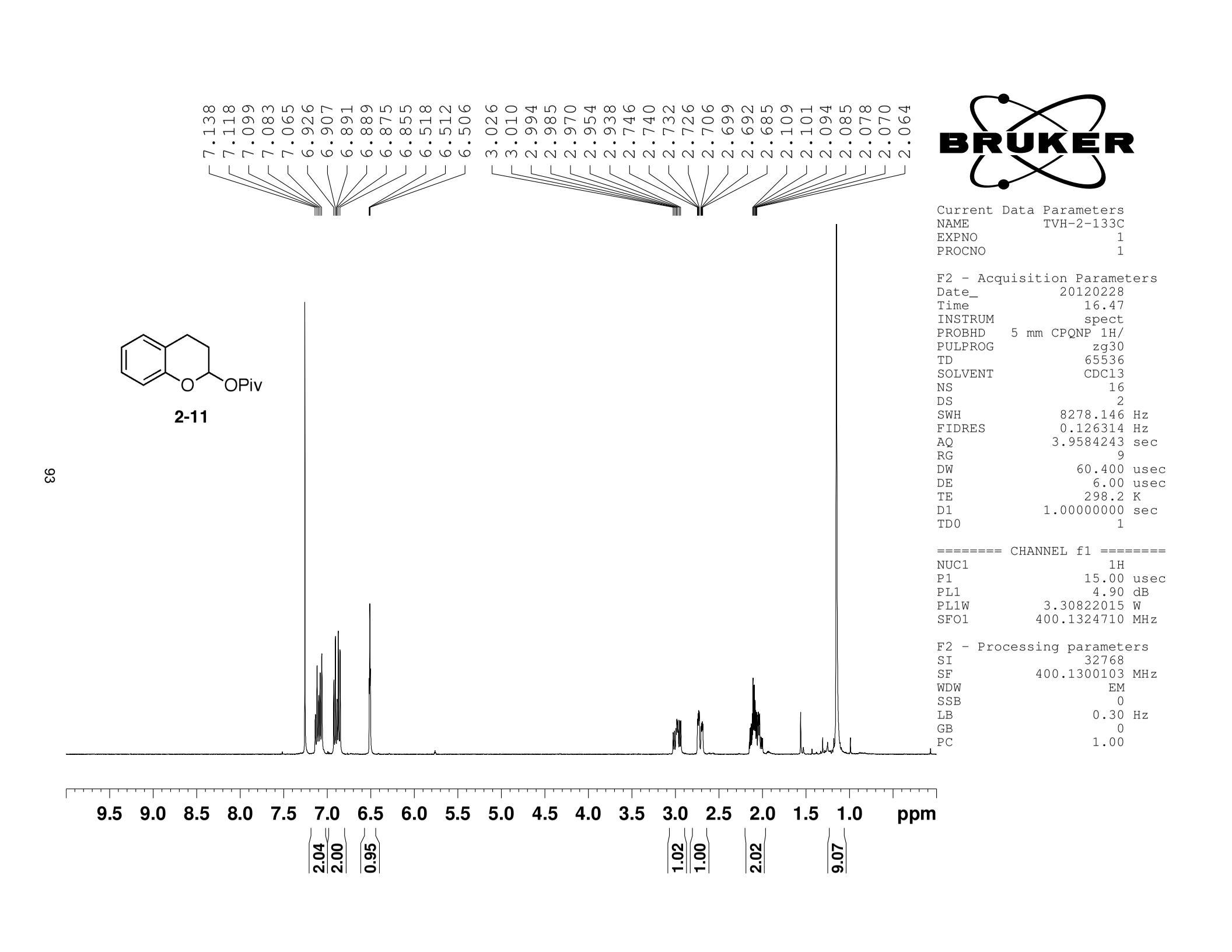
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RG 9
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DE 6.00 usec
TE 298.2 K
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PL1W 3.30822015 W
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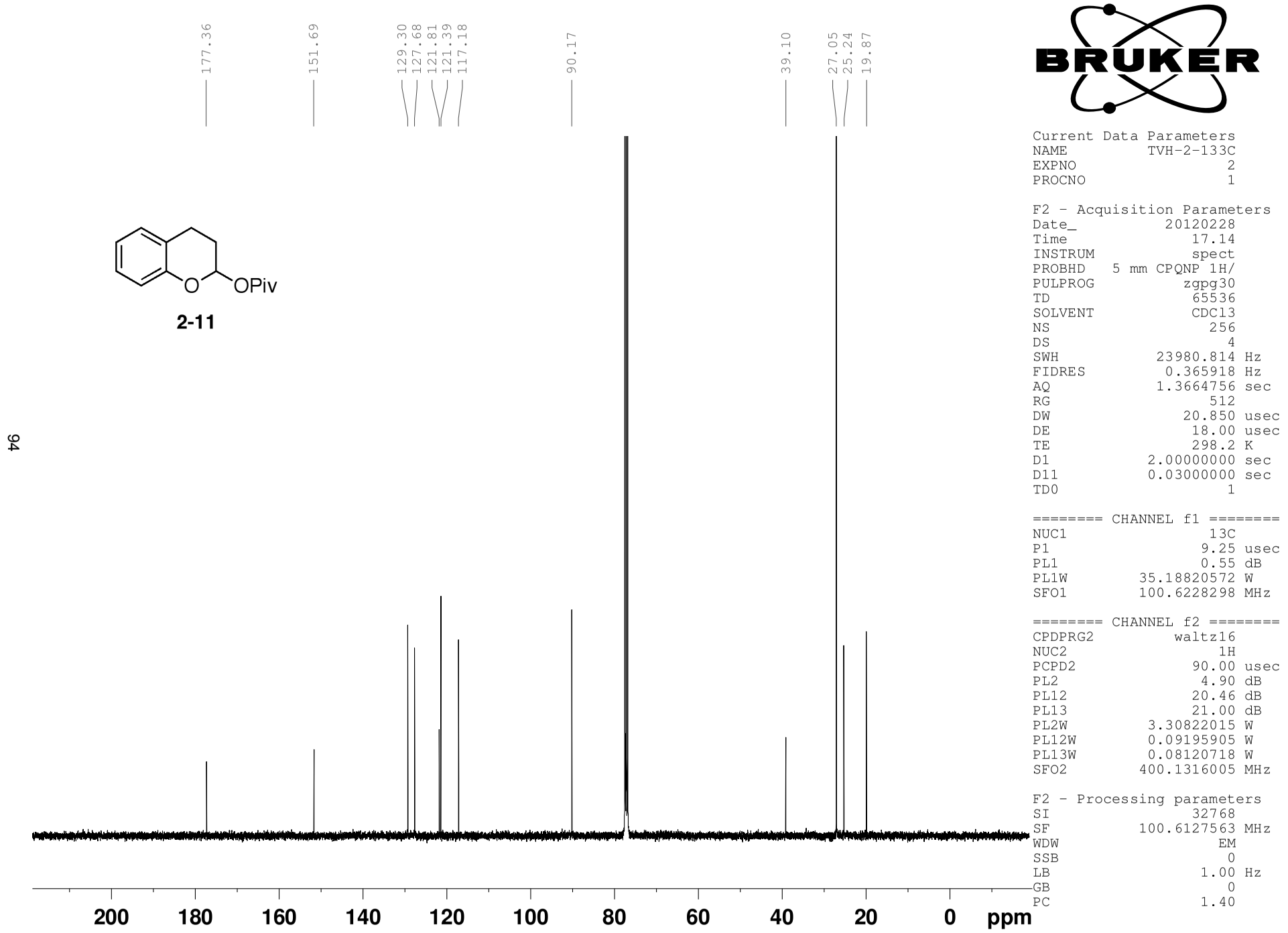

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AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

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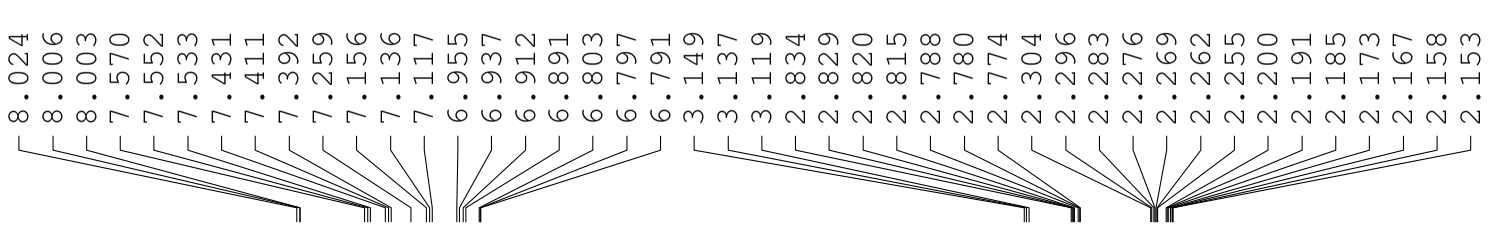

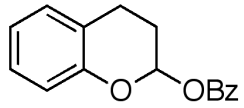

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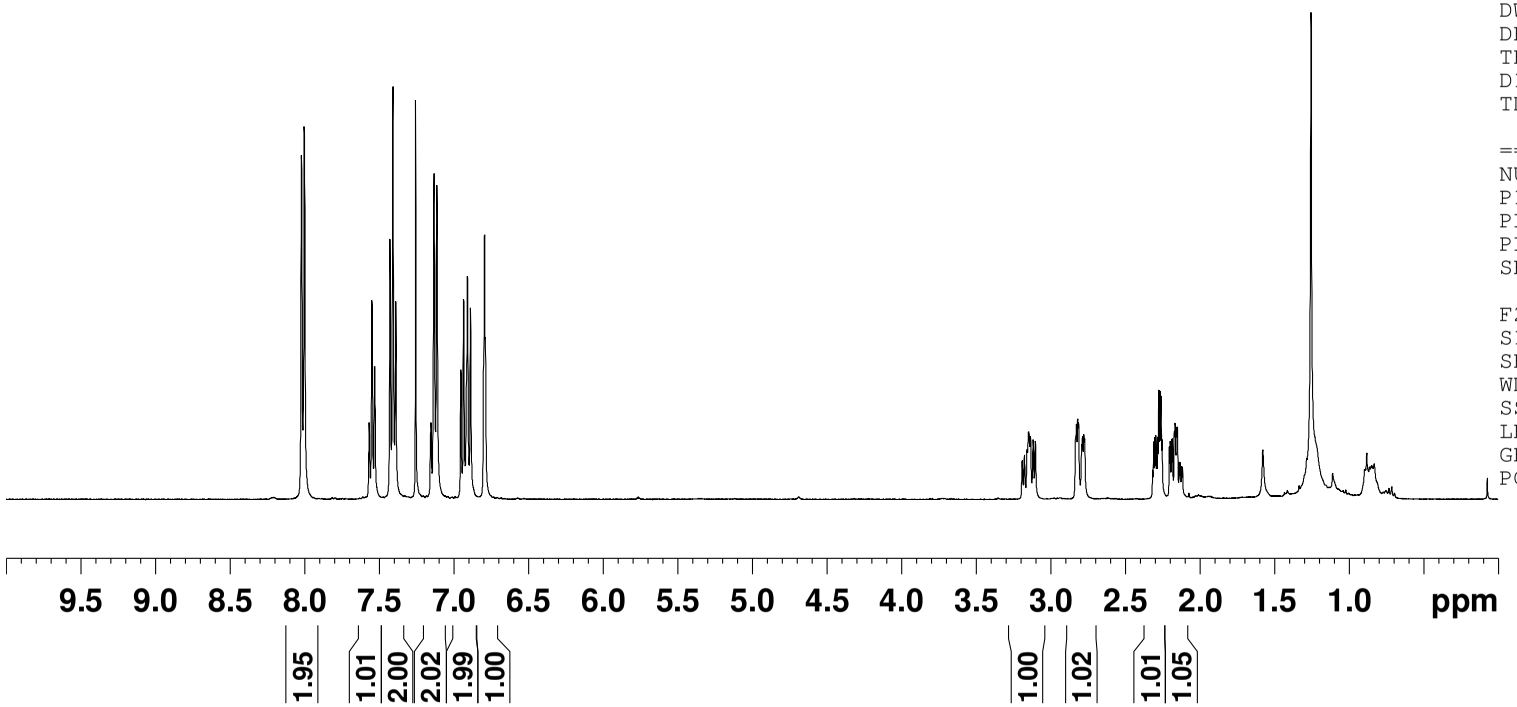
96



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SOLVENT CDCl3
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FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
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P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
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F2 - Processing parameters
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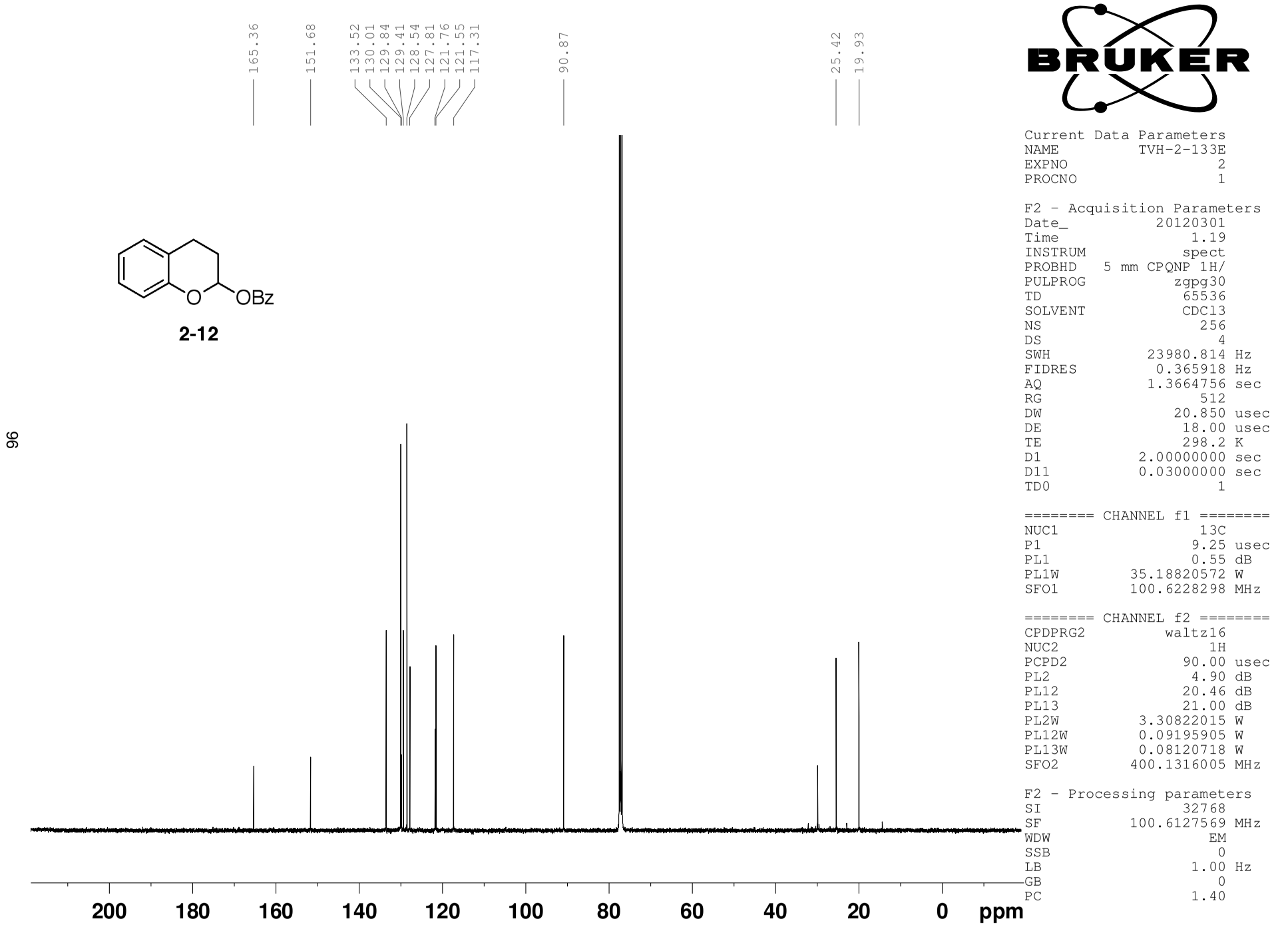

BRUKER

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SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
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PL12W 0.09195905 W
PL13W 0.08120718 W
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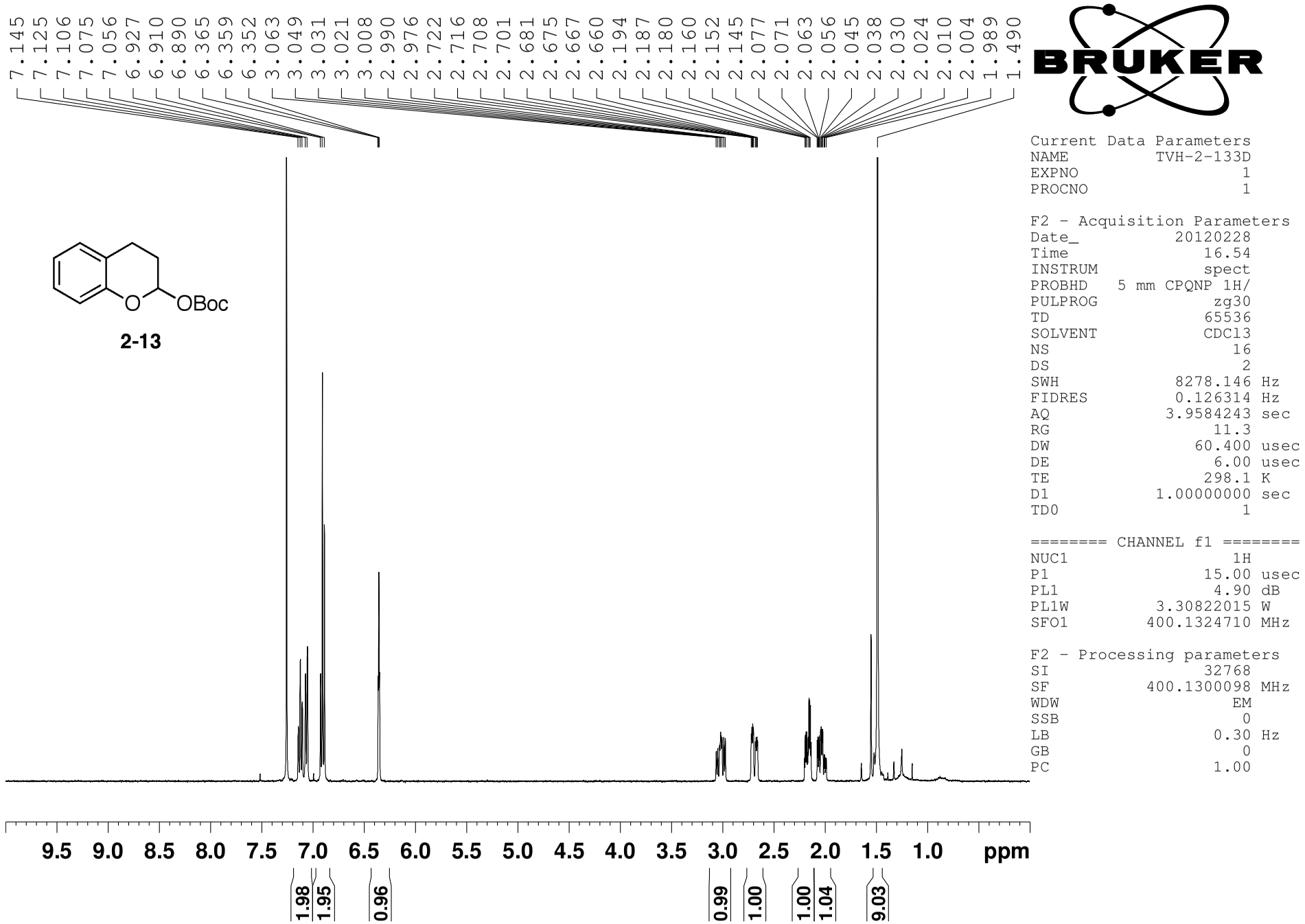

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TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                  11.3
DW                60.400 usec
DE                 6.00 usec
TE                298.1 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

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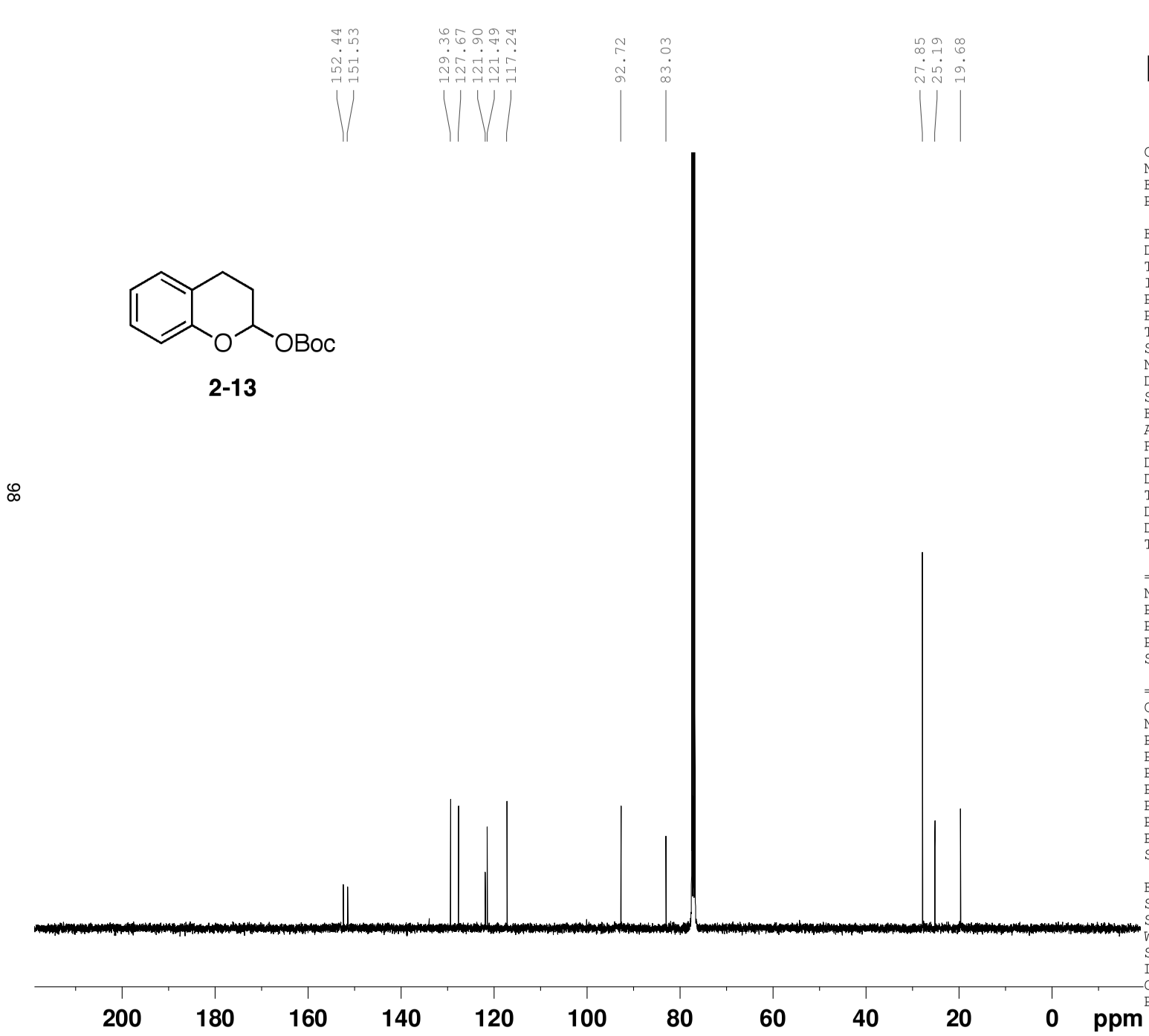

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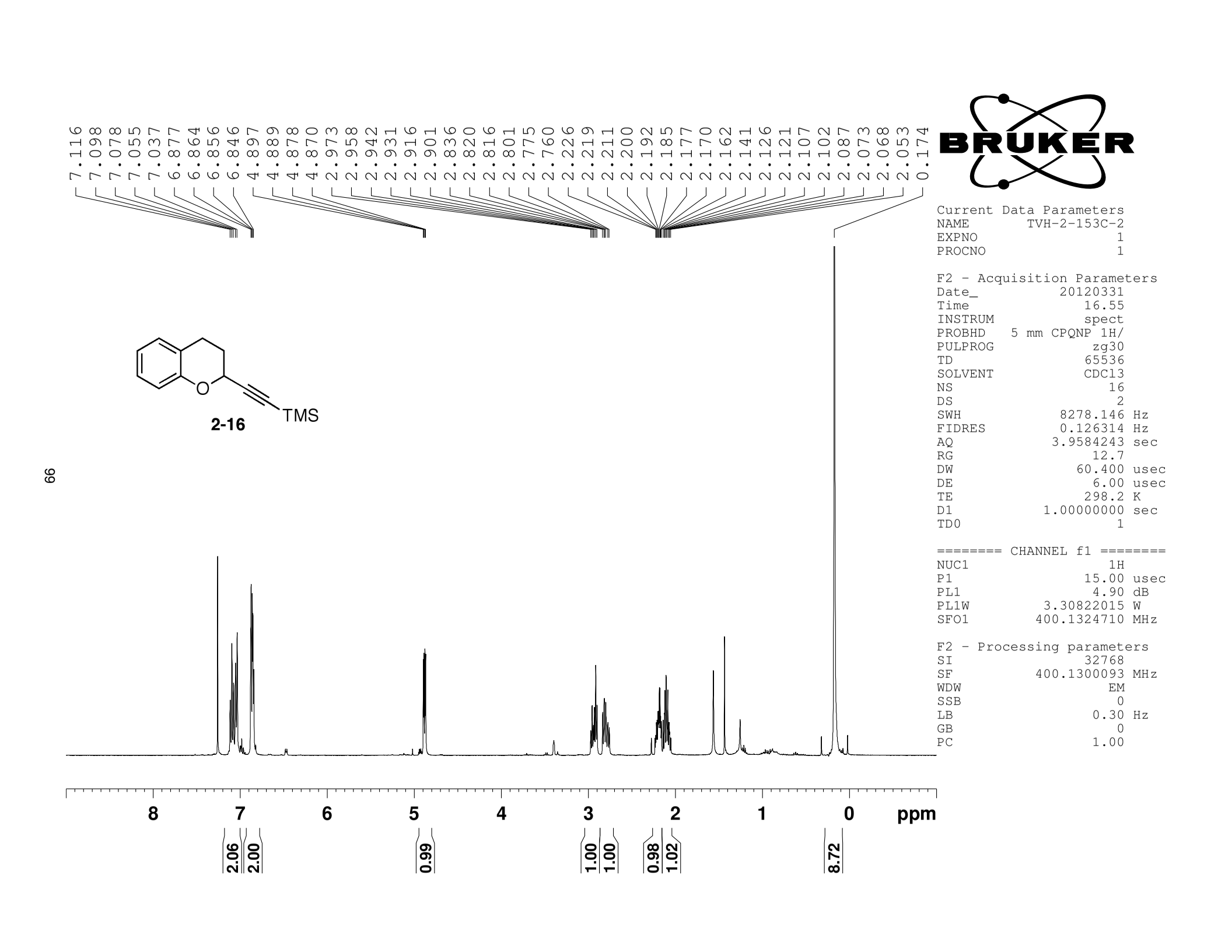
Date_ 20120228
Time 18.20
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127579 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40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6.846
4.897
4.889
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4.870
2.973
2.958
2.942
2.931
2.916
2.901
2.836
2.820
2.816
2.801
2.775
2.760
2.226
2.219
2.211
2.200
2.192
2.185
2.177
2.170
2.162
2.141
2.126
2.121
2.107
2.102
2.087
2.073
2.068
2.053
0.174
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TMS
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66
8
7
6
5
4
3
2
1
0
ppm
2.06
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0.99
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1.02
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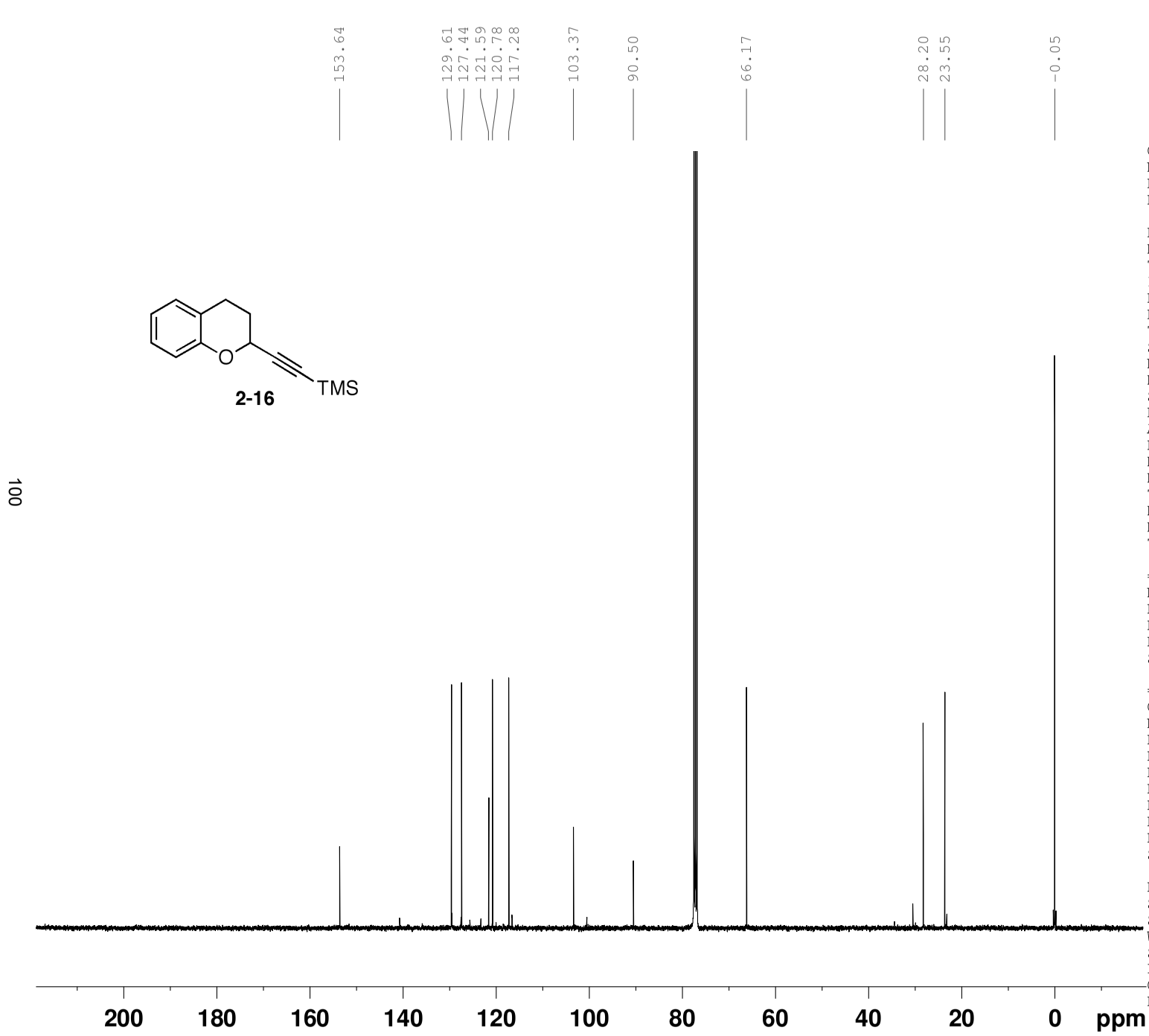
Current Data Parameters
NAME TVH-2-153C-2
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120331
Time 16.55
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 12.7
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300093 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



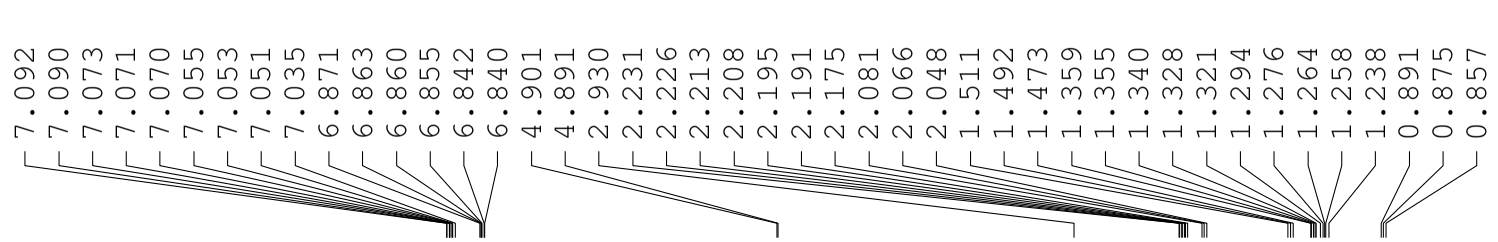
Current Data Parameters
NAME TVH-2-153C-2
EXPNO 2
PROCNO 1

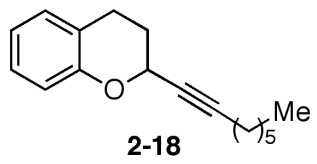
F2 - Acquisition Parameters
Date_ 20120331
Time 17.23
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127575 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40





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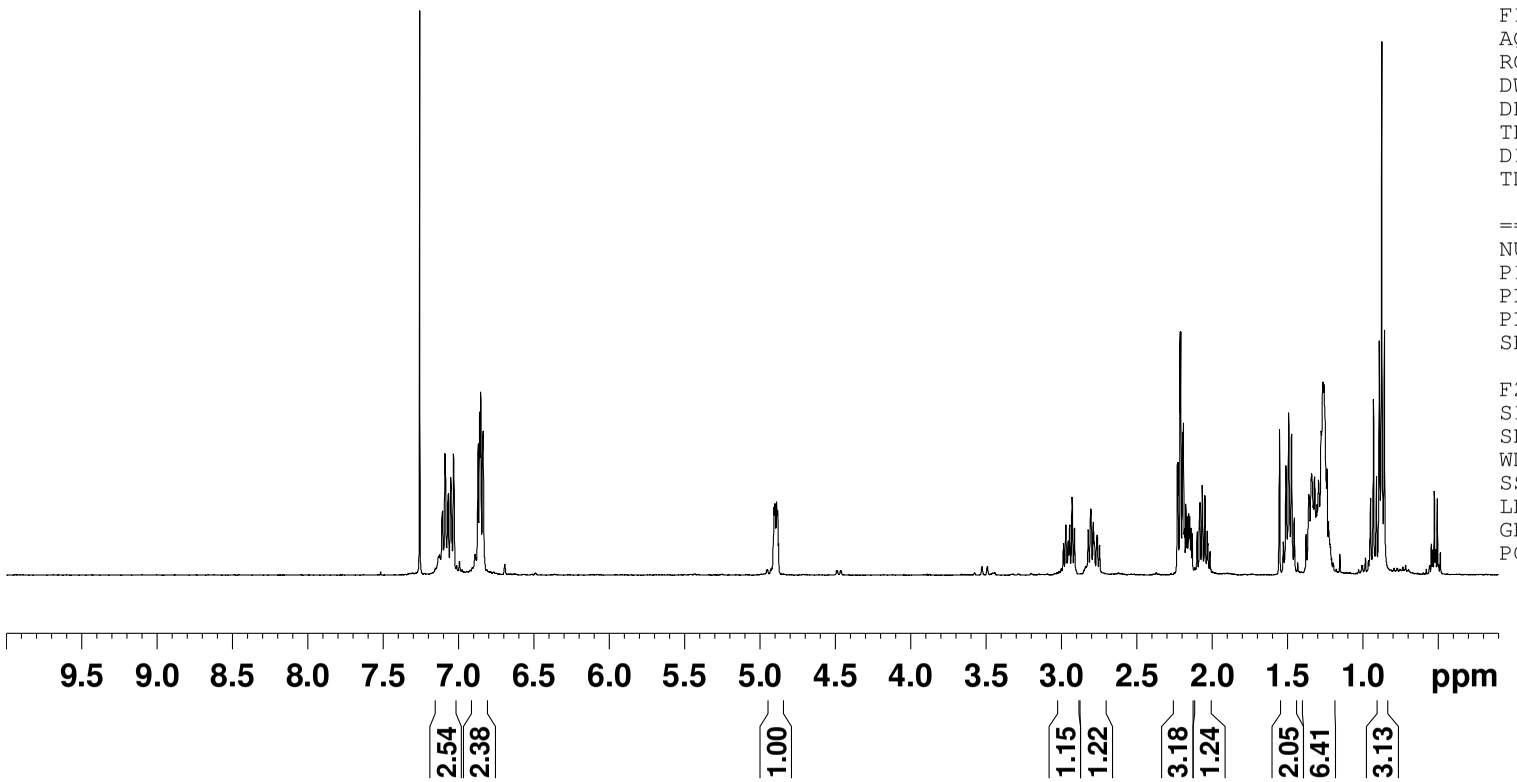
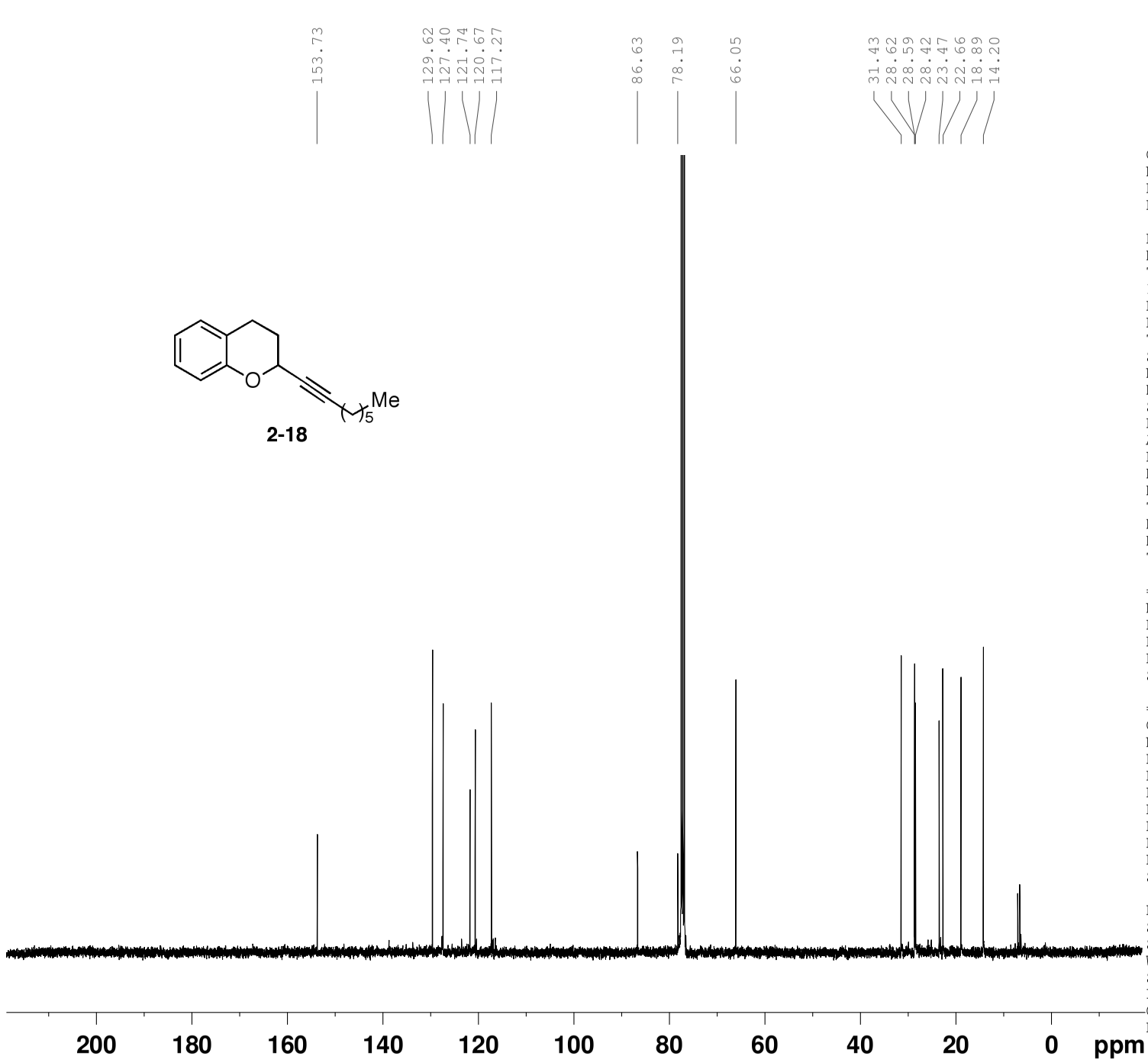


Current Data Parameters
NAME TVH-2-159C
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120421
Time 9.06
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300093 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



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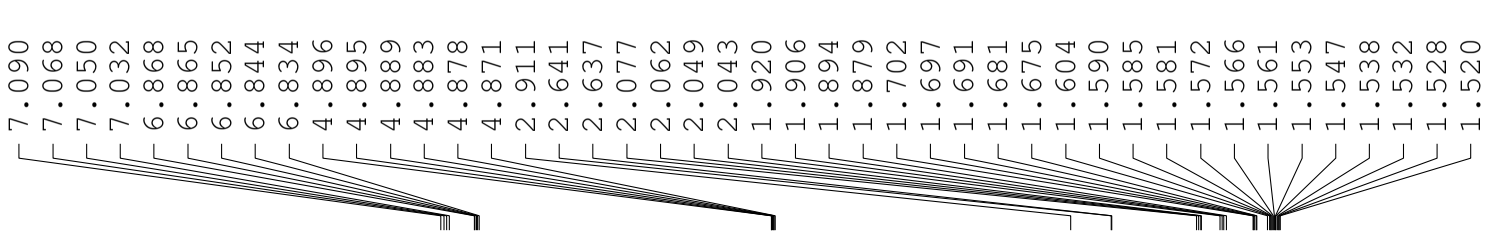
Current Data Parameters
NAME TVH-2-159C
EXPNO 2
PROCNO 1

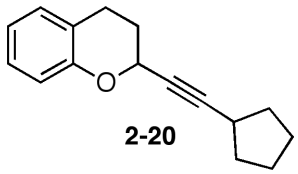
F2 - Acquisition Parameters
Date_ 20120421
Time 10.12
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.1 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

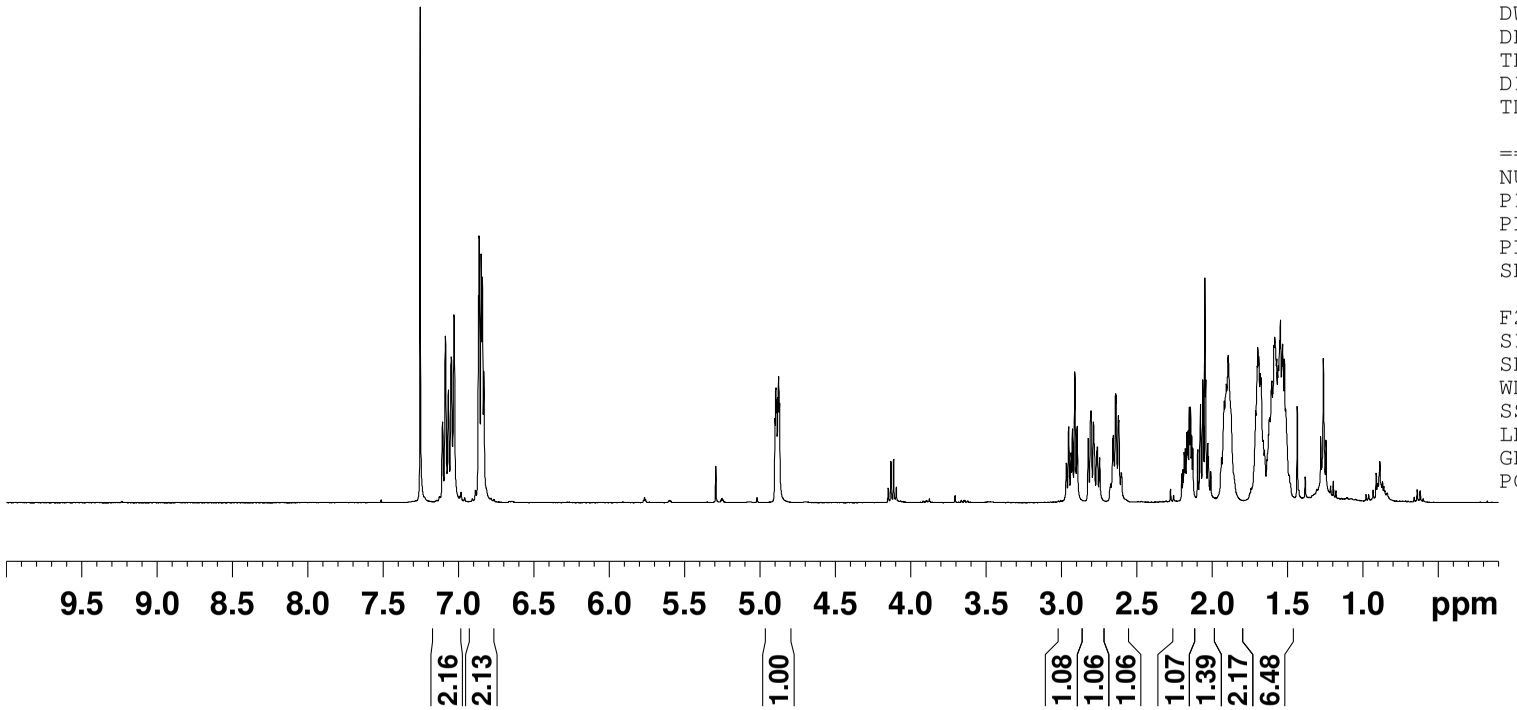
F2 - Processing parameters
SI 32768
SF 100.6127571 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40





2-20

103

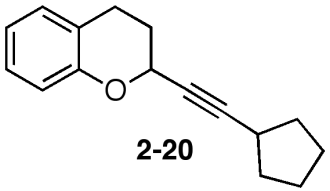


Current Data Parameters
NAME TVH-2-153B-2
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120402
Time 16.17
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 9
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300113 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



2-20

104

153.78
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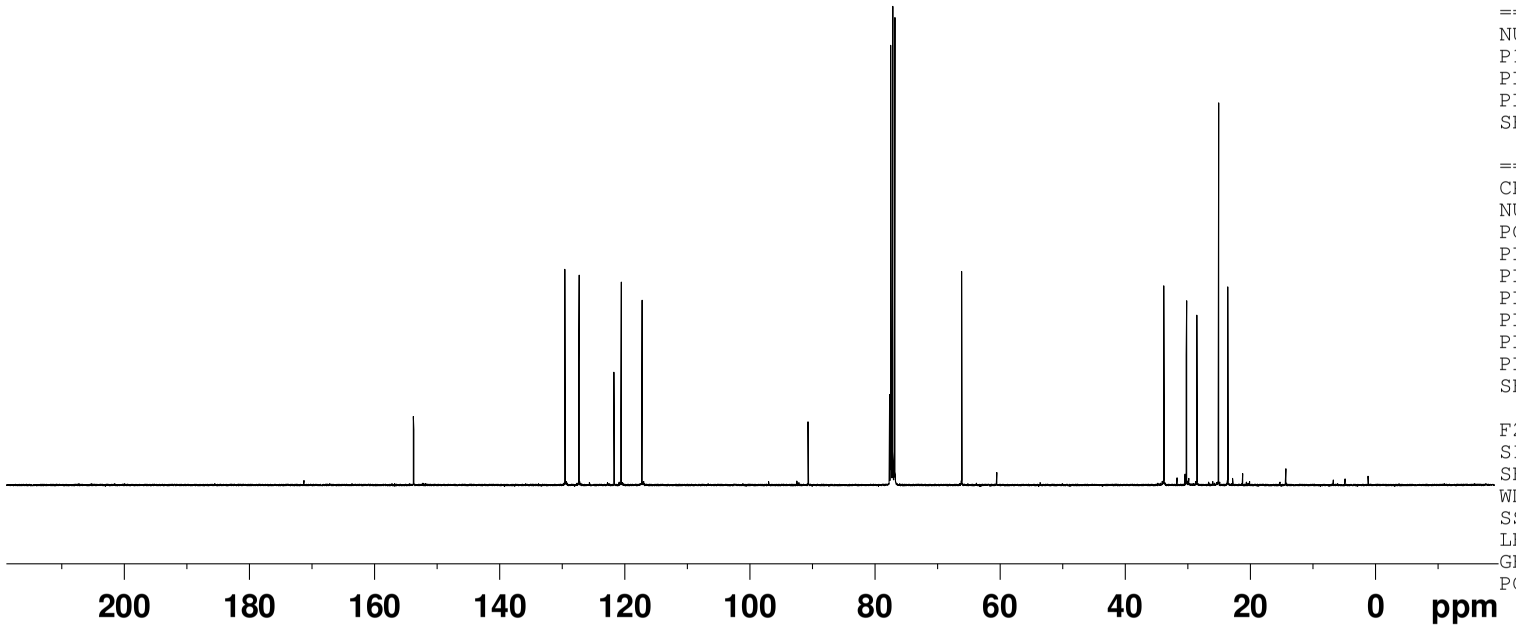
121.73
120.60
117.25
90.70
77.68
77.36
66.14
33.82
33.79
30.20
28.53
25.07
23.58



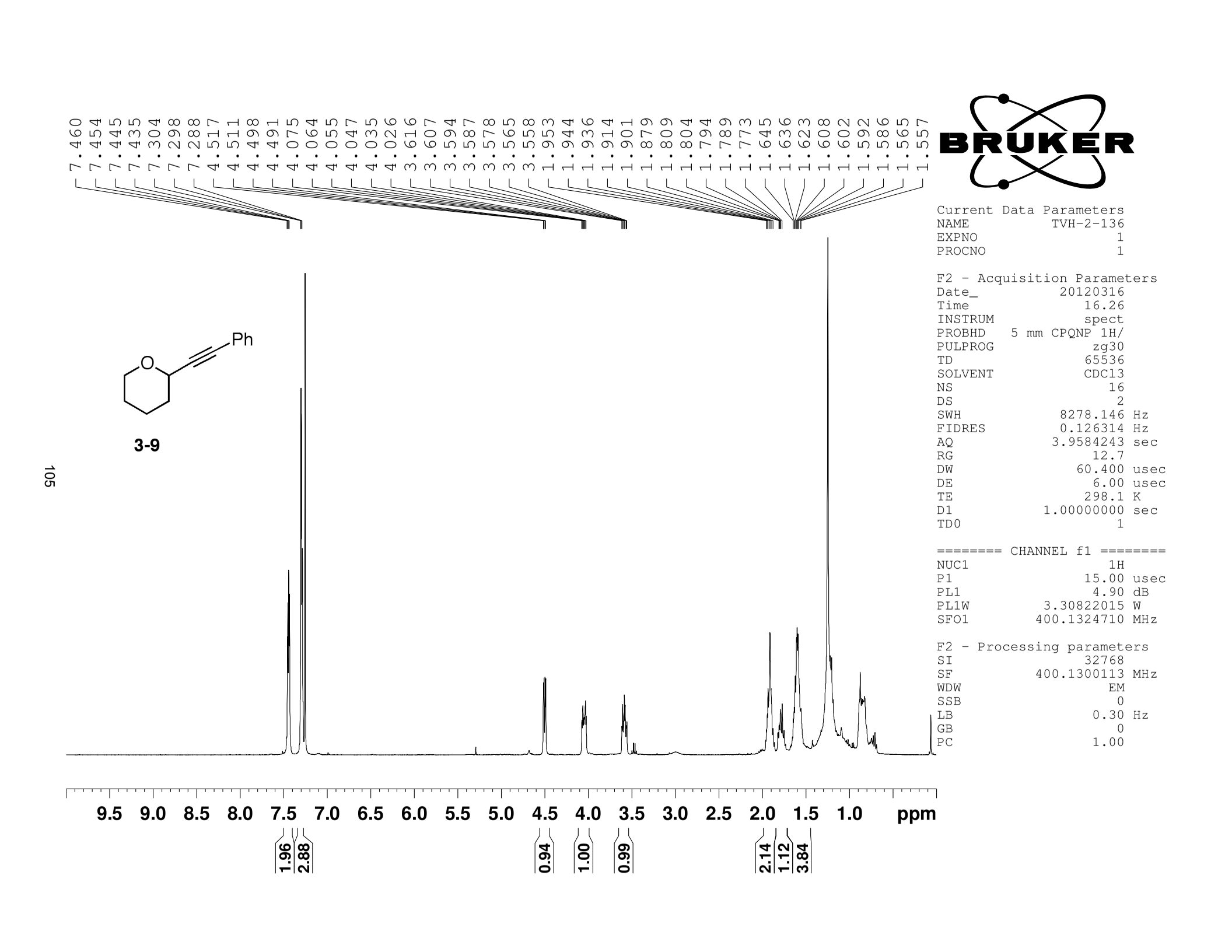
Current Data Parameters
NAME TVH-2-153B-2
EXPNO 4
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120402
Time 20.38
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127602 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40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4.055
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4.026
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3.607
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3.587
3.578
3.565
3.558
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1.944
1.936
1.914
1.901
1.879
1.809
1.804
1.794
1.789
1.773
1.645
1.636
1.623
1.608
1.602
1.592
1.586
1.565
1.557
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3-9
105
Current Data Parameters
NAME TVH-2-136
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120316
Time 16.26
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 12.7
DW 60.400 usec
DE 6.00 usec
TE 298.1 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300113 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
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 ppm
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2.88
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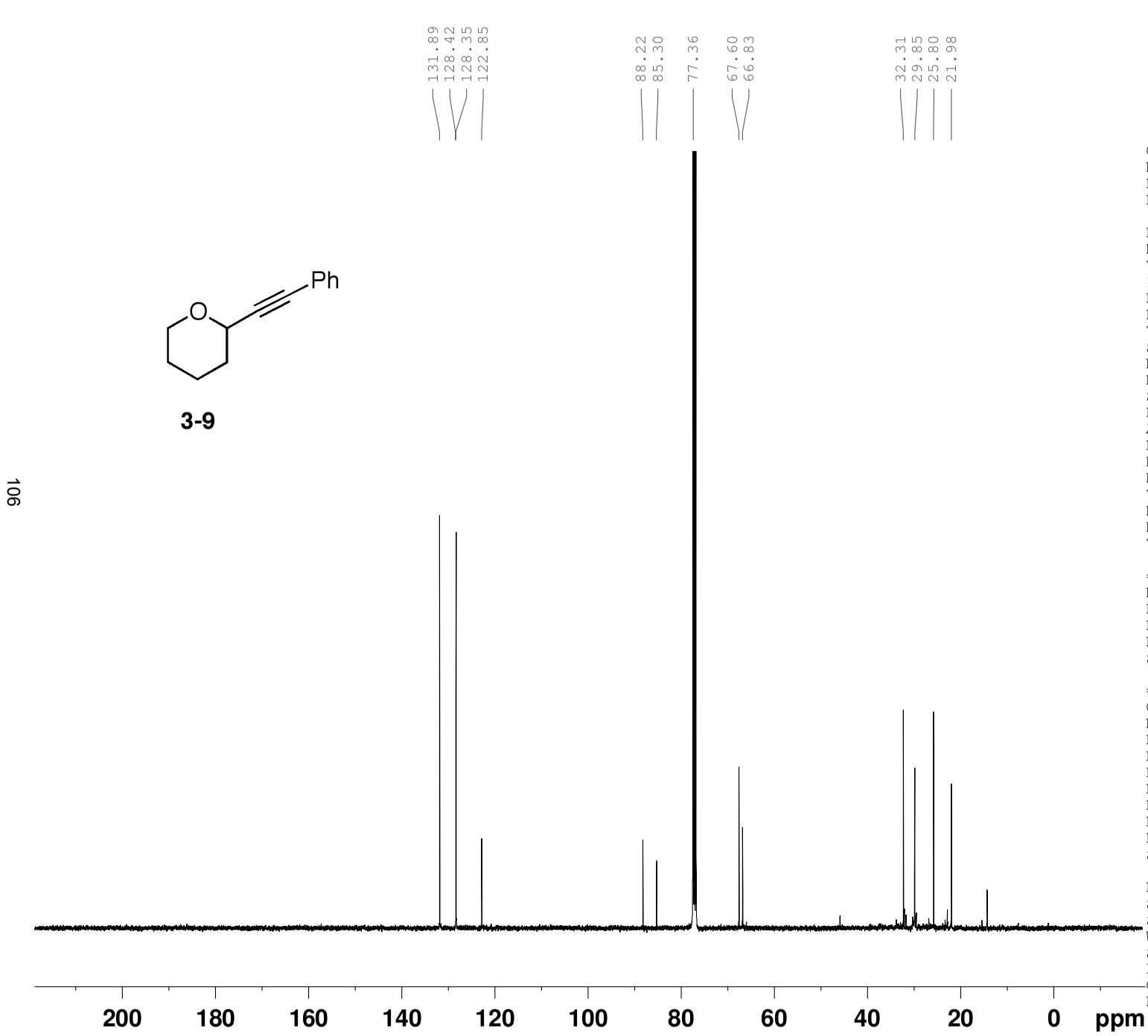
1.00
0.99
2.14
1.12
3.84



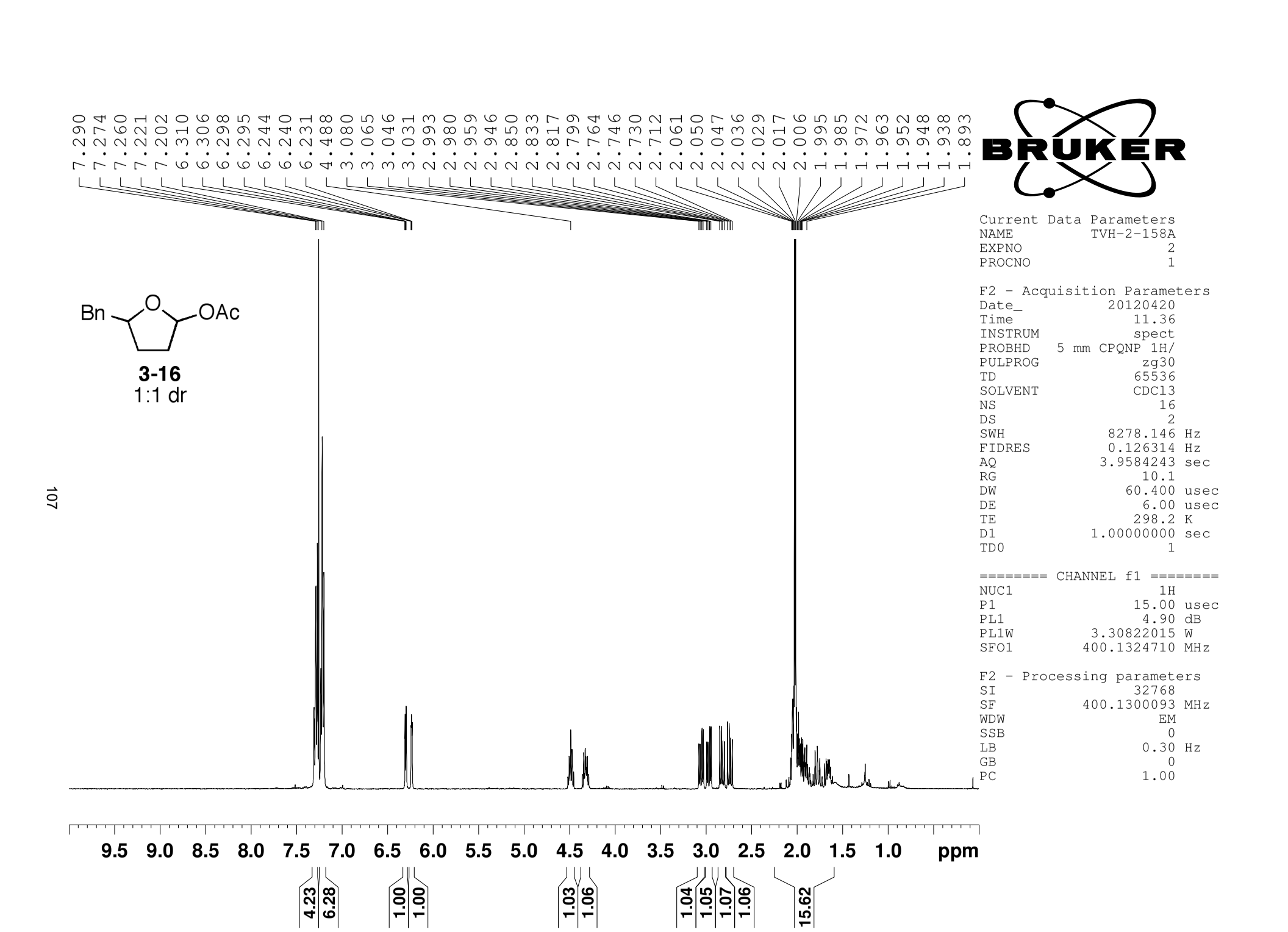
Current Data Parameters
NAME TVH-2-136
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120317
Time 8.48
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127576 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



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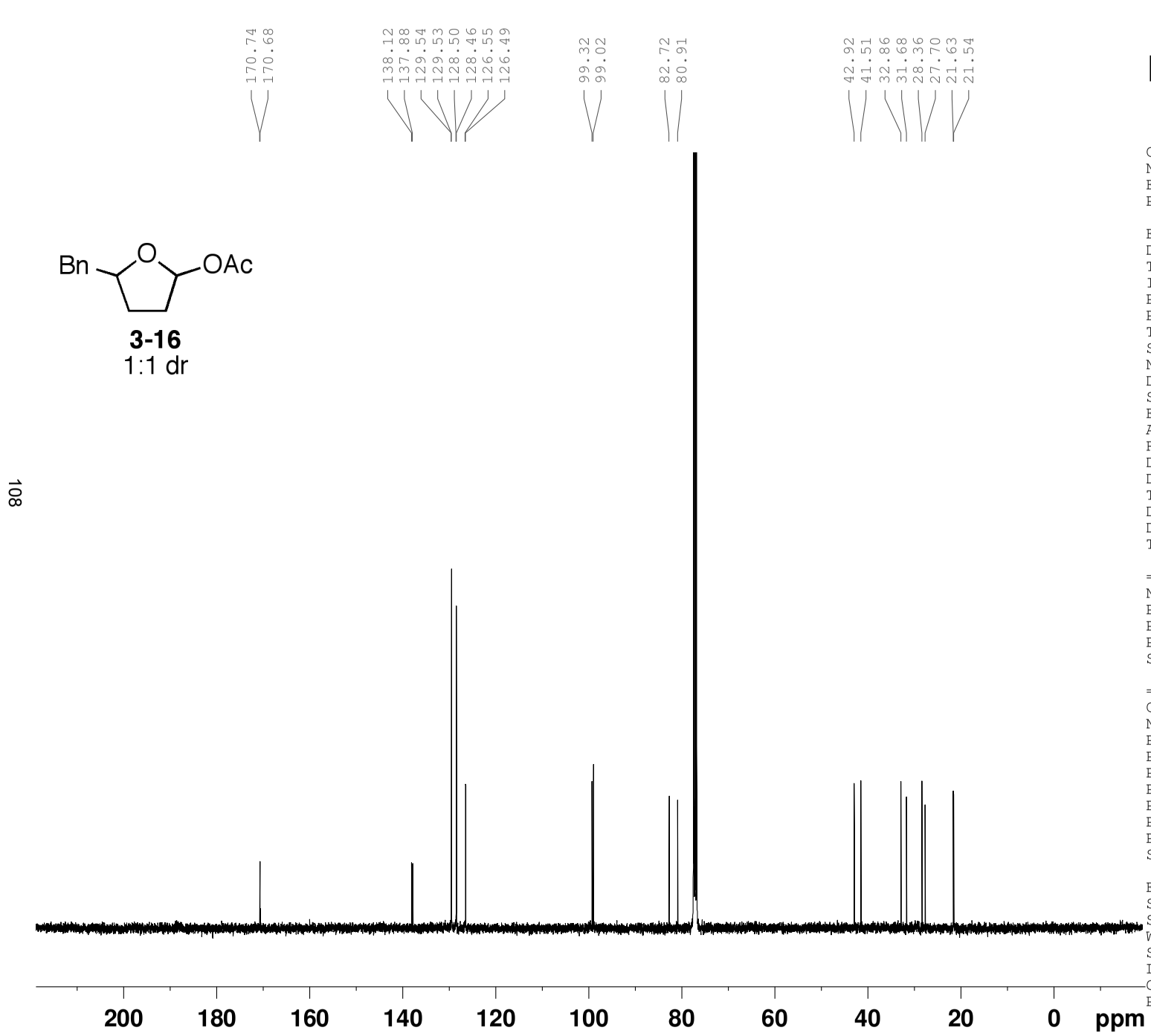
Current Data Parameters
NAME TVH-2-158A
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120420
Time 11.36
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 10.1
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300093 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



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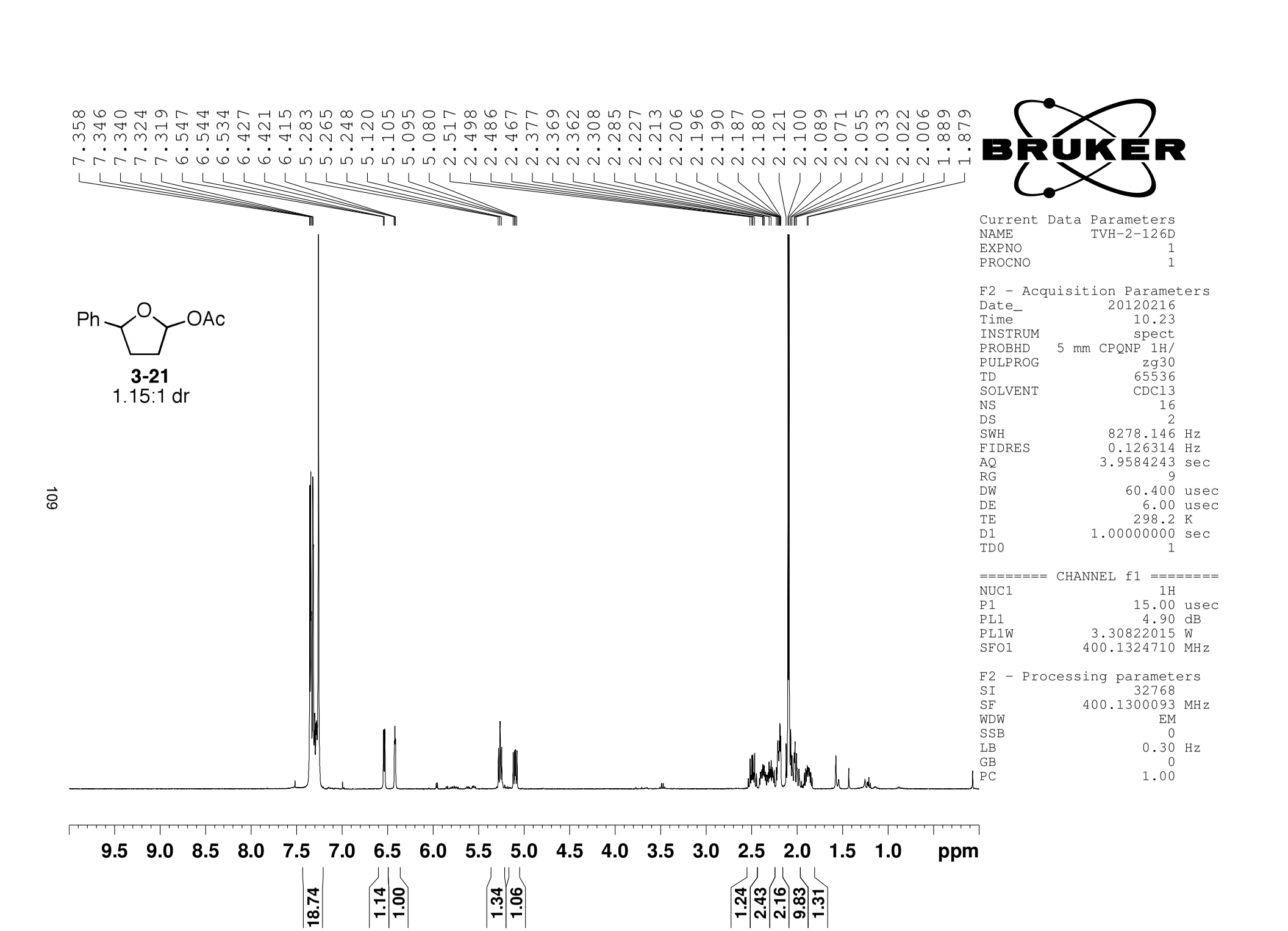
```
Current Data Parameters
NAME          TVH-2-158A
EXPNO                  3
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120420
Time               13.38
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ             1.3664756 sec
RG                  512
DW               20.850 usec
DE               18.00 usec
TE                298.1 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                13C
P1                9.25 usec
PL1               0.55 dB
PL1W        35.18820572 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2         waltz16
NUC2                1H
PCPD2            90.00 usec
PL2               4.90 dB
PL12             20.46 dB
PL13             21.00 dB
PL2W         3.30822015 W
PL12W        0.09195905 W
PL13W        0.08120718 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                32768
SF         100.6127588 MHz
WDW                EM
SSB                 0
LB               1.00 Hz
GB                  0
PC                1.40
```

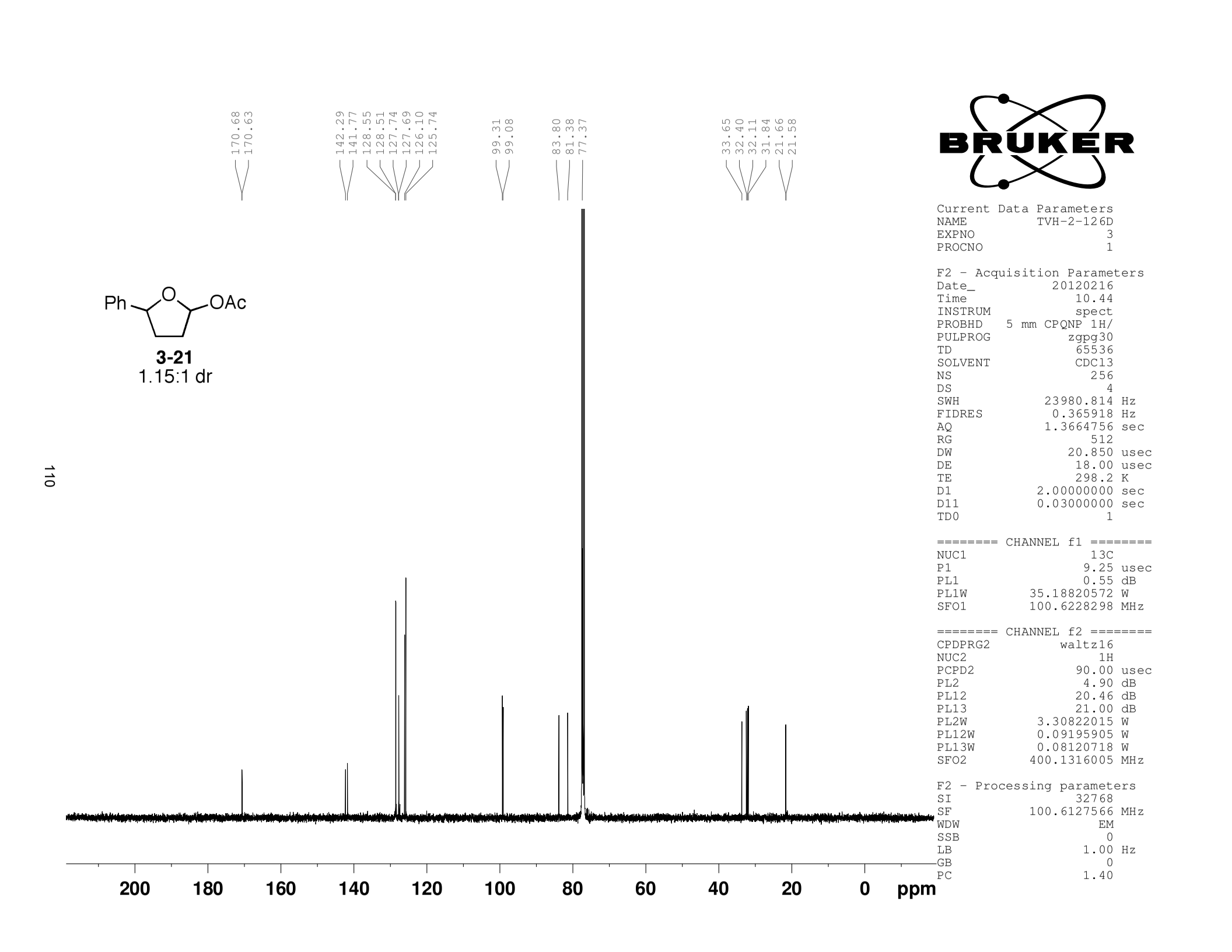



```
Current Data Parameters
NAME          TVH-2-126D
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120216
Time               10.23
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                     9
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300093 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```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141.77
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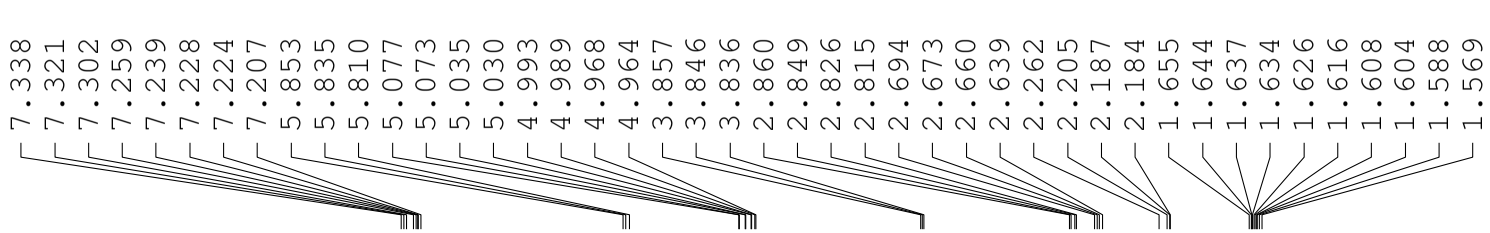
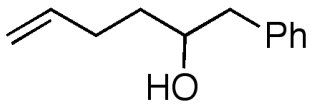
128.51
127.74
127.69
126.10
125.74
99.31
99.08
83.80
81.38
77.37
33.65
32.40
32.11
31.84
21.66
21.58
Ph
O
OAc
3-21
1.15:1 dr
110
200
180
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME TVH-2-126D
EXPNO 3
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120216
Time 10.44
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127566 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40





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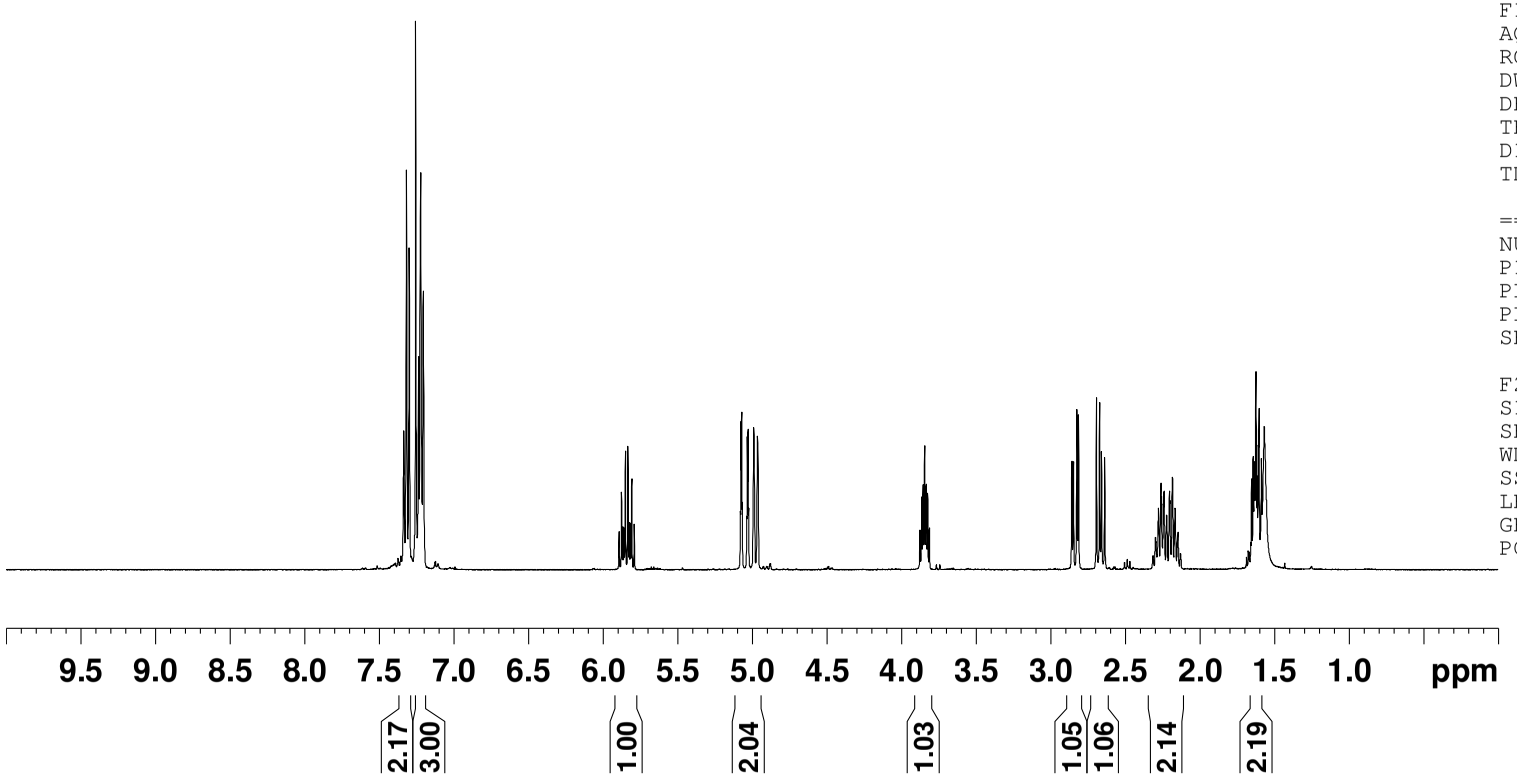
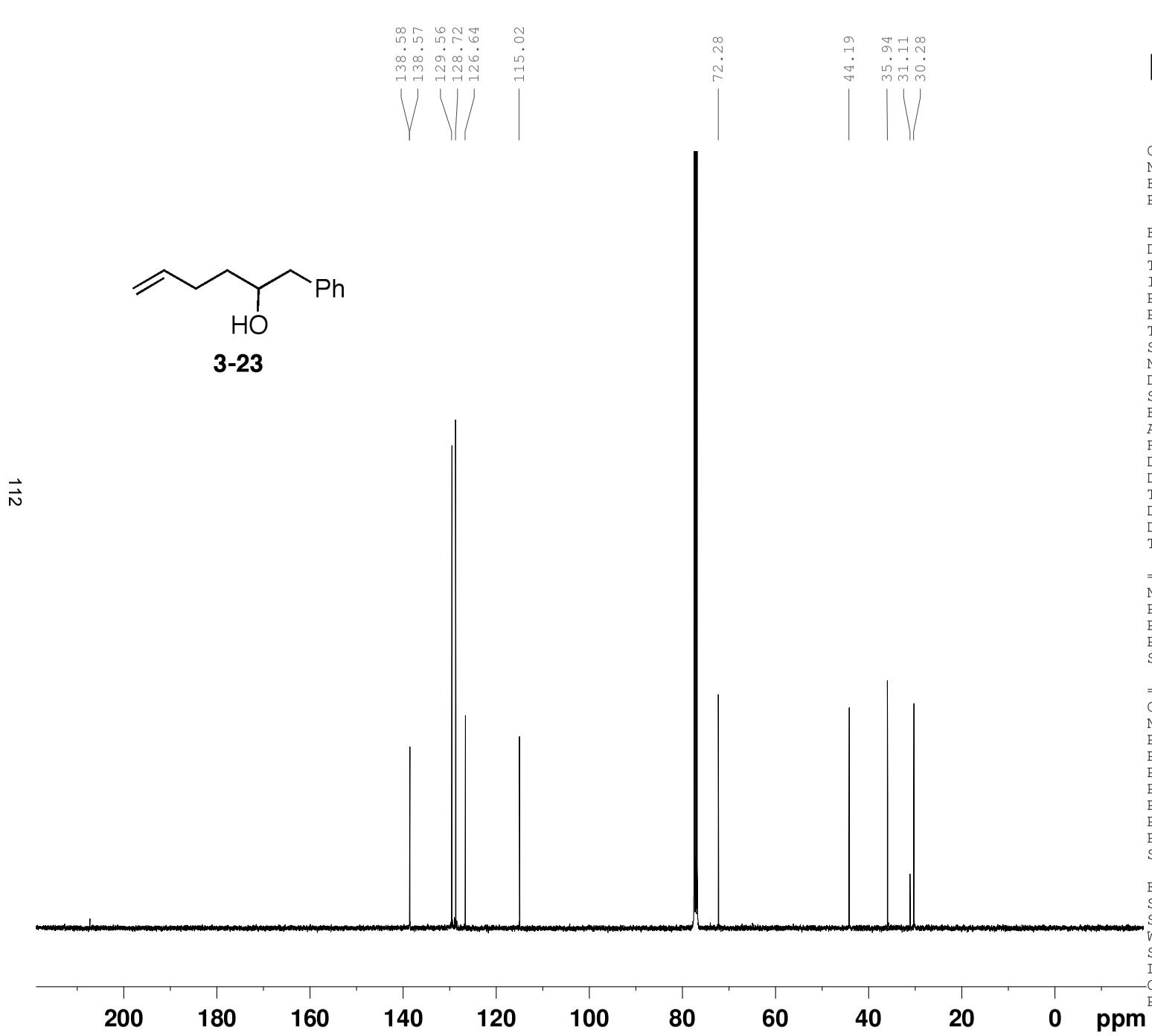


Current Data Parameters
NAME TVH-2-156B
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120418
Time 16.44
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300096 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



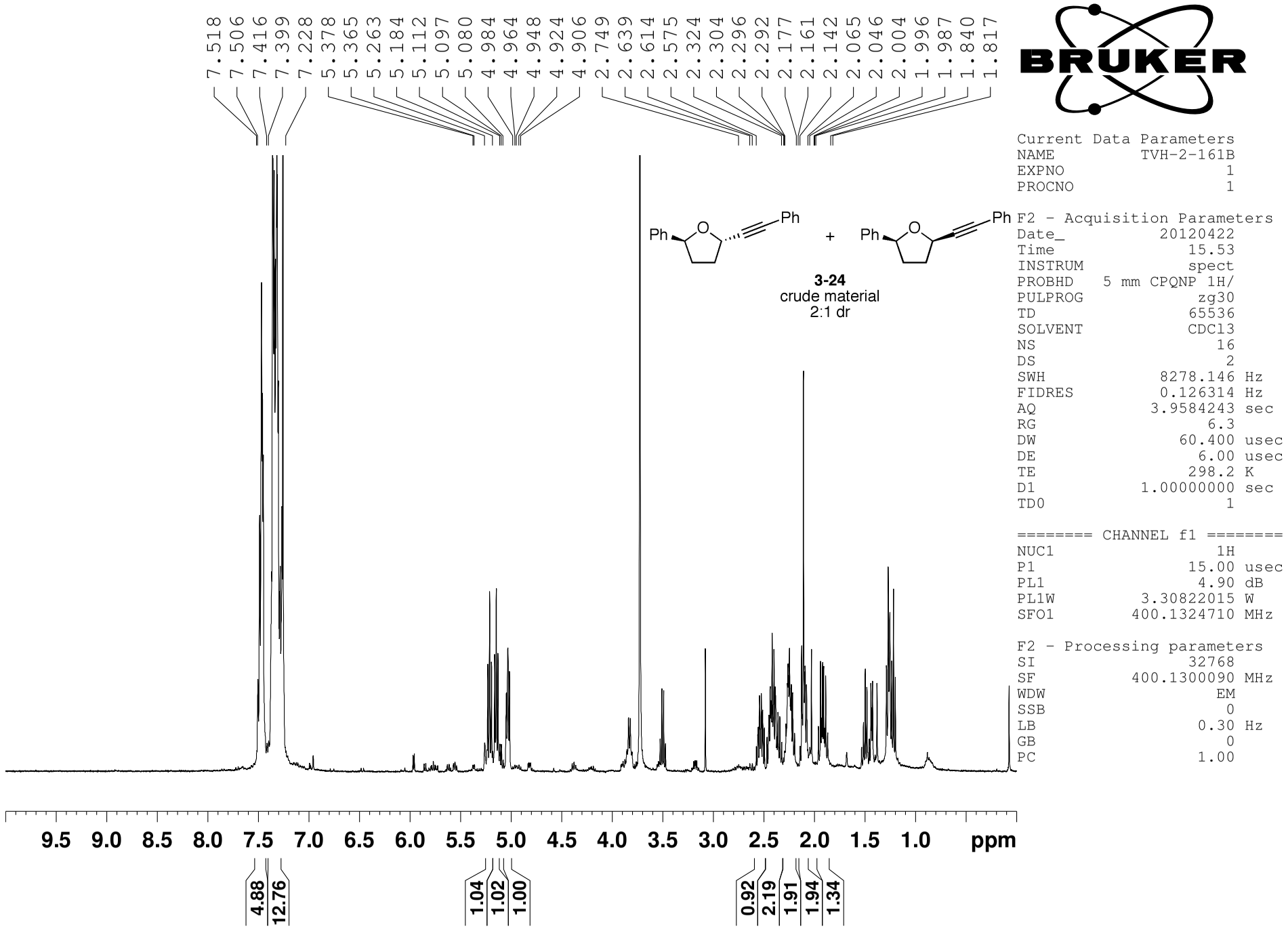
Current Data Parameters
NAME TVH-2-156B
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120420
Time 4.42
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

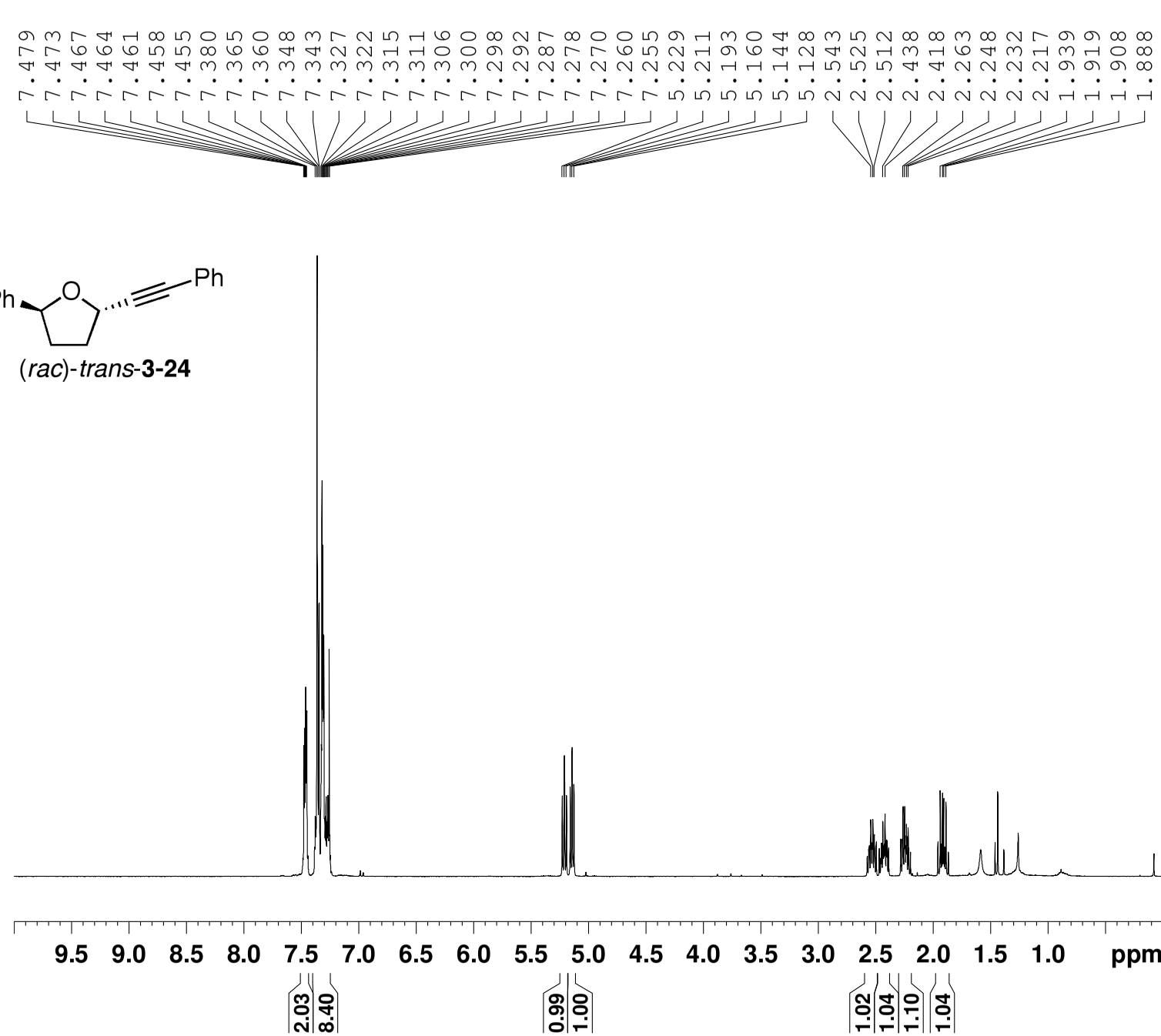
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127577 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40

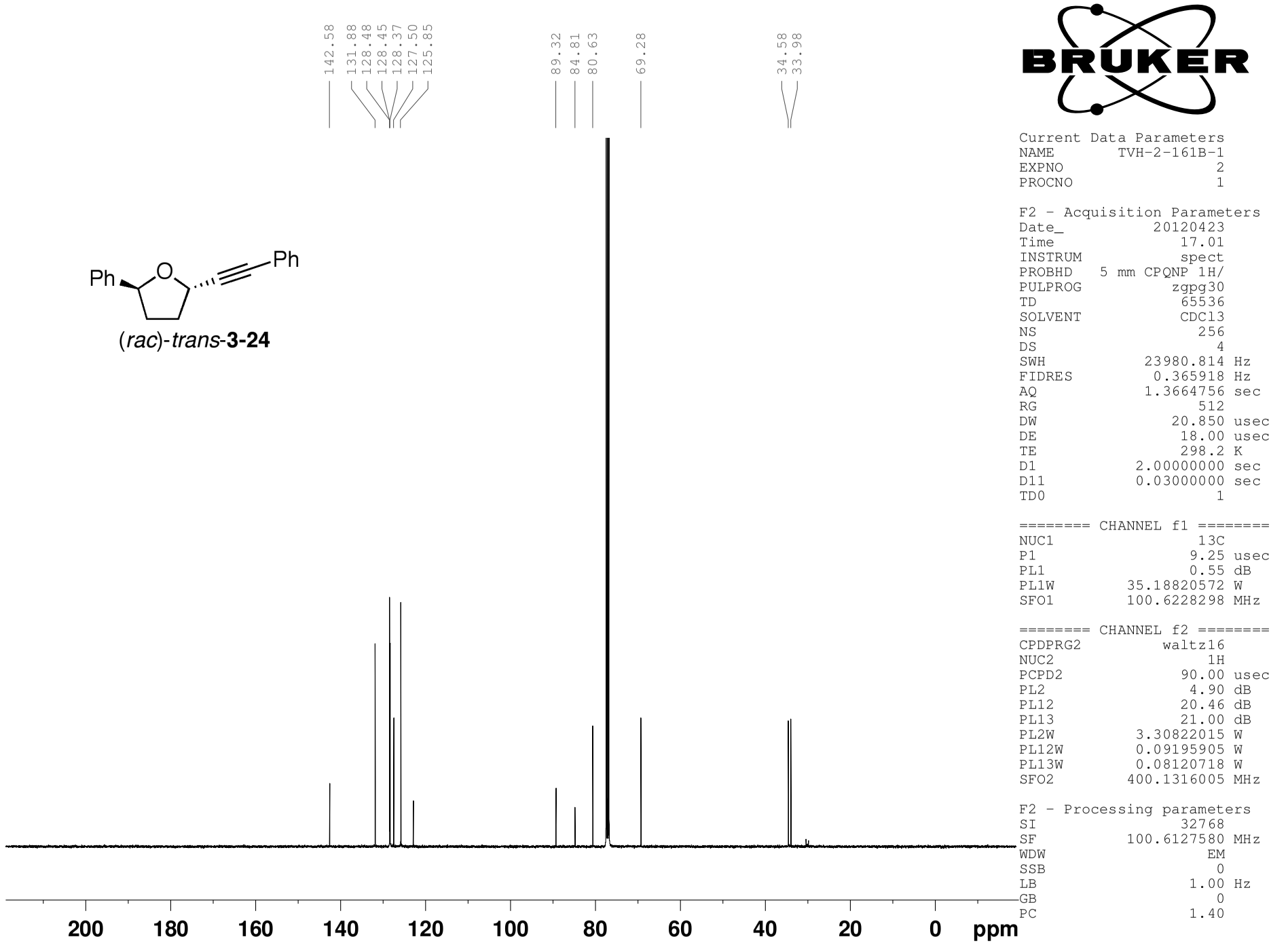



```
Current Data Parameters
NAME          TVH-2-161B
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120422
Time               15.53
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                   6.3
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300090 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```



BRUKER

```
Current Data Parameters
NAME        TVH-2-161B-1
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120423
Time               15.44
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                  12.7
DW                60.400 usec
DE                 6.00 usec
TE                298.1 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300090 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```



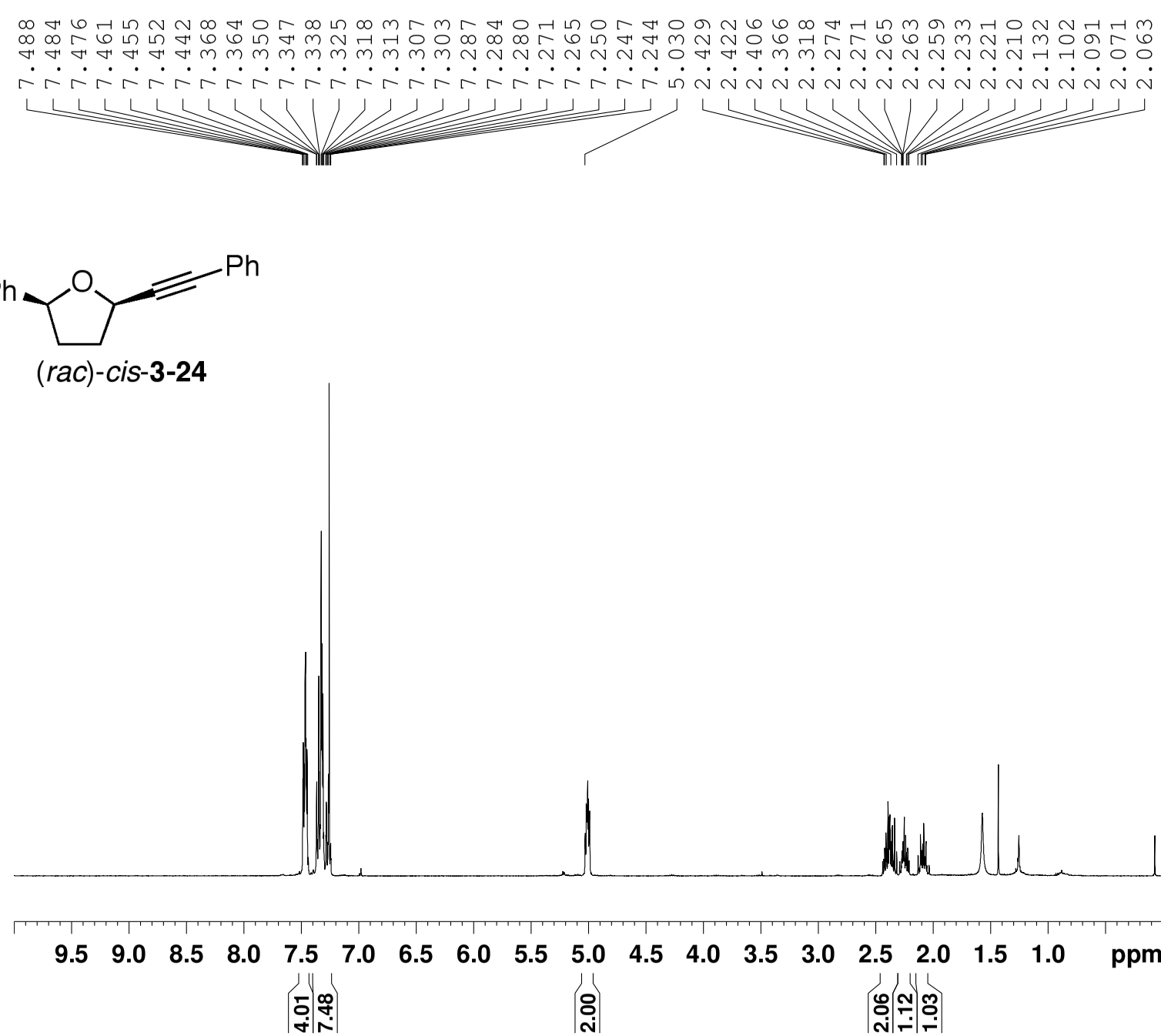
Current Data Parameters
NAME TVH-2-161B-1
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120423
Time 17.01
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

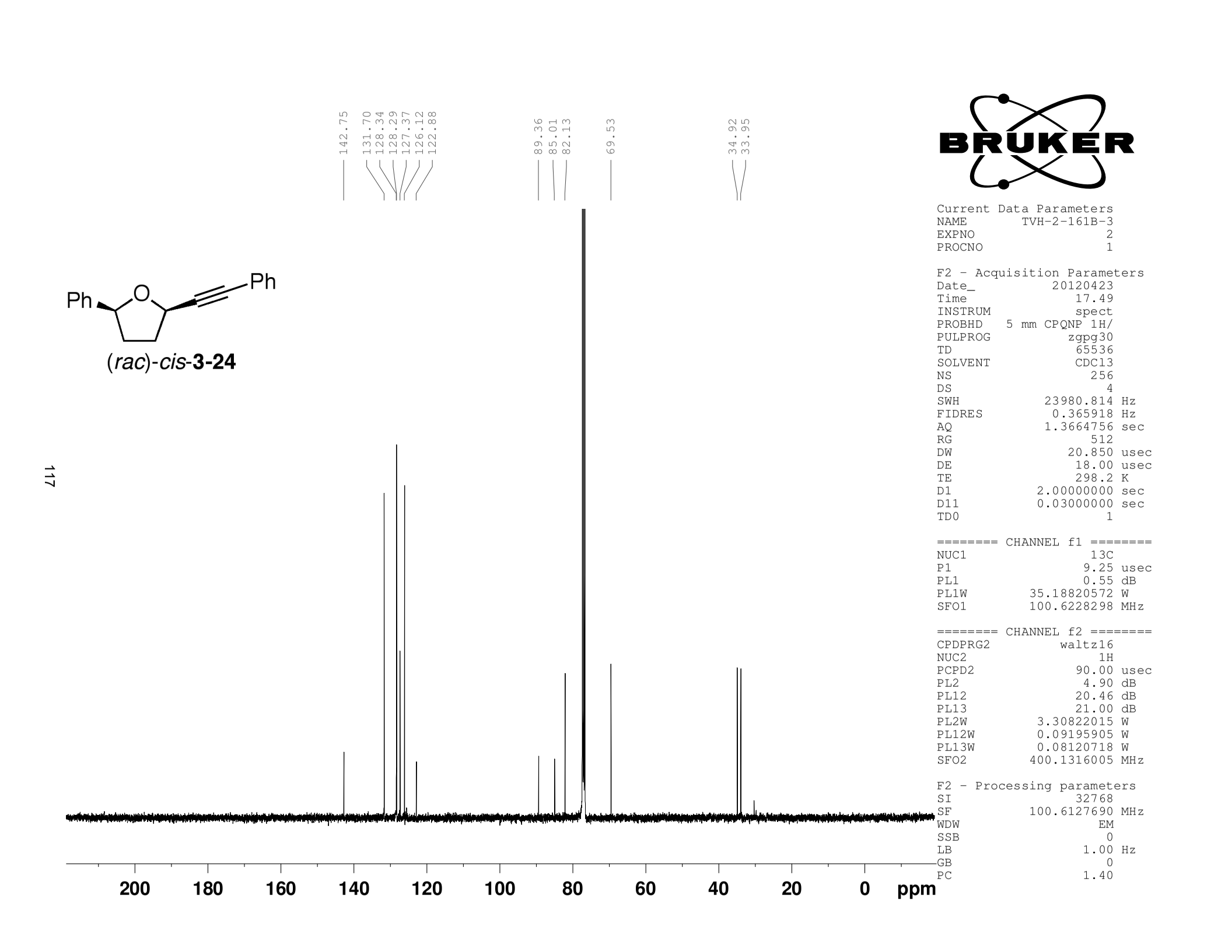
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

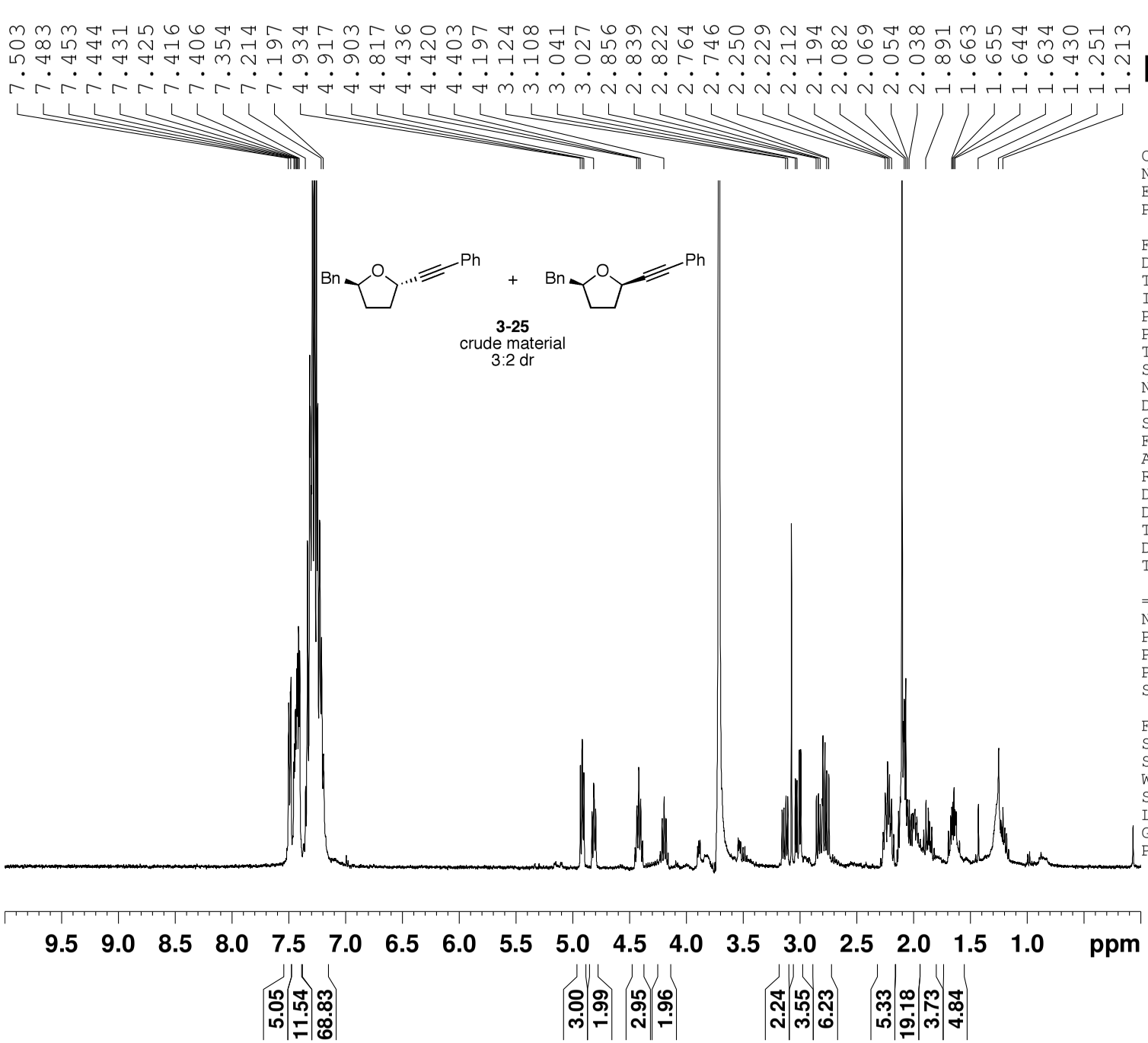
F2 - Processing parameters
SI 32768
SF 100.6127580 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



BRUKER

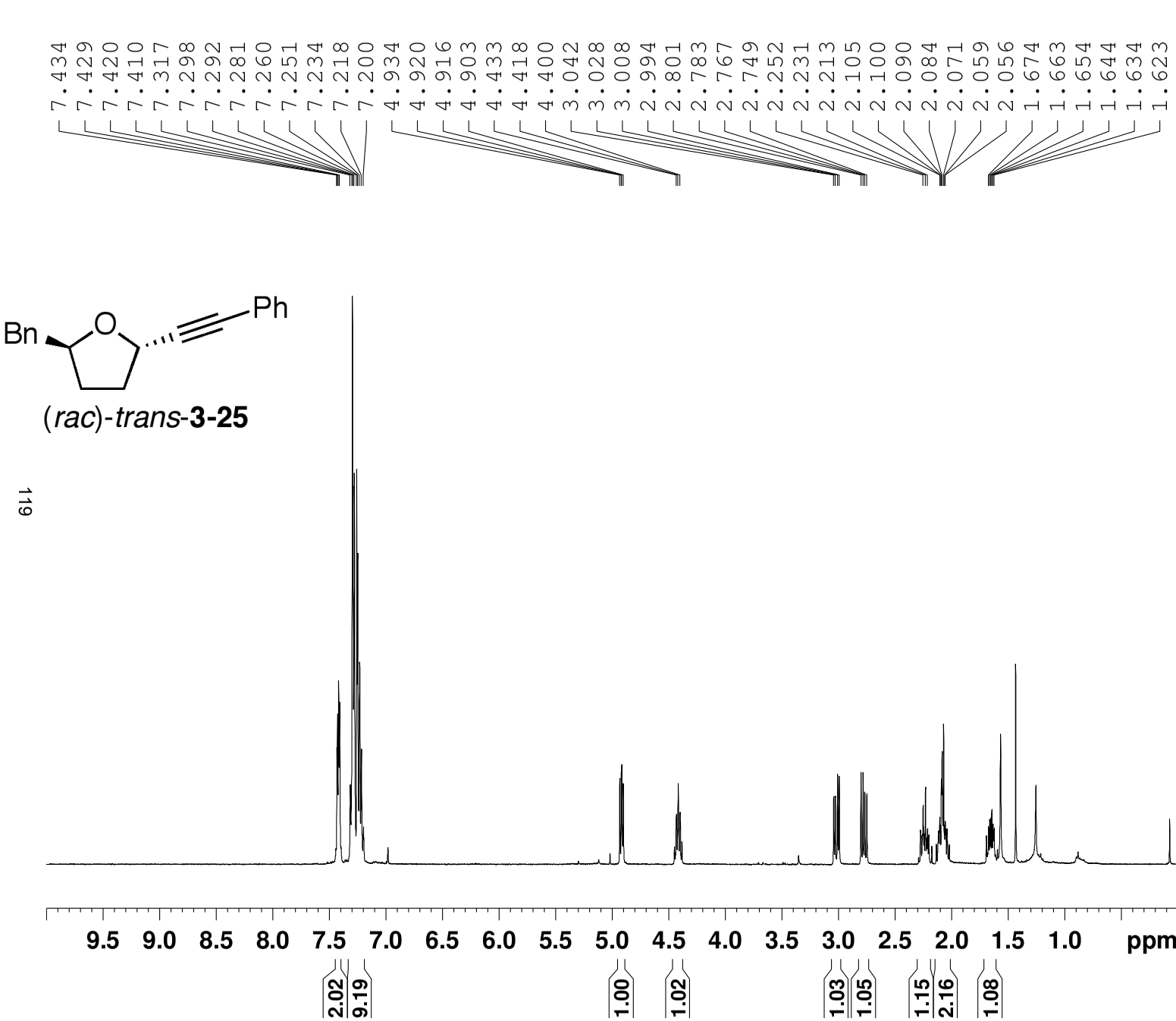
```
Current Data Parameters
NAME        TVH-2-161B-3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120423
Time               15.59
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                  11.3
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300093 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                1.00
```


142.75
131.70
128.34
128.29
127.37
126.12
122.88
89.36
85.01
82.13
69.53
34.92
33.95
Ph
O
Ph
(rac)-cis-3-24
117
200
180
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME TVH-2-161B-3
EXPNO 2
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120423
Time 17.49
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127690 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



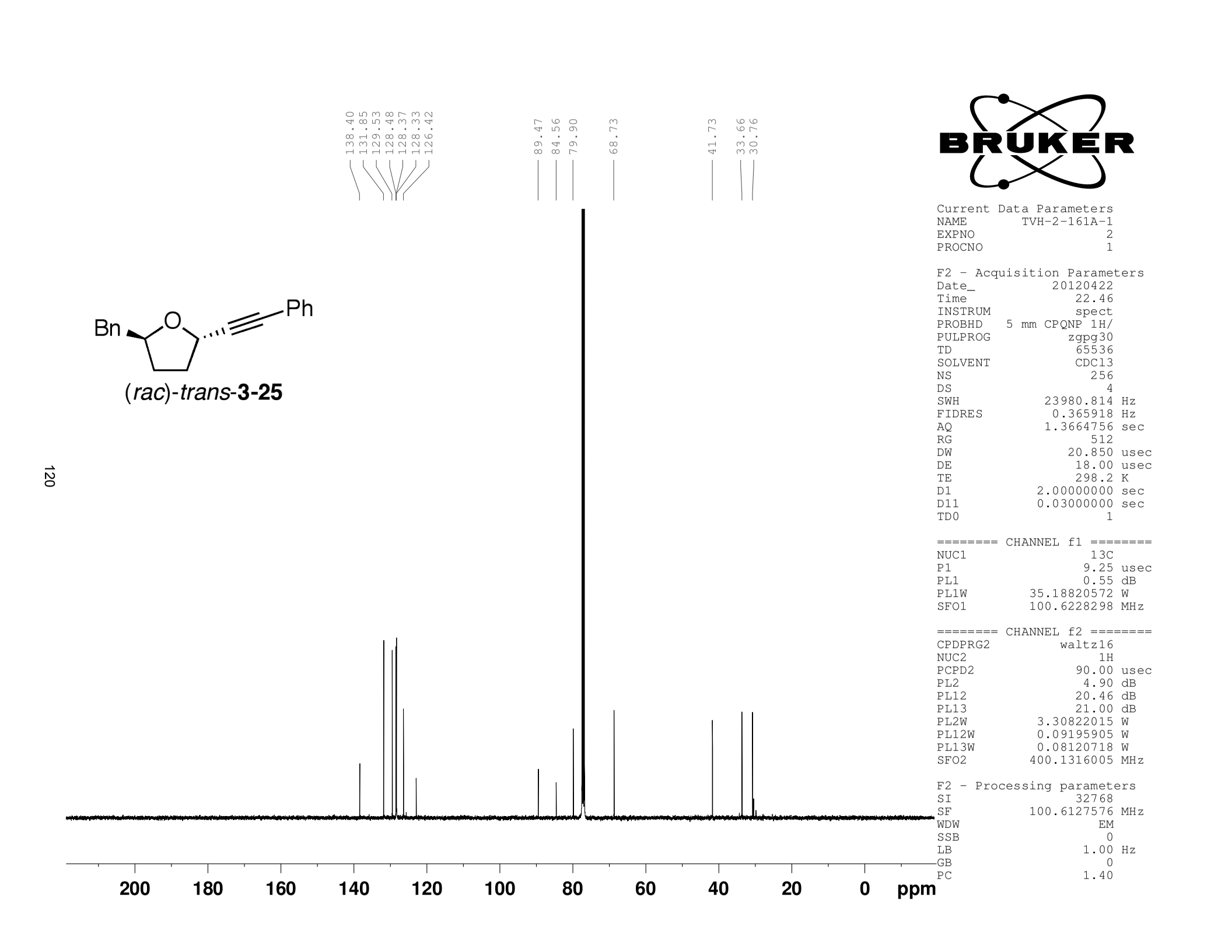
BRUKER

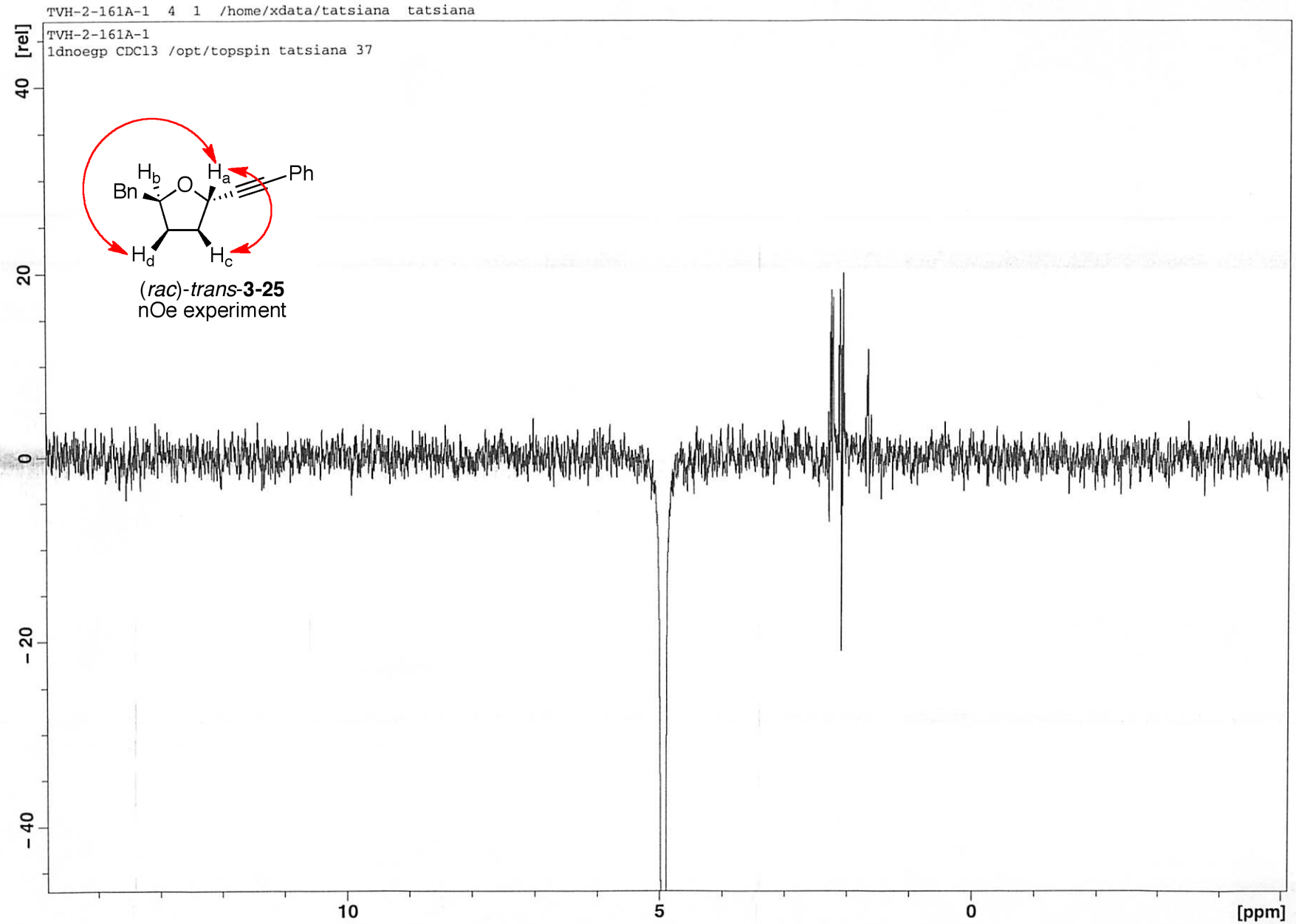
```
Current Data Parameters
NAME          TVH-2-161A
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120422
Time               16.10
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                     8
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300093 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```

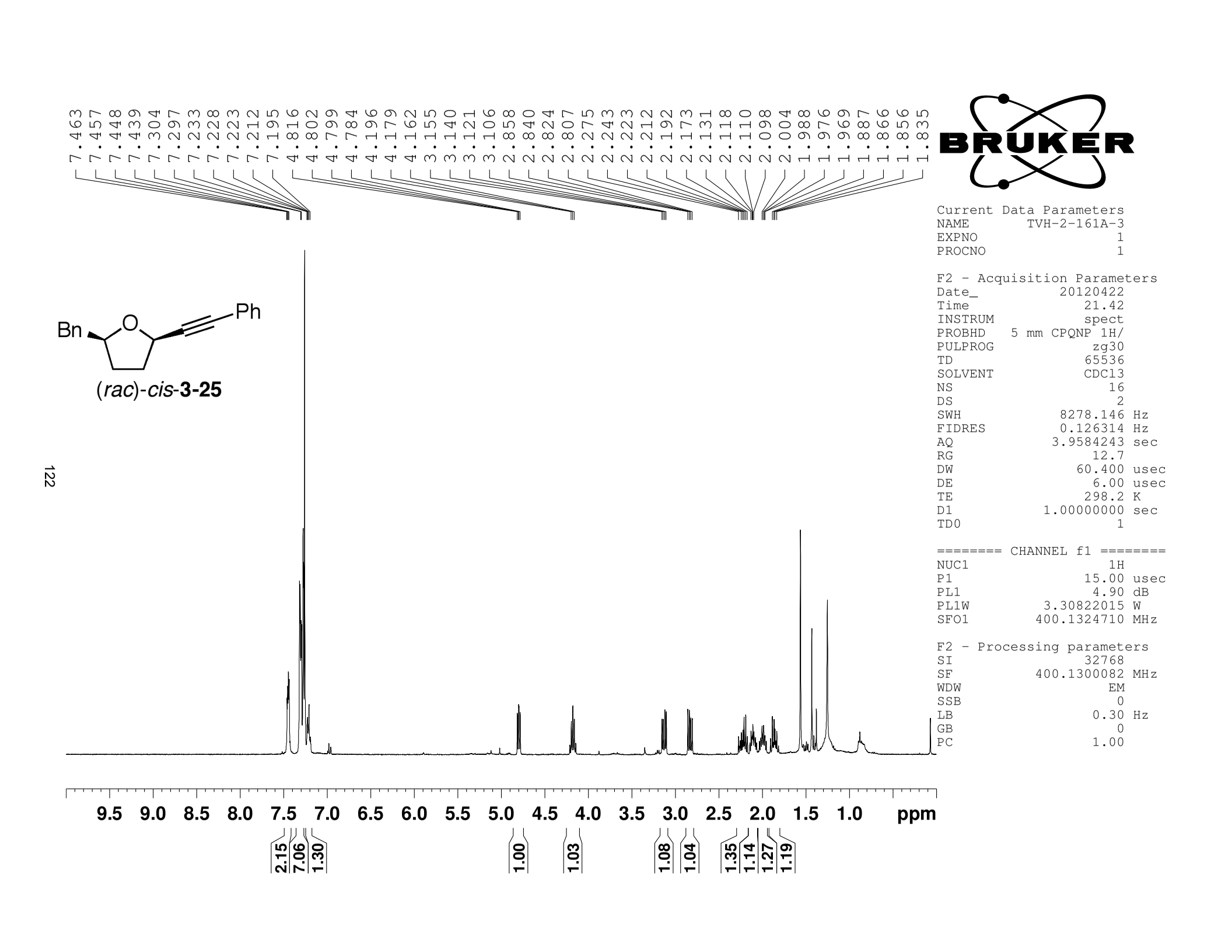


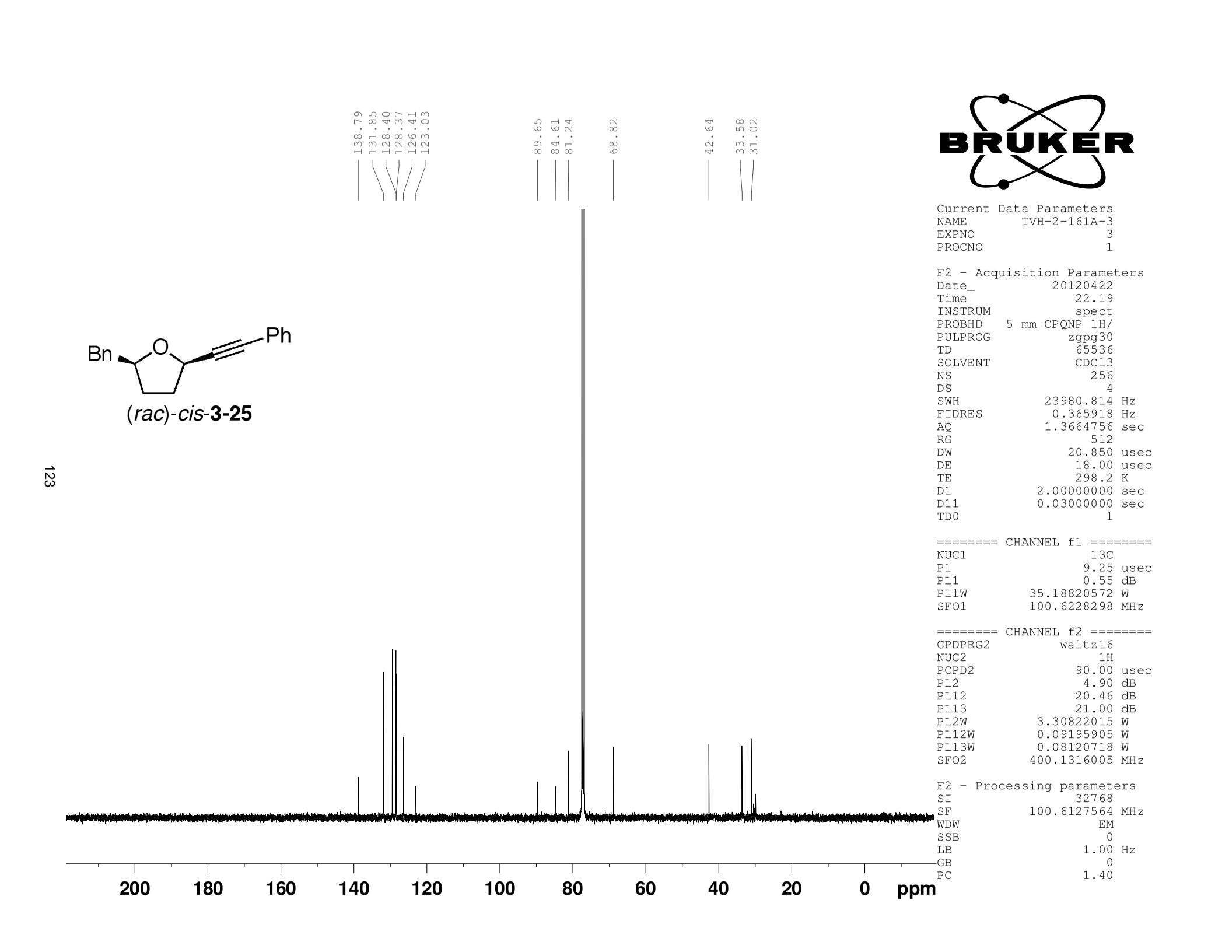
BRUKER

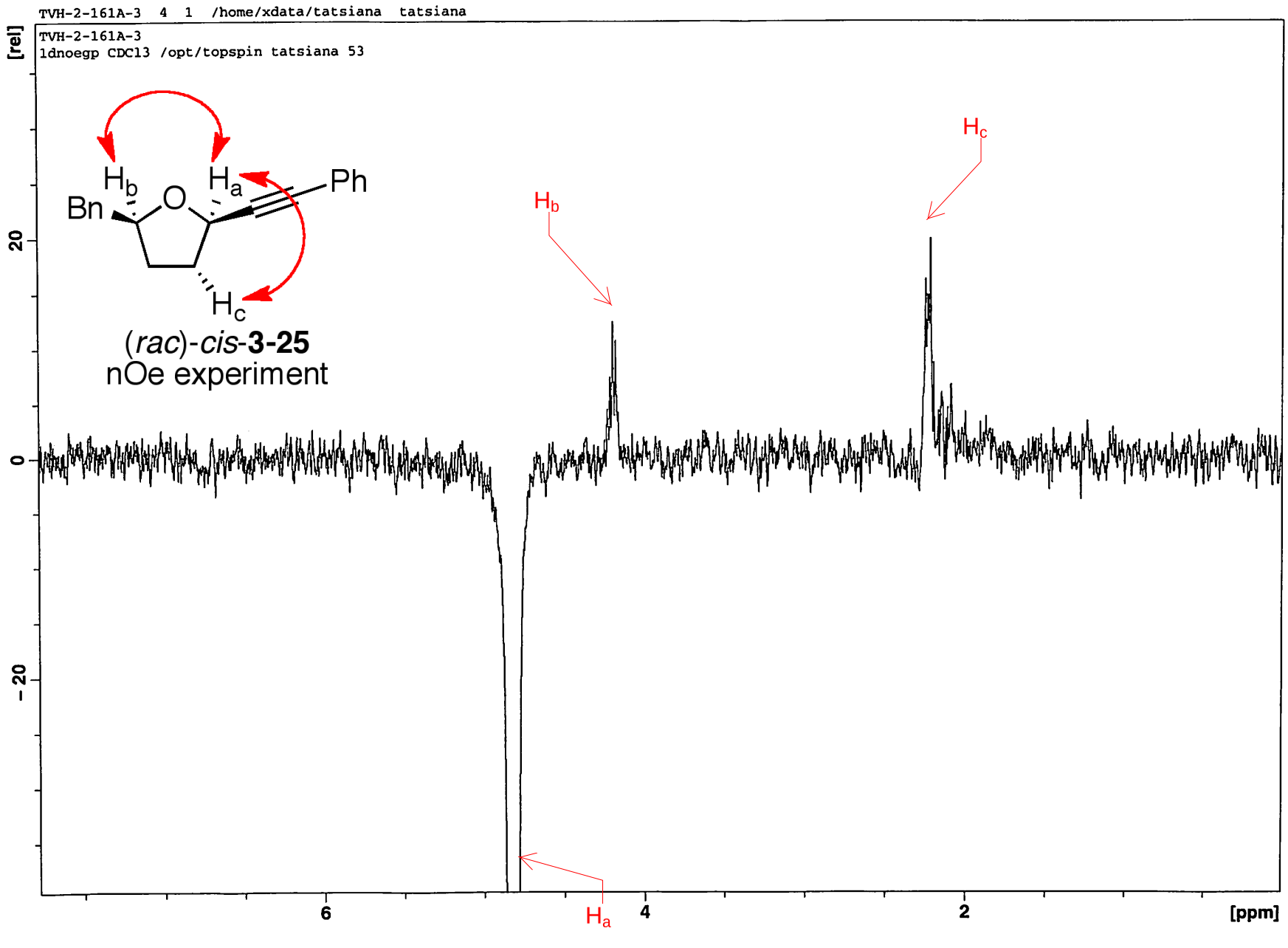
```
Current Data Parameters
NAME        TVH-2-161A-1
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120422
Time               21.29
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                   7.1
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300090 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```

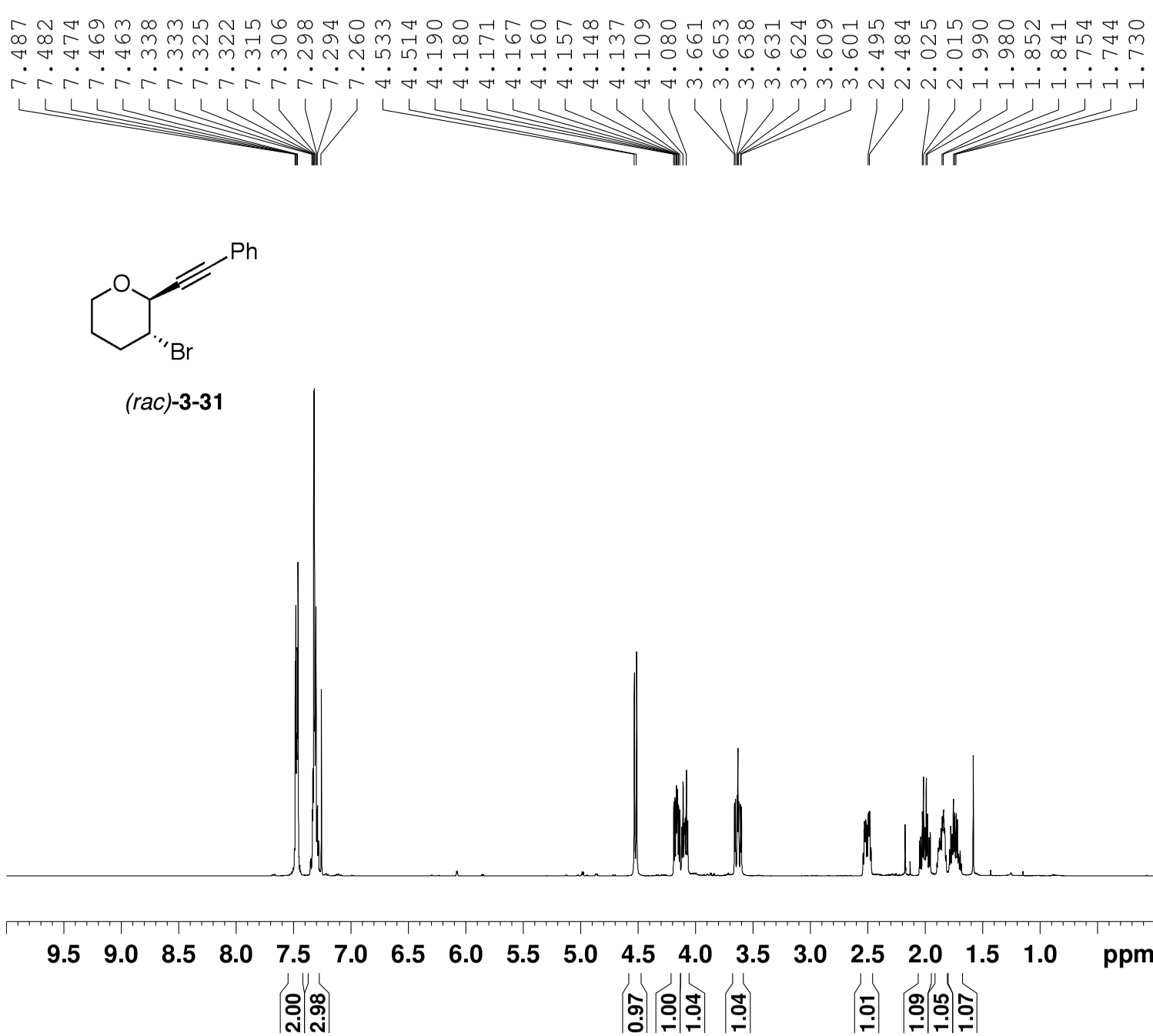

138.40
131.85
129.53
128.48
128.37
128.33
126.42
89.47
84.56
79.90
68.73
41.73
33.66
30.76
Bn
O
Ph
(rac)-trans-3-25
120
200
180
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME TVH-2-161A-1
EXPNO 2
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120422
Time 22.46
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127576 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40


TVH-2-161A-1 4 1 /home/xdata/tatsiana tatsiana
TVH-2-161A-1
1dnoegp CDCl3 /opt/topspin tatsiana 37
Hb
Ha
Ph
Bn
O
Hd
Hc
(rac)-trans-3-25
nOe experiment
40 [rel]
20
0
- 20
- 40
10
5
0
[ppm]


7.463
7.457
7.448
7.439
7.304
7.297
7.233
7.228
7.223
7.212
7.195
4.816
4.802
4.799
4.784
4.196
4.179
4.162
3.155
3.140
3.121
3.106
2.858
2.840
2.824
2.807
2.275
2.243
2.223
2.212
2.192
2.173
2.131
2.118
2.110
2.098
2.004
1.988
1.976
1.969
1.887
1.866
1.856
1.835
BRUKER
Bn
O
Ph
(rac)-cis-3-25
122
Current Data Parameters
NAME TVH-2-161A-3
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120422
Time 21.42
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 12.7
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz
F2 - Processing parameters
SI 32768
SF 400.1300082 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
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 ppm
2.15
7.06
1.30
1.00
1.03
1.08
1.04
1.35
1.14
1.27
1.19

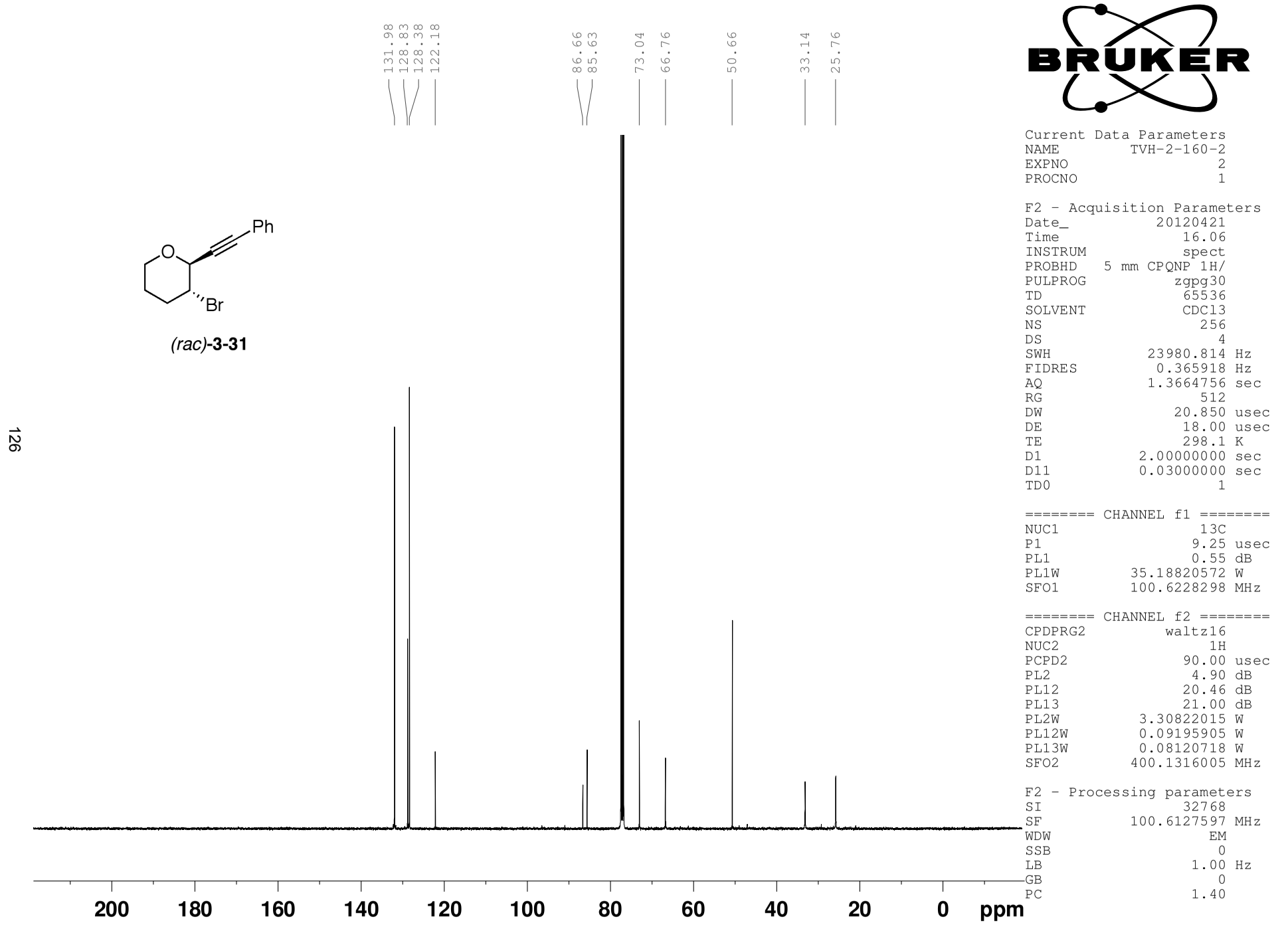

138.79
131.85
128.40
128.37
126.41
123.03
89.65
84.61
81.24
68.82
42.64
33.58
31.02
Bn
O
Ph
(rac)-cis-3-25
123
200
180
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME TVH-2-161A-3
EXPNO 3
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120422
Time 22.19
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127564 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40


TVH-2-161A-3 4 1 /home/xdata/tatsiana tatsiana
TVH-2-161A-3
1dnoegp CDCl3 /opt/topspin tatsiana 53
[rel]
20
0
-20
Hb
Ha
Ph
Bn
O
Hc
(rac)-cis-3-25
nOe experiment
Hb
Hc
Ha
6
4
2
[ppm]



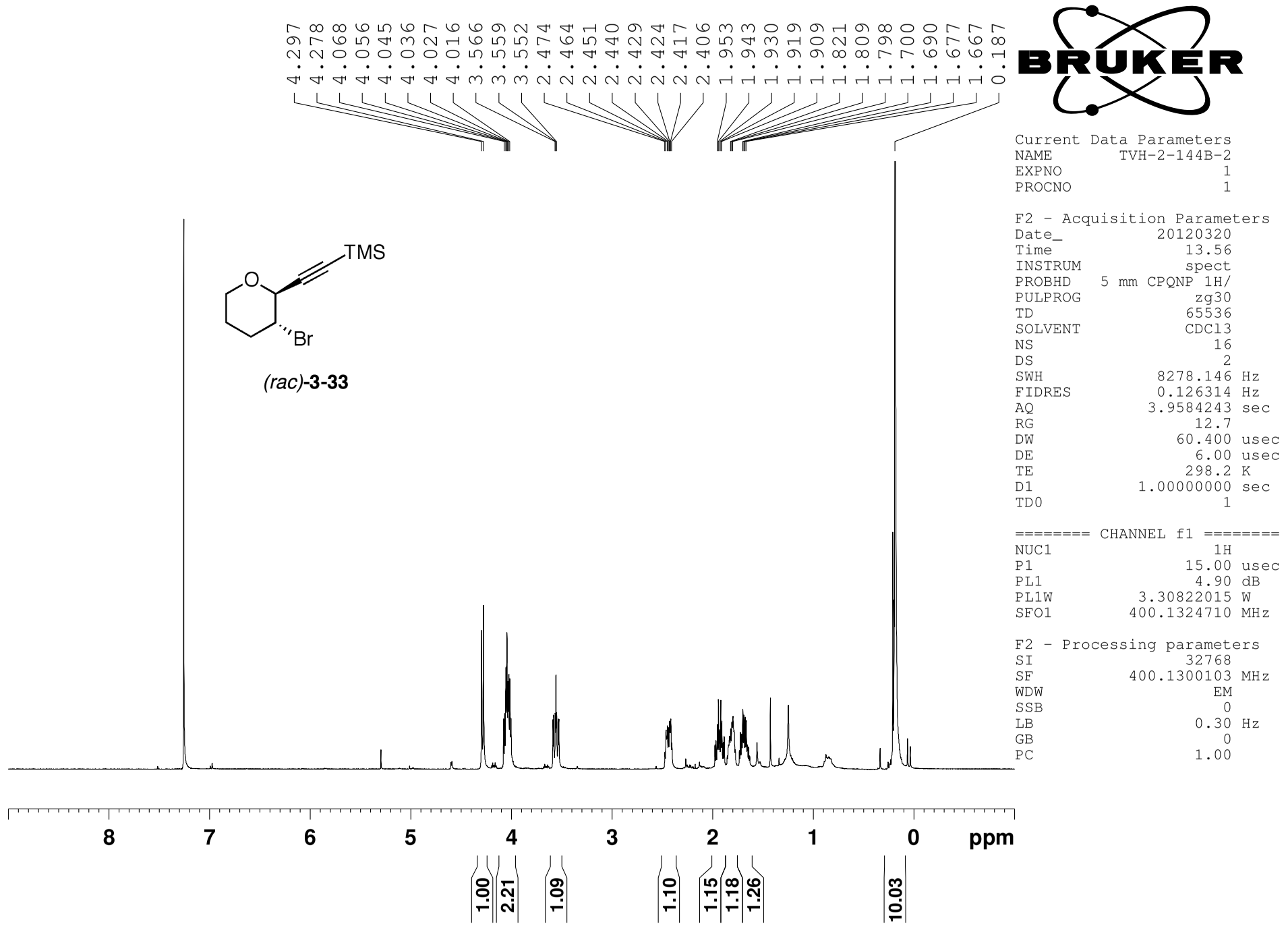
BRUKER

```
Current Data Parameters
NAME         TVH-2-160-2
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120421
Time               12.45
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ              3.9584243 sec
RG                  11.3
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300093 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```

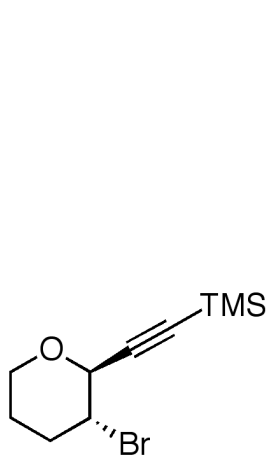


BRUKER

```
Current Data Parameters
NAME         TVH-2-160-2
EXPNO                  2
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120421
Time               16.06
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ             1.3664756 sec
RG                  512
DW                20.850 usec
DE                18.00 usec
TE                298.1 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                 13C
P1                  9.25 usec
PL1                 0.55 dB
PL1W        35.18820572 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                 1H
PCPD2              90.00 usec
PL2                 4.90 dB
PL12               20.46 dB
PL13               21.00 dB
PL2W         3.30822015 W
PL12W        0.09195905 W
PL13W        0.08120718 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF         100.6127597 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```




```
Current Data Parameters
NAME        TVH-2-144B-2
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120320
Time               13.56
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                  12.7
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300103 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```



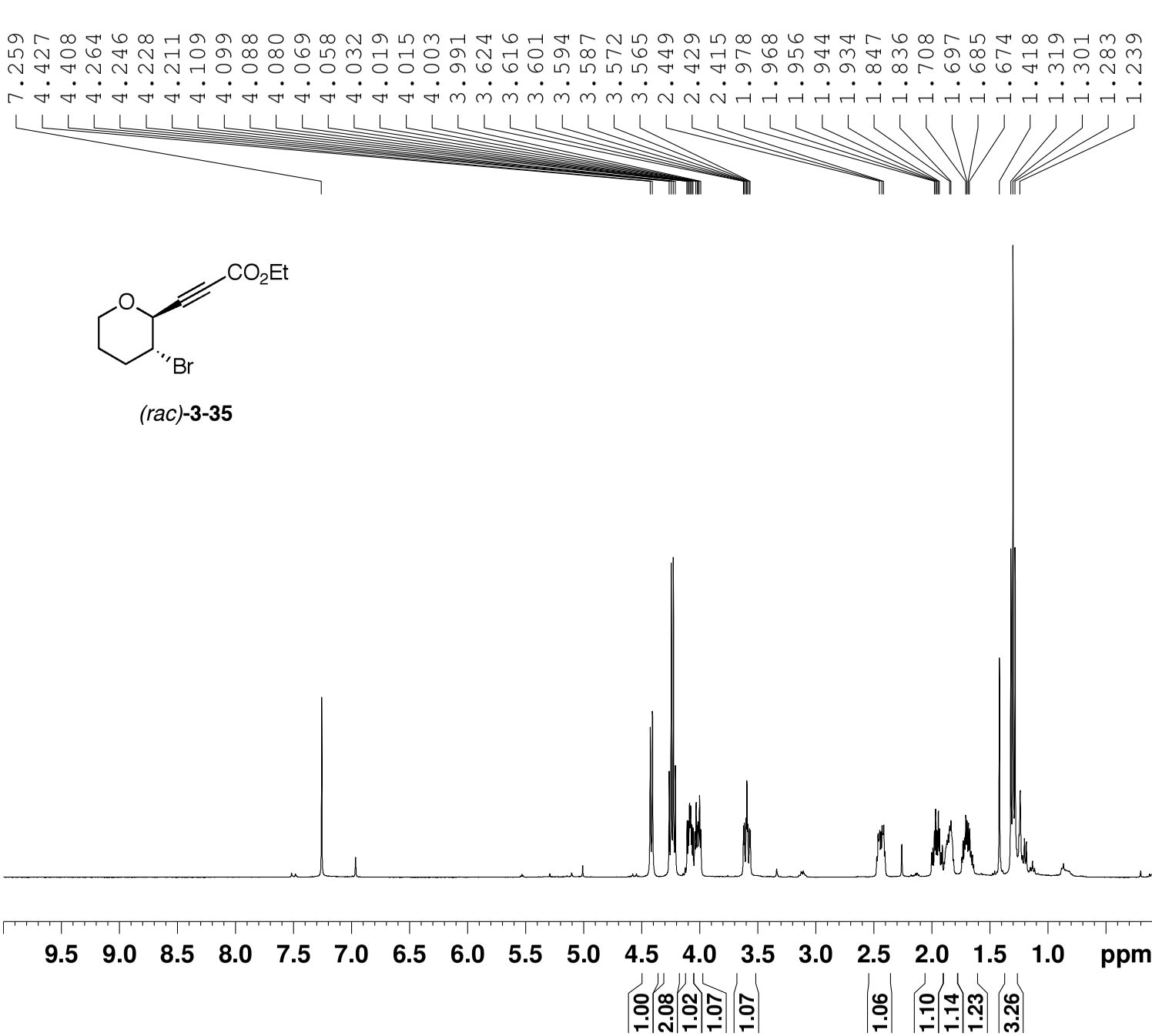
(rac)-**3-33**

128

101.53 92.02 72.82 66.56 50.38 32.91 25.59 -0.15

200 180 160 140 120 100 80 60 40 20 0 ppm

```
Current Data Parameters
NAME        TVH-2-144B-2
EXPNO                  2
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120320
Time               23.03
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ             1.3664756 sec
RG                  512
DW                20.850 usec
DE                18.00 usec
TE                298.2 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                13C
P1                 9.25 usec
PL1                0.55 dB
PL1W        35.18820572 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2         waltz16
NUC2                1H
PCPD2              90.00 usec
PL2                4.90 dB
PL12               20.46 dB
PL13               21.00 dB
PL2W         3.30822015 W
PL12W        0.09195905 W
PL13W        0.08120718 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF         100.6127583 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```



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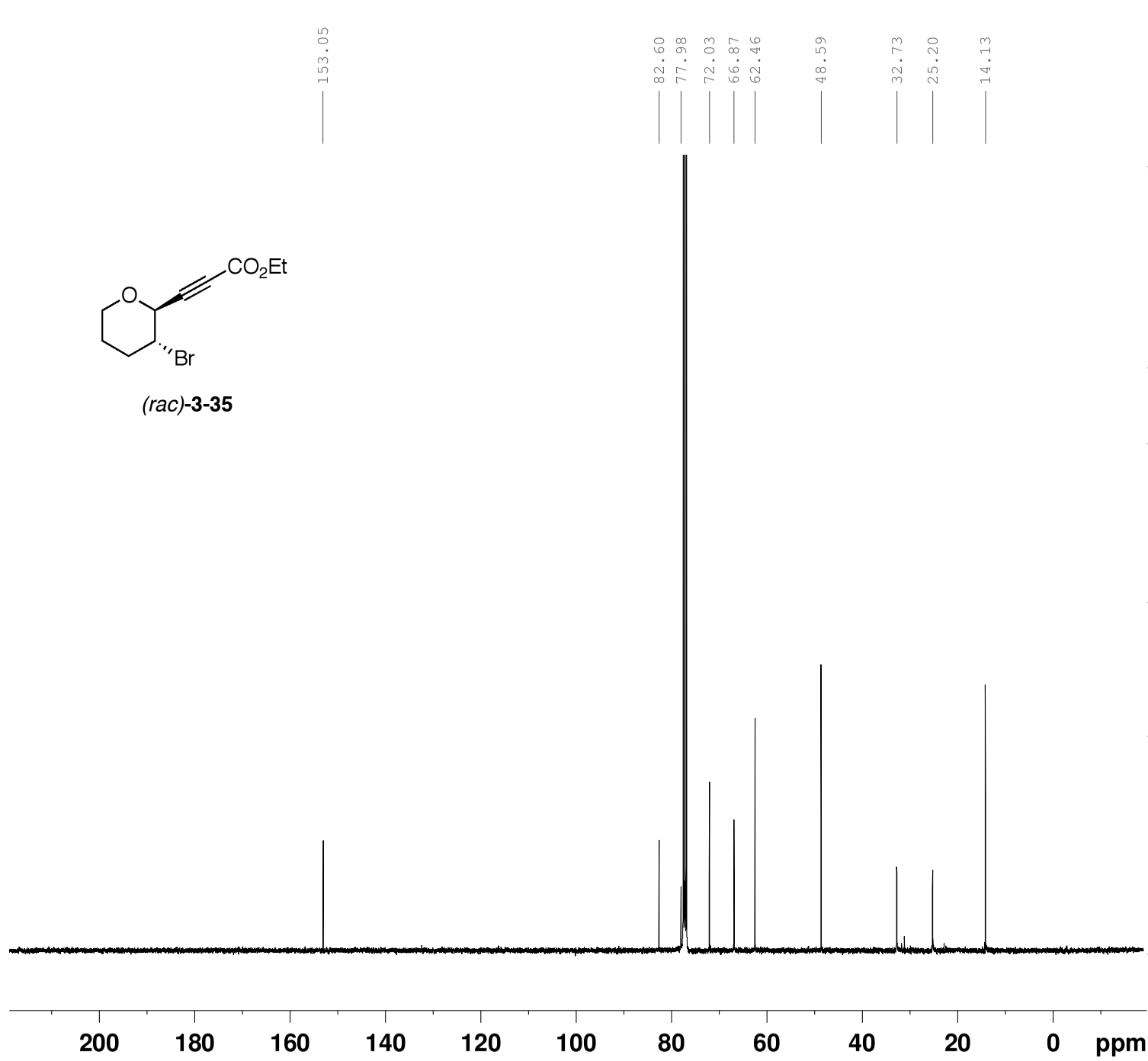
```
Current Data Parameters
NAME        TVH-2-144D-2
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120322
Time                8.26
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                     9
DW                60.400 usec
DE                 6.00 usec
TE                298.1 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300103 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```



BRUKER

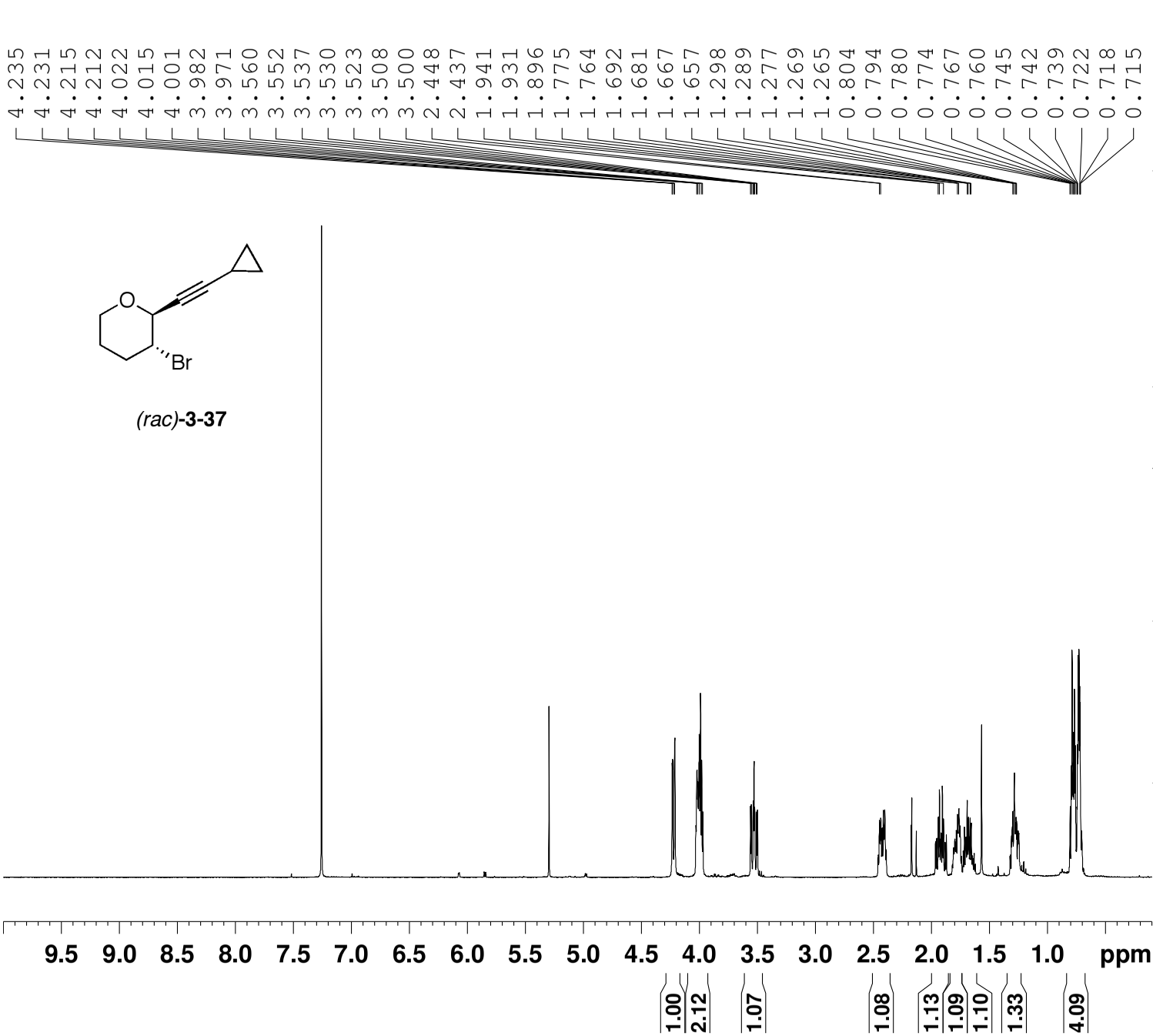
Current Data Parameters
NAME TVH-2-160D
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120421
Time 13.25
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz

F2 - Processing parameters
SI 32768
SF 100.6127567 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



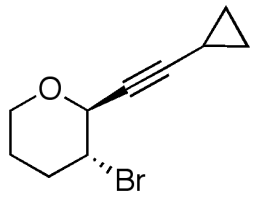
(rac)-**3-37**

Current Data Parameters
NAME TVH-2-144G
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120419
Time 18.59
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

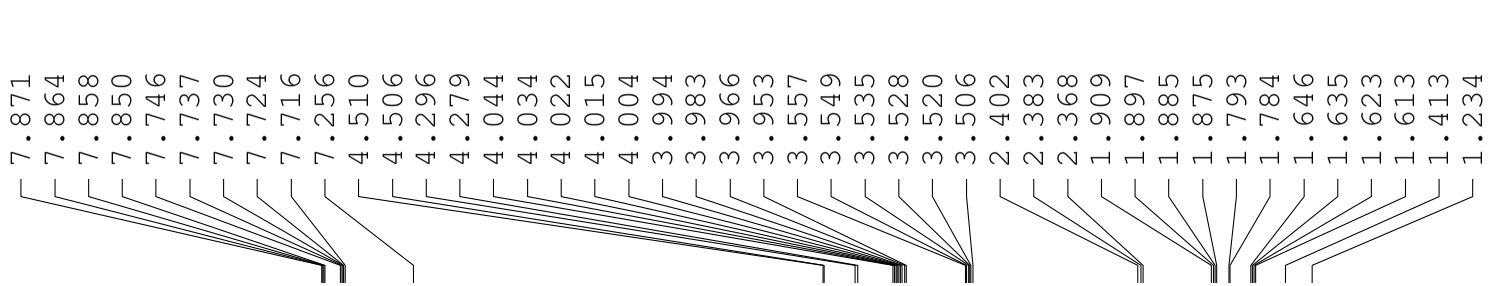
======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

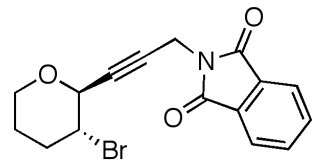
F2 - Processing parameters
SI 32768
SF 400.1300093 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



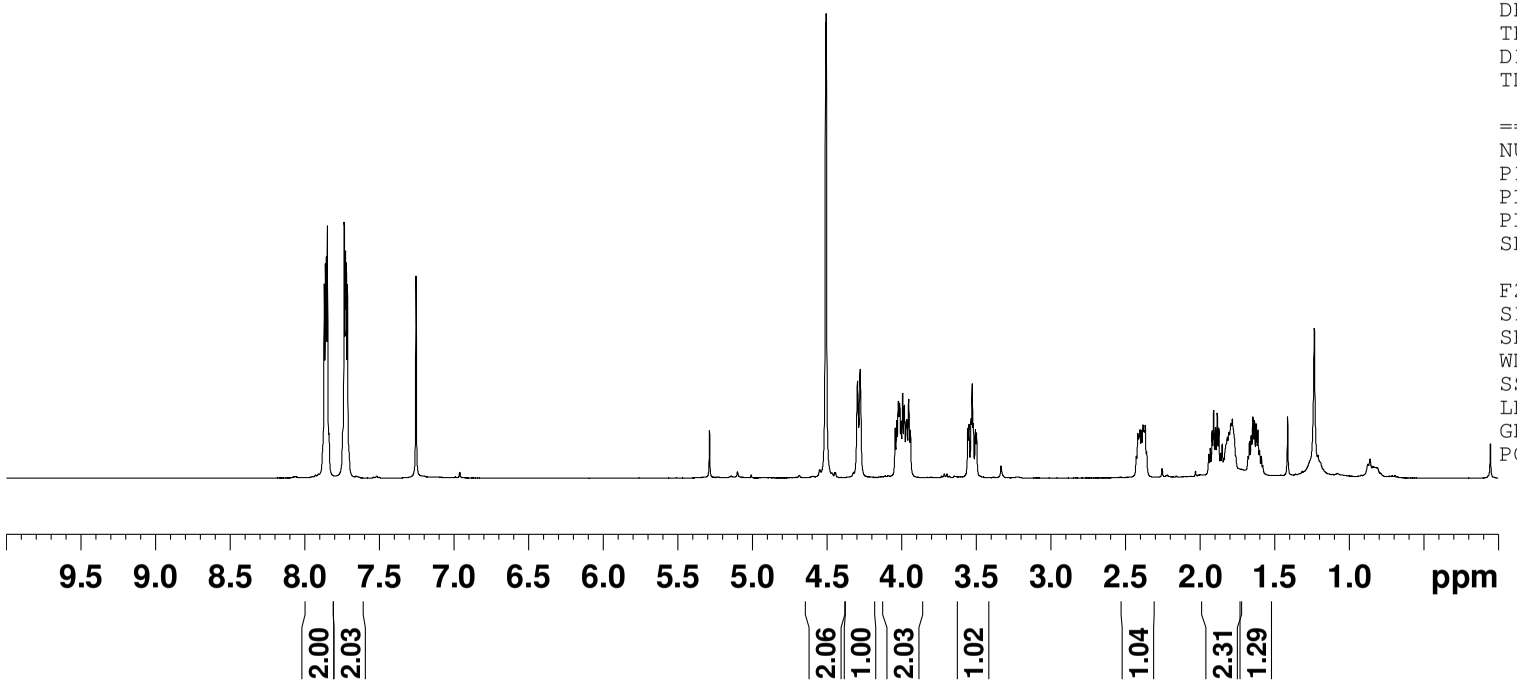
(rac)-**3-37**


```
Current Data Parameters
NAME          TVH-2-144G
EXPNO                  4
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120420
Time                9.33
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   256
DS                     4
SWH            23980.814 Hz
FIDRES          0.365918 Hz
AQ              1.3664756 sec
RG                   512
DW                20.850 usec
DE                18.00 usec
TE                298.2 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                  9.25 usec
PL1                 0.55 dB
PL1W         35.18820572 W
SFO1        100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                 1H
PCPD2              90.00 usec
PL2                 4.90 dB
PL12               20.46 dB
PL13               21.00 dB
PL2W          3.30822015 W
PL12W         0.09195905 W
PL13W         0.08120718 W
SFO2        400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF          100.6127585 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```

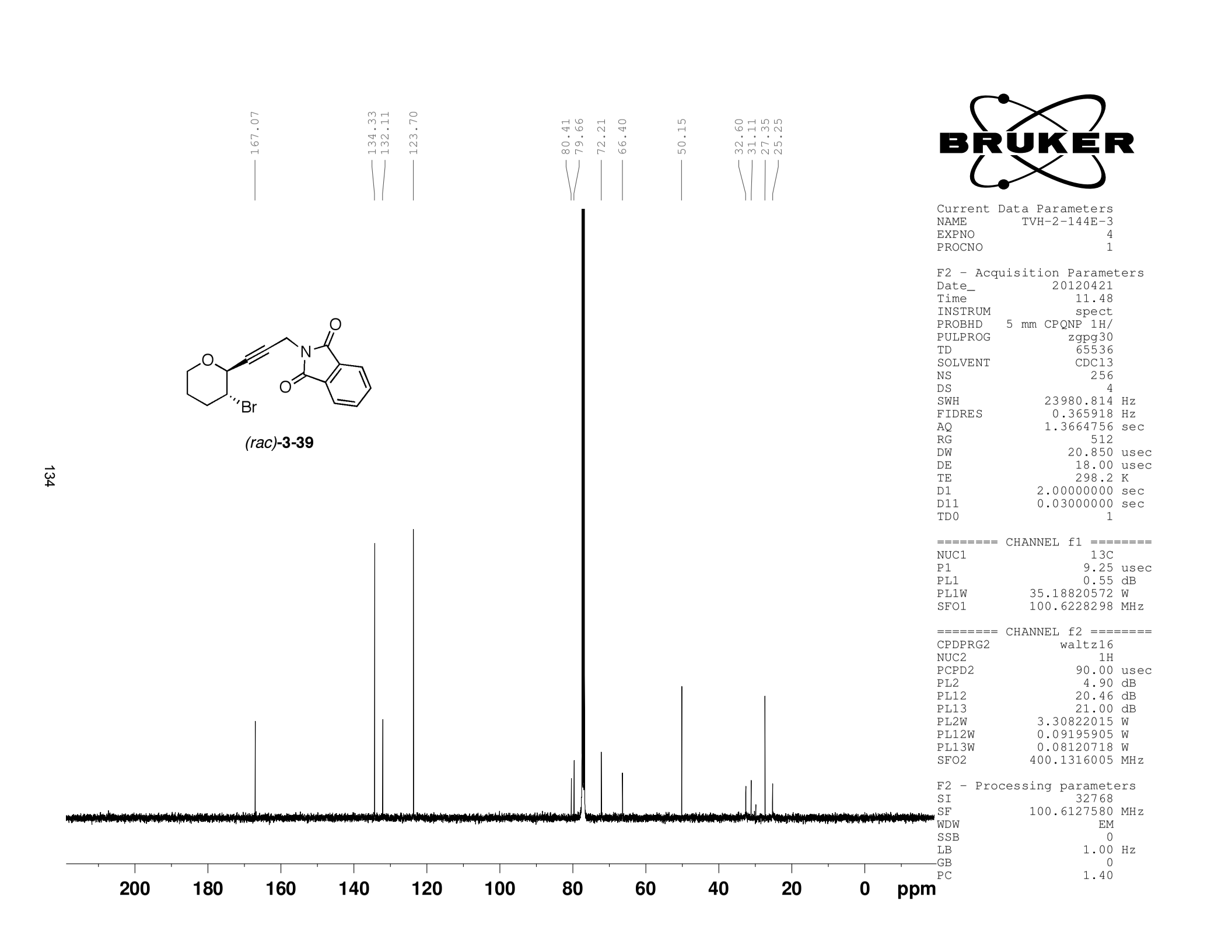




(rac)-**3-39**




```
Current Data Parameters
NAME        TVH-2-144E-3
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120322
Time               13.19
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9584243 sec
RG                  10.1
DW                60.400 usec
DE                 6.00 usec
TE                298.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                15.00 usec
PL1                4.90 dB
PL1W         3.30822015 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300113 MHz
WDW                   EM
SSB                    0
LB                0.30 Hz
GB                     0
PC                 1.00
```



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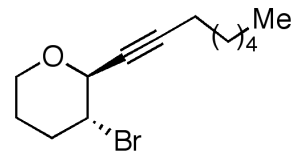
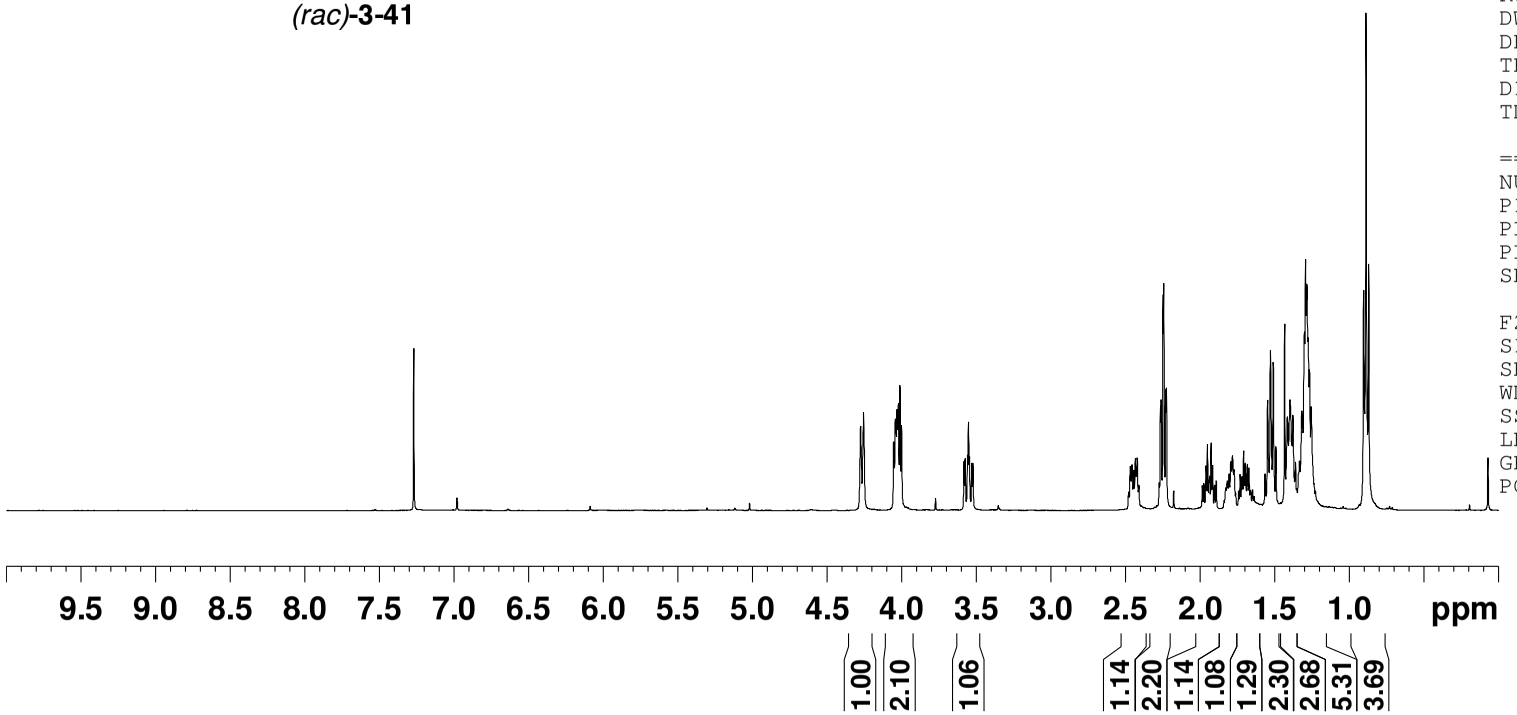
```
Current Data Parameters
NAME        TVH-2-144E-3
EXPNO                  4
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120421
Time               11.48
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ             1.3664756 sec
RG                  512
DW                20.850 usec
DE                18.00 usec
TE                298.2 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                 13C
P1                  9.25 usec
PL1                 0.55 dB
PL1W        35.18820572 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                 1H
PCPD2              90.00 usec
PL2                 4.90 dB
PL12               20.46 dB
PL13               21.00 dB
PL2W         3.30822015 W
PL12W        0.09195905 W
PL13W        0.08120718 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF         100.6127580 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```

TVH-2-144C-2
PROTON_16 CDCl3 /opt/topspin tatsiana 53

7.272 4.276 4.257 4.054 4.043 4.032 4.022 4.012 4.002 3.560 3.553 3.547 2.434 2.423 2.266 2.261 2.248 2.244 2.231 2.226 1.950 1.926 1.783 1.708 1.547 1.529 1.510 1.492 1.433 1.416 1.398 1.386 1.378 1.318 1.301 1.293 1.284 1.276 1.267 1.255 0.904 0.887 0.870 0.070



(rac)-**3-41**

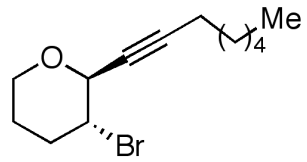


Current Data Parameters
NAME TVH-2-144C-2
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120321
Time 4.45
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

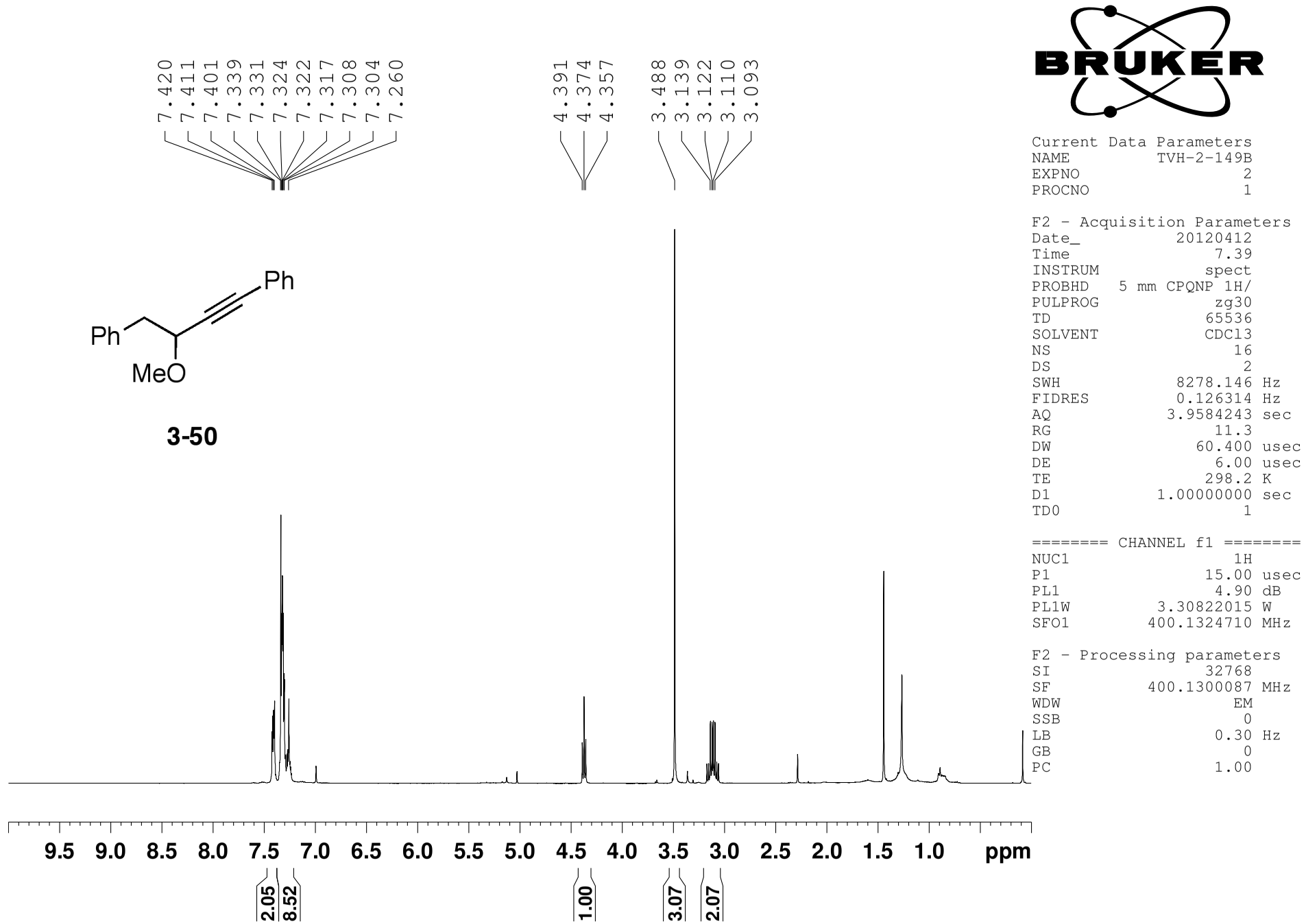
======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300051 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



(rac)-**3-41**


```
Current Data Parameters
NAME        TVH-2-144C-2
EXPNO                  2
PROCNO                 1

F2 - Acquisition Parameters
Date_           20120321
Time                5.01
INSTRUM            spect
PROBHD   5 mm CPQNP 1H/
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ             1.3664756 sec
RG                  512
DW                20.850 usec
DE                18.00 usec
TE                298.1 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                13C
P1                 9.25 usec
PL1                0.55 dB
PL1W        35.18820572 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG2         waltz16
NUC2                1H
PCPD2              90.00 usec
PL2                4.90 dB
PL12               20.46 dB
PL13               21.00 dB
PL2W         3.30822015 W
PL12W        0.09195905 W
PL13W        0.08120718 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF         100.6127585 MHz
WDW                   EM
SSB                   0
LB                 1.00 Hz
GB                    0
PC                 1.40
```

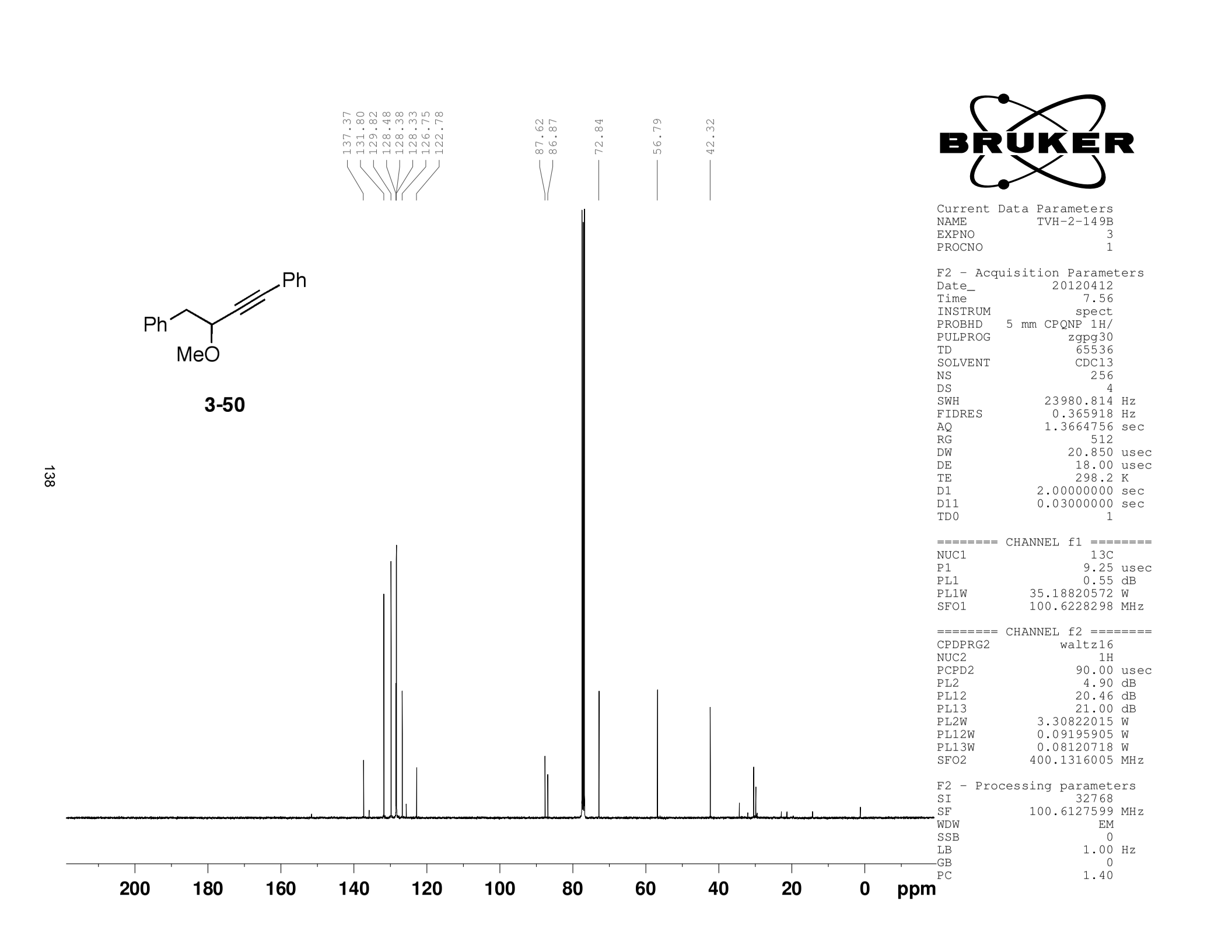


Current Data Parameters
NAME TVH-2-149B
EXPNO 2
PROCNO 1

F2 - Acquisition Parameters
Date_ 20120412
Time 7.39
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8278.146 Hz
FIDRES 0.126314 Hz
AQ 3.9584243 sec
RG 11.3
DW 60.400 usec
DE 6.00 usec
TE 298.2 K
D1 1.00000000 sec
TD0 1

======== CHANNEL f1 ========
NUC1 1H
P1 15.00 usec
PL1 4.90 dB
PL1W 3.30822015 W
SFO1 400.1324710 MHz

F2 - Processing parameters
SI 32768
SF 400.1300087 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00


137.37
131.80
129.82
128.48
128.38
128.33
126.75
122.78
87.62
86.87
72.84
56.79
42.32
Ph
Ph
MeO
3-50
138
200
180
160
140
120
100
80
60
40
20
0
ppm
BRUKER
Current Data Parameters
NAME TVH-2-149B
EXPNO 3
PROCNO 1
F2 - Acquisition Parameters
Date_ 20120412
Time 7.56
INSTRUM spect
PROBHD 5 mm CPQNP 1H/
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 256
DS 4
SWH 23980.814 Hz
FIDRES 0.365918 Hz
AQ 1.3664756 sec
RG 512
DW 20.850 usec
DE 18.00 usec
TE 298.2 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 9.25 usec
PL1 0.55 dB
PL1W 35.18820572 W
SFO1 100.6228298 MHz
======== CHANNEL f2 ========
CPDPRG2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 4.90 dB
PL12 20.46 dB
PL13 21.00 dB
PL2W 3.30822015 W
PL12W 0.09195905 W
PL13W 0.08120718 W
SFO2 400.1316005 MHz
F2 - Processing parameters
SI 32768
SF 100.6127599 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40