Discovery of Novel Methods for the Synthesis of Carbon Branched Sugars from Glycals

A thesis submitted for the degree of

DOCTOR OF PHILOSOPHY

By

Umamaheswara Rao. Boddu

To

School of Chemistry
University of Hyderabad
Hyderabad-500 046
India

December 2020

To My
Mother, Father & Friends

Declaration

I hereby declare that this Thesis entitled "Discovery of Novel Methods for the Synthesis of Carbon Branched Sugars from Glycals"submitted by me under the guidance and supervision of Prof. P. Ramu Sridhar is a bonafide research work which is free of plagiarism. I also declare that it has not been submitted previously in part or in full to this University or any other University or Institution for the award of any degree or diploma. I hereby agree that my thesis can be deposited in Shodganga/INFLIBNET.

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Umamaheswara Rao. B
14CHPH16

Prof. P. Ramu Sridhar
Professor
Office: 91-40-66794823
Fax: +91-40-23012460
E-mail:prssc@uohyd.ernet.in

School of Chemistry
University of Hyderabad
Prof. C. R. Rao Road
Gachibowli
Hyderabad-500046 India

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School of Chemistry
University of Hyderabad

Dean
SCHOOL OF CHEMISTRY
University of Hyderabad
Hyderabad-500 046

P. Ramu Sridhar
Prof. Perali Ramu Sridhar
(Research supervisor)

Dr. P. Ramu Sridhar
Professor
School of Chemistry
University of Hyderabad
Hyderabad-500 046, India.

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2. Kutcherlapati, S. N. R.; Koyilapu, R.; **Rao, B. U.**; Data, D.; Perali, R. S.; Swamy, M. J.; Jana, T., Glycopolymer-Grafted Nanoparticles: Synthesis Using RAFT Polymerization and Binding Study with Lectin. *Macromolecules*, **2017**, *50*, 7309-7320.
3. Sridhar, P. R.; **Rao, B. U.**; Reddy, G. M., Synthesis of Carbon-Branched Sugars Involving an Unprecedented 1,5- or 1,6-Alkyl Transposition Reaction. *Eur. J. Org. Chem.* **2019**, 4752–4756.
4. Sridhar, P. R.; **Rao, B. U.**, A concise and efficient approach to the stereoselective total synthesis of (+)-secosyrin 1 and (+)-syributin 1. *J. Indian Chem. Soc.* **2020,** *97*, 237-242.
5. **Rao, B. U.**; Drisya, C. S.; Sridhar, P. R., Stereoselective synthesis of 3-*C*-branched glycals involving [1,2] and [2,3] Wittig rearrangement. *(Manuscript Submitted)*.
6. **Rao, B. U.**; Sridhar, P. R., Synthesis of cis- and trans-fused bicyclic Iridoid frame works from Glucal. *(Manuscript under preparation)*.

Posters and Oral Presentations

1. Presented a poster of research work titled as "***An Unprecedented 1,6 or 1,5 Alkyl Transposition of 3-deoxy glycals : Synthesis of Carbon Branched deoxylevoglucosans***" in 8th International Collaborative & Cooperative Chemistry Symposium held at University of Hyderabad, Hyderabad in Dec-2017.

2. Presented a poster of research work titled as "***An Unprecedented 1,6 or 1,5 Alkyl Transposition of 3-deoxy glycals : Synthesis of Carbon Branched deoxylevoglucosans***" in CARBO-XXXIII International Carbohydrate Symposium held at Indian Institute of Science Education and Research, Kolkata in Dec-2018.

3. Orally presented the research work titled as "***Novel Synthetic Transformations of 3-deoxy glycals***" in Chemfest-2019 held at University of Hyderabad, Hyderabad in Feb-2019.

4. Orally presented the research work titled as "***Synthesis of Carbon-Branched Sugars Involving an Unprecedented 1,5 or 1,6 Alkyl Transposition Reaction***" in 15th Junior-National Organic Symposium Trust held at University of Delhi, Delhi in Oct-2019.

Course work

	Course. No	Title	Credits	Pass/Fail
1	CY-502	Advanced Organic Synthesis	3	Pass
2	CY-801	Research Proposal	3	Pass
3	CY-805	Instrumental Methods A	3	Pass
4	CY-806	Instrumental Methods B	3	Pass

Abstract

Chapter-1

Introduction to Unusual Sugars: Simple Glycals, Carbon branched Glycals and Deoxy Glycals

This chapter mainly deals as the introduction to the thesis. It is mainly divided into two parts. In the first part of the chapter, a detailed description of the importance of unusual sugars in synthetic carbohydrate chemistry is presented. Appropriately, collective literature reports for the synthesis of simple glycals, 1-*C*-branched glycals, 2-*C*-branched glycals, 3-*C*-branched glycals, 4-*C*-branched glycals and deoxy glycals from the carbohydrate sources are presented in detail.

In the second part of the chapter, a detailed collection of literature reports available in the area of synthetic applications of simple glycals, 1-*C*-branched glycals, 2-*C*-branched glycals, 3-*C*-branched glycals, 4-*C*-branched glycals and deoxy glycals are covered. In the conclusion of the chapter, motivation for the research work carried out is encompassed.

Chapter-2

Synthesis of Carbon-Branched Sugars Involving an Unprecedented 1,5- or 1,6-Alkyl Transposition Reaction

This chapter mainly describes the discovery of a novel C-C bond formation method for the synthesis of 2-*C*- branched acetal derivatives by 1,5 or 1,6-alkyl migration by using *p*-methoxy benzyl (PMB) protected 3-deoxy glycals . The extension of the developed methodology in the synthesis of 2-*C*- branched acetal derivatives from the prenyl protected 3-deoxy glycals is also incorporated.

Chapter-3

Sythesis of Cis- and Trans-fused Bicyclic Iridoid Frame Works from Glucal

In this chapter, a concise approach to synthesize the *cis*- and *trans*-fused bicyclic frameworks of the monoterpenoid glycoiridoids is described. Starting from commerceally available 3,4,6-triacetyl-D-glucal, a highly stereoselective cyclopropanation reaction was used to construct bicycle. Later, a couple of transformations involving Wittig olefination and cyclopropane ring opening were established to commence the essential di-carboxylate moiety. The distinct 6-oxo-cyclopenta[*c*]pyran carboxylate motif was successfully forged *via* a late-stage Dieckmann reaction.

Chapter-4

Stereo selective synthesis of 3-*C*-branched glycals involving [2,3] Wittig rearrangement

This chapter describes exclusively the synthesis of 3-*C*-branched glycals with retention of configuration from the α-*O*-glycoside derivatives via [2,3]-Wittig rearrangement. Using the same methodology, the stereo selective synthesis of 3-*C*-branched glycals from the corresponding β-*O*-glycoside derivatives via [2,3]-Wittig rearrangement are also incorporated. Influence of the protecting groups in this novel methodology for the synthesis of C-3 glycals is included.

Contents

Glossary

α	alpha
Å	angstrom
Ac	acetyl
AcOH	acetic acid
β	beta
Bn	benzyl
br.	Broad
BTCEAD	bis(2,2,2-trichloroethyl) azodicarboxylate
calcd.	calculated
COSY	correlation spectroscopy
□	delta
d	doublet
DCM	dichloromethae
dd	doublet of doublet
DIAD	diisopropyl azodicarboxylate
DIPA	diisopropylamine
DMF	dimethylformamide
dt	doublet of triplet
DMP	Dess-Martin periodinane
DMSO	dimethyl sulfoxide
EtOAc	ethyl acetate
ESI	electrospray ionization
eq/equiv.	equivalent
g	gram(s)
h/hr	hour(s)
HRMS	high resolution mass spectrometry
Hz	hertz
Im	imidazole
IR	infrared
J	coupling constant in Hz (NMR)

m	multiplet
MHz	megahertz
mL	milliliter
mmol	millimolar
MeOH	methanol
ms	molecular sieves
n-BuLi	*n*-butyl lithium
NOESY	nuclear Overhauser effect spectroscopy
NMR	nuclear magnetic resonance
Ph	phenyl
PMBCl	p-methoxybenzyl chloride
PMBzCl	p-methoxybenzoyl chloride
ppm	parts per million
R_f	retardation factor
ref	reference
RT	room temperature
s	singlet
p-TsOH/PTSA	*p*-toluenesulfonic acid
t	triplet
TBAF	tetra-*n*-butylammonium fluoride
TBSCl	*tert*-butyldimethylsilyl chloride
THF	tetrahydrofuran
TLC	thin-layer chromatography
TMEDA	tetramethylethylenediamine
TMSOTf	trimethylsilyl trifluromethanesulfonate
Tol	tolyl/p-methyl phenyl
TrCl	trityl chloride
UV	ultraviolet

Chapter-1

Introduction to Unusual Sugars: Simple Glycals, Carbon Branched Glycals and Deoxy Glycals

1.1 Introduction

1.2 Diversity-Oriented Syntheses (DOS)

1.3 Unusual Sugars

1.4 Glycals

1.5 Syntheses of simple glycals, carbon branched glycals and deoxy glycals

1.6 Synthetic applications of simple glycals, carbon branched glycals and deoxy glycals

1.7 Motivation for the work presented in the thesis

1.8 References

"Once a molecule is asymmetric, its extension proceeds also in an asymmetrical sense. This concept completely eliminates the difference between natural and artificial synthesis.

The advance of science has removed the last chemical hiding place for the once so highly esteemed vis vitalis."

-Emil Fischer

1.1 Introduction

Carbohydrates often serve biosynthetic precursors and structural elements required to sustain all living organisms. They are found to be the most abundant ubiquitous organic molecules in nature, some are playing important roles as energy supply and storage vehicles. They exist in simpler forms such as monosaccharides and disaccharides, or in more complex glycosides of type glycolipids, glycoproteins, peptidoglycans, proteoglycans, nucleic acids, poly and lipopolysaccharides.[1] Many scientists in Organic chemistry considered that among the biomolecules (nucleic acids, carbohydrates, lipids, and proteins), the study of natural carbohydrates was very complex to handle due to availability of more chiral centers with a high abundance of hydrophilic functionalities, so it had been on track lately. In the recent past, this failure had been rectified exponentially by savvy their veiled precedence in chemical synthesis, with the mounting admiration for the function of carbohydrate compounds in disease, biological processes, human health, and their applications in the progress of medicinal targets.

Emil Fisher[2] (Figure 1.1) (1852-1990), the father of Carbohydrate chemistry and he was one of the pioneering scientists from the area of organic chemistry in his time. In the carbohydrate chemistry, the first milestone was laid by this eminent scientist in the decade of the 1880s. Emil fisher had elucidated the stereochemistry of all simple carbohydrates with the less analytical facility of his research period, which had imparted the irrefutable proof for the Le Bel-Van't Hoff theory of stereoisomerism,[3] of which He was the chemist received the 1902 Noble Prize as the first in organic chemistry and second ever awarded. The impact of this study had on the further development of not only carbohydrate chemistry but also organic chemistry has been treated extensively.

Figure 1.1
Emil Fischer

Synthetic Carbohydrate chemistry is one of the fast-developing and most significant field in the area of organic-chemistry due to ample structural miscellany of carbohydrates and polygonal applications of them in glycobiology, microbiology, medicinal chemistry and biochemistry.[1] Many scientists have been attracted by the embellishment of this area due to availability of the sugars with low price by their high abundance in nature, and their accessibility in enantiomeric pure forms with direct stereocenters.[4] Also, sugars have been utilized as the starting materials for the synthesis of biologically active natural and synthetic molecules with the perception of expending them in the study of possible biological phenomena undergoing in the living organisms.

1.2 Diversity-Oriented Syntheses (DOS)

Historically, Diversity-oriented synthesis (DOS) (Figure 1.2) has focused on the generation of small-molecule gathering with the significant scaffold, stereochemical and appendage diversity rather than being directed to a single biological target.[5] Recently, it has shifted to the production of small-molecule libraries with diverse biological activities. Recent years have witnessed significant achievements in the field, which help to validate the usefulness of DOS as a tool for the

discovery of novel, biologically interesting small molecules. It is currently not clear which properties and structural features of molecules are predictive of diverse performance in biological assays, and a better understanding of this relationship is critical for the development of performance-diverse small-molecule libraries for the discovery of novel probes for challenging targets. Here, diversity refers to the change in the attached groups, functional groups, stereochemistry, and molecular frameworks. Certainly, nature has been using the diversity-oriented approach from the existence of life and carbohydrates are one of nature's best raw materials for the neat presentation of DOS. The number of organic molecules that one can synthesize is around 10^{62}-10^{200} but, nearly 10^{51} molecules are only present on earth. So, synthesizing every possible molecule is not imaginable and one cannot even come closer to it. So, one should be selective as there are many solutions available for a single biological problem (for example, reverse transcriptase inhibitors: zidovudine, abacavir, emtricitabine, lamivudine, tenofovir, etc…). For diversity-oriented synthesis to be a success, however, identification of substrates that can be derivatised and transformed into various novel scaffolds is essential. Owing to the presence of the ring oxygen among others and the different conformations they can adopt, glycals have shown great potential as suitable substrates in DOS and in a Chiron approach to the synthesis of natural products and their analogues.

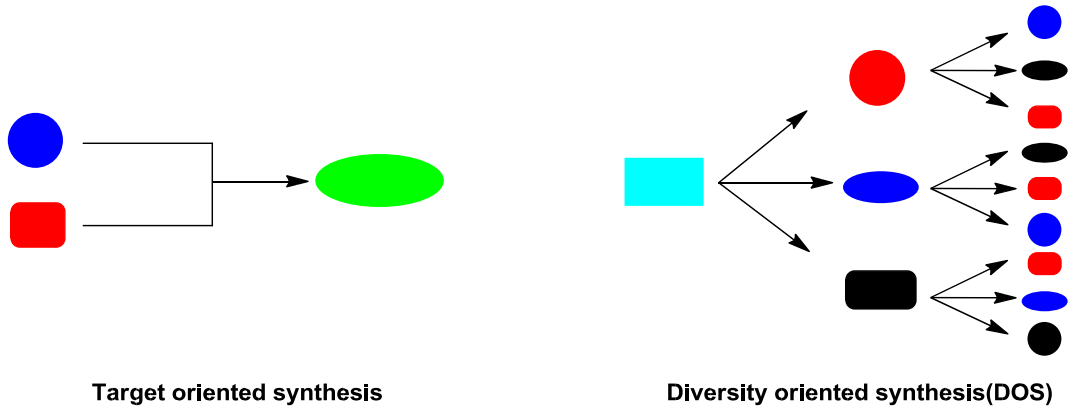


Figure 1.2 Target oriented syntheses and diversity oriented syntheses.

1.3 Unusual sugars

Normal sugars whose are certain hydroxyl groups substituted by other atom or group called unusual sugars. These are mainly classified into three modifications (Figure 1.3),

1. Deoxygenation
2. Amino group substitution
3. Branch chain modification

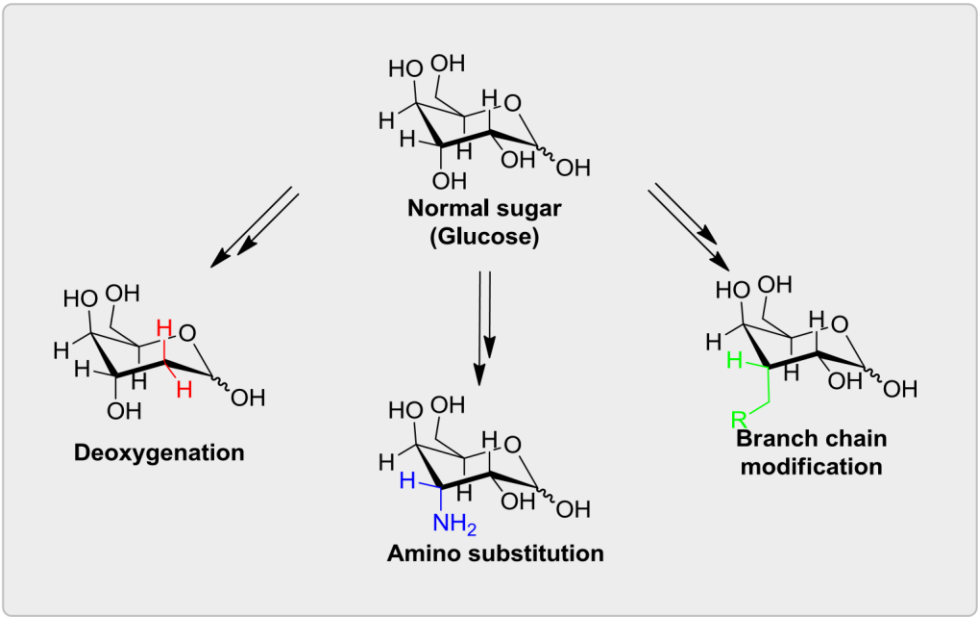


Figure 1.3 General modifications of normal sugars to unusual sugars.

Deoxysugars, aminosugars, and carbon branched sugars are very frequently seen in the secondary metabolites, which generated by microorganisms and plants, such as antibiotics, cardio glycosides, and anticancer agents, in cell signaling pathways, immune responses, like targets for antibodies, toxins, and defines mechanisms.[6] These sugar residues play key roles in conferring to the optimal biological activity of many natural products. Their removal might result in the total loss of biological activity of the parent molecule. It is very difficult to estimate the activity relevance's of the unusual sugars as nature produces them in a complex manner[7] and sometimes replacing the natural-sugars with unusual-sugars expose the biological contribution of

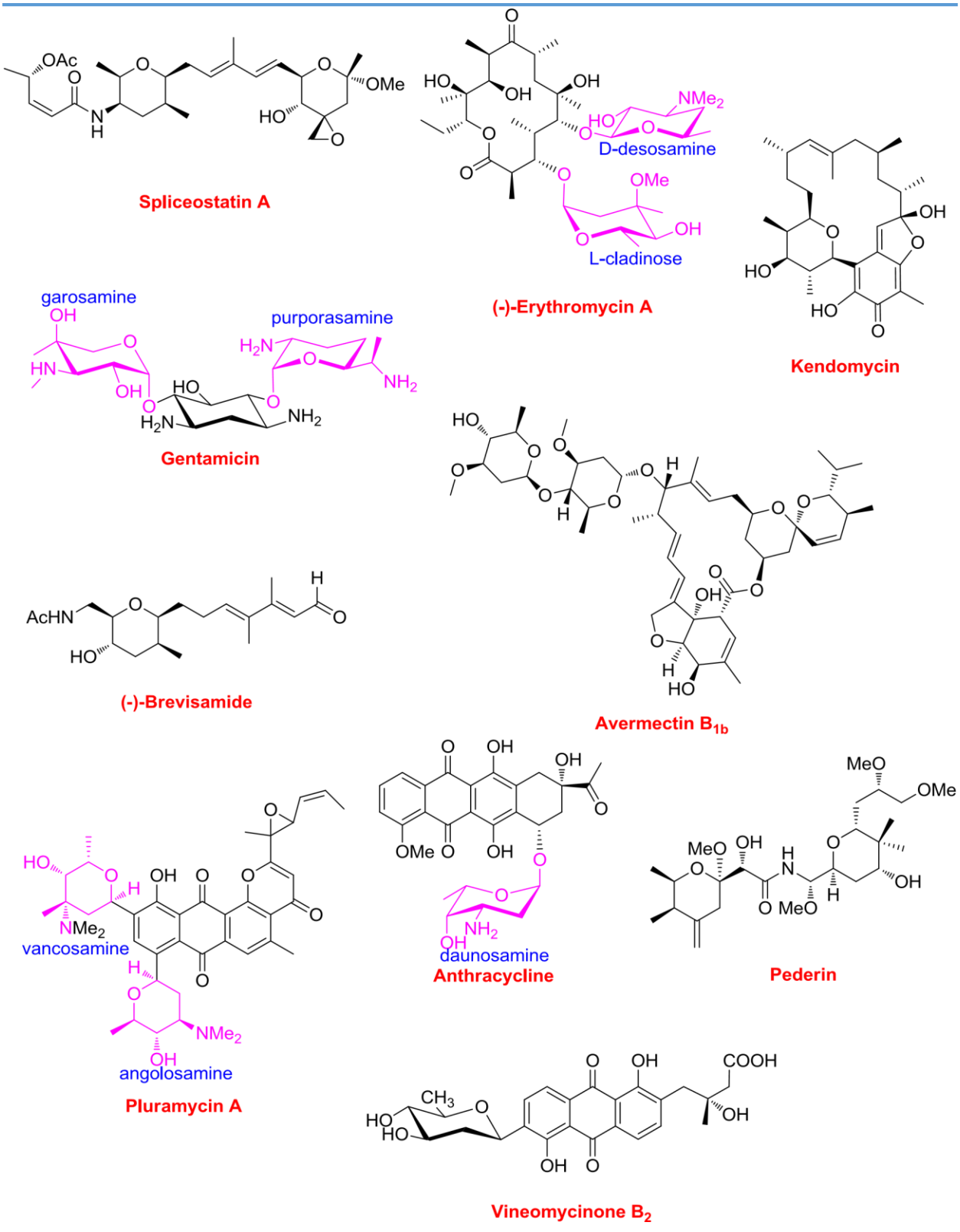


Figure 1.4 Biologically active natural compounds possessing unusual sugars.

before the parent molecule. Few natural substances provided by the living organisms which are majorly utilized in defense their mechanism, cell-cell interactions, as antibiotics, toxins, and antibodies are displayed in Figure 1.4. In all these compounds, an unusual sugar molecule/s is attached to the parent molecule which differs from the natural sugar molecule by at least one of the above-mentioned modifications. Synthesis of biologically active unusual-sugar skeletons and natural products by employing natural sugars is challenging and is the recent trend in synthetic sugar chemistry. Since the major part of the thesis is generalized on the syntheses and synthetic use of unusual sugars namely 3-*C*-branched glycals and 3deoxy glycals, a brief summary of simple glycals, carbon branched glycals and deoxy sugar glycals would be more appropriate and so, such emphasis is done in the remaining part of the introduction.

1.4 Glycals

1, 2-Unsaturated cyclic sugar derivatives are called as glycals (Figure 1.5). Glycal is a name created by mistake (as the molecule does not having an aldehyde functionality) to carbohydrate substrates, which possess a double bond between C1 and C2 positions of the furan or pyran moieties of the carbohydrate compound. While glycal is a general name, while specific derivatives originate from glucose are called as glucals, while those derived from galactose are called as galactals commonly. Many advantages of the unsaturated sugars like glycals have been explored due to ample increase in the varied synthesis and applications such as epoxidation, halogenation and also cyclopropanation reactions like simple olefins in organic synthesis. Moreover, Glycals are transformed into stereoselective and regioselective molecular scaffolds, which is due to the oxygen present in-ring as well as size and electronic of the substituents in glycals. Glycals were played an important role for the synthesis of different kinds of sugar derivatives like *O*-glycosides, *S*-glycosides, *N*-glycosides, *C*-glycosides, and biologically relevant natural products[8] by employing as starting material.

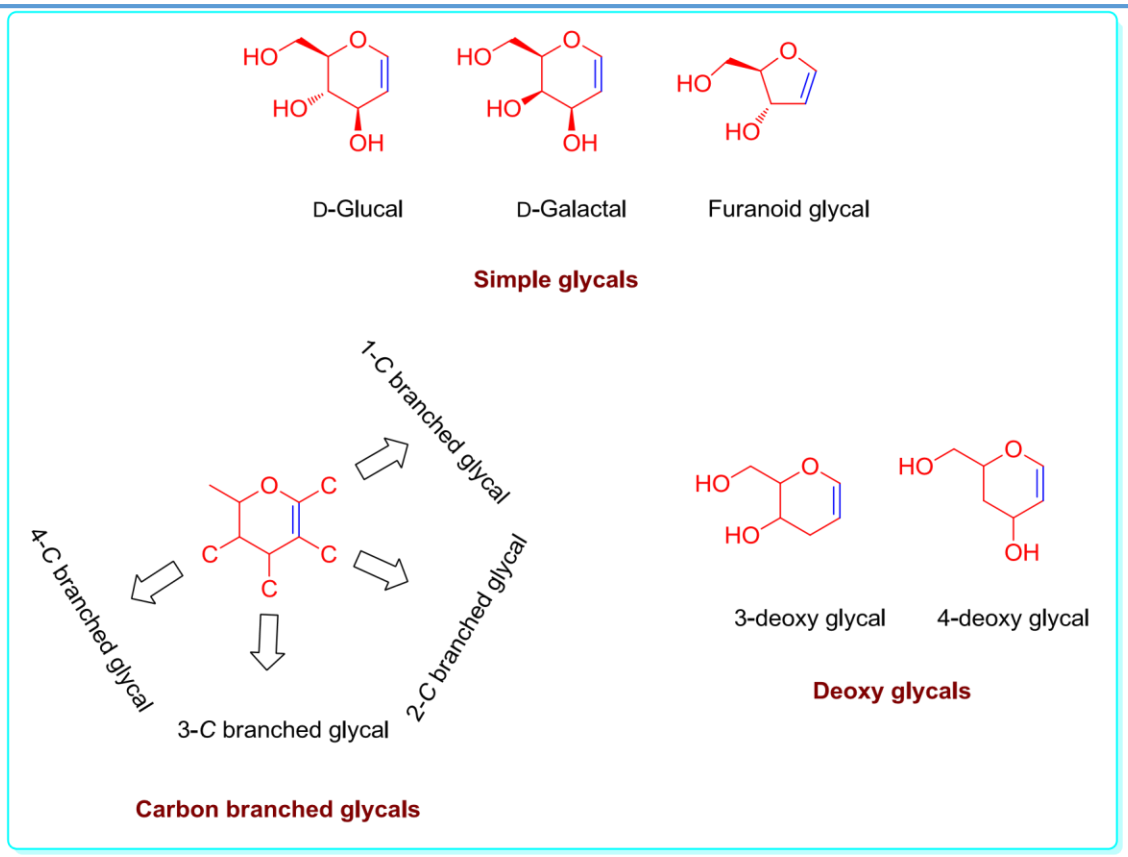
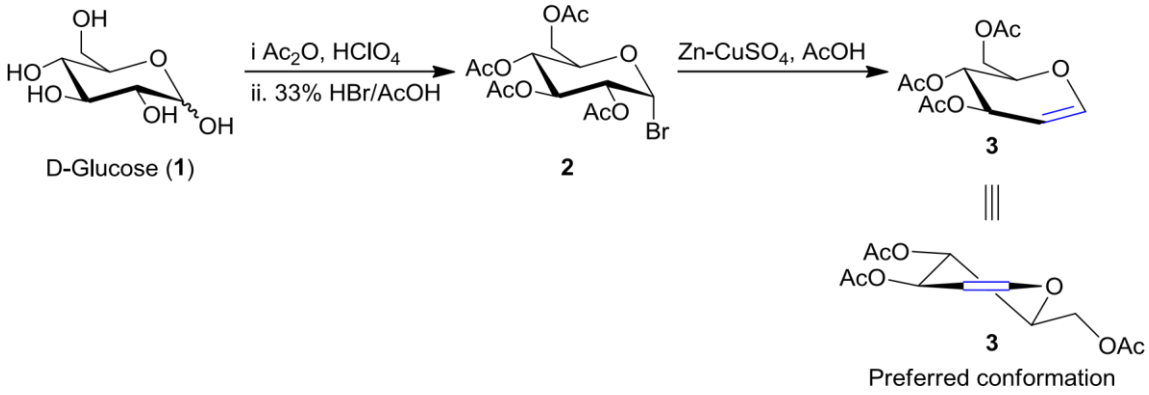


Figure 1.5 Examples of glycals.

4 5 Syntheses of simple glycals, carbon branched glycals and deoxy glycals

1.5.1 Syntheses of simple glycals

The first efficient synthesis of 3,4,6-tri-*O*-acetyl D-glucal **3** (trivial name glucal was anomalous due to the incorrect observation of aldehydic properties by Fehling's test) has been reported by Emil Fischer and Zach[9] from D-glucose **1** via 2,3,4,6-tetra-*O*-acetyl glucopyranosyl bromide **2** (Scheme 1.1). It has been using as traditional method for the synthesis of glycals on bulk scale since 1913. This synthetic methodology is failed for the synthesis of furanoid glycals by performing under similar reaction conditions and a laborious workup to neutralize the acidic nature of the reaction. It is the major drawback of this methodology.



Scheme 1.1 Fischer-Zach method for the synthesis of glucal.

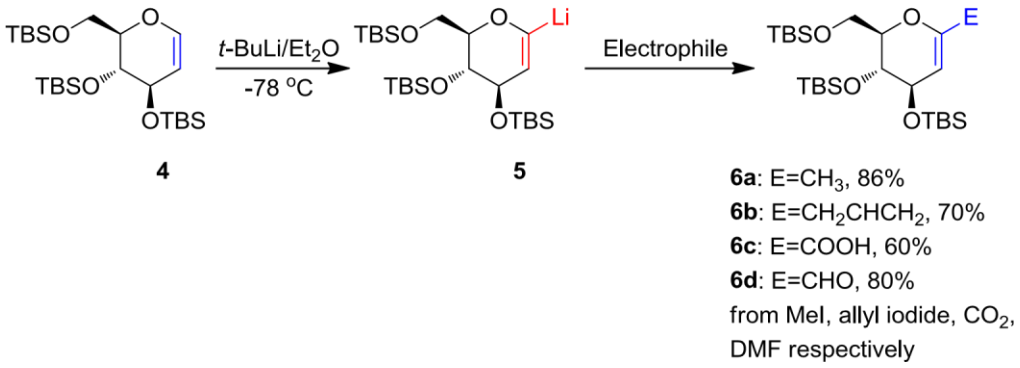
Over a century of time, several other methods have been developed by various research groups for the syntheses of glycals from all over the world. few of the most important methods include reductive elimination of phenyl thioglycosides,[10] Danishefsky's hetero Diels-Alder approach,[11] from glycosyl sulfoxides,[12] glycosyl sulfones,[13] by electrochemical approach,[14] ring closing metathesis,[15] via tungsten and molybdenum-promoted alkynol *endo*-cycloisomerization,[16] and transformation of glycosyl halides using reducing agents like sodium and potassium metal,[17] sodium naphthalide,[17] zinc/silver graphite,[18] aluminum amalgam,[19] samarium iodide,[20] potassium graphite,[21] lithium/ammonia,[22] chromium(II),[23] cobalt(II)[24] and titanium(III).[25]

1.5.2 Syntheses of carbon branched glycals

1.5.2.1 Syntheses of 1-*C*-Branched glycals

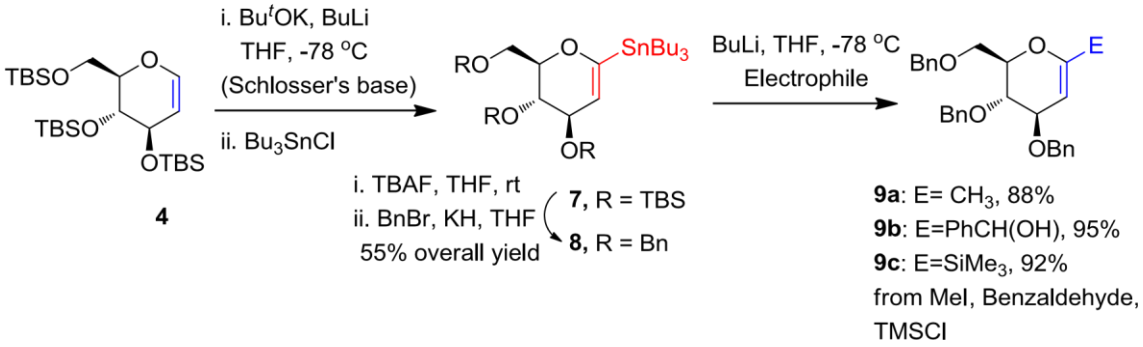
K. C. Nicolaou[26] and J-M. Beau[27] had reported the first synthesis of *C*-1 carbon branched glycals from *C*-1 lithiated glycal species, which was formed by direct proton abstraction at anomeric position of glycals. Initially, *C*-1 lithiated glucal **5** was generated by treatment of TBS protected glucal **4** with *tert*-butyl lithium, followed by treatment with different electrophiles like

CH_3I, allyl iodide, CO_2 and DMF to produce the corresponding *C*-1 carbon branched glycals such as **6** (Scheme 1.2).



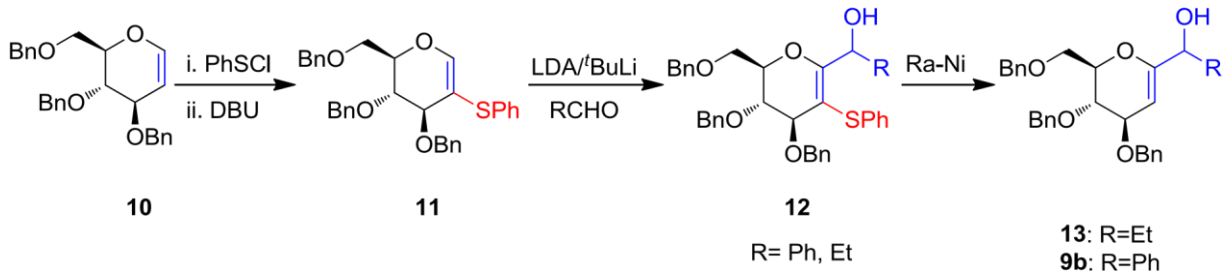
Scheme 1.2 Beau's syntheses of 1-*C*-branched glycals by lithiation.

Later, S. Hanessian[28] and coworkers had reported the synthesis of 1-*C*-branched glycals from fully protected glycals via *C*-1 tributylstannyl glycal. A tri TBS protected glucal **4** had treated with potassium *tert*-butoxide and BuLi, followed by reaction with tributyltin chloride to obtain *C*-1 tributylstannyl glucal **7**, then converted to benzyl protected *C*-1 tributylstannyl glucal **8**, which was transmetalated with butyllithium followed by treatment with various electrophiles to achieve 1-*C*-branched glucal of type **9** (Scheme 1.3). This synthetic methodology was applied to furanoid glycals[29] also and attempted with various electrophiles like alkyl halides,[26] aldehydes,[28] ketones[30] and quinones.[31]



Scheme 1.3 Hanessian's synthesis of 1-*C*-branched glycals by transmetalation.

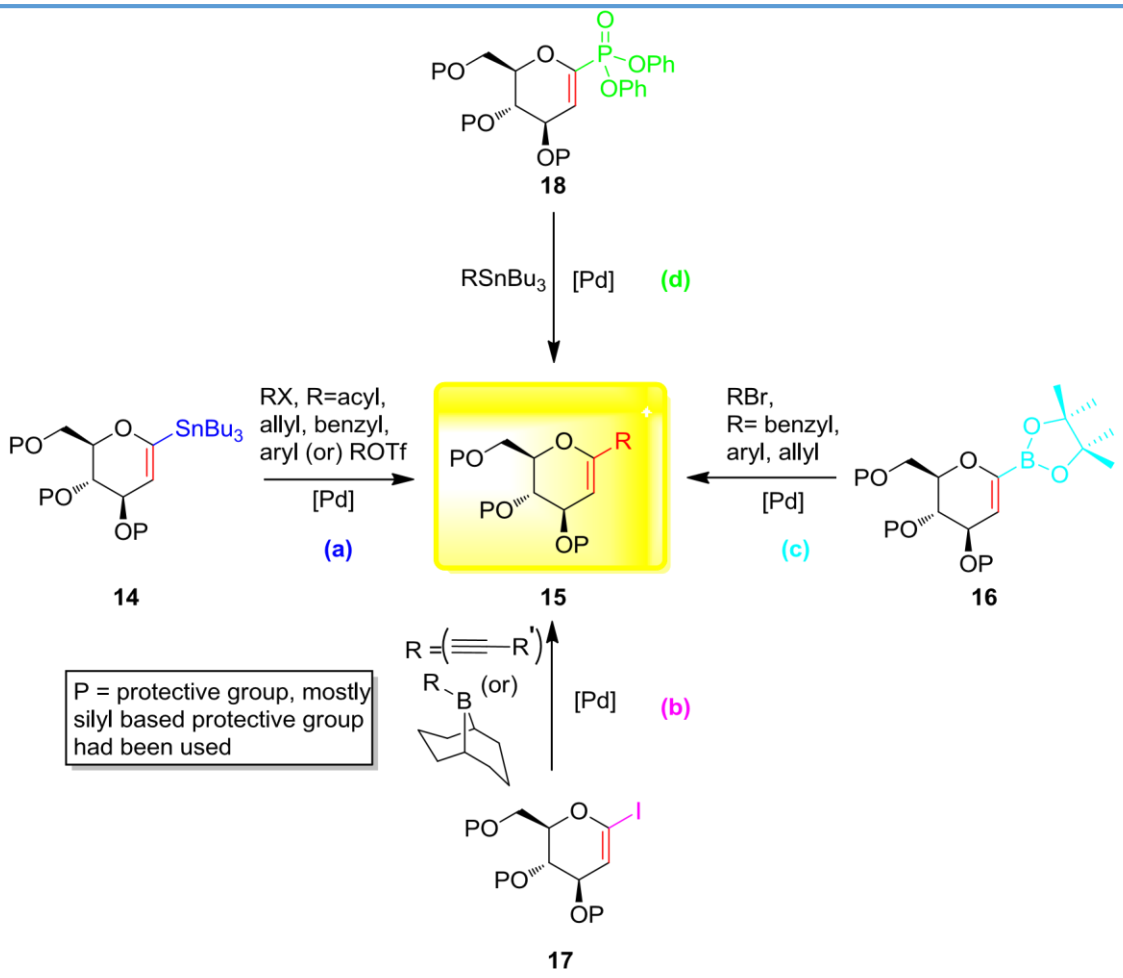
The synthesis of lithiated alkenyl intermediates is straightforward and challenging[32], the good results were not observed with 3,4,6-tri-*O*-benzyl- D-glucal **10**. To overcome these problems, Schmidt and coworkers had used the phenylsulfinyl group at the *C*-2 position by treating with phenylsulfinyl chloride and DBU, the resulted 2-phenylsulfinyl-D-glucal **11**[33] was treated with butyl lithium to achieve lithiated species[33h] by inductive effects of sulfinyl group and followed by reaction with various aldehydic electrophiles to obtain α-hydroxy glucals of type **12**. Finally, phenylsulfinyl group was removed by using raney-nickel to produce α-hydroxy-1-*C*-branched glucals such as **13** and **9b** (Scheme 1.4).



Scheme 1.4 Schmidt's syntheses of 1-*C*-branched glucals from 2-phenylsulfinyl-D-glucal.

Due to the massive improvements in the C-H activation through Pd mediated coupling reactions, 1-*C*-branched glycals were synthesised by using the methodologies with palladium were noteworthy.

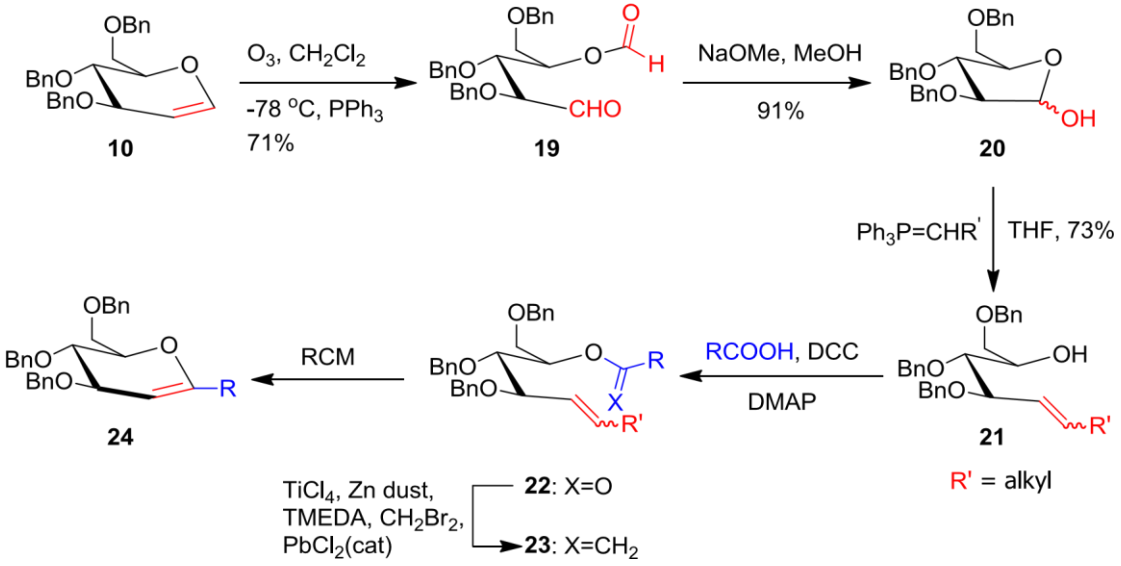
T Ishiyama and N Miyaura[34] had reported that Ir catalyzed vinylic C-H borylation by using Bis(pinacolato)diboron to produce the *C*-1-borylated glycals of type **16,** then which was transformed to *C*-glycosides such as **15** (Scheme 1.5c) by Pd mediated coupling reaction with allyl, benzyl and aryl halides. 1-*C*-pyranoid glycals of type **15** (Scheme 1.5a) were synthesized from *C*-1-stannyl glycals[35] such as **14** under Pd catalyzed coupling reaction (Stille cross-coupling reaction) with alkyl, allyl, benzyl, aryl, acyl halides and *O*-triflates. *C*-1-stannyl furanoid glycals were also utilized for the synthesis of 1-*C*-furanoid glycals[36] in good yield with $Pd(OAc)_2$. *C*-1-iodo glycals such as **17** are the next most exerted starting materials for the syntheses of 1-*C*-branched glycals. D. S. Tan[37] and coworkers had carried out the hydroboration of olefines by using 9-BBN, then



Scheme 1.5 palladium catalysed syntheses of 1-*C*-branched glucals.

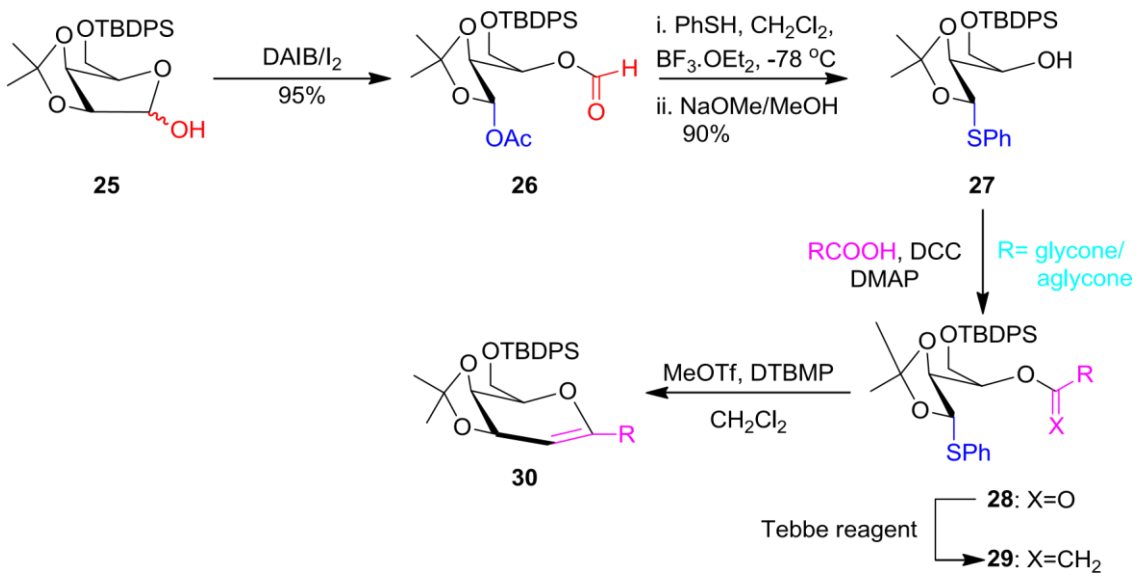
treated them with iodo glycals under Suzuki-miyaura coupling reaction conditions (Scheme 1.5b). Martin and coworkers[38] had also employed the *C*-1-iodo glycals such as **17** to ring open the dimethoxy oxabenzonorbornadiene to produce the corresponding dihydro-naphthol derivatives such as **15**. Later, Werz[39] and co-workers have employed Sonogashira-Hagihara coupling reaction conditions to *C*-1-iodo glycals and alkynes to provide the *C*-1- carbon branched glycal derivatives of type **15** (Scheme 1.5b). K. C. Nicolaou[40] and coworkers had performed Electrophilic coupling reagents such as glycal phosphates of type **18** in Stille cross coupling to produce the *C*-1 glycals such as 15 (Scheme 1.5d).

Also ring closing metathesis has been applied for the synthesis of *C*-1 carbon branched glucals by Postema[41]. In this approach, initially, 3,4,6-tri-*O*-benzyl-D-glucal **10** was converted to anomeric mixture of lactol **20** through ozonolysis performed with ozone, followed by de-esterification with sodium methoxide. Lactol **20** was transformed to hydroxy olefin **21** by Wittig olefination reaction, then the hydroxyl group was coupled with different kind of carboxylic acids like aliphatic,[41-42] sugar based mono[15a, 15b, 43], di[44] and tri[45] acids under DCC mediated reaction to obtain the esters such as **22**, which was treated with Takai reagent to provide the acyclic enol ethers of type **23**. Schrock catalyst (some methods also involved the use of Grubb's 2nd generation catalyst) was employed to the acyclic enol ethers **23** to obtain 1-*C* branched glucals which, include mono, di, tri and tetra saccharide derivatives of type **24** in moderated to good yield (Scheme 1.6).



Scheme 1.6 Postema RCM approach of the syntheses of 1-*C*-branched glucals.

Mootoo[46] and coworkers had employed the lactol **25** firstly into (diacetoxyiodo)benzene (DIAB)/I_2 (Suarez procedure) to obtain the acetate **26**, which on reaction with thiophenol/boron trifluoride etherate at low temperature, followed by basic hydrolysis produced the 1-thio-1,2-*O*-isopropylidine derivative **27**. The resulted hydroxyl group was esterified with various carboxylic acids (use of both glycone and aglycone carboxylic acids were reported) using DCC/DMAP. The acetate and enol ether system in a single molecule. Finally, the oxocarbenium ion was successfully

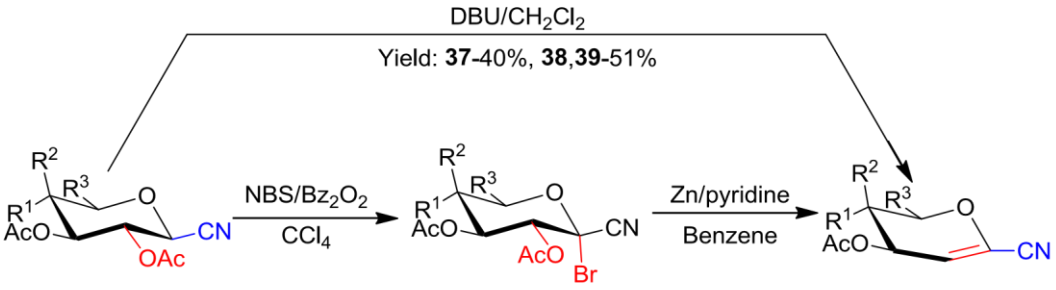


Scheme 1.7 Mootoo's approach for the synthesis of 1-*C*-branched glycals.

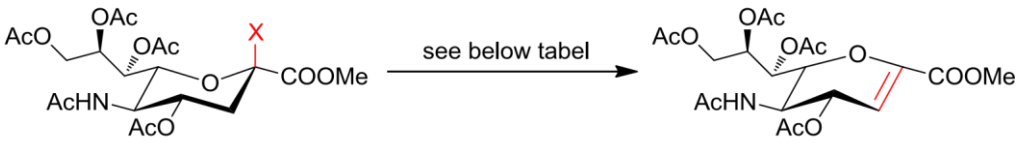
generated and performed the intramolecular oxocarbenium ion-alkene cyclization using MeOTf/2,6-di-*tert*-butyl-4-methylpyride (DTBMP) to obtain the required 1-*C*-branched glycals such as **30** (Scheme 1.7).

Somsak had reported the first Syntheses of 1-cyanoglycals by performing the reaction with 1-bromo-D-glycosylcyanides and zinc (Scheme 1.8).[47] 1-bromo-D-glycosylcyanides **34-36** were prepared from the corresponding acetylated sugar substrates **31-33** by employing *N*-bromosuccinimide (NBS) and benzoyl peroxide in nonpolar aprotic solvents like carbon tetrachloride, dichloromethane and benzene. The resulted 1-Bromo sugars were treated with zinc/pyridine to obtain the 1-cyanoglycals **37-39**. The observed overall yield was 60% in two steps. Later, they had attempted with DBU for the synthesis of 1-cyanoglycals from acetylated sugar derivatives **31-33** by direct elimination of the acetic acid (Scheme 1.8).[48] But this attempt was unsatisfied in terms of yield, they had reasoned that the poor yield was resulted due to applying the basic reaction conditions for direct elimination of the *O*-acetyl group. In other few reports, elimination strategies were applied for the synthesis of 1-*C*-branched glycal derivatives such as 2-deoxy-2, 3-dihydro-*N*-acetylneuraminic acid methyl ester **43.** Various reaction conditions like

DBU/PhH,[49] Flash vacuum pyrolysis,[50] PPh_3HBr/CH_3CN[51] and dimethyl(methylthio)sulfonium triflate (DMTST)/DBU[52] were utilized for the synthesis of 1-*C*-branched glycals such as **43** based on the leaving group present at the 2nd position of *N*-acetylneuraminic acid methyl ester derivatives **40**-**42** in good yield.



31: R^1=H, R^2=OAc, R^3=CH_2OAc
32: R^1=OAc, R^2=H, R^3=H
33: R^1=H, R^2=OAc, R^3=H
34: R^1=H, R^2=OAc, R^3=CH_2OAc, 80%
35: R^1=OAc, R^2=H, R^3=H, 70%
36: R^1=H, R^2=OAc, R^3=H, 72%
37: R^1=H, R^2=OAc, R^3=CH_2OAc, 75%
38: R^1=OAc, R^2=H, R^3=H, 51%
39: R^1=H, R^2=OAc, R^3=H, 78%



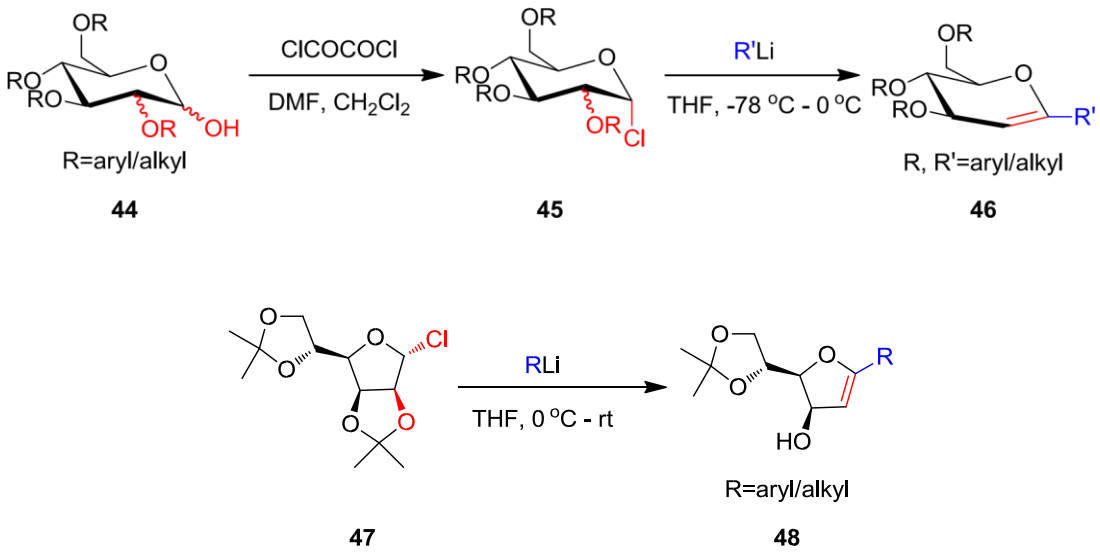
40: X= Cl
41: X=OAc
42: X=SPh

43

X	Reaction conditions	Yield
Cl	DBU, Benzene, rt	81%
OAc	Flash vacuum pyrolysis, 390-420 °C	93%
OAc	PPh_3HBr, CH_3CN	96%
SPh	DMTST, DBU, -20 °C	95%

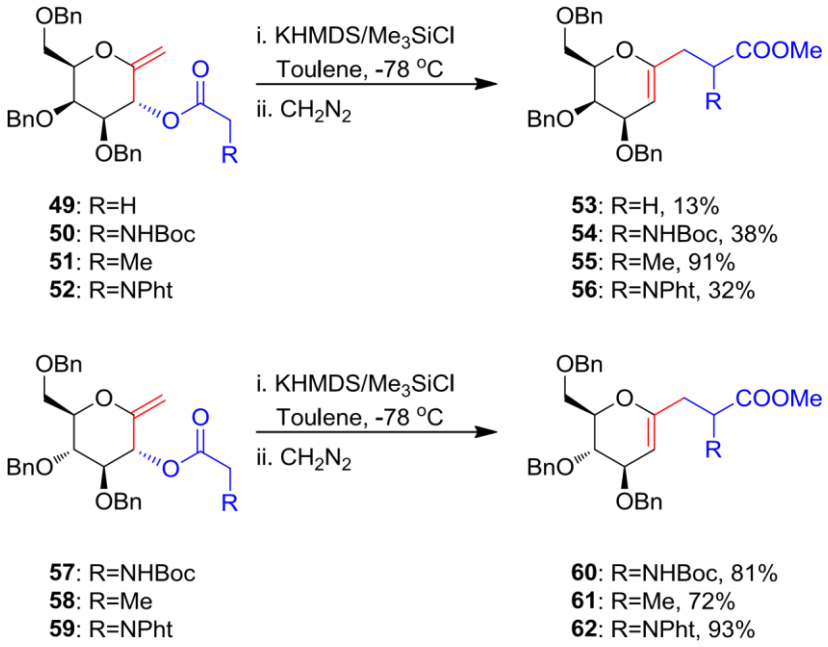
Scheme 1.8 Syntheses of 1-*C*-branched glycals by base facilitated elimination.

Synthesis of 1-*C* branched pyranoid and furanoid glycals from the corresponding glycosyl chlorides using organolithium reagents was reported by Cristobal Lopez and co-workers.[53] The glycosyl chlorides such as **45** and **47** were obtained by employing oxalyl chloride or PPh_3/CCl_4 into protected acetals, the resulted glycosyl chlorides were further treated with organo lithium reagent to provide required 1-*C*-branched glycals **46** and **48** (Scheme 1.9). In this protocol, lithium reagent abstracts the proton from the anomeric carbon, which leads to form 1-chloroglycal by the elimination of the hydroxy group present at *C*-2. The nucleophilic part like alkyl/aryl group in organo lithium reagent attacks at anomeric position to provide the 1-*C*-branched glycals by the elimination of LiCl.

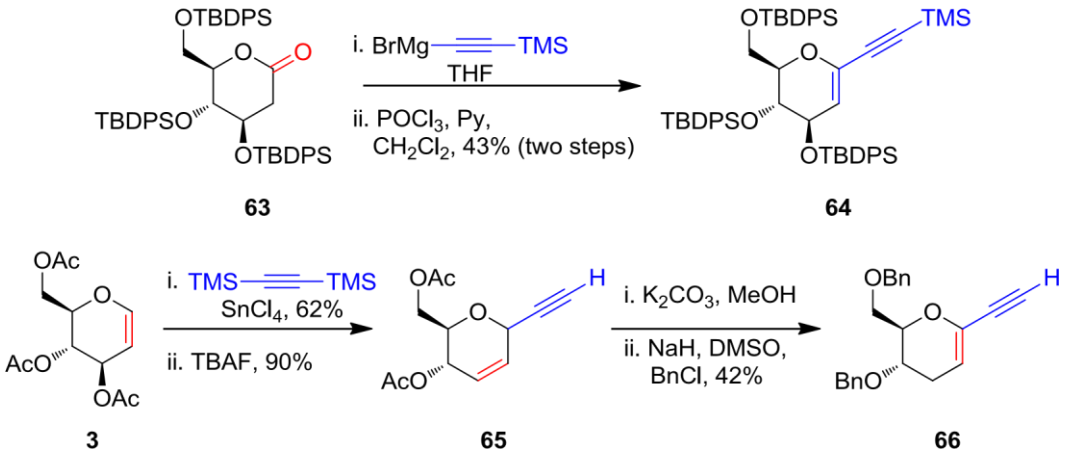


Scheme 1.9 Syntheses of 1-*C*-branched pyranoid/furanoid glycals from glycosyl chlorides.

Ireland-Claisen rearrangement is one of the best approaches for the syntheses of 1-*C*-branched glycals from allylic esters. 1-*C*-branched glycals **53**-**56** and **60**-**62** were synthesised from the allylic esters namely *exo*-glycals of type **49**-**52** and **57**-**59** by [3,3] sigmatropic rearrangement and it was reported by Langlois[54] and coworkers. In this protocol, KHMDS and Me_3SiCl were employed to generate the silyl-stabilized enolate at low temperature, further on refluxing to obtained 1-*C*-branched glycals and then immediately esterified using diazomethane (Scheme 1.10). They had observed better results with the glucose series than the galactose series.



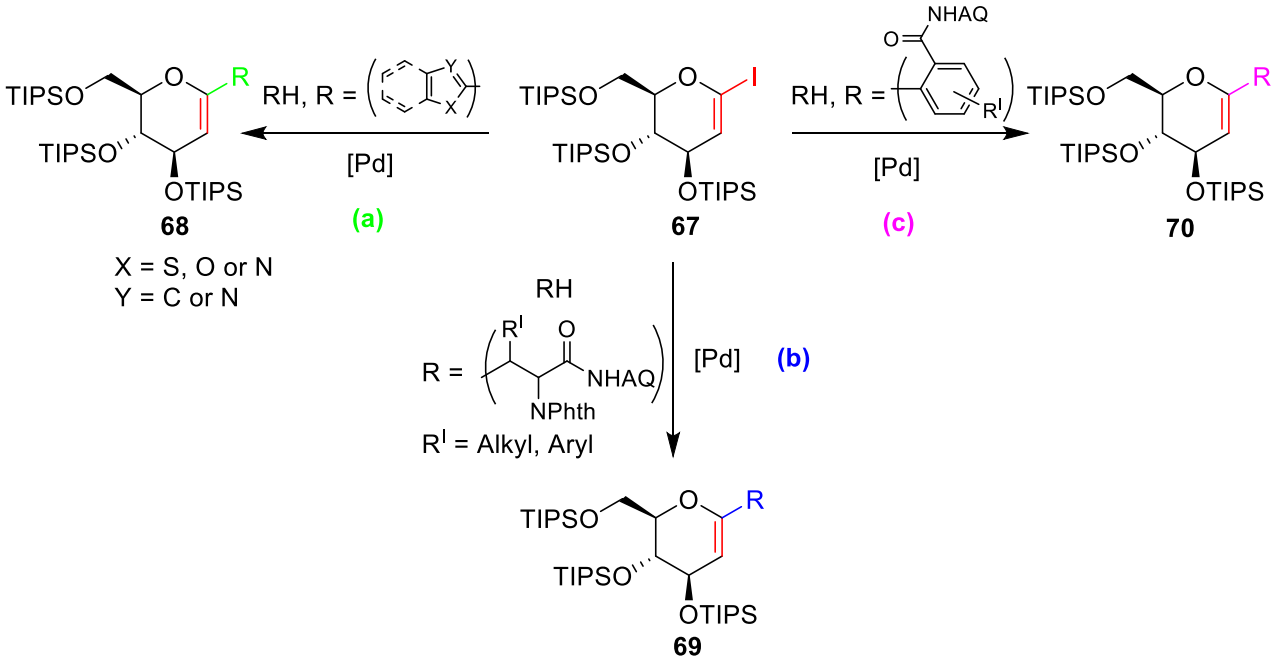
Scheme 1.10 Ireland-Claisen rearrangement approach for Syntheses of 1-*C*-branched glycals.



Scheme 1.11 Syntheses of 1-*C*-branched glycals from *C*-1-alkynyl derivatives.

McDonald[55] and Pulley[56] had utilized *C*-1-alkynyl substrates as synthetic precursors for the syntheses of 1-*C*-branched glycals. the glycal such as **64** was synthesised by performing the reaction on 2-deoxy-D-glucanolactone **63** with 2-(trimethylsilyl)ethynyl magnesium bromide to generate cyclic lactol and dehydrated in one pot using $POCl_3$. In an alternative way, 3,4,6-tri-*O*-acetyl-D-glucal **3** was treated with bis(trimethylsilyl)acetylene in the presence of Lewis acid like $SnCl_4$ to produce the α,β-unsaturated sugar substrate **65**, which was on further deacetylation and protection of alcohols with benzyl group in the basic medium led to form the 1-*C*-branched glycals such as **66** by the migration of double bond (Scheme 1.11).

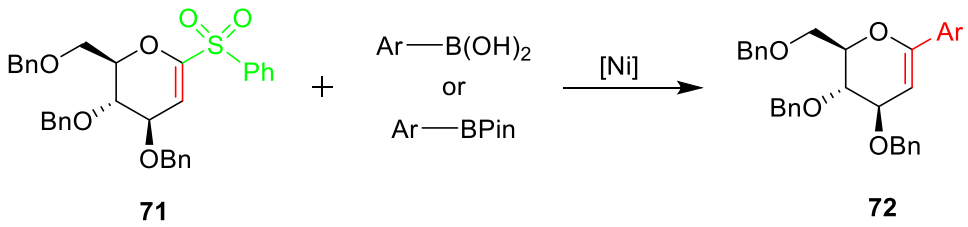
C-1-iodo glycals of type **67** are the most exploited substrates for the syntheses of *C*-1 carbon branched glycals. Recently, Ye and coworkers had developed direct regio-selective method for the synthesis of 1-*C*-branched hetero aryl glucal **68** from 1-iodo glucal **67** with indoles in the C-H activation strategy by using $Pd(OAc)_2$/CuI cocatalysed cross coupling reaction condition (Scheme 1.12a).[57] Also, this method has been applied to various heterocycle substrates like imidazoles,



Scheme 1.12 Palladium catalysed syntheses of 1-*C*-branched glucals.

thiazoles, benzimidazoles, benzothiazoles, and benzoxazoles. 1-Iodo glucal has been used again to employ in the reaction of N-phthalonyl alanine, $Pd(OAc)_2$ and Ag_2CO_3 to obtain *C*-1 glucal **69** (Scheme 1.12b).[58] Y-F Wu and X-S Ye[59] had performed the reaction of N-quinolyl benzamides with various 1-iodoglucal **67** via palladium mediated C−H functionalization to obtain 1-*C*-branched aryl glycals such as **70** in a straightforward and environmentally friendly (Scheme 1.12c).

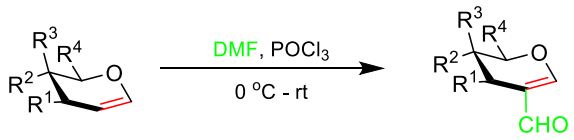
Niu[60] and coworkers have synthesised the 1-*C* aryl glucal **72** under Ni-mediated Suzuki−Miyaura cross-coupling reaction conditions with readily available α-oxo-vinylsulfones **71,** which are electrophilic partners competently in this strategy (Scheme 1.13).



Scheme 1.13 Nickel catalysed syntheses of 1-*C*-branched aryl glucals.

1.5.2.2 Syntheses of 2-*C*-Branched glycals

The first synthesis of 2-*C*-branched glycals has been reported by Ramesh and Balasubramanian[61] by using Vilsmeier-Haack reaction conditions by direct formylation. 2-*C*-formyl glycals are the most exerted substrates in the synthesis of sugar derivatives among the 2-*C*-branched glycals. it is



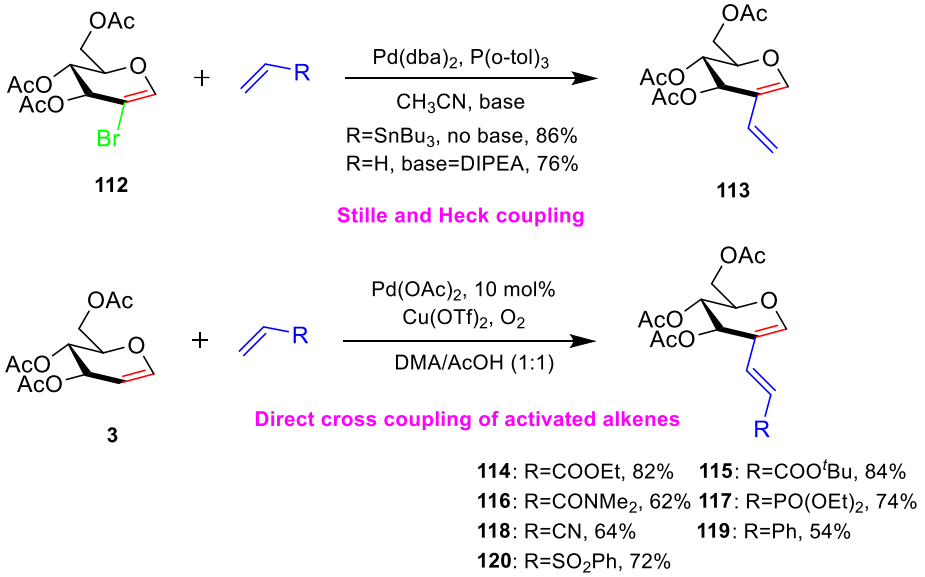
Entry	Glycal	R^1	R^2	R^3	R^4	Product	Yield
1	**73**	OMe	OMe	H	CH_2OMe	**74**	60%
2	**10**	OBn	OBn	H	CH_2OBn	**75**	55%
3	**76**	OBn	H	OBn	CH_2OBn	**77**	85%
4	**78**	OMe	H	OMe	CH_2OMe	**79**	80%
5	**80**	OAllyl	OAllyl	H	$CH_2OAllyl$	**81**	61%
6	**82**	OMe	H	OMe	CH_2OTr	**83**	72%
7	**84**	OBn	H	OBn	CH_2OTr	**85**	54%
8	**86**	OBn	OBn	H	H	**87**	44%
9	**88**	OBn	H	OBn	H	**89**	73%
10	**90**	OBn	Me	OBn	$CH_2C_6H_{13}$	**91**	93%
11	**92**	OBn	N_3	H	CH_2OBn	**93**	44%
12	**94**	OBn	H	N_3	CH_2OBn	**95**	71%
13	**96**	OMe	N_3	H	CH_2OMe	**97**	42%
14	**98**	OBn	H	OBn	CH_3	**99**	50%
15	**100**	H	OBn	H	CH_2OBn	**101**	93%
16	**102**	H	H	OBn	CH_2OBn	**103**	86%
17	**104**	OPMB	OPMB	H	CH_2OTr	**105**	63%
18	**106**	OPMB	H	OPMB	CH_2OTr	**107**	64%
19	**108**	OAllyl	H	OAllyl	$CH_2OAllyl$	**109**	77%
20	**110**	OPMB	OPMB	H	CH_2OPMB	**111**	70%

Bn = benzyl, Tr = triphenylmethyl, PMB = p-methoxybenzyl

Table 1.1 Syntheses of 1-*C*-formyl glycals by Vilsmeier-Haack reaction.

the easiest and widely used method out of all the methods[62] available in the literature survey. They had attempted with various protecting groups with good yields (Table 1.1)[63]. But in the case of TBS protected glycals, C_6- formylated instead of at C_2-position. Which is a drawback to this methodology.

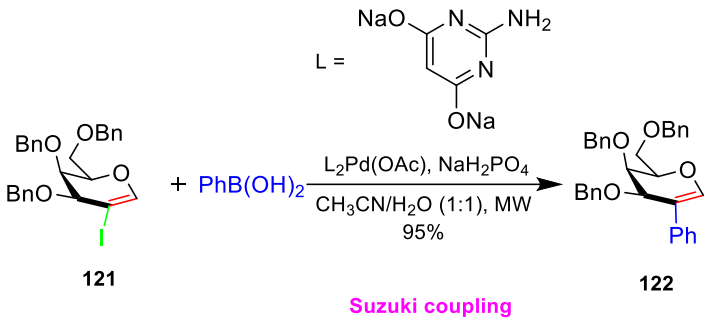
The scope of palladium mediated coupling reactions is also extended to the syntheses of 2*C*-branched glycals. M. Hayashi[64] and coworkers had developed palladium mediated synthesis of 2-vinyl glucal **112** from 2-bromo glucal **113** and vinyltributylstannane/ethylene under Stille/Heck reaction conditions respectively. They found that the suitable condition for Stille coupling reaction with 2-bromo glucal and vinyltributylstannane for the synthesis of 2-vinyl glucal is the combination of bis(dibenzylideneacetone)Pd(0) ($Pd(dba)_2$) and tri(o-tolyl)phosphine (P(*o*-tol)$_3$) in CH_3CN by screening various conditions.



Scheme 1.14 Palladium catalysed vinylation of glycals to form 2-*C*-branched glycals.

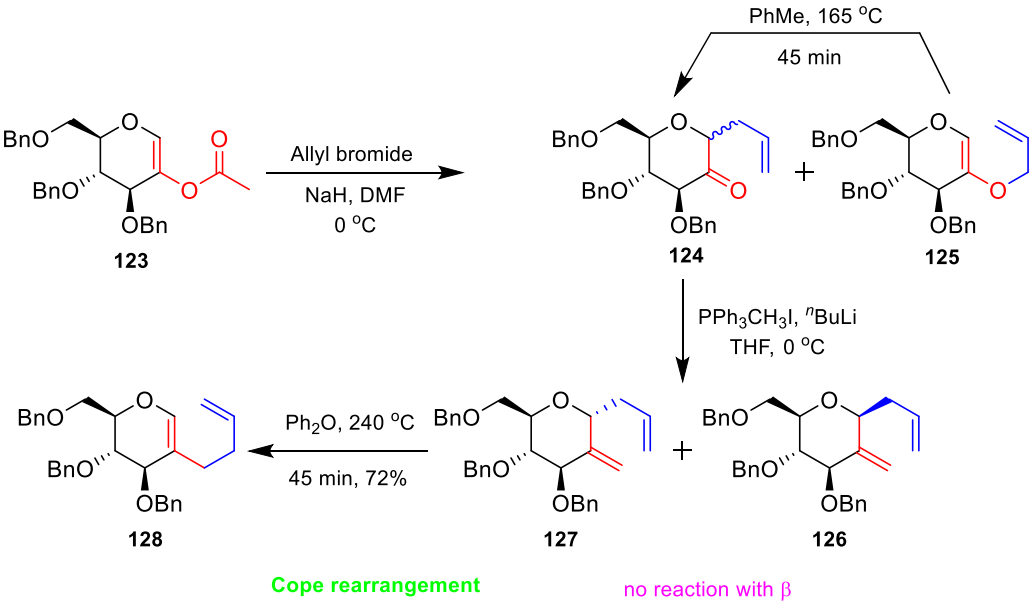
Heck coupling reaction had also performed with the same catalytic condition by using ethelene and Diisopropylethylamine (DIPEA) base to achieve 2-*C*-branched sugar derivatives (Scheme 1.14) in good yield. In another report, Liu[65] and coworkers had performed the direct cross-coupling of activated alkenes with glycals for the synthesis of 2-*C*-branched glycals **114-120** I the presence of $Pd(OAc)_2$, $Cu(OTf)_2$ and oxygen gas (Scheme 1.14). Later, Davis[66] and

coworkers had reported the phosphine free Suzuki coupling reaction for the synthesis of 2-*C*-aryl glycals **122** from 2-iodo glycals **121** by using palladium complex and different aryl substituted boronic acids and microwave conditions (Scheme 1.15).



Scheme 1.15 Suzuki coupling of 2-iodo glycals to form 2-*C*-aryl glycals.

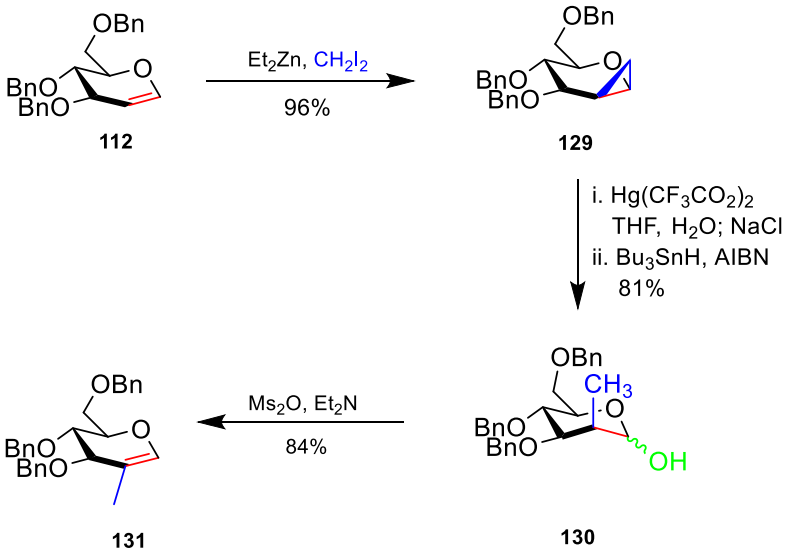
Jayaraman[67] and coworkers had developed the syntheses of 2-*C*-branched glycals from 2-hydroxy glycal ester such as **123** by using Cope rearrangement conditions. They were first treated 2-hydroxy glycal ester with allyl bromide and sodium hydride for C- allylation to produce the inseparable mixture of *C*-glycosides **124**and allyl vinyl ether **125**, later which was converted to *C*-glycoside **124** by applying Claisen rearrangement conditions. The mixture of α and β-



Scheme 1.16 Syntheses of 2-*C*-alkyl glycals from 2-hydroxy glycal ester.

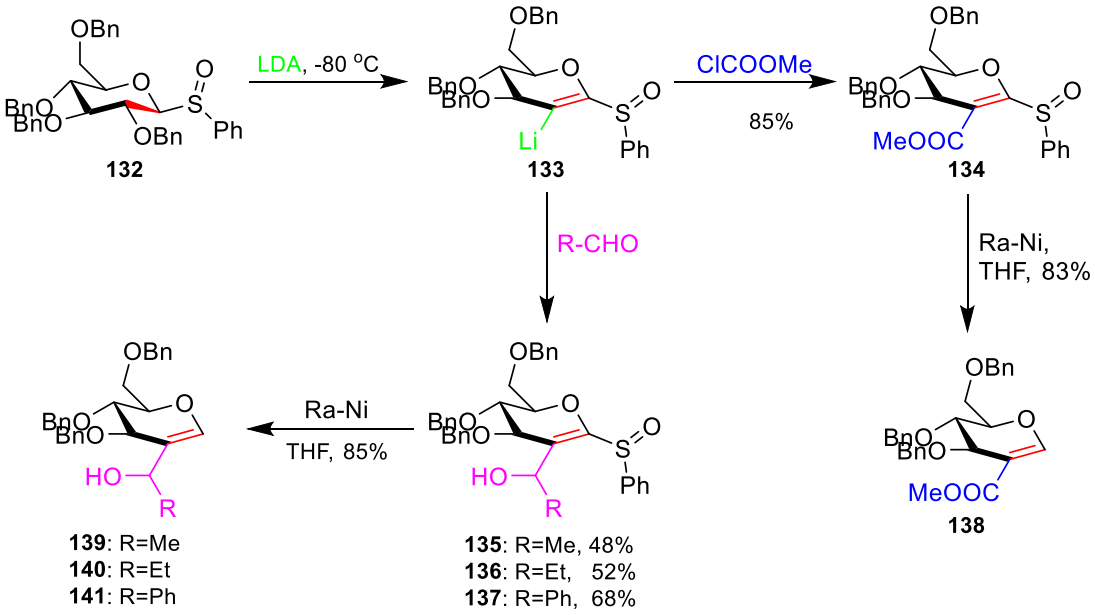
diastereomers were performed under Wittig olefination reaction conditions to obtain the *C*-2 methylene glycosides **126** and **127,** which were further performed under cope rearrangement conditions to obtained 2-C-branched glycals. But β-anomer **126** could not go forward by ring-flipping to initiate the reaction for the formation of 2-*C*-branched glycals such as **128** (Scheme 1.16).

Heathcock[68] and coworkers were reported the syntheses of tri benzyl protected 2-*C*-branched glucal **131** from tribenzyl glucal **10** via cyclopropane ring opening in regioselective fasion, stereoselective cyclo propanation of tri benzyl glucal was done by using Simmons-smith reaction conditions to provide cyclopropane diastereomers **129** as major. 2-*C*-methyl lactol **130** was obtained by treatment of mercury complex of sugar derivative with Bu_3SnH and AIBN, which formed by cyclopropane ring-opening of cyclopropane ring of the compound **129** by regio selectively using mercuric trifluoroacetate $Hg(CF_3COO)_2$ and water. Anomeric hydroxyl group was activated with mesyl group y treating with Ms_2O and Et_3N, followed by the elimination of mesylate by treatment of Et_3N to provide the 2-*C*-branched glycal **131** in 65% yield on overall (Scheme 1.17).



Scheme 1.17 Syntheses of 2-*C*-methyl glycals by Hg mediated ring opening of cyclopropane.

Schmidt[69] and coworkers had reported the synthesis of 2-C-branched glycals through β-lithiation of phenyl sulfoxide group, which is present at anomeric position. Phenyl sulfoxide sugar derivative **132** had performed the reaction with LDA at -80 °C for direct lithiation at C_2 position to form lithiated sugar derivative **133**, which is treated with different types of electrophiles like aldehydes and methyl chloroformate provided 2-C-branched glycals type **134-137**. Further treated with Raney Ni to remove phenylsulfoxide group to obtained 2-C-branched sugar derivatives such as **138-141** (Scheme 1.18). Later Hall et al[70] had reported the synthesis of 2-cyano glycals by treating with chlorosulphonyl isocyanate for direct cyanation at C_2 position with very poor yield.

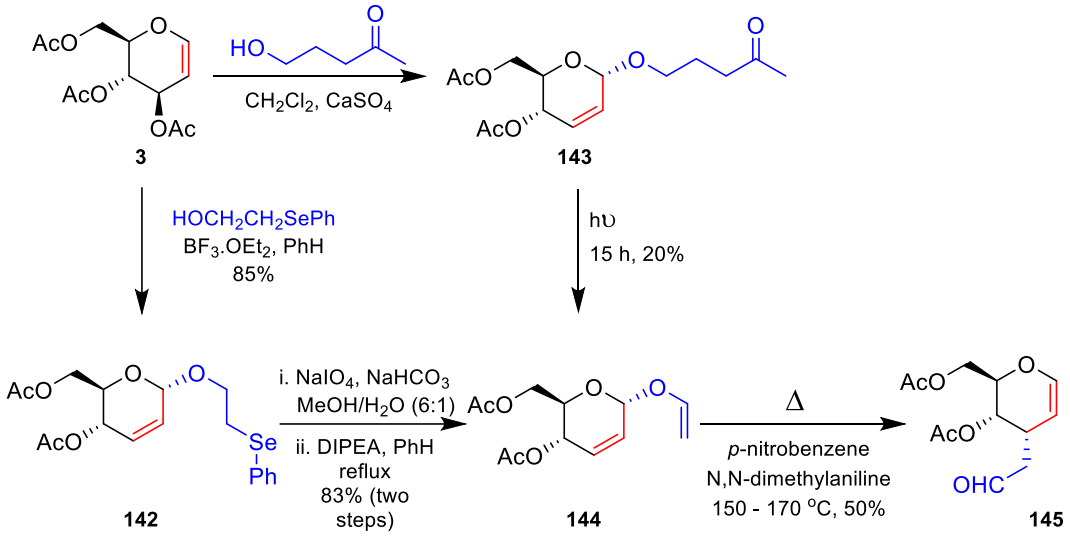


Scheme 1.18 Syntheses of 2-*C*-branched glycals by direct lithiation of glycals.

1.5.2.3 Syntheses of 3-*C*-Branched glycals

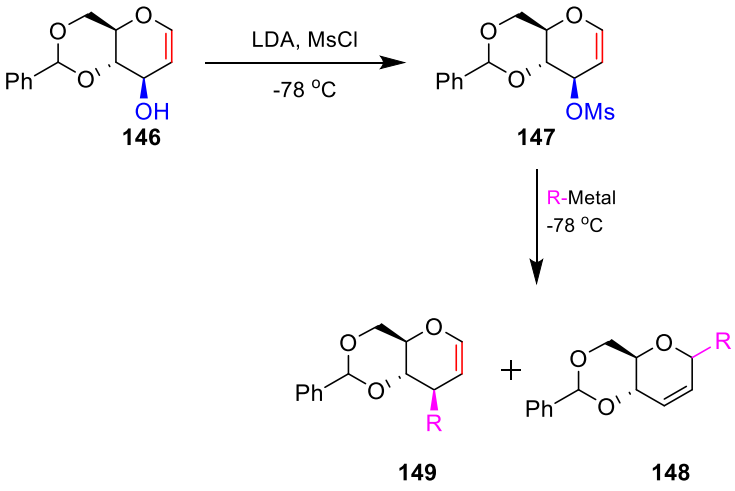
Till today, 3-*C*-branched glycals are synthetically less explored, due to difficulty in the formation of carbon branch at the *C*-3 position in a stereoselective fashion.

The first synthesis of 3-*C*- branched glycals had reported from the sugar derived allyl vinyl ethers by [3,3]-sigma tropic rearrangement and it became as a traditional method for the synthesis of 3-*C*-branched glycals. G. Descotes[71] and coworkers had achieved the allyl vinyl ether sugar derivative **144** from (4-oxopentyl)-D-glycoside **143** by photolysis, obtained by Ferrier rearrangement of D-glucal **3** with 5-hydroxy-2-pentanone, in very less yield. The allyl vinyl ether derivative in *p*-nitrobenzene on heating at 150-170 °C for obtaining 3-*C*-branched glycal derivative via [3,3]-sigma tropic rearrangement, in 50% yield. Later, Sinay[72] had reported 3-*C*-branched glycals from the oxidation of 2-(phenylselenenyl) ethyl ether**142** by using sodium periodate, followed by the elimination of resulted selenoxide group on heating, obtained allyl vinyl ether**144**in good yield, performed allylic rearrangements under similar reaction conditions to obtained 3-*C*-branched sugar derivative**145** (Scheme 1.19). Balasubramanian[73] and coworkers had synthesized 3-*C*-aryl glycals by aromatic Claisen rearrangement in a stereoselective fashion under the same reaction conditions.



Scheme 1.19 Syntheses of 3-*C*-branched glycals using claisen rearrangement.

Mitsunobu[74] and coworkers were reported 1-*C* and 3-*C*-branched glycals in regio-selective fashion by using a Grignard reagent. The free hydroxyl group was activated with a mesyl group under basic mediation. The mesylate produced 3-*C*- branched glycal derivatives of type **149** in the presence of additives such as CuI/CuBr-S(CH_3)$_2$ or Gilman reagent, produced 1-*C*- branched glycals such as **148** in absence of additives. Regioselectivity of the carbon branch formation was explained based on Hard and soft acids and bases concept. *C*-3 position in **147** is softer than the *C*-1 position. So, organic cuprates are softer nucleophiles than the Grignard reagents, which attack the *C*-3 position than the *C*-1 position to produce 3-*C*-branched glycals **149** (Scheme 1.20).

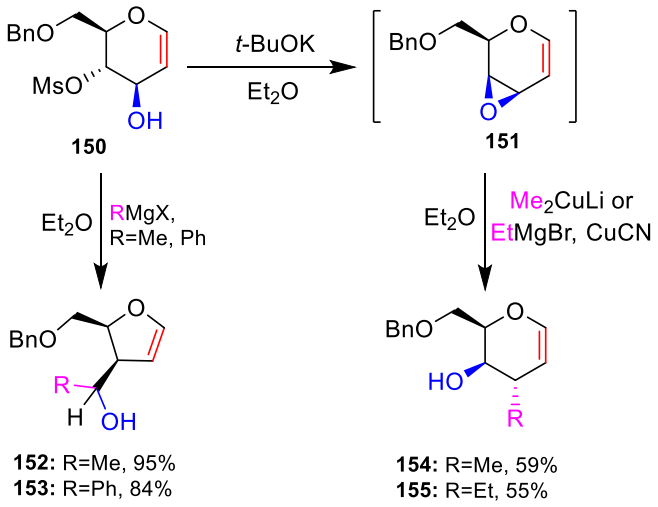


R-Metal	**148** Yield (α:β)	**149** Yield
C_2H_5MgBr	61% (1:10)	14%
C_2H_5MgBr/ CuI	–	24%
CH_3MgBr	65% (1:2)	–
CH_3MgBr/ CuI	–	42%
CH_3MgBr/ CuBr-	–	63%
Me_2CuLi	–	62%

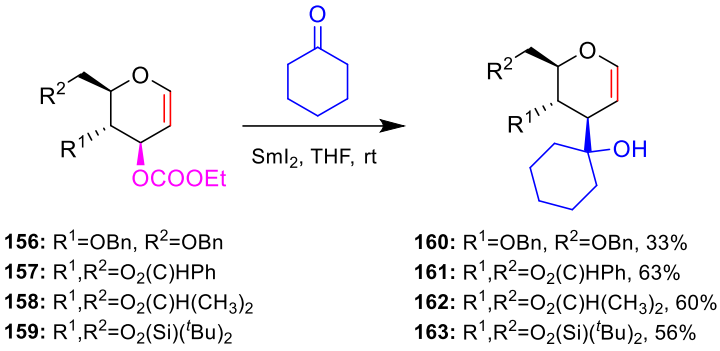
Scheme 1.20 3-*C*-branched glycals by regioselective alkylation.

Similarly, P. Crotti[75] reported the synthesis of 3-*C*-branched furanoid glycals **152** and **153** from hydroxy mesylate **150**, by the direct addition of Grignard reagent to the intermediate epoxide **151** formed under basic reaction conditions through the isomerization and ring contraction of epoxide **151**. On the other hand, treating the epoxide **151** with (CH_3)$_2$CuLi or C_2H_5MgBr in presence of cuprous cyanide produced the 3-*C*-methyl glycals **154** and 3-*C*-ethyl glycal **155** in moderate yield (Scheme 1.21). Gallagher[76] and coworkers also had reported the syntheses of 3-

C-branched Sugar derivatives from glycals by treating with $NCCH_2CH_2Cu(CN)ZnI$ in the presence of BF_3OEt_3 in good yield.



Scheme 1.21 Syntheses of 3-*C*-furanoid/pyranoid glycals by Grignard and Cuprate reagents.

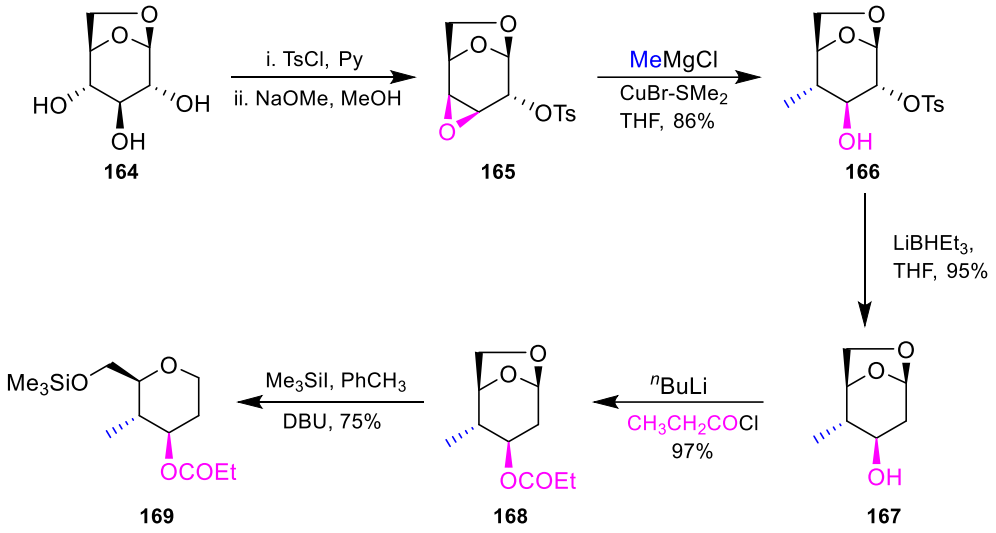


Scheme 1.22 umpolung syntheses of 3-*C*-branched sugars with SmI_2.

Later, Beau[77] and coworkers had treated allylic carbonated glycals **156-159** with cyclohexanone and samarium iodide to obtain the 3-*C*-glycals of type **160-163** by allylic radical intermediation. The carbon chain was formed from the less hindered side. One more synthesis of 3-*C*-branched glycals was discussed in the detail in the later chapter of this thesis. They are not shown here.

1.5.2.4 Syntheses of 4-*C*-Branched glycals

4-*C*-branched glycals were not synthesised by simple and direct methods, the reported methods are available in a multistep synthetic approach and very less in number.



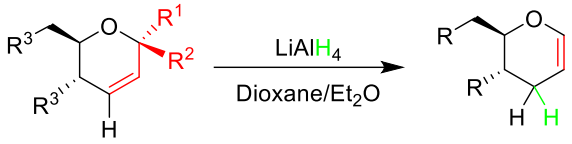
Scheme 1.23 Syntheses of 4-*C*-branched sugar from levoglucosan.

Ley[78] and coworkers had synthesised the 4-*C*-branched glycal **169** from 1,6-andydro-β-D-glucose (levoglucosan) **164** in six steps. In this synthesis, key steps are epoxide ring opening with Methyl magnesium chloride and anhydro-bridge opening with Me_3SiI to produce 4-*C*-glycal such as **169** by employing DBU for the elimination of anomeric iodide (Scheme 1.23). Similarly, the other few methods[79] were also reported in multistep synthetic approach, these are not appropriate to describe in detail.

1.5.3 Syntheses of deoxy glycals

Fraser-Reid[80] had reported the first an obvious synthetic path for the syntheses of 3-deoxy glycals employing Lithium Aluminium-Hydride (LAH). Due to acetals stability towards LAH and the absence of acid catalyst, A single step reaction with the allylic acetals of type **170-175** reductive rearrangement has been reported to obtain vinyl ethers such as **176-178** employing $LiAlH_4$

(Scheme 1.24). The acetals **170-175** could be prepared easily from simple glycals by applying Ferrier rearrangement reaction conditions. These resulted β,γ-unsaturated systems were treated with $LiAlH_4$ in refluxing ether or dioxane to obtain the expected 3-deoxy glycals via generating pentacoordinate complex with LAH.

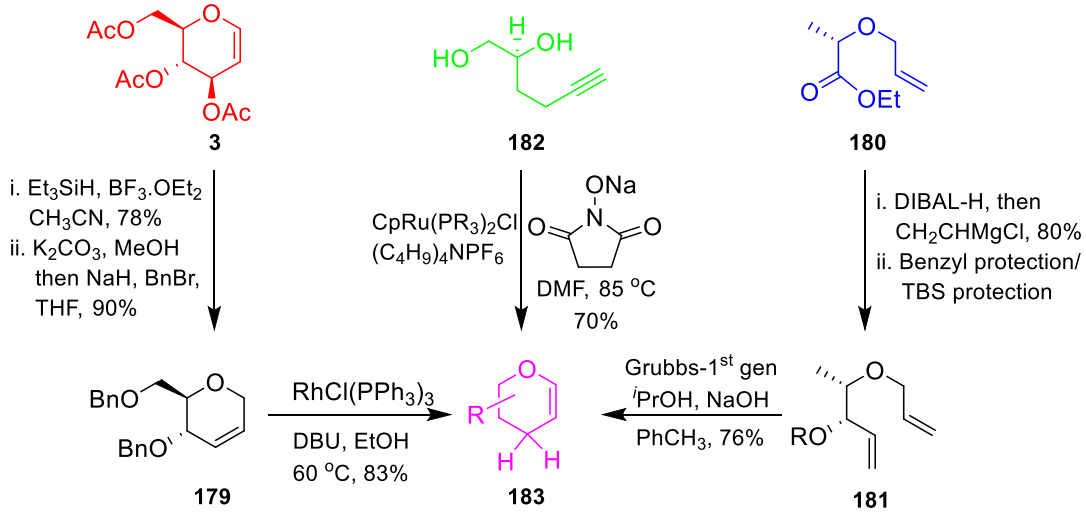


170: R^1=OCH_3, R^2=H, R^3=O_2(C)HPh
171: R^1=H, R^2=OCH_3, R^3=O_2(C)HPh
172: R^1=OC_2H_5, R^2=H, R^3=OH
173: R^1=OC_2H_5, R^2=H, R^3=OAc
174: R^1=OC_2H_5, R^2=H, R^3=OCH_3
175: R^1=H, R^2=OCH_3, R^3=OCH_3

176: R=O_2(C)HPh, 95%
176: R=O_2(C)HPh
177: R=OH
177: R=OH
178: R=OCH_3
178: R=OCH_3

Scheme 1.24 LAH mediated Syntheses of 3-deoxy glycals.

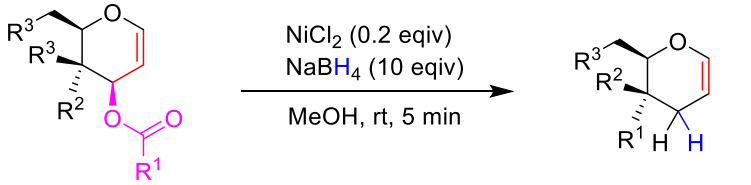
The next significant approach towards 3-deoxy glycals is with transition metal-mediated isomerization or cyclization of unsaturated compounds. Van Boom[81] had synthesised cyclic vinyl ethers **183** by the isomerization of allyl ether **179**, using Wilkinson's catalyst. This allyl ether **179** was prepared by employing glycal with triethyl silane in the presence of lewis acid (Scheme 1.25). Later, Schmidt[82] had also reported the one pot synthesis of 3-deoxy glycals by ring closing-



Scheme 1.25 Syntheses of 3-deoxy glycals by RCM and isomerization.

metathesis (RCM)and isomerization[83] in sequence, treating Grubb's 1st generation catalyst. Firstly, the diene **181** was prepared from the ester compound **180** by a sequence of reactions, then RCM catalyst was employed to produce cyclic allyl ether intermediate. Once the reaction goes to end, due to using NaOH and propanol the Grubb's catalyst is further transformed to isomerization catalyst (in situ) to produce the required 3-deoxy glycal **183** (Scheme 1.25). Likewise, Trost[84] had reported dihydropyran such as **183** by probing the strategy of cyclo-isomerization of ynediol of type **182** using Ru catalyst (Scheme 1.23). The compound **182** was obtained by Barbier addition of propargyl bromide to (*R*)-glyceraldehyde using zinc in diastereo-selective manner.

In 1988, Keinan[85] performed the deoxygenation of allylic-ester in regioselective manner by treating with Pd(0)/Ph_2SiH_2/$ZnCl_2$ system. But, the moderate yields only were observed. Later, B.Yin[86] and co-workers explored the same reaction with various reagents in order to enhance the yield. They were found successfully $NiCl_2$/$NaBH_4$/MeOH system as the better choice for the reductive cleavage of allylic esters in a regio-selective manner to achieve good yields. Sodium



184: R^1=CH_3, R^2=H, R^3=OAc, R^4=OAc
003: R^1=CH_3, R^2=OAc, R^3=H, R^4=OAc
185: R^1=Ph, R^2=OBz, R^3=H, R^4=OBz
186: R^1=CH_3, R^2=OAc, R^3=H, R^4=OTBDPS
187: R^1=Ph, R^2=OBz, R^3=H, R^4=OTBDPS
188: R^1=CH_3, R^2=OAc, R^3=H, R^4=OBn

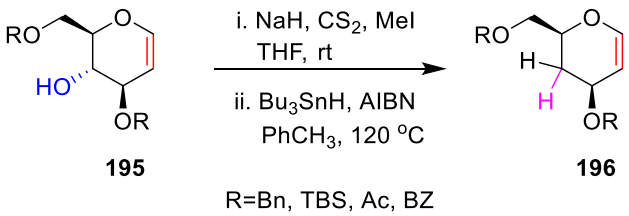
189: R^1=H, R^2=OAc, R^3=OAc, 88%
190: R^1=OAc, R^2=H, R^3=OAc, 93%
191: R^1=OBz, R^2=H, R^3=OBz, 84%
192: R^1=OAc, R^2=H, R^3=OTBDPS, 89%
193: R^1=OBz, R^2=H, R^3=OTBDPS, 83%
194: R^1=OAc, R^2=H, R^3=OBn, 92%

Scheme 1.26 Syntheses of 3-deoxy glycals by regioselective deoxygenation of allylic esters.

borohydride with Nickel(II)chloride forms $(Ni_2B)_2.H_3$ as active species, which generates a π-allylnickel complex by releasing of AcOH, then the hydride ion attacks at *C*-3 position to produce the 3-deoxy glycal. 3-*O*-acetyl esters and 3-*O*-benzoyl esters of type **3**, **184**-**188** were examined in the same reaction conditions with different 4,6-*O*-protective groups such as acetyl (Ac), benzoyl

(Bz), benzyl (Bn), TBDPS and TBS to achieve 3-deoxy glycals of type **189-194** (Scheme 1.26), and all the 3-deoxy compounds were recorded to be achieved in good yield.

4-deoxy glycals were obtained by applying Barton-McCombie deoxygenation[87] reaction condition over glycals such as **195** with a free hydroxyl group at *C*-4 position. *C*-3 and *C*-6 hydroxyl groups could be protected with a stable *O*-protective group in the reaction condition. In this strategy, the free *C*-4 hydroxy group is transformed to thiocarbonyl/xanthate derivative, then it is further performed with Bu_3SnH and AIBN to provide glycals such as **196** (Scheme 1.27) in good yield.



Scheme 1.27 Barton-McCombie deoxygenation of Syntheses of 4-deoxy glycals.

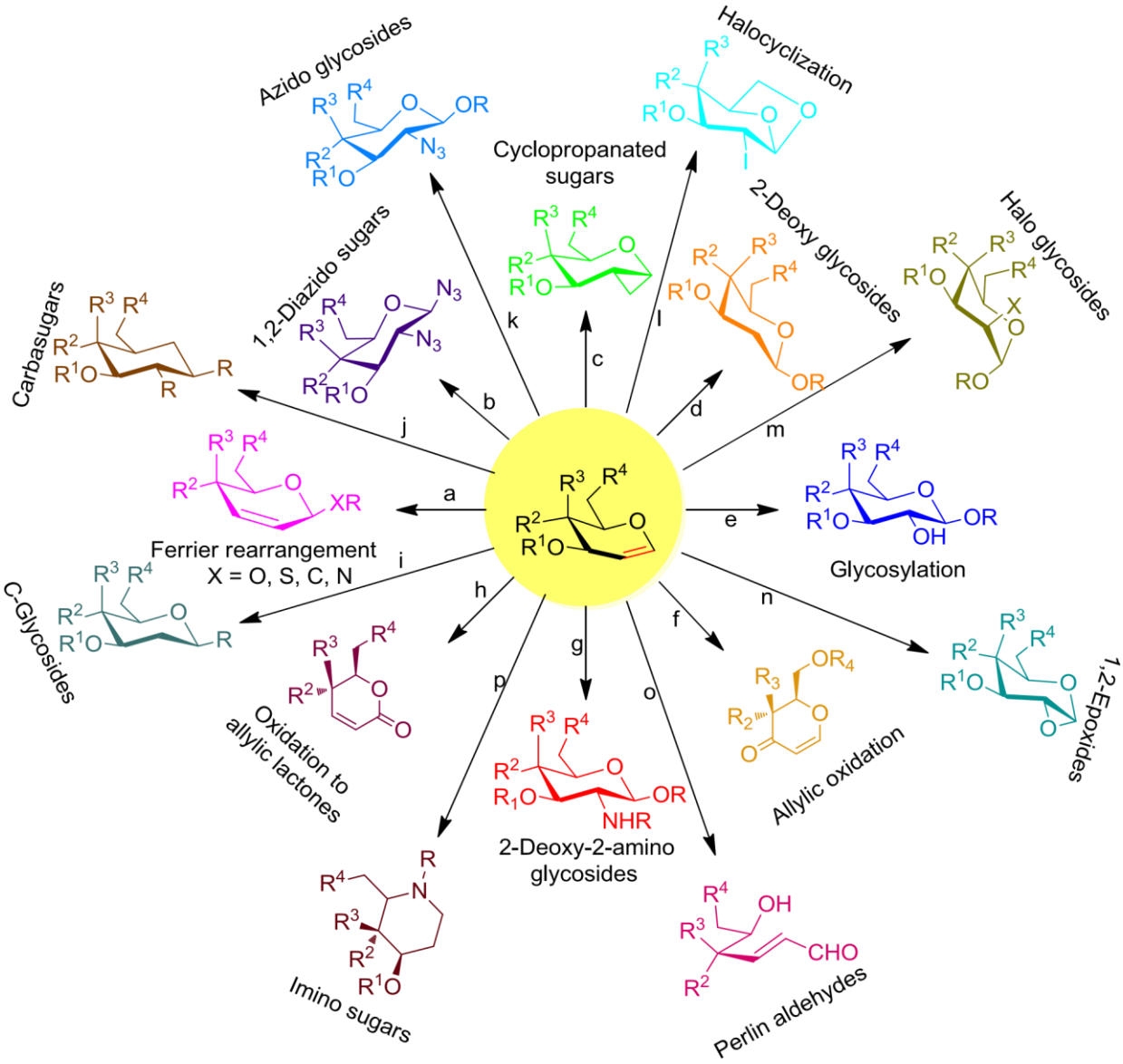
1.6 Synthetic applications of simple glycals, carbon branched glycals and deoxy glycals

1.6.1 Few synthetic applications of simple glycals

Glycals are well known to be one of the excellent merchandises in synthetic sugar chemistry as they provide several synthetic applications (Scheme 1.28). Due to the presence of a double bond in glycals, various functional groups have been introduced in mono and disaccharides with good stereo and regioselectivity. The enol-ether possesses nucleophilic substitution and electrophilic addition reactions because of the intervention of endo-cyclic oxygen to generate products, which include synthesis of polysaccharides from the modified monosaccharide derivatives. Ferrier rearrangement[88] is being used as one of the highly exerted reactions of glycals to produce 2,3-unsaturated glycosides using allylic rearrangement of nucleophilic substitution.

which was first reported by Ferrier. However, Emil Fischer[89] had investigated a similar kind of reaction with water as the nucleophile much before Ferrier reported. Ferrier had investigated with various nucleophiles like *O*, *C*, *N*, *S*-nucleophiles to generate the corresponding 2,3-unsaturated glycosides in good stereoselective[90] manner (Scheme 1.28a). Glycal derivatives have been explored as glycosyl donors to attain *O*-glycosides, which are generally found in living-organisms (Scheme 1.28e).[91] The stability of the *C*-Glycosides[92] in metabolic processing had drawn the attention of scientists to develop novel methodologies for *C*-Glycosides synthesis. Such *C*-glycosides also could be synthesized employing glycals (Scheme 1.28i). 2-Deoxy glycosides,[93] are a most important category of glycosides, which take place in several natural products, anticancer agents (doxorubicin), antibiotics (erythromycin), insecticides (avermectins) and antiparasite agents (amphotericin), have been mainly synthesized utilizing glycals as glycosyl donors in acidic condition (Scheme 1.28d). Haloglycosylation[93a, 94] is one of the earliest methods among glycosylations reported by Lemieux, by employing glycals as glycosyl-donors to generate halo-glycosides (Scheme 1.28m). Various biologically active oligosaccharides, natural products (ciclamycin[91], avermectins, etc.) have been synthesised by using halo glycosides. Danishefsky[95] has developed a systematic protocol for the synthesis of 1,2-Anhydro sugars (or 1,2-epoxy sugars) by oxidation of glycals using DMDO. Afterward, these glycals have been using as extraordinary glycosyl donors in the synthesis of different higher ordered general glycosides of glucose, mannose, and galactose(Scheme 1.28n).[91] 2-Deoxy-2-amino glycosides are widely occur in living organisms as glycoproteins, glycolipids, many naturally occurring antibiotics and blood- group oligosaccharides and this type of amino sugars also could be simply produced through the nitrogen attacked to glycals (Scheme 1.28g, 1.28k).[91, 96] Glycals are also used to generate modified carbohydrate residues like 2-halo anhydro sugars[97] (Scheme 1.28*l*), 1,2-cyclopropanated sugars[98] (Scheme 1.28c), Perlin aldehydes[99] (Scheme 1.28o), allylic ketones[100] (Scheme 1.28f), 1,2diazido sugars[101] (Scheme 1.28b), allylic lactones[102] (Scheme 1.28h), imino sugars[103] (Scheme 1.28p), and carbasugars[104] (Scheme 1.28j) , these are used for the syntheses of revised sugar molecules, natural

products, their advanced intermediates, and secondary metabolites generated by the living-organisms.



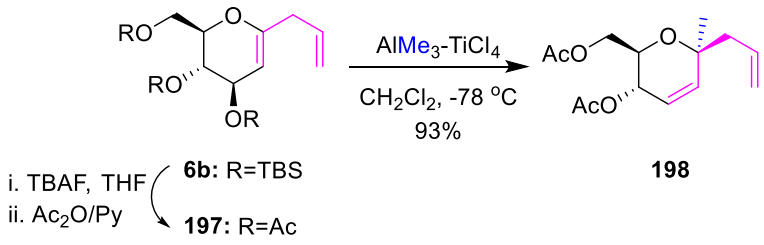
Scheme 1.28 Few synthetic applications of simple glycals in sugar chemistry.

1.6.2 Few synthetic applications of carbon branched glycals

1.6.2.1 Synthetic applications of 1-*C*-Branched glycals

Over the past three decades, *C*-glycosides are emerged to be main targets for methodologists and medicinal chemists due to the stability of *C*-glycosides to numerous glycosidase enzymes which usually cleave the corresponding counterparts, *O*-glycosides.[105] In this case, 1-*C*-branched glycals are become as the finest materials for the syntheses of *C*-glycosides due to more retrosynthetic correlation of *C*-1 glycals with numerous biological targets and because of the availability of previously adorned carbon branch at the compatible position along with the enol-ether function for furthermore addition of needed functionalities to obtain the attached carbohydrate moiety.[106] Thus, the 1-*C*-branched carbohydrates are converted to various significant carbohydrate skeletons, employing various synthetic transformations.

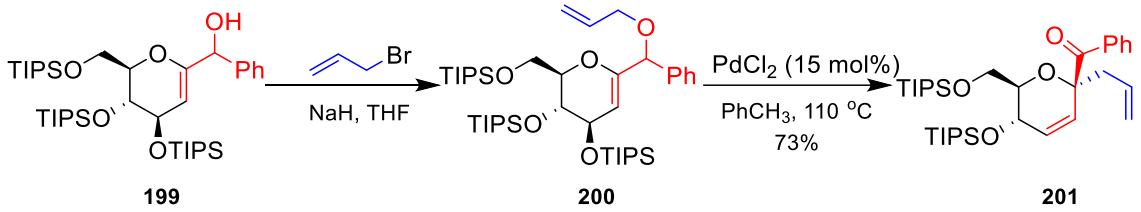
K. C. Nicolaou required 1,1-dialkyl glycosides of type **198** as an intermediate to obtain the natural product brevitoxin B.[107] He took the 1-*C*-branched glucal such as **197** (see Scheme 1.2 for syntheses) for the syntheses of tertiary anomeric centers in a stereospecific manner by Ferrier rearrangement employing $AlMe_3$-$TiCl_4$ system at low temperature in good yield (Scheme 1.29).[26] and also attempted with various nucleophiles for the stereospecific-synthesis of different 1,1-dialkyl glycosides such as **198** moderate to good yield.



Scheme 1.29 Syntheses of 1,1-dialkylglucosides to synthesise brevitoxin B.

Similarly, Echavarren[108] had synthesized the same kind of 1,1-dialkyl glycosides by isomerization Claisen rearrangement-strategy e Pd catalysis. The functionalized-*C*-glycosides

were synthesized successfully by treating with various catalysts like $PdCl_2$, $AuCl_3$ and $IrCl_3$. Among them, Palladium (II) chloride was produced a good yield. Firstly, the secondary hydroxyl group in compound **199** (see Scheme 1.4 for syntheses) was protected by employing allyl bromide to achieve compound **200**, which further treated with $PdCl_2$ to generate the *C*-glycoside **201**.

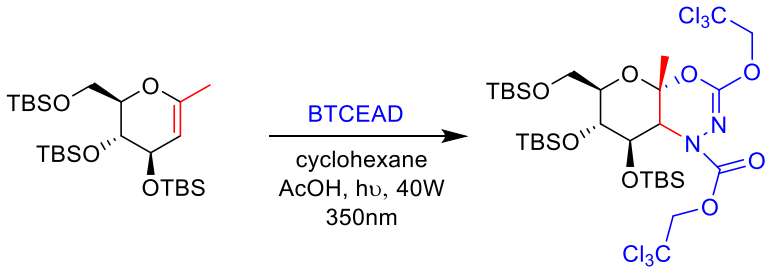


199 **200** **201**

Scheme 1.30 Claisen rearrangement of 1-*C*-branched sugars

initially, $PdCl_2$ has generated the allyl-vinyl ether by isomerization of 1,2-H migration, which further converted to α-ketones such as **201** by sustaining the claisen-rearrangement (Scheme 1.30).

Leblanc[109] and coworkers had employed the 1-*C*-branched sugars of type **6a** (see Scheme 1.2 for syntheses) in the Hetero-Diels-Alder reaction to generate bicyclic-sugar derivatives such as **202**. These substrates were further used for the syntheses of 2-amino-*C*-glycoside-spiroketals, which are possessing the biologically importance. They have treated the 1-methyl glycal derivative such as **6a** with bis(2,2,2trichloroethyl)azodicarboxylate (BTCEAD) at 40W and 350nm to attain Diels-Alder product **202,** which was utilized later for the syntheses of amino sugars (Scheme 1.31).

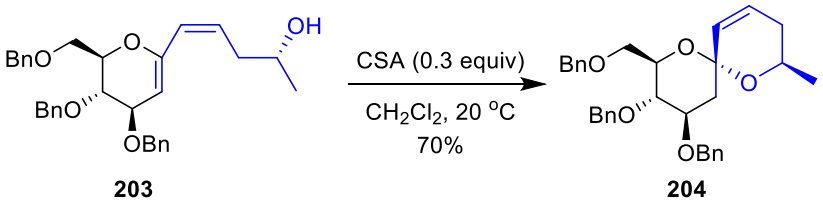


6a **202**

Scheme 1.31 Diels-Alder reaction of 1-*C*-branched sugars.

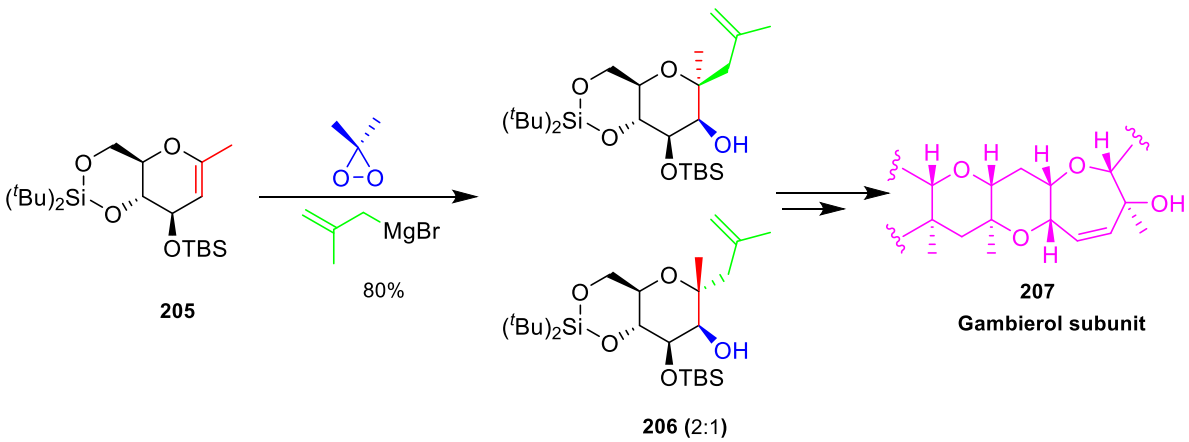
The spiroketal structural skeletons are widely spread in several natural products, steroids, antibiotics, secondary metabolites and insect pheromones.[110] These skeletons of spiroketal are

mainly synthesized using 1-*C*-branched sugar derivatives of type **203**. Quayle[111] and Sasaki[112] had employed camphorsulfonic acid (CSA) in the reaction of the sugar derivative **203** to attain spiroketal such as **204** in good yield (Scheme 1.32), the resulted spiroketals were further used for the syntheses of biologically important compounds such as milbemycins and avermectins.



Scheme 1.32 Syntheses of spiroketal from 1-*C*-branched sugar.

1-*C*-glycoside of type **205** was used in the synthesis of gambierol subunit **207**, which marine ladder toxin. Instead of using ferrier rearrangement, glucal derivative **205** (see Scheme 1.2 for syntheses) was treated with dimethyldioxirane(DMDO) to obtain the epoxide derivative, later which was opened with different nucleophiles which Grignard reagent based to attain the *C*-glycoside such as **206**. The intermediate **206** was utilized in the formal total syntheses of gambierol with different groups (Scheme 1.33).[113] The other significant synthetic conversions of 1-*C*-branched glycals are functionalized *C*-glycosides, natural products and their intermediates including epoxidation,[114] hydroboration,[106] hydrogenation,[115] azidoselenation,[116] mercuration,[117] dihydroxylation[118] and electrophilic radical addition reaction.[119]

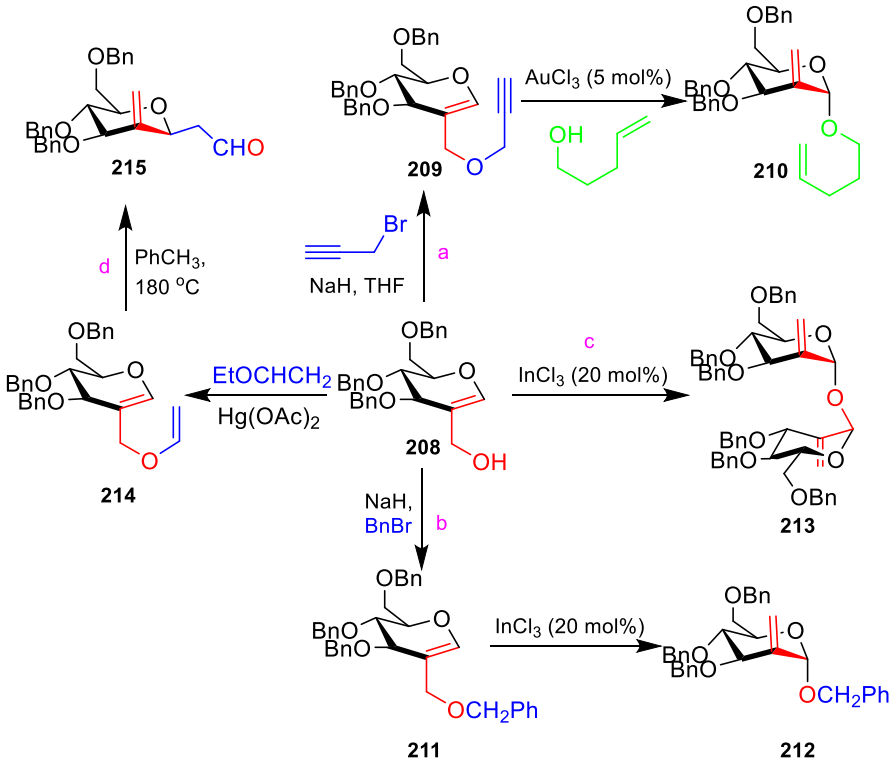


Scheme 1.33 Syntheses of gambierol subunit from 1-*C*-branched sugars.

1.6.2.2 Synthetic applications of 2-*C*-Branched glycals

2-*C*- Formyl glycals and their oxidised/reduced substrates use for the synthetic applications[63] of 2-*C*-branched sugar derivatives preferably, due to no difficulty in their production. The 2-*C*-formyl glycal derivatives were involved in various transformations to synthesise *O*-glycosides, *C*-glycosides, amino sugars, bicyclic to polycyclic skeletons etc.

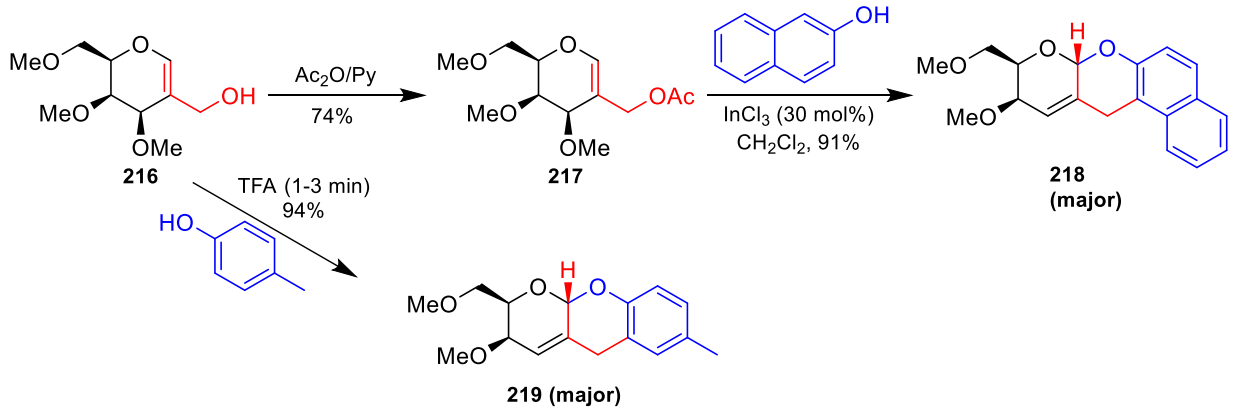
Balasubramanian et. al had reported the first synthesis of 2-*C*-methylene-*O*-glycosides from 2-*C*-acetoxymethyl glycals.[120] Later, various methods applied for the synthesis of 2-*C*-methylene-*O*-glycosides of types **210**-**212** by using the corresponding 2-*C*-formyl glycals of type **69**, upon reduction to the corresponding alcohol of type **208**, due to their importance in the synthesis of many natural and unnatural carbohydrate analogs.[63] Srinivas Hotha et. al had reported the alkynophilicity of $AuCl_3$ for synthesis of *O*-glycosides by using 2-*C*-propargyloxy- methyl glycals (Scheme 1.34a).[121] Similarly, N.G Ramesh and coworkers were used $InCl_3$ for the



Scheme 1.34 Syntheses of 2-*C*-methylene-*O*/*C*-glycosides from 2-*C*-formyl glycals.

syntheses of 2-*C*-methylene-*O*-glycosides by 1,3-alkoxy migration (Scheme 1.34b),[122] the intermolecular *O*-glycosylation reaction through the direct allylic substitution of nucleophile (Scheme 1.34c).[123] Later, the synthesis of 2-*C*-methylene-C-glycosides have been reported by our group by [3,3]-sigmatropic shift of the allyl vinyl ethers by using the 2-*C*-hydroxymethyl glycal of type **208** (Scheme 1.34d).[124]

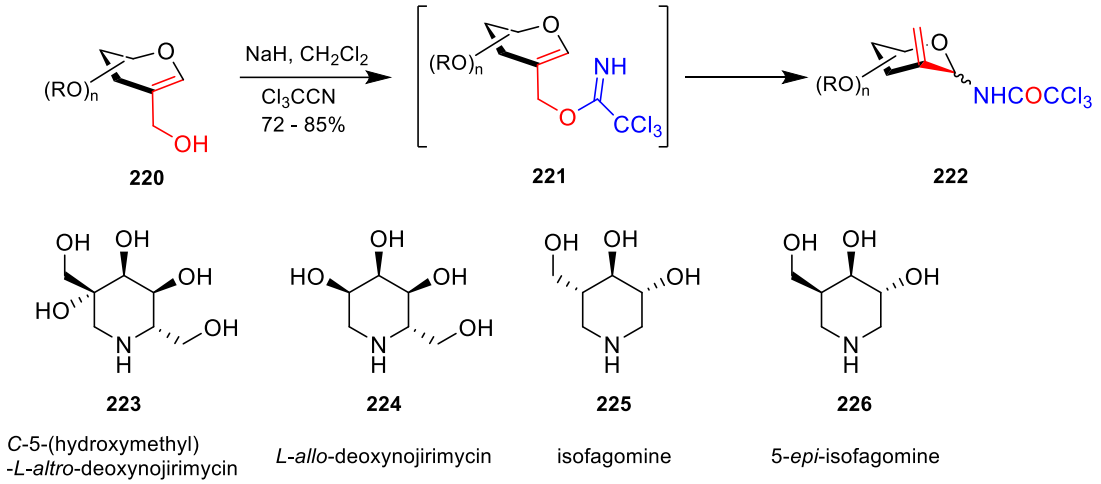
Ghosh and co-workers had extended the research in methodology by using $InCl_3$ and naphthol substrates to produce pyranonaphthopyrans such as **218** (Scheme 1.35),[125] after Balasubramanian report with $BF_3.OEt_2$, due to bezopyrans wide importance in natural products as the core structure. Later, Bhagavathy et. al had reported the synthesis of pyranopyran derivatives such as **219** by using phenolic derivatives and triflic acid in less time with good yield(Scheme 1.35).[126]



Scheme 1.35 Syntheses of chiral pyranopyrans from 2-*C*-hydroxymethyl-glycal.

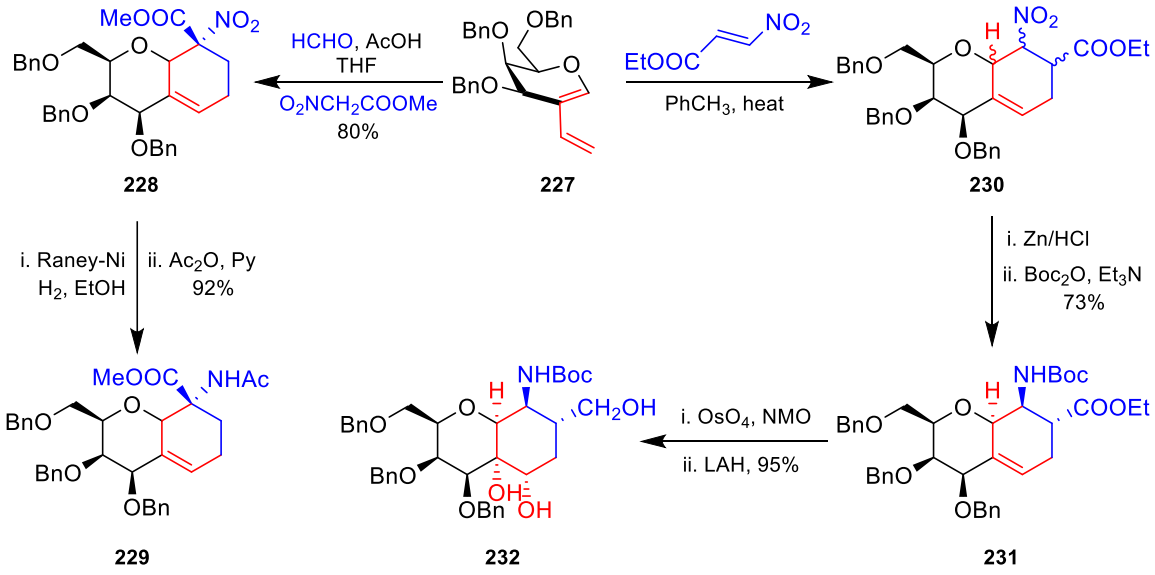
The wide range importance of azasugars as drugs and glycosidase inhibitors have been drawn the attention towards their synthesis. In this sinario, Vankar et. al had tried to obtain the trichloroacetamidates such as **221** by using 2-*C*-hydroxymethyl glycal derivative such as **220**. In this process interestingly, insitu aza-claisen rearrangement took place to obtain directly 2-*C*-methylene *N*-glycosides type **222** under the used same reaction condition for the synthesis of

trichloroacetamidates (Scheme 1.36). the same group of aza-sugars such as **223-226** had synthesised by using same methodology (Scheme 1.36).[127]



Scheme 1.36 Syntheses of aza-sugars by using aza-Claisen rearrangement.

C-glycosyl amino acids have been synthesised using Diels-alder reaction. Lukacs[128] and coworkers had reported the first Diels-Alder carbocyclic adducts with 2-*C*-branched derivatives.

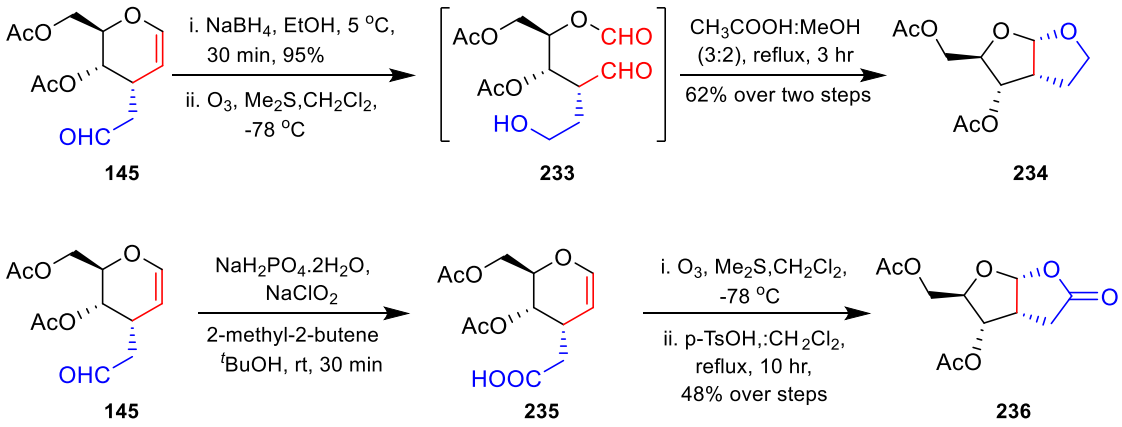


Scheme 1.37 Syntheses of *C*-glycosyl amino acids by Diels-Alder reaction.

Later, Y D Vakar and coworkers had applied the Diels-alder reaction condition with 2-*C*-vinylglycals to produce α and β-*C*-glycosyl amino acids of type **229** and **231** (Scheme 1.37), due to more advantages than the *O*-glycosides. These amino acid substrates are further transformed to the fully carbocyclic sugar hybrids such as **232** (Scheme 1.37).[129] few more important synthetic applications of 2-*C*-branched sugar derivatives had found in the syntheses of GABA analogs, isoxazoline analogs, chiral benzimidazoles derivatives, , heterocyclic compounds and natural products.[63]

1.6.2.3 Synthetic applications of 3 and 4-*C*-Branched glycals

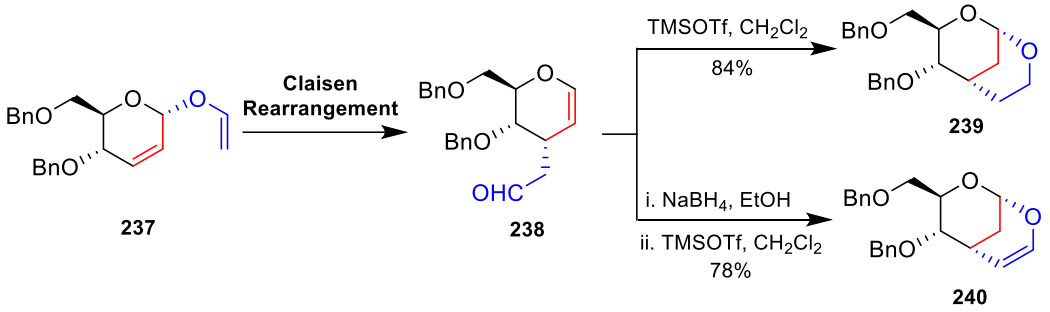
3-*C*-branched glycals are the less explored glycals due to the multistep protocols involved in their syntheses. Few straight synthetic applications of *C*-3 glycals were disclosed in detail from our research group. Our research group had reported few synthetic applications of 3-*C*-branched glycals, *cis* fused pehydrofuro[2,3,*b*]furanes of type **234** synthesized from 3-*C*-branched glycals such as **145**, aldehyde reduced to alcohol followed by ozonolysis and cyclization with CH_3COOH:MeOH, in good yield (Scheme 1.38). Also, *cis* fused pehydro-5-oxo-furo[2,3,*b*]-furanes such as **236** could be synthesised using *C*-3 glycals, 3-*C*-branched aldehyde **145**



Scheme 1.38 Synthesis of *cis*-fused perhydrofuro and 5-oxofuro[2, 3-*b*]furans from *C*-3 glycals.

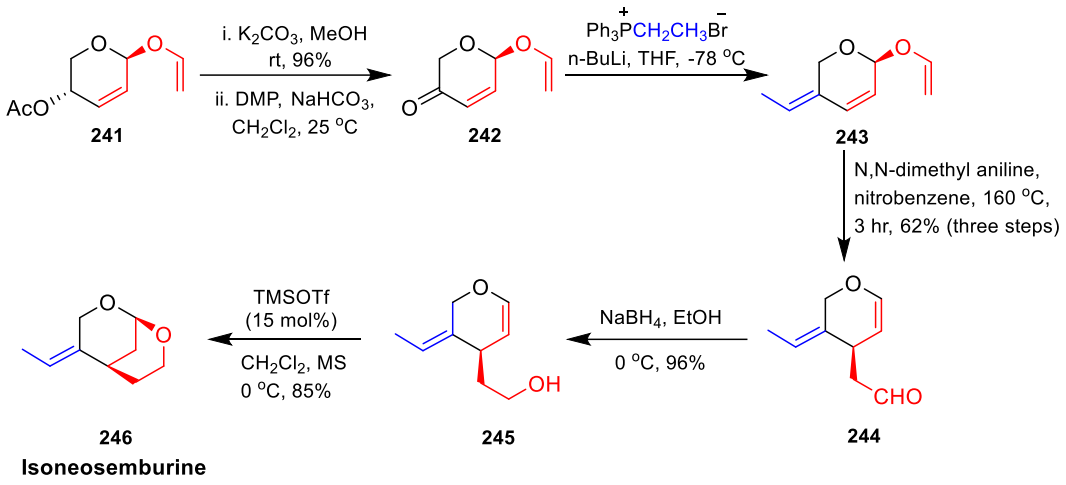
converted to acid by Pinnick oxidation, which further converted to pehydro-5-oxo-furo[2,3,*b*]furanes **236** using ozonolysis followed by cyclization with a cat. *p*-TsOH in a moderate yield (Scheme 1.38).[130]

Our research group had again reported the one more synthetic application of *C*-3 glycals to the synthesis of 2,8-dioxabicyclo[3,3,1]nonane derivatives of type **239** and **240**. It was obtained by trapping of oxonium ion intermediate in intramolecularly by silyl vinyl ethers, which formed by treatment of TMOTf, in good yield (Scheme 1.39).[131] On the other hand, bridged bicyclic acetals **240** were synthesized by treatment of TMSOTf to alcohols of 3-*C*-branched sugars, which were obtained by reduction of aldehyde such as **238** with a $NaBH_4$, in good yield (Scheme 1.39).[131]

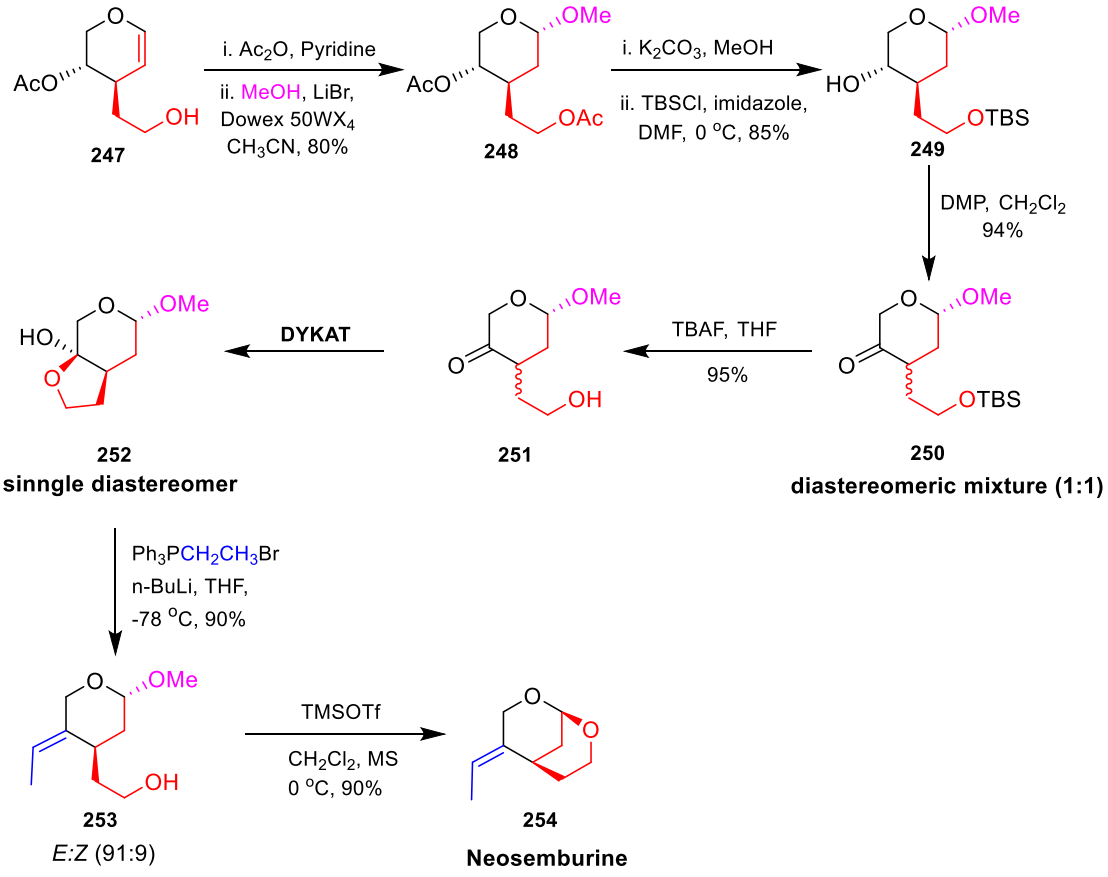


Scheme 1.39 Synthesis of 2,8-dioxabicyclo[3,3,1]nonane system from *C*-3 glycals

By using this mathodology, the same research group had reported the total synthesis of Isoneosemburine **246** and neosemburine from allyl vinyl ether via a 3-C-branched glycal derivative. Allyl vinyl ether **241** were deacetylated, then oxidation and olefination by using DMP and Wittig reagent in sequence. Later converted to 3-*C*-aldehyde **244** by Claisen rearrangement reaction conditions. Finally, isoneosemburine **246** obtained from aldehyde **244** by $NaBH_4$ reduction and TMSOTf catalyzed Acetylysation, in a better yield (Scheme 1.40).[131]



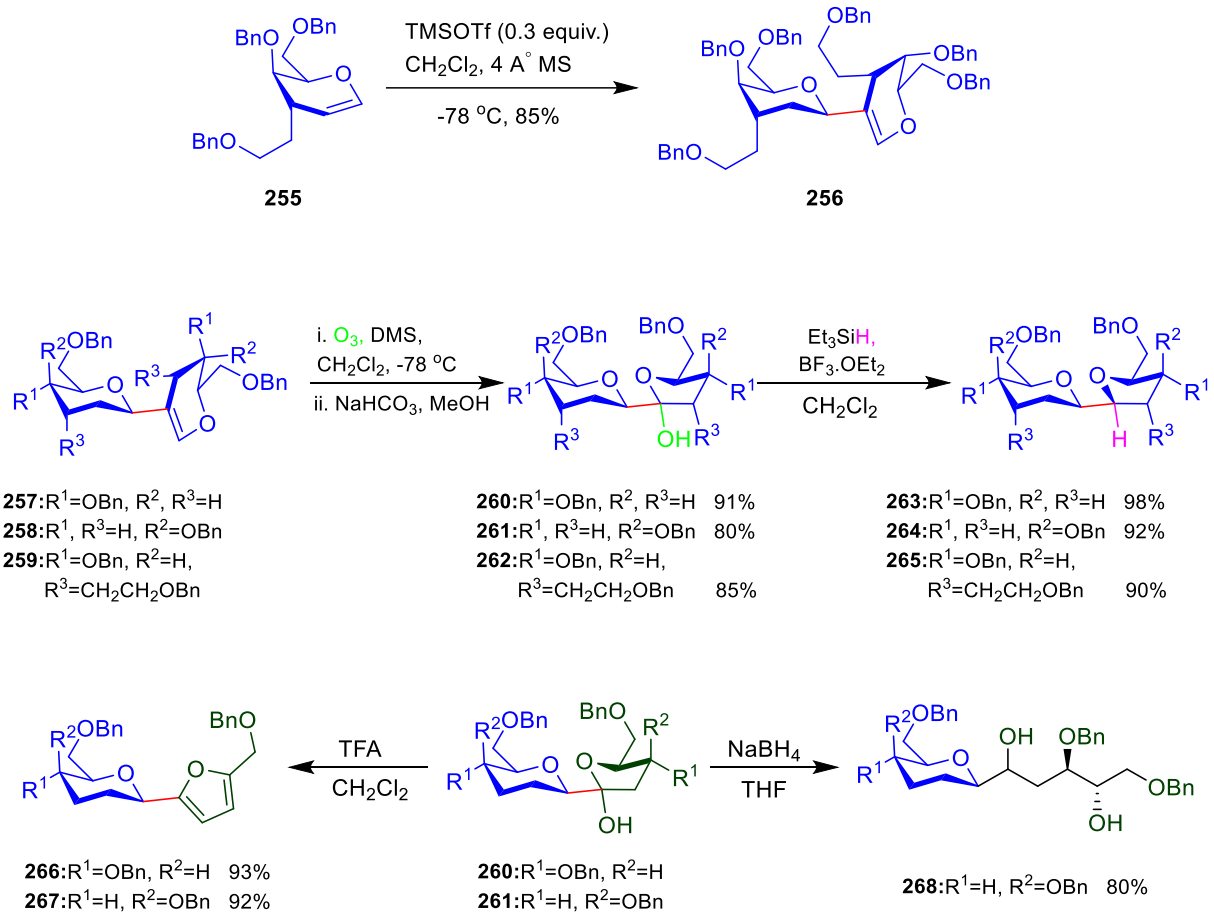
Scheme 1.40 Synthesis of isoneosemburine from 3-*C*- branched glycal.



Scheme 1.41 Synthesis of Neosemburine from 3-*C*- branched glycal.

On the other hand, neosemburine was synthesised from δ-hydroxy ketone 27, through dynamic kinetic asymmetric transformation, Wittig olefination and TMSOTf catalytic acetalysation, which could be synthesised from 3-*C*-branched alcohol 5 by acetylation, acetalysation with methanol, selective TBS protection of 1° alcohol, oxidation of 2° alcohol to ketone and TBS deprotection with TBAF, in good yield (Scheme 1.41).[131]

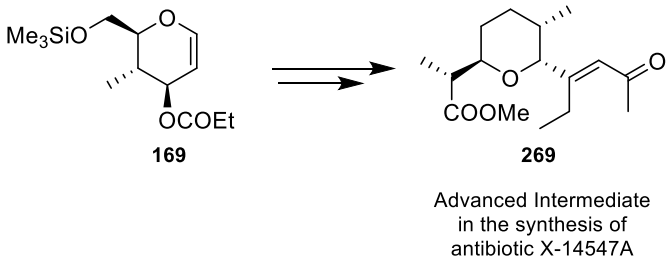
Recently, Sridhar et al.[132] reported a stereoselective synthesis of β-*C*-disaccharides of type **256** from the 3-*C*-branched and 3-deoxy glycals such as **255** by treatment of TMSOTf, in good to better yield (Scheme 1.42). The resulted β-*C*-disaccharides **257-259** converted into hemiketals of



Scheme 1.42 Synthesis and applications of β-*C*-disaccharides using *C*-3 glycals.

type **260-262** by ozonolysis and deformylation. β-*C*-disaccharide derived adjacent THP-THF ring systems such as **263-265** were obtained by treating with triethyl silane in the presence of $BF_3.OEt_2$. The natural product mucosine possesses the same framework (Scheme 1.42). Later, β-*C*-glycosyl furans **266** and **267** had been synthesised by using trifluoroacetic acid, and β-*C*-glycosides such as **268** had also been sythesised with $NaBH_4$ from the corresponding hemiacetals formed from β-*C*-disaccharides (Scheme 1.42).

Similarly, 4-*C*-branched glycals are also found as the intermediates in the syntheses of natural products and one such example is given below (Scheme 1.42).[78, 79c, 133]

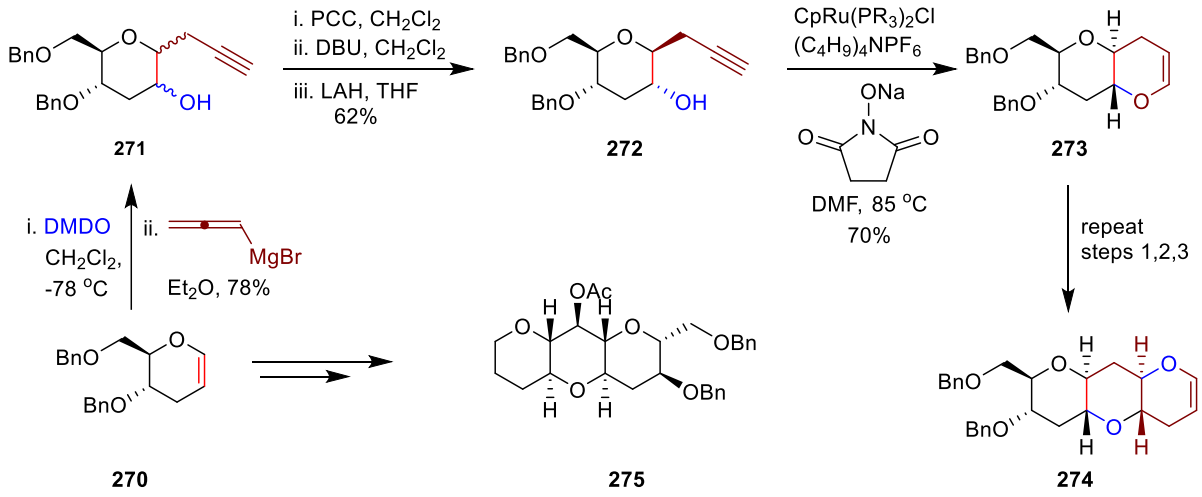


Scheme 1.42 4-*C*-branched glycal in the syntheses of natural products.

1.6.3 Few synthetic applications of deoxy glycals

Deoxy sugars are observed in several natural products usually in toxins called ladder toxins, because of their structure, generated majorly by marine organisms.[134] In this context, deoxy glycals are plenteous starting material in their syntheses.

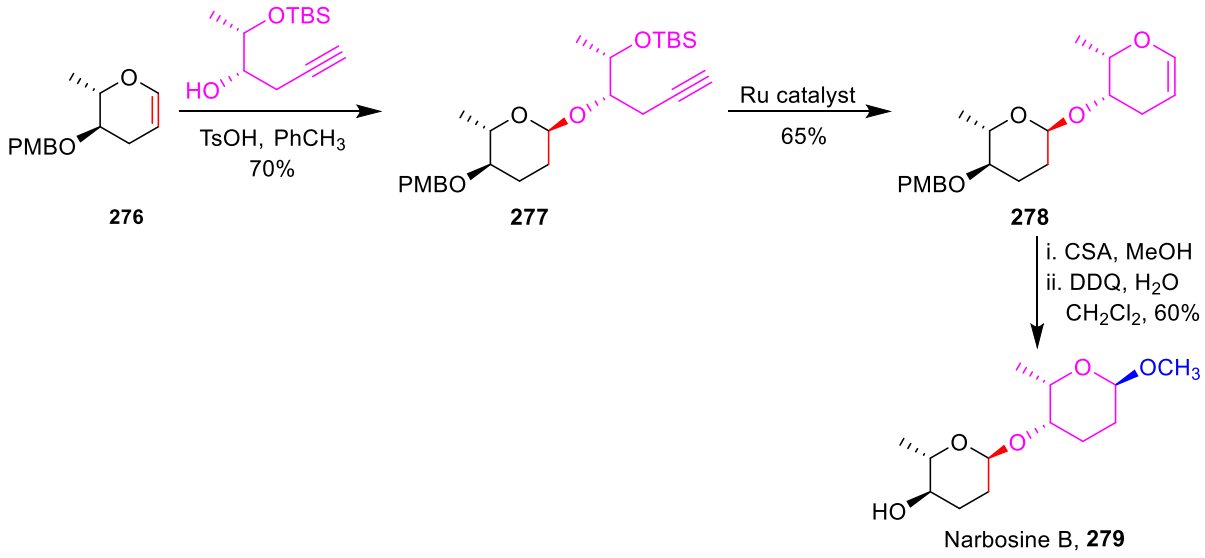
Torst had proposed an iterative procedure for the syntheses of *trans*-fused polycyclic tetrahydro-pyrans by using 3-deoxy glycals to synthesis the ring skeletons of prymnesin and yossotoxin. Firstly, The 3-deoxy glucal **270** was transformed to propargylic alcohol such as **271**, then the stereochemistry at *C*-2 hydroxyl group was later inverted using a series of reagents PCC, DBU and LAH in sequence. Using Ruthenium catalysis, the propargyl glycoside **272** was transformed to the bicyclic-dihydropyran derivative **273**. They had successfully converted the compound **273** to tricyclic tetrahydropyaran derivative **274** (Scheme 1.43),[135] which was utilized for the synthesis of biologically active molecules. Later days, Oguri had reported the same kind of tricyclic ether of type **275** by using samarium iodide catalyzed coupling reaction (Scheme 1.43).[136]



Scheme 1.43 3-deoxy-glucal based iterative approach to polycyclic tetrahydropyrans.

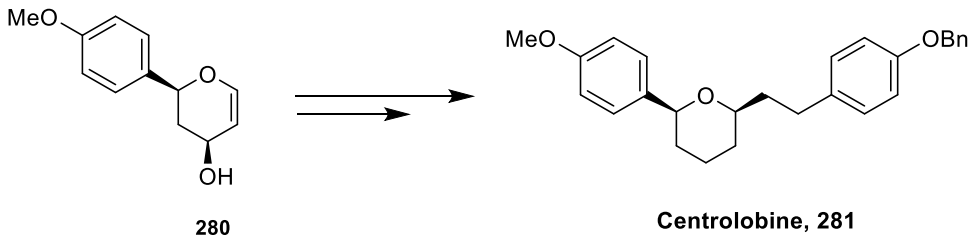
2,3-dideoxy-*O*-glycosides are found in various glycosidase inhibitors as most vital *O*-glycosidic skeletons and 3-deoxy-glucals provide as the sugar platform to construct such *O*-glycosides.[91] Trost and coworkers constructed narbosine **279** (Scheme 1.44) by employing ruthenium mediated

cyclo isomerization as an important step from the deoxy glycal **276.**[137] Along with all these reports, 3-deoxy glycals provided as starting-materials in the synthesis of several natural products.



Scheme 1.44 Syntheses of O-glycoside from 3-deoxy-glucal.

Similarly, 4-deoxy-glycals also are utilized as starting material in the syntheses of various natural compounds. Such an example is the syntheses of centrolobine **281** by using 4-deoxy-glycal which shown below (Scheme 1.45).[138]



Scheme 1.45 Syntheses of centrolobine from 4-deoxy-glucal.

1.7 Motivation for the work presented in the thesis

With these confined reports of literature accessible over the simple-glycals, Carbon-branched glycals, and deoxy glycals, we were attracted more towards the 3-*C*-branched-glycals because of they possess undermined status among the all-carbon branchedglycals. We strongly trusted the 3-*C*-branched skeleton can be used to obtain the significant skeletons possessing biological and medicinal applications or can be involved in the syntheses of natural products. In the next chapters of this thesis, we have reported the reasonable work to explore the synthesis of 3-*C*-branched glycals, their direct synthetic applications, and the synthetic application of deoxy glycals from the different sugars available.

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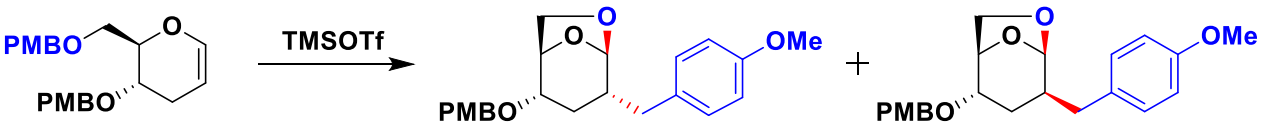
Chapter-2

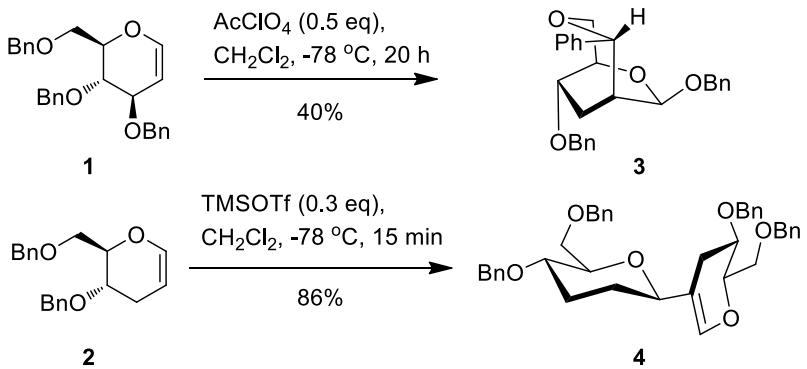
Synthesis of Carbon-Branched Sugars Involving an Unprecedented 1,5- or 1,6-Alkyl Trasposition Reaction



2.1 Introduction

The structural reorganizational "shifts" in carbocation intermediates has received immense importance in the development of novel methodologies and innovative protocols for the total synthesis of several natural products.[1] The study of such intermediates form the basis of fundamental and practical chemistry.[2] A couple of named reactions have been evolved based on the skeletal reorganization of this reactive species.[3] In this context, the oxocarbenium ion rearrangement reactions in carbohydrate derivatives have been immensely studied for a long time.[4] By virtue of the presence of the *endo*cyclic oxygen in these substrates stabilize the carbocation at the anomeric position by forming the oxocarbenium ion.[5] Glycals, the 1,2-unsaturated cyclic sugar derivatives, have been one of the primary sources for the generation of oxocarbenium ion, in the presence of an acid catalyst, to study various glycosylation reactions.[6] Appropriately functionalized glycals undergo rearrangement reactions in the presence of a Lewis acid catalyst.[7] Apart from the Ferrier type rearrangement of glycals, dimerization of glycals[8] and Gin's[9] hypervalent iodine mediated oxidative ring contraction of 6-deoxy-gulal are noteworthy. Recently, Steel *et al*. showed that 3,4,6-tri-*O*-benzyl D-glucal **1** in the presence of catalytic amount of acetyl perchlorate converts into a bicyclic acetal **3** through an unusual 1,7-hydrogen shift.[10] While carrying out this transformation using 3-deoxy 4,6-di-*O*-benzyl glycal **2** we have observed a stereoselective dimerization reaction which led to the formation of 2-(β-*C*-glycosyl)-glycal **4**[11] (Scheme 2.1).

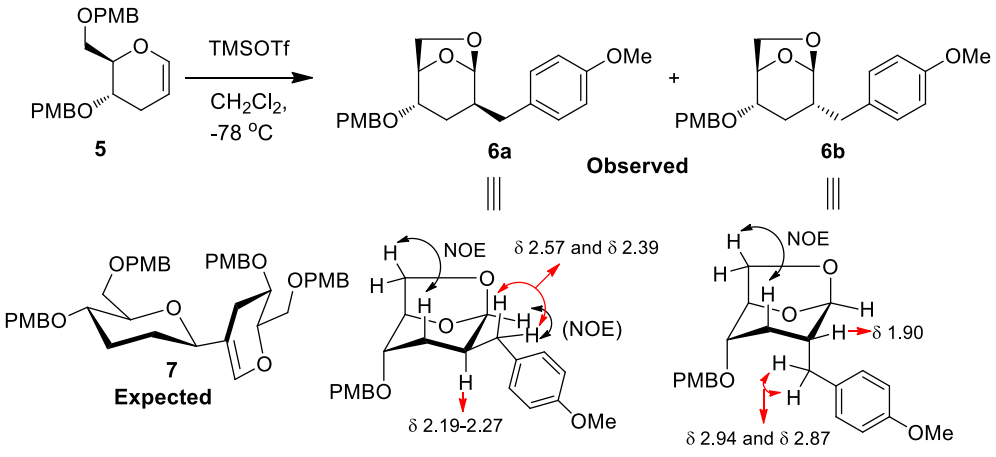
Scheme 2.1 Lewis acid catalysed 1,7-hydrogen shift and glycal dimerization reactions.



This typical reactivity of 3-deoxy glycals under Lewis acid conditions prompted us to investigate further on the fate of oxocarbenium ion generated using these scaffolds. Thus, herein we report an unusual 1,6 or 1,5 alkyl transposition reaction of 3-deoxy glycals providing carbon branched 1,6-anhydrosugar derivatives.

2.2 Results and Discussion

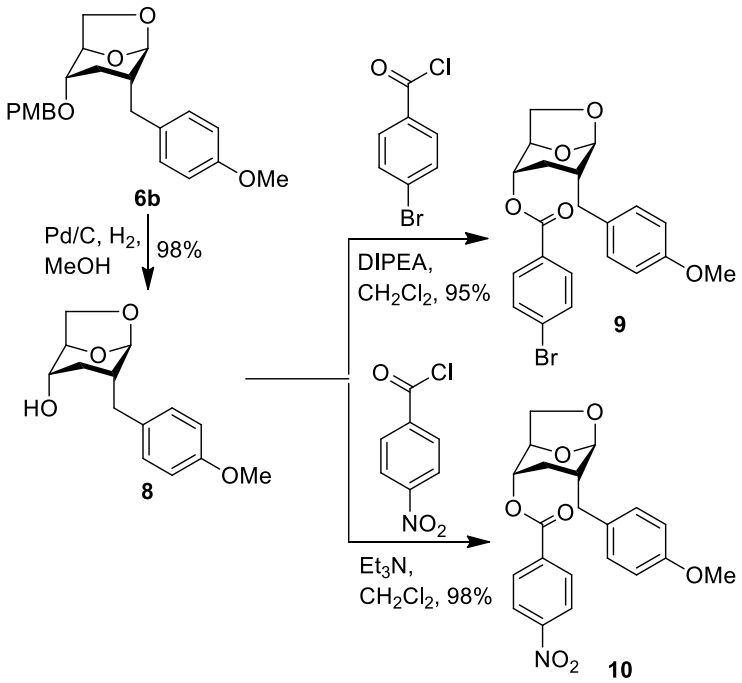
On To study the influence of the protecting groups in the *C*-disaccharide formation using 3-deoxy glycals, we have attempted to carry out the dimerization reaction of 3-deoxy 4,6-di-*O*-(*p*-methoxybenzyl) glucal **5**. However, to our surprise, glycal **5** upon treatment with TMSOTf (0.1 eq) at -78 ^{o}C in dichloromethane did not provided the expected dimer **7**. Instead, the major product was found to be the 1,6-anhydro 2-*C*-branched levoglucosan derivatives **6a** and **6b**. The structure and stereochemistry of the products were fully established by ^{1}H, ^{13}C, COSY and NOESY NMR experiments (Scheme 2). In the proton NMR spectra of **6a** the axial hydrogen at C2 position appeared as a multiplet at δ2.19-2.27 whereas in compound **6b** the equatorial hydrogen at C2 appeared at δ1.90. This is apparent due to the 1,3-diaxial interactions of the axial oxygen at C4 which deshield the C2 axial hydrogen to a lower δ value in **6a**. Similarly, the protons on the benzyl carbon at C2 in compound **6a** appeared δ 2.39 and δ 2.57 whereas in **6b** they have δ 2.87 and δ 2.94.



Scheme 2.2. An unprecedented 1,6-alkyl shift in 3-deoxy glucal derivative

This again provide the ample evidence for the assigned stereochemistry at the C2 position for compound **6a** and **6b** (Scheme 2).

However, in view of obtaining the crystal structure various methods to crystalize either compound **6a** or **6b** were unsuccessful. Then, we planned to synthesize derivatives of the compounds **6a** or **6b** expecting to get a crystal. Towards this, compound **6b** was subjected to the hydrogenolysis to get alcohol **8** which was esterified with 4-bromobenzoyl chloride and 4-nitrobenzoyl chloride1 to give the benzoate derivatives **9** and **10**, respectively (Scheme 3). To our fortune, compound **9** was found to be a solid and we were able to crystalize this using ethylacetae and hexane. The ORTEP diagram of ester **9** is provided in the figure 1.[12]



Scheme 2.3. Synthesis of the derivatives of compound **6b**.

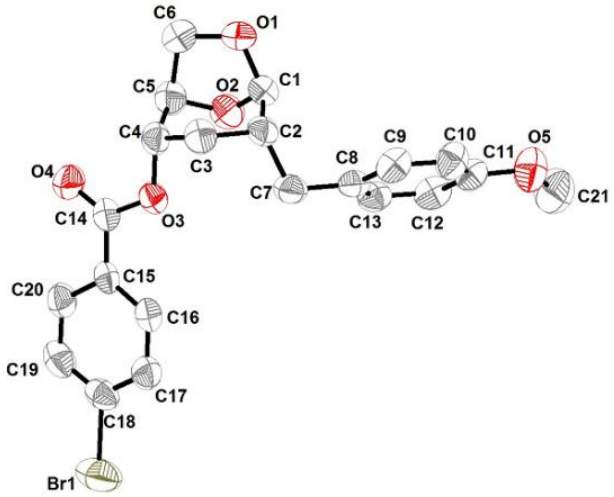
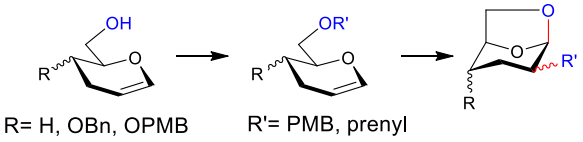
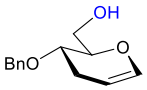
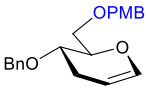
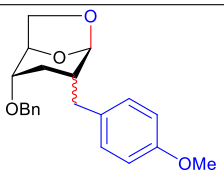
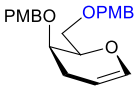
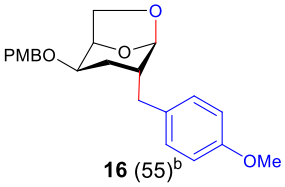
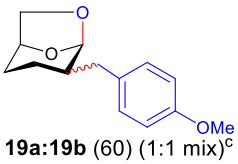
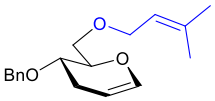
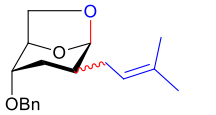
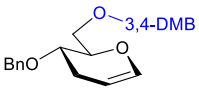
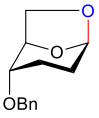
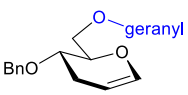
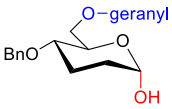
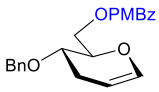
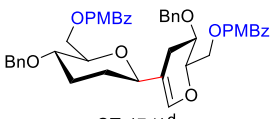


Figure 2.1. The ORTEP diagram of compound **9**.[12]

The unprecedented formation of the C2-branched bicyclic acetals **6a** and **6b** and the importance of levoglucosan (1,6-anhydrosugar) derivatives in the total synthesis of natural products made us curious to study the generality of various orthogonally protected 3-deoxy glycal derivatives. Thus, 3-deoxy 4-*O*-benzyl 6-*O*-(*p*-methoxybenzyl) glucal **12**[13] was synthesized from 3-deoxy 4-*O*-benzyl glucal **11**[14] and subjected to TMSOTf (0.1 eq) at -78 ^{o}C. Interestingly, this reaction also provided the 2-*C*- branched levoglucosans **13a** and **13b**, as 1:1 mixture of diastereomers and no isolable amount of the corresponding 2-(β-*C*-glycosyl)-glycal derivative was observed. Application of the similar method on 3-deoxygalactal derivative **15**, synthesized from **14**, provided the corresponding 1,6-anhydro 2-(*p*-methoxybenzyl) 3-deoxy galactose derivative **16** as a single diastereomer in moderate yield (Table 1, entry 2). Interestingly, 6-*O*-(*p*-methoxybenzyl)-3,4-dideoxy glucal **18**,[15] obtained by the *p*-methoxybenzylation of **17**,[16] upon treating with TMSOTf provided a 1:1 diastereomeric mixture of 2-*C*-branched levoglucosan derivatives **19a** and **19b** via an unprecedented 1,6-migration of the *p*-methoxybenzyl (PMB) group. We assumed that the possible reason for the migration of the PMB group from C6-oxygen to the C2 might be due to its higher carbocation stabilization than the unsubstituted benzyl group.

Table 2.1. Synthesis of 2-*C*-branched levoglycosan derivatives by 1,6-alkyl transposition.



Entry	3-deoxy glycal	Fully protected 3-deoxyglycals (%)[a]	6,8-dioxabicyclo[3.2.1] octane (%)[a]
1	 **11**	 **12** (95)	 **13a:13b** (90) (1:1 mix)[b]
2	 **14**	 **15** (98)	 **16** (55)[b]
3	 **17**	 **18** (95)	 **19a:19b** (60) (1:1 mix)[c]
4	**11**	 **20**(80)	 **21a:21b** (50) (1:1 mix)[b,c]
5	**11**	 **22**(80)	 **23** (50)
6	**11**	 **24**(90)	 **25** (52)[c]
7	**11**	 **26** (85)	 **27** (51)[d]

[a] Yield refers to pure and isolated products. [b] the major byproduct was found to be the corresponding 2-(4-alkyloxy)6,8-dioxabicyclo[3.2.1] octane derivative. [c] the diasteriomericratio was calculated based on the ^{1}H NMR spectra of crude product. [d] the stereochemistry at the anomeric position was assigned based on ^{1}H-^{1}H NOESY experiment.

Keeping this in mind, we further investigated the alkyl groups which could stabilize the carbocation. In this process, we have chosen to use the prenyl group in place of PMB. Thus, prenylation of glucal **11** provided the 3-deoxy 6-*O*-prenyl glucal derivative **20**, and it was

subjected to the acid catalyzed 1,6-migration reaction. To our delight, under the similar reaction conditions, prenyl group underwent the 1,6-migration and provided the 2-*C*-prenyl levoglucosan derivatives **21a** and **21b** in 50% yield. To evaluate the feasibility of dimethoxy substituted benzyl migration the C-6 position of the glycal **11** was alkylated with 3,4-dimethoxy benzyl bromide to give compound **22** and subjected to catalytic TMSOTf at -78 ^{o}C. However, this reaction did not yield the expected 2-*C*-branched glycal. Instead, the reaction provided only the 2,3-dideoxy levoglucosan derivative **23**. Later, a C-6 geranylated glycal **24** was synthesized and subjected to the migration reaction conditions. Surprisingly, it was found that the geranyl group was very stable under the reaction conditions and no reaction was observed at -78 ^{o}C. When the reaction mixture was allowed to 0 ^{o}C, hydration of the glycal was observed and the product **25** was isolated in 52% yield. These results suggest that only some typical carbocation stabilizing groups could be allowed to this novel unprecendented migration reaction. Further, to investigate the migratory aptitude of the *p*-methoxybenzoyl group, 3-deoxy 4-*O*-benzyl 6-*O*-benzoyl glucal **26** was synthesized by *p*-methoxybenzoylation of **11**, and subjected to TMSOTf. However, the reaction provided the 2-(β-*C*-glycosyl)-glycal derivative **27** as the only isolable product in 51% yield (Table 1, entry 7).

Based on the product formation, a possible mechanism is proposed for the formation of the 2-*C*-branched levoglucosan derivative. Accordingly, glycal **5** upon reaction with TMSOTf might form the corresponding oxo-carbenium ion intermediate **5a**. This oxocarbenium ion can further undergo deprotonation to give the 2-trimethylsilyl glycal derivative **5b** and triflic acid. On the other hand, intermediate **5a** can have the resonance structure **5c** by the participation of the lone pair of electrons present on the C6-oxygen which further will have the extended resonance structures **5d** and **5e**. Finally, regeneration of the catalyst, TMSOTf, by reaction of the triflate anion on to the trimethylsilyl group which could help in the formation of a new C-C bond between C2 and the *p*-methoxybenzyl carbon will lead to the formation of the 1,6-migrated products **6a** and **6b** (Figure 2).

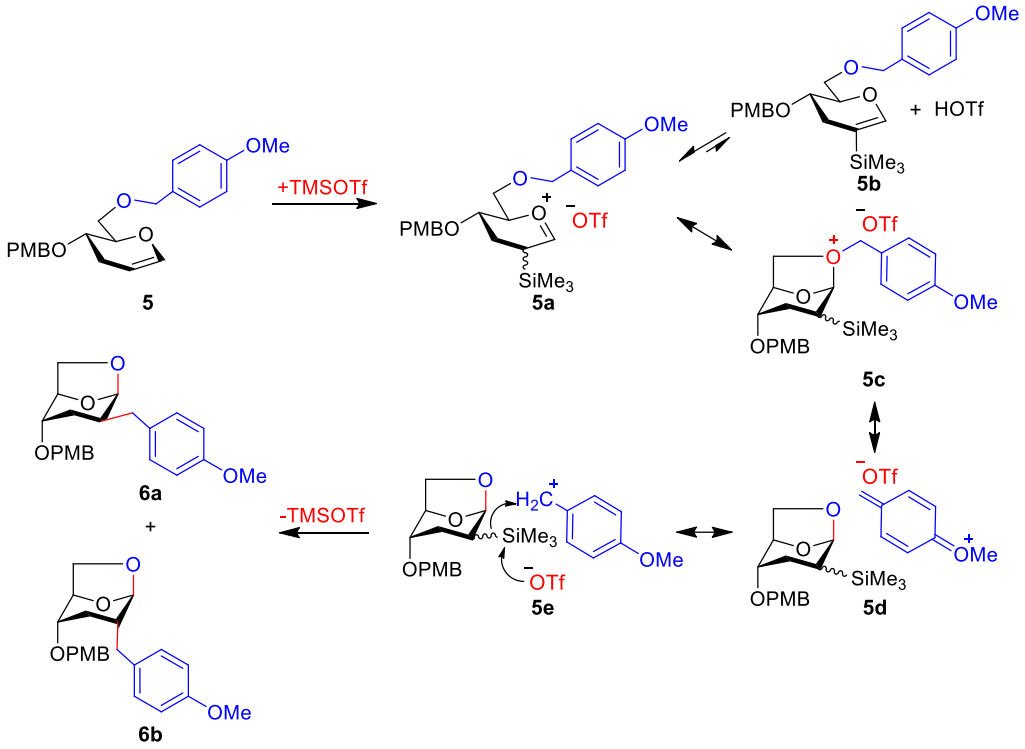
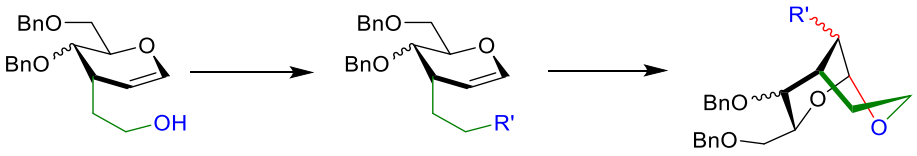
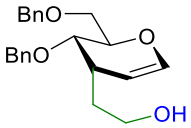
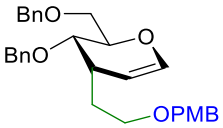
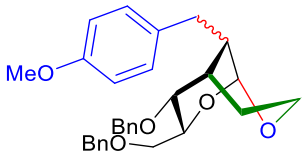
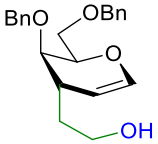
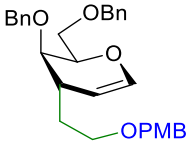
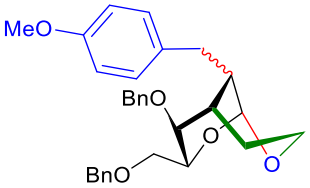
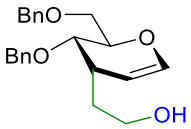
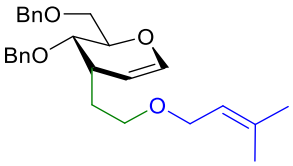
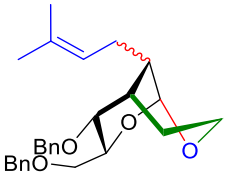
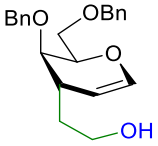
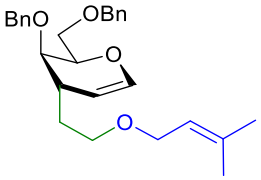
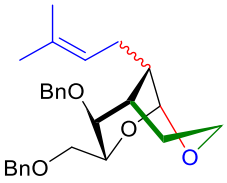
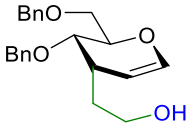
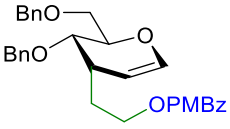
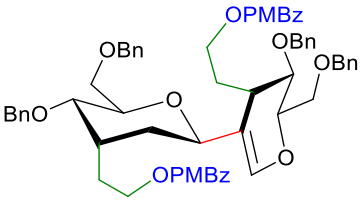


Figure 2.2. Proposed mechanism for the 1,6-alkyl transposition reaction; synthesis of 2-*C*-branched levoglycosan derivatives.

Having synthesized, a series of 2-*C*-branched levoglycosan derivatives involving 1,6-transposition reaction, we focused our attention on incorporating the *p*-methoxy benzyl or prenyl group on another oxygen atom, apart from the C6 position. Thus, *p*-methoxy benzyl protected 3-deoxy 3-*C*-branched glycal **29** was synthesized from glycal **28**[17] and subjected to TMSOTf mediated 1,6-transposition reaction. Interestingly, this reaction also proceeded smoothly and gave the expected 2,3-dideoxy carbon-branched bicyclic acetal **30** as a 1:1 mixture of diastereomers in 60% yield (Table 2, entry 1). Extending the methodology to other PMB protected 3-*C*-branched galactal derivative **32**, synthesized from **31**, also led to the formation of the 1,5-alkyl migrated carbon-branched bicyclic acetal **33** (table 2, entry 2). Further, we proceeded to investigate the generality of this 1,5- alkyl transposition reaction using prenyl protected 3-*C*-branched glycals. Thus, the hydroxyl group in 3-*C*-branched glycals **28** and **31** were treated with prenyl bromide in the presence of NaH in THF to obtain prenyl ether containing 3-*C*-branched glycals **34** and **36**. Subjecting these glycals to TMSOTf

Table 2. Synthesis of 2,3-dideoxy 2- and 3-*C*-branched bicyclic acetal derivatives by 1,5-alkyl transposition reaction.



Entry	3-*C*-Branched alcohol	Protected-3-*C*-Branched glycal (%)[a]	2,8-dioxabicyclo[3.3.1] nonane derivative (%)[a]
1	 **28**	 **29** (96)	 **30a:30b** (60) (1:1)[b,c]
2	 **31**	 **32** (95)	 **33a:33b** (50) (1:1)[b,c]
3	 **28**	 **34** (95)	 **35a:35b** (50) (1:1)[b,c]
4	 **31**	 **36** (95)	 **37a:37b** (50) (1:1)[b,c]
5	 **28**	 **38** (70)	 **39** (80)[d]

[a] Yield refers to pure and isolated products. [b] the diasteriomeric ratio was calculated based on the ^{1}H NMR spectra of crude product. [c] the major byproduct was found to be the corresponding 4-(benzyloxy)-3-((benzyloxy)methyl)-2,8-dioxabicyclo[3.3.1]nona ne derivative. [d] the stereochemistry at the anomeric position was assigned based on ^{1}H-^{1}H NOESY experiment.

at -78 ^{o}C provided the 2-*C*-prenyl substituted 3-*C*-branched bicyclic acetals **35** and **37**, respectively, as a 1:1 mixture of diastereomers. However, 1,5-alkyl transposition of the *p*-

methoxybenzoyl group in glycal derivative **38** was again unsuccessful. Instead, this reaction provided the *C*-disaccharide **39** as a single diastereomer (table 2, entry 5).

2.3 Conclusions

In conclusion, we have reported an unprecedented 1,5- and 1,6-alkyl transposition reaction of 3-deoxy glycals. The methodology provides access to the synthesis of various 2-*C*-branched levoglycosan derivatives as well as 2,8-dioxabicyclo[3.3.1]nonane systems. To the best of knowledge, this is the first of its kind in the literature. The application of the developed methodology in the total synthesis of natural products and novel sugar derived scaffolds is in progress.

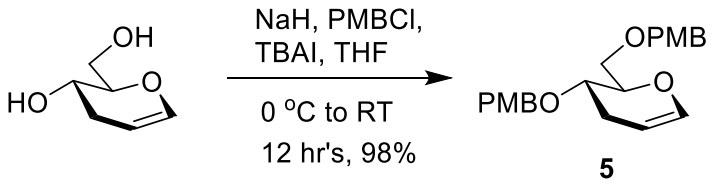
2.4 Experimental Section

2.4.1 General Methods

All the reactions were carried out under nitrogen or argon atmosphere and monitored by thin layer chromatography (TLC) using silica gel GF_{254} plates with detection by charring with 5% (v/v) H_2SO_4 in methanol or by phosphomolybdic acid (PMA) stain or by ultra violet (UV) detection. All the chemicals were purchased from local suppliers and Sigma-Aldrich Chemicals Company. Solvents used in the reactions were distilled over dehydrated agents. Silica-gel (100-200 mesh) was used for column chromatography. ^{1}H, ^{13}C, DEPT, COSY, NOESY spectra were recorded on Bruker 400 MHz and 500 MHz spectrometer in $CDCl_3$. ^{1}H NMR chemical shifts were reported in ppm (δ) with TMS as internal standard (δ 0.00) and ^{13}C NMR were reported in chemical shifts with solvent reference ($CDCl_3$, δ 77.00). High resolution mass spectra (HRMS) were obtained in the ESI mode.

2.4.2 Experimental procedures and spectral data

2.1 (2*R*,3*S*)-3-((4-methoxybenzyl)oxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2*H*-pyran (5)



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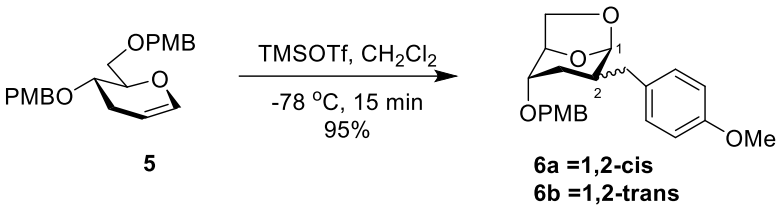
A stirred solution of 3-deoxy D-glucal (1.7 g, 13.0 mmol) in anhydrous THF (20 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 1.56 g, 39.0 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (5.12 g, 32.67 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2R,3S)-3-((4-methoxybenzyl)oxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2H-pyran **5** (4.94 g) in 98% yield. R_f: 0.8 (20% EtOAc/hexanes). $[\alpha]_D^{25}$ 70.2 (*c* 1.0, $CHCl_3$); IR (neat): 3070, 2992, 2910, 2863, 1653, 1612, 1513 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.30 (d, 2H, *J* = 8.5 Hz), 7.20 (d, 2H, *J* = 8.5 Hz), 6.89 (d, 2H, *J* = 8.5 Hz), 6.87 (d, 2H, *J* = 8.5 Hz), 6.38 (dt, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 4.64-4.66 (m, 1H), 4.59 (d, 1H, *J* = 12.0 Hz), 4.58 (d, 1H, *J* = 11.0 Hz), 4.53 (d, 1H, *J* = 11.5 Hz), 4.46 (d, 1H, *J* = 11.0 Hz), 3.88-3.91 (m, 1H), 3.82 (s, 3H), 3.81 (s, 3H), 3.76-3.79 (m, 3H), 2.35-2.41 (m, 1H), 2.08 (ddt, 1H, *J* = 2.5 Hz, *J* = 8.5 Hz, *J* = 16.5 Hz. **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.13, 159.11, 143.01, 130.21, 130.11, 129.41, 129.26, 113.68, 113.66, 97.58, 76.71,

73.08, 70.70, 70.03, 68.54, 55.17, 55.16, 26.52. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5$+NH_4 388.2124, found 388.2124.

2.2 (1*R*,2*S*,4*S*,5*R*)-4-(4-methoxybenzyl)-2-((4-methoxybenzyl)oxy)-6,8-dioxabicyclo[3. 2.1] octane(6a); (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-2-((4-methoxybenzyl)oxy)-6,8-dioxabicyclo [3.2.1]octane (6b)



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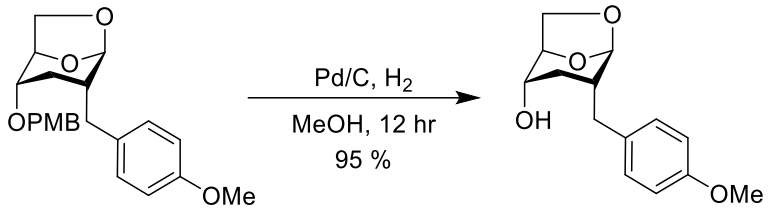
6a =1,2-cis
6b =1,2-trans

A stirred solution of compound **5** (700 mg, 1.9 mmol) in dry dichloromethane (20 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (34 µL, 0.19 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~60 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (20 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the mixture of 2-*C*-branced levoglucosan derivatives **6a** and **6b** (1:1) (666 mg) as a colorless gum in 95% yield. R_f: 0.75 (20% EtOAc/hexanes). **6a:** IR (neat): 2934, 2892, 2835, 1610, 1509 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.27 (d, 2H, *J* = 8.4 Hz), 7.08 (d, 2H, *J* = 8.8 Hz), 6.88 (d, 2H, *J* = 8.8 Hz), 6.83 (d, 2H, *J* = 8.4 Hz), 5.26 (s, 1H), 4.56-4.58 (m, 1H), 4.50-4.54 (m, 2H), 3.82 (s, 3H), 3.81 (s, 3H), 3.77-3.79 (m, 1H), 3.71-3.73 (m, 1H), 3.35-3.36 (m, 1H), 2.57 (dd, 1H, *J* = 8.0 Hz, *J* = 13.6 Hz), 2.39 (dd, 1H, *J* = 6.8 Hz, *J* = 13.6 Hz), 2.19-2.27 (m, 1H), 1.74-1.79 (m, 1H), 1.44-1.49 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 159.19, 157.90, 131.07, 130.23, 129.90, 129.22, 113.79, 113.75, 103.36, 74.58, 72.58, 70.07, 66.41, 55.25, 55.21, 39.12, 37.30, 27.64. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5$+Na^+ 393.1672, found 393.1672. **6b:** $[\alpha]_D^{25}$ -50.4 (*c* 0.63, $CHCl_3$); IR (neat): 2956, 2920, 2853, 1608, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.33 (d, 2H, *J* = 8.8 Hz), 7.14 (d, 2H, *J* = 8.8 Hz), 6.91 (d, 2H, *J* = 8.8 Hz), 6.84 (d, 2H, *J* = 8.8 Hz), 5.37 (s, 1H), 4.61-4.64 (m, 2H), 4.54 (d, 1H, *J* = 12.0 Hz), 3.83 (s, 3H), 3.80 (s, 3H), 3.75-3.79 (m, 2H), 3.32-3.33 (m, 1H), 2.94 (dd, 1H, *J* = 7.2 Hz, *J* = 13.6 Hz), 2.87 (dd, 1H, *J* = 9.2 Hz, *J* = 14.0 Hz), 1.90 (dd, 1H, *J* = 7.6 Hz, *J* = 15.6 Hz), 1.78-1.84 (m, 1H), 1.67 (d, 1H, *J* = 14.8

Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 159.18, 157.84, 132.76, 130.46, 130.16, 129.05, 113.83, 113.74, 104.09, 75.33, 73.17, 70.12, 66.03, 55.28, 55.24, 40.48, 36.40, 23.17. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5$+Na^+ 393.1672, found 393.1671.

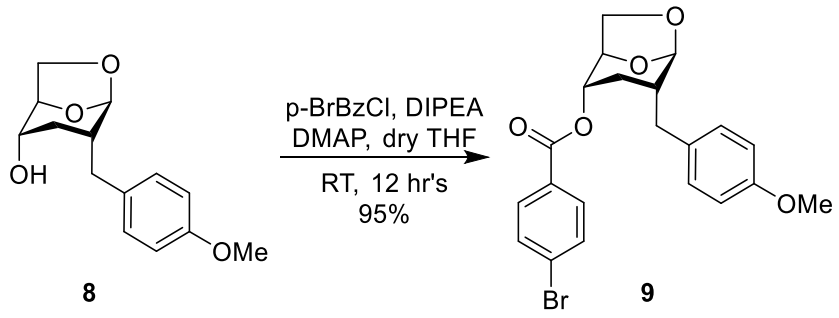
2.3 (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-ol (8)



6b **8**

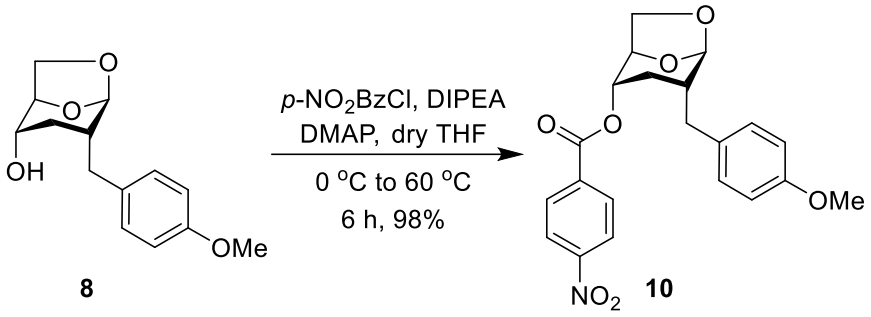
A stirred solution of compound **6b** (200 mg, 0.27 mmol) in dry methanol (10 mL) under inert atmosphere was added Pd/C (10 mol %) at RT. The reaction mixture was degasified followed by purged hydrogen gas and continued stirring at the same temperature under hydrogen atmosphere for 12 hrs. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with methanol (5 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the pure (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-ol **8** (128 mg) in 95% yield. R_f: 0.35 (50% EtOAc/hexanes). IR (neat): 3407, 2926, 1652, 1610, 1582, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.15 (d, 2H, *J* = 4.4 Hz), 6.85 (d, 2H, *J* = 8.4 Hz), 5.36 (s, 1H), 4.53 (d, 1H, *J* = 1.8 Hz), 3.83 (m, 2H), 3.80 (s, 3H), 3.70 (s,1H), 2.91(dd, 1H, *J* = 7.2 Hz, *J* = 13.6 Hz), 2.79 (dd, 1H, *J* = 8.4 Hz, *J* = 13.6 Hz), 2.19 (bs, 1H), 1.88-1.98 (m, 2H), 1.59 (d, 1H, *J* = 13.2 Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 157.89, 132.01, 130.05, 113.79, 103.99, 77.65, 67.59, 65.95, 55.21, 40.34, 37.45, 26.67. **HRMS (ESI)** calcd for $C_{14}H_{18}O_4$+Na^+ 273.1097, found 273.1092.

2.4 (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-yl 4-bromoben - zoate (9)



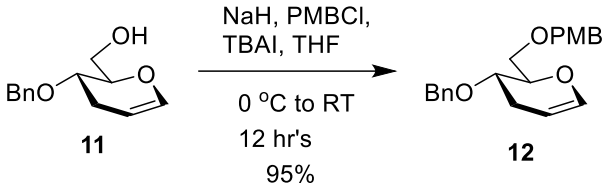
To a solution of **8** (60 mg, 0.24 mmol) in anhydrous tetrahydrofuran (1 mL) cooled at 0 ^{o}C were added N,N-diisopropylethylamine (100 μL, 0.574 mmol) and 4-(dimethylamino)pyridine (12 mg, 0.1 mmol) followed by p-bromobenzoyl chloride (94 mg, 0.48 mmol), and the resulting mixture was stirred at 60 ^{o}C for 6 h. The mixture was cooled to room temperature, ethyl acetate and water were added, and the organic phase was successively washed with 0.5 M aqueous hydrochloric acid solution and brine. The organic phase was dried over anhydrous Na_2SO_4, concentrated and the crude material was purified by column chromatography over silica gel using hexane and ethyl acetate provided pure (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-yl 4-bromobenzoate **9** (99 mg) in 95% yield. $R_{f.}$ 0.37 (20% EtOAc/hexane). IR (neat): 2949, 2894, 2830, 1712, 1610, 1588, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.04 (d, 2H, *J* = 8.5 Hz), 7.66 (d, 2H, *J* = 8.5 Hz), 7.06 (d, 2H, *J* = 8.5 Hz), 6.81 (d, 2H, *J* = 8.5 Hz), 5.42 (s, 1H), 4.98-4.99 (m, 1H), 4.71-4.73 (m, 1H), 3.96 (d, 1H, *J* = 7.6 Hz), 3.84-3.88 (m, 1H), 3.78 (s, 3H), 3.01 (dd, 1H, *J* = 7.2 Hz, *J* = 13.6 Hz), 2.85 (dd, 1H, *J* = 8.4 Hz, *J* = 13.6 Hz), 2.14-2.21 (m, 1H), 1.95-2.01 (m, 1H), 1.73 (d, 1H, *J* = 15.6 Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 165.29, 157.96, 131.90, 131.85, 131.17, 129.87, 129.02, 128.40, 113.89, 103.85, 74.95, 70.00, 65.98, 55.19, 40.01, 36.51, 24.26. **HRMS (ESI)** calcd for $C_{21}H_{21}BrO_5$+NH_4^+ 450.0911, found 450.0910.

2.5 (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-yl 4-nitrobenz - oate (10)



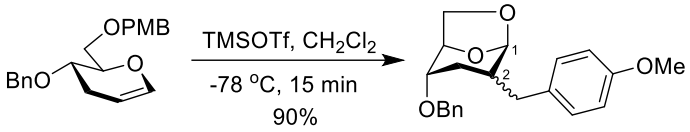
To a solution of **8** (60 mg, 0.24 mmol) in anhydrous tetrahydrofuran (1 mL) cooled at 0 °C were added *N*,*N*-diisopropylethylamine (100 μL, 0.574 mmol) and 4-(dimethylamino) pyridine (12 mg, 0.1 mmol) followed by *p*-nitrobenzoyl chloride (94 mg, 0.48 mmol), and the resulting mixture was stirred at 60 °C for 6 h. The mixture was cooled to room temperature, ethyl acetate and water were added, and the organic phase was successively washed with 0.5 M aqueous hydrochloric acid solution and brine. The organic phase was dried over anhydrous Na_2SO_4, concentrated and the crude material was purified by column chromatography over silica gel using hexane and ethyl acetate provided pure (1*R*,2*S*,4*R*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan-2-yl 4-nitrobenzoate **10** (94 mg) in 98% yield. $R_{f.}$ 0.4 (20% EtOAc/hexane). IR (neat): 2917, 2849, 1718, 1608, 1526, 1511 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.24-8.38 (m, 4H), 7.06 (d, 2H, *J* = 8.4 Hz), 6.81 (d, 2H, *J* = 12 Hz), 5.44 (s, 1H), 5.04(s, 1H), 4.75 (d, 1H, *J* = 4.8 Hz), 3.99 (d, 1H, *J* = 8.0 Hz), 3.89 (d, 1H, *J* = 5.8 Hz), 3.78 (s, 3H), 3.03 (dd, 1H, *J* = 7.5 Hz, *J* = 13.7 Hz), 2.85 (dd, 1H, *J* = 8.6 Hz, *J* = 13.7 Hz), 2.22 (dt, 1H, *J* = 6.0 Hz, *J* = 15.5 Hz), 2.01-2.06 (m,1H), 1.76 (d,1H, *J* = 16.1 Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 164.13, 158.00, 150.66, 135.44, 131.61, 130.75, 129.78, 123.69, 113.90, 103.79, 74.78, 70.81, 65.94, 55.17, 39.86, 36.56, 24.32. **HRMS (ESI)** calcd for $C_{21}H_{21}NO_7$+Na^+ 422.1210, found 422.1206.

2.6 (2*R*,3*S*)-3-(benzyloxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2H-pyran (12)



A stirred solution of 3-deoxy-4-benzyl D-glucal **11** (0.507 g, 2.3 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.14 g, 3.5 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (0.47 g, 3 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*)-3-(benzyloxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2H-pyran **12** (0.78 g) in 95% yield. R_f: 0.5 (10% EtOAc/hexanes). $[\alpha]_D^{25}$ +44.3 (*c* 1.1, CH_2Cl_2); IR (neat): 3407, 3063, 3031, 2909, 2865, 1653, 1611, 1586, 1513 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.30 - 7.38 (m, 7H), 6.90 (d, 2H, *J* = 8.5 Hz), 6.40 (d, 1H, *J* = 6.0 Hz), 4.66-4.70 (m, 2H), 4.54-4.62 (m, 3H), 3.92-3.96 (m, 1H), 3.82 (s, 3H), 3.80-3.82 (m, 3H), 2.43 (dt, 1H, *J* = 5.5 Hz, *J* = 16.5 Hz), 2.12 (dd, 1H, *J* = 8.0 Hz, *J* = 16.5 Hz). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.11, 143.01, 138.17, 130.12, 129.33, 128.24, 127.57, 127.54, 113.65, 97.47, 76.70, 73.05, 70.99, 70.44, 68.54, 55.11, 26.44. **HRMS (ESI)** calcd for $C_{21}H_{24}O_4$+NH_4^+ 358.2013, found 358.2012.

2.7 (1*R*,2*S*,4*S*,5*R*)-2-(benzyloxy)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octane (13a); (1*R*,2*S*,4*R*,5*R*)-2-(benzyloxy)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octan e (13b)

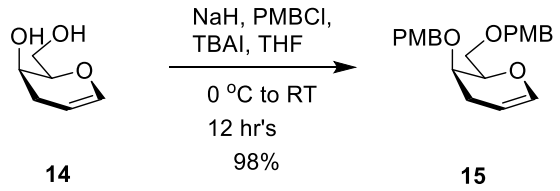


12

13a = 1,2-cis
13b = 1,2-trans

A stirred solution of compound **12** (116 mg, 0.34 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (6.2 µL, 0.034 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~15 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the mixture of 2-*C*-branced levoglucosan derivatives **13a** and **13b** (1:1) (105 mg) as a colorless gum in 90% yield. R_f: 0.45 (10% EtOAc/hexane). **13a:** IR (neat): 2934, 2889, 1610, 1582, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.30 - 7.40 (m, 5H), 7.10 (d, 2H, *J* = 8.8 Hz), 6.85 (d, 2H, *J* = 8.8 Hz), 5.28 (s, 1H), 4.58-4.65 (m, 3H), 3.81 (s, 3H), 3.72-3.79 (m, 2H), 3.38-3.39 (m, 1H), 2.59 (dd, 1H, *J* = 8.0 Hz, *J* = 13.6 Hz), 2.41 (dd, 1H, *J* = 7.6 Hz, *J* = 13.6 Hz), 2.22-2.30 (m, 1H), 1.78-1.84 (m, 1H), 1.44-1.51 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 157.86, 138.16, 131.00, 129.85, 128.38, 127.63, 127.58, 113.72, 103.31, 74.50, 72.93, 70.38, 66.35, 55.17, 39.08, 37.24, 27.57. **HRMS (ESI)** calcd for $C_{21}H_{24}O_4$+NH_4^+ 358.2013, found 358.2014. **13b:** $[\alpha]_D^{25}$ -26.72 (*c* 0.3, $CHCl_3$); IR (neat): 2915, 2853, 1655, 1608, 1515 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.31 - 7.40 (m, 5H), 7.14 (d, 2H, *J* = 8.8 Hz), 6.84 (d, 2H, *J* = 8.8 Hz), 5.88 (s, 1H), 4.68 (d, 1H, *J* = 12.4 Hz), 4.64-4.66 (m, 1H), 4.62 (d, 1H, *J* = 12.4 Hz), 3.80 (s, 3H), 3.78-3.79 (m, 2H), 3.35 (m, 1H), 2.95 (dd, 1H, *J* = 6.8 Hz, *J* = 13.6 Hz), 2.88 (dd, 1H, *J* = 8.8 Hz, *J* = 14.0 Hz), 1.88-1.94 (m, 1H), 1.79-1.86 (m, 1H), 1.67-1.71 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 157.85, 138.41, 132.73, 130.17, 128.43, 127.61, 127.48, 113.75, 104.13, 75.22, 73.58, 70.50, 66.03, 55.25, 40.47, 36.41, 23.22. **HRMS (ESI)** calcd for $C_{21}H_{24}O_4$+Na^+ 363.1567, found 363.1568.

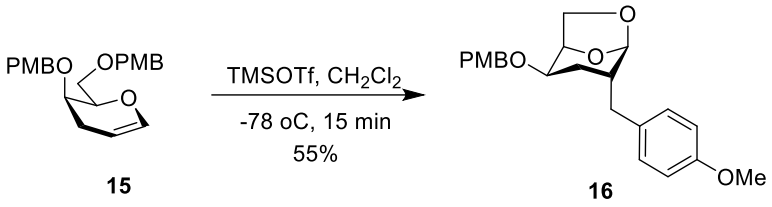
2.8 (2*R*,3*R*)-3-((4-methoxybenzyl)oxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro -2*H*-pyran (15)



14 **15**

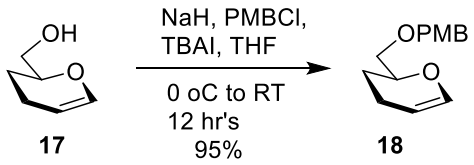
A stirred solution of 3-deoxy D-glucal **14** (0.85 g, 6.5 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.78 g, 19.5 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (2.56 g, 16.33 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*R*)-3-((4-methoxybenzyl)oxy)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2H-pyran **15** (2.47 g) in 98% yield. R_f: 0.65 (30% EtOAc/hexanes). $[\alpha]_D^{25}$-1.44 (*c* 0.28, $CHCl_3$); IR (neat): 3009, 2909, 2863, 1651, 1611, 1511 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.25 (d, 2H, *J* = 9.0 Hz), 7.24 (d, 2H, *J* = 8.5 Hz), 6.89 (d, 2H, *J* = 9.0 Hz), 6.88 (d, 2H, *J* = 9.5 Hz), 6.41 (dt, 1H, *J* = 2.0 Hz, *J* = 6.5 Hz), 4.64-4.67 (m, 1H), 4.61 (d, 1H, *J* = 12.0 Hz), 4.51 (d, 1H, *J* = 11.5 Hz), 4.42 (d, 1H, *J* = 12.0 Hz), 4.41 (d, 1H, *J* = 11.5 Hz), 4.07-4.09 (m, 1H), 3.81-3.82 (m, 7H), 3.68 (dd, 1H, *J* = 7.0 Hz, *J* = 10.0 Hz), 3.58 (dd, 1H, *J* = 5.0 Hz, *J* = 10.0 Hz), 2.16-2.22 (m, 1H), 2.09-2.14 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.23, 159.20, 142.93, 130.28, 130.16, 129.48, 129.42, 113.73, 97.81, 75.24, 73.05, 70.62, 69.38, 68.39, 55.23, 55.22, 24.20. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5$+NH_4^+ 388.2118, found 388.2119.

2.9 (1*R*,2*R*,4*R*,5*R*)-4-(4-methoxybenzyl)-2-((4-methoxybenzyl)oxy)-6,8-dioxabicyclo [3.2.1] octane (16)



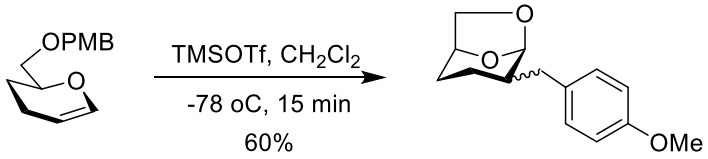
A stirred solution of compound **15** (100 mg, 0.27 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 ^{o}C. TMSOTf (5 µL, 0.027 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~10 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the pure (1*R*,2*R*,4*R*,5*R*)-4-(4-methoxybenzyl)-2-((4-methoxybenzyl)oxy)-6,8-dioxabicyclo[3.2.1]octa--ne **16** (55 mg) as a colorless gum in 55% yield. R_f: 0.6 (5% EtOAc/Toluene). $[\alpha]_D^{25}$ -0.144 (*c* 0.91, $CHCl_3$); IR (neat): 2947, 2893, 2832, 2361, 1610, 1583, 1517 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.23 (d, 2H, *J* = 8.5 Hz), 7.07 (d, 2H, *J* = 8.5 Hz), 6.89 (d, 2H, *J* = 9.0 Hz), 6.84 (d, 2H, *J* = 8.5 Hz), 4.51 (d, 1H, *J* = 11.5 Hz), 4.42-4.47 (m, 2H), 4.16 (d, 1H, *J* = 7.5 Hz), 3.83-3.84 (m, 1H), 3.82 (s, 3H), 3.80 (s, 3H), 3.71 (dd, 1H, *J* = 5.0 Hz, *J* = 7.0 Hz), 3.65-3.69 (m, 1H), 2.63 (dd, 1H, *J* = 7.0 Hz, *J* = 14.0 Hz), 2.40 (dd, 1H, *J* = 7.5 Hz, *J* = 13.5 Hz), 1.91-1.95 (m, 2H), 1.26-1.34 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.23, 157.92, 131.26, 130.24, 129.86, 129.15, 113.82, 113.76, 102.73, 73.58, 72.60, 70.33, 65.03, 55.24, 55.20, 42.99, 37.08, 29.61. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5+NH_4^+$ 388.2118, found 388.2118.

2.10 (*S*)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2*H*-pyran (18)



A stirred solution of 3,4-dideoxy D-glucal **17** (0.07 g, 0.613 mmol) in anhydrous THF (5 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.098 g, 2.45 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (0.288 g, 1.84 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (*S*)-2-(((4-methoxybenzyl)oxy)methyl)-3,4-dihydro-2*H*-pyran **18** (0.137 g) in 95% yield. R_f: 0.6 (10% EtOAc/hexanes). **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29 (d, 2H, *J* = 8.5 Hz), 6.89 (d, 2H, *J* = 8.5 Hz), 6.41 (d, 1H, *J* = 6.5 Hz), 4.68-4.71 (m, 1H), 4.56 (d, 1H, *J* = 12.0 Hz), 4.51 (d, 1H, *J* = 12.0 Hz), 4.00-4.05 (m, 1H), 3.82 (s, 3H), 3.57 (dd, 1H, *J* = 6.0 Hz, *J* = 10.0 Hz), 3.50 (dd, 1H, *J* = 4.5 Hz, *J* = 10.0 Hz), 2.07-2.10 (m, 1H), 1.96-2.00 (m, 1H), 1.83-1.87 (m, 1H), 1.65-1.73 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.17, 143.54, 130.17, 129.28, 113.72, 100.37, 74.02, 73.00, 72.09, 55.17, 24.56, 19.29. **HRMS (ESI)** calcd for $C_{14}H_{18}O_3$+Na^+ 257.1148, found 257.1149.

2.11 (1*S*,5*R*)-4-(4-methoxybenzyl)-6,8-dioxabicyclo[3.2.1]octane (19a and 19b)

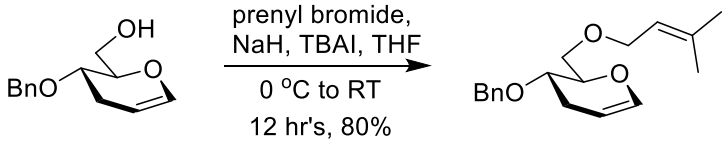


18 **19a:19b** (1:1)

A stirred solution of compound **18** (70 mg, 0.298 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (5.4 µL, 0.0298 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~10 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (5 mL). Evaporation of the solvent under

reduced pressure follow by column chromatography of the obtained crude product provided compounds **19a** and **19b** (42 mg) as an inseparable mixture of diastereomers in 1:1 ratio, as a colorless gum in 60% yield. R_f: 0.40 (10% EtOAc/hexanes); IR (neat): 2937, 2888, 1611, 1511 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.05 - 7.10 (m, 4H), 6.81-6.83 (m, 4H), 5.25 (s, 1H), 5.22 (s, 1H), 4.49-4.52 (m, 2H), 3.92 (d, 1H, *J* = 6.5 Hz), 3.87 (d, 1H, *J* = 7.0 Hz), 3.74-3.79 (m, 8H), 2.78 (dd, 1H, *J* = 7.0 Hz, *J* = 13.5 Hz), 2.60 (dd, 1H, *J* = 8.5 Hz, *J* = 14.0 Hz), 2.56 (dd, 1H, *J* = 7.5 Hz, *J* = 13.5 Hz), 2.37 (dd, 1H, *J* = 8.0 Hz, *J* = 13.5 Hz), 2.04-2.10 (m, 1H), 1.80-1.93 (m, 4H), 1.53-1.58 (m, 1H), 1.48-1.52 (m, 1H), 1.42-1.47 (m, 1H), 1.35-1.40 (m, 2H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 157.92, 132.46, 131.64, 129.89, 129.86, 113.82, 113.77, 104.03, 103.65, 73.86, 73.31, 68.14, 67.27, 55.24, 42.73, 41.05, 37.76, 35.22, 28.50, 25.36, 22.67, 19.04. **HRMS (ESI)** calcd for $C_{14}H_{18}O_3$+Na^+ 257.1148, found 257.1147.

2.12 (2*R*,3*S*)-3-(benzyloxy)-2-(((3-methylbut-2-en-1-yl)oxy)methyl)-3,4-dihydro-2*H*-pyran (20)

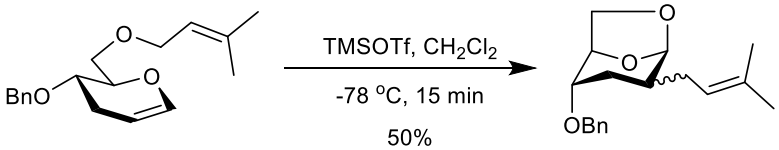


11 **20**

A stirred solution of 3-deoxy-4-benzyl D-glucal **11** (0.55 g, 2.5 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.2 g, 5.0 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, 3,3-dimethylallyl bromide (0.56 g, 3.7 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*)-3-(benzyloxy)-2-(((3-methylbut-2-en-1-yl)oxy)methyl)-3,4-dihydro-2H-pyran **20** (0.574 g) in 80% yield. R_f: 0.8 (20% EtOAc/hexanes). $[\alpha]_D^{25}$ 75.86

(*c* 0.788, $CHCl_3$); IR (neat): 3063, 3023, 2919, 2860, 1742, 1654 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29 - 7.38 (m, 5H), 6.37(dt, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.38-5.41 (m, 1H), 4.68 (d, 1H, *J* = 12.0 Hz), 4.62-4.67 (m, 1H), 4.59 (d, 1H, *J* = 11.5 Hz), 3.99-4.15 (m, 2H), 3.90 (ddd, 1H, *J* = 3.0 Hz, *J* = 5.5 Hz, *J* = 8.5 Hz), 3.75-3.80 (m, 2H), 3.73 (dd, 1H, *J* = 5.5 Hz, *J* = 10.5 Hz), 2.40 (dtd, 1H, *J* = 1.5 Hz, *J* = 5.5 Hz, *J* = 15.5 Hz), 2.11 (dtd, 1H, *J* = 2.5 Hz, *J* = 8.5 Hz, *J* = 16.5 Hz), 1.76 (s, 3H), 1.69 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 143.07, 138.22, 136.76, 128.31, 127.63, 127.60, 121.05, 97.47, 76.68, 71.06, 70.53, 68.64, 67.79, 26.52, 25.72, 17.97. **HRMS (ESI)** calcd for $C_{18}H_{24}O_3$+Na^+ 311.1618, found 311.1618.

2.13 (1*R*,2*S*,5*R*)-2-(benzyloxy)-4-(3-methylbut-2-en-1-yl)-6,8-dioxabicyclo[3.2.1]octa- -ne (21a and 21b)

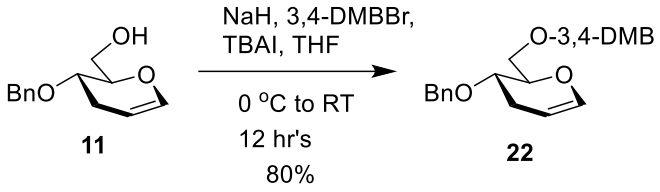


20 **21a:21b** (1:1)

A stirred solution of compound **20** (0.14 g, 0.0.48 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (8.8 µL, 0.048 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~20 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided compounds **21a** and **21b** (70 mg) as an inseparable mixture of diastereomers in 1:1 ratio, as a colorless gum in 50% yield. R_f: 0.65 (20% EtOAc/hexanes). IR (neat): 3029, 2927, 2888 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.28-7.40 (m, 12H), 5.38 (s, 1H), 5.32 (s, 1H), 5.07-5.13 (m, 2H), 4.57-4.68 (m, 5H), 3.75-3.79 (m, 2H), 3.68 (d, 1H, *J* = 7.5 Hz), 3.72-3.80 (m, 1H), 3.33-3.34 (m, 1H), 2.29-2.41 (m, 2H), 1.94-2.06 (m, 3H), 1.83-1.91 (m, 2H), 1.79 (dd, 1H, *J* = 7.0 Hz, *J* = 13.5 Hz), 1.73 (s, 3H), 1.71 (s, 3H), 1.65 (s, 3H), 1.62 (s, 3H), 1.37-1.44 (m, 2H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 138.44, 138.37, 133.34, 133.17, 128.43, 128.36, 127.66, 127.63, 127.52,

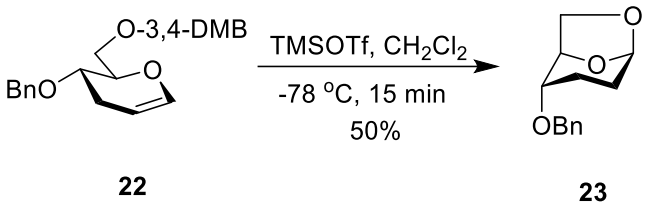
122.88, 121.25, 104.35, 103.88, 75.14, 74.53, 73.54, 73.25, 70.46, 70.36, 66.38, 65.97, 39.04, 37.97, 30.39, 30.02, 27.65, 25.80, 25.75, 23.87, 17.89, 17.79. **HRMS (ESI)** calcd for $C_{18}H_{24}O_3$+Na^+ 311.1618, found 311.1615.

2.14 (2*R*,3*S*)-3-(benzyloxy)-2-(((3,4-dimethoxybenzyl)oxy)methyl)-3,4-dihydro-2*H*-pyran (22)



A stirred solution of 3-deoxy-4-benzyl D-glucal **11** (0.57 g, 2.588 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.207 g, 5.176 mmol) was added portion wise to the solution with stirring over a period of 20 m in. After continuous stirring for further 1 h at 0 °C, 3,4-dimethoxy benzyl bromide (0.897 g, 3.88 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*)-3-(benzyloxy)-2-(((3,4-dimethoxybenzyl)oxy)methyl)-3,4-dihydro-2H-pyran **22** (0.767 g) in 80% yield. R_f: 0.45 (20% EtOAc/hexanes). $[\alpha]_D^{25}$ +72.13 (*c* 1.0, $CHCl_3$); IR (neat): 2930, 2863, 1587, 1510 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.32 - 7.36 (m, 2H), 7.28 – 7.31 (m, 3H), 6.93 (d, 1H, *J* = 2.0 Hz), 6.90 (dd, 1H, *J* = 2.0 Hz, *J* = 8.0 Hz), 6.82 (d, 1H, *J* = 8.0 Hz), 6.38 (dt, 1H, *J* = 2.0 Hz, *J* = 4.0 Hz), 4.64-4.67 (m, 2H), 4.52-4.59 (m, 3H), 3.91-3.94 (m, 1H), 3.88 (s, 3H), 3.87 (s, 3H), 3.75-3.82 (m, 3H), 2.37-2.43 (m, 1H), 2.08-2.14 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 148.98, 148.58, 143.02, 138.18, 130.68, 128.31, 127.62, 127.56, 120.35, 111.23, 110.90, 97.54, 76.77, 73.37, 71.04, 70.58, 68.76, 55.85, 55.76, 26.50. **HRMS (ESI)** calcd for $C_{22}H_{26}O_5$+Na^+ 393.1672, found 393..1671.

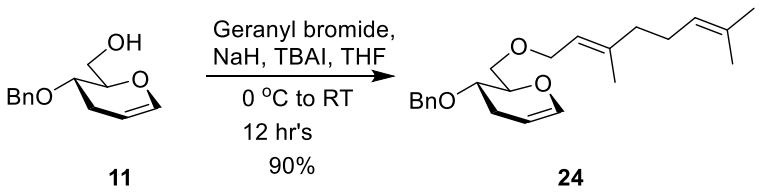
2.15 (1*R*,2*S*,5*R*)-2-(benzyloxy)-6,8-dioxabicyclo[3.2.1] octane (23)



22 **23**

A stirred solution of compound **22** (125 mg, 0.34 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (6.1 µL, 0.034 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~15 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the pure (1*R*,2*S*,5*R*)-2-(benzyloxy)-6,8-dioxabicyclo[3.2.1]octane **23** (37 mg) as a colourless gum in 60% yield. R_f: 0.3 (20% EtOAc/hexanes). IR (neat): 3463, 3028, 2947, 2887, 1715 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.35 - 7.41 (m, 4H), 7.28-7.33 (m, 1H), 5.57 (s, 1H), 4.67 (d, 1H, J = 12.4 Hz), 4.63 (d, 1H, J = 12.4 Hz), 4.59-4.60 (m, 1H), 3.76-3.81 (m, 2H), 3.37 (d, 1H, *J* = 2.0 Hz), 1.92-2.02 (m, 1H), 1.78-1.91 (m, 2H), 1.56-1.61 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 138.30, 128.41, 127.65, 127.61, 101.74, 74.84, 72.92, 70.43, 66.31, 27.95, 20.24. **HRMS (ESI)** calcd for $C_{13}H_{16}O_3$+Na^+ 243.0992, found 243.0990.

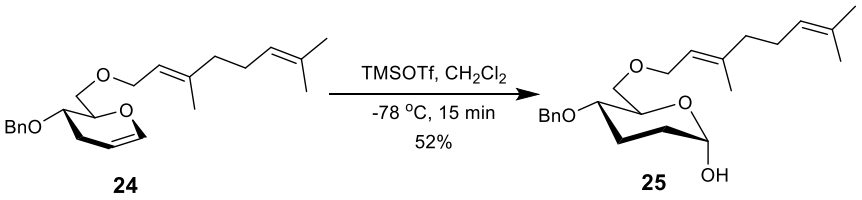
2.16 (2*R*,3*S*)-3-(benzyloxy)-2-((((*E*)-3,7-dimethylocta-2,6-dien-1-yl)oxy)methyl)-3,4-dihydro-2*H*-pyran (24)



11 **24**

A stirred solution of 3-deoxy-4-benzyl D-glucal **11** (0.364 g, 1.652 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 0.132 g, 3.3 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, geranyl bromide (0.54 g, 2.5 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*)-3-(benzyloxy)-2-((((*E*)-3,7-dimethylocta-2,6-dien-1-yl)oxy)methyl)-3,4-dihydro-2*H*-pyran **24** (0.530 g) in 90% yield. R_f: 0.7 (10% EtOAc/hexanes). $[\alpha]_D^{25}$ 67.51 (*c* 1.0, $CHCl_3$); IR (neat): 3420, 3028, 2920, 1719, 1654 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.35 (d, 4H, *J* = 3.2 Hz), 7.27-7.33(m, 1H), 6.36 (dt, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.39 (td, 1H, *J* = 1.2 Hz, *J* = 6.8 Hz), 5.10 (tt, 1H, *J* = 1.2 Hz, *J* = 6.8 Hz), 4.68 (d, 1H, *J* = 11.6 Hz), 4.62-4.65 (m, 1H), 4.58 (d, 1H, *J* = 11.6 Hz), 4.04-4.13 (m, 2H), 3.88-3.92 (m, 1H), 3.70-3.79 (m, 3H), 2.35-2.42 (m, 1H), 2.07-2.14 (m, 3H), 2.02-2.06 (m, 2H), 1.68 (s, 3H), 1.67 (s, 3H), 1.60 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 143.08, 139.91, 138.23, 131.55, 128.32, 127.65, 127.62, 123.93, 120.81, 97.49, 76.68, 71.06, 70.52, 68.70, 67.90, 39.55, 26.53, 26.30, 25.63, 17.62, 16.42. **HRMS (ESI)** calcd for $C_{23}H_{32}O_3$+Na^+ 379.2244, found 379.2243.

2.17 (2*S*,5*S*,6*R*)-5-(benzyloxy)-6-((((*E*)-3,7-dimethylocta-2,6-dien-1-yl)oxy)methyl) tetrahydro -2*H*-pyran-2-ol (25)

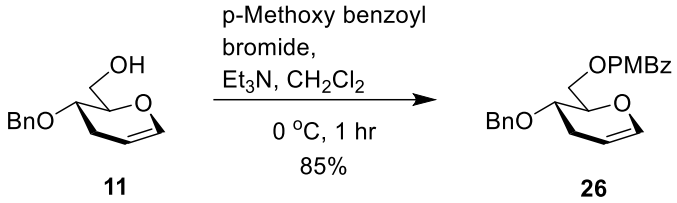


24 **25**

A stirred solution of compound **24** (0.1 g, 0.28 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (5.1 µL, 0.028 mmol) was added dropwise and continued stirring at the same temperature. After

15 min the reaction was quenched by the addition of Et_3N (~20 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided (2*R*,3*S*,6*R*)-6-(benzyloxy)-2-((((*E*)-3,7-dimethylocta-2,6-dien-1-yl)oxy)methyl)tetrahydro-2*H*-pyran-3-ol **25** (56 mg) as a colourless gum in 52% yield. R_f: 0.4 (15% EtOAc/hexanes). **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.35 (d, 4H, *J* = 4.2 Hz), 7.29-7.32(m, 1H), 5.37 (t, 1H, *J* = 6.4 Hz), 5.16 (s, 1H), 5.10 (t, 1H, *J* = 6.8 Hz), 4.65 (d, 1H, *J* = 11.2 Hz), 4.52 (d, 1H, *J* = 11.2 Hz), 4.00-4.12 (m, 2H), 3.69-3.75 (m, 2H), 3.53-3.61 (m, 2H), 2.08-2.13 (m, 2H), 2.01-2.05 (m, 3H), 1.75-1.89 (m, 3H), 1.69 (s, 3H), 1.66 (s, 3H), 1.61 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 139.50, 138.53, 131.57, 128.35, 127.76, 127.61, 124.04, 121.22, 91.79, 72.86, 71.85, 71.06, 68.90, 67.92, 39.61, 28.81, 26.39, 25.68, 23.89, 17.68, 16.46. **HRMS (ESI)** calcd for $C_{23}H_{34}O_4$+Na^+ 397.2349, found 397.2347.

2.18 ((2*R*,3*S*)-3-(benzyloxy)-3,4-dihydro-2*H*-pyran-2-yl)methyl 4-methoxy benzoate (26)

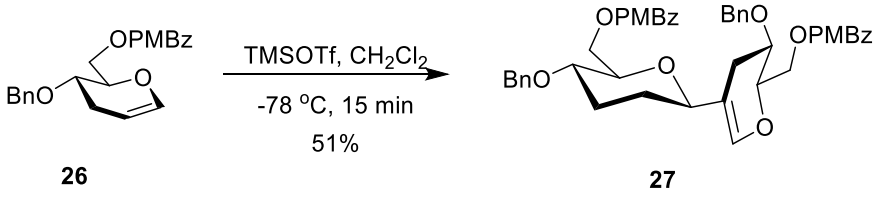


11 **26**

A stirred solution of 3-deoxy-4-benzyl D-glucal **11** (0.24 g, 1.1 mmol) in anhydrous DCM (20 mL) under inert atmosphere was cooled to 0 °C.Et_3N (0.456 mL, 3.3 mmol) was added drop wise to the solution with stirring over a period of 5 min. After continuous stirring for further 20 min at 0 °C, *p*-methoxy benzoyl chloride (0.28 g, 1.64 mmol) was added and stirring was continued for 1 h at 0 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure ((2*R*,3*S*)-3-(benzyloxy)-3,4-dihydro-2*H*-pyran-2-yl)methyl 4-methoxy benzoate

26 (328 mg) in 85% yield. R_f: 0.3 (10% EtOAc/hexanes). $[\alpha]_D^{25}$ 116.0 (*c* 1.0, $CHCl_3$); IR (neat): 3066, 2902, 1714, 1654, 1606, 1511 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.98 (d, 2H, *J* = 9.2 Hz), 7.24-7.35 (m, 5H), 6.92 (d, 2H, *J* = 9.2 Hz), 6.37 (d, 1H, *J* = 4.0 Hz), 4.55-4.73 (m, 5H), 4.05-4.09 (m, 1H), 3.88 (s, 3H), 3.80-3.85 (m, 1H), 2.46-2.53 (m, 1H), 2.13-2.21 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 166.1, 163.4, 143.0, 137.7, 131.7, 128.4, 127.9, 127.8, 122.4, 113.5, 97.7, 75.4, 70.9, 70.0, 63.3, 55.4, 26.4. **HRMS (ESI)** calcd for $C_{21}H_{22}O_5$+H 355.1545, found 355.1547.

2.19 ((2*R*,3*S*)-3-(benzyloxy)-5-((2*R*,5*S*,6*R*)-5-(benzyloxy)-6-(((4-methoxy benzoyl)oxy) methyl)tetrahydro-2*H*-pyran-2-yl)-3,4-dihydro-2*H*-pyran-2-yl)methyl 4-methoxy ben - zoate (27)

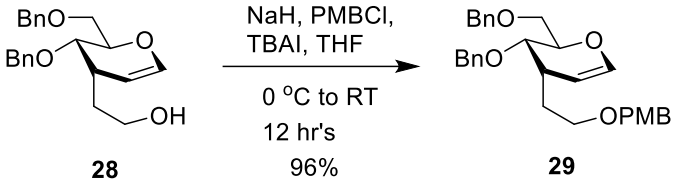


26 **27**

A stirred solution of compound **26** (100 mg, 0.28 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (5 µL, 0.028 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~10 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the pure ((2*R*,3*S*)-3-(benzyloxy)-5-((2*R*,5*S*,6*R*)-5-(benzyloxy)-6-(((4-methoxybenzoyl)oxy)methyl) tetrahydro-2*H*-pyran-2-yl)-3,4-dihydro-2*H*-pyran-2-yl)methyl 4-methoxy benzoate **27** (51 mg) as a colorless gum in 51% yield. R_f: 0.6 (30% EtOAc/hexanes). $[\alpha]_D^{25}$ +78.50 (*c* 1.0, $CHCl_3$); IR (neat): 3015, 2934, 2854, 1709, 1673, 1605, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.02(d, 2H, *J* = 8.8 Hz), 7.96 (d, 2H, *J* = 8.8 Hz), 7.25-7.35 (m, 10H), 6.90-6.92 (m, 4H), 6.48

(s, 1H), 4.61-4.69 (m, 4H), 4.49 -4.57 (m, 3H), 4.46 (d, 1H, *J* = 11.6 Hz), 4.00-4.04 (m, 1H), 3.87 (s, 3H), 3.81-3.83 (m, 5H), 3.67-3.71 (m, 1H), 3.41-3.47 (m, 1H), 2.61 (dd, 1H, *J* = 6.0 Hz, *J* = 16.4 Hz), 2.41-2.42(m, 1H), 2.08-2.19 (m, 1H), 1.85-1.88 (m, 1H), 1.56-1.66 (m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 166.14, 166.03, 163.31, 163.19, 139.70, 137.88, 137.55, 131.69, 131.59, 128.38, 128.36, 127.80, 127.72, 122.70, 122.26, 113.47, 110.65, 78.85, 77.15, 75.33, 73.09, 70.72, 70.54, 69.52, 64.28, 63.00, 55.35, 55.29, 29.03, 28.63, 26.75. **HRMS (ESI)** calcd for $C_{42}H_{44}O_{10}$+Na^+ 731.2827, found 731.2832.

2.20 (2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((4-methoxybenzyl) oxy) ethyl)-3,4-dihydro-2*H*-pyran (29)

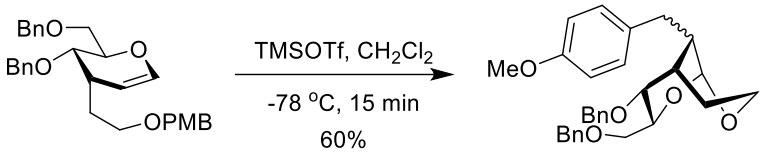


28 **29**

A stirred solution of 3-deoxy-3-*C*-branched D-glucal **28** (0.26 g, 0.734 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 44 mg, 1.1 mmol) was added portion wise to the solution with stirring over a period of 2 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (0.15 g, 0.95 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((4-methoxybenzyl) oxy) ethyl)-3,4-dihydro-2*H*-pyran **29** (334 mg) in 96% yield. R_f: 0.3 (10% EtOAc/hexanes). $[\alpha]_D^{25}$ 2.304 (*c* 1.0, $CHCl_3$); IR (neat): 3406, 3065, 3030, 2932, 2861, 1611, 1512 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.26 - 7.36 (m, 12H), 6.89 (d, 2H, *J* = 9.0 Hz), 6.33 (dd, 1H, *J* = 1.0 Hz, *J* = 6.0 Hz), 4.68 (dd, 1H, *J* = 4.5 Hz, *J* = 6.0

Hz), 4.58-4.63 (m, 3H), 4.51 (d, 1H, *J* = 11.5 Hz), 4.44 (bs, 2H), 4.09-4.12 (m, 1H), 3.82 (s, 3H), 3.78-3.81 (m, 1H), 3.74-3.75 (m, 2H), 3.52-3.55 (m, 2H), 2.59-2.64 (m, 1H), 2.03-2.09 (m, 1H), 1.49-1.55 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 159.15, 142.13, 138.16, 138.10, 130.69, 129.17, 128.32, 127.79, 127.72, 127.62, 127.57, 113.77, 101.73, 73.56, 73.11, 73.00, 72.53, 71.14, 69.51, 67.65, 55.25, 30.94, 29.69. **HRMS (ESI)** calcd for $C_{30}H_{34}O_5$+H 475.2484, found 475.2482.

2.21 4-(benzyloxy)-3-((benzyloxy)methyl)-9-(4-methoxybenzyl)-2,8-dioxabicyclo[3.3.1] nonane (30a and 30b)

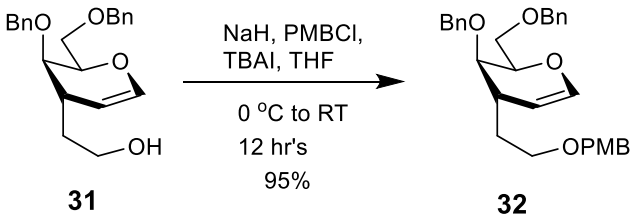


29 **30a:30b** (1:1)

A stirred solution of compound **29** (110 mg, 0.23 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (4 µL, 0.023 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~8 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided an inseparable diastereomeric mixture, 1:1 ratio, of bicyclic acetals **30a** and **30b** (66 mg) as a colorless gum. Yield 60%. R_f: 0.5 (10% EtOAc/Toluene). IR (neat): 3030, 2908, 2861, 2359, 1611, 1511 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.26 - 7.40 (m, 16H), 7.18-7.22 (m, 4H), 7.13 (d, 2H, *J* = 8.5 Hz), 7.04 (d, 2H, *J* = 8.5 Hz), 6.87 (d, 2H, *J* = 8.5 Hz), 6.84 (d, 2H, *J* = 8.5 Hz), 5.01 (s, 1H), 4.87 (s, 1H), 4.71 (d, 1H, *J* = 12.0 Hz), 4.63 (d, 1H, *J* = 12.0 Hz), 4.44-4.56 (m, 4H), 4.26-4.28 (m, 2H), 4.14-4.21 (m, 2H), 4.03-4.10 (m, 2H), 3.96 (dd, 1H, *J* = 8.5 Hz, *J* = 11.5 Hz), 3.82 (bs, 6H), 3.71-3.78 (m, 5H), 3.65 (dd, 1H, *J* = 2.0 Hz, *J* = 10.5

Hz), 3.55 (dd, 1H, *J* = 4.) Hz, *J* = 10.5 Hz), 2.95 (dd, 1H, *J* = 7.5 Hz, *J* = 14.0 Hz), 2.74-2.78 (m, 2H), 2.69 (dd, 1H, *J* = 8.5 Hz, *J* = 14.0 Hz), 2.12-2.31 (m, 5H), 1.90 (dd, 1H, *J* = 5.5 Hz, *J* = 14.5 Hz), 1.73-1.82(m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 158.05, 158.00, 138.49, 138.26, 138.02, 137.91, 131.30, 129.87, 129.82, 128.35, 128.30, 128.28, 127.86, 127.84, 127.73, 127.68, 127.56, 127.48, 113.92, 113.89, 94.80, 93.75, 76.17, 73.38, 73.17, 70.72, 70.60, 70.26, 70.10, 61.98, 61.25, 55.27, 40.33, 40.06, 34.85, 34.10, 28.36, 26.79, 23.81, 18.22. **HRMS (ESI)** calcd for $C_{30}H_{34}O_5$+Na^+ 497.2298, found 497.2297.

2.22 (2*R*,3*R*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((4-methoxybenzyl) oxy) ethyl)-3,4-dihydro-2*H*-pyran (32)

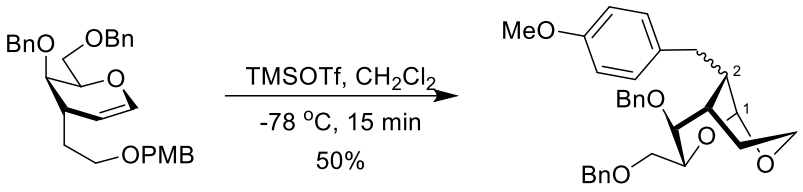


31 **32**

A stirred solution of 3-deoxy-3-*C*-branched-D-galactal **31** (400 mg, 1.13 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 70 mg, 1.7 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, *p*-methoxy benzyl chloride (230 mg, 1.467 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*R*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((4-methoxybenzyl)oxy) ethyl)-3,4-dihydro-2*H*-pyran **32** (509.5 mg) in 95% yield. R_f: 0.45 (10% EtOAc/hexanes). $[\alpha]_D^{27}$ 27.557 (*c* 1.0, $CHCl_3$); IR (neat): 3054, 3030, 2912, 2863, 1722, 1648, 1611, 1512 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.28 - 7.39 (m, 12H), 6.91 (d, 2H, *J* = 8.4 Hz), 6.45 (d, 1H, *J* = 6.4 Hz), 4.72 (t, 1H, *J* = 5.2 Hz), 4.64 (d,

1H, *J* = 12.0 Hz), 4.59 (d, 1H, *J* = 12.4 Hz), 4.43-4.51 (m, 4H), 4.04 (t, 1H, *J* = 5.6 Hz), 3.82 (s, 3H), 3.78 (dd, 1H, *J* = 11.2 Hz), 3.60 (dd, 1H, *J* = 4.8 Hz, *J* = 10.0 Hz), 3.51-3.55 (m, 3H), 2.41-2.43 (m, 1H), 1.55-1.71(m, 2H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 159.14, 142.51, 138.08, 138.00, 130.36, 129.25, 128.30, 128.27, 128.05, 127.77, 127.67, 127.59, 113.74, 102.50, 74.45, 73.41, 72.67, 72.62, 71.22, 69.25, 67.11, 55.19, 35.35, 31.25. **HRMS (ESI)** calcd for $C_{30}H_{34}O_5$+Na^+ 497.2298, found 497.2297.

2.23 (1*S*,3*R*,4*R*,5*S*,9*R*)-4-(benzyloxy)-3-((benzyloxy)methyl)-9-(4-methoxybenzyl)-2,8-dioxabi cyclo[3.3.1]nonane (33a) and (1*S*,3*R*,4*R*,5*S*,9*S*)-4-(benzyloxy)-3-((benzyloxy) methyl)-9-(4-methoxybenzyl)-2,8-dioxabicyclo[3.3.1]nonane (33b)



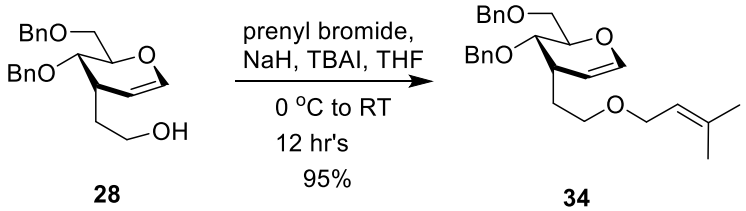
32

33a = 1,2-cis
33b = 1,2-trans

A stirred solution of compound **32** (104 mg, 0.22 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (4 µL, 0.022 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~8 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure followed by column chromatography of the obtained crude product provided the 1:1 diastereomeric mixture of 2-*C*-branced bicyclic acetal derivatives **33a** and **33b** (52 mg) as a colorless gum in 50% yield. R_f: 0.4 (20% EtOAc/Hexane). **33a**: $[\alpha]_D^{25}$ -14.00 (*c* 0.1, $CHCl_3$); IR (neat): 3061, 3030, 2951, 2921, 2853, 1720, 1611, 1511 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.28 - 7.34 (m, 8H), 7.16 (dd, 2H, *J* = 2.0 Hz, *J* = 5.5 Hz), 7.14 (d, 2H, *J* = 8.5 Hz), 6.85 (d, 2H, *J* = 8.5 Hz), 4.91 (s, 1H), 4.60 (d, 1H, *J* = 12.0 Hz), 4.56 (dt, 1H, *J* = 3.5 Hz, *J* = 6.0 Hz), 4.2 (d, 1H, *J* = 12.0 Hz), 4.38 (d, 1H, *J* = 11.5 Hz), 4.31 (d, 1H, *J* = 11.5 Hz), 4.20 (dt, 1H, *J*

= 6.5 Hz, *J* = 12.0 Hz), 4.04-4.09 (m, 1H), 3.81 (s, 3H), 3.72 (dd, 1H, *J* = 6.5 Hz, *J* = 9.5 Hz), 3.61-3.64 (m, 2H), 2.86 (dd, 1H, *J* = 7.0 Hz, *J* = 14.0 Hz), 2.69 (dd, 1H, *J* = 10..0 Hz, *J* = 14.0 Hz), 2.51-2.53 (m, 1H), 2.34-2.43 (m, 1H), 2.11-2.16 (m, 1H), 1.44 (dd, 1H, *J* = 6.5 Hz, *J* = 14.5 Hz). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 158.07, 138.24, 131.39, 129.78, 128.35, 128.25, 127.87, 127.65, 127.61, 127.55, 113.88, 94.78, 77.81, 74.17, 73.61, 71.51, 70.50, 61.48, 55.27, 34.95, 34.50, 28.08, 20.84. **HRMS (ESI)** calcd for $C_{30}H_{34}O_5$+Na^+ 497.2298, found 497.2302. **33b**: $[\alpha]_D^{25}$ -13.00 (*c* 0.5, $CHCl_3$); IR (neat): 2954, 2923, 2853, 1610, 1511 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29 - 7.36 (m, 10H), 7.09 (d, 2H, *J* = 8.5 Hz), 6.79 (d, 2H, *J* = 8.5 Hz), 5.11 (bs, 1H), 4.66 (d, 1H, *J* = 12.0 Hz), 4.63 (d, 1H, *J* = 12.5 Hz), 4.58 (dt, 1H, *J* = 3.0 Hz, *J* = 6.0 Hz), 4.53 (d, 1H, *J* = 12.0 Hz), 4.40 (d, 1H, *J* = 11.5 Hz), 3.95 (ddd, 1H, *J* = 3.5 Hz, *J* = 8.0 Hz, *J* = 11.5 Hz), 3.73-3.83 (m, 6H), 3.32 (bs, 1H), 3.04 (dd, 1H, *J* = 8.5 Hz, *J* = 14.0 Hz), 2.95 (dd, 1H, *J* = 7.0 Hz, *J* = 14.0 Hz), 2.41 (bd, 1H, 10.0 Hz), 2.16 (t, 1H, *J* = 8.0 Hz), 2.01-2.08 (m, 1H), 1.67-1.73 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 157.83, 138.50, 138.29, 132.87, 130.11, 128.32, 128.30, 127.88, 127.56, 127.49, 113.67, 95.79, 78.86, 73.53, 72.15, 70.05, 67.83, 59.89, 55.25, 37.24, 35.22, 27.73, 27.29. **HRMS (ESI)** calcd for $C_{30}H_{34}O_5$+Na^+ 497.2298, found 497.2299.

2.24 (2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((3-methylbut-2-ene-1-yl)oxy)ethyl)-3,4-dihydro-2*H*-pyran (34)

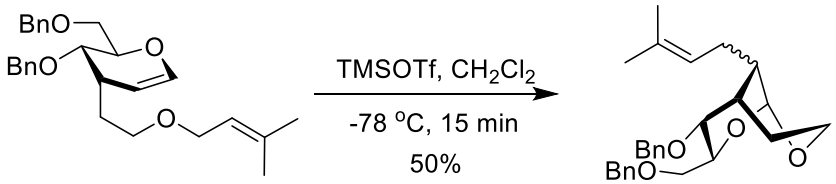


28 **34**

A stirred solution of 3-deoxy-3-*C*-branched-D-glucal **28** (252 mg, 0.71 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 57 mg, 1.42 mmol) was added portion wise to the solution with stirring over a period of 20 min. After continuous stirring for further 1 h at 0 °C, 3,3-dimethyl allyl bromide (159 mg, 1.07 mmol),

TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((3-methylbut-2-ene-1-yl)oxy)ethyl)-3,4-dihydro-2*H*-pyran **34** (285 mg) in 95% yield. R_f: 0.45 (10% EtOAc/hexanes). $[\alpha]_D^{25}$ 39.78 (*c* 1.82, $CHCl_3$); IR (neat): 3385, 3063, 3030, 2928, 2862, 1722, 1603 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.30 - 7.36 (m, 10H), 6.35 (dd, 1H, *J* = 1.2 Hz, *J* = 6.0 Hz), 5.35-5.39 (m, 1H), 4.72 (dd, 1H, *J* = 4.8 Hz, *J* = 6.0 Hz), 4.61-4.66 (m, 3H), 4.53 (d, 1H, *J* = 11.6 Hz), 4.10-4.14 (m, 1H), 3.96 (d, 2H, *J* = 6.8 Hz), 3.81 (dd, 1H, *J* = 5.6 Hz, *J* = 8.0 Hz), 3.74-3.75 (m, 2H), 3.49-3.53 (m, 2H), 2.58-2.63 (m, 1H), 1.99-2.08 (m, 1H), 1.77 (s, 3H), 1.69 (s, 3H), 1.47-1.56 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 142.09, 138.06, 138.02, 136.66, 128.30, 127.77, 127.71, 127.61, 127.56, 121.24, 101.67, 73.51, 73.02, 72.91, 71.07, 69.42, 67.67, 67.22, 30.88, 29.61, 25.76, 17.99. **HRMS (ESI)** calcd for $C_{27}H_{34}O_4$+Na^+ 445.2349, found 445.2361.

2.25 Diastereomeric mixture of (1S,3R,4S,5S)-4-(benzyloxy)-3-((benzyloxy)methyl)-9-(3-methylbut-2-en-1-yl)-2,8-dioxabicyclo[3.3.1]nonane (35a and 35b)

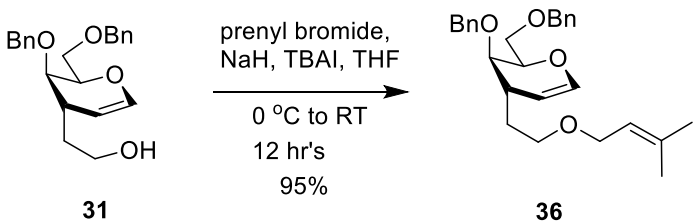


34 **35a:35b** (1:1)

A stirred solution of compound **34** (150 mg, 0.35 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (6.4 µL, 0.035 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~15 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad

of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided an inseparable diastereomeric mixture of **35a** and **35b** (75 mg) as a colorless gum in 50% yield. R_f: 0.35 (10% EtOAc/hexanes).IR (neat): 3031, 2923, 1720, 1512 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.22 - 7.36 (m, 10H), 5.11 (t, 0.5H, 7.6 Hz), 5.06 (t, 0.5H, *J* = 6.8 Hz), 5.00 (s, 0.5H), 4.88 (s, 0.5H), 4.67 (d, 0.5H, *J* = 12.0 Hz), 4.65 (d, 0.5H, *J* = 12.0 Hz), 4.58 (d, 0.5H, *J* = 11.2 Hz), 4.53 (d, 0.5H, *J* = 12.0 Hz), 4.51 (d, 0.5H, *J* = 12.0 Hz), 4.50 (d, 0.5H, *J* = 12.0 Hz), 4.33 (d, 0.5H, *J* = 11.2 Hz), 4.31 (d, 0.5H, *J* = 11.6 Hz), 4.27 (dd, 0.5H, 2.4 Hz, *J* = 6.0 Hz), 4.25 (dd, 0.5H, *J* = 2.4 Hz, *J* = 4.0 Hz), 4.10-4.18 (m, 1H), 4.06 (t, 0.5H, *J* = 6.8 Hz), 4.03 (t, 0.5H, *J* = 6.8 Hz), 3.89 – 3.95 (m, 1H), 3.79-3.87 (m, 1H), 3.65-3.76 (m, 1.5H), 3.58 (dd, 0.5H, *J* = 4.0 Hz, *J* = 10.6 Hz), 2.34-2.41 (m, 1H), 2.19-2.28 (m, 2H), 1.99-2.09 (m, 1H), 1.80-1.91 (m, 1H), 1.73 (s, 1.5H), 1.72 (s, 1.5H), 1.67 (s, 1.5H), 1.57 (s, 1.5H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 138.46, 138.33, 138.19, 138.04, 133.71, 128.38, 128.34, 128.30, 128.21, 127.85, 127.75, 127.54, 127.42, 121.41, 121.33, 95.03, 94.02, 76.27, 73.37, 72.78, 70.77, 70.69, 70.63, 70.44, 70.05, 61.92, 61.14, 38.58, 28.76, 28.12, 27.60, 27.49, 25.81, 23.73, 18.34, 17.90, 17.87. **HRMS (ESI)** calcd for $C_{27}H_{34}O_4$+NH_4^+ 440.2795, found 440.2799.

2.26 (2*R*,3*R*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((3-methylbut-2-ene-1-yl)oxy) ethyl)-3,4-dihydro-2*H*-pyran (36)

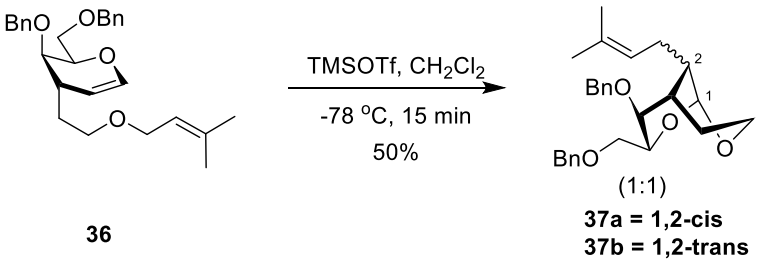


31 **36**

A stirred solution of 3-deoxy-3-*C*-branched-D-galactal **31** (320 mg, 0.90 mmol) in anhydrous THF (10 mL) under inert atmosphere was cooled to 0 °C. NaH (60%, 73 mg, 1.80 mmol) was added portion wise to the solution with stirring over a period of 20 min. After

continuous stirring for further 1 h at 0 °C, 3,3-dimethyl allyl bromide (202 mg, 1.35 mmol), TBAI (cat) were added and stirring was continued for overnight at 25 °C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure (2*R*,3*R*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-4-(2-((3-methylbut-2-ene-1-yl)oxy)ethyl)-3,4-dihydro-2*H*-pyran **36** (363 mg) in 95% yield. R_f: 0.65 (20% EtOAc/hexanes). $[\alpha]_D^{25}$ 28.6 (*c* 0.622, $CHCl_3$); IR (neat): 3428, 3062, 3029, 2922, 2854, 1648 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.28 - 7.38 (m, 10H), 6.45 (d, 1H, *J* = 6.0 Hz), 5.35-5.39 (m, 1H), 4.73 (t, 1H, *J* = 5.2 Hz), 4.67 (d, 1H, *J* = 12.0 Hz), 4.58 (d, 1H, *J* = 12.0 Hz), 4.48 (d, 1H, *J* = 12.4 Hz), 4.47 (d, 1H, *J* = 12.4 Hz), 4.01-4.04 (m, 1H), 3.97 (d, 2H, *J* = 6.8 Hz), 3.77 (dd, 1H, *J* = 7.2 Hz, *J* = 10.0 Hz), 3.59 (dd, 1H, *J* = 4.4 Hz, *J* = 10.0 Hz), 3.54 (bs, 1H), 3.48 (t, 2H, *J* = 6.0 Hz), 2.40 (bs, 1H), 1.77 (s, 3H), 1.70 (s, 3H), 1.54-1.67 (m, 2H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 142.5, 138.1, 138.0, 136.8, 128.3, 128.1, 127.8, 127.7, 127.6, 121.1, 102.6, 74.5, 73.5, 72.7, 71.2, 69.3, 67.3, 67.2, 35.4, 31.2, 25.8, 18.0. **HRMS (ESI)** calcd for $C_{27}H_{34}O_4$+Na^+ 445.2349, found 445.2348.

2.27 (1*S*,3*R*,4*R*,5*S*,9*R*)-4-(benzyloxy)-3-((benzyloxy)methyl)-9-(3-methylbut-2-en-1-yl) -2,8-dioxabicyclo[3.3.1]nonane (37a) and (1*S*,3*R*,4*R*,5*S*,9*S*)-4-(benzyloxy)-3-((benzyl oxy)methyl)-9-(3-methylbut-2-en-1-yl)-2,8-dioxabicyclo[3.3.1]nonane (37b)

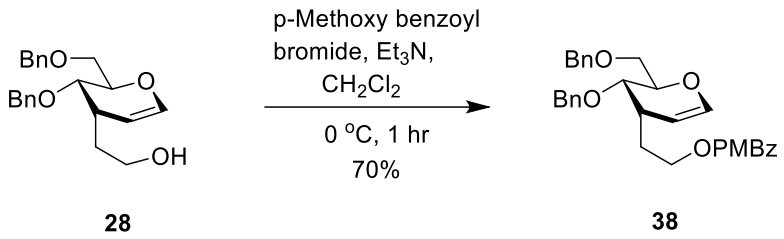


36

A stirred solution of compound **36** (120 mg, 0.28 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (5.2 µL, 0.028 mmol) was added dropwise and continued stirring at the same temperature. After

15 min the reaction was quenched by the addition of Et_3N (~12 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the mixture of 2-*C*-branched bicyclic acetal derivatives **37a** and **37b** (60 mg) as a colorless gum in 50% yield. R_f: 0.55 (20% EtOAc/hexanes). **37a**: $[\alpha]_D^{25}$ -3.00 (*c* 0.1, $CHCl_3$); IR (neat): 3087, 3063, 3029, 2953, 2922, 2854, 1510 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29 - 7.35 (m, 10H), 5.10 (t, 1H, *J* = 6.5 Hz), 4.89 (s, 1H), 4.61 (d, 1H, *J* = 12.0 Hz), 4.60 (d, 1H, *J* = 12.0 Hz), 4.51-4.56 (m, 2H), 4.47 (d, 1H, *J* = 12.0 Hz), 4.13-4.19 (m, 1H), 3.97-4.01 (m, 1H), 3.73 (dd, 1H, *J* = 6.5 Hz, *J* = 9.5 Hz), 3.62-3.65 (m, 2H), 2.22-2.32 (m, 4H), 2.10-2.16 (m, 1H), 1.72 (s, 3H), 1.66 (s, 3H). 1.44 (dd, 1H, *J* = 7.5 Hz, *J* = 14.5 Hz). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 138.53, 138.30, 133.51, 128.35, 128.32, 127.87, 127.60, 127.58, 121.55, 94.85, 78.11, 73.85, 73.62, 71.71, 70.55, 61.40, 33.71, 29.06, 27.95, 25.77, 21.12, 17.87. **HRMS (ESI)** calcd for $C_{27}H_{34}O_4$+Na^+ 445.2349, found 445.2350. **37b:** $[\alpha]_D^{25}$ -11.00 (*c* 0.1, $CHCl_3$); IR (neat): 3087, 3062, 3029, 2922, 2854, 1510 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29 - 7.34 (m, 10H), 5.12-5.13 (m, 2H), 4.69 (d, 1H, *J* = 11.5 Hz), 4.60 (d, 1H, *J* = 12.0 Hz), 4.54 (td, 1H, *J* = 3.0 Hz, *J* = 6.0 Hz), 4.51 (d, 1H, *J* = 12.0 Hz), 4.40 (d, 1H, *J* = 12.0 Hz), 3.96 (ddd, 1H, *J* = 3.5 Hz, *J* = 8.0 Hz, *J* = 12.0 Hz), 3.82 (ddd, 1H, *J* = 6.5 Hz, *J* = 10.0 Hz, *J* = 12.0 Hz), 3.73-3.80 (m, 2H), 3.69 (dd, 1H, *J* = 6.5 Hz, *J* = 9.5 Hz), 3.30 (s, 1H), 2.56 (dt, 1H, *J* = 8.0 Hz, *J* = 15.0 Hz), 2.43 (d, 1H, *J* = 10.0 Hz), 2.34 (dt, 1H, *J* = 6.5 Hz, *J* = 14.5 Hz), 2.02-2.09 (m, 1H), 1.90 (t, 1H, *J* = 8.0 Hz), 1.69 (s, 3H), 1.58 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 138.69, 138.40, 133.10, 128.30, 128.22, 127.82, 127.51, 127.38, 127.36, 122.94, 96.11, 78.70, 73.48, 71.81, 70.09, 67.80, 59.86, 35.70, 28.70, 27.64, 27.19, 25.73, 17.93. **HRMS (ESI)** calcd for $C_{27}H_{34}O_4$+Na^+ 445.2349, found 445.2345.

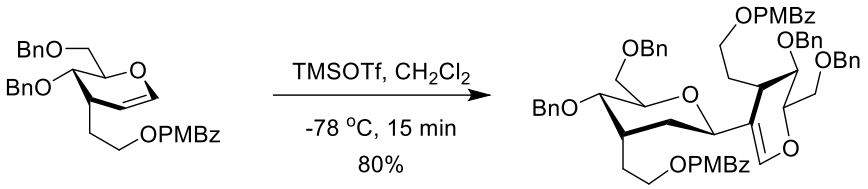
2.28 2-((2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl) ethyl 4-methoxy benzoate (38)



28 **38**

A stirred solution of 3-deoxy-3-*C*-branched D-glucal **28** (0.25 g, 0.7 mmol) in anhydrous DCM (15 mL) under inert atmosphere was cooled to 0 ^{o}C.Et_3N (0.293 mL, 2.1 mmol) was added drop wise to the solution with stirring over a period of 5 min. After continuous stirring for further 20 min at 0 ^{o}C, *p*-methoxy benzoyl chloride (0.18 g, 1.05 mmol) was added and stirring was continued for 1 h at 0 ^{o}C. The reaction was quenched with slow addition of cold water and extracted with ethyl acetate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided the pure 3-*C*-branched glycal **38** (239 mg) in 70% yield. R_f: 0.7 (30% EtOAc/hexanes). $[\alpha]_D^{25}$ 99.30 (*c* 1.0, $CHCl_3$); IR (neat): 3013, 2923, 2864, 1707, 1649, 1605, 1510 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 8.02 (d, 2H, *J* = 8.8 Hz), 7.28-7.37 (m, 10H), 6.94 (d, 2H, *J* = 8.8 Hz), 6.39 (dd, 1H, *J* = 1.2 Hz, *J* = 6.0 Hz), 4.78 (dd, 1H, *J* = 0.8 Hz, *J* = 6.0 Hz), 4.64 (d, 1H, *J* = 11.6 Hz), 4.62 (d, 1H, *J* = 5.2 Hz), 4.60 (d, 1H, *J* = 12.0 Hz), 4.56 (d, 1H, *J* = 11.6 Hz), 4.40-4.44 (m, 2H), 4.11-4.15 (m, 1H), 3.90 (dd, 1H, *J* = 5.6 Hz, *J* = 8.4 Hz), 3.88 (s, 3H), 3.79 (m, 2H), 2.59-2.66 (m, 1H), 2.19-2.28 (m, 1H), 1.66-1.75 (m, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 166.23, 163.28, 142.61, 138.03, 137.83, 131.48, 128.35, 128.30, 127.80, 127.72, 127.68, 127.56, 122.71, 113.56, 101.08, 73.54, 72.94, 72.90, 71.39, 69.30, 62.71, 55.34, 30.22, 30.00. **HRMS (ESI)** calcd for $C_{30}H_{32}O_6$+Na^+ 511.2091, found 511.2095.

2.29 2-((2*R*,3*S*,4*S*)-3-(benzyloxy)-5-((2*R*,4*S*,5*S*,6*R*)-5-(benzyloxy)-6-((benzyloxy)meth yl)-4-(2-((4-methoxybenzoyl)oxy)ethyl)tetrahydro-2*H*-pyran-2-yl)-2-((benzyloxy)met -hyl)-3,4-dihydro-2*H*-pyran-4-yl)ethyl 4-methoxybenzoate (39)



38 **39**

A stirred solution of compound **38** (150 mg, 0.31 mmol) in dry dichloromethane (10 mL) under inert atmosphere was added 4 A MS and the suspension was cooled to -78 °C. TMSOTf (5.6 µL, 0.031 mmol) was added dropwise and continued stirring at the same temperature. After 15 min the reaction was quenched by the addition of Et_3N (~11 µL) and allowed it to come to room temperature. The reaction mixture was filtered through a small pad of Celite and the filter cake was washed with dichloromethane (10 mL). Evaporation of the solvent under reduced pressure follow by column chromatography of the obtained crude product provided the pure 2-(β-*C*-glycosyl)-glycal **39** (120 mg) as a colorless gum in 80% yield. R_f: 0.45 (30% EtOAc/hexanes). $[\alpha]_D^{25}$ +61.30 (*c* 1.0, $CHCl_3$); IR (neat): 2955, 2923, 2854, 1708, 1605, 1510 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.98 (d, 2H, *J* = 9.0 Hz), 7.97 (d, 2H, *J* = 9.0 Hz), 7.23-7.35 (m, 20H), 6.92 (d, 2H, *J* = 9.0 Hz), 6.86 (d, 2H, *J* = 9.0 Hz), 6.44, (s, 1H), 4.70 (d, 1H, *J* = 11.5 Hz), 4.62 (d, 1H, *J* = 12.0 Hz), 4.58 (d, 1H, *J* = 12.5 Hz), 4.57 (d, 1H, *J* = 12.0 Hz), 4.56 (d, 1H, *J* = 11.5 Hz), 4.49-4.53 (m, 3H), 4.43-4.48 (m, 2H), 4.34-4.38 (m, 2H), 4.14 (d, 1H, *J* = 9.5 Hz), 4.05-4.08 (m, 1H), 3.86 (s, 3H), 3.79-3.85 (m, 5H), 3.73 (dd, 1H, *J* = 4.5 Hz, *J* = 10.5 Hz), 3.60-3.69 (m, 3H), 3.56 (dd, 1H, *J* = 5.0 Hz, *J* = 9.5 Hz), 2.92 (q, 1H, *J* = 5.5 Hz), 2.43 (bs, 1H), 2.20 – 2.26 (m, 1H), 2.12-2.18 (m, 1H), 1.94-2.01 (m, 1H), 1.83-1.92 (m, 2H), 1.78-1.81 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 166.28, 166.15, 163.32, 163.20, 141.01, 138.58, 138.17, 138.10, 137.81, 131.50, 131.49, 128.36, 128.30, 128.19, 127.86, 127.71, 127.61, 127.56, 127.55, 127.32, 122.96, 122.67, 113.94, 113.61, 113.52,

77.20, 75.49, 75.37, 73.64, 73.51, 73.34, 73.10, 71.63, 71.17, 70.76, 70.32, 69.54, 64.01, 63.58, 55.36, 55.33, 32.08, 31.48, 30.86, 29.83, 24.57 cm^{-1} **HRMS (ESI)** calcd for $C_{60}H_{64}O_{12}+Na^{+}$ 999.4290, found 999.429

2.5 References

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12. Crystal data for compound **8** ($C_{21}H_{21}O_5Br$), M.Wt = 433.29, orthorhombic, space group $P\,2_12_12_1$ a = 6.3899 Å, b = 16.3327 Å, c = 19.0663 Å, V = 1989.84(15) $Å^3$, Z = 4, Mo-K_α radiation (λ = 0.71073), T = 297.68 K; R 1 = 0.0349, wR 2 = 0.0780 [$I \geq 2\sigma$ (I)]; R 1 = 0.0490, wR 2 = 0.0841 (all data). CCDC 1887125 (for **8**) contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre.

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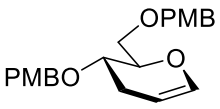

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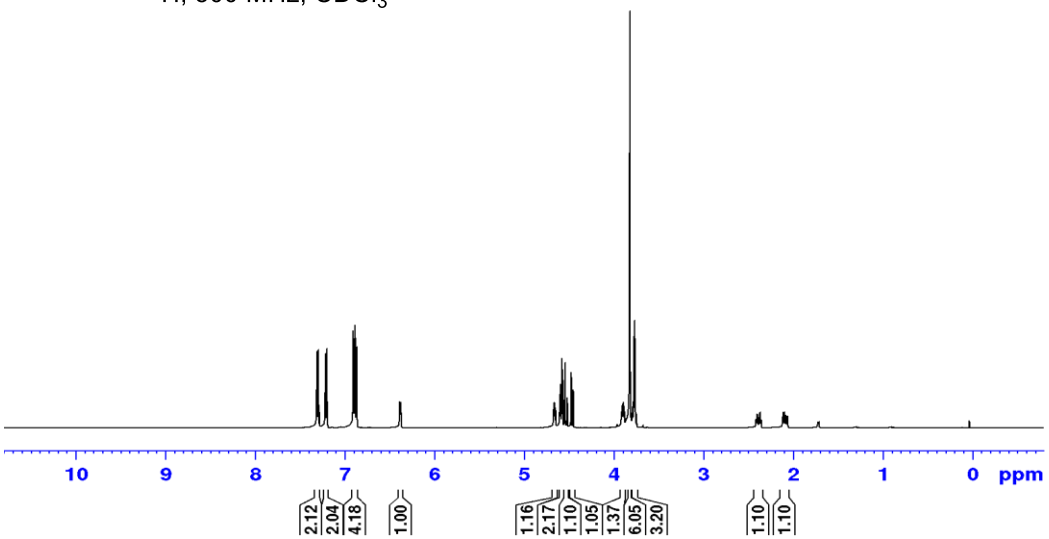
^{1}H, 500 MHz, $CDCl_3$

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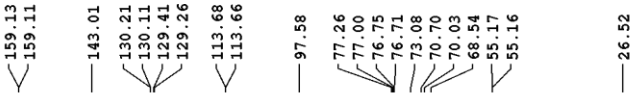

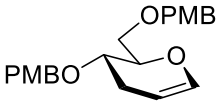

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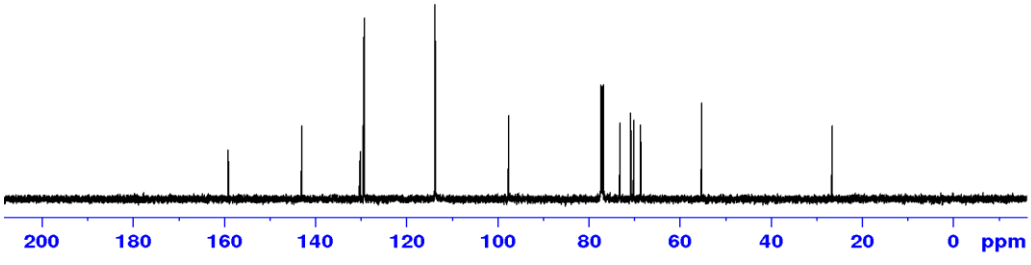
^{13}C, 125 MHz, $CDCl_3$

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PL13W              0.04709999 W
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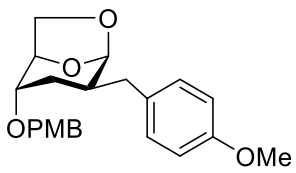

6a = 1,2-cis

^{1}H, 400 MHz, $CDCl_3$


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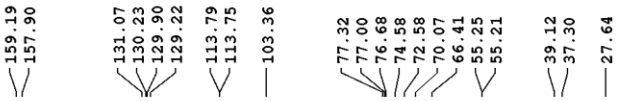
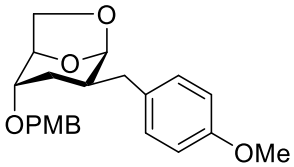
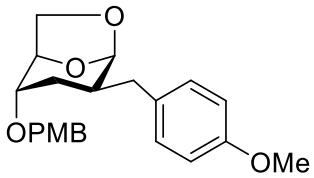




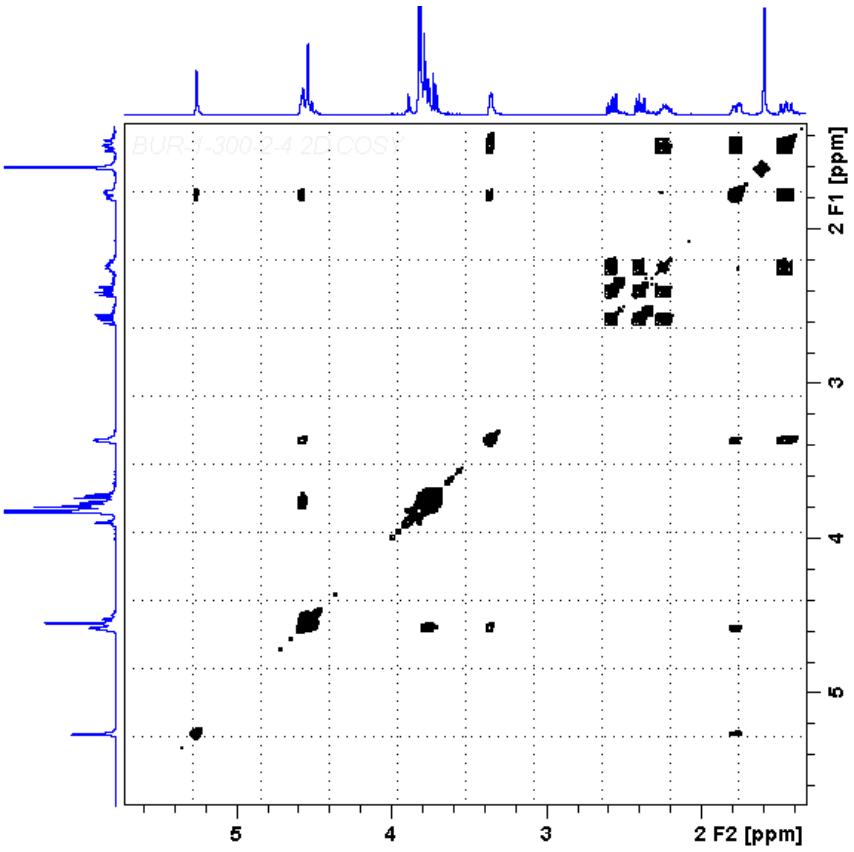
6a = 1,2-cis

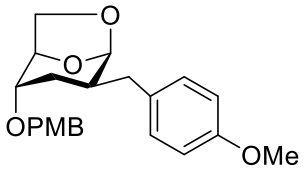
^{13}C, 100 MHz, $CDCl_3$


```
Current Data Parameters
NAME                  BUR 400
EXPNO                  130022
PROCNO                      1

F2 - Acquisition Parameters
Date_                20160426
Time                    12.09
INSTRUM                 spect
PROBHD    5 mm PABBO BB-
PULPROG                 zgpg30
TD                     65536
SOLVENT                CDCl3
NS                       5563
DS                          4
SWH                24038.461 Hz
FIDRES              0.366798 Hz
AQ                  1.3631488 sec
RG                       28.5
DW                    20.800 usec
DE                     6.50 usec
TE                    298.2 K
D1                 2.00000000 sec
D11                0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      10.00 usec
PL1                      2.00 dB
PL1W               49.44866943 W
SFO1              100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   90.00 usec
PL2                      1.50 dB
PL12                    17.18 dB
PL13                    20.18 dB
PL2W               15.18650627 W
PL12W               0.41063678 W
PL13W               0.20580591 W
SFO2              400.0926004 MHz

F2 - Processing parameters
SI                       32768
SF                100.6029660 MHz
WDW                         EM
SSB          0
LB                       1.00 Hz
GB           0
PC                       1.40
```

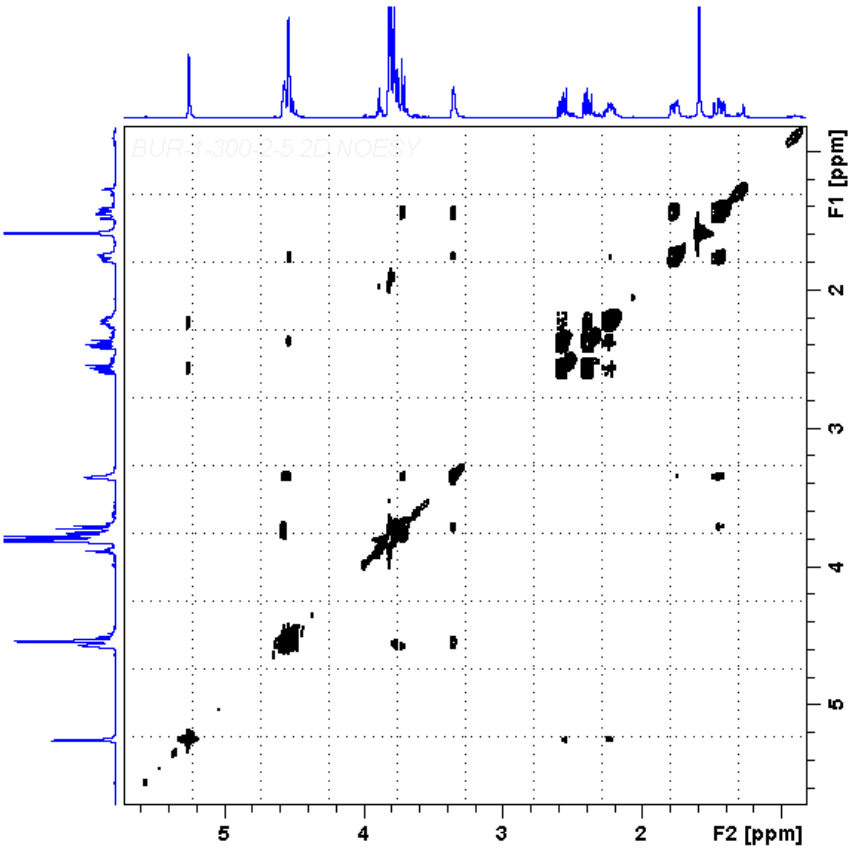


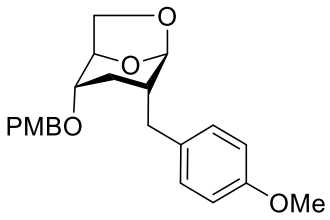
6a = 1,2-cis
(COSY, 400MHz)





6a = 1,2-cis
(NOESY, 400MHz)

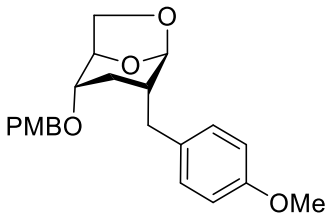




6b = 1,2-trans

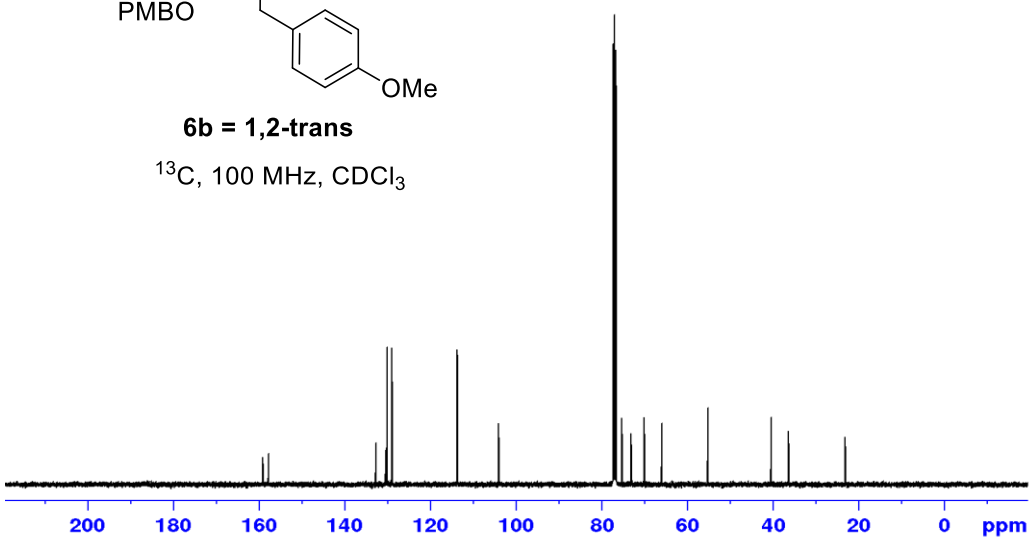
^{1}H, 400 MHz, $CDCl_3$


```
Current Data Parameters
NAME                  BUR 400
EXPNO                  126711
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160113
Time                    9.17
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                 zg30
TD                     65536
SOLVENT                CDCl3
NS                        16
DS                         2
SWH                 8223.685 Hz
FIDRES              0.125483 Hz
AQ                  3.9845889 sec
RG                       322
DW                    60.800 usec
DE                     6.50 usec
TE                    297.2 K
D1                  1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     1.50 dB
PL1W              15.18650627 W
SFO1              400.0934707 MHz

F2 - Processing parameters
SI                     32768
SF                400.0909996 MHz
WDW                       EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

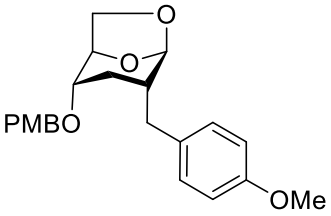


6b = 1,2-trans

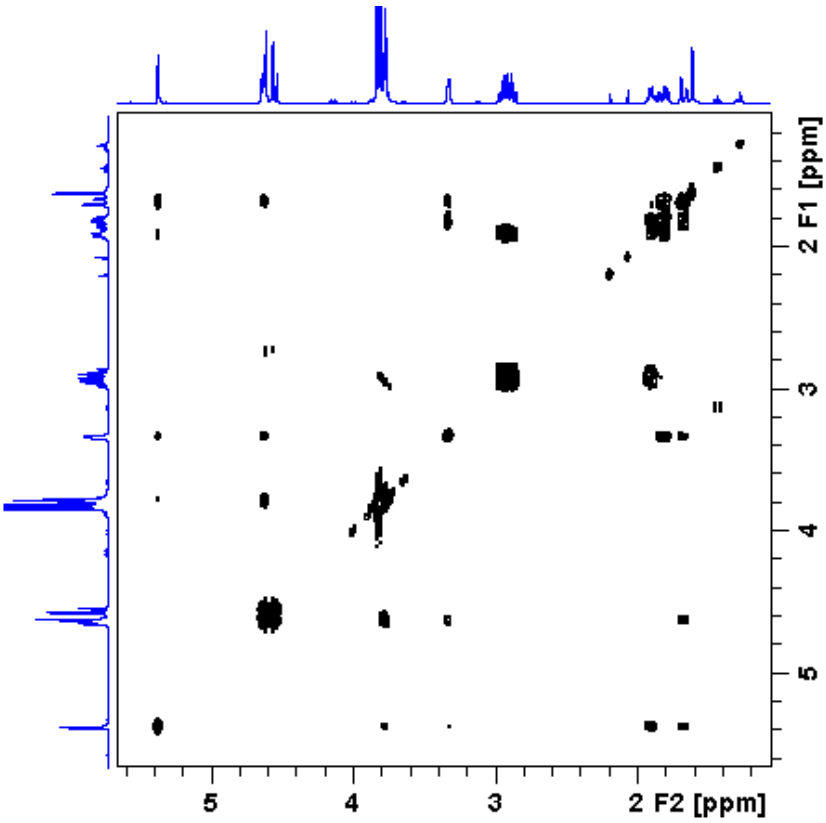
^{13}C, 100 MHz, $CDCl_3$

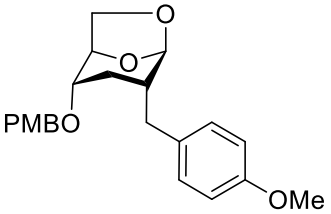



```
Current Data Parameters
NAME                  BUR 400
EXPNO                  126712
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160113
Time                    9.21
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                     65536
SOLVENT                CDCl3
NS                      1024
DS                         4
SWH                24038.461 Hz
FIDRES              0.366798 Hz
AQ                  1.3631488 sec
RG                       575
DW                    20.800 usec
DE                     6.50 usec
TE                    297.9 K
D1                  2.00000000 sec
D11                 0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                     13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W              49.44866943 W
SFO1              100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2            waltz16
NUC2                      1H
PCPD2                  90.00 usec
PL2                     1.50 dB
PL12                   17.18 dB
PL13                   20.18 dB
PL2W              15.18650627 W
PL12W              0.41063678 W
PL13W              0.20580591 W
SFO2              400.0926004 MHz

F2 - Processing parameters
SI                     32768
SF                100.6029630 MHz
WDW                       EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

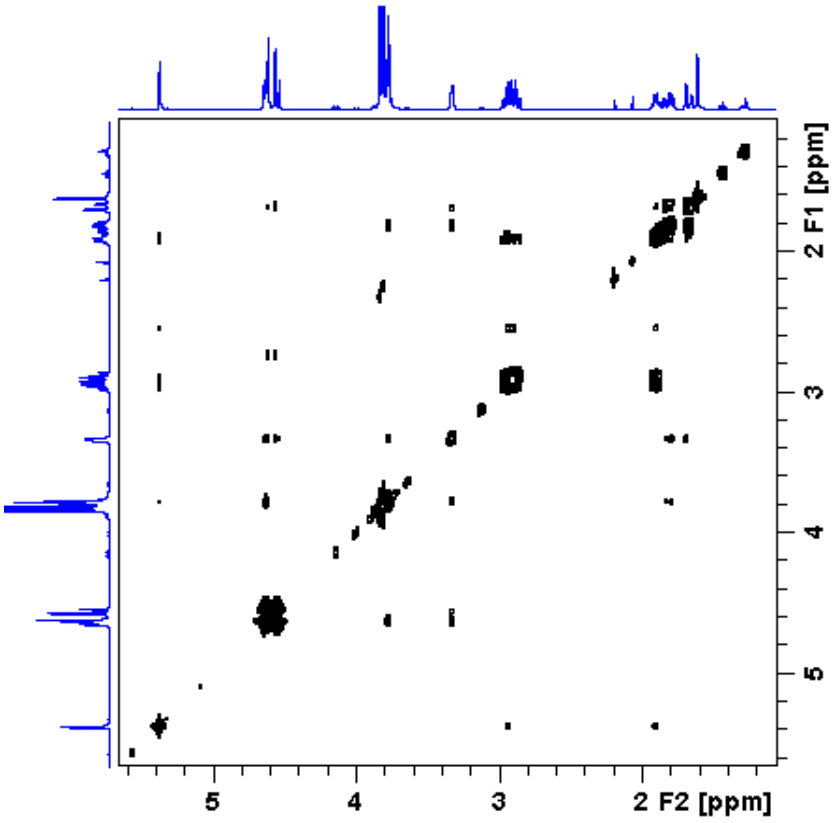


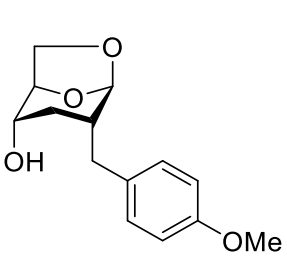
6b = 1,2-trans
(COSY, 400MHz)





6b = 1,2-trans
(NOESY, 400MHz)

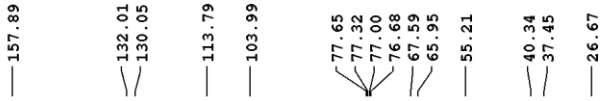


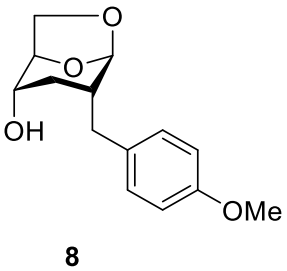


8

^{1}H, 400 MHz, $CDCl_3$

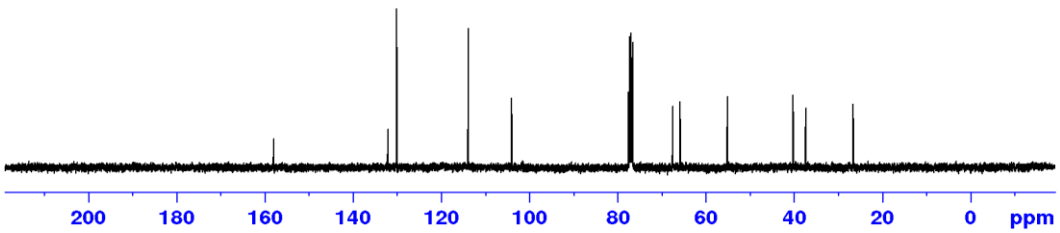

```
Current Data Parameters
NAME         BUR student NMR
EXPNO              204111
PROCNO                  1

F2 - Acquisition Parameters
Date_           20181218
Time               17.40
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES             0.126314 Hz
AQ              3.9583745 sec
RG                  71.8
DW                 60.400 usec
DE                  6.50 usec
TE                673.2 K
D1              1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                  9.20 usec
PL1                -1.00 dB
PL1W         10.72012138 W
SFO1          400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF            400.1300022 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```



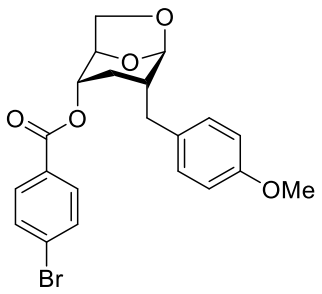


8

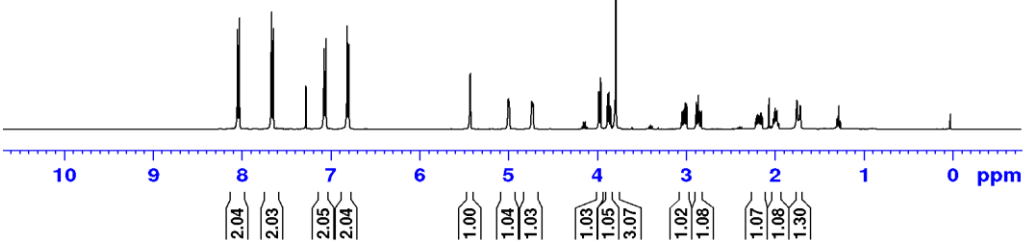
^{13}C, 100 MHz, $CDCl_3$



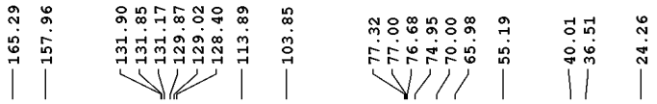

```
Current Data Parameters
NAME             BUR 400
EXPNO              204112
PROCNO                  1

F2 - Acquisition Parameters
Date_           20181218
Time               17.46
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   226
DS                     4
SWH            23980.814 Hz
FIDRES             0.365918 Hz
AQ              1.3664256 sec
RG                   181
DW                 20.850 usec
DE                  6.50 usec
TE                673.2 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                 30.00 usec
PL1                -4.50 dB
PL1W         94.86473846 W
SFO1          100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2              90.00 usec
PL2                -1.00 dB
PL12               18.81 dB
PL13              120.00 dB
PL2W         10.72012138 W
PL12W         0.11199529 W
PL13W     0 W
SFO2          400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF            100.6127756 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

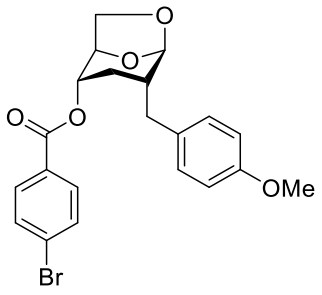


9

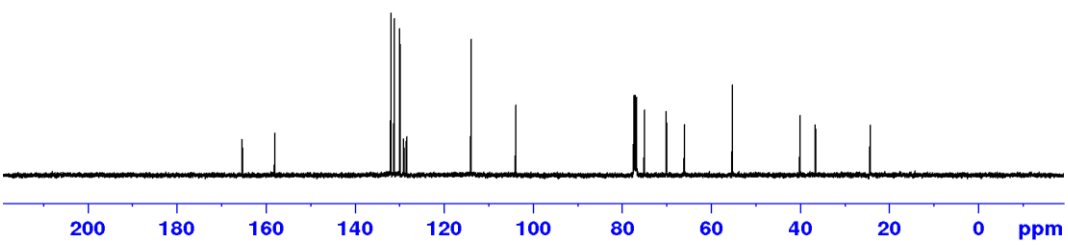



```
Current Data Parameters
NAME       BUR student NMR
EXPNO              204711
PROCNO                  1

F2 - Acquisition Parameters
Date_           20181120
Time                7.38
INSTRUM            spect
PROBHD    5 mm BBI 1H/D-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8278.146 Hz
FIDRES             0.126314 Hz
AQ              3.9583745 sec
RG                  45.3
DW                 60.400 usec
DE                  6.50 usec
TE                 673.2 K
D1              1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                   1H
P1                   9.20 usec
PL1                 -1.00 dB
PL1W          10.72012138 W
SFO1          400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF            400.1300022 MHz
WDW                   EM
SSB       0
LB                  0.30 Hz
GB        0
PC                  1.00
```

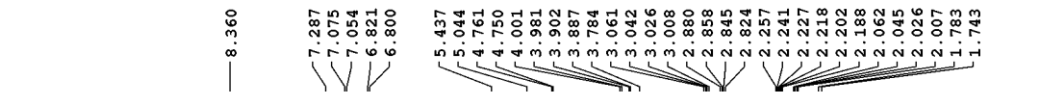


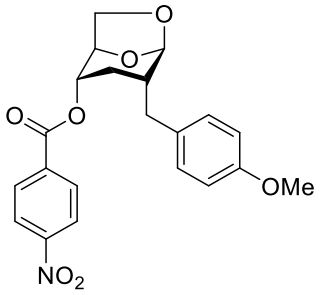


9

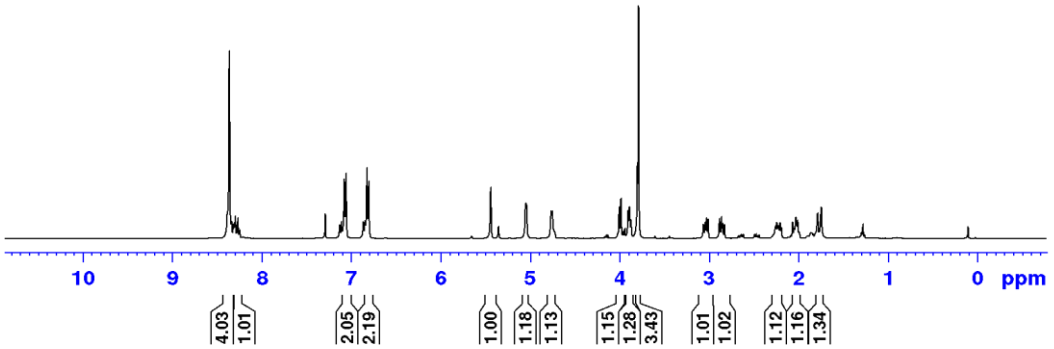



```
Current Data Parameters
NAME       BUR student NMR
EXPNO              204712
PROCNO                  1

F2 - Acquisition Parameters
Date_           20181120
Time                7.44
INSTRUM            spect
PROBHD    5 mm BBI 1H/D-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   503
DS                     4
SWH            23980.814 Hz
FIDRES             0.365918 Hz
AQ              1.3664256 sec
RG                   181
DW                 20.850 usec
DE                  6.50 usec
TE                 673.2 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  13C
P1                 30.00 usec
PL1                -4.50 dB
PL1W          94.86473846 W
SFO1          100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                   1H
PCPD2              90.00 usec
PL2                -1.00 dB
PL12               18.81 dB
PL13              120.00 dB
PL2W          10.72012138 W
PL12W          0.11199529 W
PL13W     0 W
SFO2          400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF            100.6127756 MHz
WDW                   EM
SSB       0
LB                  1.00 Hz
GB        0
PC                  1.40
```

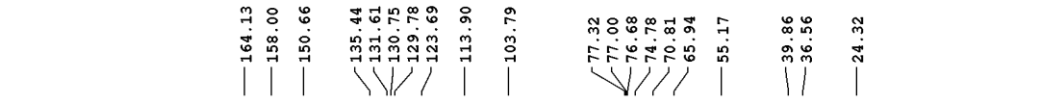


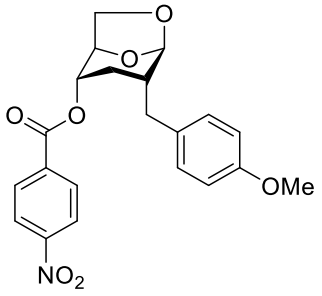


10

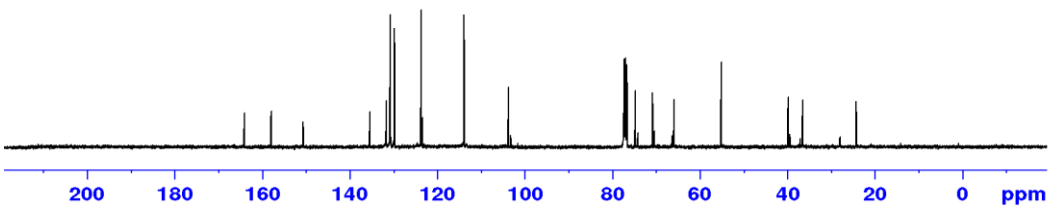


```
Current Data Parameters
NAME      BUR student NMR
EXPNO             204021
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181101
Time               13.28
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8278.146 Hz
FIDRES          0.126314 Hz
AQ             3.9583745 sec
RG                 35.9
DW               60.400 usec
DE                6.50 usec
TE               673.2 K
D1            1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 9.20 usec
PL1               -1.00 dB
PL1W         10.72012138 W
SFO1         400.1324710 MHz

F2 - Processing parameters
SI                32768
SF          400.1300000 MHz
WDW                  EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

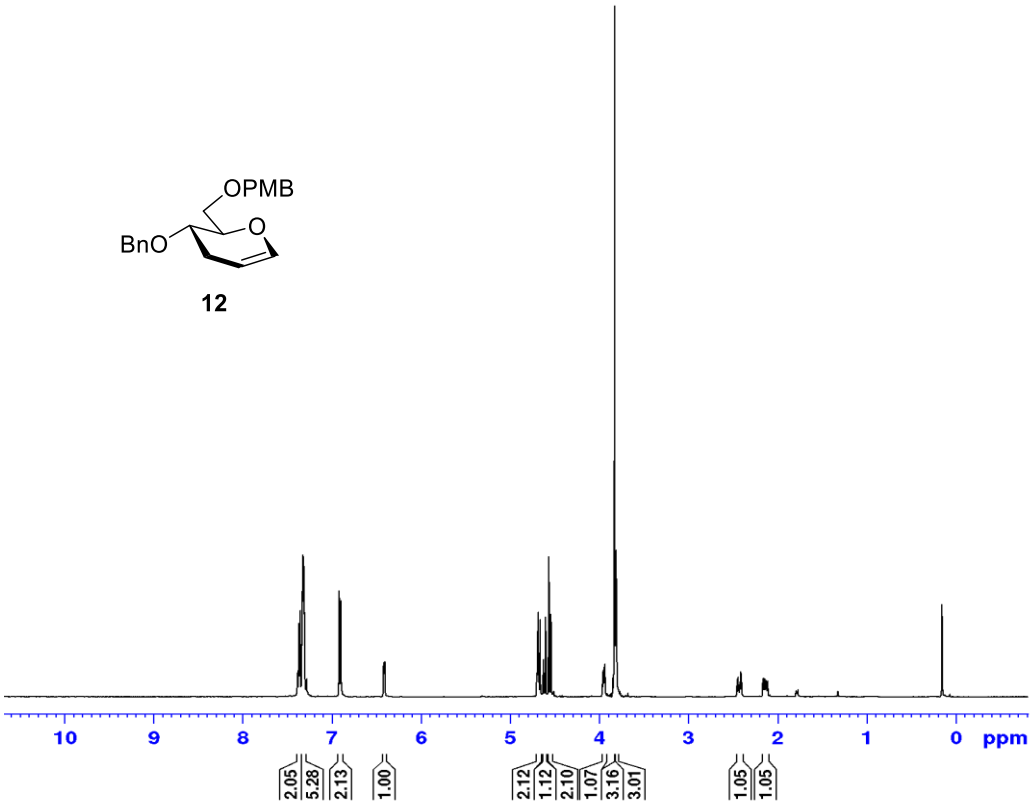




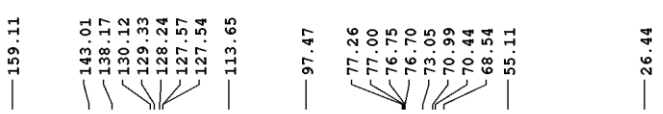
10

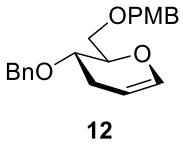


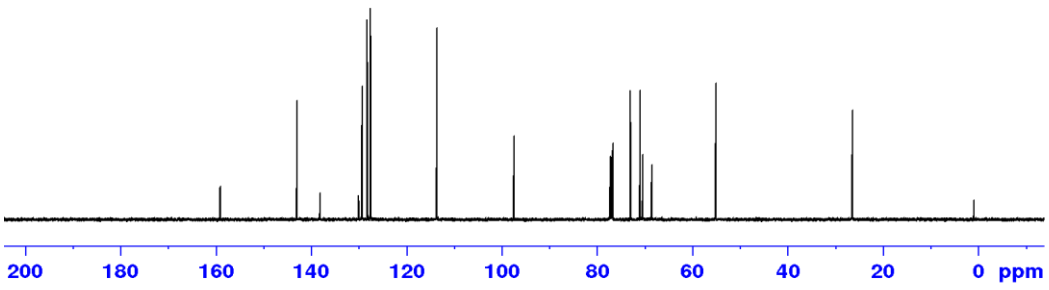
```
Current Data Parameters
NAME      BUR student NMR
EXPNO             204022
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181101
Time               13.35
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                 1228
DS                    4
SWH           23980.814 Hz
FIDRES          0.365918 Hz
AQ             1.3664256 sec
RG                 161.3
DW               20.850 usec
DE                6.50 usec
TE               673.2 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                30.00 usec
PL1               -4.50 dB
PL1W         94.86473846 W
SFO1        100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             90.00 usec
PL2               -1.00 dB
PL12              18.81 dB
PL13             120.00 dB
PL2W         10.72012138 W
PL12W         0.11199529 W
PL13W     0 W
SFO2        400.1316005 MHz

F2 - Processing parameters
SI                32768
SF          100.6127777 MHz
WDW                  EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



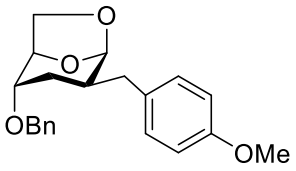

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  129711
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160729
Time                   21.54
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                       36
DW                   48.400 usec
DE                    6.50 usec
TE                   296.5 K
D1                1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     1H
P1                    14.90 usec
PL1                    2.00 dB
PL1W           12.85348415 W
SFO1          500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF               500.1800000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```



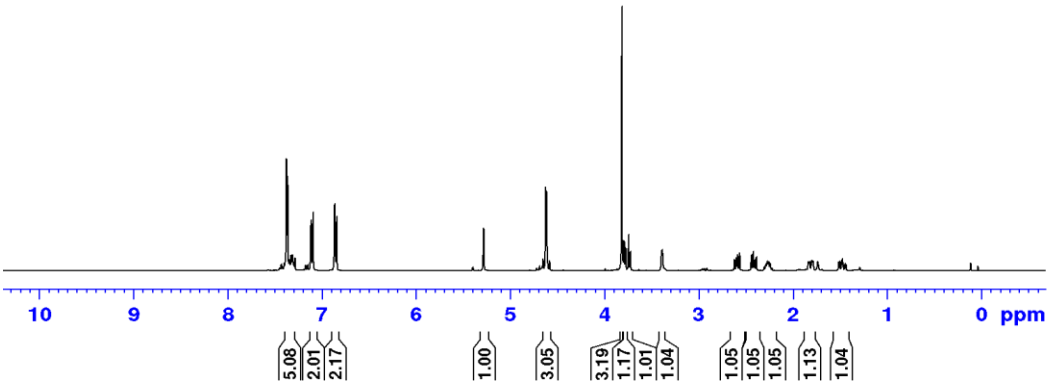


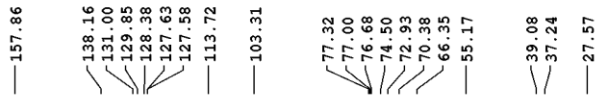


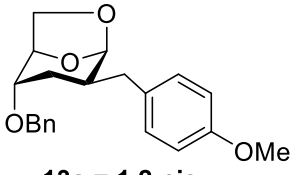

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  129712
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160729
Time                   22.01
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                       88
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   297.8 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                    13C
P1                    9.60 usec
PL1           0 dB
PL1W           76.36135101 W
SFO1          125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                     1H
PCPD2                80.00 usec
PL2                    2.00 dB
PL12                  16.50 dB
PL13                  16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
PL13W           0.45605880 W
SFO2          500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF               125.7703807 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```



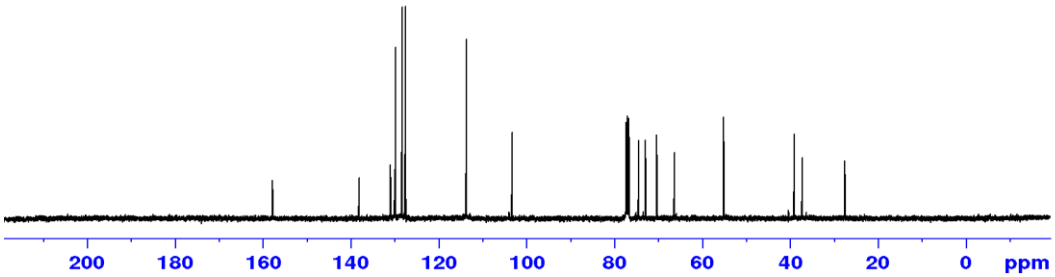
13a = 1,2-cis





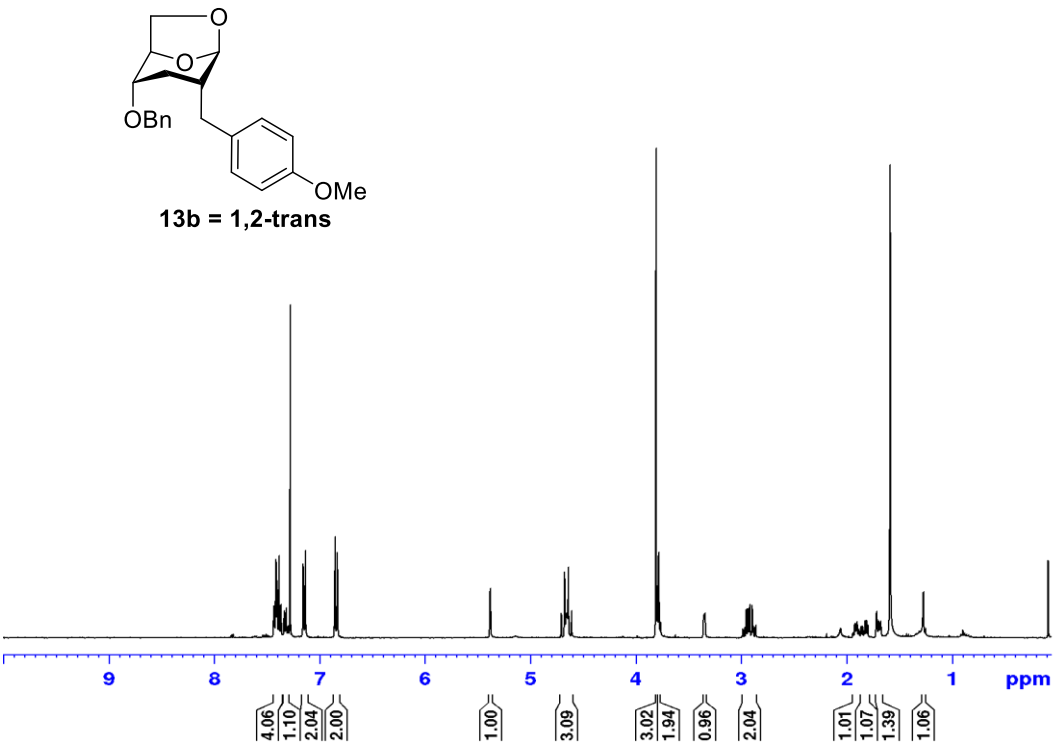


13a = 1,2-cis

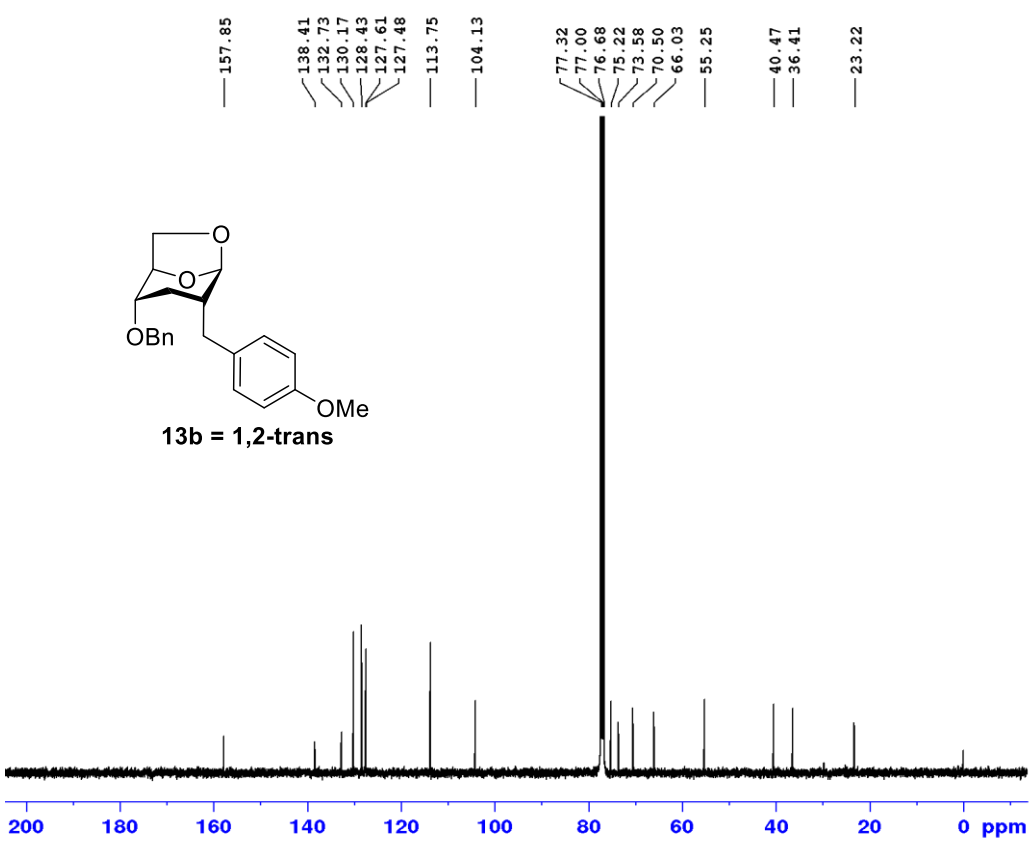



```
Current Data Parameters
NAME      BUR student NMR
EXPNO            1299211
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181231
Time               8.13
INSTRUM           spect
PROBHD   5 mm BBI 1H/D-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8278.146 Hz
FIDRES        0.126314 Hz
AQ            3.9583745 sec
RG                35.9
DW              60.400 usec
DE               6.50 usec
TE              673.2 K
D1          1.00000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                  1H
P1                 9.20 usec
PL1               -1.00 dB
PL1W       10.72012138 W
SFO1       400.1324710 MHz

F2 - Processing parameters
SI                32768
SF          400.1300000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```

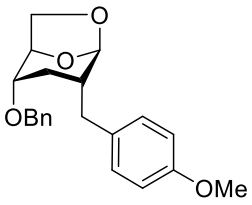
```
Current Data Parameters
NAME      BUR student NMR
EXPNO            1299221
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181231
Time               8.21
INSTRUM           spect
PROBHD   5 mm BBI 1H/D-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  308
DS                    4
SWH           23980.814 Hz
FIDRES        0.365918 Hz
AQ            1.3664256 sec
RG                322.5
DW              20.850 usec
DE               6.50 usec
TE              673.2 K
D1          2.00000000 sec
D11         0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                 13C
P1                30.00 usec
PL1               -4.50 dB
PL1W       94.86473846 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             90.00 usec
PL2               -1.00 dB
PL12              18.81 dB
PL13             120.00 dB
PL2W       10.72012138 W
PL12W       0.11199529 W
PL13W     0 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                32768
SF          100.6127789 MHz
WDW                  EM
SSB       0
LB             1.00 Hz
GB        0
PC                1.40
```



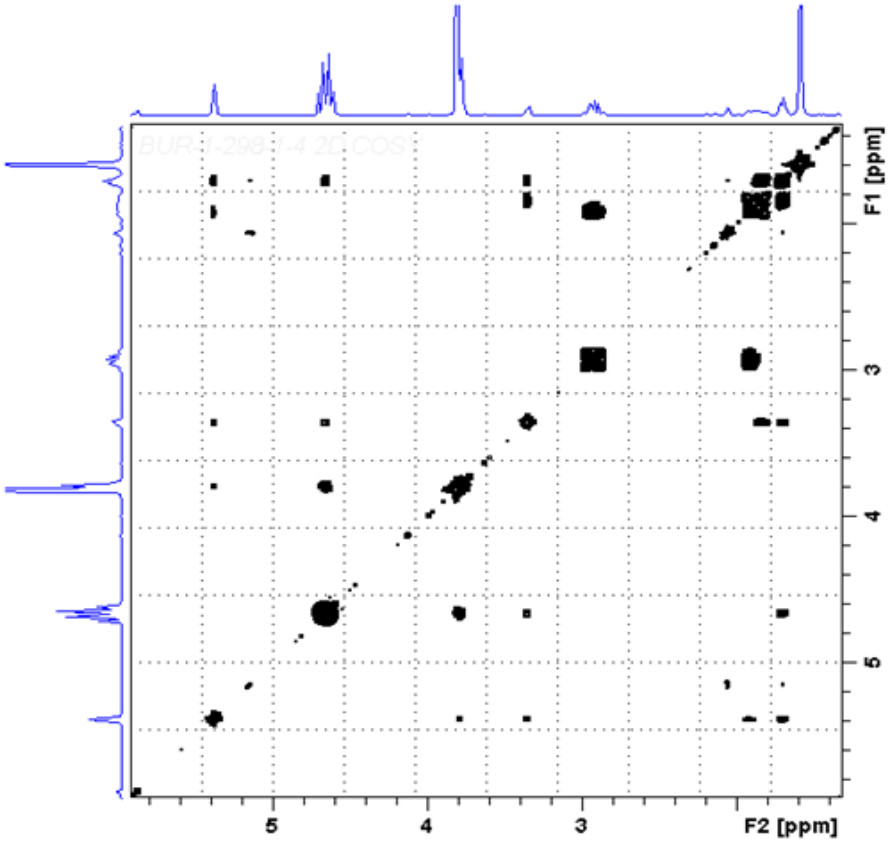

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  129811
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160417
Time                   22.19
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8223.685 Hz
FIDRES            0.125483 Hz
AQ                 3.9845889 sec
RG                      512
DW                   60.800 usec
DE                    6.50 usec
TE                   296.8 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     1.50 dB
PL1W             15.18650627 W
SFO1            400.0934707 MHz

F2 - Processing parameters
SI                        32768
SF               400.0910000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

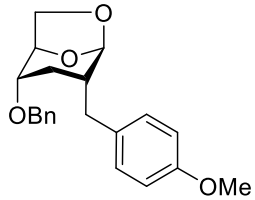



```
Current Data Parameters
NAME                  BUR 400
EXPNO                  129812
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160417
Time                   12.03
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     6024
DS                        4
SWH               24038.461 Hz
FIDRES            0.366798 Hz
AQ                 1.3631488 sec
RG                     1030
DW                   20.800 usec
DE                    6.50 usec
TE                   298.6 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                     13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W             49.44866943 W
SFO1            100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                      1H
PCPD2                  90.00 usec
PL2                     1.50 dB
PL12                   17.18 dB
PL13                   20.18 dB
PL2W             15.18650627 W
PL12W             0.41063678 W
PL13W             0.20580591 W
SFO2            400.0926004 MHz

F2 - Processing parameters
SI                        32768
SF               100.6029624 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

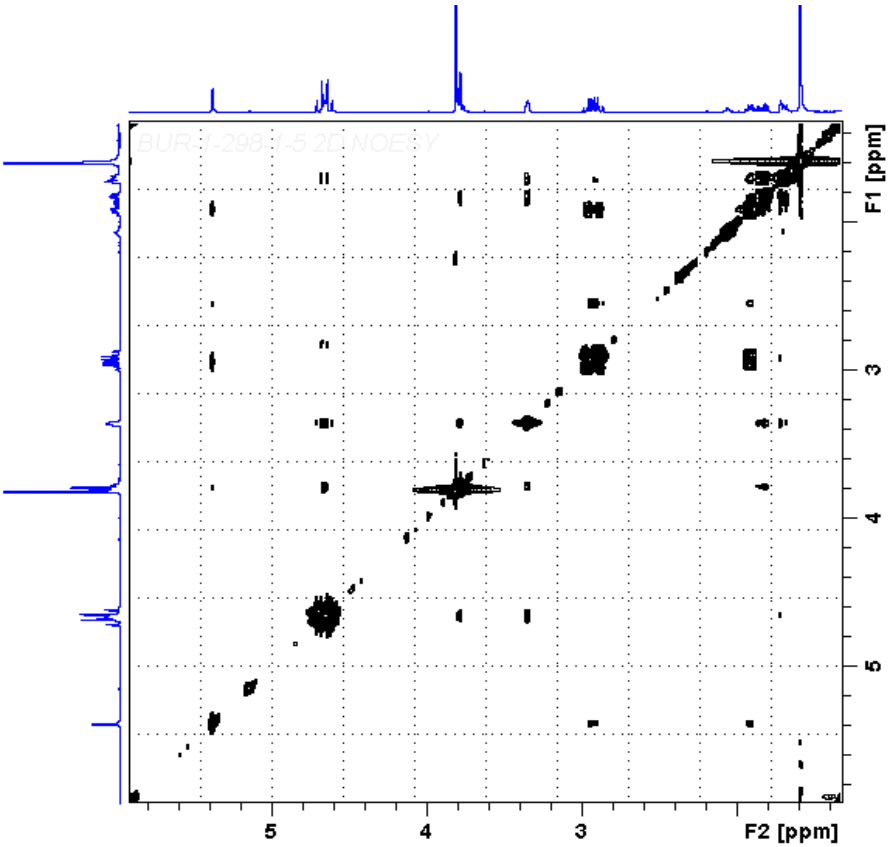


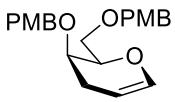
13b = 1,2- trans
(COSY, 400MHz)





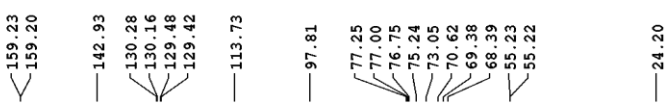
13b = 1,2-trans
(NOESY, 400MHz)

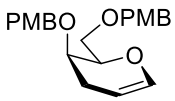




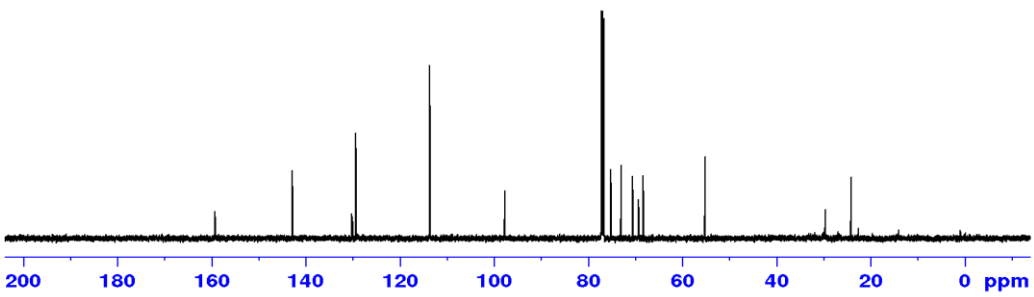
15


```
Current Data Parameters
NAME                  BUR 500
EXPNO                  315711
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160126
Time                   17.25
INSTRUM                spect
PROBHD    5 mm TXI 1H/D-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      128
DW                   48.400 usec
DE                    6.50 usec
TE                   294.1 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      7.00 usec
PL1                     1.20 dB
PL1W             15.45328617 W
SFO1            500.1830888 MHz

F2 - Processing parameters
SI                      32768
SF               500.1800000 MHz
WDW                        EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```

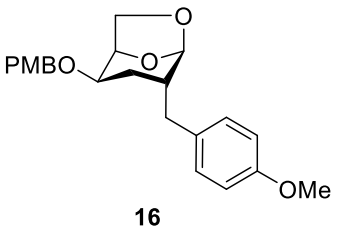




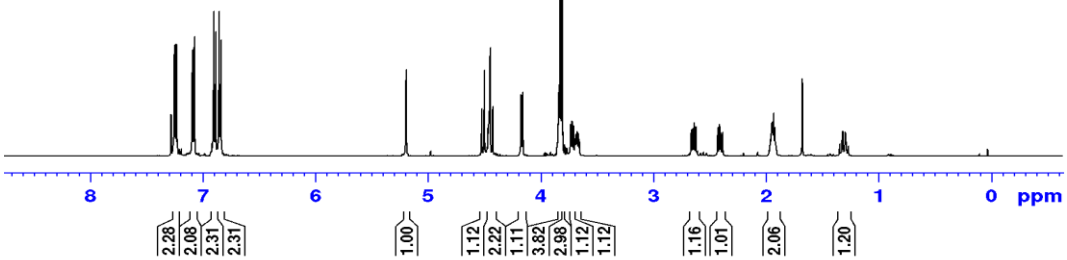
15



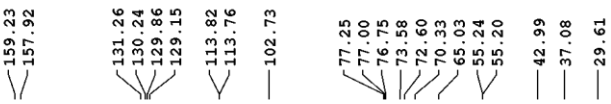

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  145012
PROCNO                      1

F2 - Acquisition Parameters
Date_               20171018
Time                   17.15
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      341
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   296.4 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      9.60 usec
PL1          0 dB
PL1W             76.36135101 W
SFO1            125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W             12.85348415 W
PL12W             0.45605880 W
PL13W             0.45605880 W
SFO2            500.1820007 MHz

F2 - Processing parameters
SI                      32768
SF               125.7703656 MHz
WDW                        EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```

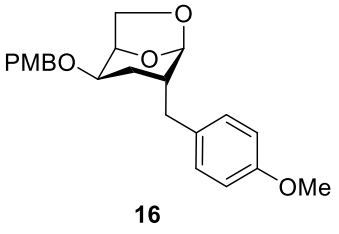


16

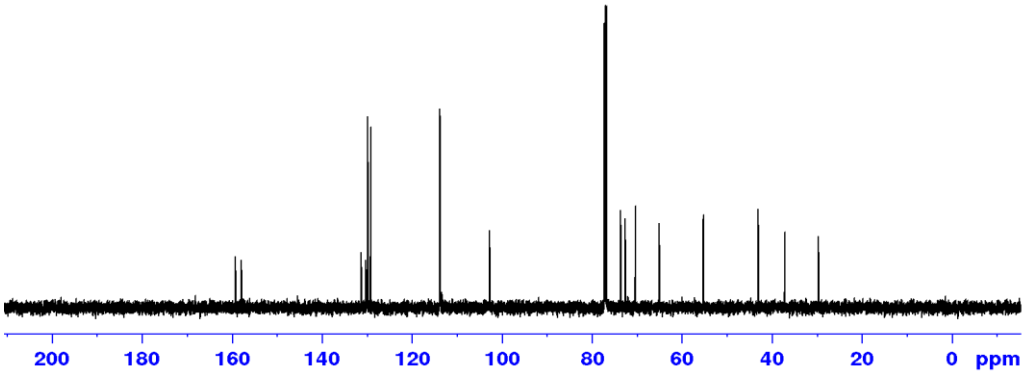



```
Current Data Parameters
NAME           madhu(PRS)
EXPNO              315911
PROCNO                  1

F2 - Acquisition Parameters
Date_            20160127
Time                18.16
INSTRUM             spect
PROBHD   5 mm TXI 1H/D-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH            10330.578 Hz
FIDRES          0.157632 Hz
AQ             3.1719425 sec
RG                  50.8
DW                48.400 usec
DE                 6.50 usec
TE                294.2 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 7.00 usec
PL1                1.20 dB
PL1W         15.45328617 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF           500.1800000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

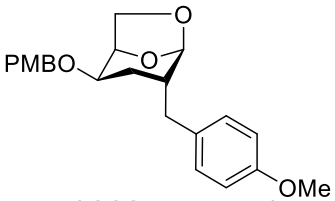




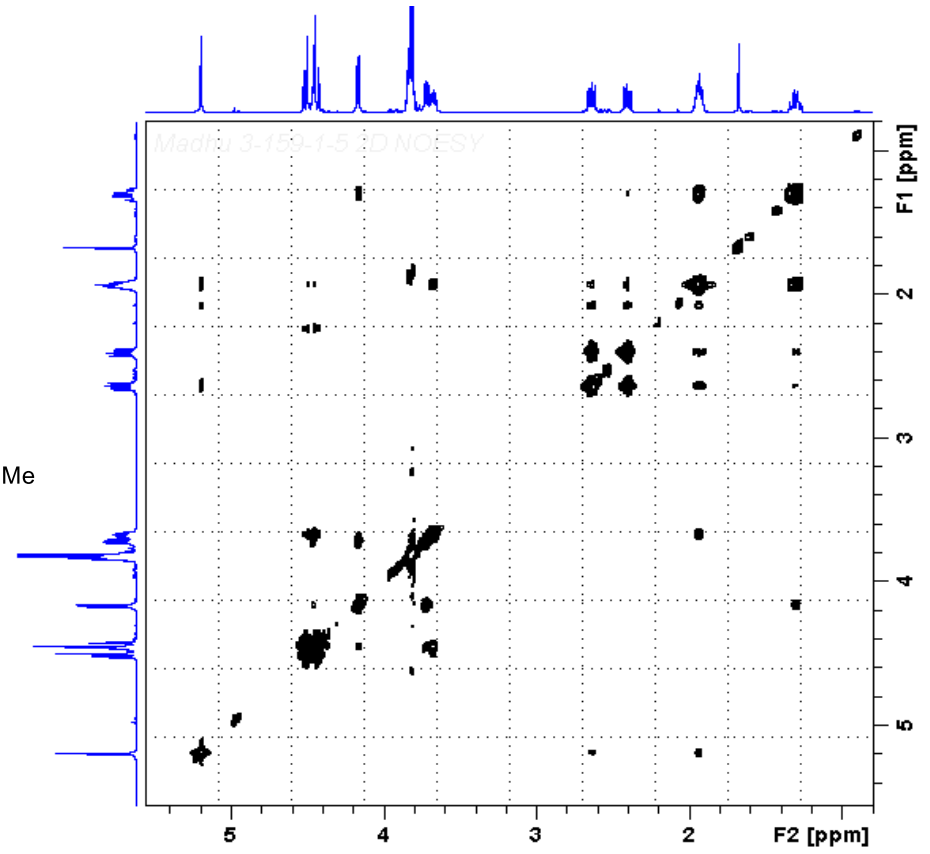
16

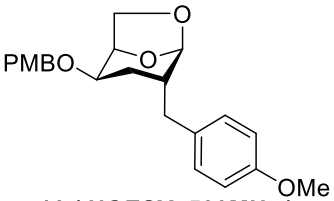



```
Current Data Parameters
NAME           madhu(PRS)
EXPNO              315912
PROCNO                  1

F2 - Acquisition Parameters
Date_            20160127
Time                18.20
INSTRUM             spect
PROBHD   5 mm TXI 1H/D-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   128
DS                     4
SWH            29761.904 Hz
FIDRES          0.454131 Hz
AQ             1.1010048 sec
RG                  645
DW                16.800 usec
DE                 6.50 usec
TE                294.4 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                11.00 usec
PL1               -4.77 dB
PL1W        229.02009583 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             80.00 usec
PL2                1.20 dB
PL12              22.36 dB
PL13              26.36 dB
PL2W         15.45328617 W
PL12W         0.11830982 W
PL13W         0.04709999 W
SFO2         500.1820007 MHz

F2 - Processing parameters
SI                 32768
SF           125.7703697 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

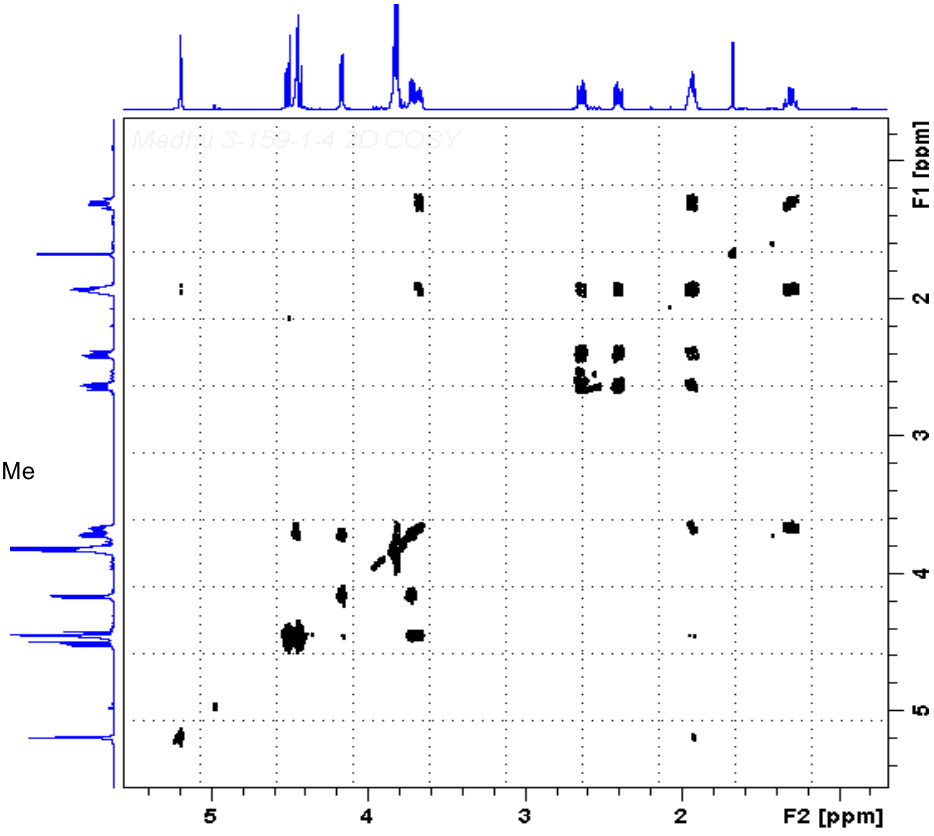


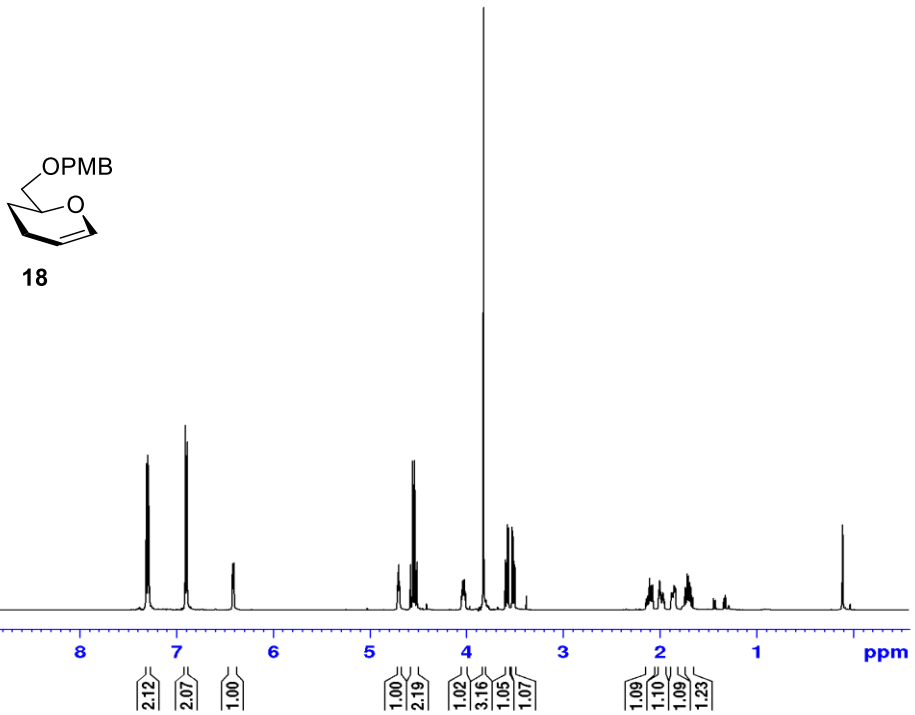
16 (COSY, 500MHz)



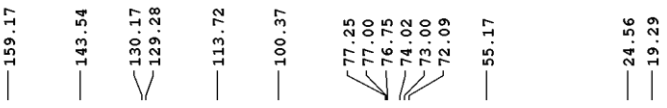


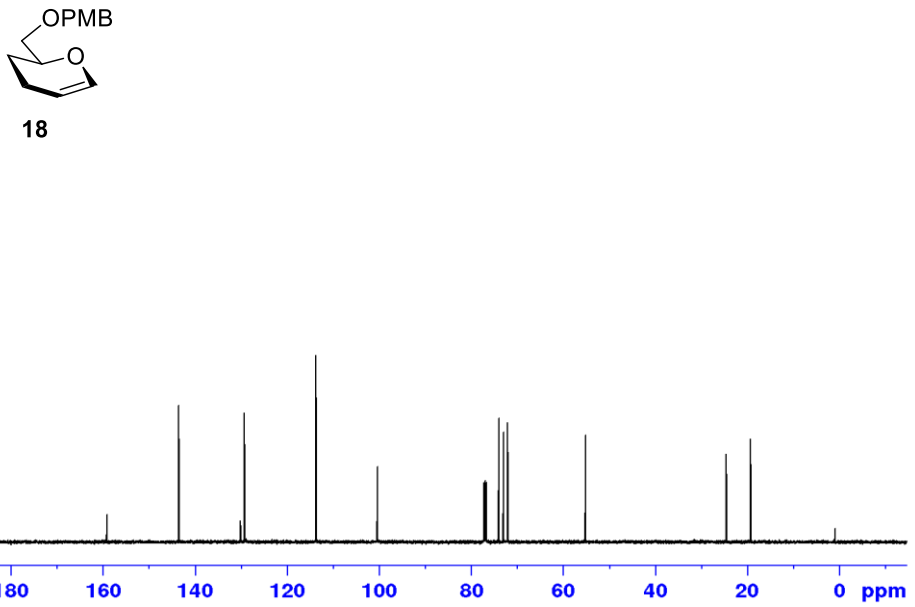
16 (NOESY, 500MHz)



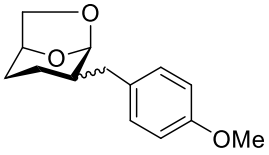



```
Current Data Parameters
NAME                  BUR 500
EXPNO                  134211
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160819
Time                   20.35
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                3.1719425 sec
RG                     45.2
DW                   48.400 usec
DE                    6.50 usec
TE                   296.6 K
D1                1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     1H
P1                    14.90 usec
PL1                    2.00 dB
PL1W            12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```



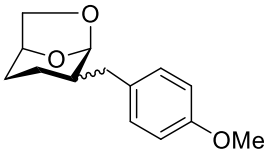



```
Current Data Parameters
NAME                  BUR 500
EXPNO                  134212
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160819
Time                   20.38
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                       88
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   297.6 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                    13C
P1                    9.60 usec
PL1         0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                     1H
PCPD2                 80.00 usec
PL2                    2.00 dB
PL12                  16.50 dB
PL13                  16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF             125.7703719 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```



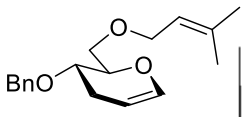
19 (mix 1:1)


```
Current Data Parameters
NAME                  BUR 500
EXPNO                  134811
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160826
Time                   19.06
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      203
DW                   48.400 usec
DE                    6.50 usec
TE                   296.0 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      2.00 dB
PL1W            12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                      32768
SF             500.1800102 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                      1.00
```

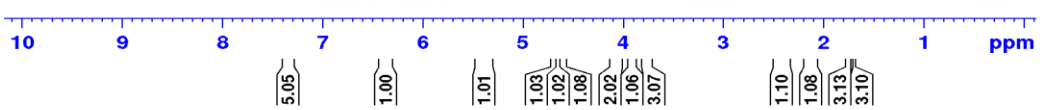


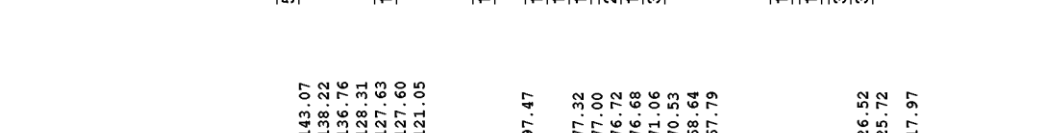
19 (mix 1:1)


```
Current Data Parameters
NAME                  BUR 500
EXPNO                  134812
PROCNO                      1

F2 - Acquisition Parameters
Date_               20160826
Time                   19.10
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      256
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   297.1 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                       9.60 usec
PL1                 0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                      2.00 dB
PL12                    16.50 dB
PL13                    16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                      32768
SF             125.7703626 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                      1.40
```

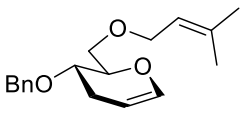


20

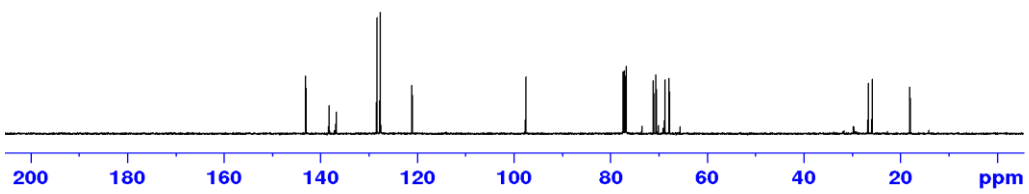




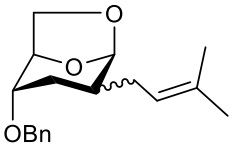

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  136511
PROCNO                      1

F2 - Acquisition Parameters
Date_               20161010
Time                   18.50
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      50.8
DW                    48.400 usec
DE                     6.50 usec
TE                    295.8 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      2.00 dB
PL1W              12.85348415 W
SFO1             500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                          EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```

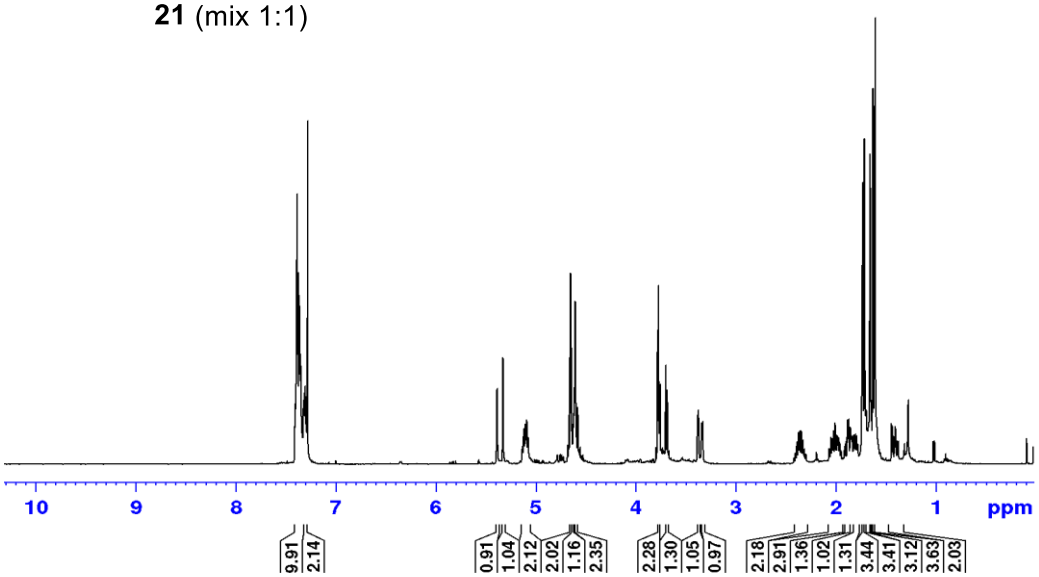
20



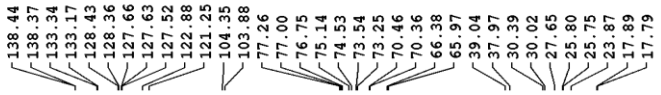

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  136512
PROCNO                      1

F2 - Acquisition Parameters
Date_               20161018
Time                   18.34
INSTRUM                spect
PROBHD     5 mm PABBO BB/
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      265
DS                        4
SWH               23980.814 Hz
FIDRES             0.365918 Hz
AQ                 1.3664256 sec
RG                     812.7
DW                    20.850 usec
DE                     6.50 usec
TE                    295.0 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      13.50 usec
PL1          0 dB
PL1W              33.65927887 W
SFO1             100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                     -1.30 dB
PL12                    13.24 dB
PL13                    13.24 dB
PL2W              11.48681641 W
PL12W              0.40383106 W
PL13W              0.40383106 W
SFO2             400.1316005 MHz

F2 - Processing parameters
SI                        32768
SF               100.6127800 MHz
WDW                          EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```

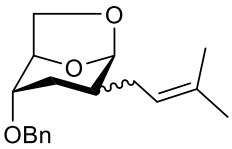


21 (mix 1:1)



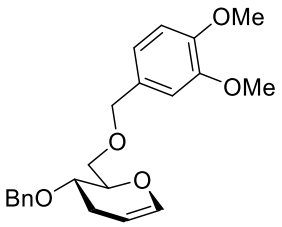

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 136811
PROCNO                     1

F2 - Acquisition Parameters
Date_               20161022
Time                   13.27
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES            0.157632 Hz
AQ                3.1719425 sec
RG                      256
DW                   48.400 usec
DE                    6.50 usec
TE                   295.9 K
D1                1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W            12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF             500.1800000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```



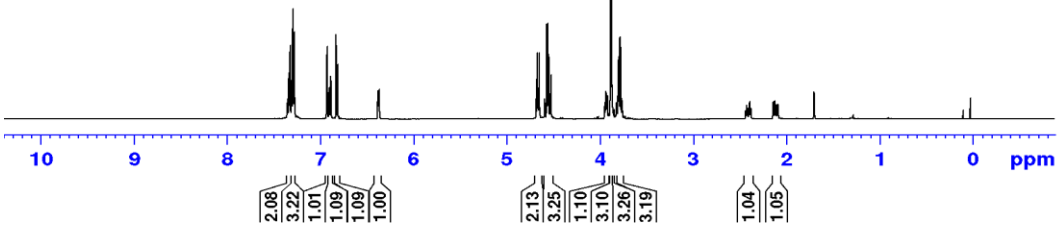


21 (mix 1:1)

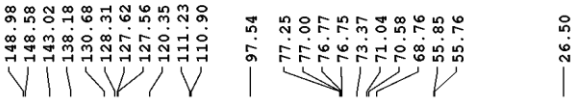

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 136812
PROCNO                     1

F2 - Acquisition Parameters
Date_               20161022
Time                   13.35
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     2000
DS                        4
SWH               29761.904 Hz
FIDRES            0.454131 Hz
AQ                1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   297.7 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     9.60 usec
PL1          0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                      1H
PCPD2                 80.00 usec
PL2                    2.00 dB
PL12                  16.50 dB
PL13                  16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF             125.7703624 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

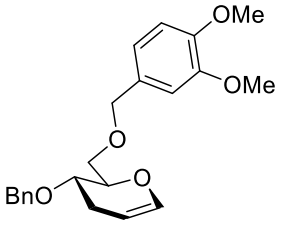


22

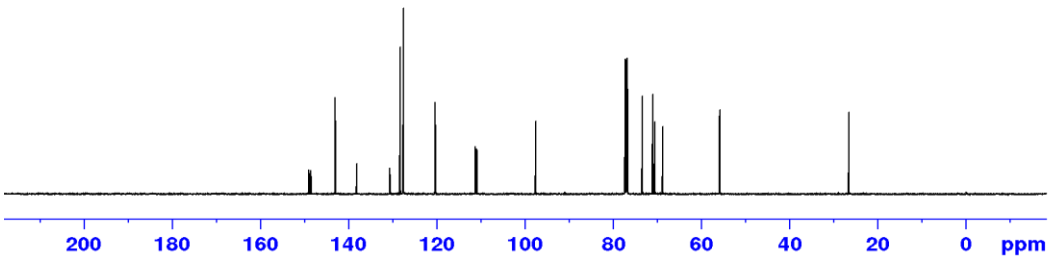



```
Current Data Parameters
NAME                  BUR 500
EXPNO                  136411
PROCNO                      1

F2 - Acquisition Parameters
Date_               20161010
Time                   21.21
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                       57
DW                   48.400 usec
DE                    6.50 usec
TE                   294.2 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W             12.85348415 W
SFO1            500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

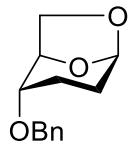




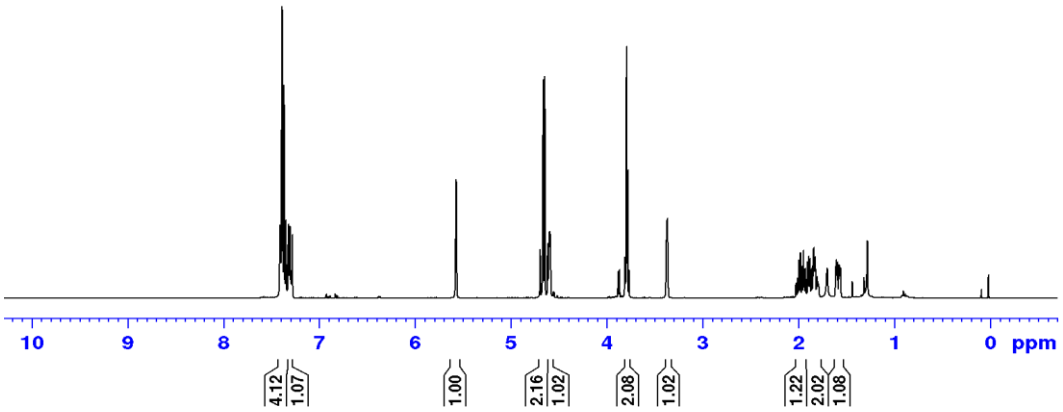
22



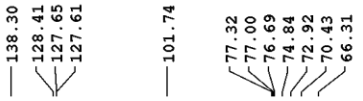

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  136412
PROCNO                      1

F2 - Acquisition Parameters
Date_               20161010
Time                   21.24
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     1024
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   295.6 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                     13C
P1                     9.60 usec
PL1           0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W             12.85348415 W
PL12W             0.45605880 W
PL13W             0.45605880 W
SFO2            500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703703 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

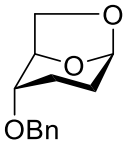


23

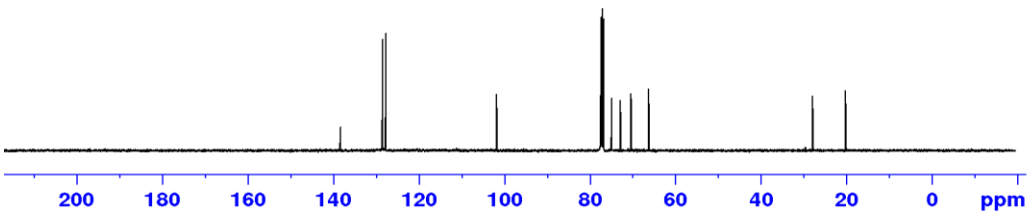



```
Current Data Parameters
NAME      BUR 400 BY 20-02-2018
EXPNO          12382125
PROCNO                1

F2 - Acquisition Parameters
Date_          20161015
Time               4.48
INSTRUM           spect
PROBHD    5 mm BBI 1H/D-
PULPROG           zg30
TD               65536
SOLVENT          CDCl3
NS                  16
DS                   2
SWH           8223.685 Hz
FIDRES        0.125483 Hz
AQ            3.9845889 sec
RG                80.6
DW              60.800 usec
DE               6.50 usec
TE              297.0 K
D1           1.00000000 sec
TD0                  1

======== CHANNEL f1 ========
NUC1                1H
P1               8.00 usec
PL1              1.20 dB
PL1W       16.27263451 W
SFO1       400.0934707 MHz

F2 - Processing parameters
SI                32768
SF         400.0909980 MHz
WDW                  EM
SSB       0
LB              0.30 Hz
GB        0
PC              1.00
```

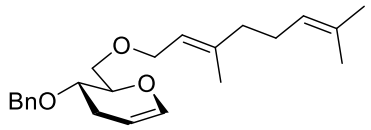




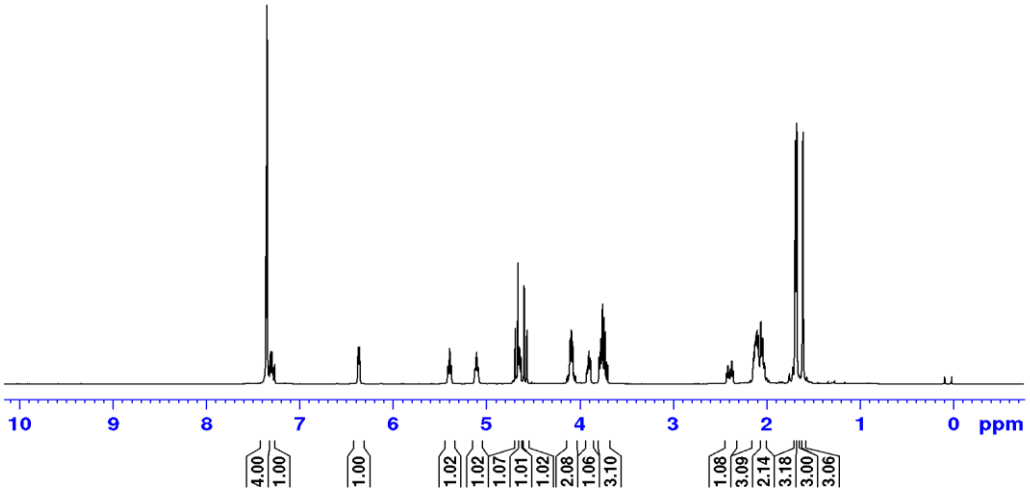
23



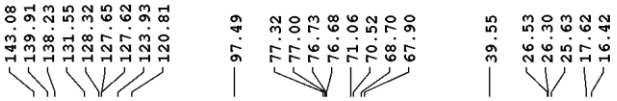

```
Current Data Parameters
NAME      BUR 400 BY 20-02-2018
EXPNO          12382126
PROCNO                1

F2 - Acquisition Parameters
Date_          20161015
Time               5.38
INSTRUM           spect
PROBHD    5 mm BBI 1H/D-
PULPROG         zgpg30
TD               65536
SOLVENT          CDCl3
NS                 844
DS                   4
SWH           24038.461 Hz
FIDRES        0.366798 Hz
AQ            1.3631488 sec
RG                 912
DW              20.800 usec
DE               6.50 usec
TE              297.2 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                  1

======== CHANNEL f1 ========
NUC1                13C
P1              15.00 usec
PL1             -1.60 dB
PL1W      113.28035736 W
SFO1       100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2         waltz16
NUC2                1H
PCPD2            80.00 usec
PL2              1.20 dB
PL12             21.20 dB
PL13             21.20 dB
PL2W       16.27263451 W
PL12W       0.16272631 W
PL13W       0.16272631 W
SFO2       400.0926004 MHz

F2 - Processing parameters
SI                32768
SF         100.6029664 MHz
WDW                  EM
SSB       0
LB              1.00 Hz
GB        0
PC              1.40
```

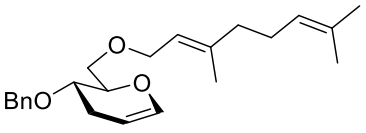


24

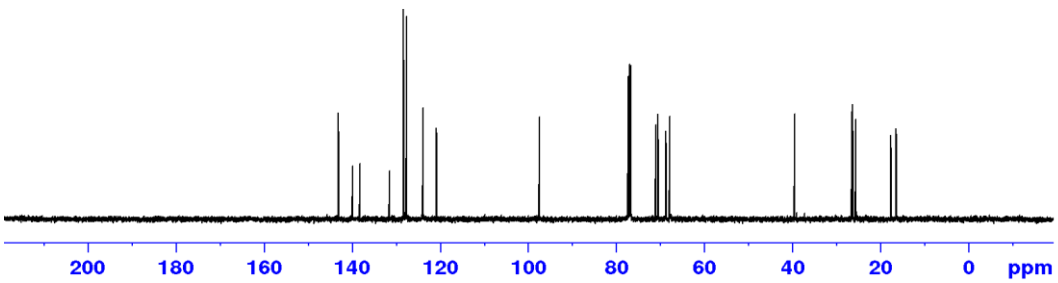



```
Current Data Parameters
NAME                  BUR 400
EXPNO                 137711
PROCNO                     1

F2 - Acquisition Parameters
Date_               20161112
Time                   12.13
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8278.146 Hz
FIDRES              0.126314 Hz
AQ                 3.9583745 sec
RG                      40.3
DW                    60.400 usec
DE                     6.50 usec
TE                    294.2 K
D1                 1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     15.00 usec
PL1                    -1.30 dB
PL1W              11.48681641 W
SFO1             400.1324710 MHz

F2 - Processing parameters
SI                     32768
SF                400.1300078 MHz
WDW                       EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

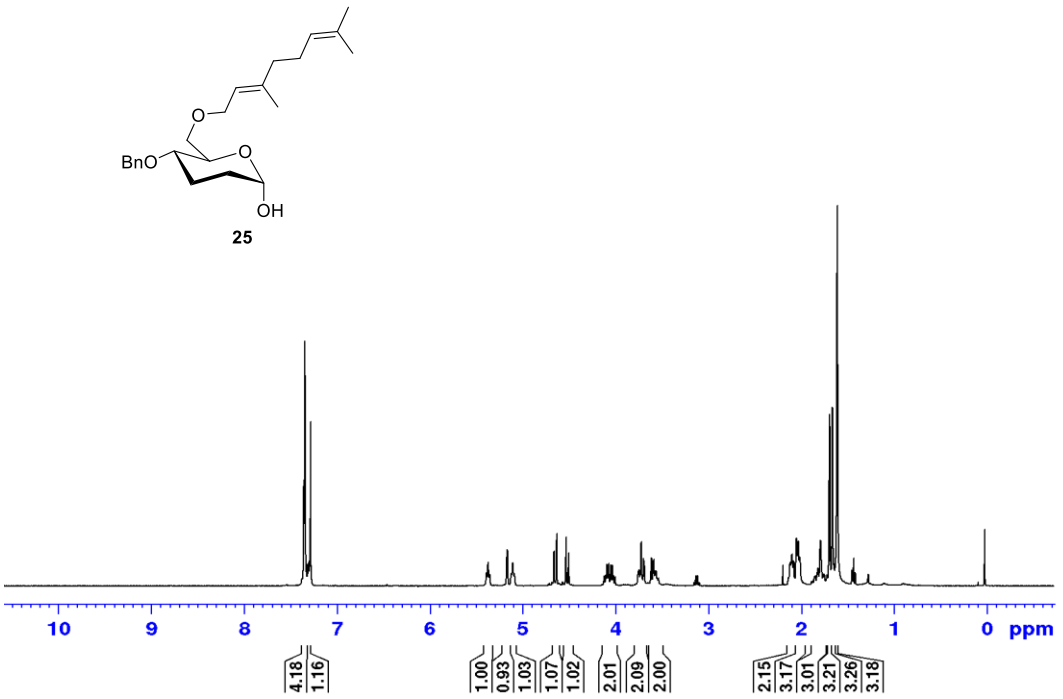




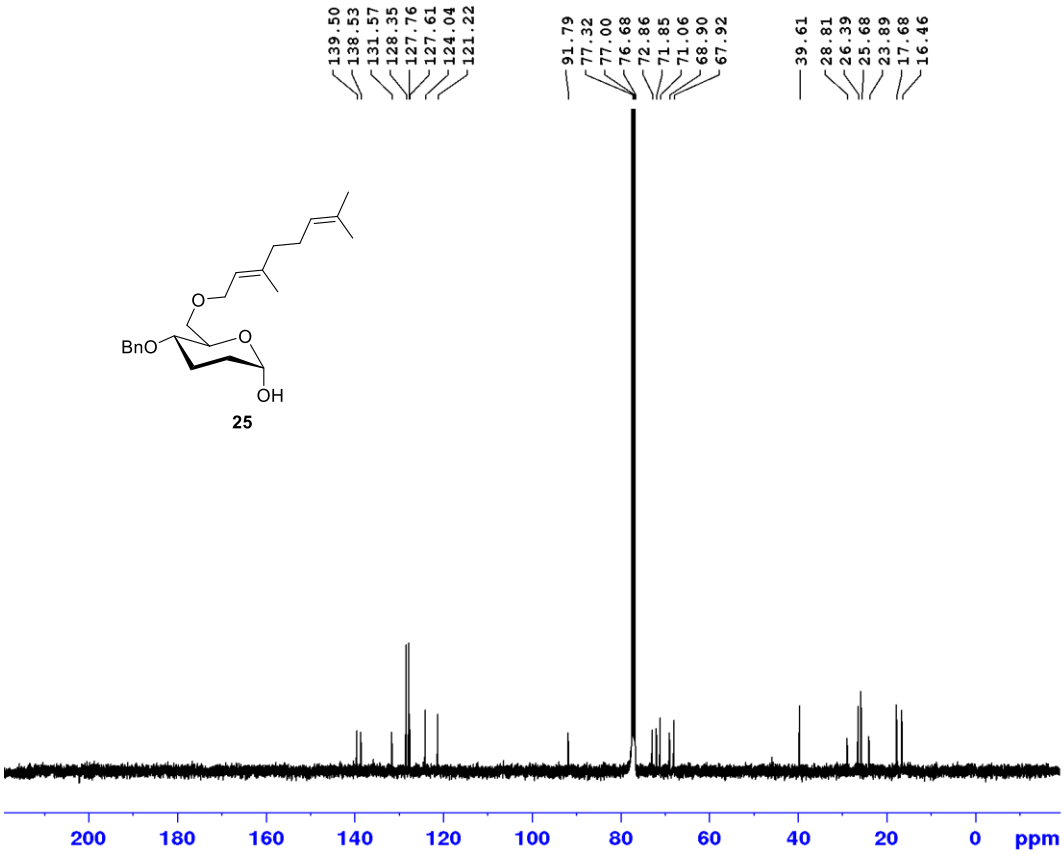
24



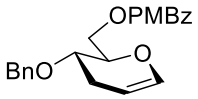

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 137712
PROCNO                     1

F2 - Acquisition Parameters
Date_               20161112
Time                   12.21
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      117
DS                        4
SWH               23980.814 Hz
FIDRES              0.365918 Hz
AQ                 1.3664256 sec
RG                    812.7
DW                    20.850 usec
DE                     6.50 usec
TE                    295.0 K
D1                 2.00000000 sec
D11                0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     13.50 usec
PL1          0 dB
PL1W              33.65927887 W
SFO1             100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                    -1.30 dB
PL12                   13.24 dB
PL13                   13.24 dB
PL2W              11.48681641 W
PL12W              0.40383106 W
PL13W              0.40383106 W
SFO2             400.1316005 MHz

F2 - Processing parameters
SI                     32768
SF                100.6127782 MHz
WDW                       EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```



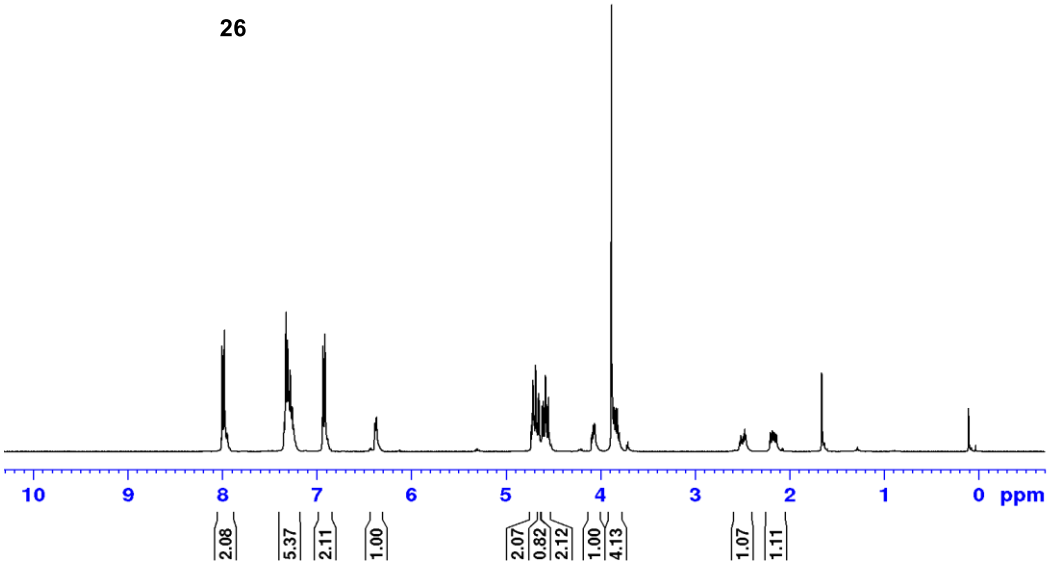

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 137921
PROCNO                     1

F2 - Acquisition Parameters
Date_              20161117
Time                    3.43
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       32
DS                        2
SWH                8278.146 Hz
FIDRES              0.126314 Hz
AQ                 3.9583745 sec
RG                     322.5
DW                    60.400 usec
DE                     6.50 usec
TE                     295.4 K
D1                 1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     15.00 usec
PL1                    -1.30 dB
PL1W              11.48681641 W
SFO1              400.1324710 MHz

F2 - Processing parameters
SI                        32768
SF                400.1300000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

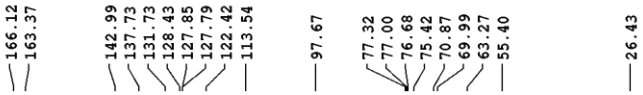



```
Current Data Parameters
NAME                  BUR 400
EXPNO                 137922
PROCNO                     1

F2 - Acquisition Parameters
Date_              20161117
Time                    3.47
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     2048
DS                        4
SWH               23980.814 Hz
FIDRES              0.365918 Hz
AQ                 1.3664256 sec
RG                     574.7
DW                    20.850 usec
DE                     6.50 usec
TE                     295.6 K
D1                 2.00000000 sec
D11                0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     13.50 usec
PL1          0 dB
PL1W              33.65927887 W
SFO1              100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2               waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                    -1.30 dB
PL12                   13.24 dB
PL13                   13.24 dB
PL2W              11.48681641 W
PL12W              0.40383106 W
PL13W              0.40383106 W
SFO2              400.1316005 MHz

F2 - Processing parameters
SI                        32768
SF                100.6127705 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

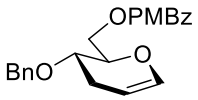


26

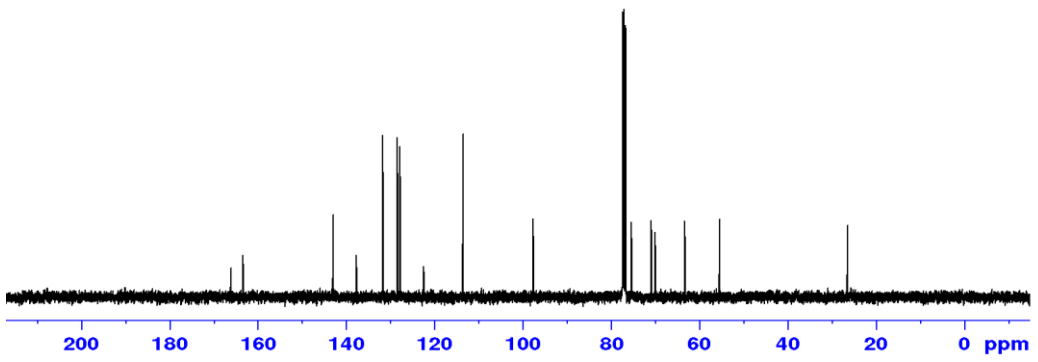




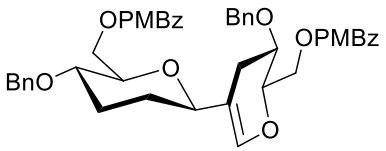

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 138111
PROCNO                     1

F2 - Acquisition Parameters
Date_              20161214
Time                  17.51
INSTRUM               spect
PROBHD    5 mm PABBO BB/
PULPROG               zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8278.146 Hz
FIDRES                0.126314 Hz
AQ                 3.9583745 sec
RG                      128
DW                     60.400 usec
DE                      6.50 usec
TE                     295.2 K
D1                 1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     15.00 usec
PL1                    -1.30 dB
PL1W              11.48681641 W
SFO1             400.1324710 MHz

F2 - Processing parameters
SI                     32768
SF                400.1300000 MHz
WDW                       EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```



26

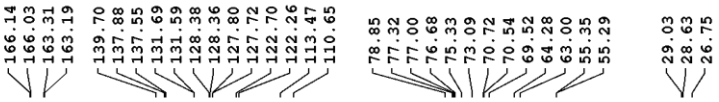


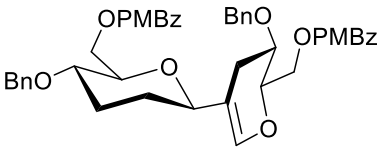

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 138112
PROCNO                     1

F2 - Acquisition Parameters
Date_              20161214
Time                  17.57
INSTRUM               spect
PROBHD    5 mm PABBO BB/
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      135
DS                        4
SWH               23980.814 Hz
FIDRES                0.365918 Hz
AQ                 1.3664256 sec
RG                    812.7
DW                     20.850 usec
DE                      6.50 usec
TE                     295.8 K
D1                 2.00000000 sec
D11                0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                     13C
P1                     13.50 usec
PL1          0 dB
PL1W              33.65927887 W
SFO1             100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                    -1.30 dB
PL12                   13.24 dB
PL13                   13.24 dB
PL2W              11.48681641 W
PL12W              0.40383106 W
PL13W              0.40383106 W
SFO2             400.1316005 MHz

F2 - Processing parameters
SI                     32768
SF                100.6127735 MHz
WDW                       EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```



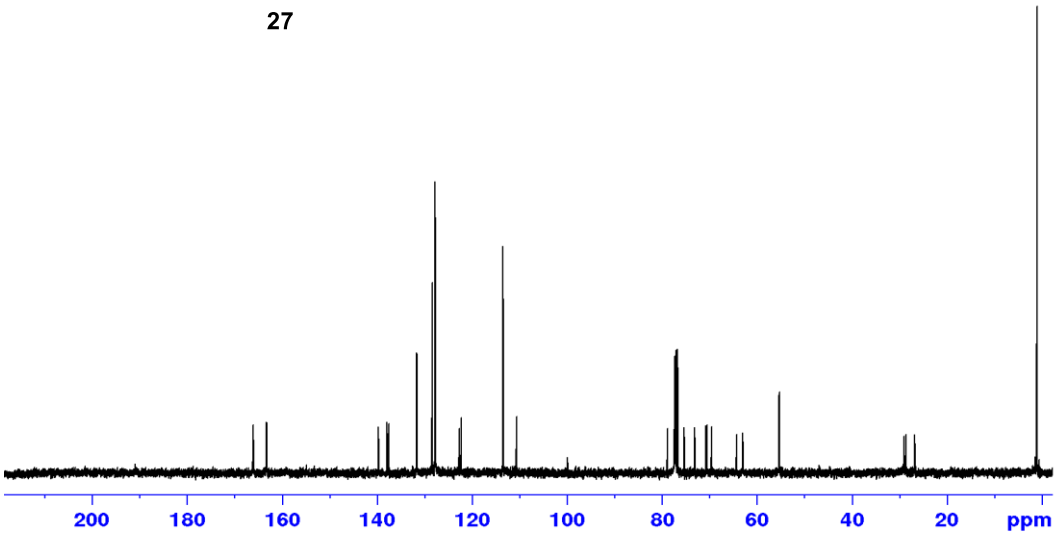
27


```
Current Data Parameters
NAME      bur student NMR
EXPNO             145121
PROCNO                 1

F2 - Acquisition Parameters
Date_           20171114
Time                8.43
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8278.146 Hz
FIDRES        0.126314 Hz
AQ            3.9583745 sec
RG                 22.6
DW               60.400 usec
DE                6.50 usec
TE               673.2 K
D1            1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 9.20 usec
PL1               -1.00 dB
PL1W        10.72012138 W
SFO1        400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300000 MHz
WDW                   EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```

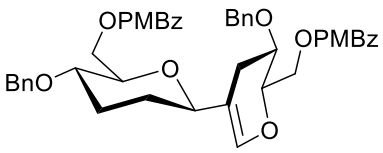




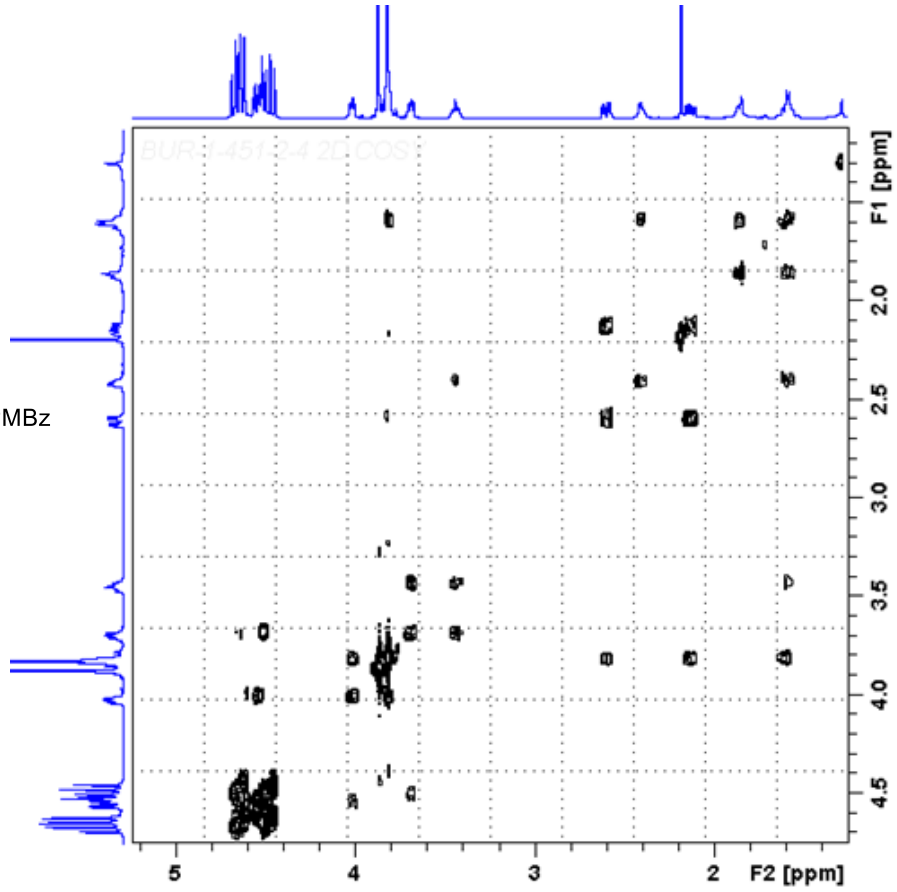
27

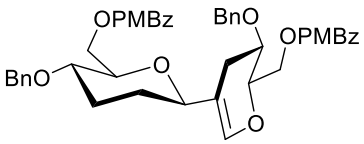



```
Current Data Parameters
NAME      bur student NMR
EXPNO             145122
PROCNO                 1

F2 - Acquisition Parameters
Date_           20171114
Time                8.51
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  148
DS                    4
SWH           23980.814 Hz
FIDRES         0.365918 Hz
AQ            1.3664256 sec
RG                   57
DW               20.850 usec
DE                6.50 usec
TE               673.2 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                30.00 usec
PL1               -4.50 dB
PL1W        94.86473846 W
SFO1        100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             90.00 usec
PL2               -1.00 dB
PL12              18.81 dB
PL13             120.00 dB
PL2W        10.72012138 W
PL12W        0.11199529 W
PL13W     0 W
SFO2        400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF          100.6127797 MHz
WDW                   EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```

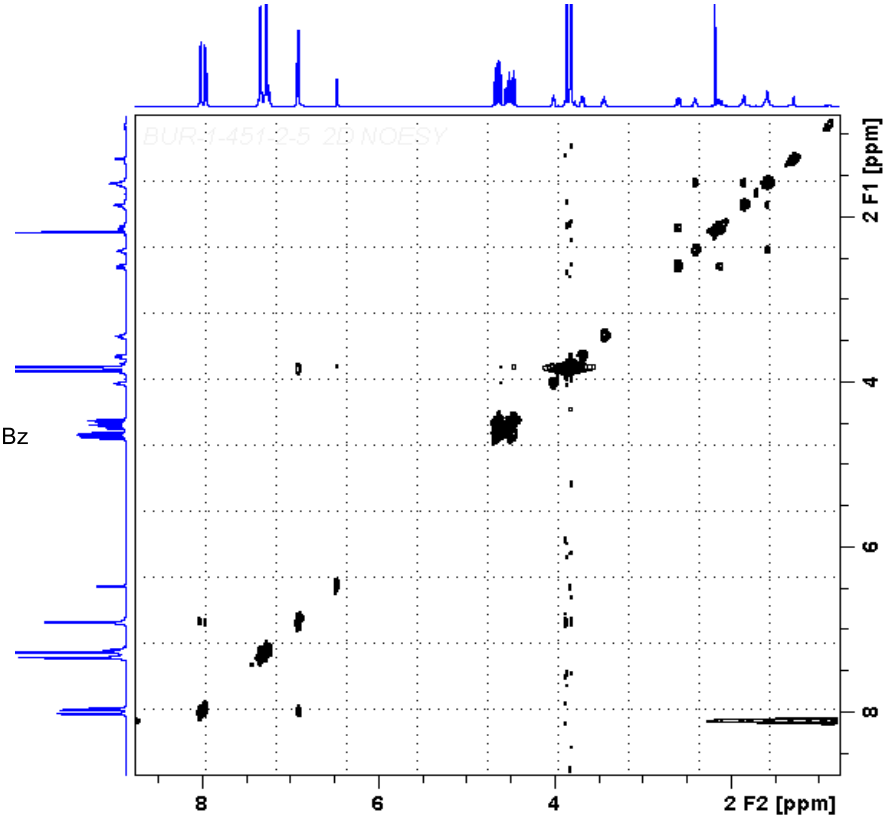


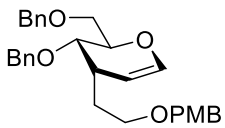
27 (COSY, 500MHz)



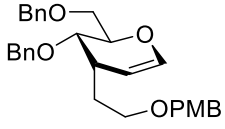


27 (NOESY, 500MHz)





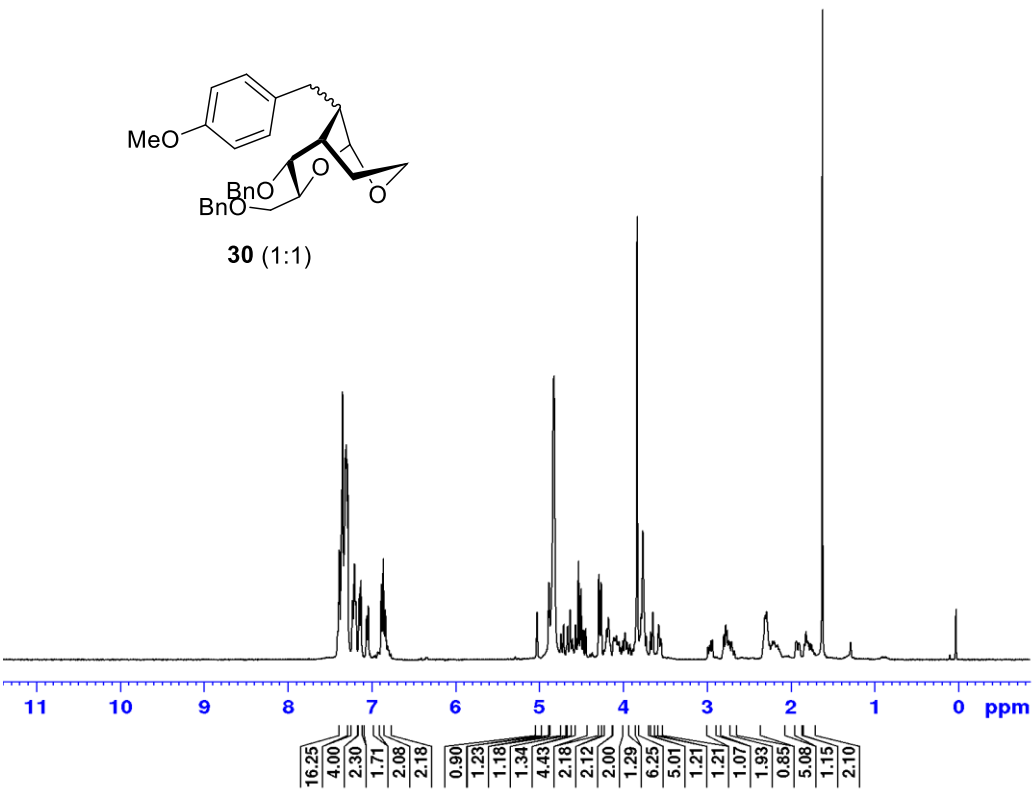
29



29

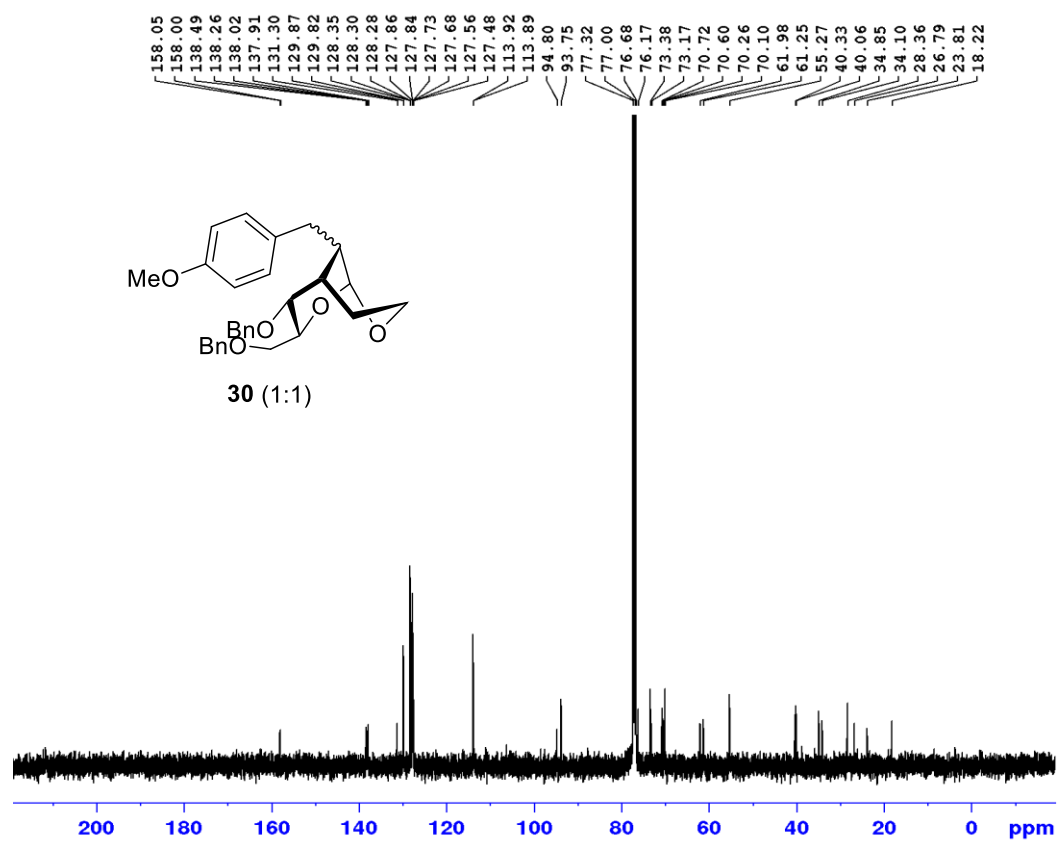

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  138711
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170110
Time                   21.29
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      144
DW                   48.400 usec
DE                    6.50 usec
TE                   299.6 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W              12.85348415 W
SFO1             500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  138712
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170110
Time                   21.32
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      256
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   300.6 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                     9.60 usec
PL1            0 dB
PL1W              76.36135101 W
SFO1             125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                 80.00 usec
PL2                    2.00 dB
PL12                  16.50 dB
PL13                  16.50 dB
PL2W              12.85348415 W
PL12W              0.45605880 W
PL13W              0.45605880 W
SFO2             500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703649 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```



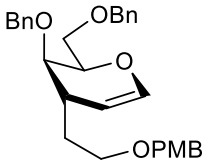
30 (1:1)

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  139411
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170114
Time                   16.59
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8278.146 Hz
FIDRES            0.126314 Hz
AQ                3.9583745 sec
RG                      256
DW                   60.400 usec
DE                    6.50 usec
TE                   294.2 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      15.00 usec
PL1                     -1.30 dB
PL1W            11.48681641 W
SFO1            400.1324710 MHz

F2 - Processing parameters
SI                      32768
SF              400.1300000 MHz
WDW                        EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```



30 (1:1)

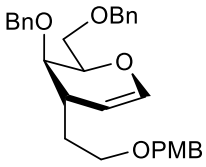
```
NAME                  BUR 400
EXPNO                  139412
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170114
Time                   17.13
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      1444
DS                         4
SWH               23980.814 Hz
FIDRES            0.365918 Hz
AQ                1.3664256 sec
RG                     812.7
DW                   20.850 usec
DE                    6.50 usec
TE                    294.9 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      13.50 usec
PL1          0 dB
PL1W            33.65927887 W
SFO1            100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                     -1.30 dB
PL12                    13.24 dB
PL13                    13.24 dB
PL2W            11.48681641 W
PL12W            0.40383106 W
PL13W            0.40383106 W
SFO2            400.1316005 MHz

F2 - Processing parameters
SI                      32768
SF              100.6127720 MHz
WDW                        EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```



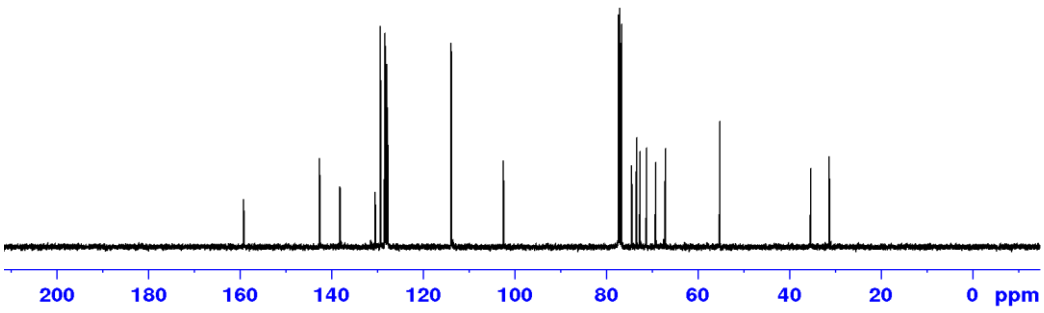
32

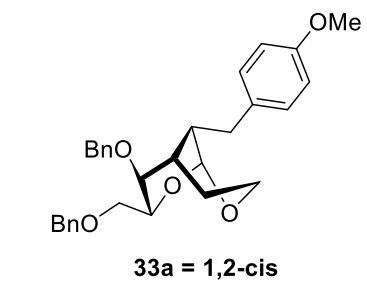
```
Current Data Parameters
NAME                  BUR 400
EXPNO                  140911
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170407
Time                   14.26
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8278.146 Hz
FIDRES            0.126314 Hz
AQ                3.9583745 sec
RG                     71.8
DW                   60.400 usec
DE                    6.50 usec
TE                   296.8 K
D1              1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                      1H
P1                    15.00 usec
PL1                   -1.60 dB
PL1W           12.30834579 W
SFO1           400.1324710 MHz

F2 - Processing parameters
SI                    32768
SF               400.1300000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  140912
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170407
Time                   14.32
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      276
DS                        4
SWH               23980.814 Hz
FIDRES            0.365918 Hz
AQ                1.3664256 sec
RG                     574.7
DW                   20.850 usec
DE                    6.50 usec
TE                   297.4 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     13C
P1                    13.50 usec
PL1           0 dB
PL1W            33.65927887 W
SFO1           100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                 80.00 usec
PL2                   -1.60 dB
PL12                  12.94 dB
PL13                  13.24 dB
PL2W           12.30834579 W
PL12W           0.43271279 W
PL13W           0.40383106 W
SFO2           400.1316005 MHz

F2 - Processing parameters
SI                    32768
SF               100.6127785 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```

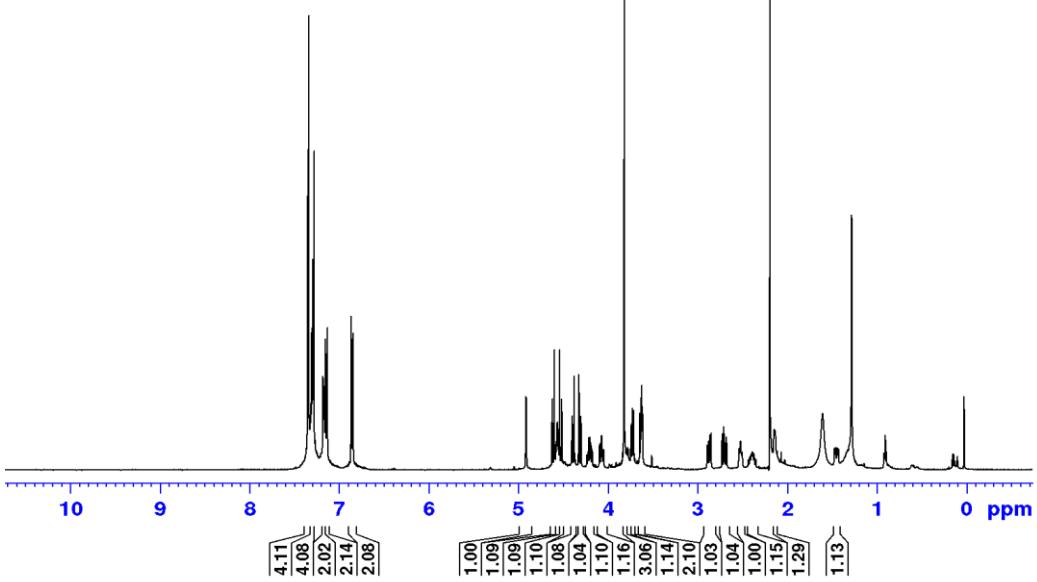


32

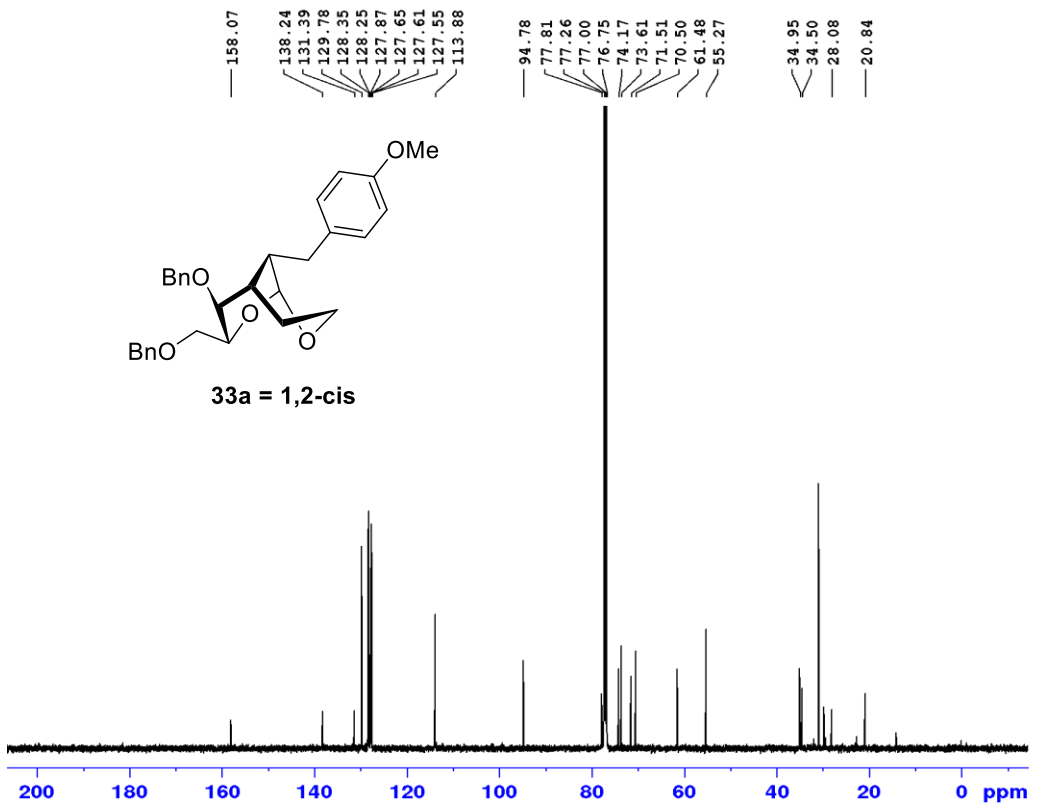




33a = 1,2-cis

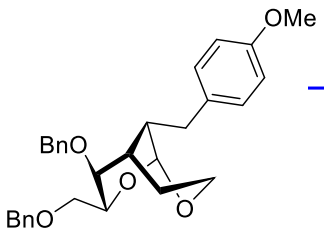



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 145831
PROCNO                     1

F2 - Acquisition Parameters
Date_               20180117
Time                   22.53
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      322
DW                   48.400 usec
DE                    6.50 usec
TE                   299.2 K
D1                1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W             12.85348415 W
SFO1            500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF              500.1800000 MHz
WDW                          EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```



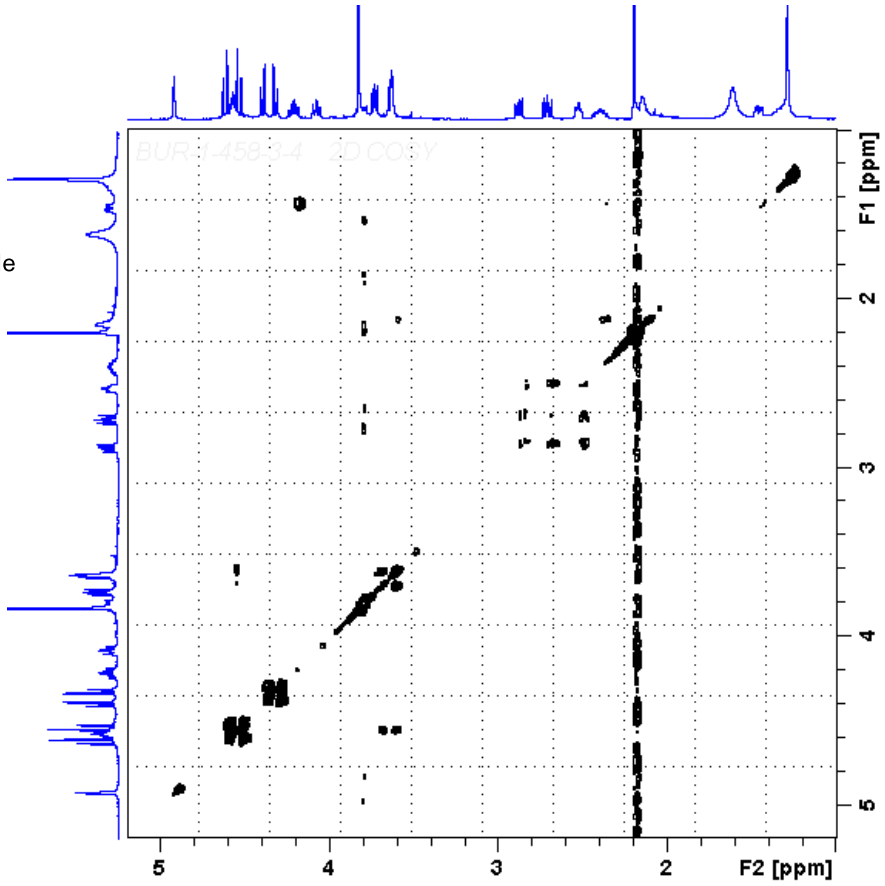
33a = 1,2-cis

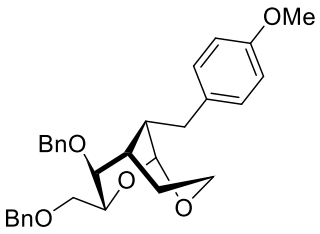
```
Current Data Parameters
NAME                  BUR 500
EXPNO                 145832
PROCNO                     1

F2 - Acquisition Parameters
Date_               20180121
Time                   16.17
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     8000
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                      2050
DW                   16.800 usec
DE                    6.50 usec
TE                   295.5 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                     13C
P1                      9.60 usec
PL1          0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W             12.85348415 W
PL12W             0.45605880 W
PL13W             0.45605880 W
SFO2            500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF             125.7703622 MHz
WDW                          EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```



33a = 1,2-cis

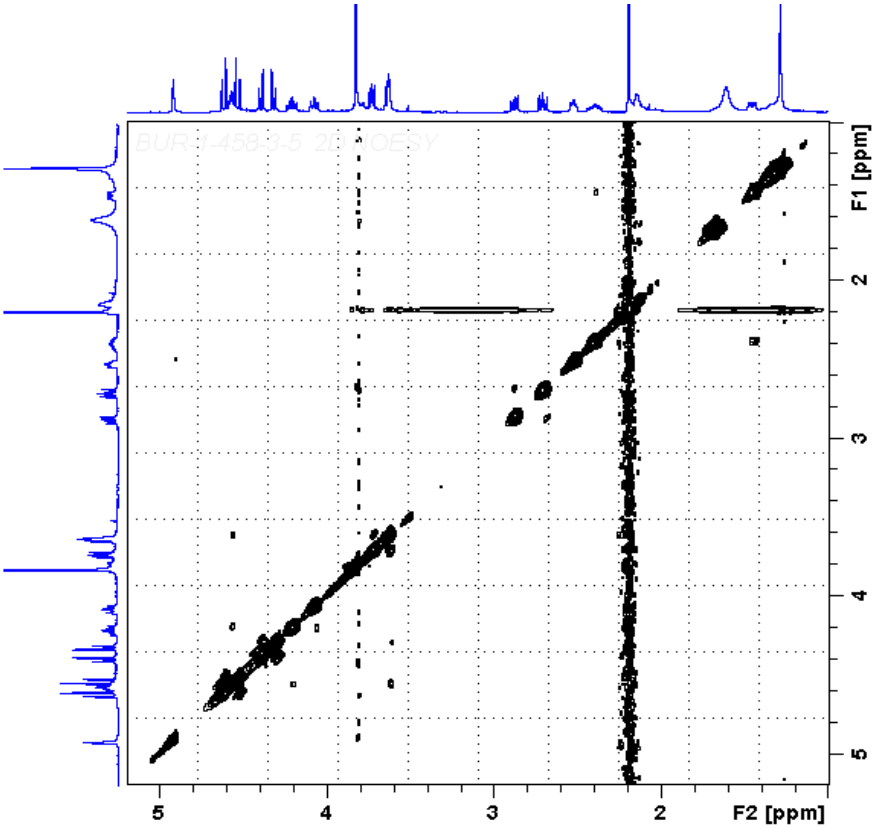
(COSY, 500 MHz)

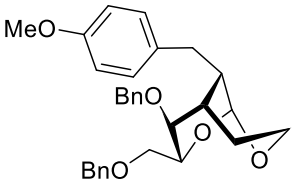




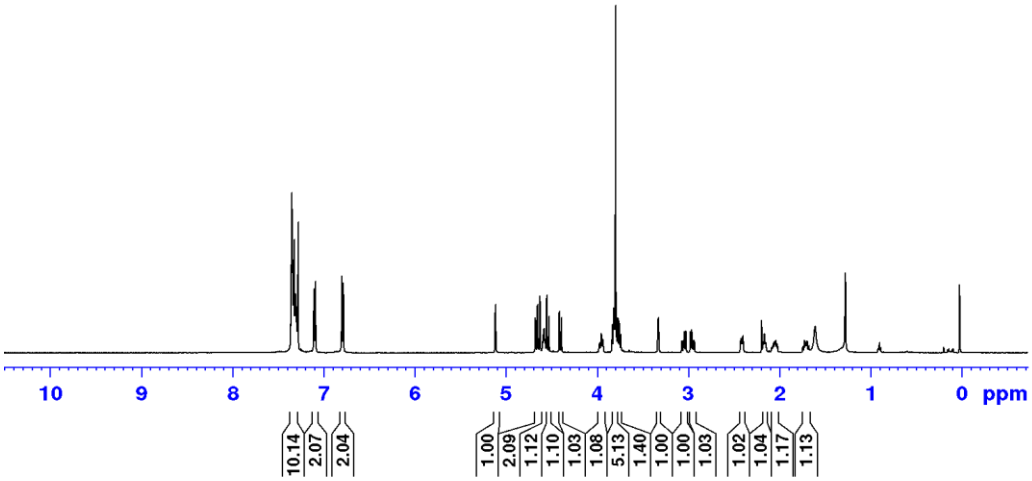
33a = 1,2-cis

(NOESY, 500 MHz)

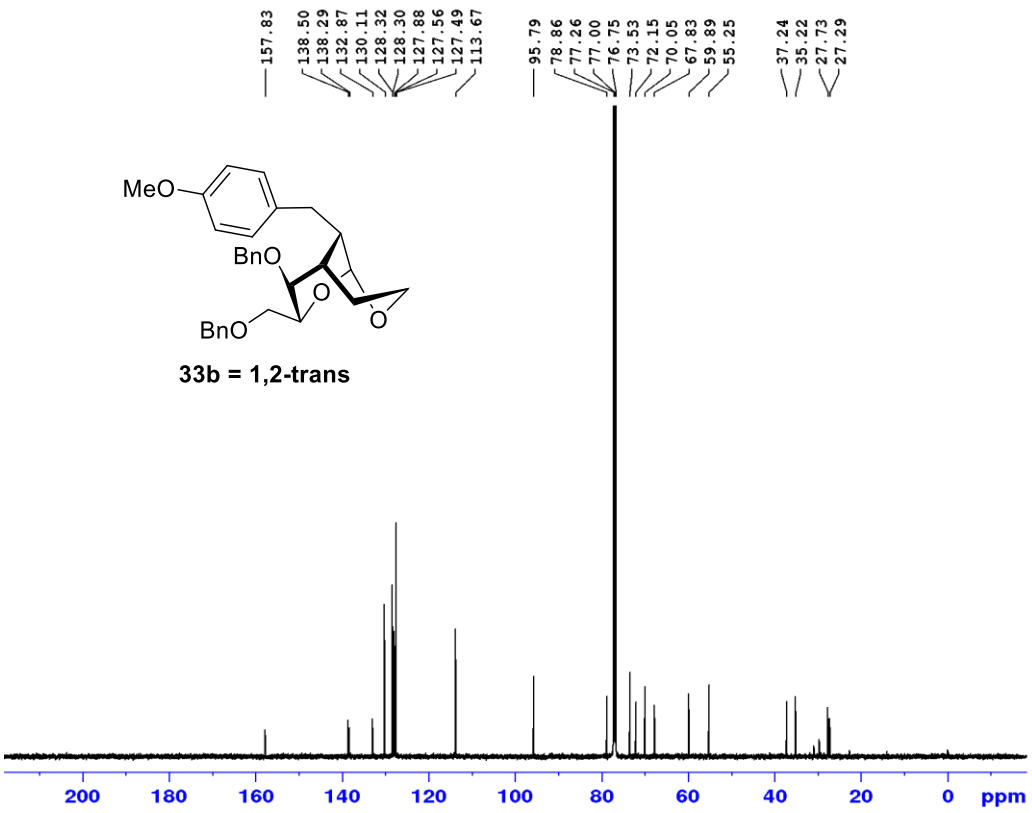




33b = 1,2-trans

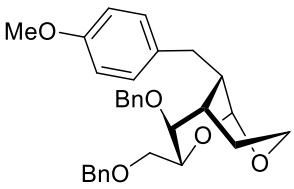



```
Current Data Parameters
NAME                  BUR 500
EXPNO                  145841
PROCNO                      1

F2 - Acquisition Parameters
Date_               20180122
Time                   16.10
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      287
DW                   48.400 usec
DE                    6.50 usec
TE                   294.8 K
D1                1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W             12.85348415 W
SFO1            500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                        EM
SSB          0
LB                     0.30 Hz
GB           0
PC                     1.00
```



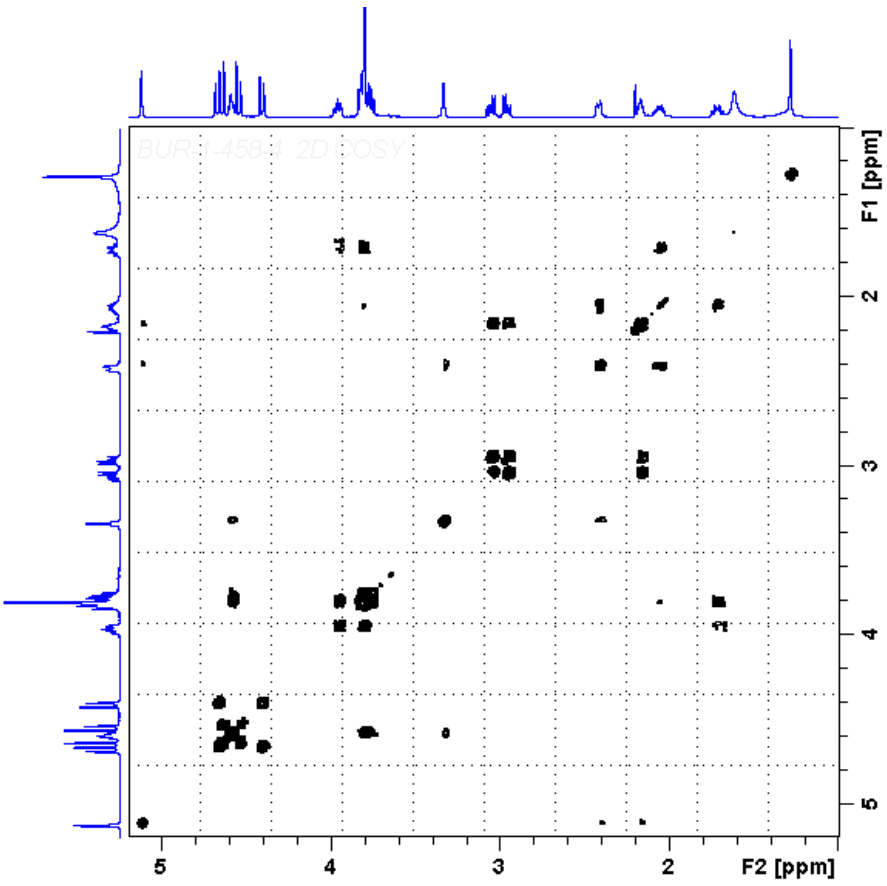
33b = 1,2-trans

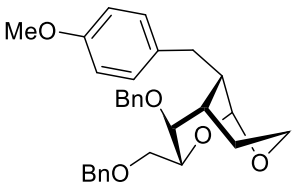
```
Current Data Parameters
NAME                  BUR 500
EXPNO                  145842
PROCNO                      1

F2 - Acquisition Parameters
Date_               20180122
Time                   17.16
INSTRUM                spect
PROBHD     5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     4400
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                     2050
DW                   16.800 usec
DE                    6.50 usec
TE                   295.0 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     13C
P1                     9.60 usec
PL1          0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2            waltz16
NUC2                      1H
PCPD2                80.00 usec
PL2                   2.00 dB
PL12                 16.50 dB
PL13                 16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703620 MHz
WDW                        EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```



33b = 1,2-trans

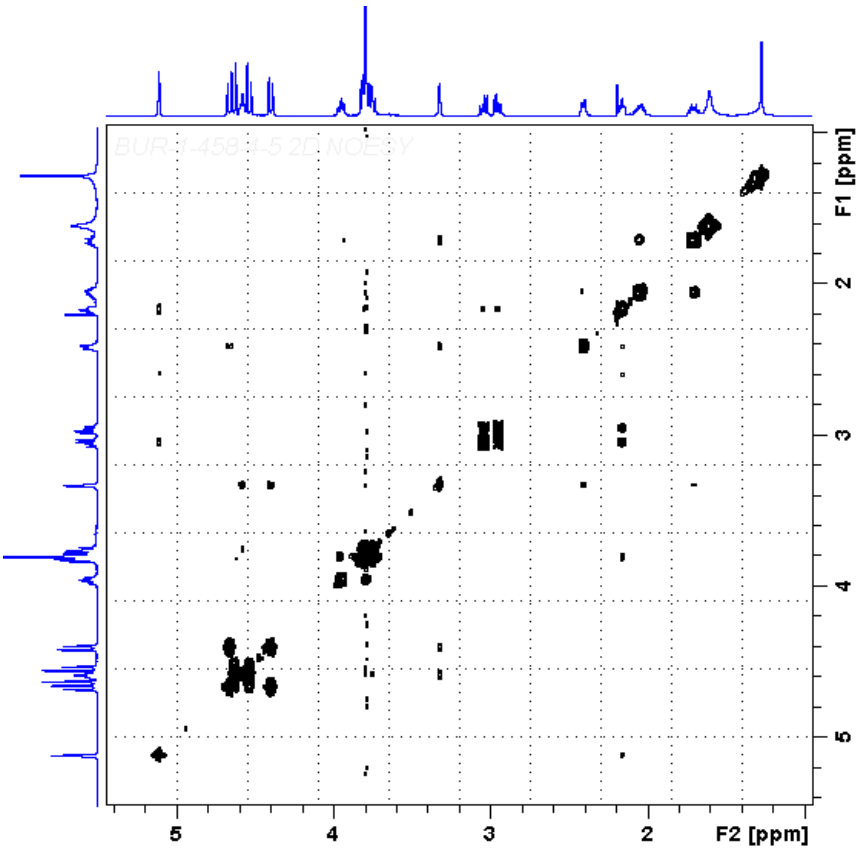
(COSY, 500MHz)

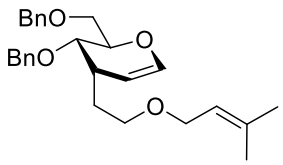




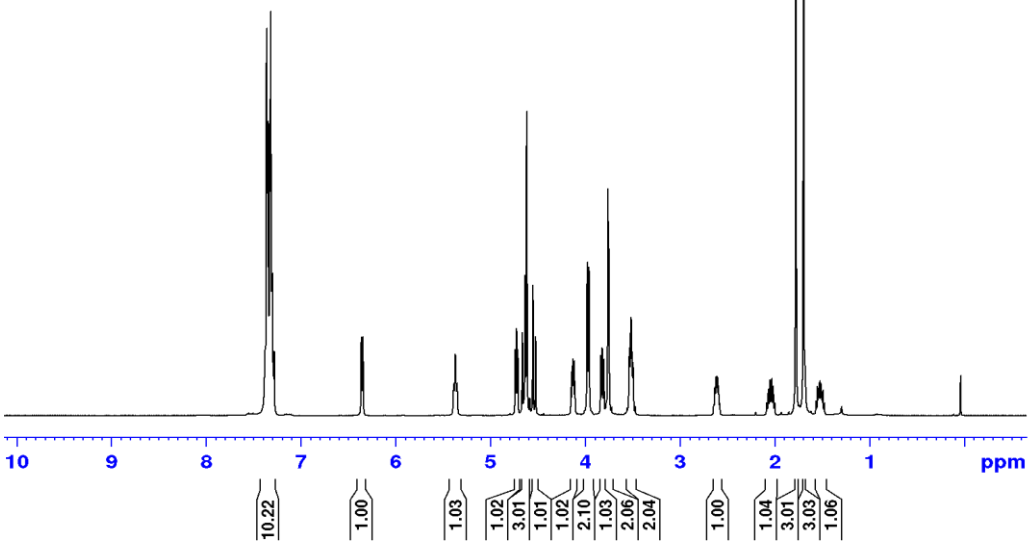
33b = 1,2-trans

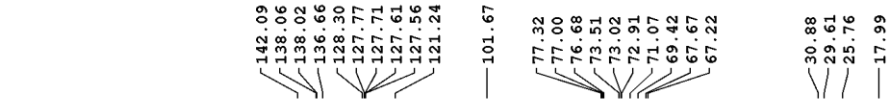
(NOESY, 500MHz)



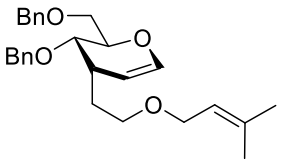


34

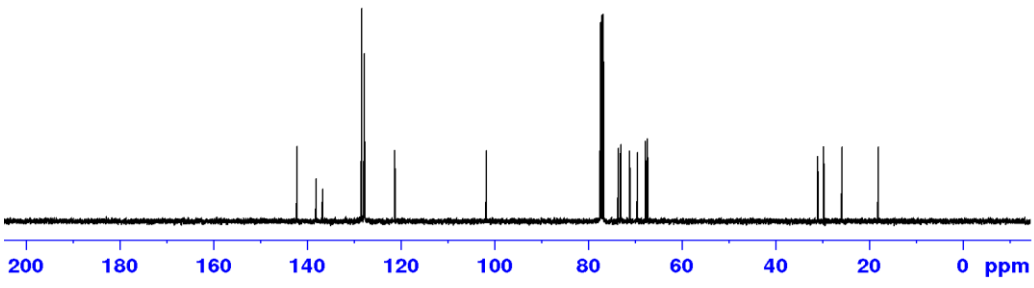




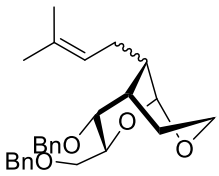

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  138811
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170104
Time                    2.05
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                 zg30
TD                     65536
SOLVENT                CDC13
NS                        16
DS                         2
SWH                 8278.146 Hz
FIDRES              0.126314 Hz
AQ                  3.9583745 sec
RG                       90.5
DW                     60.400 usec
DE                      6.50 usec
TE                     294.3 K
D1                1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     15.00 usec
PL1                    -1.30 dB
PL1W            11.48681641 W
SFO1           400.1324710 MHz

F2 - Processing parameters
SI                     32768
SF              400.1300000 MHz
WDW                       EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```



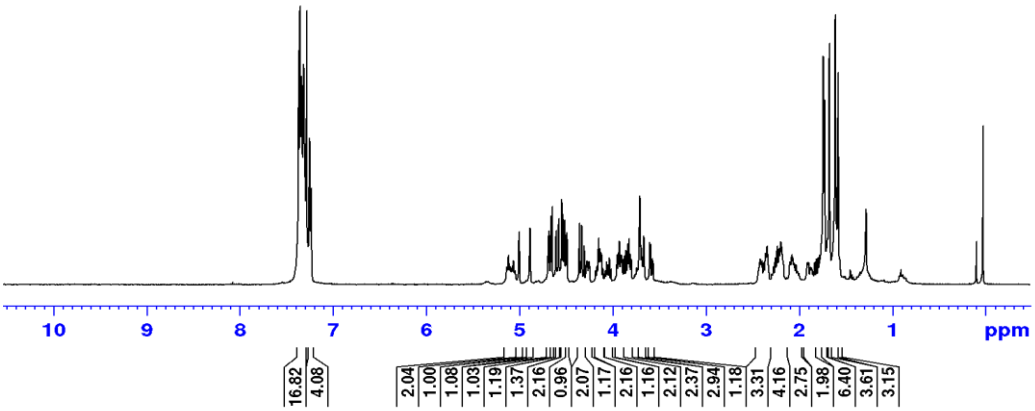
34



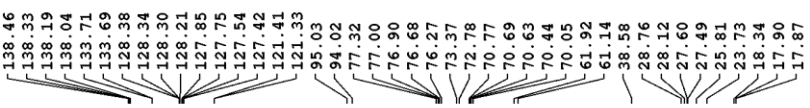

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  138812
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170104
Time                    2.16
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG              zgpg30
TD                     65536
SOLVENT                CDC13
NS                       226
DS                         4
SWH                23980.814 Hz
FIDRES              0.365918 Hz
AQ                  1.3664256 sec
RG                       812.7
DW                     20.850 usec
DE                      6.50 usec
TE                     295.1 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     13.50 usec
PL1          0 dB
PL1W            33.65927887 W
SFO1           100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                      1H
PCPD2                  80.00 usec
PL2                    -1.30 dB
PL12                   13.24 dB
PL13                   13.24 dB
PL2W            11.48681641 W
PL12W            0.40383106 W
PL13W            0.40383106 W
SFO2           400.1316005 MHz

F2 - Processing parameters
SI                     32768
SF              100.6127761 MHz
WDW                       EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```

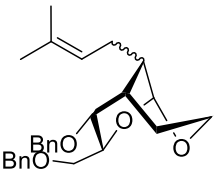


35 (mix 1:1)



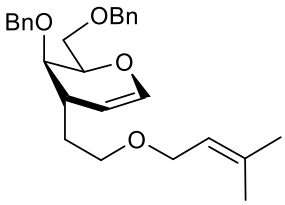

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  139111
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170109
Time                   17.23
INSTRUM                spect
PROBHD     5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       33
DS                        2
SWH                8278.146 Hz
FIDRES            0.126314 Hz
AQ                3.9583745 sec
RG                      256
DW                   60.400 usec
DE                    6.50 usec
TE                   295.0 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      15.00 usec
PL1                     -1.30 dB
PL1W             11.48681641 W
SFO1            400.1324710 MHz

F2 - Processing parameters
SI                        32768
SF                400.1300000 MHz
WDW                          EM
SSB                0
LB                        0.30 Hz
GB                 0
PC                        1.00
```



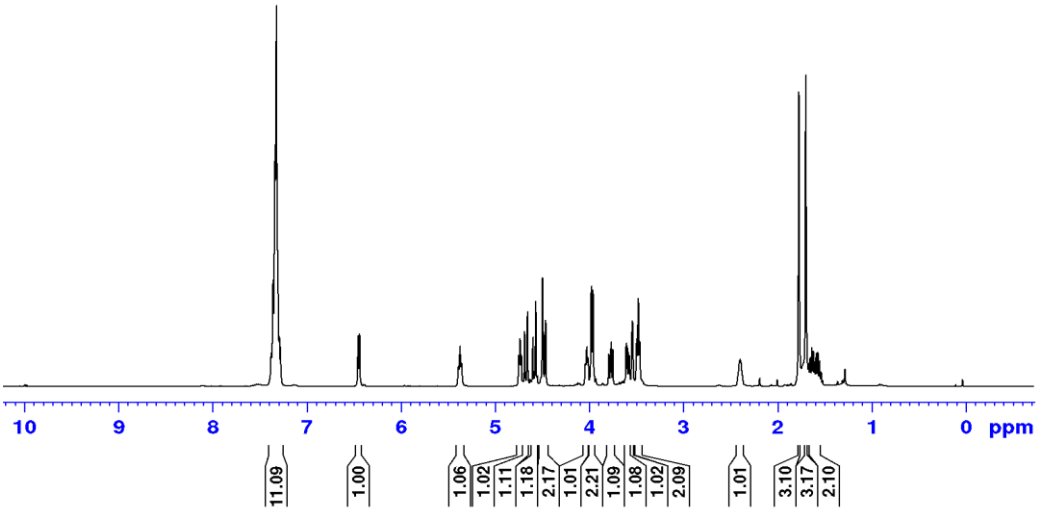


35 (mix 1:1)

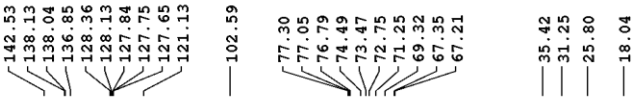

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  139112
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170109
Time                   17.01
INSTRUM                spect
PROBHD     5 mm PABBO BB/
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                     1519
DS                        4
SWH               23980.814 Hz
FIDRES            0.365918 Hz
AQ                1.3664256 sec
RG                     812.7
DW                   20.850 usec
DE                    6.50 usec
TE                   295.4 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      13.50 usec
PL1                0 dB
PL1W             33.65927887 W
SFO1            100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                     -1.30 dB
PL12                    13.24 dB
PL13                    13.24 dB
PL2W             11.48681641 W
PL12W             0.40383106 W
PL13W             0.40383106 W
SFO2            400.1316005 MHz

F2 - Processing parameters
SI                        32768
SF                100.6127717 MHz
WDW                          EM
SSB                0
LB                        1.00 Hz
GB                 0
PC                        1.40
```

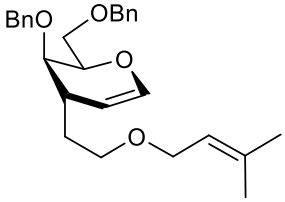


36

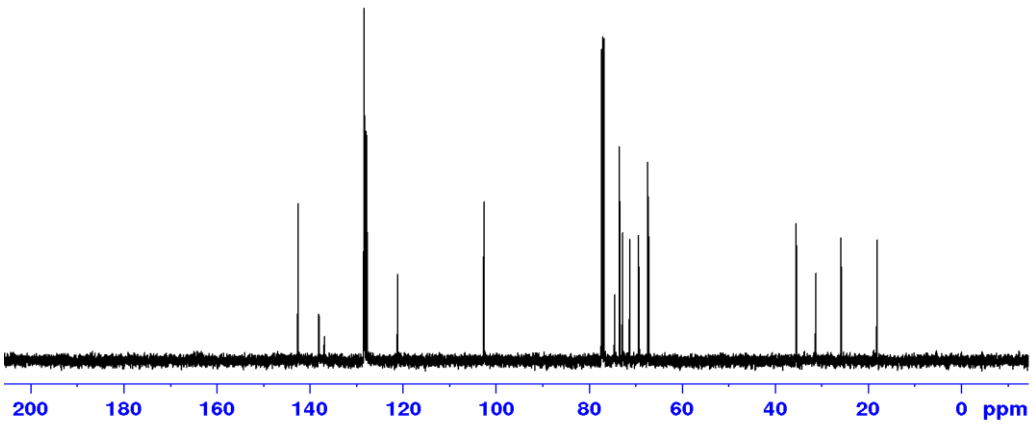



```
Current Data Parameters
NAME                  BUR 400
EXPNO                  141411
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170808
Time                    5.46
INSTRUM                spect
PROBHD    5 mm BBI 1H/D-
PULPROG                 zg30
TD                     65536
SOLVENT                CDCl3
NS                        16
DS                         2
SWH                 8278.146 Hz
FIDRES              0.126314 Hz
AQ                  3.9583745 sec
RG                       35.9
DW                     60.400 usec
DE                      6.50 usec
TE                     673.2 K
D1                  1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                       1H
P1                       9.20 usec
PL1                     -1.00 dB
PL1W               10.72012138 W
SFO1              400.1324710 MHz

F2 - Processing parameters
SI                         32768
SF                400.1300000 MHz
WDW                           EM
SSB          0
LB                       0.30 Hz
GB           0
PC                        1.00
```

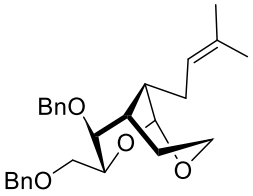




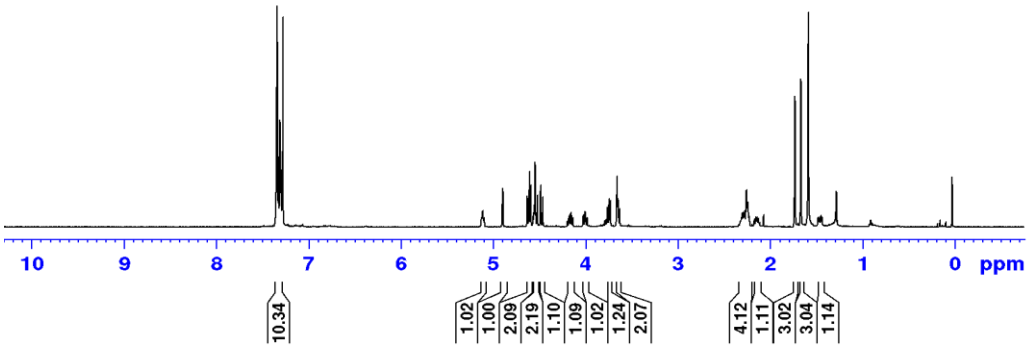
36



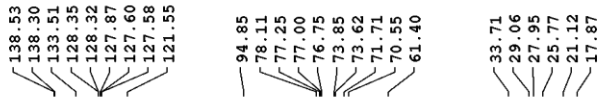

```
Current Data Parameters
NAME      BUR PRS 500 By 17-02-18
EXPNO                  141412
PROCNO                      1

F2 - Acquisition Parameters
Date_               20170807
Time                   20.59
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                     65536
SOLVENT                CDCl3
NS                        88
DS                         4
SWH                29761.904 Hz
FIDRES              0.454131 Hz
AQ                  1.1010048 sec
RG                      2050
DW                     16.800 usec
DE                      6.50 usec
TE                     295.1 K
D1                  2.00000000 sec
D11                 0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                       9.60 usec
PL1             0 dB
PL1W               76.36135101 W
SFO1              125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                       1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W               12.85348415 W
PL12W               0.45605880 W
PL13W               0.45605880 W
SFO2              500.1820007 MHz

F2 - Processing parameters
SI                         32768
SF                125.7703641 MHz
WDW                           EM
SSB          0
LB                       1.00 Hz
GB           0
PC                        1.40
```

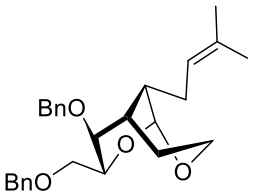


37a = 1,2-cis

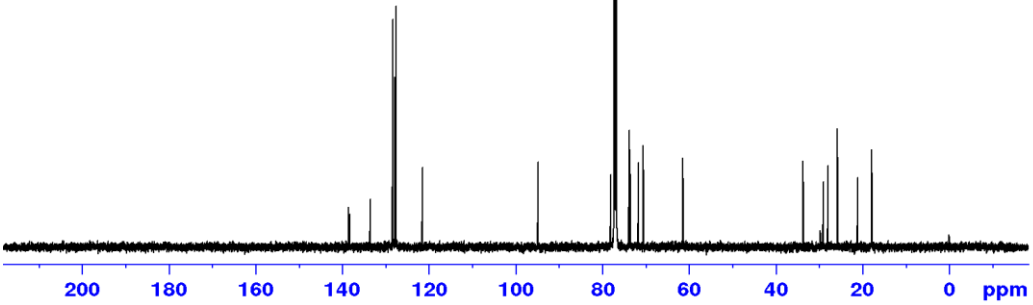



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 145911
PROCNO                     1

F2 - Acquisition Parameters
Date_              20180116
Time                  21.28
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG               zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH              10330.578 Hz
FIDRES            0.157632 Hz
AQ                3.1719425 sec
RG                      406
DW                 48.400 usec
DE                  6.50 usec
TE                  298.1 K
D1              1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     1H
P1                  14.90 usec
PL1                  2.00 dB
PL1W           12.85348415 W
SFO1          500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800000 MHz
WDW                      EM
SSB       0
LB                   0.30 Hz
GB        0
PC                   1.00
```

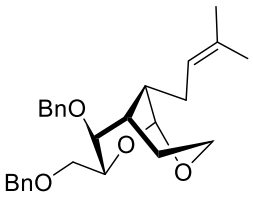




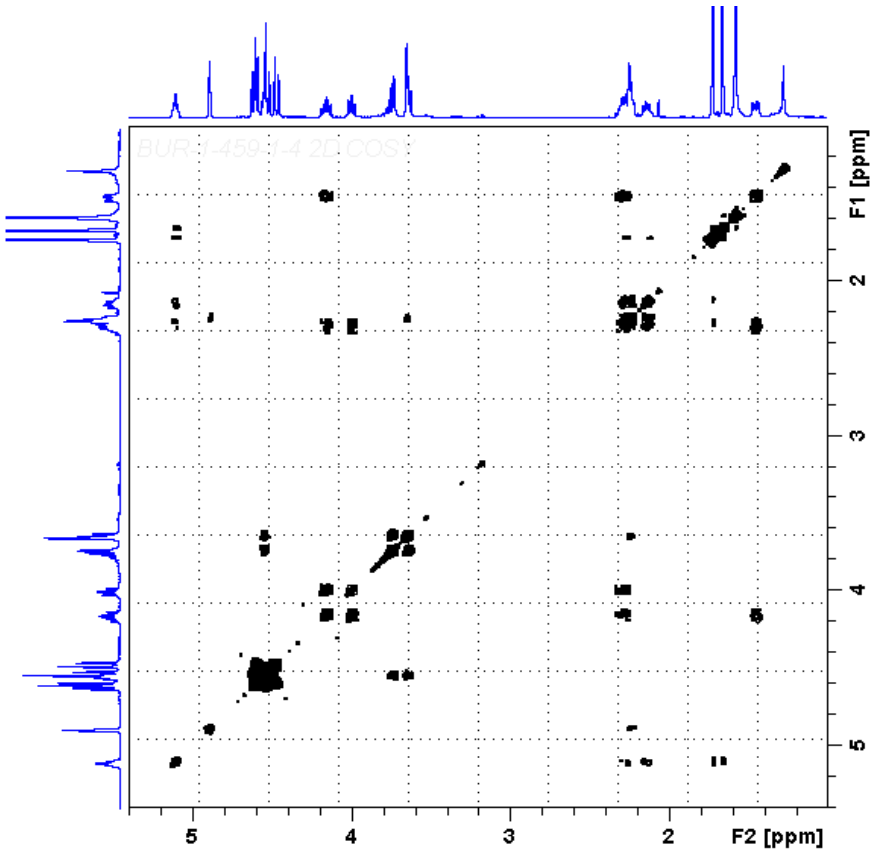
37a = 1,2-cis

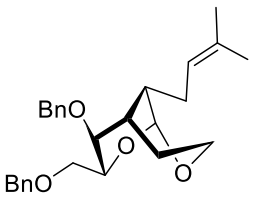



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 145912
PROCNO                     1

F2 - Acquisition Parameters
Date_              20180116
Time                  21.37
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                    10000
DS                        4
SWH              29761.904 Hz
FIDRES            0.454131 Hz
AQ                1.1010048 sec
RG                     2050
DW                 16.800 usec
DE                  6.50 usec
TE                  299.5 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                    13C
P1                   9.60 usec
PL1        0 dB
PL1W          76.36135101 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                     1H
PCPD2               80.00 usec
PL2                  2.00 dB
PL12                16.50 dB
PL13                16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
PL13W           0.45605880 W
SFO2          500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF             125.7703602 MHz
WDW                      EM
SSB       0
LB                   1.00 Hz
GB        0
PC                   1.40
```

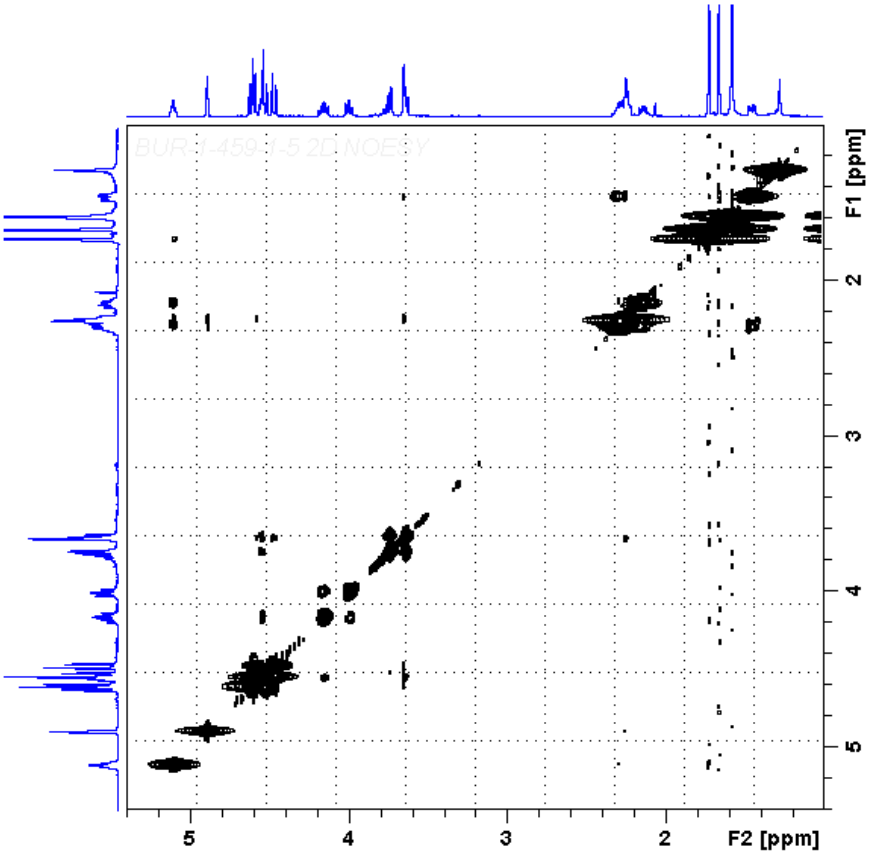


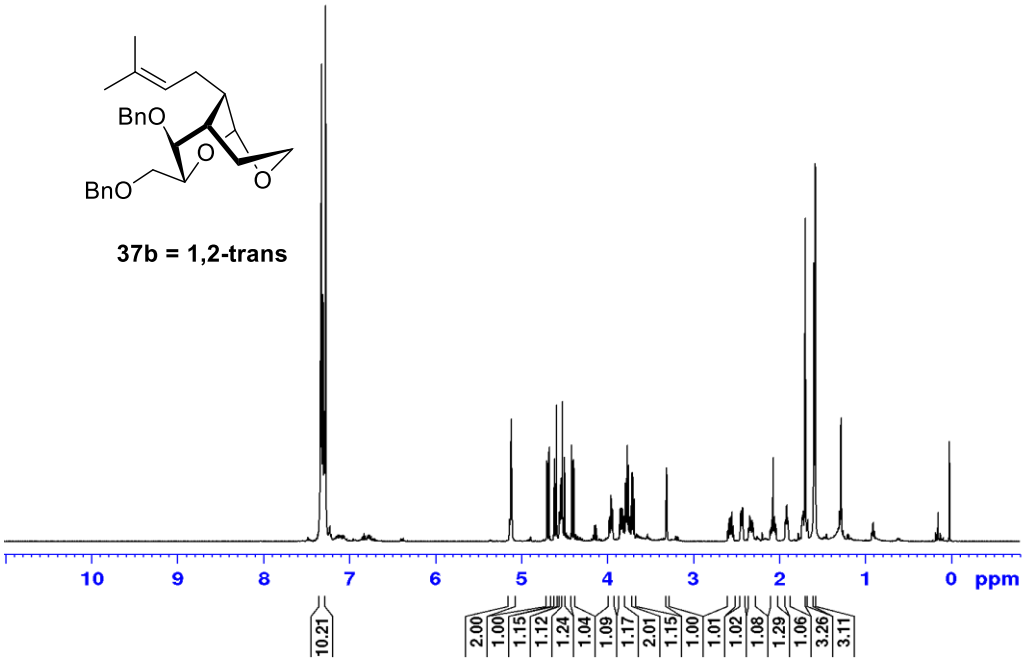
37a = 1,2-cis
(COSY, 500MHz)





37a = 1,2-cis
(NOESY, 500MHz)






```
Current Data Parameters
NAME                  BUR 500
EXPNO                 145921
PROCNO                     1

F2 - Acquisition Parameters
Date_               20180117
Time                   19.12
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
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RG                       362
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DE                   6.50 usec
TE                   297.8 K
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======== CHANNEL f1 ========
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PL1                   2.00 dB
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SFO1          500.1830888 MHz

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PC                    1.00
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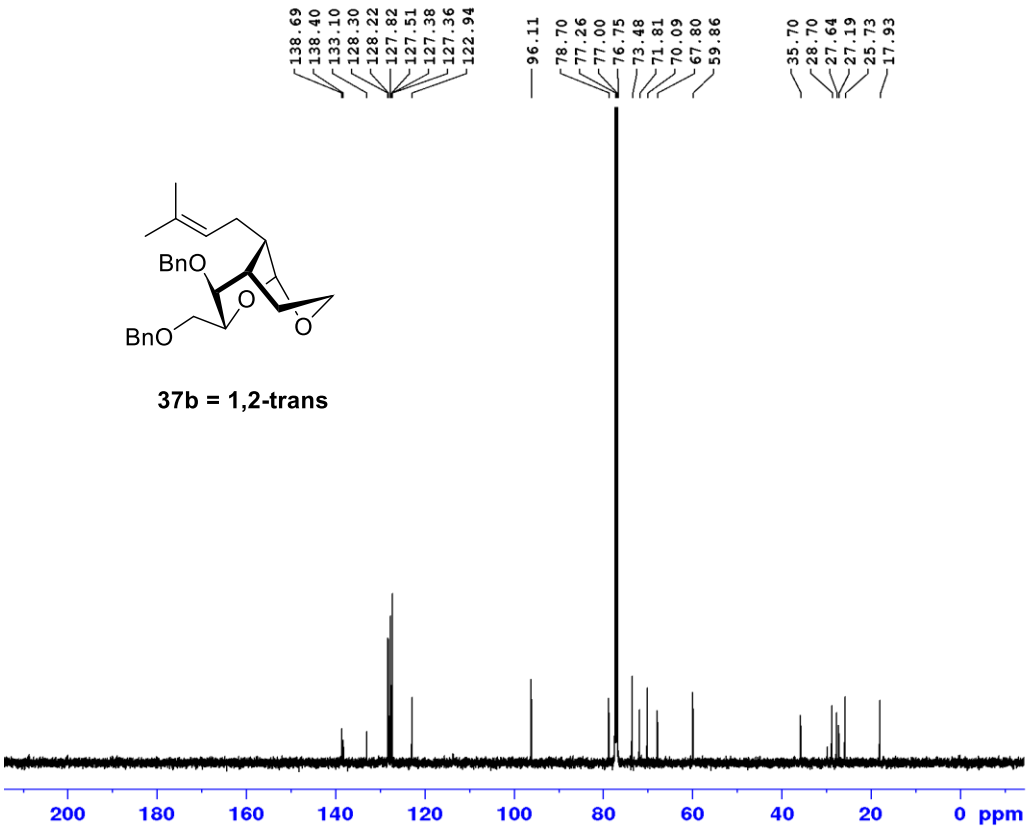


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PL13                 16.50 dB
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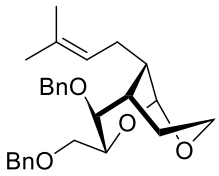

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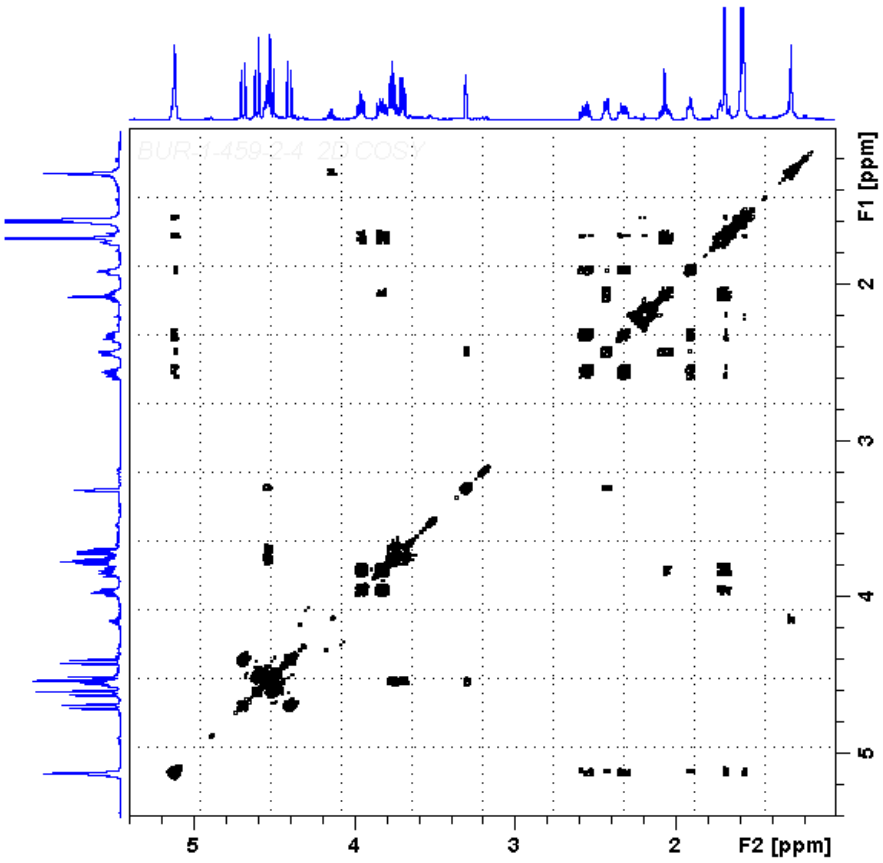

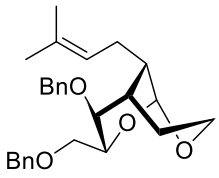

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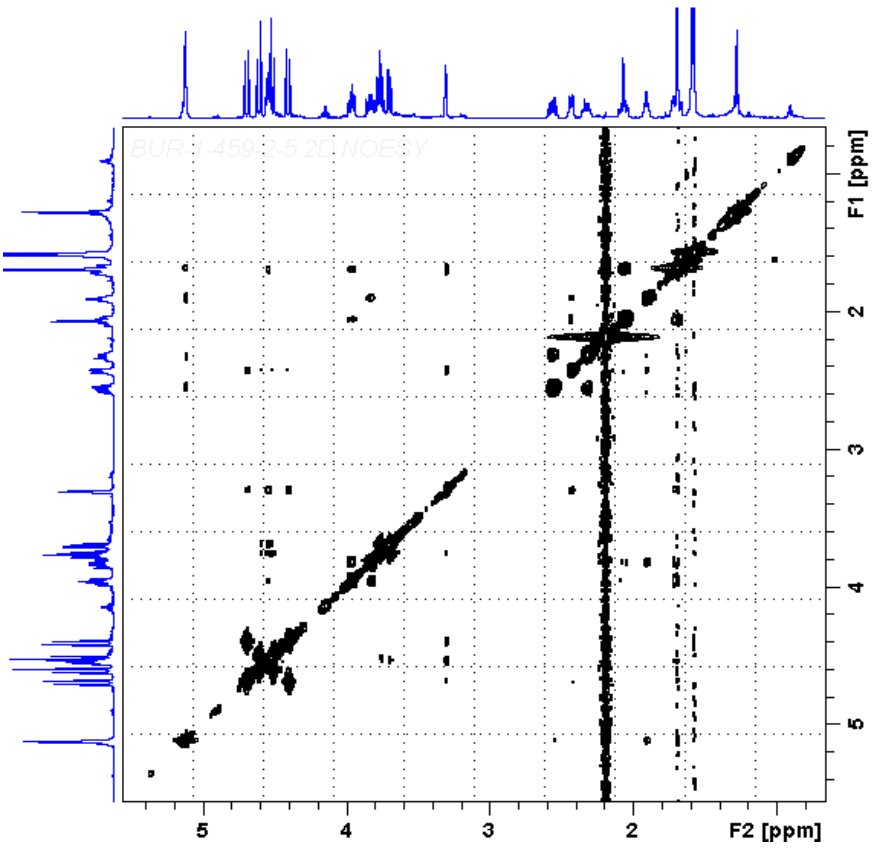

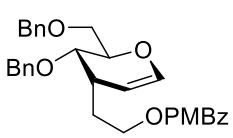

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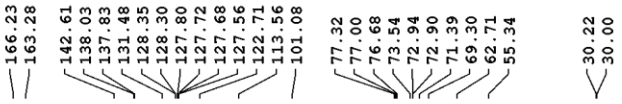

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RG 57
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======== CHANNEL f1 ========
NUC1 1H
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PL1W 15.18650627 W
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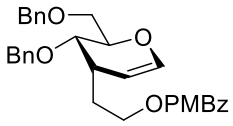

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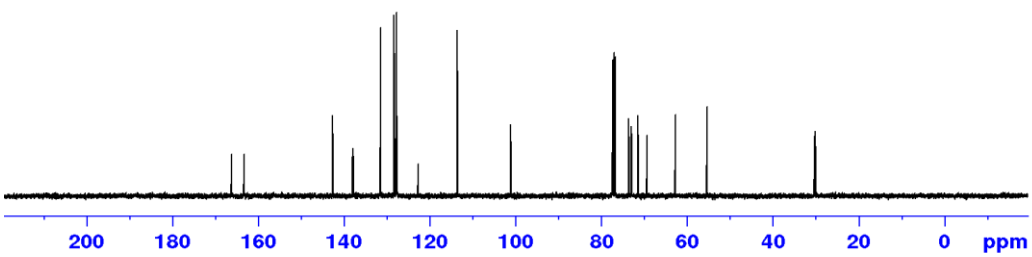

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PL1 2.00 dB
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PCPD2 90.00 usec
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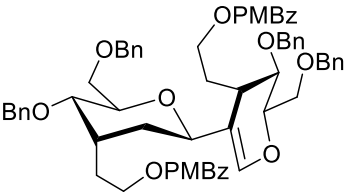

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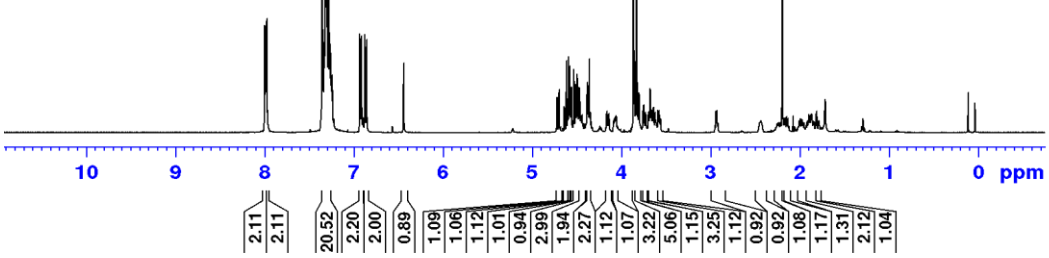


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RG                 90.5
DW               48.400 usec
DE                6.50 usec
TE               296.5 K
D1            1.00000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                  1H
P1                14.90 usec
PL1                2.00 dB
PL1W         12.85348415 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                32768
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WDW                  EM
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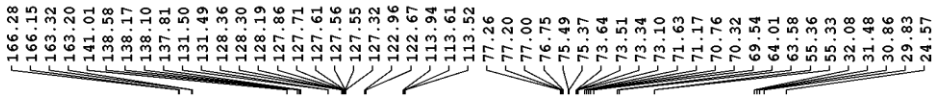

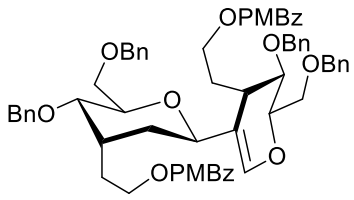

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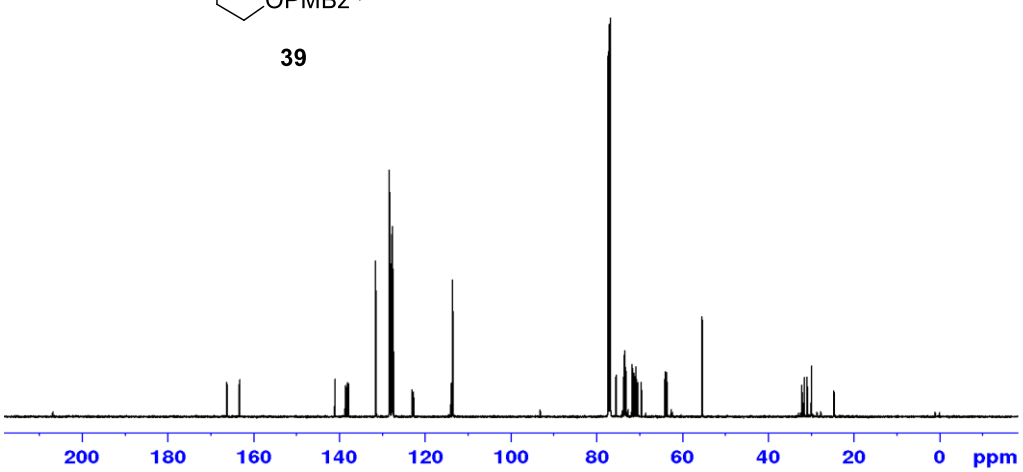


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SOLVENT           CDCl3
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FIDRES         0.454131 Hz
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DW               16.800 usec
DE                6.50 usec
TE               299.2 K
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======== CHANNEL f1 ========
NUC1                 13C
P1                9.60 usec
PL1        0 dB
PL1W         76.36135101 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             80.00 usec
PL2                2.00 dB
PL12              16.50 dB
PL13              16.50 dB
PL2W         12.85348415 W
PL12W         0.45605880 W
PL13W         0.45605880 W
SFO2         500.1820007 MHz

F2 - Processing parameters
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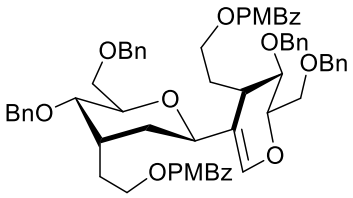

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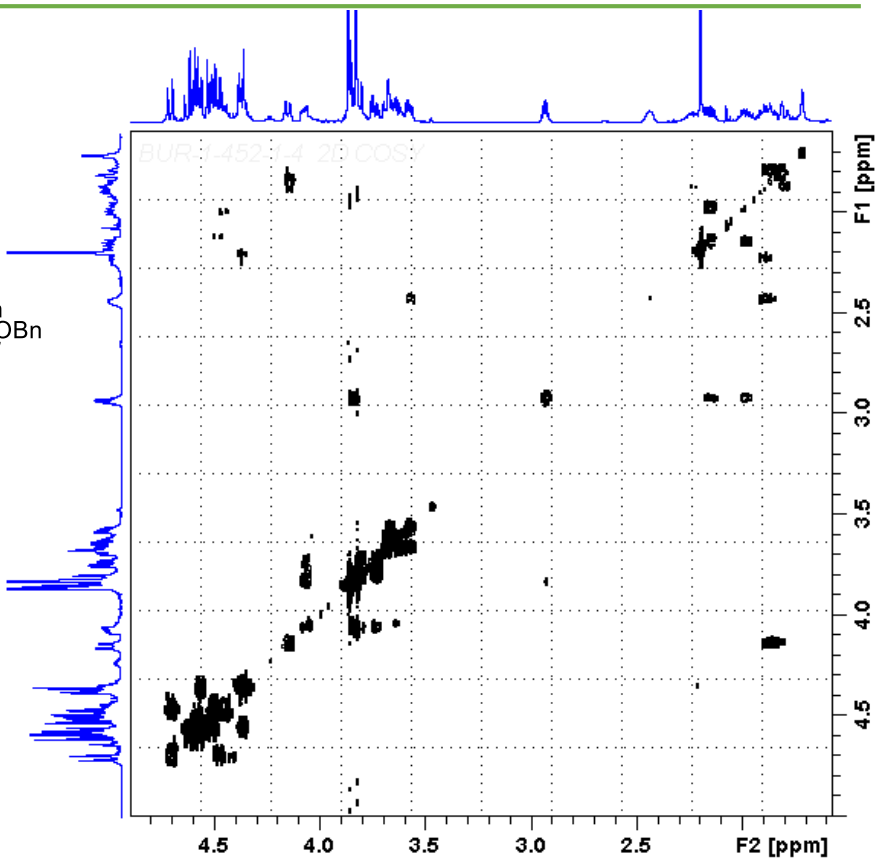
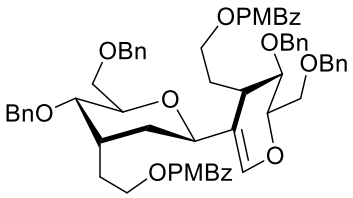
(COSY, 500MHz)





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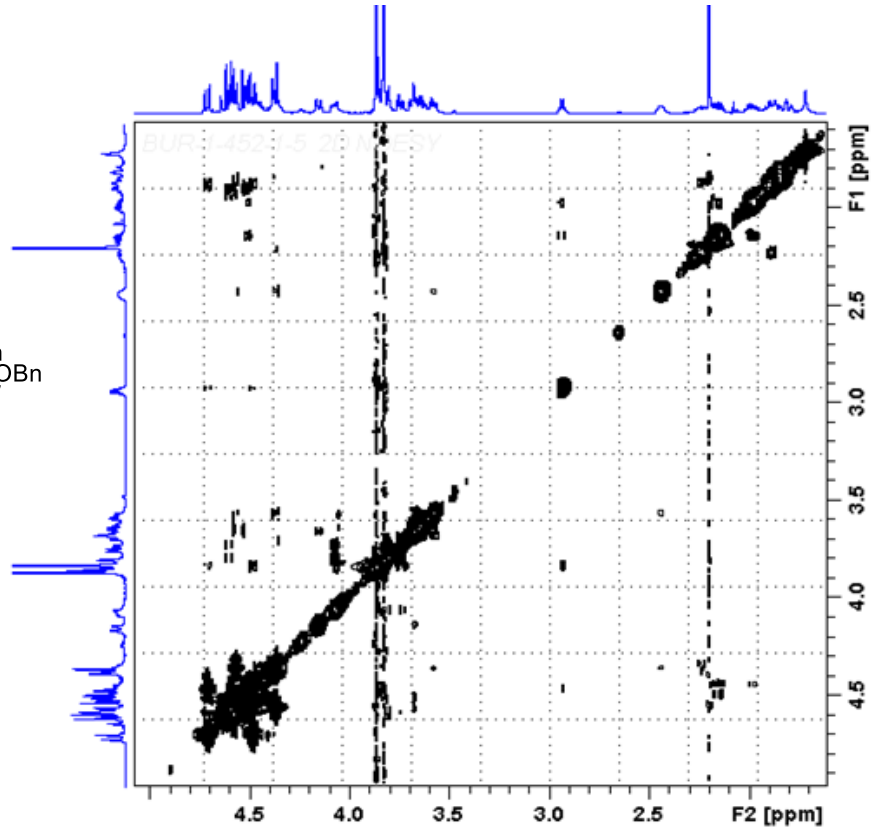

HRMS of intermediate **5d**

Display Report

Analysis Info

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Sample Name	BUR-A	Instrument	maXis 10138
Comment			

Acquisition Parameter

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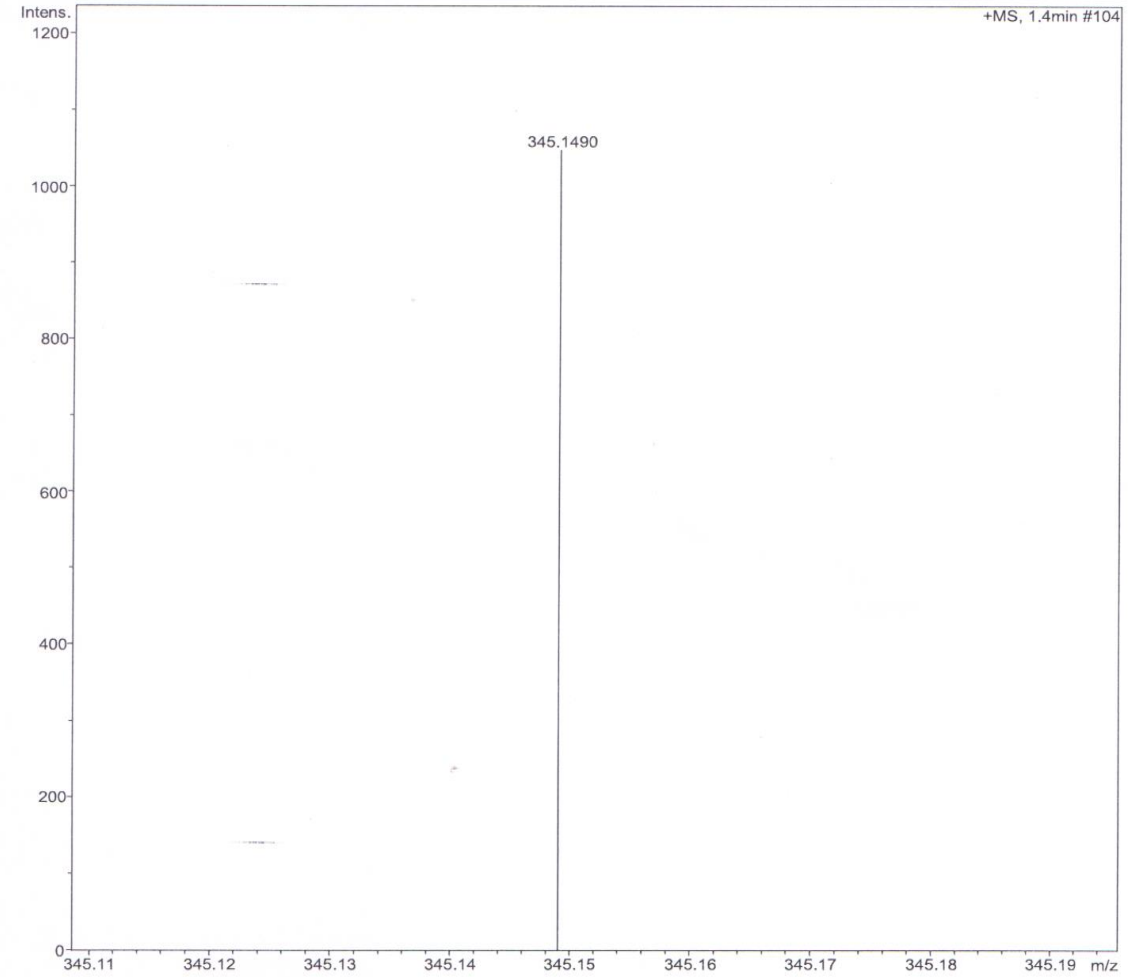

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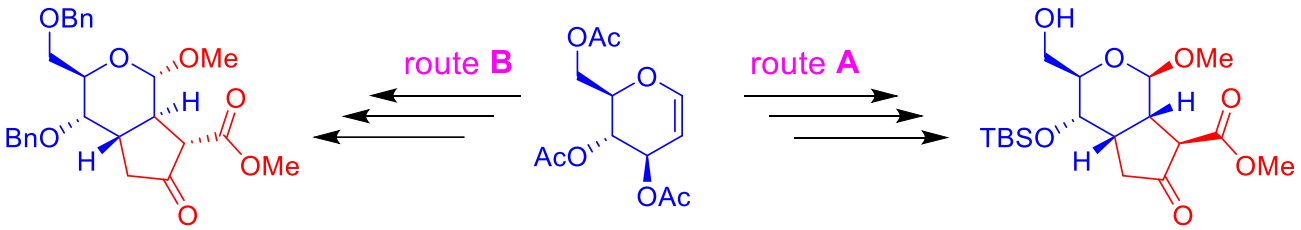
Chapter-3

Synthesis of Cis- and Trans-fused Bicyclic Iridoid Frame Works from Glucal



3 **1** **2**

3.1 Introduction

Iridoids are a class of monoterpenoids that made up of the cyclopentan[c]-pyran system.[1,2] Iridoids are the compounds, which widely exist in the plant kingdom, and have been extracted from numerous plant families (like Rubiaceae, Scrophulariaceae, Plantaginaceae, and Verbenaceae….etc). This kind of compounds are shown to exhibit a broad range of biological activities such as anticancer, antileishmanial, antiplasmodial, Hsp90 inhibition, DNA polymerase inhibition, and NF-κB mediated anti-inflammatory potency and divulged their therapeutic potentiality as drug candidates.[3] Furthermore, some of the isolated cytotoxic iridoids would be very important in treating various cancers, namely, breast, ovarian, liver, lung, osteosarcoma, rectum/colon, leukemia, gastric cancer cell, and pancreatic cancer. Most of the patents claiming the biological evaluation of iridoids are reported as anticancer agents present only in vitro evaluation, especially on different cancer cell lines.[4] A novel iridoid **i** (Figure 1) was isolated from *Gardenia jasminoides*, and which was shown strong in vitro anti-cancer effects towards the renal cancer cell line (RC-2).[5] Another novel iridoid **ii,** Which was extracted from *Swertia mussotii Franch* and was acted as a good anti-cancer agent towards ovarian cancer (SKOV3).[6] A new iridoid **iii** was isolated from *Swertia mussotii Franch* , which enhanced the cell viability of human umbilical vein endothelial cells injured by oxidized low-density lipoprotein (ox-LDL).[7] The isolated new iridoid **iv** from the bark of *Eucommia ulmoides* was inherently increased the survival rate of myocardial cells of hydrogen peroxide stress injury. In cell culture, the effect of LDH is reduced considerably by iridoid **iv**.[8]

On the other hand, genipin-1-β-gentiobioside (**v)** has been revealed significant results for the treatment of acute influenza, hepatitis B, respiratory infection, Epstein Barr virus, Herpes zoster infection, pneumonia, viral myocarditis, retroviral, simplex keratitis, and bacterial infection diseases.[9] Further, genipin ether B (**vi**) (isolated from *Gardenia jasminoides Ellis*.) was shown good results for the treatment of diabetes mellitus, Parkinson's disease, scleroderma, depression, periodontal disease, systemic lupus erythematosus, and asthma.[10] Tetracyclic iridoids **vii–ix** were isolated from *Morinda lucida*. These three iridoids are

revealed strong anti-trypanosomal effects as well as good anti-cancer activity.[11] Many chemists have been reporting over the isolation and synthesis of iridoids for many decades continuously, because of their numerous biological activities and therapeutic potentiality.[12,13,14]

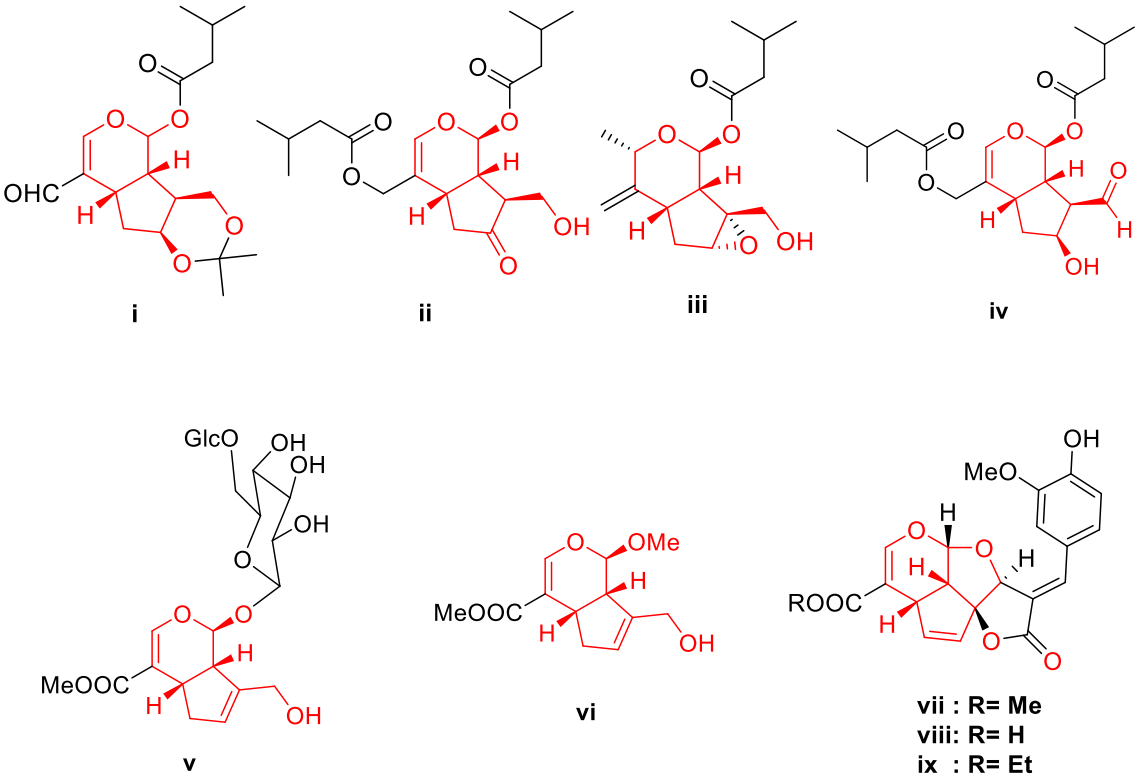


Figure 3.1 Few natural products possessing cis-fused cyclopentan[c]-pyran unit.

Figure 3.2 Few natural products possessing trans-fused cyclopentan[c]-pyran unit.

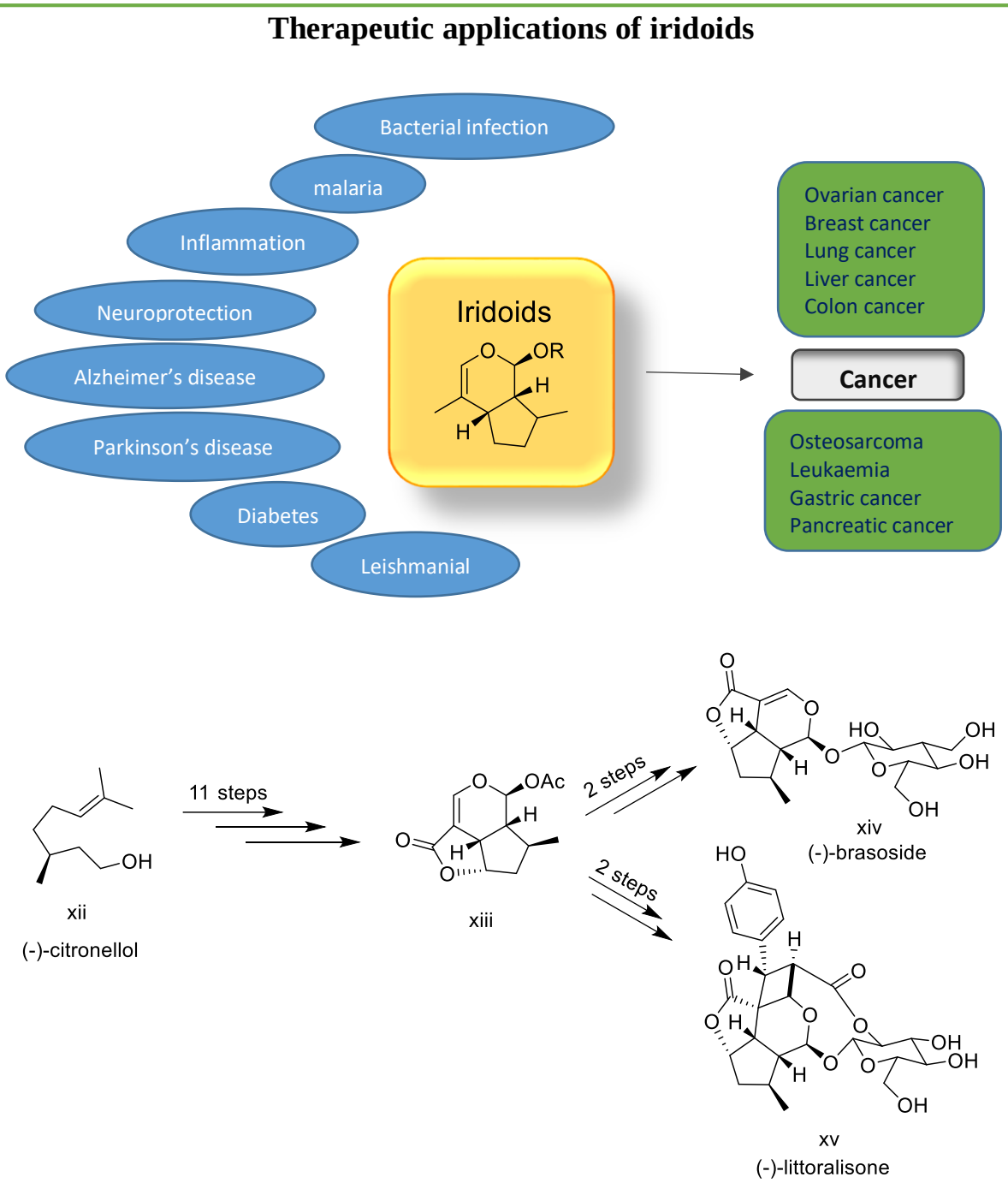


Figure 3.3 Total Synthesis of brasoside and littoralisone.

The total synthesis of brasoside **xiv** and littoralisone **xv** has been reported by MacMillan.[15] These natural products were synthesised from citronellol **xii** in 13 steps via tricyclic lactone **xiii** (Figure 3.3). However, the synthesis of diverse iridoids have not yet been discovered, and they are still challenging targets for organic chemists. Interestingly, the above mentioned iridoids **i-ix** commonly possess a *cis* fused cyclopenta[c]pyran backbone, which consists of carbon atoms in different oxidation states. By noticing the importance of iridoids

with cis-fused cyclopentan[c]pyran backbone and their therapeutic potential,[3] we envisioned a facile retrosynthetic route for the synthesis of cis-fused cyclopenta[c]pyran framework from the commercially available and inexpensive carbohydrate derived starting material, D-glucal. In addition, we also envisioned a stereoselective synthetic protocol for the construction of trans-fused cyclopentan[c]pyran skeleton, which is present in the core unit of the biologically active trans-fused iridoids namely, 7-*O*-acetyl-10-*O*-acetoxyloganin **x** and Methoxygaertneroside **xi** (figure 3.2). Very interestingly, to date, the synthesis of trans-fused iridoids has not yet been reported from the carbohydrate precursors. The only report in the literature found to synthesize the trans-fused iridoid framework was using the natural product limonene[16].

3.2 Results and Discussion

In the initial retrosynthetic strategy, we planned to introduce the new C-C bond to construct the cyclopentane ring for *cis*-fused cyclopenta[c]pyran unit by Dieckmann condensation of pyran diester **4**, which could be obtained by deiodination of α-iodo ester derivative **4** as shown in figure 3.3. The synthesis of the sugar derived α-iodo ester **5** could be achieved by the stereoselective ring-opening of fused cyclopropane[b]pyran derivative **6** using

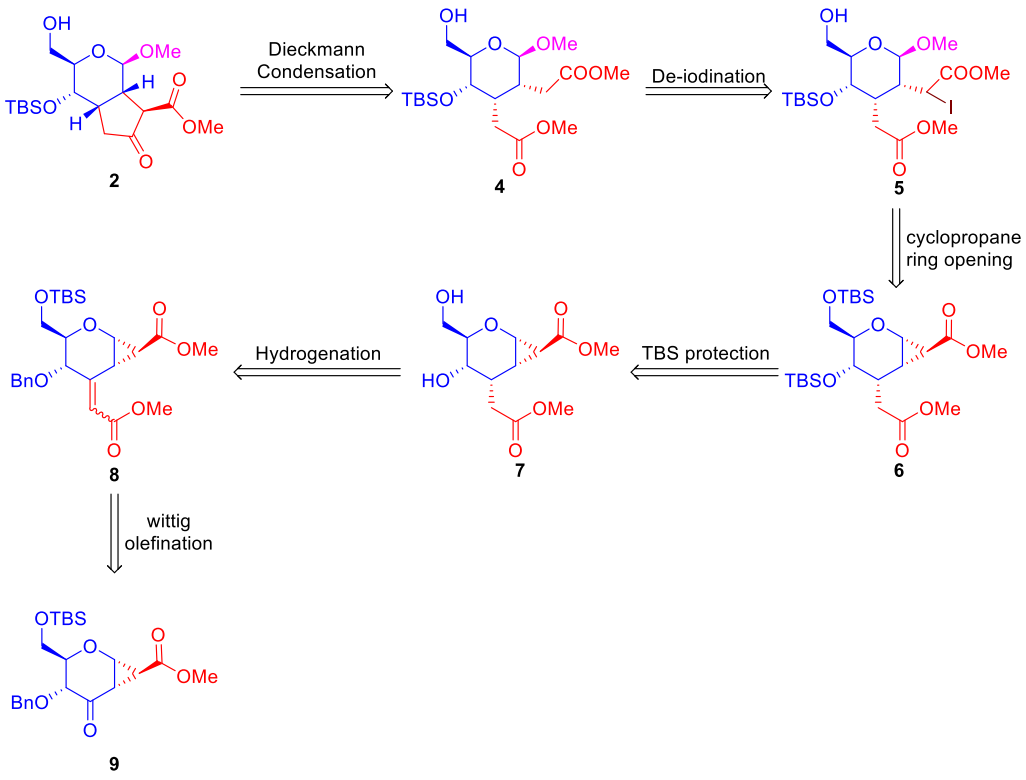
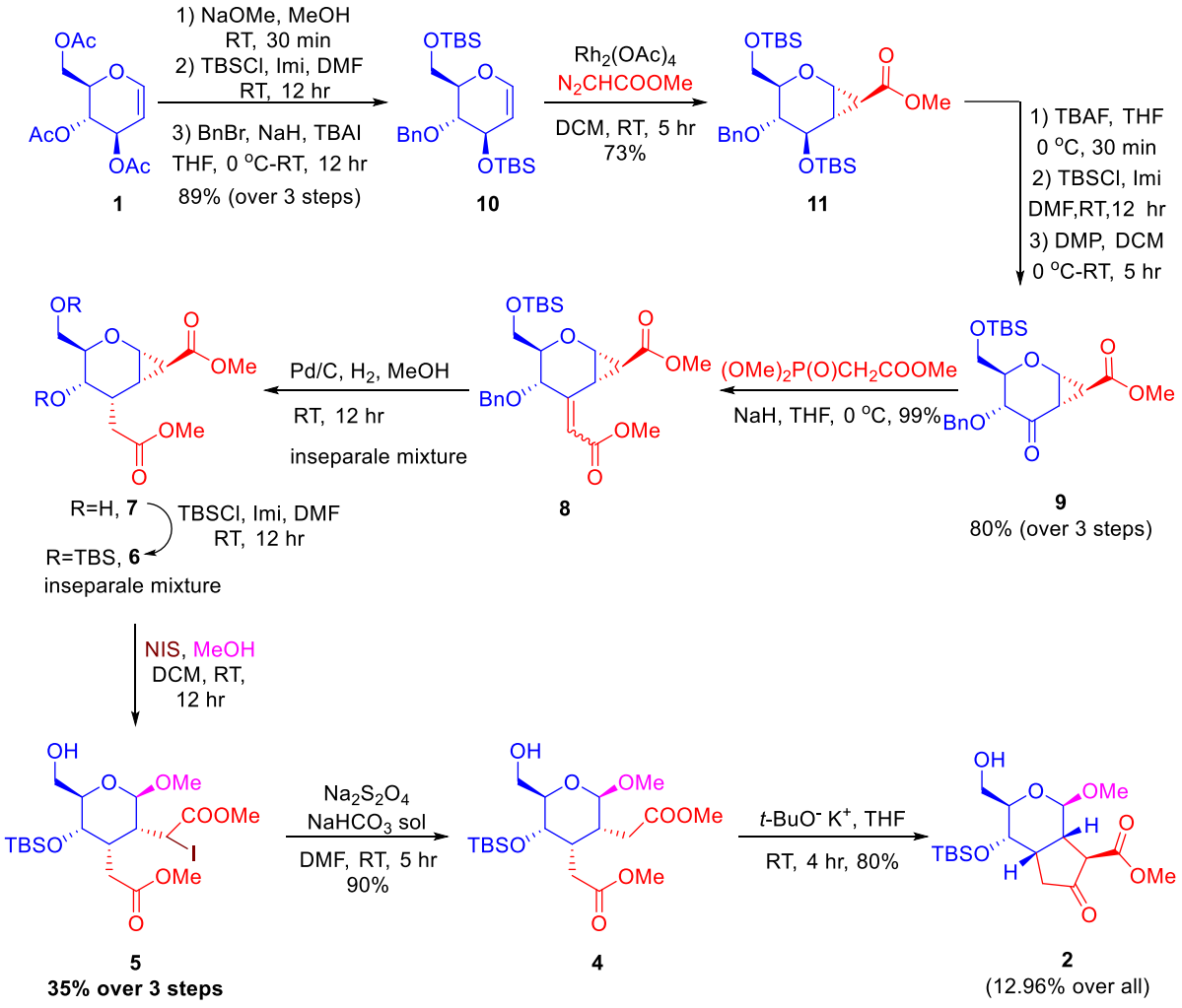


Figure 3.4 Retrosynthetic approach towards cis-fused cyclopentan[c]-pyran unit of iridoids.

N-iodo succinamide. The bicyclic sugar derivative **6** would be obtained by TBS protection of diol **7,** which could be systematically achieved by hydrogenation of conjugated ester **8.** The conjugated ester **8** was expected to be synthesized by Wittig olefination of known γ-keto ester derivative **9** (figure 3.4).

Our synthesis started off with the preparation of the common intermediate **9**, as indicated in Scheme 3.1. To introduce a keto function at the γ-position to the ester group of the cyclopropa[b]pyran unit, 3,4,6-tri-*O*-acetyl-D-glucal **1** was converted to fully protected glucal **10** via sequential reactions involving *Zemplén deacetylation* using NaOMe solution, region-selective protection of 3-OH and 6-OH with TBS, by employing TBSCl and Imidazole, and benzylation reaction.[17] The differentially protected glucal **10** was transformed to 1,2-cyclopropane carboxylate derivative **11** by cyclopropanation of compound **10** with methyl diazoacetate (MDA) in the presence of $Rh_2(OAc)_4$ catalyst. Later, the cyclopropane derived sugar **11** was transformed to the desired intermediate **9** by applying known protocols.[18]



Scheme 3.1 Synthesis of cis-fused cyclopentan[c]-pyran unit of cytotoxic iridoids.

Satisfyingly, Reaction of **9** under Wittig olefination reaction conditions[19] (Trimethyl phosphono acetate, NaH) led to formation of α,β-unsaturated ester derivative **8** with 99% yield. Immediately, the resulted unsaturated ester **8** produced the saturated ester derivative **7** as an inseparable mixture *via* diastereoselective hydrogenation along with double deprotection of *O*-benzyl and *O*-*tert*-butyl dimethylsilyl groups under hydrogenation conditions (Pd/C, H_2). Afterward, to reduce the nucleophilicity of oxygen for convenience of further transformations, the hydroxyls in the obtained inseparable mixture **7** were protected with TBS groups using known protocol[17] (TBSCl, Imidazole) to obtaine **6** as inseparable mixture. Subsequently, the electrophilic ring-opening of cyclopropane in the resulted di-*O*-TBS protected cyclopropan[b]pyran derivative **6** was commenced by subjecting it to *N*-iodo succinamide and methanol in dry dichloromethane solution,[20] to produce the α-iodo ester derivative **5** in 35% yield over 3 steps. Later, deiodination of **5** using sodium dithionite ($Na_2S_2O_4$) produced the carbohydrate derived diester **4** with 90% yield. Finally, subjecting compound **4** to Dieckmann condensation reaction conditions (*t*-BuO^-K^+ in THF, RT)[21] for cyclization via formation of new C-C bond to produce the targeted cyclopenta[c]pyran skeleton **2** in 80% yield. The overall yield of the targeted compound **2** was obtained as 12.9% over 13 steps.

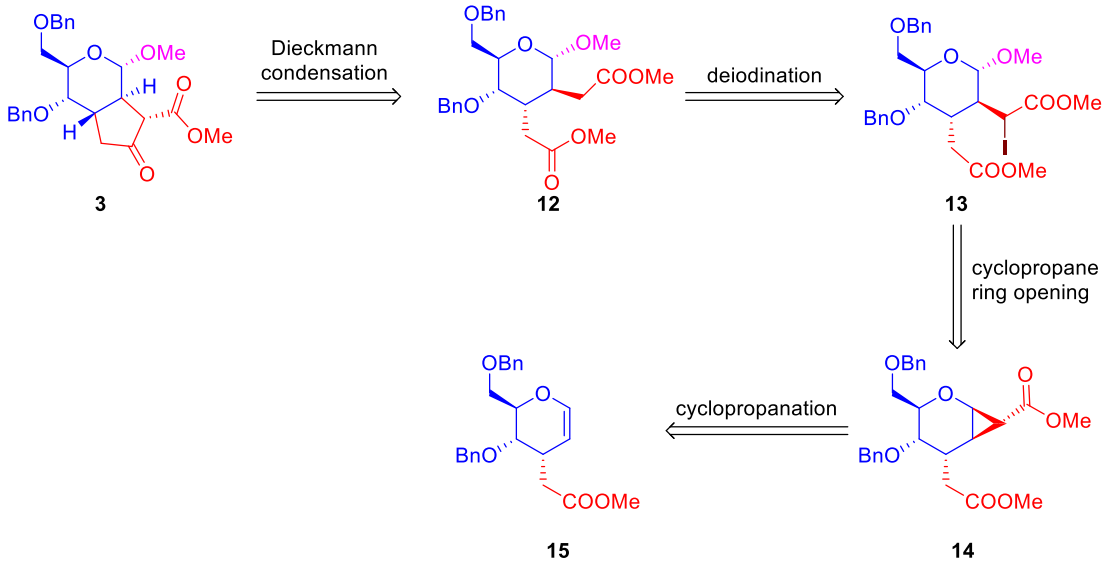
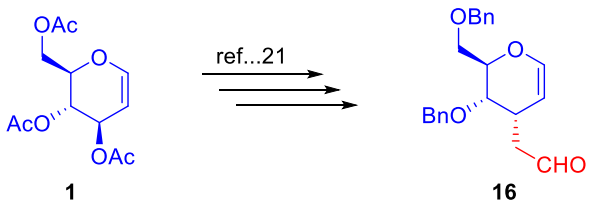


Figure 3.5 Retrosynthetic approach towards trans-fused cyclopentan[c]-pyran unit of iridoid.

We next turned our attention towards a retro synthetic strategy of *trans*-fused cyclopetan[c]pyran **3** unit of trans-iridoids. As shown in figure 3.5. we envisaged that the *trans*-fused cyclopetan[c]pyran **3** could be constructed via new C-C bond formation of sugar derived diester **12**, which would be obtained by deiodination of α-iodo ester derivative **13**. The iodo sugar **13** could be diastereoselectively achieved via ring-opening of cyclopropane derivative **14**, which was anticipated to be prepared by stereoselective cyclopropanation of 3-*C*-branched glucal **15**.

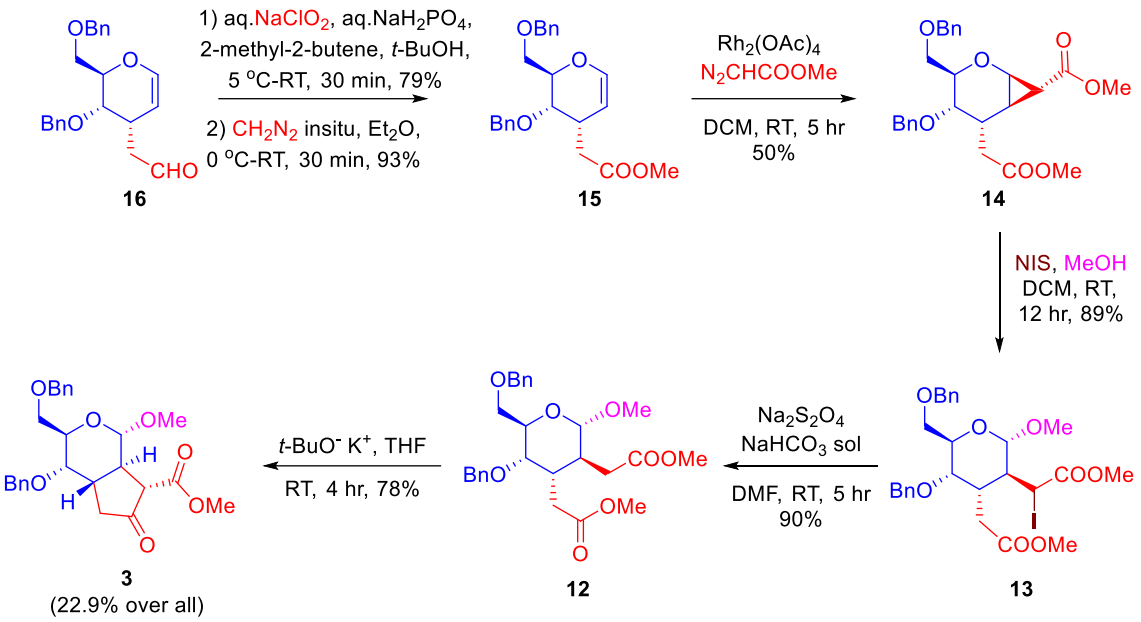
The commercially available tri-acetyl glucal **1** was converted to the 3-*C*-branched aldehyde **16** involving a [3,3] sigmatropic Claisen rearrangement reaction that was reported previously from our research group (scheme 3.2).[22]



1 **16**

Scheme 3.2 Synthesis of 3-*C*-branched glycal from 3,4,6-triacetyl-D-glucal.

The aldehyde group in 3-*C*-branched glycal **16** was transformed into the corresponding methyl ester **15** by pinnic-oxidation[23] followed by methylation[24] of the resulted carboxylic acid with diazomethane. Then, $Rh_2(OAc)_4$ catalyzed cyclopropanation of the resulted glucal **15** with methyl diazo acetate (MDA) produced the ester derived cyclopropane **14** in moderate yield.[18] In the next reaction, the cyclopropane ring in **14** was subjected to electrophilic ring opening by using *N*-iodo succinamide (NIS) and methanol to provide α-iodo ester derivative **13** in 89% good yield.[20] Subsequently, the iodo group of **13** was removed by treatment with sodium dithionite and $NaHCO_3$ solution to afford diester compound **12** in 90% good yield. Finally, the resulted sugar-derived diester **12** was subjected to Dieckmann condensation reaction to obtain *trans*-fused bicyclic iridoid skeleton **3** with 78% yield.[21] The overall yield of the targeted compound **3** was obtained as 22.9 % over 6 steps. The formation of fused bicyclic derivatives were confirmed by ^1H, ^{13}C, and COSY spectral analysis.



Scheme 3.3 Synthesis of trans-fused bicyclic iridoid skeleton from 3-*C*-branched glucal.

3.3 Conclusions

In summary, we have successfully reported a stereoselective pathway for the synthesis of *cis*-and *trans*-fused bicyclic iridoid skeletons from the commercially inexpensive material 3,4,6-triacetyl-D-glucal. The successful synthesis involves the cyclopropanation, Wittig olefination, Dieckmann condensation and electrophilic ring opening of cyclopropane reactions as the key functional group transformation for the C-C bond formation reactions. We look forward to further developing the novel route for the total synthesis of biologically important iridoid natural products from this type of frameworks using the same pathway.

3.4 Experimental section

3.4.1 General Methods

All reactions were carried out under an inert atmosphere with dry solvents under anhydrous conditions unless otherwise mentioned. Dichloromethane, methanol, and benzene were intially dried and stored over molecular sieves (4 Å). TLC was run on silica gel 60 F254 (Merck) plates, and the spots were detected by staining with H_2SO_4 in methanol (5%, V/V) or

phosphomolybdic acid in ethanol (5%, W/V) and heating. Silica gel (100-200 mesh) was used as a stationary phase for column chromatography. NMR spectra were recorded at 25 ^{o}C on a Bruker Avance III 400 (400 MHz for ^{1}H and 100 MHz for ^{13}C) or 500 (500 MHz for ^{1}H and 125 MHz for ^{13}C) instrument in $CDCl_3$, using residual $CHCl_3$ (δH = 7.26 ppm)as internal standard for ^{1}H, and $CDCl_3$ (δC = 77.0 ppm) as internal standard for ^{13}C. Chemical shifts are given in δ (ppm) and coupling constants (*J*) in Hz. IR spectra were recorded with a JASCO FTIR-5300 instrument. High resolution mass spectra were recorded on Bruker maXis ESI-TOF spectrometer.

3.4.2 Experimental procedures and spectral data

2.1 General procedure for deiodination of *α*-iodo esters 5 and 13 : (for the preparation 4 and 12)

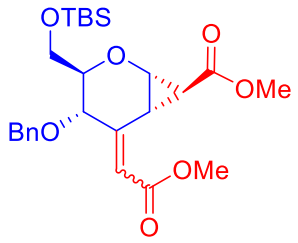
The iodo compound (0.124 mmol, 1eq) was dissolved in 1.24 mL of DMF and 1.24 mL of a solution of H_2O/$NaHCO_3$ (10 mol eq) was added followed by solid sodium dithionite (4 eq). The reaction was allowed to proceed under stirring for 5 hours at room temperature. Then, the reaction mixture was diluted with EtOAc (50 mL) and washed with water 4 times (50 mL each), followed by brine (50 mL). The organic layer was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure di carboxylate sugar derivative in 90% yield.

2.2 General procedure for Dieckmann Cyclization of Diester :(for the synthesis of 2 and 3):

The diester (0.15 mmol, 1eq) was dissolved in dry THF (or dry Benzene) (15 mL), potassium *tert*-butoxide (1.5 mmol, 10 eq) was added under argon, and the solution was stirred at room temperature for 4 h, at which time TLC indicated the complete disappearance of starting material and the formation of a new product. The reaction mixture was diluted with diethyl ether (20 mL), and 5% hydrochloric acid was added until the aqueous layer remained acidic.

The organic fraction was collected, dried over anhydrous Na_2SO_4, and evaporated to yield as an amber oil (78%-80%).

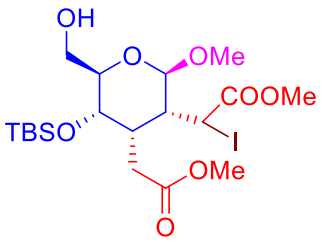
2.3 methyl (1*S*,3*R*,4*S*,6*R*)-4-(benzyloxy)-3-(((tert-butyldimethylsilyl)oxy)methyl)-5-(2-methoxy-2-oxoethylidene)-2-oxabicyclo[4.1.0]heptane-7-carboxylate (8)



8
(mix 1:2)

Yield: 99%, R_f: 0.45 (10% EtOAc/hexane). **8:** IR (neat): 2951, 2859, 1720, 1645, 1438 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.31-7.38 (m, 10H), 5.95 (s, 1H), 4.97 (d, 1H, *J* = 12.0 Hz), 4.66 (d, 1H, *J* = 12.0 Hz), 4.58 (d, 1H, *J* = 12.0 Hz), 4.43 (d, 1H, *J* = 12.0 Hz), 4.31 (dd, 1H, *J* = 2.5 Hz, *J* = 7.0 Hz), 4.06 (dd, 2H, *J* = 2.5 Hz, *J* = 7.0 Hz), 3.90 (s, 3H), 3.86-3.92 (m, 2H), 3.78 (s, 3H), 3.72 (s, 3H), 3.73-3.75 (m, 2H), 3.70 (s, 3H), 3.51-3.56 (m, 2H), 2.64 (dd, 1H, *J* = 2.5 Hz, *J* = 5.5 Hz), 2.51 (t, 1H, *J* = 6.0 Hz), 2.33 (dd, 1H, *J* = 2.0 Hz, *J* = 5.5 Hz), 1.68 (d, 1H, *J* = 2.5 Hz), 0.91 (s, 9H), 0.84 (s, 9H), 0.08 (s, 6H), 0.03 (s, 3H). 0.02 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 199.01, 171.28, 169.32, 165.96, 146.12, 137.23, 137.10, 128.53, 128.47, 128.03, 127.91, 127.88, 127.79, 121.99, 80.72, 76.95, 76.12, 75.50, 73.17, 70.44, 61.98, 61.60, 61.44, 59.04, 52.31, 52.00, 51.47, 35.05, 33.51, 30.45, 25.83, 25.69, 25.04, 18.40, 18.05, -5.53, -5.56, -5.75, -5.79. **HRMS (ESI)** calcd for $C_{25}H_{36}O_7Si+Na^+$ 499.2123, found 499.2134.

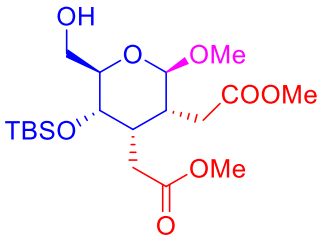
2.4 methyl (*S*)-2-((2*R*,3*R*,4*S*,5*S*,6*R*)-5-((tert-butyldimethylsilyl)oxy)-6-(hydroxymethyl)-2-methoxy-4-(2-methoxy-2-oxoethyl)tetrahydro-2*H*-pyran-3-yl)-2-iodoacetate (5)



5

Yield: 85%, R_f: 0.5 (30% EtOAc/hexane). **8:** IR (neat): 3498, 2951, 2858, 1731, 1435, 1381, 1251 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.13 (s, 1H), 4.21 (d, 1H, *J* = 8.0 Hz), 3.91 (dd, 1H, *J* = 4.5 Hz, *J* = 10.0 Hz), 3.86 (t, 1H, *J* = 9.5 Hz), 3.79 (dd, 1H, *J* = 7.5 Hz, *J* = 10.0 Hz), 3.72 (s, 3H), 3.65 (s, 3H), 3.47-3.52 (m, 1H), 3.49 (s, 3H), 3.36-3.41 (m, 1H), 2.66 (dd, 1H, *J* = 3.5 Hz, *J* = 17.0 Hz), 2.40 (dd, 1H, *J* = 6.5 Hz, *J* = 17.0 Hz), 2.06-2.13 (m, 1H), 1.78 (t, 1H, *J* = 9.0 Hz), 0.89 (s, 9H), 0.09 (s, 6H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 172.63, 169.64, 103.48, 76.42, 72.20, 65.61, 56.72, 53.52, 51.43, 44.33, 43.97, 32.01, 25.75, 25.10, 18.12, -5.59. **HRMS (ESI)** calcd for $C_{19}H_{35}O_8ISi+Na^+$ 569.1038, found 569.1046.

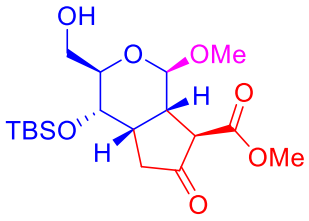
2.5 dimethyl 2,2'-((2*R*,3*R*,4*S*,5*S*,6*R*)-5-((tert-butyldimethylsilyl)oxy)-6-(hydroxymethyl) -2-methoxytetrahydro-2*H*-pyran-3,4-diyl)diacetate (4)



4

Yield: 90%, R_f: 0.45 (30% EtOAc/hexane). **8:** IR (neat): 3495, 2951, 2880, 2857, 1733, 1436, 1360, 1251 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 4.33 (d, 1H, *J* = 8.0 Hz), 3.93 (dd, 1H, *J* = 4.5 Hz, *J* = 10.0 Hz), 3.78 (dd, 1H, *J* = 7.5 Hz, *J* = 10.0 Hz), 3.67 (s, 3H), 3.66 (s, 3H), 3.64 (d, 1H, *J* = 2.0 Hz), 3.47-3.51 (m, 1H), 3.44 (s, 3H), 3.35-3.40 (m, 1H), 2.55-2.61 (m, 2H), 2.52 (dd, 1H, *J* = 4.5 Hz, *J* = 16.0 Hz), 2.37 (dd, 1H, *J* = 6.5 Hz, *J* = 16.0 Hz), 1.96-2.02 (m, 1H), 1.88-1.94 (m, 1H), 0.90 (s, 9H), 0.11 (s, 3H), 0.10 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 173.18, 172.46, 104.64, 75.90, 73.23, 66.01, 56.76, 51.67, 51.51, 41.97, 41.60, 33.72, 32.91, 25.78, 18.14, -5.59, -5.61. **HRMS (ESI)** calcd for $C_{19}H_{36}O_8Si+Na^+$ 443.2072, found 443.2075.

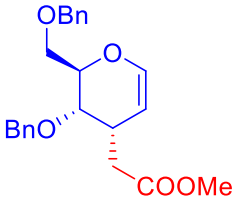
2.6 methyl (1*R*,3*R*,4*S*,4a*S*,7*R*,7a*S*)-4-((tert-butyldimethylsilyl)oxy)-3-(hydroxymethyl)-1-methoxy-6-oxooctahydrocyclopenta[c]pyran-7-carboxylate (2)



2

Yield: 80%, R_f: 0.43 (30% Acetone/hexane). **2:** IR (neat): 3494, 2950, 2931, 2886, 2857, 1758, 1725, 1438, 1399, 1254 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 4.42 (d, 1H, *J* = 8.0 Hz), 4.00 (dd, 1H, *J* = 4.5 Hz, *J* = 10.0 Hz), 3.85 (dd, 1H, *J* = 7.5 Hz, *J* = 10.5 Hz), 3.81 (s, 3H), 3.65-3.69 (m, 1H), 3.51-3.55 (m, 1H), 3.48-3.51 (m, 1H), 3.50 (s, 3H), 3.13 (d, 1H, *J* = 12.5 Hz), 2.55 (dd, 1H, *J* = 7.0 Hz, *J* = 18.0 Hz), 2.45-2.50 (m, 1H), 2.19 (t, 1H, *J* = 18.0 Hz), 1.90-1.98 (m, 1H), 0.92 (s, 9H), 0.12 (s, 3H), 0.11 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 207.64, 169.72, 104.91, 77.74, 74.17, 65.68, 59.62, 56.50, 52.75, 49.19, 42.21, 39.96, 25.85, 18.26, -5.51, -5.56. **HRMS (ESI)** calcd for $C_{18}H_{32}O_7Si+Na^+$ 411.1810, found 411.1811.

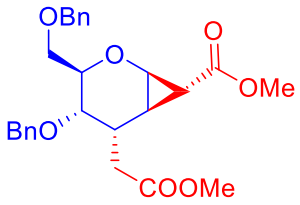
2.7 methyl 2-((2*R*,3*S*,4*S*)-3-(benzyloxy)-2-((benzyloxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)acetate (15)



15

Yield: 93%, R_f: 0.5 (20% EtOAc/hexane). **15: ^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.27-7.36 (m, 10H), 6.37 (dd, 1H, *J* = 0.8 Hz, *J* = 6.0 Hz), 4.72 (t, 1H, *J* = 1.2 Hz), 4.57-4.65 (m, 3H), 4.52 (d, 1H, *J* = 11.6 Hz), 3.99-4.03 (m, 1H), 3.91 (dd, 1H, *J* = 5.6 Hz, *J* = 8.8 Hz), 3.78 (d, 2H, *J* = 4.0 Hz), 3.57 (s, 3H), 3.05-3.11 (m, 1H), 2.64 (dd, 1H, *J* = 6.8 Hz, *J* = 16.0 Hz), 2.27 (dd, 1H, *J* = 7.2 Hz, *J* = 16.0 Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 173.04, 143.08, 137.92, 137.71, 128.34, 128.28, 127.77, 127.68, 127.62, 101.25, 73.57, 72.86, 72.65, 71.88, 69.05, 51.44, 36.19, 30.14. **HRMS (ESI)** calcd for $C_{23}H_{26}O_5+H^+$ 383.1853, found 383.1850.

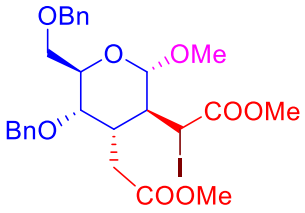
2.8 methyl (1*R*,3*R*,4*S*,5*S*,6*R*)-4-(benzyloxy)-3-((benzyloxy)methyl)-5-(2-methoxy-2-oxoethyl)-2-oxabicyclo[4.1.0]heptane-7-carboxylate (14)



14

Yield: 50%, R_f: 0.5 (30% EtOAc/hexane). **14:** IR (neat): 2951, 2850, 1738, 1493, 1435 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$** δ 7.24-7.37 (m, 10H), 4.56 (dd, 2H, *J* = 9.6 Hz, *J* = 13.6 Hz), 4.51 (d, 1H, *J* = 9.2 Hz), 4.44 (d, 1H, *J* = 9.6 Hz), 3.91 (dd, 1H, *J* = 1.2 Hz, *J* = 5.6 Hz), 3.84 (q, 1H, *J* = 4.0 Hz), 3.66 (s, 3H), 3.61 (s, 3H), 3.56 (t, 1H, *J* = 3.6 Hz), 3.49 (d, 2H, *J* = 3.6 Hz), 2.75 (dd, 1H, *J* = 5.2 Hz, *J* = 12.8 Hz), 2.59 (dd, 1H, *J* = 6.0 Hz, *J* = 12.8 Hz), 2.36-2.41 (m, 1H), 1.77 (dd, 1H, *J* = 1.2 Hz, *J* = 4.0 Hz), 1.64-1.67 (m,1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 172.64, 171.88, 137.80, 137.63, 128.28, 128.24, 127.78, 127.66, 127.59, 76.32, 75.04, 73.47, 71.46, 70.08, 57.55, 51.66, 51.52, 34.54, 32.56, 28.21, 25.87. **HRMS (ESI)** calcd for $C_{26}H_{30}O_7$+Na^+ 477.1884, found 477.1881.

2.9 methyl (*R*)-2-((2*S*,3*S*,4*S*,5*S*,6*R*)-5-(benzyloxy)-6-((benzyloxy)methyl)-2-methoxy-4-(2-methoxy-2-oxoethyl)tetrahydro-2*H*-pyran-3-yl)-2-iodoacetate (13)

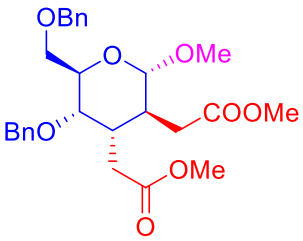


13

Yield: 89%, R_f: 0.55 (30% EtOAc/hexane). **13:** IR (neat): 2923, 2361, 1733, 1495, 1359, 1258 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.22-7.34 (m, 10H), 4.58-4.62 (m, 2H), 4.55 (d, 1H, *J* = 3.6 Hz) 4.50-4.53 (m, 2H), 4.34 (d, 1H, *J* = 11.2 Hz), 3.85 (ddd, 1H, *J* = 2.0 Hz, *J* = 4.4 Hz, *J* = 10.0 Hz), 3.76 (s, 3H), 3.64-3.71 (m, 2H), 3.59 (dd, 1H, *J* = 5.6 Hz, *J* = 15.6 Hz), 3.59 (s, 3H), 3.34 (s, 3H), 3.31-3.33 (m, 1H), 2.91 (dd, 1H, *J* = 6.4 Hz, *J* = 16.8 Hz), 2.79 (dd, 1H, *J* =

7.2 Hz, *J* = 16.8 Hz), 2.50 (d, 1H, *J* = 11.6 Hz). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 173.69, 171.68, 138.05, 137.51, 128.31, 128.28, 127.98, 127.72, 127.70, 127.57, 97.25, 73.47, 71.12, 69.68, 69.24, 67.24, 55.37, 53.03, 51.52, 45.35, 35.63, 33.17, 23.50. **HRMS (ESI)** calcd for $C_{27}H_{33}O_8I+Na^+$ 635.1112, found 635.1114.

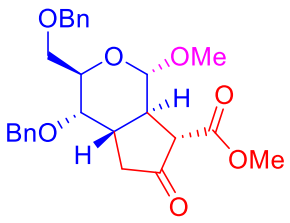
2.10 dimethyl 2,2'-((2*S*,3*S*,4*S*,5*S*,6*R*)-5-(benzyloxy)-6-((benzyloxy)methyl)-2-methoxy tetrahydro-2*H*-pyran-3,4-diyl)diacetate (12)



12

Yield: 90%, R_f: 0.5 (30% EtOAc/hexane). **12:** IR (neat): 2911, 1731, 1495, 1435 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.20-7.36 (m, 10H), 4.65 (d, 1H, *J* = 12.5 Hz), 4.56 (s, 1H), 4.54 (d, 1H, *J* = 7.5 Hz), 4.51 (d, 1H, *J* = 7.0 Hz), 4.32 (d, 1H, *J* = 11.0 Hz), 3.85-3.88 (m, 1H), 3.79 (dd, 1H, *J* = 5.0 Hz, *J* = 10.0 Hz), 3.70-3.76 (m, 2H), 3.71 (s, 3H), 3.54 (s, 3H), 3.36 (s, 3H), 2.82-2.88 (m, 1H), 2.68-2.75 (m, 2H), 2.65 (dd, 1H, *J* = 8.5 Hz, *J* = 15.5 Hz), 2.47 (dd, 1H, *J* = 6.0 Hz, *J* = 16.0 Hz), 2.42 (t, 1H, *J* = 7.0 Hz). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 173.90, 172.32, 138.16, 137.76, 128.21, 128.14, 127.67, 127.58, 127.51, 127.43, 101.10, 73.42, 71.19, 70.81, 69.42, 66.98, 54.98, 51.64, 51.31, 39.27, 36.51, 35.10, 33.41. **HRMS (ESI)** calcd for $C_{27}H_{34}O_8+NH_4^+$ 504.2592, found 504.2592.

2.11 methyl (1*S*,3*R*,4*S*,4a*S*,7S,7a*R*)-4-(benzyloxy)-3-((benzyloxy)methyl)-1-methoxy-6-oxooctahydrocyclopenta[c]pyran-7-carboxylate (3)



3

Yield: 78%, R_f: 0.35 (30% EtOAc/hexane). **3:** IR (neat): 2911, 1758, 1731, 1494, 1435 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.28-7.39 (m, 8H), 7.21-7.24 (m, 2H), 4.70 (d, 1H, *J* = 7.6 Hz), 4.58 (d, 1H, *J* = 12.4 Hz), 4.47 (d, 1H, *J* = 12.4 Hz), 4.43 (d, 1H, *J* = 11.6 Hz), 4.35 (d, 1H, *J* = 11.6 Hz), 3.99-4.02 (m, 1H), 3.83-3.89 (m, 1H), 3.76 (s, 3H), 3.63 (dd, 1H, *J* = 3.2 Hz, *J* = 10.4 Hz), 3.53 (dd, 1H, *J* = 3.2 Hz, *J* = 10.8 Hz), 3.40 (s, 3H), 3.00 (d, 1H, *J* = 12.0 Hz), 2.78 (td, 1H, *J* = 7.2 Hz, *J* = 12.8 Hz), 2.54 (dd, 1H, *J* = 12.8 Hz, *J* = 17.6 Hz), 2.38 (dd, 1H, *J* = 7.2 Hz, *J* = 18.0 Hz), 2.13-2.16 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 208.71, 168.79, 137.83, 137.58, 128.44, 128.40, 127.96, 127.92, 127.87, 127.83, 127.79, 103.72, 73.27, 73.13, 72.97, 72.81, 69.89, 59.12, 55.42, 52.56, 42.97, 38.66, 36.93. **HRMS (ESI)** calcd for $C_{26}H_{30}O_7$+Na^+ 477.1884, found 477.1887.

3.5 References

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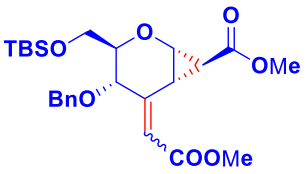

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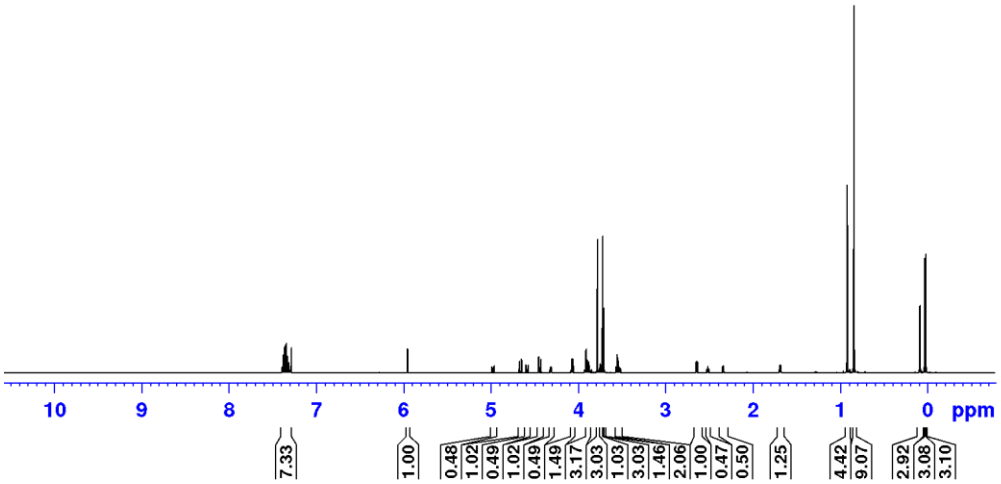


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PROCNO                1

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PROBHD   Z119470_0291 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ            3.2767999 sec
RG                31.25
DW               50.000 usec
DE                6.50 usec
TE               294.8 K
D1           1.00000000 sec
TD0                   1
SFO1        500.3720898 MHz
NUC1                1H
P1                10.00 usec
PLW1        23.23100090 W

F2 - Processing parameters
SI                65536
SF          500.3690000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
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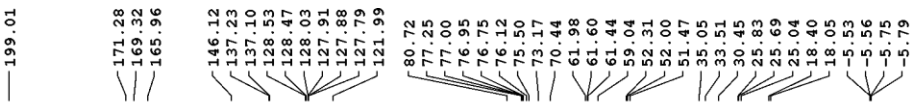

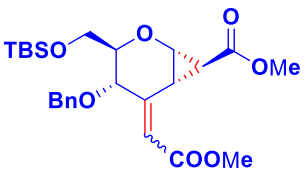

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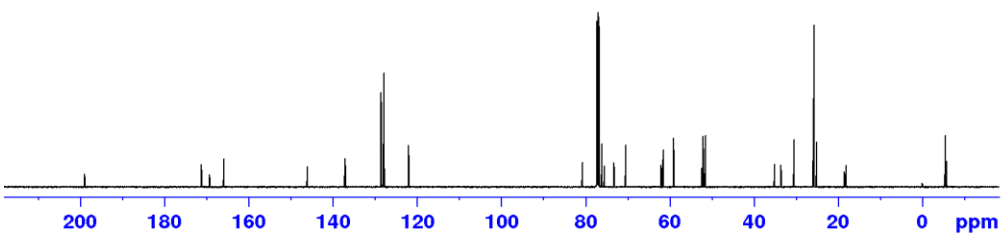


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Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               191
PROCNO                1

F2 - Acquisition Parameters
Date_          20200929
Time              15.29 h
INSTRUM            spect
PROBHD   Z119470_0291 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                 1560
DS                    4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ            1.1010048 sec
RG                192.83
DW               16.800 usec
DE                6.50 usec
TE               295.5 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1
SFO1        125.8304669 MHz
NUC1                13C
P1                10.00 usec
PLW1       115.01000214 W
SFO2        500.3710015 MHz
NUC2                1H
CPDPRG[2         waltz16
PCPD2             80.00 usec
PLW2        23.23100090 W
PLW12        0.36298999 W
PLW13        0.18257999 W

F2 - Processing parameters
SI                32768
SF          125.8178911 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
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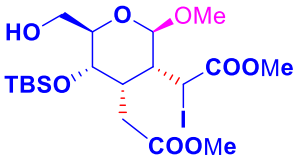

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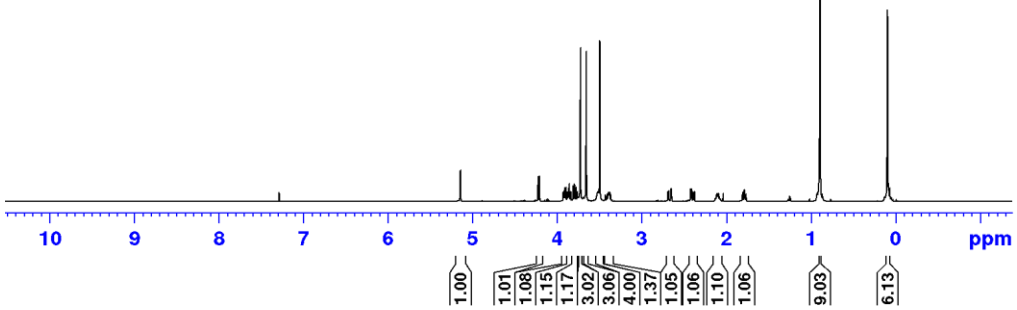


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Current Data Parameters
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EXPNO                 33
PROCNO                 1

F2 - Acquisition Parameters
Date_           20201029
Time              15.28 h
INSTRUM             spect
PROBHD    Z109128_0042 (
PULPROG              zg30
TD                  65536
SOLVENT             CDCl3
NS                     16
DS                      2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ            3.2767999 sec
RG                     57
DW               50.000 usec
DE               13.04 usec
TE                 516.2 K
D1            1.00000000 sec
TD0                    1
SFO1          500.1830886 MHz
NUC1                  1H
P0                 5.00 usec
P1                15.00 usec
PLW1          4.84679985 W

F2 - Processing parameters
SI                  65536
SF            500.1800000 MHz
WDW                    EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
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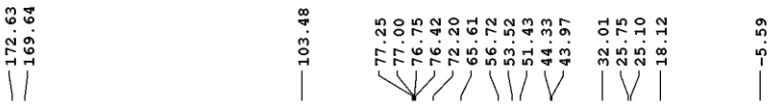

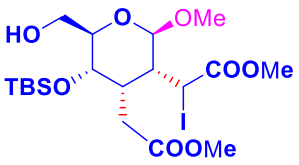

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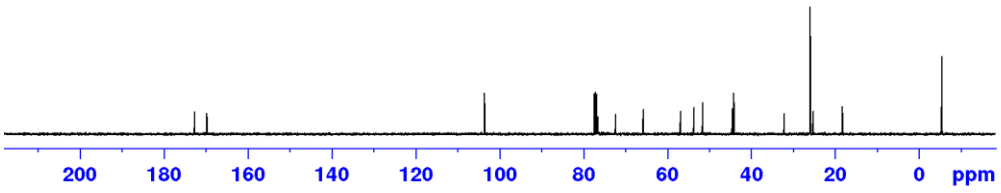


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Current Data Parameters
NAME      BUR PRS UPDATED 500
EXPNO                 35
PROCNO                 1

F2 - Acquisition Parameters
Date_           20201102
Time              11.18 h
INSTRUM             spect
PROBHD    Z109128_0042 (
PULPROG           zgpg30
TD                  65536
SOLVENT             CDCl3
NS                     64
DS                      4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ            1.1010048 sec
RG                    203
DW               16.800 usec
DE                6.50 usec
TE                297.1 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1
SFO1          125.7829381 MHz
NUC1                  13C
P0                 3.33 usec
P1                10.00 usec
PLW1          64.00399780 W
SFO2          500.1820007 MHz
NUC2                  1H
CPDPRG[2          waltz65
PCPD2             80.00 usec
PLW2           4.84679985 W
PLW12          0.17039999 W
PLW13          0.08570800 W

F2 - Processing parameters
SI                  32768
SF            125.7703686 MHz
WDW                    EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```

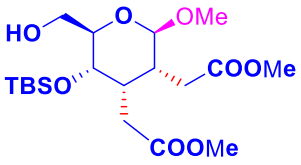

4


```
Current Data Parameters
NAME      BUR PRS UPDATED 500
EXPNO                   36
PROCNO                   1

F2 - Acquisition Parameters
Date_              20201104
Time                 14.29 h
INSTRUM              spect
PROBHD    Z109128_0042 (
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH             10000.000 Hz
FIDRES              0.305176 Hz
AQ                3.2767999 sec
RG                     71.8
DW                   50.000 usec
DE                   13.04 usec
TE                   297.0 K
D1              1.00000000 sec
TD0                       1
SFO1           500.1830886 MHz
NUC1                     1H
P0                    5.00 usec
P1                   15.00 usec
PLW1            4.84679985 W

F2 - Processing parameters
SI                    65536
SF             500.1800000 MHz
WDW                      EM
SSB         0
LB                    0.30 Hz
GB          0
PC                    1.00
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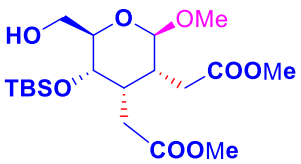

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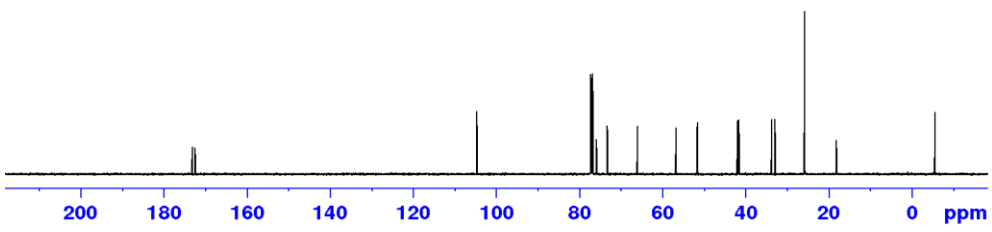


```
Current Data Parameters
NAME      BUR PRS UPDATED 500
EXPNO                   38
PROCNO                   1

F2 - Acquisition Parameters
Date_              20201104
Time                 15.01 h
INSTRUM              spect
PROBHD    Z109128_0042 (
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      350
DS                        4
SWH             29761.904 Hz
FIDRES              0.908261 Hz
AQ                1.1010048 sec
RG                     203
DW                   16.800 usec
DE                    6.50 usec
TE                   297.8 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                       1
SFO1           125.7829381 MHz
NUC1                     13C
P0                    3.33 usec
P1                   10.00 usec
PLW1           64.00399780 W
SFO2           500.1820007 MHz
NUC2                     1H
CPDPRG[2          waltz65
PCPD2                80.00 usec
PLW2            4.84679985 W
PLW12           0.17039999 W
PLW13           0.08570800 W

F2 - Processing parameters
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SF             125.7703646 MHz
WDW                      EM
SSB         0
LB                    1.00 Hz
GB          0
PC                    1.40
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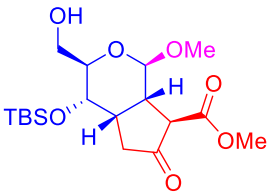
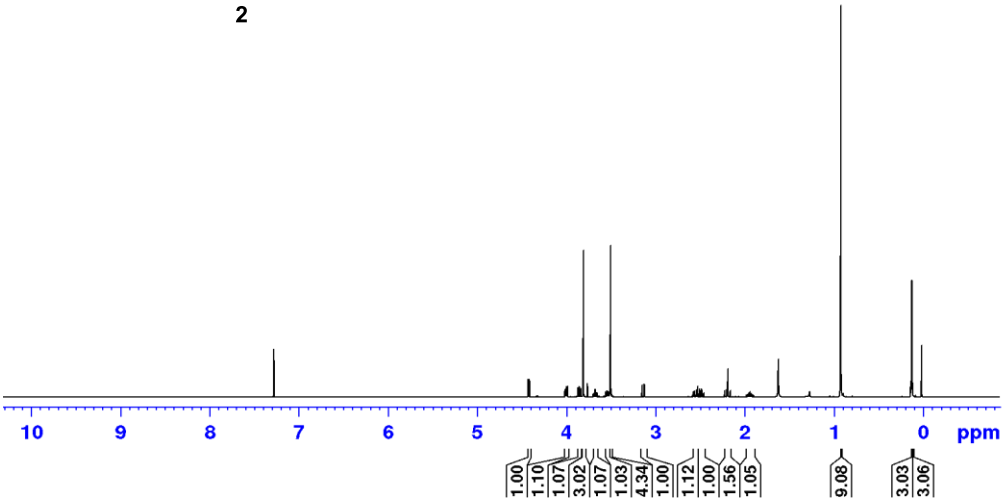


2




```
Current Data Parameters
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EXPNO               204
PROCNO                1

F2 - Acquisition Parameters
Date_          20201115
Time               9.00 h
INSTRUM            spect
PROBHD   Z119470_0291 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ            3.2767999 sec
RG                 95.6
DW               50.000 usec
DE                6.50 usec
TE                296.9 K
D1           1.00000000 sec
TD0                   1
SFO1         500.3720898 MHz
NUC1                 1H
P1                10.00 usec
PLW1         23.23100090 W

F2 - Processing parameters
SI                65536
SF           500.3690020 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
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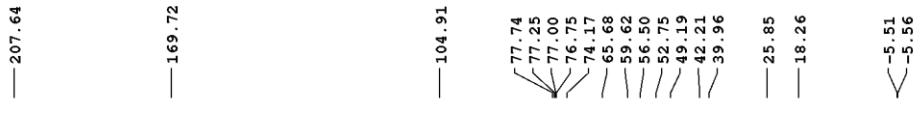

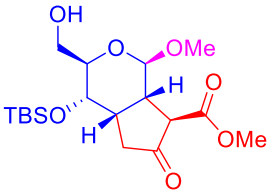

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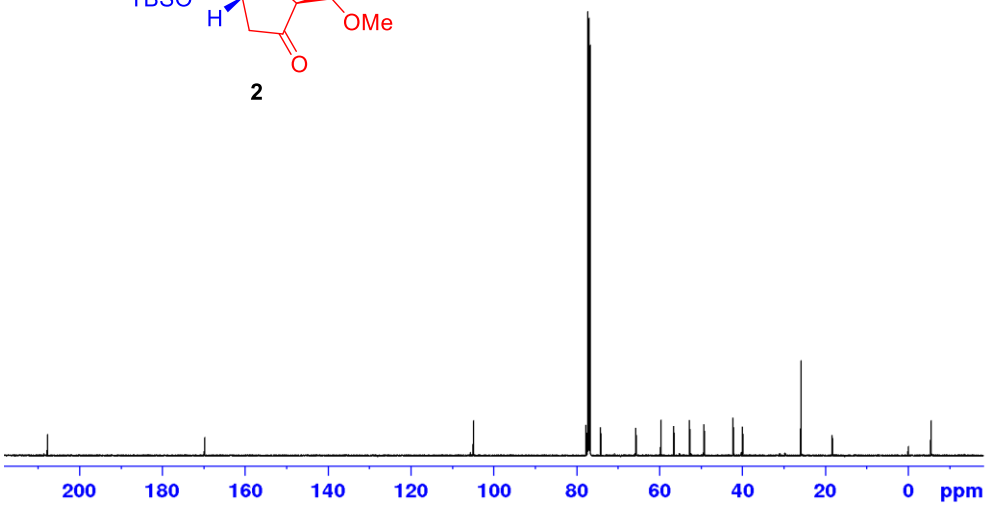


```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               201
PROCNO                1

F2 - Acquisition Parameters
Date_          20201113
Time              22.25 h
INSTRUM            spect
PROBHD   Z119470_0291 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                 5120
DS                    4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ            1.1010048 sec
RG                192.83
DW               16.800 usec
DE                6.50 usec
TE                297.5 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1
SFO1         125.8304669 MHz
NUC1                 13C
P1                10.00 usec
PLW1         115.01000214 W
SFO2          500.3710015 MHz
NUC2                 1H
CPDPRG[2          waltz16
PCPD2             80.00 usec
PLW2         23.23100090 W
PLW12         0.36298999 W
PLW13         0.18257999 W

F2 - Processing parameters
SI                32768
SF           125.8178881 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
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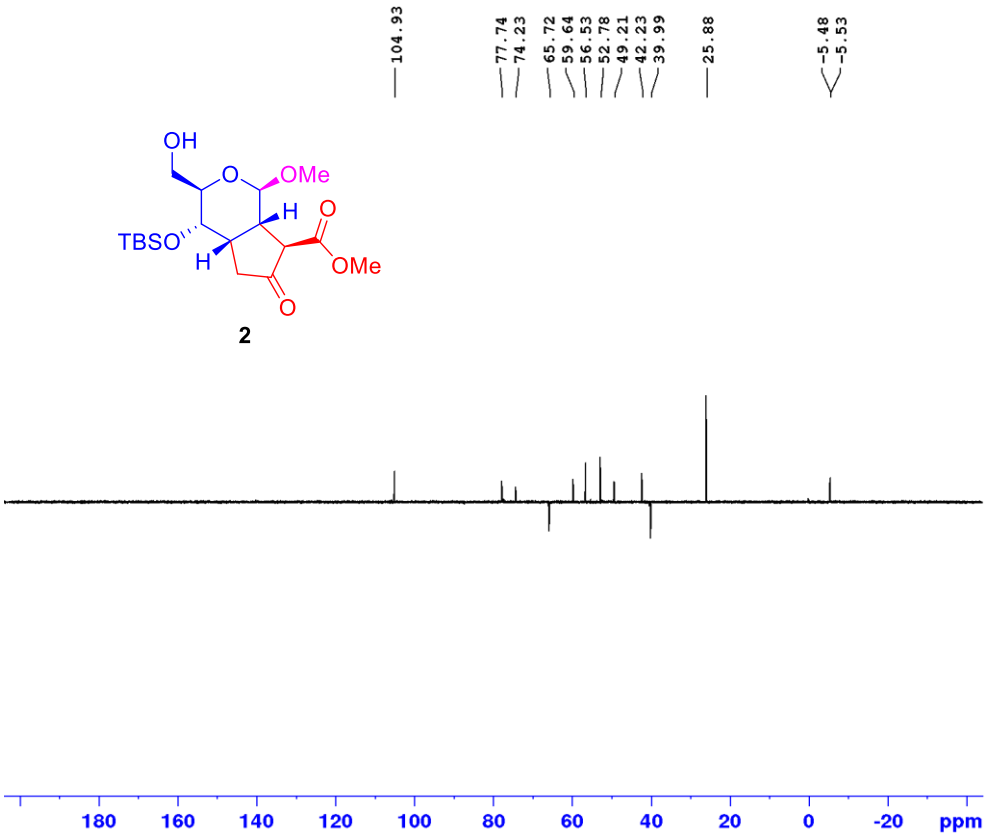


```
Current Data Parameters
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EXPNO                200
PROCNO                 1

F2 - Acquisition Parameters
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Time              17.55 h
INSTRUM             spect
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PULPROG         deptsp135
TD                  65536
SOLVENT             CDCl3
NS                    512
DS                      8
SWH             31250.000 Hz
FIDRES          0.953674 Hz
AQ              1.0485760 sec
RG                 192.83
DW                 16.000 usec
DE                   6.50 usec
TE                 296.9 K
CNST2          145.0000000
D1              2.00000000 sec
D2              0.00344828 sec
D12             0.00002000 sec
TD0                     1
SFO1          125.8279506 MHz
NUC1                  13C
P1                  10.00 usec
P13               2000.00 usec
PLW0       0 W
PLW1       115.01000214 W
SPNAM[5]     Crp60comp.4
SPOAL5             0.500
SPOFFS5    0 Hz
SPW5          17.57200050 W
SFO2          500.3710015 MHz
NUC2                  1H
CPDPRG[2           waltz16
P3                  10.00 usec
P4                  20.00 usec
PCPD2               80.00 usec
PLW2          23.23100090 W
PLW12          0.36298999 W

F2 - Processing parameters
SI                  32768
SF            125.8178851 MHz
WDW                    EM
SSB        0
LB                  1.00 Hz
GB         0
PC                  1.40
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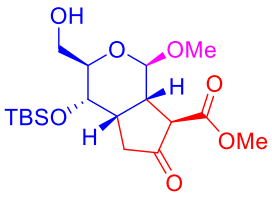
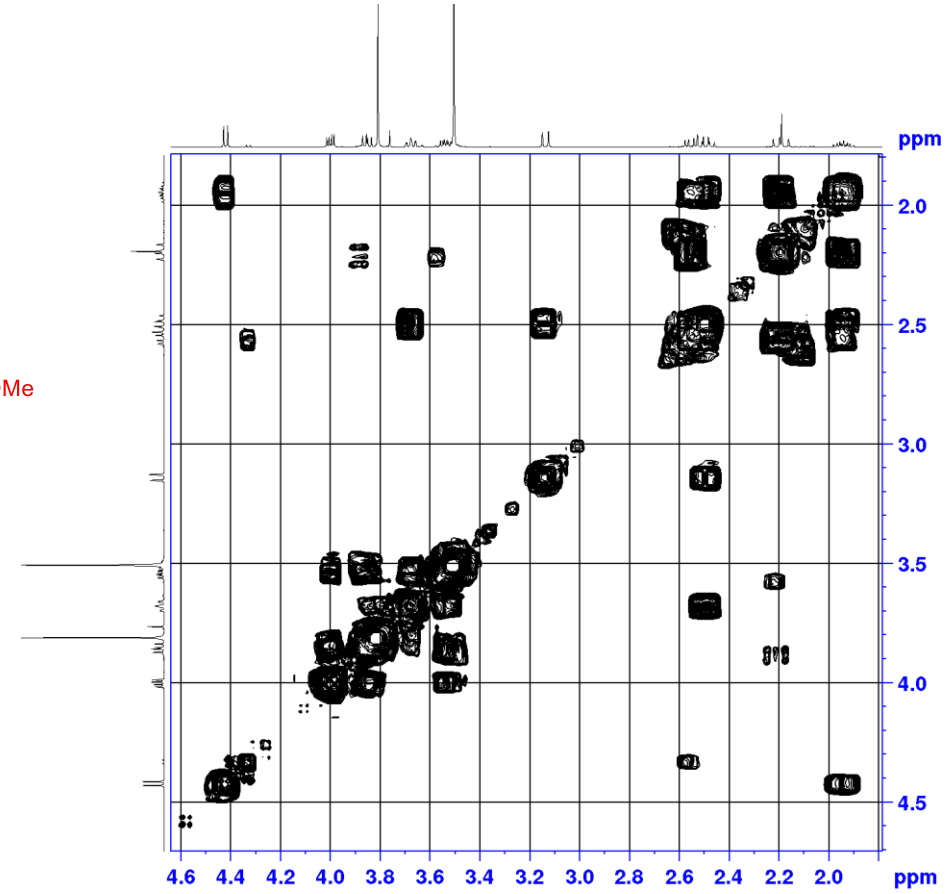
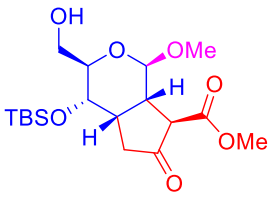


2

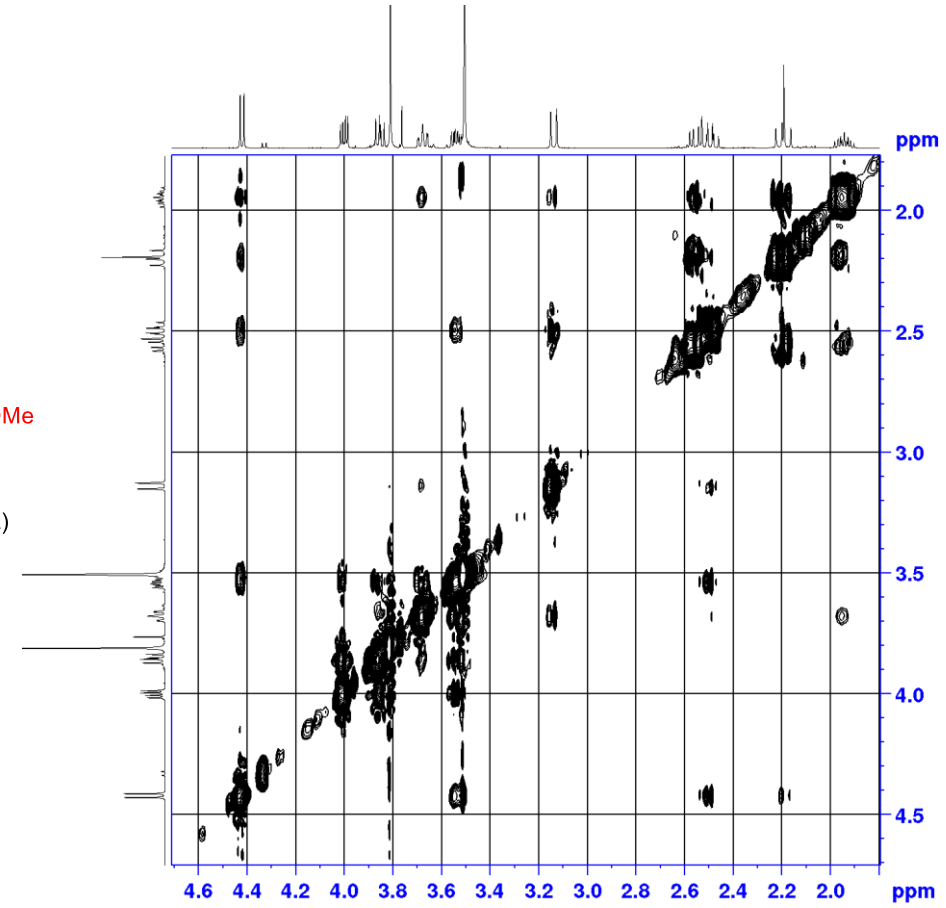
(COSY, 500MHz)

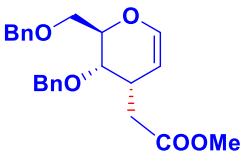




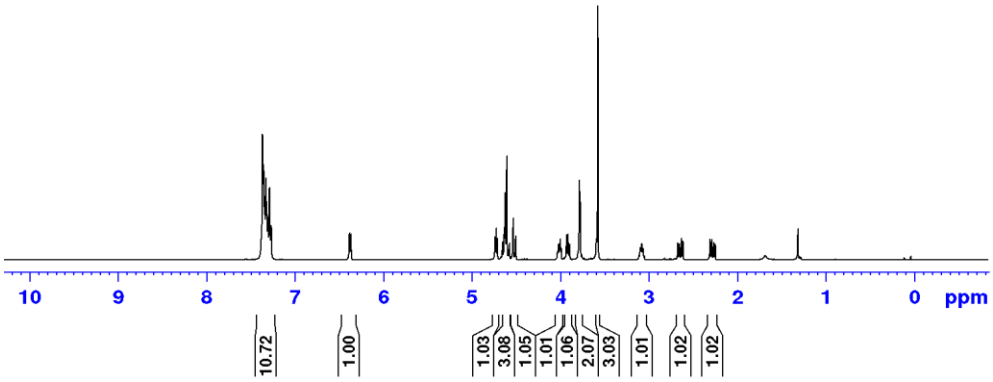
2

(NOESY, 500MHz)





15

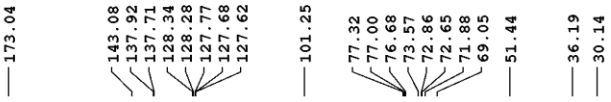


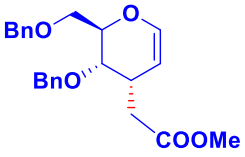

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  123511
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151023
Time                   17.02
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG                zg30
TD                    65536
SOLVENT               CDC13
NS                       16
DS                        2
SWH                8278.146 Hz
FIDRES             0.126314 Hz
AQ                 3.9583745 sec
RG                      22.6
DW                   60.400 usec
DE                    6.50 usec
TE                   294.7 K
D1                1.00000000 sec
TD0                         1

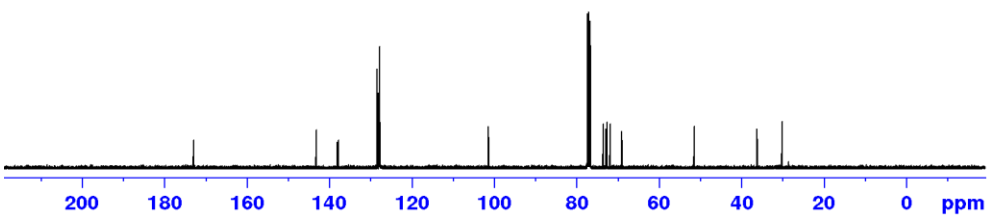
======== CHANNEL f1 ========
NUC1                       1H
P1                      15.00 usec
PL1                     -2.50 dB
PL1W             15.14257336 W
SFO1            400.1324710 MHz

F2 - Processing parameters
SI                        32768
SF                400.1300000 MHz
WDW                          EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```





15



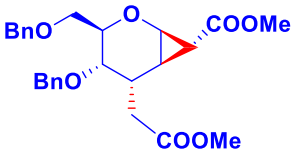

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  123512
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151023
Time                   17.05
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG             zgpg30
TD                    65536
SOLVENT               CDC13
NS                      121
DS                        4
SWH               23980.814 Hz
FIDRES             0.365918 Hz
AQ                 1.3664256 sec
RG                    9195.2
DW                   20.850 usec
DE                    6.50 usec
TE                   294.9 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

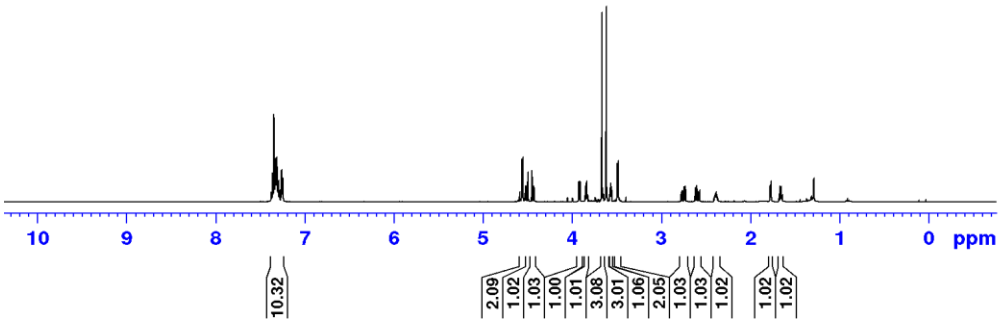
======== CHANNEL f1 ========
NUC1                      13C
P1                      11.00 usec
PL1           0 dB
PL1W            33.65927887 W
SFO1           100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                     -2.50 dB
PL12                    12.04 dB
PL13                    14.00 dB
PL2W             15.14257336 W
PL12W             0.53235298 W
PL13W             0.33899999 W
SFO2            400.1316005 MHz

F2 - Processing parameters
SI                        32768
SF                100.6127764 MHz
WDW                          EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```



14

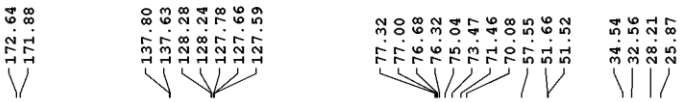


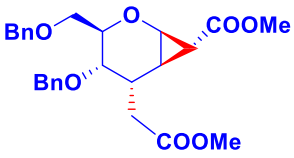

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  123711
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151108
Time                    1.19
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                3.1719425 sec
RG                       36
DW                   48.400 usec
DE                    6.50 usec
TE                   296.3 K
D1               1.00000000 sec
TD0                       1

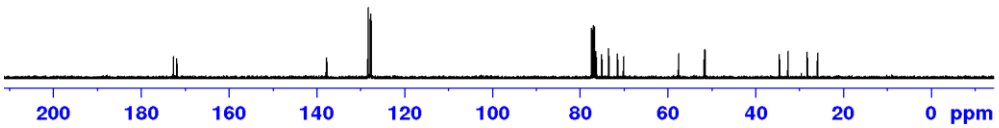
======== CHANNEL f1 ========
NUC1                     1H
P1                    14.90 usec
PL1                    2.00 dB
PL1W           12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```





14



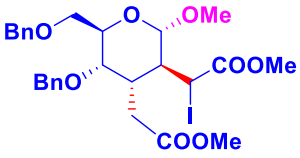

```
Current Data Parameters
NAME                  BUR 400
EXPNO                  123712
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151028
Time                   12.49
INSTRUM                spect
PROBHD    5 mm PABBO BB/
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      405
DS                        4
SWH               23980.814 Hz
FIDRES             0.365918 Hz
AQ                1.3664256 sec
RG                   20642.5
DW                   20.850 usec
DE                    6.50 usec
TE                   295.3 K
D1               2.00000000 sec
D11              0.03000000 sec
TD0                       1

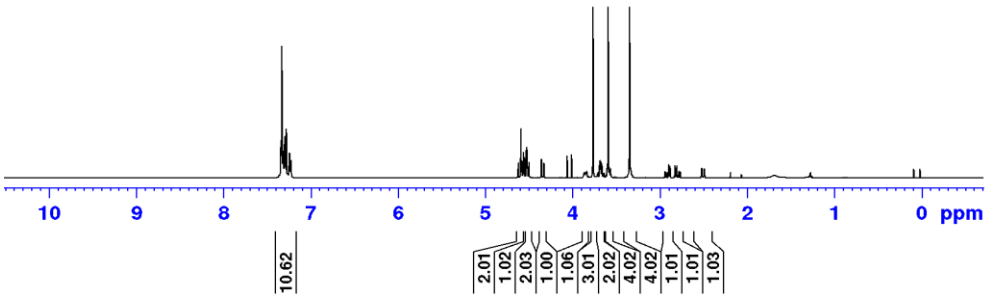
======== CHANNEL f1 ========
NUC1                    13C
P1                    11.00 usec
PL1          0 dB
PL1W           33.65927887 W
SFO1           100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                     1H
PCPD2                 80.00 usec
PL2                   -2.50 dB
PL12                  12.04 dB
PL13                  14.00 dB
PL2W           15.14257336 W
PL12W           0.53235298 W
PL13W           0.33899999 W
SFO2           400.1316005 MHz

F2 - Processing parameters
SI                    32768
SF             100.6127836 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```



13

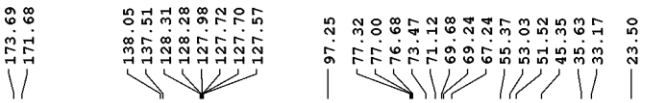


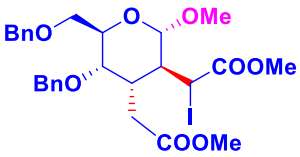

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 1238211
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151104
Time                    9.52
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8223.685 Hz
FIDRES             0.125483 Hz
AQ                 3.9845889 sec
RG                      128
DW                   60.800 usec
DE                    6.50 usec
TE                   300.0 K
D1                1.00000000 sec
TD0                         1

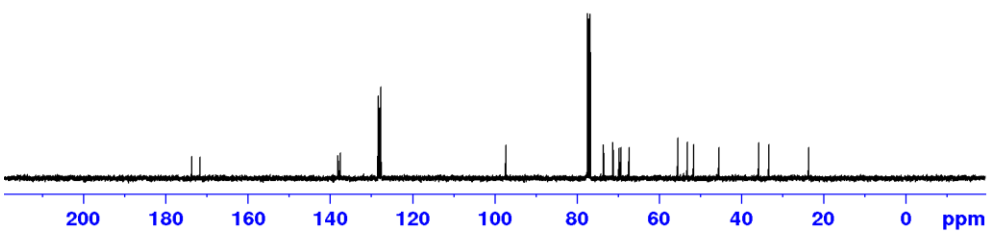
======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      1.50 dB
PL1W            15.18650627 W
SFO1            400.0934707 MHz

F2 - Processing parameters
SI                      32768
SF              400.0910000 MHz
WDW                        EM
SSB          0
LB                       0.30 Hz
GB           0
PC                       1.00
```





13



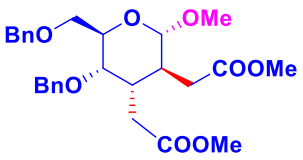

```
Current Data Parameters
NAME                  BUR 400
EXPNO                 1238212
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151104
Time                   10.02
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      128
DS                        4
SWH               24038.461 Hz
FIDRES             0.366798 Hz
AQ                 1.3631488 sec
RG                     28.5
DW                   20.800 usec
DE                    6.50 usec
TE                   300.0 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

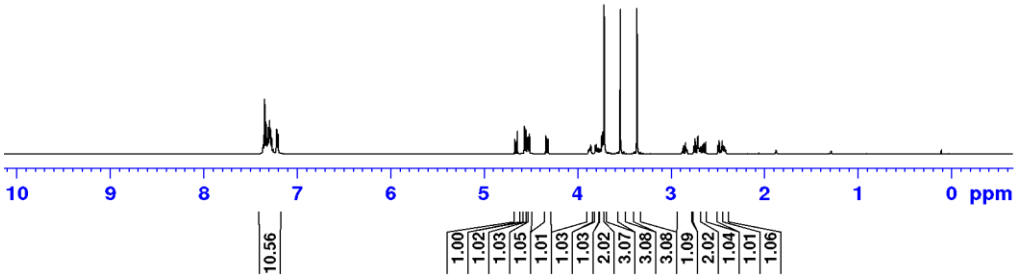
======== CHANNEL f1 ========
NUC1                      13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W           49.44866943 W
SFO1           100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                      1H
PCPD2                 90.00 usec
PL2                    1.50 dB
PL12                  17.18 dB
PL13                  20.18 dB
PL2W           15.18650627 W
PL12W           0.41063678 W
PL13W           0.20580591 W
SFO2           400.0926004 MHz

F2 - Processing parameters
SI                      32768
SF             100.6029673 MHz
WDW                        EM
SSB          0
LB                       1.00 Hz
GB           0
PC                       1.40
```



12

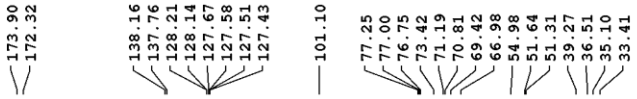


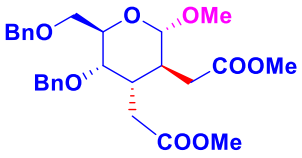

```
Current Data Parameters
NAME      BUR 2 (500MHz)
EXPNO           124211
PROCNO               1

F2 - Acquisition Parameters
Date_         20180802
Time             17.45
INSTRUM          spect
PROBHD   5 mm PABBO BB-
PULPROG          zg30
TD              65536
SOLVENT          CDCl3
NS                  16
DS                   2
SWH          10330.578 Hz
FIDRES        0.157632 Hz
AQ            3.1719425 sec
RG                  36
DW               48.400 usec
DE                6.50 usec
TE               295.8 K
D1           1.00000000 sec
TD0                  1

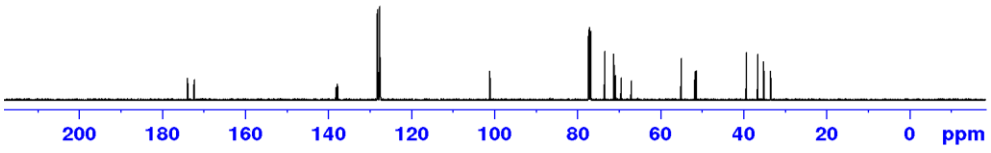
======== CHANNEL f1 ========
NUC1                1H
P1               14.90 usec
PL1               2.00 dB
PL1W        12.85348415 W
SFO1       500.1830888 MHz

F2 - Processing parameters
SI                32768
SF         500.1800000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```





12



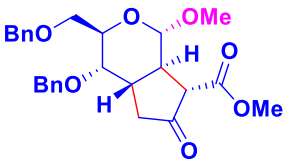

```
Current Data Parameters
NAME      BUR 2 (500MHz)
EXPNO           124212
PROCNO               1

F2 - Acquisition Parameters
Date_         20180802
Time             17.51
INSTRUM          spect
PROBHD   5 mm PABBO BB-
PULPROG        zgpg30
TD              65536
SOLVENT          CDCl3
NS                  64
DS                   4
SWH          29761.904 Hz
FIDRES        0.454131 Hz
AQ            1.1010048 sec
RG                2050
DW               16.800 usec
DE                6.50 usec
TE               296.9 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                  1

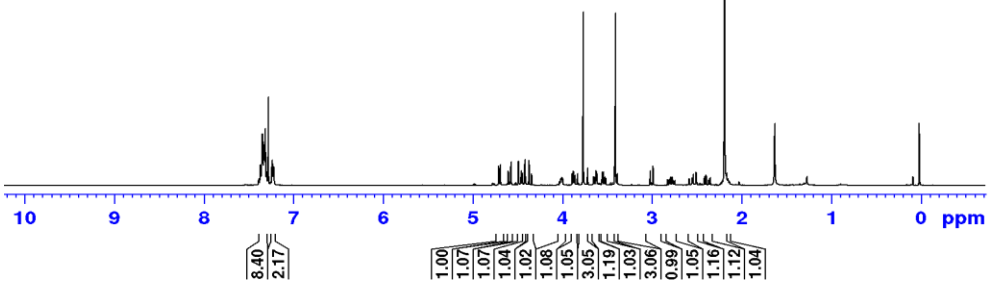
======== CHANNEL f1 ========
NUC1                13C
P1                9.60 usec
PL1       0 dB
PL1W        76.36135101 W
SFO1       125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                1H
PCPD2            80.00 usec
PL2               2.00 dB
PL12             16.50 dB
PL13             16.50 dB
PL2W        12.85348415 W
PL12W        0.45605880 W
PL13W        0.45605880 W
SFO2       500.1820007 MHz

F2 - Processing parameters
SI                32768
SF         125.7703759 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



3

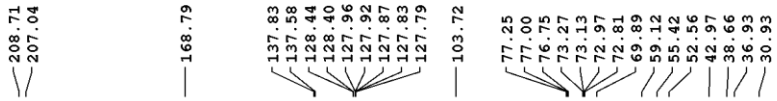


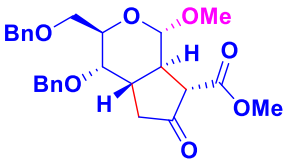

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  124811
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151201
Time                   11.21
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       32
DS                        2
SWH                8223.685 Hz
FIDRES             0.125483 Hz
AQ                 3.9845889 sec
RG                      362
DW                   60.800 usec
DE                    6.50 usec
TE                   295.1 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      1.50 dB
PL1W            15.18650627 W
SFO1            400.0934707 MHz

F2 - Processing parameters
SI                      32768
SF              400.0910000 MHz
WDW                        EM
SSB          0
LB                       0.30 Hz
GB           0
PC                       1.00
```





3

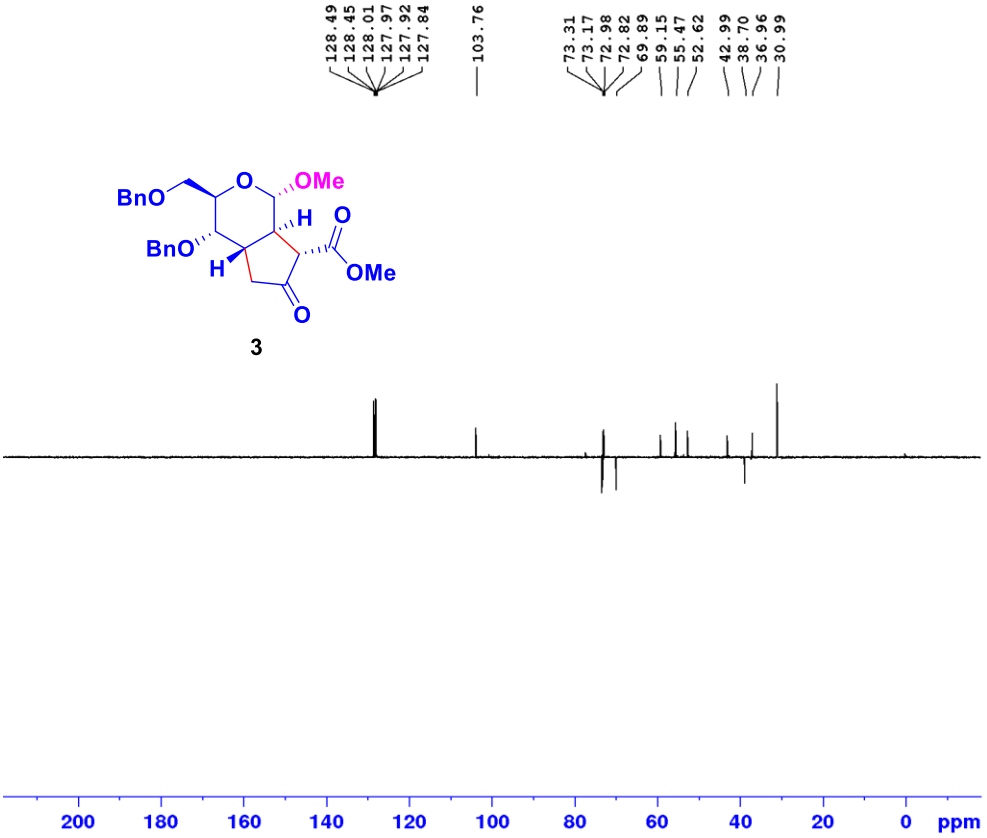

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  124812
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151129
Time                    7.19
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                    10240
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                      724
DW                   16.800 usec
DE                    6.50 usec
TE                   294.5 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                       9.60 usec
PL1           0 dB
PL1W            76.36135101 W
SFO1            125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                   80.00 usec
PL2                      2.00 dB
PL12                    16.50 dB
PL13                    16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2            500.1820007 MHz

F2 - Processing parameters
SI                      32768
SF              125.7703657 MHz
WDW                        EM
SSB          0
LB                       1.00 Hz
GB           0
PC                       1.40
```



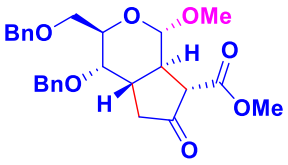

```
Current Data Parameters
NAME                  BUR 500
EXPNO                  124813
PROCNO                      1

F2 - Acquisition Parameters
Date_               20151129
Time                   11.42
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              dept135
TD                     65536
SOLVENT                CDCl3
NS                      5000
DS                         4
SWH                29761.904 Hz
FIDRES              0.454131 Hz
AQ                  1.1010048 sec
RG                        36
DW                    16.800 usec
DE                     6.50 usec
TE                    292.7 K
CNST2             145.0000000
D1                 2.00000000 sec
D2                 0.00344828 sec
D12                0.00002000 sec
TD0                        1

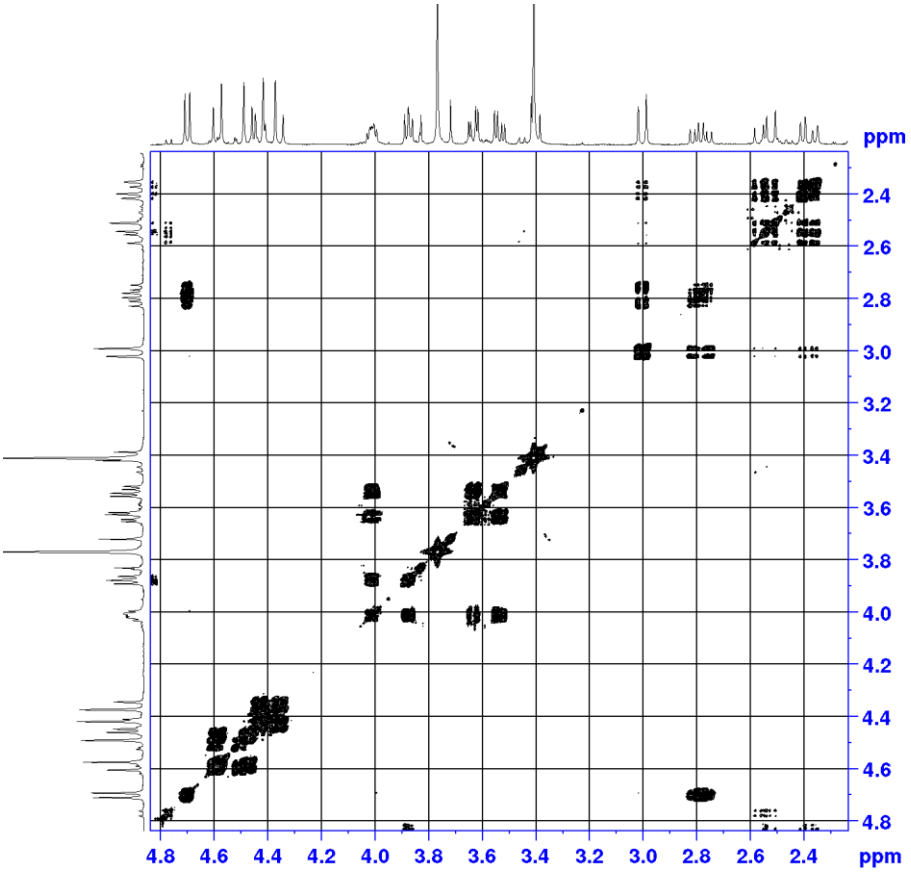
======== CHANNEL f1 ========
NUC1                     13C
P1                     9.60 usec
P2                    19.20 usec
PL1          0 dB
PL1W           76.36135101 W
SFO1          125.7829381 MHz

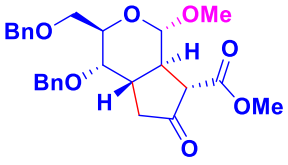
======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                     1H
P3                    14.90 usec
P4                    29.80 usec
PCPD2                 80.00 usec
PL2                    2.00 dB
PL12                  16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
SFO2          500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF                125.7703610 MHz
WDW                          EM
SSB          0
LB                     1.00 Hz
GB           0
PC                     1.40
```

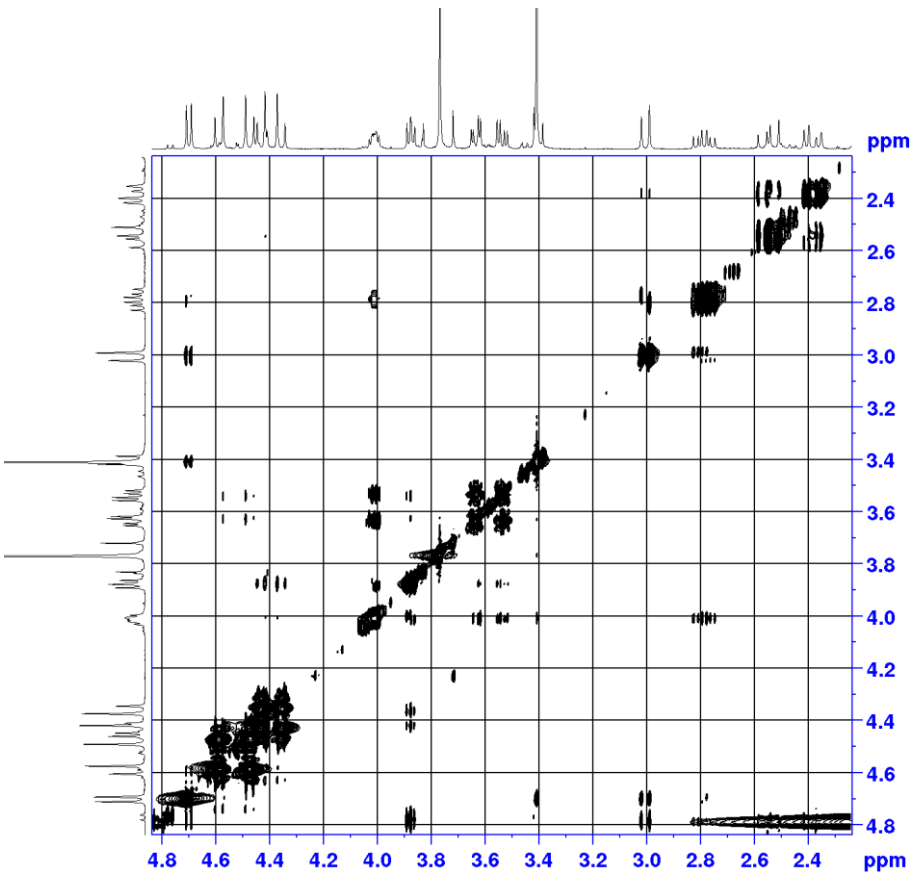


3
(COSY, 400 MHz)



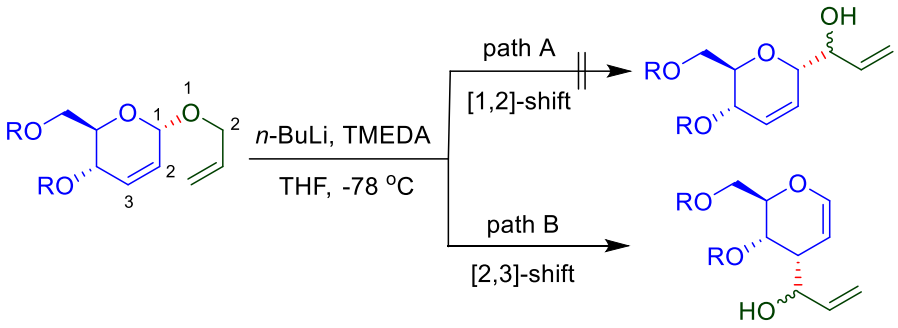


3
(NOESY, 400 MHz)



Chapter-4

Stereoselective synthesis of 3-*C*-branched glycals involving [2,3] Wittig rearrangement



4.1 Introduction

The rearrangement of α-ethereal carbanion, stabilised by phenyl or vinyl, to the corresponding alkoxide known as Wittig rearrangement is one the finest method for the stereoselective formation of C-C bond. Out of different variants of this classic sigmatropic rearrangement, the [1,2]- and [2,3]- were the most synthetically useful techniques. The mechanistic investigations revealed that the [1,2]-Wittig rearrangement involves a radical pair dissociation-recombination mechanism, whereas the [2,3]-Wittig rearrangement follows the Woodward-Hoffmann rule that proceeds through a concerted thermally allowed sigmatropic process. In many such type of rearrangements, depending on the structure and temperature it was observed that the [1,2]-shift competes with the [2,3]-shift in an appreciable extent. Despite these difficulties, [2,3]-Wittig rearrangement has been used as a key step in achieving the total synthesis of several natural products. Whereas, due the formation of various by-products in [1,2]-Wittig rearrangement, it was not very successful. In this context, the reports on the execution of Wittig rearrangement on a carbohydrate derived framework are very limited. Thus, in view of investigating the Witting rearrangement in carbohydrate derived scaffolds, the [1,2]-[1–3] or [2,3]-[4–9]Wittig rearrangement of carbohydrate acetals was studied to convert the *O*-glycosides into *C*-glycosides. On the other hand, few studies on the use of Wittig rearrangement of pyranose derived allyl propargyl ethers was revealed recently.[10]

In continuation of our research towards the synthesis of carbon-branched sugars[11–15] involving Claisen rearrangement[16] we were prompted investigate the Wittig rearrangement on a carbohydrate frame work. We reasoned that the five membered cyclic transition state of [2,3]-sigma tropic rearrangement, when compared to the six-membered transition state in [3,3]-sigmatropic rearrangemet, will be more susceptible to the effects of stereochemical control by substituents. Moreover, Wittig rearrangement is frequently carried out at low temperature than the Claisen the rearrangement. These important characteristics of Wittig rearrangement prompted us to investigate Wittig rearrangement on a carbohydrate scaffold. Previously, a reaction of 3*H*-3,4-en-2-*O*-propargyl ether under Wittig reaction conditions [*n*-BuLi, THF, −78 °C, 1 h] has been reported by Isobe, Yu and their groups, and which was provided [2,3]-and

[1,2]- Wittig rearranged products with 4:1 ratio in 72% yield, respectively (figure 4.1, eq.1).[17] And They could observe the no reaction with the terminal acetylenic 4α-ether under similar reaction conditions. By raising the temperature to -40 °C for 3.5 h, [2,3]-and [1,2]-Wittig rearranged products were obtained with 10:1ratio in 46% yield, respectively (figure 4.1, eq.2).

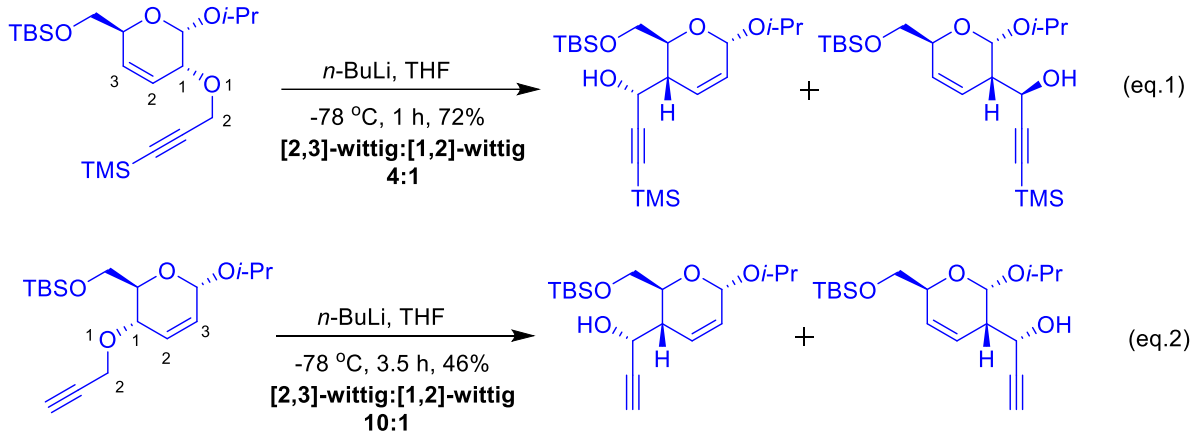
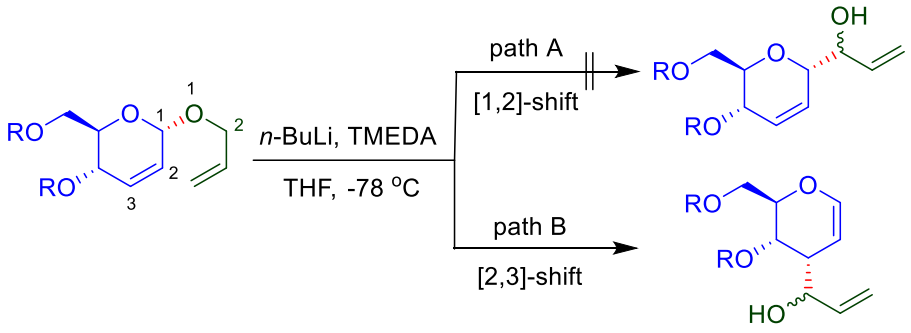


Figure 4.1 Wittig rearrangement of sugar derived 2α-and 4α-Propargyl ethers.

We envisaged that the acetal systems derived by Ferrier rearrangement of glycals could be excellent precursors to study. In general, these substrates would undergo either [1,2]-shift owing to the higher stability of the alkoxy radical which is further stabilised by the ring-allyl group to form the *C*-glycosides or [2,3]-shift to form the 3-*C*-branched glycals (scheme 4.1). However, both the rearrangement reaction are expected to provide retention of stereochemistry at the newly forming C-C bond.

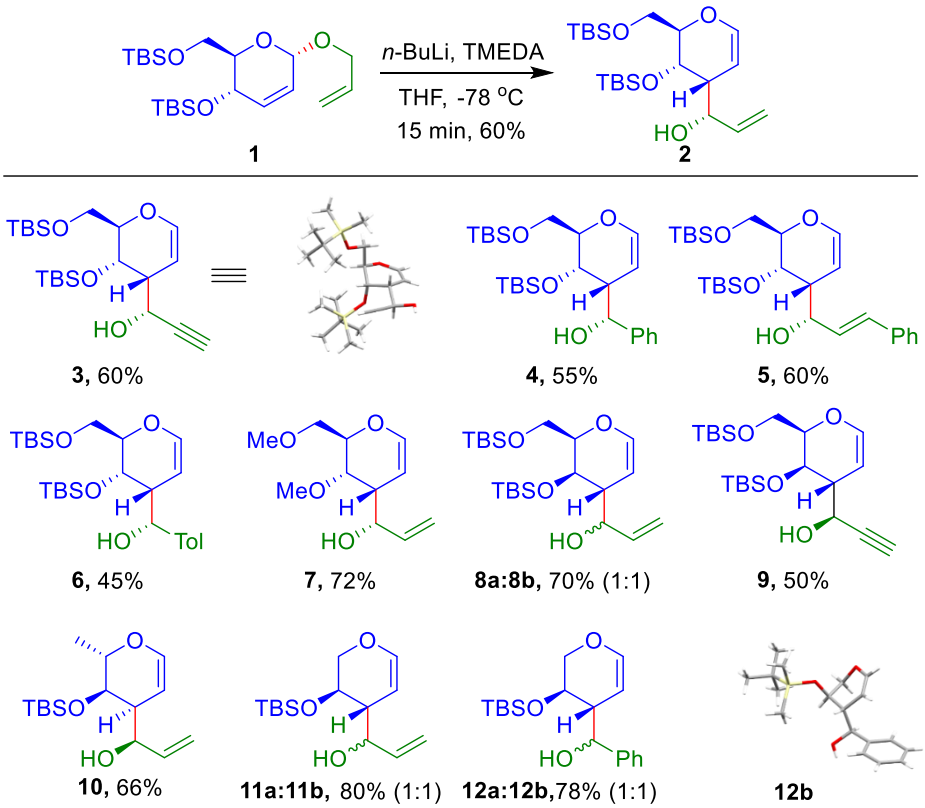


Scheme 4.1 Synthesis of *C*-3-branched glycals from sugar derived acetals.

4.2 Results and Discussion

At the outset, we examined the rearrangement of D-glucal derived diene **1** under Wittig reaction conditions [n-BuLi (2-3 equiv), TMEDA, THF, -78 ^{o}C]. This reaction revealed that the rearrangement proceeded with complete transfer of stereochemistry from the anomeric position to the *C*-3 position to give [2,3]-wittig product **2** in 60% yield, as a single stereo isomer. Surprisingly, no [1,2]-Wittig rearrangement product was observed. However, under the similar reaction conditions, with properglyl, benzyl, cinnamyl and tolyl acetals provided the *C*-3-branched glycals, via [2,3]-Wittig rearrangement, **3-6** as single diastereomers. Replacing the TBS protecting group

Table 4.1. Synthesis of 3-*C*-branched glycal derivatives via [2,3]-Wittig rearrangement.



with methyl provided compound **7** in good yield. A similar kind of products were observed even with D-galactal derived diene which upon rearrangement provided the 3-*C*-branched galactal derivatives **8a** and **8b**, in 1:1 ratio, Whereas the propargyl acetal provided the single diastereomer **9**. Interestingly, D-rahmnose derived allyl acetal also provided the corresponding 3-*C*- branched rhamnal **10** as single diastereomer with 66% yield.

Extending the methodology to pentopyranoses, D-arabinose derived allyl and benzyl acetals gave the 3-*C*-branched glycals **11a**, **11b** and **12a**, **12b**, respectively, in 1:1 ratio (Table 1). These results suggest Wittig precursors derived from Ferrier rarrangement of glycasl with appropriate *O*-nucleophiles undergo a stereoselective [2,3]-Wittig rearrangement. In addition, the substituents on the pyranose as well as the migrating alkyl group does influence the stereochemistry at the hydroxyl carbon. Finally, the 3-*C*-branched glycals **2**, **6** and **10** were cyclised to the corresponding bicyclic acetals catalysed by PTSA to obtain bridged bicycles **2a, 6a** and **10a,** respectively (Figure 4.2). These compounds were used to assign the stereochemistry at the newly formed stereocenters. The exact stereochemistry was assigned by using 2D-COSY and 2D-NOESY NMR spectral analysis of **2a, 6a** and **10a**. The stereochemistry of the formation of 3-*C*-branched glycals all the other compounds were confirmed by ^{1}H, ^{13}C, COSY and NOESY spectral analysis along with few single crystal X-ray diffraction studies.

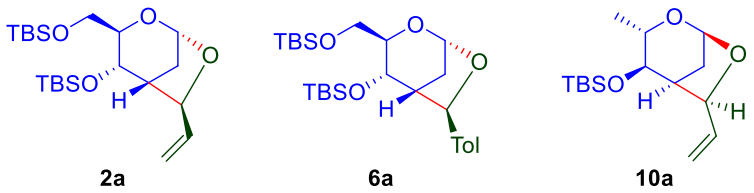
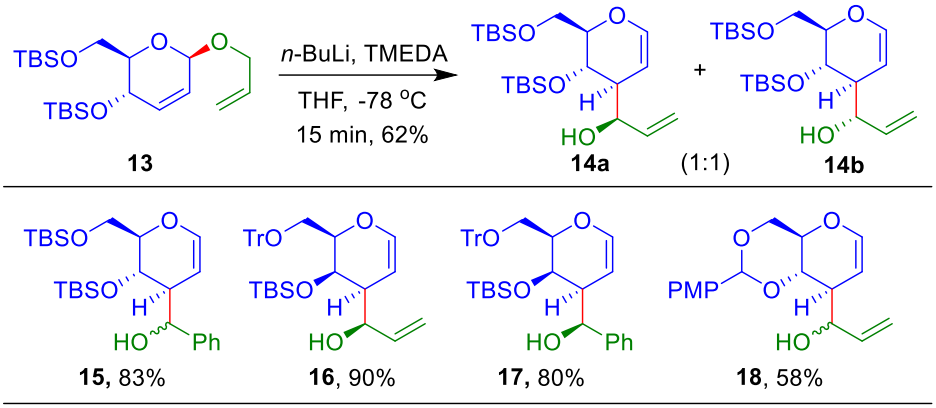


Figure 4.2 Wittig rearrangement of sugar derived 2α-and 4α-Propargyl ethers.

With these information in hand, we further investigated the influence of stereochemistry at the anomeric position. Thus, the β-*O*-glycoside **13** was synthesized and subjected to Wittig rearrangement conditions. Interestingly, **13** also underwent the [2,3]-Wittig rearrangement leading the formation of 3-*C*-branched glycals **14a** and **14b** (Table 4.2), however, as a 1:1 mixture of diastereomers. Applying the methodology to benzyl glycoside, derived from triacetyl glucal, provide the compound **15**. The methodology was found to be equally applicable to other appropriate β-*O*-glycoside derivatives that was tested in the case of galactose, which led to the formation of 3-*C*-branched glycals **16** and **17** (Table 2). It is interesting to note that, incorporating a more bulky protecting group could increase the yield of the rearrangement product. Finally, we planned to investigate the *p*-methoxy benzylidene acetylated β-*O*-glycoside derivative under similar reaction conditions, which also produced the

3-*C*-branched glycal **18.** As all the above glycosides upon Wittig rearrangement provided exclusively the 3-*C*-branched glycals.

Table 4.2. Synthesis of 3-*C*-branched glycal derivatives from β-*O*-glycoside derivatives via [2,3]-Wittig rearrangement.



In view of assigning the stereochemistry at the newly formed stereo-centres, compound **16** was acetylated using acetic anhydride and pyridine and subjected to crystallization. To our fortunate, compound **16a**, formed the crystals in EtOAc/Hexane solvent system. Based on the single crystal X-ray diffraction studies of **16a** (Figure 4.3), 2D and 3D NMR spectral analysis, the stereochemistry of the 3-*C*-branched glycals as shown in table 4.2 were confirmed.

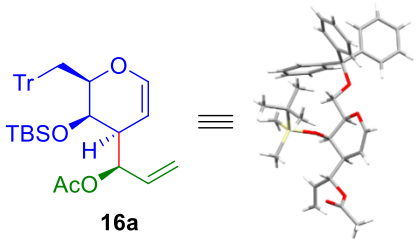


Figure 4.3 Crystal structure of **16a**

4.3 Conclusions

In conclusion, exclusively 3-*C*-branched glycals have been synthesised with retention of configuration from the α-*O*-glycoside derivatives via [2,3]-Wittig rearrangement. Using the same methodology, 3-*C*-branched glycals are synthesised from the β-*O*-glycoside derivatives also via [2,3]-Wittig rearrangement with retention of configuration. Influence of the protecting groups has been observed to produce the yields in the [2,3]-Wittig rearrangement.

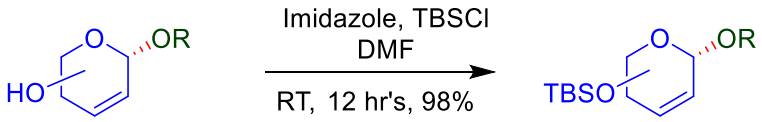
4.4 Experimental section

4.4.1 General Methods

All the reactions were carried out under nitrogen or argon atmosphere and monitored by thin layer chromatography (TLC) using silica gel GF_{254} plates with detection by charring with 5% (v/v) H_2SO_4 in methanol or by phosphomolybdic acid (PMA) stain or by ultra violet (UV) detection. All the chemicals were purchased from local suppliers and Sigma-Aldrich Chemicals Company. Solvents used in the reactions were distilled over dehydrated agents. Silica-gel (100-200 mesh) was used for column chromatography. ^{1}H, ^{13}C, DEPT, COSY, NOESY spectra were recorded on Bruker 400 MHz and 500 MHz spectrometer in $CDCl_3$. ^{1}H NMR chemical shifts were reported in ppm (δ) with TMS as internal standard (δ 0.00) and ^{13}C NMR were reported in chemical shifts with solvent reference ($CDCl_3$, δ 77.00). High resolution mass spectra (HRMS) were obtained in the ESI mode. IR spectra were recorded with a JASCO FTIR-5300 instrument. High resolution mass spectra were recorded on Bruker maXis ESI-TOF spectrometer.

4.4.2 Experimental procedures and spectral data

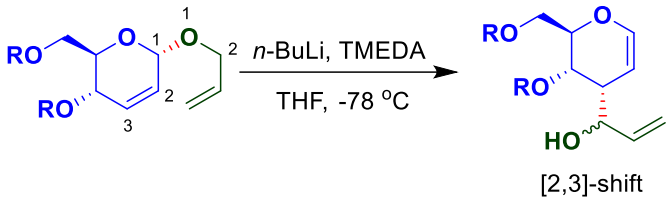
2.1 General procedure for TBS Protection of alcohol: (for the synthesis of S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, 13, S15, S16, and S17)



To a stirred solution of alcohol (1eq) in anhydrous DMF (10 mL/gr) under inert atmosphere was added imidazole (3 eq) followed by TBSCl (3 eq) at RT and stirred for overnight at RT. The reaction was quenched with slow addition of cold water and extracted with diethyl ether and washed with aqueous cupric sulphate. The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure to obtain crude

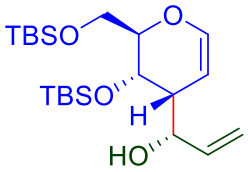
product. Purification of the crude product by column chromatography over silica gel using hexanes and ethyl acetate provided pure di TBS protected sugar derivative in 98% yield.

2.2 General procedure for Wittig Rearrangement reaction: (for the synthesis of 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17 and 18)



A solution of cyclic allyl ether (1eq) in anhydrous THF (5 mL/100 mg) under argon was cooled to -78 °C and 1 eq of TMEDA were added and stirred for 5 minutes. Then a solution of *n*-BuLi (5 eq) was added and stirred at -78 °C for 30 minutes. Then the temperature was allowed to rise to 0 °C over a period of 45 minutes. The reaction was quenched with water and the product was extracted with ethyl acetate, washed with brine solution. The solvent was removed in vacuum, purification by silica gel chromatography.

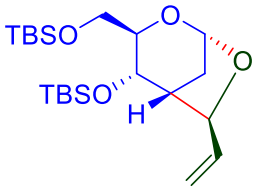
2.3 (*S*)-1-((2*R*,3*S*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (2)



2

Yield: 50%, R_f: 0.45 (5% EtOAc/hexane). **2:** IR (neat): 2929, 2856, 2165, 1737, 1362, 1254, 1113 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 6.53 (dd, 1H, *J* = 1.6 Hz, *J* = 6.0 Hz), 5.85-5.93 (m, 1H), 5.32 (dt, 1H, *J* = 1.6 Hz, *J* = 17.2 Hz), 5.18 (dt, 1H, *J* = 1.6 Hz, *J* = 10.8 Hz), 4.56-4.60 (m, 1H), 4.51 (dd, 1H, *J* = 4.4 Hz, *J* = 6.0 Hz), 4.11-4.19 (m, 2H), 3.78 (t, 2H, *J* = 4.0 Hz), 2.34-2.38 (m, 1H), 2.24 (d, 1H, *J* = 6.8 Hz), 0.94 (s, 9H), 0.91 (s, 9H), 0.16 (s, 3H), 0.14 (s, 3H), 0.08 (s, 3H), 0.07 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 145.74, 139.99, 114.27, 93.80, 77.16, 69.34, 66.68, 62.25, 40.26, 25.92, 25.78, 18.41, 18.03, -4.41, -4.85, -5.18, -5.34 **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found 415.2693.

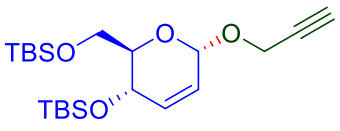
2.4 *tert*-butyl(((1*S*,3*R*,4*S*,5*R*,6*S*)-4-((*tert*-butyldimethylsilyl)oxy)-6-vinyl-2,7-dioxabicyclo[3.2.1]octan-3-yl)methoxy)dimethylsilane (2a)



2a

Yield: 90%, R_f: 0.6 (5% EtOAc/hexane). **2a:** IR (neat): 2952, 2928, 2887, 2855, 1461, 1388, 1360, 1251 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.80 (ddd, 1H, *J* = 5.5 Hz, *J* = 10.5 Hz, *J* = 17.0 Hz), 5.42 (d, 1H, *J* = 3.0 Hz), 5.27 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.13 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.85 (d, 1H, *J* = 5.5 Hz), 3.89 (dd, 1H, *J* = 3.5 Hz, *J* = 8.5 Hz), 3.72-3.78 (m, 2H), 3.52 (dt, 1H, *J* = 2.0 Hz, *J* = 8.5 Hz), 2.28 (dd, 1H, *J* = 3.5 Hz, *J* = 5.5 Hz), 1.84 (ddd, 1H, *J* = 3.0 Hz, *J* = 5.5 Hz, *J* = 11.5 Hz), 1.58 (d, 1H, *J* = 11.5 Hz), 0.91 (s, 9H), 0.90 (s, 9H), 0.10 (s, 3H), 0.09 (s, 3H), 0.07 (s, 3H), 0.06 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 137.78, 115.21, 98.91, 78.71, 76.19, 66.35, 61.89, 45.17, 33.68, 25.90, 25.66, 18.33, 17.84, -4.38, -4.98, -5.04, -5.43. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found 415.2691.

2.5 *tert*-butyl(((2*R*,3*S*,6*S*)-3-((*tert*-butyldimethylsilyl)oxy)-6-(prop-2-yn-1-yloxy)-3,6-dihydro-2*H*-pyran-2-yl)methoxy)dimethylsilane (S3)

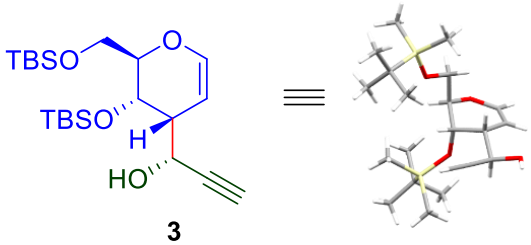


S3

Yield: 98%, R_f: 0.55 (5% EtOAc/hexane). **3s:** IR (neat): 3311, 2952, 2928, 2892, 2856, 2359, 2339, 1738 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.88 (d, 1H, *J* = 10 Hz), 5.70 (dt, 1H, *J* = 2.5 Hz, *J* = 10.5 Hz), 5.16 (s, 1H), 4.31 (d, 2H, *J* = 2.5 Hz), 4.17 (dq, 1H, *J* = 1.5 Hz, *J* = 9.0 Hz), 3.87 (dd, 1H, *J* = 2.0 Hz, *J* = 11.0 Hz), 3.73 (dd, 1H, *J* = 6.0 Hz, *J* = 11.0 Hz), 3.66-3.70 (m, 1H), 2.43 (t, 1H, *J* = 2.5 Hz), 0.92 (s, 9H), 0.89 (s, 9H), 0.10 (s, 3H), 0.09 (s, 9H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 134.98, 124.94, 92.30, 79.49, 74.29, 72.82, 64.00, 62.51,

54.34, 25.90, 25.64, 18.38, 17.86, -4.31, -4.91, -5.17, -5.36 **HRMS (ESI)** calcd for $C_{21}H_{40}O_4Si_2+Na^+$ 435.2357, found 435.2356.

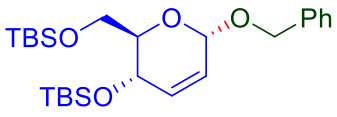
2.6 (*R*)-1-((2*R*,3*S*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl) -3,4-dihydro-2*H*-pyran-4-yl)prop-2-yn-1-ol (3)



3

Yield: 60%, R_f: 0.4 (5% EtOAc/hexane). **3:** IR (neat): 3309, 2953, 2928, 2856, 1972, 1648, 1469, 1389, 1360, 1254, 1105, 1023 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.59 (dd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 4.77 (dd, 1H, *J* = 5.0 Hz, *J* = 6.0 Hz), 4.74 (dt, 1H, *J* = 2.5 Hz, *J* = 9.0 Hz), 4.16 (dd, 1H, *J* = 5.5 Hz, *J* = 8.0 Hz), 4.07-4.10 (m, 1H), 3.78 (t, 2H, *J* = 3.5 Hz), 2.51-2.55 (m, 1H), 2.45 (d, 1H, *J* = 2.0 Hz), 2.13 (d, 1H, *J* = 9.0 Hz), 0.93 (s, 9H), 0.91 (s, 9H), 0.14 (s, 3H), 0.13 (s, 3H), 0.08 (s, 3H), 0.07(s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 146.39, 93.67, 84.45, 76.99, 72.51, 65.59, 62.05, 59.87, 42.26, 25.91, 25.75, 18.42, 18.02, -4.48, -4.98, -5.14, -5.36 **HRMS (ESI)** calcd for $C_{21}H_{40}O_4Si_2+H^+$ 413.2538, found 413.2538.

2.7 (((2*R*,3*S*,6*S*)-6-(benzyloxy)-2-(((tert-butyldimethylsilyl)oxy)methyl)-3,6-dihydro-2H-pyran -3-yl)oxy)(tert-butyl)dimethylsilane (S4)

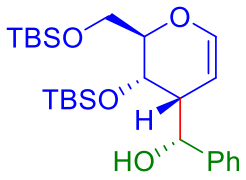


S4

Yield: 98%, R_f: 0.55 (5% EtOAc/hexane). **S4:** IR (neat): 2952, 2928, 2885, 2855, 2359, 2339, 1738 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.29-7.43 (m, 5H), 5.90 (d, 1H, *J* = 10.5 Hz), 5.75 (d, 1H, *J* = 10 Hz), 5.10 (s, 1H), 4.87 (d, *J* = 11.5 Hz), 4.62 (d, 1H, *J* = 12.0 Hz), 4.22-4.23 (m, 1H), 3.88 (d, 1H, *J* = 9.5 Hz), 3.78-3.83 (m, 2H), 0.97 (s, 9H), 0.95 (s, 9H), 0.14-0.15 (m, 12H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 138.07, 134.55, 128.30, 128.08, 127.54,

125.44, 93.31, 72.69, 69.65, 64.11, 62.68, 25.97, 25.68, 18.44, 17.89, -4.30, -4.88, -5.09, -5.29 **HRMS (ESI)** calcd for $C_{25}H_{44}O_4Si_2+NH_4^+$ 482.3116, found 482.3116.

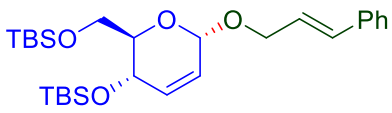
2.8 (*R*)-((2*R*,3*S*,4*R*)-3-((tert-butyldimethylsilyl)oxy)-2-(((tert-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl)methanol (4)



4

Yield: 55%, R_f: 0.45 (5% EtOAc/hexane). **4:** IR (neat): 2952, 2928, 2855, 1736 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.27-7.39 (m, 5H), 6.50 (dd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 5.19 (dd, 1H, *J* = 1.5 Hz, *J* = 5.0 Hz), 4.38 (dd, 1H, *J* = 4.0 Hz, *J* = 6.5 Hz), 4.29 (t, 1H, *J* = 6.0 Hz), 4.18-4.21 (m, 1H), 3.75-3.83 (m, 2H), 2.85 (d, 1H, *J* = 5.5 Hz), 2.56-2.58 (m, 1H), 1.00 (s, 9H), 0.93 (s, 9H), 0.23 (s, 3H), 0.21 (s, 3H), 0.10 (s, 3H), 0.09 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 145.26, 143.57, 128.18, 126.92, 125.58, 93.89, 77.30, 71.02, 67.32, 62.19, 42.02, 25.91, 25.85, 18.37, 18.07, -4.24, -4.71, -5.22, -5.34. **HRMS (ESI)** calcd for $C_{25}H_{44}O_4Si_2+NH_4^+$ 482.3116, found 482.3116.

2.9 *tert*-butyl(((2*R*,3*S*,6*S*)-3-((tert-butyldimethylsilyl)oxy)-6-(cinnamyloxy)-3,6-dihydro-2*H*-pyran-2-yl)methoxy)dimethylsilane (S5)

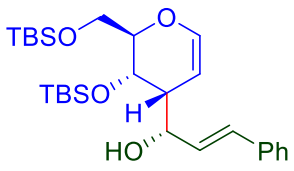


S5

Yield: 98%, R_f: 0.65 (5% EtOAc/hexane). **S5:** IR (neat): 2952, 2927, 2887, 2855 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.32-7.42 (m, 4H), 7.25-7.28 (m, 1H), 6.66 (d, 1H, *J* = 10.5 Hz), 6.35 (dt, 1H, *J* = 6.0 Hz, *J* = 16.0 Hz), 5.90 (d, 1H, *J* = 10.0 Hz), 5.75 (dt, 1H, *J* = 2.5 Hz, *J* = 10.0 Hz), 5.10 (s, 1H), 4.48 (ddd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz, *J* = 13.0 Hz), 4.20-4.27 (m, 2H), 3.90-3.93 (m, 1H), 3.77-3.81 (m, 2H), 0.96 (s, 9H), 0.93 (s, 9H), 0.13-0.12 (m, 12H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 136.78, 134.61, 132.69, 128.48, 127.59, 126.47,

125.79, 125.46, 93.26, 72.68, 68.26, 64.14, 62.72, 25.97, 25.69, 18.44, 17.90, -4.28, -4.86, -5.09, -5.29. **HRMS (ESI)** calcd for $C_{27}H_{46}O_4Si_2+NH_4^+$ 508.3273, found 508.3272.

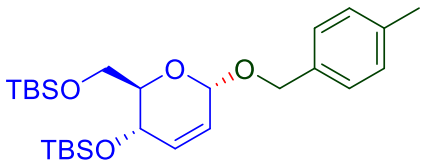
2.10 (*S*,*E*)-1-((2*R*,3*S*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl) oxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)-3-phenylprop-2-en-1-ol (5)



5

Yield: 60%, R_f: 0.45 (5% EtOAc/hexane). **5:** IR (neat): 3438, 2952, 2928, 2856, 1736, 1649 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.40-7.42 (m, 2H), 7.31-7.35 (m, 3H), 6.68 (dd, 1H, *J* = 1.5 Hz, *J* = 16.0 Hz), 6.54 (dd, 1H, *J* = 1.5 Hz, *J* = 6.5 Hz), 6.24 (dd, 1H, *J* = 5.0 Hz, *J* = 15.5 Hz), 4.75 (bd, 1H, *J* = 4.5 Hz), 4.58 (dd, 1H, *J* = 4.0 Hz, *J* = 6.0 Hz), 4.23 (dd, 1H, *J* = 5.5 Hz, *J* = 6.5 Hz), 4.14-4.17 (m, 1H), 3.78-3.81 (m, 3H), 2.45-2.47 (m, 1H), 0.97 (s, 9H), 0.92 (s, 9H), 0.18 (s, 6H), 0.09 (s, 3H), 0.08 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 145.62, 136.96, 131.45, 129.70, 128.54, 127.43, 126.42, 94.16, 77.33, 69.56, 66.91, 62.26, 40.57, 25.93, 25.83, 18.40, 18.07, -4.33, -4.76, -5.19, -5.32. **HRMS (ESI)** calcd for $C_{27}H_{46}O_4Si_2+NH_4^+$ 508.3273, found 508.3275.

2.11 *tert*-butyl(((2*R*,3*S*,6*S*)-3-((*tert*-butyldimethylsilyl)oxy)-6-((4-methylbenzyl)oxy)-3,6-dihydro-2*H*-pyran-2-yl)methoxy)dimethylsilane (S6)

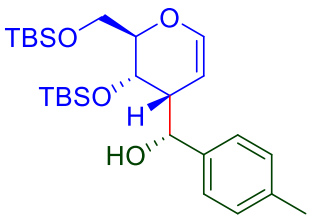


S6

Yield: 98%, R_f: 0.65 (5% EtOAc/hexane). **S6:** IR (neat): 2952, 2927, 2885, 2855, 2359, 2339, 1516 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.31 (d, 2H, *J* = 8.0 Hz), 7.18 (d, 2H, *J* = 8.0 Hz), 5.88 (d, 1H, *J* = 10.0 Hz), 5.72 (dt, 1H, *J* = 2.5 Hz, *J* = 10.0 Hz), 5.07-5.08 (m, 1H), 4.82 (d, 1H, *J* = 11.5 Hz), 4.58 (d, 1H, *J* = 11.5 Hz), 4.21 (dd, 1H, *J* = 1.5 Hz, *J* = 8.5 Hz), 3.86-3.89 (m, 1H), 3.78-3.82 (m, 2H), 2.38 (s, 3H), 0.97 (s, 9H), 0.93 (s, 9H), 0.15 (s, 3H), 0.14 (s, 3H), 0.13 (s, 3H), 0.13 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 137.21, 135.01, 134.46, 128.98,

128.23, 125.55, 93.11, 72.66, 69.48, 64.14, 62.71, 25.98, 25.68, 21.14, 18.46, 17.89, -4.30, -4.87, -5.09, -5.29. **HRMS (ESI)** calcd for $C_{26}H_{46}O_4Si_2+H^+$ 479.3007, found 479.3008.

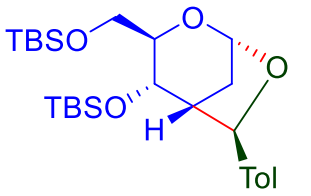
2.12 (*R*)-((2*R*,3*S*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)(*p*-tolyl)methanol (6)



6

Yield: 45%, R_f: 0.35 (5% EtOAc/hexane). **6:** IR (neat): 2952, 2927, 2855, 1736, 1649, 1513 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.25 (d, 2H, *J* = 8.0 Hz), 7.17 (d, 2H, *J* = 8.0 Hz), 6.49 (dd, 1H, *J* = 2.0 Hz, *J* = 16.0 Hz), 5.15 (d, 1H, *J* = 4.4 Hz), 4.39 (dd, 1H, *J* = 4.0 Hz, *J* = 6.4 Hz, H2), 4.25-4.28 (m, 1H), 4.17-4.21 (m, 1H), 3.73-3.82 (m, 2H), 2.80 (d, 1H, *J* = 5.2 Hz), 2.53-2.56 (m, 1H), 2.36 (s, 3H), 0.99 (s, 9H), 0.92 (s, 9H), 0.22 (s, 3H), 0.20 (s, 3H), 0.09 (s, 3H), 0.08 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 145.16, 140.61, 136.46, 128.86, 125.50, 94.04, 77.32, 70.89, 67.33, 62.22, 42.03, 25.91, 25.85, 21.04, 18.37, 18.07, -4.25, -4.71, -5.22, -5.34. **HRMS (ESI)** calcd for $C_{26}H_{46}O_4Si_2+H^+$ 479.3007, found 479.3008.

2.13 *tert*-butyl(((1*S*,3*R*,4*S*,5*R*,6*R*)-4-((*tert*-butyldimethylsilyl)oxy)-6-(*p*-tolyl)-2,7-dioxabi cyclo[3.2.1]octan-3-yl)methoxy)dimethylsilane (6a)

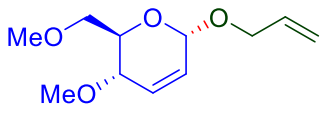


6a

Yield: 95%, R_f: 0.65 (5% EtOAc/hexane). **6a:** IR (neat): 2952, 2927, 2891, 2855, 2359, 2328, 1725, 1513 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.17 (s, 4H), 5.60 (d, 1H, *J* = 3.0 Hz), 5.48 (s, 1H), 3.95 (dd, 1H, *J* = 3.5 Hz, *J* = 8.5 Hz),3.77-3.83 (m, 2H), 3.63 (dt, 1H, *J* = 1.5 Hz, *J* = 8.5 Hz), 2.41 (dd, 1H, *J* = 3.5 Hz, *J* = 5.0 Hz), 2.35 (s, 3H), 1.85 (ddd, 1H, *J* = 3.5 Hz, *J* =

5.5 Hz, *J* = 12.0 Hz), 1.54 (d, 1H, *J* = 11.5 Hz), 0.98 (s, 9H), 0.92 (s, 9H), 0.15 (s, 3H), 0.14 (s, 3H), 0.09 (s, 3H), 0.08 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 139.43, 136.44, 128.86, 124.96, 99.30, 79.19, 76.44, 66.59, 61.81, 48.21, 33.12, 25.92, 25.78, 21.01, 18.36, 17.90, -4.12, -5.00, -5.10, -5.41. **HRMS (ESI)** calcd for $C_{26}H_{46}O_4Si_2+H^+$ 479.3007, found 479.3008.

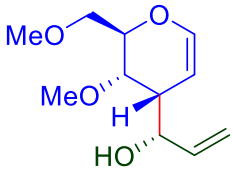
2.14 (2*R*,3*S*,6*S*)-6-(allyloxy)-3-methoxy-2-(methoxymethyl)-3,6-dihydro-2*H*-pyran (S7)



S7

Yield: 99%, R_f: 0.25 (10% EtOAc/hexane). **S7:** IR (neat): 2934, 2892, 2835, 1647 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.07 (d, 1H, *J* = 10.5 Hz), 5.88-5.96 (m, 1H), 5.76-5.78 (m, 1H), 5.26-5.30 (m, 1H), 5.15-5.17 (m, 1H), 5.03 (bs, 1H), 4.24-4.28 (m, 1H), 4.03-4.07 (m, 1H), 3.88-3.90 (m, 1H), 3.83-3.86 (m, 1H), 3.59-3.65 (m, 2H), 3.42 (s, 3H), 3.39 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 134.41, 130.23, 126.50, 116.99, 93.79, 71.79, 71.52, 68.90, 68.73, 59.23, 56.36. **HRMS (ESI)** calcd for $C_{11}H_{18}O_4+Na^+$ 237.1097, found 237.1099.

2.15 (*S*)-1-((2*R*,3*S*,4*R*)-3-methoxy-2-(methoxymethyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (7)

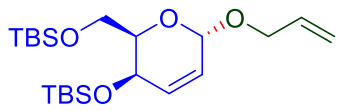


7

Yield: 72%, R_f: 0.25 (20% EtOAc/hexane). **7:** IR (neat): 3068, 2934, 2892, 2835, 1647 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.48 (dd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 5.90 (ddd, 1H, *J* = 5.0 Hz, *J* = 10.5 Hz, *J* = 17.0 Hz), 5.33 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.20 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.63 (dd, 1H, *J* = 3.5 Hz, *J* = 6.0 Hz), 4.44 (bs, 1H), 4.37-4.40 (m, 1H), 3.64 (t, 1H, *J* = 4.0 Hz), 3.58-3.61 (m, 1H), 3.49-3.52 (m, 1H), 3.46 (s, 3H), 3.40 (s, 3H), 2.52 (bs, 1H), 2.44-2.47 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 144.48, 139.41,

114.98, 95.45, 75.75, 72.80, 71.51, 70.69, 59.32, 57.33, 37.59. **HRMS (ESI)** calcd for $C_{11}H_{18}O_4$+Na^+ 237.1097, found 237.1099.

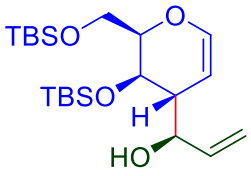
2.16 (((2*R*,3*R*,6*S*)-6-(allyloxy)-2-(((*tert*-butyldimethylsilyl)oxy)methyl)-3,6-dihydro-2H-pyran-3-yl)oxy)(*tert*-butyl)dimethylsilane (S8)



S8

Yield: 98%, R_f: 0.5 (5% EtOAc/hexane). **S8:** IR (neat): 2952, 2928, 2885, 2856 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.00-6.04 (m, 1H), 5.92-5.99 (m, 1H), 5.89 (dd, 1H, *J* = 3.0 Hz, *J* = 10.0 Hz), 5.29 (dq, 1H, *J* = 1.5 Hz, *J* = 17.5 Hz), 5.18 (dq, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 5.08 (d, 1H, *J* = 2.5 Hz), 4.29 (tdd, 1H, *J* = 1.5 Hz, *J* = 5.5 Hz, *J* = 12.5 Hz), 4.07 (tdd, 1H, *J* = 1.5 Hz, *J* = 6.5 Hz, *J* = 13.0 Hz), 3.98-4.01 (m, 1H), 3.91 (dd, 1H, *J* = 2.5 Hz, *J* = 5.0 Hz), 3.83 (dd, 1H, *J* = 5.5 Hz, *J* = 10.5 Hz), 3.77 (dd, 1H, *J* = 7.0 Hz, *J* = 10.5 Hz), 0.92 (s, 9H), 0.90 (s, 9H), 0.10 (s, 3H), 0.09 (s, 6H), 0.08 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 134.55, 129.77, 127.79, 117.28, 93.21, 71.84, 68.42, 62.76, 62.00, 25.88, 25.80, 18.28, 18.16, -4.04, -4.73, -5.32, -5.42. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2$+K^+ 453.2253, found 453.2250.

2.17 (*R*)-1-((2*R*,3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (8a)

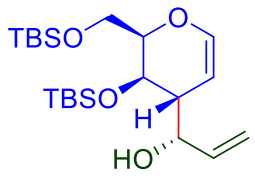


8a

Yield: 35%, R_f: 0.4 (5% EtOAc/hexane). **8a:** IR (neat): 2953, 2928, 2885, 2856, 1647 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.48 (dd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 5.87-5.93 (m, 1H), 5.30 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.25 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.56 (dd, 1H, *J* = 3.5 Hz, *J* = 6.0 Hz), 4.14-4.15 (m, 1H), 4.06 (dd, 1H, J = 3.5 Hz, J = 5.0 Hz), 3.95-3.98 (m, 1H), 3.78-3.80 (m, 2H), 2.15-2.18 (m, 1H), 1.64 (d, 1H, *J* = 7.0 Hz), 0.91 (s, 18H), 0.17

(s, 3H), 0.15 (s, 3H), 0.08 (s, 3H), 0.07 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 144.90, 139.36, 115.50, 95.79, 77.32, 72.78, 66.03, 60.68, 43.61, 25.91, 25.75, 18.31, 17.95, -4.53, -4.72, -5.24, -5.36. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found 415.2695.

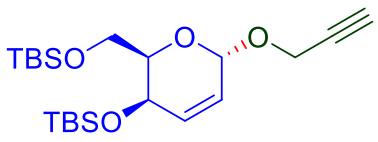
2.18 (*S*)-1-((2*R*,3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (8b)



8b

Yield: 35%, R_f: 0.37 (5% EtOAc/hexane). **8b:** IR (neat): 2954, 2928, 2886, 2856, 2158, 2036, 1737, 1648 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.46 (dd, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 5.87-5.94 (m, 1H), 5.31 (dt, 1H, *J* = 1.5 Hz, *J* = 17.5 Hz), 5.24 (dt, 1H, *J* = 1.0 Hz, *J* = 10.0 Hz), 4.52-4.55 (m, 1H), 4.15-4.16 (m, 1H), 3.98 (t, 1H, *J* = 6.5 Hz), 3.82-3.86 (m, 1H), 3.76-3.80 (m, 2H), 2.10-2.14 (m, 1H), 1.83 (s, 1H), 0.91 (s, 9H), 0.90 (s, 9H), 0.11 (s, 3H), 0.10 (s, 3H), 0.08 (s, 6H), **^{13}C NMR (125 MHz, $CDCl_3$):** δ 144.18, 138.31, 116.57, 97.82, 76.26, 75.20, 65.31, 61.76, 44.56, 25.91, 25.76, 18.32, 17.98, -4.51, -4.55, -5.23, -5.35. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found415.2695.

2.19 *tert*-butyl (((2*R*,3*S*,6*S*)-3-((*tert*-butyldimethylsilyl)oxy)-6-(prop-2-yn-1-yloxy)-3,6-dihydro-2*H*-pyran-2-yl)methoxy)dimethylsilane (S9)

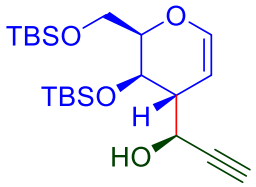


S9

Yield: 97%, R_f: 0.55 (5% EtOAc/hexane). **S9:** IR (neat): 3310, 2953, 2928, 2886, 2856 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.05 (ddd, 1H, *J* = 1.0 Hz, *J* = 5.5 Hz *J* = 10.0 Hz), 5.89 (dd, 1H, *J* = 2.5 Hz, *J* = 10.0 Hz), 5.25 (d, 1H, *J* = 3.0 Hz), 4.31 (t, 2H, *J* = 2.0 Hz), 3.93-3.96 (m, 1H), 3.90-3.92 (m, 1H), 3.75-3.83 (m, 2H), 2.43 (t, 1H, *J* = 2.5 Hz), 0.91 (s, 9H),

0.89 (s, 9H), 0.09 (s, 6H), 0.08 (s, 6H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 130.18, 127.37, 92.16, 79.47, 74.33, 72.14, 62.66, 61.88, 53.98, 25.87, 25.78, 18.26, 18.15, -4.01, -4.72, -5.32, -5.42 **HRMS (ESI)** calcd for $C_{21}H_{40}O_4Si_2+K^+$ 451.2097, found 451.2092.

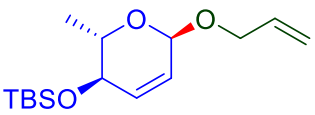
2.20 (*S*)-1-((2*R*,3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-yn-1-ol (5)



9

Yield: 60%, R_f: 0.45 (5% EtOAc/hexane). **9:** IR (neat): 3308, 2953, 2928, 2856, 1972, 1648 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 6.50 (dd, 1H, *J* = 1.6 Hz, *J* = 6.0 Hz), 4.72 (ddd, 1H, *J* = 0.8 Hz, *J* = 4.0 Hz, *J* = 6.0 Hz), 4.31-4.32 (m, 1H) , 4.20 (t, 1H, *J* = 2.8 Hz), 3.88 (td, 1H, J = 2.4 H, J = 6.0 Hz), 3.81 (dd, 2H, *J* = 2.4 Hz, *J* = 6.0 Hz), 2.55 (d, 1H, *J* = 2.0 Hz), 2.29-2.33 (m, 1H), 2.02 (d, 1H, *J* = 3.2 Hz), 0.92 (s, 9H), 0.91 (s, 9H), 0.13 (s, 3H), 0.13 (s, 3H), 0.09 (s, 3H), 0.09(s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 144.60, 96.80, 82.63, 76.51, 74.74, 65.43, 64.42, 61.38, 44.60, 25.92, 25.73, 18.34, 17.95, -4.59, -4.62, -5.21, -5.33 **HRMS (ESI)** calcd for $C_{21}H_{40}O_4Si_2+Na^+$ 435.2357, found 435.2357.

2.21 (((2*S*,3*R*,6*R*)-6-(allyloxy)-2-methyl-3,6-dihydro-2*H*-pyran-3-yl)oxy)(*tert*-butyl) dimethy-l silane (S10)

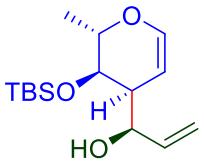


S10

Yield: 98%, R_f: 0.65 (5% EtOAc/hexane). **S10:** IR (neat): 2953, 2929, 2857, 1728 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.90-5.98 (m, 1H), 5.84 (d, 1H, *J* = 10.0 Hz), 5.68 (dt, 1H, *J* = 2.5 Hz, *J* = 10.5 Hz), 5.30 (dq, 1H, *J* = 1.5 Hz, *J* = 17.5 Hz), 5.18 (dq, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.96 (s, 1H), 4.25 (ddt, 1H, *J* = 1.5 Hz, *J* = 5.5 Hz, *J* = 13.0 Hz), 4.04 (ddt, 1H, *J* = 1.5 Hz, *J* = 6.5 Hz, *J* = 13.0 Hz), 3.87 (dq, 1H, *J* = 1.5 Hz, *J* = 9.0 Hz), 3.75-3.80 (m, 1H),

1.25 (d, 3H, *J* = 6.5 Hz), 0.90 (s, 9H), 0.09 (s, 3H), 0.08 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 134.66, 134.61, 125.40, 116.96, 93.68, 70.15, 68.81, 67.66, 25.66, 18.10, 17.89, -4.27, -4.78. **HRMS (ESI)** calcd for $C_{15}H_{28}O_3Si+Na^+$ 307.1700, found 307.1692.

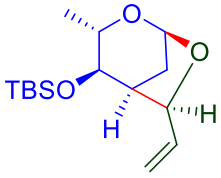
2.22 (*R*)-1-((2*S*,3*R*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-methyl-3,4-dihydro-2*H*-pyran-4-yl) prop-2-en-1-ol (10)



10

Yield: 66%, R_f: 0.3 (5% EtOAc/hexane). **10:** IR (neat): 3445, 2953, 2929, 2857, 1728 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 6.50 (dd, 1H, *J* = 1.6 Hz, *J* = 6.0 Hz), 5.89 (ddd, 1H, *J* = 4.8 Hz, *J* =10.4 Hz, *J* = 17.2 Hz), 5.31 (dt, 1H, *J* = 1.6 Hz, *J* = 17.2 Hz), 5.18 (dt, 1H, *J* = 1.6 Hz, *J* = 10.8 Hz), 4.56-4.60 (m, 1H), 4.53 (dd, 1H, *J* = 4.0 Hz, *J* = 6.4 Hz), 4.18-4.25 (m, 1H), 3.79 (dd,1H, *J* = 5.6 Hz, *J* = 7.6 Hz), 2.35-2.38 (m, 1H), 2.18 (d, 1H, *J* = 6.0 Hz), 1.25 (d, 3H, *J* = 6.4 Hz) 0.94 (s, 9H), 0.14 (s, 3H), 0.13 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 145.61, 139.99, 114.22, 94.34, 72.94, 72.25, 69.27, 40.79, 25.75, 18.12, 18.00, -4.31, -4.75. **HRMS (ESI)** calcd for $C_{15}H_{28}O_3Si+Na^+$ 307.1700, found 307.1690.

2.23 *tert*-butyldimethyl(((1*R*,3*S*,4*R*,5*S*,6*R*)-3-methyl-6-vinyl-2,7-dioxabicyclo[3.2.1] octan-4-yl)oxy)silane (10a)

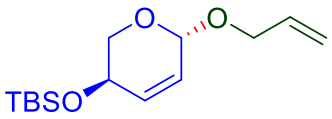


10a

Yield: 95%, R_f: 0.6 (5% EtOAc/hexane). **10a:** IR (neat): 2953, 2929, 2896, 2857, 1730 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.79 (ddd, 1H, *J* = 5.5 Hz, *J* = 10.5 Hz, *J* = 16.0 Hz), 5.37 (t, 1H, *J* = 2.5 Hz), 5.26 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.12 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.83 (d, 1H, *J* = 5.0 Hz), 3.61-3.66 (m, 1H), 3.36 (dt, 1H, *J* = 2.5 Hz, *J* = 8.0 Hz), 2.25 (t,1H, *J* = 3.0 Hz), 1.87 (dq, 1H, *J* = 2.5 Hz, *J* = 12.0 Hz), 1.62 (d, 1H, *J* = 11.5 Hz), 1.22 (d, 3H, *J* = 6.5 Hz), 0.90 (s, 9H), 0.08 (s, 6H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 137.57, 115.28,

98.69, 78.94, 73.77, 71.29, 45.36, 34.13, 25.61, 18.43, 17.81, -4.28, -4.82. **HRMS (ESI)** calcd for $C_{15}H_{28}O_3Si+Na^+$ 307.1700, found 307.1691.

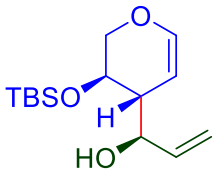
2.24 (((3R,6S)-6-(allyloxy)-3,6-dihydro-2H-pyran-3-yl)oxy)(tert-butyl)dimethylsilane (S11)



S11

Yield: 98%, R_f: 0.47 (5% EtOAc/hexane). **S11:** IR (neat): 2952, 2928, 2885, 2856 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 5.96-6.00 (m, 1H), 5.91-5.94 (m, 1H), 5.85 (ddd, 1H, *J* = 0.5 Hz, *J* = 3.0 Hz, *J* = 10.0 Hz), 5.29 (dq, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.19 (dq, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 5.04 (d, 1H, *J* = 2.5 Hz), 4.25 (ddt, 1H, *J* = 1.5 Hz, *J* = 5.0 Hz, *J* = 12.5 Hz), 4.04-4.10 (m, 2H), 3.98-4.00 (m, 1H), 3.68(dq, 1H, *J* = 1.5 Hz, *J* = 12.0 Hz), 0.91 (s, 9H), 0.10 (s, 6H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 134.33, 130.05, 127.66, 117.28, 92.90, 68.62, 65.30, 62.31, 25.82, 18.22, -4.54, -4.63. **HRMS (ESI)** calcd for $C_{14}H_{26}O_3Si+Na^+$ 293.1543, found 293.1540.

2.25 (*R*)-1-((3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (11a)

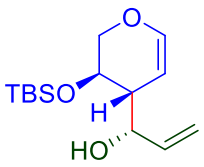


11a

Yield: 40%, R_f: 0.25 (5% EtOAc/hexane). **11a:** IR (neat): 3451, 2926, 2854, 1740, 1641cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.47 (dd, 1H, *J* = 2.5 Hz, *J* = 6.0 Hz), 5.91 (ddd, 1H, *J* = 4.0 Hz, *J* = 11.0 Hz, *J* = 17.5 Hz), 5.36 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.25 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.50 (dd, 1H, *J* = 2.5 Hz, *J* = 6.0 Hz), 4.36-4.39 (m, 1H), 4.06 (ddd, 1H, *J* = 4.5 Hz, *J* = 8.0 Hz, *J* = 12.0 Hz), 4.00 (dd, 1H, *J* = 4.0 Hz, *J* = 10.0 Hz), 3.61 (t, 1H, *J* = 10.0 Hz), 2.36-2.39 (m, 1H), 1.68 (d, 1H, *J* = 8.5 Hz), 0.92 (s, 9H), 0.15 (s, 3H), 0.13 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 146.36, 139.36, 114.83, 96.07, 70.43, 69.02, 65.37,

46.07, 25.73, 17.92, -4.28, -4.83. **HRMS (ESI)** calcd for $C_{14}H_{26}O_3Si+Na^+$ 293.1543, found 293.1540.

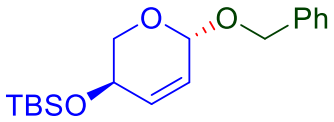
2.26 (*S*)-1-((3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (11b)



11b

Yield: 40%, R_f: 0.25 (5% EtOAc/hexane). **11b:** IR (neat): 3452, 3070, 2954, 2929, 2888, 2857, 1738, 1649 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.39 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.83-5.90 (m, 1H), 5.30 (dt, 1H, *J* = 1.5 Hz, *J* = 17.5 Hz), 5.24 (dt, 1H, *J* = 1.0 Hz, *J* = 10.5 Hz), 4.61 (dd, 1H, *J* = 2.5 Hz, *J* = 6.0 Hz), 4.13 (t, 1H, *J* = 6.5 Hz), 3.90-3.96 (m, 2H), 3.62-3.67 (m, 1H), 2.35-2.38 (m, 2H), 0.91 (s, 9H), 0.13 (s, 3H), 0.12 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 144.39, 137.90, 117.40, 98.33, 75.10, 68.47, 67.08, 45.78, 25.72, 17.90, -3.99, -4.67. **HRMS (ESI)** calcd for $C_{14}H_{26}O_3Si+Na^+$ 293.1543, found 293.1540.

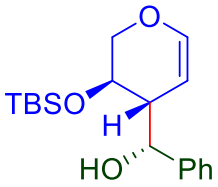
2.27 (((3*R*,6*S*)-6-(benzyloxy)-3,6-dihydro-2*H*-pyran-3-yl)oxy)(*tert*-butyl)dimethylsilane (S12)



S12

Yield: 98%, R_f: 0.45 (5% EtOAc/hexane). **S12:** IR (neat): 2952, 2927, 2856 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.28-7.40 (m, 5H), 5.99-6.03 (m, 1H), 5.87-5.90 (m, 1H), 5.12 (d, 1H, *J* = 2.8 Hz), 4.82 (d, 1H *J* = 11.6 Hz), 4.60 (d, 1H, *J* = 12.0 Hz), 4.15 (dd, 1H, *J* = 3.2 Hz, *J* = 8.0 Hz), 4.00-4.02 (m, 1H), 3.72-3.76 (m, 1H), 0.93 (s, 9H), 0.13 (m, 3H), 0.12 (m, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 137.82, 130.00, 128.37, 128.05, 127.69, 127.67, 92.80, 69.56, 65.34, 62.32, 25.86, 18.27, -4.51, -4.60. **HRMS (ESI)** calcd for $C_{18}H_{28}O_3Si+K^+$ 359.1439, found 359.1439.

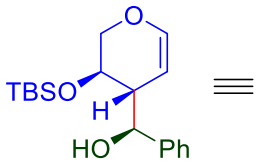
2.28 (*R*)-((3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl) methanol (12a)



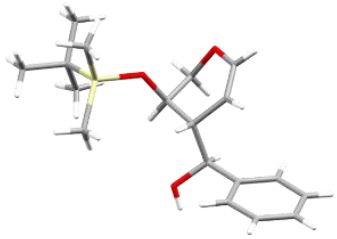
12a

Yield: 39%, R_f: 0.25 (5% EtOAc/hexane). **12a:** IR (neat): 3455, 3063, 3029, 2953, 2927, 2855, 1738, 1648 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.34-7.40 (m, 4H), 7.28-7.33 (m, 1H), 6.33 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 4.54 (dd, 1H, *J* = 1.5 Hz, *J* = 8.5 Hz), 4.17 (dd, 1H, *J* = 3.0 Hz, *J* = 6.0 Hz), 4.12-4.15 (m, 1H), 3.99 (dd, 1H, *J* = 3.0 Hz, *J* = 10.5 Hz), 3.74-3.77 (m, 1H), 3.11 (d, 1H, *J* = 2.0 Hz), 2.51-2.54 (m, 1H), 0.94 (s, 9H), 0.16 (s, 3H), 0.14 (s, 3H).**^{13}C NMR (125 MHz, $CDCl_3$):** δ 144.41, 141.67, 128.31, 127.85, 127.02, 98.43, 78.01, 68.50, 68.24, 46.75, 25.75, 17.95, -4.01, -4.76 **HRMS (ESI)** calcd for $C_{18}H_{28}O_3Si+Na^+$ 343.1700, found 343.1705.

2.29 (*S*)-((3*R*,4*R*)-3-((*tert*-butyldimethylsilyl)oxy)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl) methanol (12b)



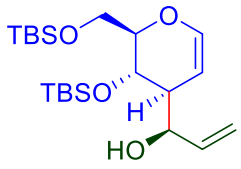
12b



Yield: 39%, R_f: 0.24 (5% EtOAc/hexane). **12b:** IR (neat): 3467, 2952, 2927, 2855, 1737, 1647 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.35-7.41 (m, 4H), 7.28-7.31 (m, 1H), 6.46 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.02 (dd, 1H, *J* = 2.5 Hz, *J* = 7.0 Hz), 4.40 (dd, 1H, *J* = 2.5 Hz, *J* = 6.0 Hz), 4.11-4.16 (m, 1H), 4.02 (dd, 1H, *J* = 4.0 Hz, *J* = 10.5 Hz), 3.63 (t, 1H, *J* = 10.0 Hz), 2.55-2.58 (m, 1H), 1.96 (d, 1H, *J* = 7.0 Hz), 0.96 (s, 9H), 0.18 (s, 3H), 0.15 (s, 3H).**^{13}C NMR (125 MHz, $CDCl_3$):** δ 146.57, 142.90, 128.30, 127.13, 125.44, 95.67, 71.17, 68.99,

65.45, 48.46, 25.76, 17.98, -4.31, -4.92 **HRMS (ESI)** calcd for $C_{18}H_{28}O_3Si+Na^+$ 343.1700, found 343.1701.

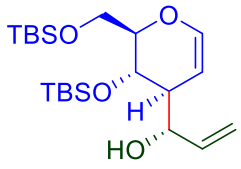
2.30 (*R*)-1-((2*R*,3*S*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl) -3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (14a)



14a

Yield: 31%, R_f: 0.45 (5% EtOAc/hexane). **14a:** IR (neat): 3068, 2953, 2928, 2885, 2856, 2359, 2339, 1736, 1646 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 6.42 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.88 (ddd, 1H, *J* = 6.8 Hz, *J* = 10.4 Hz, *J* = 17.2 Hz), 5.34 (dt, 1H, *J* = 1.2 Hz, *J* = 17.2 Hz), 5.27 (dt, 1H, *J* = 1.2 Hz, *J* = 10.2 Hz), 4.73 (dd, 1H, *J* = 2.4 Hz, *J* = 6.0 Hz), 4.42-4.45 (m, 1H), 3.84-3.92 (m, 2H), 3.79 (t, 1H, *J* = 8.0 Hz), 3.59 (dt, 1H, *J* = 3.2 Hz, *J* = 8.4 Hz), 2.52-2.56 (m, 1H), 1.66 (bs, 1H), 0.93 (s, 9H), 0.91 (s, 9H), 0.16 (s, 3H), 0.14 (s, 3H), 0.09 (s, 3H), 0.07 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 143.96, 137.28, 117.73, 98.48, 79.20, 72.41, 65.72, 61.93, 46.98, 26.04, 25.91, 18.38, 18.32, -4.01, -4.03, -4.99, -5.35. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found415.2693.

2.31 (*S*)-1-((2*R*,3*S*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (14b)

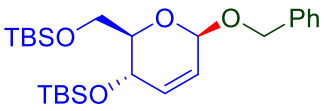


14b

Yield: 31%, R_f: 0.4 (5% EtOAc/hexane). **14b:** IR (neat): 3068, 2953, 2928, 2885, 2856, 2359, 2339, 1736, 1646 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 6.53 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.89 (ddd, 1H, *J* = 4.0 Hz, *J* = 11.0 Hz, *J* = 17.5 Hz), 5.33 (dt, 1H, *J* = 1.5 Hz, *J* = 17.5 Hz), 5.24 (dt, 1H, *J* = 1.5 Hz, *J* = 11.0 Hz), 4.45-4.47 (m, 2H), 4.06 (t, 1H, *J* = 3.5 Hz), 3.86-3.94 (m, 2H), 3.59-3.62 (m, 1H), 2.35 (dq, 1H, *J* = 2.0 Hz, *J* = 8.0 Hz), 1.41 (d, 1H, *J* = 8.5

Hz), 0.92 (s, 9H), 0.91 (s, 9H), 0.18 (s, 3H), 0.17 (s, 3H), 0.09 (s, 3H), 0.08 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 147.05, 139.90, 114.53, 95.28, 79.80, 68.71, 64.89, 62.31, 46.97, 26.02, 25.96, 18.48, 18.29, -4.14, -4.88, -4.94, -5.30. **HRMS (ESI)** calcd for $C_{21}H_{42}O_4Si_2+H^+$ 415.2694, found415.2693.

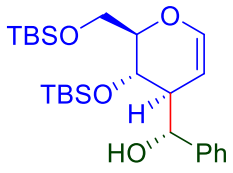
2.32 (((2R,3S,6R)-6-(benzyloxy)-2-(((tert-butyldimethylsilyl)oxy)methyl)-3,6-dihydro-2H-pyran-3-yl)oxy)(tert-butyl)dimethylsilane (S15)



S15

Yield: 98%, R_f: 0.55(5% EtOAc/hexane). **S15:** IR (neat): 2957, 2929, 2881, 2856 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.29-7.41 (m, 5H), 5.93 (dq, 1H, *J* = 1.6 Hz, *J* = 10.0 Hz), 5.78 (dt, 1H, *J* = 1.6 Hz, *J* = 10 Hz), 5.24-5.26 (m, 1H), 4.88 (d, 1H, *J* = 11.6 Hz), 4.64 (d, 1H, *J* = 11.6 Hz), 4.31-4.34 (m, 1H), 3.82-3.92 (m, 2H), 3.61-3.65 (m, 1H), 0.96 (s, 9H), 0.94 (s, 9H), 0.14-0.15 (m, 12H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 137.73, 132.90, 128.33, 128.11, 127.65, 127.47, 95.45, 79.31, 69.02, 63.21, 62.77, 25.93, 25.78, 18.41, 18.02, -4.40, -4.82, -5.16, -5.26. **HRMS (ESI)** calcd for $C_{25}H_{44}O_4Si_2+NH_4^+$ 482.3116, found 482.3116.

2.33 (*R*)-((2*R*,3*S*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl)methanol (15a)

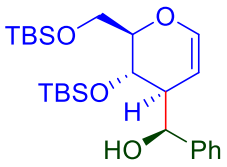


15a

Yield: 32%, R_f: 0.4 (5% Acetone/hexane). **15a:** IR (neat): 3531, 2926, 2855, 2020, 1732, 1652 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.35-7.41 (m, 4H), 7.27-7.31 (m, 1H), 6.50 (dd, 1H, *J* = 2.4 Hz, *J* = 6.0 Hz), 5.14 (dd, 1H, *J* = 1.6 Hz, *J* = 8.0 Hz), 4.26 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 4.18-4.22 (m, 1H), 3.91-3.98 (m, 2H), 3.61-3.65 (m,1H), 2.63 (dq, 1H, *J* = 2.4 Hz, *J* = 8.4 Hz), 1.85 (d, 1H, *J* = 8.0 Hz), 1.0 (s, 9H), 0.95 (s, 9H), 0.26 (s, 3H), 0.24 (s, 3H),

0.12 (s, 6H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 147.07, 143.24, 128.29, 126.91, 125.23, 95.13, 79.87, 69.67, 65.24, 49.45, 26.15, 25.99, 18.51, 18.33, -4.13, -4.75, -4.90, -5.27. **HRMS (ESI)** calcd for $C_{25}H_{44}O_4Si_2+NH_4^+$ 482.3116, found 482.3114.

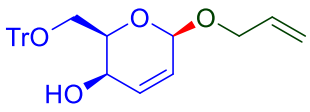
2.34 (*S*)-((2*R*,3*S*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-(((*tert*-butyldimethylsilyl)oxy) methyl)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl)methanol (15b)



15b

Yield: 51%, R_f: 0.4 (5% EtOAc/hexane). **15b:** IR (neat): 3532, 2953, 2927, 2855, 1736 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.29-7.39 (m, 5H), 6.28 (dd, 1H, *J* = 2.0 Hz, *J* = 6.4 Hz), 4.69 (dd, 1H, *J* = 2.4 Hz, *J* = 7.6 Hz), 4.36 (dd, 1H, *J* = 3.6 Hz, *J* = 6.4 Hz), 4.25-4.28 (m, 1H), 3.83-3.89 (m, 3H), 2.55-2.60 (m, 1H), 2.42 (d, 1H, *J* = 2.4 Hz), 0.95 (s, 9H), 0.91 (s, 9H), 0.21 (s, 3H), 0.20 (s, 3H), 0.09 (s, 3H), 0.05 (s, 3H).**^{13}C NMR (100 MHz, $CDCl_3$):** δ 143.02, 142.06, 128.22, 127.80, 127.02, 98.85, 79.02, 75.84, 66.78, 61.70, 47.20, 26.02, 25.86, 18.31, 18.28, -3.79, -3.92, -5.28, -5.34. **HRMS (ESI)** calcd for $C_{25}H_{44}O_4Si_2+NH_4^+$ 482.3116, found 482.3116.

2.35 (2*R*,3*R*,6*R*)-6-(allyloxy)-2-((trityloxy)methyl)-3,6-dihydro-2*H*-pyran-3-ol (SS16)

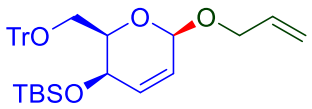


SS16

Yield: 85%, R_f: 0.25 (20% EtOAc/hexane). **SS16:** IR (neat): 3430, 3056, 3020, 2926, 2871, 2359, 2342, 1961, 1711, 1644, 1596 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.48-7.52 (m, 6H), 7.24-7.34 (m, 9H), 6.15 (ddd, 1H, *J* = 1.5 Hz, *J* = 5.0 Hz, *J* = 10.0 Hz), 5.94-6.02 (m, 1H), 5.88 (d, 1H, *J* = 10.0 Hz), 5.33-5.37 (m, 1H), 5.23-5.25 (m, 1H), 5.17 (d, 1H, *J* = 1.0 Hz), 4.43 (ddt, 1H, *J* = 1.0 Hz, *J* = 5.0 Hz, *J* = 12.5 Hz), 4.21 (dd, 1H, *J* = 6.5 Hz, *J* = 13.0 Hz), 3.95 (bs, 1H), 3.83 (td, 1H, *J* = 2.0 Hz, *J* = 6.5 Hz), 3.51 (dd, 1H, *J* = 6.5 Hz, *J* = 10.0 Hz),

3.31 (dd, 1H, *J* = 5.5 Hz, *J* = 10.0 Hz), 1.87 (d, 1H, *J* = 5.5 Hz). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 143.91, 134.10, 130.89, 130.87, 128.70, 127.82, 127.03, 117.60, 97.11, 86.73, 74.87, 69.14, 63.35, 62.89. **HRMS (ESI)** calcd for $C_{28}H_{28}O_4$+Na^+ 451.1880, found 451.1883.

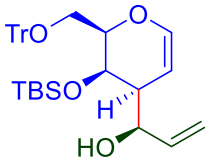
2.36 (((2*R*,3*R*,6*R*)-6-(allyloxy)-2-((trityloxy)methyl)-3,6-dihydro-2*H*-pyran-3-yl)oxy) (*tert*-butyl)dimethylsilane (S16)



S16

Yield: 98%, R_f: 0.75 (20% EtOAc/hexane). **S16:** IR (neat): 3091, 3057, 2953, 2927, 2876, 2854, 1596 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.53-7.55 (m, 6H), 7.32-7.35 (m, 6H), 7.25-7.29 (m, 3H), 5.99-6.09 (m, 1H), 5.93-5.97 (m, 1H), 5.86 (d, 1H, *J* = 10.0 Hz), 5.36-5.40 (m, 1H), 5.26 (dd, 1H, *J* = 1.6 Hz, *J* = 10.4 Hz), 5.22 (s, 1H), 4.47-4.51 (m, 1H), 4.29-4.34 (m, 1H), 3.97 (bs, 1H), 3.86-3.89 (m, 1H), 3.59-3.64 (m, 1H), 3.13 (dd, 1H, *J* = 3.6 Hz, *J* = 6.0 Hz), 0.76 (s, 9H), -0.01 (s, 3H), -0.12 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 144.21, 134.51, 130.89, 129.95, 128.73, 127.72, 126.84, 117.40, 96.18, 86.57, 75.42, 68.46, 64.53, 63.63, 25.72, 17.99, -4.27, -4.93. **HRMS (ESI)** calcd for $C_{34}H_{42}O_4Si$+Na^+ 565.2745, found 565.2750.

2.37 (*R*)-1-((2*R*,3*R*,4*S*)-3-((tert-butyldimethylsilyl)oxy)-2-((trityloxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)prop-2-en-1-ol (16)

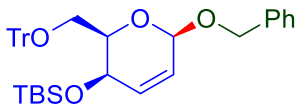


16

Yield: 90%, R_f: 0.65 (20% EtOAc/hexane). **16:** IR (neat): 3554, 3060, 3023, 2950, 2928, 2886, 2855, 2359, 2339, 1646, 1596 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.48-7.50 (m, 6H), 7.31-7.34 (m, 6H), 7.25-7.28 (m, 3H), 6.62 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 5.87 (ddd, 1H, *J* = 4.0 Hz, *J* = 11.0 Hz, *J* = 17.0 Hz), 5.39 (dt, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.22 (dt, 1H, *J* = 1.5 Hz, *J* = 10.5 Hz), 4.67 (dt, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 4.38-4.39 (m, 1H), 4.11

(d, 1H, *J* = 4.5 Hz), 3.99 (dd, 1H, *J* = 4.5 Hz, *J* = 7.5 Hz), 3.53 (dd, 1H, *J* = 7.5 Hz, *J* = 10.0 Hz), 3.06 (dd, 1H, *J* = 4.5 Hz, *J* = 10.0 Hz), 2.75 (s, 1H), 2.53-2.54 (m, 1H), 0.77 (s, 9H), 0.12 (s, 3H), -0.21 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 145.65, 143.84, 138.63, 128.70, 127.82, 127.02, 114.89, 96.21, 86.96, 77.65, 71.18, 68.79, 64.46, 42.66, 25.75, 18.09, -3.86, -4.41. **HRMS (ESI)** calcd for $C_{34}H_{42}O_4Si+Na^+$ 565.2745, found 565.2750.

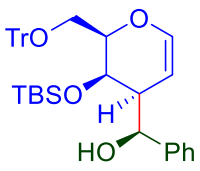
2.38 (((2R,3R,6R)-6-(benzyloxy)-2-((trityloxy)methyl)-3,6-dihydro-2H-pyran-3-yl)oxy) (tert-butyl)dimethylsilane (S17)



S17

Yield: 97%, R_f: 0.75 (20% EtOAc/hexane). **S17:** IR (neat): 3084, 3058, 3030, 2951, 2927, 2883, 2855, 2359, 2339, 1738, 1596 cm^{-1}. **^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.54-7.56 (m, 6H), 7.31-7.337.47 (m, 11H), 7.24-7.29 (m, 3H), 5.94 (ddd, 1H, *J* = 1.2 Hz, *J* = 4.4 Hz, *J* = 10.0 Hz), 5.87 (d, 1H, *J* = 10.4 Hz), 5.20-5.21 (m, 1H), 4.99 (d, *J* = 12.0 Hz), 4.87 (d, 1H, *J* = 12.0 Hz), 3.96-3.98 (m, 1H), 3.85-3.89 (m, 1H), 3.64 (dd, 1H, *J* = 8.0 Hz, *J* = 10.4 Hz), 3.13 (dd, 1H, *J* = 3.2 Hz, *J* = 10.0 Hz), 0.76 (s, 9H), -0.01 (s, 3H), -0.12 (s, 3H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 144.23, 137.75, 130.88, 130.02, 128.75, 128.34, 128.29, 127.75, 127.64, 126.87, 95.63, 86.61, 75.49, 68.91, 64.64, 63.72, 25.74, 18.01, -4.23, -4.89. **HRMS (ESI)** calcd for $C_{38}H_{44}O_4Si+Na^+$ 615.2901, found 615.2908.

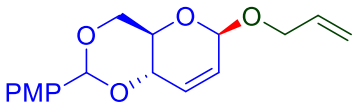
2.39 (*S*)-((2*R*,3*R*,4*S*)-3-((*tert*-butyldimethylsilyl)oxy)-2-((trityloxy)methyl)-3,4-dihydro-2*H*-pyran-4-yl)(phenyl)methanol (17)



17

Yield: 80%, R_f: 0.7 (20% EtOAc/hexane). **17:** IR (neat): 3544, 3059, 3027, 2953, 2929, 2886, 2855, 2359, 2332, 1650, 1598 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.48-7.50 (m, 6H), 7.25-7.41 (m, 14H), 6.61 (dd, 1H, *J* = 2.5 Hz, *J* = 6.5 Hz), 5.01 (s, 1H) , 4.56 (dt, 1H, *J* = 1.5 Hz, *J* = 6.0 Hz), 4.25 (d, 1H, *J* = 4.0 Hz), 3.98 (dd, 1H, *J* = 4.5 Hz, *J* = 8.0 Hz), 3.55 (dd, 1H, *J* = 8.0 Hz, *J* = 10.0 Hz), 3.18 (s, 1H), 3.08 (dd, 1H, *J* = 4.0 Hz, *J* = 10.0 Hz), 2.75-2.76 (m, 1H), 0.80 (s, 9H), 0.17(s, 3H), -0.17 (s, 3H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 145.87, 143.85, 142.69, 128.72, 128.20, 127.91, 127.85, 127.05, 125.72, 95.67, 87.00, 77.66, 72.73, 69.54, 64.51, 45.03, 25.78, 18.12, -3.89, -4.35. **HRMS (ESI)** calcd for $C_{38}H_{44}O_4Si+Na^+$ 615.2901, found 615.2908.

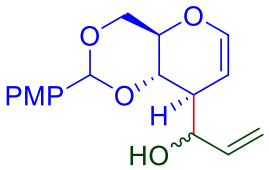
2.40 (4a*R*,6*R*,8a*S*)-6-(allyloxy)-2-(4-methoxyphenyl)-4,4a,6,8a-tetrahydropyrano[3,2-d][1,3]di oxine (S18)



S18

Yield: 62%, R_f: 0.6 (20% EtOAc/hexane). **S18:** IR (neat): 3006, 2954, 2872, 1615, 1589, 1515 cm^{-1}. **^{1}H NMR (500 MHz, $CDCl_3$):** δ 7.44 (d, 1H, *J* = 8.5 Hz), 6.91 (d, 1H, *J* = 8.5 Hz), 6.16 (d, 1H, *J* = 10.5 Hz), 5.92-6.00 (m, 1H), 5.72 (d, 1H, *J* = 10.5 Hz), 5.58 (s, 1H), 5.40 (s, 1H), 5.33 (dd, 1H, *J* = 1.5 Hz, *J* = 17.0 Hz), 5.23 (d, 1H, *J* = 10.5 Hz), 3.81 (s, 3H), 3.74-3.79 (m, 1H). **^{13}C NMR (125 MHz, $CDCl_3$):** δ 160.19, 134.01, 131.46, 129.86, 128.21, 127.50, 117.50, 113.69, 102.04, 97.87, 74.98, 70.55, 69.04, 68.67, 55.28. **HRMS (ESI)** calcd for $C_{17}H_{20}O_5+Na^+$ 327.1203, found 327.1201.

2.41 1-((4a*R*,8*S*,8a*S*)-2-(4-methoxyphenyl)-4,4a,8,8a-tetrahydropyrano[3,2-d][1,3]di oxin-8-yl) prop-2-en-1-ol (18)



18a:18b (2.3:1)

Yield: 58%, R_f: 0.5 (30% EtOAc/hexane). **18a** and **18b:** IR (neat): 3503, 3091, 3072, 3005, 2968, 2897, 2866, 1686, 1637, 1613, 1588, 1516 cm^{-1}. **18a : ^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.42 (d, 2H, *J* = 8.4 Hz), 6.91 (d, 2H, *J* = 8.8 Hz), 6.39 (dd, 1H, *J* = 2.4 Hz, *J* = 6.0 Hz), 5.88 (ddd, 1H, *J* = 7.2 Hz, *J* = 10.0 Hz, *J* = 17.2 Hz), 5.60 (s, 1H), 5.31 (dt, 1H, *J* = 1.2 Hz, *J* = 17.2 Hz), 5.26 (dq, 1H, *J* = 0.8 Hz, *J* = 10.4 Hz), 4.69 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 4.40 (dd, 1H, *J* = 4.0 Hz, *J* = 10.0 Hz), 4.22 (t, 1H, *J* = 6.8 Hz), 3.85-3.87 (m, 2H), 3.82 (s, 3H), 3.80-3.81 (m, 1H), 2.67-2.72 (m, 1H), 1.94 (bs, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 160.14, 143.96, 137.62, 129.46, 127.32, 117.62, 113.65, 101.39, 99.27, 77.98, 75.60, 68.70, 55.26, 42.57. **HRMS (ESI)** calcd for $C_{17}H_{20}O_5$+Na^+ 327.1203, found 327.1201. **18b: ^{1}H NMR (400 MHz, $CDCl_3$):** δ 7.43 (d, 2H, *J* = 9.6 Hz), 6.93 (d, 2H, *J* = 11.7 Hz), 6.46 (dd, 1H, *J* = 2.4 Hz, *J* = 6.0 Hz), 5.93 (ddd, 1H, *J* = 4.0 Hz, *J* = 10.8 Hz, *J* = 17.2 Hz), 5.60 (s, 1H), 5.38 (dt, 1H, *J* = 1.6 Hz, *J* = 17.2 Hz), 5.26 (t, 1H, *J* = 1.6 Hz), 4.62 (dd, 1H, *J* = 2.0 Hz, *J* = 6.0 Hz), 4.40 (dd, 1H, *J* = 4.0 Hz, *J* = 10.0 Hz), 4.01 (t, 1H, *J* = 9.2 Hz), 3.86-3.92 (m, 2H), 3.82 (s, 3H), 3.77-3.78 (m, 1H), 2.67-2.72 (m, 1H), 1.75 (bs, 1H). **^{13}C NMR (100 MHz, $CDCl_3$):** δ 160.09, 145.47, 138.61, 129.74, 127.36, 115.20, 113.65, 101.44, 97.65, 75.23, 70.11, 69.14, 55.26, 42.42. **HRMS (ESI)** calcd for $C_{17}H_{20}O_5$+Na^+ 327.1203, found 327.1201.

4.5 References

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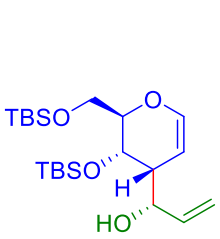

2


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TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     1.50 dB
PL1W             15.18650627 W
SFO1             400.0934707 MHz

F2 - Processing parameters
SI                        32768
SF                400.0910000 MHz
WDW                        EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```
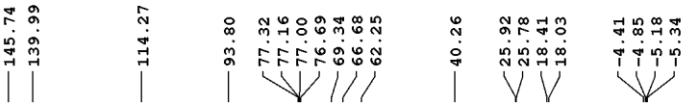
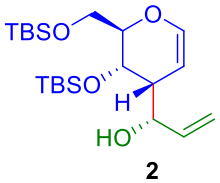
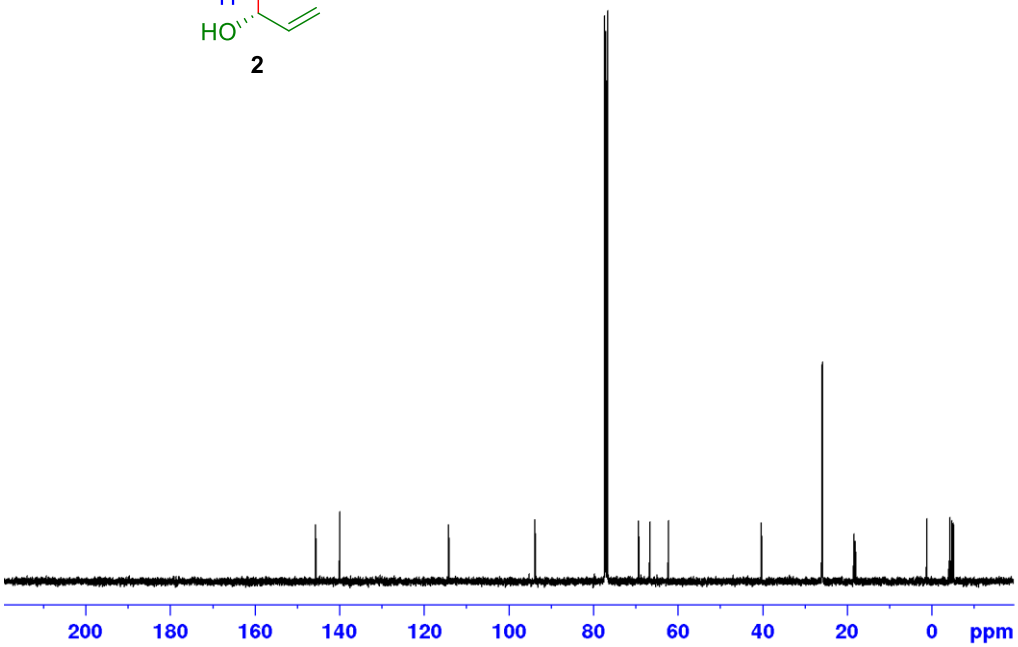
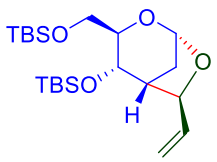





2

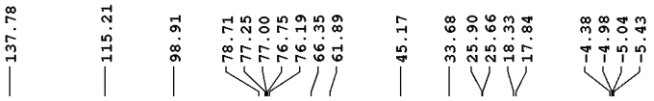


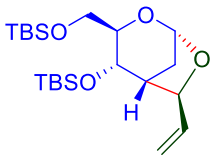

```
Current Data Parameters
NAME                  BUR 400
EXPNO               12382156
PROCNO                     1

F2 - Acquisition Parameters
Date_               20181201
Time                    6.04
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                       516
DS                         4
SWH               24038.461 Hz
FIDRES             0.366798 Hz
AQ                 1.3631488 sec
RG                       724
DW                  20.800 usec
DE                   6.50 usec
TE                   295.4 K
D1                 2.00000000 sec
D11                0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                     13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W             49.44866943 W
SFO1             100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                      1H
PCPD2                  90.00 usec
PL2                     1.50 dB
PL12                   17.18 dB
PL13                   20.18 dB
PL2W             15.18650627 W
PL12W             0.41063678 W
PL13W             0.20580591 W
SFO2             400.0926004 MHz

F2 - Processing parameters
SI                        32768
SF                100.6029640 MHz
WDW                        EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```



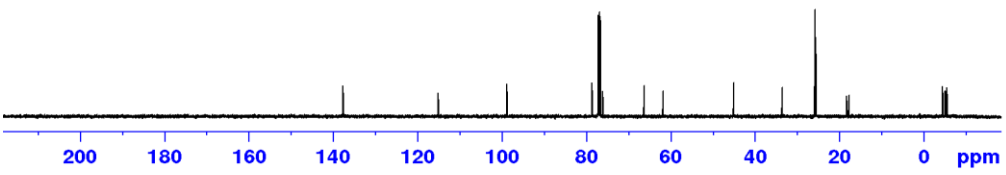
2a


```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459348
PROCNO                      1

F2 - Acquisition Parameters
Date_               20200315
Time                   13.08
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                3.1719425 sec
RG                     90.5
DW                   48.400 usec
DE                    6.50 usec
TE                   297.7 K
D1                1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     1H
P1                    14.90 usec
PL1                    2.00 dB
PL1W             12.85348415 W
SFO1             500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF               500.1800000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```

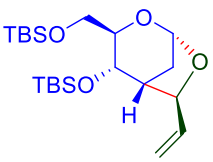




2a

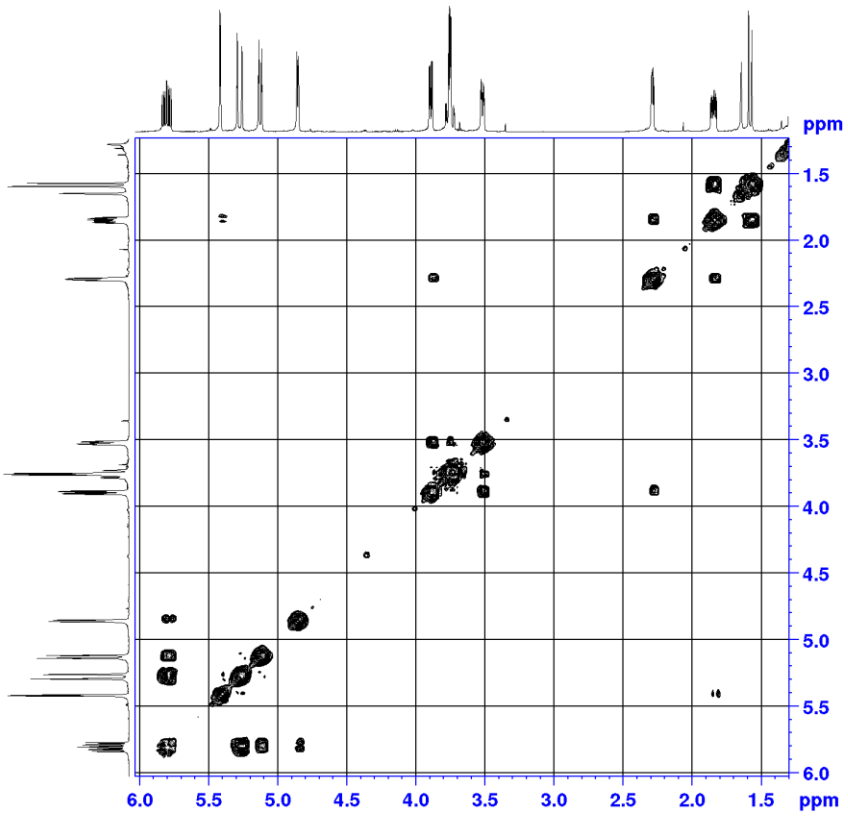


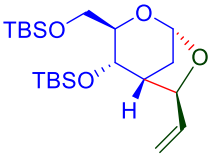

```
Current Data Parameters
NAME          BUR ASCEND 500
EXPNO                    154
PROCNO                     1

F2 - Acquisition Parameters
Date_               20200302
Time                  10.14 h
INSTRUM                spect
PROBHD    Z125331_0034 (
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      256
DS                        4
SWH               29761.904 Hz
FIDRES             0.908261 Hz
AQ                1.1010048 sec
RG                   192.83
DW                   16.800 usec
DE                    6.50 usec
TE                   297.8 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                       1
SFO1             125.8304669 MHz
NUC1                     13C
P1                    12.00 usec
PLW1            172.66999817 W
SFO2             500.3710015 MHz
NUC2                     1H
CPDPRG[2            waltz16
PCPD2                 80.00 usec
PLW2             12.18000031 W
PLW12             0.12180000 W
PLW13             0.06126500 W

F2 - Processing parameters
SI                    32768
SF               125.8178875 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```



2a

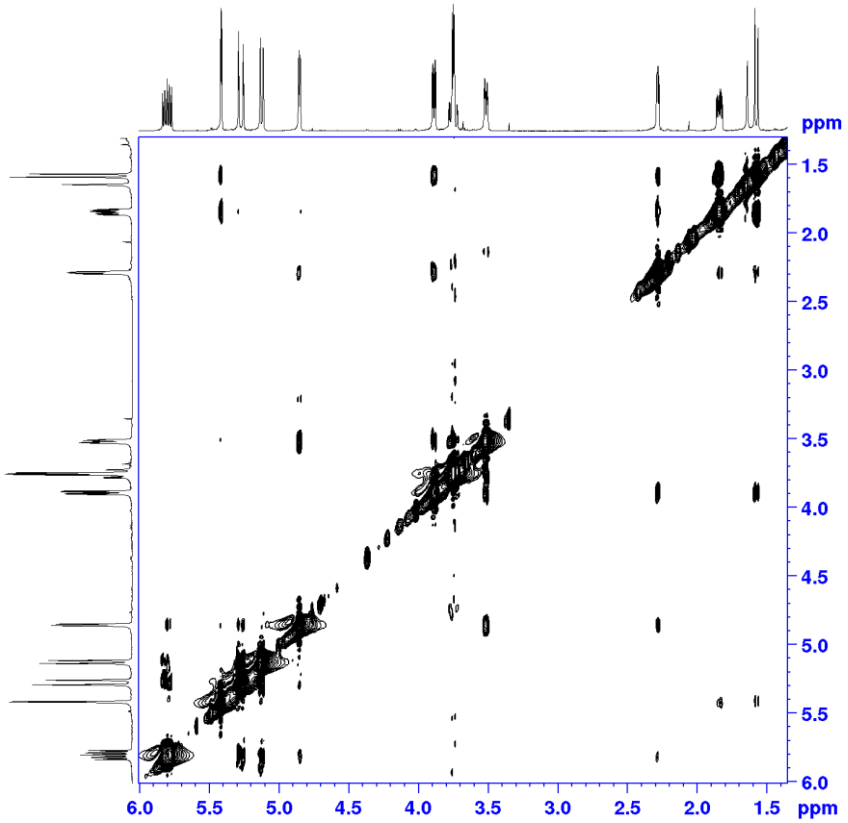
(COSY, 500 MHz)

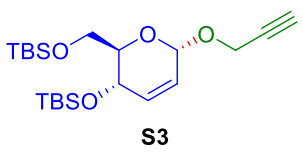




2a

(NOESY, 500 MHz)

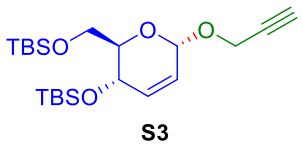




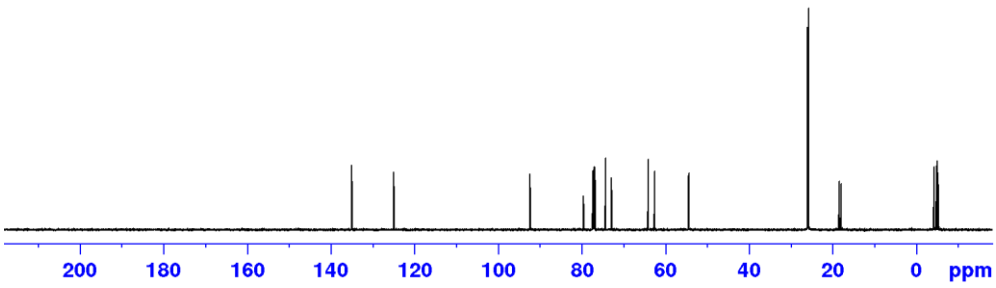
S3

BRUKER

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                17
PROCNO                1

F2 - Acquisition Parameters
Date_          20181204
Time               17.00 h
INSTRUM            spect
PROBHD   Z125331_0034 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES            0.305176 Hz
AQ             3.2767999 sec
RG                15.92
DW                50.000 usec
DE                 6.50 usec
TE                -2.8 K
D1            1.00000000 sec
TD0                   1
SFO1          500.3720898 MHz
NUC1                 1H
P1                 8.00 usec
PLW1          12.18000031 W

F2 - Processing parameters
SI                65536
SF            500.3690021 MHz
WDW                  EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

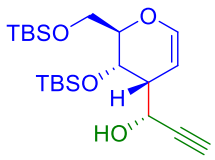


S3



BRUKER

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                19
PROCNO                1

F2 - Acquisition Parameters
Date_          20181204
Time               17.28 h
INSTRUM            spect
PROBHD   Z125331_0034 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  374
DS                    4
SWH           29761.904 Hz
FIDRES            0.908261 Hz
AQ             1.1010048 sec
RG                12.76
DW                16.800 usec
DE                 6.50 usec
TE                -2.8 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                   1
SFO1          125.8304669 MHz
NUC1                 13C
P1                12.00 usec
PLW1         172.66999817 W
SFO2          500.3710015 MHz
NUC2                 1H
CPDPRG[2          waltz16
PCPD2             80.00 usec
PLW2          12.18000031 W
PLW12          0.12180000 W
PLW13          0.06126500 W

F2 - Processing parameters
SI                32768
SF            125.8178903 MHz
WDW                  EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

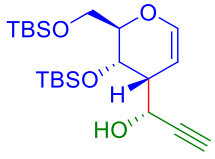


3

Current Data Parameters
NAME BUR ASCEND 500
EXPNO 20
PROCNO 1

F2 - Acquisition Parameters
Date_ 20181207
Time 16.05 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 10000.000 Hz
FIDRES 0.305176 Hz
AQ 3.2767999 sec
RG 152.9
DW 50.000 usec
DE 6.50 usec
TE 294.7 K
D1 1.00000000 sec
TD0 1
SFO1 500.3720898 MHz
NUC1 1H
P1 8.00 usec
PLW1 12.18000031 W

F2 - Processing parameters
SI 65536
SF 500.3690020 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00

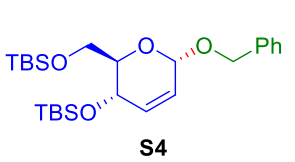


3

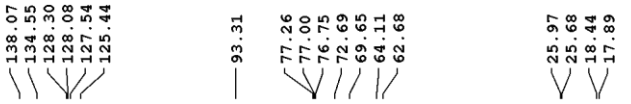
Current Data Parameters
NAME BUR ASCEND 500
EXPNO 22
PROCNO 1

F2 - Acquisition Parameters
Date_ 20181208
Time 18.07 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 25600
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 12.76
DW 16.800 usec
DE 6.50 usec
TE 294.1 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 125.8304669 MHz
NUC1 13C
P1 12.00 usec
PLW1 172.66999817 W
SFO2 500.3710015 MHz
NUC2 1H
CPDPRG[2 waltz16
PCPD2 80.00 usec
PLW2 12.18000031 W
PLW12 0.12180000 W
PLW13 0.06126500 W

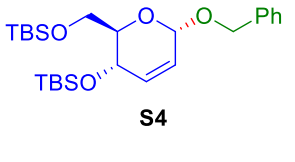
F2 - Processing parameters
SI 32768
SF 125.8178892 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



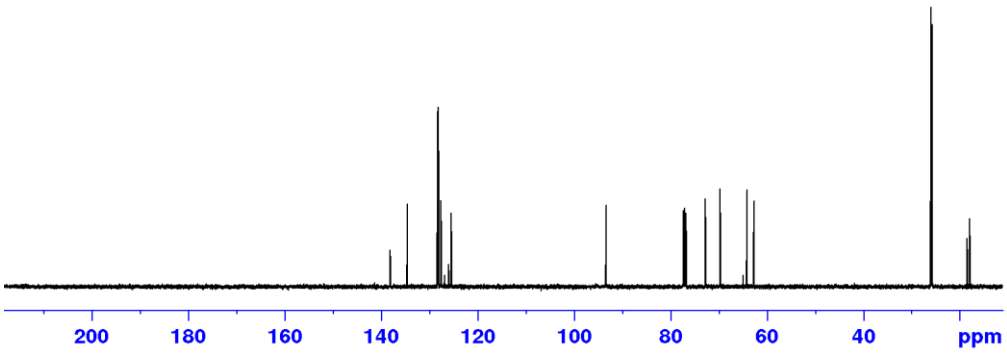
S4



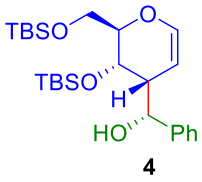

```
Current Data Parameters
NAME      BUR 2 (500MHz)
EXPNO             205911
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181204
Time               17.38
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1719425 sec
RG                  20.2
DW                48.400 usec
DE                 6.50 usec
TE                295.1 K
D1            1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 14.90 usec
PL1                2.00 dB
PL1W         12.85348415 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF           500.1800000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```



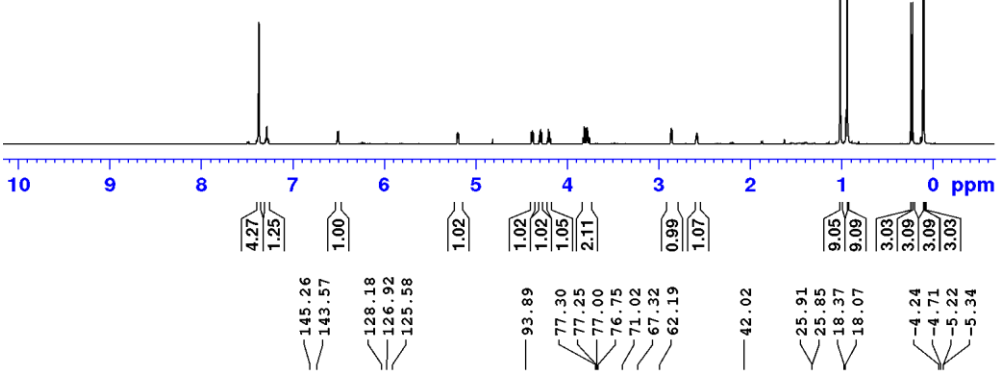
S4




```
Current Data Parameters
NAME      BUR 2 (500MHz)
EXPNO             205912
PROCNO                 1

F2 - Acquisition Parameters
Date_           20181204
Time               17.40
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                    22
DS                     4
SWH           29761.904 Hz
FIDRES         0.454131 Hz
AQ             1.1010048 sec
RG                  2050
DW                16.800 usec
DE                 6.50 usec
TE                296.0 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                 9.60 usec
PL1       0 dB
PL1W         76.36135101 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2              80.00 usec
PL2                2.00 dB
PL12               16.50 dB
PL13               16.50 dB
PL2W         12.85348415 W
PL12W         0.45605880 W
PL13W         0.45605880 W
SFO2         500.1820007 MHz

F2 - Processing parameters
SI                 32768
SF           125.7703710 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



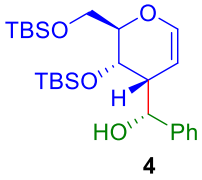
4



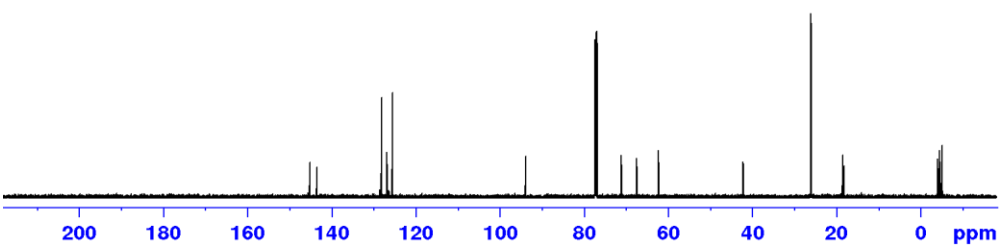
Current Data Parameters
NAME BUR ASCEND 500
EXPNO 149
PROCNO 1

F2 - Acquisition Parameters
Date_ 20200219
Time 13.53 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zg30
TD 65536
SOLVENT CDC13
NS 16
DS 2
SWH 10000.000 Hz
FIDRES 0.305176 Hz
AQ 3.2767999 sec
RG 31.25
DW 50.000 usec
DE 6.50 usec
TE 298.8 K
D1 1.00000000 sec
TD0 1
SFO1 500.3720898 MHz
NUC1 1H
P1 8.00 usec
PLW1 12.18000031 W

F2 - Processing parameters
SI 65536
SF 500.3690000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



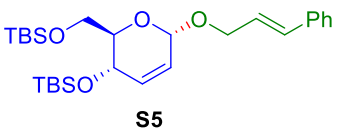
4



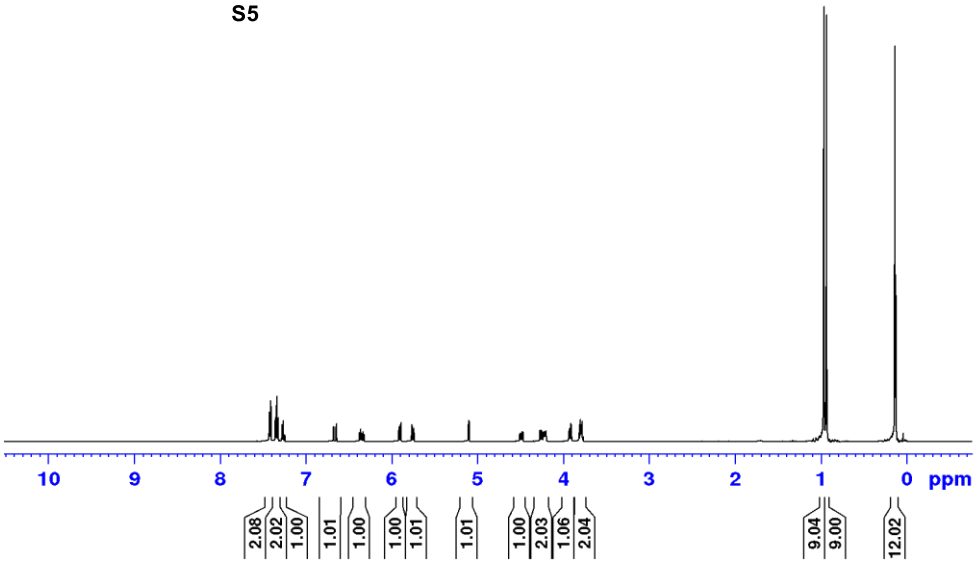
Current Data Parameters
NAME BUR ASCEND 500
EXPNO 151
PROCNO 1

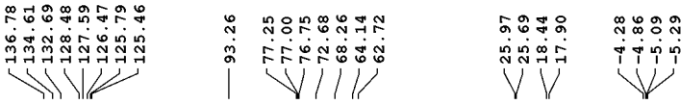
F2 - Acquisition Parameters
Date_ 20200219
Time 14.06 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDC13
NS 187
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 192.83
DW 16.800 usec
DE 6.50 usec
TE 298.8 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 125.8304669 MHz
NUC1 13C
P1 12.00 usec
PLW1 172.66999817 W
SFO2 500.3710015 MHz
NUC2 1H
CPDPRG[2 waltz16
PCPD2 80.00 usec
PLW2 12.18000031 W
PLW12 0.12180000 W
PLW13 0.06126500 W

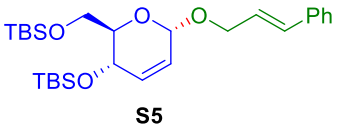
F2 - Processing parameters
SI 32768
SF 125.8178885 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



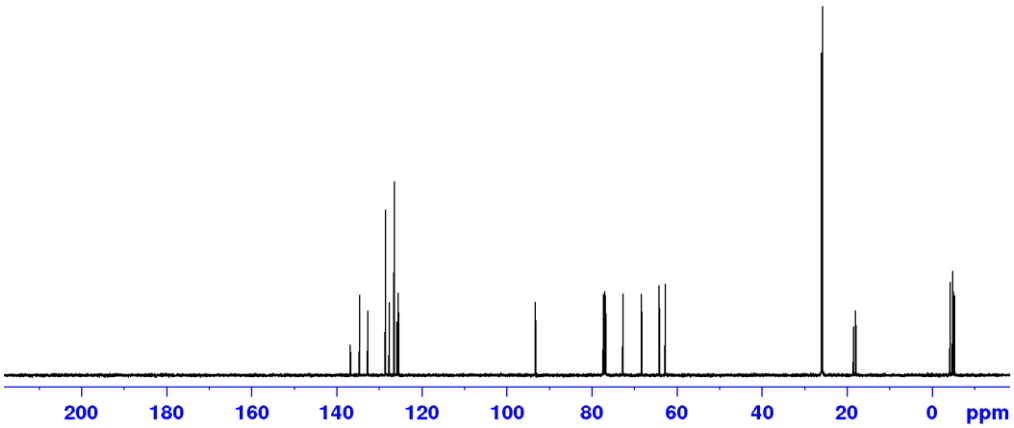
S5





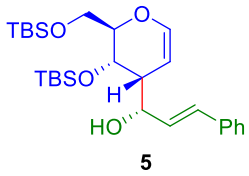


S5



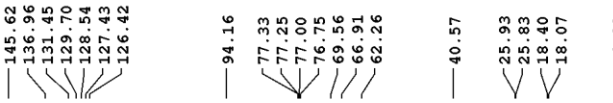

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459345
PROCNO                      1

F2 - Acquisition Parameters
Date_               20200312
Time                   14.39
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      28.5
DW                    48.400 usec
DE                     6.50 usec
TE                    297.3 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      2.00 dB
PL1W              12.85348415 W
SFO1             500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                          EM
SSB           0
LB                       0.30 Hz
GB            0
PC                       1.00
```

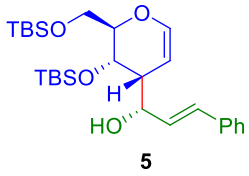
```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459347
PROCNO                      1

F2 - Acquisition Parameters
Date_               20200312
Time                   14.49
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      145
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                      2050
DW                    16.800 usec
DE                     6.50 usec
TE                    299.0 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      9.60 usec
PL1           0 dB
PL1W             76.36135101 W
SFO1            125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W              12.85348415 W
PL12W              0.45605880 W
PL13W              0.45605880 W
SFO2             500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703660 MHz
WDW                          EM
SSB           0
LB                       1.00 Hz
GB            0
PC                       1.40
```



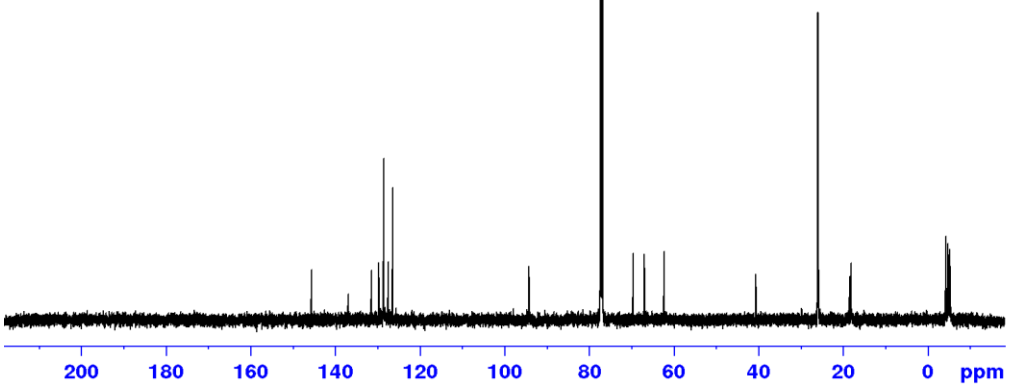
5


```
Current Data Parameters
NAME          BUR PRS 500
EXPNO            1459260
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190501
Time               13.33
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ            3.1719425 sec
RG                  144
DW               48.400 usec
DE                6.50 usec
TE                297.5 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                14.90 usec
PL1                2.00 dB
PL1W         12.85348415 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF           500.1800000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.40
```

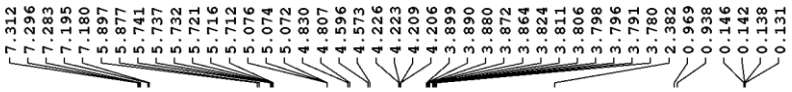


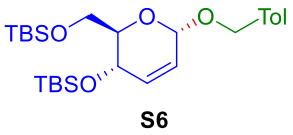


5

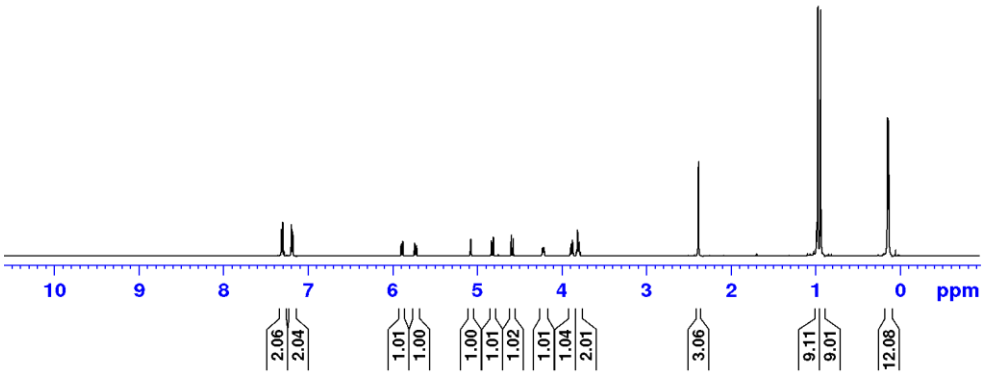



```
Current Data Parameters
NAME          BUR PRS 500
EXPNO            1459262
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190501
Time               13.34
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  485
DS                    4
SWH           29761.904 Hz
FIDRES         0.454131 Hz
AQ            1.1010048 sec
RG                 2050
DW               16.800 usec
DE                6.50 usec
TE                297.6 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                9.60 usec
PL1          0 dB
PL1W         76.36135101 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             80.00 usec
PL2                2.00 dB
PL12              16.50 dB
PL13              16.50 dB
PL2W         12.85348415 W
PL12W         0.45605880 W
PL13W         0.45605880 W
SFO2         500.1820007 MHz

F2 - Processing parameters
SI                 32768
SF           125.7703602 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

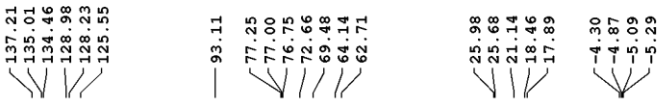


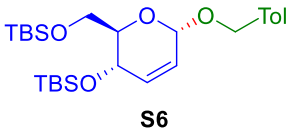


S6

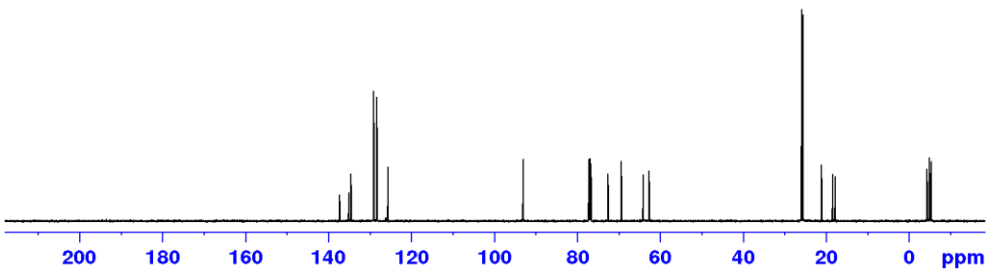



```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               157
PROCNO                1

F2 - Acquisition Parameters
Date_          20200309
Time              12.07 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES            0.305176 Hz
AQ              3.2767999 sec
RG                12.76
DW                50.000 usec
DE                 6.50 usec
TE                297.5 K
D1             1.00000000 sec
TD0                   1
SFO1          500.3720898 MHz
NUC1                 1H
P1                 8.00 usec
PLW1          12.18000031 W

F2 - Processing parameters
SI                65536
SF            500.3690000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```

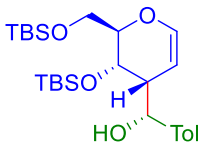




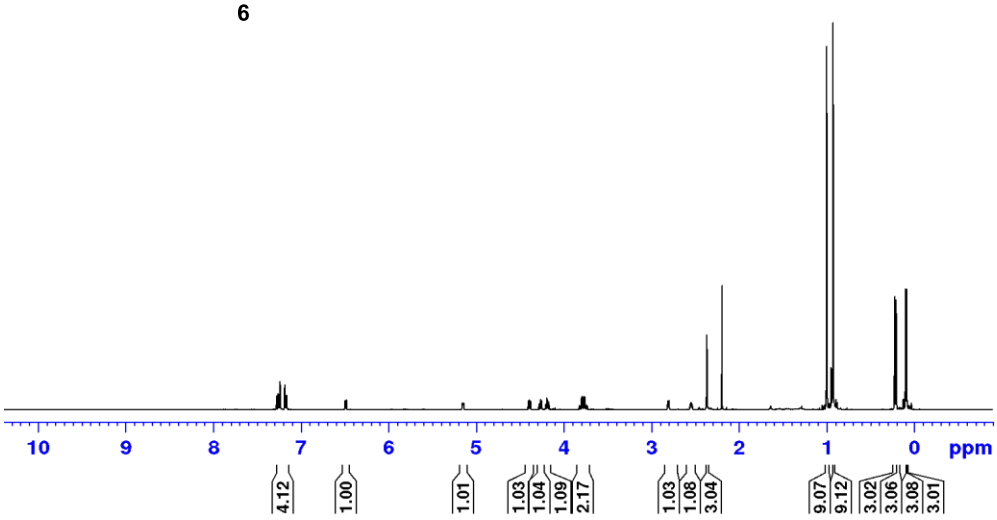
S6

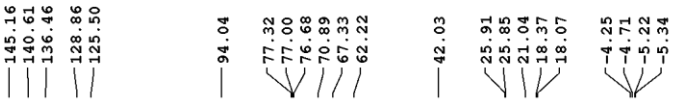


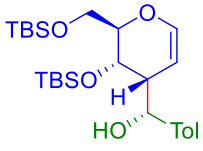

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               159
PROCNO                1

F2 - Acquisition Parameters
Date_          20200309
Time              12.25 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  291
DS                    4
SWH           29761.904 Hz
FIDRES            0.908261 Hz
AQ              1.1010048 sec
RG                192.83
DW                16.800 usec
DE                 6.50 usec
TE                298.0 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                   1
SFO1          125.8304669 MHz
NUC1                 13C
P1                12.00 usec
PLW1         172.66999817 W
SFO2          500.3710015 MHz
NUC2                 1H
CPDPRG[2          waltz16
PCPD2             80.00 usec
PLW2          12.18000031 W
PLW12          0.12180000 W
PLW13          0.06126500 W

F2 - Processing parameters
SI                32768
SF            125.8178928 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



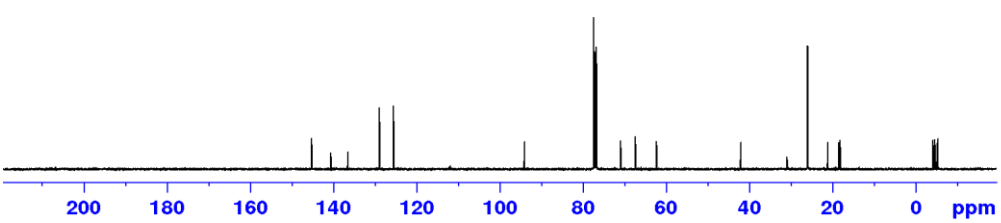
6





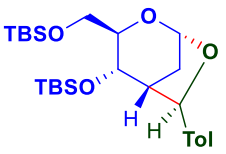


6

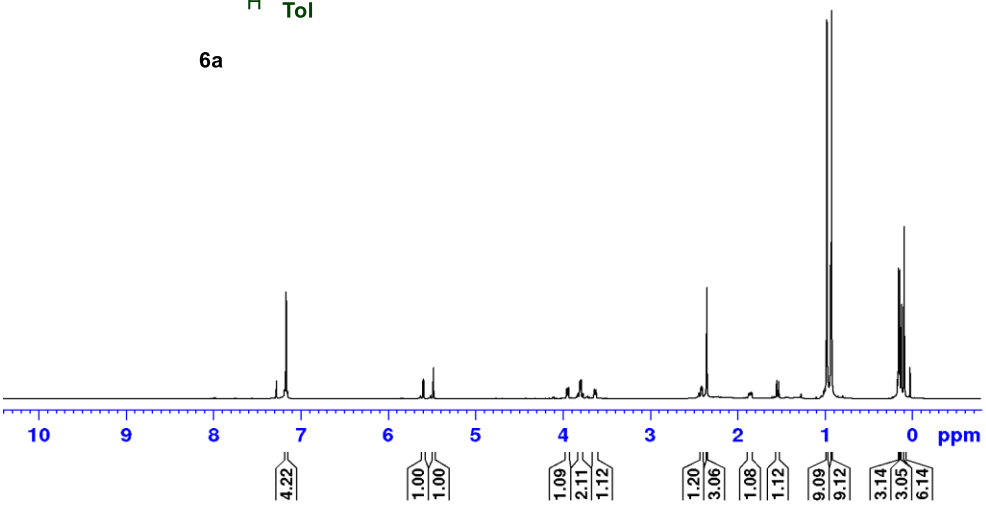


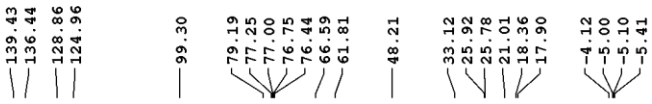

```
Current Data Parameters
NAME          BUR PRS 400
EXPNO           12382200
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190507
Time                4.21
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8223.685 Hz
FIDRES          0.125483 Hz
AQ              3.9845889 sec
RG                   114
DW                60.800 usec
DE                 6.50 usec
TE                299.2 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 14.90 usec
PL1                 1.50 dB
PL1W         15.18650627 W
SFO1         400.0934707 MHz

F2 - Processing parameters
SI                 32768
SF           400.0910000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

```
Current Data Parameters
NAME          BUR PRS 400
EXPNO           12382202
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190507
Time                4.53
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   414
DS                     4
SWH            24038.461 Hz
FIDRES          0.366798 Hz
AQ              1.3631488 sec
RG                  2050
DW                20.800 usec
DE                 6.50 usec
TE                300.7 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                 10.00 usec
PL1                 2.00 dB
PL1W         49.44866943 W
SFO1         100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2              90.00 usec
PL2                 1.50 dB
PL12               17.18 dB
PL13               20.18 dB
PL2W         15.18650627 W
PL12W         0.41063678 W
PL13W         0.20580591 W
SFO2         400.0926004 MHz

F2 - Processing parameters
SI                 32768
SF           100.6029635 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



6a

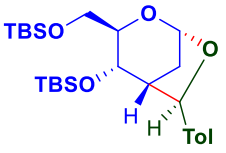




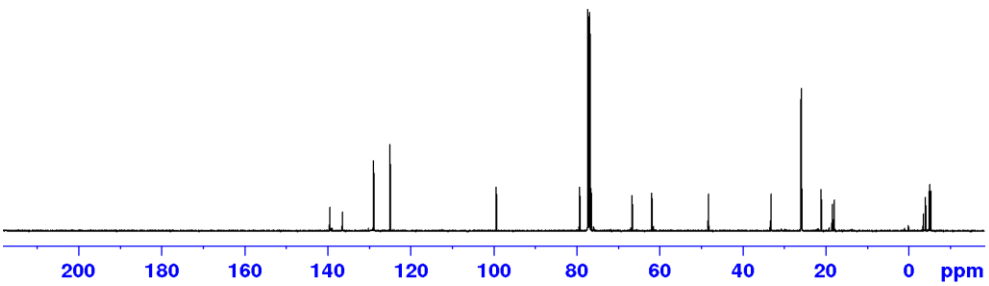
Current Data Parameters
NAME BUR PRS UPDATED 500
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20200820
Time 14.24 h
INSTRUM spect
PROBHD Z109128_0042 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 10000.000 Hz
FIDRES 0.305176 Hz
AQ 3.2767999 sec
RG 90.5
DW 50.000 usec
DE 13.04 usec
TE 295.2 K
D1 1.00000000 sec
TD0 1
SFO1 500.1830886 MHz
NUC1 1H
P0 5.00 usec
P1 15.00 usec
PLW1 4.84679985 W

F2 - Processing parameters
SI 65536
SF 500.1800000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



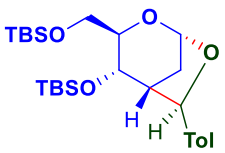
6a



Current Data Parameters
NAME BUR PRS UPDATED 500
EXPNO 2
PROCNO 1

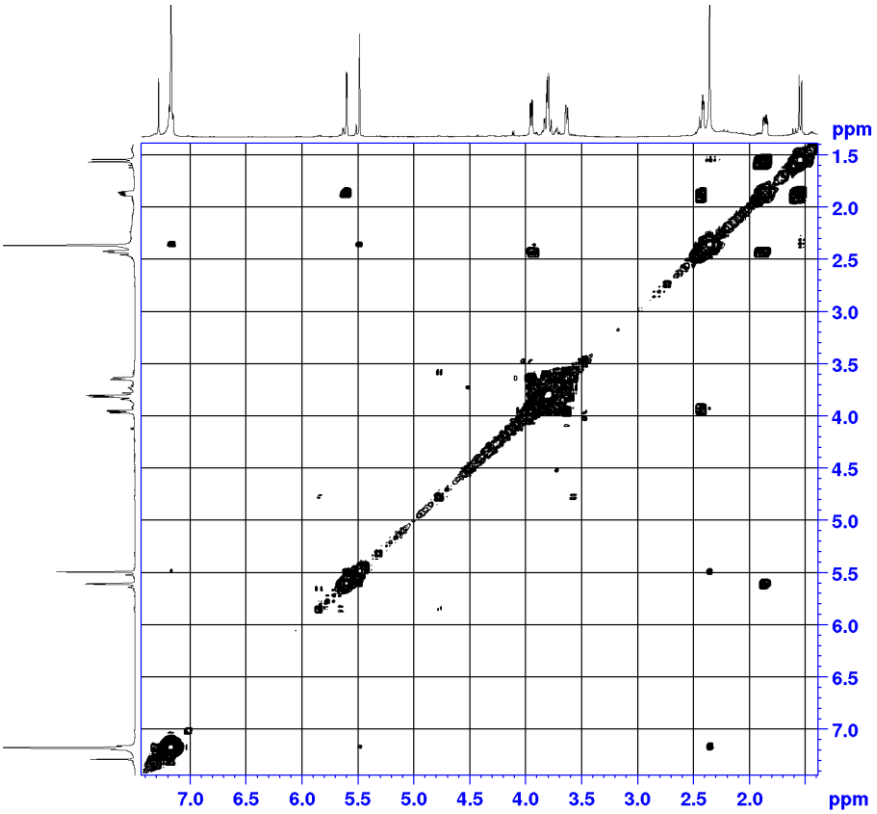
F2 - Acquisition Parameters
Date_ 20200820
Time 16.13 h
INSTRUM spect
PROBHD Z109128_0042 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 2048
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 203
DW 16.800 usec
DE 6.50 usec
TE 295.7 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 125.7829381 MHz
NUC1 13C
P0 3.33 usec
P1 10.00 usec
PLW1 64.00399780 W
SFO2 500.1820007 MHz
NUC2 1H
CPDPRG[2 waltz65
PCPD2 80.00 usec
PLW2 4.84679985 W
PLW12 0.17039999 W
PLW13 0.08570800 W

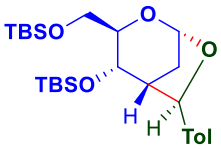
F2 - Processing parameters
SI 32768
SF 125.7703637 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



6a

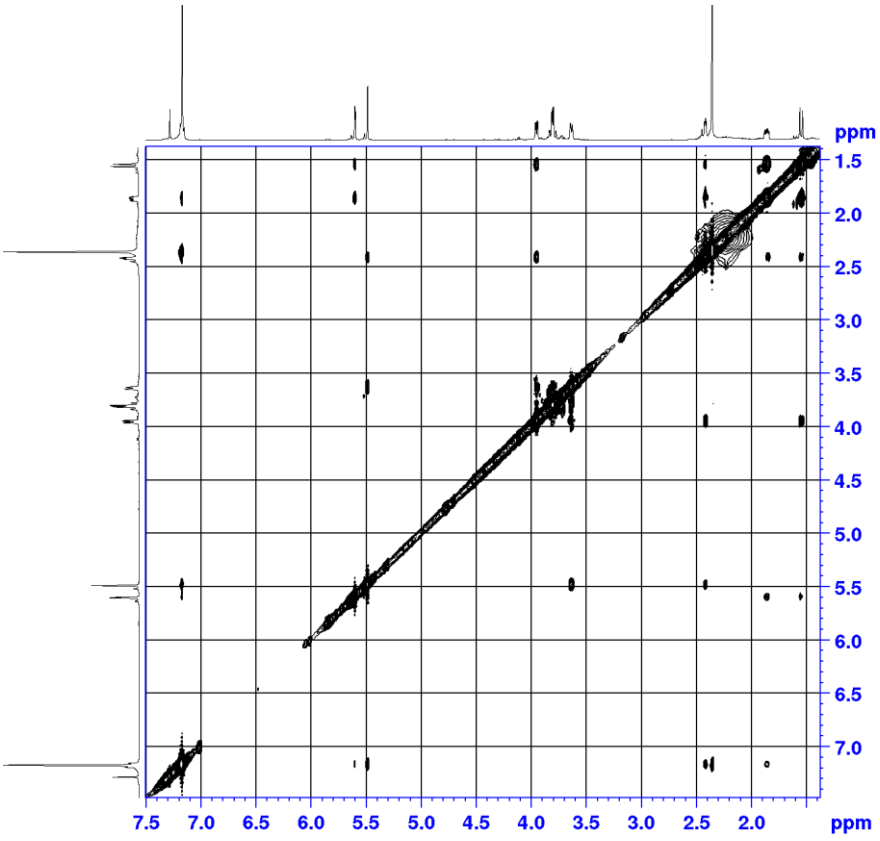
(COSY, 500MHz)

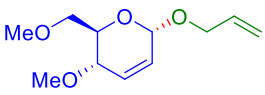




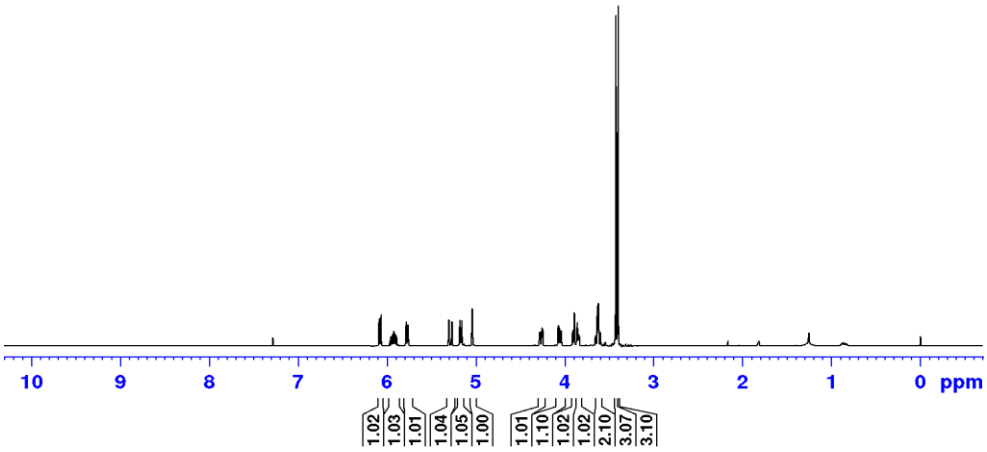
6a

(NOESY, 500MHz)

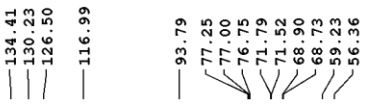


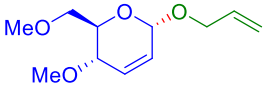


S7

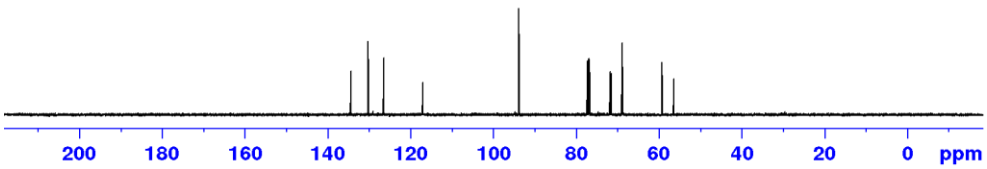



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459321
PROCNO                      1

F2 - Acquisition Parameters
Date_               20200217
Time                   10.01
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                3.1719425 sec
RG                      45.2
DW                    48.400 usec
DE                     6.50 usec
TE                    295.8 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      2.00 dB
PL1W             12.85348415 W
SFO1            500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                          EM
SSB          0
LB                       0.30 Hz
GB           0
PC                       1.00
```

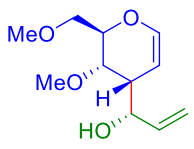




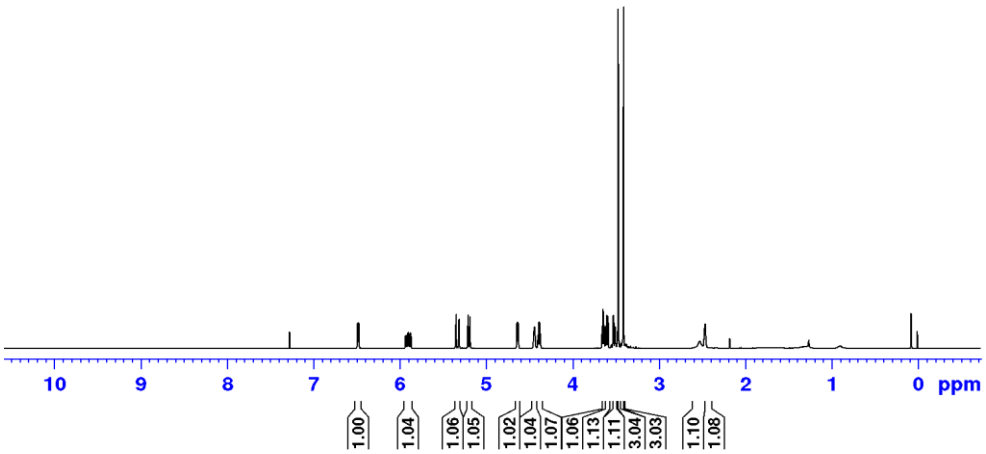
S7



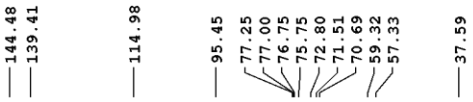

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459323
PROCNO                      1

F2 - Acquisition Parameters
Date_               20200217
Time                   10.10
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG              zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      101
DS                        4
SWH              29761.904 Hz
FIDRES             0.454131 Hz
AQ                1.1010048 sec
RG                     2050
DW                    16.800 usec
DE                     6.50 usec
TE                    297.4 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      9.60 usec
PL1            0 dB
PL1W            76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                       1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W            12.85348415 W
PL12W            0.45605880 W
PL13W            0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703688 MHz
WDW                          EM
SSB          0
LB                       1.00 Hz
GB           0
PC                       1.40
```

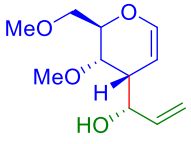


7

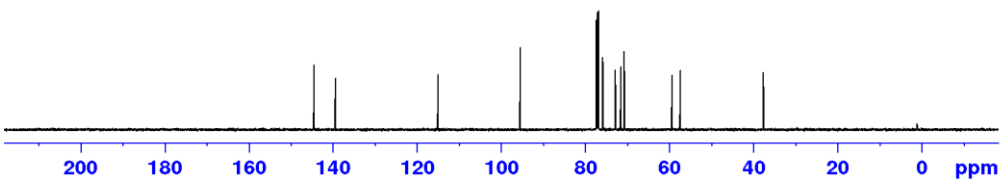



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459324
PROCNO                      1

F2 - Acquisition Parameters
Date_              20200219
Time                  10.00
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG               zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH              10330.578 Hz
FIDRES            0.157632 Hz
AQ               3.1719425 sec
RG                      128
DW                 48.400 usec
DE                  6.50 usec
TE                  298.4 K
D1              1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                    1H
P1                  14.90 usec
PL1                  2.00 dB
PL1W           12.85348415 W
SFO1          500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800000 MHz
WDW                      EM
SSB         0
LB                   0.30 Hz
GB          0
PC                   1.00
```

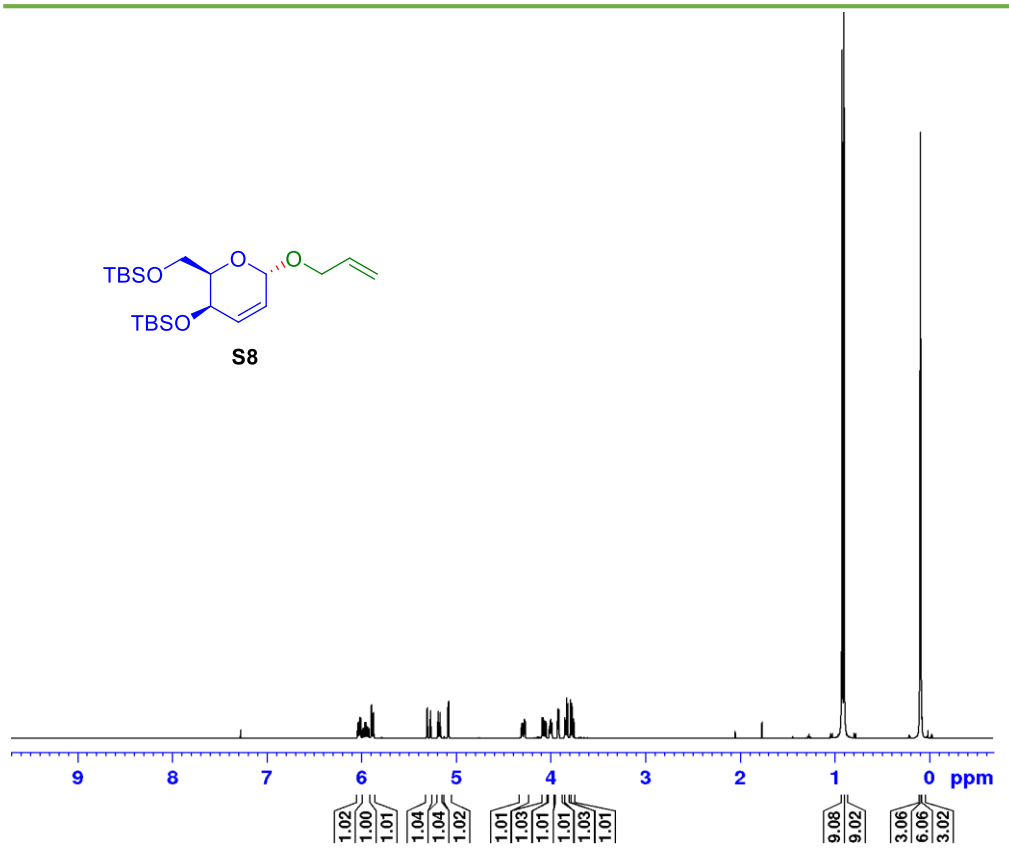




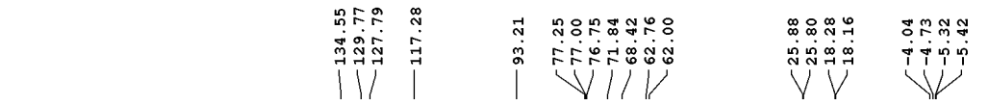
7

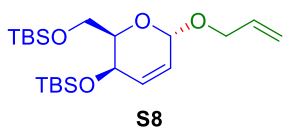


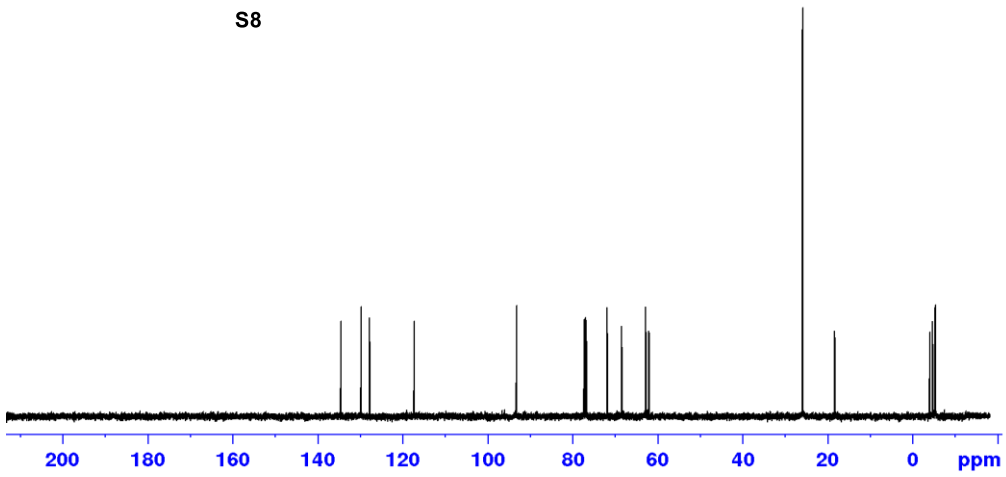

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459326
PROCNO                      1

F2 - Acquisition Parameters
Date_              20200219
Time                  10.04
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      427
DS                        4
SWH              29761.904 Hz
FIDRES            0.454131 Hz
AQ               1.1010048 sec
RG                     2050
DW                 16.800 usec
DE                  6.50 usec
TE                  298.5 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                   13C
P1                   9.60 usec
PL1         0 dB
PL1W           76.36135101 W
SFO1          125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2            waltz16
NUC2                    1H
PCPD2                80.00 usec
PL2                   2.00 dB
PL12                 16.50 dB
PL13                 16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
PL13W           0.45605880 W
SFO2          500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF             125.7703635 MHz
WDW                      EM
SSB         0
LB                   1.00 Hz
GB          0
PC                   1.40
```



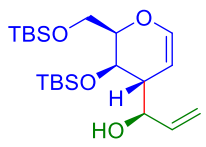

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                26
PROCNO                1

F2 - Acquisition Parameters
Date_          20190111
Time              15.43 h
INSTRUM           spect
PROBHD    Z125331_0034 (
PULPROG           zg30
TD               65536
SOLVENT          CDCl3
NS                  16
DS                   2
SWH          10000.000 Hz
FIDRES           0.305176 Hz
AQ            3.2767999 sec
RG                15.92
DW              50.000 usec
DE               6.50 usec
TE              298.2 K
D1           1.00000000 sec
TD0                  1
SFO1        500.3720898 MHz
NUC1                 1H
P1                8.00 usec
PLW1        12.18000031 W

F2 - Processing parameters
SI                65536
SF          500.3690019 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```





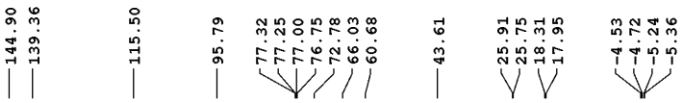


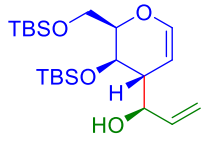

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                28
PROCNO                1

F2 - Acquisition Parameters
Date_          20190111
Time              16.00 h
INSTRUM           spect
PROBHD    Z125331_0034 (
PULPROG         zgpg30
TD               65536
SOLVENT          CDCl3
NS                  55
DS                   4
SWH          29761.904 Hz
FIDRES           0.908261 Hz
AQ            1.1010048 sec
RG                12.76
DW              16.800 usec
DE               6.50 usec
TE              298.2 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                  1
SFO1        125.8304669 MHz
NUC1                 13C
P1               12.00 usec
PLW1       172.66999817 W
SFO2        500.3710015 MHz
NUC2                 1H
CPDPRG[2         waltz16
PCPD2            80.00 usec
PLW2        12.18000031 W
PLW12        0.12180000 W
PLW13        0.06126500 W

F2 - Processing parameters
SI                32768
SF          125.8178901 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



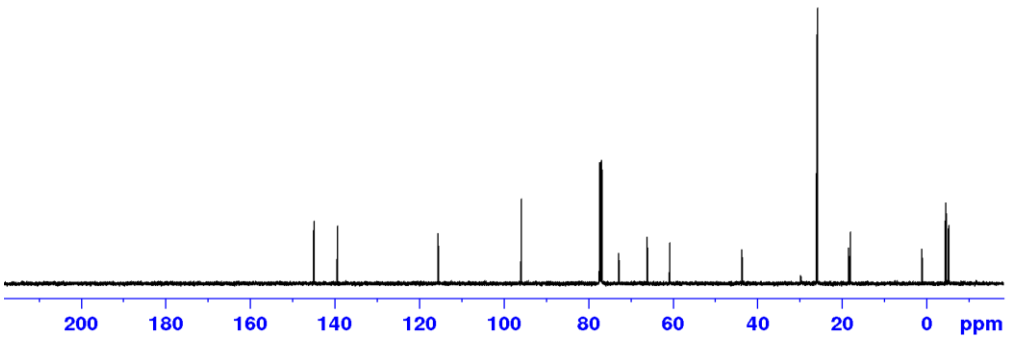
8a


```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459222
PROCNO                      1

F2 - Acquisition Parameters
Date_              20190122
Time                  15.15
INSTRUM               spect
PROBHD     5 mm PABBO BB-
PULPROG               zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                 3.1719425 sec
RG                      45.2
DW                    48.400 usec
DE                     6.50 usec
TE                    294.9 K
D1                1.00000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                       1H
P1                      14.90 usec
PL1                      2.00 dB
PL1W             12.85348415 W
SFO1             500.1830888 MHz

F2 - Processing parameters
SI                        32768
SF               500.1800000 MHz
WDW                        EM
SSB           0
LB                      0.30 Hz
GB            0
PC                      1.00
```

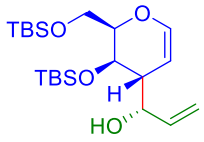




8a

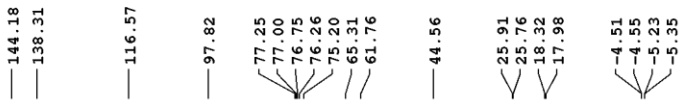


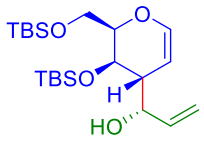

```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459224
PROCNO                      1

F2 - Acquisition Parameters
Date_              20190122
Time                  15.24
INSTRUM               spect
PROBHD     5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      143
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                 1.1010048 sec
RG                      2050
DW                    16.800 usec
DE                     6.50 usec
TE                    295.7 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                         1

======== CHANNEL f1 ========
NUC1                      13C
P1                      9.60 usec
PL1            0 dB
PL1W             76.36135101 W
SFO1             125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                       1H
PCPD2                  80.00 usec
PL2                     2.00 dB
PL12                   16.50 dB
PL13                   16.50 dB
PL2W             12.85348415 W
PL12W             0.45605880 W
PL13W             0.45605880 W
SFO2             500.1820007 MHz

F2 - Processing parameters
SI                        32768
SF               125.7703626 MHz
WDW                        EM
SSB           0
LB                      1.00 Hz
GB            0
PC                      1.40
```



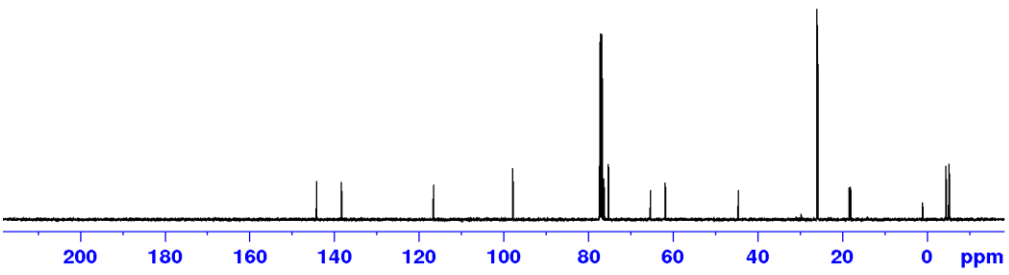
8b


```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459225
PROCNO                      1

F2 - Acquisition Parameters
Date_               20190122
Time                   15.34
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH               10330.578 Hz
FIDRES             0.157632 Hz
AQ                3.1719425 sec
RG                       101
DW                  48.400 usec
DE                   6.50 usec
TE                   295.1 K
D1              1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     2.00 dB
PL1W           12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800002 MHz
WDW                      EM
SSB         0
LB                     0.30 Hz
GB          0
PC                     1.00
```

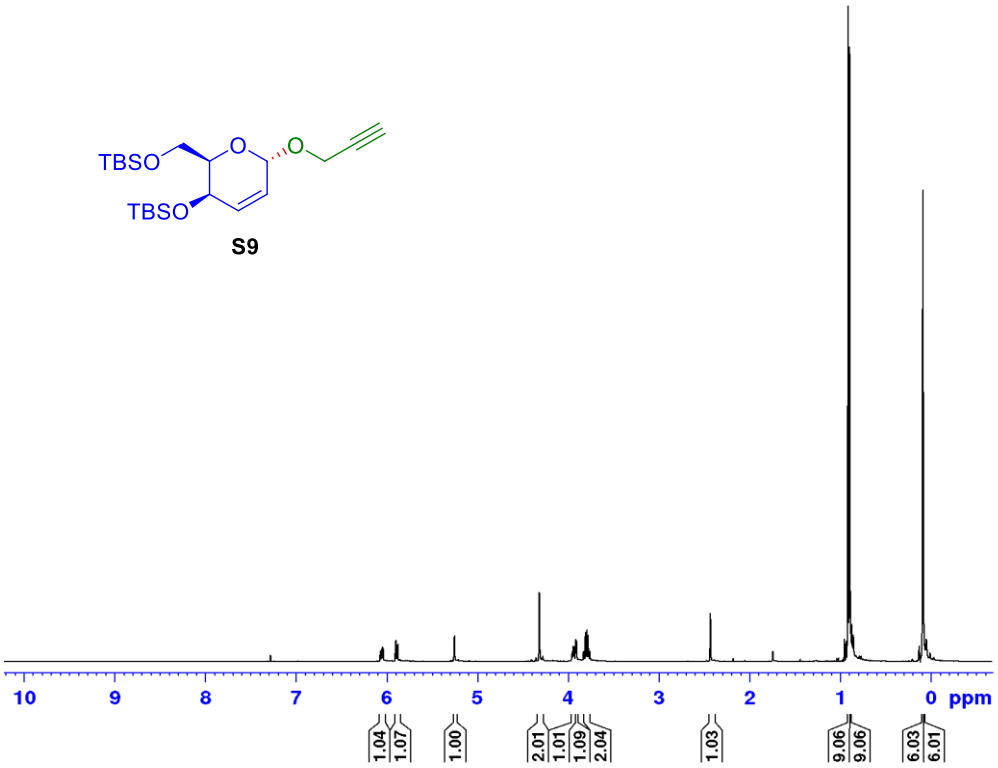




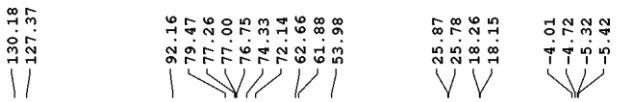
8b

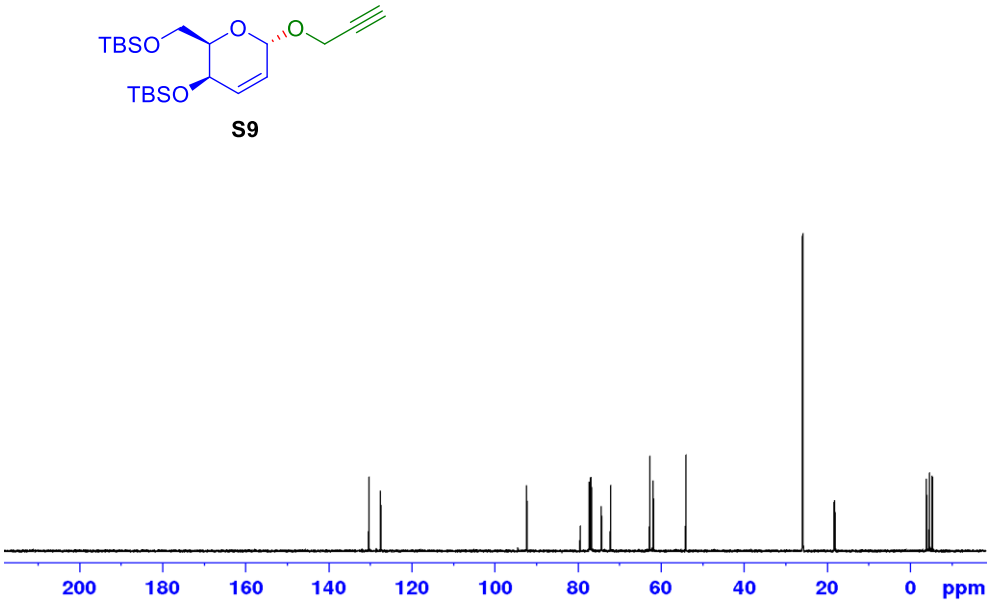



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459227
PROCNO                      1

F2 - Acquisition Parameters
Date_               20190122
Time                   16.04
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      477
DS                        4
SWH               29761.904 Hz
FIDRES             0.454131 Hz
AQ                1.1010048 sec
RG                      2050
DW                  16.800 usec
DE                   6.50 usec
TE                   296.9 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                     13C
P1                     9.60 usec
PL1          0 dB
PL1W           76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                      1H
PCPD2                80.00 usec
PL2                   2.00 dB
PL12                 16.50 dB
PL13                 16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
PL13W           0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF             125.7703615 MHz
WDW                      EM
SSB         0
LB                     1.00 Hz
GB          0
PC                     1.40
```

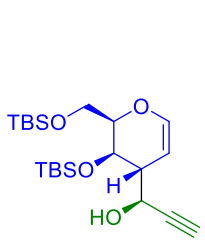



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459219
PROCNO                      1

F2 - Acquisition Parameters
Date_              20190122
Time                  14.46
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG               zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH              10330.578 Hz
FIDRES            0.157632 Hz
AQ               3.1719425 sec
RG                     28.5
DW                  48.400 usec
DE                   6.50 usec
TE                  294.6 K
D1               1.00000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                    1H
P1                   14.90 usec
PL1                   2.00 dB
PL1W           12.85348415 W
SFO1           500.1830888 MHz

F2 - Processing parameters
SI                    32768
SF             500.1800000 MHz
WDW                      EM
SSB          0
LB                    0.30 Hz
GB           0
PC                    1.00
```



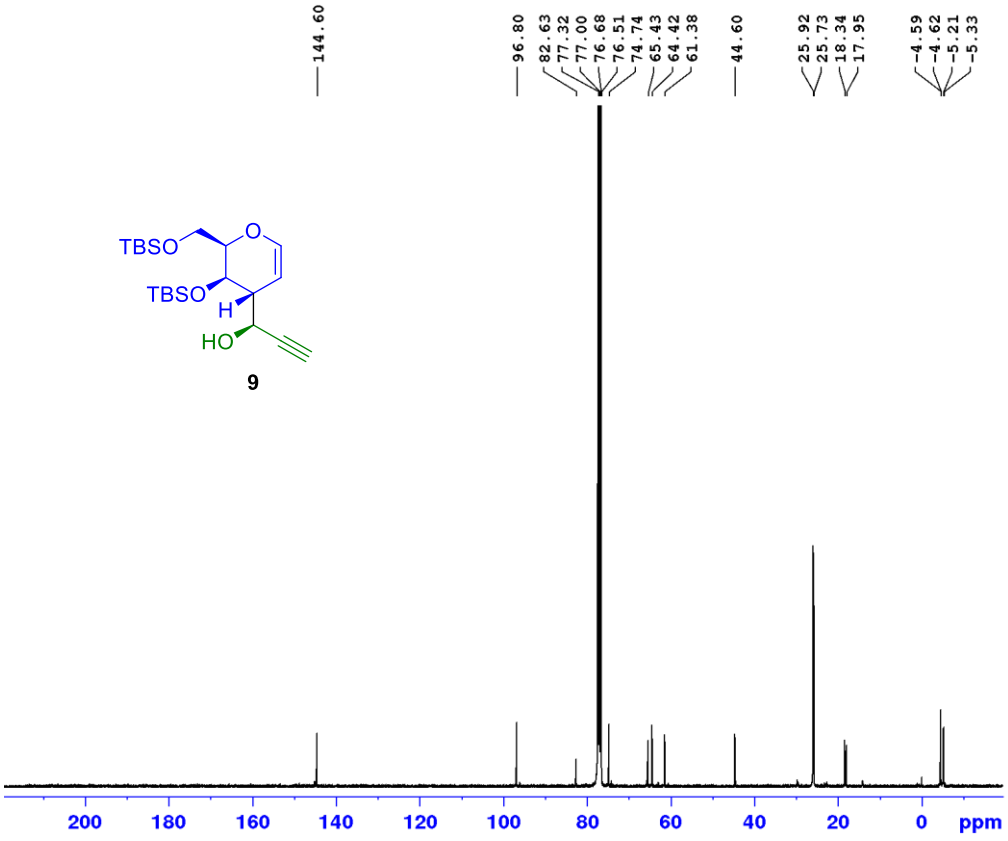



```
Current Data Parameters
NAME                  BUR 500
EXPNO                 1459221
PROCNO                      1

F2 - Acquisition Parameters
Date_              20190122
Time                  15.02
INSTRUM               spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      131
DS                        4
SWH              29761.904 Hz
FIDRES            0.454131 Hz
AQ               1.1010048 sec
RG                     2050
DW                  16.800 usec
DE                   6.50 usec
TE                  295.1 K
D1               2.00000000 sec
D11              0.03000000 sec
TD0                       1

======== CHANNEL f1 ========
NUC1                   13C
P1                    9.60 usec
PL1          0 dB
PL1W           76.36135101 W
SFO1           125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2            waltz16
NUC2                    1H
PCPD2                80.00 usec
PL2                   2.00 dB
PL12                 16.50 dB
PL13                 16.50 dB
PL2W           12.85348415 W
PL12W           0.45605880 W
PL13W           0.45605880 W
SFO2           500.1820007 MHz

F2 - Processing parameters
SI                    32768
SF             125.7703642 MHz
WDW                      EM
SSB          0
LB                    1.00 Hz
GB           0
PC                    1.40
```



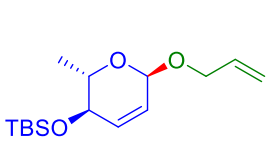
9


```
Current Data Parameters
NAME          BUR PRS 400
EXPNO           12382188
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190413
Time               6.01
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8223.685 Hz
FIDRES         0.125483 Hz
AQ             3.9845889 sec
RG                  256
DW               60.800 usec
DE                6.50 usec
TE                299.7 K
D1            1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                14.90 usec
PL1                1.50 dB
PL1W         15.18650627 W
SFO1         400.0934707 MHz

F2 - Processing parameters
SI                 32768
SF           400.0910000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

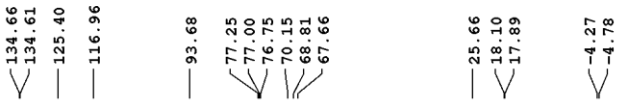


9

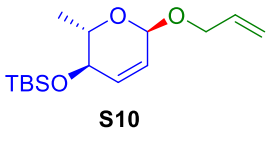
```
Current Data Parameters
NAME          BUR PRS 400
EXPNO           12382190
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190413
Time               23.09
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                14936
DS                    4
SWH           24038.461 Hz
FIDRES         0.366798 Hz
AQ             1.3631488 sec
RG                 2050
DW               20.800 usec
DE                6.50 usec
TE                299.4 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                10.00 usec
PL1                2.00 dB
PL1W         49.44866943 W
SFO1         100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2             90.00 usec
PL2                1.50 dB
PL12              17.18 dB
PL13              20.18 dB
PL2W         15.18650627 W
PL12W         0.41063678 W
PL13W         0.20580591 W
SFO2         400.0926004 MHz

F2 - Processing parameters
SI                 32768
SF           100.6029630 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



S10

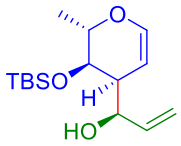



```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               160
PROCNO                1

F2 - Acquisition Parameters
Date_          20200311
Time              11.10 h
INSTRUM            spect
PROBHD   Z125331_0034 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES            0.305176 Hz
AQ             3.2767999 sec
RG                11.34
DW               50.000 usec
DE                6.50 usec
TE               296.9 K
D1            1.00000000 sec
TD0                   1
SFO1          500.3720898 MHz
NUC1                 1H
P1                8.00 usec
PLW1          12.18000031 W

F2 - Processing parameters
SI                65536
SF            500.3690000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



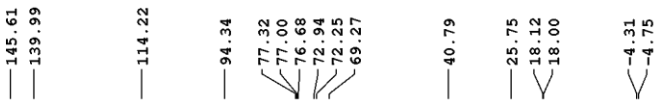
S10

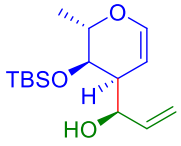

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               162
PROCNO                1

F2 - Acquisition Parameters
Date_          20200311
Time              11.25 h
INSTRUM            spect
PROBHD   Z125331_0034 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  129
DS                    4
SWH           29761.904 Hz
FIDRES            0.908261 Hz
AQ             1.1010048 sec
RG                192.83
DW               16.800 usec
DE                6.50 usec
TE               297.2 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                   1
SFO1          125.8304669 MHz
NUC1                 13C
P1               12.00 usec
PLW1         172.66999817 W
SFO2          500.3710015 MHz
NUC2                 1H
CPDPRG[2          waltz16
PCPD2            80.00 usec
PLW2          12.18000031 W
PLW12          0.12180000 W
PLW13          0.06126500 W

F2 - Processing parameters
SI                32768
SF            125.8178904 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



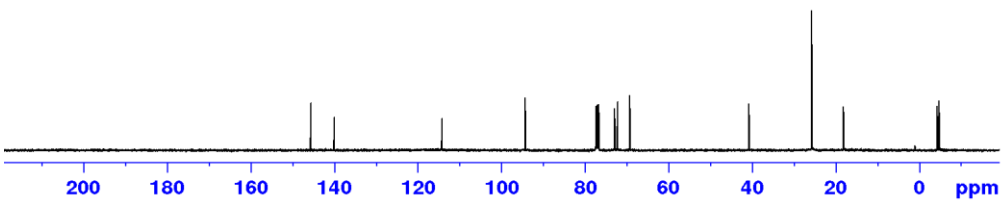
10


```
Current Data Parameters
NAME      BUR student NMR
EXPNO             210411
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190310
Time               9.22
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           8278.146 Hz
FIDRES        0.126314 Hz
AQ            3.9583745 sec
RG                 35.9
DW               60.400 usec
DE                6.50 usec
TE                673.2 K
D1           1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 9.20 usec
PL1               -1.00 dB
PL1W        10.72012138 W
SFO1       400.1324710 MHz

F2 - Processing parameters
SI                 32768
SF          400.1300000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

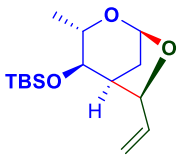




10

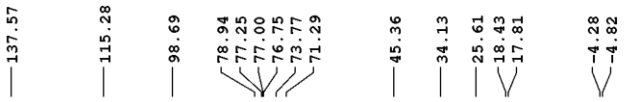


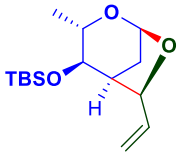

```
Current Data Parameters
NAME      BUR student NMR
EXPNO             210412
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190310
Time               9.28
INSTRUM            spect
PROBHD   5 mm BBI 1H/D-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  598
DS                    4
SWH          23980.814 Hz
FIDRES        0.365918 Hz
AQ            1.3664256 sec
RG                  256
DW               20.850 usec
DE                6.50 usec
TE                673.2 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                30.00 usec
PL1               -4.50 dB
PL1W        94.86473846 W
SFO1       100.6228298 MHz

======== CHANNEL f2 ========
CPDPRG[2         waltz16
NUC2                  1H
PCPD2              90.00 usec
PL2               -1.00 dB
PL12              18.81 dB
PL13             120.00 dB
PL2W        10.72012138 W
PL12W        0.11199529 W
PL13W     0 W
SFO2       400.1316005 MHz

F2 - Processing parameters
SI                 32768
SF          100.6127731 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



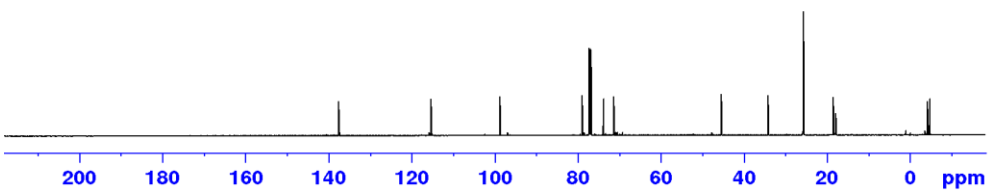
10a


```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               163
PROCNO                1

F2 - Acquisition Parameters
Date_          20200820
Time              15.28 h
INSTRUM             spect
PROBHD   Z119470_0291 (
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH           10000.000 Hz
FIDRES            0.305176 Hz
AQ             3.2767999 sec
RG                 31.25
DW                50.000 usec
DE                 6.50 usec
TE                294.8 K
D1             1.00000000 sec
TD0                    1
SFO1          500.3720898 MHz
NUC1                  1H
P1                10.00 usec
PLW1          23.23100090 W

F2 - Processing parameters
SI                 65536
SF            500.3690000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

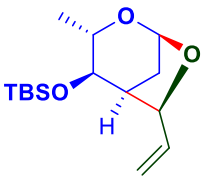




10a

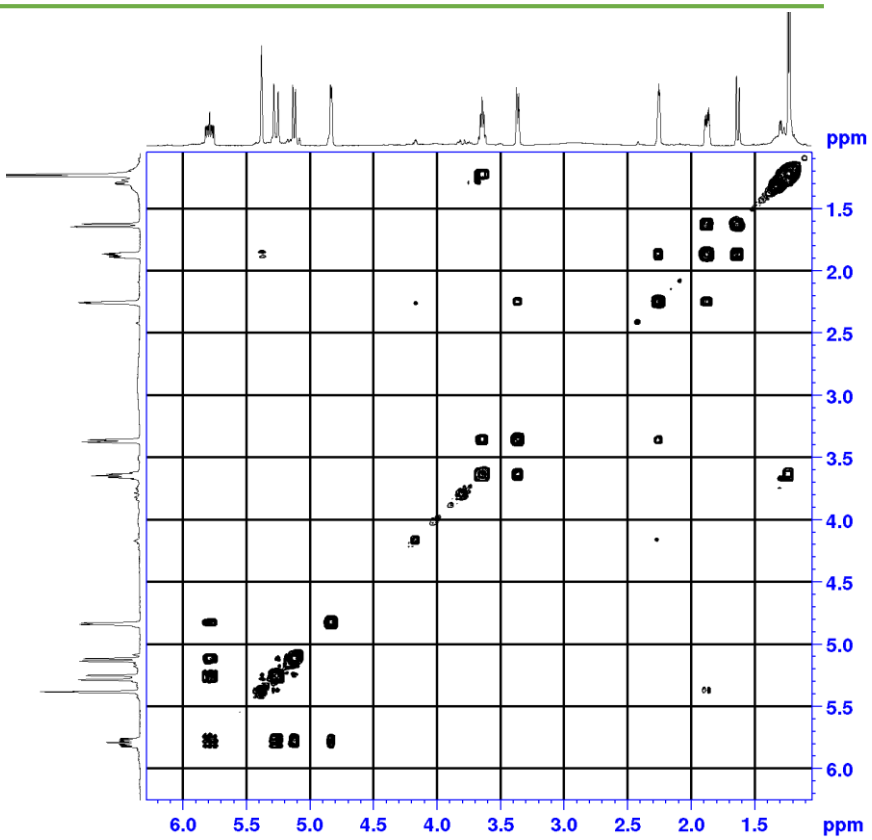


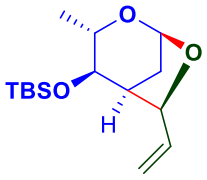

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               165
PROCNO                1

F2 - Acquisition Parameters
Date_          20200820
Time              17.25 h
INSTRUM             spect
PROBHD   Z119470_0291 (
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                  2048
DS                     4
SWH           29761.904 Hz
FIDRES            0.908261 Hz
AQ             1.1010048 sec
RG                192.83
DW                16.800 usec
DE                 6.50 usec
TE                295.9 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1
SFO1          125.8304669 MHz
NUC1                  13C
P1                10.00 usec
PLW1         115.01000214 W
SFO2          500.3710015 MHz
NUC2                  1H
CPDPRG[2          waltz16
PCPD2             80.00 usec
PLW2          23.23100090 W
PLW12          0.36298999 W
PLW13          0.18257999 W

F2 - Processing parameters
SI                 32768
SF            125.8178907 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



10a

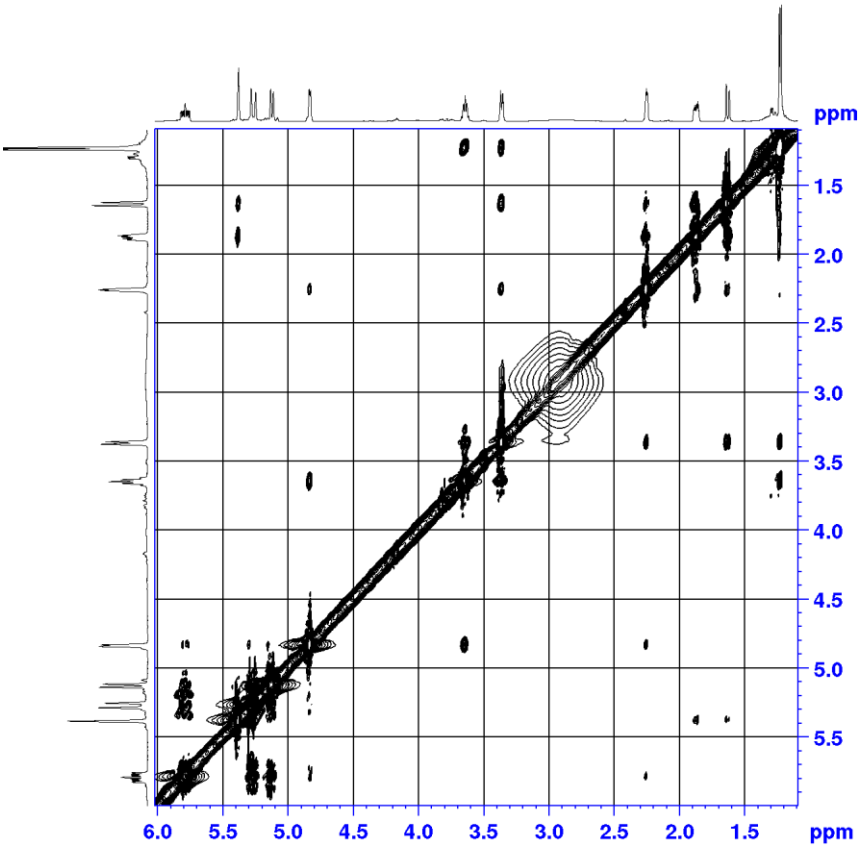
(COSY, 500MHz)

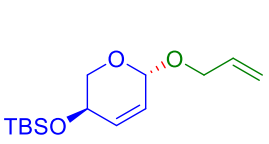




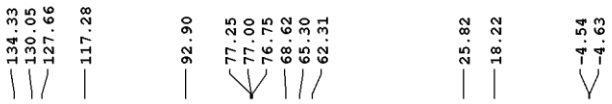
10a

(NOESY, 500MHz)

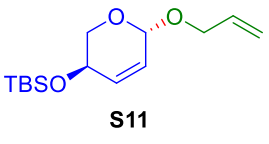




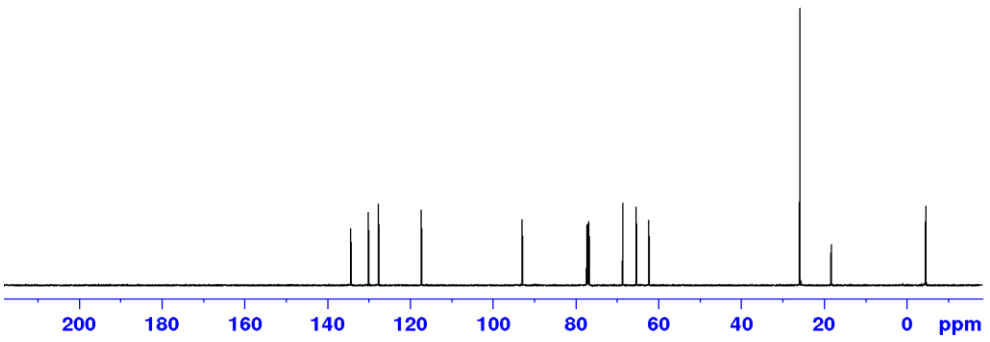
S11



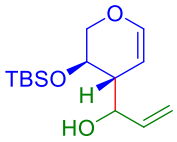

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                41
PROCNO                1

F2 - Acquisition Parameters
Date_          20190211
Time              15.20 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ             3.2767999 sec
RG                31.25
DW               50.000 usec
DE                6.50 usec
TE               298.2 K
D1            1.00000000 sec
TD0                   1
SFO1         500.3720898 MHz
NUC1                 1H
P1                8.00 usec
PLW1         12.18000031 W

F2 - Processing parameters
SI                65536
SF           500.3690000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



S11

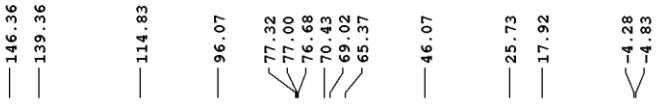


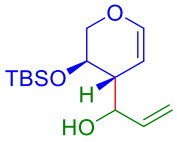

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO                43
PROCNO                1

F2 - Acquisition Parameters
Date_          20190211
Time              15.57 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  430
DS                    4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ             1.1010048 sec
RG                192.83
DW               16.800 usec
DE                6.50 usec
TE               298.1 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                   1
SFO1         125.8304669 MHz
NUC1                 13C
P1               12.00 usec
PLW1        172.66999817 W
SFO2         500.3710015 MHz
NUC2                 1H
CPDPRG[2          waltz16
PCPD2            80.00 usec
PLW2         12.18000031 W
PLW12         0.12180000 W
PLW13         0.06126500 W

F2 - Processing parameters
SI                32768
SF           125.8178924 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



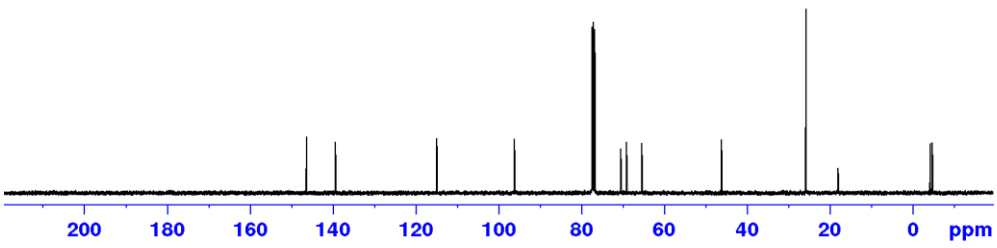
11a


```
Current Data Parameters
NAME          BUR PRS 500
EXPNO            1459234
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190206
Time               17.24
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG            zg30
TD                65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH           10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1719425 sec
RG                   144
DW                48.400 usec
DE                 6.50 usec
TE                295.6 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 14.90 usec
PL1                 2.00 dB
PL1W         12.85348415 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF           500.1800000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

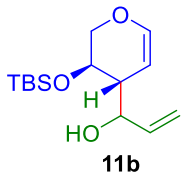




11a

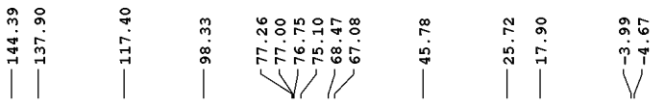


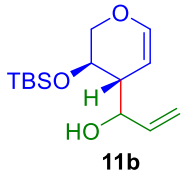

```
Current Data Parameters
NAME          BUR PRS 400
EXPNO            12382161
PROCNO                 1

F2 - Acquisition Parameters
Date_           20190209
Time               6.20
INSTRUM            spect
PROBHD   5 mm PABBO BB-
PULPROG          zgpg30
TD                65536
SOLVENT            CDCl3
NS                   543
DS                     4
SWH           24038.461 Hz
FIDRES         0.366798 Hz
AQ             1.3631488 sec
RG                  25.4
DW                20.800 usec
DE                 6.50 usec
TE                297.6 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                10.00 usec
PL1                2.00 dB
PL1W         49.44866943 W
SFO1         100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2         waltz16
NUC2                  1H
PCPD2              90.00 usec
PL2                1.50 dB
PL12              17.18 dB
PL13              20.18 dB
PL2W         15.18650627 W
PL12W         0.41063678 W
PL13W         0.20580591 W
SFO2         400.0926004 MHz

F2 - Processing parameters
SI                 32768
SF           100.6029640 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



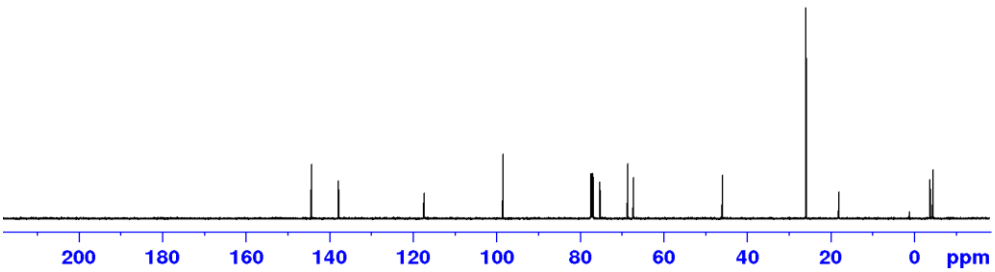
11b


```
Current Data Parameters
NAME         BUR PRS 500
EXPNO           1459228
PROCNO                1

F2 - Acquisition Parameters
Date_          20190204
Time              16.51
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG           zg30
TD               65536
SOLVENT          CDCl3
NS                  16
DS                   2
SWH          10330.578 Hz
FIDRES        0.157632 Hz
AQ           3.1719425 sec
RG                45.2
DW              48.400 usec
DE               6.50 usec
TE              295.8 K
D1           1.00000000 sec
TD0                  1

======== CHANNEL f1 ========
NUC1                1H
P1               14.90 usec
PL1               2.00 dB
PL1W        12.85348415 W
SFO1       500.1830888 MHz

F2 - Processing parameters
SI                32768
SF         500.1800000 MHz
WDW                  EM
SSB       0
LB               0.30 Hz
GB        0
PC               1.00
```

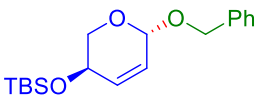




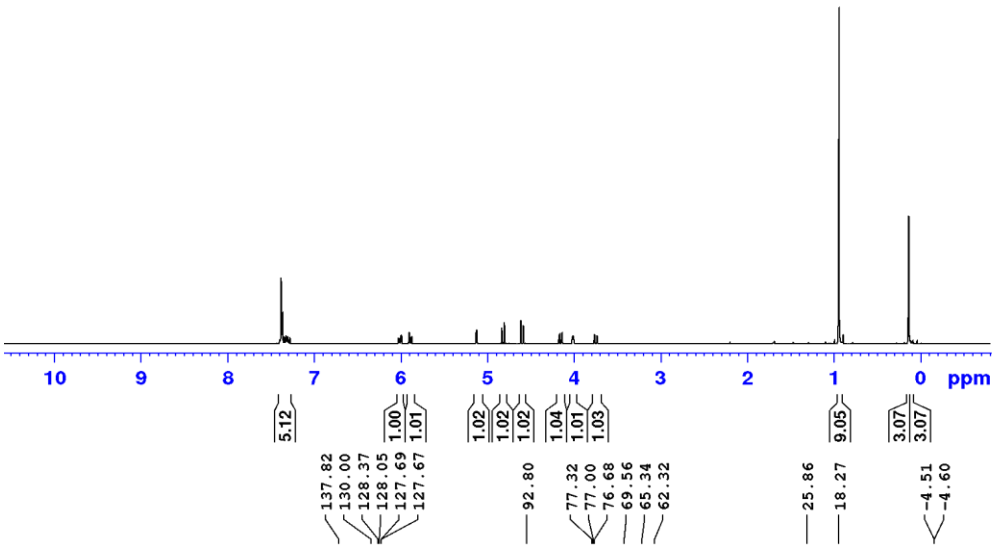
11b




```
Current Data Parameters
NAME         BUR PRS 500
EXPNO           1459230
PROCNO                1

F2 - Acquisition Parameters
Date_          20190204
Time              17.06
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG          zgpg30
TD               65536
SOLVENT          CDCl3
NS                 151
DS                   4
SWH          29761.904 Hz
FIDRES        0.454131 Hz
AQ           1.1010048 sec
RG                2050
DW              16.800 usec
DE               6.50 usec
TE              297.3 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                  1

======== CHANNEL f1 ========
NUC1                13C
P1               9.60 usec
PL1       0 dB
PL1W        76.36135101 W
SFO1       125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                1H
PCPD2            80.00 usec
PL2               2.00 dB
PL12             16.50 dB
PL13             16.50 dB
PL2W        12.85348415 W
PL12W        0.45605880 W
PL13W        0.45605880 W
SFO2       500.1820007 MHz

F2 - Processing parameters
SI                32768
SF         125.7703636 MHz
WDW                  EM
SSB       0
LB               1.00 Hz
GB        0
PC               1.40
```

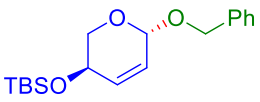


S12

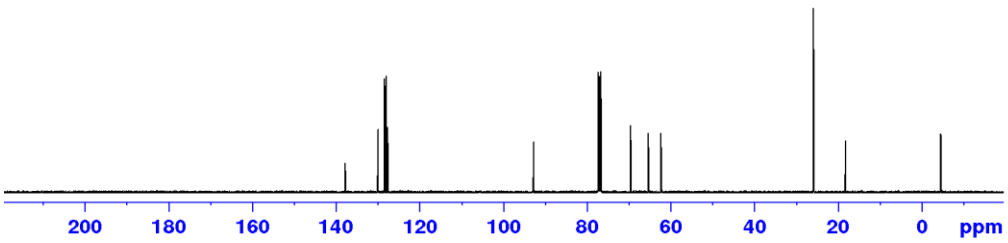


BRUKER

```
Current Data Parameters
NAME                  BUR 400
EXPNO                12382185
PROCNO                      1

F2 - Acquisition Parameters
Date_                20190411
Time                     4.51
INSTRUM                 spect
PROBHD    5 mm PABBO BB-
PULPROG                 zg30
TD                     65536
SOLVENT                CDCl3
NS                        16
DS                         2
SWH                 8223.685 Hz
FIDRES              0.125483 Hz
AQ                  3.9845889 sec
RG                       71.8
DW                     60.800 usec
DE                      6.50 usec
TE                     295.8 K
D1                1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     1.50 dB
PL1W             15.18650627 W
SFO1             400.0934707 MHz

F2 - Processing parameters
SI                     32768
SF               400.0910000 MHz
WDW                       EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```

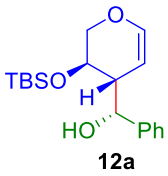


S12

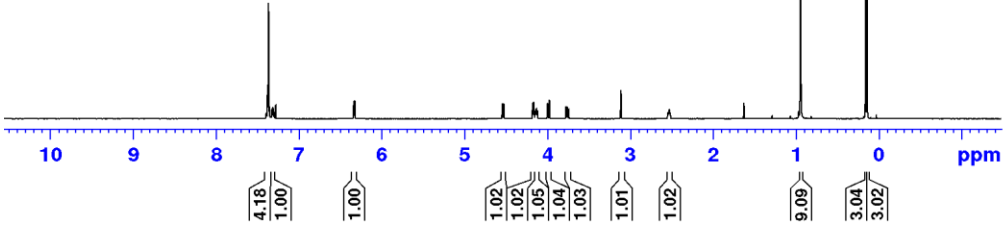


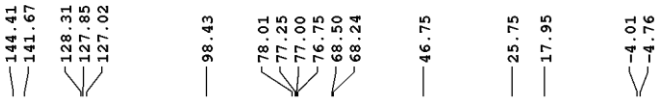
BRUKER

```
Current Data Parameters
NAME                  BUR 400
EXPNO                12382187
PROCNO                      1

F2 - Acquisition Parameters
Date_                20190411
Time                     5.06
INSTRUM                 spect
PROBHD    5 mm PABBO BB-
PULPROG                zgpg30
TD                     65536
SOLVENT                CDCl3
NS                       256
DS                         4
SWH                24038.461 Hz
FIDRES              0.366798 Hz
AQ                  1.3631488 sec
RG                      2050
DW                     20.800 usec
DE                      6.50 usec
TE                     296.5 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W             49.44866943 W
SFO1             100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2              waltz16
NUC2                      1H
PCPD2                  90.00 usec
PL2                     1.50 dB
PL12                   17.18 dB
PL13                   20.18 dB
PL2W             15.18650627 W
PL12W             0.41063678 W
PL13W             0.20580591 W
SFO2             400.0926004 MHz

F2 - Processing parameters
SI                     32768
SF               100.6029680 MHz
WDW                       EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```



12a

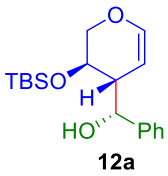




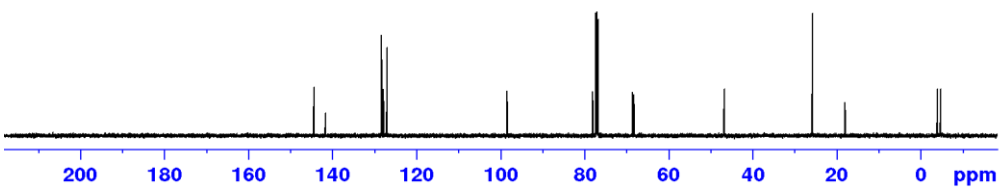
Current Data Parameters
NAME BUR PRS ASCEND 500
EXPNO 32
PROCNO 1

F2 - Acquisition Parameters
Date_ 20190207
Time 16.42 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 10000.000 Hz
FIDRES 0.305176 Hz
AQ 3.2767999 sec
RG 76.68
DW 50.000 usec
DE 6.50 usec
TE 298.1 K
D1 1.00000000 sec
TD0 1
SFO1 500.3720898 MHz
NUC1 1H
P1 8.00 usec
PLW1 12.18000031 W

F2 - Processing parameters
SI 65536
SF 500.3690000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



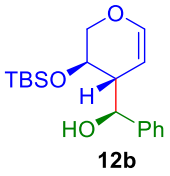
12a



Current Data Parameters
NAME BUR PRS ASCEND 500
EXPNO 34
PROCNO 1

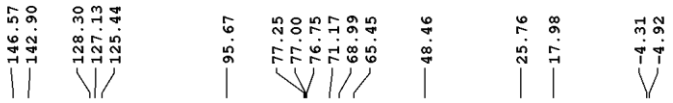
F2 - Acquisition Parameters
Date_ 20190207
Time 16.55 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 180
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 192.83
DW 16.800 usec
DE 6.50 usec
TE 298.1 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 125.8304669 MHz
NUC1 13C
P1 12.00 usec
PLW1 172.66999817 W
SFO2 500.3710015 MHz
NUC2 1H
CPDPRG[2 waltz16
PCPD2 80.00 usec
PLW2 12.18000031 W
PLW12 0.12180000 W
PLW13 0.06126500 W

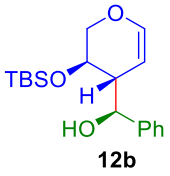
F2 - Processing parameters
SI 32768
SF 125.8178900 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



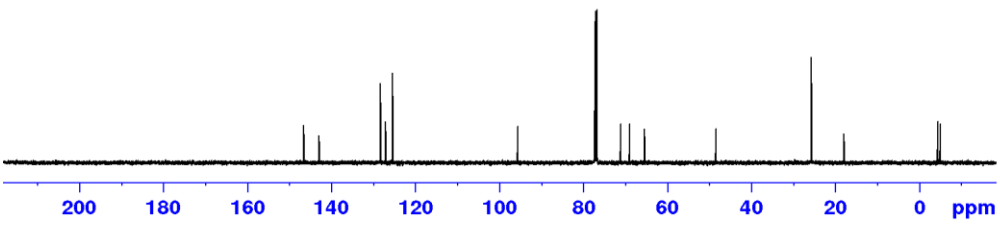
12b


```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                  35
PROCNO                  1

F2 - Acquisition Parameters
Date_              20190207
Time                 17.04 h
INSTRUM              spect
PROBHD    Z125331_0034 (
PULPROG              zg30
TD                  65536
SOLVENT              CDCl3
NS                     16
DS                      2
SWH             10000.000 Hz
FIDRES              0.305176 Hz
AQ                3.2767999 sec
RG                     95.6
DW                  50.000 usec
DE                   6.50 usec
TE                  298.2 K
D1              1.00000000 sec
TD0                     1
SFO1           500.3720898 MHz
NUC1                   1H
P1                   8.00 usec
PLW1           12.18000031 W

F2 - Processing parameters
SI                  65536
SF             500.3690000 MHz
WDW                    EM
SSB       0
LB                   0.30 Hz
GB        0
PC                   1.00
```

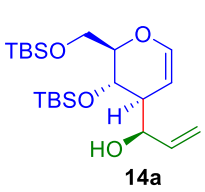




12b

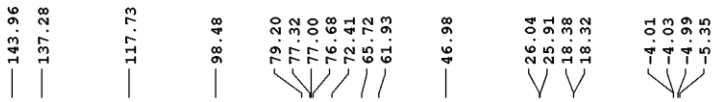


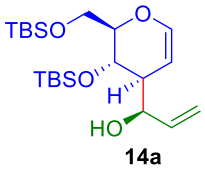

```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                  37
PROCNO                  1

F2 - Acquisition Parameters
Date_              20190207
Time                 17.25 h
INSTRUM              spect
PROBHD    Z125331_0034 (
PULPROG            zgpg30
TD                  65536
SOLVENT              CDCl3
NS                    262
DS                      4
SWH            29761.904 Hz
FIDRES              0.908261 Hz
AQ                1.1010048 sec
RG                    192.83
DW                  16.800 usec
DE                   6.50 usec
TE                  298.1 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                     1
SFO1           125.8304669 MHz
NUC1                   13C
P1                  12.00 usec
PLW1           172.66999817 W
SFO2           500.3710015 MHz
NUC2                   1H
CPDPRG[2           waltz16
PCPD2               80.00 usec
PLW2           12.18000031 W
PLW12           0.12180000 W
PLW13           0.06126500 W

F2 - Processing parameters
SI                  32768
SF             125.8178895 MHz
WDW                    EM
SSB       0
LB                   1.00 Hz
GB        0
PC                   1.40
```



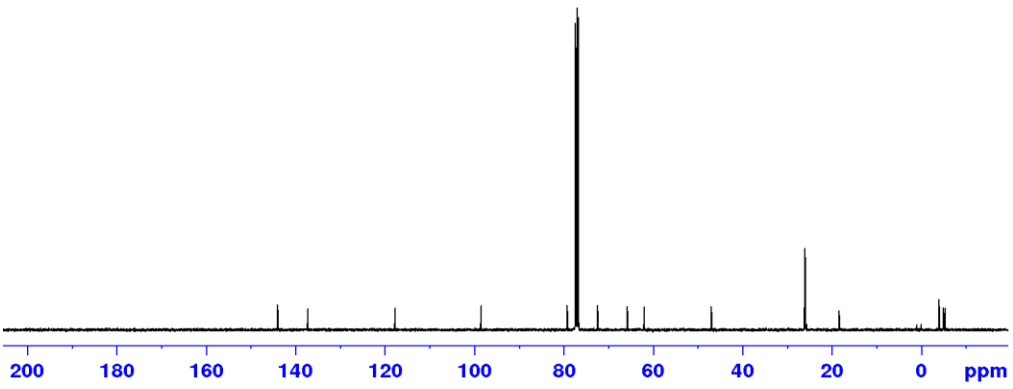
14a


```
Current Data Parameters
NAME      BUR PRS UPDATED 400
EXPNO                   20
PROCNO                   1

F2 - Acquisition Parameters
Date_           20200818
Time              10.29 h
INSTRUM             spect
PROBHD   Z108618_0098 (
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH             8012.820 Hz
FIDRES          0.244532 Hz
AQ              4.0894465 sec
RG                   228
DW                62.400 usec
DE                16.93 usec
TE                299.6 K
D1             1.00000000 sec
TD0                    1
SFO1          400.0934706 MHz
NUC1                  1H
P0                 4.97 usec
P1                14.90 usec
PLW1          15.18599987 W

F2 - Processing parameters
SI                 65536
SF            400.0910000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

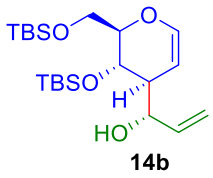




14a

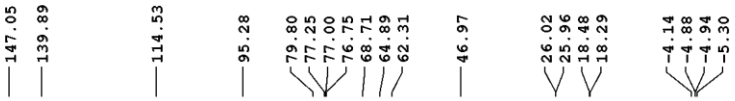


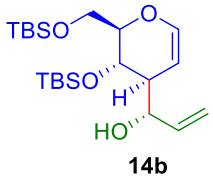

```
Current Data Parameters
NAME      BUR PRS UPDATED 400
EXPNO                   78
PROCNO                   1

F2 - Acquisition Parameters
Date_           20201125
Time              12.27 h
INSTRUM             spect
PROBHD   Z108618_0098 (
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                  1388
DS                     4
SWH            24038.461 Hz
FIDRES          0.733596 Hz
AQ              1.3631488 sec
RG                   203
DW                20.800 usec
DE                 6.50 usec
TE                311.7 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1
SFO1          100.6130223 MHz
NUC1                 13C
P0                 3.33 usec
P1                10.00 usec
PLW1          49.43999863 W
SFO2          400.0926004 MHz
NUC2                  1H
CPDPRG[2          waltz65
PCPD2             90.00 usec
PLW2          15.18599987 W
PLW12          0.41622999 W
PLW13          0.20936000 W

F2 - Processing parameters
SI                 32768
SF            100.6029623 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



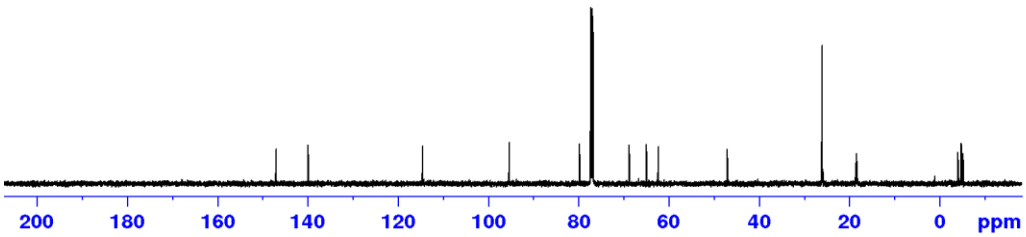
14b


```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                 100
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191028
Time              15.28 h
INSTRUM             spect
PROBHD   Z125331_0034 (
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ             3.2767999 sec
RG                54.81
DW                50.000 usec
DE                 6.50 usec
TE                294.8 K
D1            1.00000000 sec
TD0                    1
SFO1          500.3720898 MHz
NUC1                  1H
P1                 8.00 usec
PLW1         12.18000031 W

F2 - Processing parameters
SI                 65536
SF           500.3690022 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

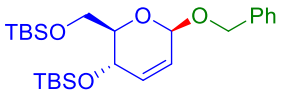




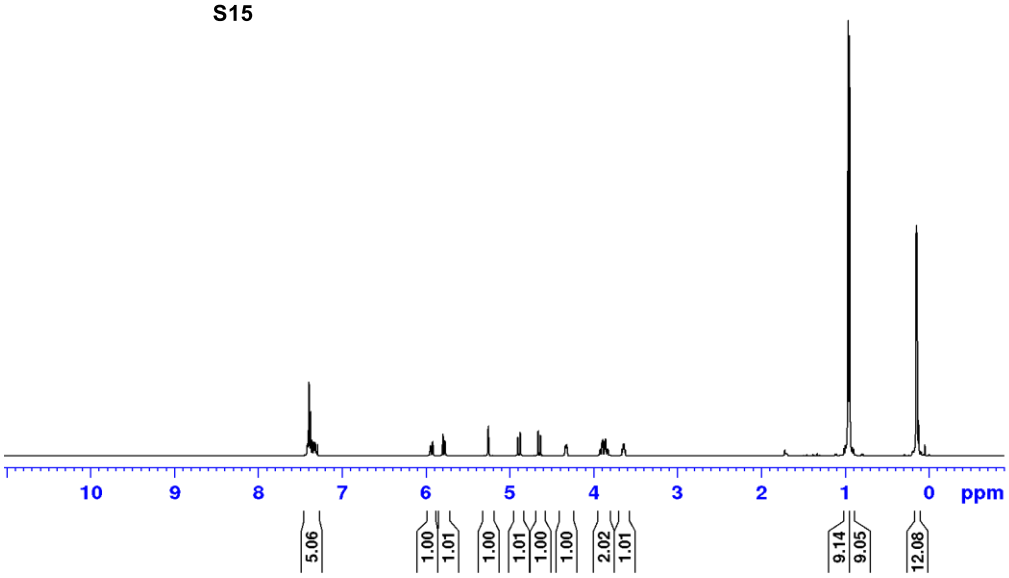
14b

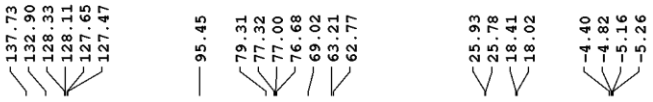



```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                 102
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191028
Time              15.58 h
INSTRUM             spect
PROBHD   Z125331_0034 (
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   295
DS                     4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ             1.1010048 sec
RG                192.83
DW                16.800 usec
DE                 6.50 usec
TE                295.2 K
D1            2.00000000 sec
D11           0.03000000 sec
TD0                    1
SFO1          125.8304669 MHz
NUC1                 13C
P1                12.00 usec
PLW1        172.66999817 W
SFO2          500.3710015 MHz
NUC2                  1H
CPDPRG[2          waltz16
PCPD2             80.00 usec
PLW2         12.18000031 W
PLW12         0.12180000 W
PLW13         0.06126500 W

F2 - Processing parameters
SI                 32768
SF           125.8178891 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



S15

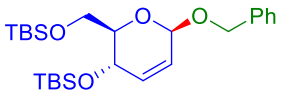




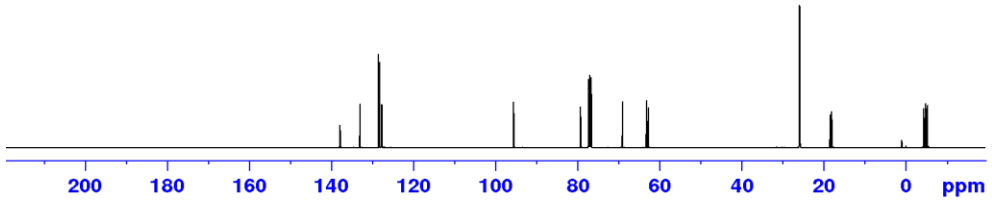
Current Data Parameters
NAME BUR PRS UPDATED 400
EXPNO 47
PROCNO 1

F2 - Acquisition Parameters
Date_ 20200828
Time 19.17 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.244532 Hz
AQ 4.0894465 sec
RG 64
DW 62.400 usec
DE 16.93 usec
TE 295.0 K
D1 1.00000000 sec
TD0 1
SFO1 400.0934706 MHz
NUC1 1H
P0 4.97 usec
P1 14.90 usec
PLW1 15.18599987 W

F2 - Processing parameters
SI 65536
SF 400.0910000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



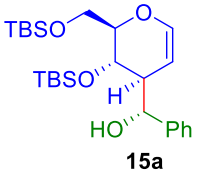
S15



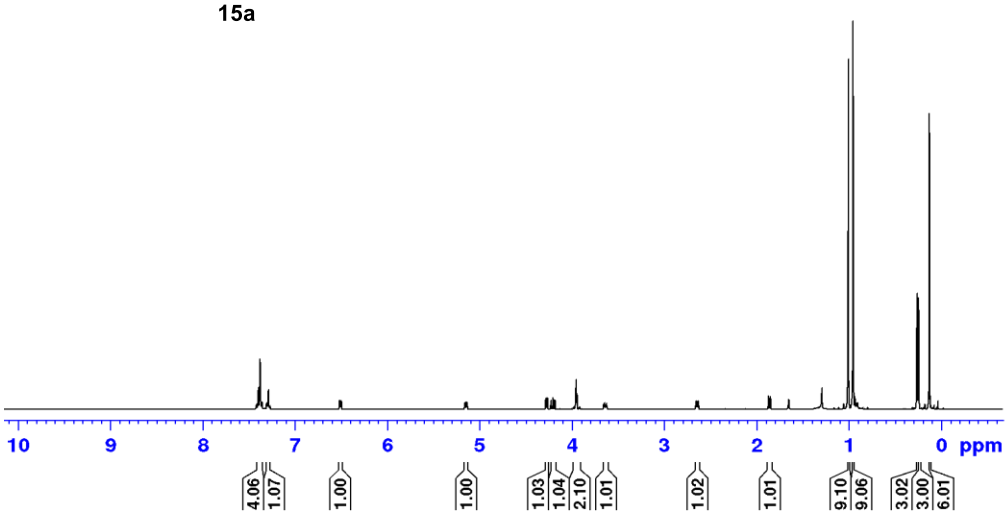
Current Data Parameters
NAME BUR PRS UPDATED 400
EXPNO 53
PROCNO 1

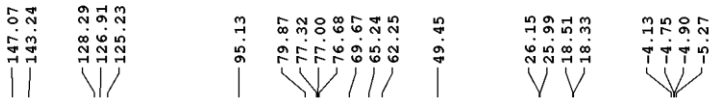
F2 - Acquisition Parameters
Date_ 20200829
Time 9.26 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 14009
DS 4
SWH 24038.461 Hz
FIDRES 0.733596 Hz
AQ 1.3631488 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 294.9 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 100.6130223 MHz
NUC1 13C
P0 3.33 usec
P1 10.00 usec
PLW1 49.43999863 W
SFO2 400.0926004 MHz
NUC2 1H
CPDPRG[2 waltz65
PCPD2 90.00 usec
PLW2 15.18599987 W
PLW12 0.41622999 W
PLW13 0.20936000 W

F2 - Processing parameters
SI 32768
SF 100.6029682 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



15a

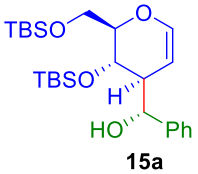




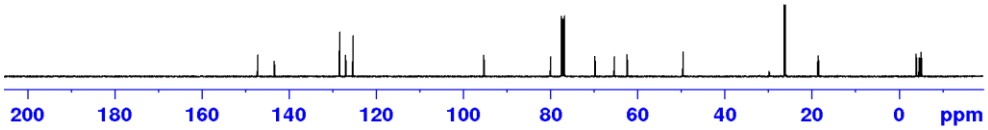
Current Data Parameters
NAME Drisya updated 400
EXPNO 4
PROCNO 1

F2 - Acquisition Parameters
Date_ 20201113
Time 17.41 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.244532 Hz
AQ 4.0894465 sec
RG 90.5
DW 62.400 usec
DE 16.93 usec
TE 308.9 K
D1 1.00000000 sec
TD0 1
SFO1 400.0934706 MHz
NUC1 1H
P0 4.97 usec
P1 14.90 usec
PLW1 15.18599987 W

F2 - Processing parameters
SI 65536
SF 400.0910000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



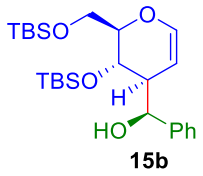
15a



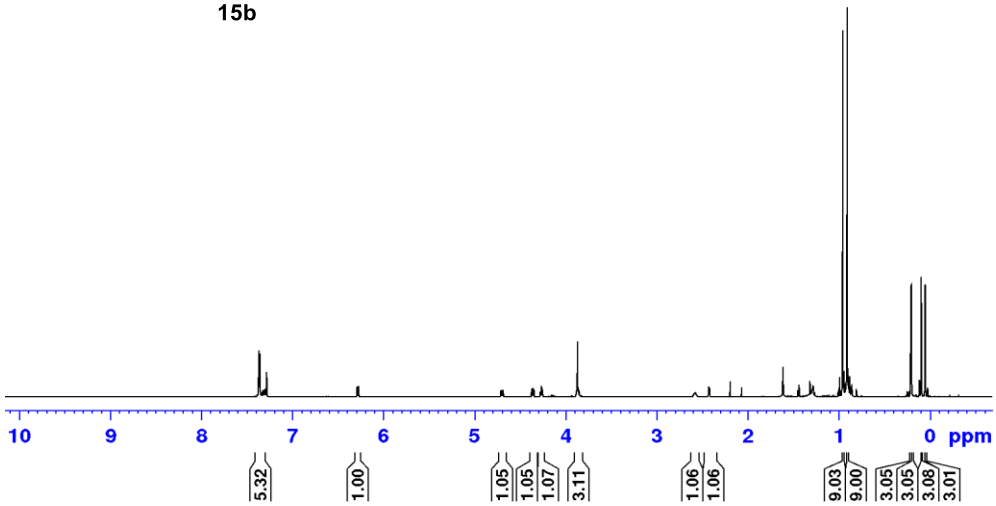
Current Data Parameters
NAME Drisya updated 400
EXPNO 6
PROCNO 1

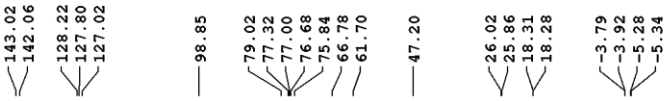
F2 - Acquisition Parameters
Date_ 20201116
Time 11.20 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 334
DS 4
SWH 24038.461 Hz
FIDRES 0.733596 Hz
AQ 1.3631488 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 310.7 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 100.6130223 MHz
NUC1 13C
P0 3.33 usec
P1 10.00 usec
PLW1 49.43999863 W
SFO2 400.0926004 MHz
NUC2 1H
CPDPRG[2 waltz65
PCPD2 90.00 usec
PLW2 15.18599987 W
PLW12 0.41622999 W
PLW13 0.20936000 W

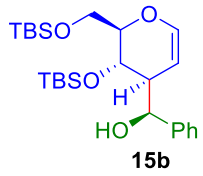
F2 - Processing parameters
SI 32768
SF 100.6029643 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40



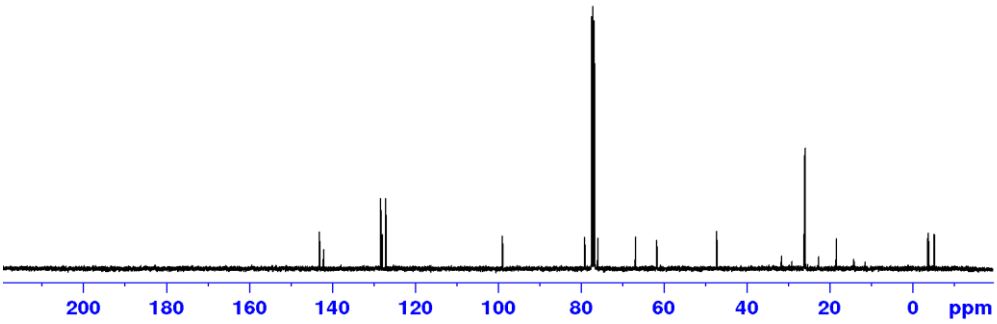
15b





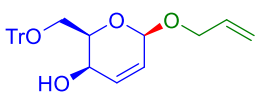


15b

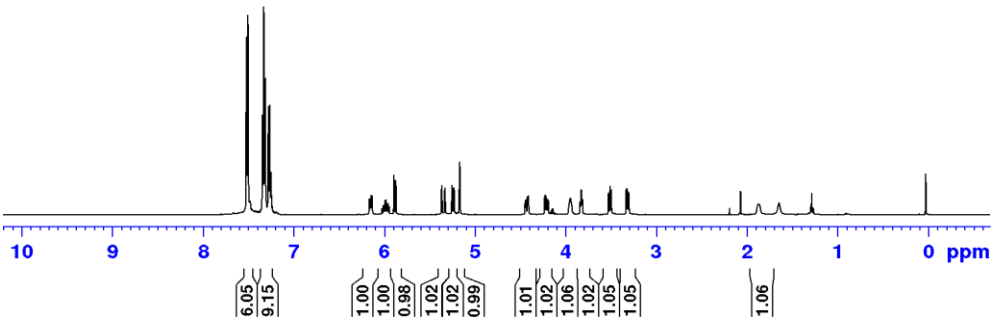


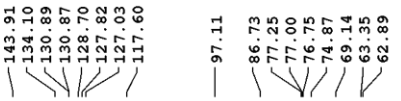

```
Current Data Parameters
NAME         BUR PRS 400
EXPNO          12382230
PROCNO                1

F2 - Acquisition Parameters
Date_          20191113
Time              16.30
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH            8223.685 Hz
FIDRES         0.125483 Hz
AQ             3.9845889 sec
RG                  181
DW                60.800 usec
DE                 6.50 usec
TE                296.7 K
D1             1.00000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                 1H
P1                14.90 usec
PL1                1.50 dB
PL1W         15.18650627 W
SFO1         400.0934707 MHz

F2 - Processing parameters
SI                32768
SF          400.0910000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```

```
Current Data Parameters
NAME         BUR PRS 400
EXPNO          12382232
PROCNO                1

F2 - Acquisition Parameters
Date_          20191113
Time              16.51
INSTRUM           spect
PROBHD   5 mm PABBO BB-
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  287
DS                    4
SWH           24038.461 Hz
FIDRES         0.366798 Hz
AQ             1.3631488 sec
RG                 2050
DW                20.800 usec
DE                 6.50 usec
TE                297.8 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                13C
P1                10.00 usec
PL1                2.00 dB
PL1W         49.44866943 W
SFO1         100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                 1H
PCPD2             90.00 usec
PL2                1.50 dB
PL12              17.18 dB
PL13              20.18 dB
PL2W         15.18650627 W
PL12W         0.41063678 W
PL13W         0.20580591 W
SFO2         400.0926004 MHz

F2 - Processing parameters
SI                32768
SF          100.6029640 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```

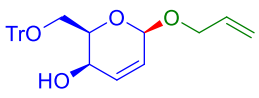


SS16

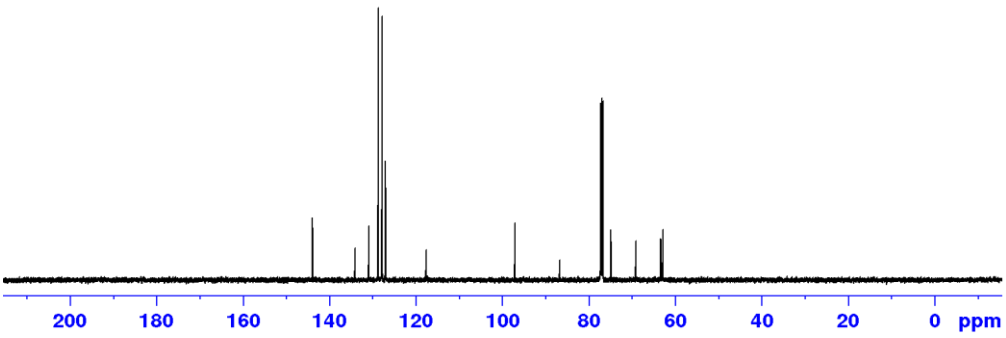




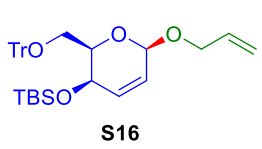

```
EXPNO                1459306
PROCNO                     1

F2 - Acquisition Parameters
Date_              20200103
Time                 16.27
INSTRUM              spect
PROBHD    5 mm PABBO BB-
PULPROG              zg30
TD                  65536
SOLVENT             CDCl3
NS                     16
DS                      2
SWH            10330.578 Hz
FIDRES          0.157632 Hz
AQ             3.1719425 sec
RG                    181
DW                48.400 usec
DE                 6.50 usec
TE                297.1 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                14.90 usec
PL1                2.00 dB
PL1W         12.85348415 W
SFO1         500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF           500.1800000 MHz
WDW                   EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```



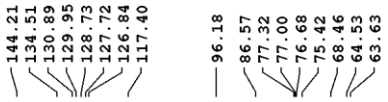
SS16




```
Current Data Parameters
NAME              BUR 500
EXPNO             1459308
PROCNO                  1

F2 - Acquisition Parameters
Date_              20200103
Time                 16.41
INSTRUM              spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                  65536
SOLVENT             CDCl3
NS                    304
DS                      4
SWH            29761.904 Hz
FIDRES          0.454131 Hz
AQ             1.1010048 sec
RG                   2050
DW                16.800 usec
DE                 6.50 usec
TE                298.9 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                 9.60 usec
PL1       0 dB
PL1W         76.36135101 W
SFO1         125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2              80.00 usec
PL2                2.00 dB
PL12              16.50 dB
PL13              16.50 dB
PL2W         12.85348415 W
PL12W         0.45605880 W
PL13W         0.45605880 W
SFO2         500.1820007 MHz

F2 - Processing parameters
SI                 32768
SF           125.7703632 MHz
WDW                   EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```



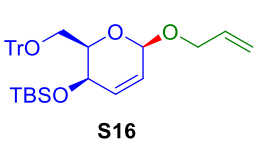
S16



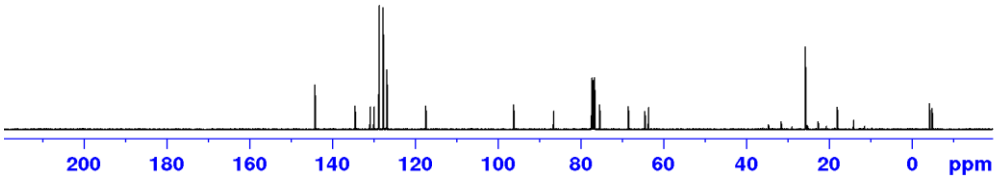
Current Data Parameters
NAME BUR PRS 400 NEW
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters
Date_ 20191224
Time 16.13 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 16
DS 2
SWH 8012.820 Hz
FIDRES 0.244532 Hz
AQ 4.0894465 sec
RG 71.8
DW 62.400 usec
DE 16.93 usec
TE 293.8 K
D1 1.00000000 sec
TD0 1
SFO1 400.0934706 MHz
NUC1 1H
P0 4.97 usec
P1 14.90 usec
PLW1 15.18599987 W

F2 - Processing parameters
SI 65536
SF 400.0910000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00



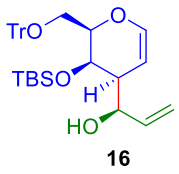
S16



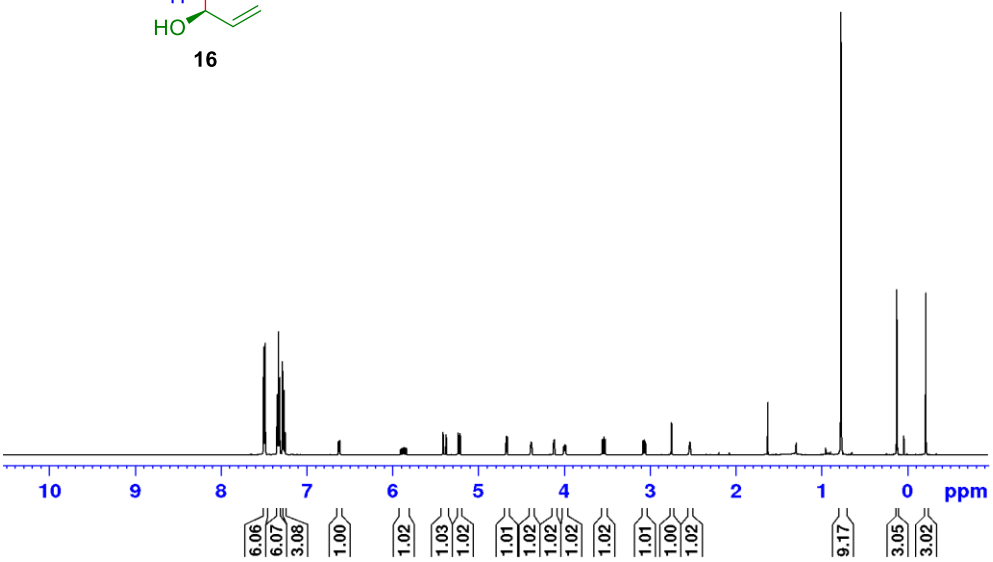
Current Data Parameters
NAME BUR PRS 400 NEW
EXPNO 3
PROCNO 1

F2 - Acquisition Parameters
Date_ 20191224
Time 16.32 h
INSTRUM spect
PROBHD Z108618_0098 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 132
DS 4
SWH 24038.461 Hz
FIDRES 0.733596 Hz
AQ 1.3631488 sec
RG 203
DW 20.800 usec
DE 6.50 usec
TE 294.7 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 100.6130223 MHz
NUC1 13C
P0 3.33 usec
P1 10.00 usec
PLW1 49.43999863 W
SFO2 400.0926004 MHz
NUC2 1H
CPDPRG[2 waltz65
PCPD2 90.00 usec
PLW2 15.18599987 W
PLW12 0.41622999 W
PLW13 0.20936000 W

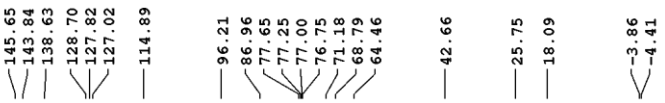
F2 - Processing parameters
SI 32768
SF 100.6029701 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40

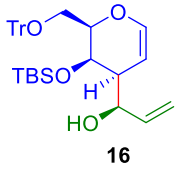


16

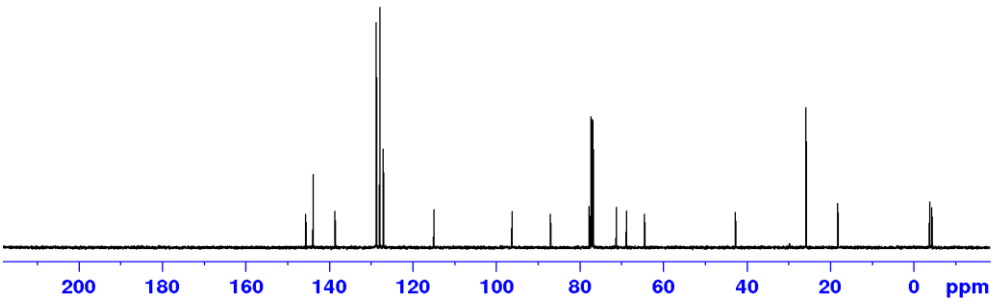



```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                 109
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191226
Time              15.05 h
INSTRUM             spect
PROBHD    Z125331_0034 (
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH           10000.000 Hz
FIDRES            0.305176 Hz
AQ                3.2767999 sec
RG                   31.25
DW                 50.000 usec
DE                  6.50 usec
TE                 298.2 K
D1              1.00000000 sec
TD0                    1
SFO1           500.3720898 MHz
NUC1                  1H
P1                  8.00 usec
PLW1           12.18000031 W

F2 - Processing parameters
SI                 65536
SF            500.3690000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

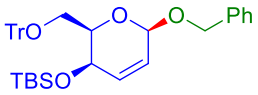




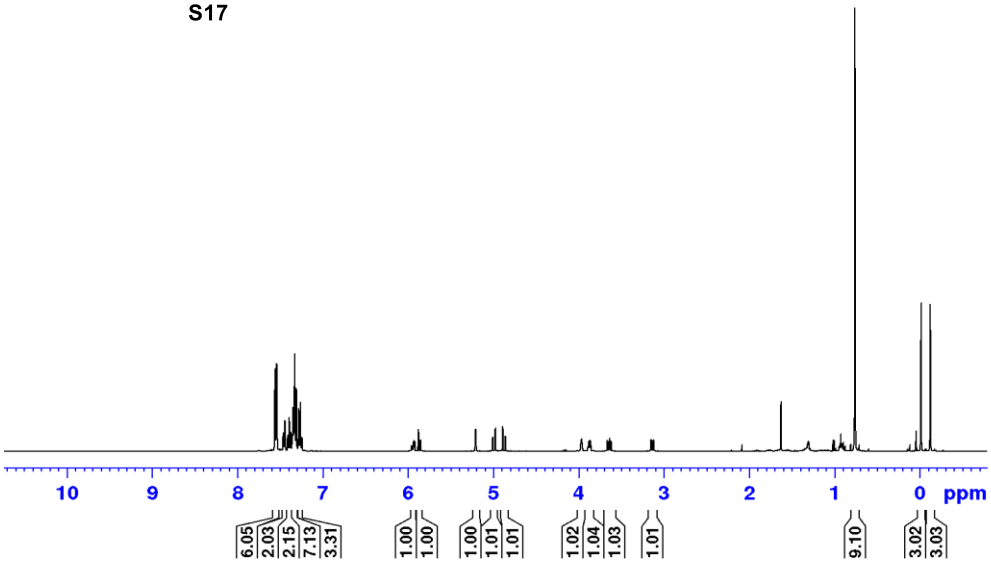
16



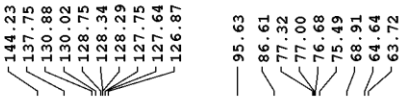

```
Current Data Parameters
NAME      BUR PRS ASCEND 500
EXPNO                 111
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191226
Time              15.33 h
INSTRUM             spect
PROBHD    Z125331_0034 (
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   378
DS                     4
SWH           29761.904 Hz
FIDRES            0.908261 Hz
AQ                1.1010048 sec
RG                 192.83
DW                 16.800 usec
DE                  6.50 usec
TE                 298.2 K
D1              2.00000000 sec
D11             0.03000000 sec
TD0                    1
SFO1           125.8304669 MHz
NUC1                  13C
P1                 12.00 usec
PLW1          172.66999817 W
SFO2           500.3710015 MHz
NUC2                  1H
CPDPRG[2          waltz16
PCPD2              80.00 usec
PLW2           12.18000031 W
PLW12           0.12180000 W
PLW13           0.06126500 W

F2 - Processing parameters
SI                 32768
SF            125.8178917 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```

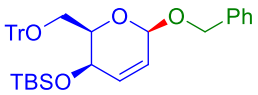


S17

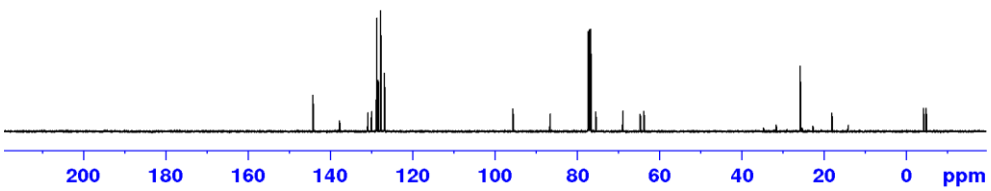



```
Current Data Parameters
NAME      BUR PRS 400 NEW
EXPNO                   4
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191224
Time              16.36 h
INSTRUM            spect
PROBHD    Z108618_0098 (
PULPROG             zg30
TD                 65536
SOLVENT            CDC13
NS                    16
DS                     2
SWH             8012.820 Hz
FIDRES          0.244532 Hz
AQ              4.0894465 sec
RG                   128
DW                62.400 usec
DE                16.93 usec
TE                293.7 K
D1             1.00000000 sec
TD0                    1
SFO1          400.0934706 MHz
NUC1                  1H
P0                 4.97 usec
P1                14.90 usec
PLW1          15.18599987 W

F2 - Processing parameters
SI                 65536
SF            400.0910000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

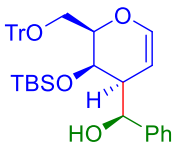




S17

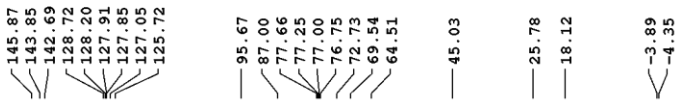


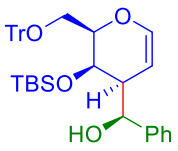

```
Current Data Parameters
NAME      BUR PRS 400 NEW
EXPNO                   6
PROCNO                  1

F2 - Acquisition Parameters
Date_           20191224
Time              17.05 h
INSTRUM            spect
PROBHD    Z108618_0098 (
PULPROG          zgpg30
TD                 65536
SOLVENT            CDC13
NS                   412
DS                     4
SWH            24038.461 Hz
FIDRES          0.733596 Hz
AQ              1.3631488 sec
RG                   203
DW                20.800 usec
DE                 6.50 usec
TE                294.6 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1
SFO1          100.6130223 MHz
NUC1                  13C
P0                 3.33 usec
P1                10.00 usec
PLW1          49.43999863 W
SFO2          400.0926004 MHz
NUC2                  1H
CPDPRG[2         waltz65
PCPD2             90.00 usec
PLW2          15.18599987 W
PLW12          0.41622999 W
PLW13          0.20936000 W

F2 - Processing parameters
SI                 32768
SF            100.6029681 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



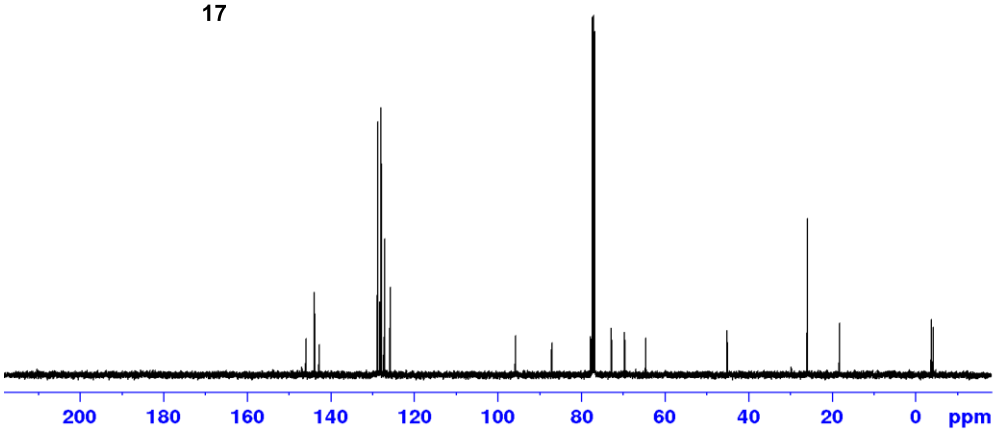
17


```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               115
PROCNO                1

F2 - Acquisition Parameters
Date_          20191227
Time              16.34 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG            zg30
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           10000.000 Hz
FIDRES         0.305176 Hz
AQ            3.2767999 sec
RG                69.79
DW               50.000 usec
DE                6.50 usec
TE               298.2 K
D1           1.00000000 sec
TD0                   1
SFO1         500.3720898 MHz
NUC1                 1H
P1                8.00 usec
PLW1         12.18000031 W

F2 - Processing parameters
SI                65536
SF           500.3690000 MHz
WDW                  EM
SSB       0
LB                0.30 Hz
GB        0
PC                1.00
```

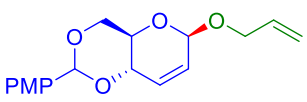




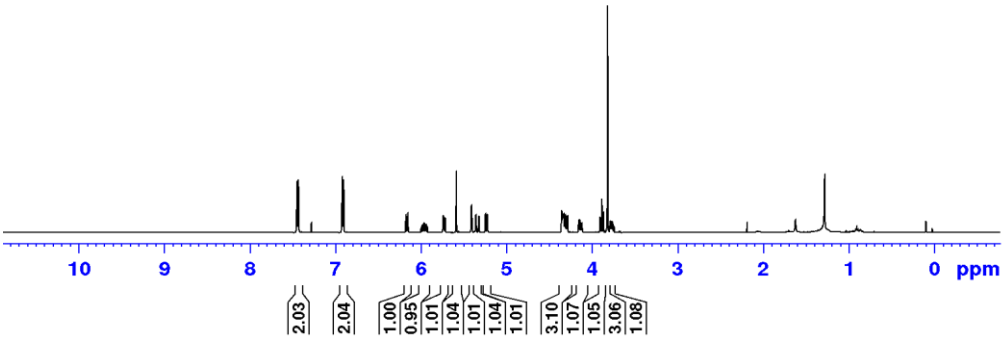
17



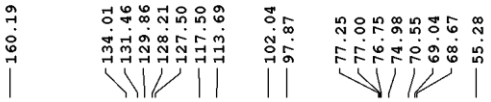

```
Current Data Parameters
NAME      BUR ASCEND 500
EXPNO               117
PROCNO                1

F2 - Acquisition Parameters
Date_          20191227
Time              16.56 h
INSTRUM            spect
PROBHD    Z125331_0034 (
PULPROG          zgpg30
TD                65536
SOLVENT           CDCl3
NS                  336
DS                    4
SWH           29761.904 Hz
FIDRES         0.908261 Hz
AQ            1.1010048 sec
RG                192.83
DW               16.800 usec
DE                6.50 usec
TE               298.1 K
D1           2.00000000 sec
D11          0.03000000 sec
TD0                   1
SFO1         125.8304669 MHz
NUC1                 13C
P1               12.00 usec
PLW1        172.66999817 W
SFO2         500.3710015 MHz
NUC2                 1H
CPDPRG[2         waltz16
PCPD2             80.00 usec
PLW2         12.18000031 W
PLW12         0.12180000 W
PLW13         0.06126500 W

F2 - Processing parameters
SI                32768
SF           125.8178899 MHz
WDW                  EM
SSB       0
LB                1.00 Hz
GB        0
PC                1.40
```

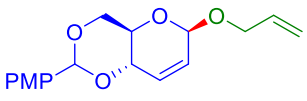


S18

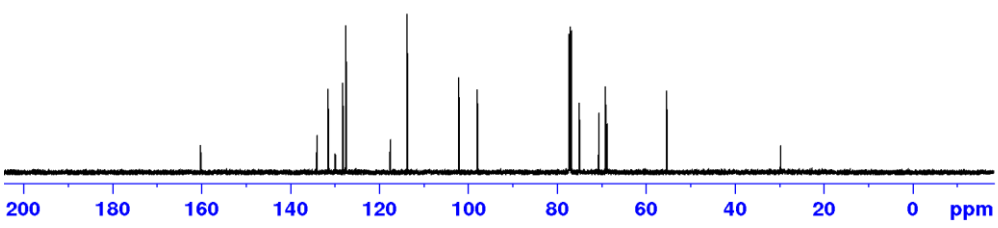



```
Current Data Parameters
NAME          BUR PRS 500
EXPNO             1459286
PROCNO                  1

F2 - Acquisition Parameters
Date_           20190716
Time               17.15
INSTRUM            spect
PROBHD    5 mm PABBO BB-
PULPROG             zg30
TD                 65536
SOLVENT            CDCl3
NS                    16
DS                     2
SWH            10330.578 Hz
FIDRES         0.157632 Hz
AQ             3.1719425 sec
RG                   128
DW                48.400 usec
DE                 6.50 usec
TE                300.1 K
D1             1.00000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  1H
P1                 14.90 usec
PL1                2.00 dB
PL1W          12.85348415 W
SFO1          500.1830888 MHz

F2 - Processing parameters
SI                 32768
SF            500.1800000 MHz
WDW                   EM
SSB       0
LB                 0.30 Hz
GB        0
PC                 1.00
```

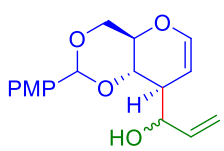




S18

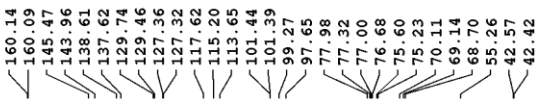


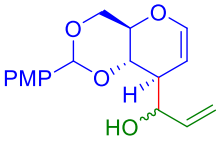

```
Current Data Parameters
NAME          BUR PRS 500
EXPNO             1459288
PROCNO                  1

F2 - Acquisition Parameters
Date_           20190716
Time               17.23
INSTRUM            spect
PROBHD    5 mm PABBO BB-
PULPROG           zgpg30
TD                 65536
SOLVENT            CDCl3
NS                   112
DS                     4
SWH            29761.904 Hz
FIDRES         0.454131 Hz
AQ             1.1010048 sec
RG                  2050
DW                16.800 usec
DE                 6.50 usec
TE                300.9 K
D1             2.00000000 sec
D11            0.03000000 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                 9.60 usec
PL1       0 dB
PL1W          76.36135101 W
SFO1          125.7829381 MHz

======== CHANNEL f2 ========
CPDPRG[2          waltz16
NUC2                  1H
PCPD2              80.00 usec
PL2                2.00 dB
PL12              16.50 dB
PL13              16.50 dB
PL2W          12.85348415 W
PL12W          0.45605880 W
PL13W          0.45605880 W
SFO2          500.1820007 MHz

F2 - Processing parameters
SI                 32768
SF            125.7703641 MHz
WDW                   EM
SSB       0
LB                 1.00 Hz
GB        0
PC                 1.40
```



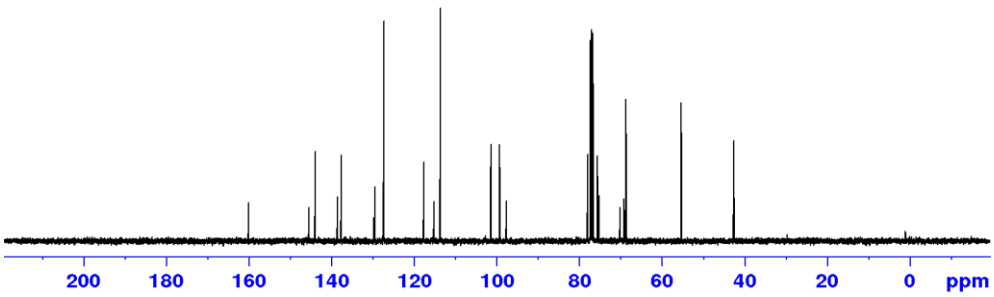
18


```
Current Data Parameters
NAME                  BUR 400
EXPNO               12382222
PROCNO                     1

F2 - Acquisition Parameters
Date_               20190921
Time                    5.28
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG                zg30
TD                    65536
SOLVENT               CDCl3
NS                       16
DS                        2
SWH                8223.685 Hz
FIDRES             0.125483 Hz
AQ                 3.9845889 sec
RG                       114
DW                  60.800 usec
DE                   6.50 usec
TE                   297.4 K
D1                1.00000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      1H
P1                     14.90 usec
PL1                     1.50 dB
PL1W           15.18650627 W
SFO1           400.0934707 MHz

F2 - Processing parameters
SI                        32768
SF              400.0910000 MHz
WDW                        EM
SSB          0
LB                      0.30 Hz
GB           0
PC                      1.00
```





18




```
Current Data Parameters
NAME                  BUR 400
EXPNO               12382224
PROCNO                     1

F2 - Acquisition Parameters
Date_               20190921
Time                    5.42
INSTRUM                spect
PROBHD    5 mm PABBO BB-
PULPROG             zgpg30
TD                    65536
SOLVENT               CDCl3
NS                      114
DS                        4
SWH               24038.461 Hz
FIDRES             0.366798 Hz
AQ                 1.3631488 sec
RG                      2050
DW                  20.800 usec
DE                   6.50 usec
TE                   298.2 K
D1                2.00000000 sec
D11               0.03000000 sec
TD0                        1

======== CHANNEL f1 ========
NUC1                      13C
P1                     10.00 usec
PL1                     2.00 dB
PL1W           49.44866943 W
SFO1           100.6130223 MHz

======== CHANNEL f2 ========
CPDPRG[2             waltz16
NUC2                      1H
PCPD2                  90.00 usec
PL2                     1.50 dB
PL12                   17.18 dB
PL13                   20.18 dB
PL2W           15.18650627 W
PL12W           0.41063678 W
PL13W           0.20580591 W
SFO2           400.0926004 MHz

F2 - Processing parameters
SI                        32768
SF              100.6029689 MHz
WDW                        EM
SSB          0
LB                      1.00 Hz
GB           0
PC                      1.40
```

Discovery of Novel Methods for the Synthesis of Carbon Branched Sugars from Glycals

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