CALCIUM-CATALYZED *IN-SITU* SYNTHESIS AND CYCLIZATION REACTIONS OF TETRASUBSTITUTED ALLENES

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

By

P. RAJESH

Reg. No. 16CHPH42

Dr. Srinivasarao Yaragorla

(Supervisor)

SCHOOL OF CHEMISTRY, UNIVERSITY OF HYDERABAD

HYDERABAD - 500 046, INDIA

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DEDICATED TO

MY FAMILY

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FRIENDS

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DECLARATION

I hereby declare that the matter embodied in the thesis entitled **"Calcium-Catalyzed *In-Situ* Synthesis and Cyclization Reactions of Tetrasubstituted Allenes"** is the result of examination carried out by me in the School of Chemistry, University of Hyderabad, Hyderabad, India, under the supervision of **Dr. Srinivasarao Yaragorla**.

In keeping with the general practice reporting scientific explanations, due acknowledgements have been made on the basis of the finding of other investigators. Any omission, which might have occurred by oversight or error, is regretted. This research work is free from Plagiarism. I hereby agree that my thesis can be deposited in Shodhganga/INFLIBNET. A report on plagiarism statistics from the University Librarian is enclosed.

P. Rajesh

P. Rajesh

(16CHPH42)

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Dr. Srinivasarao Yaragorla

(Supervisor)

Dr. Srinivasarao Yaragorla
Associate Professor
School of Chemistry
University of Hyderabad
Hyderabad-500 046, India.

CERTIFICATE

This is to certify that the thesis entitled. **"Calcium-Catalyzed *In-Situ* Synthesis and Cyclization Reactions of Tetrasubstituted Allenes"** submitted by **Mr. P. RAJESH** bearing registration number **16CHPH42** in partial fulfillment of the requirements for award of Doctor of Philosophy in the School of Chemistry, University of Hyderabad is a bonafide work carried out by him under my supervision and guidance.

This thesis is free from plagiarism and has not been submitted previously in part or in full to this or any other University or Institution for award of any degree or diploma.

Parts of this thesis have been published in the following Four publications:

1. S. Yaragorla, **P. Rajesh**, A. Pareek, A. Kumar, *Adv. Synth. Catal.* **2018**, *360*, 4422-4428.
2. S. Yaragorla, **P. Rajesh,** *Eur. J. Org. Chem.* **2019**, 5740-5748.
3. S. Yaragorla, **P. Rajesh**, *Org. Biomol. Chem.* **2019**, *17*, 1924-1928.
4. S. Yaragorla, **P. Rajesh,** *Eur. J. Org. Chem.* **2020**, 7243-7251.

He has also made presentations in the following conferences:

1. Poster presentation in the **8th International Collaborative & Cooperative Chemistry Symposium -2017** held at University of Hyderabad, Hyderabad, India (Dec 18-19, 2017).

2. Poster presentation in the National Organic Symposium Trust (***XIV J-NOST 2018***) held at CSIR-Indian Institute of Chemical Technology, Hyderabad, India (28th Nov to 1st Dec 2018).

3. Poster presentation in the *"**Chemfest 2018**"* in house symposium held at University of Hyderabad, India (Mar 9-10, 2018).

4. Poster presentation in the *"**Chemfest 2019**"* in house symposium held at University of Hyderabad, India (Feb 22-23, 2019).

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Further the student has passed the following courses towards fulfillment of coursework requirement for Ph.D.

Sl. No.	Course	Title	Credits	Pass/Fail
1.	CY801	Research Proposal	3	Pass
2.	CY802	Chemistry Pedagogy	3	Pass
2.	CY806	Instrumental Methods-B	3	Pass
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6/4/22

Dr. Srinivasarao Yaragorla

(Thesis supervisor)

Dr. Srinivasarao Yaragorla
Associate Professor
School of Chemistry
University of Hyderabad
Hyderabad-500 046, India.

Dean

School of Chemistry

Dean
SCHOOL OF CHEMISTRY
University of Hyderabad
Hyderabad-500 046

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P. RAJESH

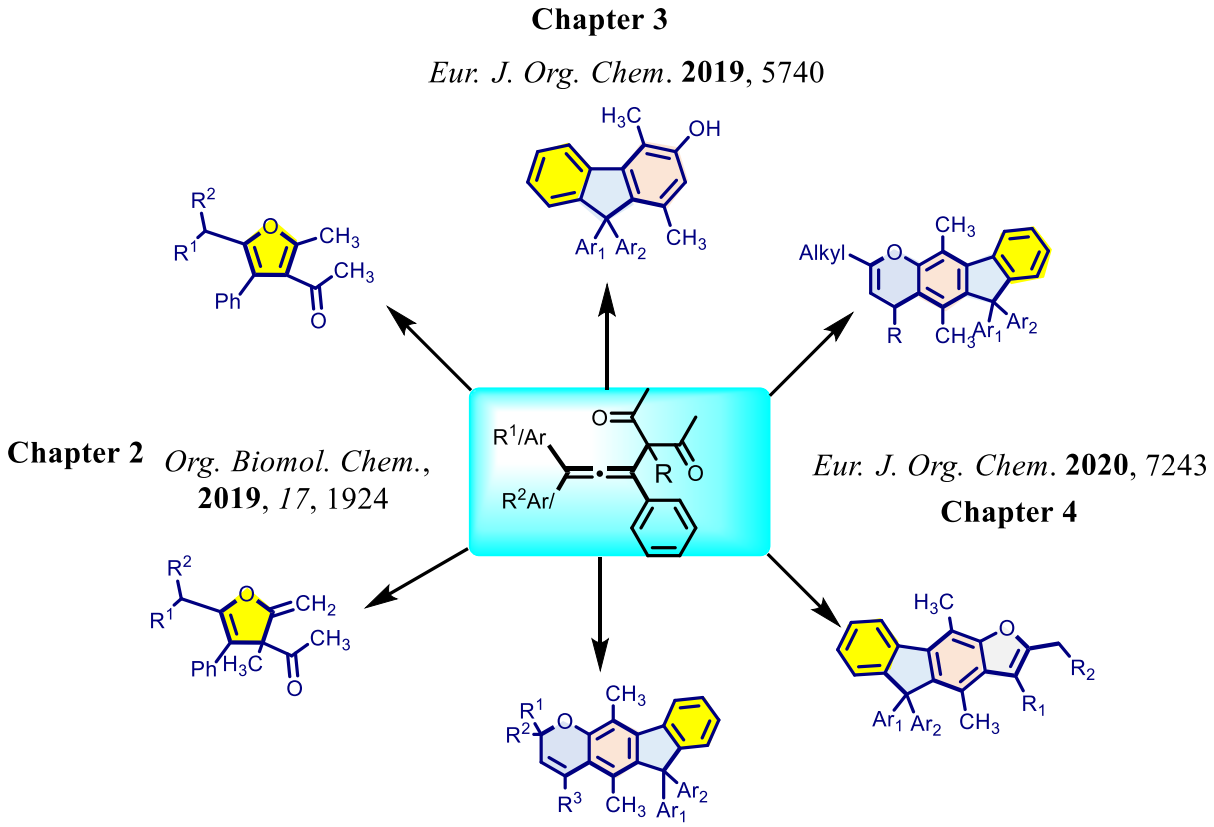
List of Abbreviations

[α]	:	specific rotation (expreessed in without units)
Ac	:	acetyl
aq.	:	aqueous
α	:	alpha
Ar	:	aryl
Bn	:	benzyl
bp	:	boiling point
brs	:	broad singlet (spectral)
^{t}Bu	:	*tert*-butyl
β	:	beta
^{o}C	:	degree Celsius
cat.	:	catalytic
CCDC	:	Cambridge Crystallographic Data Centre
cm^{-}	:	wavenumber
δ	:	chemicalshift
CSA	:	camphorsulphonic acid
DCM	:	dichloromethane
DCE	:	1,2-dichloroethane
DMF	:	dimethylformamide
DMSO	:	dimethyl sulfoxide
EAA	:	ethyl acetoacetate
EI	:	electron impact (in mass spectrometry)
eq.	:	equation
EtOAc	:	ethyl acetate
EtOH	:	ethanol
Equiv.	:	equivalent
g	:	gram (s)
h	:	hour (s)
HRMS	:	high resolution mass spectrum
Hz	:	hertz
IR	:	infrared

J	:	coupling constant (in NMR spectroscopy)
LHMDS	:	lithium bis(trimethylsilyl)amide
m	:	multiplet (In nmr spectra)
Me	:	methyl
mg	:	milligram
MeOH	:	methanol
mmol	:	millimoles
MHz	:	megahertz
mp	:	melting point
MsOH	:	methanesulfonic acid
Nu	:	nucleophile
NMR	:	nuclear magnetic resonance
OTf	:	trifluoromethanesulfonate
ORTEP	:	Oak Ridge Thermal Ellipsoid Plot
PE	:	hexane
Ph	:	phenyl
ppm	:	parts per million
p-TSA	:	*p*-toluenesulfonic acid
q	:	quartet
rt	:	room temperature
s	:	singlet
THF	:	tetrahydrofuran
TLC	:	thin layer chromatography
Ts	:	toluenesulfonyl/tosyl
UV	:	ultraviolet

SYNOPSIS

The thesis entitled "**Calcium-Catalyzed *in-situ* Synthesis and Cyclization Reactions of Tetrasubstituted Allenes**" consists five chapters; chapter-I is divided in two sections, Section-A: Introduction to tetrasubstituted allene synthesis and cyclization, Section-B: Introduction to calcium catalysis; chapter-II: Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access substituted furans; chapter-III: Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tricyclic fluorenols; chapter-IV: Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tetracyclic fluorenofurans; chapter-V: Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tetracyclic fluorenopyrans. The compounds reported in this thesis are characterized by ^{1}H NMR, ^{13}C NMR, IR, MS, and HRMS spectral data. Structure of some of the representative compounds are unambiguously elucidated by X-ray crystallography.



CHAPTER–I This chapter is divided in two sections.

Section-A: Introduction to tetrasubstituted allene synthesis and cyclization

Allenes are cumulative dienes with three carbon atoms, and the central "sp" carbon is the key unit in allene chemistry. Their orthogonal cumulative π systems often lead to a complementary and unique reactivity compared to olefins and alkynes. This structural aspect has only been well adapted in cyclization reactions to give products with olefins in a ring system. Allenes, their imitations, and especially the quaternary carbon center, is an extraordinarily important key structural unit that plays an essential role in reactive intermediates that lead to highly complex structures, bioactive useful intermediates, a wide range of natural products and pharmaceutical molecules, and they are also versatile building blocks in organic synthesis. This cumulative double bond formed by Lewis's acid is particularly useful as it enables nucleophilic attack that, due to its axial chirality, leads to the intramolecular formation of a new carbon - carbon or carbon - heteroatom bond.

Section-B: Introduction to calcium catalysis

The following of environmental friendliness, atom economy and sustainability have long been important goals of chemists in current organic synthesis. Alkaline Earth metals are across the board in nature, at lower cost and less environmental impact compared to rare metals. About over the past twenty years we have seen various elegant modification made possible by alkaline earth metal complexes. There are just a few examples of alkaline earth metals in the structure of heterocyclic compounds based on their special properties: sensitive to moisture, with one d^0 electron, and +2 as the highest transition state. Their biocompatibility and potent chemical activities are devoted to chemists to use the alkaline earth metals in organic synthesis.

The reactivity of calcium (II) compounds can be divided into two sections. (i) alkali metal compounds have a strong ionic character, due to their low electronegativity and (ii) Calcium-bound anionic residues therefore have a strong nucleophilic character, coupled with strong basicity. At the same time, the calcium center is itself Lewis acidic, similar to the Group 3 metals. Although the Lewis acidity of calcium compounds is believed that it contributes to the result of the polymerization and asymmetric addition reactions for organic synthesis. The best results have been achieved with weakly coordinating, non-basic anions such as TfO^-, F^-, F_6iPrO^- and a 1:1 mixture of triflimidate $(NTf_2)^-$ and hexafluorophosphate $(PF_6)^-$. In contrast to before mentioned, strongly basic calcium catalysts, these new Lewis acids based on calcium are easy to handle because of their relatively high tolerance to air and moisture."

CHAPTER–II Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access substituted furans

The annulation of *tert*-propargyl alcohols with 1,3-dicarbonyl compounds through a regiospecific S_N2 type mechanism to provide a regiodivergent synthetic protocol for furans.

In continuation of our research interests to explore the ambident reactivity of propargyl alcohols, particularly towards the annulation reactions, herein we reported a Ca(II)-catalyzed formal [3+2] annulation of *tert*-propargyl alcohols and 1,3-diketones in one–pot (Figure 1).

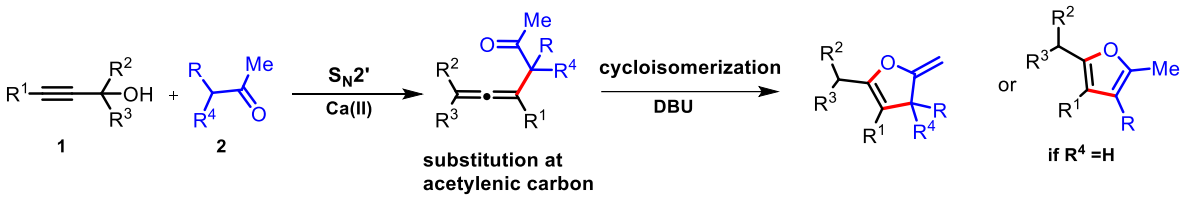
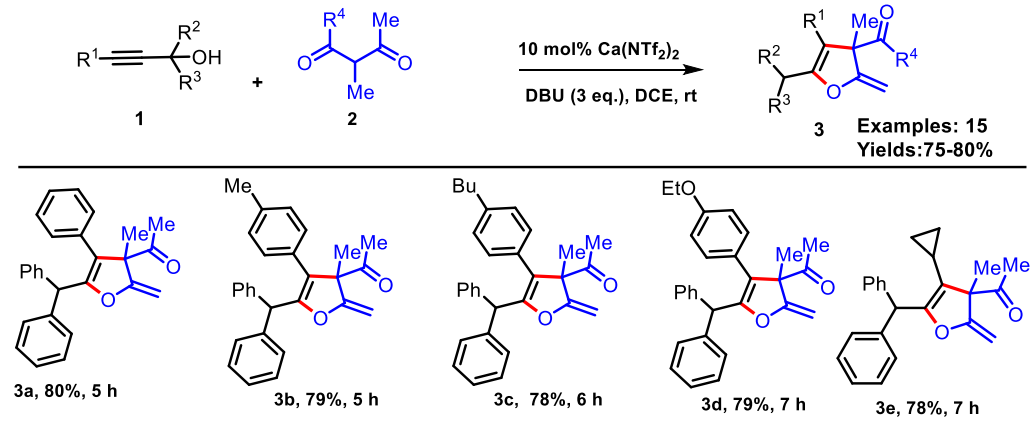


Figure 1: One-pot synthesis via S_N2', followed by cycloisomerization of homoallenyl-ketone

The present reaction allows the synthesis of various substituted furans with good yields. Gratefully, different propargyl alcohols were synthesized by employing the variety of terminal alkynes (keeping the benzophenone constant) such as 4-methylphenyl **1b**, 4-butylphenyl **1c**, 4-ethoxyphenyl **1d**, cyclopropyl **1e** acetylenes and treated them with **2a** under standard optimized conditions and obtained the respective 2-methylene-2,3-dihydrofurans **3b**-**3e** in good yields (Scheme 1).

Scheme 1: Selected examples of Ca(II)-catalyzed regiospecific annulation of **1** and **2**.

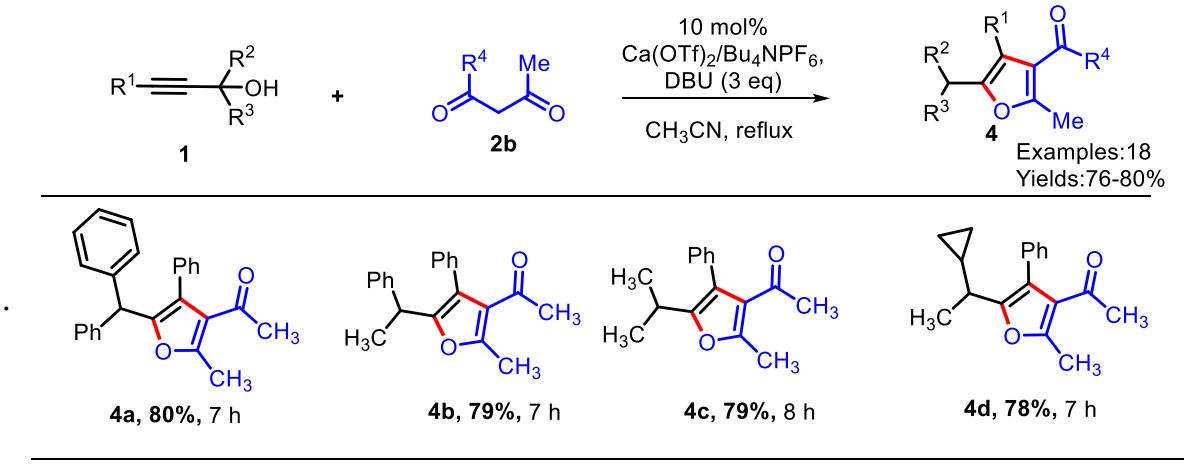


Ca(II)-catalyzed regiospecific [3+2] annulation of propargyl alcohol 1 and 1,3-diketones (2b)

Substituted furans were synthesized by upon treatment of propargyl alcohol **1** with simple 1,3-diketone **2** under $Ca(OTf)_2$ conditions (Scheme 2). This method involves the isomerization of homo-allenyl ketones followed by 5-*exo*-*trig* cyclization. Having successfully optimized the

calcium (II)-catalyzed annulation reaction, the scope and limitation of propargylic alcohols **1** and diketones **2** were investigated (Scheme 2). Furthermore, the annulation reaction of **2b** was compatible with the propargylic substitutions **1** such as diphenyl, dimethyl, phenyl-methyl and cyclopropyl-methyl in providing the corresponding furans with diversity at 5th position (**4a** to **4d**) in good yields (Scheme 2).

Scheme 2: Selected examples of Ca(II)-catalyzed regiospecific [3+2] annulation of propargyl alcohol 1 and 1,3-diketones 2b



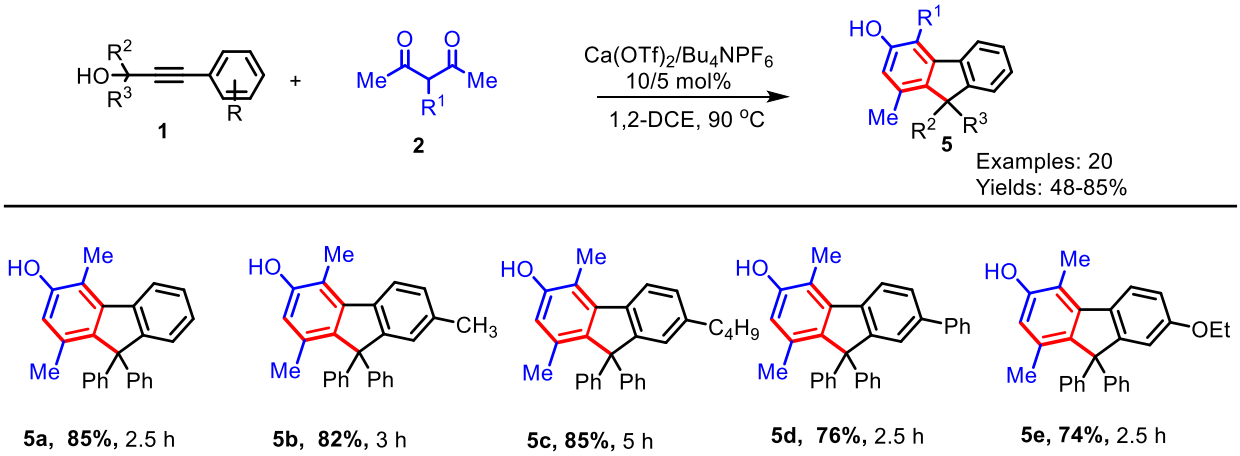
CHAPTER–III. Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tricyclic fluorenols

To further explore the applications of Ca(II)-catalyzed annulation reactions, a one-pot cascade benzannulation protocol was developed for the synthesis 9,9-diaryl-9*H*-fluorenol, which is a key structure of many important natural products which exhibit the significant biological activities particularly phosphodiesterase-4 (PDE4) inhibitory activity. This approach proceeds *via* the annulation of *tert*-propargyl alcohols with 2-methyl acetylacetone through an Intramolecular-Allene-Friedel-Crafts reaction employing $Ca(OTf)_2$ as the environmentally benign catalyst. Synthetic transformations of these compounds to useful materials are also presented here with the aid of cross-coupling and Ring-closing metathesis reactions.

After sucessfull exporation of optimized reaction conditions for one-pot cascade benzannulation reaction, the scope and generality of the reaction was examined. Various propargyl alcohols **1** tethered with alkyl substitutions on aryl ring moieties were subjected with diketones **2** under

standard conditions to furnish the corresponding fluorenols such as **5b-5e,** C7-methyl, ^{n}butyl, phenyl, ethoxy substituents respectively, in excellent yields.

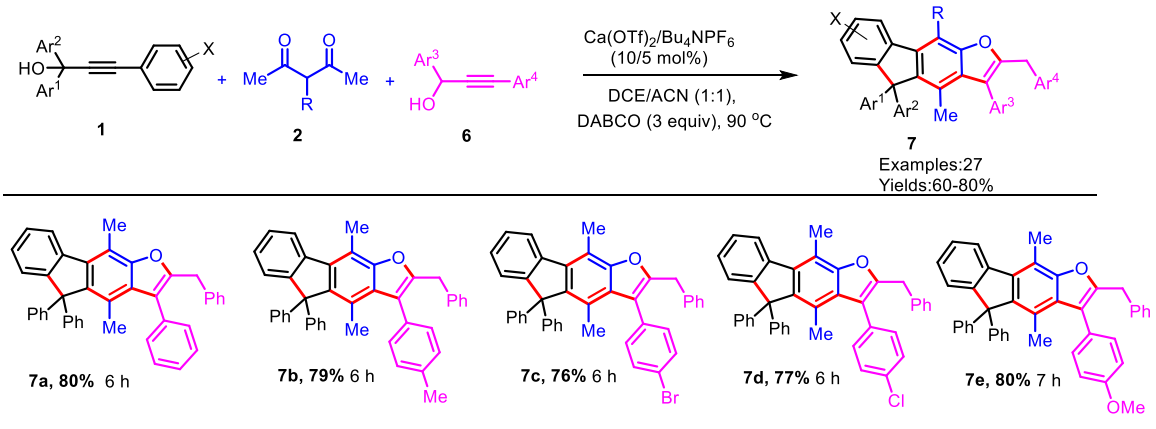
Scheme 3: Selected examples of Ca(II)-catalyzed Intramolecular-Allene-Friedel-Crafts Annulation



CHAPTER–IV Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tetracyclic fluorenofurans

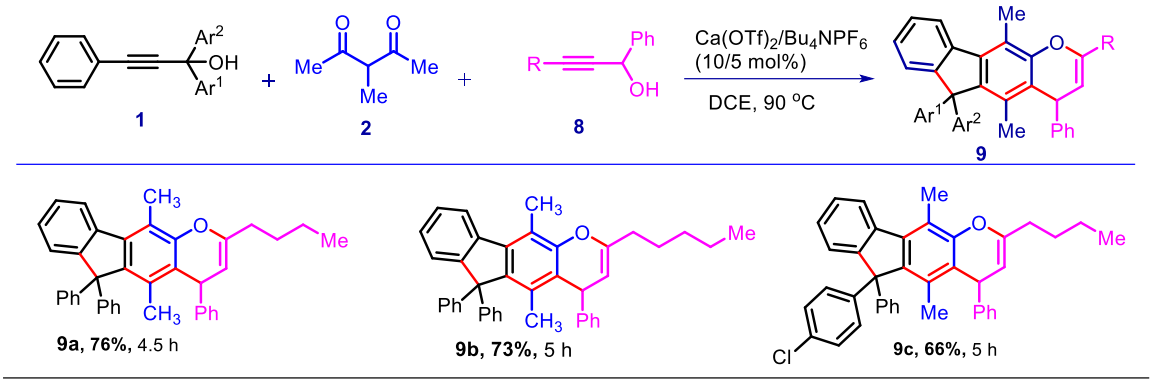
A novel synthetic methodology for the synthesis of *tetra*-annulated fluorenofurans and fluorenopyrans are developed using calcium(II)-catalyzed one-pot, three-component reaction. In this context, *tert*-propargyl alcohols react with 1,3-dicarbonyls to afford highly substituted allenes, which are subsequently undergoing regiodivergent annulation with *sec*-propargyl alcohols to produce the tetracyclic compounds. The significant features of the present methodology are broad substrate scope, regioselectivity, gram-scale synthesis and benzylic functionalization of products.

Scheme 4: Selected examples of Ca(II)-catalyzed Annulation reactions.



Initially, variety of *sec*-propargyl alcohols **6** were chosen which are tethered with different substitutions on benzylic aryl ring (such as 4–methyl, 4-bromo, 4-chloro and 4-methoxy groups) and treated with **1a** and **2a** under standard reaction conditions. Subsequently, the wide range of flourenofurans **7b**-**7e** was synthesized by employing the present developed methodology.

Scheme 5. Selected examples of Calcium(II)-Catalyzed, annulation reaction of 1, 2 with 8 bearing alkyl groups on alkyne terminus.

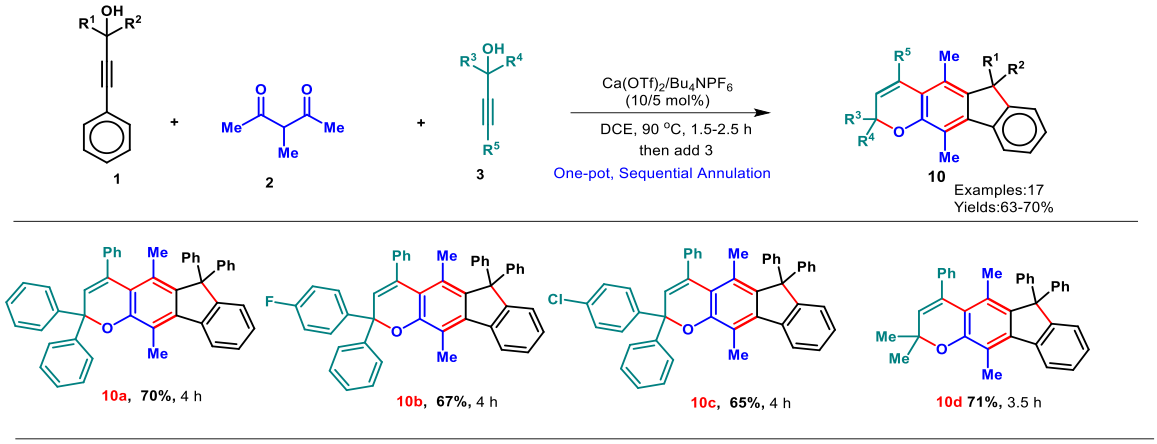


Then we sought to look at the regioselectivity of *sec*-propargyl alcohols bearing an alkyl group on the alkyne-terminus (Scheme 5). Hence substrates *sec*-propargyl alcohols **1a**, diketones **2a** and 1-phenylhept-2-yn-1-ol **8a** were refluxed in DCE with 10/5 mol% $Ca(OTf)_2/Bu_4NPF_6$ (standard reaction conditions of Scheme 5) for 4.5 hours and obtain the product **9a** in 76% yield. The same regioselectivity was again noticed when *tert*-propargyl alcohol **1**, diketones **2a** were subjected with 1-phenyloct-2-yn-1-ol **8a, 8b** under optimized conditions and afforded the corresponding fluorenopyrans **9b, 9c** in good yields (Scheme 5).

CHAPTER-V Synthesis and *in-situ* cyclization of tetrasubstituted allenes to access tetracyclic fluorenopyrans

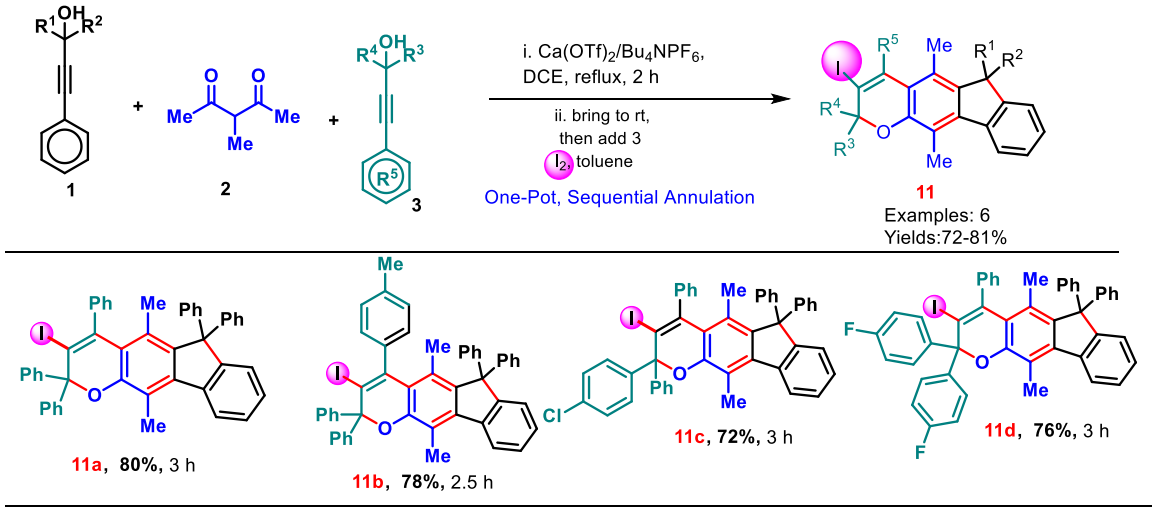
In continuation, an unprecedented approach of tetracyclic fluorenopyrans from simple acyclic reactants was developed by employing with propargyl alcohols and 3-methylpentane-2,4-dione under calcium catalysis. The present novel one-pot 3-component reaction proceeds *via* a sequential allene formation followed by Friedel-Crafts cyclization/ cycloisomerization, then intramolecular aldol reaction, subsequently, Claisen rearrangement and 6-*endo dig* cyclization to afford the formation of fluorenopyrans (indeno[2,1-g]chromenes). This strategy was further utilized for the synthesis of 3-iodo-fluorenopyrans by iodocyclization to the above sequence of reactions (4-CR). Notably, this highly practical, atom and the step-economic procedure is catalyzed by a sustainable (alkaline earth) metal salt and tolerates the broad substrate scope, allowing the further transformations and synthetic utilities of these complex polycyclic moieties.

Scheme 6: Selected examples of Ca(II)-catalyzed synthesis of fluorenopyrans



After discovering the best reaction conditions for the regioselective, one-pot, annulation of propargyl alcohol **1a** and 2-methyl acetylacetone **2** to form fluorenopyran **10a**, next, the scope of the reaction was examined (Scheme 6). Accordingly, propargyl alcohol **1a** and 2-methyl acetylacetone **2** were refluxed in 1,2-DCE along with 10 mol% Ca(II)/5 mol% Bu_4NPF_6 until the consumption of starting materials (monitored by TLC) then propargyl alcohol **3b** was added to the reaction pot and continued the reaction till completion to isolate the fluorenopyran **10b** in 67% yield. Similarly, other propargyl alcohols **3c**-**3d** were subjected with propargyl alcohol **1a** and 2-methyl acetylacetone **2** under standard reaction conditions to show the diversity at the quaternary-C2-center and synthesized the flurenopyrans **10a**-**10d** in good yields.

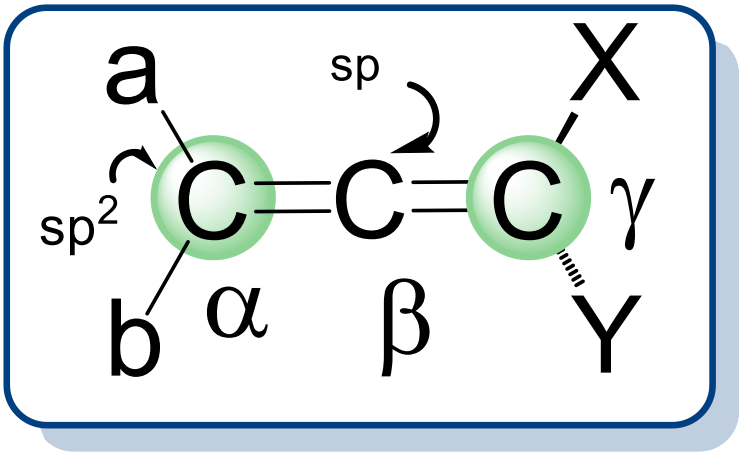
Scheme 7: Selected examples of Ca(II)-catalyzed, one-pot, 4-component Iodo-cycloisomerization reaction



A careful observation of propargylic ether in reaction mechanism revealed that it is possible to activate the triple bond with molecular iodine so that an intramolecular-iodocyclization can occur (scheme 7) to furnish the iodo-fluorenopyrans. Based on this objective, the present experiment was designed accordingly; propargyl alcohol **1a** and 2-methyl acetylacetone **2** were subjected to standard reaction condition to obtain the fluorenol then brought the reaction to room temperature and **3** was added as second alcoholic partner along with molecular iodine and 2 mL of toluene. Presumably, the iodocyclization proceeded well to yield 3-iodoflurenopyran **11a** in 80% yield (Scheme 7).

Section-A:

Introduction to Tetrasubstituted Allene Synthesis and Cyclizations



1.1 INTRODUCTION

Allenes are structurally important components in most natural products, biologically active compounds, and pharmaceuticals.[1] The existence of two cumulative carbon-carbon double bonds characterizes them structurally and contributes to their high reactivity. They are employed in pharmaceuticals and complex compounds because of their widespread abundance in vitamins,[2] hormones,[3] dyes,[4] antibiotics,[5] antitumors,[6] anti-thrombotic,[7] hepatites-B-virus,[8] antiviral [9], anti-HIV,[10] antidiabetic,[11] and natural products, etc, [1] Moreover, they are of paramount importance for responding to harmful microorganisms and lead a healthy human life. Among all known allene compounds, fused cyclic derivatives possess an important role in medicinal chemistry with a broad spectrum of biological applications i.e. antifungal,[12] inhibitors of Hepatitis B,[13] anti-inflammatories,[14,] etc., (Figure 1).

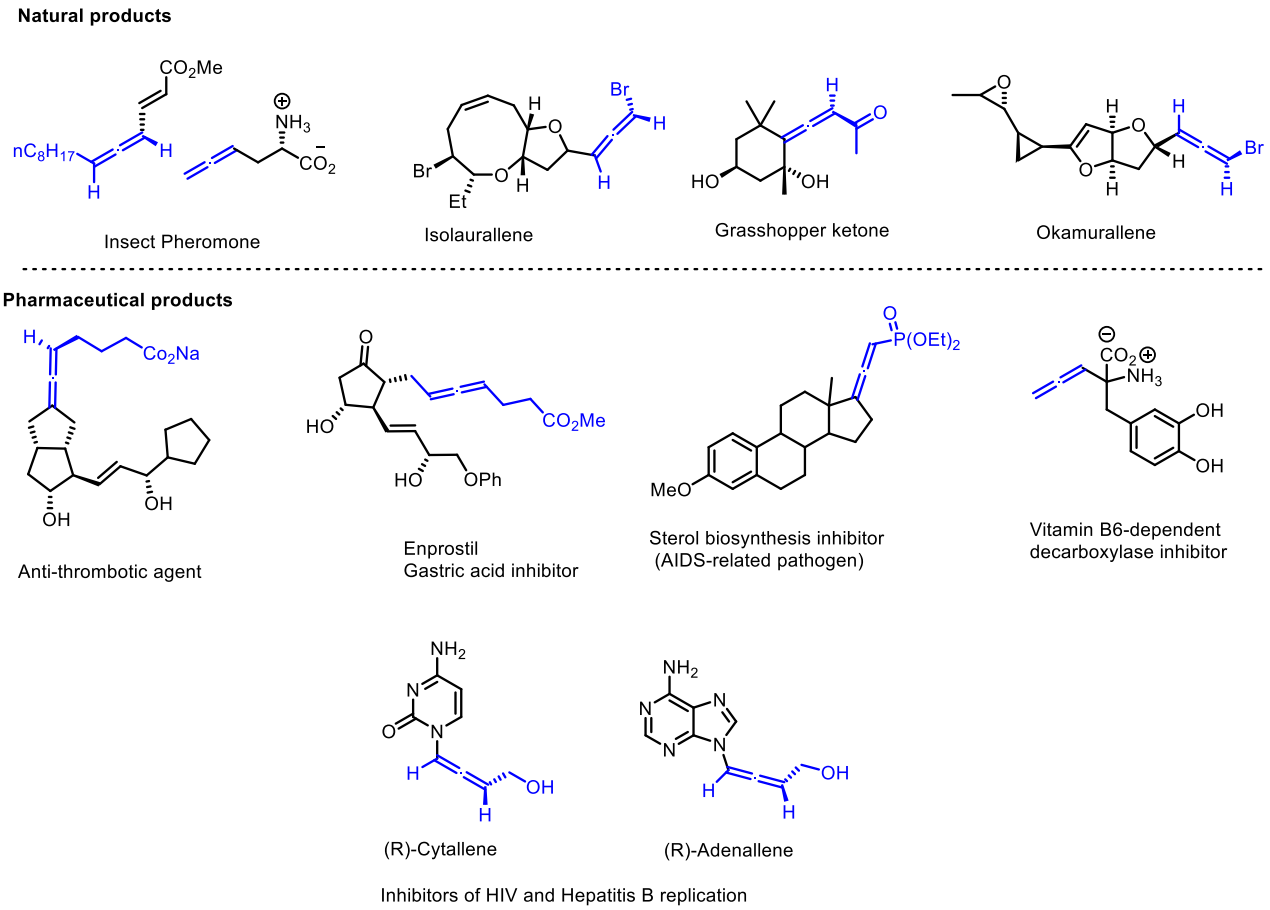
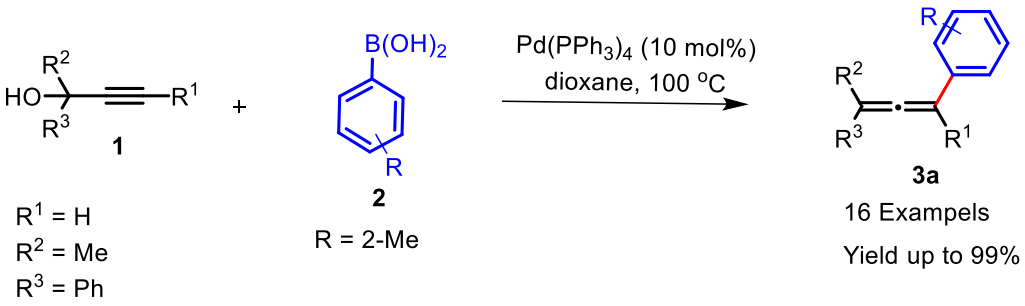


Figure 1. Representative examples of natural and pharmaceutical compounds having allene moieties.

In the last few generations, significant progress has been achieved in the development of allene frameworks, direct synthetic transformation of propargylic compounds is the most widely employed strategy among all those developed. Propargylic alcohols are useful synthons for building a variety of key structural frameworks in synthetic chemistry because of their unusual amphiphilic character.[15] Propargylic alcohols have flexibility and accessibility, they can go through a lot of different reaction conditions to get different molecules.

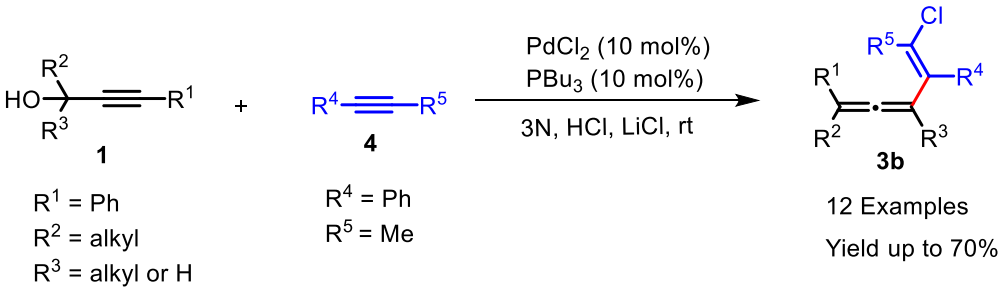
1.2 PREVIOUS REPORTS

Yoshida *et al*. demonstrated the use of palladium catalyst to directly couple various propargylic alcohols and aryl boronic acids to form corresponding tetrasubstituted allene, this reaction proceeds through S_N2 mechanism (Scheme 1).[15]



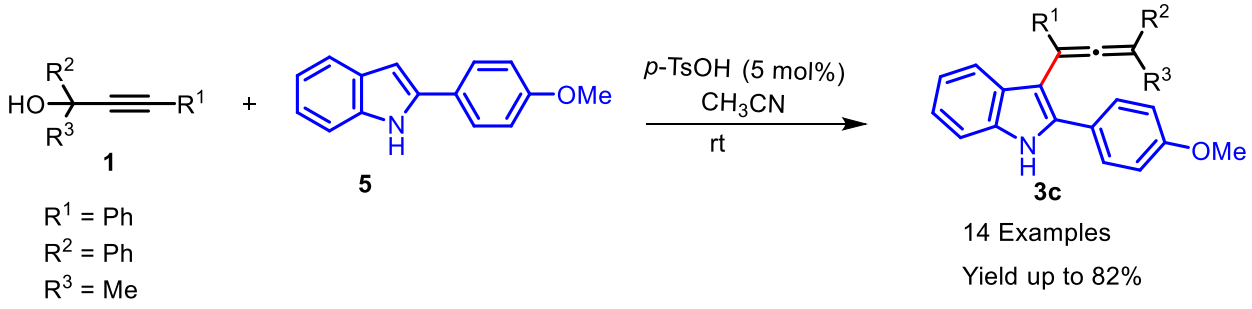
Scheme 1. Direct coupling reaction of propargylic alcohols with aryl boronic acids using Pd(0) as a catalyst.

In 2008 H. Jiang *et al*. reported the allenylation of alkynoates which uses inactive propargyl alcohols as "allenylating" reagents and could be performed in the presence of water without any additional organic solvent. Hydroxyl being the leaving group on one of the alkyne molecules, permits the selective insertion of different alkynes in this water-promoted reaction (Scheme 2).[16]



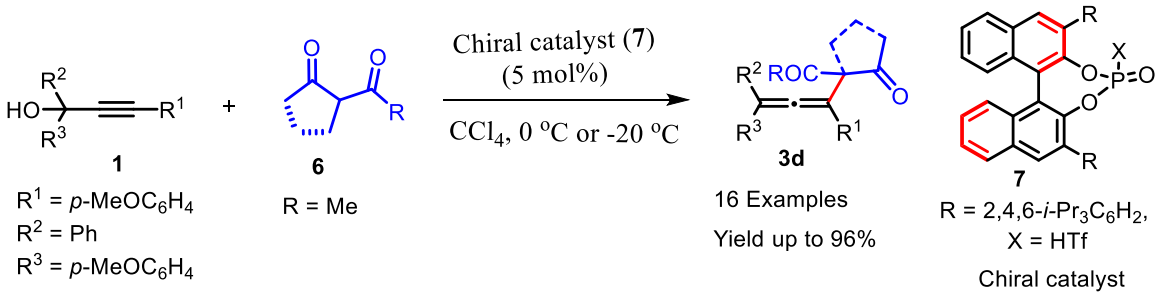
Scheme 2. Pd(II)-catalyzed allenylation of alkynoates with propargyl alcohols .

In 2009 Sanz *et al*. reported the synthesis of allenylindoles by using *tert*-propargylic alcohols and 2-aryl-substituted indoles catalyzed by Brønsted acid *via* nucleophilic substitution. With the exact substituents on the alkynol molecule, a competitive allenylation reaction occurs (Scheme 3).[17]



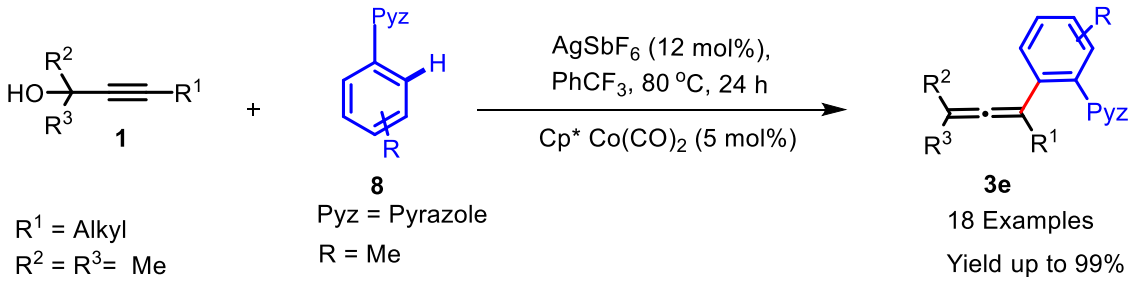
Scheme 3. Brønsted acid-catalyzed synthesis of 3-allenylindoles.

Sun *et al*. established an efficient catalytic system for performing the asymmetric transformation for direct coupling of propargylic alcohols with 1,3-diketones using chiral phosphoric acid, resulting in chiral tetrasubstituted allenes up to 96% yield and 97% ee (Scheme 4).[18]



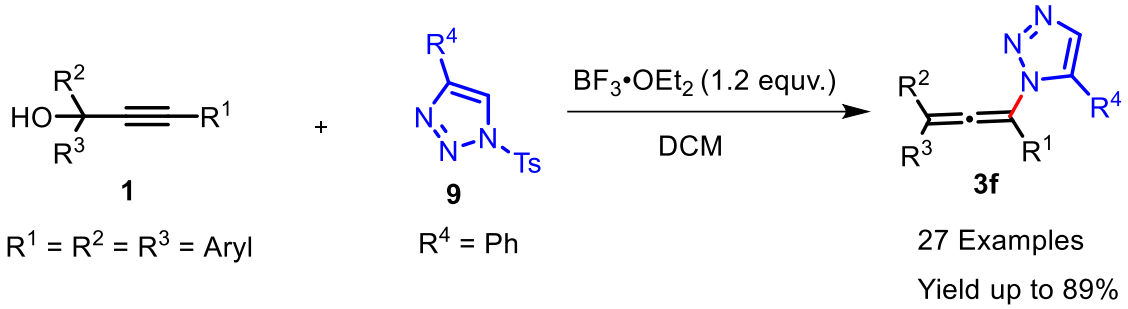
Scheme 4. Asymmetric synthesis of tetrasubstituted allenes.

Sundararaju's group reported an allenylation reaction between *tert*-propargylic alcohols and substituted arenes containing electron-rich group by cobalt catalysis to generate several tetrasubstituted allenes (Scheme 5).[19]



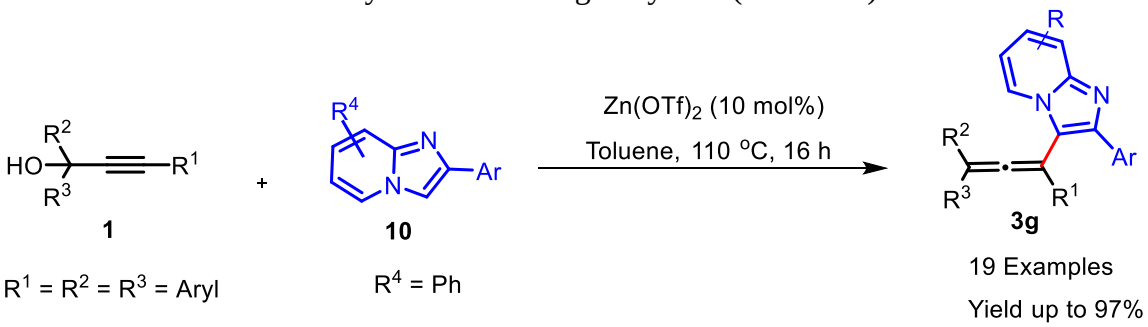
Scheme 5. Co(III)-catalyzed synthesis of tetrasubstituted allenes.

In 2017 Wang *et al*. reported an efficient, regioselective preparation of allenyltriazoles from triazoles and *tert*-propargylic alcohols with trifluoro boron etherate as a catalyst (Scheme 6). [20]



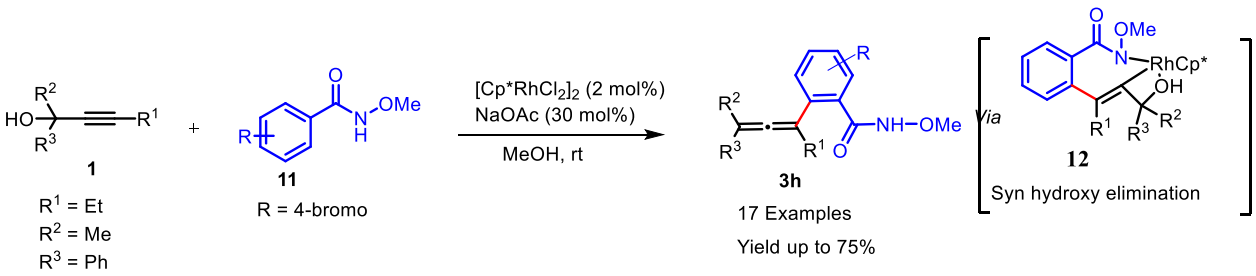
Scheme 6. $BF_3 \cdot Et_2O$-catalyzed synthesis of triazole substituted allenes.

$Zn(OTf)_2$-catalyzed reaction between *tert*-propargylic alcohols and imidazo heterocycles are reported to form imidazole-substituted allene molecules. A majority of fullysubstituted allenes with wide functionalities were synthesized with good yields (Scheme 7). [21]



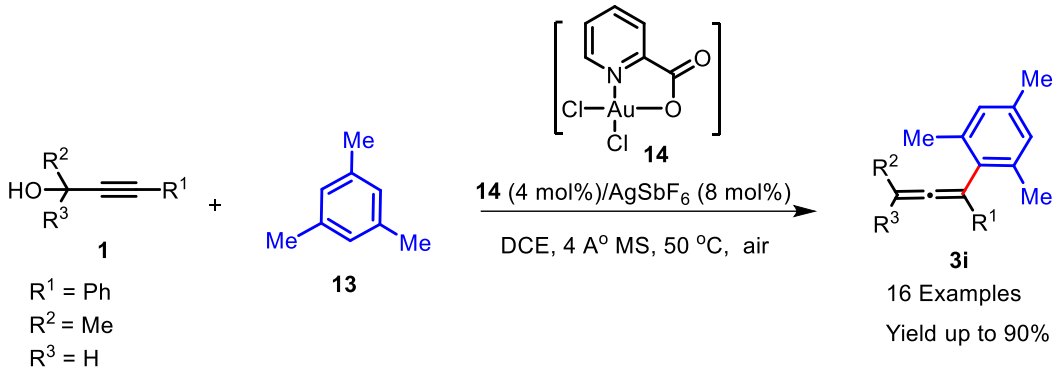
Scheme 7. Zn(II)-catalyzed synthesis of imidazole substituted allenes.

Ma and his group established a unique Rh(II)-catalyzed "syn-OH elimination" method for the preparation of tetrasubstituted allenes from propargyl alcohols and arenes as the starting materials, with water as the only by-product, this method gave access to tetrasubstituted allenes with excellent yields tolerating different functional groups (Scheme 8). [22]



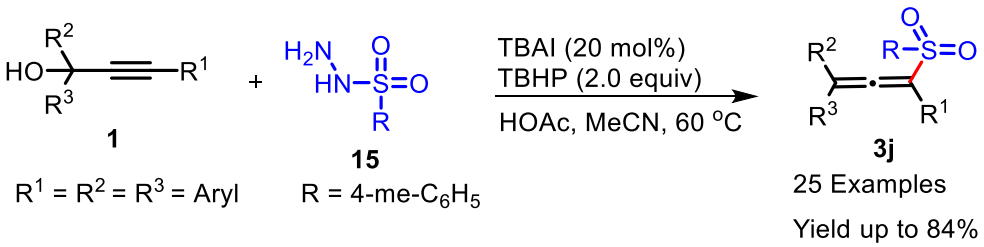
Scheme 8. Rh(II)-catalyzed preparation of tetrasubstituted allenes.

In 2012 C.Y. Li *et al*. reported Au(II)-catalyzed intermolecular reactions of *tert*-propargylic alcohols with aromatic molecules to produce functionalized allenes with moderate to high yields (Scheme 9).[23]



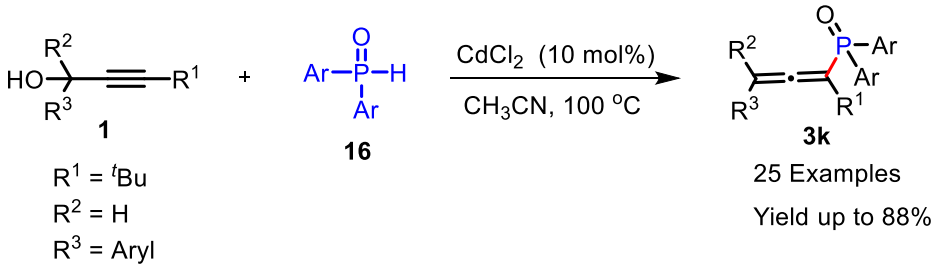
Scheme 9. Au-catalyzed synthesis of tetrasubstituted allenes.

In 2015 S.-J. Tu *et al*. demonstrated a novel synthesis of tetrasubstituted allenes from *tert*-propargyl alcohols and sulfonyl hydrazides catalyzed by TBHP/TBAI in the presence of HOAc with moderate to good yields (Scheme 10).[24]



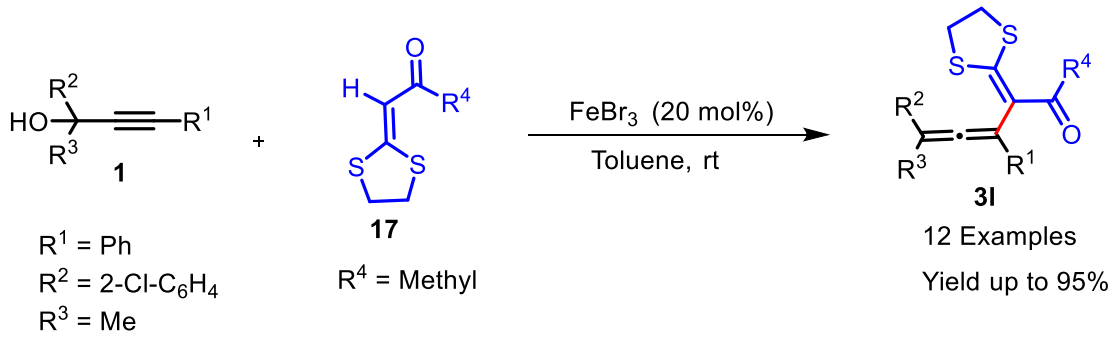
Scheme 10. Allenyl sulfones from propargyl alcohols and sulfonyl hydrazides.

In 2017 Wang *et al*. reported a dehydrative carbon-phosphorus cross-coupling reaction between *tert*-propargyl alcohols and P(O)H compounds catalyzed by $CdCl_2$. The ability of propargyl alcohols with sterically demanding substituents present at the triple bond is to generate products in high yields is a promising advantage of the reaction (Scheme 11).[25]



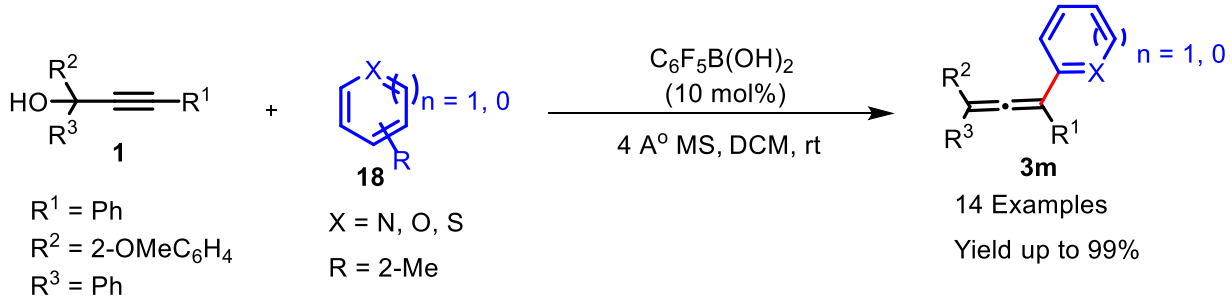
Scheme 11. Cd(II)-catalyzed C-P coupling of propargyl alcohols with di arylphosphine oxides.

Bi *et al*. reported the synthesis of [*gem*bis(alkylthio)vinyl]allenes using easily available starting materials and an environment-friendly iron catalyst. This method provides a quick and easy way to obtain fully substituted vinylallenes (Scheme 12).[26]



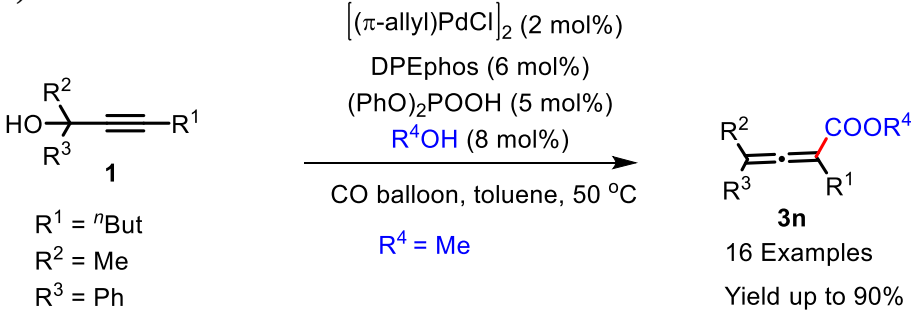
Scheme 12. Fe(III)-catalyzed synthesis of gembis(alkylthio)-substituted vinylallenes.

In 2011, McCubbin *et al*. developed a broad approach for the synthesis of propargyl/allenyl-substituted moieties from *tert*-propargylic alcohols and aromatic heterocycles by using perfluorophenylboronic acid with high yields and selectivity (Scheme 13). [27]



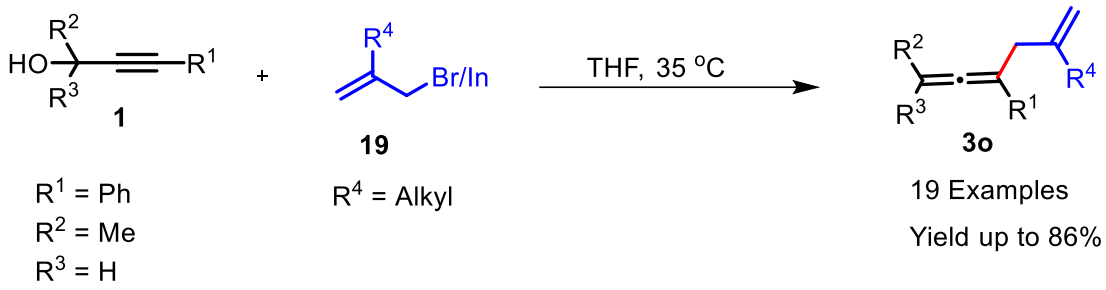
Scheme 13. Brønsted acid-catalyzed aryl-substituted allenes.

In 2017 Ma *et al*. demonstrated a method for the carboxylation of propargylic alcohols to synthesize allenes, which produced a broad scope of tetrasubstituted allenoates that tolerated beneficial efficient groups due to the cooperative binary catalysis of Pd and a phosphoric acid (Scheme 14).[28]



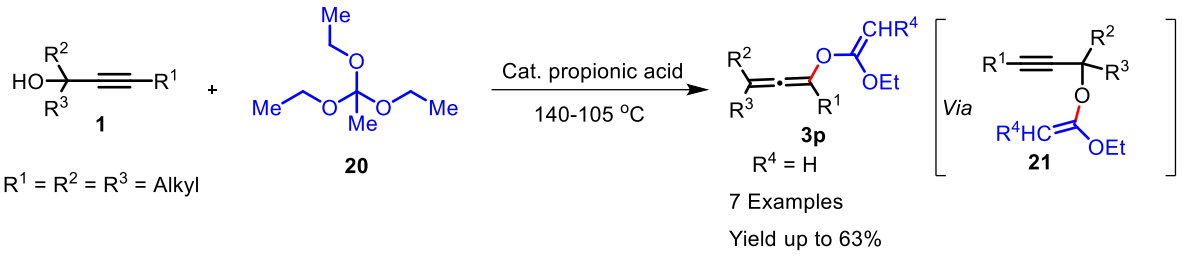
Scheme 14. Pd(II)-catalyzed synthesis of multi-substituted 2,3- allenoates.

In 2008 K. Lee *et.al* reported the reactions of allyl indiums produced *in vitro* from indium & allyl halides with *tert*-propargylic alcohols, for preparing fully substituted allenes with allyl & methallyl (Scheme 15).[29]



Scheme 15. In-promoted synthesis of allenes.

Crandall *et al*. demonstrated the preparation of allenic esters between propargylic alcohols (terminal and internal) and triethyl orthoacetate using propionic acid. Propargylic alcohols and triethyl orthoacetates underwent nucleophilic addition, which created propargylic vinyl ethers a crucial intermediate in this reaction which is involved in a 3,3- Claisen rearrangement with the release of EtOH, resulting in the end products (Scheme 16).[30]



Scheme 16. Brønsted acid-catalyzed synthesis of allenic esters.

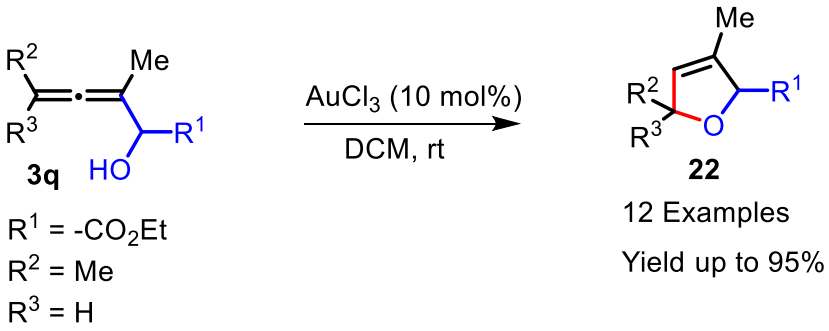
1.3 ALLENE CYCLIZATION

Allenes can undergo a wide variety of reactions like cyclization, cycloaddition, nucleophilic and electrophilic addition reactions *etc*[31]. This flexible nature of allenes makes them a valuable synthetic intermediate in the field of organic chemistry. Axial-to-central chirality transfer of allenes is another important feature that makes it a useful intermediate in asymmetric synthesis.[32] Hence allenes have become one of the most studied topics among synthetic chemists.

Cumulative double bond activation using Brønsted or Lewis's acid is beneficial among many different reaction modes as it permits the nucleophilic attack which results in a new carbon-carbon or carbon-hetero bond intermolecularly/intramolecularly.[33]

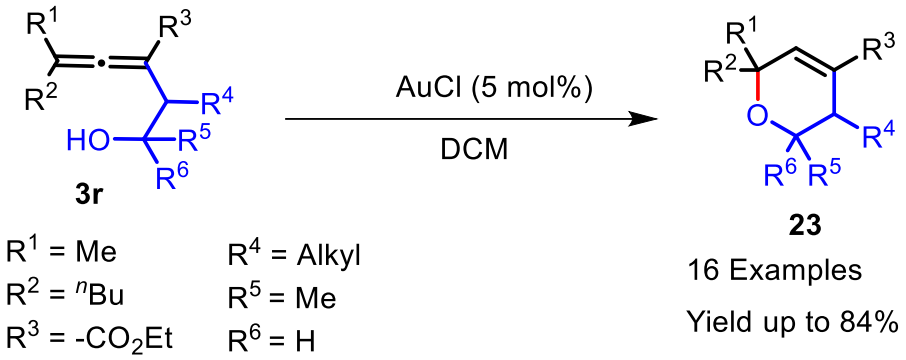
PREVIOUS REPORTS

A catalytic amount of $AuCl_3$ can be used to convert functionalized hydroxy allenes into their corresponding 2,5-dihydrofurans. At ambient temperature, this moderate and efficient cyclization method was used on allenes with alkyl and alkenyl substituents, to create different substituted dihydrofurans with moderate to outstanding yields, and a complete "axis to center chirality transfer" was reported (Scheme 17).[34]



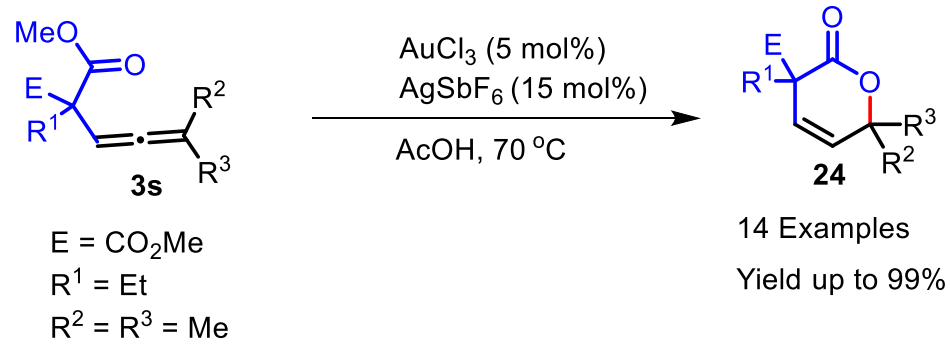
Scheme 17. Au(III)-catalyzed cyclization of a-hydroxy allenes to 2,5-dihydrofurans.

In 2006 N. Krause *et al*. developed the Au(I)-catalyzed *6-endo* cycloisomerization of *β*-hydroxy allenes to give chiral functionalized dihydropyrans with good yields at room temperature with "axis-to-center chirality transfer" (Scheme 18).[35]



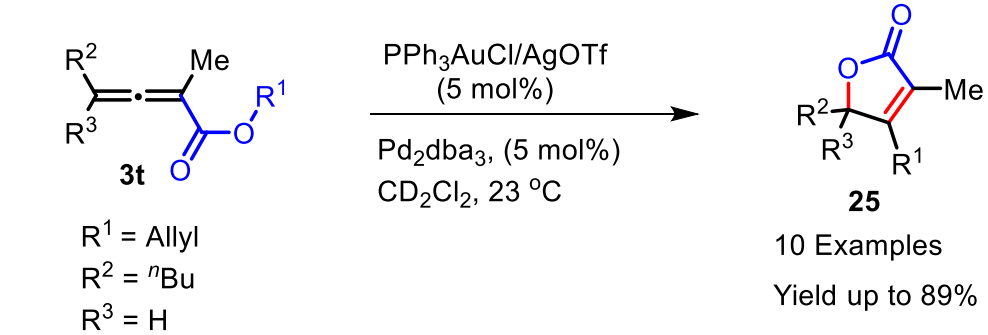
Scheme 18. Au(I)-catalyzed cyclization of *β*-hydroxy allene.

An efficient system for producing, *β*, *γ*-unsaturated *δ*-lactones was reported using allene-substituted malonates, which can be cyclized by the nucleophilic attack of an ester moiety on allene in an Au-catalyzed reaction (Scheme 19).[36]



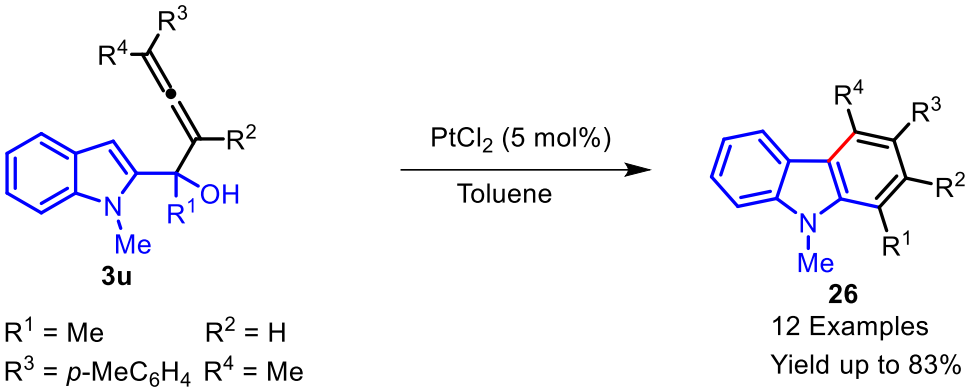
Scheme 19. Au(III)-catalyzed formation of *β*, *γ*-unsaturated *δ*-lactones.

In 2009 S. A. Blum *et al*. reported a novel method using Au and Pd as dual catalysts that improved the synthetic usefulness of vinyl gold intermediates by facilitating carbon-carbon cross-coupling as opposed to protodemetalation. Substituted butenolides and isocoumarins were also synthesized using this approach from the corresponding allyl esters (Scheme 20).[37]



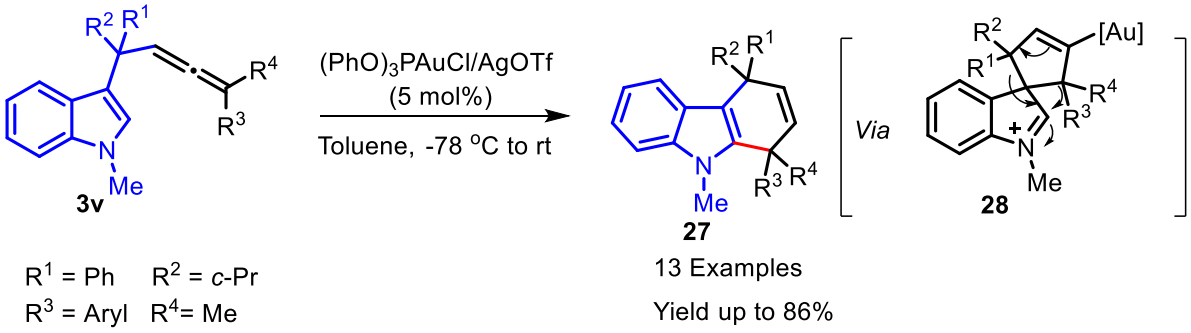
Scheme 20. Au and Pd-catalyzed butenolide rearrangement.

In the presence of $PtCl_2$, an efficient cyclization reaction of 3-allenylindols was reported to form multisubstituted carbazoles through 1,2-methyl migration of metal carbenes. (Scheme 21).[38]



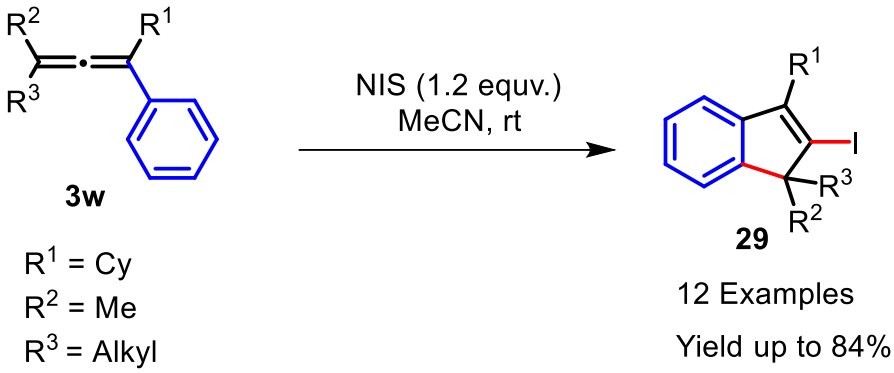
Scheme 21. Pt(II)-catalyzed cyclization of 2-allenylindole.

In 2013 R. Sanz *et al*. proposed an Au(I) catalyzed reaction of 3-allenylmethylindole for the preparation of carbazoles. This reaction proceeds *via* C2-H bond functionalization between indole and allene units, whose selectivity depends on substrates (Scheme 22).[39]



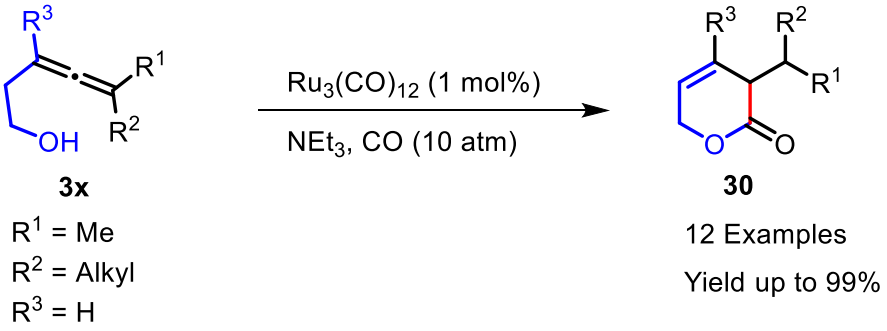
Scheme 22. Cycloisomerization of 3-allenylmethylindole.

A new and delicate protocol was reported to synthesize 2- iodoindenes, *via* "iodonium-induced carbocyclization" of a wide range of activated allenes in good to outstanding yields using N-iodosuccinimide, showing different functional group compatibility. Variations in allenic structures revealed a strong 5-*endo* selectivity as well as certain competing cyclization routes (Scheme 23).[40]



Scheme 23. Iodocyclization of arylallenes induced by iodonium.

Takahashi *et al*. reported a Ru-catalyzed unique cyclic carbonylation of allenic alcohols to generate lactones with more selectivity. This intramolecular tandem reaction selectively synthesizes *γ*, *δ*-lactones from allenyl alcohols and carbon monoxide (Scheme 43).[41]



Scheme 24. Carbonylation of allenyl alcohols.

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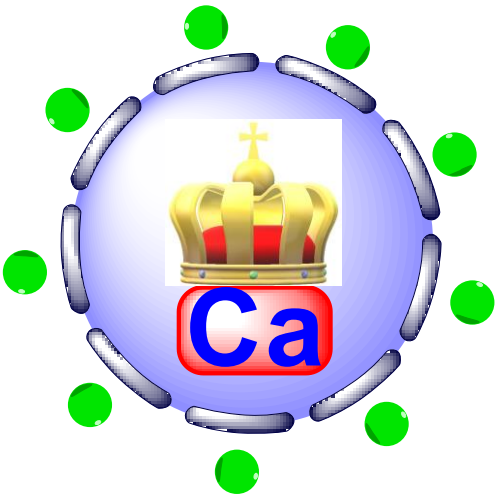
Section-B:

Introduction to Calcium Catalysis



1.6 INTRODUCTION

Chemists in modern organic synthesis have long pursued environmental friendliness, atom economy, and sustainability as major goals.[1] In the synthesis of heterocyclic compounds, traditional transition metals have prevailed, while Group-II metals received less attention.[2] In comparison to rare metals, alkaline earth metals are easily available, cheaper, and are environmentally friendly. Group-II metal complexes have permitted a variety of graceful transformations over the last two decades.[2, 3, 4,5] Even though Mg-based chemicals are produced as reliable stoichiometric catalysts in organic synthesis.[6] There are very few elements of Group-II metals being used to make heterocyclic compounds, which can be attributed to their unique properties. With a d^0 electron, they are sensitive to moisture, and the highest oxidation state is +2. Because there is less variation in their valence electrons than in other transition metals (Rh, Ni, Pd, etc) oxidative addition or reductive elimination is not easy. Alkaline earth metals are used in organic synthesis because of their abundance, bioactivity, and powerful chemical activity.[7, 8]

1.7 LEWIS ACIDIC CALCIUM CATALYSIS

Calcium is one of the common metals found on earth and one of the very few which has no harmful effects. Calcium is found in abundance in the human body, with its primary quantitative function being the maintenance of the endoskeleton[9]. It also plays an important role in complex biological systems, where elaborate control mechanisms govern the attention of these ions in metabolic pathways [10]. In addition, the atmosphere and hydrosphere also contain 3.4 % by weight of calcium. All these figures illustrate that Ca is one of the easily available metals on the planet. It exists in nature as sulfate, silicate, carbonate, phosphate, and fluoride. Calcium is redox-inert in all of these compounds and exists mostly in +2 oxidation state.

Calcium ions have a redox potential of E^o = -2.869 V, which makes them inert metals in redox reactions. Whereas, reactions involving redox processes such as “oxidative addition and reductive elimination” in their catalytic cycles will be mainly a “transition-metal mediated catalysis”. This is both a disadvantage and a benefit of these catalysts since unwanted side reactions caused by redox activity do not interfere with the desired pathway. Unevenly spoken, the responsiveness of Ca(II) compounds could be separated into two parts (Figure 1).[11] Similarly Group-II metal compounds calcium have highly ionic, because of their low

electronegativity values. Thus, anionic residues bound to calcium(II) have nucleophilic character coupled with a strong basic nature.[12]

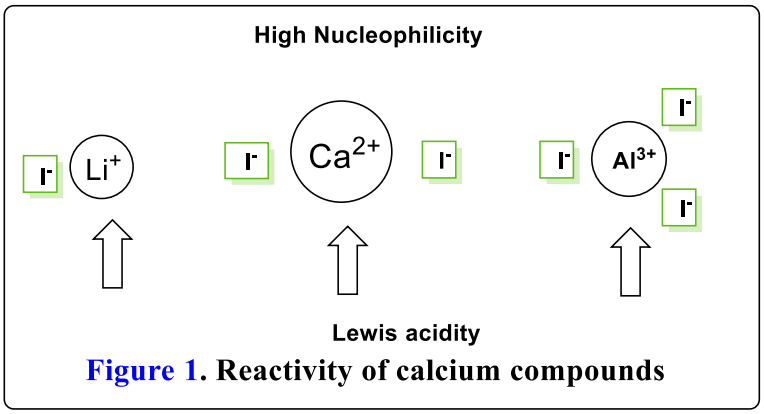


Figure 1. Reactivity of calcium compounds

Although calcium's acidic nature was thought to play a role in polymerization reactions and asymmetric addition reactions, there weren't many studies conducted to explore it as a catalyst in organic synthesis until recently. F_6iPrO^-, F^-, TfO^-, and an equal mixture of triflimidate (NTf_2^-) and hexafluorophosphate (PF_6^-) being weakly coordinating non-basic anions have produced the best results (Figure 2). Unlike the very basic Ca-catalysts specified above, these novel Ca-based Lewis acids are much better in terms of the ease to handle them and their tolerance to moisture and oxygen.

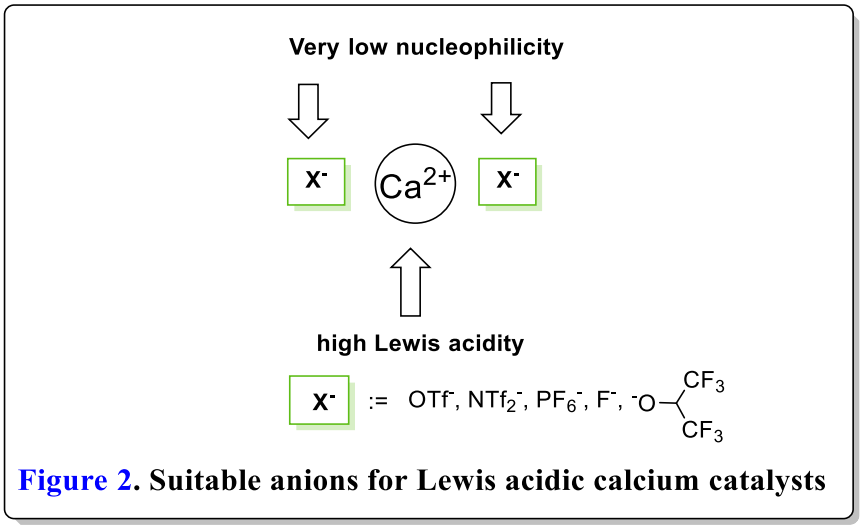
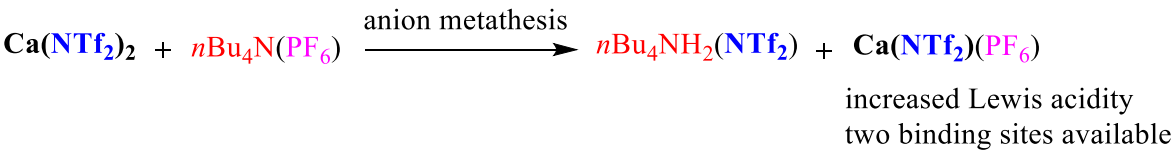


Figure 2. Suitable anions for Lewis acidic calcium catalysts



Scheme 25. Formation of Ca(II) active species.

However, constraints like cost, toxicity, and waste management limit the growth of cost-effective and sustainable catalytic processes.[12] Calcium, among the Group-II earth metals, has

a lot of potentials to meet these requirements and act as a good Lewis acid because of its high availability and low toxicity.[13] Niggemann was the first to use Ca complexes as Lewis acids in the field of synthetic chemistry.[14, 15] Highly stable $Ca(NTf_2)_2$ [NTf_2 = bis(triflimide)] catalyst along with Bu_4NPF_6 as an additive are used. The complex $Ca(NTf_2)(PF_6)$ formed by anion metathesis enhances Lewis acidity (Scheme 25).[14] The peculiar characteristics of the Tf_2N^- anion have a significant impact on the chemistry of metal triflimidates.[15] Metal triflimidates when compared to metal triflates, are stronger Lewis acids, considering the fact that Tf_2NH is a poor proton donor than TfOH.[16] This is due to

(i) the negative charge on the Tf_2N^- anion which is widely delocalized.

(ii) its relatively large volume".[17] Except for Ca, Sr, and Ba complexes, where it exists in η^2-N, O binding geometry, the Tf_2N^- anion functions as a ligand and accepts a η^2-O, O binding geometry to the metal.[18]

We were interested in the fact that when $Ca(NTf_2)_2$ reacts with Bu_4NPF_6, not only a more Lewis acidic $Ca(NTf_2)(PF_6)$ complex formed, but also two binding sites on $Ca(NTf_2)(PF_6)$ become available.[18]

1.8 Why Is It Important to Develop Calcium-Catalyzed Reactions?

d-block metal catalysis has developed to be the best prevailing cascade for the formation of C-C and C-X (where X = hetero-atom) bonds in organic chemistry over the last few decades, with utilization in total synthesis of an excess of natural products, medicines, and resources.[19] However, transition-metal catalysts do have certain essential drawbacks, to commence with, transition-metal catalysts are frequently hazardous, therefore, removing metallic contaminants from the required medicinal end products is a key distillation issue in d-block metal-catalyzed reactions. Secondly, most transition metals are precious metals, such as Pd, Au, Rh, and Ru. Thirdly, the pairing of d-block metals and complex ligands is essential to increase the reaction efficiency in most transition-metal catalyzed processes. Finally, as our finite natural resources are depleted, the accessibility of d-block metals is becoming gradually limited. As a result, the construction of high feasible replacements is in high necessity whenever possible. In this sense, processes catalyzed by low-priced, harmless, and abundant metals provide a new path to feasibility.

Being the 5th most abundant element in our planet's crust, Ca is generally considered non-toxic even in high amounts making it ideal for enduring sustainability. As a result, from an

environmental and commercial standpoint, reactions that are catalyzed by Ca are generally favored in synthetic organic chemistry.

1.9 REACTIONS OF ALCOHOLS

With the increase in the complexity of reactions, there is a need to find the best replacements for the existing common catalysts. It is also critical to replace inefficient reagents with more alternatives. The straight usage of alcohols as alkylation agents is one of the twelve concepts that this "ACS GCI Pharmaceutical Round table" strongly favors, as it offers solutions to various environmental issues. Water is generated as the only by-product during the reaction, and alcohols are easily available in a wide range of forms from natural sources. It is not essential to convert the -OH group to any other good leaving group and hence the overall salt load is significantly decreased. Alcohols can be employed as electrophilic coupling agents through S_N1 reactions involving Brønsted or Lewis acids.[20] -OH being poor leaving group requires harsh reaction conditions. The Lewis acidic Ca-catalyst created by combining $Ca(NTf_2)_2$ with Bu_4NPF_6 was found to catalyze this reaction even at room temperature, unlike previously known catalysts. This is because of the calcium catalyst's dual role. Firstly, it stimulates the carbon-oxygen bond to undergo bond cleavage through the formation of a coordinate bond of the hydroxyl oxygen with the attacking calcium. Secondly, calcium-oxygen bonds create a short "activating group" for the -OH group due to its unique stability. Catalyst activity is regained through the protonation of -OH at Ca^{2+} ion followed by H_2O release. (Figure 3).

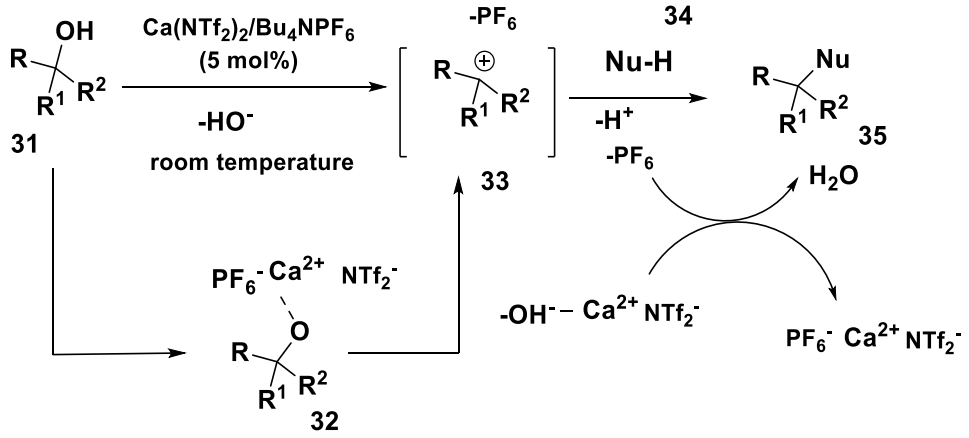
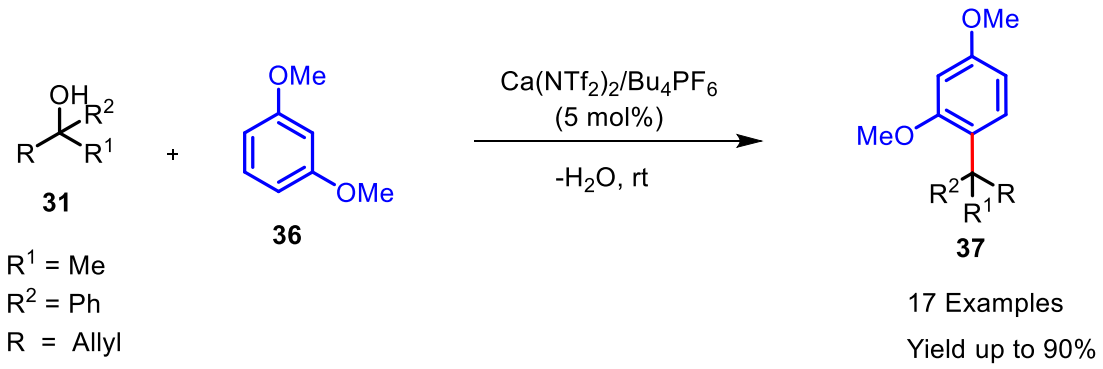


Figure 3. Calcium-catalyzed dehydration of alcohols

1.9.1 Ca(II)-CATALYZED FRIEDEL–CRAFTS REACTIONS

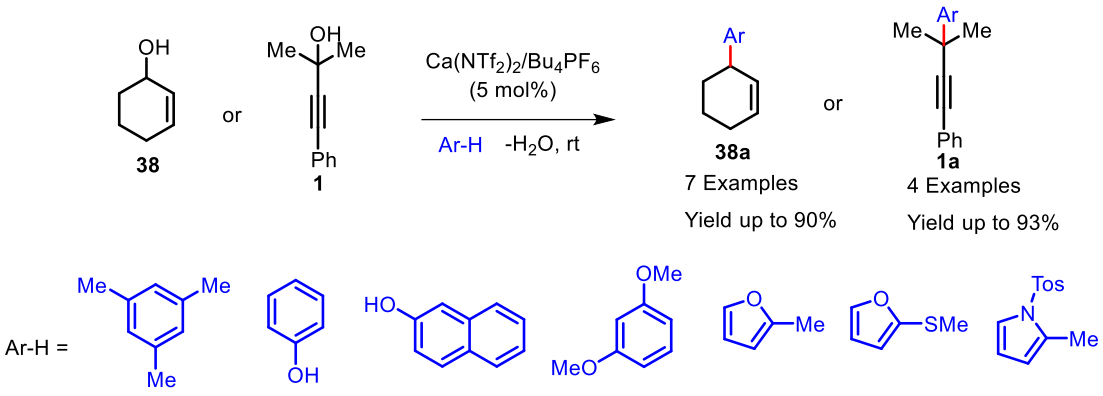
The Friedel–Crafts (FC) alkylation reactions are very well known for their exceptional synthetic ability for the functionalization of arenes.[21] Though, certain subjects of the original type, especially related to the environment, have to be addressed during the last 130 years to reach the current international deployment of FC techniques in industry and academia. Seminal FC procedures are unfeasible on a bulk scale due to the nature of the alkylating agents and promoters (i.e. high quantities of toxic metal salts). Most of these issues are solved when solid LAs /Bronsted acidic additives are used as promoters.

The electron-rich aromatic compounds were the first nucleophilic coupling partners studied in depth for the Ca-catalyzed substitution of alcohols. As a result, a Ca-catalyzed FC reaction with alcohols as alkylating agents can be an alternative to the organohalides (Scheme 26).[22] The very clement reaction conditions, wide substrate scope, as well as strong functional group tolerance, are some of the primary properties of the Ca-catalyzed reaction. Resorcinol dimethyl ether, a typical nucleophile was used to treat a diversity of secondary and tertiary alcohols. In all cases, the resultant arene was substituted in the *o,p* position with respect to resorcinol's ether moiety (Scheme 26). Reaction times were faster for tertiary alcohols compared to secondary alcohols.



Scheme 26. Ca(II)-catalyzed Friedel-Crafts reaction with resorcinol dimethyl ether.

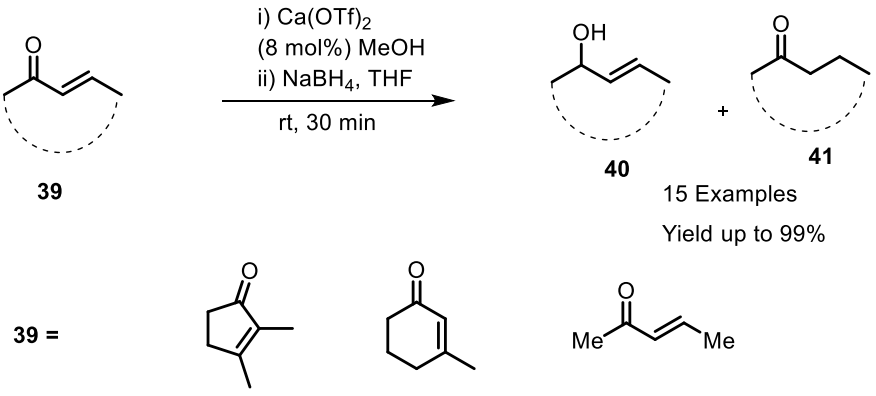
To demonstrate the adaptability of the latest Ca-catalyzed FC reaction, various arenes and heteroarenes were used to treat cyclohexenol **34** and the *tert*-propargylic alcohol [14]. Both of these alcohols had never been converted before in a reaction like this using a Lewis acidic catalyst (Scheme 27).



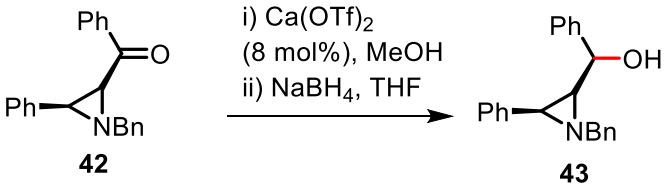
Scheme 27. Cal(II)-catalyzed addition of arenes to allylic and propargylic alcohols.

1.9.2 REDUCTION OF CARBONYL COMPOUNDS USING Ca(II)

Fuchter and co-workers reported an effective Calcium-based procedure for a Luche-type reduction reaction that can compete with the traditional $CeCl_3$-catalyzed reaction.[23] Using $Ca(OTf)_2$ and $NaBH_4$ in a mixture of MeOH and THF, regioselective 1,2-reduction of different, α, β-unsaturated ketones, including the difficult 2-cyclopentenone, was effectively performed (Scheme 28). The resultant allylic alcohols were synthesized with excellent yields and regioselectivity. In addition, the approach was found to be effective for the selective reduction of aziridinyl ketones **42** (Scheme 29).

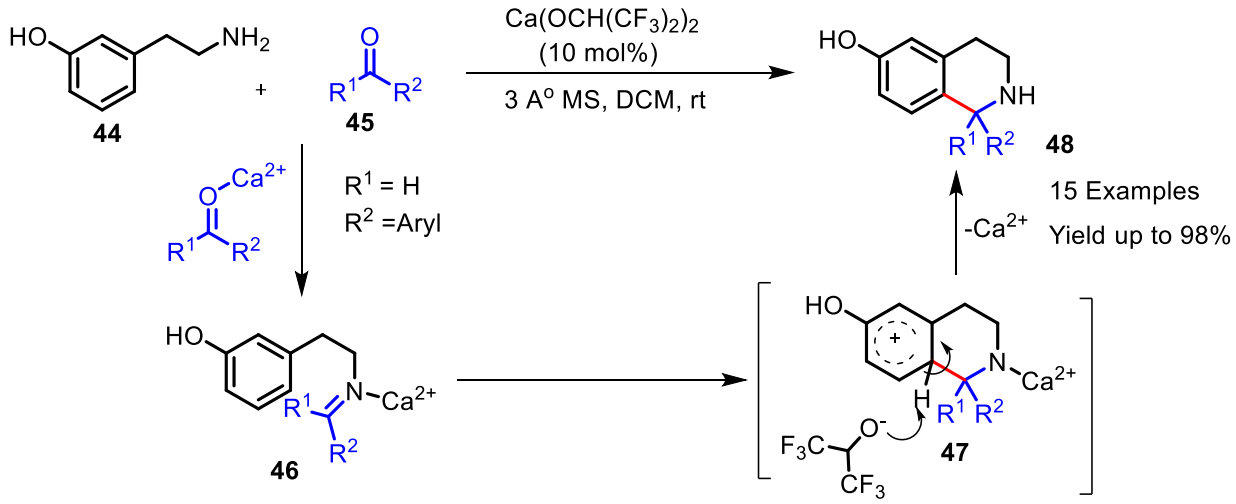


Scheme 28. Ca(II) mediated reduction of *α*, *β*-unsaturated ketones.



Scheme 29. Stereoselective reduction of *α*, *β*-aziridinyl ketones by calcium.

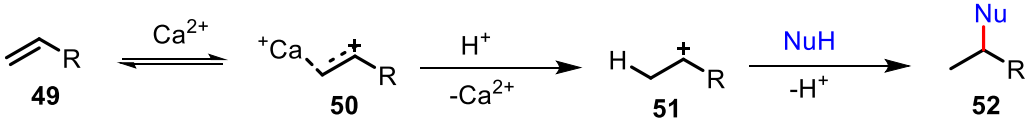
The first demonstration of Ca(II)-catalyzed selective Pictet-Spengler reactions was demonstrated by Stambuli and co-workers in 2008 for the reaction between *m*-tyramines **44** and aldehydes **45.** The Pictet-Spengler reaction is a well-known method for synthesizing tetrahydroisoquinolines and *β*-carbonyl alkaloids. Furthermore, stoichiometric amounts with powerful Brønsted acids were utilized to promote it, leading to a number of drawbacks due to the severe conditions required for these transformations, like its inability to tolerate different kinds of functional groups, the Pictet-Spengler reaction, which is catalyzed by ecologically friendly calcium salts.[24] Calcium catalysts are responsible for triggering the aldehyde **45** and imines **46** (Scheme 30).[24] Stambuli *et al*. discovered two years later that ketones considered less reactive were also acceptable for the Ca(II)-catalyzed Pictet-Spengler reaction.[24a]



Scheme 30. Ca(II)-catalyzed Pictet-Spengler reactions.

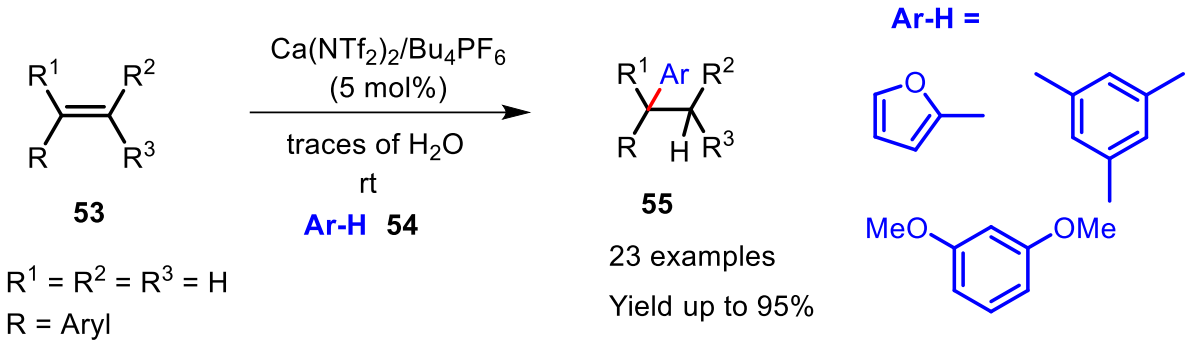
1.9.3 REACTIONS OF OLEFINS

In addition to the conversion of alcohols, calcium catalysis could also efficiently convert alkenes into their corresponding carbocations, which can be captured by aryl nucleophiles. As a result, calcium-catalyzed alkene hydroarylation was introduced in 2010. Moreover, calcium efficiently catalyzed the hydroarylation of a broad range of substituted alkenes and dienes.



Scheme 31. Classical transformation of alkenes.

Niggemann *et al*. in 2010 demonstrated a highly effective intermolecular hydroarylation process of aromatic and aliphatic olefins using calcium as a catalyst. Within an hour at room temperature, a lot of electron-rich, electron-poor, and substituted olefine molecules were transformed into required diaryl alkanes. Because of the strong reactivity of the $Ca(NTf_2)_2/Bu_4NPF_6$ system, dienes & evenly substituted alkenes were easily arylated. Under very moderate reaction conditions, a variety of starting materials are also tolerated. Typical reactions take place at ambient temperature, and no additional precautions to exclude moisture and air are required (Scheme 32).[25]

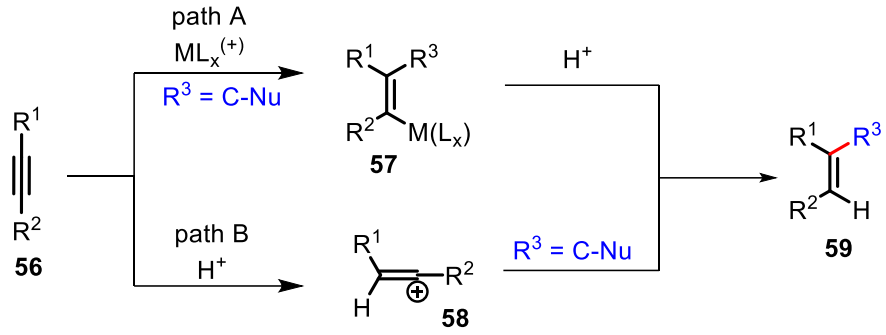


Scheme 32. Ca(II)-catalyzed hydroarylation of alkenes.

1.9.4 Ca(II)-CATALYZED CARBOARYLATION OF ALKYNES

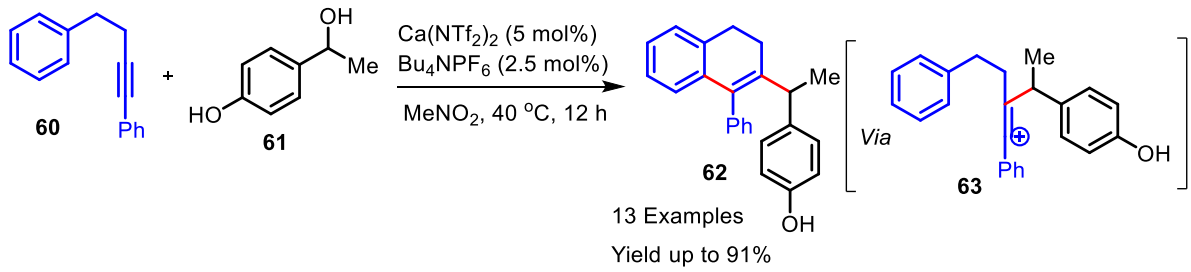
Background

Natural products, pharmaceuticals, and materials frequently contain all-carbon tetrasubstituted olefins, which are resourceful starting materials for the preparation of complex fine chemicals.[25] However, the obstructed character of these alkenes makes them difficult to synthesize using traditional methods like carbonyl olefination or olefin metathesis.[26a] Despite the fact that numerous ways for accessing them from alkynes in a stepwise manner have been established,[26b,] catalytic conventions for the single-step assembly of these densely substituted building blocks remain a difficulty for organic chemists. This is certainly because most processes for adding substituents to alkynes involve a carbometallation phase followed by additional expansion of the resulting vinyl-metal species **57** (Scheme 33) this elaboration is frequently merely a simple protodemetallation in catalytic one-step methods, restricting the range of available olefins to trisubstituted ones. Furthermore, humidity responsive stoichiometric metal-organic reagents, as well as transition-metal catalysts such as Ni,27 Pd,28Cu 29, or Fe, salts [30] are required.



Scheme 33. Classical transformation of alkynes.

Niggemann *et al*. in 2015 have established a method for carboarylation of alkynes using viable and broadly existing alcohols as alkylation reagents to give a short way for the single-step synthesis of tetrasubstituted olefins in the presence of Ca-catalyst.[31] Because the reaction is catalyzed by a very reactive trisubstituted vinyl cation, deactivated fluorine-substituted arenes can be used as a nucleophile, and it also tolerates steric crowding, most helpful because it allows the formation of potentially bioactive chromene and dihydroquinoline derivatives (Scheme 34).

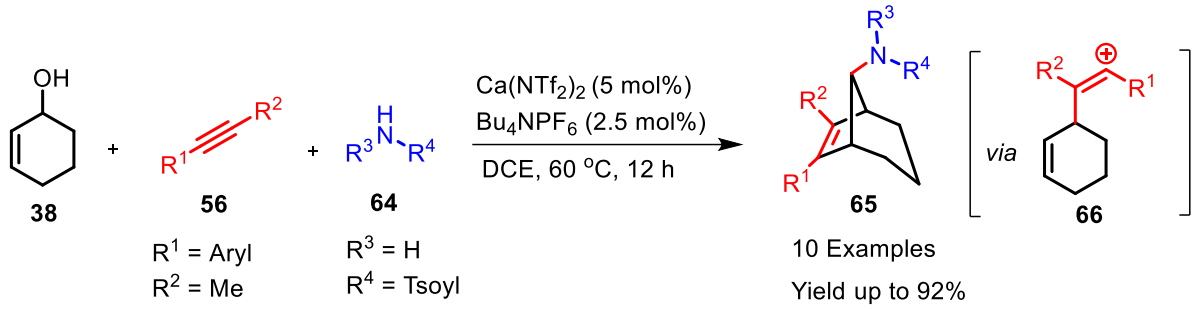


Scheme 34. Ca(II)-catalyzed carboarylation of alkynes.

1.9.5 CALCIUM-CATALYZED MULTICOMPONENT REACTIONS

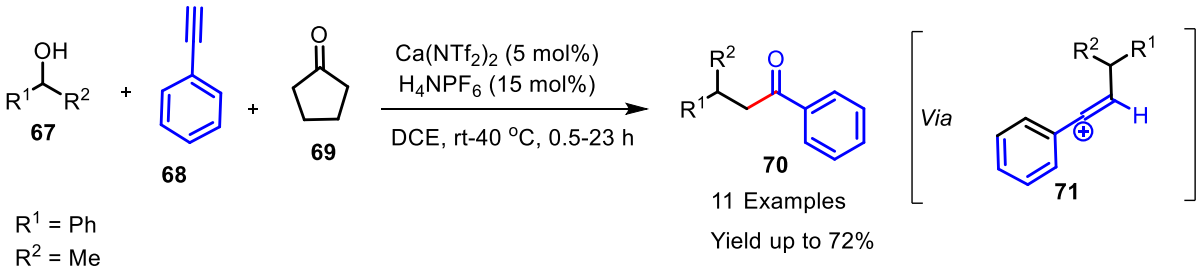
Niggemann *et al*. reported the dehydroxylation of 2-cyclohexenol in presence of bisubstituted alkynes is likely to produce the vinylic cation, which then rearranges to the highly stable non-symmetrical carbocation. It can then be trapped by H_2NTs, resulting in a single diastereomer of the bicyclic amine.[32] The method described here is a simplified version of a considerably more complicated scenario involving the production of reversible covalent bonds. In fact,

amines can react readily with the hydroxyl group that has been extracted from it, and the hydroxyl group that has been removed from it can be trapped (Scheme 35).



Scheme 35. Ca(II)-catalyzed multicomponent reaction.

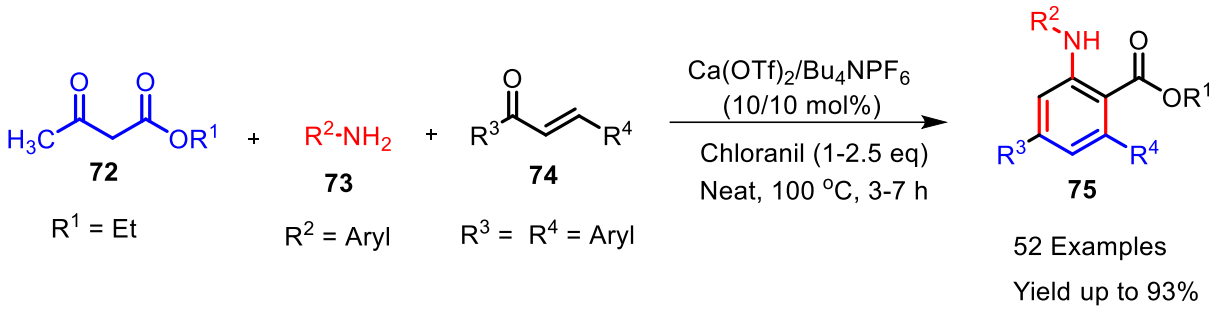
Niggemann *et al*. in 2015 revealed that, when used in combination with calcium-based catalytic technology, cyclopentanone, is extremely effective at stabilizing allyl and vinyl cation intermediates.[33] As a result, the intermolecular carbohydroxylation of alkynes, which is generally pestered by side reactions arising from the passing nature of weakly stabilized cationic intermediates, was achieved using allylic and propargylic alcohols as alkylating agents (Scheme 36).



Scheme 36. Ca(II)-catalyzed intermolecular carbohydroxylation of alkynes.

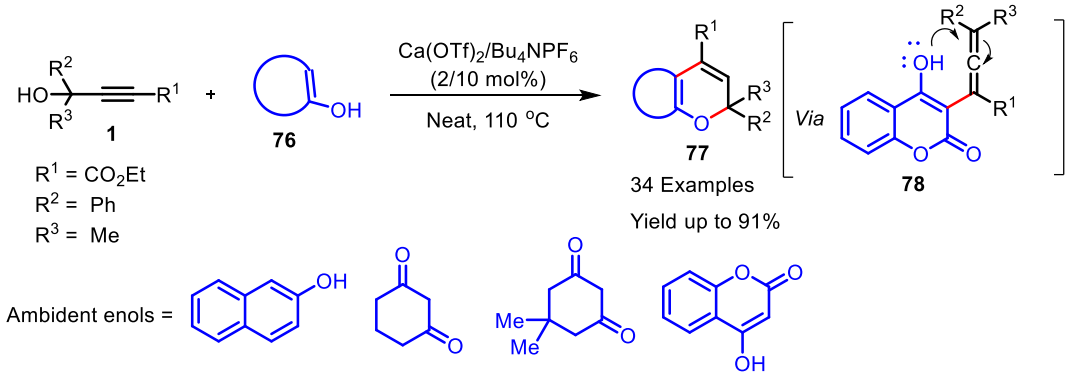
1.9.6 EXPLORATION OF Ca(II)-CATALYZED REACTIONS FROM OUR GROUP

Yaragorla *et al*. have developed a method for the benzannulation of easily available compounds in single-step without solvent by $Ca(OTf)_2$ as a catalyst. This reaction proceeds through a high regioselective cascade involving "*β*-enamino ester" formation, Michael addition, intramolecular aldol reaction, elimination, aromatization, oxidative debenzylation, lactonization" with a wide range of substrate scope in good yields (Scheme 37).[34]



Scheme 37. Ca(II)-catalyzed amine-triggered benzannulation reaction.

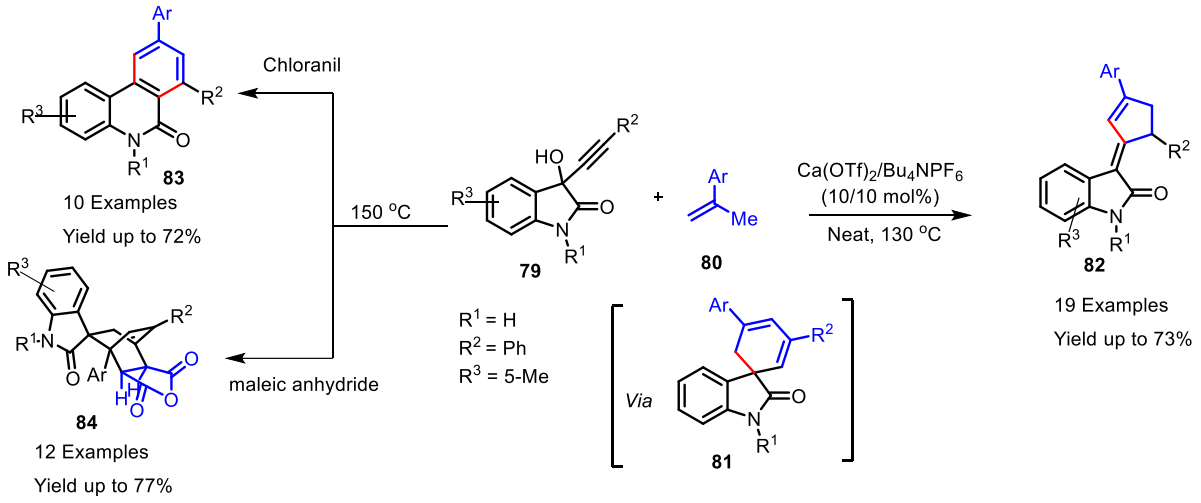
Yaragorla *et al*. reported a selective cyclization reaction of *tert*-propargyl alcohols with cyclic nucleophiles using $Ca(OTf)_2$ as a suitable catalyst. We were able to introduce the acid derivatives of benzochromene moieties with novelty. An etherification, Claisen rearrangement, allene synthesis, and *endo* cyclization are all part of the reaction's cascade annulation (Scheme 38).[35]



Scheme 38. Ca(II)-catalyzed regioselective annulation of propargyl alcohols with ambident enols.

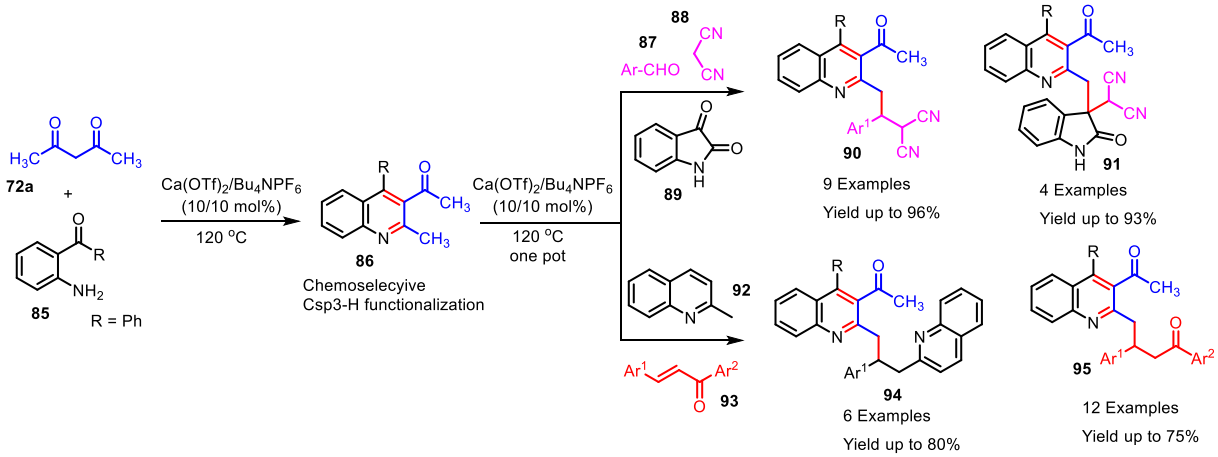
Yaragorla *et al*. demonstrated a Ca(II)-catalyzed one-pot approach for the synthesis of oxindole-derived 1,5-enyne which then cycloisomerized to yield trisubstituted

cyclopentenylidenes, "benzannulation to yield phenanthridinones," and Diels-Alder cyclo additions which yields stereoselective 3-spirocyclic 2-indolinone derivatives (Scheme 39).[36]



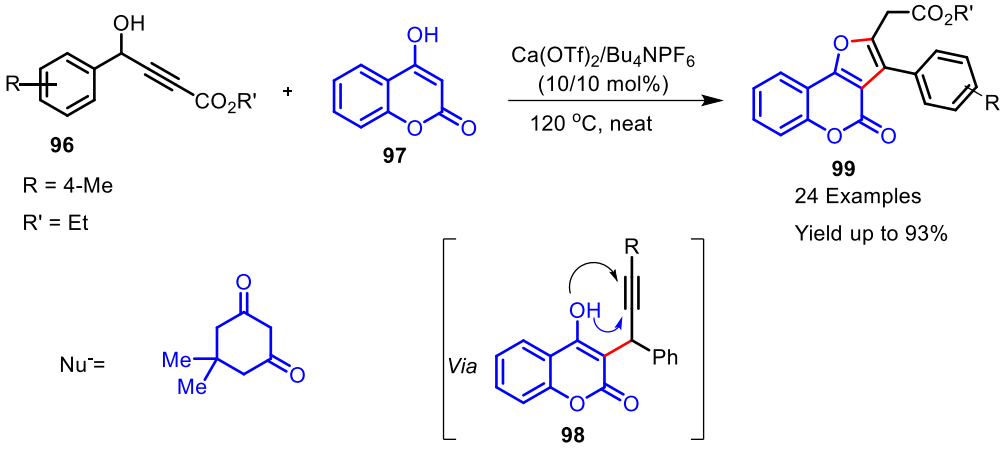
Scheme 39. Ca(II)-catalyzed synthesis of phenanthridinones, 3-(Cyclopentenylidene)indolin-ones, and 3- spirocyclic indolin-2-ones in a one-Pot.

Yaragorla and co-workers demonstrated Ca(II)-catalyzed regioselective synthesis of 2-methyl-3-acyl quinolines in solvent-free conditions. These quinolines undergoes *in situ* Csp3-H functionalization and produce a variety of quinoline heterocycles with good yields, atom and step economy for the first time in the literature (Scheme 40).[37]



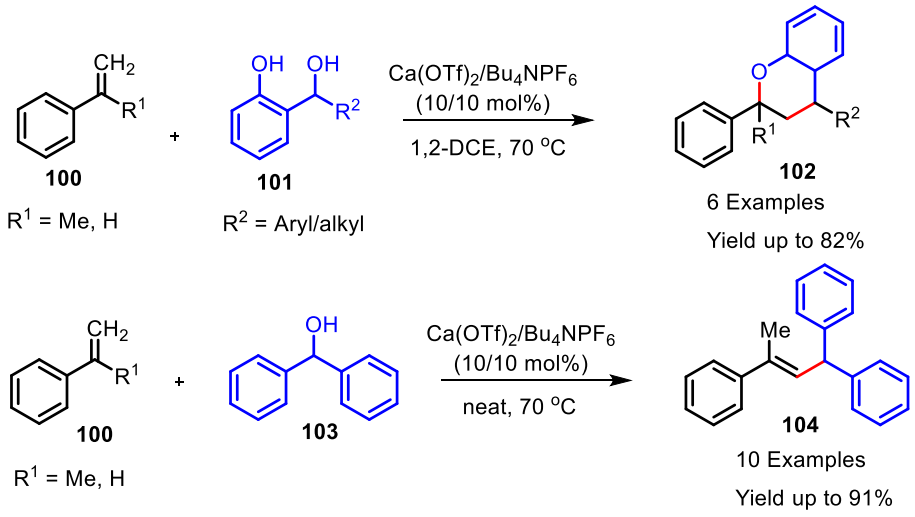
Scheme 40. Ca(II)-catalyzed tandem Friedlander annulation and Michael addition for the synthesis of substituted quinoline derivatives.

Yaragorla *et al*. reported a solvent-free single-step method for the preparation of fully functionalized furans using an environmentally benign and abundant calcium catalyst with high selectivity, broad substrate scope, and with excellent yields (Scheme 41).[38]



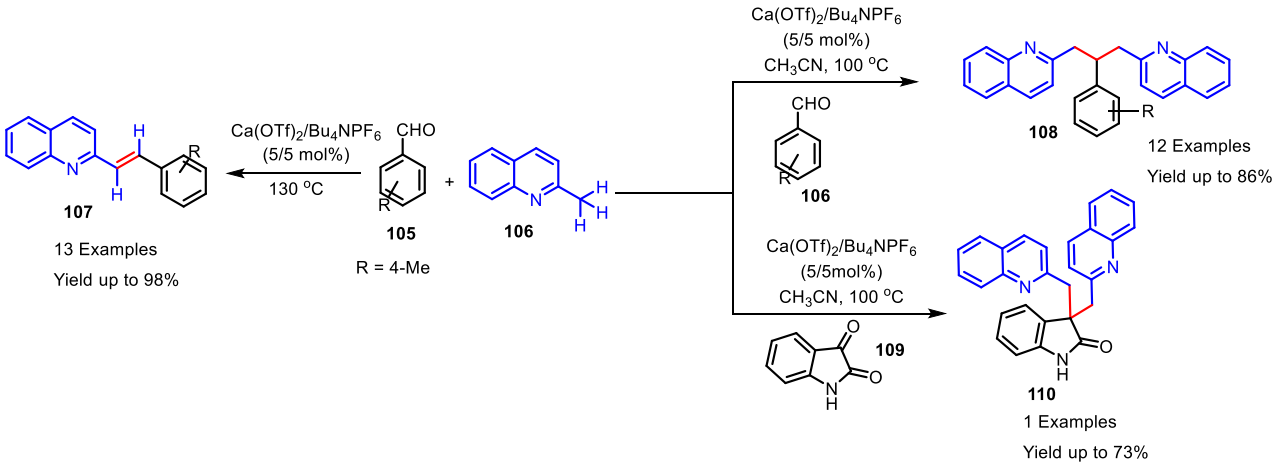
Scheme 41. Ca(II)-catalyzed regioselective synthesis of fully substituted furans.

Yaragorla *et al*. reported an uncomplicated methodology for the regioselective preparation of internal olefines by dehydrative cross-coupling/direct coupling procedure, in presence of calcium as a catalyst. Several olefines and hydroxy compounds have experienced this kind of coupling process under solvent-free conditions in no time to synthesize corresponding olefines. This approach is further developed to demonstrate its use in the cascade preparation of new benzopyran moieties (Scheme 42).[39]



Scheme 42. Ca(II)-catalyzed regioselective dehydrative cross-coupling reactions.

Yaragorla and co-workers developed the preparation of physiologically significant styryl azaarenes/1,3-bis azaarenes, & bisazaarenyl indolinones *via* S_N1 reaction by using calcium catalyzed Csp3-H functionalization of 2-methyl azaarenes. In the first step, methyl azaarenes react with aromatic aldehydes to form *β*-OH derivatives, which are then thermodynamically eliminated by Ca(II) to form styryl azaarenes in one step (Scheme 43).[40]



Scheme 43. Ca(II)-catalyzed facile synthesis of (*E*)-2-styryl azaarenes and 2-aryl-1,3-bisazaarenes.

1.9.7 REFERENCES

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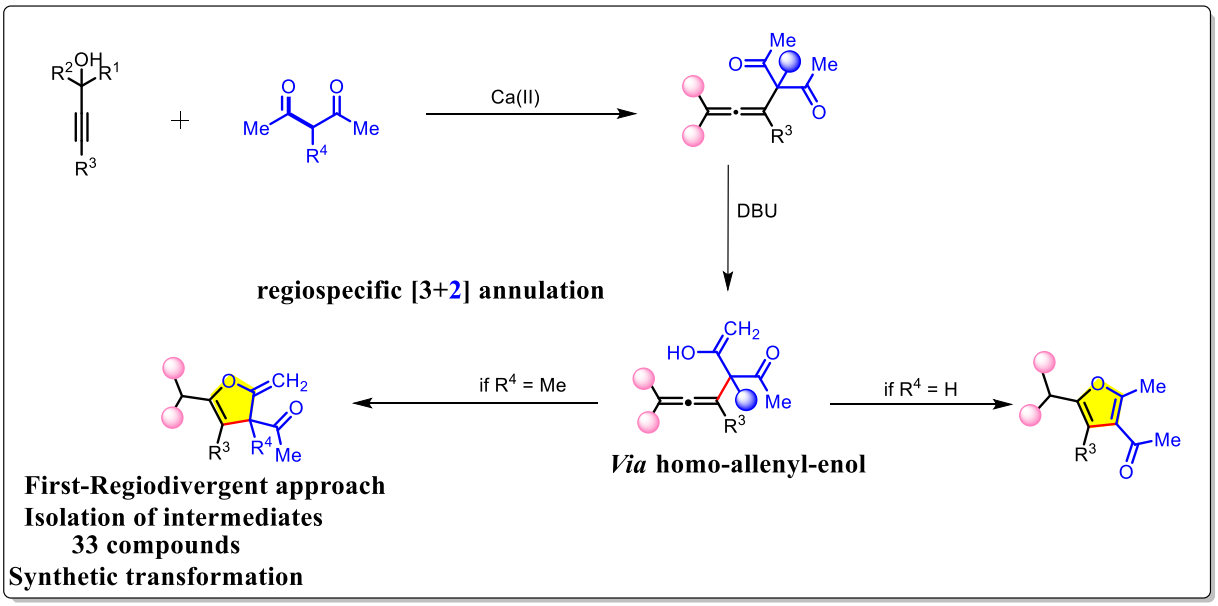
Synthesis and in-situ cyclization of tetrasubstituted allenes to access substituted furans



Org. Biomol. Chem. **2019**, *17*, 1924-1928

2.1 INTRODUCTION

Furans and their derivatives are important 5-membered oxygen-containing aromatic heterocycles that occur in many biologically important natural products (Figure 1) and synthetic molecules.[1] In particular, condensed and substituted furans, due to their structural features and biological activities, such as antifungal, antiviral, antidiabetic, antiparasitic, and pharmaceutical applications,[2,3] chemists have devised new synthetic methods for these scaffolds, which are both exciting and hard from a synthetic standpoint.[4-7] Although many practical synthetic methods, most of them suffer from multistep synthesis, regioselectivity, usage of unavailable starting materials, expensive transition metal catalysts, strong bases, or acids.[4-7] Therefore, it is very desirable to have a regioselective, and atom-economical synthesis of substituted furans.

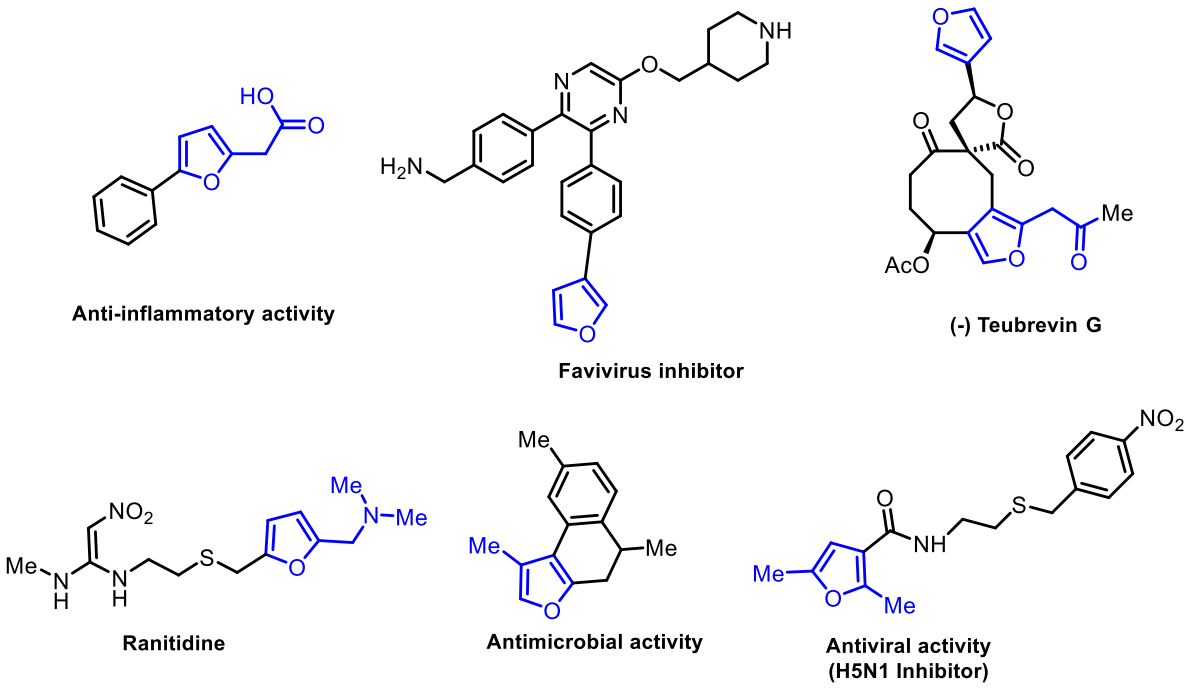
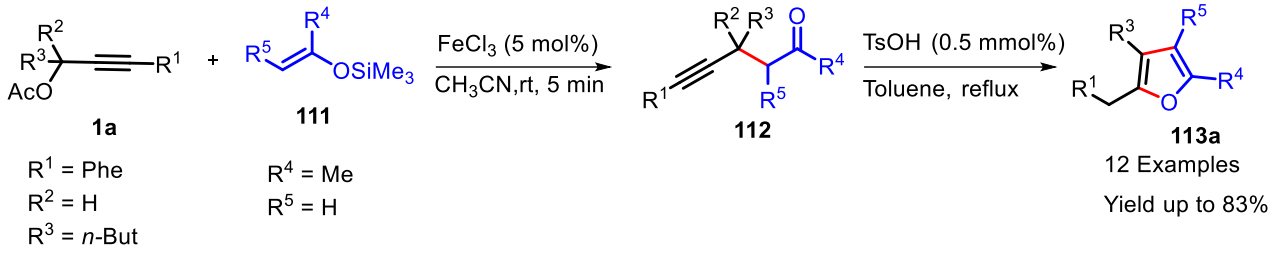


Figure 1. Representative examples of biologically important natural products containing furan moiety.

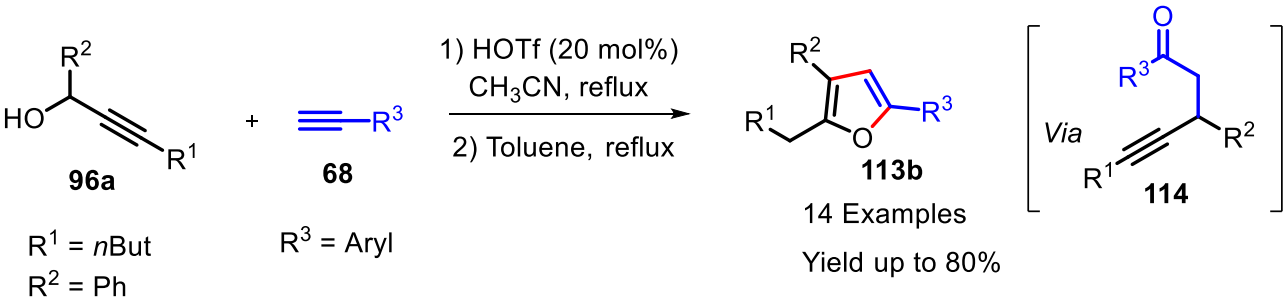
2.2 PREVIOUS APPROACHES

Two-step synthesis (through S_N1): In 2007 Zhan and co-workers developed iron-catalyst two-step preparation of furans from propargylic acetates and enoxysilanes. These reactions were performed by using $FeCl_3$ and TsOH as a catalyst (Scheme 1).[8a]



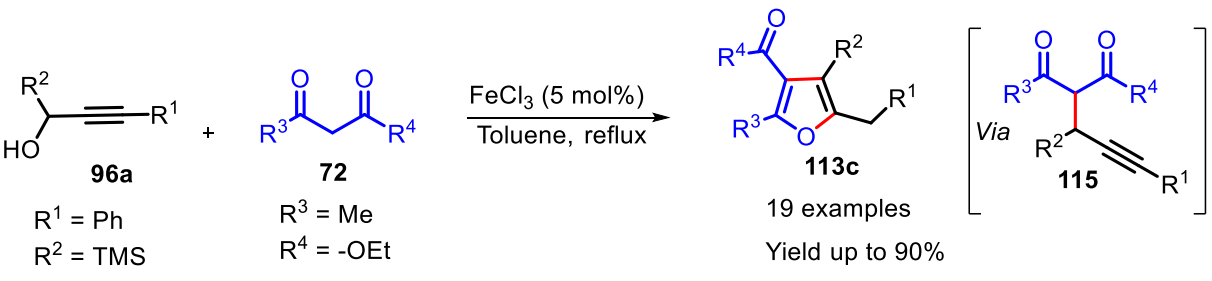
Scheme 1. Two-step synthesis of furan *via* $FeCl_3$ catalyzed *β*-alkynyl ketones followed by TsOH-catalyzed cyclization.

Zhan *et al*. have demonstrated that polysubstituted furans could be synthesized from propargyl alcohols and terminal alkynes. Furans were synthesized *via* diynes, and the strategy for the furan synthesis is 100% atom economy (Scheme 2).[8b]



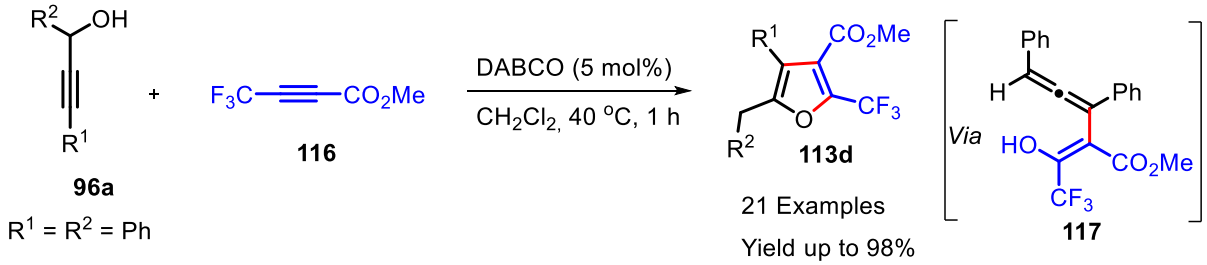
Scheme 2. HOTf-catalyzed synthesis of substituted furans from propargylic alcohols and terminal alkynes.

Preparation of fully substituted furans from propargylic alcohols and 1,3-diketone compounds was described by Zhan and co-workers. under $FeCl_3$-catalysis. Furans were synthesized *via* a one-step procedure involving the cycloisomerization reaction (Scheme 3).[8c]



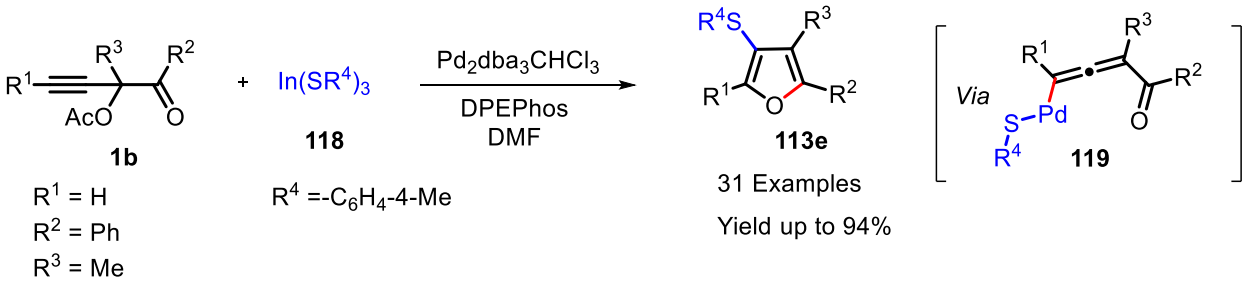
Scheme 3. Fe(III)-catalyzed synthesis of fully substituted furans from propargylic alcohols and 1,3-dicarbonyl compounds.

A synthesis of fully substituted furans from propargyl alcohols and methyl 2-perfluoroalkynoate to give trifluoromethylated furans (up to 98% yield) under mild conditions using DABCO was reported. This reaction proceeds through a "Michael addition" and Claisen rearrangement/cyclization process (Scheme 4).[8d]



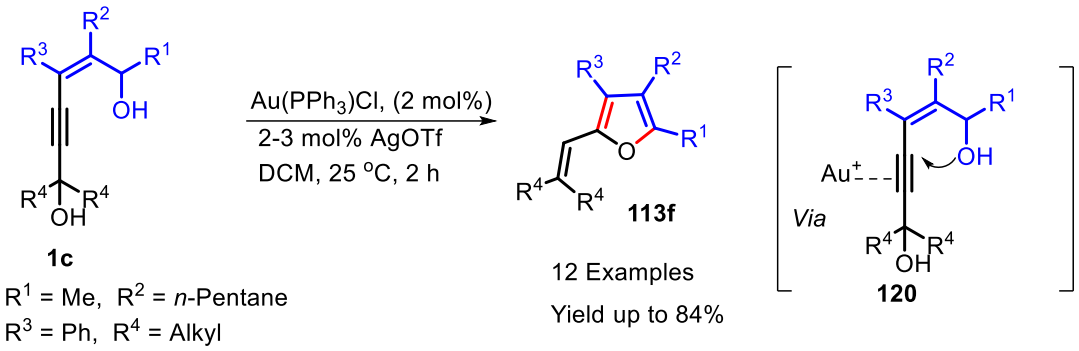
Scheme 4. DABCO-catalyzed synthesis of trifluoromethylated furans from propargylic alcohols and methyl 2-perfluoroalkynoate.

In 2017 Phil Ho Lee and co-workers reported a cascade for the preparation of furan using Pd-catalyzed, propargyl substitution, and cycloisomerization reaction from propargyl acetates and indium organothiolates in one pot (Scheme 5).[8e]



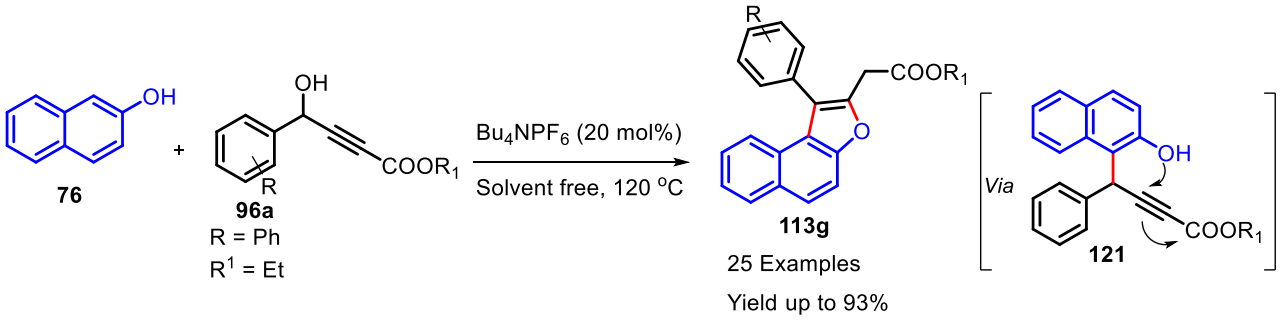
Scheme 5. Pd(II)-catalyzed synthesis of multisubstituted furans from propargyl acetate and indium organothiolates.

Preparation of polysubstituted furans from Propargylic alcohols using $Au(PPh_3)Cl$ and AgOTf as the catalyst was demonstrated. This reaction proceeds through a cyclization elimination-aromatization process (Scheme 6).[8f]



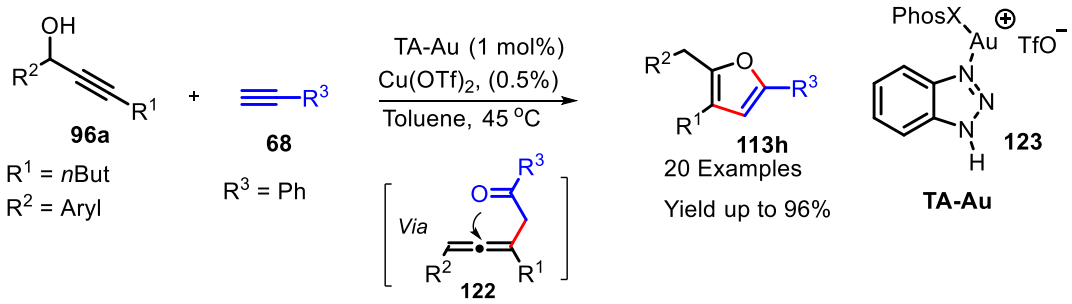
Scheme 6. Au(I)-catalyzed cycloisomerization reaction.

We have reported a valuable method for the one-pot scalable synthesis of Naphthofurans from ambident nucleophiles and propargyl alcohols, this reaction proceeds through a method of benzylation and isomerization by using additive(Scheme 7).[8g]



Scheme 7. Bu_4NPF_6 catalyzed one-pot cascade synthesis of 2-alkyl-3-aryl naphtho [2,1-*b*] furans.

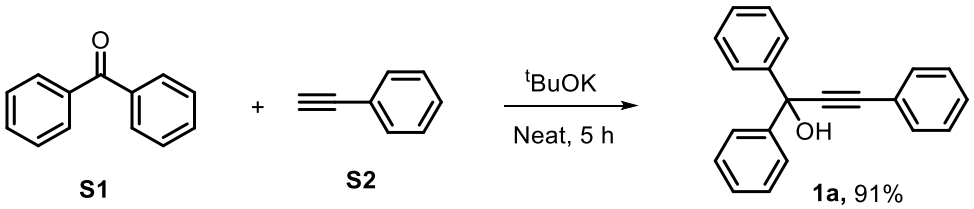
They have reported the preparation of trisubstituted and tetra substituted furans using simple starting materials, a combination of triazole-Au and Cu catalysts, the furans were formed in a single step reaction cascade with good to excellent yields (Scheme 8).[8h]



Scheme 8. Cu(II)-catalyzed propargyl alcohol addition to alkynes as an approach for the synthesis of substituted furans.

So far schemes 1-8 involved the synthesis of furans from propargylic alcohols through S_N1 mechanism by using transition metal catalysts, so we were intrigued to check the synthesis of furans from propargylic alcohols *via* allenes. In addition, we want to try this reaction with sustainable lewis acid catalyst Ca(II).

All starting materials are synthesized from the reported procedure[9] A mixture of aryl alkyne (1.2 equiv), *t*-BuOK (1.5 equiv), and respective ketone (1 equiv) was placed into a reaction flask at room temperature under nitrogen atmosphere and the mixture was stirred for 2−6h. After completion of the reaction (monitored by TLC), the resulting mixture was quenched with water and extracted into ethyl acetate (thrice). Combined organic layers were washed with brine solution and dried over anhydrous $Na_2SO_4$and the solvent was evaporated to obtain the pure compounds in good yield (Scheme 9).



Scheme 9. Synthesis of *tert*-propargylic alcohol

2.3 RESULTS AND DISCUSSION

In this figure, the explanation for regiodivergent one-pot annulation and cycloisomerization is shown (Figure 2). The allene intermediate is formed by nucleophilic substitution of activated propargyl alcohol with 1,3-diketone at the acetylenic carbon through the S_N2' mechanism, which is followed by regioselective cyclization to create the tetrasubstituted furan. Pearson's[10] popular concept of the hard-soft acid-base theory can also be used to support this hypothesis. Soft-soft interactions result in the formation of the allene intermediate[11], which would be followed by hard-hard interactions of carbonyl oxygen with acetylenic carbon (sp hybridized) of allenyl ketone to produce the substituted furan (S_N2') (Figure 2).

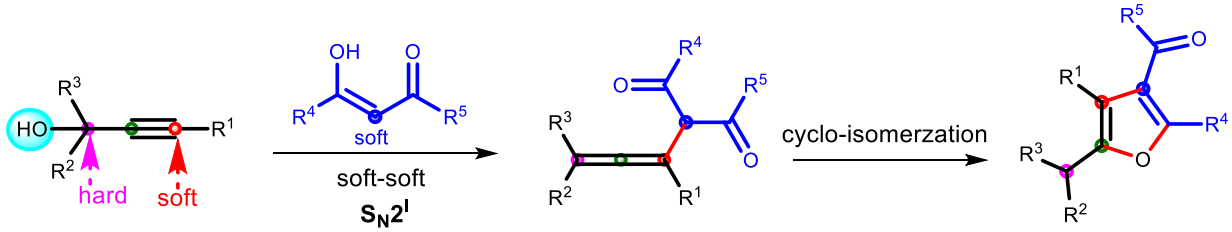
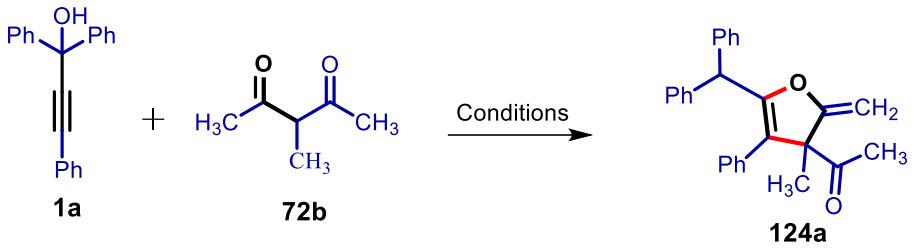


Figure. 2 Rationale for our synthetic design.

2.4 Optimization studies

The implementation of our hypothesis was started by stirring a mixture of 1,1,3-triphenylprop-2-yn-1-ol (**1a**, 0.35 mmol),[12] methylpentane-2,4-dione (63,0.52 mmol), and 10% $Ca(OTf)_2/Bu_4NPF_6$ in DCE at rt resulted in the synthesis of allene intermediate (**3ya**) in 45% after 40 minutes, but not the desired product. There is no more change in the reaction even after for 24 h. We added DBU (1 equiv.) after the generation of allene (around 40 minutes, monitored by TLC), assuming that a base is required for cyclization of this allene (110a) 1-(5-benzhydryl-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethan-1-one with some unreactive allene and **1a** in a yield of 20% (entry 2, Table 1). The coupling constant of olefinic protons of **124a** is (2.8 Hz) found to be in the range of geminal coupling. The reaction yield was slightly increased to 37%, when DBU was introduced in 3 equiv. (entry 3). An attempt with $Ca(NTf_2)_2/Bu_4NPF_6$ (10/5 mol%) yielded **124a** in 64 %, using DBU (3 equiv.) at rt (entry 4). Intriguingly, the combination of 10 mol% $Ca(NTf_2)_2$/DBU (3 equiv.) yielded 80% of **124a** at rt in 6 h (entry 5). Nevertheless, increasing the catalyst loading did not improve the reaction yield. (entry 6).[12] Our attempts to minimize the loading of catalyst or base (entries 7 and 8), and search for their alternatives by replacing DBU with other bases such as DABCO, K_2CO_3 (entries 9, 10); and replacing Ca(II) with Mg(II), PTSA and by changing DCE with other solvents like acetonitrile, toluene and ethanol or the absence of solvent were unsuccessful (entries 9-16).

Table 1. Optimization studies for the synthesis of 2,3-dihydrofuran **124a**

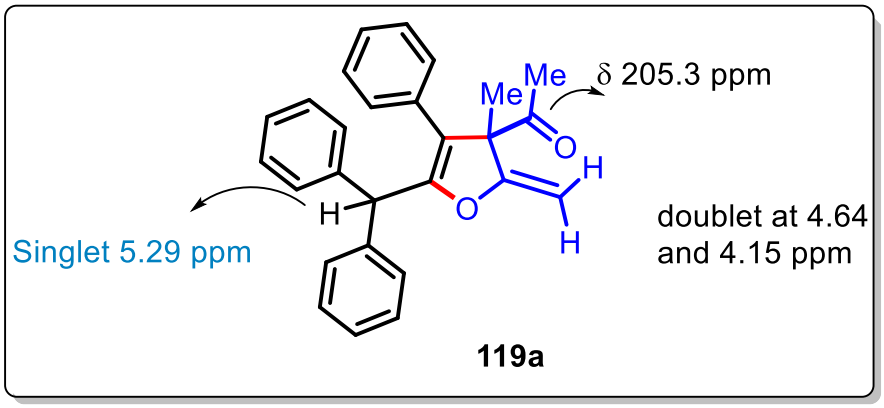


Entry	Catalyst (mol%)	Base (equiv.)	Reaction conditions	Yield **119a**(%)[b]
1	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)		DCE, rt, 24 h	0[c]
2	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DBU (1)	DCE, rt, 12 h	20[c]
3	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DBU (3)	DCE, rt, 12 h	37[c]
4	$Ca(NTf_2)_2/Bu_4NPF_6$(10/5)	DBU (3)	DCE, rt, 12 h	64
5[d]	**$Ca(NTf_2)_2$(10)**	**DBU (3)**	**DCE, rt, 6 h**	**80**
6	$Ca(NTf_2)_2$(20)	DBU (3)	DCE, rt, 6 h	80
7	$Ca(NTf_2)_2$(5)	DBU (3)	DCE, rt, 6 h	71
8	$Ca(NTf_2)_2$(10)	DBU (1)	DCE, rt, 6 h	68
9	$Ca(NTf_2)_2$(10)	DABCO(3)	DCE, rt, 12 h	55
10	$Ca(NTf_2)_2$(10)	K_2CO_3 (3)	DCE, rt, 12 h	45
11	Mg(OTf)2/Bu_4NPF_6 (10/10)	DBU (3)	DCE, rt, 12 h	35
12	PTSA (10)	DBU (3)	DCE, rt, 12 h	56
13	$Ca(NTf_2)_2$(10)	DBU (3)	CH_3CN, rt, 12 h	40
14	$Ca(NTf_2)_2$(10)	DBU (3)	toluene, rt, 12 h	25
15	$Ca(NTf_2)_2$(10)	DBU (3)	EtOH, rt, 12, h	nr
16	$Ca(NTf_2)_2$(10)	DBU (3)	neat, rt, 12 h	50

[a]Reaction conditions: substrates **1a** (0.35 mmol), **72b** (0.52 mmol), [b]isolated yields. **124a** was not formed but 45% of allene intermediate (**3ya**) formed, [c]remaining mixture contains allene and 1a, [d]optimized condition.

2.4a Characterization of Compound

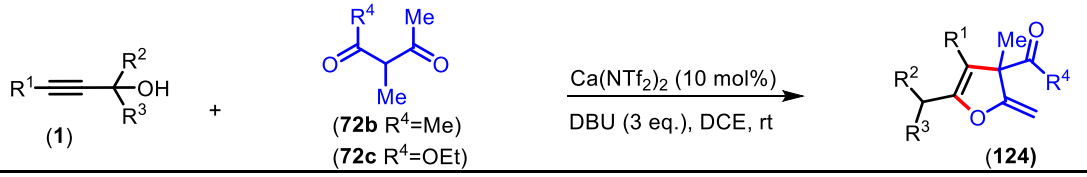
The isolated compound **124a** was fully characterized by ^{1}H NMR, ^{13}C NMR & melting point. The characteristic olefin proton has appeared as a doublet at 4.64 and 4.15 ppm in ^{1}H NMR spectra and carbons at 64.6 ppm in ^{13}C NMR spectra respectively. And carbonyl was confirmed by ^{13}C NMR spectra shown at 205.5. The melting point was also recorded.

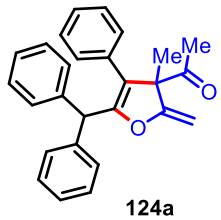


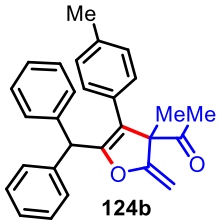
2.4b SCOPE OF THE REACTION

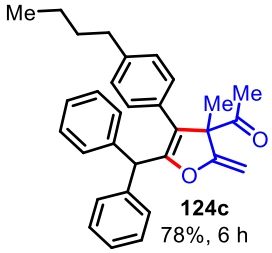
We were keen to check the generality of this approach after establishing the standard (optimum) reaction conditions (entry 5, Table 1) for the regiospecific annulation of **1a** and **72b**. As a result, we prepared various propargyl alcohols[13,14] using a variety of terminal alkynes (while keeping benzophenone constant) such as 4-methylphenyl (**1d**), 4-butylphenyl (**1e**), 4-ethoxyphenyl (**1f**), cyclopropyl (**1g**) acetylenes and treated them with **72b** under standard reaction conditions, yielding the respective 2-methylene-2,3-dihydrofurans **124b-124e** (Table 2).The extent of the substitutions on propargylic phenyls was then examined, and we established that they are consistent with the procedure, giving the dihydrofurans **124f-124l** in good yields. The structural conformation of **124h** was further supported by the single crystal X-ray data. Compound **124m** was prepared from 9-(phenylethynyl)-9H-fluoren-9-ol (**1h**) and **72b** in 77% yield. By synthesising the respective dihydrofurans **124n** and **124o** in good yields, the scope of ethyl 2-methyl-3-oxobutanoate (**72c**) as the nucleophilic partner were investigated (Table 2).

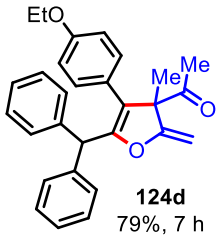
Table 2. Scope of Ca(II)-catalyzed regiospecific annulation of **1** and **72b**.[a]

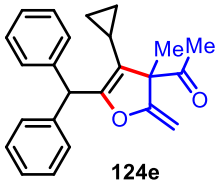


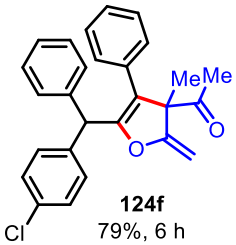

124a
80%, 5 h

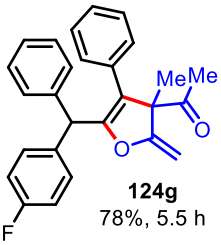

124b
79%, 5 h

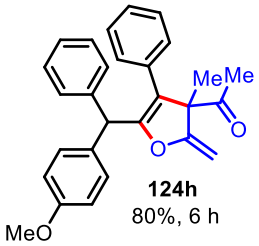

124c
78%, 6 h

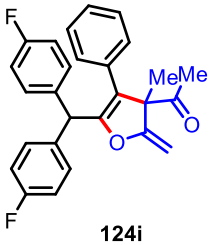

124d
79%, 7 h

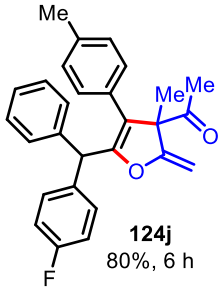

124e
78%, 7 h

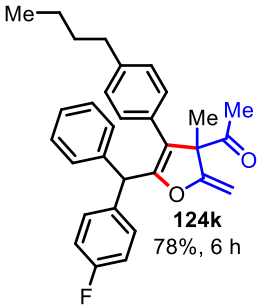

124f
79%, 6 h

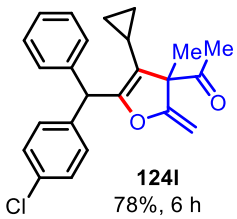

124g
78%, 5.5 h

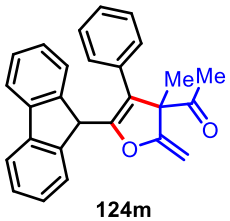

124h
80%, 6 h
Confirmed by single Crystal
CCDC:1863704

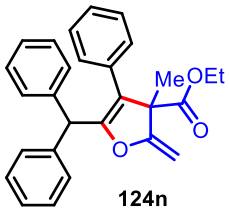

124i
79%, 6 h

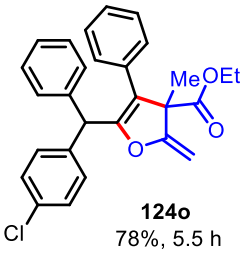

124j
80%, 6 h


124k
78%, 6 h


124l
78%, 6 h


124m
77%, 5.5 h


124n
79%, 6 h


124o
78%, 5.5 h

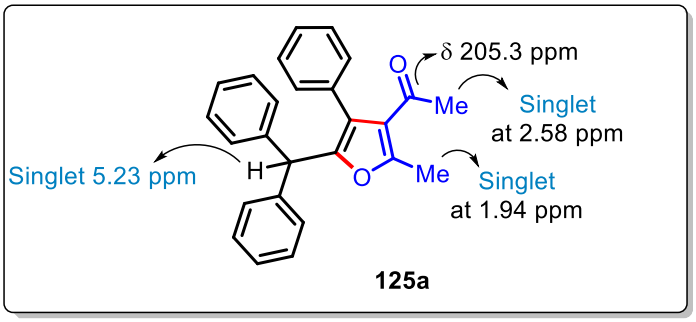
[a]A mixture of **1** (1 equiv.), **72b** (1.5 equiv.) was used, DBU was added after the consumption of **1** or after the formation of allene (monitored by TLC)

2.5 Synthesis of fully substituted furans:

We wanted to see if a simple 1,3-diketone (without a methyl substitution on the α-carbon) like acetylacetone might react with ynols in the same way as this innovative regiospecific annulation process of ynols (**1**) with α-methyl-1,3-dicarbonyl compounds (**72b**, **72c**). Therefore a mixture of **1a**, pentane-2,4-dione (**72**), and $Ca(NTf_2)_2$ (10 mol%) was stirred in DCE at rt for 50 min and then added DBU (3 equiv) and continued the reaction for 18 h and obtained the desired furan **125a** in 15 % yield along with diene **3y**. The reaction yield was increased to 75% by refluxing it in DCE for 18 h. In the next experiment, we refluxed **1a** and **72** in acetonitrile with 10 mol% of $Ca(OTf)_2/Bu_4NPF_6$ for 50 minutes and added 3 equiv. DBU and obtained the yield of **125a** by 80% after 8 h. Therefore, we considered this as a suitable condition and extended this to check the generality of this protocol (Table 3).

2.5a Characterization of Compound

The isolated compound **125a** was fully characterized by ^{1}H NMR, ^{13}C NMR & melting point. The characteristic benzylic proton has appeared as a singlet at 5.23 and two methyl's at 2.58, 1.94 ppm in ^{1}H NMR spectra, and carbonyl was confirmed by ^{13}C NMR spectra shown at 205.5 ppm.

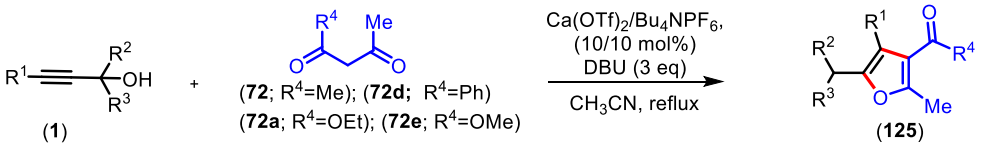


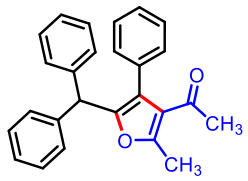
2.5b SCOPE OF THE REACTION

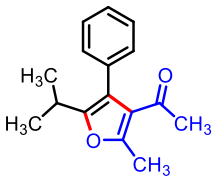
The annulation process of **72** was found to be compatible with propargylic substitutions of **1** such as diphenyl, dimethyl, phenyl-methyl, and cyclopropyl-methyl in yielding the corresponding furans with variety at the 5th position (**125a** to **125d**) good yields (Table 3). This technique also permitted substitutions on the propargylic phenyl groups of **1** and produced good yields of the respective tetra-substituted furans **125e-125j**.The structure of **125h** was further conformed by the single-crystal X-ray data. 1-phenylbutane-1,3-dione (**67d**) is proved as a good annulation partner with **1a** and furnished the corresponding furan derivatives **125k-125m** in good yields. Under standard reaction conditions, ethyl acetoacetate and methyl acetoacetates

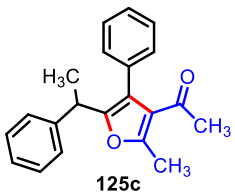
also engage in the annulation with **1a**, yielding the furans **125n** to **125r** in good yields (Table 3).

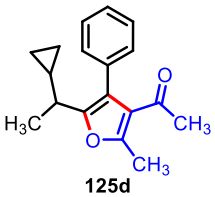
Table 3. Scope of Ca(II)-catalyzed regiospecific [3+2] annulation of **1** and 1,3-diketones.[a]

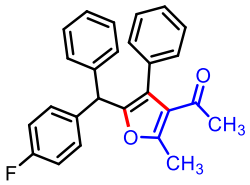


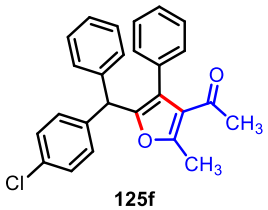

125a
80%, 7 h

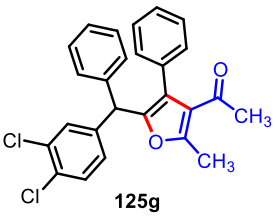

125b
79%, 8 h

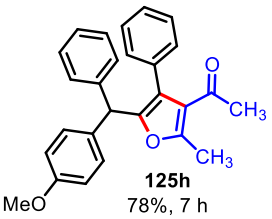

125c
79%, 7 h

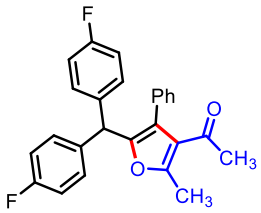

125d
78%, 7 h

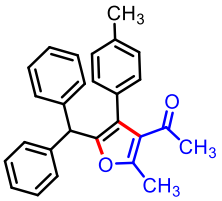

125e
78%, 7 h

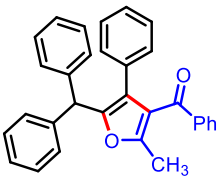

125f
78%, 8 h

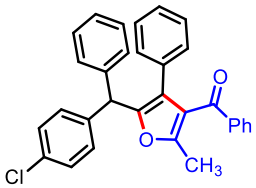

125g
78%, 6 h

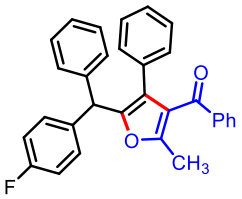

125h
78%, 7 h
Confirmed by single crystal
CCDC:1851361

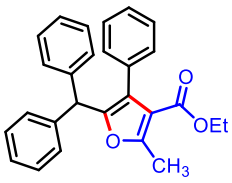

125i
79%, 6 h

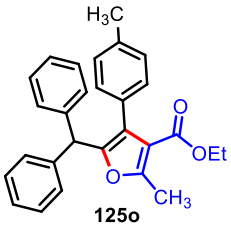

125j
78%, 7 h

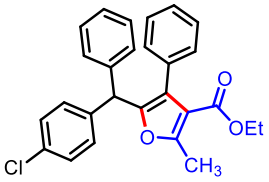

125k
78%, 7h

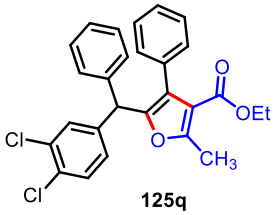

125l
79%, 7 h

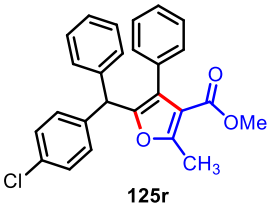

125m
79%, 7 h


125n
79%, 6 h


125o
78%, 6 h


125p
78%, 6 h

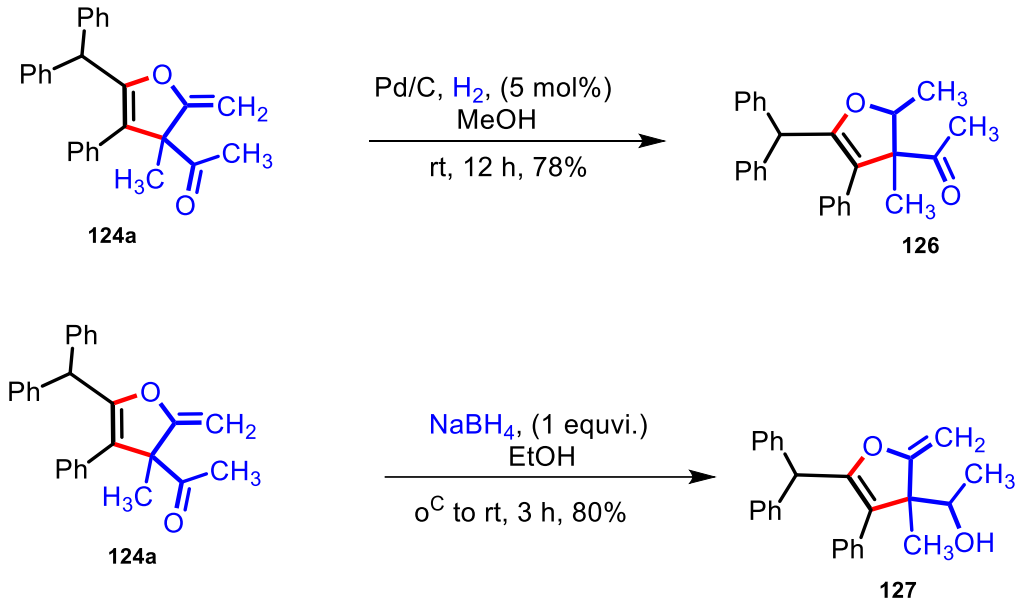

125q
78%, 6 h


125r
79%, 7 h

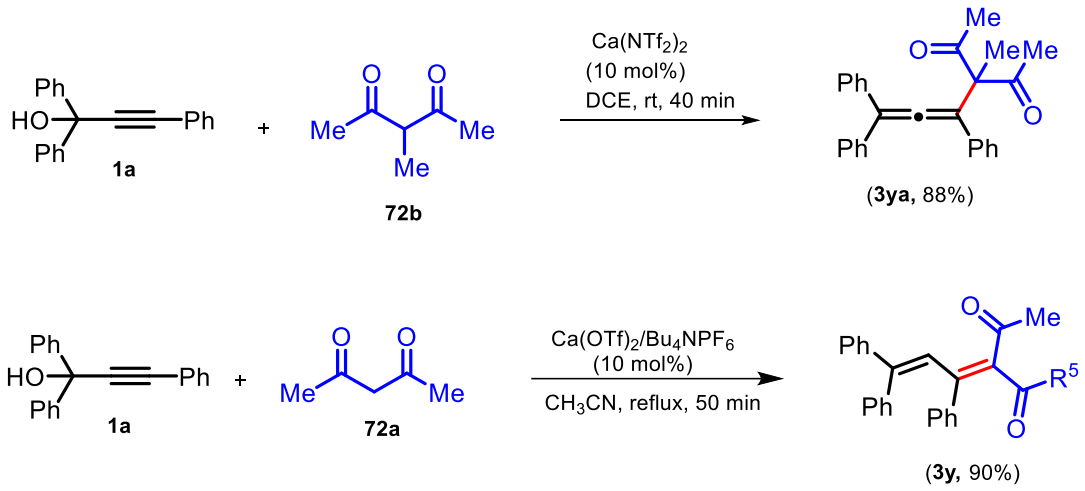
[a]A mixture of **1** (1 equiv.), **72** (1.5 equiv.) was used, DBU was added after the consumption of **1a** or after the formation allene (monitored by TLC).

2.6 Functional group transformation of dihydrofuran 110a

Synthetic transformation of dihydrofuran **124a** is depicted in Scheme 8, hydrogenation of *exo*-double bond (5% Pd/C, H_2, MeOH) gave the dihydrofuran derivative **126** in 78% yield. A reduction of ketone functionality of **124a** was also performed with $NaBH_4$ to obtain the alcohol **127** in 80% yield.

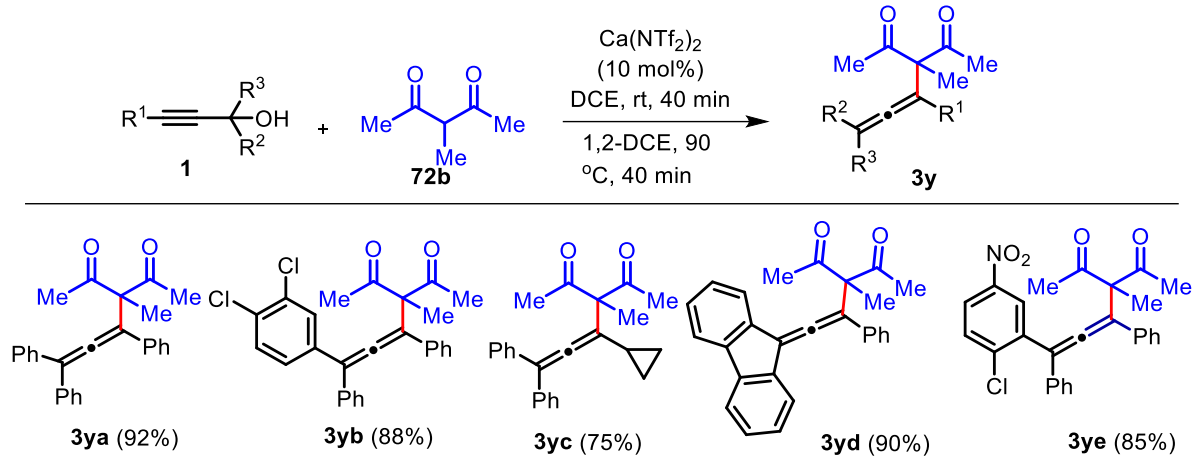


Before suggesting the reaction mechanism, we have isolated the homo-allenyl ketone intermediate **3ya** formed during the synthesis of **124a** by the annulation of **1a** and **72b**. Similarly, diene intermediate **3y** was isolated from the annulation reaction of **1a** and **72a** during the synthesis of **125a.**

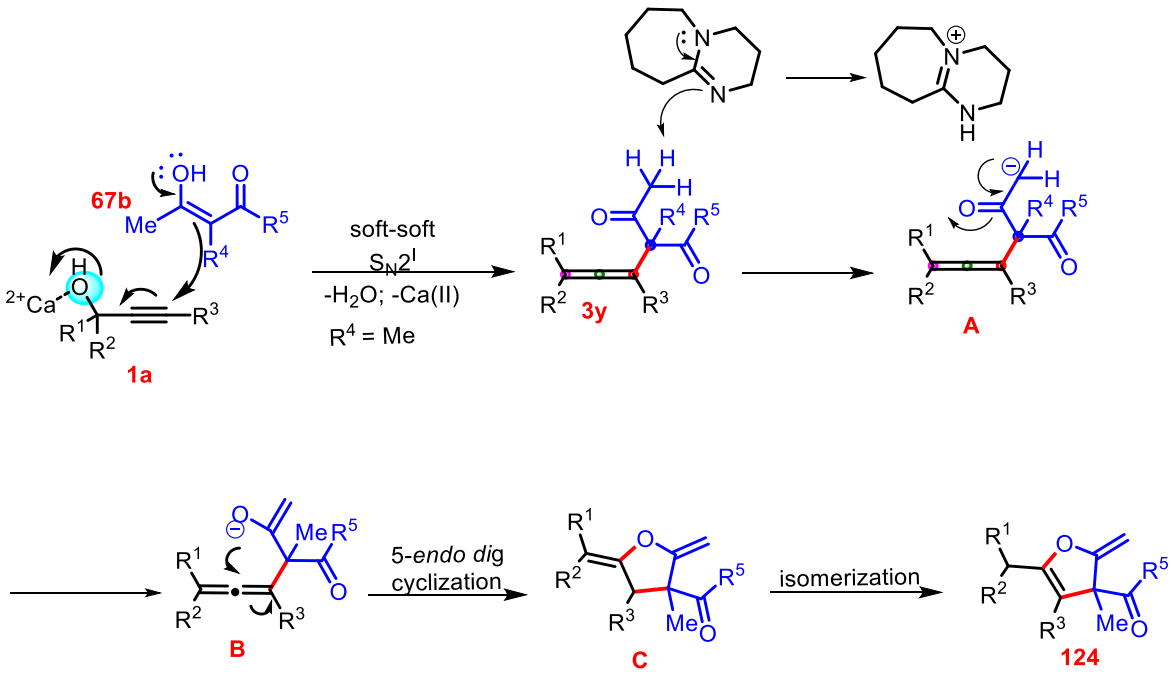


Scheme 10. Isolation of intermediates to propose the reaction mechanism.

Table 4. Synthesis of tetrasubstituted allenes using Ca(II)

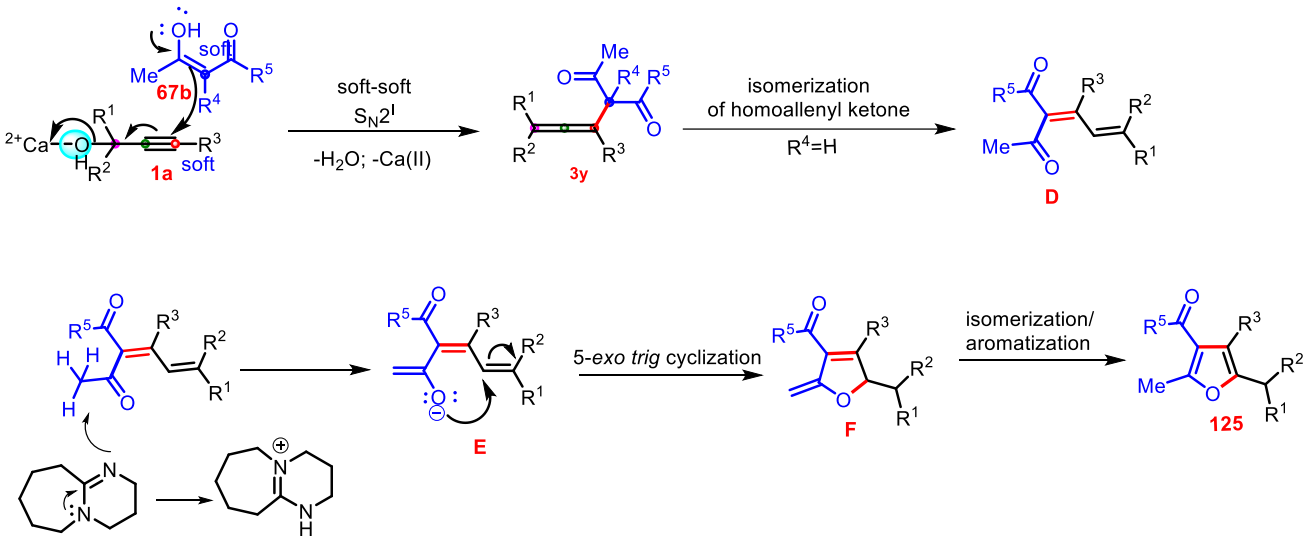


We were able to distinguish allenes **3ya-3ye** in great yields in a short time, after successfully isolating homo-allenyl ketone, which we believe is the crucial intermediate in this cyclization reaction, it was under $Ca(NTf_2)_2$ for 1h to confirm that the allene **3yc** is also the intermediate for the synthesis of **124a**, as the cyclopropyl ring present in **3yc**



Scheme 11. Possible reaction mechanism.

The possible reaction mechanism for the Ca(II)/DBU mediated annulation of **1** and **72a** is described in (Scheme 10). Initially, the tautomer of **72a** adds to the activated propargyl alcohol through the S_N2' mechanism, which is facilitated by the soft-soft interactions and yields the kinetically stable homo-allenyl ketone intermediate, allene-**3y**. This allenyl intermediate further reacts with DBU and gives enol intermediate (**3y**) which then undergo cyclization (**B**) and isomerization provides the quaternary centered dihydrofuran **124**.



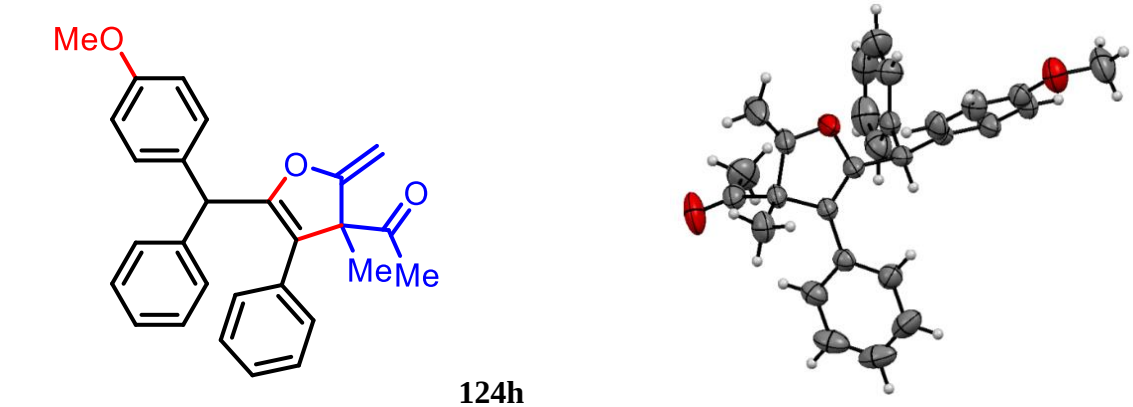
Scheme 12. Possible reaction mechanism.

If there is no substitution on the α-carbon (R^4 = H) of allene-1, it will undergo isomerization to give a 1,6-conjugated system (**D**). Then DBU reacts with methyl ketone of **D** and gives enol **E**, which subsequently undergoes cycloisomerization *via 5-exo trig* passion to furnish fully substituted furan **125**.

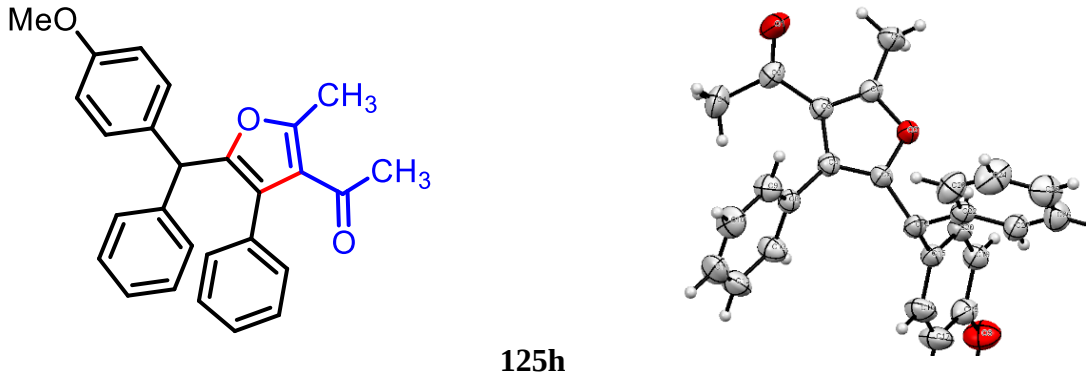
2.7 X-ray Crystallography

Single crystal X-ray data for the compound **124h** and **125h** were collected using the Bruker D8 Quest CMOS detector system [λ(Mo-Kα) = 0.71073 Å] at 291, graphite monochromator with a ω scan width of 0.3º, crystal-detector distance 60 mm, collimator 0.5 mm, The SMART software was used for the intensity data acquisition and the SAINTPLUS software was used data extraction. In each case, absorption correction was performed with the help of the SADABS program an empirical absorption correction using equivalent reflections was performed with the program. The crystal was solved using SHELX-97, and full-matrix least-

squares refinement against F^2 was carried out using SHELX-97. All non-hydrogen atoms were refined anisotropically. Aromatic and methyl hydrogens were introduced on calculated positions and included in the refinement riding on their respective parent atoms



124h
CCDC-1851361



125h
CCDC-1863704

Figure 3. Thermal ellipsoidal plot of compound **124h** and **125h** with atom labelling scheme. Displacement ellipsoids are drawn at 50% probability.

2.8 CONCLUSION

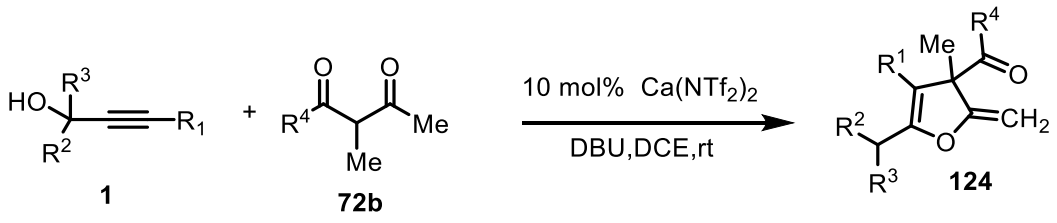
A simple Ca(II)-catalyzed regiospecific [3+2] annulation of *tert*-propargyl alcohols and acyclic 1,3-diketones has been developed. This is the first and only approach in terms of the mode of annulation, which involves the formation of homoallenyl ketone (S_N2') and regioselective cycloisomerization to create functionally related furans. At room temperature, dihydrofurans were produced. In both series, intermediates were detected. Dihydrofuran functional group transformations were shown. This work's highlights include a wide range of substrates, high yields, the use of Ca(II) as a catalyst, and a one-pot reaction. Because of their structural uniqueness and, of course, their privileged

character, we are confident that this technique will allow us to investigate the medical and material uses of these new chemical entities.

2.9 EXPERIMENTAL SECTION

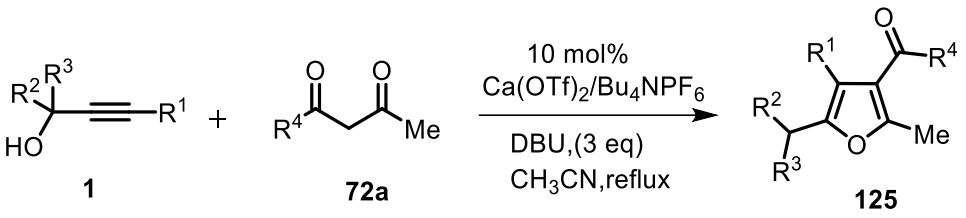
2.9.1 General Information: Unless otherwise noted, all reagents were used as received from commercial suppliers. Reactions were performed in flame-dried or oven-dried glassware with magnetic stirring. Reactions were monitored using thin-layer chromatography (TLC) with aluminum sheets silica gel 60 F_{254} from Merck. TLC plates were visualized with UV light (254 nm), iodine treatment, or using *p*-anisaldehyde or $KMnO_4$ stain. Column chromatography was carried out using silica gel 60−120 mesh as a stationary phase. NMR spectra were recorded at 500 MHz and 400 MHz (^{1}H) and at 125 MHz and 100 MHz (^{13}C), respectively on the Avance Bruker spectrometer. Chemical shifts (δ) are reported in ppm, using the residual solvent peak in $CDCl_3$ (^{1}H: δ= 7.26 and ^{13}C: δ = 77.16 ppm) as internal standard, and coupling constants (*J*) are given in Hz. HRMS were recorded using ESI-TOF techniques. Melting points were measured with LAB INDIA mepa melting apparatus.

2.9.2 General experimental procedure for the synthesis 1-(5-benzhydryl-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethan-1-one (124): A mixture of *tert*-propargylic alcohol **1** (1 equiv) and respective 3-methylpentane-2,4-dione **72b** (1.5 equiv) were stirred at rt in presence of $Ca(NTf_2)_2$ (10 mol%) for appropriate time till the formation of the allene (monitored by TLC). Then 3 equiv of DBU was added to the reaction mixture stirred till the completion of the reaction (monitored by TLC), the crude product was purified by using silica gel column chromatography (2-3 % EtOAc in pet ether) to obtain the desired product **124** in good yield.

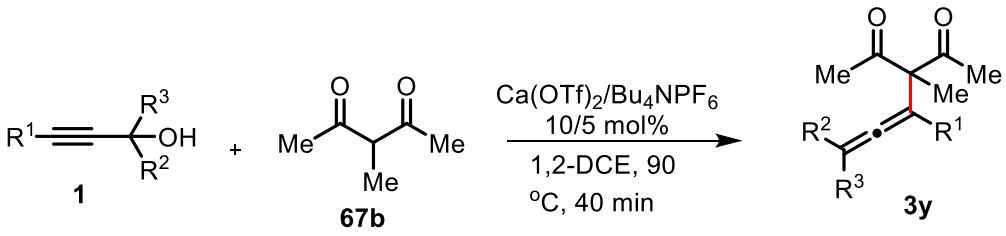


2.9.3 General experimental procedure for the synthesis of tetra substituted (125): A mixture of *tert*-propargylic alcohol **1** (1 equiv) and respective acetyl acetone **72a** (1.5 equiv) were stirred at 90 ^{o}C presence of $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) for appropriate time till the

formation of the alkylated product (monitored by TLC). Then 3 equiv of DBU was added to the reaction mixture stirred till the completion of the reaction (monitored by TLC), the crude product was purified by using silica gel column chromatography (3-5 % EtOAc in pet ether) to obtain the desired product **125** in moderate to good yield.



2.9.4 Experimental Procedure for the Synthesis of 3-Methyl-3-(1,3,3- triphenylpropa-1,2-dien-1-yl)pentane-2,4-dione(3y): To a mixture of **1** (0.35 mmol) and 1,3-dicarbonyl compound **67b** (0.45 mmol) in DCE (2 mL), $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) was added. The reaction was stirred at 90 °C, for 30-40 min and was stopped after the formation of allene (monitor by TLC), the solvent was removed under reduced pressure, and the resultant residue was purified by silica gel column chromatography using EA/PE (10:90, v/v) to obtain the desired product **3y** in 92 % yield.



2.9.4 SPECTRAL DATA

1-(5-benzhydryl-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethanone) (124a). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as White solid 107 mg (80%); mp 137-138 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37-7.32 (m, 5H), 7.30-7.24 (m, 5H), 7.21 (t, *J* = 1.6 Hz, 3H), 7.04-7.01 (m, 2H), 5.29 (s, 1H), 4.63 (d, *J* = 2.8 Hz, 1H), 4.14 (d, *J* = 2.8 Hz, 1H), 2.13 (s, 3H), 1.38 (s, 3H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ 205.3, 164.7, 154.2, 140.3, 140.1, 131.8, 130.1, 128.9, 128.8, 128.7, 128.6, 128.4, 128.3, 127.6, 127.1, 126.9, 118.5, 85.5,

64.5, 48.4, 25.2, 21.4 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{24}O_2$ $[M+H]^+$: 381.1856, found: 381.1855.

1-(5-benzhydryl-3-methyl-2-methylene-4-(p-tolyl)-2,3-dihydrofuran-3-yl)ethanone (124b). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 104 mg (79%).^{1}H NMR (500 MHz, $CDCl_3$): δ 7.36-7.22 (m, 9H), 7.13 (d, *J* = 8.5 Hz, 2H), 6.94 (d, *J* = 7.5Hz, 3H), 5.31 (s, 1H), 4.64 (d, *J* = 2.5 Hz, 1H), 4.15 (d, *J* = 2.5 Hz, 1H), 2.35 (s, 3H), 2.15 (s, 3H), 1.40 (s, 3H) ppm. ^{13}C NMR (125 MHz, $CDCl_3$): δ 205.3, 164.8, 153.8, 140.4, 140.2, 137.4, 129.5, 128.9, 128.6, 128.6, 128.3, 128.2, 126.9, 118.4, 64.6, 48.4, 25.2, 21.4, 21.1 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{26}O_2$ $[M+H]^+$: 395.2013, found: 395.2014.

1-(5-benzhydryl-4-(4-butylphenyl)-3-methyl-2-methylene-2,3-dihydrofuran-3-l)ethenone (124c). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 100 mg (78%).^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.41-7.30 (m, 5H), 7.28-7.23 (m, 5H), 7.14 (d, *J* = 8 Hz, 2H), 6.96 (d, *J* = 8 Hz, 2H), 5.33 (s, 1H), 4.64 (d, *J* = 2.4 Hz, 1H), 4.15 (d, *J* = 2.8 Hz, 1H), 2.61 (t, *J* = 7.6 Hz, 2H), 2.16 (s, 3H), 1.65-1.58 (m, 2H), 1.41 (s, 3H), 1.39-31 (m, 2H), 0.96 (t, *J* = 7.2 Hz, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.6, 164.9, 153.8, 142.5, 140.5, 140.4, 129.1, 128.9, 128.8, 128.7, 128.5, 127.1, 127.0, 118.6, 85.4, 64.7, 48.5, 35.4, 33.5, 25.4, 22.5, 21.6, 14.1 ppm. HRMS (ESI): *m/z* calculated for $C_{31}H_{32}O_2$ $[M+H]^+$: 437.2562, found: 437.2561.

1-(5-benzhydryl-4-(4-ethoxyphenyl)-3-methyl-2-methylene-2,3-dihydrofuran-3-l)ethanone (124d). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 100 mg (78%).^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.39 (q, *J* = 7.5 Hz, 2H), 7.35-7.31 (m, 5H), 7.30 (d, *J* = 1 Hz, 1H), 7.28-7.22 (m, 2H), 6.96 (q, *J* = 6.5 Hz, 2H), 6.84 (q, *J* = 7 Hz, 2H), 5.28 (s, 1H), 4.63 (d, *J* = 2.5 Hz, 1H), 4.14 (d, *J* = 2.5 Hz, 1H), 4.04 (q, *J* = 14 Hz, 2H), 2.14 (s, 3H), 1.43 (t, *J* = 7 Hz, 3H), 1.39 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.5, 165.1, 158.6, 153.6, 140.5, 140.4, 129.8, 129.1, 128.8, 128.7, 128.5, 127.1, 123.9, 118.3, 114.9, 85.3, 64.8, 63.5, 48.5, 25.3, 21.6, 14.9 ppm. HRMS (ESI): *m/z* calculated for $C_{29}H_{28}O_3$ $[M+H]^+$: 425.2118, found: 425.2119.

1-(5-benzhydryl-4-cyclopropyl-3-methyl-2-methylene-2,3-dihydrofuran-3-yl)ethanone 124e). Following general experimental procedure 2.9.2 then purified by flash chromatography

(silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 108 mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32 (d, *J* = 1.6 Hz, 1H), 7.31 (d, *J* = 2.8 Hz, 1H), 7.29-7.26 (m, 3H), 7.24-7.21 (m, 4H), 7.18 (d, *J* = 8.4 Hz, 1H), 5.41 (d, *J* = 2.8 Hz, 1H), 4.51 (d, *J* = 2.8 Hz, 1H), 4.01 (d, *J* = 2.8 Hz, 1H), 1.98 (s, 3H), 1.40 (s, 3H), 1.21-1.15 (m, 1H), 0.77-0.61 (m, 2H), 048-0.29 (m, 2H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.5, 205.5, 164.8, 164.8, 153.8, 153.7, 139.8, 139.7, 138.8, 138.7, 132.8, 132.7, 130.2, 130.1, 128.7, 128.7, 128.6, 128.6, 128.5, 127.1, 127.1, 116.9, 116.9, 84.9, 64.5, 64.5, 47.1, 47.1, 25.1, 25.1, 21.8, 21.7, 5.2, 5.2, 5.1, 3.9, 3.9 ppm. HRMS (ESI): *m/z* calculated for $C_{24}H_{24}O_2$ $[M+H]^+$: 344.1776, found: 344.1775.

1-(5-((4-chlorophenyl)(phenyl)methyl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-)ethanone (124f). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 102.8 mg (79%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.40 (d, *J* = 7 Hz, 1H), 7.37-7.32 (m, 6H), 7.30-7.28 (m, 3H), 7.21 (d, *J* = 7 Hz, 1H), 7.17 (d, *J* = 8.5 Hz, 1H), 7.03 (t, *J* = 6.5 Hz, 2H), 5.28 (d, *J* = 11.5 Hz, 1H), 4.67 (d, *J* = 3 Hz, 1H), 4.18 (d, *J* = 2.5 Hz, 1H), 2.16 (s, 3H), 1.42 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.1, 164.6, 164.5, 153.6, 153.5, 139.8, 139.7, 138.8, 138.7, 132.9, 132.9, 131.6, 131.6, 130.3, 130.1, 128.8, 128.8, 128.8, 128.8, 128.6, 128.5, 128.5, 128.4, 128.3, 127.7, 127.7, 127.2, 118.8, 85.7, 64.6, 64.5, 47.8, 25.2, 25.2, 21.5, 21.4 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{23}ClO_2$ $[M+H]^+$: 414.1387, found: 414.1388.

1-(5-((4-fluorophenyl)(phenyl)methyl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethanone (124g). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as White solid 102.8 mg (78%); mp 108-109 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.41-7.28 (m, 8H), 7.28-7.18 (m, 2H), 7.09-6.99 (m, 4H), 5.29 (d, *J* = 11 Hz, 1H), 4.67 (d, *J* = 3 Hz, 1H), 4.18 (d, *J* = 5 Hz, 1H), 2.16 (s, 3H), 1.41 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 205.1, 164.6, 164.5, 162.8, 162.8, 160.8, 153.9, 153.8, 140.1, 140.1, 136.1, 135.8, 131.7, 131.6, 130.5, 130.4, 130.2, 130.2, 128.4, 128.3, 127.7, 127.6, 127.1, 127.1, 115.6, 115.4, 115.3, 115.2, 85.6, 64.6, 64.5, 47.7, 25.2, 21.5, 21.4 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{23}FO_2$ $[M+H]^+$: 399.1762, found: 399.1766.

1-(5-((4-methoxyphenyl)(phenyl)methyl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethanone (124h). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as White solid

104.5 mg (80%); mp 108-109 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32-7.29 (m, 4H), 7.28-7.25 (m, 4H), 7.22 (t, *J* = 1.6 Hz, 2H),7.06-7.04 (m, 2H), 6.94-6.92 (m, 2H), 5.27 (s, 1H), 4.65 (d, *J* = 2.8 Hz, 1H), 4.15 (d, *J* = 2.8 Hz, 1H), 3.85 (s, 3H), 2.16 (s, 3H), 1.40 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 205.6, 164.7, 158.6, 154.5, 140.7, 132.2, 131.9, 129.8, 128.9, 128.5, 128.4, 127.6, 127.1, 118.3, 114.1, 85.6, 64.6, 55.4, 47.7, 25.4, 21.5 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{26}O_3$ $[M+H]^+$: 410.1882; found: 410.1881.

1-(5-(bis(4-fluorophenyl)methyl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethanone (124i). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 102.7 mg (79%).^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.32 (t, *J* = 7.5 Hz, 2H), 7.29 (t, *J* = 2 Hz, 3H), 7.19 (q, *J* = 5.5 Hz, 2H),7.08 (t, *J* = 8.5 Hz, 2H),7.0 2 (q, *J* = 8.5 Hz, 4H), 5.25 (s, 1H), 4.67 (d, *J* = 2.5 Hz, 1H), 4.19 (d, *J* = 2.5 Hz, 1H), 2.15 (s, 3H), 1.41 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.1, 164.6, 163.1, 162.9, 161.1, 161.1, 153.7, 136.1, 135.9, 135.8, 135.8, 131.6, 130.5, 130.4, 130.2, 130.2, 129.1, 128.4, 127.9, 118.9, 115.8, 115.6, 115.6, 115.4, 85.9, 64.7, 47.1, 25.3, 21.6 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{22}F_2O_2$ $[M+H]^+$: 416.1588, found: 416.1587.

1-(5-((4-fluorophenyl)(phenyl)methyl)-3-methyl-2-methylene-4-(p-tolyl)-2,3-dihydrofuran-3-yl)ethanone (124j) Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 104.3 mg (80%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.39 (d, *J* = 7.5 Hz, 1H), 7.34-7.28 (m, 4H), 7.22-7.19 (m, 2H), 7.15- 7.00 (m, 4H), 6.94 (d, *J* = 2 Hz, 1H), 6.92 (d, *J* = 2 Hz, 1H), 5.27 (d, *J* = 10.5 Hz, 1H), 4.65 (d, *J* = 2.5 Hz, 1H), 4.16 (d, *J* = 2.5 Hz, 1H), 2.36 (s, 3H), 2.14 (s, 3H), 1.40 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.2, 164.7, 164.6, 153.4, 140.2, 140.1, 137.5, 30.5, 130.4, 130.2, 130.2, 129.5, 128.7, 128.7, 128.6, 128.5, 128.4, 128.3, 128.2, 127.1, 118.6, 115.5, 115.3, 115.3, 115.1, 85.4, 64.6, 64.5, 47.6, 25.2, 21.5, 21.4, 21.1 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{25}FO_2$ $[M+H]^+$: 413.1919, found: 413.1919.

1-(5-benzhydryl-4-(4-butylphenyl)-3-methyl-2-methylene-2,3-dihydrofuran-3-yl)ethanone (124k). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 98.9 mg (78%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.87 (t, *J* = 3.5 Hz, 1H), 7.81-7.79 (m, 1H), 7.52 (d, *J* = 8 Hz, 1H), 7.34-7.28 (m, 2H), 7.21-2.00 (m, 7H), 6.95-6.93 (m, 2H), 5.30 (d, *J* = 10 Hz, 1H), 4.64 (d,

J = 2.5Hz, 1H), 4.16 (d, *J* = 2.5Hz, 1H), 2.60 (t, *J* = 1.5 Hz, 2H), 2.15 (s, 3H), 1.63-1.41 (m, 2H), 1.40 (s, 3H), 1.39-0.95 (m, 2H), 0.94 (t, *J* = 1.0 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 205.4, 195.4, 164.7, 153.6, 153.5, 142.6, 140.3, 140.2, 137.6, 130.1, 128.9, 128.8, 128.4, 118.7, 115.6, 115.5, 115.5, 115.4, 115.2, 85.6, 64.7, 64.6, 47.7, 35.4, 33.5, 25.4, 22.5, 21.6, 21.5, `14.1 ppm. HRMS (ESI): *m/z* calculated for $C_{31}H_{32}O_2$ $[M+H]^+$: 436.2402, found: 436.2401.

1-(5-((4-chlorophenyl)(phenyl)methyl)-4-cyclopropyl-3-methyl-2-methylene-2,3-dihydrofuran-3-yl)ethanone (124l). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 104.5 mg (78%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.62-7.34 (m, 5H), 7.33-7.27 (m, 4H), 5.48 (s, 1H), 4.54 (d, *J* = 2.4 Hz, 1H), 4.03 (d, *J* = 2.8 Hz, 1H), 2.01 (s, 3H), 1.43 (s, 3H), 1.25-1.21 (m, 1H), 0.77-0.74 (m, 2H), 0.68-0.66 (m, 1H), 0.50-0.36 (m, 1H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 205.9, 165.1, 154.4, 140.3, 140.3, 132.5, 130.2, 128.9, 128.7, 128.6, 128.5, 128.4, 127.1, 126.9, 116.7, 84.8, 64.7, 47.8, 25.2, 21.8, 5.4, 5.2, 4.1 ppm. HRMS (ESI):*m/z* calculated for $C_{24}H_{23}ClO_2$ $[M+H]^+$: 378.1387, found: 378.1387.

1-(5-(9H-fluoren-9-yl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-l)ethanone(124m). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 103.2 mg (77%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.37 (d, *J* = 7.5 Hz, 1H), 7.80-7.43 (m, 2H), 7.42 (d, *J* = 7.5 Hz, 1H), 7.42-7.32 (m, 6H), 7.29-7.16 (m, 3H), 5.20 (d, *J* = 3 Hz, 1H), 5.12 (s, 1H), 4.52 (d, *J* = 3 Hz, 1H), 2.33 (s, 3H), 1.03 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 205.1, 164.6, 164.5, 162.8, 162.8, 160.8, 153.9, 153.8, 140.1, 140.1, 136.1, 135.8, 135.8, 131.6, 131.6, 130.5, 130.4, 130.2, 130.2, 128.4, 128.3, 127.7, 127.6, 127.1, 127.1, 115.6, 115.4, 115.3, 115.2, 85.6, 64.6, 64.5, 47.7, 25.2, 25.1, 21.5, 21.4 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{22}O_2$ $[M+H]^+$: 379.1700, found: 379.1700.

Ethyl5-benzhydryl-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-carboxylate(124n). Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 114.10 mg (79%).^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.39 (d, *J* = 1.5 Hz, 1H), 7.38-7.35 (m, 3H), 7.34-7.31 (m, 3H), 7.28 (t, *J* = 8.5 Hz, 4H), 7.24 (d, *J* = 7.5 Hz, 2H), 7.16-7.15 (m, 2H), 5.15 (s, 1H), 4.61 (d, *J* = 2.5 Hz, 1H), 4.29 (d, *J* = 3 Hz, 1H), 4.28-4.20 (m, 2H), 1.50 (s, 3H), 1.30 (t, *J* = 7 Hz, 3H)

ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 172.6, 165.1, 153.2, 140.8, 140.3,132.2, 129.3, 128.6, 128.5, 128.5, 128.1, 127.5, `126.1, 126.5,118.5, 84.4, 61.6, 58.1, 47.8, 22.9, 13.9 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{26}O_3$ $[M+H]^+$: 411.1962, found: 411.1961.

***Ethyl5-((4-chlorophenyl)(phenyl)methyl)-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-carboxylate* (124o).** Following general experimental procedure 2.9.2 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 108.9 mg (78%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.39 (d, *J* = 7 Hz, 1H), 7.35-7.32 (m, 6H), 7.31-7.28 (m, 2H), 7.24 (d, *J* = 9 Hz, 2H), 7.16 (d, *J* = 8.5 Hz, 1H), 7.14 (t, *J* = 1.5 Hz, 2H), 5.10 (s, 1H), 4.62 (d, *J* = 2.5 Hz, 1H), 4.31 (d, *J* = 3 Hz, 1H), 4.26 (q, *J* = 7 Hz, 2H), 1.50 (s, 3H), 1.31 (t, *J* = 7 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 172.4, 172.3, 164.9, 152.7, 140.3, 139.8, 139.3, 138.8, 132.8, 132.4, 132.1, 130.6, 130.1, 129.3, 129.2, 129.9, 128.7, 128.7, 128.6, 128.5, 128.5, 128.2, 127.7, 127.6, 127.1, 126.7, 118.8, 84.6, 61.7, 61.6, 58.2, 58.1, 47.3, 22.9, 14.1 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{25}ClO_3$ $[M+H]^+$: 445.1572, found: 445.1573.

1-(5-benzhydryl-2-methyl-4-phenylfuran-3-yl)ethanone(125a Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 103. mg (80%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.44-7.40 (m, 5H), 7.33-7.28 (m, 5H), 7.27 (t, *J* = 7 Hz, 2H), 7.18 (d, *J* = 7.5 Hz, 3H), 5.23 (s, 1H), 2.58 (s, 3H), 1.94 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 195.9, 157.7, 150.1, 141.6,133.3, 132.6, 130.1, 129.7, 128.7, 128.6, 128.4, 128.4, 128.3, 128.0, 127.8, 126.6, 124.0, 122.9, 122.5, 47.8, 30.7, 14.5 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{22}O_2$ $[M+H]^+$: 367.1700,found:367.1701.

1-(5-isopropyl-2-methyl-4-phenylfuran-3-yl)ethanone (125b). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 119. mg (79%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.50-7.47 (m, 2H), 7.27-7.18 (m, 1H), 7.09 (t, *J* = 7.6 Hz, 2H), 5.36 (s, 1H), 2.35 (s, 3H), 2.27 (s, 3H), 1.40 (s, 6H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 193.3, 164.2, 163.1, 135.1, 128.3, 127.9, 125.9, 123.4, 99.4, 47.9, 30.7, 28.4, 15.7 ppm. HRMS (ESI): *m/z* calculated for $C_{16}H_{18}O_2$ $[M+H]^+$: 243.1387, found: 243.1389.

1-(2-methyl-4-phenyl-5-(1-phenylethyl)furan-3-yl)ethanone (125c). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc

in pet ether) the product was obtained as yellow liquid; 108. mg (79%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.71 (d, *J* = 1.6 Hz, 1H) 7.69 (d, *J* = 3.2 Hz, 1H) 7.58-7.32 (m, 2H), 7.32-7.20 (m, 1H), 5.33 (s, 1H), 2.44 (s, 3H), 2.40 (s, 3H), 1.51 (s, 3H), 0.60-0.57 (m, 1H), 0.47-0.43 (m, 1H), 0.35-0.31 (m, 1H), 0.09-0.02 (m, 2H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.1, 164.8, 163.8, 144.8, 134.7, 128.5, 128.3, 128.1, 126.8, 126.4, 126.2, 123.2, 102.4, 54.2, 29.9, 26.6, 15.3 ppm. HRMS (ESI): *m/z* calculated for $C_{21}H_{20}O_2$ $[M+H]^+$: 305.1543, found*:* 305.1543.

1-(5-(1-cyclopropylethyl)-2-methyl-4-phenylfuran-3-yl)ethanone (125d). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 113. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.71 (d, *J* = 1.6 Hz, 1H) 7.69 (d, *J* = 3.2 Hz, 1H) 7.58-7.32 (m, 2H), 7.32-7.20 (m, 1H), 5.33 (s, 1H), 2.44 (s, 3H), 2.40 (s, 3H), 1.51 (s, 3H), 0.60-0.57 (m, 1H), 0.47-0.43 (m, 1H), 0.35-0.31 (m, 1H), 0.09-0.02 (m, 2H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.6, 163.1, 159.3, 145.1, 134.7, 131.7, 128.3, 128.3, 128.2, 127.7, 126.1, 126.1, 126.1, 123.4, 102.4, 51.4, 30.9, 24.5, 19.7, 15.6, 1.4, 1.3 ppm. HRMS (ESI): *m/z* calculated for $C_{18}H_{20}O_2$ $[M+Na]^+$: 291.1360, found*:* 291.1354.

***1-(5-((4-fluorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-yl)ethanone* (125e).** Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 92. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.43-7.40 (m, 3H), 7.32-7.30 (m, 2H), 7.27 (t, *J* = 2 Hz, 3H), 7.16-7.10 (m, 4H), 6.99 (t, *J* = 8.4 Hz, 2H), 5.20 (s, 1H), 2.58 (s, 3H), 1.93 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 196.0, 162.7, 160.8, 157.9, 149.9, 141.5, 137.4, 137.4, 133.3, 130.4, 130.3, 130.1, 128.7, 128.6, 128.0, 126.9, 123.0, 122.7, 115.4, 115.2, 47.2, 30.8, 14.7 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{21}FO_2$ $[M+H]^+$: 385.1606, found*:* 385.1607.

1-(5-((4-chlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-yl)ethanone (125f). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 98. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.44 (d, *J* = 7.2 Hz, 3H), 7.33-7.27 (m, 7H), 7.16 (d, *J* = 7.2 Hz, 2H), 7.10 (d, *J* = 7.2 Hz, 2H), 5.20 (s, 1H), 2.59 (s, 3H), 1.95 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz):δ 195.9, 157.9, 149.5, 141.1, 140.1, 133.1, 132.5, 130.1, 130.1, 128.6, 128.5, 127.9, 126.9, 122.9, 122.7, 47.1, 30.8, 14.6 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{21}ClO_2$ $[M+Na]^+$: 400.1230, found: 400.1230.

1-(5-((3,4-dichlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-yl)ethanone(125g). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 95. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.43-7.41(m, 3H), 7.36-7.29 (m, 3H), 7.28-7.21 (m, 4H), 7.15-6.98 (m, 3H), 5.16 (s, 1H), 2.58 (s, 3H), 1.93 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 195.7, 158.1, 148.8, 141.8, 140.4, 132.9, 132.4, 130.8, 130.6, 130.3, 129.9, 129.6, 128.7, 128.7, 128.6, 128.4, 128.4, 128.3, 128.1, 128.1, 127.1, 123.1, 122.9, 47.1, 30.7, 15.2, 14.6 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{20}Cl_2O_2$ $[M+Na]^+$ 435.0920, found*:* 435.0920.

1-(5-((4-methoxyphenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-yl)ethanone **(125h).** Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 95. mg (78%); mp 135-136 ^{o}C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.39-7.34 *(*m, 3H), 7.25 (t, *J* = 7.5 Hz, 4H), 7.21-7.17 (m, 1H), 7.13 (d, *J* = 7.5 Hz, 2H), 7.06 (d, *J* = 8.5 Hz, 2H), 6.81 (d, *J* = 9 Hz, 2H), 5.15 (s, 1H), 3.75 (s, 3H), 2.54 (s, 3H), 1.90 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 195.9, 158.3, 157.7, 150.4, 142.1, 133.7, 133.4, 130.1, 129.8, 128.7, 128.6, 128.4, 127.8, 126.6, 122.9, 122.3, 55.2, 47.1, 30.8, 12.6 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{24}O_3$ $[M+H]^+$: 397.1805, found: 397.1805.

1-(5-(bis(4-fluorophenyl)methyl)-2-methyl-4-phenylfuran-3-yl)ethanone (125i). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 99. mg (79%); mp 116-117 ^{o}C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.42 (d, *J* = 7.5 Hz, 3H), 7.24 (d, *J* = 6 Hz, 2H), 7.09 (t, *J* = 7.5 Hz, 4H), 6.99 (t, *J* = 8.5 Hz, 4H), 5.17 (s, 1H), 2.57 (s, 3H), 1.92 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 195.7, 162.6, 160.7, 157.8, 149.5, 137.1, 137.1, 133.1, 130.1, 130.1, 129.5, 128.6, 127.9, 122.9, 122.6, 115.4, 115.2, 64.3, 30.7, 15.6 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{20}F_2O_2$ $[M+Na]^+$: 403.1511, found: 403.1511.

1-(5-benzhydryl-2-methyl-4-(p-tolyl)furan-3-yl)ethanone (125j). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 99. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32-7.28 (m, 6H), 7.26 (t, *J* = 0.8 Hz, 4H), 7.23-7.16 (m, 4H), 5.22 (s, 1H), 2.56 (s, 3H), 2.42 (s, 3H), 1.94 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 196.2, 157.7, 155.1, 149.9,

141.7, 173.5, 130.2, 129.9, 129.3, 128.7, 128.4, 128.1, 126.6, 122.5, 47.6, 30.8, 21.3, 14.6 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{24}O_2$ $[M+H]^+$: 381.1856, found: 381.1855.

(5-benzhydryl-2-methyl-4-phenylfuran-3-yl)(phenyl)methanone (125k). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 99. mg (78%); mp 122-123 ^oC. ^1H NMR ($CDCl_3$, 500 MHz): δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.39-7.28 (m, 8H), 7.28-7.25 (m, 4H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 7.5 Hz, 2H), 7.16-7.12 (m, 3H), 5.49 (s, 1H), 2.40 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 192.5, 156.3, 149.8, 141.8, 138.2, 132.4, 132.3, 129.6, 129.5, 129.5, 128.8, 128.8, 128.7, 128.5, 128.5, 128.4, 128.1, 127.9, 127.5, 126.9, 126.7, 123.6, 121.8, 47.8, 13.9 ppm. HRMS (ESI): *m/z* calculated for $C_{31}H_{24}O_2$ $[M+H]^+$: 429.1856, found*:* 429.1857.

(5-((4-chlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-yl)(phenyl)methanone (125l). Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 114. mg (79%). ^1H NMR ($CDCl_3$, 400 MHz): δ 7.66 (t, *J* = 7.2 Hz, 2H), 7.36 (t, *J* = 6.4 Hz, 3H), 7.35-7.30 (m, 5H), 7.26-7.23 (m, 3H), 7.19-7.16 (m, 5H), 7.12 (d, *J* = 1.6 Hz, 1H), 5.45 (s, 1H), 2.40 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 192.4, 156.4, 149.3, 141.3, 140.3, 138.2, 132.6, 130.2, 129.4, 128.8, 128.6, 128.2, 128.1, 127.5, 127.1, 126.9, 123.8, 121.9, 47.3, 13.9 ppm. HRMS (ESI): *m/z* calculated for $C_{31}H_{23}ClO_2$ $[M+H]^+$: 463.1467, found*:* 463.1467.

***(5-((4-fluorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-l)(phenyl)methano*(125m).** Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 116. mg (79%). ^1H NMR ($CDCl_3$, 500 MHz): δ 7.67 (t, *J* = 1 Hz, 2H), 7.36 (t, *J* = 8.0 Hz, 3H), 7.28-7.22 (m, 4H), 7.21-7.17 (m, 6H), 7.11 (t, *J* = 1.5 Hz, 2H), 7.02 (t, *J* = 8.5 Hz, 2H), 5.45 (s, 1H), 2.39 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 192.4, 162.6, 160.7, 156.3, 149.6, 141.6, 138.2, 137.5, 137.5, 132.4, 132.2, 130.3, 129.4, 128.7, 128.5, 128.1, 127.9, 126.8, 123.6, 121.9, 115.3, 115.2, 47.2, 13.8 ppm. HRMS (ESI): *m/z* calculated for $C_{31}H_{23}FO_2$ $[M+H]^+$: 447.1762, found*:* 447.1768.

***Ethyl 5-benzhydryl-2-methyl-4-phenylfuran-3-carboxylate* (125n).** Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 99. mg (78%); mp 120-121 ^oC. ^1H NMR ($CDCl_3$, 500 MHz): δ 7.90 (d, *J* = 8 Hz, 1H),7.39-7.32 (m, 5H) 7.28-7.21 (m, 5H), 7.18-7.10

(m, 4H), 5.26 (s, 1H), 4.08 (q, *J* = 7 Hz, 2H) 2.57 (s, 3H), 1.05 (t, *J* = 7.5 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 192.8, 164.3, 158.8, 154.7, 141.9, 141.5, 139.1, 138.4, 132.8, 130.2, 129.9, 129.4, 128.9, 128.8, 128.7, 128.5, 128.5, 128.4, 128.1, 127.8, 127.2, 126.7, 124.2, 59.9, 47.9, 14.4, 14.1 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{24}O_3$ $[M+H]^+$: 397.1805; found: 397.1806.

***Ethyl 5-benzhydryl-2-methyl-4-(p-tolyl)furan-3-carboxylate* (125o).** Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 107. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.32-7.28 (m, 7H), 7.24-7.17 (m, 7H), 5.30 (s, 1H), 4.14 (q, *J* = 7.2 Hz, 2H) 2.60 (s, 3H), 2.40 (s, 3H), 1.13 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 164.6, 158.6, 150.1, 141.8, 136.8, 129.9, 129.7, 128.8, 128.5, 128.3, 126.5, 123.2, 59.8, 47.6, 21.3, 21.3, 14.4, 14.1 ppm. HRMS (ESI): *m/z* calculated for $C_{28}H_{26}O_3$ $[M+H]^+$: 411.1962, found: 411.1961.

***Ethyl5-((4-chlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-rboxylate*(125p).**
Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 99. mg (78%); mp 98-99 ^{o}C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.38-7.32 (m, 4H), 7.30-7.24 (m, 5H), 7.17 (t, *J* = 1.6 Hz, 3H), 7.10 (d, *J* = 8.4 Hz, 2H), 5.26 (s, 1H), 4.13 (q, *J* = 7.2 Hz, 2H), 2,61 (s, 3H), 1.09 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 164.1, 158.9, 149.6, 141.2, 140.2, 132.7, 132.5, 130.1, 130.1, 128.7, 128.5, 127.8, 127.3, 126.8, 123.5, 113.8, 59.8, 47.1, 14.3, 13.9 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{23}ClO_3$ $[M+H]^+$: 431.1416, found*:* 431.1416.

***Ethyl5-((3,4-dichlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-carboxylate* (125q).**
Following general experimental procedure 2.9.3 then purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 102. mg (78%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.45 (t, *J* = 8 Hz, 1H), 7.42-7.36 (m, 5H), 7.35-7.28 (m, 2H), 7.24-7.22 (m, 1H), 7.16-7.15 (m, 2H), 7.00-6.97 (m, 2H), 5.23 (s, 1H), 4.13 (q, *J* = 5 Hz, 2H), 2.62 (s, 3H), 1.09 (t, *J* = 7.5 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 164.0, 159.0, 148.9, 142.0, 140.6, 132.4, 131.4, 130.6, 130.2, 130.0, 129.8, 129.0, 128.7, 128.6, 128.6, 128.6, 128.6, 128.4, 128.2, 127.8, 127.4, 127.1, 124.5, 113.9, 59.9, 47.0, 14.4, 13.9 ppm. HRMS (ESI):*m/z* calculated for $C_{27}H_{22}Cl_2O_3$ $[M+H]^+$: 465.1026, found*:* 465.1028.

Methyl5-((4-chlorophenyl)(phenyl)methyl)-2-methyl-4-phenylfuran-3-carboxylate (125r)
Following general experimental procedure 2.9.3 then purified by flash chromatography (silica

gel, 2-3 % EtOAc in pet ether) the product was obtained as white solid 103. mg (79%); mp 113-114 ºC.^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.40-7.37 (m, 3H), 7.32 (d, *J* = 7.6 Hz, 2H), 7.29-7.26 (m, 5H), 7.16 (d, *J* = 7.6 Hz, 2H), 7.10 (d, *J* = 8.4 Hz, 2H), 5.27 (s, 1H), 3.68 (s, 3H), 2.62 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 164.5, 159.1, 149.7, 141.2, 140.2, 132.5, 132.5, 130.1, 129.9, 128.7, 128.5, 127.9, 127.3, 126.8, 123.5, 113.5, 51.1, 47.1, 14.4 ppm. HRMS (ESI): *m/z* calculated for $C_{26}H_{21}ClO_3$ $[M+Na]^+$: 417.1259, found: 417.1257.

1-(5-benzhydryl-2,3-dimethyl-4-phenyl-2,3-dihydrofuran-3-yl)ethanone (126). Purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 78. mg (78%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.31 (t, *J* = 2 Hz, 4H), 7.22 (t, *J* = 7.2 Hz, 3H), 7.20-7.14 (m, 4H), 7.09 (t, *J* = 1.6 Hz, 2H), 6.92-6.89 (m, 2H), 5.27 (s, 1H), 4.43 (q, *J* = 6.8 Hz, 1H), 1.95 (s, 3H), 1.18 (d, *J* = 6.8 Hz, 3H), 1.09 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 212.3, 156.5, 140.3, 133.7, 129.5, 128.8, 128.7, 128.6, 128.2, 127.5, 126.9, 126.8, 119.1, 86.7, 63.6, 49.1, 29.1, 19.4, 14.3 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{26}O_2$ $[M+H]^+$: 382.1933, found: 382.1933.

1-(5-benzhydryl-3-methyl-2-methylene-4-phenyl-2,3-dihydrofuran-3-yl)ethanol (127). Purified by flash chromatography (silica gel, 2-3 % EtOAc in pet ether) the product was obtained as yellow liquid; 80. mg (80%). ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.38 (t, *J* = 3.2 Hz, 3H), 7.37-7.32 (m, 4H), 7.30 (d, *J* = 2 Hz, 1H), 7.29-7.25 (m, 6H), 7.20 (t, *J* = 1.2 Hz, 2H), 5.01 (s, 1H), 4.60 (d, *J* = 2.5 Hz, 1H), 4.19 (d, *J* = 2.4 Hz, 1H), 3.65 (q, *J* = 6 Hz, 1H), 1.41 (s, 3H), 1.21 (d, *J* = 6.4 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.5, 152.4, 141.2, 140.7, 133.3, 130.4, 128.8, 128.6, 128.5, 128.3, 127.6, 126.7, 126.6, 118.5, 85.1, 73.1, 56.8, 47.9, 23.6, 17.1 ppm. HRMS (ESI): *m/z* calculated for $C_{27}H_{26}O_2$ $[M+H]^+$: 382.1933, found: 382.1933.

3-methyl-3-(1,3,3-triphenylpropa-1,2-dien-1-yl)pentane-2,4-dione(3ya) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 123 mg (92%); mp 121-123 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.43-7.38 (m, 8H), 7.35-7.33 (m, 6H), 7.29-7-26 (m, 1H), 2.20 (s, 6H), 1.68 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 207.3, 207.1, 135.4, 134.1, 128.7, 128.7, 128.3, 127.9, 127.7, 127.5, 114.1, 109.9, 68.7, 27.9, 20.2 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{27}H_{24}O_2$ $[M+H]^+$: 380.1776, found:380.1780.

3-(3-(3,4-dichlorophenyl)-1,3-diphenylpropa-1,2-dien-1-yl)-3-methylpentane-2,4-dione (3yb) Following general experimental procedure 3.6.2 then purified by flash chromatography

(silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 111 mg (88%); mp 125-127 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.46 (t, *J* = 2 Hz, 1H), 7.39 (d, *J* = 6.5 Hz, 2H), 7.35-7.33 (m, 3H), 7.32-7.27 (m, 3H), 7.26-7.24 (m, 4H), 2.16 (s, 6H), 1.64 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 207.2, 206.9, 135.9, 134.6, 133.8, 133.1, 133.1, 130.7, 130.1, 129.1, 128.9, 128.4, 128.3, 128.2, 127.7, 127.6, 112.3, 110.8, 69.1, 27.9, 20.4 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{27}H_{22}Cl_2O_2$ $[M+H]^+$: 448.0997,found:448.0998.

3-(1-cyclopropyl-3,3-diphenylpropa-1,2-dien-1-yl)-3-methylpentane-2,4-dione(3yc)

Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 104 mg (75%); mp 123-125 °C**.** ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.35-7.31 (m, 5H), 7.29-7.25 (m, 5H), 2.15 (s, 6H), 1.62 (s, 3H), 1.12 (d, *J* = 5.2 Hz, 1H), 0.82 (t, *J* = 2.4 Hz, 2H), 0.56 (t, *J* = 2 Hz, 2H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 207.1, 201.5, 136.1, 128.5, 128.1, 127.6, 115.1, 111.8, 69.8, 27.5, 19.2, 10.5, 8.4 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{24}H_{24}O_2[M+H]^+$: 344.1776, found:344.1780.

3-(2-(9H-fluoren-9-ylidene)-1-phenylvinyl)-3-methylpentane-2,4-dione(3yd) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 120 mg (90%); mp 121-124 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.77 (d, *J* = 8 Hz, 2H), 7.64 (d, *J* = 7.5 Hz, 2H), 7.41-7.38 (m, 2H), 7.33-7.30 (m, 2H), 7.29-7.25 (m, 5H), 2.38 (s, 6H), 1.67 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 206.6, 204.9, 139.3, 137.1, 133.7, 128.9, 128.7, 128.4, 128.1, 127.5, 123.4, 120.5, 115.1, 109.8, 69.3, 27.8, 20.6 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{27}H_{22}O_2[M+H]^+$:378.1620, found: 378.1621.

3-(3-(2-chloro-5-nitrophenyl)-1,3-diphenylpropa-1,2-dien-1-yl)-3-methylpentane-2,4-dione(3ye) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 107 mg (85%); mp 128-130 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.26 (d, *J* = 3 Hz, 1H), 8.21-8.19 (m, 2H), 7.64 (d, *J* = 8.5 Hz, 2H), 7.38-7.31 (m, 3H), 7.30-7.24 (m, 5H), 2.2 (s, 3H), 2.18 (s, 3H), 1.67 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 206.6, 206.5, 146.8, 141.3, 136.2, 133.4, 133.4, 131.1, 129.2, 128.9, 128.4, 127.9, 126.5, 124.3, 112.2, 109.9, 69.1, 28.1, 27.5, 20.5 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{27}H_{22}ClNO_4[M+H]^+$:459.1237, found:459.1228.

2.9.5 REFERENCES

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2.9.5a Crystal data and structure refinement for 124h &125h.

Identification code	shelx-97
Empirical formula	$C_{28}H_{26}O_3$
Formula weight	410.49
Temperature	291 (2) K
Wavelength	0.71073 Å
Crystal system	'Triclinic'
Space group	P-1

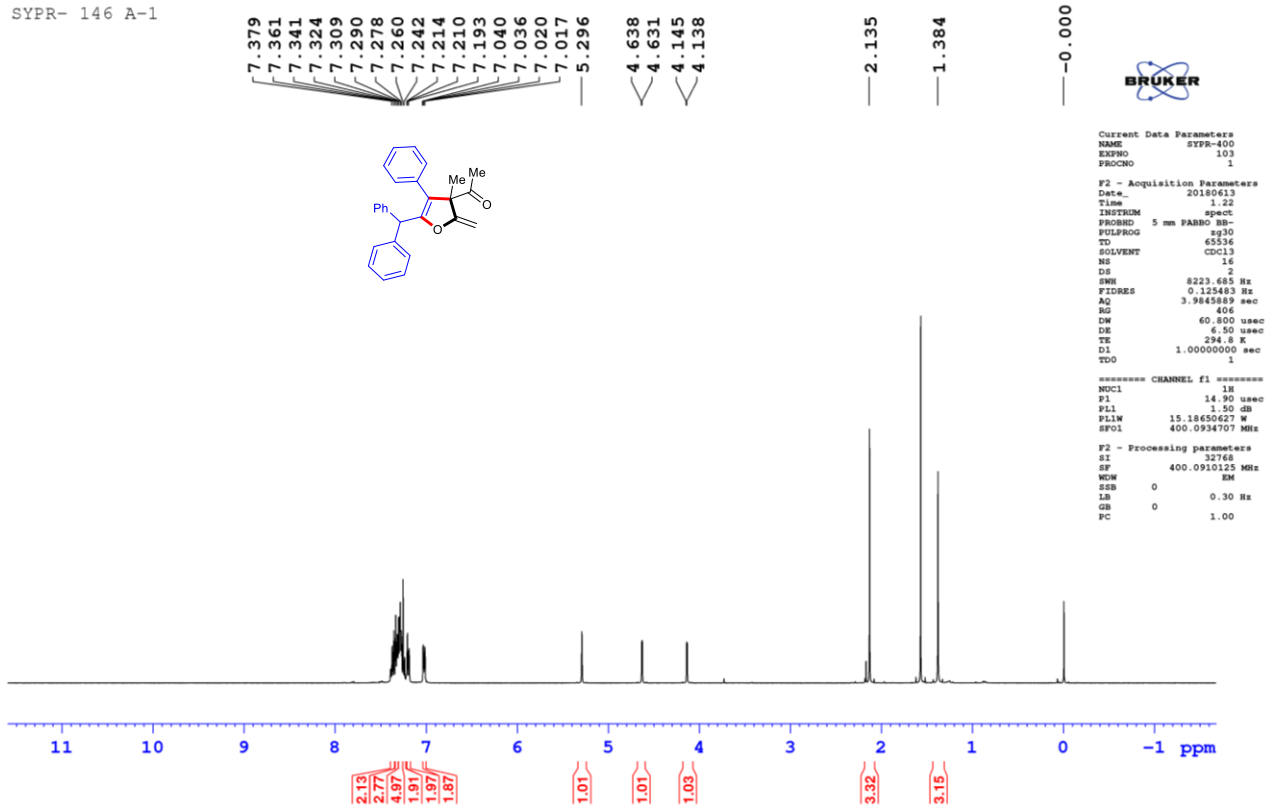
Unit cell dimensions	a = 9.9166 (11) Å	α = 106.883° (5).
	b = 10.0554 (13) Å	β = 98.953 ° (5).
	c = 12.1593 (15) Å	γ = 94.007 ° (5).
Volume	1137.6(2)	
Z	2	
Density (calculated)	1.198 Mg/m^3	
Absorption coefficient	0.077 mm^{-1}	
F(000)	436.0	
Crystal size	0.4 x 0.32 x 0.28 mm^3	
Theta range for data collection	2.32 to 27.650 °.	
Index ranges	-12<=h<=12,-13<=k<=13,-15<=l<=15	
Reflections collected	5243	
Independent reflections	2905 [R(int) = 0.0607]	
Max. and min. transmission	0.971 and 0.973	
Refinement method	Full-matrix least-squares on F^2	
restraints / parameters	0 / 287	
Goodness-of-fit on F^2	0.956	
Final R indices [I>2sigma(I)]	R1 = 0.0607, wR2 = 0.1611	
R indices (all data)	R1 = 0.1298, wR2 = 0.1322	

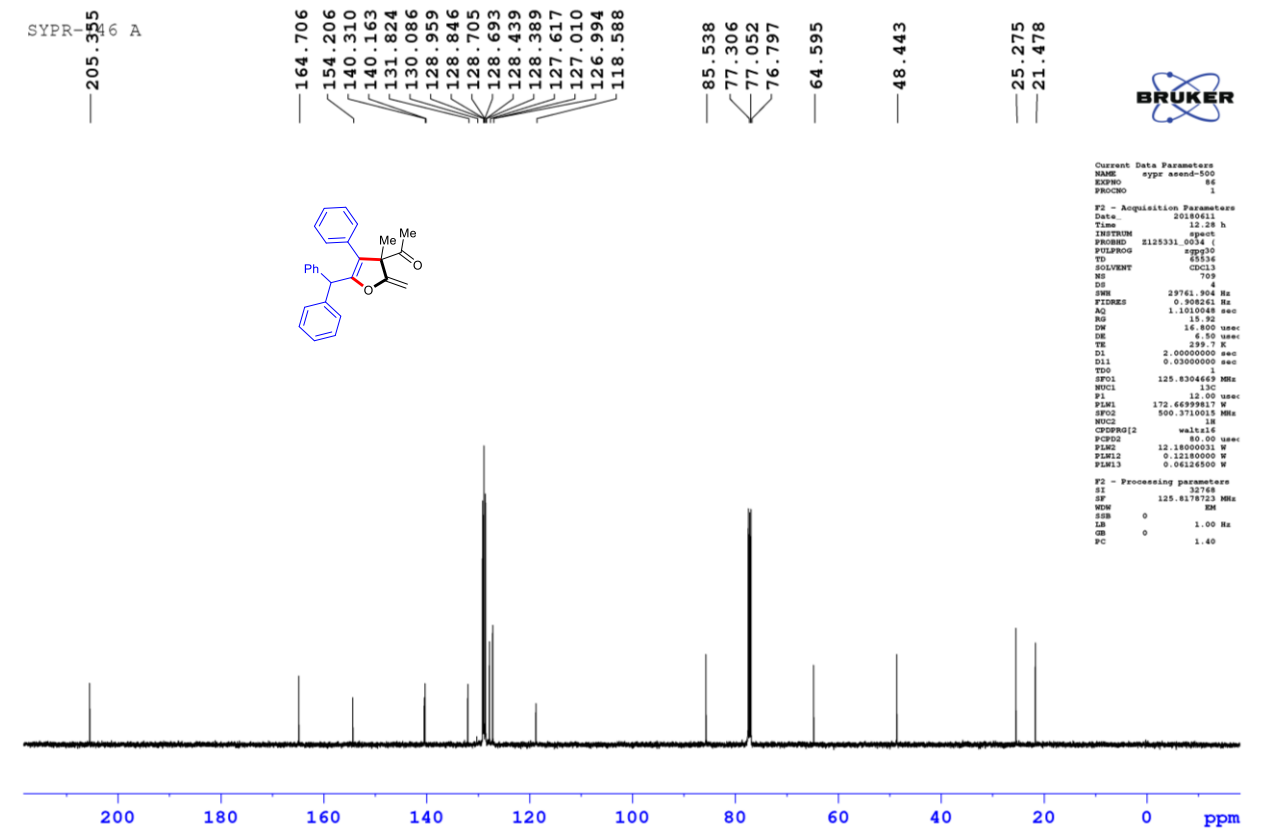
Crystal data and structure refinement for 125h.

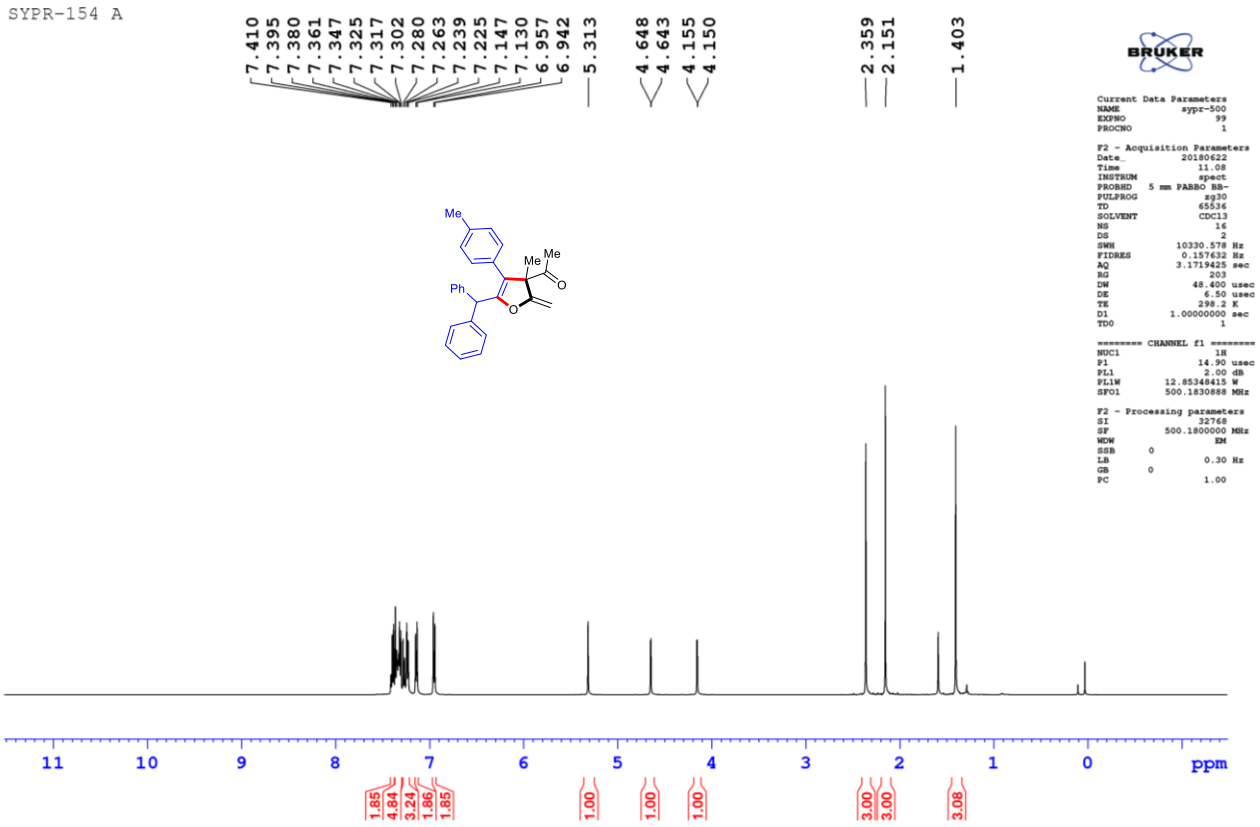
Identification code	'SHELXL-2014/7	
Empirical formula	$C_{27}H_{23}O_3$	
Formula weight	395.45	
Temperature	298 (2) K	
Wavelength	0.71073 Å	
Crystal system	'Triclinic'	
Space group	P-1	
Unit cell dimensions	a = 9.8049 (9) Å	α = 87.971° (4).
	b = 9.8109 (10) Å	β = 75.802 ° (4).
	c = 11.3980 (12) Å	γ =85.937 ° (4).
Volume	1060.08(18)	
Z	2	
Density (calculated)	1.239 Mg/m^3	

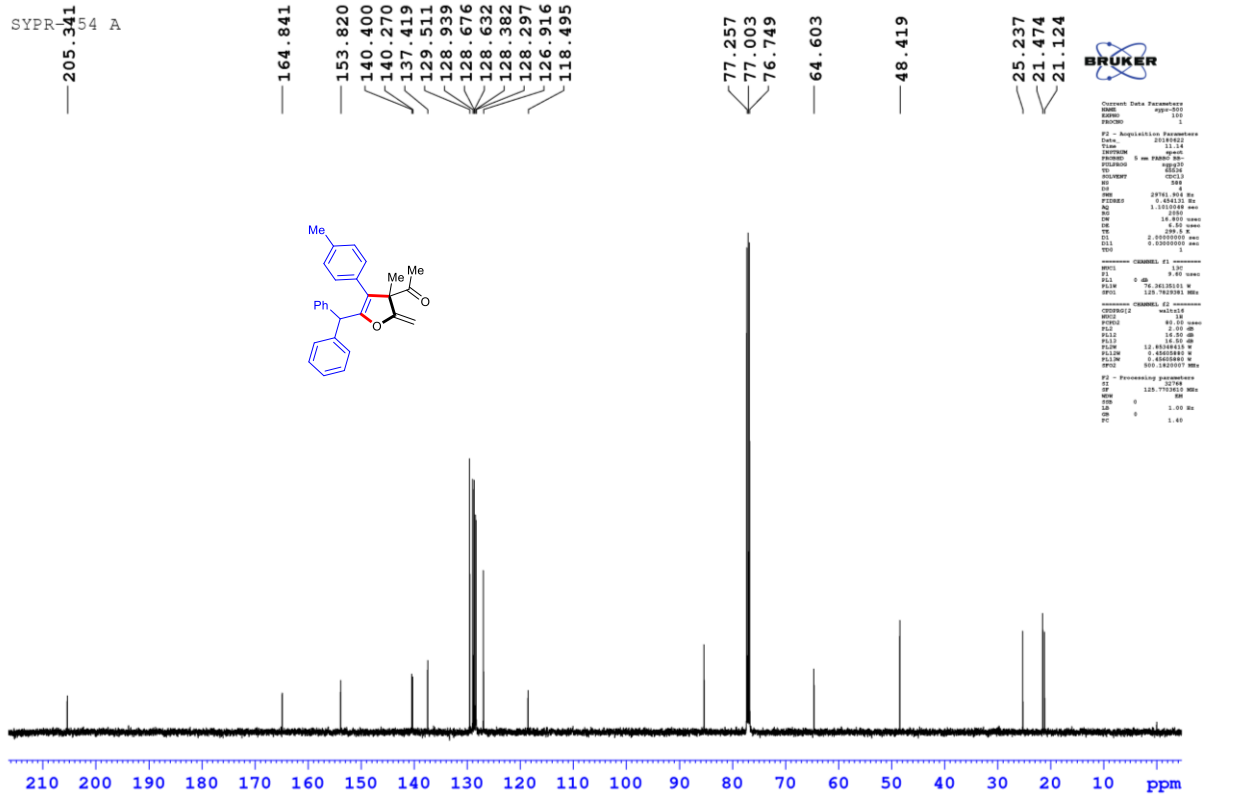
Absorption coefficient	0.080 mm^{-1}
F(000)	418.0
Crystal size	0.42 x 0.32 x 0.22 mm^3
Theta range for data collection	2.466 to 27.973 °.
Index ranges	-12<=h<=12,-12<=k<=12,-15<=l<=15
Reflections collected	5052
Independent reflections	3935 [R(int) = 0.0603]
Max. and min. transmission	0.970 and 0.983
Refinement method	Full-matrix least-squares on F^2
restraints / parameters	0 / 271
Goodness-of-fit on F^2	1.065
Final R indices [I>2sigma(I)]	R1 = 0.0603, wR2 = 0.1658
R indices (all data)	R1 = 0.0779, wR2 = 0.1761

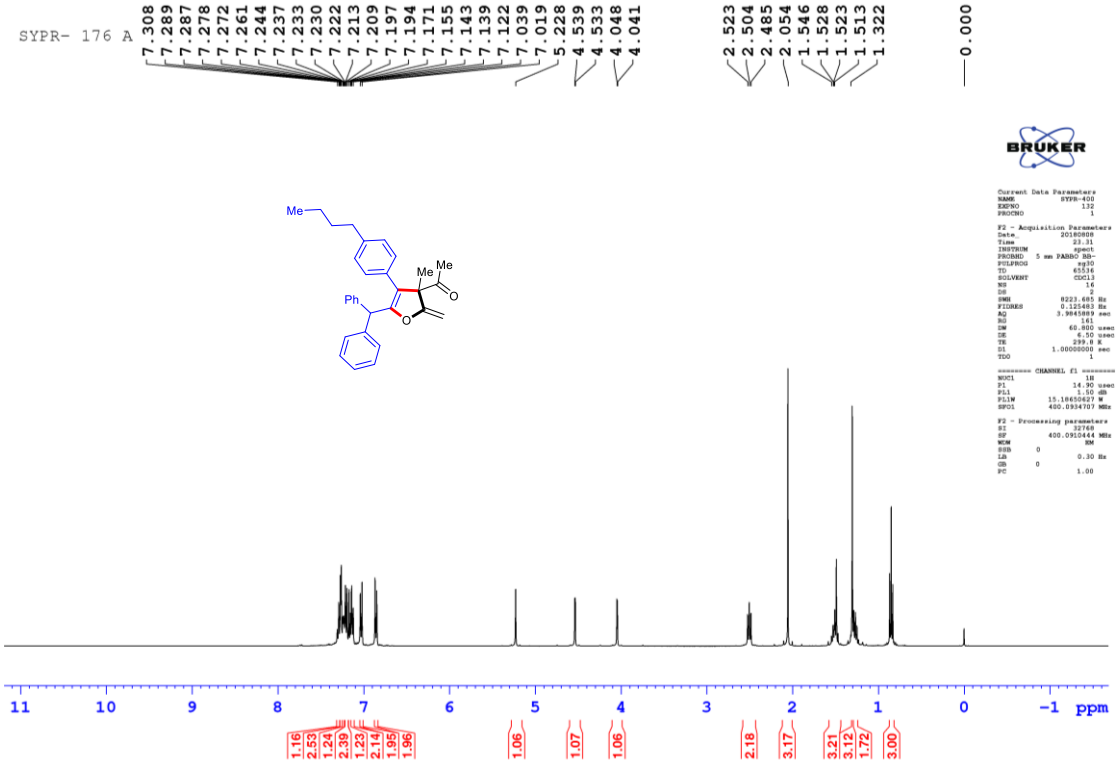
2.9.6 SPECTRAL COPIES






SYPR-154 A
7.410
7.395
7.380
7.361
7.347
7.325
7.317
7.302
7.280
7.263
7.239
7.225
7.147
7.130
6.957
6.942
5.313
4.648
4.643
4.155
4.150
2.359
2.151
1.403
BRUKER
Me
Me
Me
Ph
O
O
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.85
4.84
3.24
1.86
1.85
1.00
1.00
1.00
3.00
3.00
3.08


SYPR-154 A
205.341
164.841
153.820
140.400
140.270
137.419
129.511
128.939
128.676
128.632
128.382
128.297
126.916
118.495
77.257
77.003
76.749
64.603
48.419
25.237
21.474
21.124
BRUKER
Me
Me
Me
Ph
O
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


SYPR- 176 A
7.308
7.289
7.287
7.278
7.272
7.261
7.244
7.237
7.233
7.230
7.222
7.213
7.209
7.197
7.194
7.171
7.155
7.143
7.139
7.122
7.039
7.019
5.228
4.539
4.533
4.048
4.041
2.523
2.504
2.485
2.054
1.546
1.528
1.523
1.513
1.322
0.000
BRUKER
Me
Me
Me
Ph
O
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.16
2.53
1.24
2.39
1.23
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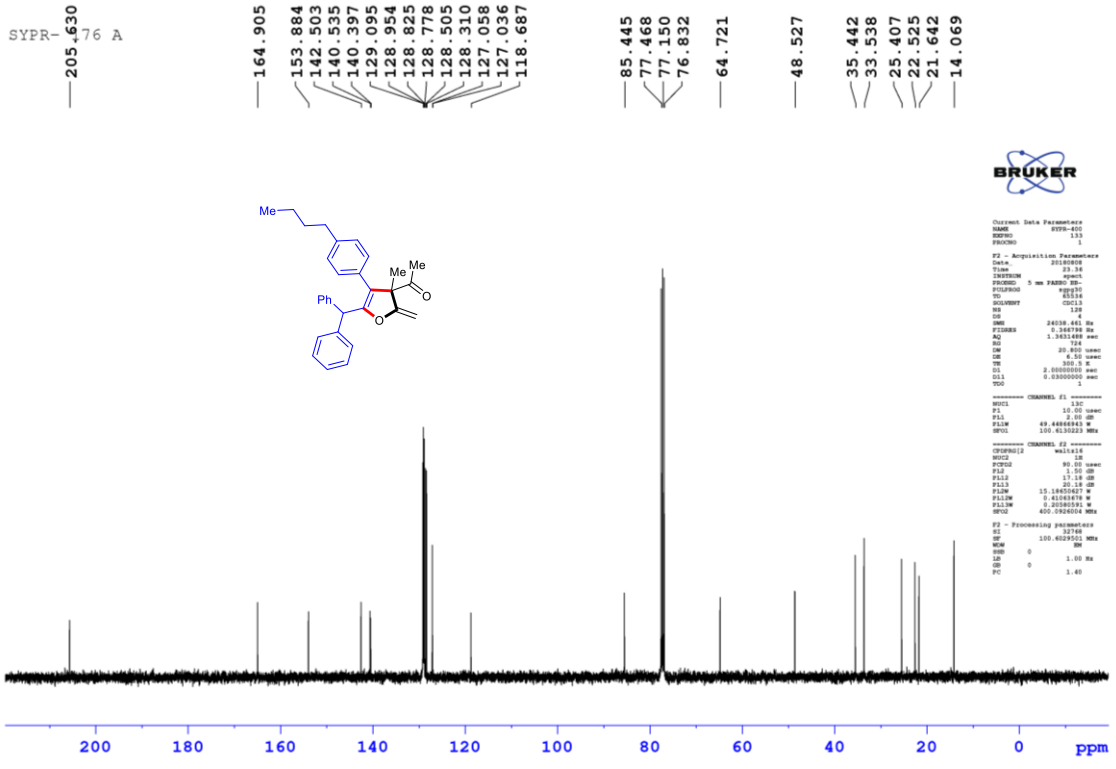
1.96
1.06
1.07
1.06
2.18
3.17
3.21
3.12
1.72
3.00


SYPR-176 A
205.630
164.905
153.884
142.503
140.535
140.397
129.095
128.954
128.825
128.778
128.505
128.310
127.058
127.036
118.687
85.445
77.468
77.150
76.832
64.721
48.527
35.442
33.538
25.407
22.525
21.642
14.069
BRUKER
Me
Me
Me
Ph
O
200
180
160
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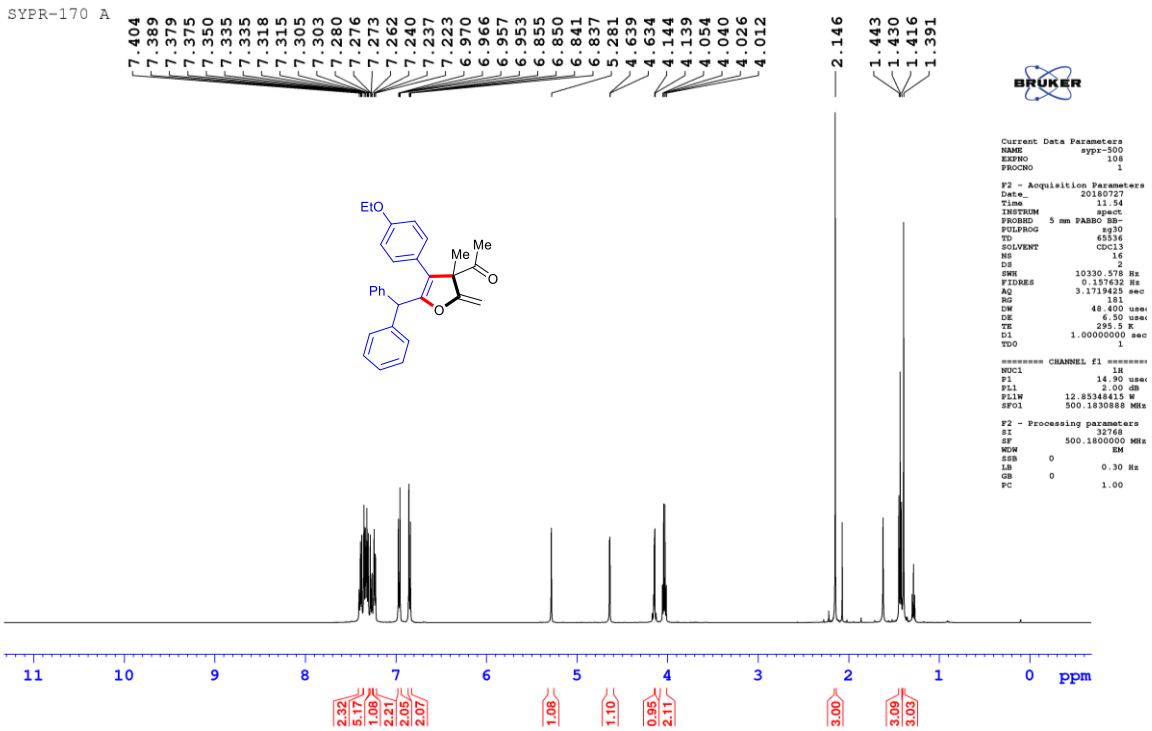
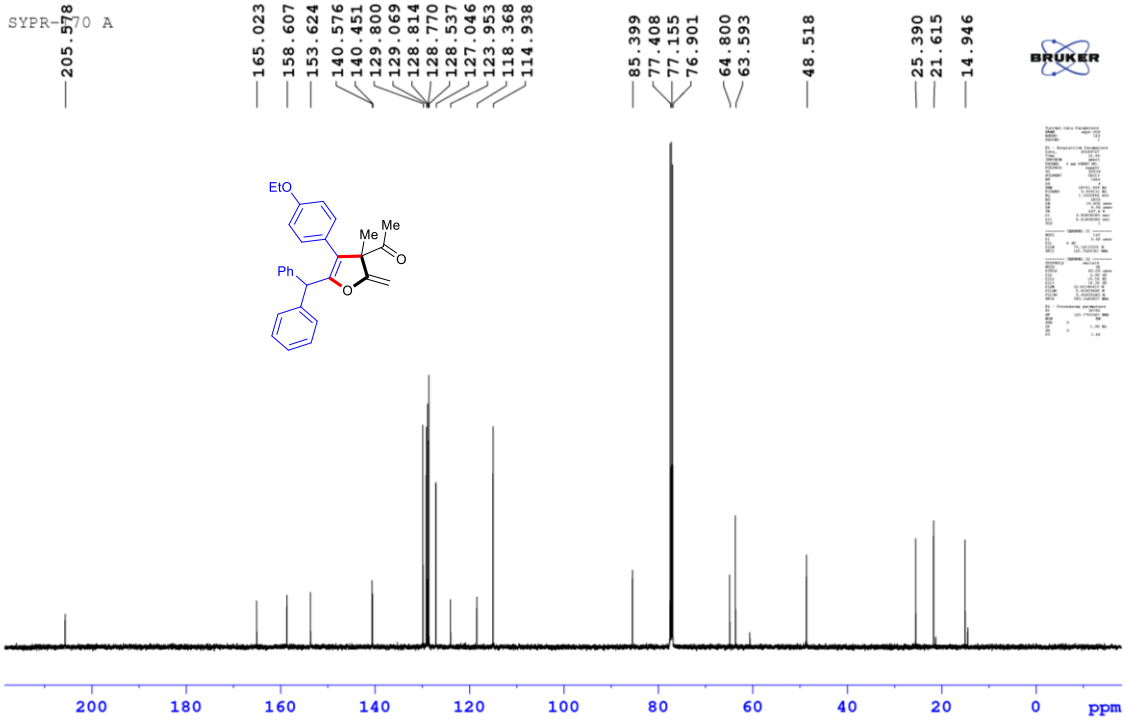
120
100
80
60
40
20
0
ppm


SYPR-170 A
7.404
7.389
7.379
7.375
7.350
7.335
7.335
7.318
7.315
7.305
7.303
7.280
7.276
7.273
7.262
7.240
7.237
7.223
6.970
6.966
6.957
6.953
6.855
6.850
6.841
6.837
5.281
4.639
4.634
4.144
4.139
4.054
4.040
4.026
4.012
2.146
1.443
1.430
1.416
1.391
BRUKER
EtO
Me
Me
Ph
O
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.32
5.17
1.08
2.21
2.05
2.07
1.08
1.10
0.95
2.11
3.00
3.09
3.03


SYPR-170 A
205.578
165.023
158.607
153.624
140.576
140.451
129.800
129.069
128.814
128.770
128.537
127.046
123.953
118.368
114.938
85.399
77.408
77.155
76.901
64.800
63.593
48.518
25.390
21.615
14.946
BRUKER
EtO
Me
Me
Ph
O
200
180
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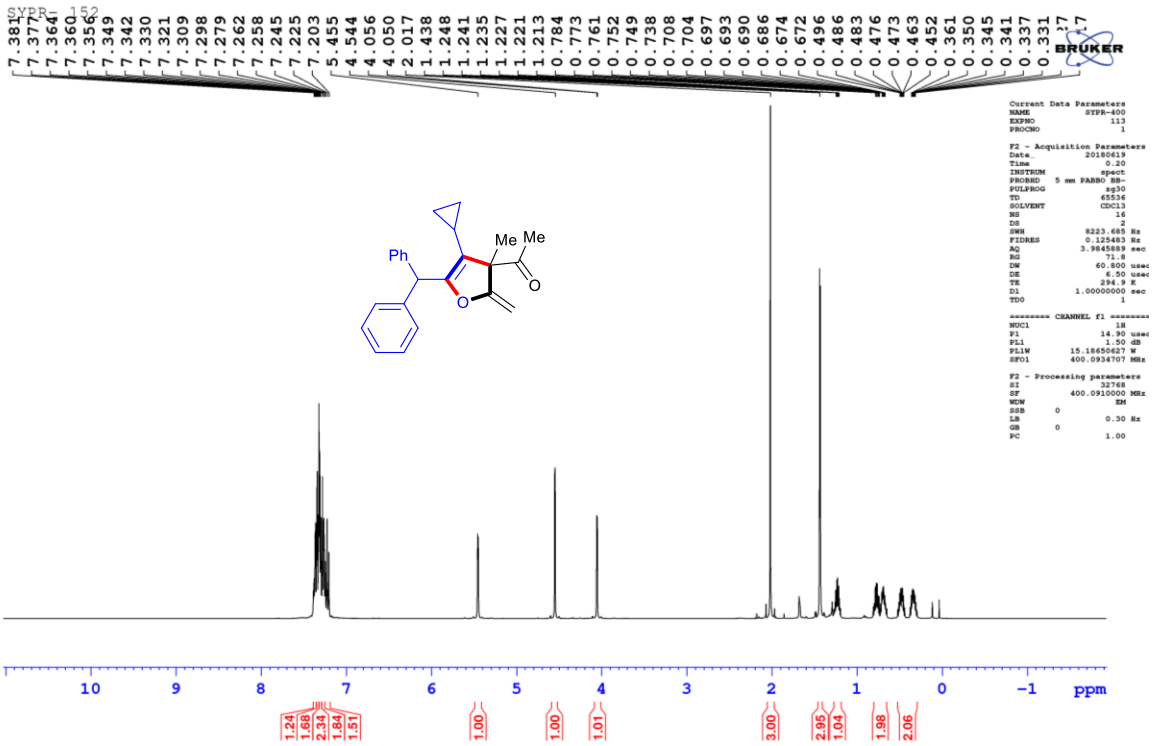
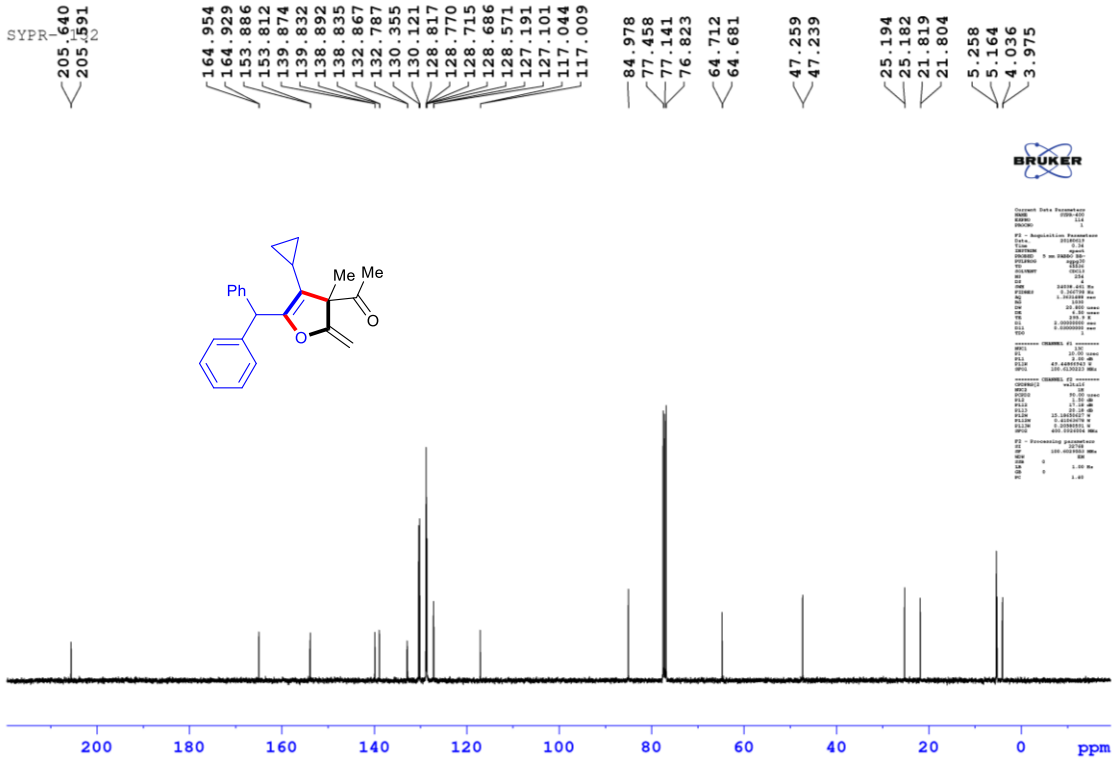
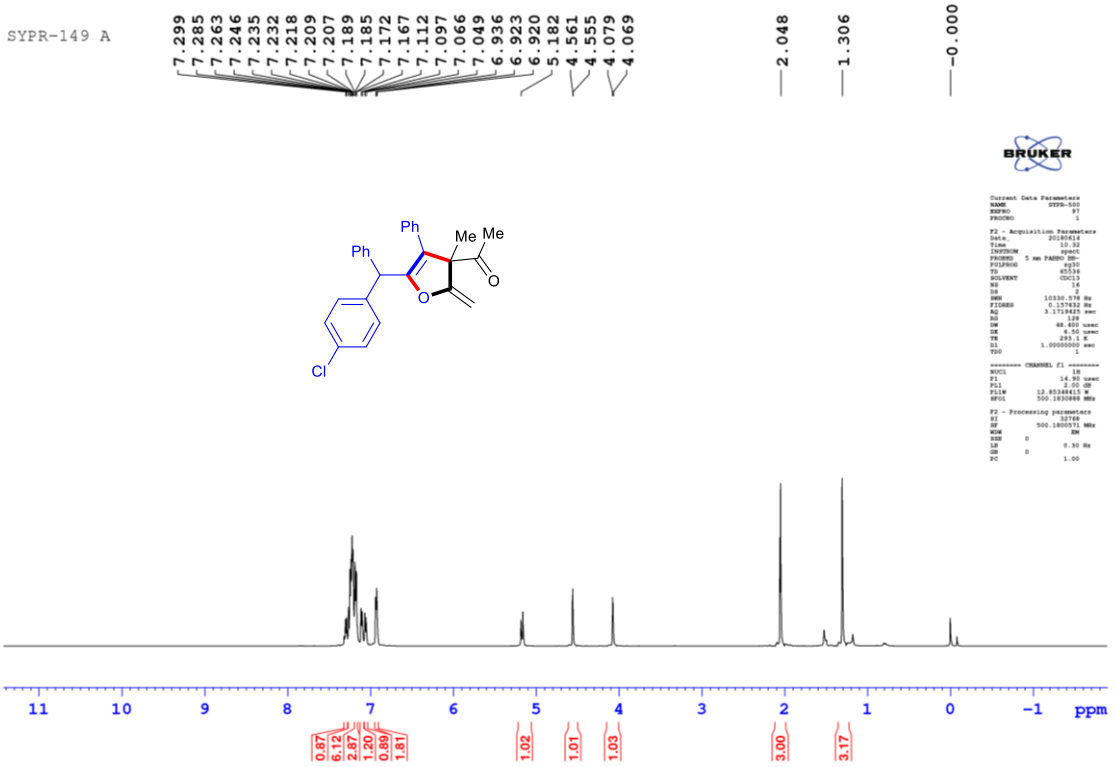
140
120
100
80
60
40
20
0
ppm


SYPR- 152
Ph
Me
Me
O
ppm


SYPR-152
Ph
Me
Me
O
ppm


SYPR-149 A
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7.285
7.263
7.246
7.235
7.232
7.218
7.209
7.207
7.189
7.185
7.172
7.167
7.112
7.097
7.066
7.049
6.936
6.923
6.920
5.182
4.561
4.555
4.079
4.069
2.048
1.306
0.000
Ph
Me
Me
Ph
O
Cl
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
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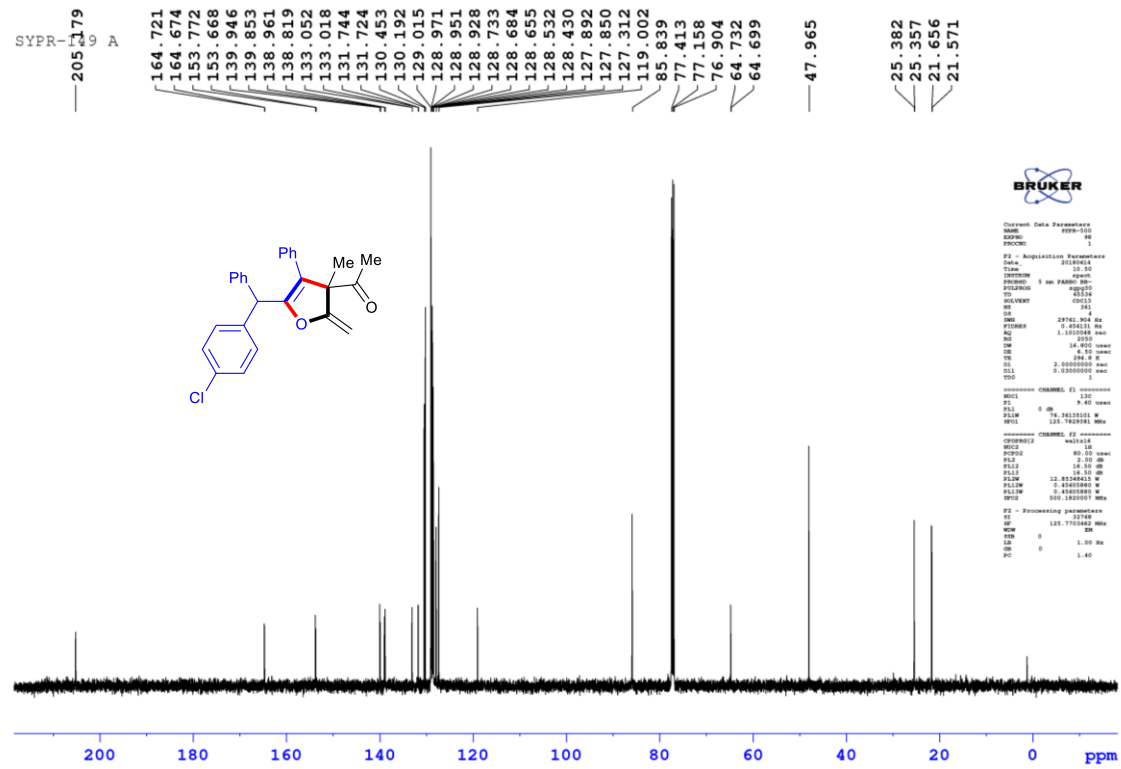
6.12
2.87
1.20
0.89
1.81
1.02
1.01
1.03
3.00
3.17


SYPR-149 A
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164.721
164.674
153.772
153.668
139.946
139.853
138.961
138.819
133.052
133.018
131.744
131.724
130.453
130.192
129.015
128.971
128.951
128.928
128.733
128.684
128.655
128.532
128.430
127.892
127.850
127.312
119.002
85.839
77.413
77.158
76.904
64.732
64.699
47.965
25.382
25.357
21.656
21.571
Ph
Me
Me
Ph
O
Cl
200
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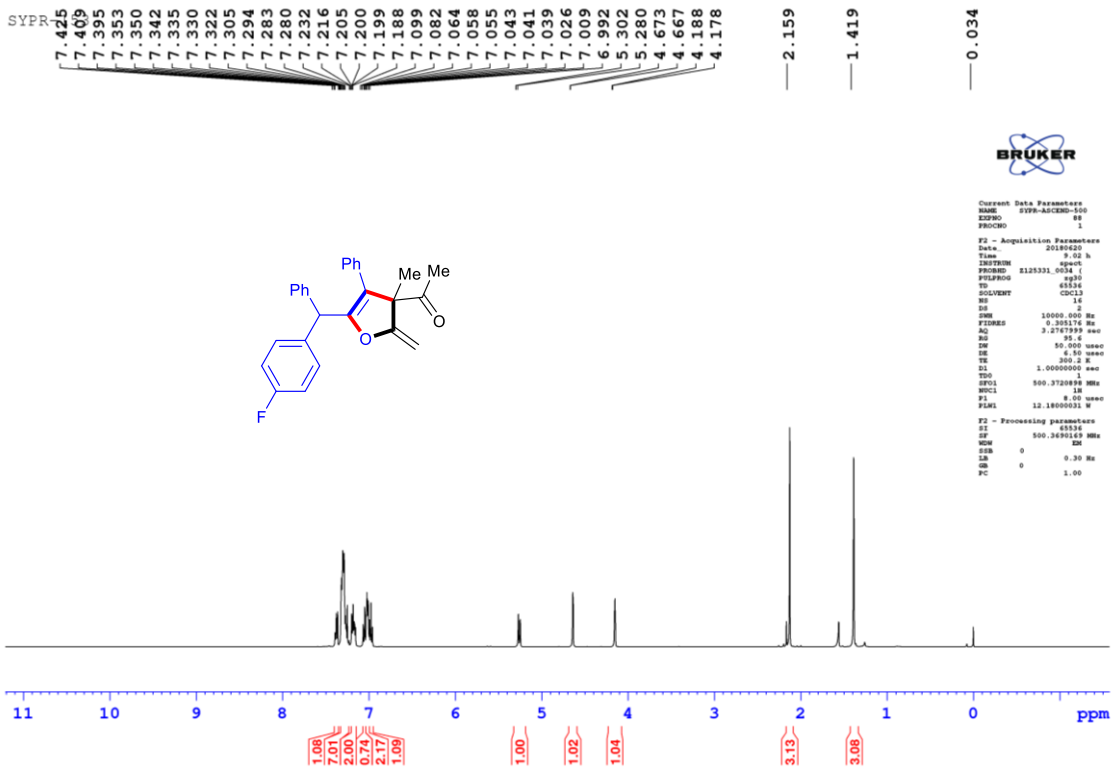
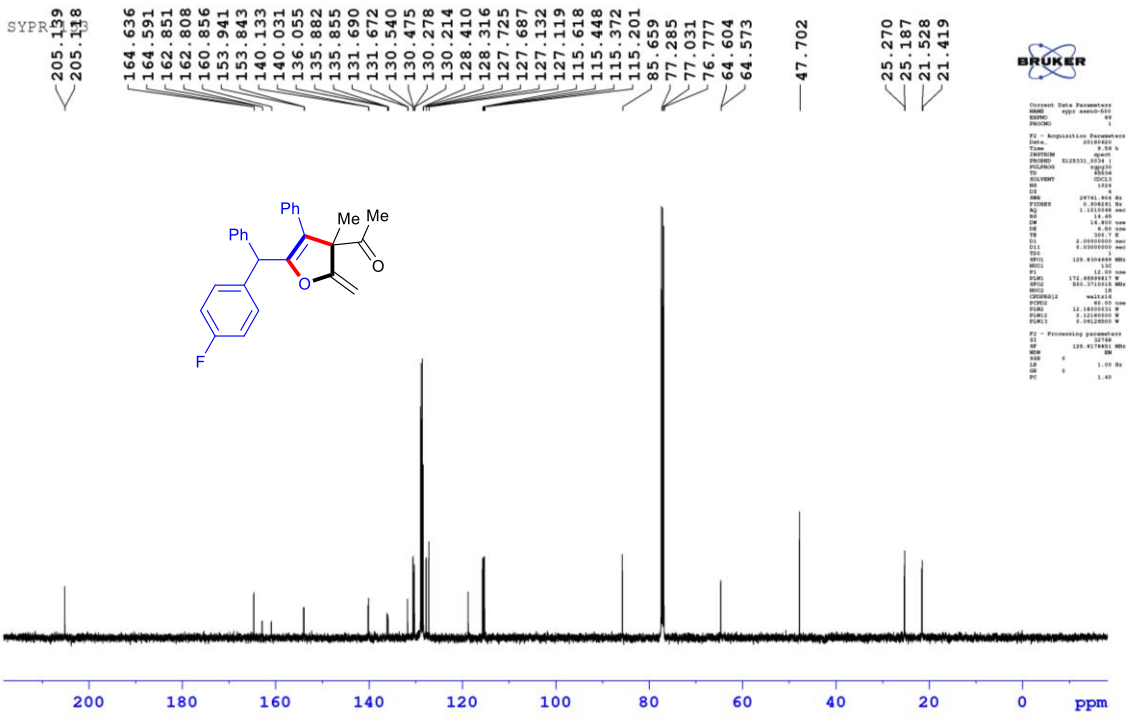
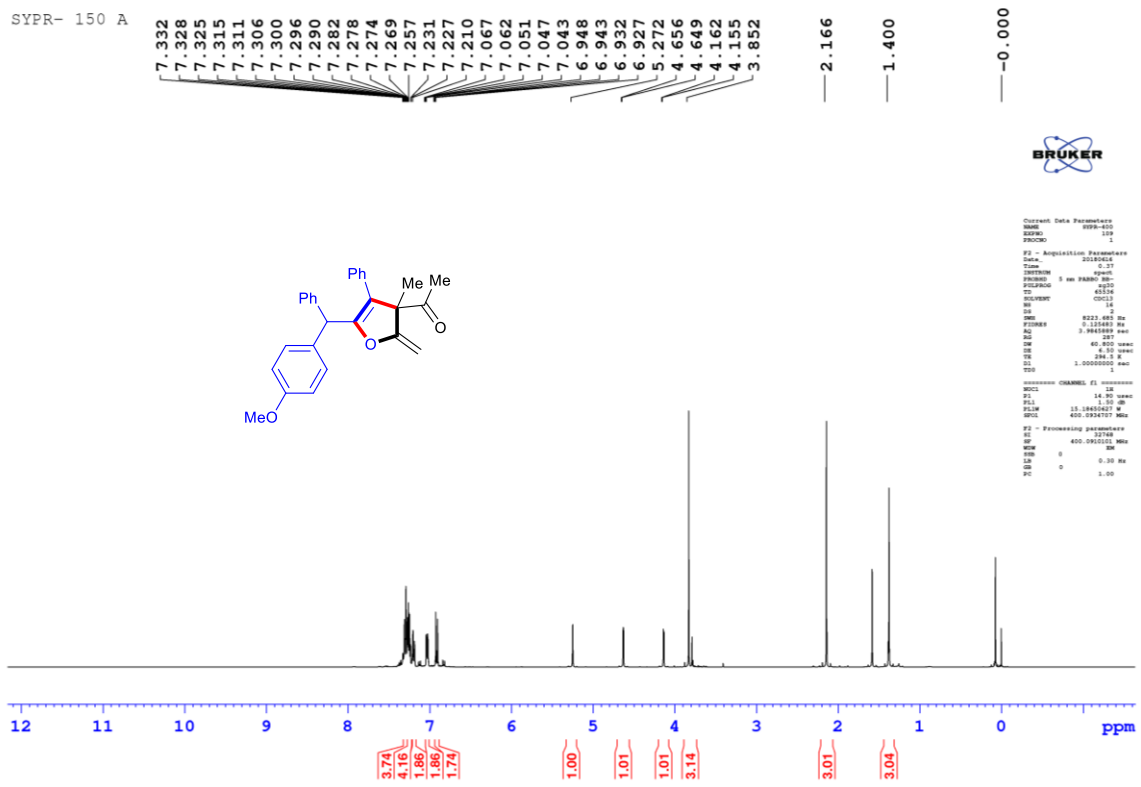
160
140
120
100
80
60
40
20
0
ppm


SYPR
7.425
7.409
7.395
7.353
7.350
7.342
7.335
7.330
7.322
7.305
7.294
7.283
7.280
7.232
7.216
7.205
7.200
7.199
7.188
7.099
7.082
7.064
7.058
7.055
7.043
7.041
7.039
7.026
7.009
6.992
5.302
5.280
4.673
4.667
4.188
4.178
2.159
1.419
0.034
Ph
Ph
Me
Me
O
F
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.08
7.01
2.00
0.74
2.17
1.09
1.00
1.02
1.04
3.13
3.08


SYPR
205.139
205.118
164.636
164.591
162.851
162.808
160.856
153.941
153.843
140.133
140.031
136.055
135.882
135.855
131.690
131.672
130.540
130.475
130.278
130.214
128.410
128.316
127.725
127.687
127.132
127.119
115.618
115.448
115.372
115.201
85.659
77.285
77.031
76.777
64.604
64.573
47.702
25.270
25.187
21.528
21.419
Ph
Ph
Me
Me
O
F
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR- 150 A
7.332
7.328
7.325
7.315
7.311
7.306
7.300
7.296
7.290
7.282
7.278
7.274
7.269
7.257
7.231
7.227
7.210
7.067
7.062
7.051
7.047
7.043
6.948
6.943
6.932
6.927
5.272
4.656
4.649
4.162
4.155
3.852
2.166
1.400
0.000
Ph
Me
Me
Ph
O
O
MeO
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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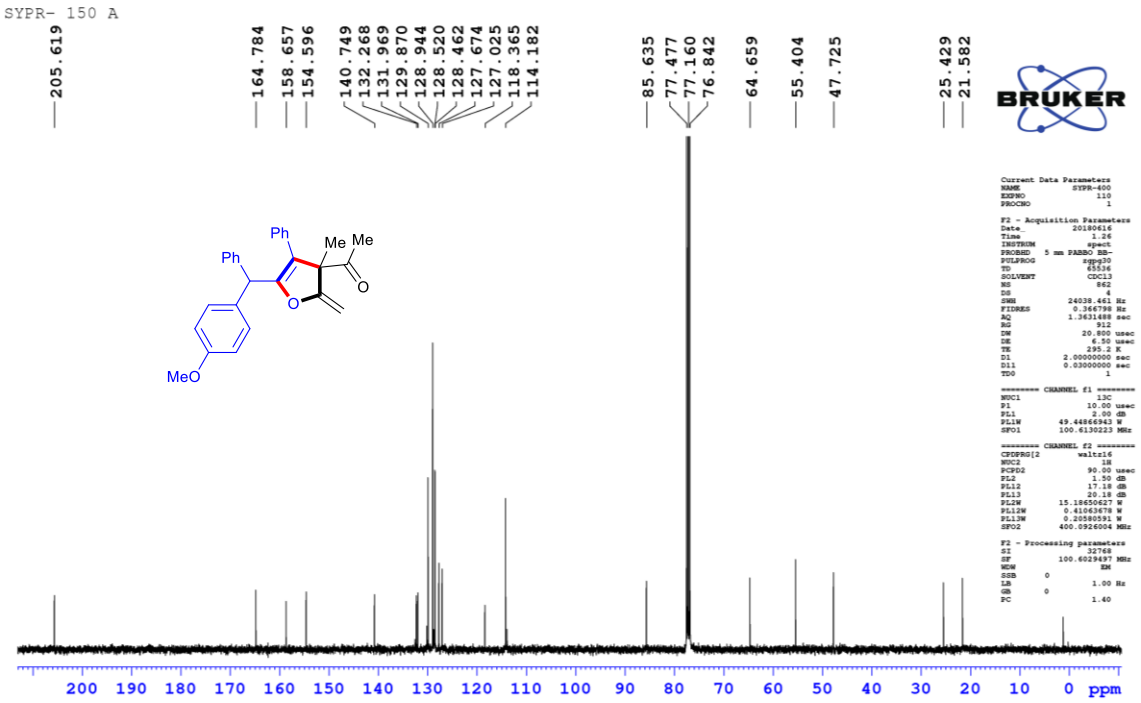
1.86
1.86
1.74
1.00
1.01
1.01
3.14
3.01
3.04


SYPR- 150 A
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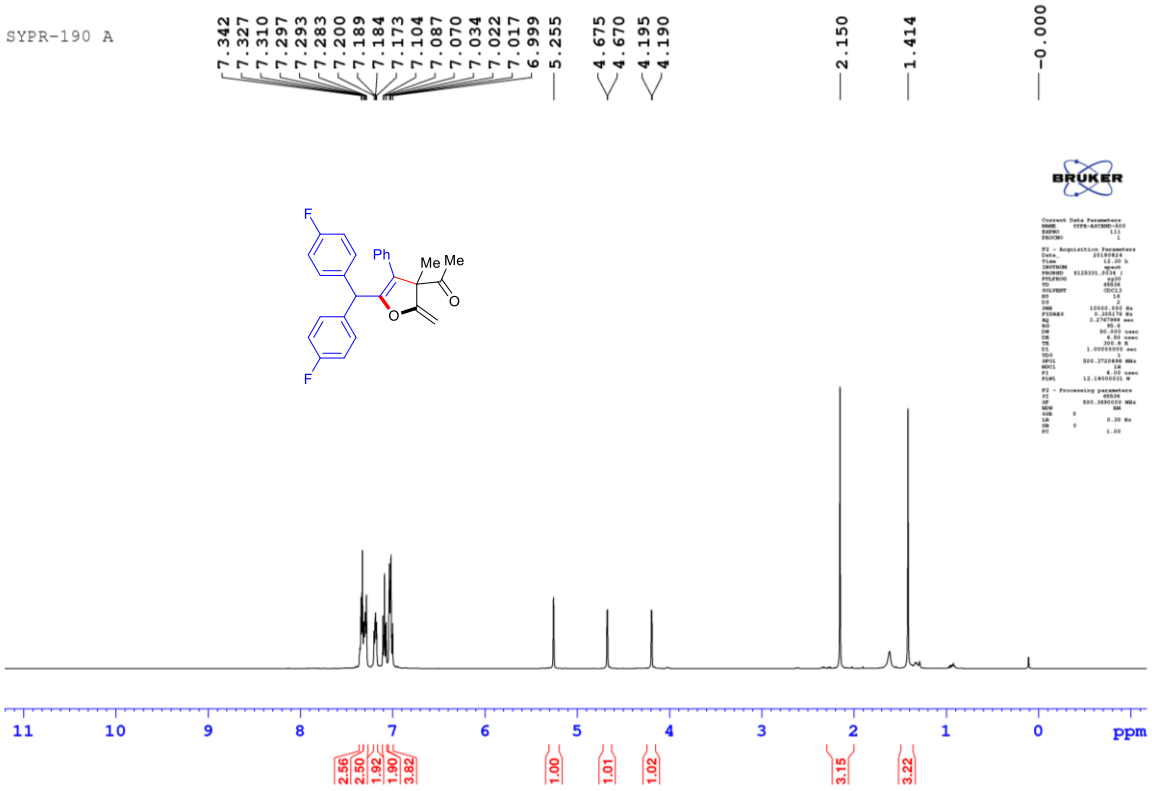
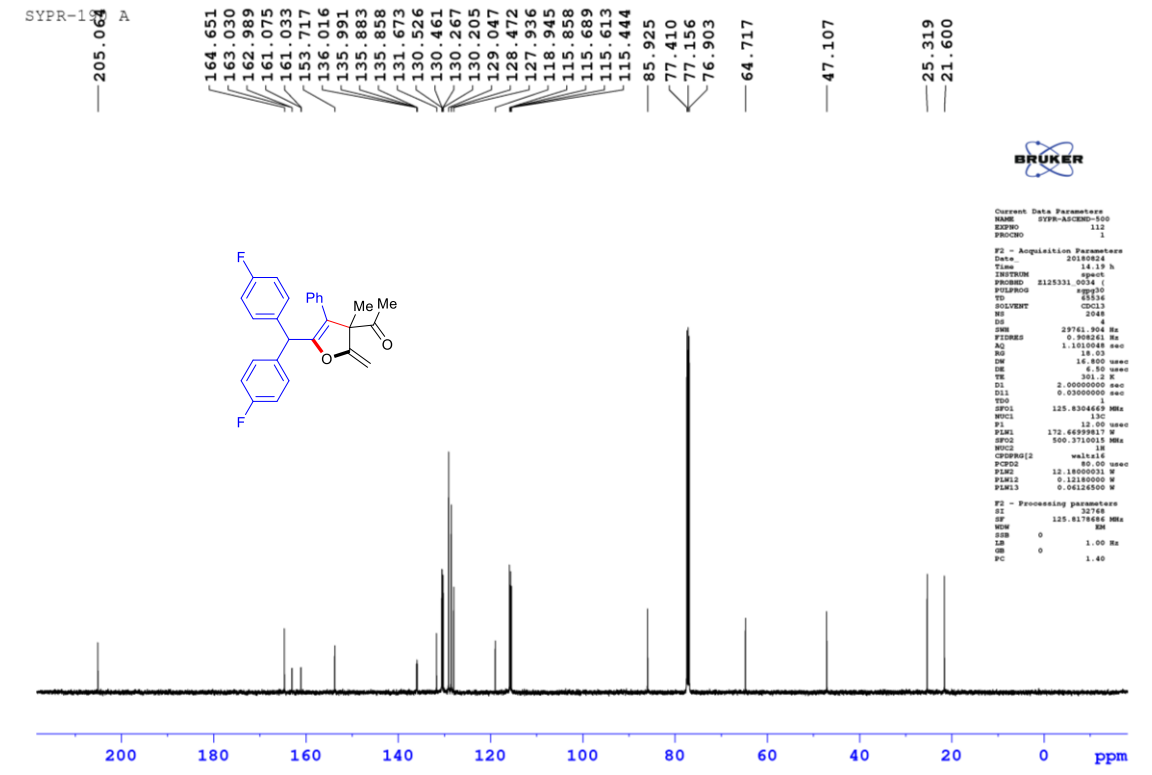
154.596
140.749
132.268
131.969
129.870
128.944
128.520
128.462
127.674
127.025
118.365
114.182
85.635
77.477
77.160
76.842
64.659
55.404
47.725
25.429
21.582
Ph
Me
Me
Ph
O
O
MeO
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


SYPR-190 A
7.342
7.327
7.310
7.297
7.293
7.283
7.200
7.189
7.184
7.173
7.104
7.087
7.070
7.034
7.022
7.017
6.999
5.255
4.675
4.670
4.195
4.190
2.150
1.414
0.000
BRUKER
F
Ph
Me
Me
O
F
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.56
2.50
1.92
1.90
3.82
1.00
1.01
1.02
3.15
3.22


205.063
164.651
163.030
162.989
161.075
161.033
153.717
136.016
135.991
135.883
135.858
131.673
130.526
130.461
130.267
130.205
129.047
128.472
127.936
118.945
115.858
115.689
115.613
115.444
85.925
77.410
77.156
76.903
64.717
47.107
25.319
21.600
BRUKER
F
Ph
Me
Me
O
F
200
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160
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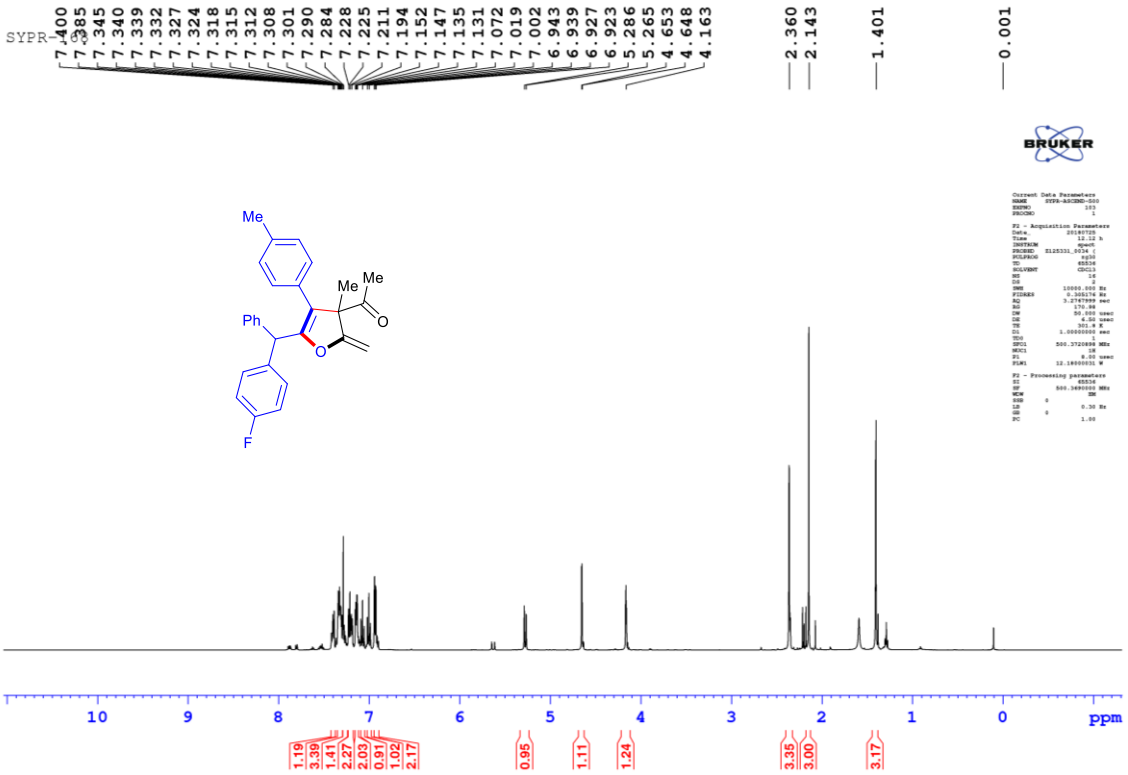
120
100
80
60
40
20
0
ppm


SYPR-ASCEND-500
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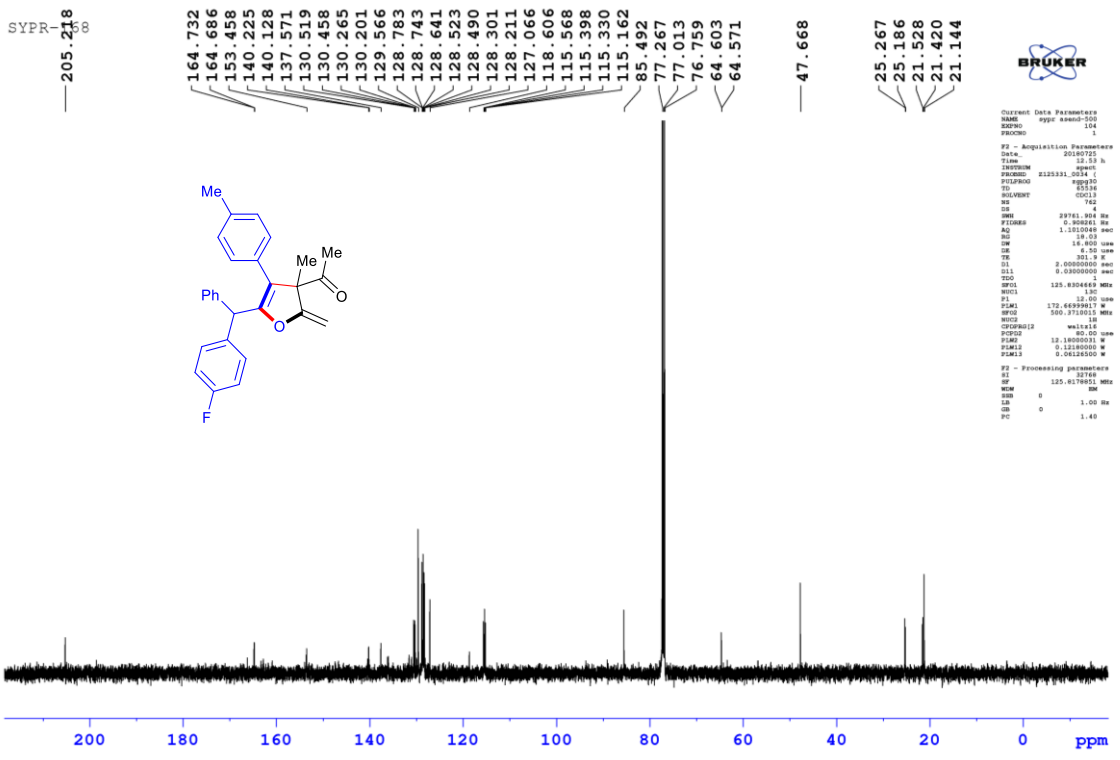
7.385
7.345
7.340
7.339
7.332
7.327
7.324
7.318
7.315
7.312
7.308
7.301
7.290
7.284
7.228
7.225
7.211
7.194
7.152
7.147
7.135
7.131
7.072
7.019
7.002
6.943
6.939
6.927
6.923
5.286
5.265
4.653
4.648
4.163
2.360
2.143
1.401
0.001
BRUKER
Me
Me
Me
Ph
O
O
F
10
9
8
7
6
5
4
3
2
1
0
ppm
1.19
3.39
1.41
2.27
2.03
0.91
1.02
2.17
0.95
1.11
1.24
3.35
3.00
3.17


SYPR-ASCEND-500
205.218
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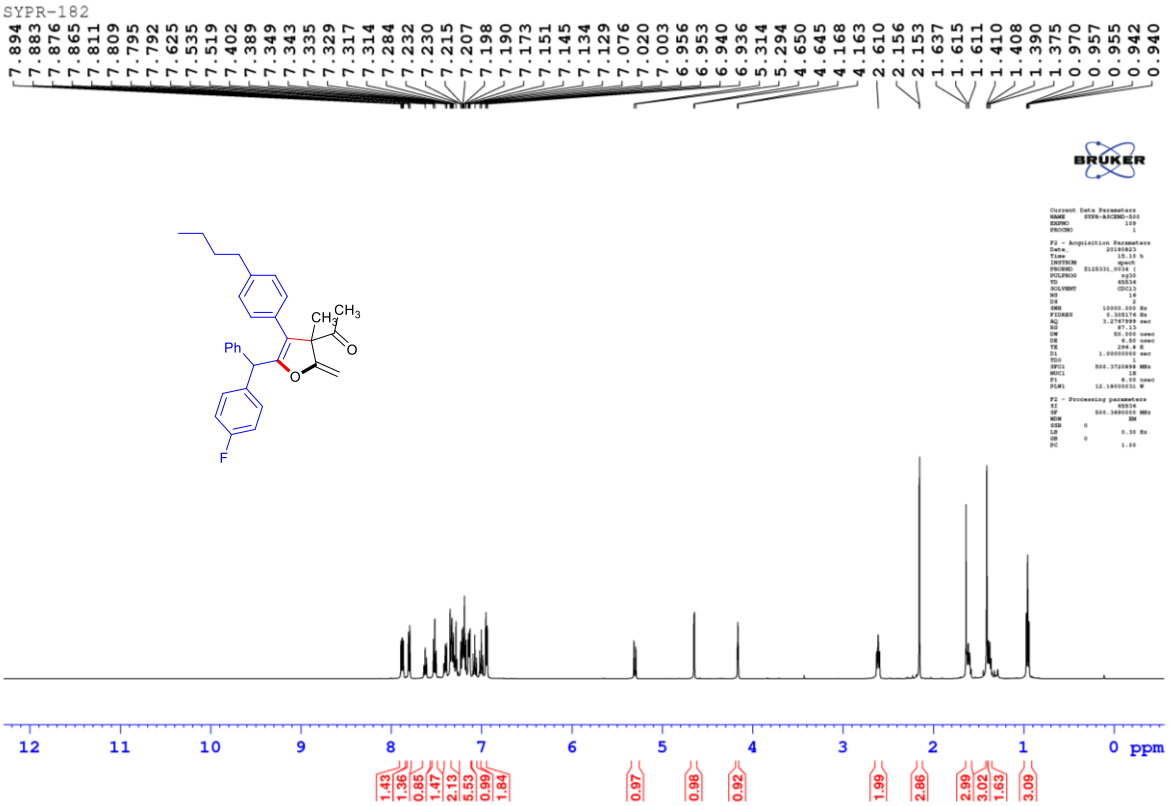
164.686
153.458
140.225
140.128
137.571
130.519
130.458
130.265
130.201
129.566
128.783
128.743
128.641
128.523
128.490
128.301
128.211
127.066
118.606
115.568
115.398
115.330
115.162
85.492
77.267
77.013
76.759
64.603
64.571
47.668
25.267
25.186
21.528
21.420
21.144
BRUKER
Me
Me
Me
Ph
O
O
F
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-182
7.894
7.883
7.876
7.865
7.811
7.809
7.795
7.792
7.625
7.535
7.519
7.402
7.389
7.349
7.343
7.335
7.329
7.317
7.314
7.284
7.232
7.230
7.215
7.207
7.198
7.190
7.173
7.151
7.145
7.134
7.129
7.076
7.020
7.003
6.956
6.953
6.940
6.936
5.314
5.294
4.650
4.645
4.168
4.163
2.610
2.156
2.153
1.637
1.615
1.611
1.410
1.408
1.390
1.375
0.970
0.957
0.955
0.942
0.940
BRUKER
Ph
CH3
CH3
O
O
F
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm
1.43
1.36
0.85
1.47
2.13
5.53
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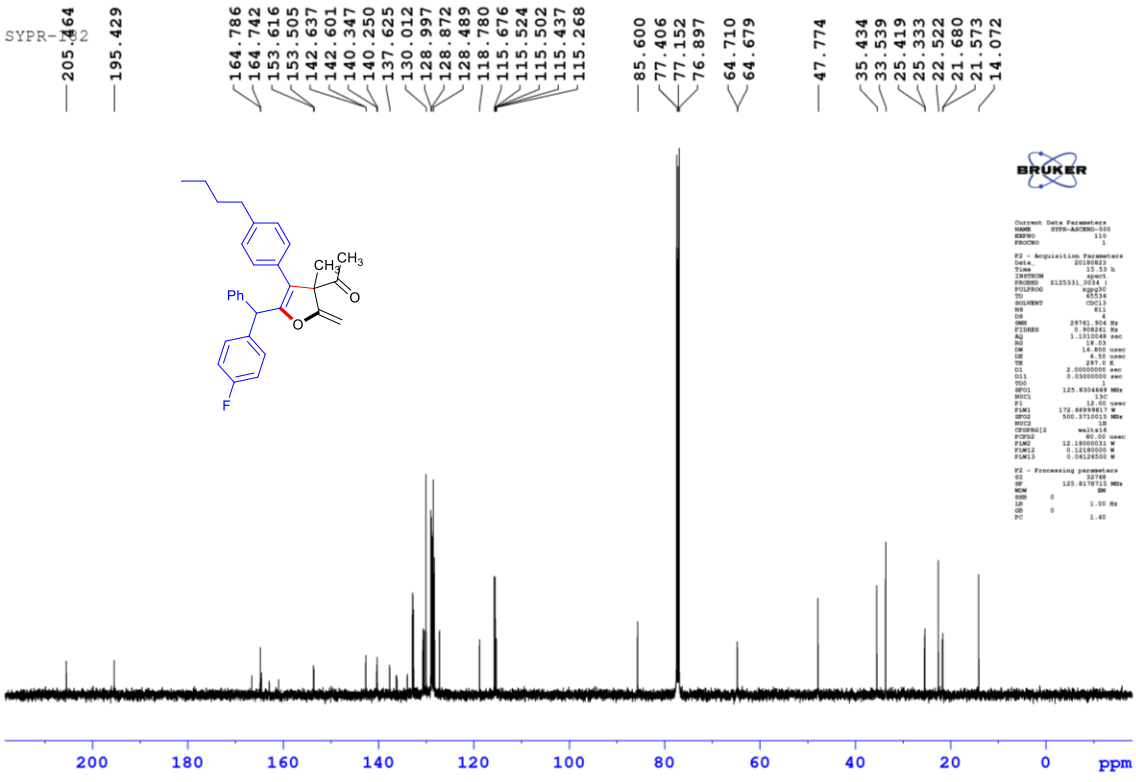
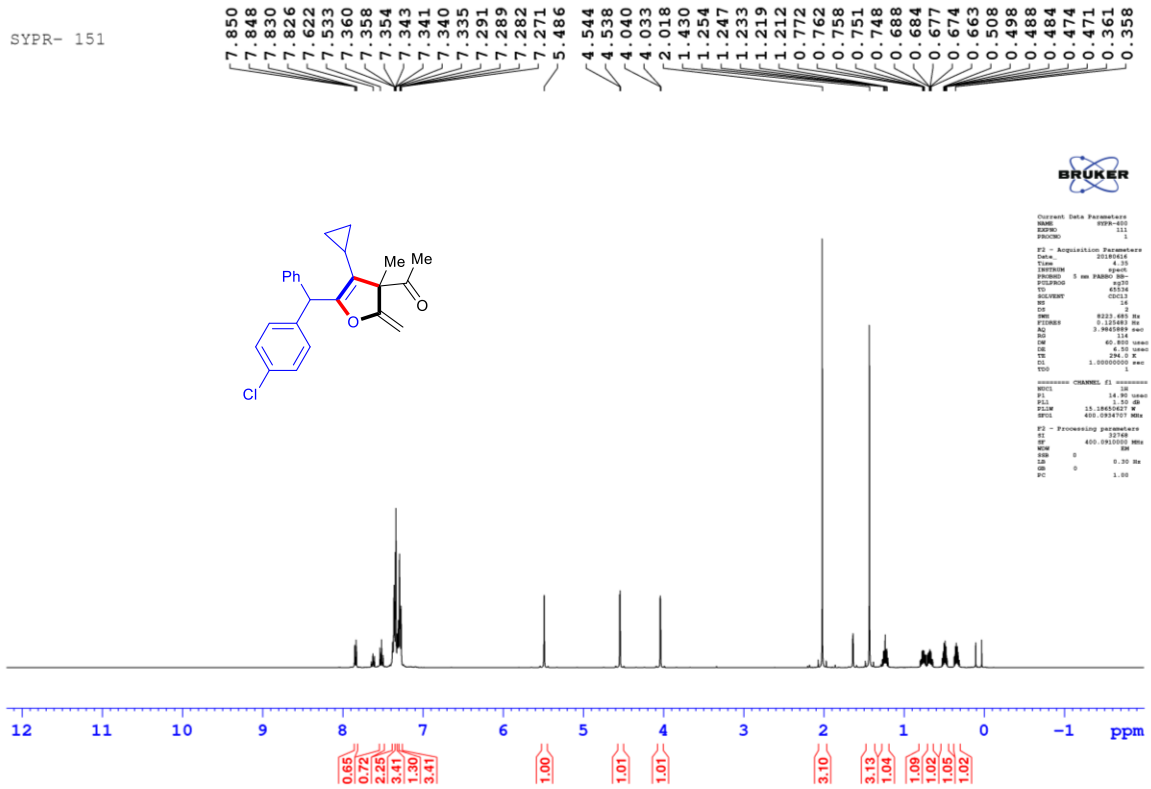
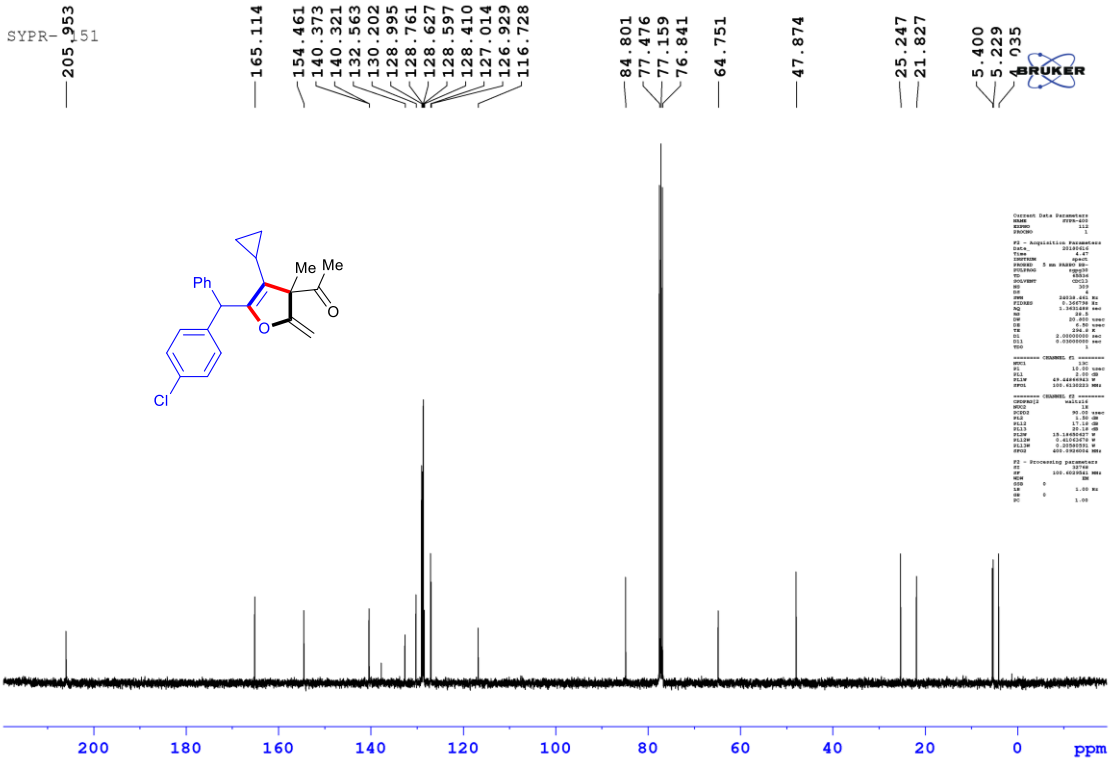
1.84
0.97
0.98
0.92
1.99
2.86
2.99
3.02
1.83
3.09


SYPR-182
205.464
195.429
164.786
164.742
153.616
153.505
142.637
142.601
140.347
140.250
137.625
130.012
128.997
128.872
128.489
118.780
115.676
115.524
115.502
115.437
115.268
85.600
77.406
77.152
76.897
64.710
64.679
47.774
35.434
33.539
25.419
25.333
22.522
21.680
21.573
14.072
BRUKER
Ph
CH3
CH3
O
O
F
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR- 151
7.850
7.848
7.830
7.826
7.622
7.533
7.360
7.358
7.354
7.343
7.341
7.340
7.335
7.291
7.289
7.282
7.271
5.486
4.544
4.538
4.040
4.033
2.018
1.430
1.254
1.247
1.233
1.219
1.212
0.772
0.762
0.758
0.751
0.748
0.688
0.684
0.677
0.674
0.663
0.508
0.498
0.488
0.484
0.474
0.471
0.361
0.358
BRUKER
Ph
Me
Me
O
Cl
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.65
0.72
2.25
3.41
1.30
3.41
1.00
1.01
1.01
3.10
3.13
1.04
1.09
1.02
1.05
1.02


SYPR-151
205.953
165.114
154.461
140.373
140.321
132.563
130.202
128.995
128.761
128.627
128.597
128.410
127.014
126.929
116.728
84.801
77.476
77.159
76.841
64.751
47.874
25.247
21.827
5.400
5.229
035
BRUKER
Ph
Me
Me
O
Cl
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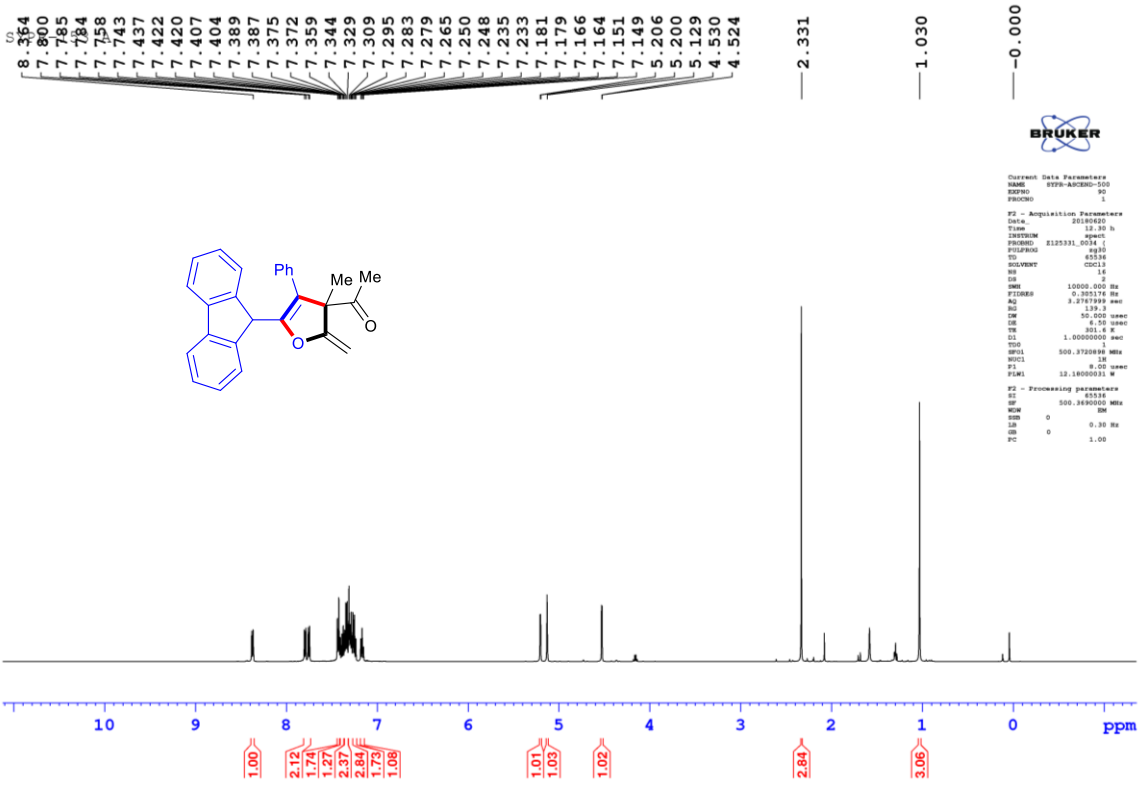
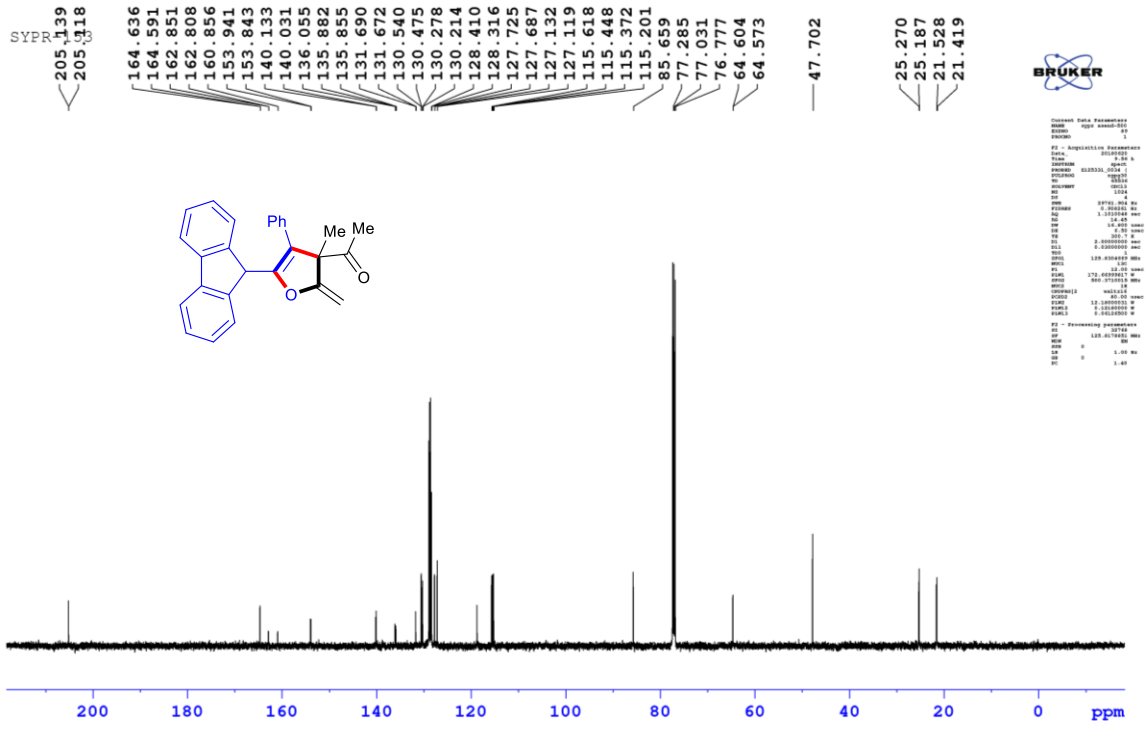
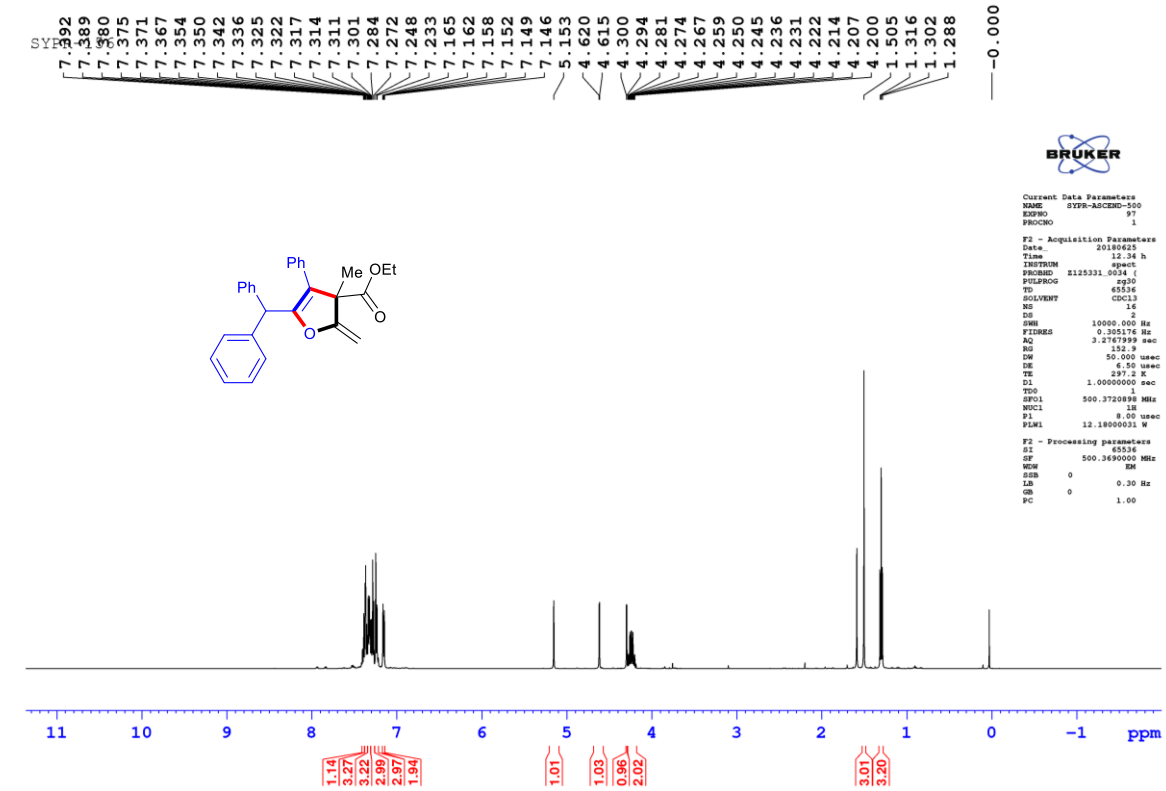
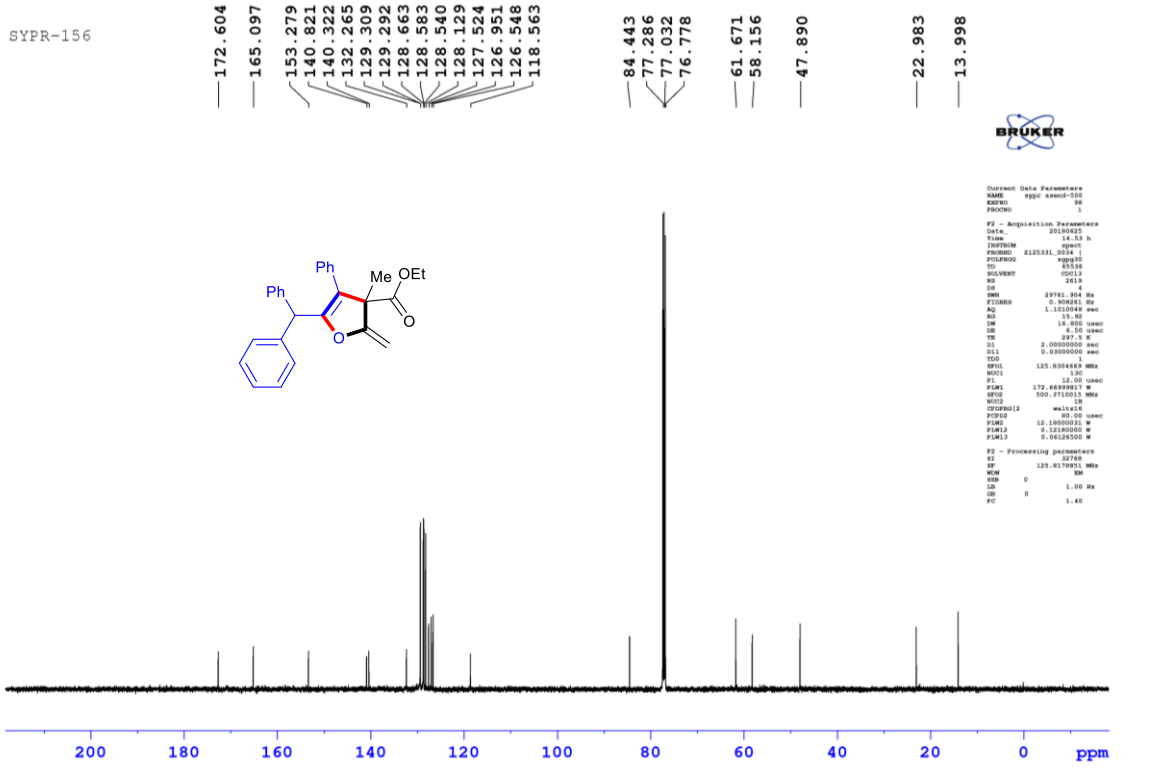
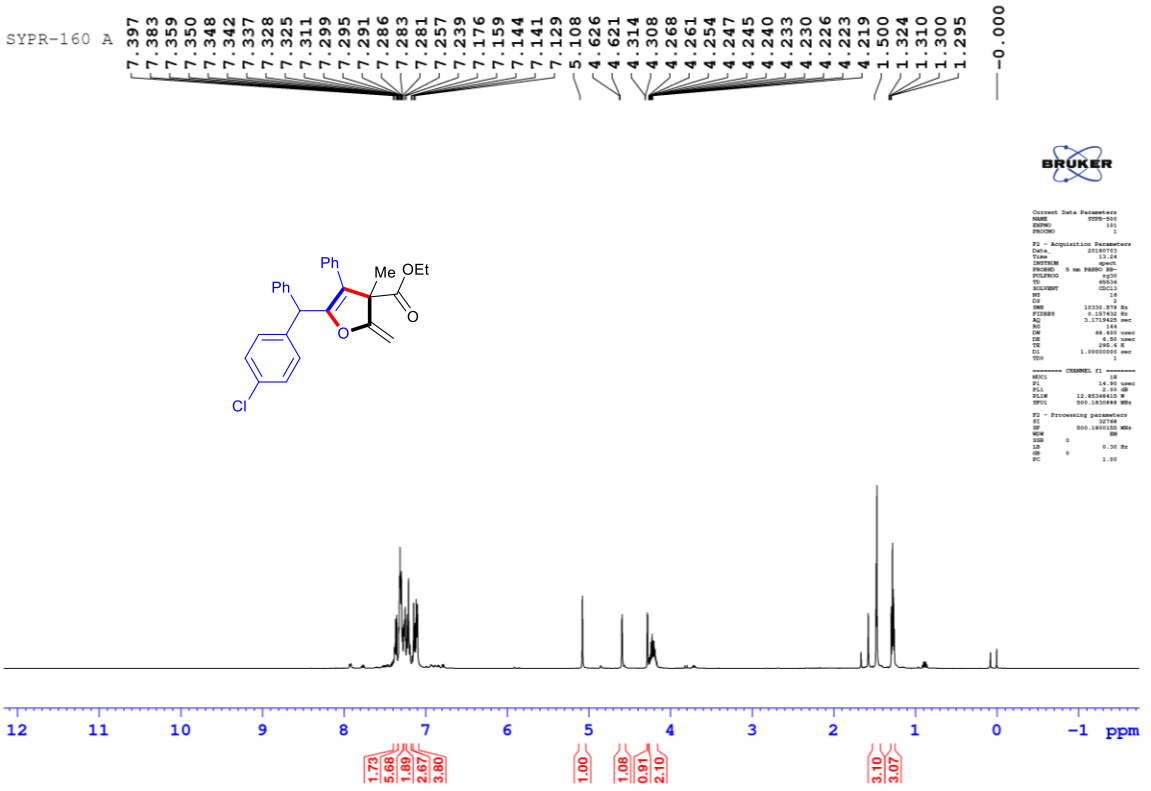
140
120
100
80
60
40
20
0
ppm

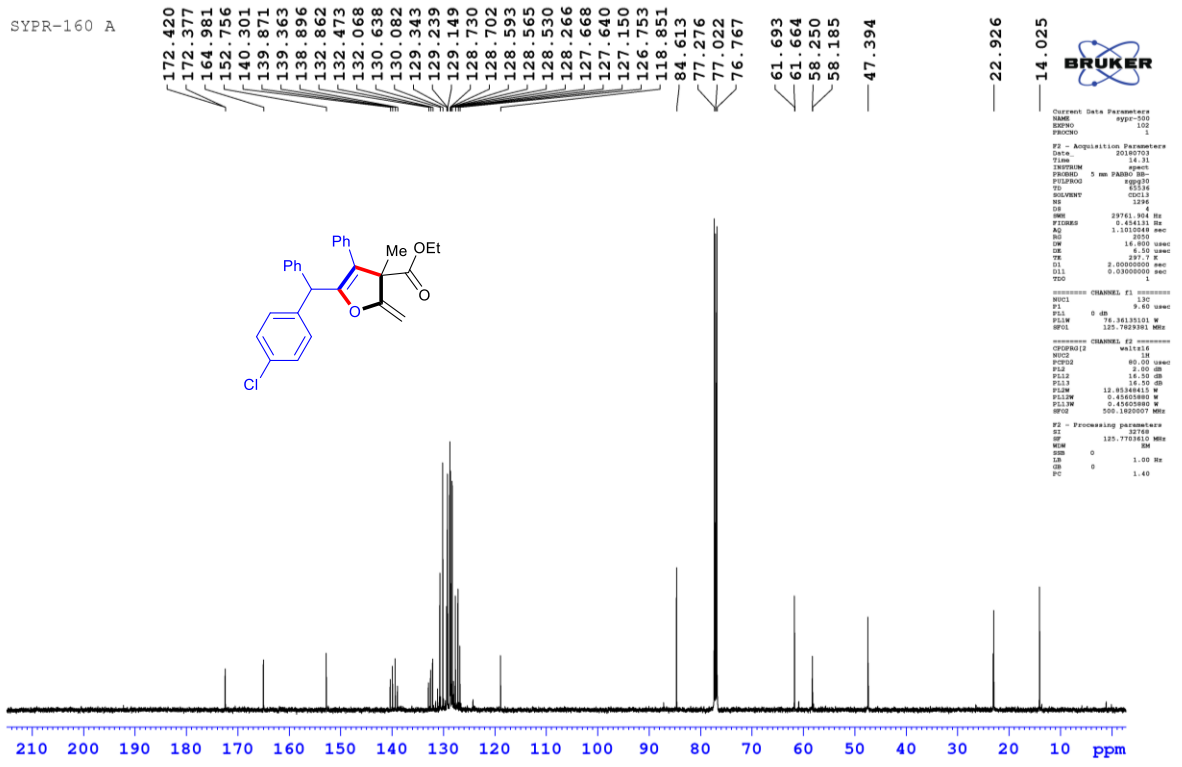

8.364
7.800
7.785
7.784
7.758
7.743
7.437
7.422
7.420
7.407
7.404
7.389
7.387
7.375
7.372
7.359
7.344
7.329
7.309
7.295
7.283
7.279
7.265
7.250
7.248
7.235
7.233
7.181
7.179
7.166
7.164
7.151
7.149
5.206
5.200
5.129
4.530
4.524
2.331
1.030
0.000
Ph
Me
Me
O
O
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
2.12
1.74
1.27
2.37
2.84
1.73
1.08
1.01
1.03
1.02
2.84
3.06

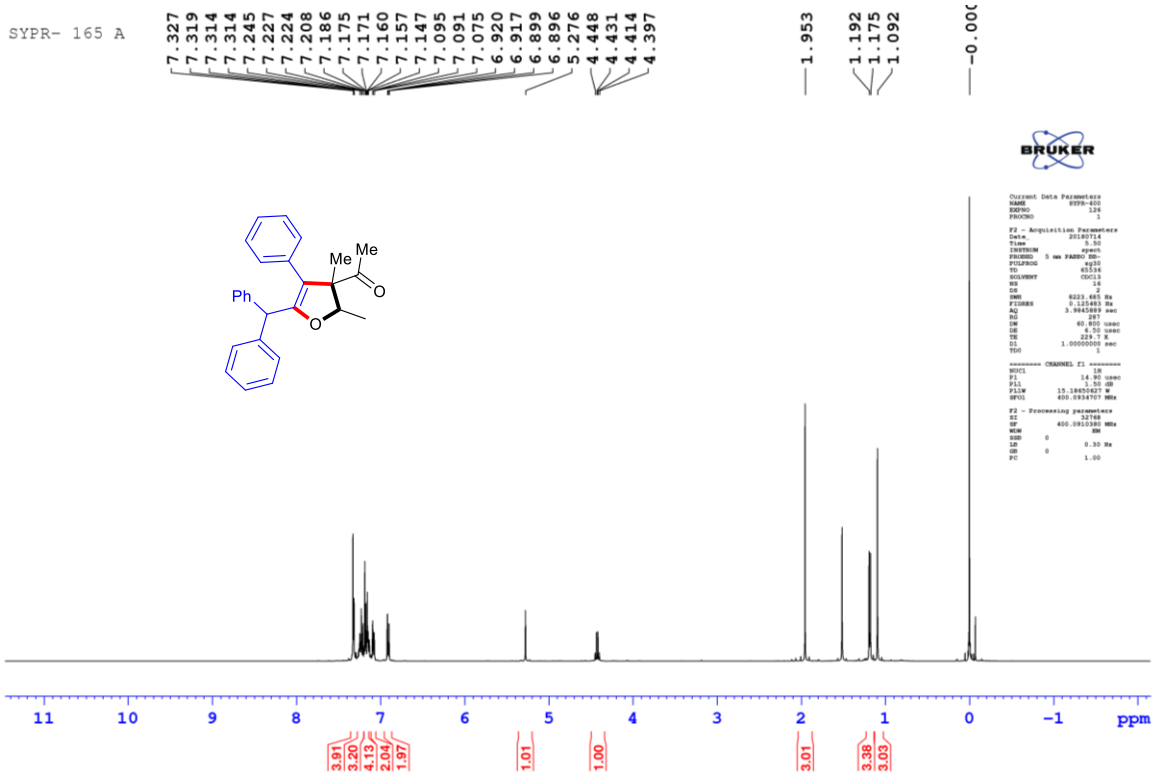

SYPR-4-3
205.139
205.118
164.636
164.591
162.851
162.808
160.856
153.941
153.843
140.133
140.031
136.055
135.882
135.855
131.690
131.672
130.540
130.475
130.278
130.214
128.410
128.316
127.725
127.687
127.132
127.119
115.618
115.448
115.372
115.201
85.659
77.285
77.031
76.777
64.604
64.573
47.702
25.270
25.187
21.528
21.419
Ph
Me
Me
O
O
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-156
7.392
7.389
7.380
7.375
7.371
7.367
7.354
7.350
7.342
7.336
7.325
7.322
7.317
7.314
7.311
7.301
7.284
7.272
7.248
7.233
7.165
7.162
7.158
7.152
7.149
7.146
5.153
4.620
4.615
4.300
4.294
4.281
4.274
4.267
4.259
4.250
4.245
4.236
4.231
4.222
4.214
4.207
4.200
1.505
1.316
1.302
1.288
0.000
Ph
Ph
Me
OEt
O
O
BRUKER
Current Data Parameters
NAME SYPR-ASCEND-500
EXPNO 97
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180625
Time 12.34 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 152.9
DW 50.000 usec
DE 6.50 usec
TE 297.2 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
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.14
3.27
3.22
2.99
2.97
1.94
1.01
1.03
0.96
2.02
3.01
3.20


SYPR-156
172.604
165.097
153.279
140.821
140.322
132.265
129.309
129.292
128.663
128.583
128.540
128.129
127.524
126.951
126.548
118.563
84.443
77.286
77.032
76.778
61.671
58.156
47.890
22.983
13.998
Ph
Ph
Me
OEt
O
O
BRUKER
Current Data Parameters
NAME sypr ascend-500
EXPNO 98
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180625
Time 14.53 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 2619
DS 4
SWH 29761.904 Hz
FIDRES 0.909261 Hz
AQ 1.1010049 sec
RG 15.92
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 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 125.8178851 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-160 A
7.397
7.383
7.359
7.350
7.348
7.342
7.337
7.328
7.325
7.311
7.299
7.295
7.291
7.286
7.283
7.281
7.257
7.239
7.176
7.159
7.144
7.141
7.129
5.108
4.626
4.621
4.314
4.308
4.268
4.261
4.254
4.247
4.245
4.240
4.233
4.230
4.226
4.223
4.219
1.500
1.324
1.310
1.300
1.295
0.000
Ph
Ph
Me
OEt
O
O
Cl
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.73
5.68
1.89
2.67
3.80
1.00
1.08
0.91
2.10
3.10
3.07


SYPR-160 A
172.420
172.377
164.981
152.756
140.301
139.871
139.363
138.896
132.862
132.473
132.068
130.638
130.082
129.343
129.239
129.149
128.730
128.702
128.593
128.565
128.530
128.266
127.668
127.640
127.150
126.753
118.851
84.613
77.276
77.022
76.767
61.693
61.664
58.250
58.185
47.394
22.926
14.025
Ph
Ph
Me
OEt
O
O
Cl
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


SYPR- 165 A
7.327
7.319
7.314
7.314
7.245
7.227
7.224
7.208
7.186
7.175
7.171
7.160
7.157
7.147
7.095
7.091
7.075
6.920
6.917
6.899
6.896
5.276
4.448
4.431
4.414
4.397
1.953
1.192
1.175
1.092
-0.000
Me
Me
Ph
O
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
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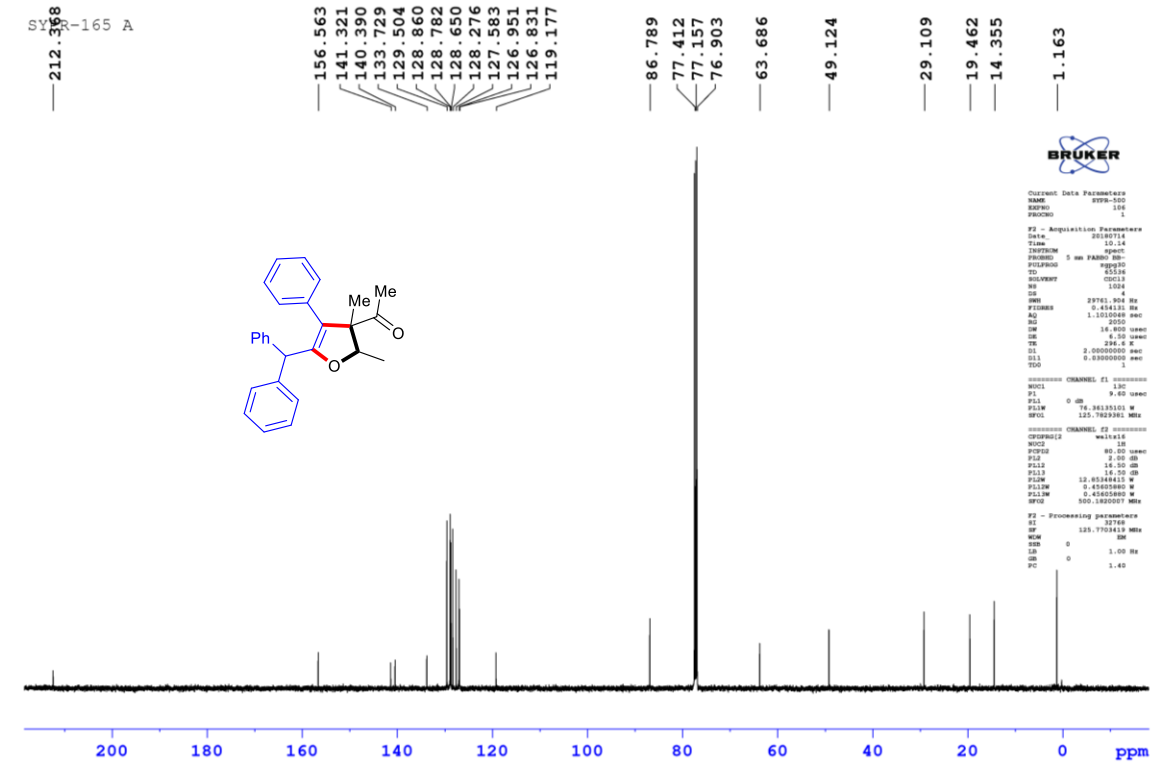
3.20
4.13
2.04
1.97
1.01
1.00
3.01
3.38
3.03


SYPR-165 A
212.368
156.563
141.321
140.390
133.729
129.504
128.860
128.782
128.650
128.276
127.583
126.951
126.831
119.177
86.789
77.412
77.157
76.903
63.686
49.124
29.109
19.462
14.355
1.163
Me
Me
Ph
O
200
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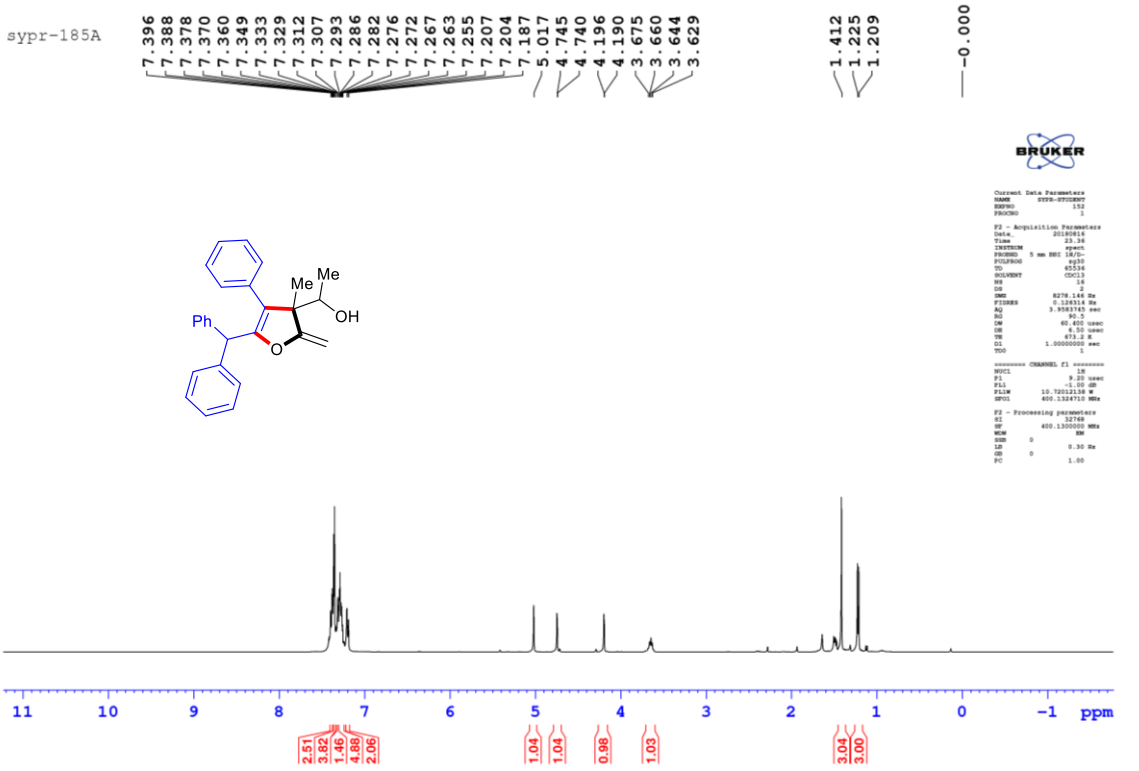
120
100
80
60
40
20
0
ppm


sypr-185A
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7.388
7.378
7.370
7.360
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7.333
7.329
7.312
7.307
7.293
7.286
7.282
7.276
7.272
7.267
7.263
7.255
7.207
7.204
7.187
5.017
4.745
4.740
4.196
4.190
3.675
3.660
3.644
3.629
1.412
1.225
1.209
0.000
Me
Me
OH
Ph
O
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
2.51
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1.46
4.88
2.06
1.04
1.04
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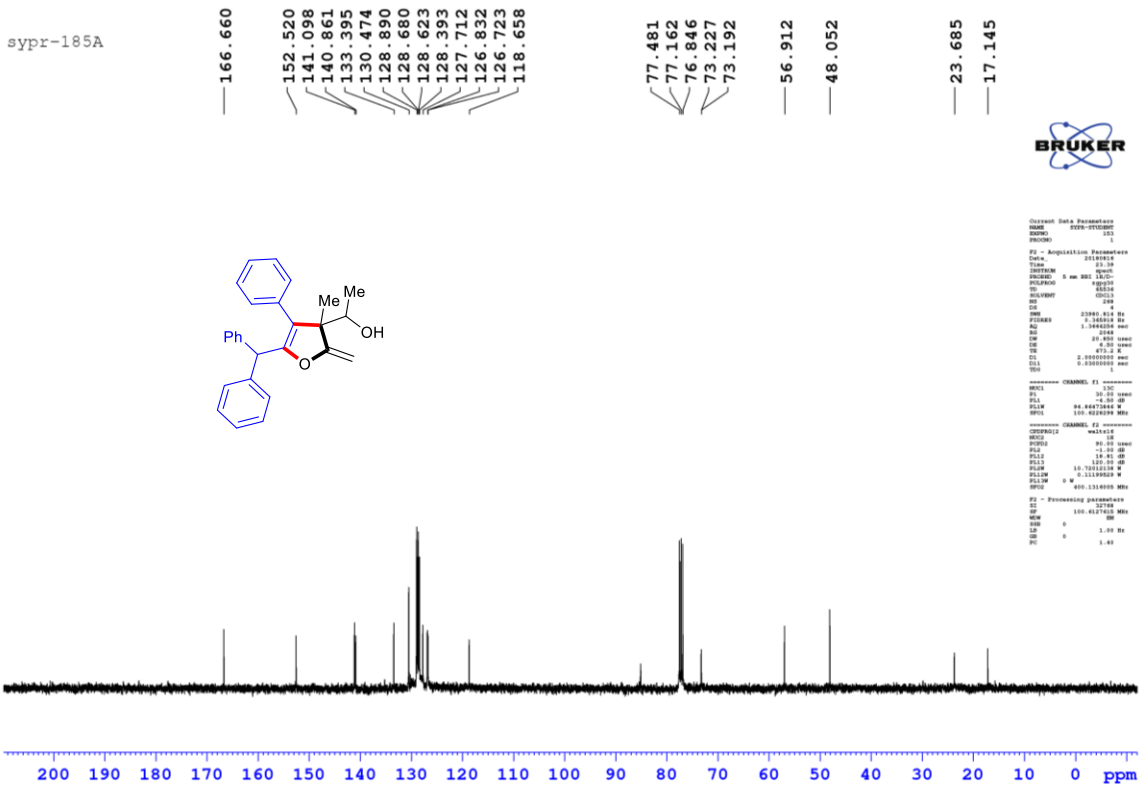
1.03
3.04
3.00


sypr-185A
166.660
152.520
141.098
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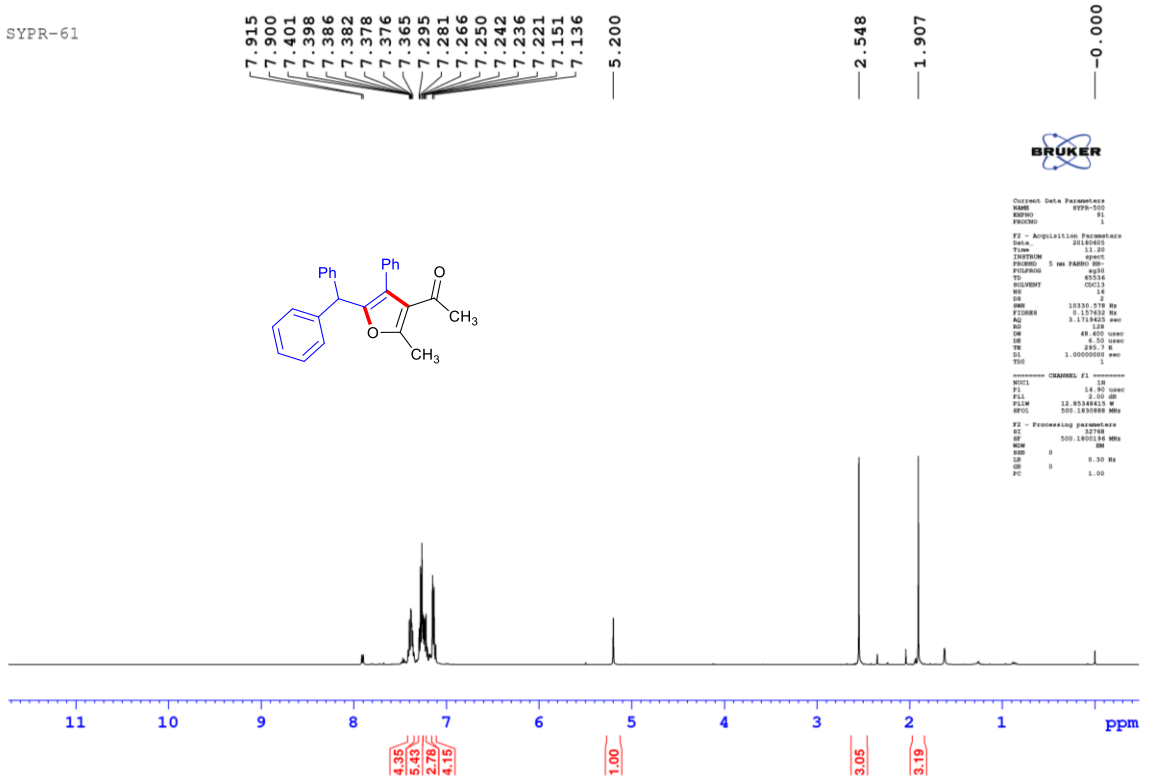
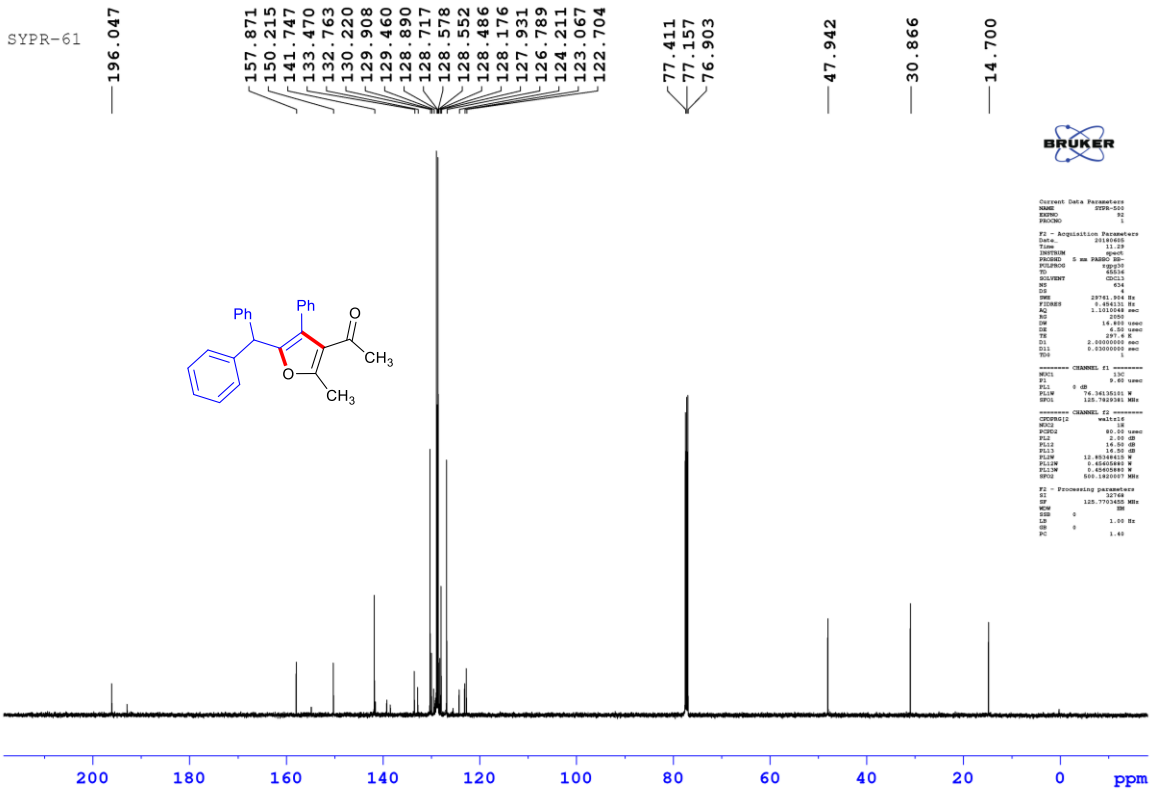
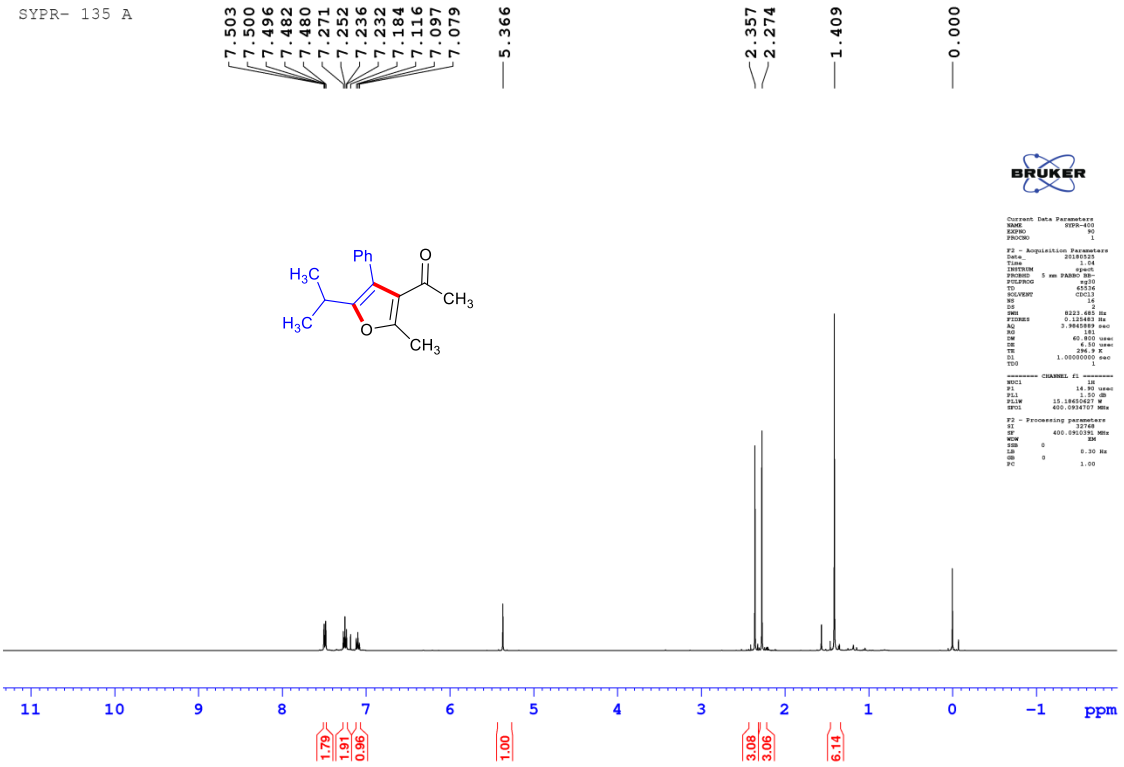
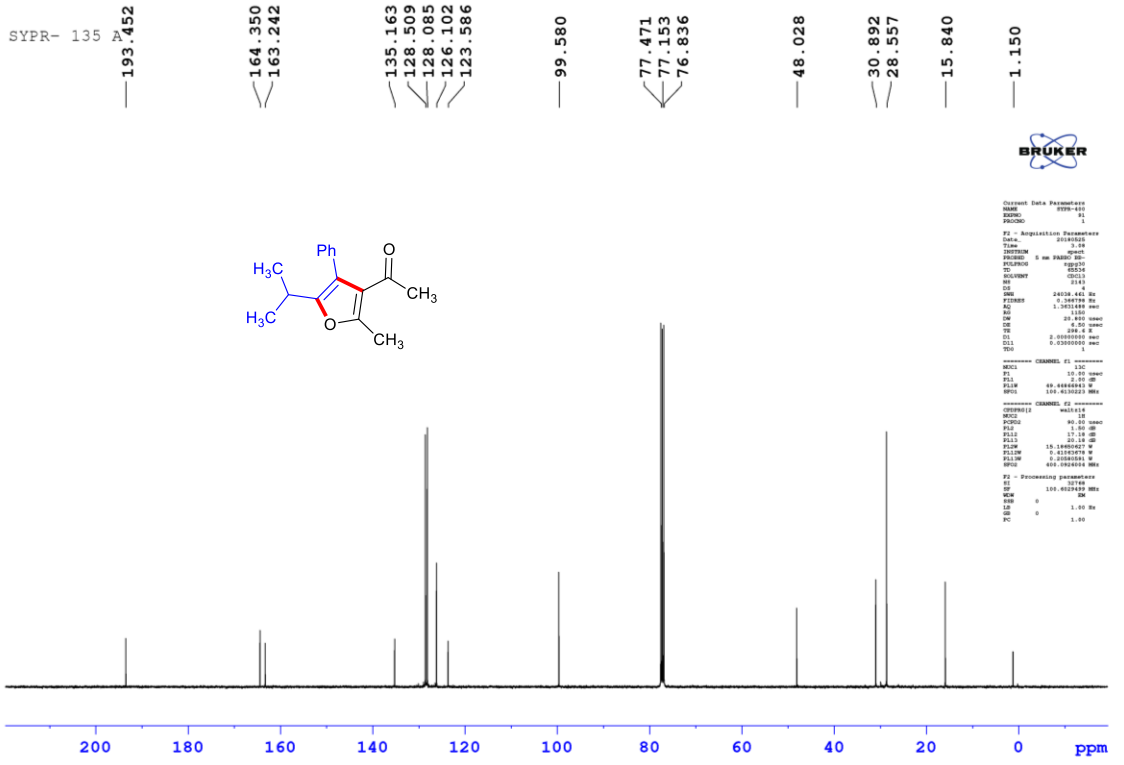
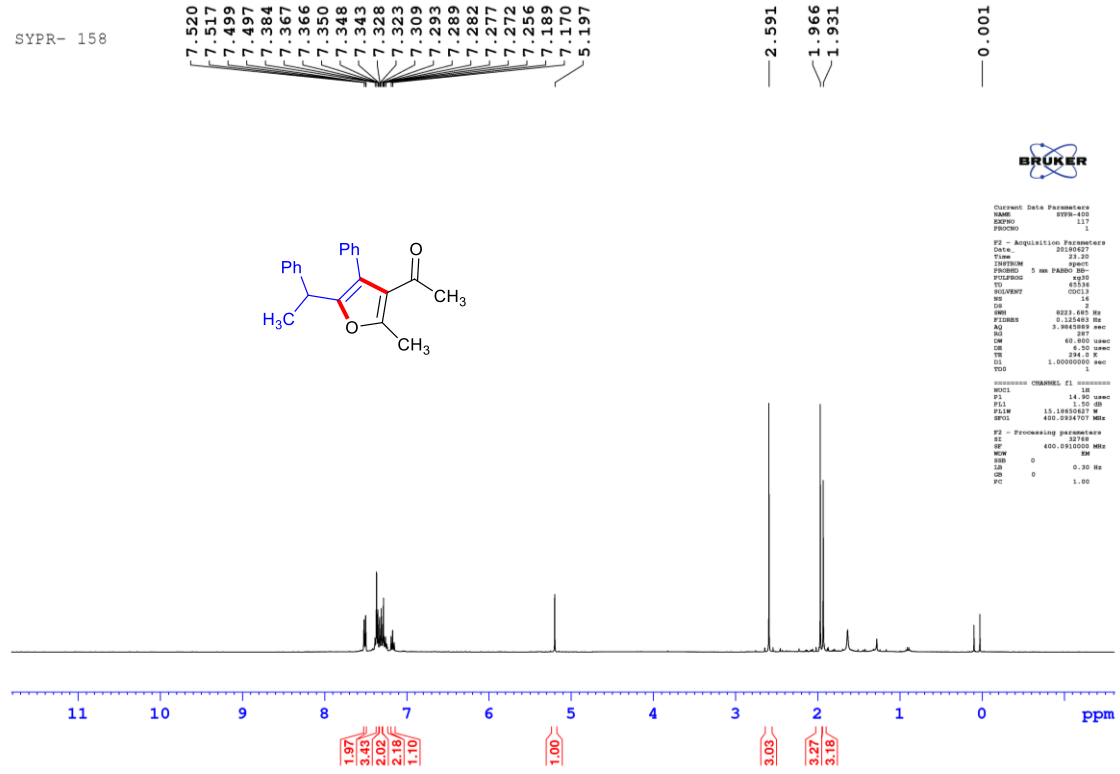
133.395
130.474
128.890
128.680
128.623
128.393
127.712
126.832
126.723
118.658
77.481
77.162
76.846
73.227
73.192
56.912
48.052
23.685
17.145
Me
Me
OH
Ph
O
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

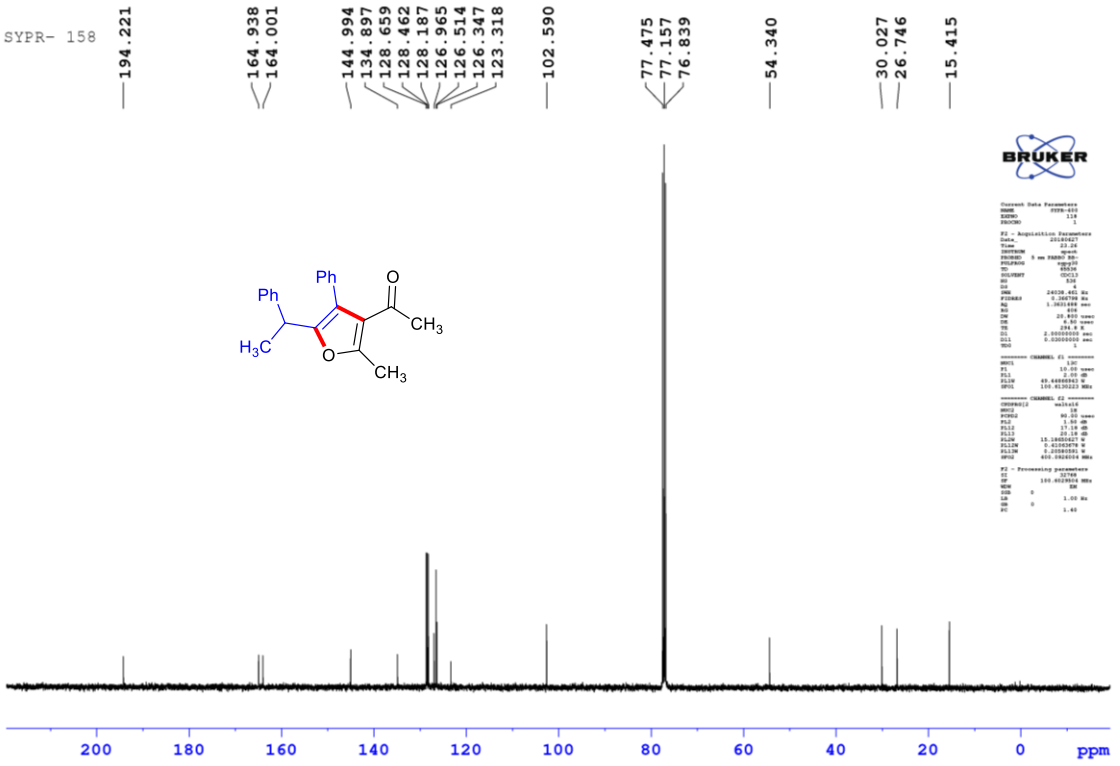

SYPR-61
7.915
7.900
7.401
7.398
7.386
7.382
7.378
7.376
7.365
7.295
7.281
7.266
7.250
7.242
7.236
7.221
7.151
7.136
5.200
2.548
1.907
0.000
BRUKER
Ph
Ph
O
CH3
O
CH3
11
10
9
8
7
6
5
4
3
2
1
ppm
4.35
5.43
2.78
4.15
1.00
3.05
3.19

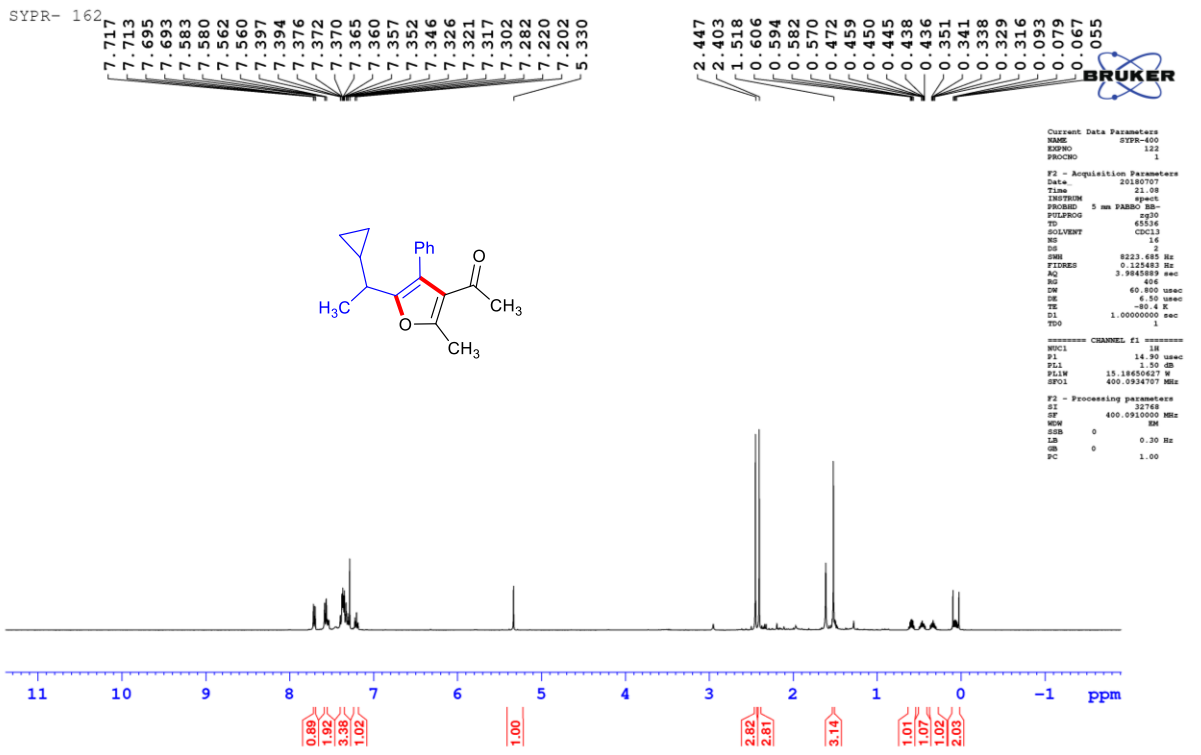

SYPR-61
196.047
157.871
150.215
141.747
133.470
132.763
130.220
129.908
129.460
128.890
128.717
128.578
128.552
128.486
128.176
127.931
126.789
124.211
123.067
122.704
77.411
77.157
76.903
47.942
30.866
14.700
BRUKER
Ph
Ph
O
CH3
O
CH3
200
180
160
140
120
100
80
60
40
20
0
ppm

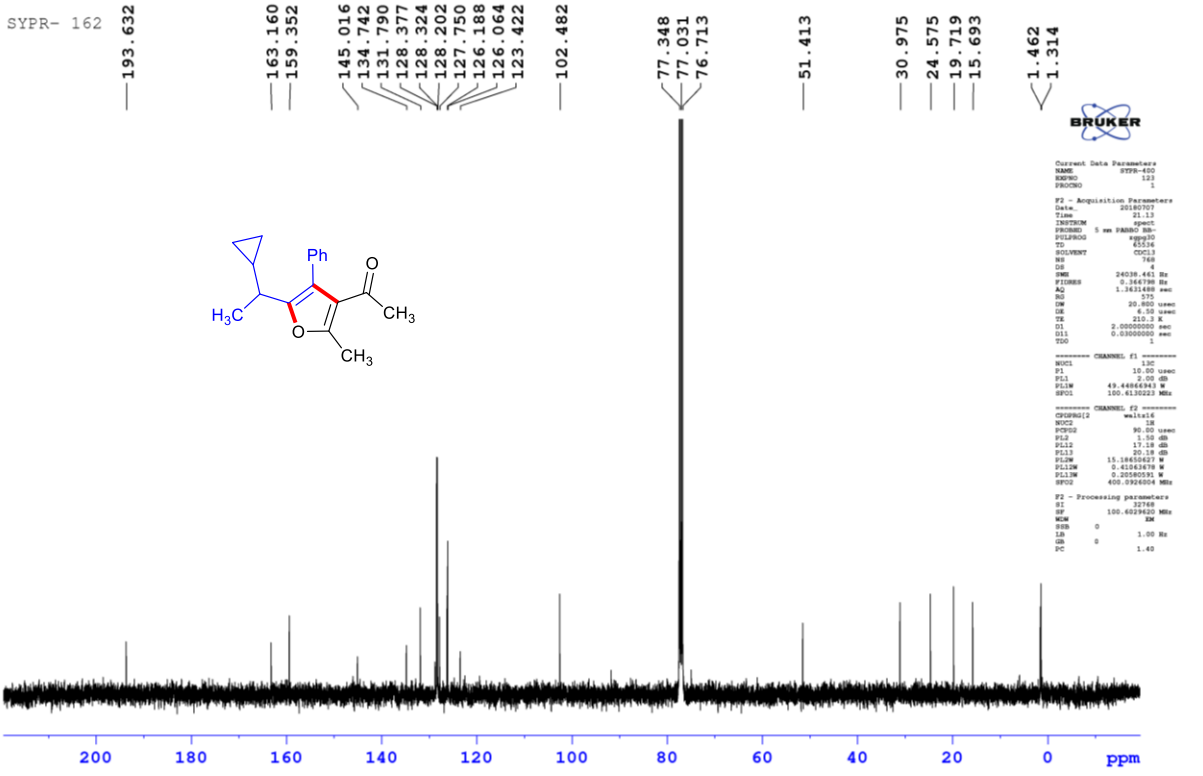

SYPR- 135 A
7.503
7.500
7.496
7.482
7.480
7.271
7.252
7.236
7.232
7.184
7.116
7.097
7.079
5.366
2.357
2.274
1.409
0.000
Ph
O
H3C
H3C
CH3
O
CH3
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.79
1.91
0.96
1.00
3.08
3.06
6.14

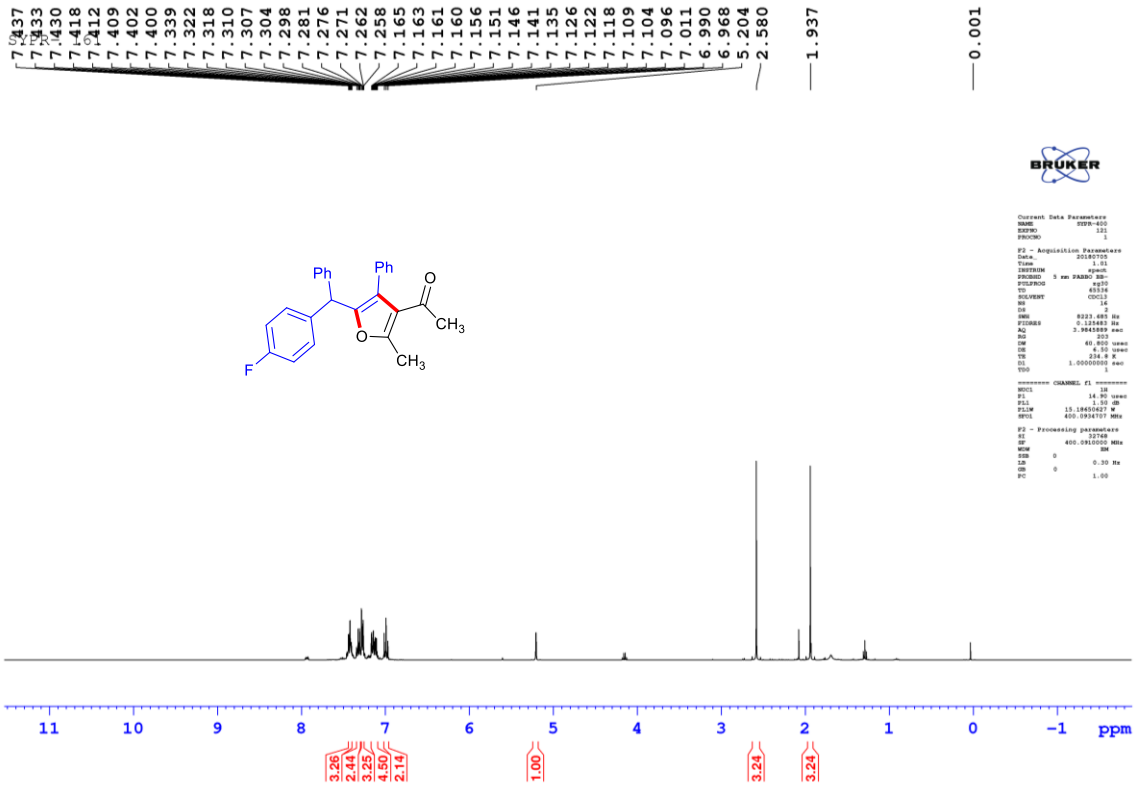

SYPR- 135 A
193.452
164.350
163.242
135.163
128.509
128.085
126.102
123.586
99.580
77.471
77.153
76.836
48.028
30.892
28.557
15.840
1.150
Ph
O
H3C
H3C
CH3
O
CH3
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

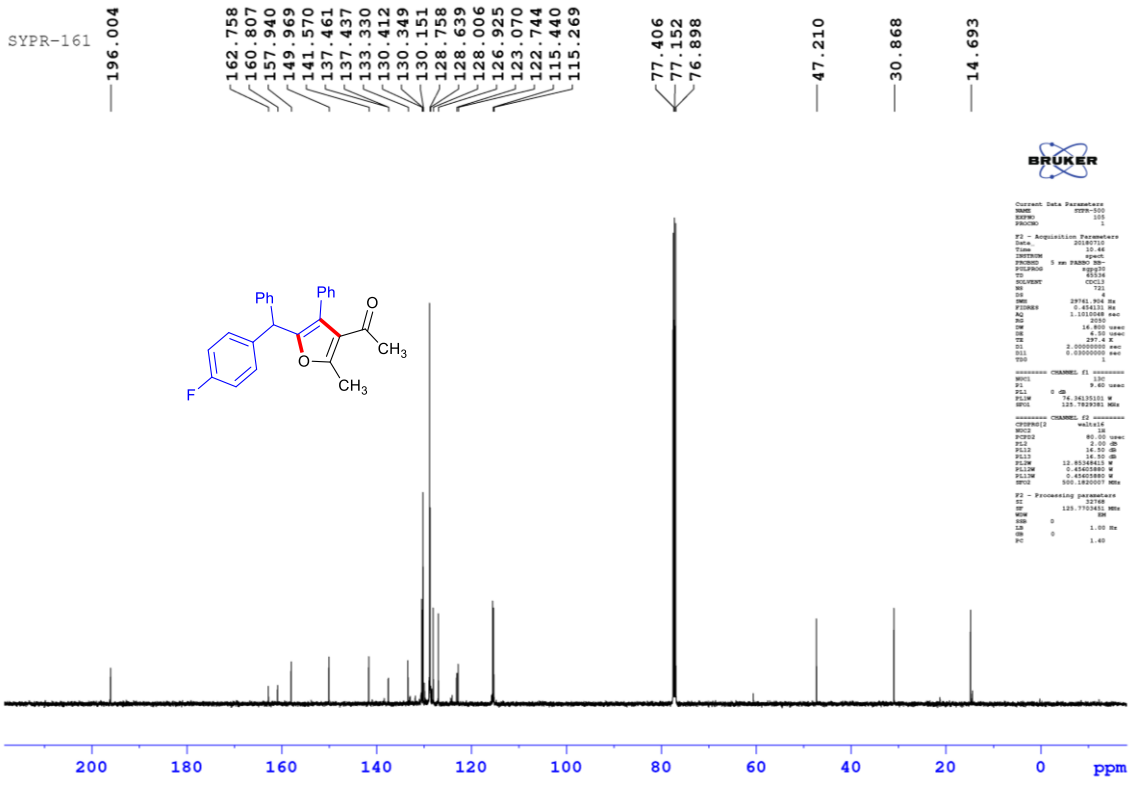

SYPR- 158
7.520
7.517
7.499
7.497
7.384
7.367
7.366
7.350
7.348
7.343
7.328
7.323
7.309
7.293
7.289
7.282
7.277
7.272
7.256
7.189
7.170
5.197
2.591
1.966
1.931
0.001
Ph
O
Ph
CH3
H3C
O
CH3
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.97
3.43
2.02
2.18
1.10
1.00
3.03
3.27
3.18

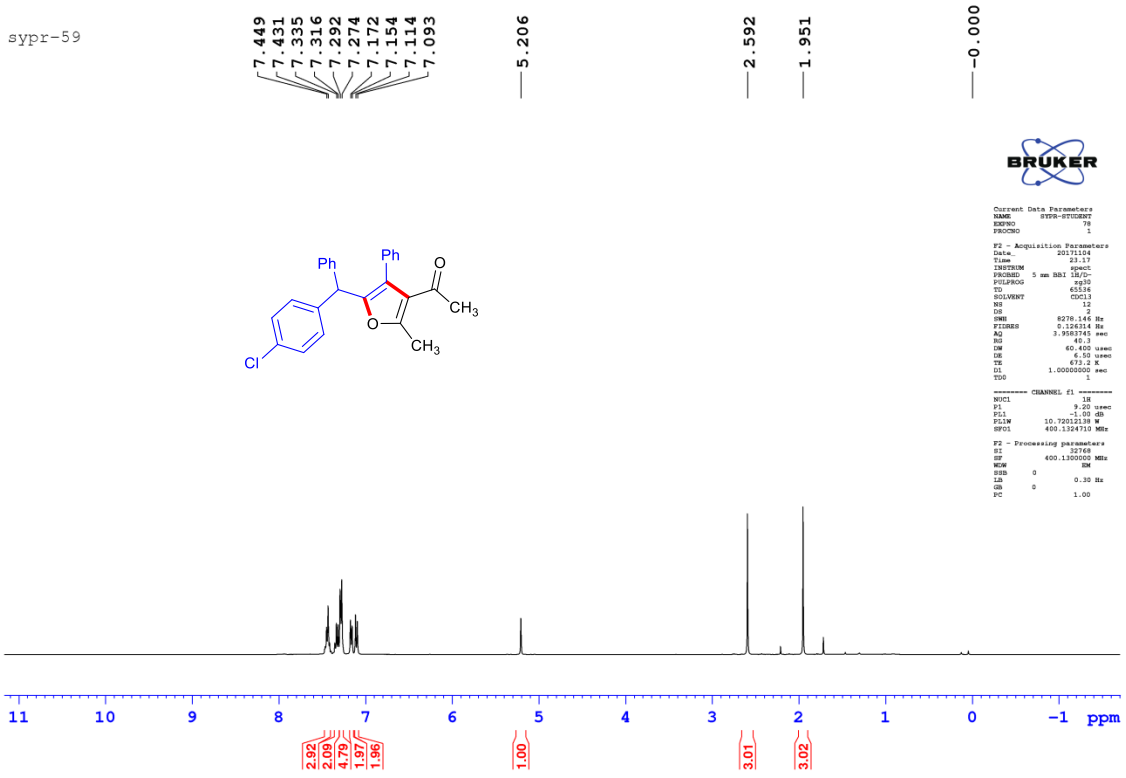

SYPR- 158
194.221
164.938
164.001
144.994
134.897
128.659
128.462
128.187
126.965
126.514
126.347
123.318
102.590
77.475
77.157
76.839
54.340
30.027
26.746
15.415
Ph
O
Ph
CH3
H3C
O
CH3
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

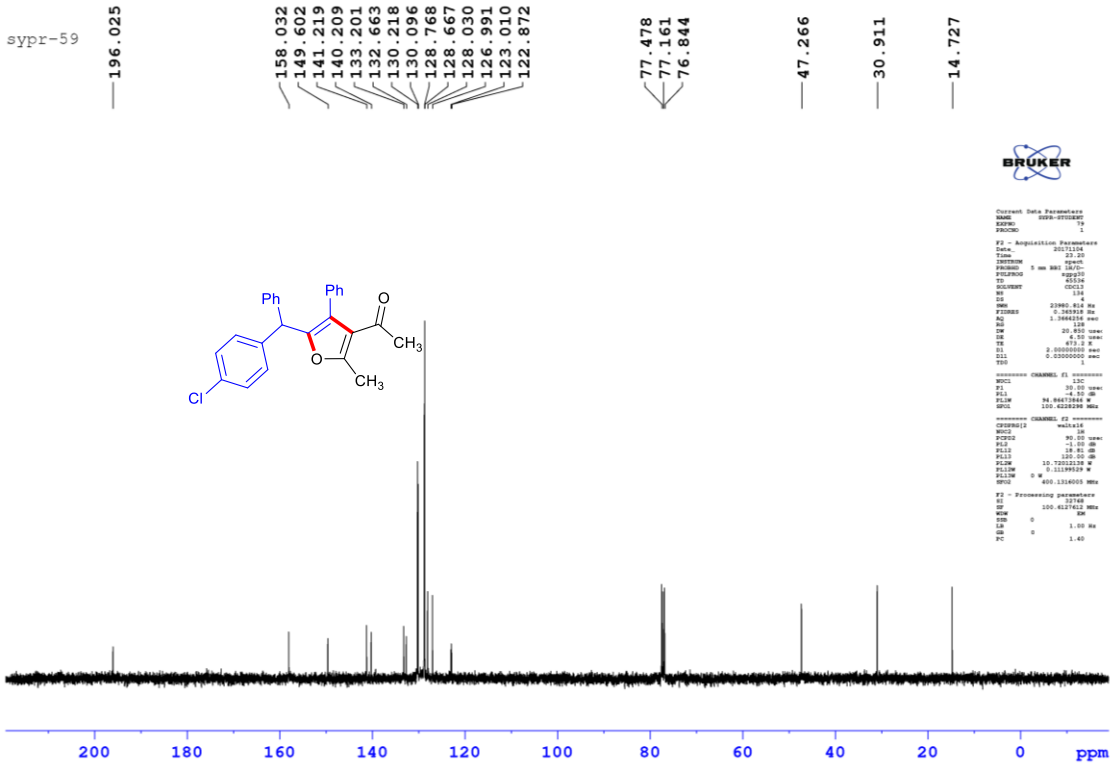

SYPR- 162
7.717
7.713
7.695
7.693
7.583
7.580
7.562
7.560
7.397
7.394
7.376
7.372
7.370
7.365
7.360
7.357
7.352
7.346
7.326
7.321
7.317
7.302
7.282
7.220
7.202
5.330
2.447
2.403
1.518
0.606
0.594
0.582
0.570
0.472
0.459
0.450
0.445
0.438
0.436
0.351
0.341
0.338
0.329
0.316
0.093
0.079
0.067
0.055
BRUKER
Ph
O
CH3
H3C
O
CH3
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
0.89
1.92
3.38
1.02
1.00
2.82
2.81
3.14
1.01
1.07
1.02
2.03

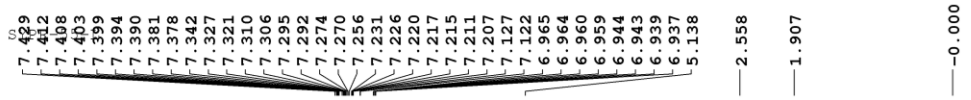

SYPR- 162
193.632
163.160
159.352
145.016
134.742
131.790
128.377
128.324
128.202
127.750
126.188
126.064
123.422
102.482
77.348
77.031
76.713
51.413
30.975
24.575
19.719
15.693
1.462
1.314
BRUKER
Ph
O
CH3
H3C
O
CH3
200
180
160
140
120
100
80
60
40
20
0
ppm

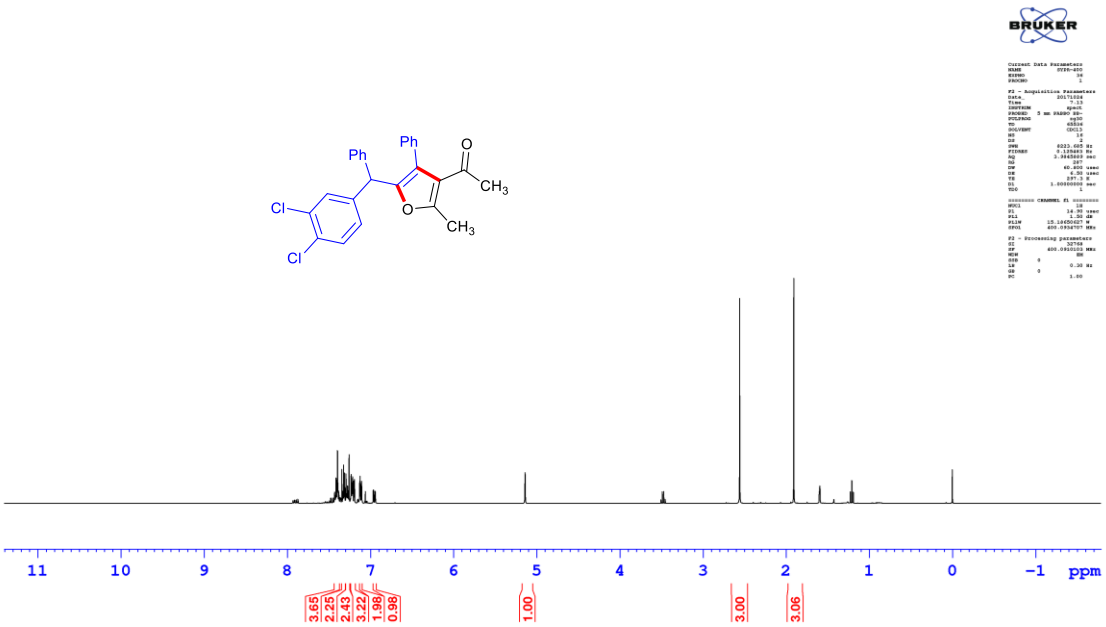

7.437
7.433
7.430
7.418
7.412
7.409
7.402
7.400
7.339
7.322
7.318
7.310
7.307
7.304
7.298
7.281
7.276
7.271
7.262
7.258
7.165
7.163
7.161
7.160
7.156
7.151
7.146
7.141
7.135
7.126
7.122
7.118
7.109
7.104
7.096
7.011
6.990
6.968
5.204
2.580
1.937
0.001
BRUKER
Ph
Ph
O
CH3
CH3
F
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
3.26
2.44
3.25
4.50
2.14
1.00
3.24
3.24

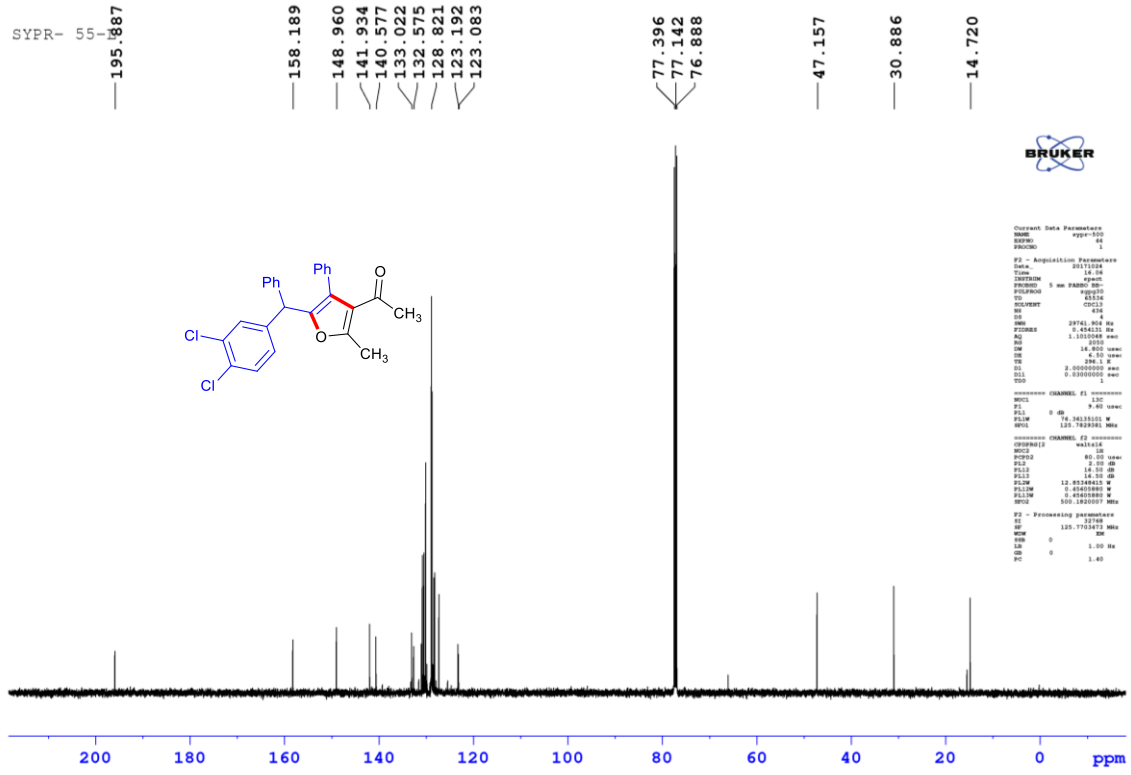

SYPR-161
196.004
162.758
160.807
157.940
149.969
141.570
137.461
137.437
133.330
130.412
130.349
130.151
128.758
128.639
128.006
126.925
123.070
122.744
115.440
115.269
77.406
77.152
76.898
47.210
30.868
14.693
BRUKER
Ph
Ph
O
CH3
CH3
F
200
180
160
140
120
100
80
60
40
20
0
ppm

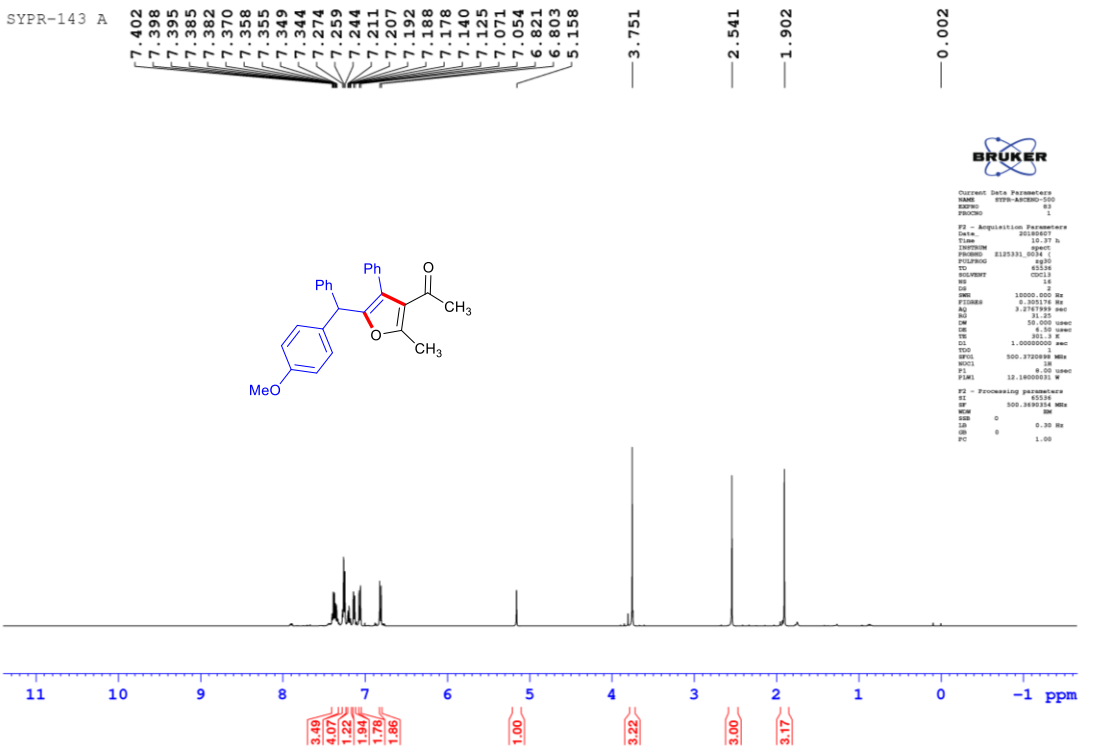

sypr-59
7.449
7.431
7.335
7.316
7.292
7.274
7.172
7.154
7.114
7.093
5.206
2.592
1.951
-0.000
Ph
Ph
O
CH3
O
CH3
Cl
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
2.92
2.09
4.79
1.97
1.96
1.00
3.01
3.02

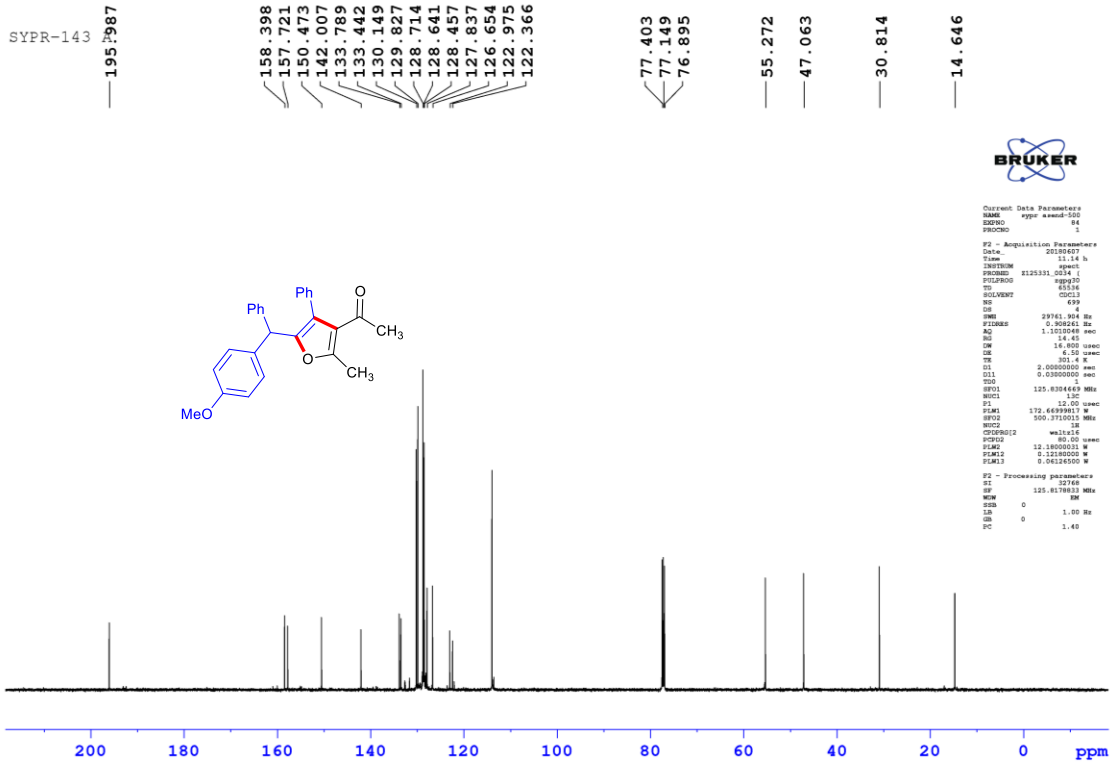

sypr-59
196.025
158.032
149.602
141.219
140.209
133.201
132.663
130.218
130.096
128.768
128.667
128.030
126.991
123.010
122.872
77.478
77.161
76.844
47.266
30.911
14.727
Ph
Ph
O
CH3
O
CH3
Cl
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


7.429
7.412
7.408
7.403
7.399
7.394
7.390
7.381
7.378
7.342
7.327
7.321
7.310
7.306
7.295
7.292
7.274
7.270
7.256
7.231
7.226
7.220
7.217
7.215
7.211
7.207
7.127
7.122
6.965
6.964
6.960
6.959
6.944
6.943
6.939
6.937
5.138
2.558
1.907
0.000

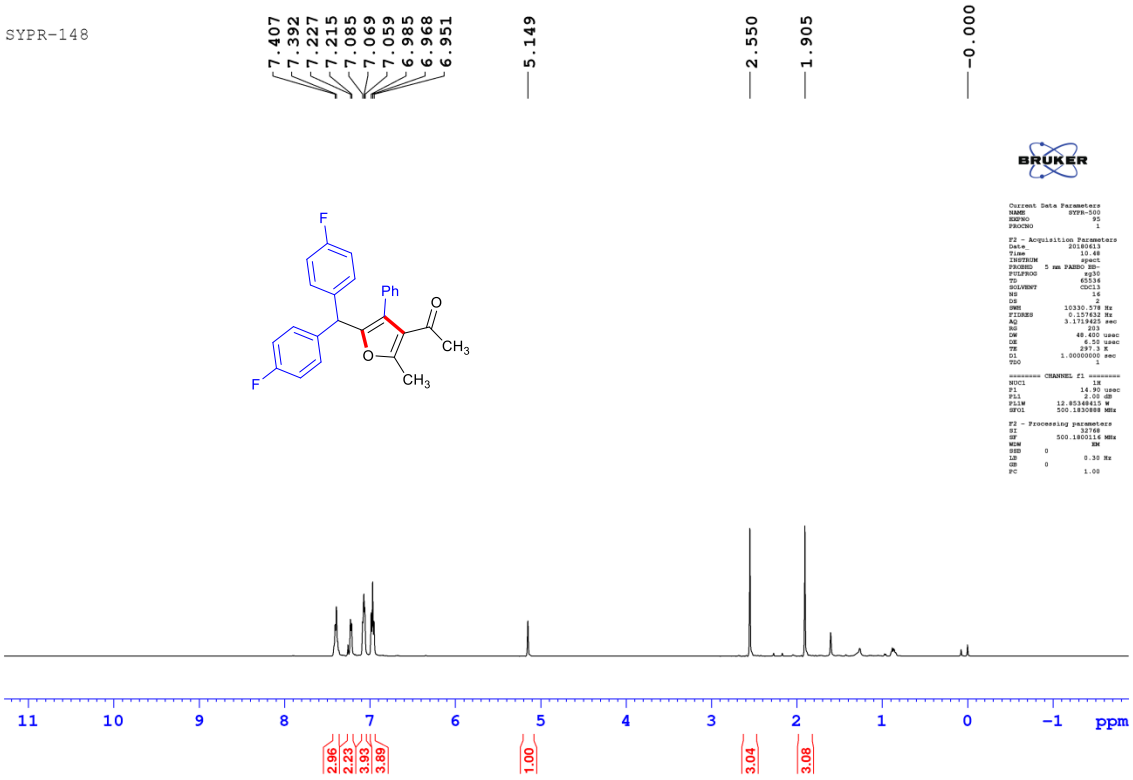

Ph
Ph
O
CH3
O
CH3
Cl
Cl
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
3.65
2.25
2.43
3.22
1.98
0.98
1.00
3.00
3.06


SYPR- 55-1
195.887
158.189
148.960
141.934
140.577
133.022
132.575
128.821
123.192
123.083
77.396
77.142
76.888
47.157
30.886
14.720
Ph
Ph
O
CH3
O
CH3
Cl
Cl
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

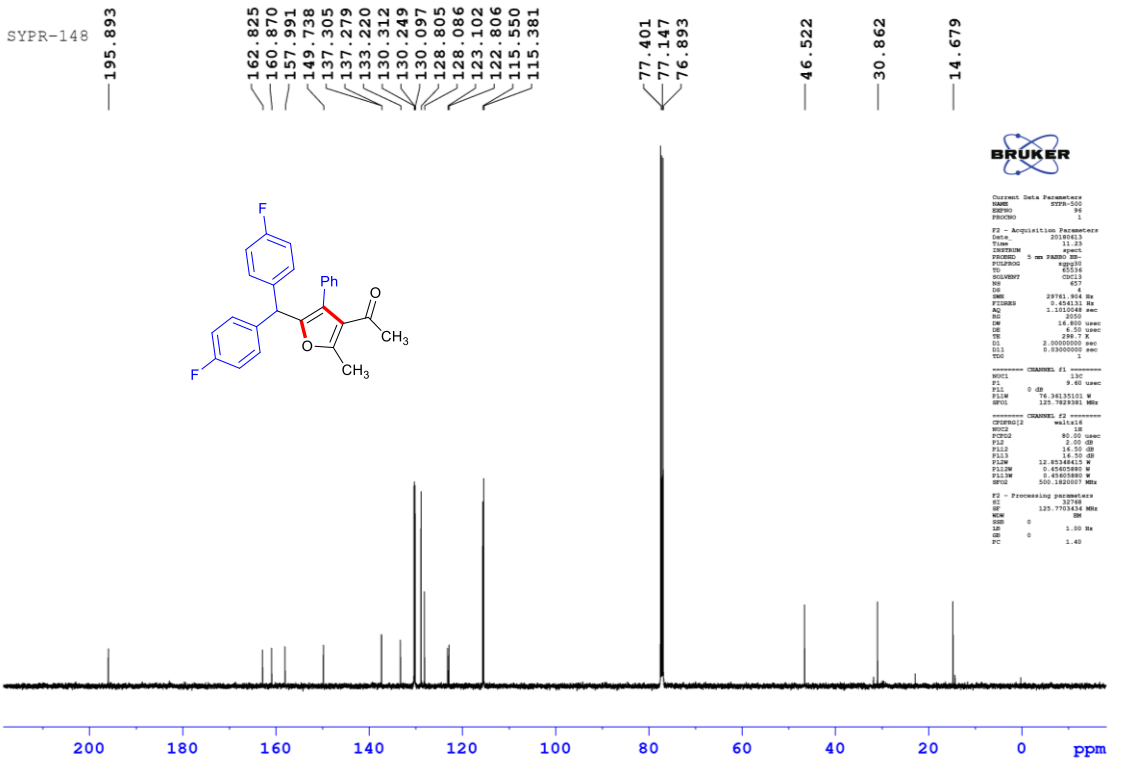

SYPR-143 A
7.402
7.398
7.395
7.385
7.382
7.370
7.358
7.355
7.349
7.344
7.274
7.259
7.244
7.211
7.207
7.192
7.188
7.178
7.140
7.125
7.071
7.054
6.821
6.803
5.158
3.751
2.541
1.902
0.002
Ph
Ph
O
CH3
CH3
O
MeO
11
10
9
8
7
6
5
4
3
2
1
0
-1 ppm
3.49
4.07
1.22
1.94
1.78
1.86
1.00
3.22
3.00
3.17

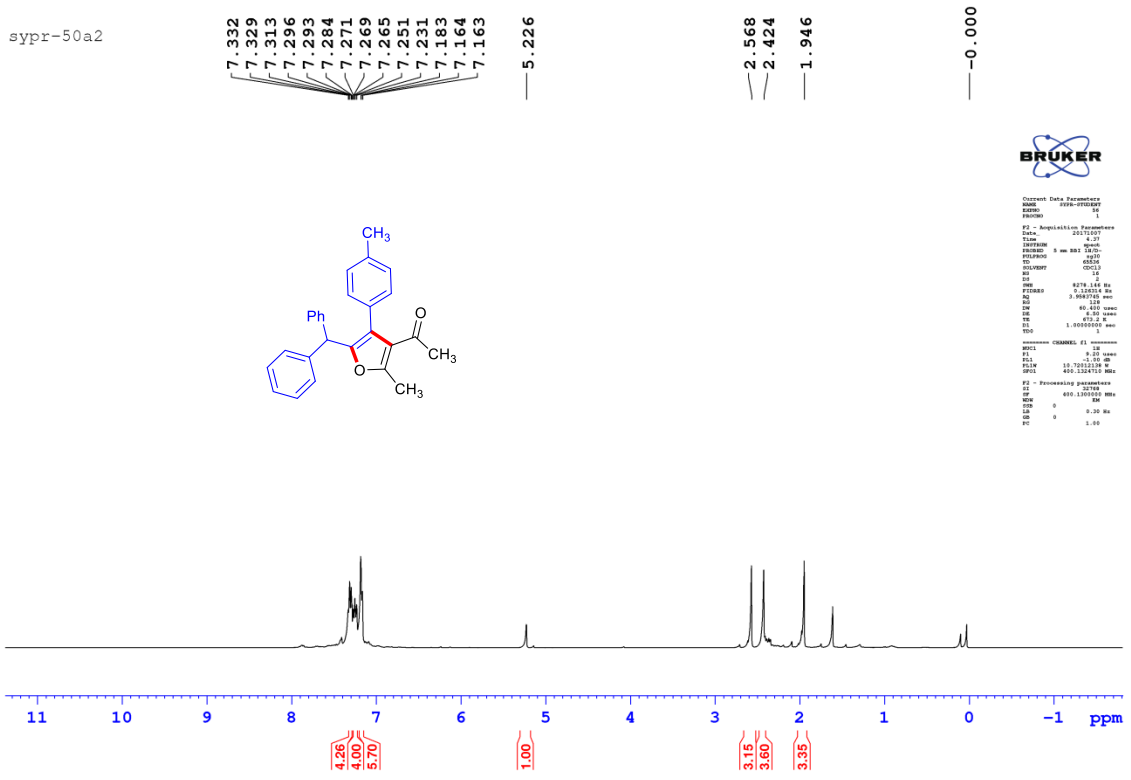

SYPR-143
195.987
158.398
157.721
150.473
142.007
133.789
133.442
130.149
129.827
128.714
128.641
128.457
127.837
126.654
122.975
122.366
77.403
77.149
76.895
55.272
47.063
30.814
14.646
Ph
Ph
O
CH3
CH3
O
MeO
200
180
160
140
120
100
80
60
40
20
0
ppm

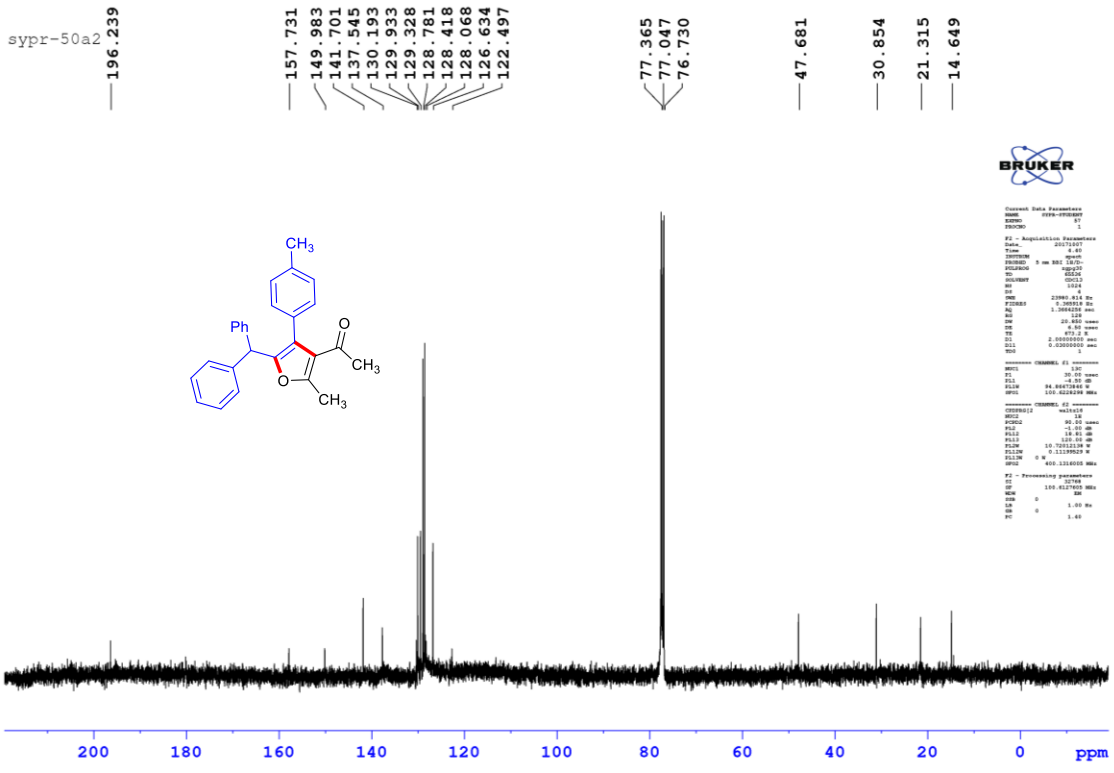
SYPR-148

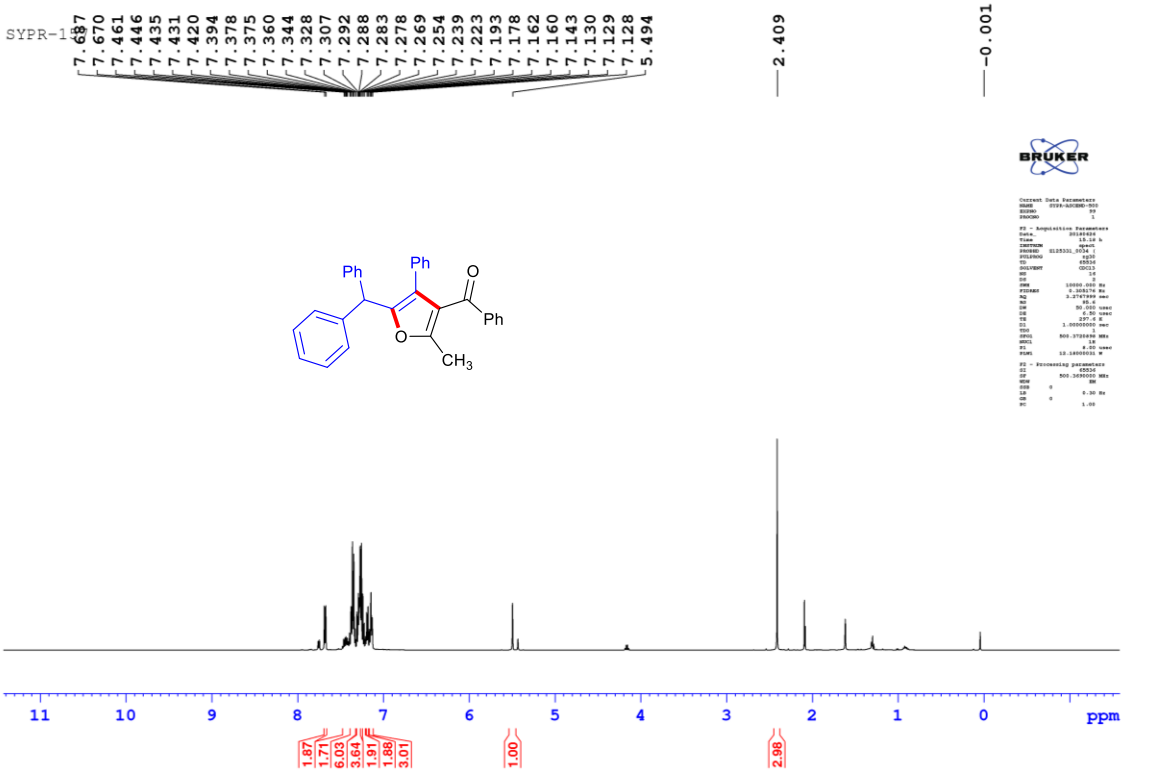


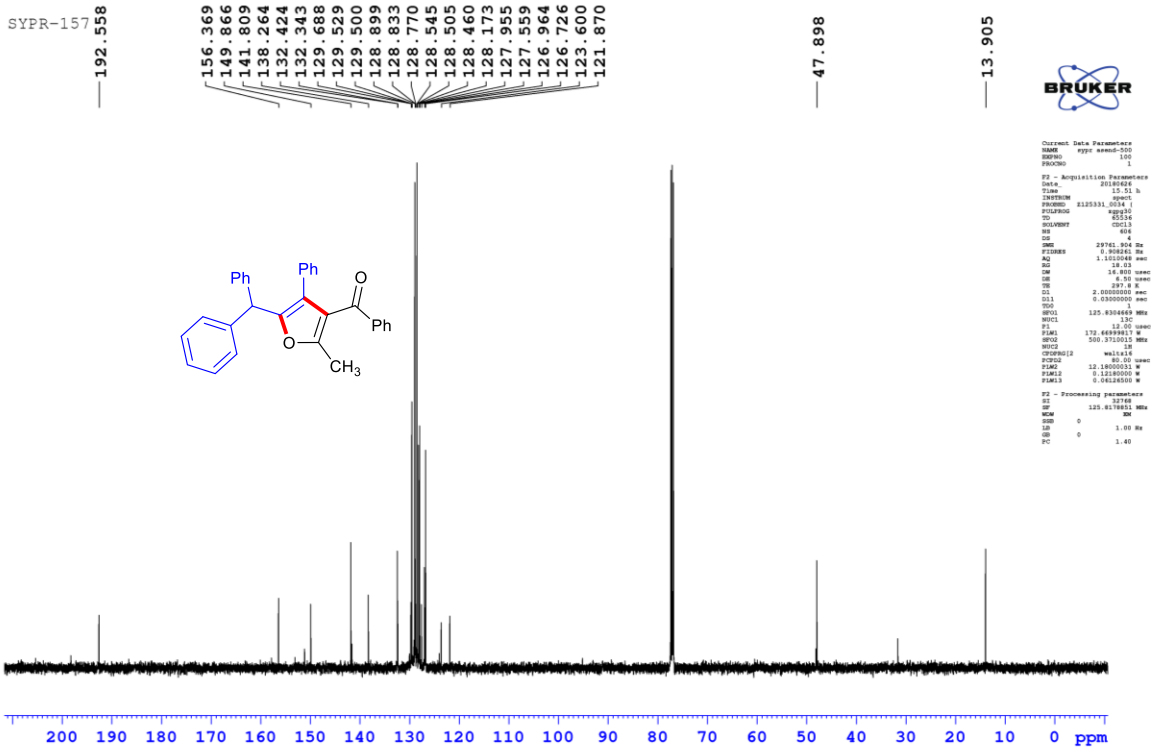
SYPR-148

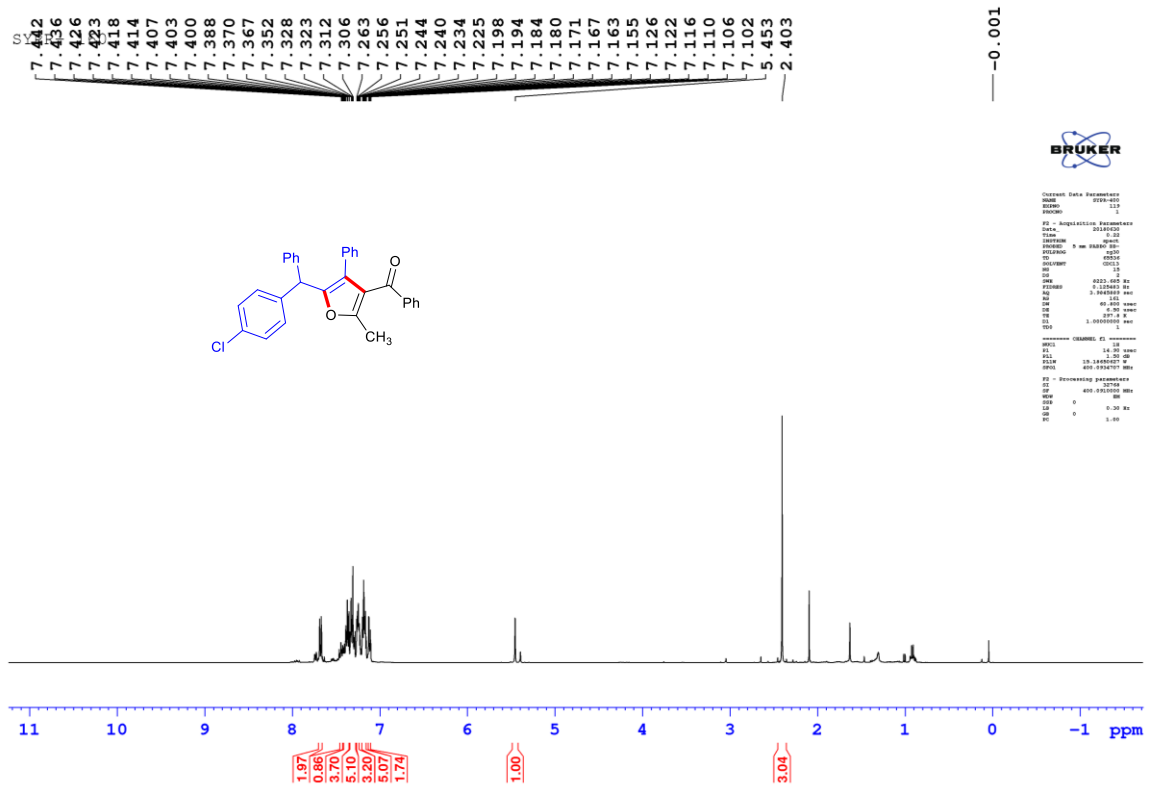


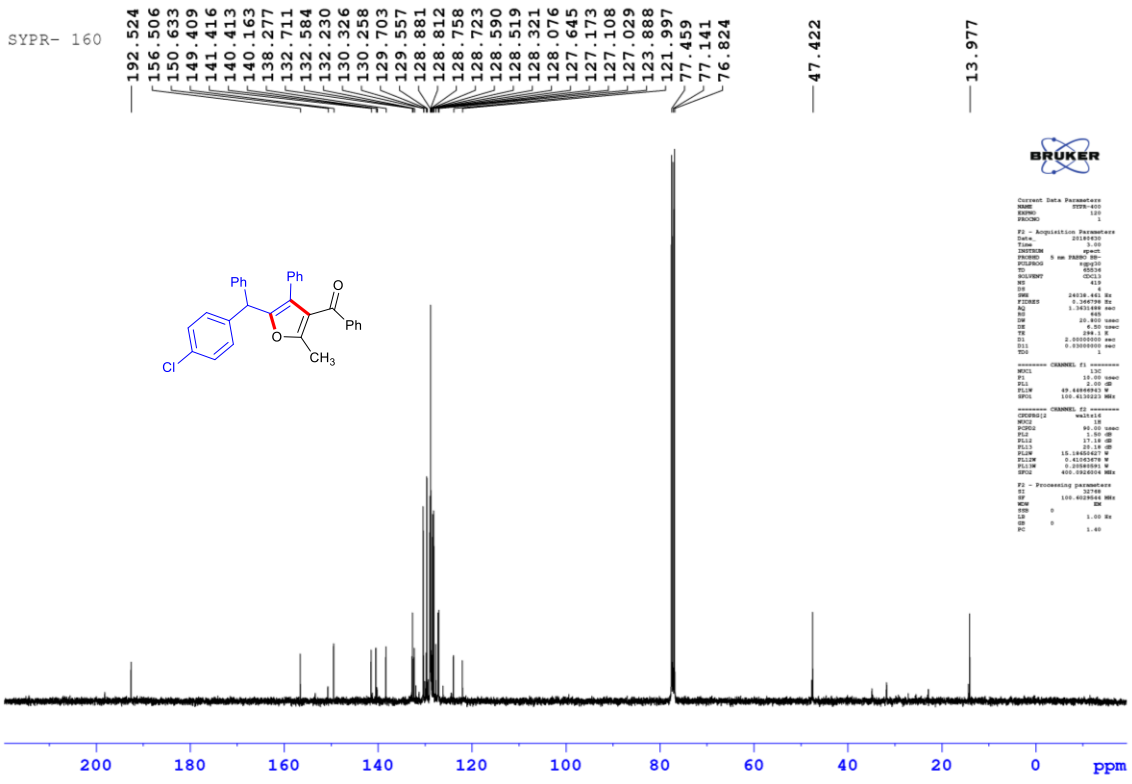

sypr-50a2
7.332
7.329
7.313
7.296
7.293
7.284
7.271
7.269
7.265
7.251
7.231
7.183
7.164
7.163
5.226
2.568
2.424
1.946
0.000
BRUKER
CH3
Ph
O
CH3
CH3
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
4.26
4.00
5.70
1.00
3.15
3.60
3.35

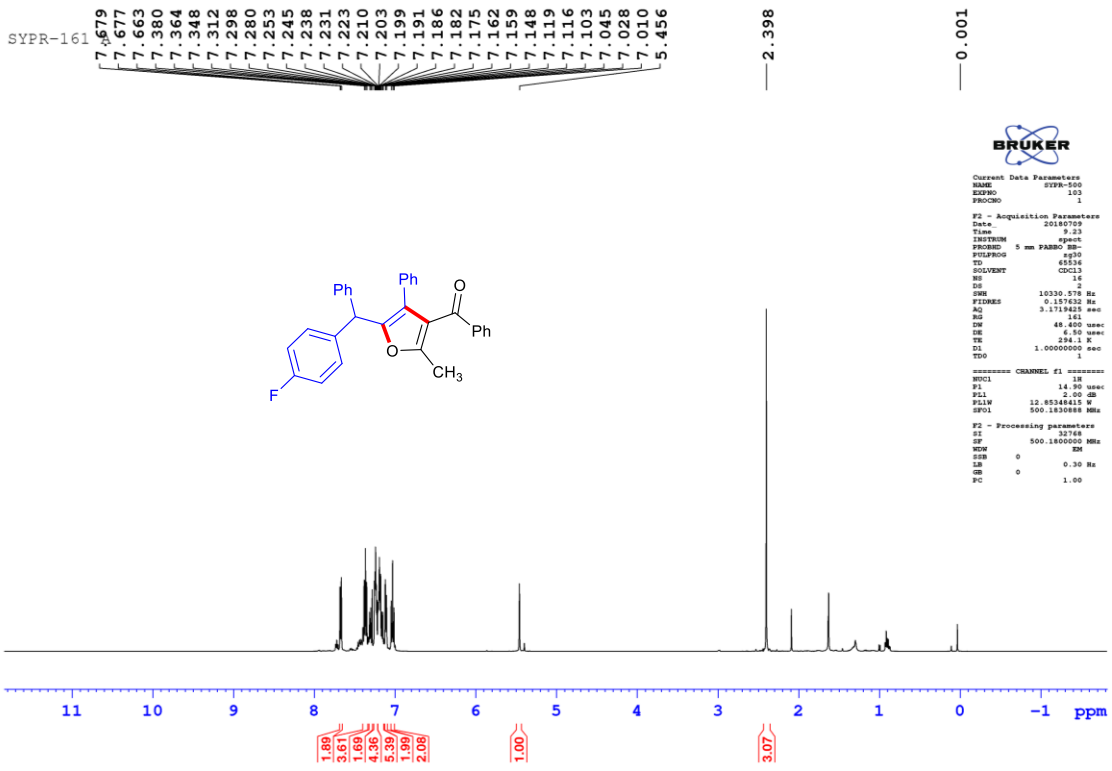

sypr-50a2
196.239
157.731
149.983
141.701
137.545
130.193
129.933
129.328
128.781
128.418
128.068
126.634
122.497
77.365
77.047
76.730
47.681
30.854
21.315
14.649
BRUKER
CH3
Ph
O
CH3
CH3
200
180
160
140
120
100
80
60
40
20
0
ppm

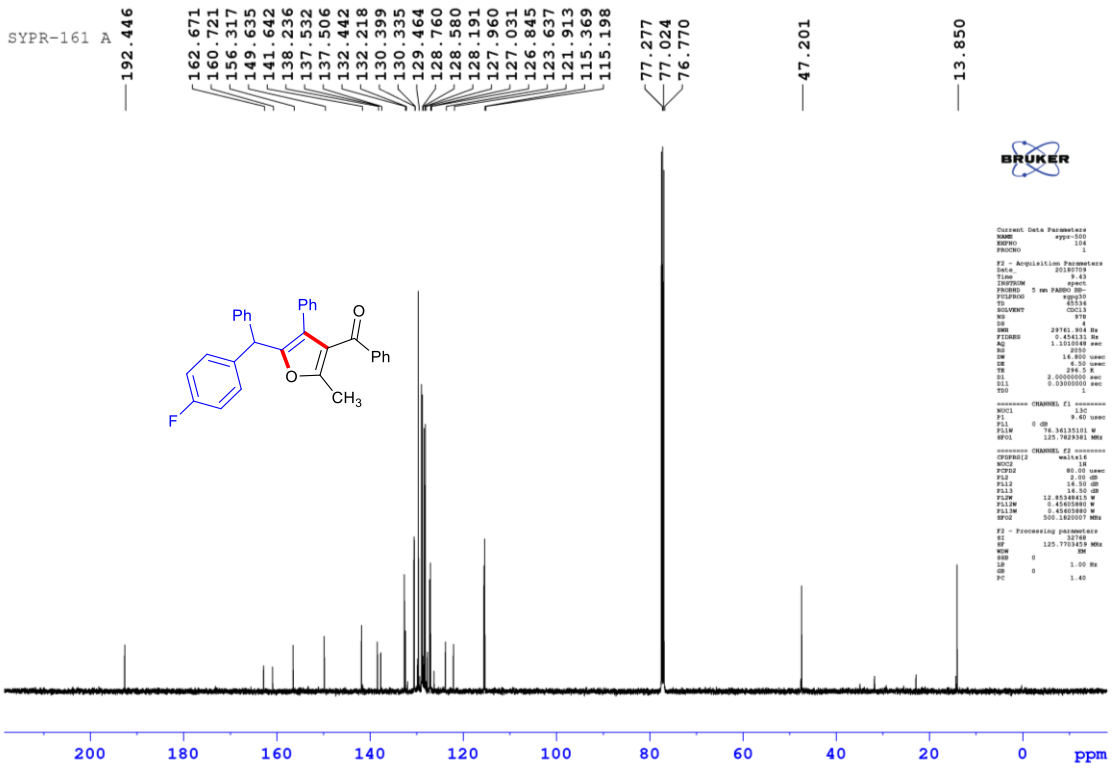

SYPR-157
7.687
7.670
7.461
7.446
7.435
7.431
7.420
7.394
7.378
7.375
7.360
7.344
7.328
7.307
7.292
7.288
7.283
7.278
7.269
7.254
7.239
7.223
7.193
7.178
7.162
7.160
7.143
7.130
7.129
7.128
5.494
2.409
0.001
Ph
Ph
O
Ph
CH3
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.87
1.71
6.03
3.64
1.91
1.88
3.01
1.00
2.98

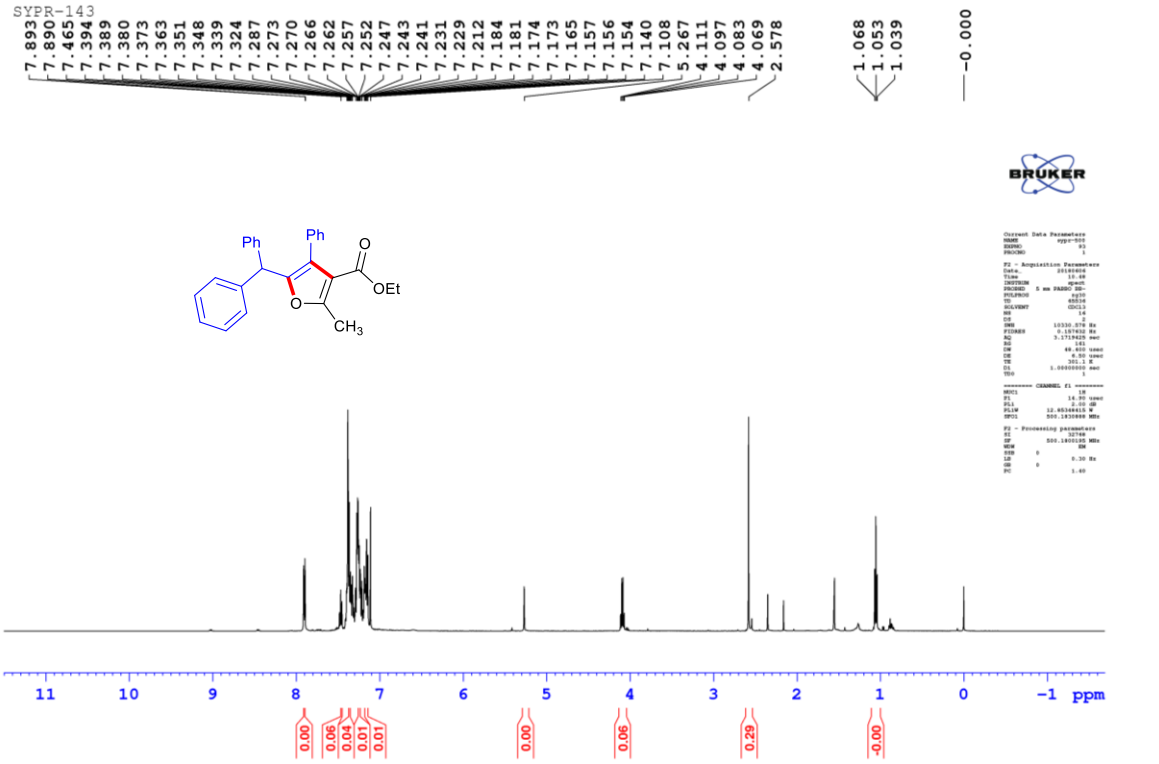

SYPR-157
192.558
156.369
149.866
141.809
138.264
132.424
132.343
129.688
129.529
129.500
128.899
128.833
128.770
128.545
128.505
128.460
128.173
127.955
127.559
126.964
126.726
123.600
121.870
47.898
13.905
Ph
Ph
O
Ph
CH3
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


SYPR- 160
7.442
7.436
7.426
7.423
7.418
7.414
7.407
7.403
7.400
7.388
7.370
7.367
7.352
7.328
7.323
7.312
7.306
7.263
7.256
7.251
7.244
7.240
7.234
7.225
7.198
7.194
7.184
7.180
7.171
7.167
7.163
7.155
7.126
7.122
7.116
7.110
7.106
7.102
5.453
2.403
0.001
BRUKER
Ph
Ph
O
Ph
Cl
O
CH3
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.97
0.86
3.70
5.10
3.20
5.07
1.74
1.00
3.04


SYPR- 160
192.524
156.506
150.633
149.409
141.416
140.413
140.163
138.277
132.711
132.584
132.230
130.326
130.258
129.703
129.557
128.881
128.812
128.758
128.723
128.590
128.519
128.321
128.076
127.645
127.173
127.108
127.029
123.888
121.997
77.459
77.141
76.824
47.422
13.977
BRUKER
Ph
Ph
O
Ph
Cl
O
CH3
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-161 A
7.679
7.677
7.663
7.380
7.364
7.348
7.312
7.298
7.280
7.253
7.245
7.238
7.231
7.223
7.210
7.203
7.199
7.191
7.186
7.182
7.175
7.162
7.159
7.148
7.119
7.116
7.103
7.045
7.028
7.010
5.456
2.398
0.001
Ph
Ph
O
Ph
O
CH3
F
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.89
3.61
1.69
4.36
5.39
1.99
2.08
1.00
3.07


SYPR-161 A
192.446
162.671
160.721
156.317
149.635
141.642
138.236
137.532
137.506
132.442
132.218
130.399
130.335
129.464
128.760
128.580
128.191
127.960
127.031
126.845
123.637
121.913
115.369
115.198
77.277
77.024
76.770
47.201
13.850
Ph
Ph
O
Ph
O
CH3
F
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-143
7.893
7.890
7.465
7.394
7.389
7.380
7.373
7.363
7.351
7.348
7.339
7.324
7.287
7.273
7.270
7.266
7.262
7.257
7.252
7.247
7.243
7.241
7.231
7.229
7.212
7.184
7.181
7.174
7.173
7.165
7.157
7.156
7.154
7.140
7.108
5.267
4.111
4.097
4.083
4.069
2.578
1.068
1.053
1.039
0.000
Ph
Ph
O
OEt
O
CH3
11
10
9
8
7
6
5
4
3
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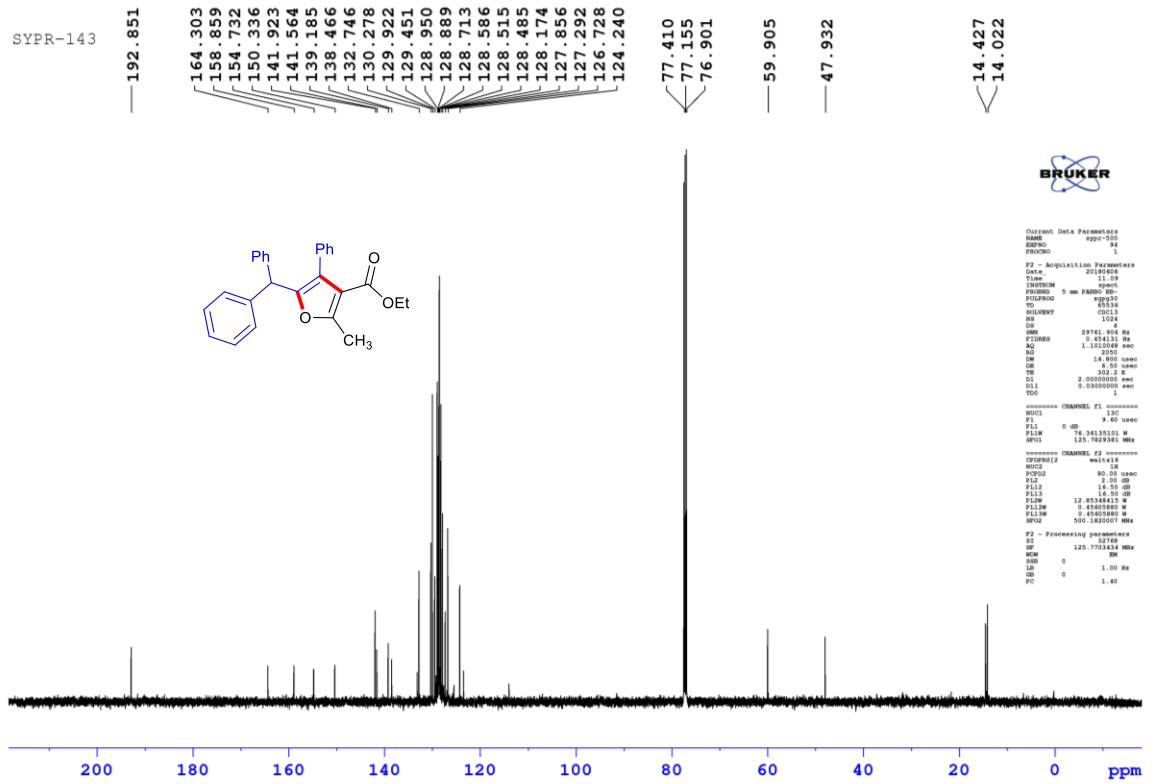
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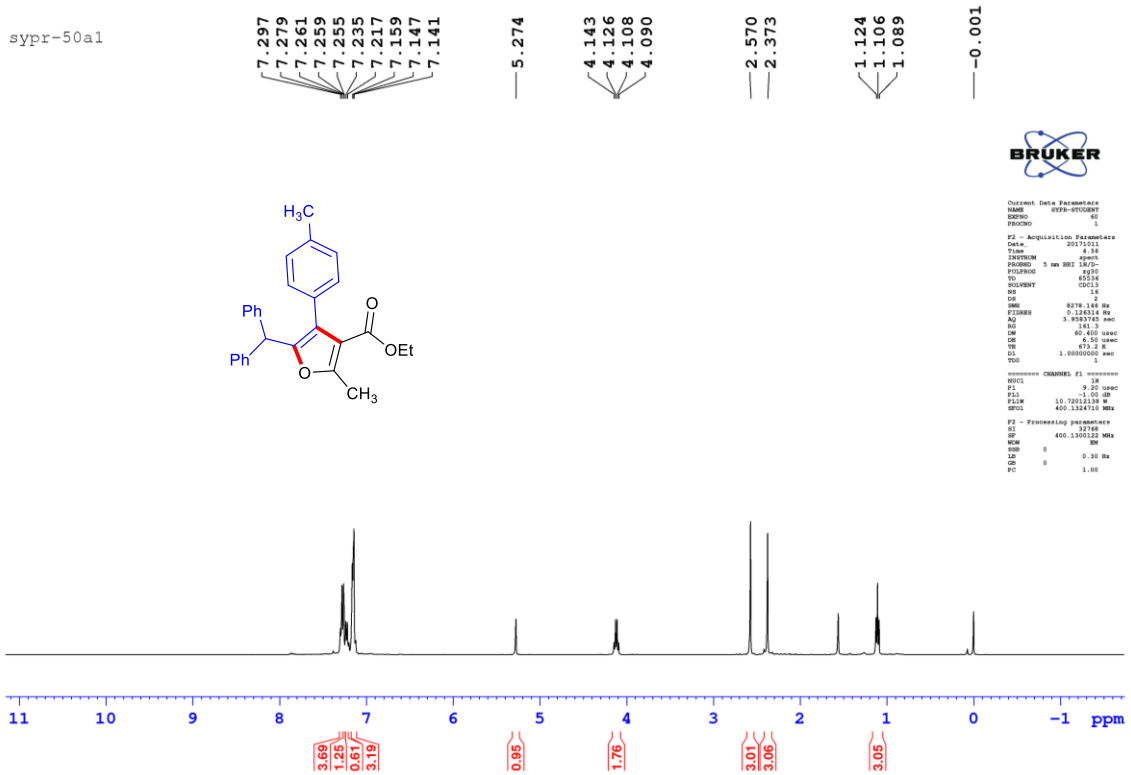
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8
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5
4
3
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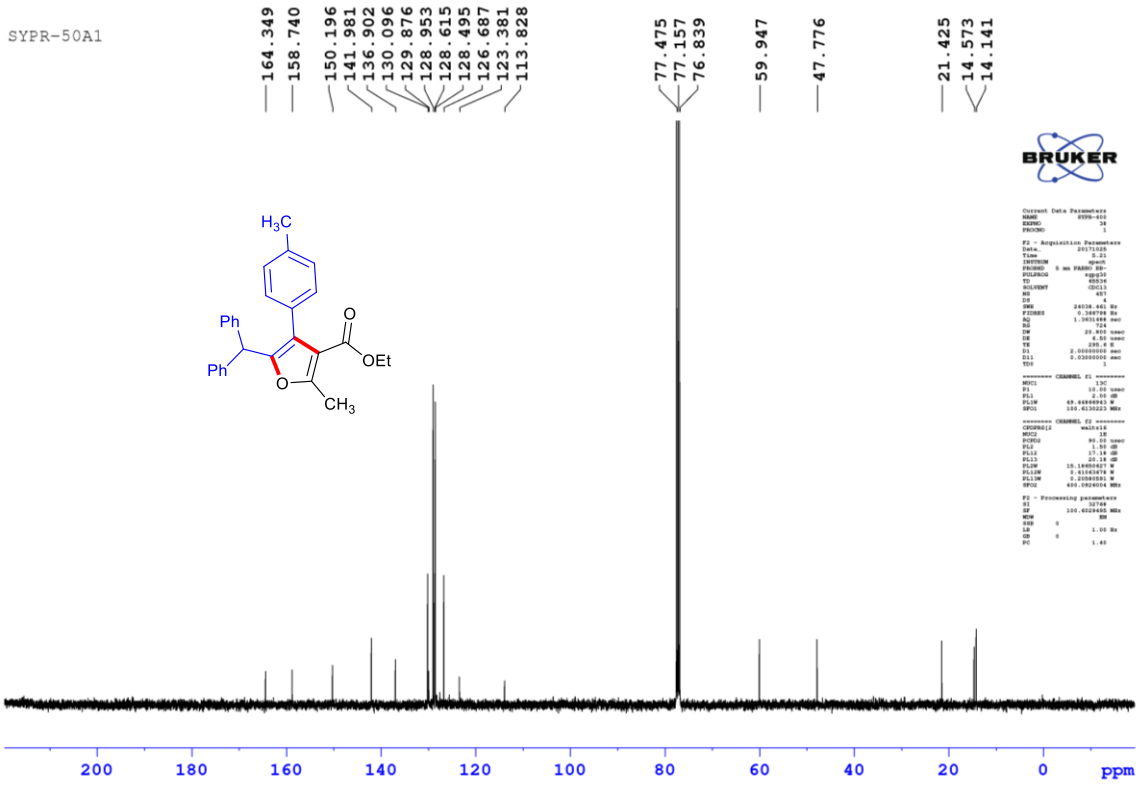
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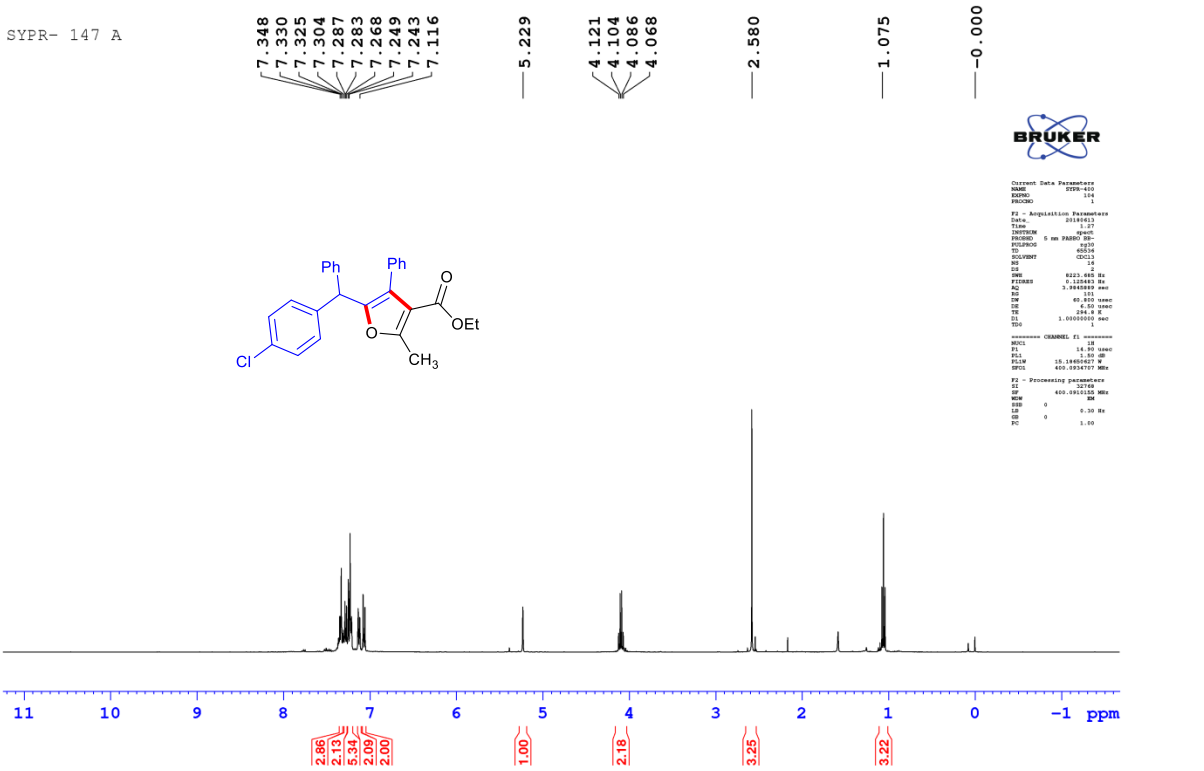
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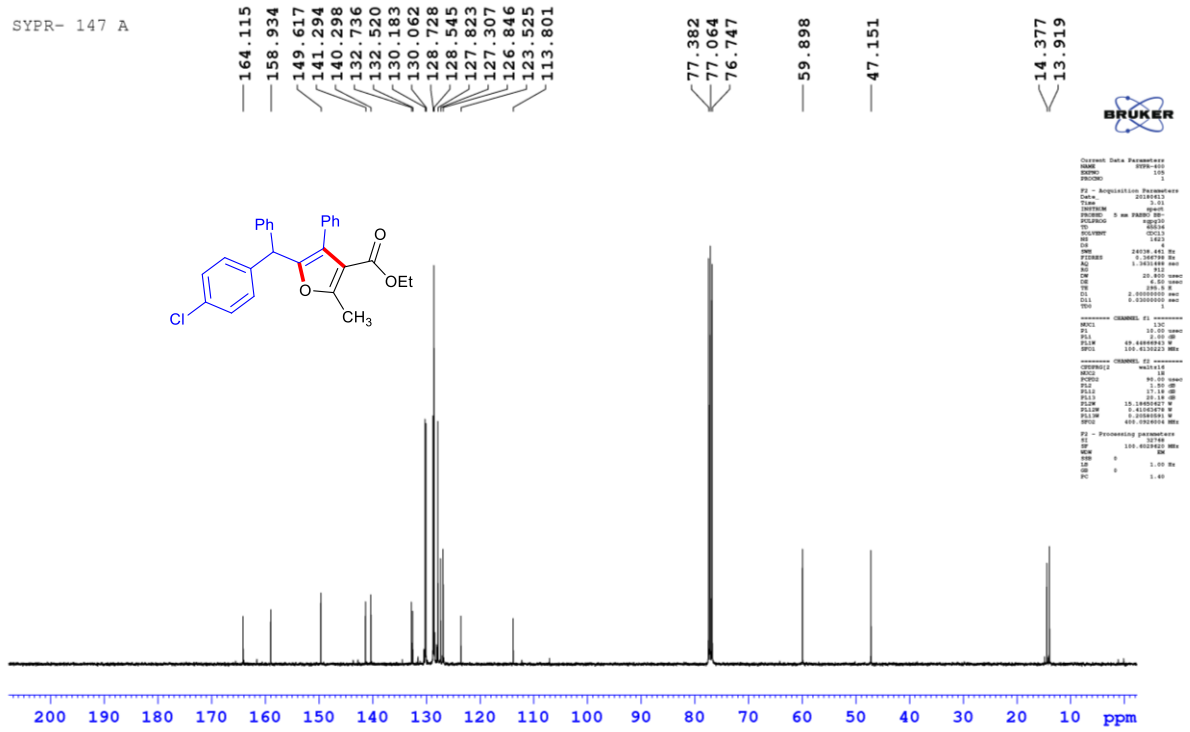
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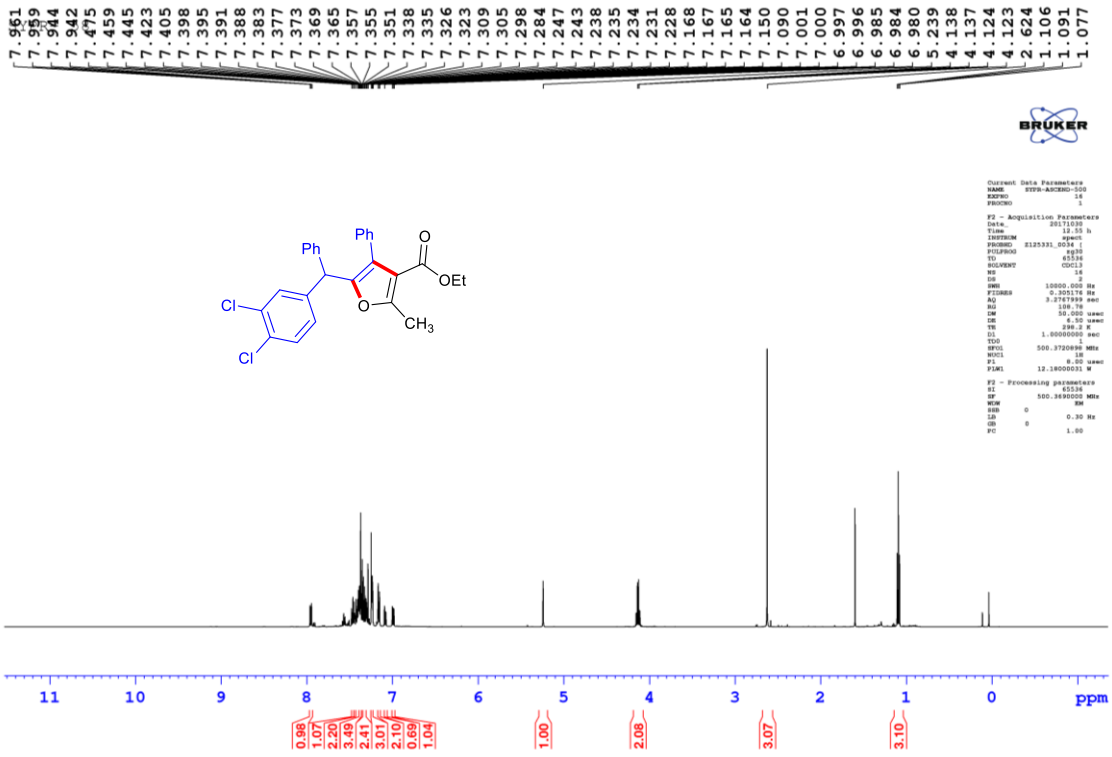
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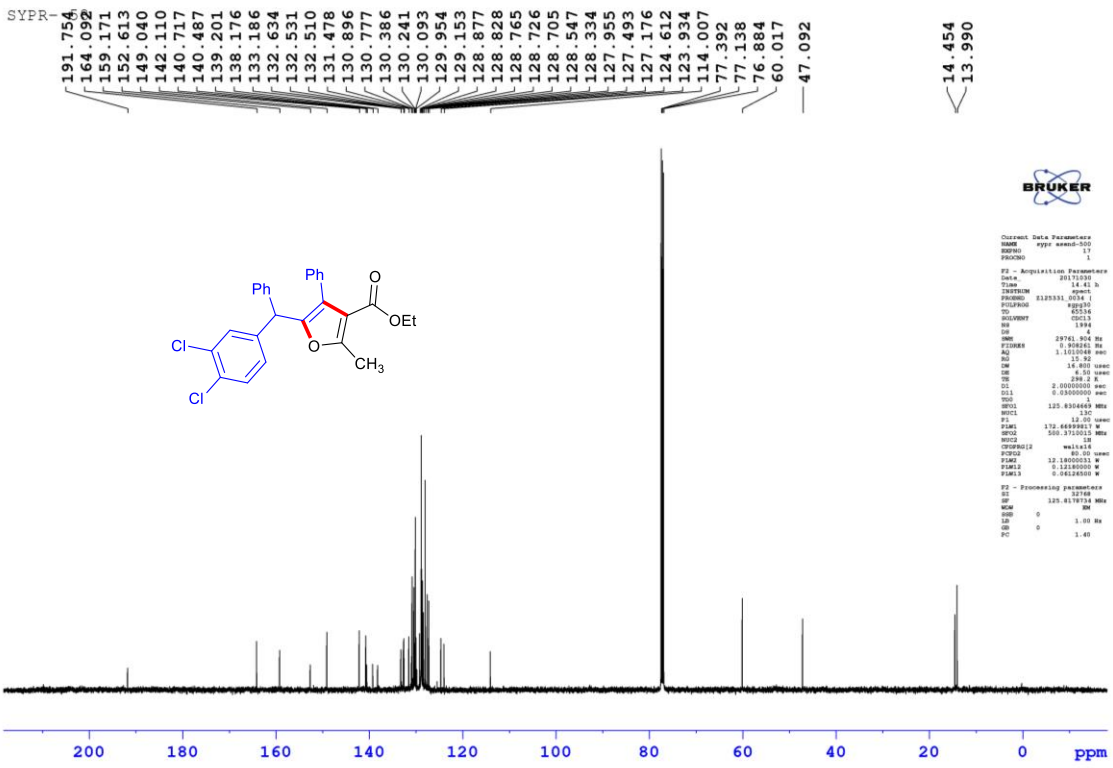
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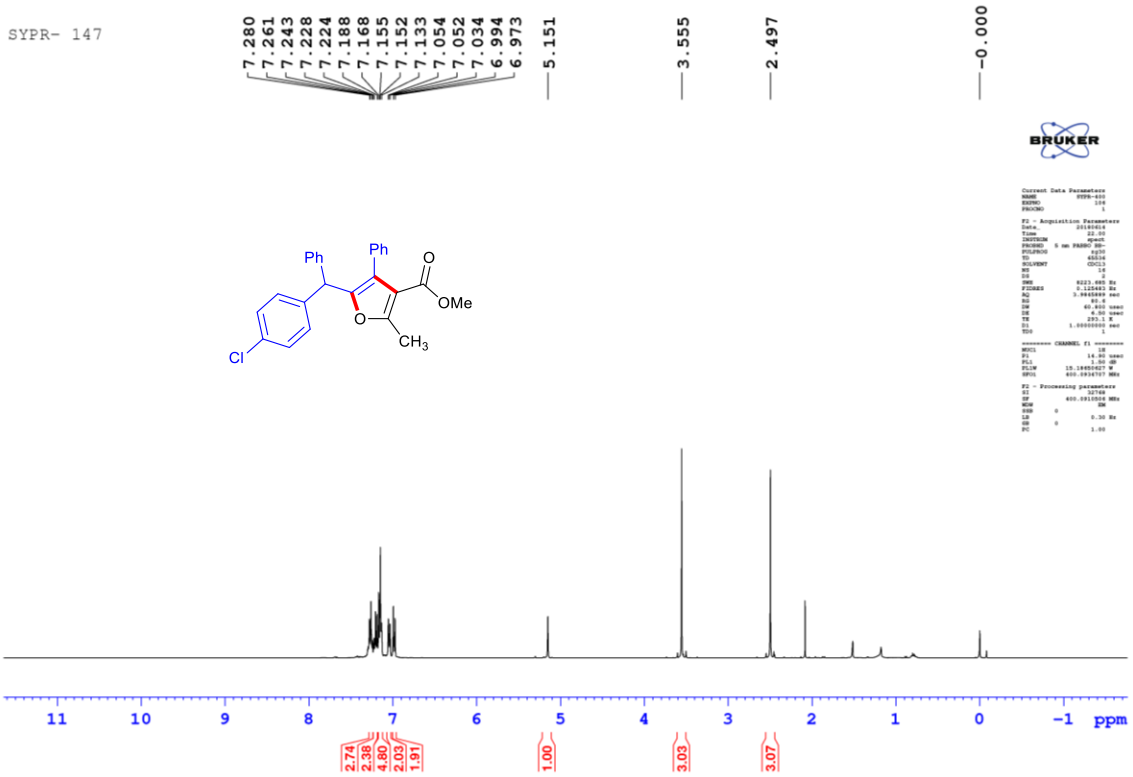
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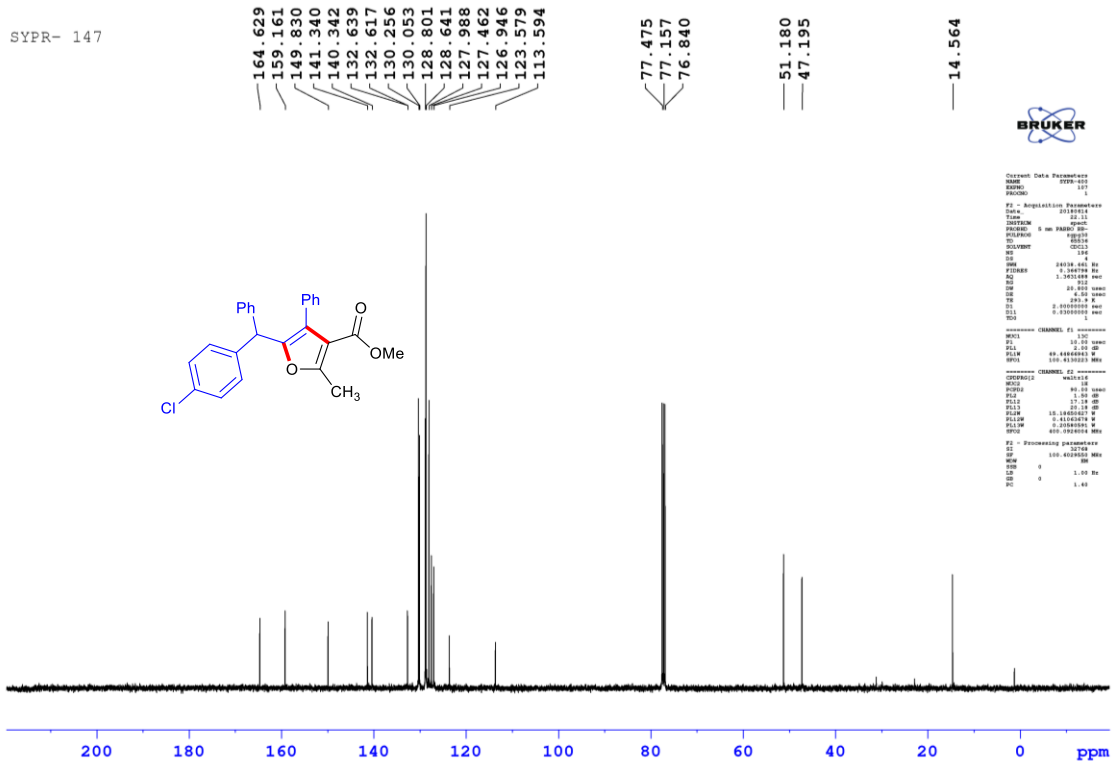
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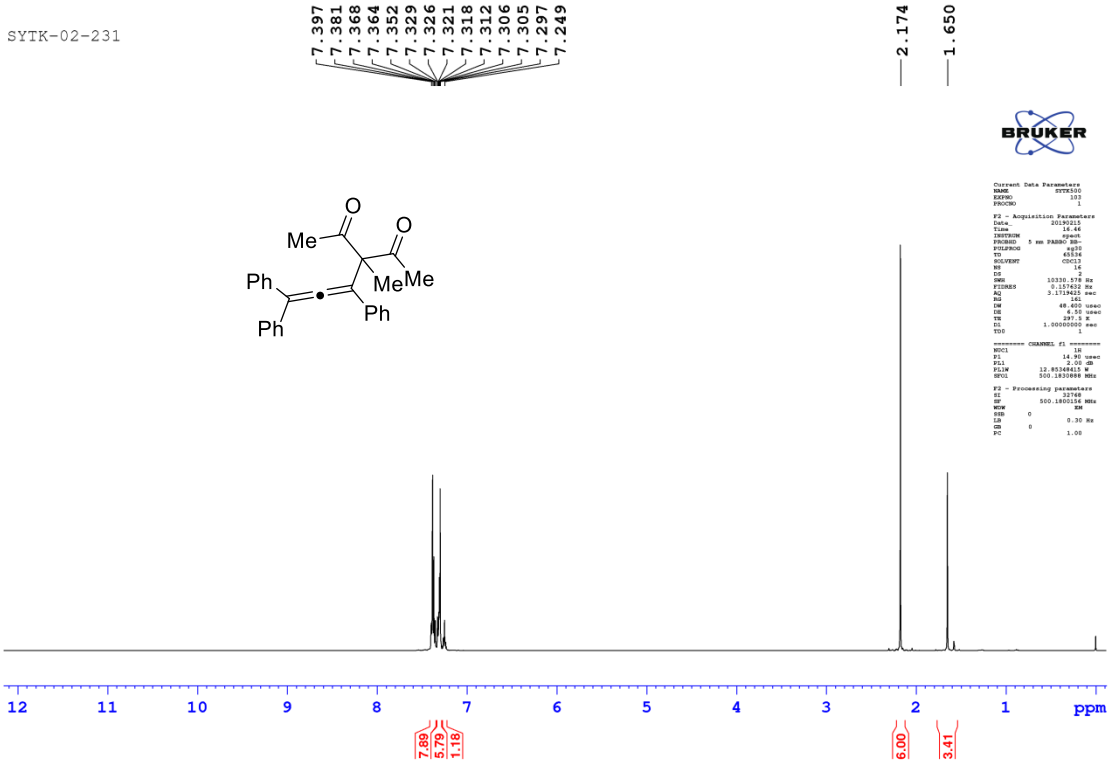
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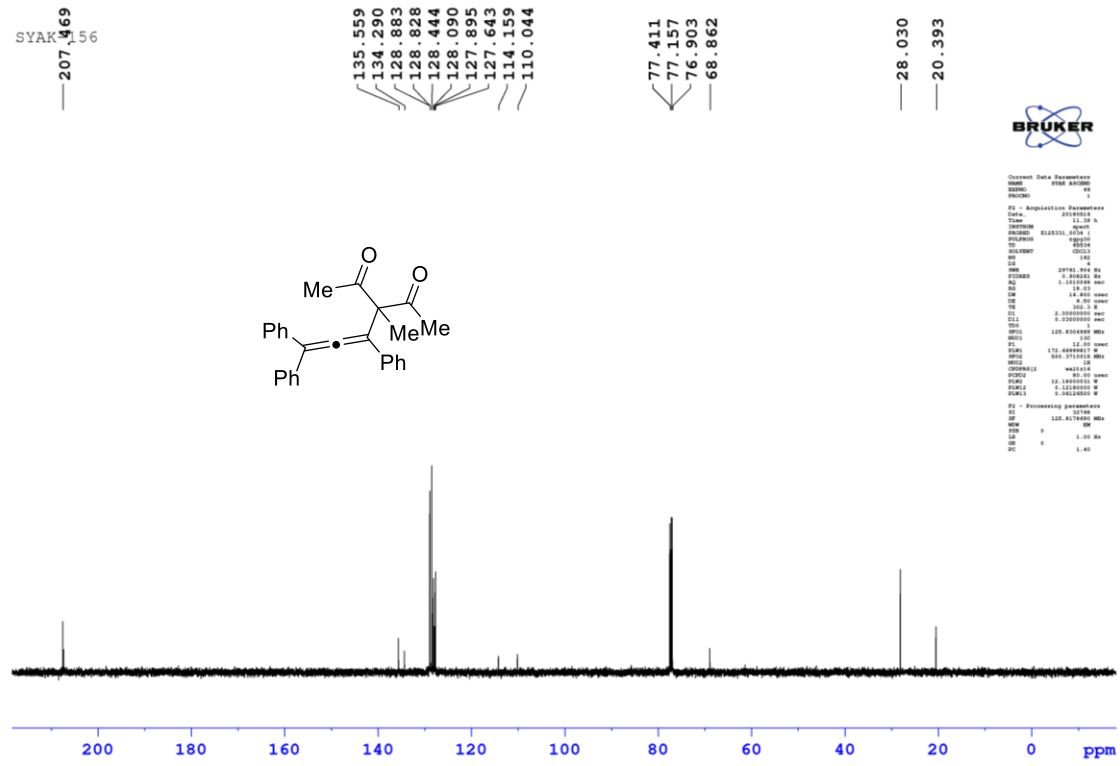
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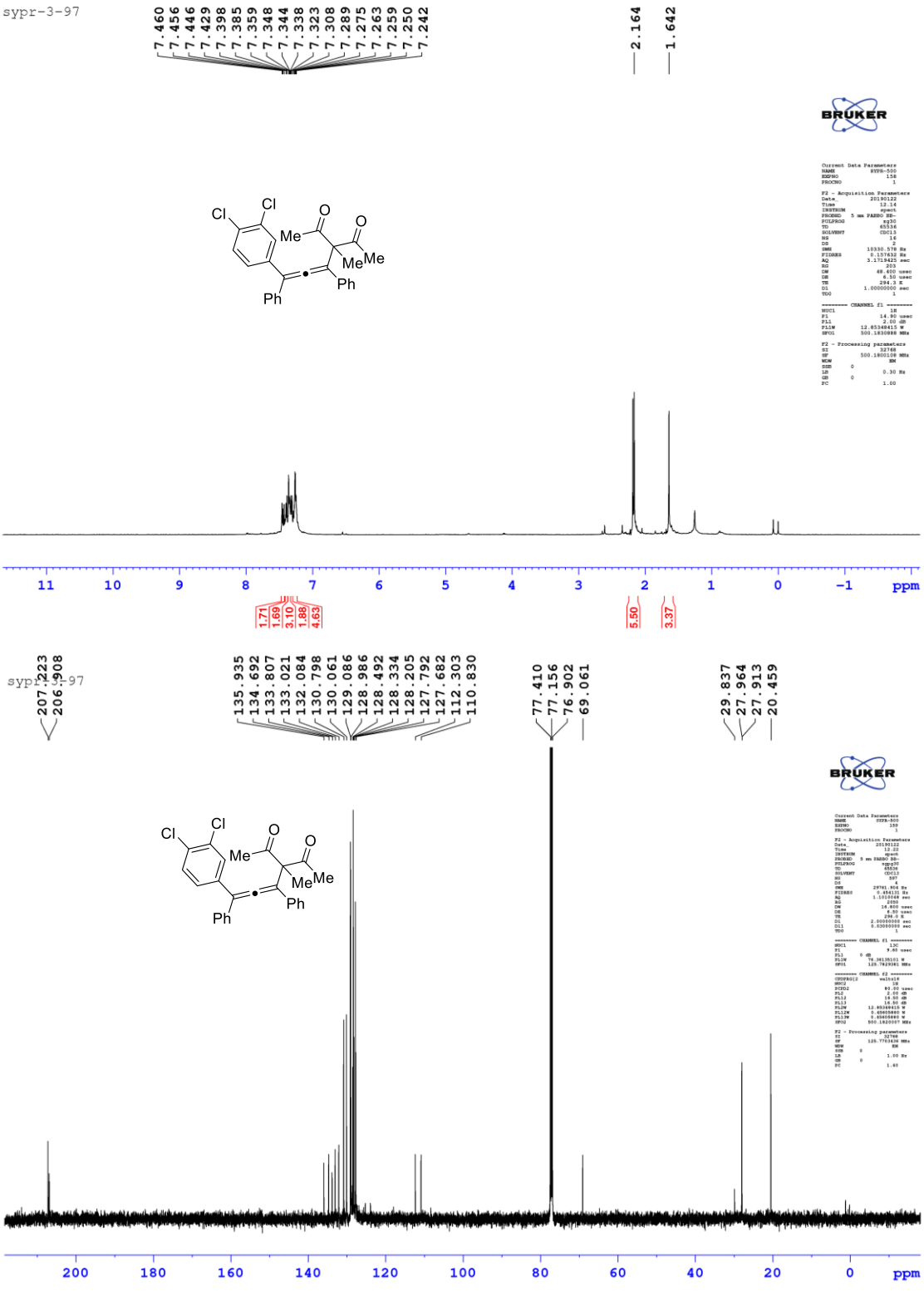
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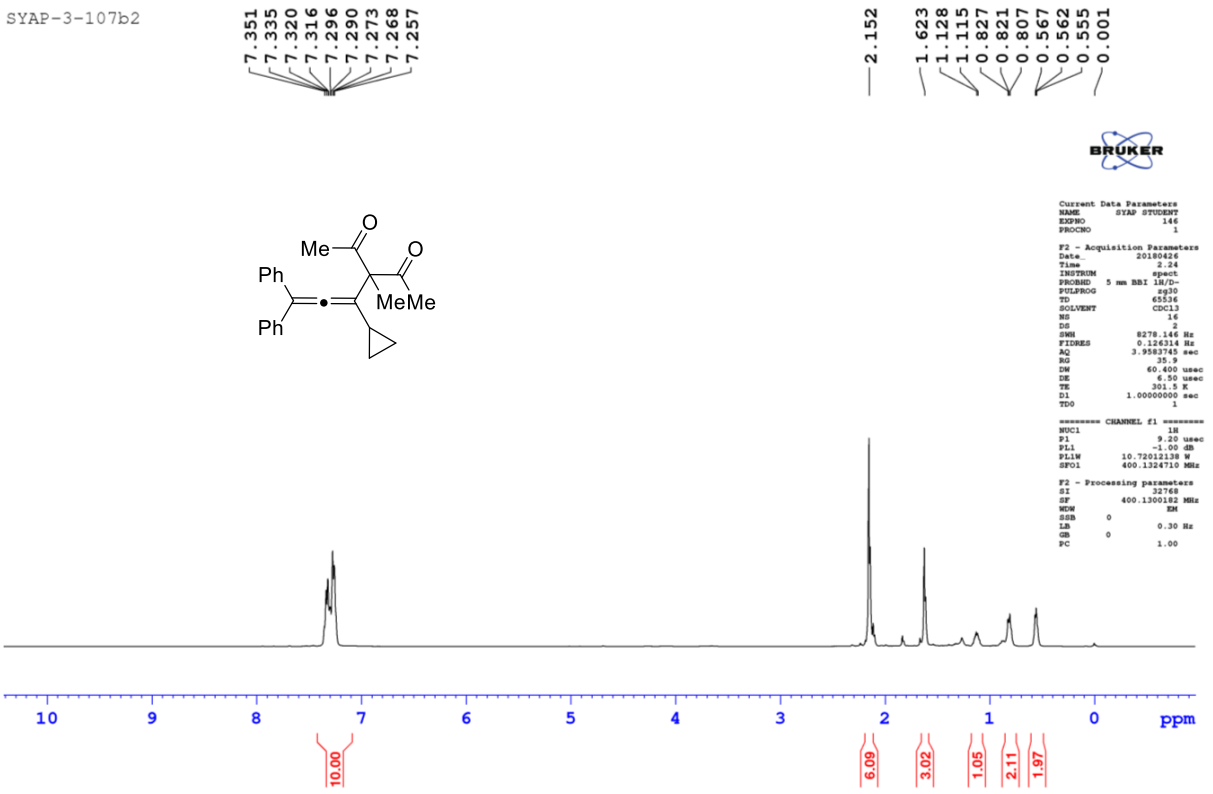

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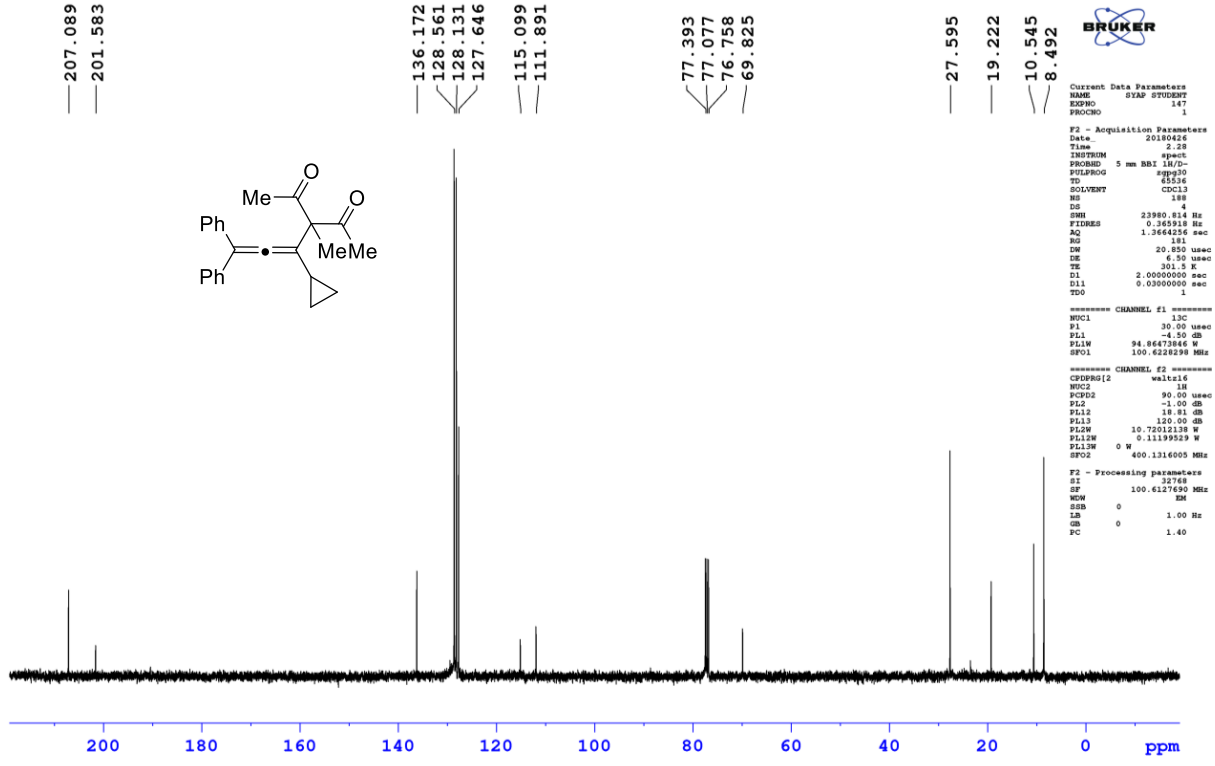

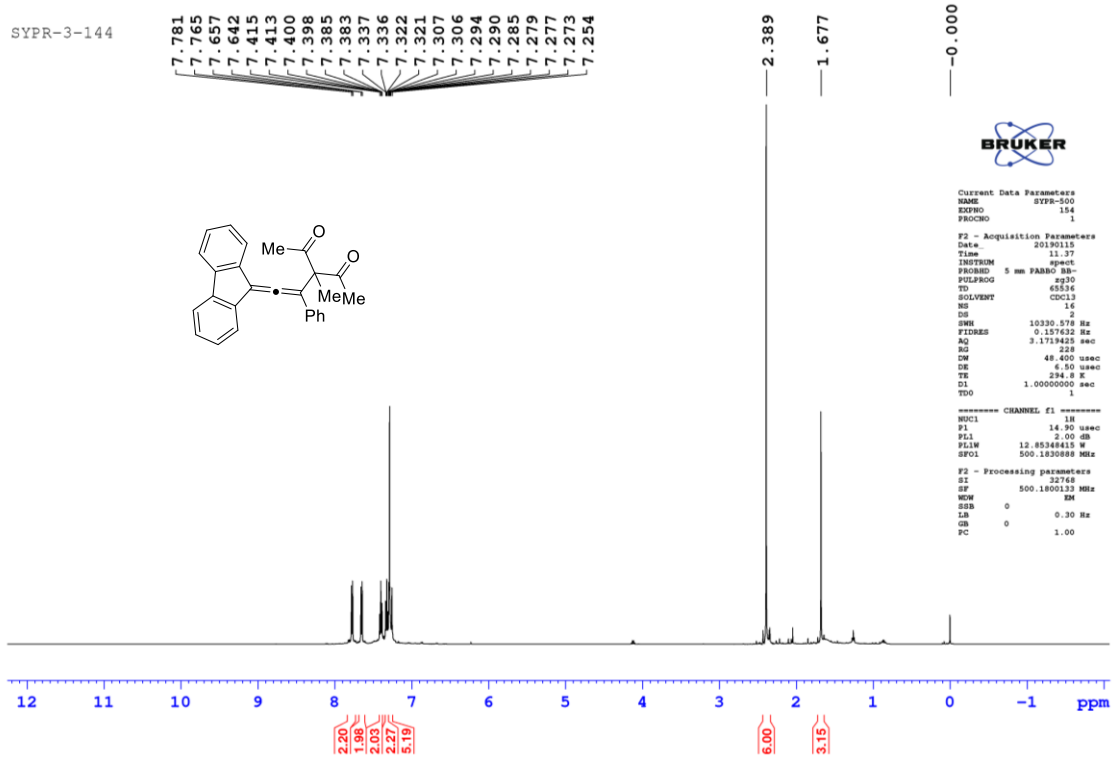
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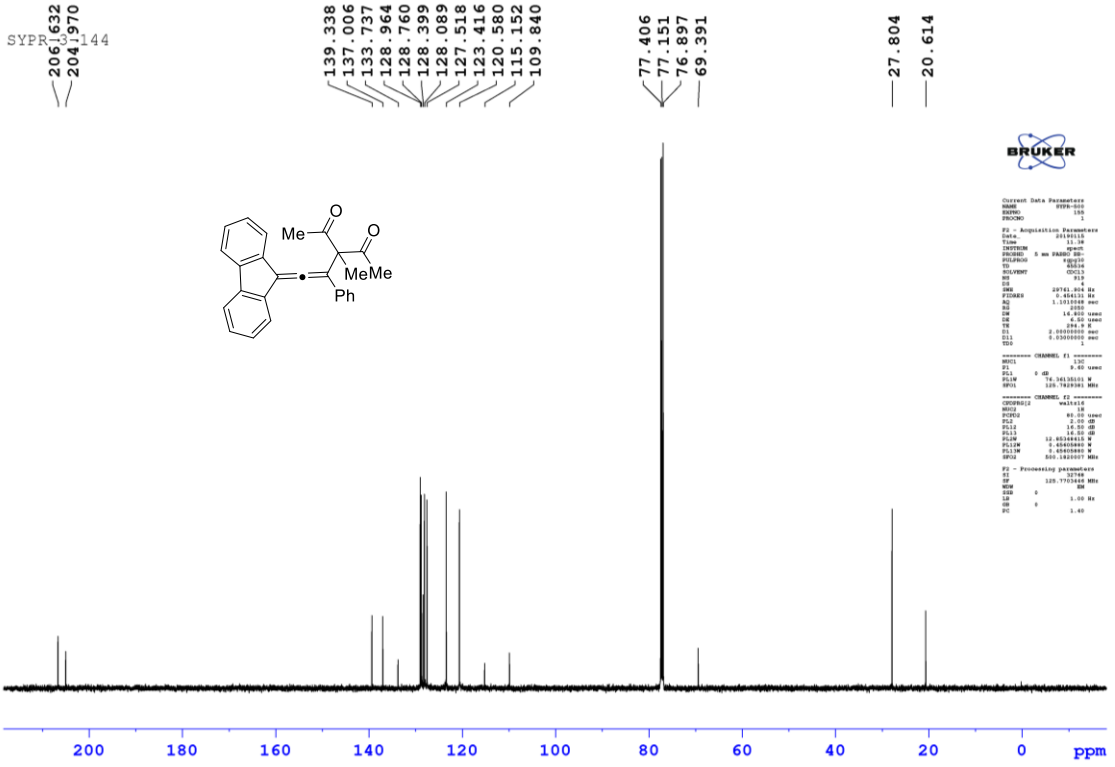
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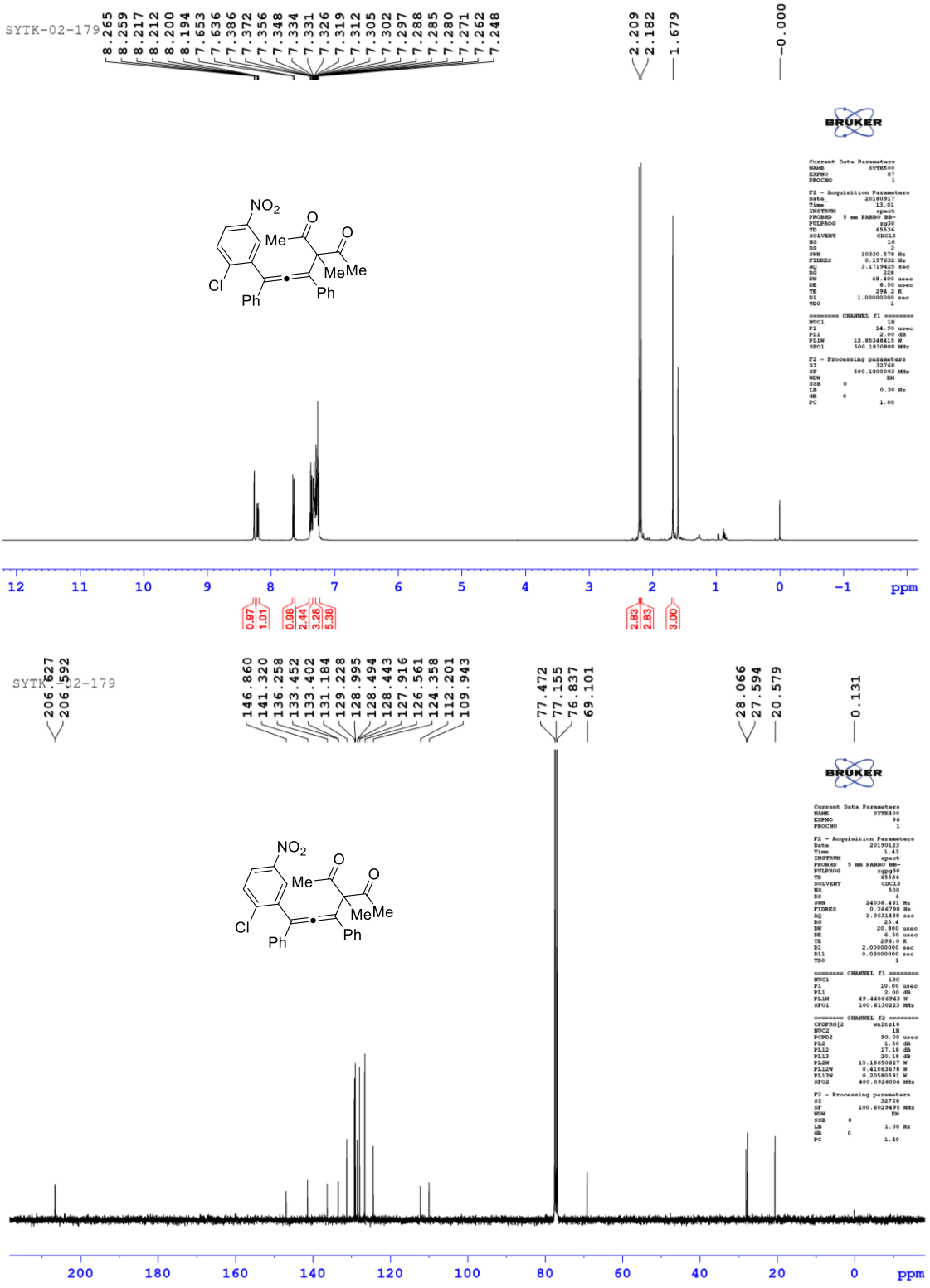
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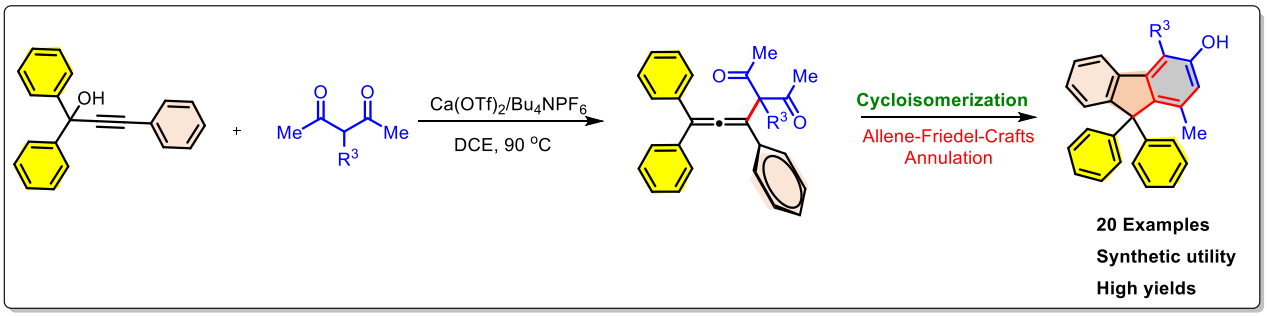
Synthesis and in-situ cyclization of tetrasubstituted allenes to access tricyclic fluorenols



Eur. J. Org. Chem. **2019**, 5740-5748

3.1 Hypothesis and planning

In continuation of our earlier experimental studies on *tert*-propargyl alcohols and their reactivity towards the generation of the new kind of heterocyclics, aryl substitution at one of the allenic carbon can change the reactivity by participating in the annulation processes, a similar kind of reaction was already discussed in the previous chapter. In that case during the optimization studies to enhance the yield of the cyclized product, a trace amount of the annulated product was also observed. Later, we found that the formed product was fluorene moiety. After this positive outcome, we wanted to work further on this chemistry to get substituted fluorene compounds, because most of the fluorene-containing molecules show greater biological activities and can also be utilized in material science. When we look at the literature for fluorene chemistry, we found that a similar kind of reaction was done by using the starting materials with different reaction conditions as shown in scheme 1.

As fluorenols were found to be an important structural theme with a 6-5-6 tricyclic framework in biologically active natural molecules. These structures are commonly known as fluorenes, which are well-known privileged structures with applications in the fields of material science and the pharmaceutical industry.[1,2] Due to their unique properties such as good charge transporters with high chemical stability, molecules with a core structure of fluorene are utilized as Dye Sensitized Solar Cells (DSSC) and light emitting diodes in material science.[1] The separation of fluostatins and pyrazolofluostatins demonstrates their abundance in natural products (Figure 1).[3,4] The fluostatin family of natural compounds has been shown to have a wide range of bioactivities, including inhibition of dipeptidyl peptidases, antibacterial, and anticancer properties.[3] Pyrazo fluostatins were recently identified from Micromonospora rosaria SCSIO N160, a sea-derived micromonospora from South China.[4] Selanginpulvilins are a series of natural compounds with a structure of 9,9-diphenyl-9H-fluorenol (Figure 1) which were isolated and exhibited strong phosphodiesterase-4 (PDE4) inhibitory activity.[5,6]

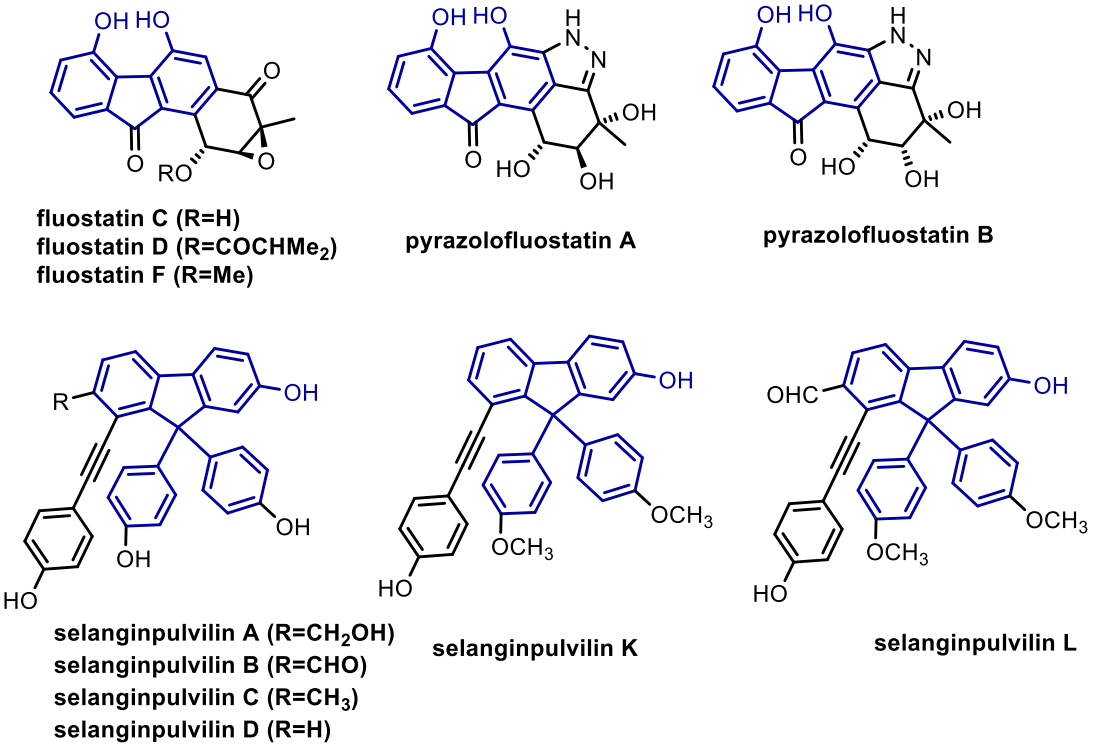
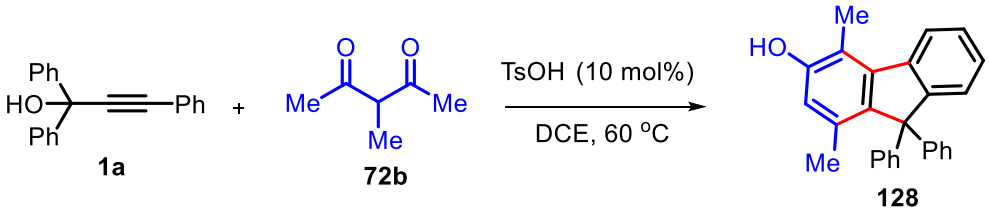


Figure.1 Representative examples of biologically active natural products with the core structure of fluorenol.

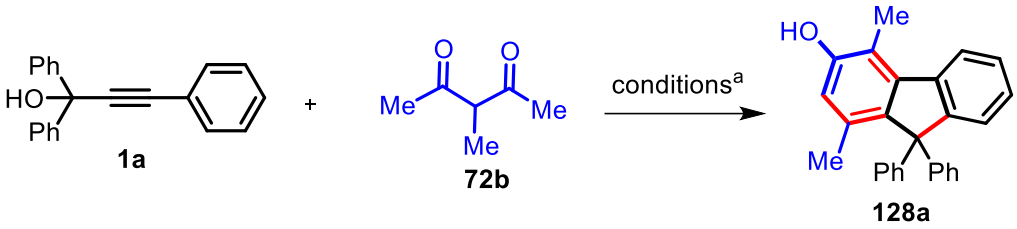
3.2 PREVIOUS REPORTS

Only one report was available in the literature till now that is by K.W. Huang *et al.*[7] in 2012, fluorenols were synthesized by the reaction of propargylic alcohol and 3-methylpentane-2,4-dione *via* Friedel-Crafts reaction, followed by a cyclization (Scheme 1).



Scheme 1. TsOH catalyzed synthesis of 1,4-dimethyl-9,9-diphenyl-9*H*-fluoren-3-ols.

Table 1. Optimization of reaction conditions for the one-pot synthesis of 1,4-dimethyl-9,9-diphenyl-9*H*-fluoren-3-ols (**128a**).[a]



Entry	Catalyst (mol%)	Solvent (Temp °C)	Time (h)	Yield (%)[b]
1	$Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)	neat (90)	3	47
2	$Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)	CH_3CN (90)	2.5	55
3	$Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)	EtOH (90)	2.5	nr
4	$Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)	toluene (100)	2.5	45
5[c]	**$Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)**	**DCE (90)**	**2.5**	**85**
6	$Ca(OTf)_2/Bu_4NPF_6$ (10/10mol%)	DCE (90)	2.5	85
7	$Ca(OTf)_2/Bu_4NPF_6$ (5/10 mol%)	DCE (90)	3	67
8	$Ca(OTf)_2/KPF_6$ (10/5 mol%)	DCE (90)	6	20
9	TsOH (10 mol%)	DCE (90)	3.5	69
10	$FeCl_3$ (10 mol%)	DCE (90)	10	28

[a]Mixture of **1a** (1 equiv.), **72b** (1.3 equiv.) were used; [b]Isolated yields; [c]Optimum conditions; DCE: 1,2- dichloroethane; rt: room temperature

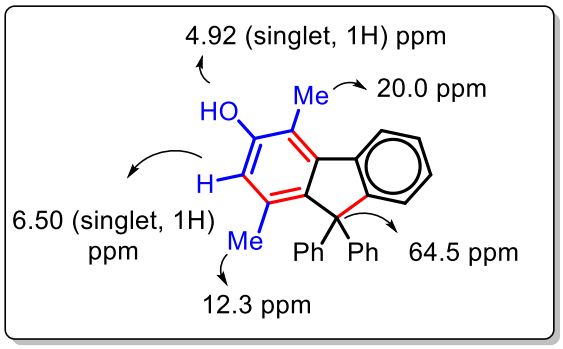
3.3 Optimization Studies

The 9,9-diaryl-9H-fluorenol core structure represents a viable lead for further biological properties study due to its unique structural framework and biological activities connected with these substances. Various research groups have released a few reports on total syntheses and a synthetic strategy in this area.[6-9] Our research group has been working on developing new synthetic methods for annulation reactions for the past few years.[10] Because of the high demand for 9,9-diaryl-9H-fluorenols, we present a single-step benzannulation synthesis of 9,9-diphenyl-9H-fluorenols. The search for tolerable reaction conditions for the synthesis of proposed 9,9-diaryl-9H-fluorenol began with the choice of 3-methylpentane-2,4-dione (**72b**)

and propargyl alcohol (**1a**) as reacting partners in the benzannulation process to produce the synthesis of (114a). **1a** (1 equiv.) and **72b** (1.3 equiv.) were heated directly (neat condition) with $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%)[10-11] at 90 °C, and 9,9-diphenyl-9H-fluorenol **128a** was produced in 47% yield after 3 h, as expected. (entry 1, Table 1). We thought that using a solvent medium would help increase the reaction yield, so we refluxed the reaction in acetonitrile (polar aprotic) for 2.5 h, yielding 55% of **128a**. Next, the solvent was switched to ethanol (polar protic solvent), but there was no reaction in ethanol, but toluene (nonpolar solvent) gave 45% yield of **128a** (entries 2-4, table 1).1,2-dichloroethane as the solvent medium gave 85% yield of **128a** (entry 5, Table 1). Attempts to improve the yield of **128a** by increasing or decreasing the catalyst loadings failed. Alternative catalysts such as TsOH (10 mol%) and $FeCl_3$ (10 mol%) were also investigated, however, both provided moderate to poor yields. (entries 8, 9). Hence entry 5 (Table 1) was the best reaction setting for the synthesis of **128a** (85% yield) from **1a** and **72b** is considered.

3.3a Characterization of Compound 123a

The isolated compound **128a** was fully characterized by ^1H NMR, ^{13}C NMR. The characteristic OH proton has appeared at 4.92 ppm in ^1H NMR spectra, and a quaternary carbon was noticed in ^{13}C NMR spectra shown at 64.5 ppm. These all data were quite identical to reported data of compound **128a**.

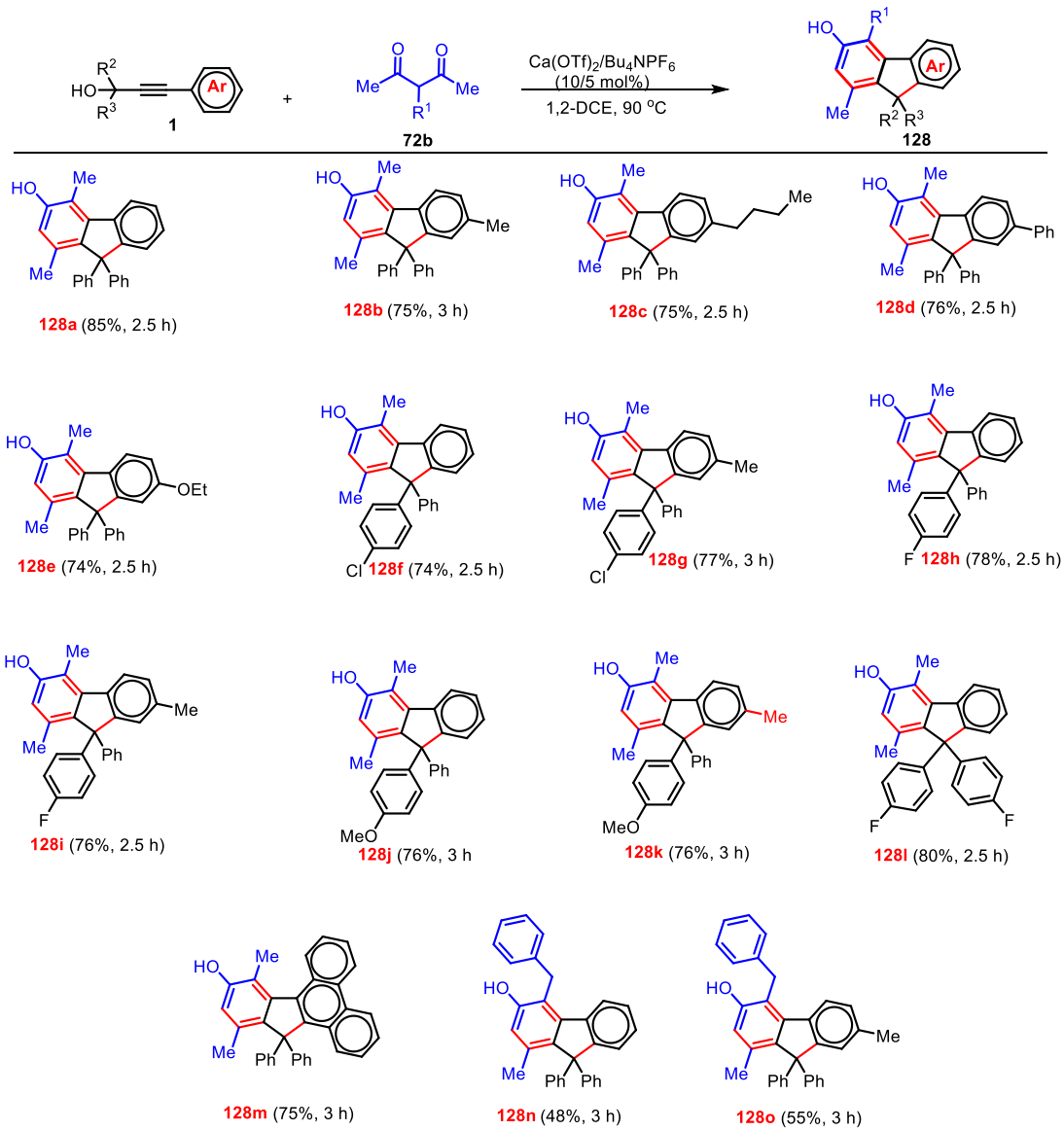


3.3b Scope of the Reaction

We wanted to generalize this approach to examine the feasibility of various substituents on the reactants after determining the best reaction conditions for the synthesis of **128a** (Table 2). As a result, we treated **72b** with a variety of propargyl alcohols (1) with alkyl substitutions on the aryl ring under optimal reaction conditions and got the fluorenols **128b** (7-methyl) and **128c**, (7-butyl) in good yields. Fluorenol **128d** was synthesized with a C7-phenyl substitution and fluorenol **128e** was synthesised with a C7-ethoxy substitution. This approach tolerated

propargylic-phenyl replacements (on substrate 2) and produced high yields of the fluorenols **128f**, **128h**, and **128j** containing *p*-chloro, *p*-fluoro, and *p*-methoxy groups. Fluorenol **128i** was made which is bearing both the phenyl groups with *p*-fluoro substitutions at the quaternary center. Products **128g**, **128i**, **128k** indicate that the protocol offers to have more than one substitution on reactant **1**. Interestingly, when the aryl moiety of propargyl alcohol **1** was taken as phenanthrenyl and it also gave the product **128m** in good yield. Then we decided to modify the methyl substitution on diketone (**72g**), so we made a diketone with a benzyl group[12] on the active methylene carbon (**1b**) and treated it with propargyl alcohols under usual circumstances to get the fluorenols **128n** and **128o** in modest yields (Table 2)

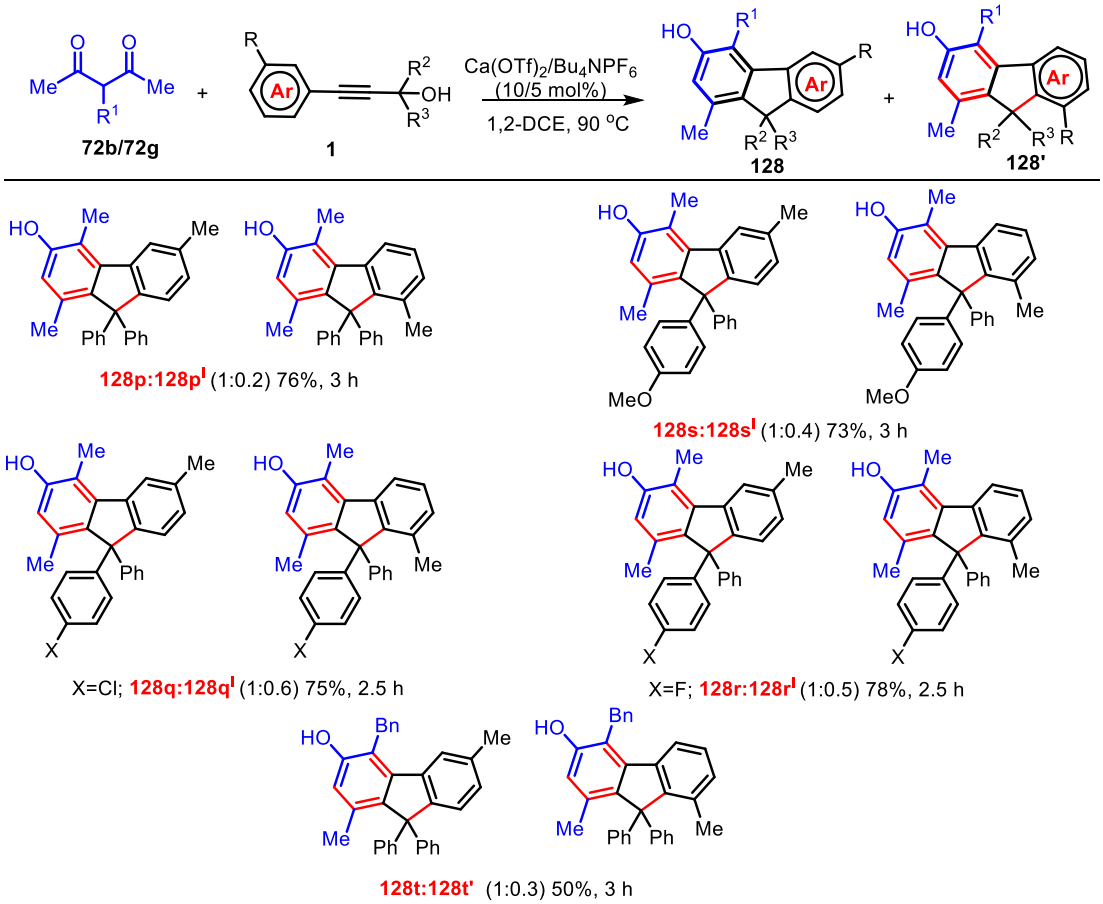
Table 2. Synthesis of 9,9-diphenyl-9*H*-fluorenols through a Ca(II)-catalyzed Intramolecular-Allene-Friedel-Crafts Annulation



All reactions were carried out using alcohol **1a** (0.35 mmol) and 1,3-diketone **72b** (0.45 mmol) under solvent DCE condition.

3.3c The formation of regioisomeric fluorenols

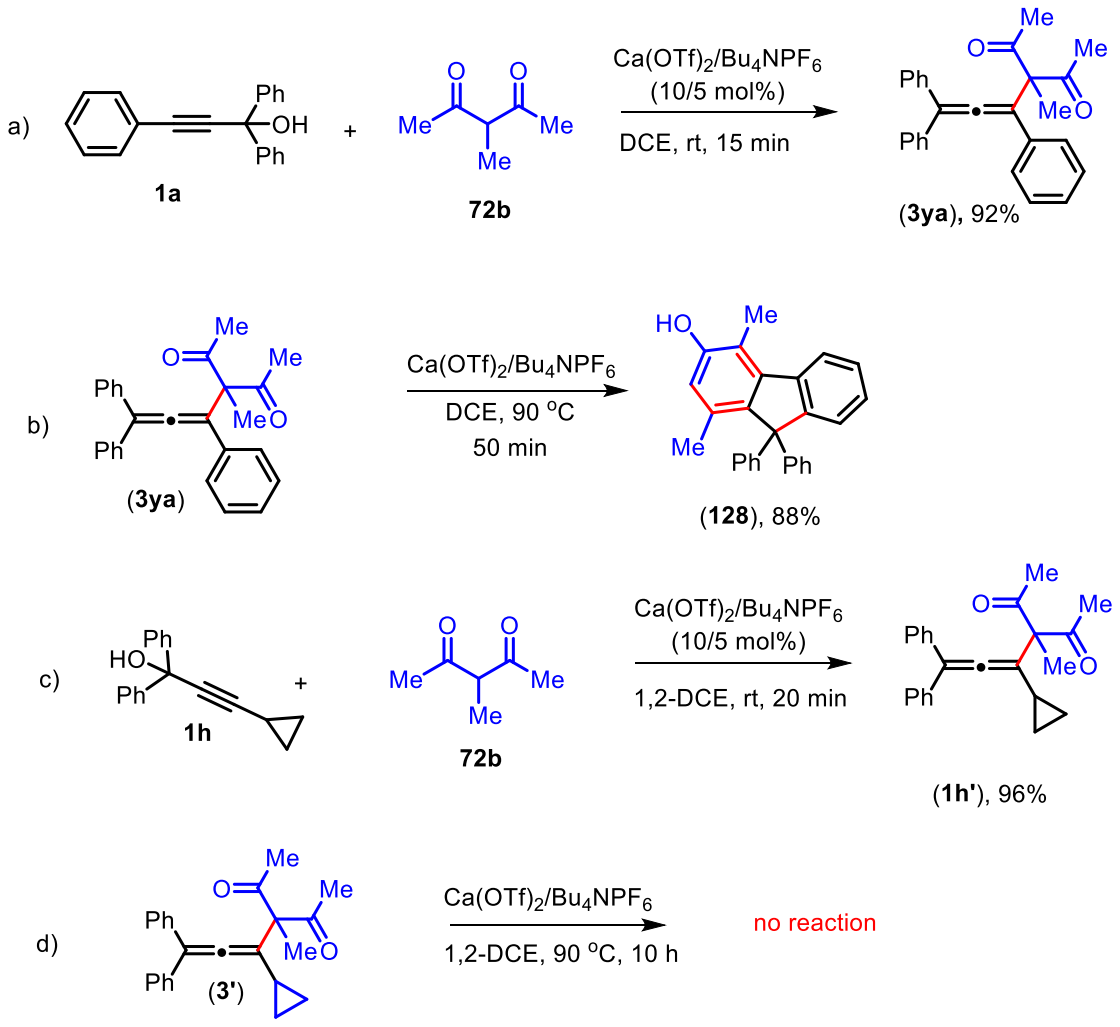
Under the same conditions, we treated **72b** with propargyl alcohol **1** bearing a 3-methyl on the aryl group (*meta* substitution), yielding a combination of two regioisomers **128p:128p^{I}** in a 1:0.2 ratio with a tot d al yield of 76 % (Scheme 3). The reaction also created a mixture of regioisomers **128q**-**128t** with the *meta*-substituted aryl ring of **2**. Careful observation of these annulated products found in Table 2 and Scheme 1 helps explain the reason for the creation of regioisomers. We could have three possibilities for this benzannulation reaction, based on the replacements of the aryl ring because the Friedel–Crafts annulation proceeds through the production of C-C bonds from ortho carbon. (*ortho*, *para*, and *meta*). Consider case-1, the *para*-substituted aryl ring, which has two equivalent ortho carbons, therefore it doesn′t matter which carbon forms the ring, resulting in a single product (Case 1, Table 2), as proven by the synthesis of **128b**-**128e**, **128g**, **128i**, **128k**, and **128o**. On the other hand, when we have an *ortho* substitution on the aryl ring (case 2), there is only one carbon to undergo the IFCA reaction, and hence we got a single product (114m). The third case is a *meta*-substitution on the aryl group of **1** where two reactive carbons (ortho and para with respect alkyl group) are present, resulting in two regio-isomeric products *via* IFCA (**128p**-**128t**, Scheme 3). Of course, steric hindrance can be used to explain why there is unequal isomeric distribution.



Scheme 3. The schematic explanation for the formation of regioisomeric fluorenols

3.3d Control experiments

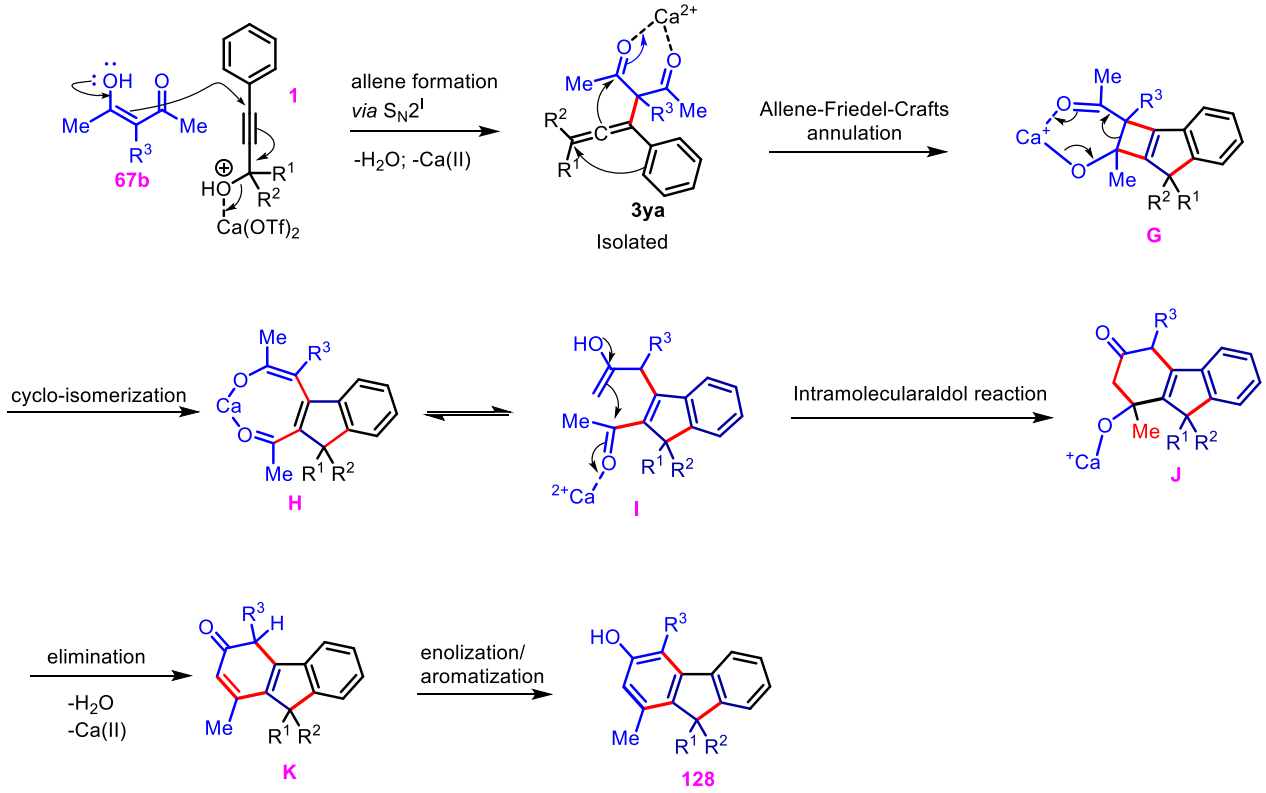
We performed control tests as shown in Scheme 4 to better understand the reaction process. The allene intermediate was produced by refluxing a combination of **1a**, **72b**and Ca(II) in DCE for 15 minutes (**3ya**) in 92% yield (eqn-a). To obtain the target product **128a**, the allene was exposed to conventional reaction conditions (eqn-b). Equations **a** and **b** indicate that fluorenol is formed from an intermediate allene (**3ya**). When 3-cyclopropyl-1,1-diphenylprop-2-yn-1-ol was utilized under conventional reaction conditions, the reaction did not proceed after allene intermediate (no fluorenol generation), confirming the necessity of the phenyl group linked to the alkyne to undergo intramolecular Friedel-Crafts annulation. we proposed the reaction mechanism depicted below based on these observations.



Scheme 4. Control experiments

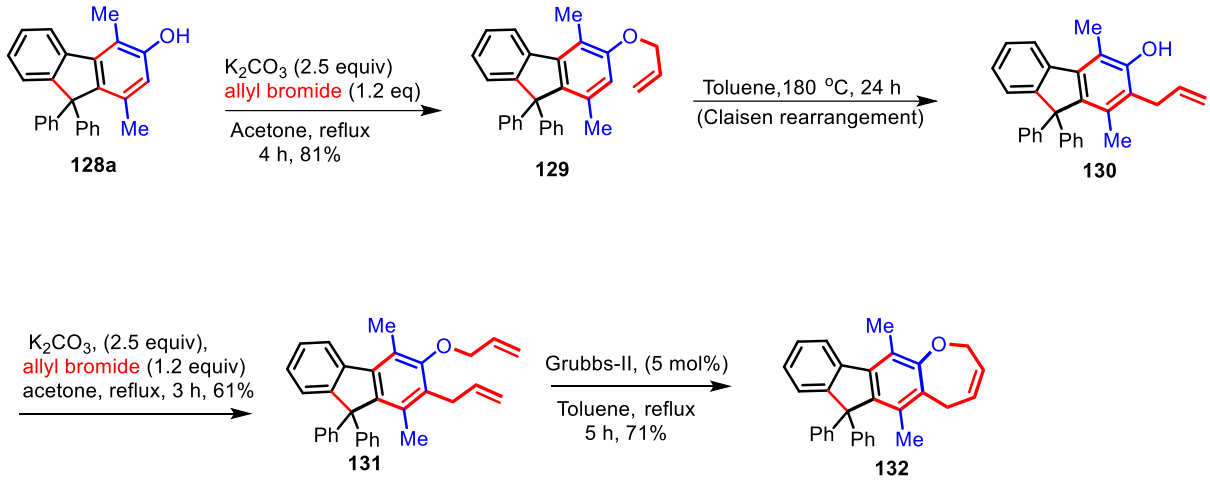
3.4 Reaction Mechanism

The reaction mechanism is depicted in Schematic Diagram 4 below. Through the S_N2' mechanism, a Ca(II) connected *tert*-propargyl alcohol **1** interacts with the nucleophilic diketone **72b** to produce the allenyl ketone **3ya**, which then undergoes an intramolecular Friedel-Crafts annulation (IFCA) to form the tricyclic molecule **G**. Strained cyclobutene **G** cycloisomerizes to create keto-enol **H**, which then goes through an intramolecular aldol annulation to give tricyclic-hydroxy ketone **J**. The fluorenol **128** is obtained by removing the aldol adduct and then aromatizing it



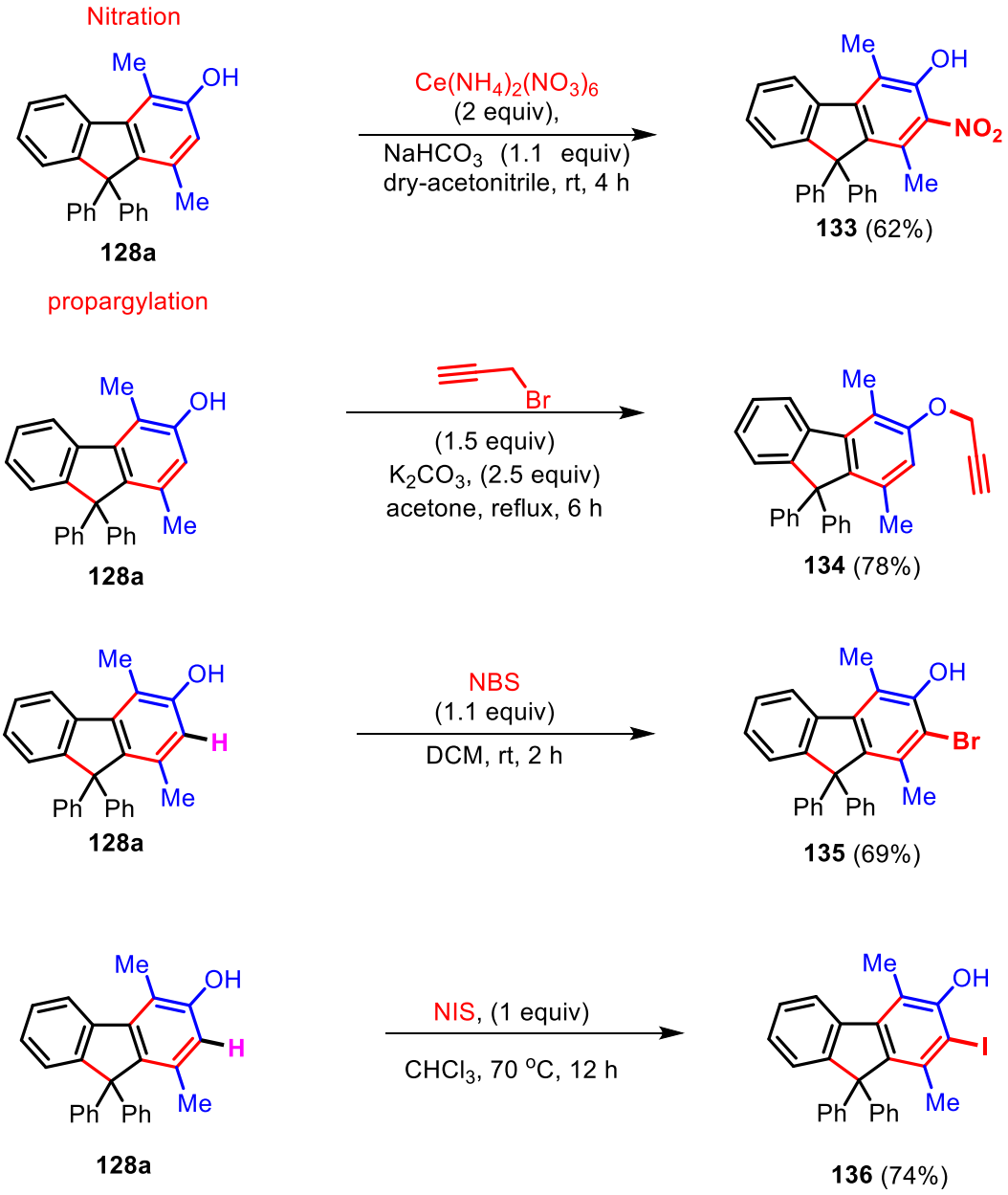
Scheme 5. Proposed reaction mechanism for the Ca(II) catalyzed annulation of fluorenol.

Furthermore, we have focused on important fluorenol synthetic transformations, for which we chose **128a** as the precursor. First, **128a** was o-allylated with allyl bromide and K_2CO_3 to give olefin **129**, and the *ortho*-allylation of **130** was obtained by a Claisen rearrangement at 180 ^oC, and the crude product was further allylated to provide a diene intermediate.[13] **131**. Ring-closing metathesis (RCM) of diene **131** with Grubbs 2nd generation catalyst gave the benzoxepine[14] fused indene **132** in 71% yield (Scheme 5).

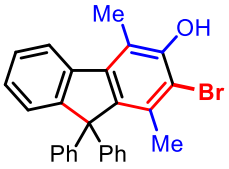


Scheme 6. Synthesis of flrouenoxepine

Fluorenol **128a** was also *o*-nitro-fluorenol **133** was obtained in 62 % yield, by *o*-nitration with ceric ammonium nitrate; it's worth noting that the aryl ring is now entirely substituted in 73. Propargylation of **128a** with propargyl bromide and K_2CO_3 yielded 78 % of **134**. (Scheme 6). Then, on **128a**, we developed a reaction sequence that included bromination followed by Heck and Sonogashira cross-coupling reactions. Next, we performed **128a** was brominated with NBS and *o*-bromo phenol **135** was produced in a 69 % yield. We tried a Heck coupling with ethyl acrylate subsequently being encouraged by this outcome. We were disappointed to discover that the reaction did not progress, so we tried a Sonogashira coupling with phenyl acetylene, which also failed. As a result, we used NIS to try to install an *ortho*-iodide functionality on **128a** and obtained *o*-iodophenol **136** in a 74 % yield. Under Heck and Sonogashira conditions, however, the cross-coupling reactions of iodide **136** likewise failed to react (Scheme 6).



Scheme 7. Synthetic transformation of fluorenol

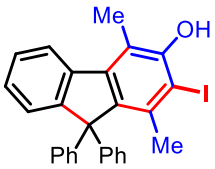


135 (69%)

1) Ethylacrylate, (2.5 equiv.)
$Pd(OAC)_2$, (5 mol%)
K_2CO_3/Bu_4NBr, (2.5 eq/ 1 equiv.)
DMF, 80 °C, 22 h, 76%

2) Phenylacetylene, (2 equiv.)
$Pd(OAc)_2$, (5 mol%)
DABCO, (3 equiv.)
CH_3CN, rt, 12 h, 61%

no reaction



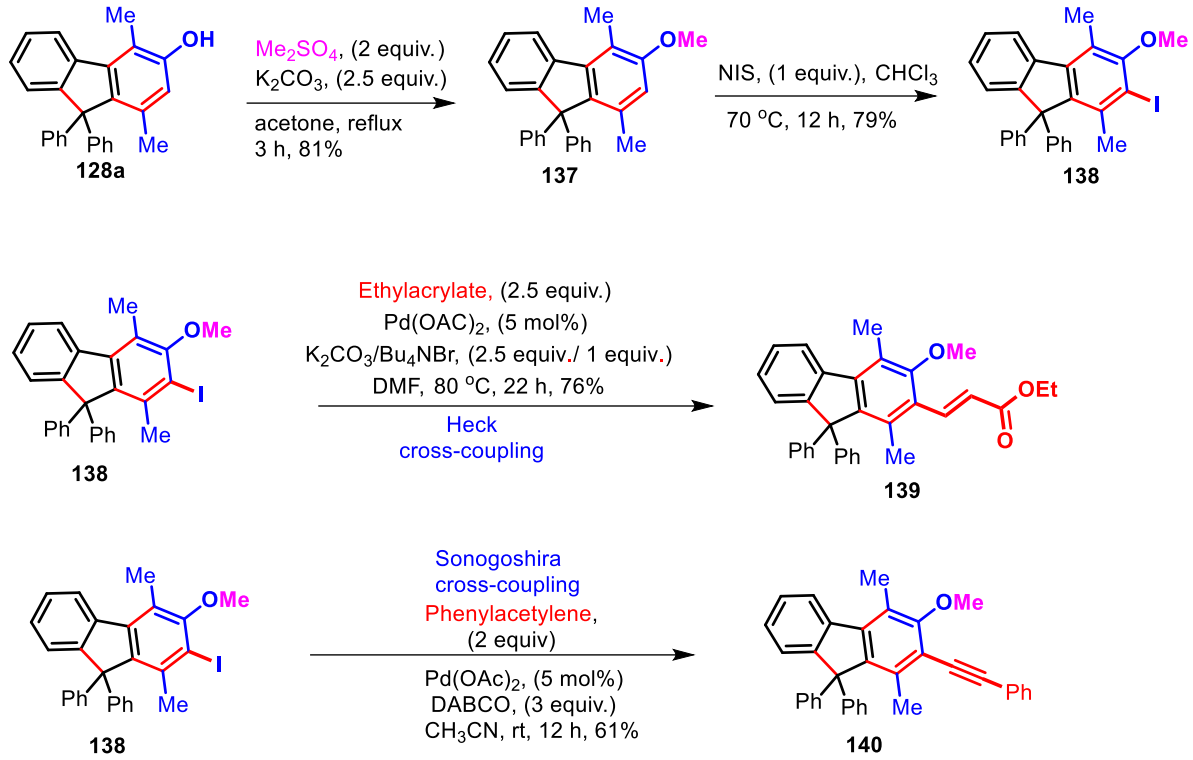
136 (74%)

1) Ethylacrylate, (2.5 equiv.)
$Pd(OAC)_2$, (5 mol%)
K_2CO_3/Bu_4NBr, (2.5 equiv./ 1 equiv.)
DMF, 80 °C, 22 h, 76%

2) Phenylacetylene, (2 equiv.)
$Pd(OAc)_2$, (5 mol%)
DABCO, (3 equiv.)
CH_3CN, rt, 12 h, 61%

no reaction

We speculated that the free hydroxyl group of **128a** was preventing the cross-coupling reaction, so we produced a methyl ether of **128a** by treating it with dimethyl sulfate (**137**),[15] and then iodinating it with NIS, yielding iodide **138**[15] in good yield. the iodide compound **133** completed a smooth cross-coupling reaction under Heck conditions, yielding the desired product **139**[16] in 76 % of the time, Sonogashira coupling of **138** with phenylacetylene was also successfully yielded **140** (Scheme 7),[17] thus our speculation was proved to be correct.



Scheme 8. Coupling reactions of **138**

3.5 CONCLUSIONS

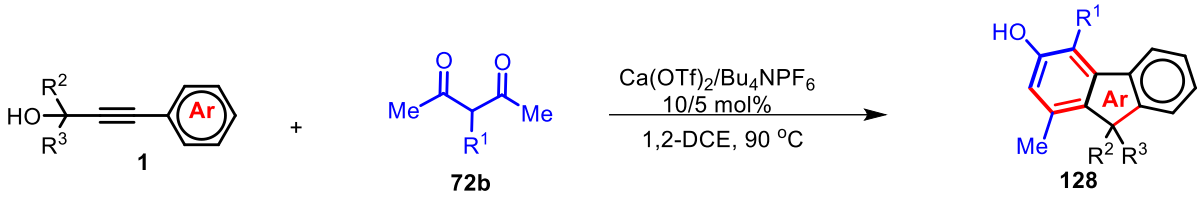
We established a one-pot benzannulation approach for the making of ideal structure 9,9-diphenyl-9H-fluorenols from basic starting materials. In addition, this approach allows you to make tetracyclic allenes. The reaction was catalyzed by the environmentally benign catalyst $Ca(OTf)_2$ and provided good to excellent yields of the products. Fluorenols have undergone synthetic transformations such as nitration, propargylation, iodination, and fluorenoxepine synthesis.

EXPERIMENTAL SECTION

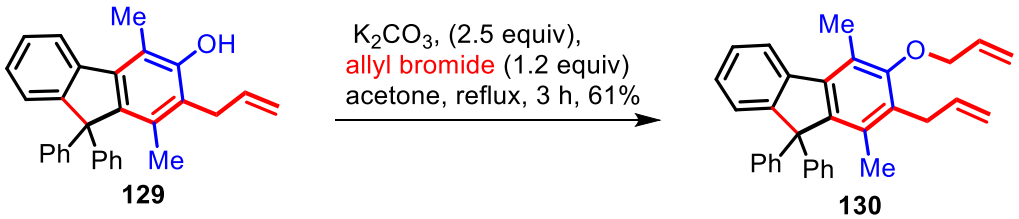
3.6.1 General information: Unless otherwise noted, all reagents were used as received from commercial suppliers. $Ca(OTf)_2$ and Bu_4NPF_6 were obtained from Sigma-Aldrich and used without further purification. Reactions were performed in flame-dried or oven-dried glassware with magnetic stirring. Reactions were monitored using thin-layer chromatography (TLC) with aluminum sheets silica gel 60 F_{254} from Merck. TLC plates were visualized with UV light (254 nm), and iodine treatment. Column chromatography was carried out using silica gel 60-120 mesh as the stationary phase. NMR spectra were recorded at 500 MHz and 400 MHz (H) and 125 MHz and 100 MHz (C), respectively on the Avance Bruker spectrometer. Chemical shifts (δ) are reported in ppm, using the residual solvent peak in $CDCl_3$ (H: δ = 7.26

and C: δ = 77.0 ppm) as an internal standard, and coupling constants (J) are given in Hz. Melting points were measured with LAB INDIA mepa melting apparatus.

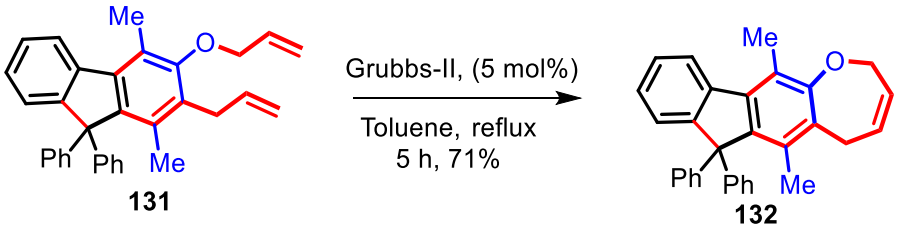
3.6.2 General experimental procedure for the synthesis of 1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol(128a): To a mixture of **1** (0.35 mmol) and 1,3-dicarbonyl compound **67b** (0.45 mmol) in DCE (2 mL), Ca(OTf) $_2$/Bu$_4$ NPF$_6$ (10/5 mol%) was added. The reaction was stirred at 90 ^{o}C, and the completion of the reaction was monitored by TLC. After completion of the reaction, the solvent was removed under reduced pressure, and the residue was purified by silica gel column chromatography using EA/PE (10:90, v/v) to obtain the desired product **128a** in 85% yield.



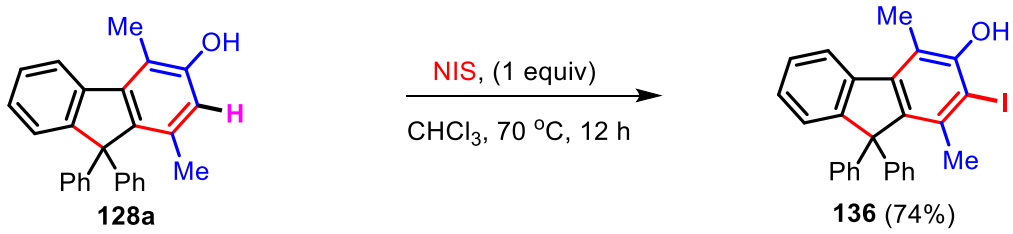
3.6.4 General Experimental Procedure for the Synthesis of 2-Allyl-3-(allyloxy)-1,4-dimethyl-9,9-diphenyl-9H-fluorene (130): To a stirring solution of 1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (100 mg, 0.27 mmol) in anhydrous acetone (5.0 mL) were added K_2CO_3 (87 mg, 0.633 mmol) and allyl bromide (26 µL, 0.33 mmol), the resulting reaction mixture was heated at 80 °C for 3 h. After completion of the reaction, it was filtered through a short plug of Celite, and the filtrate was concentrated under reduced pressure to give a crude compound which was purified by silica gel column chromatography to afford the allyl ether. The above-obtained allyl ether was dissolved in toluene (2 mL) and placed in a sealed pressure tube and heated at 180 °C for 24 h. The reaction mixture was directly purified by silica gel column chromatography to afford the rearranged allyl compound.



3.6.5 General Experimental Procedure for the Synthesis of 6,12-Dimethyl-7,7-diphenyl-5,7-dihydro-2*H*-fluoreno[3,2-*b*]oxepine(132): 2-allyl-3-(allyloxy)-1,4-dimethyl-9,9-diphenyl-9*H*-fluorene (**71**,100 mg, 0.22 mmol) was dissolved in dry toluene (4 mL) and heated to reflux before adding II generation Grubbs catalyst (9 mg, 5 mol-%). The reaction was stirred at 100 °C for 6 h. After completion of the reaction, it was cooled to room temperature, and passed through a silica gel (20 % EtOAc/hexanes) and concentrated. The residual oil was further purified by flash chromatography (silica gel, gradient elution, 3–4 % EtOAc/hexanes) to afford the desired product **132** in 71 % yield.

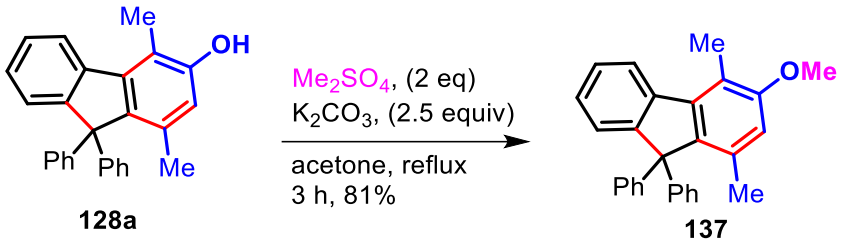


3.6.6 General Experimental Procedure for the Synthesis of 2-Iodo- 1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (136): To a solution of compound 1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (100 mg, 0.27 mmol) in $CHCl_3$ (6 mL) was added catalytic TsOH followed by the addition of N-iodosuccinimide (61 mg, 0.22 mmol). The reaction mixture was heated at 55 °C for 16 h. After completion of the reaction, the reaction mixture was quenched with saturated aqueous $NaHCO_3$ (25 mL) and extracted with CH_2Cl_2 (20 mL × 3). The collected organic fractions were dried with anhydrous Na_2SO_4 and concentrated under a vacuum to afford a white solid compound which was forwarded to the next step without further purification and characterization.

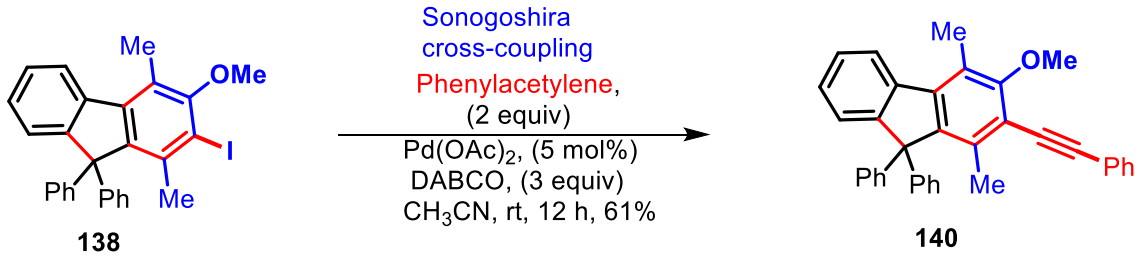


3.6.7 General Experimental Procedure for the Synthesis of 3-Methoxy- 1,4-dimethyl-9,9-diphenyl-9H-fluorene (137): To a stirring solution of 1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (100 mg, 0.27 mmol) in anhydrous acetone (10.0 mL) were added K_2CO_3 (76.0 mg, 0.55 mmol) and Me_2SO_4 (58 µL, 0.55 mmol). The resulting reaction mixture was heated at 80 °C for 3 h. After completion of the reaction, it was filtered through a short plug of

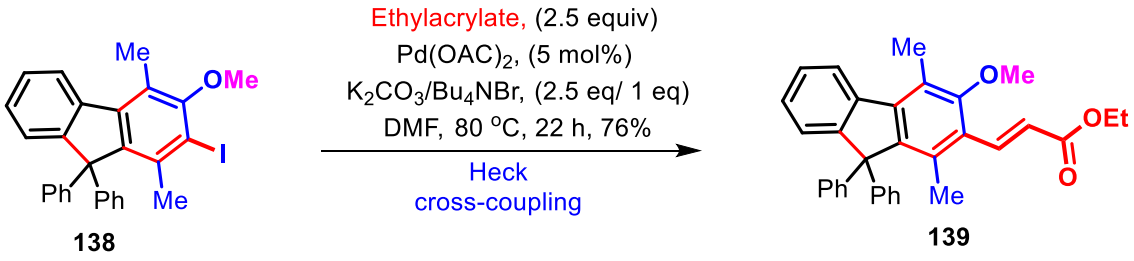
celite, and the filtrate was concentrated in rotavapor and purified by silica gel column chromatography to afford the methoxy-protected compound as a white solid.



3.6.8 Experimental procedure for Sonogashira cross-coupling of 138 to 140: $Pd(OAc)_2$ (2 mol%) was dissolved in MeCN (1 mL), and was added to a mixture of phenylacetylene (45 mg, 0.45 mmol), **9** (100 mg, 0.19 mmol), DABCO (3 equiv.), and MeCN (4 mL). Then the mixture was stirred under N_2 at room temperature for 12 h. The resulting mixture was filtered off, washed andthe filtrate was extracted with diethyl ether. The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure, and the residue was purified by column chromatography (2–4%, EtOAc in pet ether) with silica gel to give product **140** in 61% yield.



3.6.9 Experimental procedure for Heck reaction of 138 to 139: Ethyl acrylate (49.8 mg, 0.49 mmol), was added to a solution of (100 mg, 0.19 mmol) in DMF (1.8 mL) containing K_2CO_3 (2.5 equiv.) and Bu_4NBr (1 equiv.) and stirred at room temperature for 5 min. $Pd(OAc)_2$ (5 mol %) was then added, and the flask was flushed with N_2, sealed, and allowed to stir at 80 ^oC for 22 h. The resulting mixture was filtered off, and washed and the filtrate was extracted with diethyl ether. The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure, and the residue was purified by column chromatography (6–8%, EtOAc in pet ether) with silica gel to give product in 76% yield.



3.7 SPECTRAL DATA

1,4-Dimethyl-9,9-diphenyl-9H-fluoren-3-ol (128a) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 108 mg (85%); mp 205-206 °C. 1H NMR (CDCl3, 500 MHz): δ = 7.97 (d, J =8 Hz, 1H), 7.38 (d, J =7.5 Hz, 1H), 7.32–7.24(m, 5H), 7.23-7.20 (m, 7H), 6.50 (s, 1H), 4.92 (s, 1H), 2.69 (s, 3H), 1.89 (s, 3H) ppm. ^{13}C NMR (125 MHz, CDCl3): *δ* = 155.7, 153.4, 142.7, 142.4, 141.0,140.5, 133.8, 129.1, 127.9, 127.3, 127.1, 126.4, 125.4, 123.2, 116.9, 64.5, 20.0, 12.3 ppm. IR (film): ν˜*max* = 3524, 3022, 2923, 1589, 1491,1298, 1246, 1183, 1073, 912 cm–1. HRMS (ESI-TOF): *m*/*z* calcd.. For $C_{27}H_{22}O$ $[M+H]^+$:363.1751, found 363.1750.

1,4,7-Trimethyl-9,9-diphenyl-9H-fluoren-3-ol (128b) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 93 mg (75%); mp 252-254 °C. ^{1}H NMR (CDCl3, 500 MHz): *δ* =7.80 (d, *J* =8 Hz, 1H), 7.28–7.24 (m, 4H), 7.22–7.17 (m, 8H), 7.13–7.08 (m, 2H), 6.43 (s, 1H), 4.73 (s, 1H), 2.62 (s, 3H), 2.26 (s, 3H), 1.82 (s, 3H) ppm. ^{13}C NMR (125 MHz, CDCl3): *δ*=155.9, 153.4, 142.9, 142.4,140.1, 138.5, 137.2, 133.7, 129.2, 128.1, 127.9, 126.4, 126.1, 122.9, 116.7, 116.4, 64.4, 21.7, 19.9, 12.3 ppm. IR (film): ν˜*max* = 3531, 2921, 2851, 1736, 1587, 1446, 1309, 850 cm–1. (LCMS): *m*/*z* $[M + H]^+$: 377.

7-butyl-1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (128c) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 92 mg (75%); mp 248-249 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.81 (d, *J*=7.0 Hz, 1H), 7.25 (m, 5H), 7.18 (m, 5H), 7.11 (m, 2H), 6.44 (s, 1H), 4.68 (s, 1H), 2.62 (s, 3H),2.52 (t, *J*=8.0 Hz, 2H), 1.83 (s, 3H), 1.48 (m, 2H), 1.25 (m, 2H), 0.85 (t, *J*=7.0 Hz, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 155.9, 153.4, 143.0, 142.4, 142.3, 140.7, 138.6, 133.8, 129.2, 127.9, 127.3, 126.4, 125.6, 122.9, 116.7, 116.4,

64.5, 35.8, 33.7, 22.4, 20.0, 14.0, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{31}H_{30}O[M+H]^+$:419.5772, found: 419.5769.

1,4-dimethyl-7,9,9-triphenyl-9H-fluoren-3-ol(128d) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 92 mg (76%); mp 250-251 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.98 (d, *J*=6.5 Hz, 1H), 7.49 (m, 4H), 7.37 (t, *J*=7.5 Hz, 2H), 7.30 (m, 5H), 7.23 (m, 6H), 6.48 (s, 1H), 4.73 (s, 1H), 2.67 (s, 3H), 1.86 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): 156.5, 142.8, 142.7, 141.3, 140.3, 140.2, 133.9, 129.2, 128.8, 128.0, 127.3, 127.2, 126.5, 126.2, 124.2, 123.4, 117.1, 117, 64.7, 20, 12.4 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{33}H_{26}O$ $[M+H]^+$:439.2064, found: 439.2060.

7-ethoxy-1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol(128e) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 91 mg (74%); mp 246-247 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.81 (d, *J*=8.5 Hz, 1H), 7.26 (d, *J*=7.5 Hz, 5H),7.19 (m, 5H), 6.83 (m, 2H), 6.40 (s, 1H), 4.72 (s, 1H), 3.94 (m, 2H), 2.60 (s, 3H), 1.82 (s, 3H) 1.32 (t, *J*=7.0 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): 158.7, 157.6, 153.4, 142.9, 142.1, 140.5, 134.0, 129.2, 128.0, 126.4, 123.9, 116.1, 115.8, 113.1, 112.1, 64.5, 63.6, 20.0, 14.9, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for$C_{29}H_{26}O_2[M+H]^+$: 407.2013, found: 407.2010.

9-(4-chlorophenyl)-1,4-dimethyl-9-phenyl-9H-fluoren-3-ol(128f) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 92 mg (74%); mp 179-180 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.92 (d, *J*=7.5 Hz, 1H), 7.30 (t, *J*=7.5 Hz, 2H), 7.20 (m, 10H), 6.47 (s, 1H), 4.75 (s, 1H), 2.64 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$,125 MHz): 155.3, 153.6, 142.2, 142.1, 141.5, 141.0, 133.7, 132.3, 130.6, 129.0, 127.5, 127.3, 126.3, 126.7, 125.3, 117.4, 117.0, 64.1, 20.0, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{27}H_{21}ClO$ $[M+H]^+$: 397.1361,found: 397.1362.

9-(4-chlorophenyl)-1,4,7-trimethyl-9-phenyl-9H-fluoren-3-ol(128g) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 95 mg (77%); mp 180-181 °C.

^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.79 (d, *J*=6.5 Hz, 1H), 7.20 (m, 9H), 7.09 (d, *J*=9.0 Hz, 2H), 6.42 (s, 1H), 4.81 (s, 1H), 2.60 (s, 3H), 2.26 (s, 3H), 1.81 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): 155.5, 153.6, 142.4, 142.0, 141.7, 140.6, 138.4, 137.4, 133.6, 132.2, 130.6, 129.0, 128.2, 128.0, 126.6, 126.0, 123.0, 117.0, 116.6, 64, 21.7, 20, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{28}H_{23}ClO$ $[M+Na]^+$: 433.1334,found: 433.1333.

9-(4-fluorophenyl)-1,4-dimethyl-9-phenyl-9H-fluoren-3-ol(128h) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 98 mg (78%); mp 193-194 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.92 (d, *J* = 7.5 Hz, 1H), 7.24 (t, *J* = 2 Hz, 2H), 7.24-7.15 (m, 8H), 6.88 (t, *J* = 9 Hz, 2H), 6.46 (s, 1H), 4.83 (s, 1H) 2.63 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 162.5, 160.6, 155.6, 153.5, 142.5, 140.5, 140.4, 138.5, 138.5, 133.7, 130.7, 130.7, 129.1, 128.1, 127.4, 127.2, 126.6, 125.3, 123.3, 117.3, 117.1, 114.8, 114.6, 63.9, 19.9, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{27}H_{21}FO$ $[M+H]^+$:381.1656,found: 381.1655.

9-(4-fluorophenyl)-1,4,7-trimethyl-9-phenyl-9H-fluoren-3-ol(128i) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 94 mg (76%); mp 202-203 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.79 (d, *J*=7.0 Hz, 1H), 7.23 (m, 5H), 7.18 (m, 2H), 7.00 (d, *J*=5 Hz, 2H), 6.88 (m, 2H), 6.42 (s, 1H), 4.78 (s, 1H), 2.61 (s, 3H), 2.26 (s, 3H), 1.81 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 162.5, 160.6, 155.8, 153.5, 142.7, 142.2, 140.5, 138.7, 138.6, 138.3, 137.3, 133.6, 130.8, 130.7, 129.0, 128.2, 128.0, 126.5, 126.0, 123.0, 116.9, 116.5, 114.7, 114.6, 63.8, 21.7, 19.9, 12.3 ppm. (LCMS): *m/z* $[M+H]^+$: 395.

9-(4-methoxyphenyl)-1,4-dimethyl-9-phenyl-9H-fluoren-3-ol(128j) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 94 mg (76%); mp 208-209 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.90 (d, *J*=7.5 Hz, 1H), 7.27 (m, 4H), 7.18 (m, 6H), 6.75 (m,2H), 6.46 (s, 1H), 4.82 (s, 1H), 3.74 (s, 3H), 2.63 (s, 3H), 1.84 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$,125 MHz): δ 158.1, 156.0, 153.4, 143.0, 142.6, 140.9, 140.4, 134.5, 133.7, 130.2, 129.0, 127.9, 127.3, 127.0, 126.4, 125.3, 123.2, 117.1, 117.0, 63.9, 55.3, 20.0, 12.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{28}H_{24}O_2$ $[M+H]^+$: 393.1856,found: 393.1858.

9-(4-methoxyphenyl)-1,4,7-trimethyl-9-phenyl-9H-fluoren-3-ol(128k) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 92 mg (75%); mp 210-211 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.82 (d, *J*=8.0 Hz, 1H), 7.51 (m, 1H), 7.20 (m, 11H), 6.78 (m, 2H), 6.46 (s, 1H), 4.77 (s, 1H),3.78 (s, 3H), 2.64 (s, 3H), 2.30 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 158.1, 156.2, 153.4, 143.2, 142.6, 140.5, 138.3, 137.2, 134.8, 133.7, 130.3, 129.1, 128.8, 128.7, 127.9, 126.3, 126.0, 124.4, 123.0, 119.8, 116.7, 116.4, 114.9, 113.2, 63.7, 55.3, 21.7, 12.3, 10.9 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{29}H_{26}O_2[M+H]^+$: 407.2013,found:407.2013.

9,9-bis(4-fluorophenyl)-1,4-dimethyl-9H-fluoren-3-ol (128l) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 99 mg (80%); mp 236-237 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.93 (d, *J* =7.5 Hz, 1H), 7.31-7.25 (m, 3H), 7.21-7.19 (m, 5H), 6.91-6.87 (m, 3H), 6.49 (s, 1H), 4.77 (s, 1H), 2.64 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 162.8, 161.7, 155.4, 153.6, 142.1, 140.8, 140.3, 138.2, 133.5, 130.6, 130.5, 127.5, 127.4, 125.2, 123.4, 117.4, 117.1, 114.9, 114.7, 63.3, 20.1, 12.3 1 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{27}H_{20}F_2O$ $[M+H]^+$: 399. 4518, found: 399. 4516

9,12-dimethyl-13,13-diphenyl-13H-indeno[1,2-l]phenanthren-10-ol (128m) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 90 mg (75%); mp 237-238 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.68-8.33 (m, 3H), 7.67-7.57 (m, 7H), 7.39-7.18 (m, 8H), 6.54 (s, 1H), 4.93 (s, 1H), 2.59 (s, 3H), 2.07 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 154.8, 149.5, 145.4, 140.4, 135.7, 132.8, 131.6, 131.5, 129.7, 128.4, 128.1, 127.7, 126.9, 126.7, 126.1, 126.1, 126.1, 125.7, 125.2, 123.3, 123.3, 123.1, 116.1, 60.5, 19.9, 17.2 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{35}H_{26}O$ $[M+H]^+$: 463.2064, found: 463.2063.

4-Benzyl-1-methyl-9,9-diphenyl-9H-fluoren-3-ol (128n) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 74 mg (48%); mp 150-152 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): *δ* = 7.24–7.20 (m, 7H), 7.18–7.12 (m, 10H), 7.05–6.93 (m, 3H), 6.46 (s, 1H), 4.79 (s, 1H), 4.49 (s, 2H), 3.20 (s, 3H) ppm. ^{13}C NMR (125 MHz, CDCl3): *δ* = 155.8,154.2, 142.8, 142.6, 140.9, 140.2, 139.2, 136.2, 135.1, 129.8, 129.7, 129.1, 129.1, 128.8, 128.6, 128.4,

128.2, 128.1, 127.6, 127.3, 127.1, 126.5, 125.4, 123.9, 119.2, 117.4, 64.5, 37.5, 28.5 ppm. IR (film): $\tilde{\nu}_{max}$ = 3523, 3021, 2924, 1590, 1489, 1378, 1225, 1136, 868 cm–1. (LCMS): *m*/*z* [M + H]$^+$: 439.

4-benzyl-1,7-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (128o) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 83 mg (55%); mp 137-138 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.56 (d, *J* = 8 Hz, 1H), 7.31 (d, *J* = 1.6 Hz, 1H) 7.29 (t, *J* = 8 Hz, 2H), 7.27-7.25 (m, 4H), 7.23-7.19 (m, 8H), 7.11 (s, 1H), 6.94 (t, *J* = 8 Hz, 1H), 6.48 (s, 1H), 4.72 (s, 1H), 4.54 (s, 2H), 2.20 (s, 3H), 1.87 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 154.2, 142.8, 141.1, 139.3, 137.5, 137.5, 135.1, 129.2, 128.8, 128.2, 128.2, 128.1, 126.4, 126.2, 126.1, 122.7, 118.8, 116.9, 64.3, 31.7, 21.6, 20.1 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{34}H_{28}O$ [M+H]$^+$: 453. 2218, found:453. 2218.

1,4,6-trimethyl-9,9-diphenyl-9H-fluoren-3-ol(128p) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 95 mg (76%); mp 140-143 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.73 (s, 1H), 7.25 (m, 3H), 7.18 (m, 8H), 6.99 (d, *J*=8.0 Hz, 1H), 6.46 (s, 1H), 4.70 (s, 1H), 2.65 (s, 3H), 2.39 (s, 3H), 1.84 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 153.4, 153.1, 143.0, 141.2, 140.6, 136.6, 133.8, 129.3, 129.1, 128.3, 127.9, 127.8, 126.4, 125.1, 123.9, 117.1, 116.8, 64.2, 21.8, 20.0, 12.4 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{28}H_{24}O$ [M+H]$^+$: 377.1827,found:377.1828.

9-(4-chlorophenyl)-1,4,6-trimethyl-9-phenyl-9H-fluoren-3-ol(128q) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 92 mg (75%); mp 161-164 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.73 (s, 1H), 7.22 (m, 3H), 7.19 (m, 6H), 7.16 (m, 1H), 7.00 (m, 1H), 6.47 (s, 1H), 4.72 (s, 1H), 2.64 (s, 3H), 2.40 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 153.6, 152.7, 142.5, 142.4, 141.7, 141.1, 140.6, 136.9, 133.7, 132.2, 130.7, 129.0, 128.4, 128.0, 127.9, 126.6, 125.0, 124.0, 117.3, 117.0, 63.7, 21.8, 20.0, 12.4 ppm. (LCMS): *m/z* [M+H]$^+$: 411.

9-(4-fluorophenyl)-1,4,6-trimethyl-9-phenyl-9H-fluoren-3-ol(128r) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 97 mg (78%); mp 177-179 °C. ^{1}H NMR

($CDCl_3$, 500 MHz): δ 7.73 (s, 1H), 7.20 (m, 9H), 6.99 (d, *J*=7.0 Hz, 1H),6.87 (d, *J*=6.5 Hz, 1H), 6.45 (s, 1H), 4.80 (s, 1H), 2.64 (s, 3H), 2.39 (s, 3H), 1.82 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.5, 142.8, 142.7, 141.3, 140.3, 140.2, 133.9, 129.2, 128.8, 128.0, 127.3, 127.2, 126.5, 126.2, 124.2, 123.4, 117.1, 117.0, 64.7, 20.0, 12.4 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{28}H_{23}FO$ $[M+H]^+$: 395.1813,found:395.1813.

9-(4-methoxyphenyl)-1,4,6-trimethyl-9-phenyl-9H-fluoren-3-ol(128s) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 90 mg (73%); mp 137-138 °C. ^1H NMR ($CDCl_3$, 500 MHz): δ 7.26-7.24 (m, 3H), 7.22-7.14 (m, 6H), 6.99-6.97 (m, 1H), 6.75-6.73 (m, 2H), 6.43 (s, 1H), 4.90 (s, 1H), 3.73 (s, 3H), 2.63 (s, 3H), 2.38 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 158.1, 153.3, 153.3, 143.2, 142.9, 141.1, 140.4, 136.5, 134.8, 133.7, 130.3, 130.2, 129.1, 129.1, 128.2, 127.9, 127.7, 126.3, 124.9, 123.9, 117.1, 116.7, 113.2, 113.1, 63.5, 53.3, 21.8, 19.9, 12.4 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{29}H_{26}O_2$ $[M+H]^+$: 407. 2013, found:407. 2015.

4-benzyl-1,6-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (128t) Following general experimental procedure 3.6.2 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 76 mg (50%); mp 188-190 °C. ^1H NMR ($CDCl_3$, 500 MHz): δ 7.43-7.41 (m, 1H), 7.32-7.30 (m, 7H), 7.27-7.20 (m, 9H), 7.05-7.03 (m, 1H), 6.55 (s, 1H), 4.83 (s, 1H), 4.58 (s, 2H), 3.30 (s, 3H), 2.25 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 155.8, 154.2, 142.9, 142.6, 141.1, 140.2, 139.2, 135.2, 129.8, 129.1, 128.8, 128.6, 128.2, 128.1, 127.6, 127.3, 126.5, 126.3, 125.4, 123.1, 119.2, 117.4, 64.5, 37.5, 31.7, 20.1 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{34}H_{28}O$ $[M+H]^+$: 453. 2218, found:453. 2218.

3-(allyloxy)-1,4-dimethyl-9,9-diphenyl-9H-fluorene (129) Following general experimental procedure then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether) the product was obtained as yellow sticky compound 87 mg (79%). ^1H NMR ($CDCl_3$, 500 MHz): δ 7.34-7.29 (m, 3H), 7.27-7.25 (m, 4H), 7.22-7.15 (m, 7H), 6.55 (s, 1H), 6.15-6.09 (m, 1H), 5.49-5.47 (m, 1H), 5.30-5.28 (m, 1H), 4.56-4.55 (m, 2H), 2.67 (s, 3H), 1.90 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.6, 155.7, 142.8, 142.3, 141.2, 140.2, 134.1, 133.4, 129.2, 127.9, 127.3, 127.1, 126.4, 125.5, 123.4, 120.1, 117.1, 114.1, 69.8, 64.6, 20.4, 12.4 ppm. (LCMS): *m/z* $[M+H]^+$:403.

2-allyl-3-(allyloxy)-1,4-dimethyl-9,9-diphenyl-9H-fluorene(131) Following general experimental procedure 3.6.4 then purified by flash chromatography (silica gel, 7-9%, EtOAc in pet ether)) the product was obtained as White solid 66 mg (61%); mp 226-228 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.88 (d, *J* = 7.6 Hz, 1H), 7.33-7.28 (m, 4H), 7.27-7.21 (m, 5H), 7.20-7.14 (m, 4H), 6.18-6.11 (m, 2H), 5.96-5.89 (m, 1H), 5.51-5.47 (m, 1H), 5.30-5.27 (m, 1H), 4.97-4.94 (m, 1H), 4.93-4.78 (m, 1H), 4.33 (d, *J* = 5.2 Hz, 1H), 3.44-3.42 (m, 2H), 2.69 (s, 3H), 1.83 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 155.5, 146.1, 142.7, 141.1, 138.5, 137.1, 134.2, 133.4, 131.1, 129.2, 129.1, 127.9, 127.5, 127.1, 127.1, 126.4, 125.4, 124.1, 122.9, 116.9, 114.8, 65.1, 31.4, 16.6, 13.9 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{33}H_{30}O$ $[M+Na]^+$: 465.2195, found: 465.2194.

6,12-dimethyl-7,7-diphenyl-5,7-dihydro-2H-fluoreno[3,2-b]oxepine **(132)** Following general experimental procedure 3.6.5 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 71 mg (66%); mp 178-179 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.87 (d, *J* = 8 Hz, 1H), 7.30-7.18 (m, 6H), 7.17-7.14 (m, 6H), 7.11 (d, *J* = 1 Hz, 1H), 5.83-5.81 (m, 1H), 5.43-5.41 (m, 1H), 4.62 (t, *J* = 2.5 Hz, 2H), 3.44-3.42 (m, 2H), 2.68 (s, 3H), 1.88 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.5, 155.4, 145.9, 142.8, 141.1, 137.9, 136.2, 129.1, 127.9, 127.1, 126.9, 126.4, 126.2, 125.3, 123.4, 122.7, 70.6, 65.2, 25.8, 16.9, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{31}H_{26}O$ $[M+H]^+$: 414.1984 found: 414.1983.

1,4-dimethyl-2-nitro-9,9-diphenyl-9H-fluoren-3-ol(133) Purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 69 mg (62%); mp 158-160 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 10.47 (s, 1H), 8.04 (d, *J* = 8.5 Hz, 1H), 7.36-7.34 (m, 2H), 7.30-7.25 (m, 7H), 7.25-7.23 (m, 4H), 2.75 (s, 3H), 2.12 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 157.1, 153.3, 145.9, 142.4, 141.8, 138.6, 135.5, 130.6, 129.8, 128.8, 128.2, 127.9, 127.6, 127.1, 125.8, 124.9, 120.6, 65.2, 29.8, 18.7 ppm. (LCMS): *m/z* $[M+H]^+$: 406.

1,4-dimethyl-9,9-diphenyl-3-(prop-2-yn-1-yloxy)-9H-fluorene (134) Purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 85 mg (78%); mp 192-193 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (d, *J* = 7.6 Hz, 1H), 7.34-7.30 (m, 1H), 7.29-7.24 (m, 5H), 7.22-7.15 (m, 7H), 6.65 (s, 1H), 4.71 (d, *J* = 2.4 Hz, 2H), 2.65 (s, 3H), 2.52 (t, *J* = 2.4 Hz, 1H), 1.92 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ

155.8, 155.6, 142.1, 142.7, 141.1, 140.4, 133.5, 129.2, 127.9, 127.4, 127.1, 126.5, 125.5, 123.4, 120.5, 114.4, 79.3, 75.3, 64.6, 57.1, 20.4, 12.5 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{30}H_{24}O$ $[M+H]^+$: 401.1907 found: 401.1905.

2-bromo-1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol(135) Purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 66 mg (69%); mp 188-190 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (d, *J* = 7.6 Hz, 1H), 7.31 (d, *J* = 8.4 Hz, 1H), 7.28-7.25 (m, 6H), 7.22-7.19 (m, 6H), 5.80 (s, 1H), 2.74 (s, 3H), 2.01 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 155.5, 150.2, 142.9, 142.4, 140.3, 139.9, 132.3, 129.1, 128.1, 127.8, 127.3, 126.6, 125.5, 123.4, 118.2, 114.4, 65.3, 20.8, 13.6 ppm. HRMS (ESI-TOF): *m/z* calcd. for $C_{27}H_{21}BrO$ $[M-H]^+$: 439.0756,found:439.0755.

2-iodo-1,4-dimethyl-9,9-diphenyl-9H-fluoren-3-ol (136) Purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 99 mg (74%); mp 215-216 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (d, *J* = 7.6 Hz, 1H), 7.32-7.26 (m, 7H), 7.22-7.19 (m, 6H), 5.5 (s, 1H), 2.76 (s, 3H), 2.0 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.5, 152.6, 142.9, 142.4, 140.5, 140.4, 135.8, 129.1, 128.7, 128.1, 127.9, 127.3, 126.6, 125.5, 123.5, 117.3, 95.9, 65.3, 26.7, 14.1 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{27}H_{21}IO$ $[M+H]^+$: 488.0637 found: 488.0636.

3-methoxy-1,4-dimethyl-9,9-diphenyl-9H-fluorene (137) Following general experimental procedure 3.6.6 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 83 mg (81%); mp 229-230 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (d, *J* = 7.6 Hz, 1H), 7.33 (d, *J* = 7.6 Hz, 1H), 7.29-7.26 (m, 5H), 7.21-7.13 (m, 7H), 6.54 (s, 1H), 3.84 (s, 3H), 2.63 (s, 3H), 1.91 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 157.5, 155.6, 142.8, 141.9, 141.2, 140.1, 133.4, 129.1, 127.9, 127.3, 127.1, 126.4, 125.4, 123.4, 119.6, 112.5, 64.5, 56.1, 20.5, 12.2 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{28}H_{24}O$ $[M+H]^+$: 377.4975 found: 377.4973.

2-iodo-3-methoxy-1,4-dimethyl-9,9-diphenyl-9H-fluorene (138) Following general experimental procedure 3.6.6 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 105 mg (79%); mp 224-225 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.90 (d, *J* = 8 Hz, 1H), 7.32-7.29 (m, 2H), 7.27-7.25 (m, 4H), 7.24-7.17 (m, 7H), 3.82 (s, 3H), 2.76 (s, 3H), 2.1 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 158.1, 155.4, 146.5, 142.1, 140.8, 140.1, 137.5, 129.1, 128.1, 127.9, 127.3, 126.7, 125.6,

124.4, 123.4, 101.4, 65.6, 60.7, 26.8, 14.6 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{28}H_{23}IO$ $[M+H]^+$: 502.0794 found: 502. 0793.

(E)-ethyl3-(3-methoxy-1,4-dimethyl-9,9-diphenyl-9H-fluoren-2-yl)acrylate (139)
Following general experimental procedure 3.6.9 then purified by flash chromatography (silica gel, 12–15%, EtOAc in pet ether)) the product was obtained as White solid 71 mg (76%); mp 230-231 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.95-7.88 (m, 2H), 7.37-7.33 (m, 6H), 7.32-7.20 (m, 7H), 6.52 (d, *J* = 16.4 Hz, 1H), 4.29-4.24 (m, 2H), 3.74 (s, 3H), 2.74 (s, 3H), 2.19 (s, 3H), 1.33 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 207.1, 167.6, 158.1, 155.9, 146.3, 142.2, 141.5, 140.3, 140.1, 133.8, 129.1, 128.1, 127.9, 127.2, 127.1, 126.6, 125.5, 124.6, 123.5, 123.2, 65.2, 60.6, 60.4, 31.1, 18.1, 14.4, 13.3 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{33}H_{30}O_3$ $[M+H]^+$: 475.2275 found: 475. 2275.

3-methoxy-1,4-dimethyl-9,9-diphenyl-2-(phenylethynyl)-9H-fluorene (140) Following general experimental procedure 3.6.8 then purified by flash chromatography (silica gel, 7–9%, EtOAc in pet ether)) the product was obtained as White solid 57 mg (61%); mp 216-218 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.90 (d, *J* = 7.5 Hz, 1H), 7.52 (d, *J* = 6.5 Hz, 1H), 7.36-7.31 (m, 5H), 7.29-7.25 (m, 5H), 7.24-7.20 (m, 7H), 3.82 (s, 3H), 2.77 (s, 3H), 2.08 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 158.1,155.4, 146.5, 142.1, 140.8, 140.1, 137.5, 132.6, 129.3, 129.1, 128.5, 128.1, 127.9, 127.3, 126.7, 125.6, 124.4, 123.4, 101.4, 65.6, 60.7, 26.8, 14.6 6 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{36}H_{28}O$ $[M+H]^+$: 477.2220 found: 477.2219.

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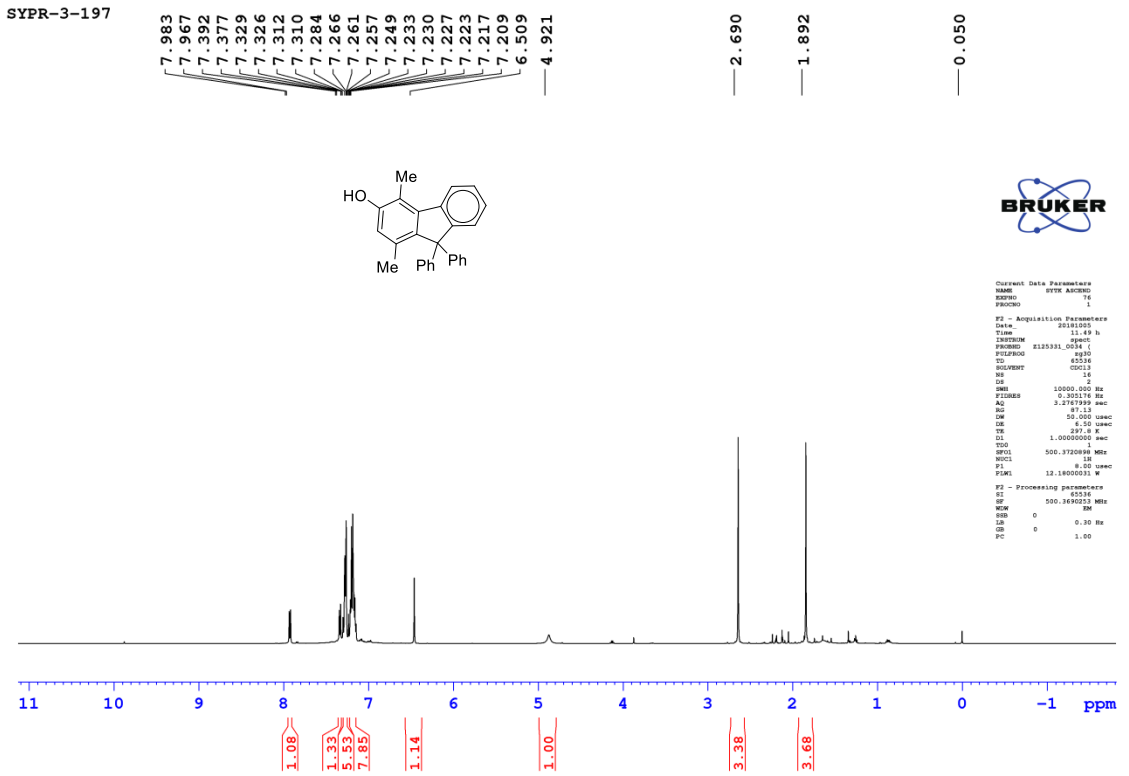
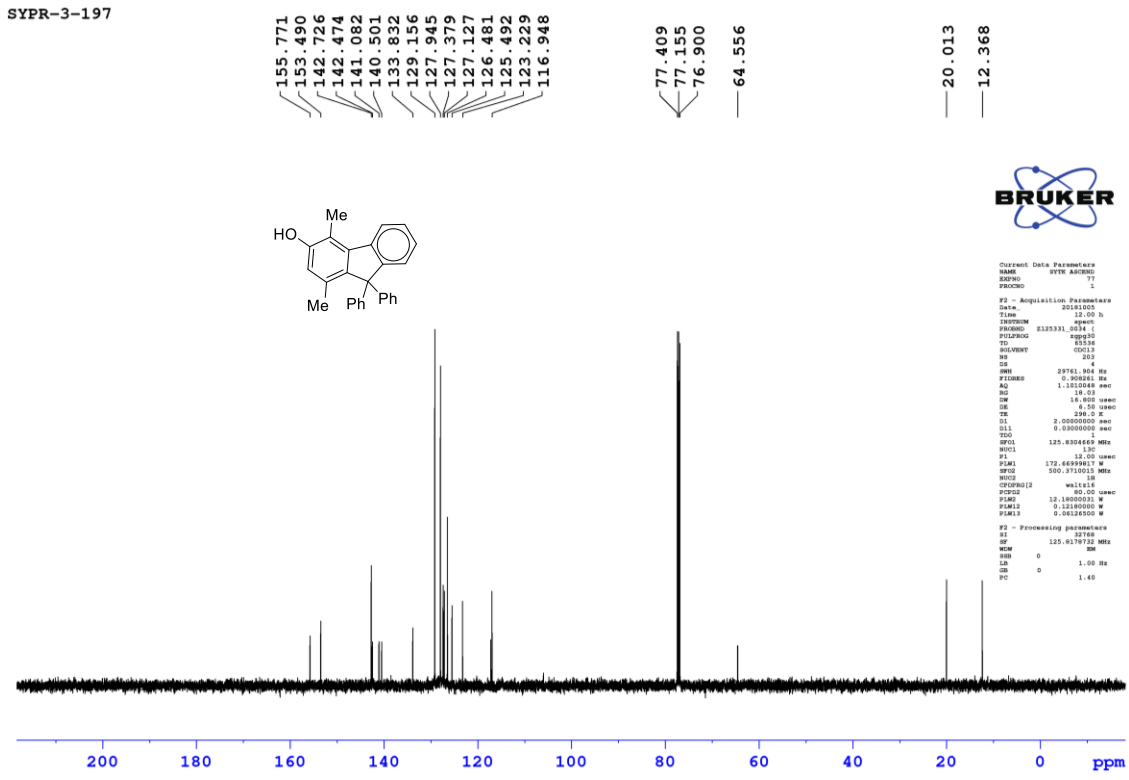
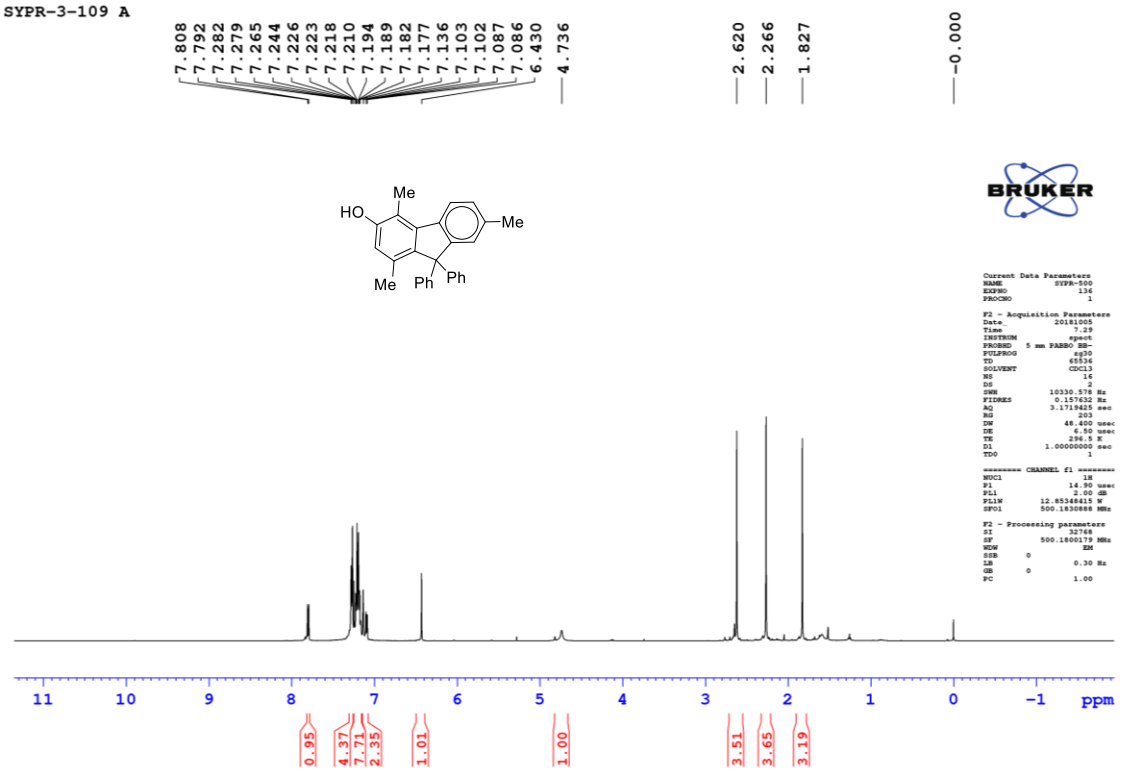
3.9 SPECTRAL COPIES



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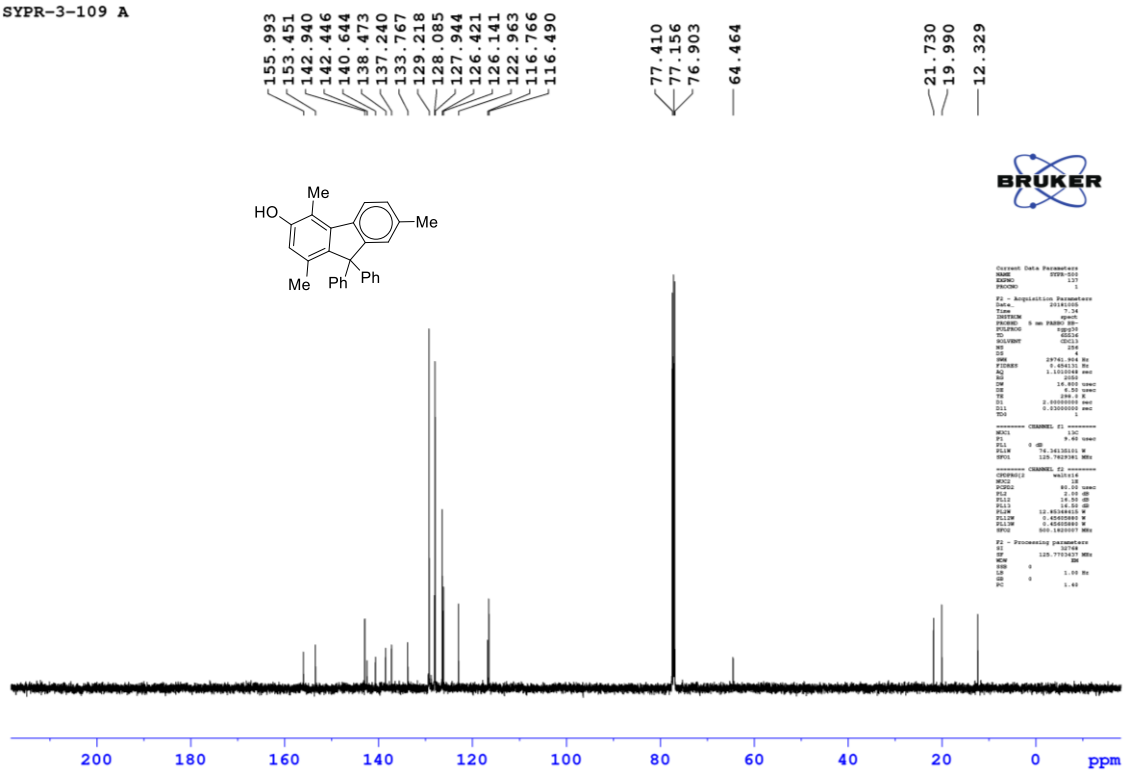
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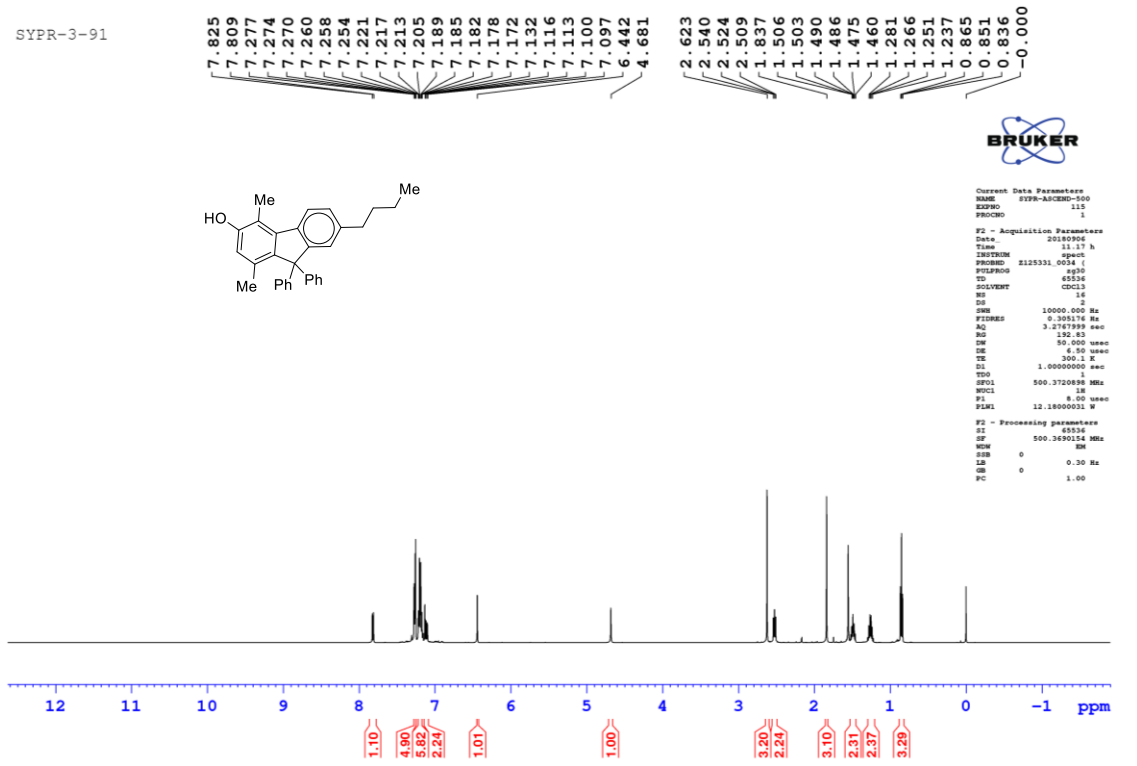
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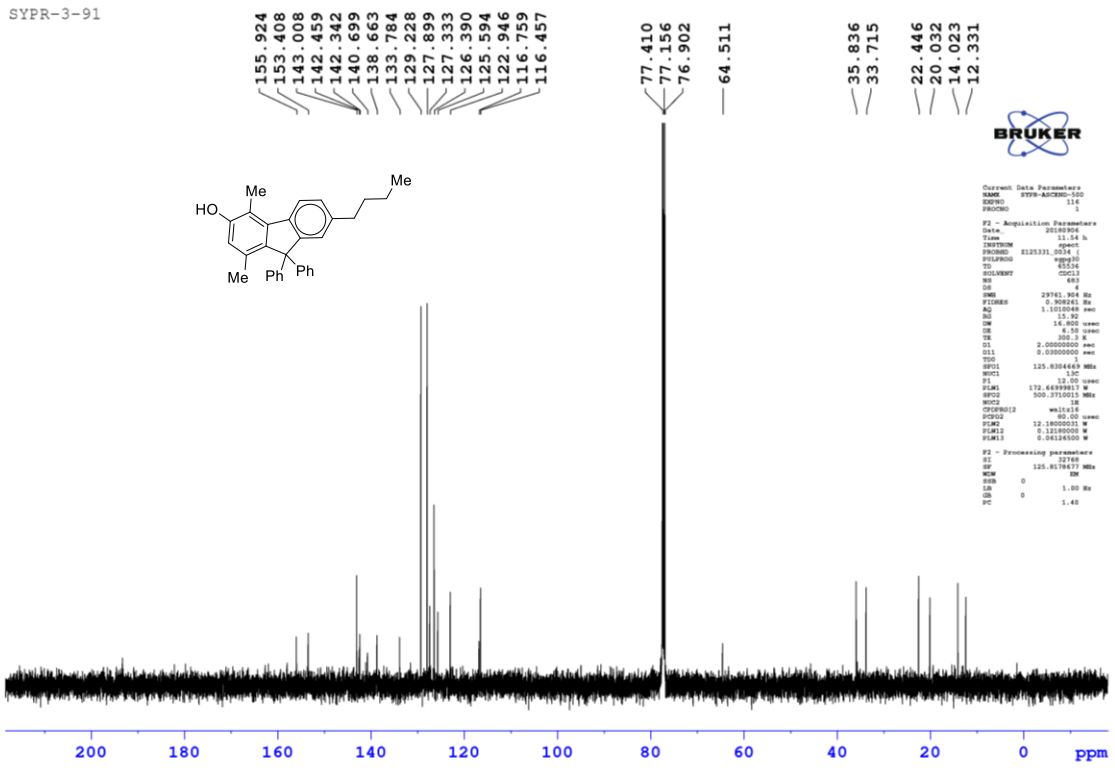
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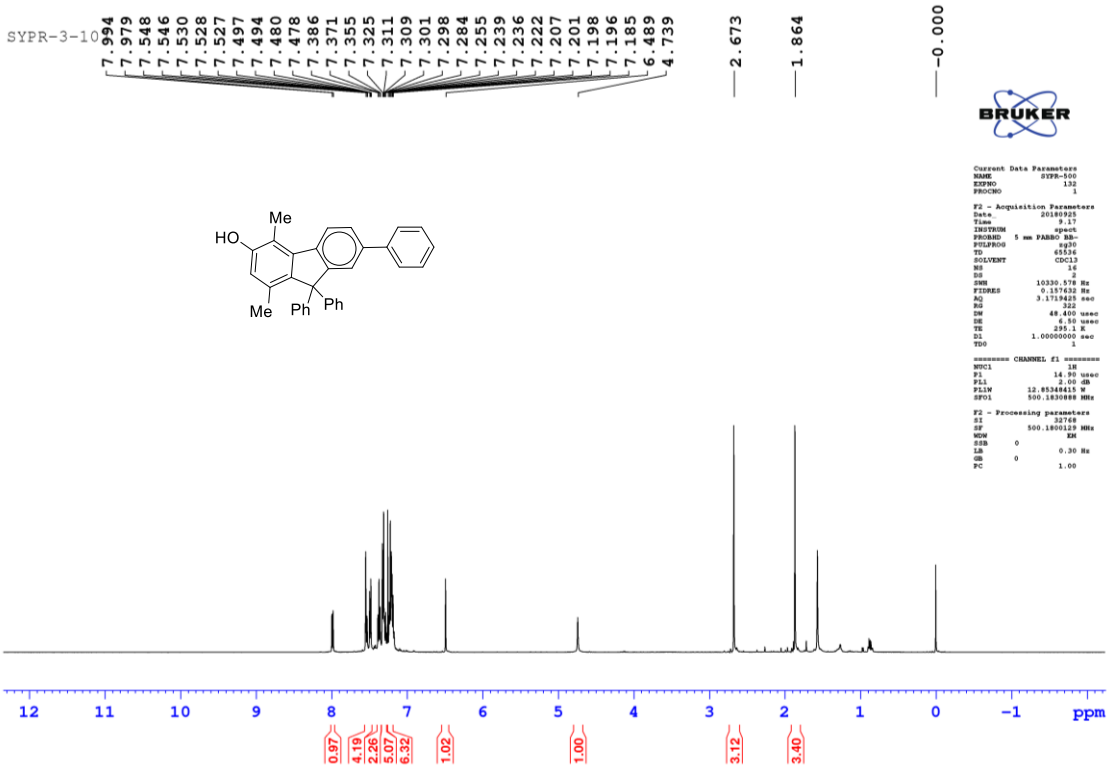
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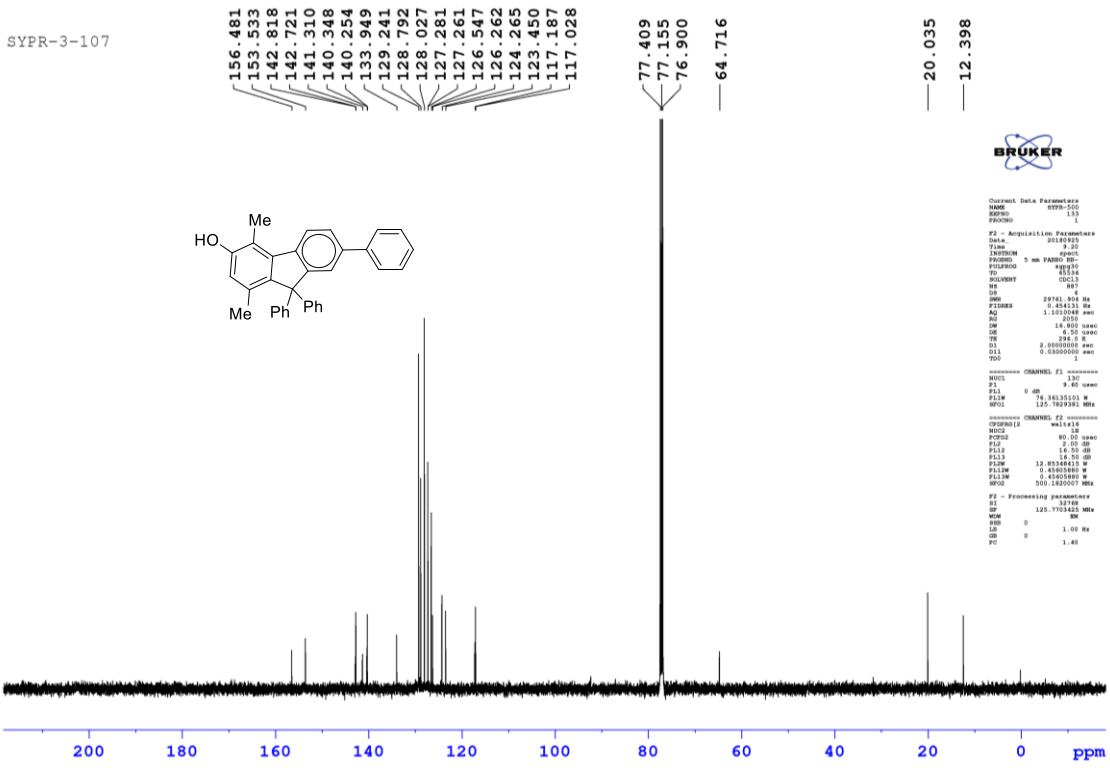
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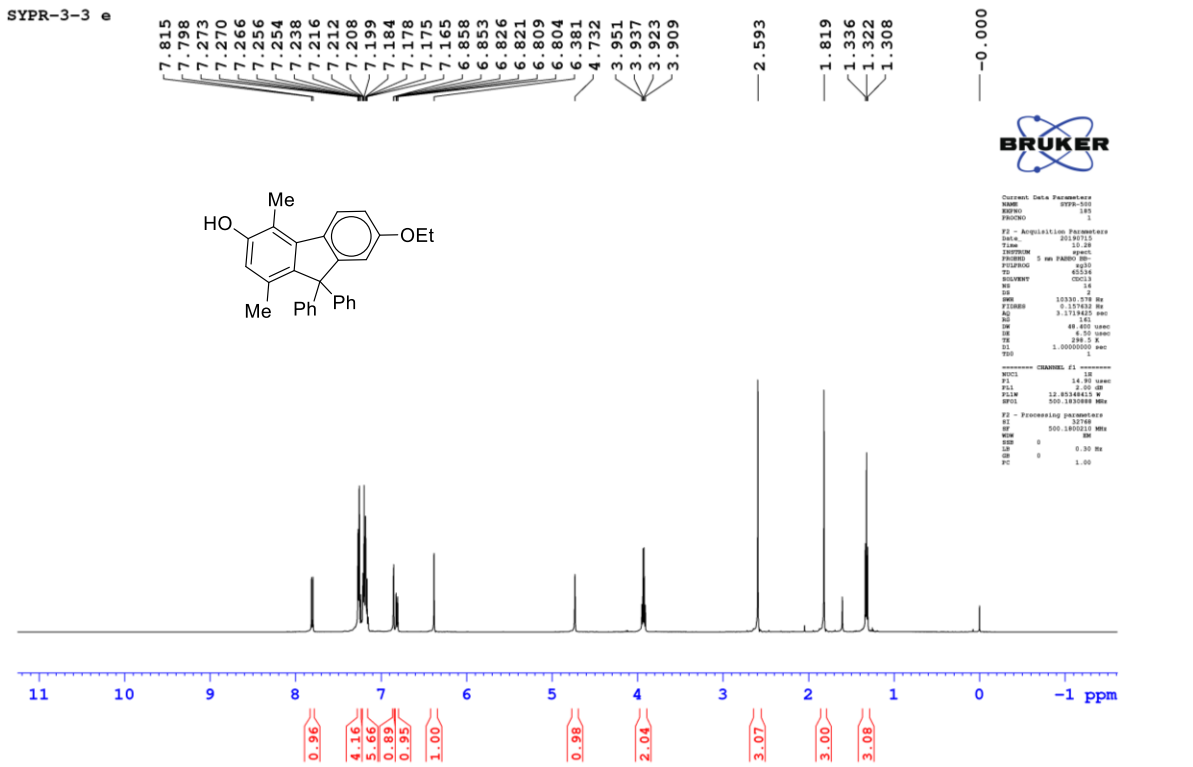
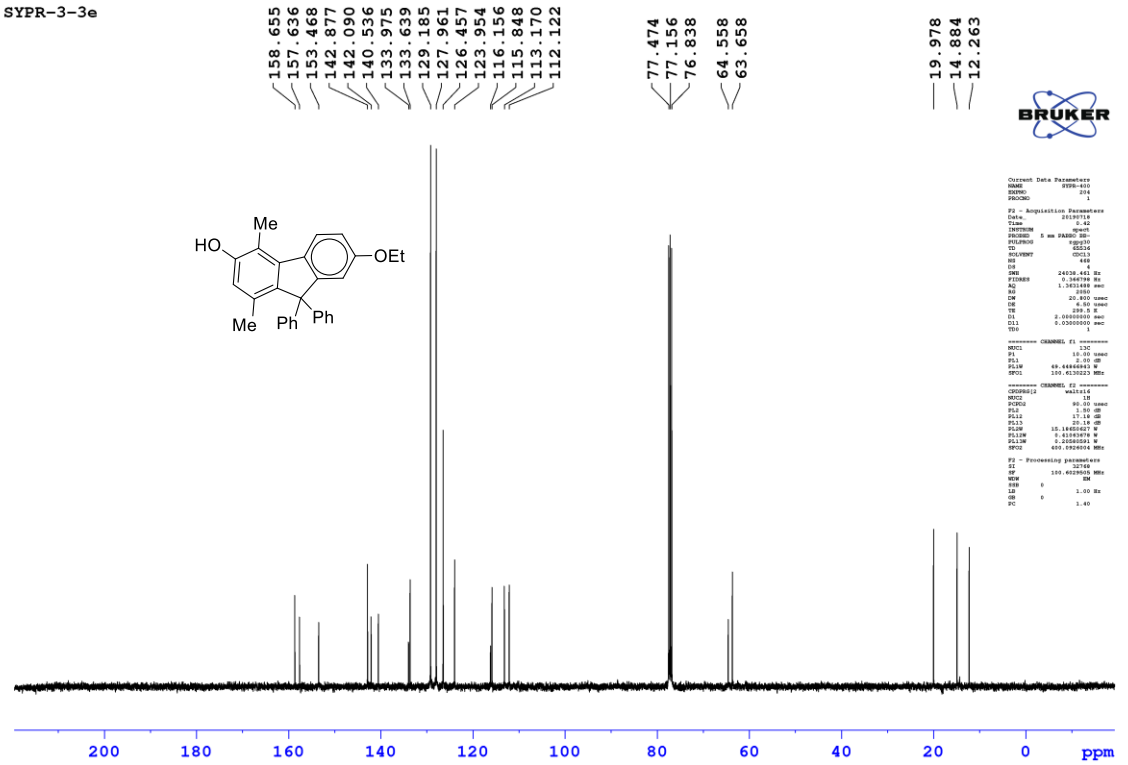

SYPR-3-3 e
7.815
7.798
7.273
7.270
7.266
7.256
7.254
7.238
7.216
7.212
7.208
7.199
7.184
7.178
7.175
7.165
6.858
6.853
6.826
6.821
6.809
6.804
6.381
4.732
3.951
3.937
3.923
3.909
2.593
1.819
1.336
1.322
1.308
-0.000
BRUKER
Me
HO
OEt
Me
Ph
Ph
11
10
9
8
7
6
5
4
3
2
1
0
-1 ppm
0.96
4.16
5.66
0.89
0.95
1.00
0.98
2.04
3.07
3.00
3.08


SYPR-3-3e
158.655
157.636
153.468
142.877
142.090
140.536
133.975
133.639
129.185
127.961
126.457
123.954
116.156
115.848
113.170
112.122
77.474
77.156
76.838
64.558
63.658
19.978
14.884
12.263
BRUKER
Me
HO
OEt
Me
Ph
Ph
200
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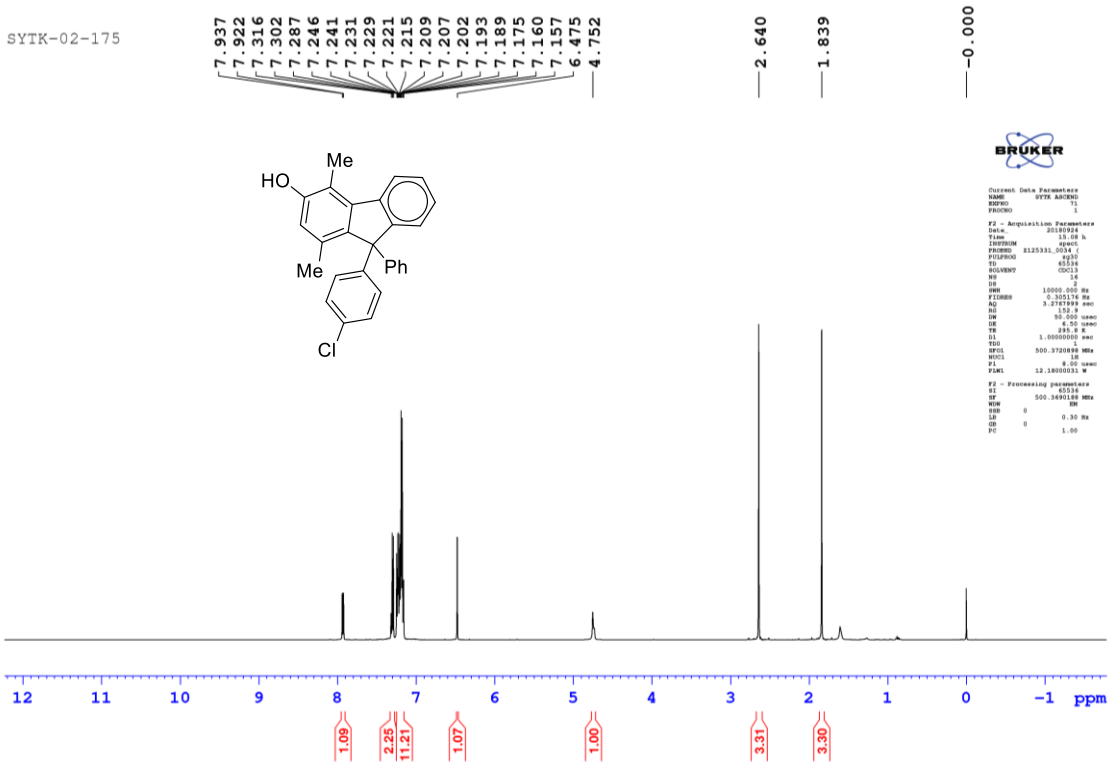
160
140
120
100
80
60
40
20
0
ppm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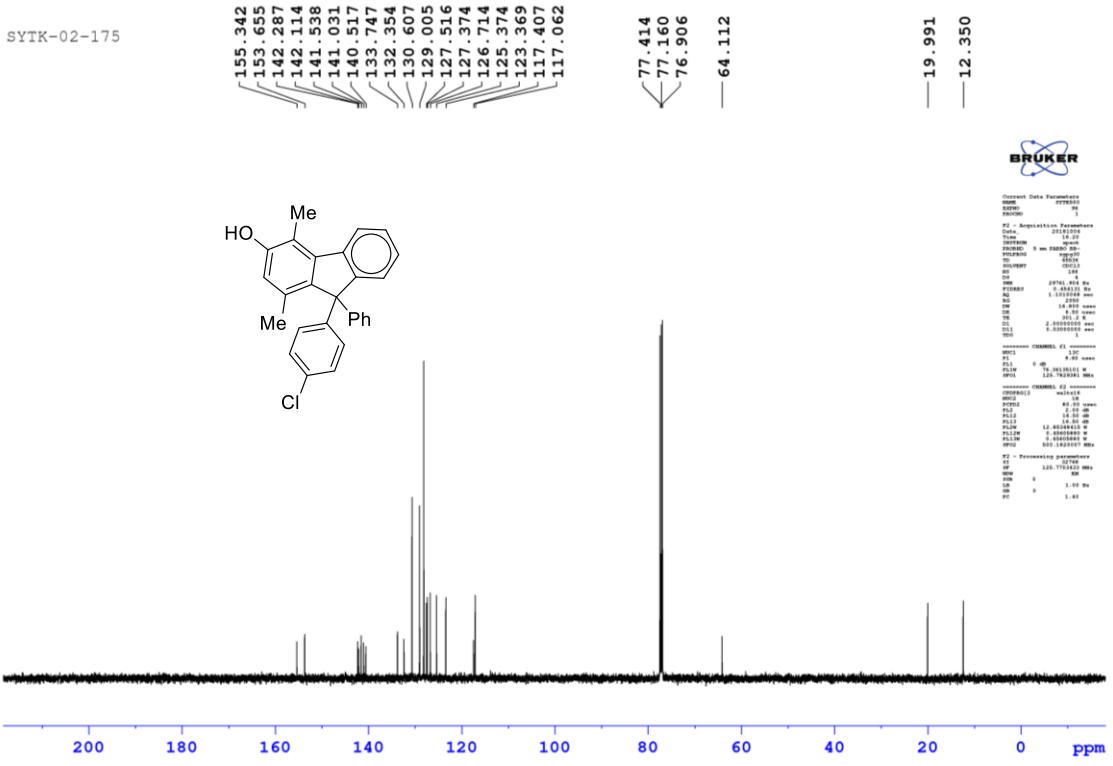
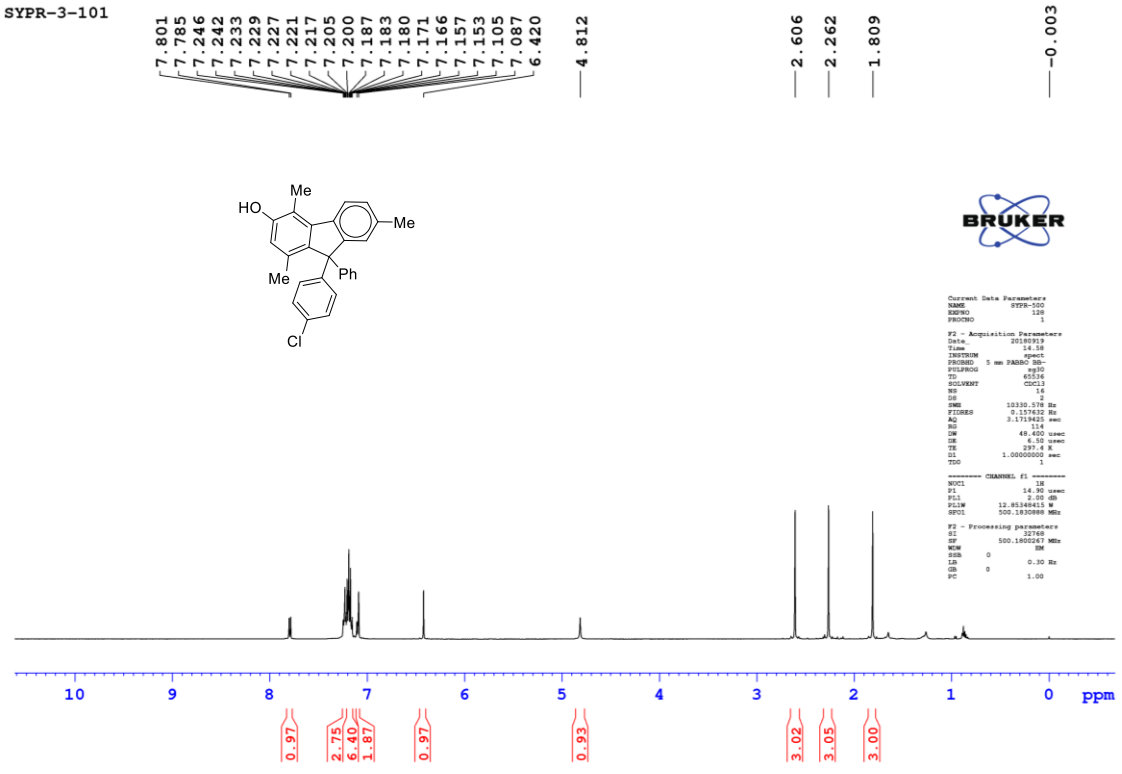
7.922
7.316
7.302
7.287
7.246
7.241
7.231
7.229
7.221
7.215
7.209
7.207
7.202
7.193
7.189
7.175
7.160
7.157
6.475
4.752
2.640
1.839
0.000
Me
HO
Me
Ph
Cl
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.09
2.25
11.21
1.07
1.00
3.31
3.30


SYTK-02-175
155.342
153.655
142.287
142.114
141.538
141.031
140.517
133.747
132.354
130.607
129.005
127.516
127.374
126.714
125.374
123.369
117.407
117.062
77.414
77.160
76.906
64.112
19.991
12.350
Me
HO
Me
Ph
Cl
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-101
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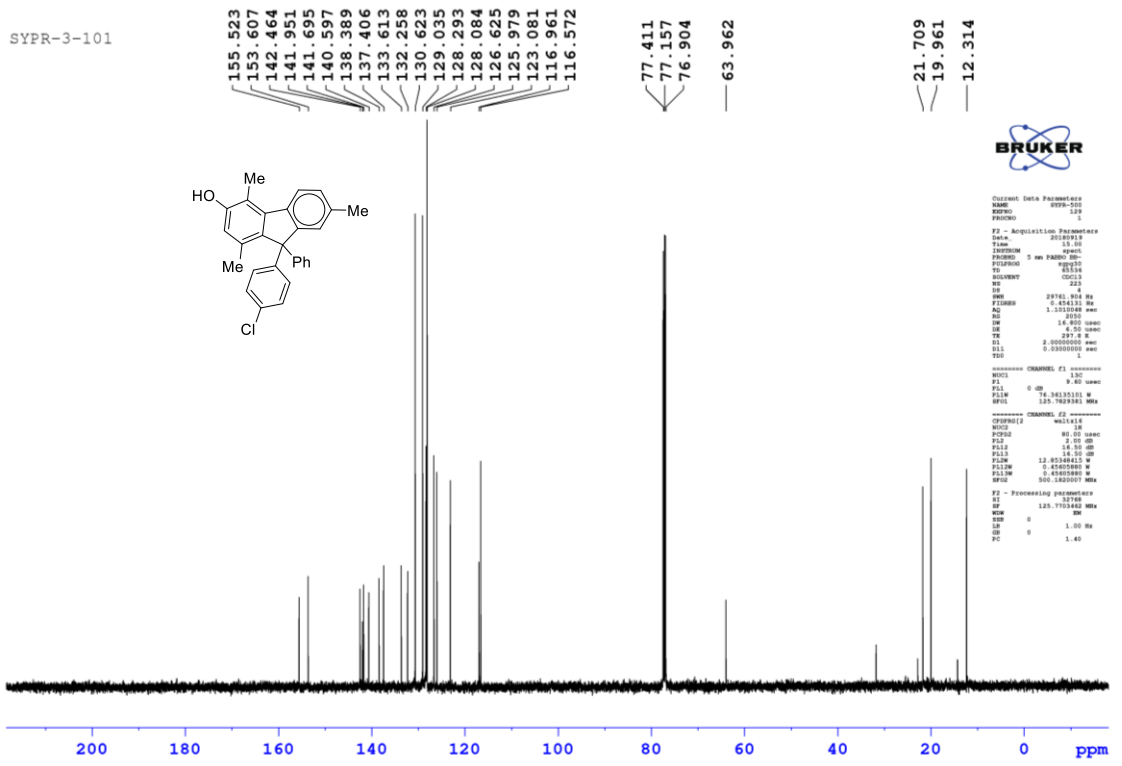
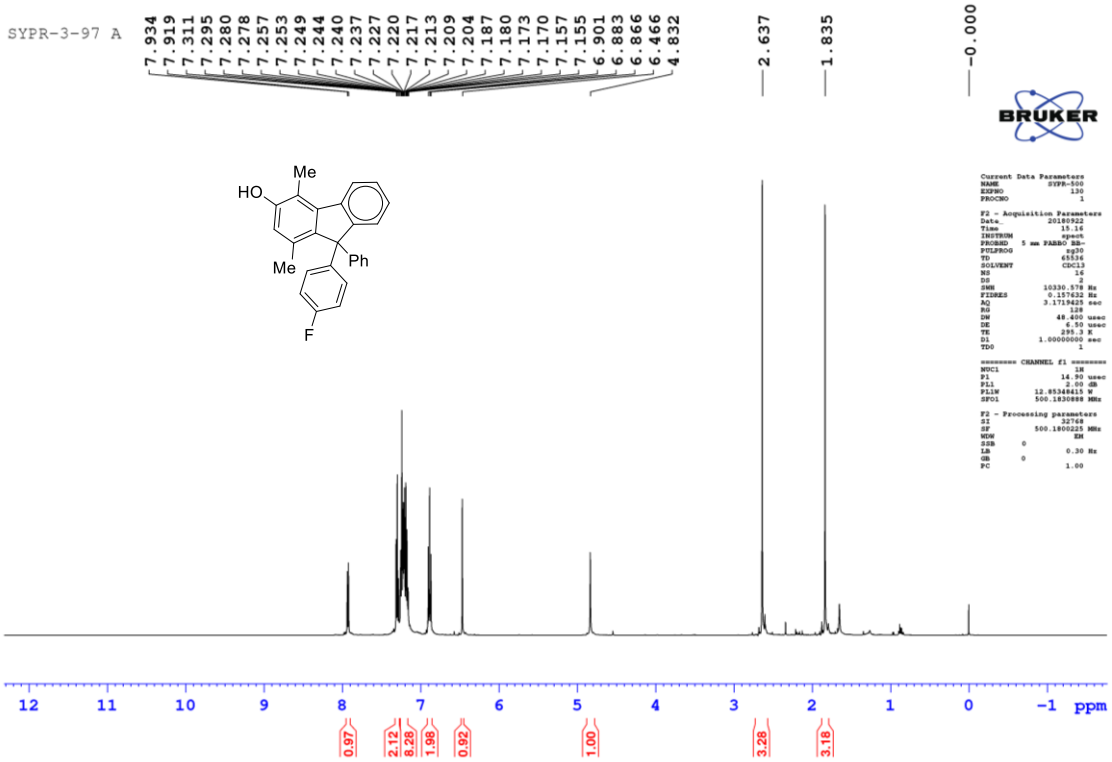
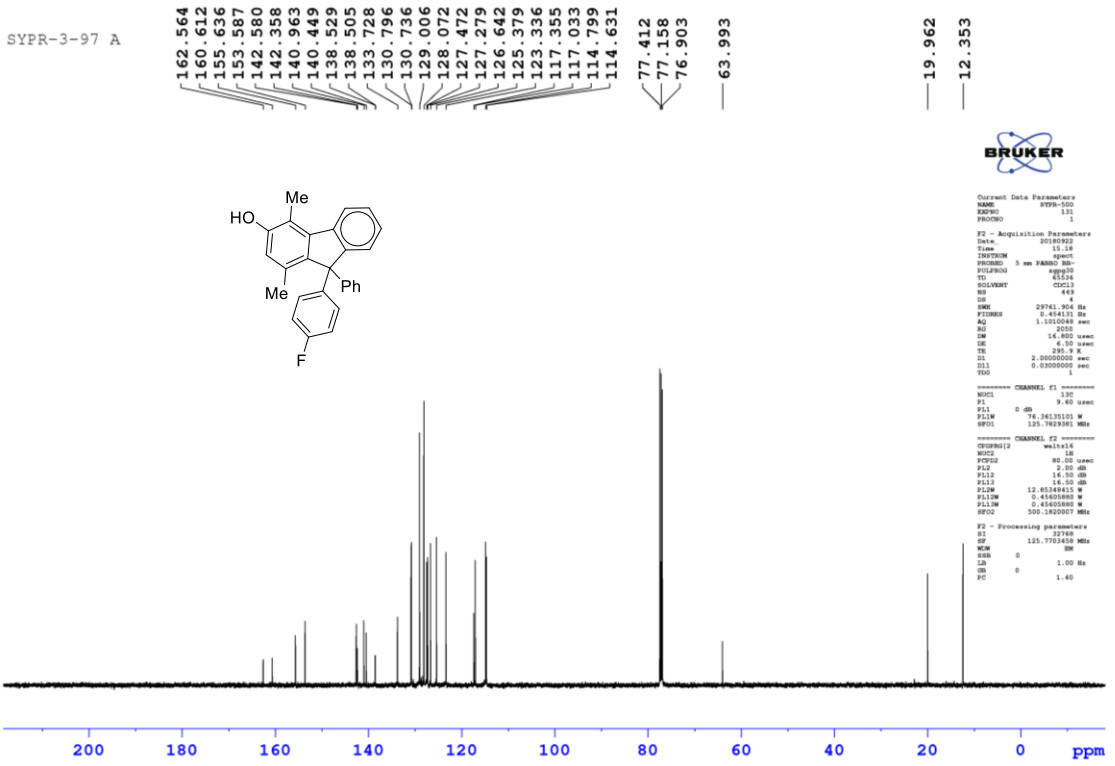
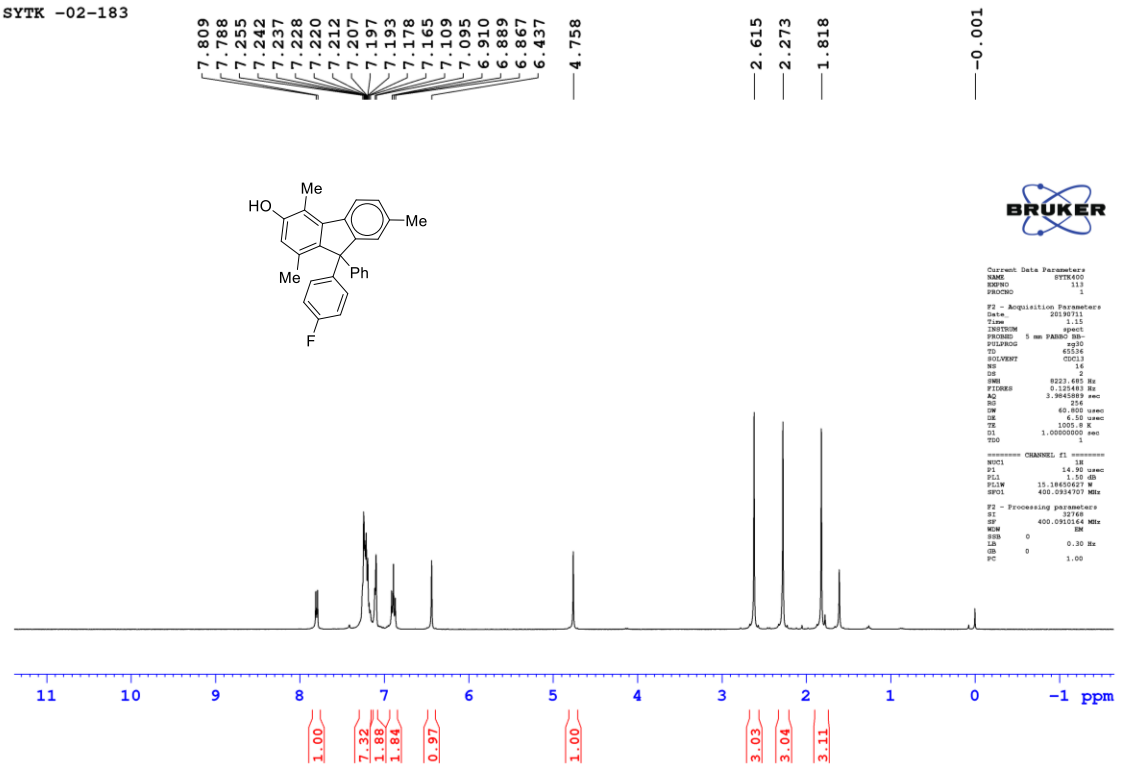
7.785
7.246
7.242
7.233
7.229
7.227
7.221
7.217
7.205
7.200
7.187
7.183
7.180
7.171
7.166
7.157
7.153
7.105
7.087
6.420
4.812
2.606
2.262
1.809
0.003
Me
HO
Me
Me
Ph
Cl
BRUKER
10
9
8
7
6
5
4
3
2
1
0
ppm
0.97
2.75
6.40
1.87
0.97
0.93
3.02
3.05
3.00


SYPR-3-101
155.523
153.607
142.464
141.951
141.695
140.597
138.389
137.406
133.613
132.258
130.623
129.035
128.293
128.084
126.625
125.979
123.081
116.961
116.572
77.411
77.157
76.904
63.962
21.709
19.961
12.314
Me
HO
Me
Me
Ph
Cl
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-97 A
7.934
7.919
7.311
7.295
7.280
7.278
7.257
7.253
7.249
7.244
7.240
7.237
7.227
7.220
7.217
7.213
7.209
7.204
7.187
7.180
7.173
7.170
7.157
7.155
6.901
6.883
6.866
6.466
4.832
2.637
1.835
0.000
Me
HO
Me
Ph
F
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
0.97
2.12
8.28
1.98
0.92
1.00
3.28
3.18


SYPR-3-97 A
162.564
160.612
155.636
153.587
142.580
142.358
140.963
140.449
138.529
138.505
133.728
130.796
130.736
129.006
128.072
127.472
127.279
126.642
125.379
123.336
117.355
117.033
114.799
114.631
77.412
77.158
76.903
63.993
19.962
12.353
Me
HO
Me
Ph
F
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYTK -02-183
7.809
7.788
7.255
7.242
7.237
7.228
7.220
7.212
7.207
7.197
7.193
7.178
7.165
7.109
7.095
6.910
6.889
6.867
6.437
4.758
2.615
2.273
1.818
0.001
HO
Me
Me
Me
Ph
F
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
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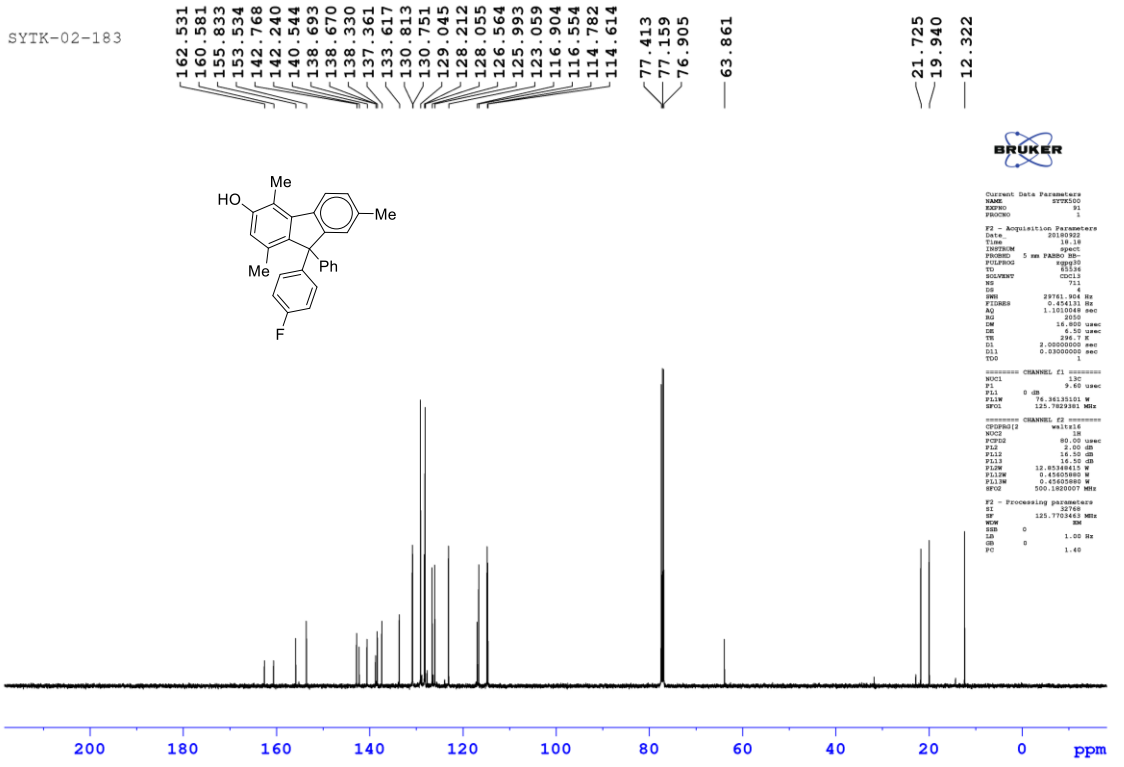
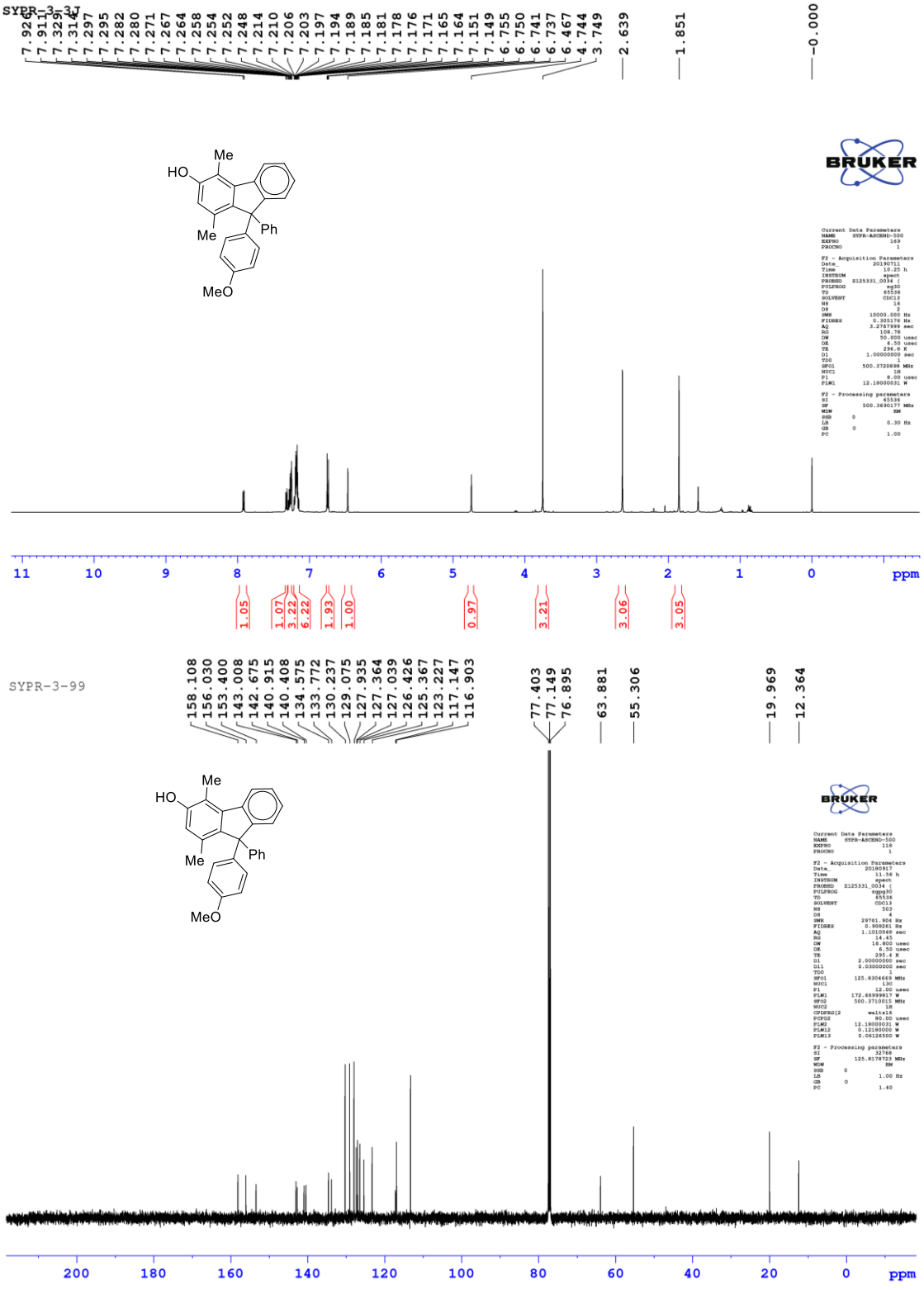
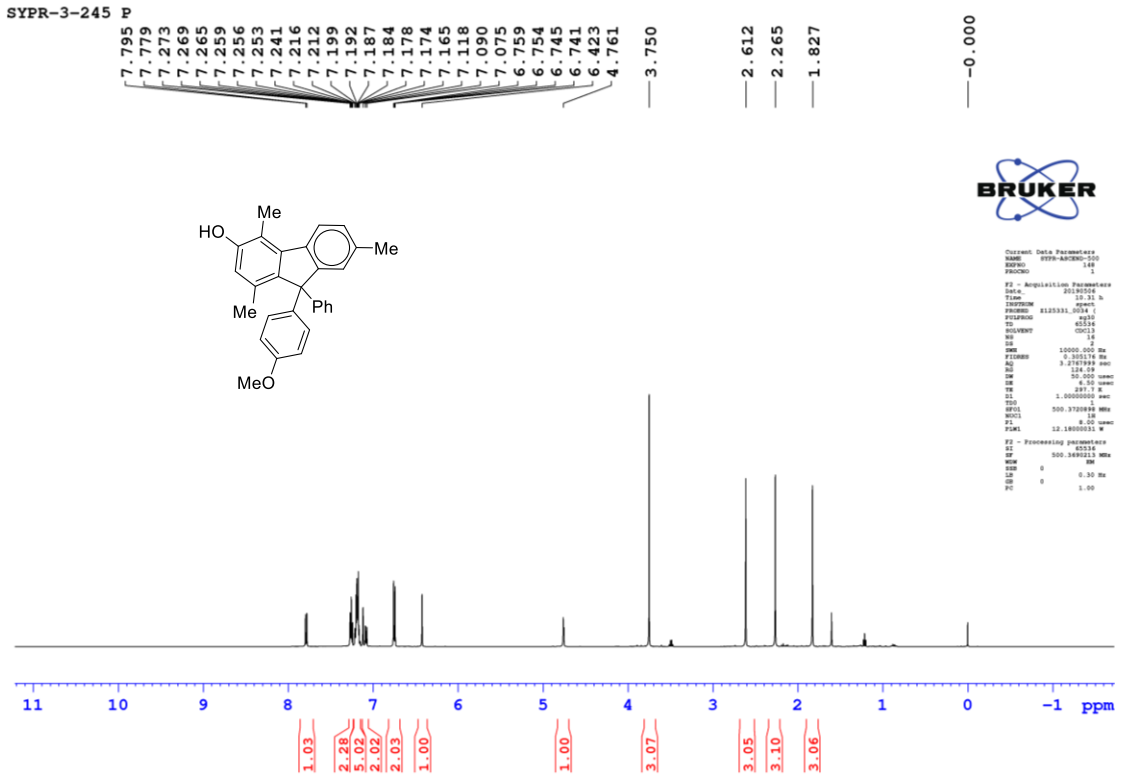
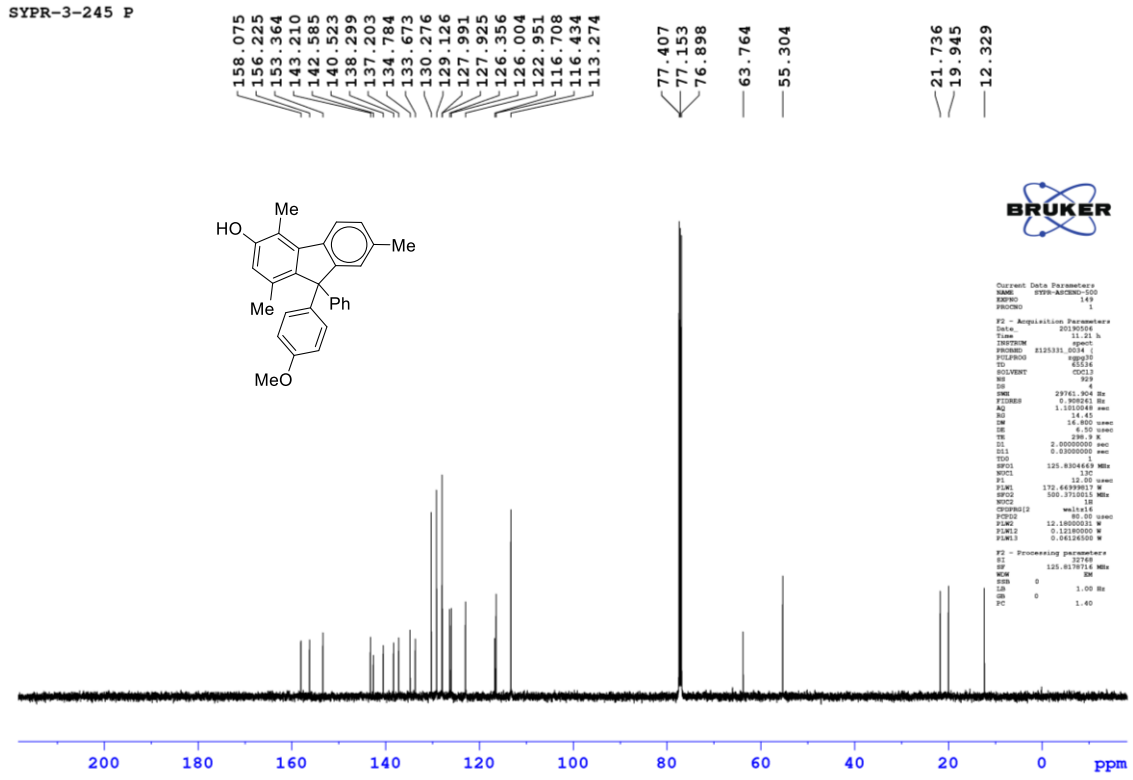
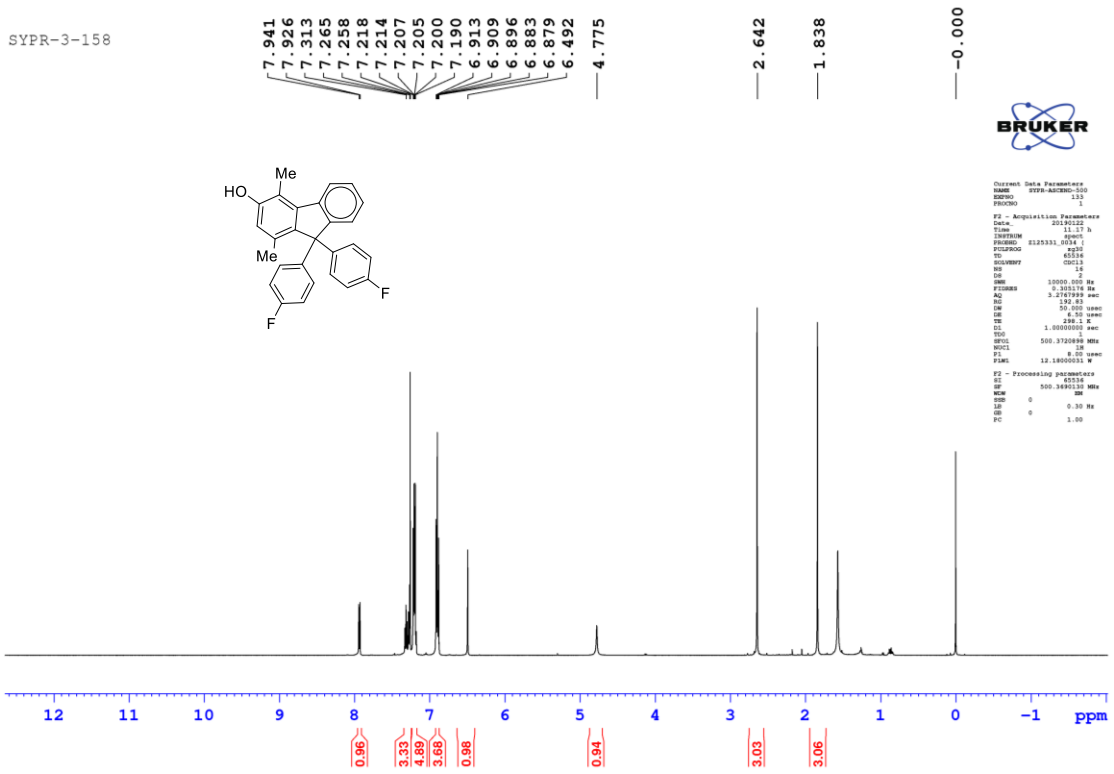
1.88
1.84
0.97
1.00
3.03
3.04
3.11


SYTK-02-183
162.531
160.581
155.833
153.534
142.768
142.240
140.544
138.693
138.670
138.330
137.361
133.617
130.813
130.751
129.045
128.212
128.055
126.564
125.993
123.059
116.904
116.554
114.782
114.614
77.413
77.159
76.905
63.861
21.725
19.940
12.322
HO
Me
Me
Me
Ph
F
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-37
7.926 7.911 7.329 7.314 7.297 7.295 7.282 7.280 7.271 7.267 7.264 7.258 7.254 7.252 7.248 7.214 7.210 7.206 7.203 7.197 7.194 7.189 7.185 7.181 7.178 7.176 7.171 7.165 7.164 7.151 7.149 6.755 6.750 6.741 6.737 6.467 4.744 3.749
2.639
1.851
0.000
Me
HO
Me
Ph
MeO
BRUKER
11 10 9 8 7 6 5 4 3 2 1 0 ppm
1.05 1.07 3.22 6.22 1.93 1.00 0.97 3.21 3.06 3.05
SYPR-3-99
158.108 156.030 153.400 143.008 142.675 140.915 140.408 134.575 133.772 130.237 129.075 127.935 127.364 127.039 126.426 125.367 123.227 117.147 116.903
77.403 77.149 76.895
63.881
55.306
19.969
12.364
Me
HO
Me
Ph
MeO
BRUKER
200 180 160 140 120 100 80 60 40 20 0 ppm


SYPR-3-245 P
7.795
7.779
7.273
7.269
7.265
7.259
7.256
7.253
7.241
7.216
7.212
7.199
7.192
7.187
7.184
7.178
7.174
7.165
7.118
7.090
7.075
6.759
6.754
6.745
6.741
6.423
4.761
3.750
2.612
2.265
1.827
0.000
HO
Me
Me
Me
Ph
MeO
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.03
2.28
5.02
2.02
2.03
1.00
1.00
3.07
3.05
3.10
3.06


SYPR-3-245 P
158.075
156.225
153.364
143.210
142.585
140.523
138.299
137.203
134.784
133.673
130.276
129.126
127.991
127.925
126.356
126.004
122.951
116.708
116.434
113.274
77.407
77.153
76.898
63.764
55.304
21.736
19.945
12.329
HO
Me
Me
Me
Ph
MeO
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-158
7.941
7.926
7.313
7.265
7.258
7.218
7.214
7.207
7.205
7.200
7.190
6.913
6.909
6.896
6.883
6.879
6.492
4.775
2.642
1.838
0.000
BRUKER
HO
Me
Me
F
F
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.96
3.33
4.89
3.68
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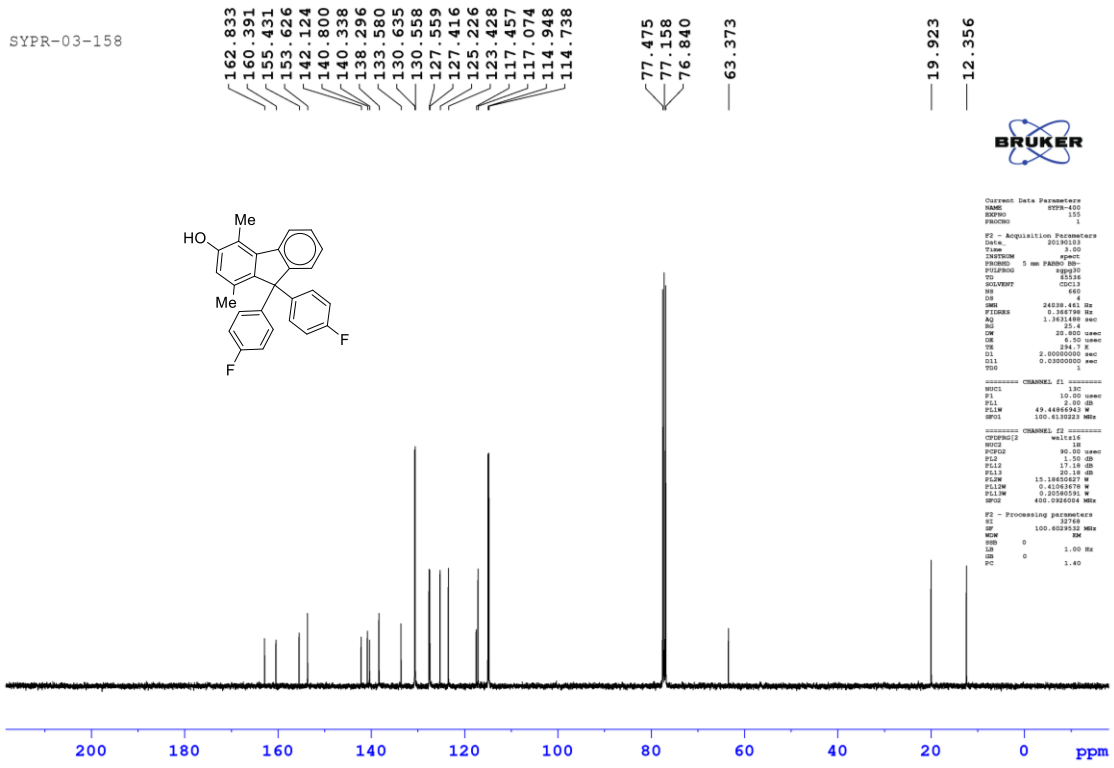
3.06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140.800
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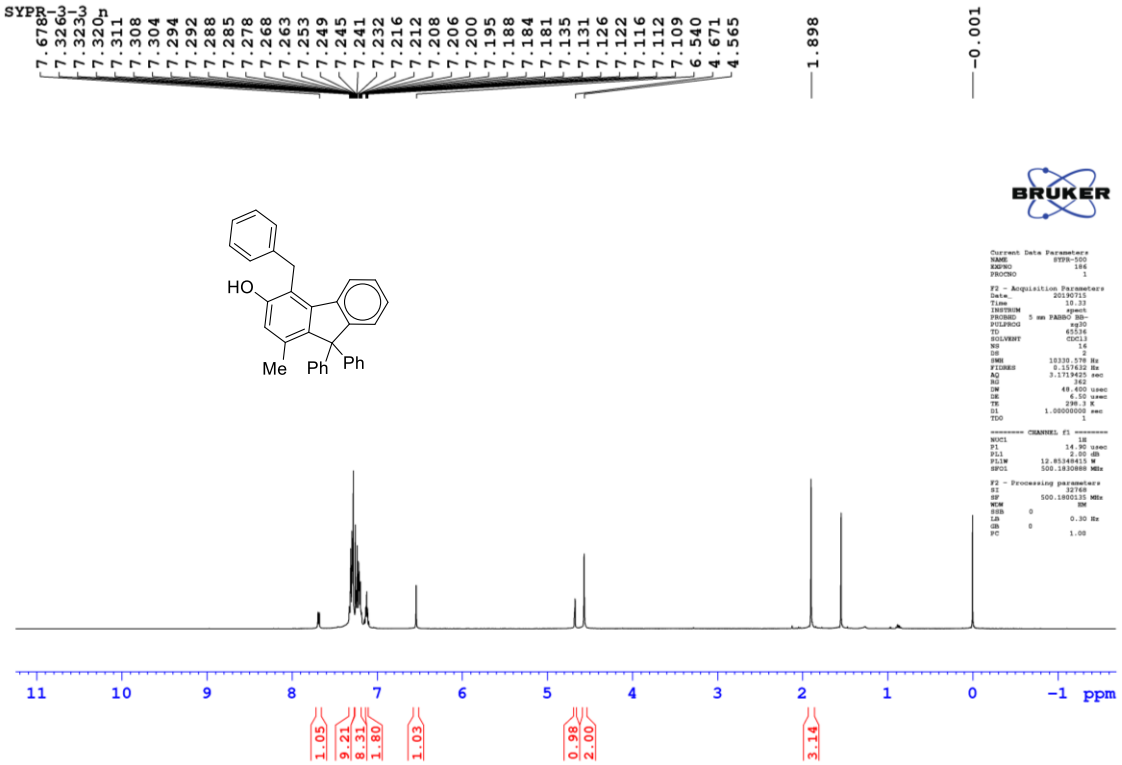
138.296
133.580
130.635
130.558
127.559
127.416
125.226
123.428
117.457
117.074
114.948
114.738
77.475
77.158
76.840
63.373
19.923
12.356
BRUKER
HO
Me
Me
F
F
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-3 n
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7.326
7.323
7.320
7.311
7.308
7.304
7.294
7.292
7.288
7.285
7.278
7.268
7.263
7.253
7.249
7.245
7.241
7.232
7.216
7.212
7.208
7.206
7.200
7.195
7.188
7.184
7.181
7.135
7.131
7.126
7.122
7.116
7.112
7.109
6.540
4.671
4.565
1.898
-0.001
HO
Me
Ph
Ph
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
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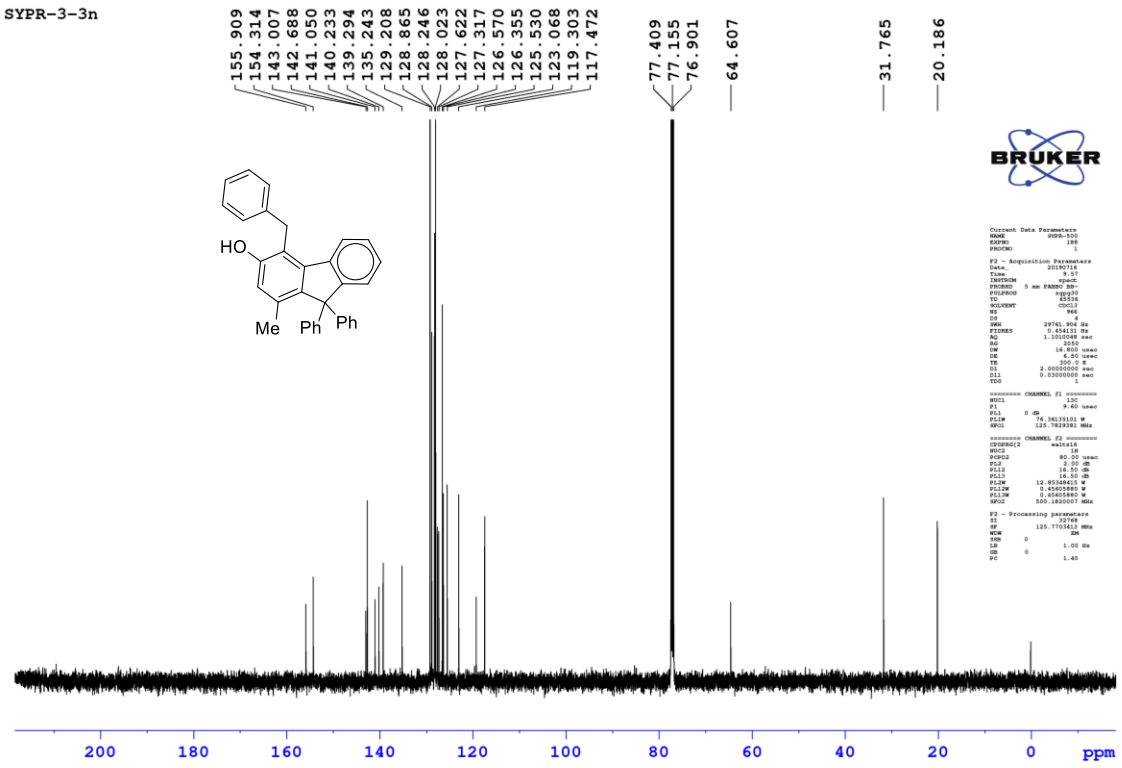
9.21
8.31
1.80
1.03
0.98
2.00
3.14


SYPR-3-3n
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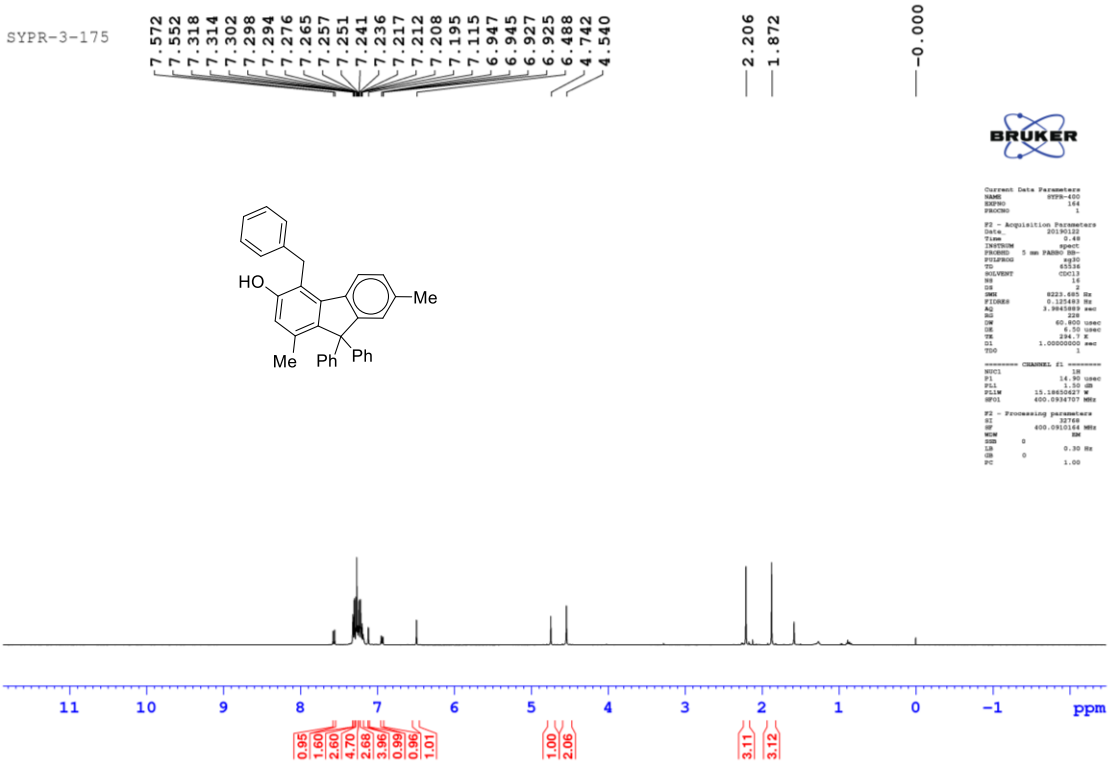
143.007
142.688
141.050
140.233
139.294
135.243
129.208
128.865
128.246
128.023
127.622
127.317
126.570
126.355
125.530
123.068
119.303
117.472
77.409
77.155
76.901
64.607
31.765
20.186
HO
Me
Ph
Ph
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-175
7.572
7.552
7.318
7.314
7.302
7.298
7.294
7.276
7.265
7.257
7.251
7.241
7.236
7.217
7.212
7.208
7.195
7.115
6.947
6.945
6.927
6.925
6.488
4.742
4.540
2.206
1.872
0.000
HO
Me
Me
Ph
Ph
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.95
1.60
2.60
4.70
2.68
3.96
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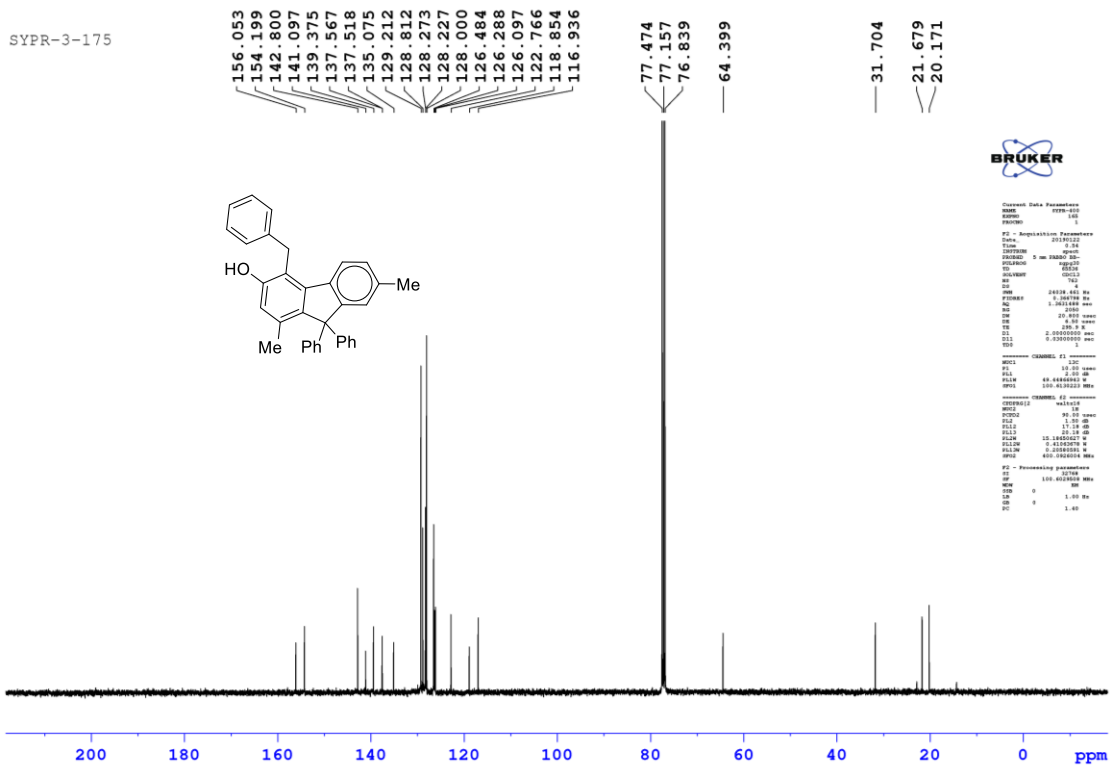
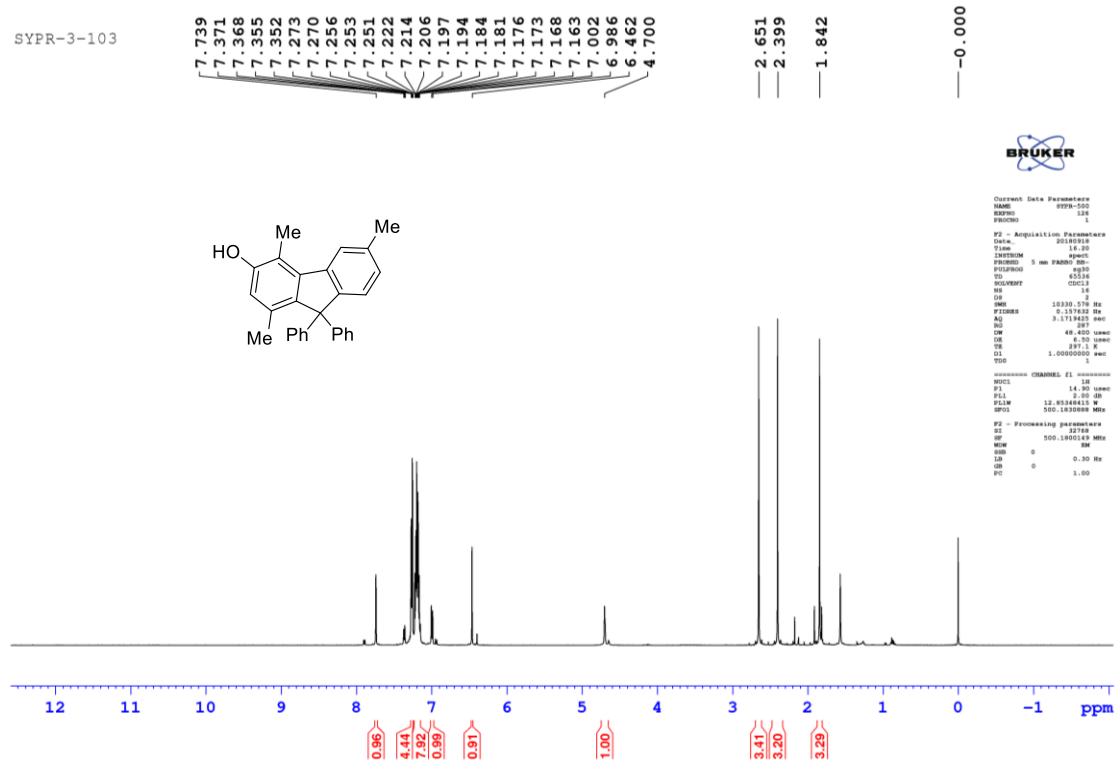
0.96
1.01
1.00
2.06
3.11
3.12


SYPR-3-175
156.053
154.199
142.800
141.097
139.375
137.567
137.518
135.075
129.212
128.812
128.273
128.227
128.000
126.484
126.288
126.097
122.766
118.854
116.936
77.474
77.157
76.839
64.399
31.704
21.679
20.171
HO
Me
Me
Ph
Ph
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-103
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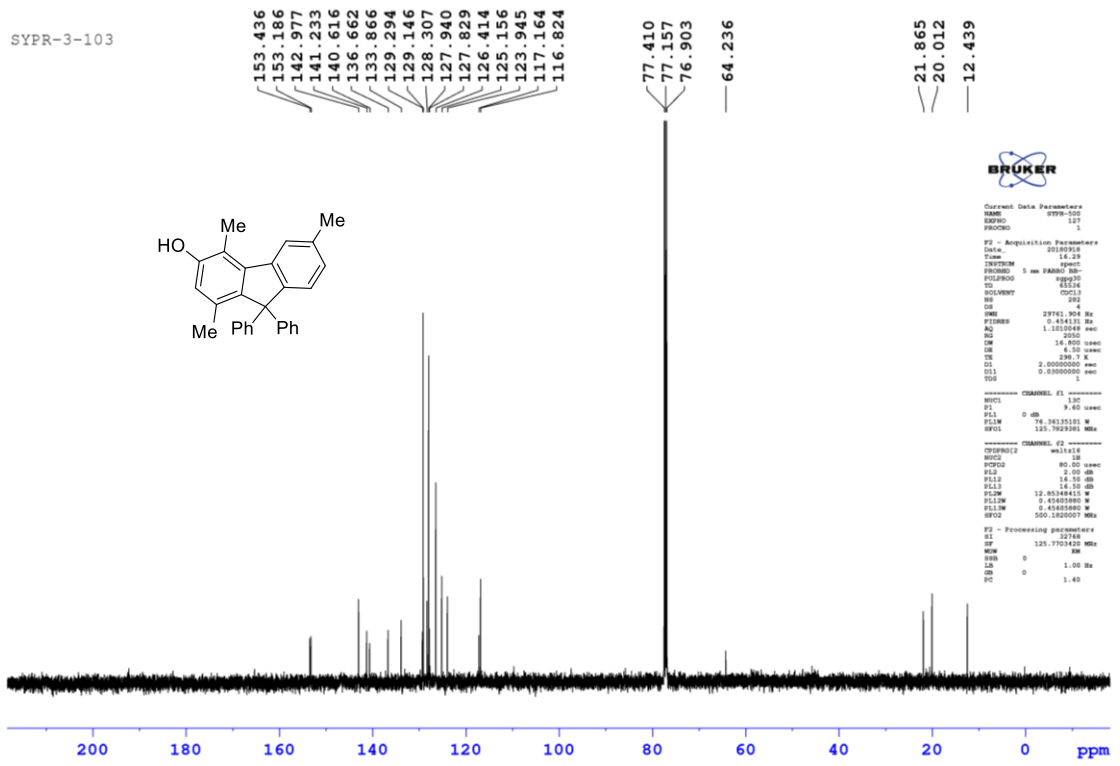
7.371
7.368
7.355
7.352
7.273
7.270
7.256
7.253
7.251
7.222
7.214
7.206
7.197
7.194
7.184
7.181
7.176
7.173
7.168
7.163
7.002
6.986
6.462
4.700
2.651
2.399
1.842
0.000
HO
Me
Me
Me
Ph
Ph
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
0.96
4.44
7.92
0.99
0.91
1.00
3.41
3.20
3.29


SYPR-3-103
153.436
153.186
142.977
141.233
140.616
136.662
133.866
129.294
129.146
128.307
127.940
127.829
126.414
125.156
123.945
117.164
116.824
77.410
77.157
76.903
64.236
21.865
20.012
12.439
HO
Me
Me
Me
Ph
Ph
BRUKER
200
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160
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120
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80
60
40
20
0
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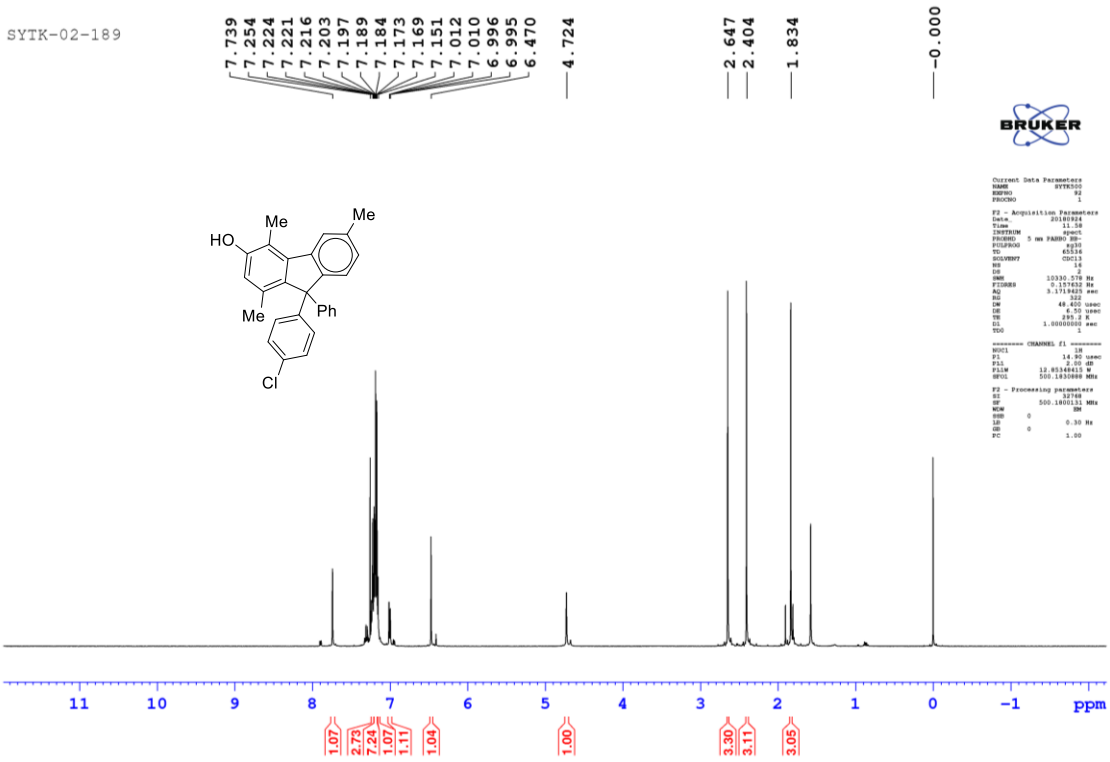
SYTK-02-189
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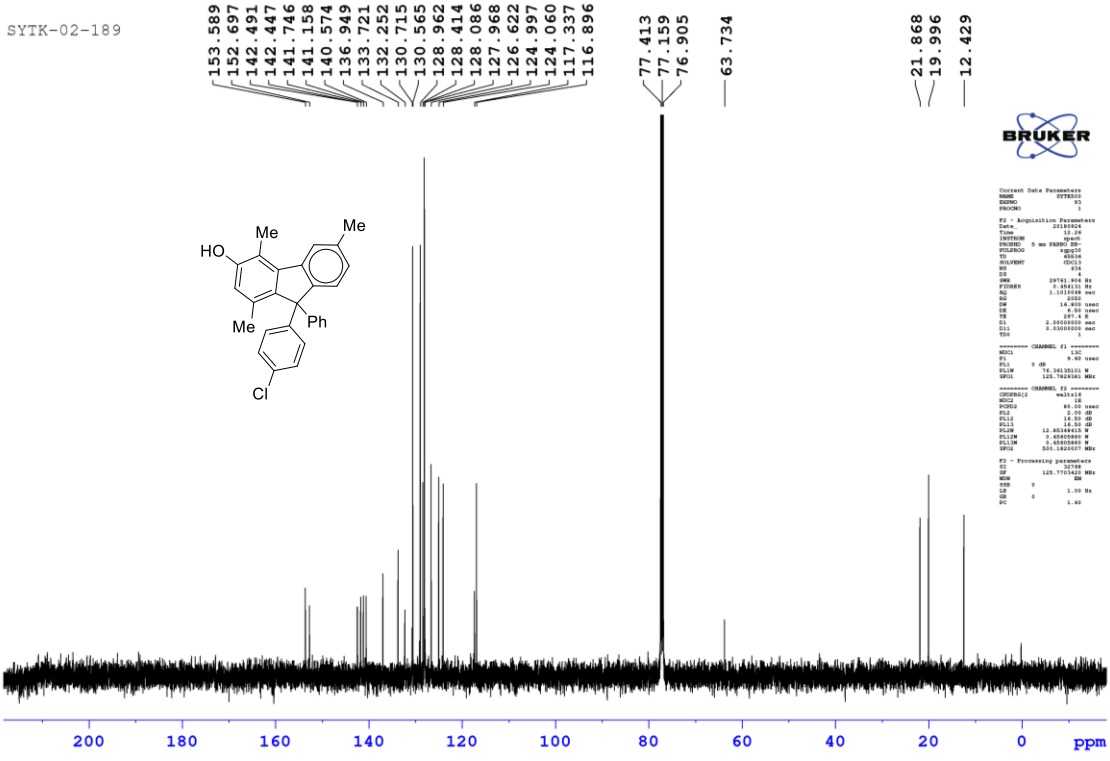
7.254
7.224
7.221
7.216
7.203
7.197
7.189
7.184
7.173
7.169
7.151
7.012
7.010
6.996
6.995
6.470
4.724
2.647
2.404
1.834
0.000
HO
Me
Me
Me
Ph
Cl
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.07
2.73
2.24
1.07
1.11
1.04
1.00
3.30
3.11
3.05


SYTK-02-189
153.589
152.697
142.491
142.447
141.746
141.158
140.574
136.949
133.721
132.252
130.715
130.565
128.962
128.414
128.086
127.968
126.622
124.997
124.060
117.337
116.896
77.413
77.159
76.905
63.734
21.868
19.996
12.429
HO
Me
Me
Me
Ph
Cl
BRUKER
200
180
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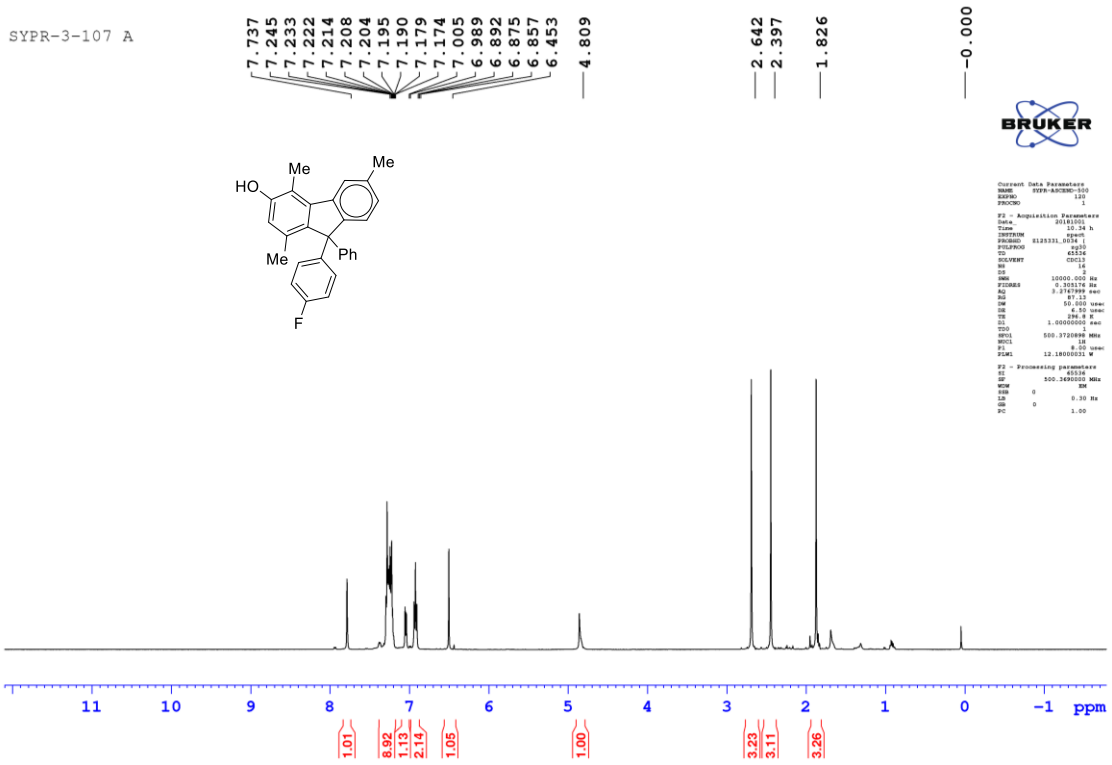
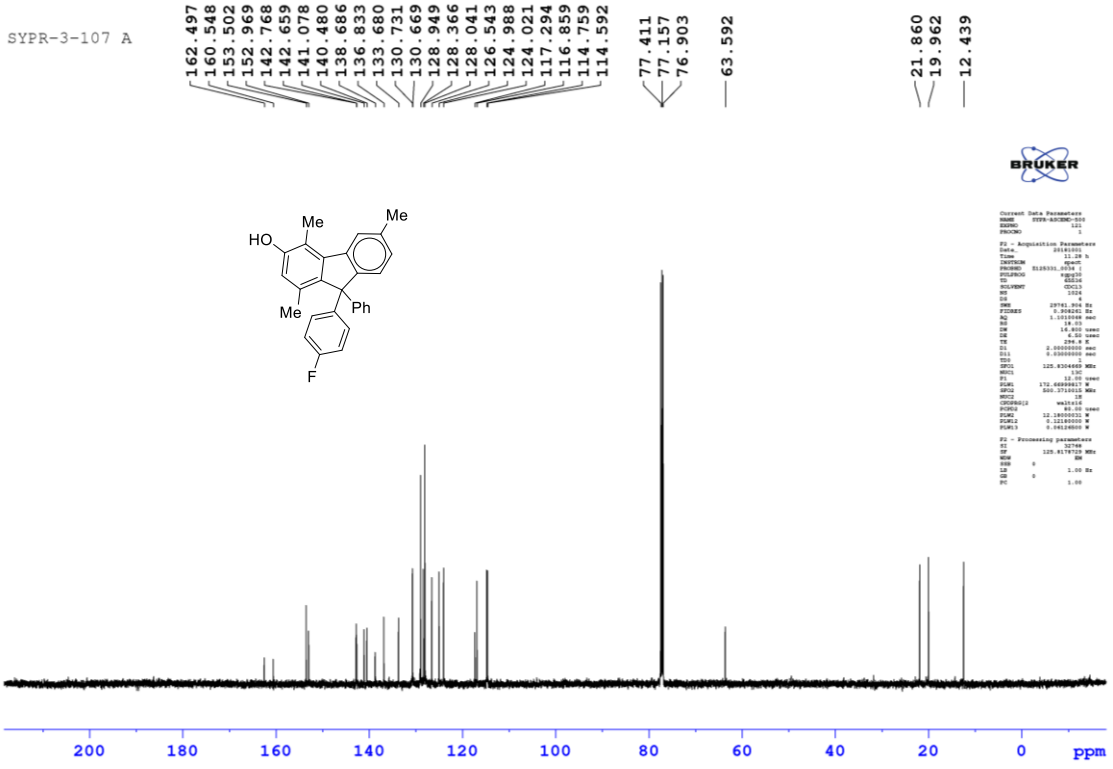
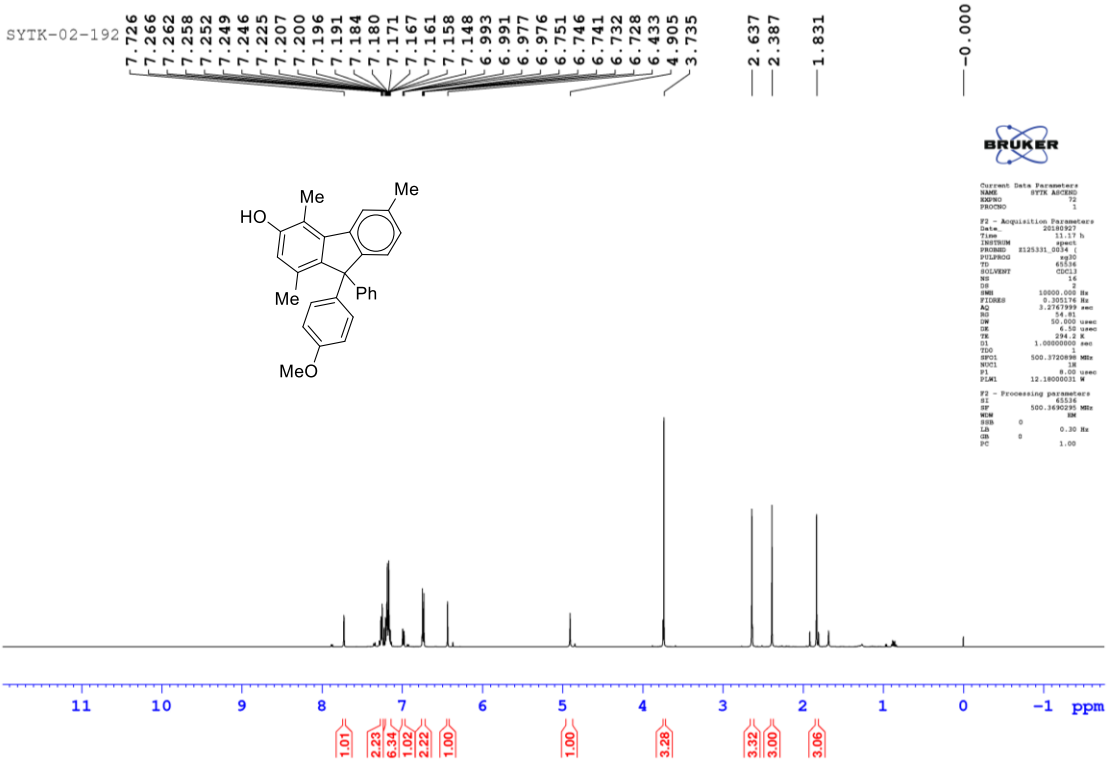
140
120
100
80
60
40
20
0
ppm


SYPR-3-107 A
7.737
7.245
7.233
7.222
7.214
7.208
7.204
7.195
7.190
7.179
7.174
7.005
6.989
6.892
6.875
6.857
6.453
4.809
2.642
2.397
1.826
0.000
BRUKER
HO
Me
Me
Me
Ph
F
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.01
8.92
1.13
2.14
1.05
1.00
3.23
3.11
3.26


SYPR-3-107 A
162.497
160.548
153.502
152.969
142.768
142.659
141.078
140.480
138.686
136.833
133.680
130.731
130.669
128.949
128.366
128.041
126.543
124.988
124.021
117.294
116.859
114.759
114.592
77.411
77.157
76.903
63.592
21.860
19.962
12.439
BRUKER
HO
Me
Me
Me
Ph
F
200
180
160
140
120
100
80
60
40
20
0
ppm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7.266
7.262
7.258
7.252
7.249
7.246
7.225
7.207
7.200
7.196
7.191
7.184
7.180
7.171
7.167
7.161
7.158
7.148
6.993
6.991
6.977
6.976
6.751
6.746
6.741
6.732
6.728
6.433
4.905
3.735
2.637
2.387
1.831
0.000
HO
Me
Me
Me
Ph
MeO
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
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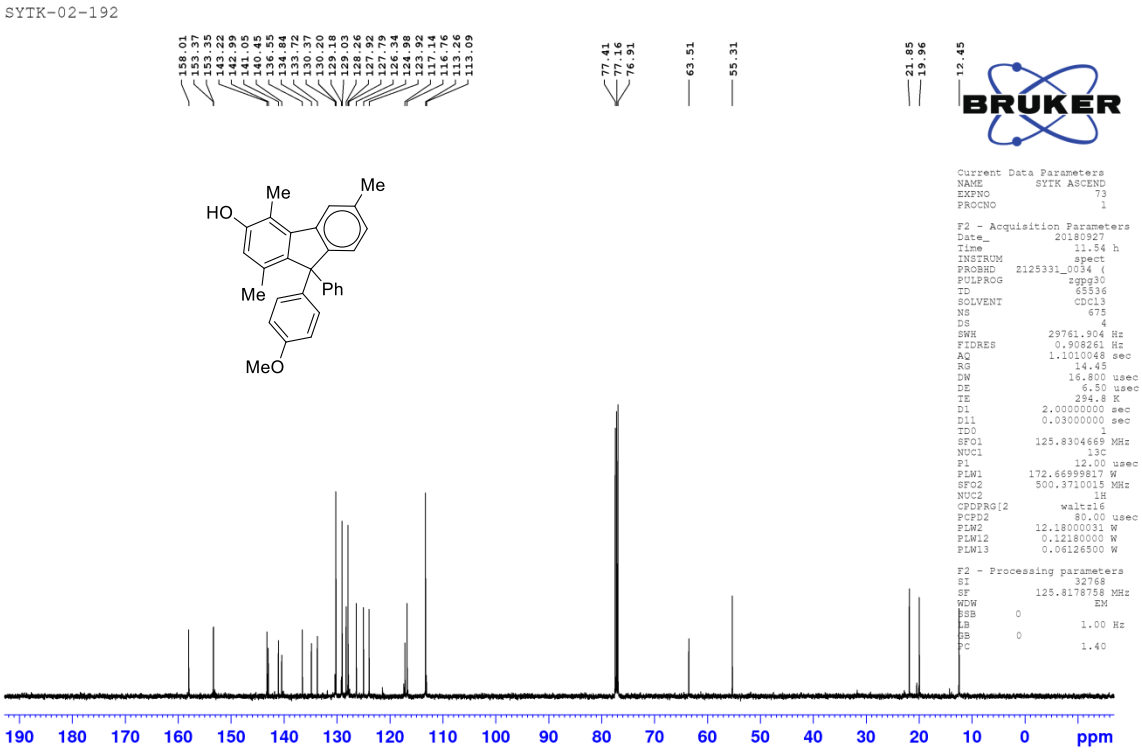
2.23
6.34
1.02
2.22
1.00
1.00
3.28
3.32
3.00
3.06


SYTK-02-192
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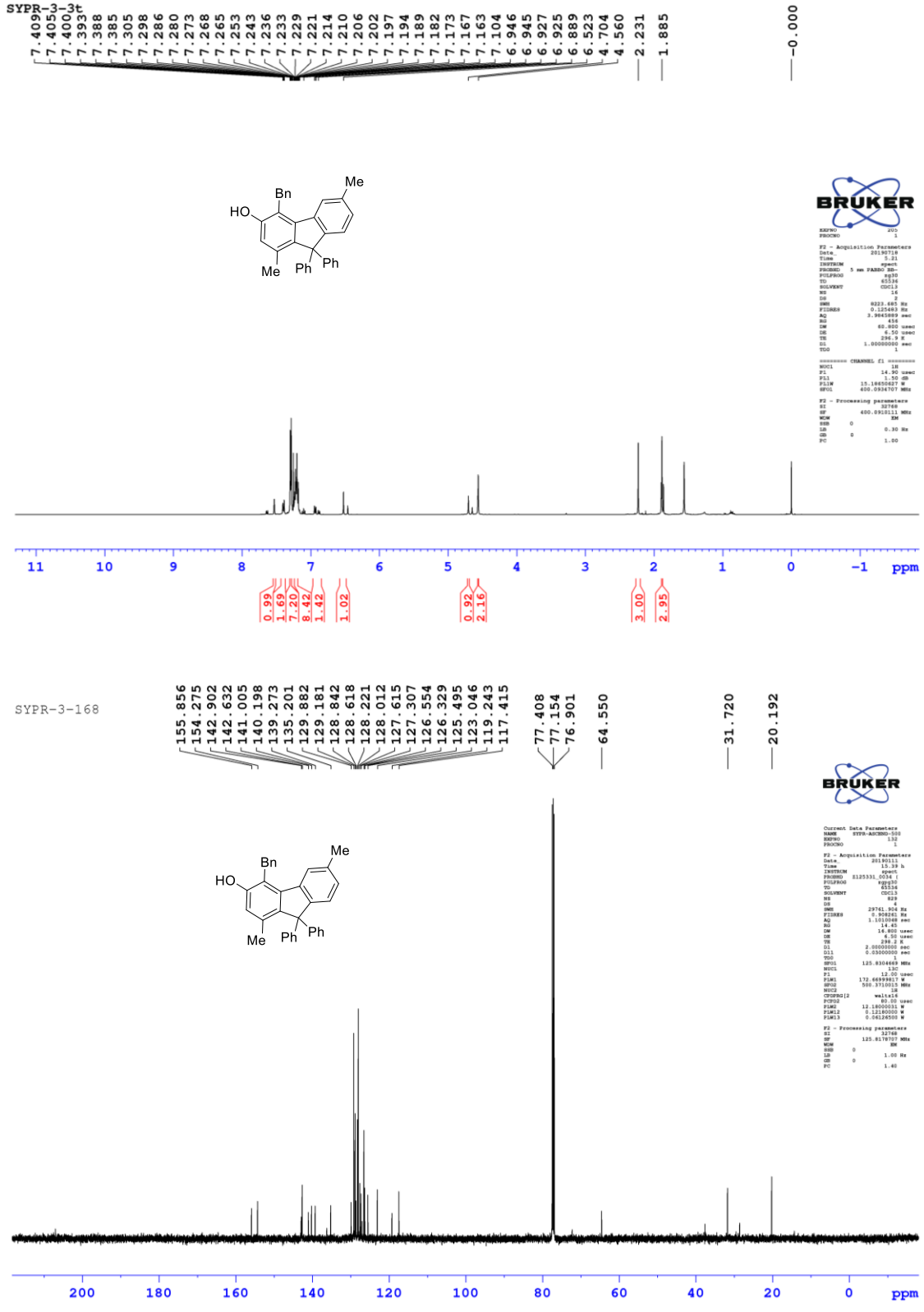
153.37
153.35
143.22
142.99
141.05
140.45
136.55
134.84
133.72
130.37
130.20
129.18
129.03
128.26
127.92
127.79
126.34
124.98
123.92
117.14
116.76
113.26
113.09
77.41
77.16
76.91
63.51
55.31
21.85
19.96
12.45
HO
Me
Me
Me
Ph
MeO
BRUKER
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


SYPR-3-3t
7.409
7.405
7.400
7.393
7.388
7.385
7.305
7.298
7.286
7.280
7.273
7.268
7.265
7.253
7.243
7.236
7.233
7.229
7.221
7.214
7.210
7.206
7.202
7.197
7.194
7.189
7.182
7.173
7.167
7.163
7.104
6.946
6.945
6.927
6.925
6.889
6.523
4.704
4.560
2.231
1.885
-0.000
Me
Bn
HO
Me
Ph
Ph
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
0.99
1.69
7.20
8.42
1.42
1.02
0.92
2.16
3.00
2.95
SYPR-3-168
155.856
154.275
142.902
142.632
141.005
140.198
139.273
135.201
129.882
129.181
128.842
128.618
128.221
128.012
127.615
127.307
126.554
126.329
125.495
123.046
119.243
117.415
77.408
77.154
76.901
64.550
31.720
20.192
Me
Bn
HO
Me
Ph
Ph
BRUKER
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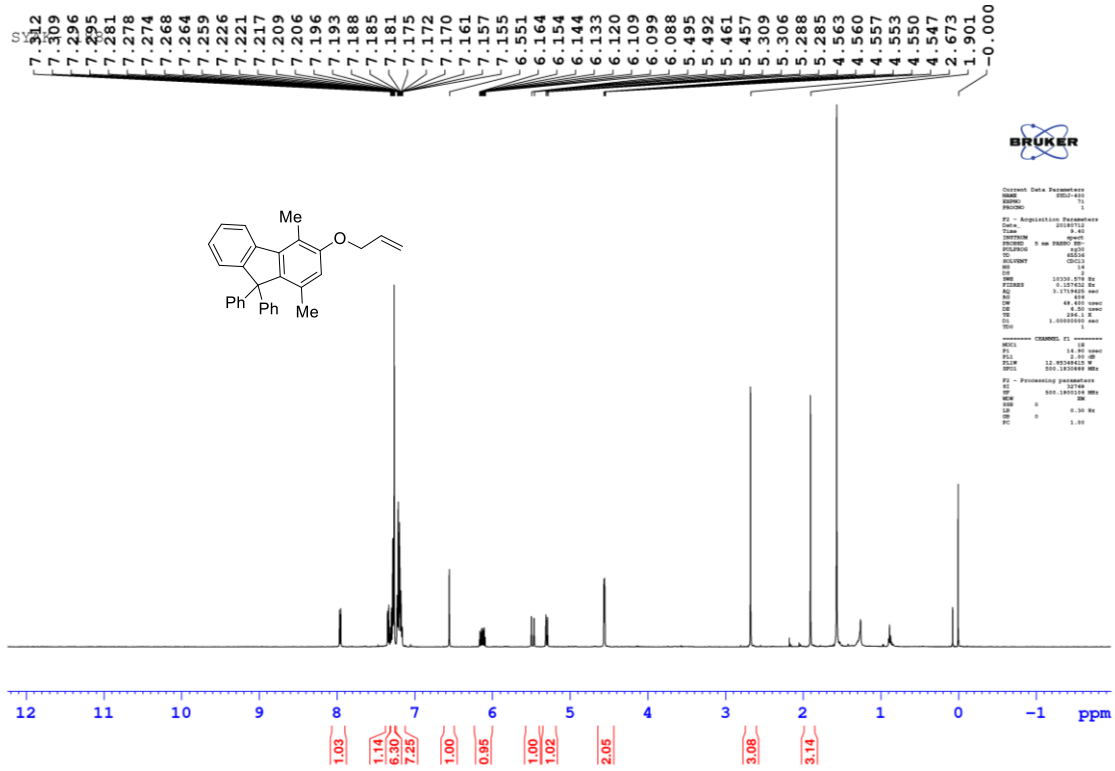
140
120
100
80
60
40
20
0
ppm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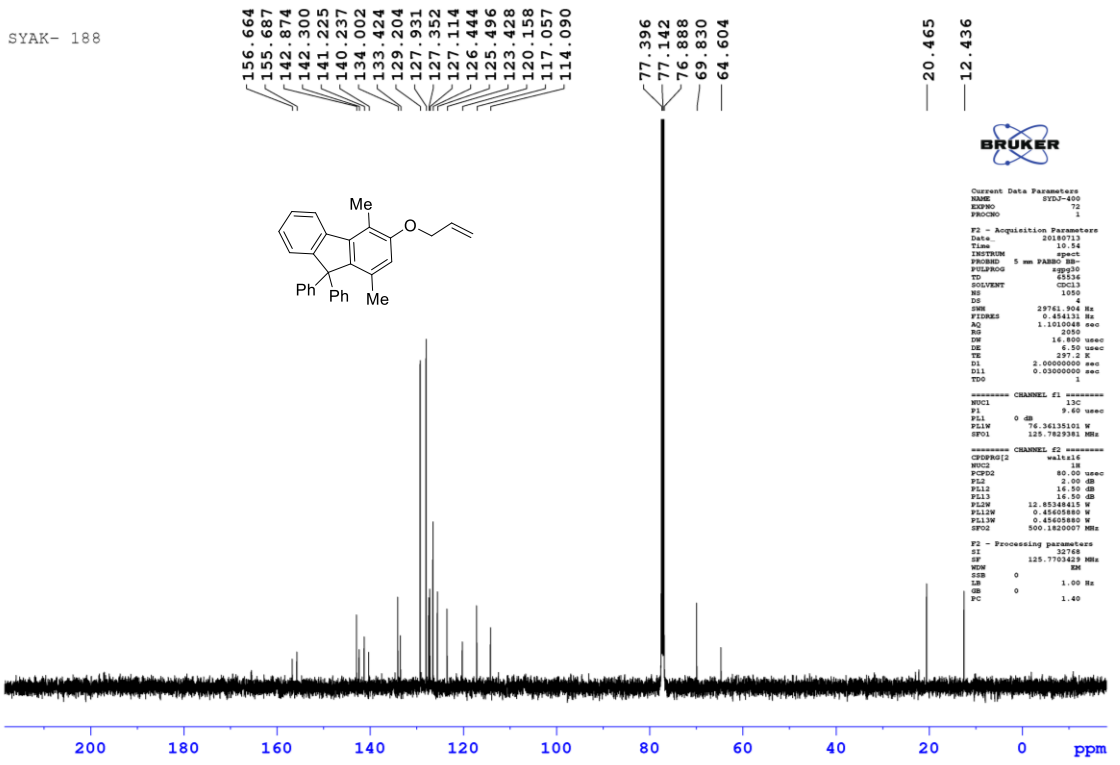
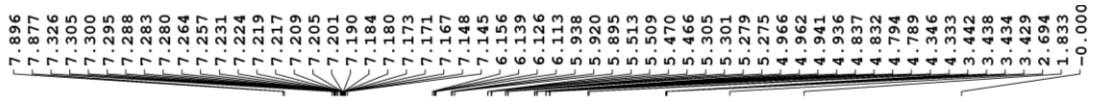
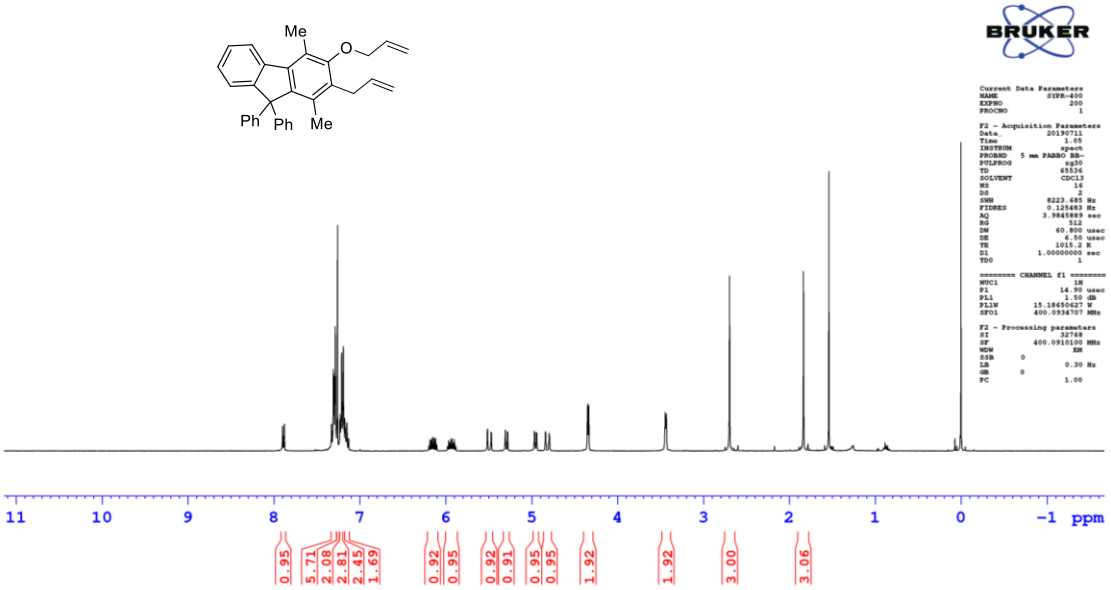
7.309
7.296
7.295
7.281
7.278
7.274
7.268
7.264
7.259
7.226
7.221
7.217
7.209
7.206
7.196
7.193
7.188
7.185
7.181
7.175
7.172
7.170
7.161
7.157
7.155
6.551
6.164
6.154
6.144
6.133
6.120
6.109
6.099
6.088
5.495
5.492
5.461
5.457
5.309
5.306
5.288
5.285
4.563
4.560
4.557
4.553
4.550
4.547
2.673
1.901
0.000
Me
O
Ph
Ph
Me
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.03
1.14
6.30
7.25
1.00
0.95
1.00
1.02
2.05
3.08
3.14

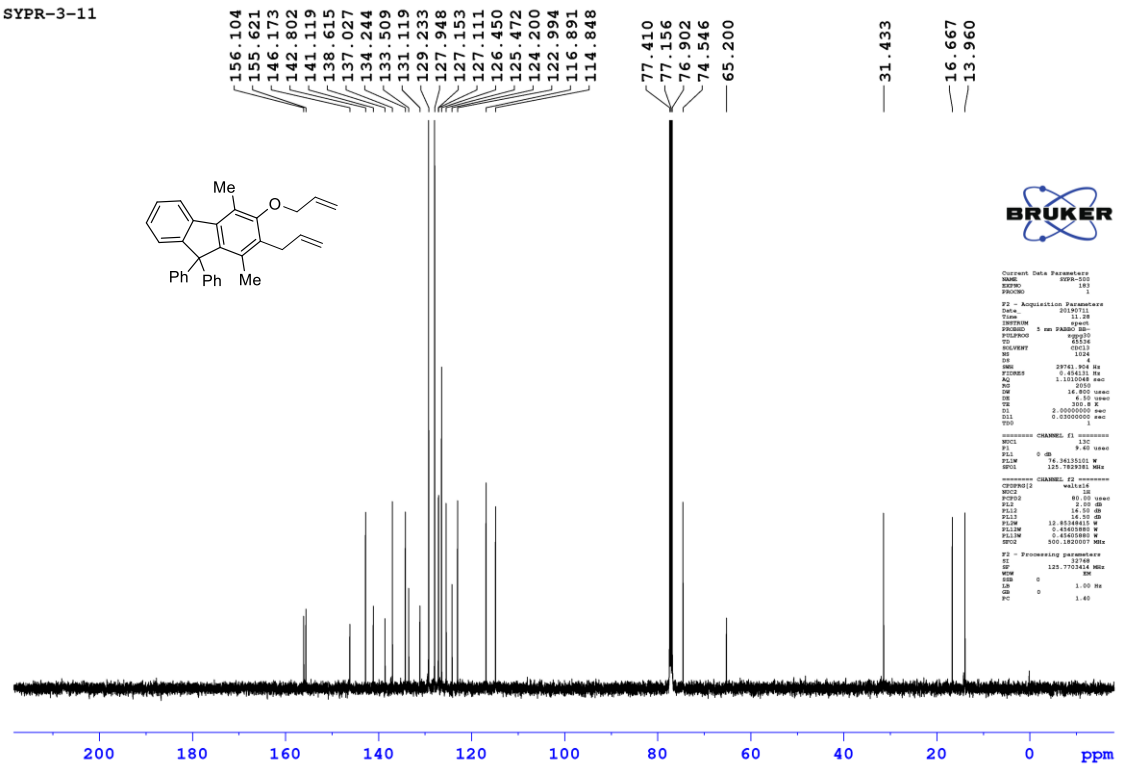

SYAK- 188
156.664
155.687
142.874
142.300
141.225
140.237
134.002
133.424
129.204
127.931
127.352
127.114
126.444
125.496
123.428
120.158
117.057
114.090
77.396
77.142
76.888
69.830
64.604
20.465
12.436
Me
O
Ph
Ph
Me
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

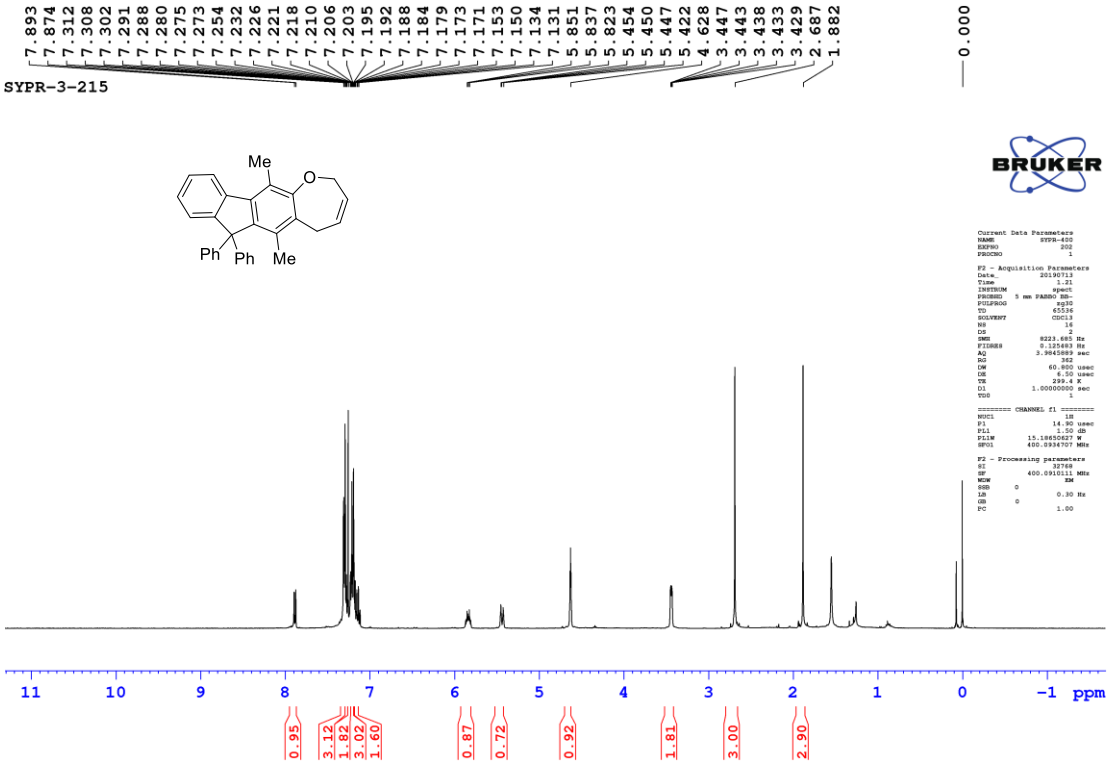


SYPR-3-11



SYPR-3-11

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7.312
7.308
7.302
7.291
7.288
7.280
7.275
7.273
7.254
7.232
7.226
7.221
7.218
7.210
7.206
7.203
7.195
7.192
7.188
7.184
7.179
7.173
7.171
7.153
7.150
7.134
7.131
5.851
5.837
5.823
5.454
5.450
5.447
5.422
4.628
3.447
3.443
3.438
3.433
3.429
2.687
1.882
0.000
SYPR-3-215
Me
Ph
Ph
Me
O
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
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1.82
3.02
1.60
0.87
0.72
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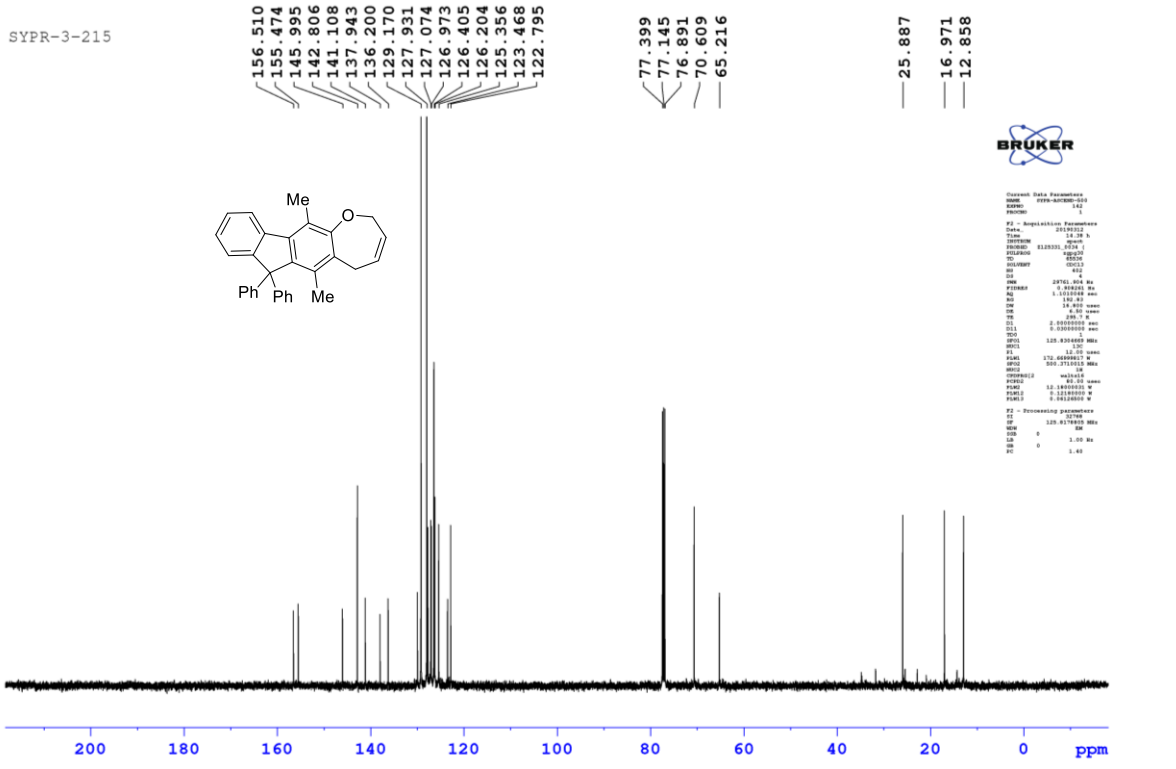
1.81
3.00
2.90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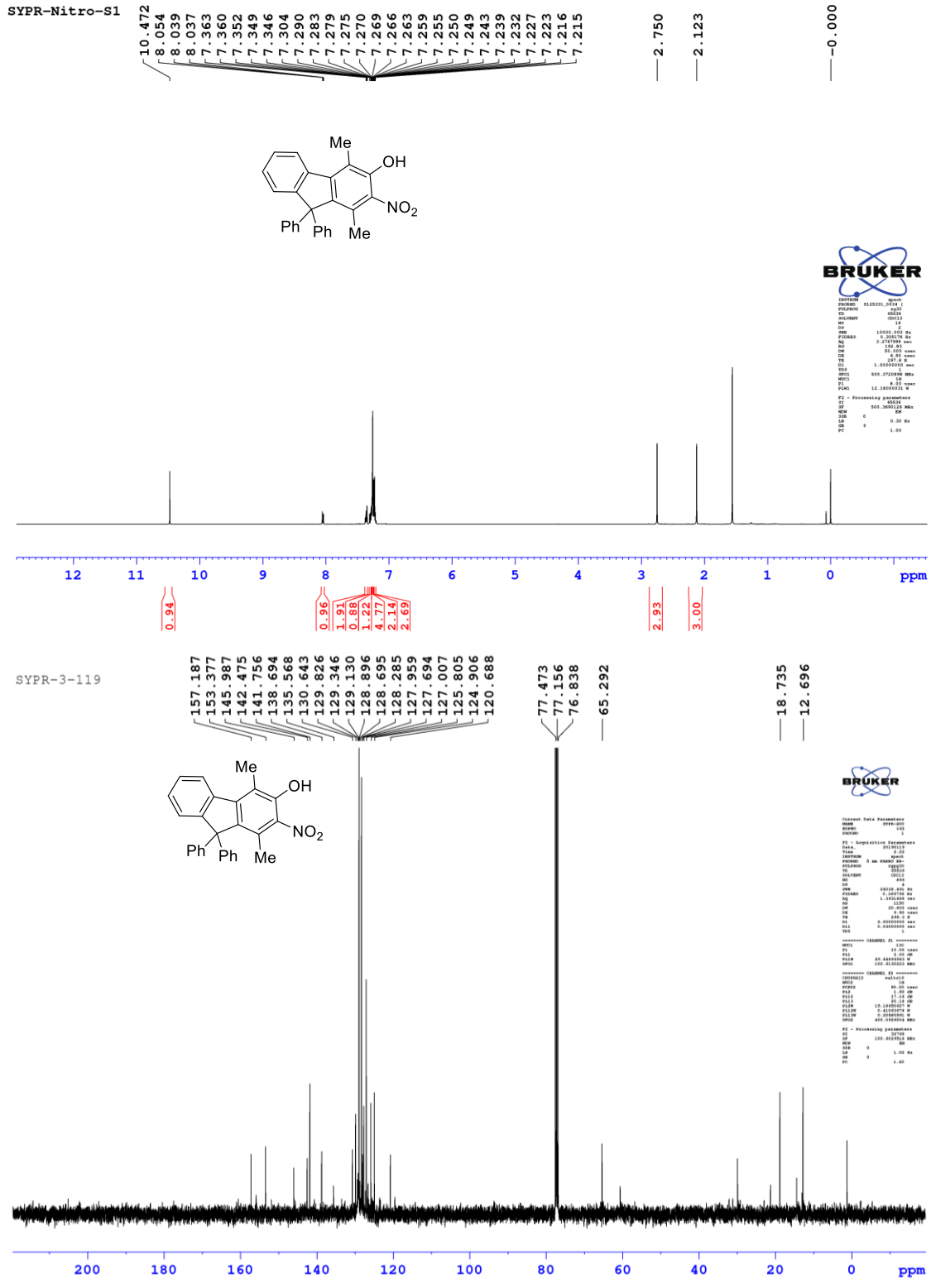
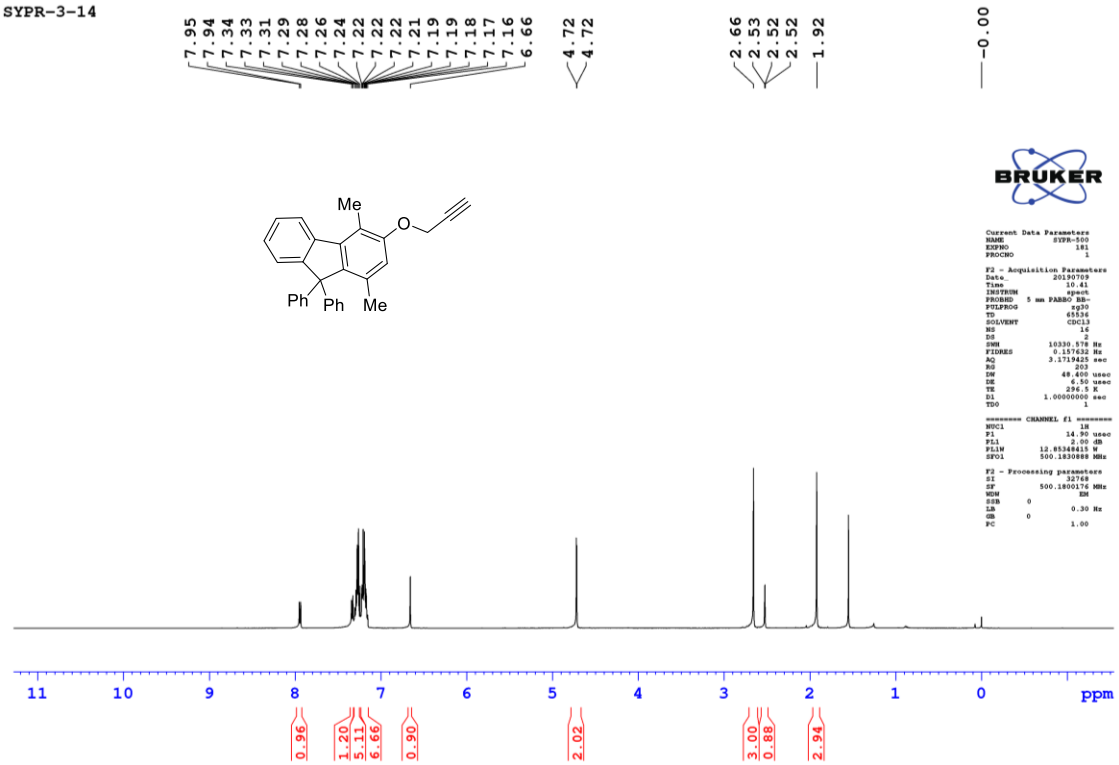
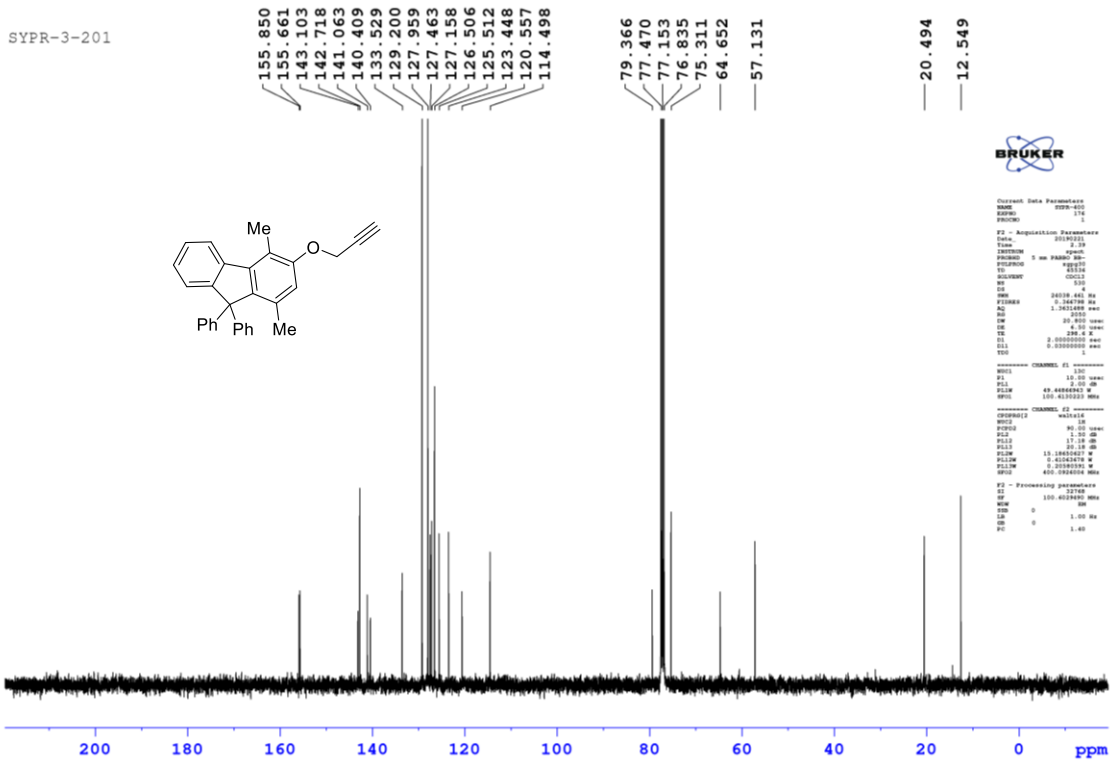
155.474
145.995
142.806
141.108
137.943
136.200
129.170
127.931
127.074
126.973
126.405
126.204
125.356
123.468
122.795
77.399
77.145
76.891
70.609
65.216
25.887
16.971
12.858
Me
Ph
Ph
Me
O
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

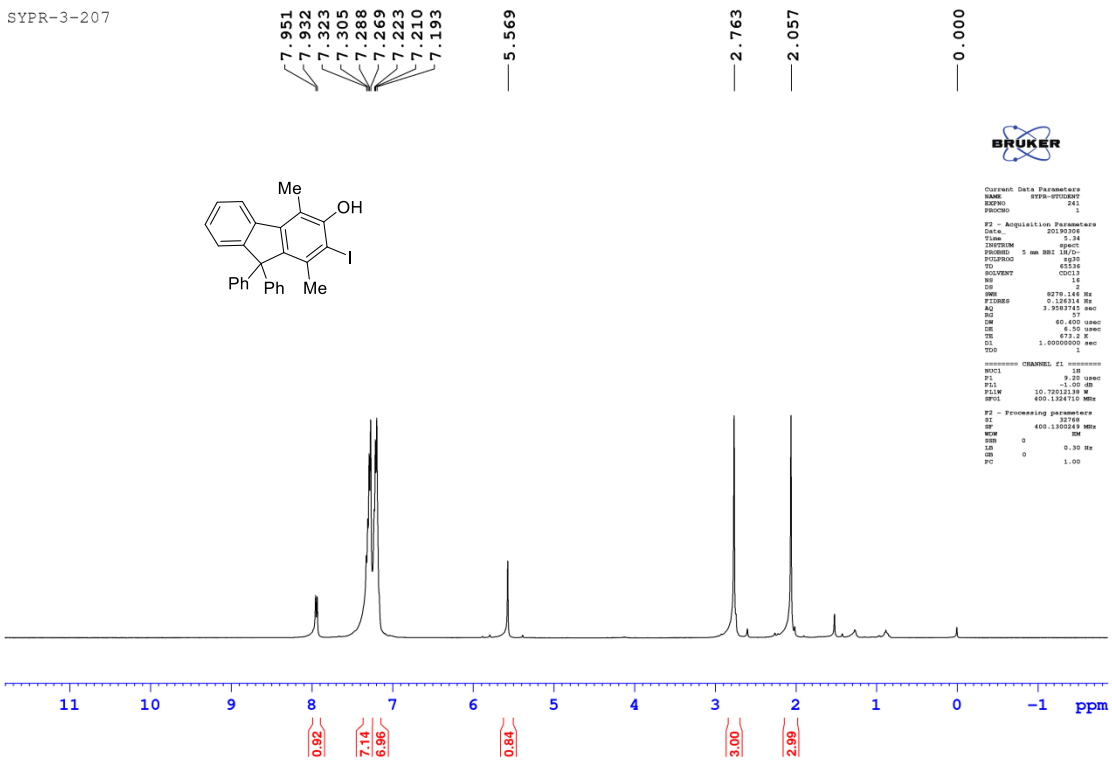

SYPR-Nitro-S1
10.472
8.054
8.039
8.037
7.363
7.360
7.352
7.349
7.346
7.304
7.290
7.283
7.279
7.275
7.270
7.269
7.266
7.263
7.259
7.255
7.250
7.249
7.243
7.239
7.232
7.227
7.223
7.216
7.215
2.750
2.123
0.000
Me
OH
NO2
Ph
Ph
Me
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.94
0.96
1.91
0.88
1.22
4.77
2.14
2.69
2.93
3.00
SYPR-3-119
157.187
153.377
145.987
142.475
141.756
138.694
135.568
130.643
129.826
129.346
129.130
128.896
128.695
128.285
127.959
127.694
127.007
125.805
124.906
120.688
77.473
77.156
76.838
65.292
18.735
12.696
Me
OH
NO2
Ph
Ph
Me
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

SYPR-3-14



SYPR-3-201

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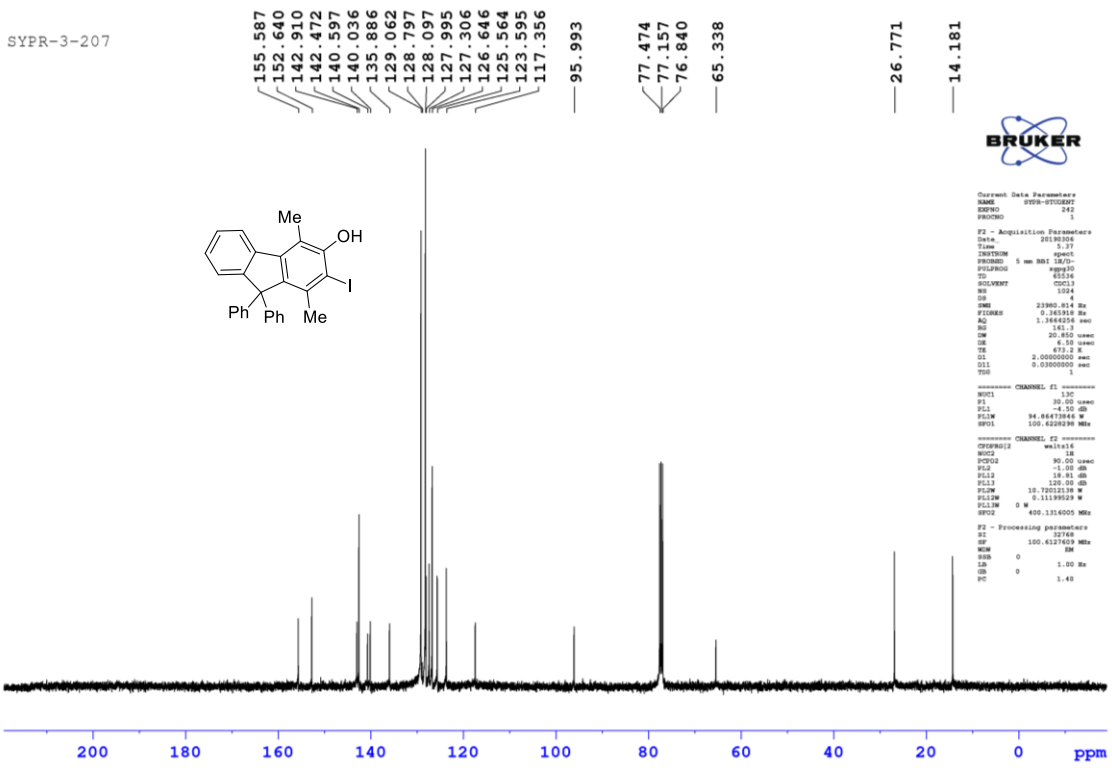
7.932
7.323
7.305
7.288
7.269
7.223
7.210
7.193
5.569
2.763
2.057
0.000
Me
OH
I
Ph
Ph
Me
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.92
7.14
6.96
0.84
3.00
2.99


SYPR-3-207
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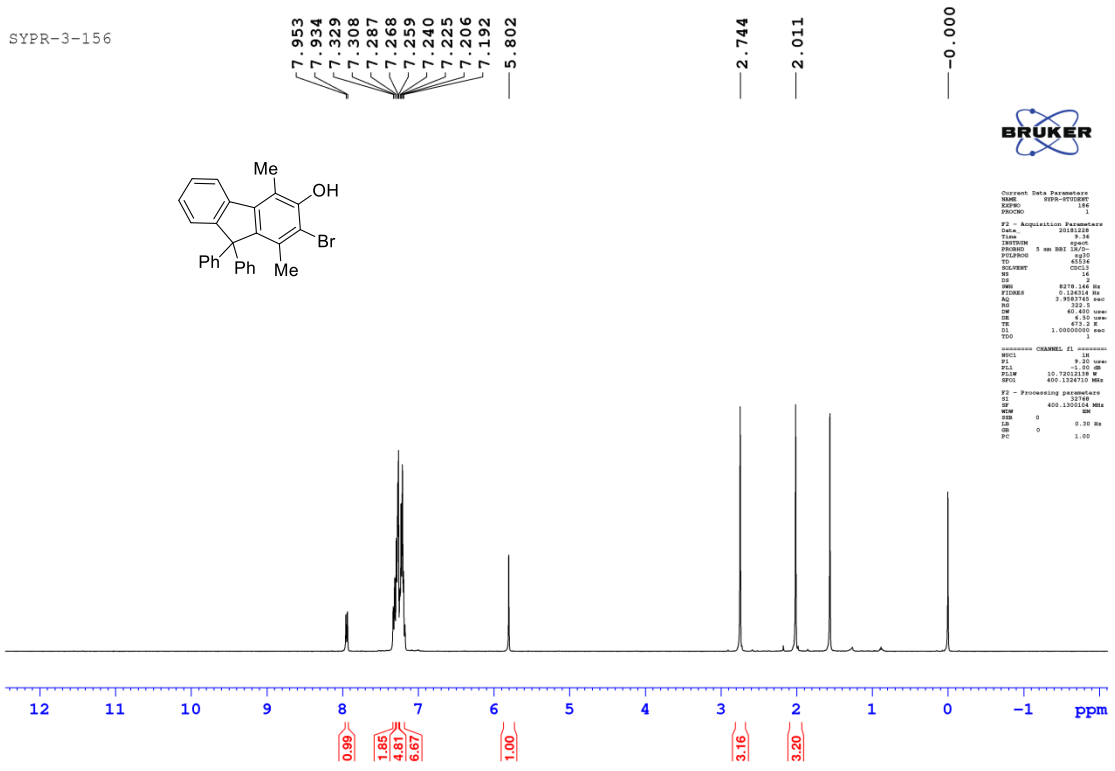
152.640
142.910
142.472
140.597
140.036
135.886
129.062
128.797
128.097
127.995
127.306
126.646
125.564
123.595
117.356
95.993
77.474
77.157
76.840
65.338
26.771
14.181
Me
OH
I
Ph
Ph
Me
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3-156
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7.934
7.329
7.308
7.287
7.268
7.259
7.240
7.225
7.206
7.192
5.802
2.744
2.011
0.000
Me
OH
Br
Ph
Ph
Me
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.99
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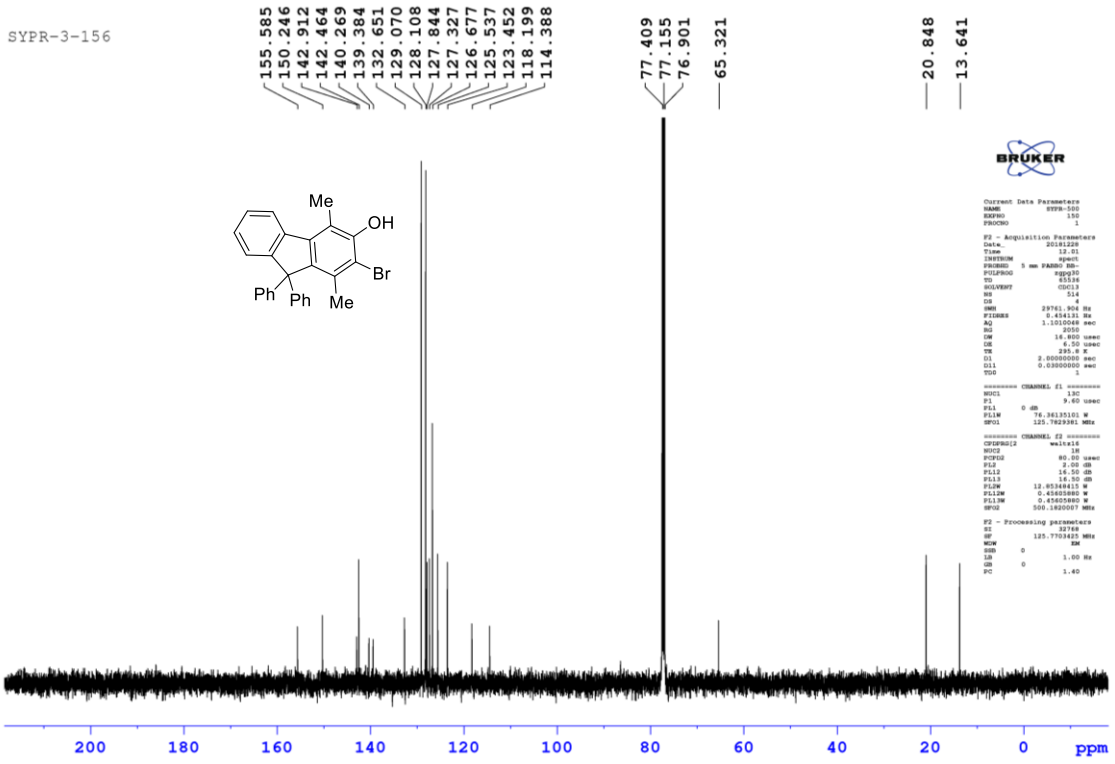
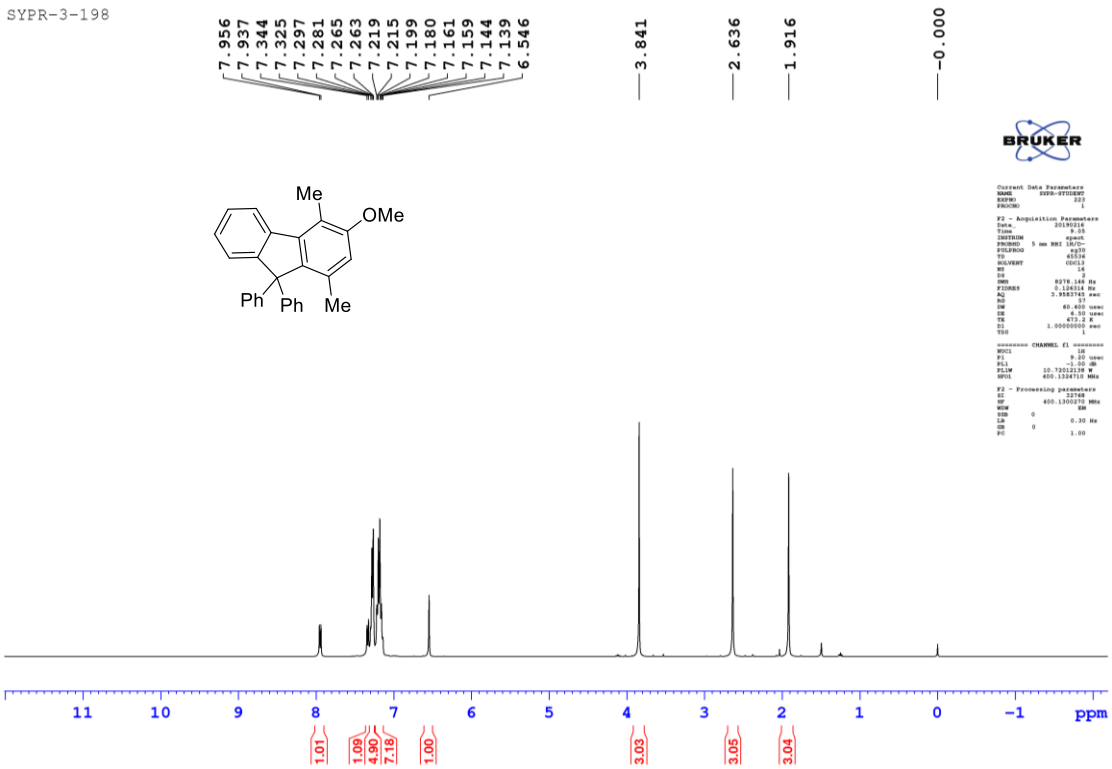
4.81
6.67
1.00
3.16
3.20


SYPR-3-156
155.585
150.246
142.912
142.464
140.269
139.384
132.651
129.070
128.108
127.844
127.327
126.677
125.537
123.452
118.199
114.388
77.409
77.155
76.901
65.321
20.848
13.641
Me
OH
Br
Ph
Ph
Me
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm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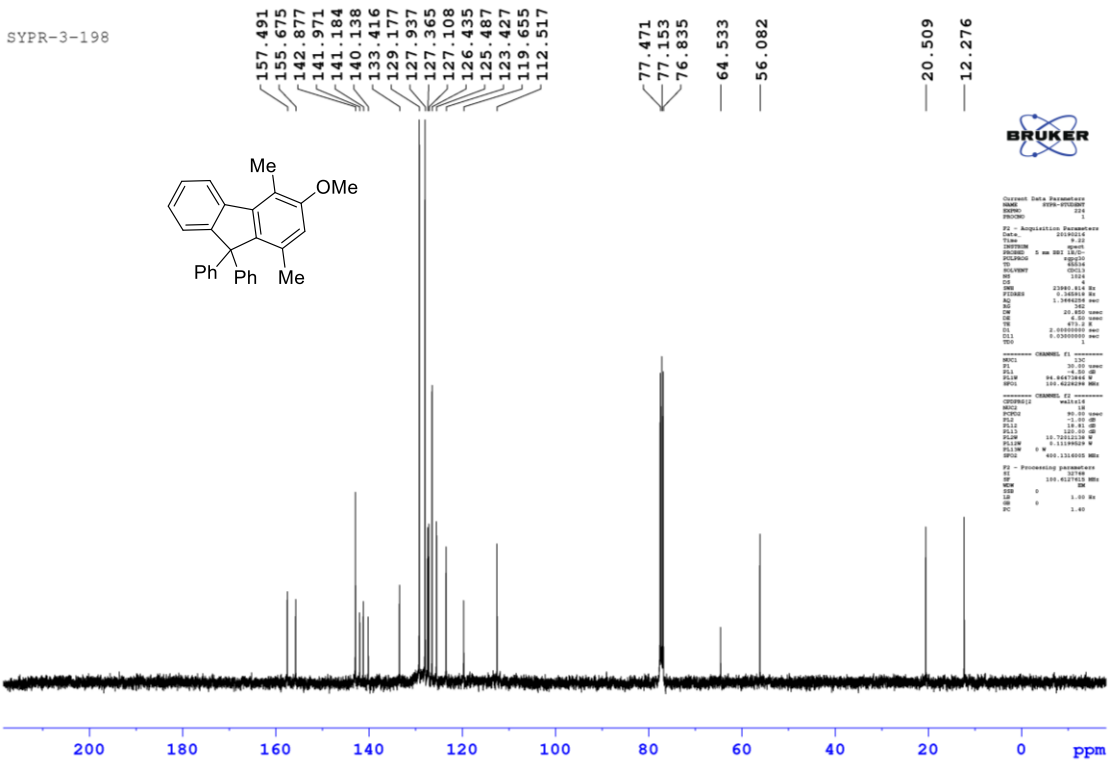
7.344
7.325
7.297
7.281
7.265
7.263
7.219
7.215
7.199
7.180
7.161
7.159
7.144
7.139
6.546
3.841
2.636
1.916
0.000
Me
OMe
Ph
Ph
Me
BRUKER
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
1.01
1.09
4.90
7.18
1.00
3.03
3.05
3.04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123.427
119.655
112.517
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77.153
76.835
64.533
56.082
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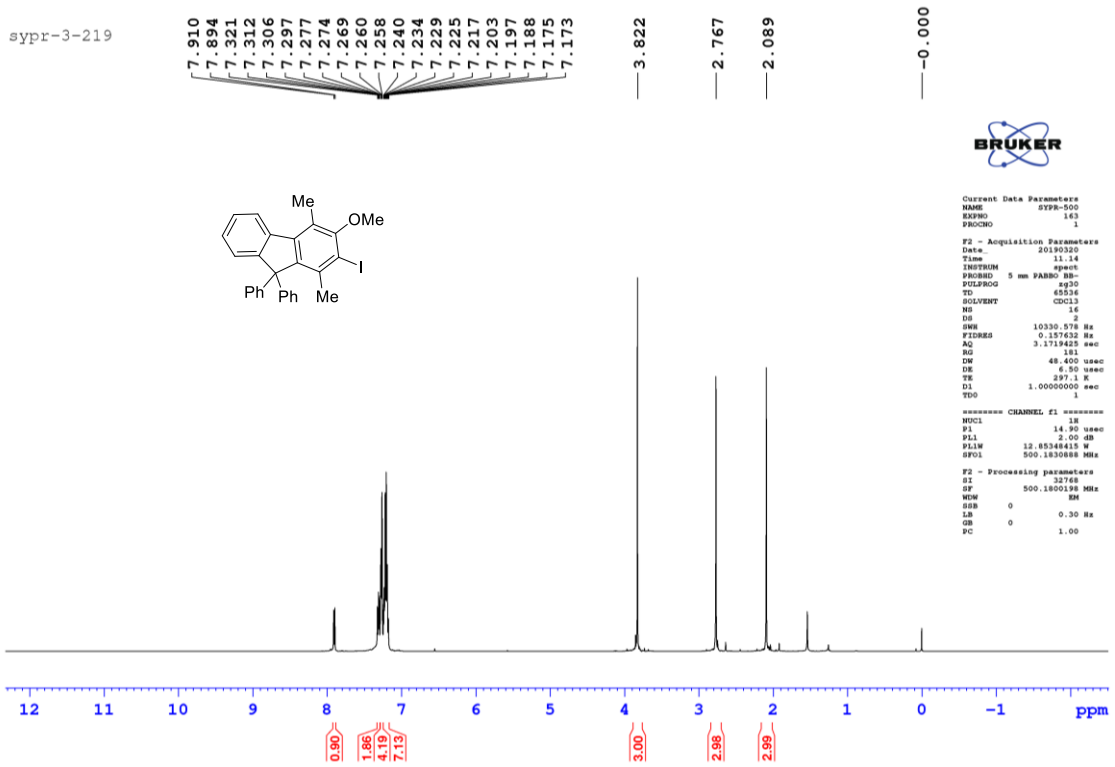
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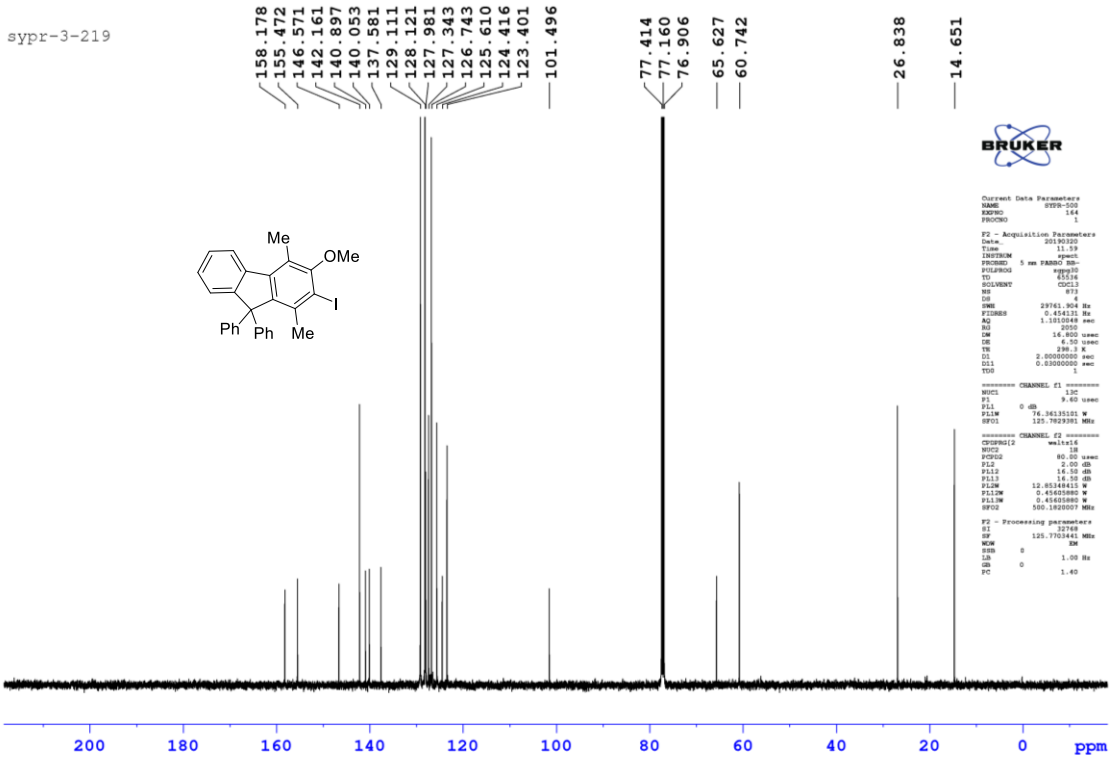
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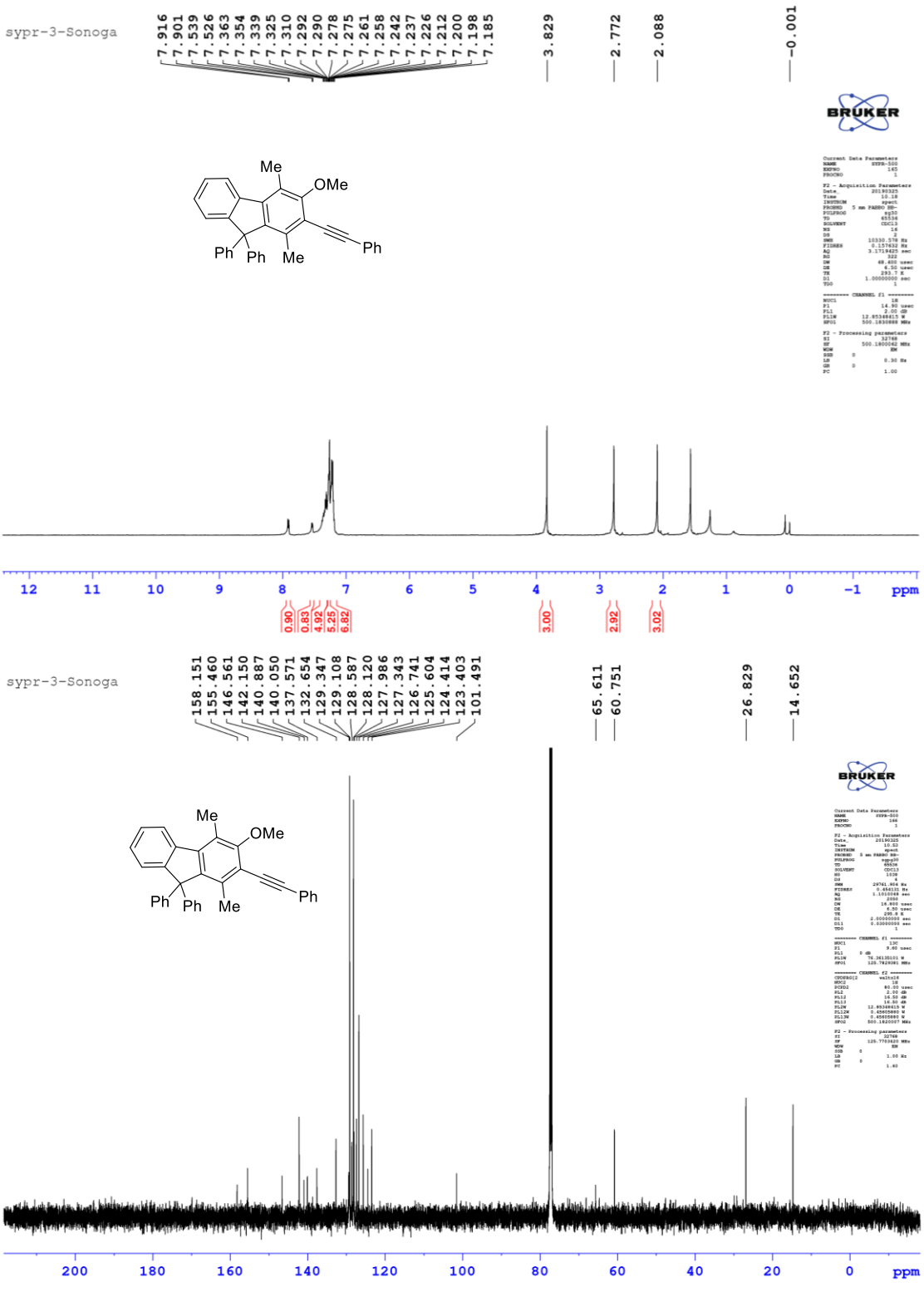
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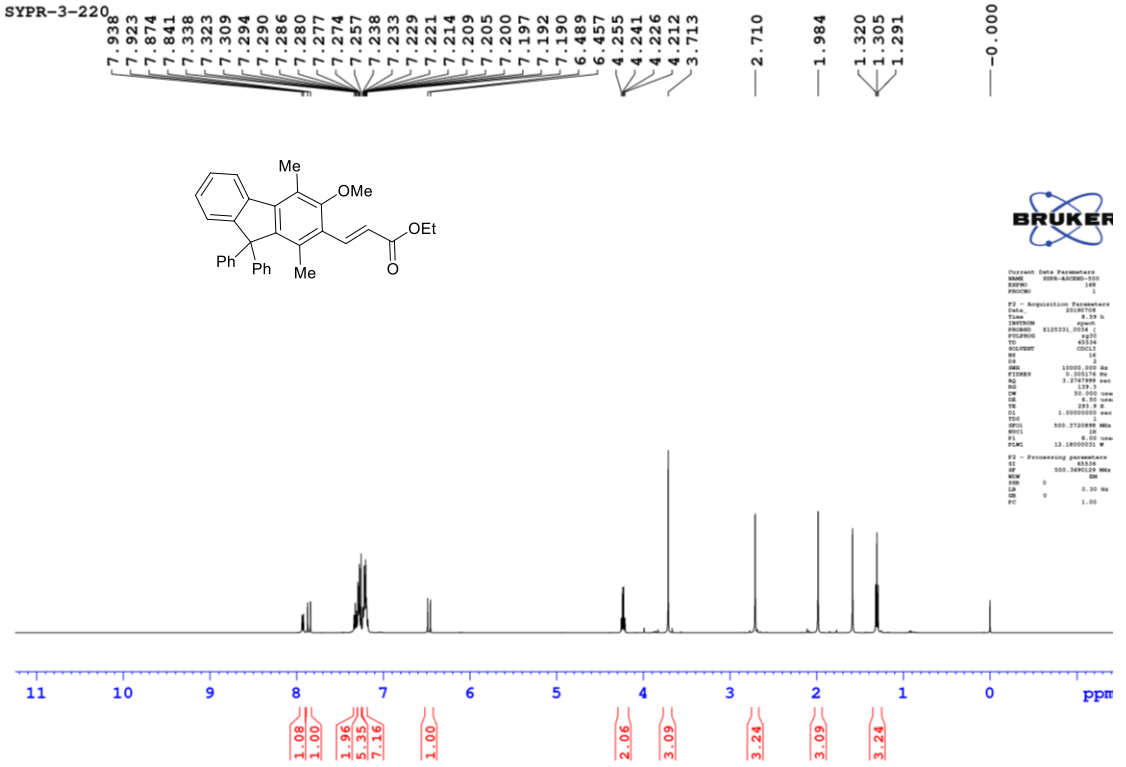
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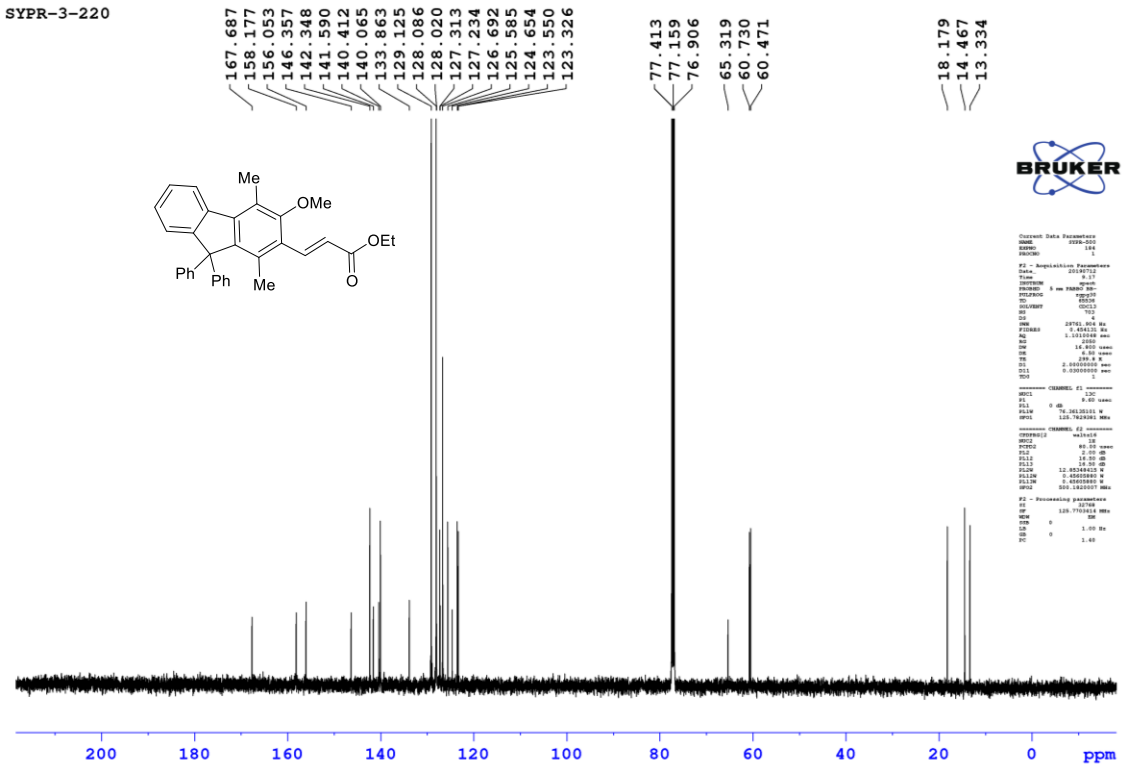
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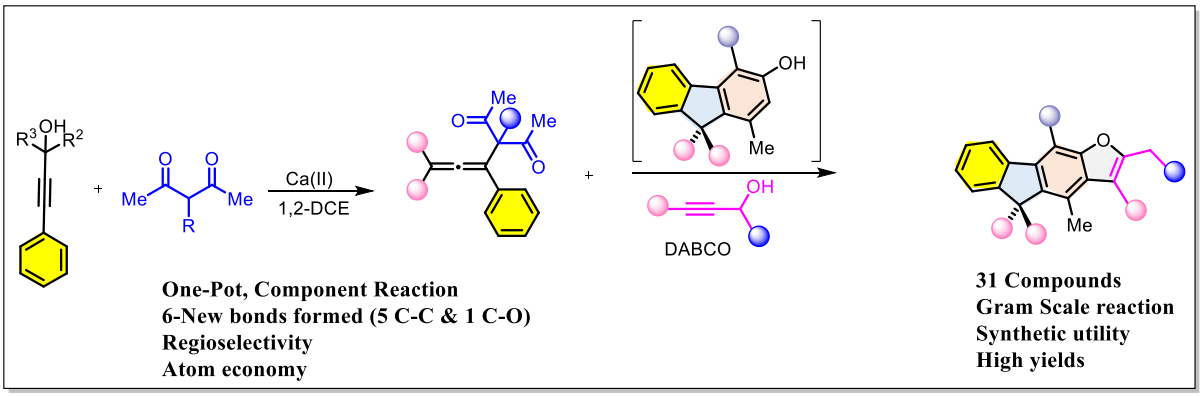
Synthesis and in-situ Cyclization of Tetrasubstituted Allenes to Access Tetracyclic Fluorenofurans



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4.1 PROPOSAL FOR THE SYNTHESIS OF FLUORENOFURAN AND PYRAN

As mentioned before, ynol **1** and diketone **67b** react in the presence of calcium-catalyst to give allene intermediate **A**, which further cyclizes to produce fluorenol **123**. At this stage, we presumed that, the addition of a *sec*-propargyl alcohol to the fluorenol **123**, may lead to formation of new C-C bond due to the soft-soft interactions over the C-O bond to give compound **138aa** which may further undergo a 5-*exo*-*dig*-cyclization to give fluorenofuran or a 6-*endo*-*dig*-cyclization to form fluorenopyran. The selectivity of such cyclization can be controlled by the R^2-group attached to the alkyne moiety.

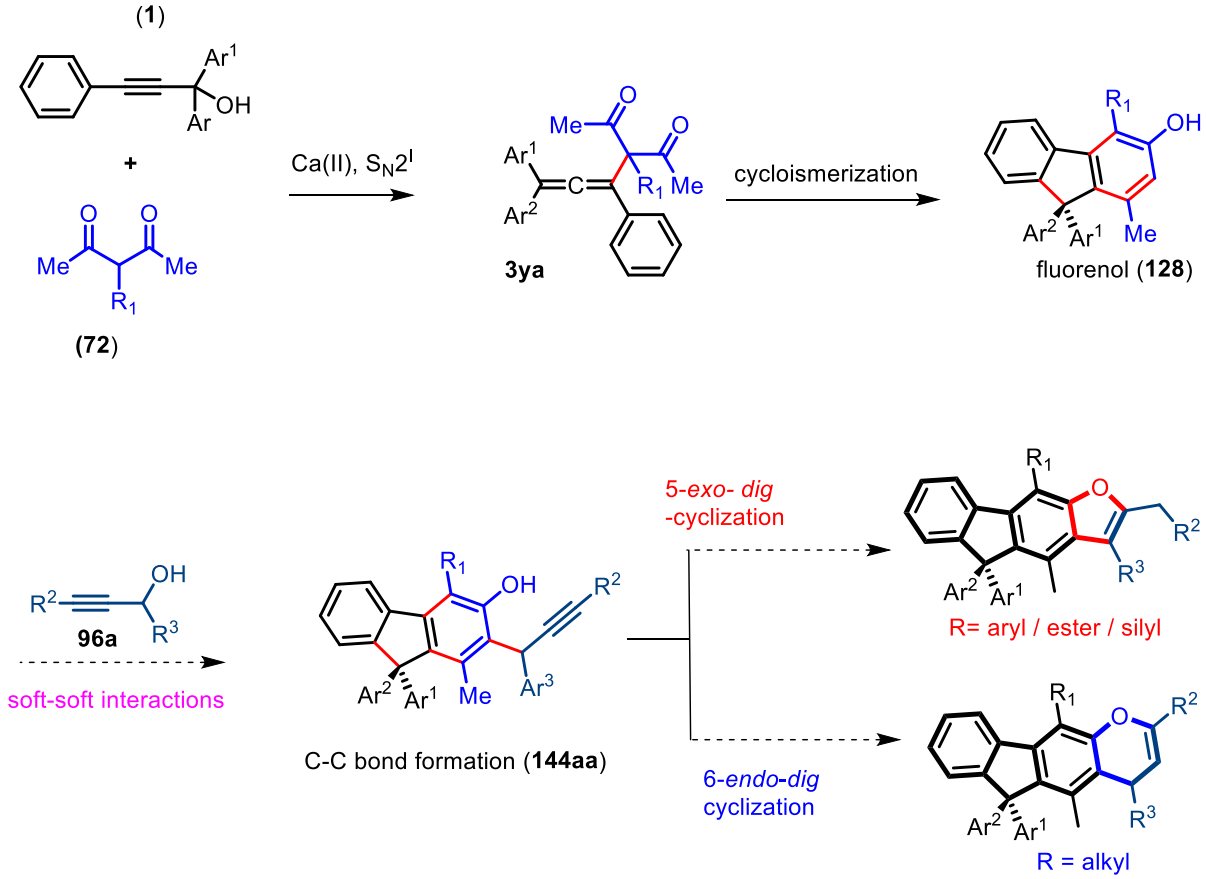
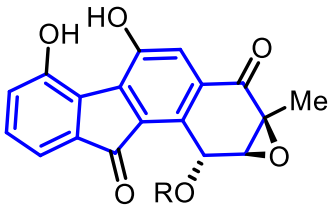


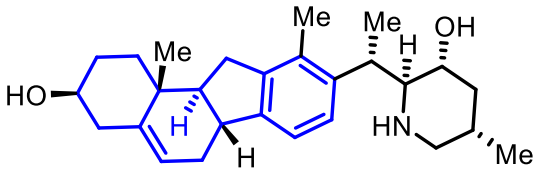
Figure 1. Conceptualization of highly regioselective synthesis of fluorenofuran and pyran derivatives

When we look at the literature for fluorene chemistry, we found that a similar kind of fluorene moiety was seen in various bioactive natural products and medicinal importants[1], and is often considered as a potential building block for the production of a variety of molecules with advanced material applications.[2] Furthermore, fluorenes fused with arenes or heteroarenes are known to exhibit interesting optoelectronic properties due to the presence of an extended π-conjugation.[3] In addition to being a constituent of a variety of natural products (Figure 2),

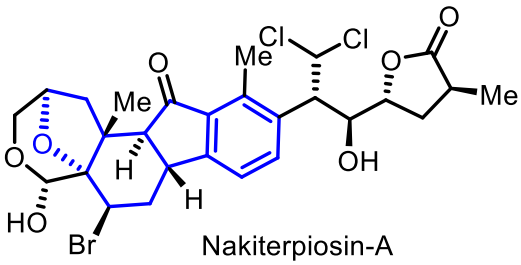
some linearly fused polyaromatic hydrocarbons (PAHs) possess significant medicinal properties as well. Due to their critical importance, the synthesis of benzofluorenes has been thoroughly studied among these linearly fused fluorenes. For example, the fluostatin family of natural products inhibits dipeptidyl peptidases and exhibits antibacterial and anticancer properties.[4] Similarly, Kinamycin natural products possess significant antibiotic and cytotoxic activities[5]; they serve as nonsteroidal drug candidates for the estrogen receptor-related treatments[6] and are often used as synthetic precursors[7]. They are also used as functional materials with promising applications.[8]



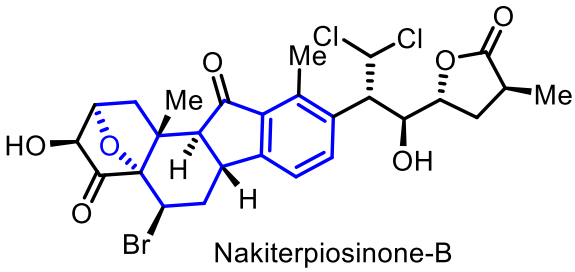
Fluostatin C (R=H)
Fluostatin D (R=COCHMe$_2$)
Fluostatin F (R=Me)



Veratramine-D



Nakiterpiosin-A

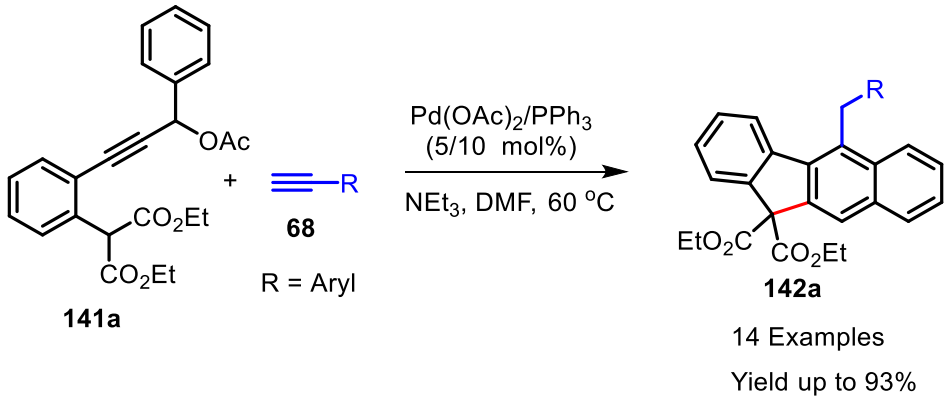


Nakiterpiosinone-B

Figure 2. Representative examples of naturally occurring [6-5-6-6] and [6-5-6-5]fused-fluorenes

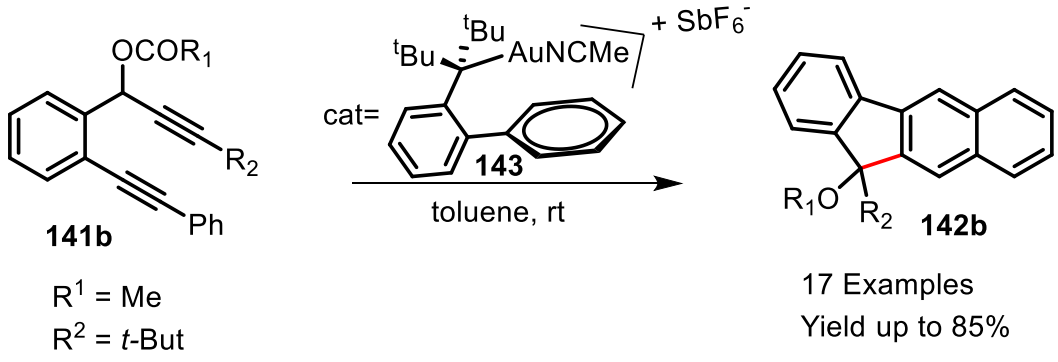
4.2 PREVIOUS REPORTS

In 2007, Y.-M. Liang *et.al* reported a palladium-catalyzed tandem bis cyclization reaction that can be used to make different benzo[*b*]fluorene and fluorene analogs from propargylic compounds having terminal alkynes. This reaction proceeds through carboannulation, coupling, CH activation, and C-C bond formation (Scheme 1).[9]



Scheme 1. Synthesis of fused polycycles from propargylic compounds with terminal alkynes *via* a palladium-catalyzed cyclization reaction.

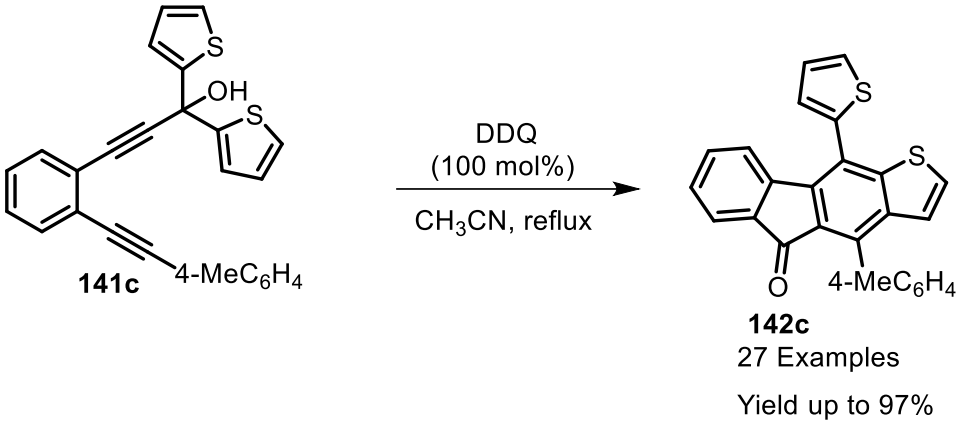
In 2012, Y. Liu *et.al* designed a new gold-catalyzed 1,6-diynylcarbonate cascade reaction that involved unusual arylation of oxocarbenium ion intermediates and decarboxylative etherification processes (Scheme 2). [10]



Scheme 2. Gold-catalyzed cyclizations of 1,6-diynyl carbonates to benzo[*b*]fluorenes.

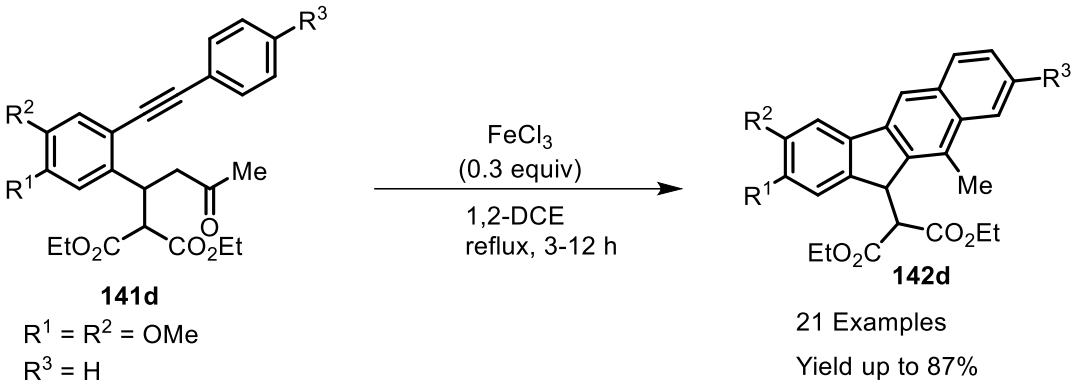
The oxidative cycloisomerization of acyclic 1,5-diynols has been performed in a regio- and chemoselective manner. The reaction proceeds with great efficiency and broad functional group tolerance under metal-free reaction conditions, offering a broad and straightforward pathway to benzo[b]fluorenones. Preliminary mechanistic studies revealed that a Meyer-

Schuster rearrangement in conjunction with an oxidative radical cyclization could be implicated (Scheme 3). [11]



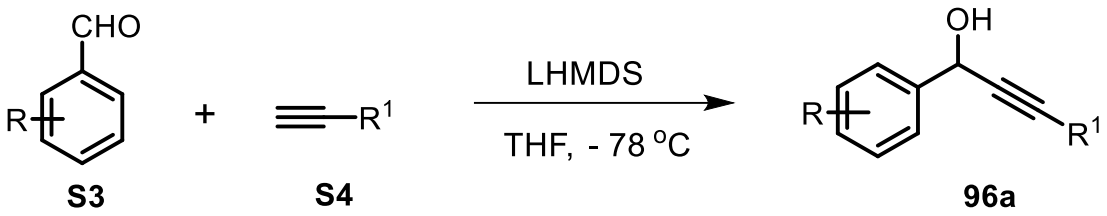
Scheme 3. Benzo[*b*]fluorenone synthesis *via* cycloisomerization protocols.

In 2016 K. Srinivasan *et.al* demonstrated a competent method for the preparation of a variety of fluorene derivatives from ortho-alkynyl dihydrochalcones. It follows a 5-*exo*-*dig* Coniaene reaction followed by Friedel-Crafts cyclization (Scheme 4).[12]



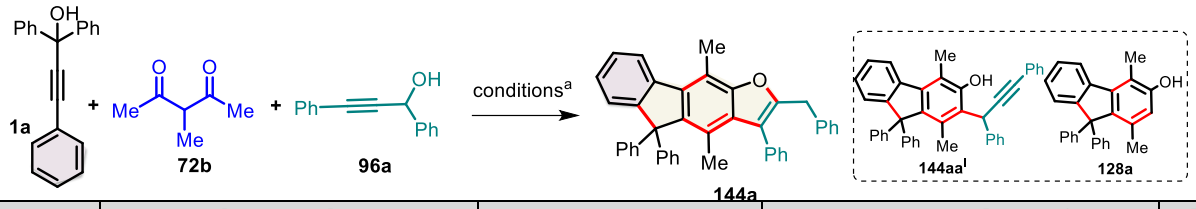
Scheme 4. Tandem catalyzed by iron access to benzo[*b*]fluorenes through coniaEne/Friedel-Crafts reactions of *o*-Alkynyl dihydrochalcones.

Previously reported procedures[14] were followed for the synthesis of starting materials. Initially, a mixture of phenylacetylene (1.1 equiv.) was dissolved in dry THF at -78 ºC, LHMDS (1.2 equiv.) was added to the reaction mixture and stirred for 20 minutes at -78 ºC, aldehyde (1 equiv.) was added slowly to the reaction mixture and the progress of the reaction was monitored by TLC. After completion, the reaction mixture was quenched with saturated NH_4Cl and extracted into EtOAc thrice. The combined organic layers were washed with brine, dried over anhydrous Na_2SO_4 and the solvent was removed under reduced pressure. The crude product was purified by silica gel column chromatography (PE:EtOAc) to obtain the desired product.



S3 **S4** **96a**

Table 1. Optimization studies for the synthesis of fluorenofuran 144a



Entry	Catalyst (mol%)	Base (equiv.)	Reaction conditions[a]	Yield(%)[b]
1	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	---	DCE, 90 °C, 12 h	10
2	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (1)	DCE, 90 °C, 12 h	30
3	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (2)	DCE, 90 °C, 12 h	42
4	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	DCE, 90 °C, 12 h	58
5	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	CH_3CN, 90 °C, 12 h	45
6	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	$PhCH_3$, 120 °C, 12 h	32
7	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	THF, 70 °C, 12 h	30
8	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	DCE + $PhCH_3$, 90 °C, 12 h	45
9	$Ca(OTf)_2/Bu_4NPF_6$ (10/10)	DABCO (3)	DCE + CH_3CN, 90 °C, 7 h	80
10	$Ca(OTf)_2/Bu_4NPF_6$ (5/10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	62
11[c]	**$Ca(OTf)_2/Bu_4NPF_6$ (10/5)**	**DABCO (3)**	**DCE + CH_3CN, 90 °C, 7 h**	**80**
12	$Ca(OTf)_2$ (10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	48
13	$Ca(OTf)_2/KPF_6$ (10/10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	25
14	$Ca(OTf)_2/Bu_4NPF_6$ (10/5)	DBU (3)	DCE + CH_3CN, 90 °C, 12 h	52
15	$Ca(OTf)_2/Bu_4NPF_6$ (10/5)	K_2CO_3 (3)	DCE + CH_3CN, 90 °C, 12 h	54
16	$Ca(OTf)_2/Bu_4NPF_6$ (10/5)	Na_2CO_3 (3)	DCE + CH_3CN, 90 °C, 12 h	51
17	$Mg(OTf)_2$ (10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	25
18	$FeCl_3$ (10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	30
19	p-TsOH (10)	DABCO (3)	DCE + CH_3CN, 90 °C, 12 h	56

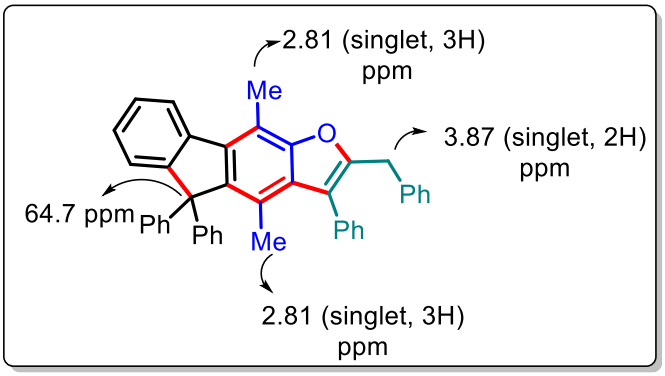
[a]conditions: **1a** (0.35mmol), **72b** (0.45 mmol), **96a** (0.42 mmol) was added after the formation of **144aa** and along with acetonitrile was added after the formation of **144aa^{I}**.[b]Isolated yields based on **1a**.[c]Optimum condition. All reactions were monitored up to 12 h.DCE: Dichloromethane

4.3 Results and optimization Studies

To test the feasibility of our theory, (Scheme 4) was repeated using different types of *tert*-propargyl alcohols. 1,1,3-triphenylprop-2-yn-1-ol (**1a**), 3-methylpentane-2,4-dione (**72b**), and 1,3-diphenylprop-2-yn-1-ol (**144a**) were employed as reacting partners in a regioselective annulation reaction. Initially, a mixture of **1a** (0.35 mol), **72b**(0.45 mmol), and 10/10 mol% of $Ca(OTf)_2/Bu_4NPF_6$ was refluxed in 1,2-dichloroethane until the formation of fluorenol **144aa**[15] (2 hours, monitored by TLC) was completed. To this, 0.42 mmol of *sec*-propargyl alcohol **96a** was added and the reflux was continued for 12 hours (entry 1, Table 1). As predicted, the reaction yielded the desired tetracyclic compound, fluoreno[3,2-*b*]furan **144a**,[16] but in poor yield (10%) and the rest of the product was **144aa^{I}**, which is the key intermediate for the formation of **144a**. Therefore, we decided to introduce a base to accelerate the cyclization of **144aa^{I}** to **144a**.[16]Accordingly, after the formation of **144aa^{I}** (as mentioned in entry 1), DABCO (1 equiv.) was added to the reaction and the reflux was continued for 12 hours, which resulted in a moderate increase of reaction yield (entry 2). Moreover, we observed that the addition of the extra-base (DABCO) into the reaction resulted in a proportional increase in the reaction yield (entries 3,4). The search for finding better solvent systems (acetonitrile, toluene and tetrahydrofuran) for this transformation did not give us satisfactory results (entries 5-7). However, a combination of solvents yielded better results. We found that a combination of DCE/CH_3CN (1:1) is the best solvent system for this transformation yielding **144a** in 80% (entries 8,9). Next, we explored the possibility of minimizing the catalyst loadings (entries 10,11), and found that 10/5 mol% of $Ca(II)/Bu_4NPF_6$ gave the best reaction yield and as predicted the reaction furnished only 48% of **144a** without the additive (entry 12).The use of KPF_6 as an alternative additive with Ca(II) combination was not effective (entry 13). The search for alternative bases such as DBU, potassium carbonate, and sodium carbonate to promote the cyclization of **144aa^{I}** to **144a** was not successful (entries, 14-16). The possibility of using other catalysts such as magnesium triflate (entry 17), ferric chloride (entry 18), and *para*-toluenesulfonic acid (entry 19) to promote the annulation reaction of **1a**, **72b**, and **96a** was also explored. After performing a series of optimization reactions (entries 1-19), we finalized that entry 11 (Table 1) was the best condition.

4.3a Characterization of Compound 144a

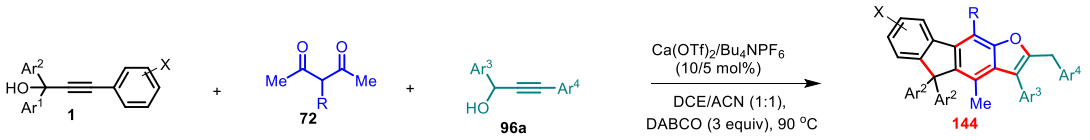
^{1}H NMR,^{13}C NMR, and melting point have been used to completely describe the isolated compound **144a**. In ^{1}H NMR spectra, the classic CH_2 proton signals were observed at 3.87 ppm, while the corresponding carbon appeared at 32.96 ppm in ^{13}C NMR spectra.

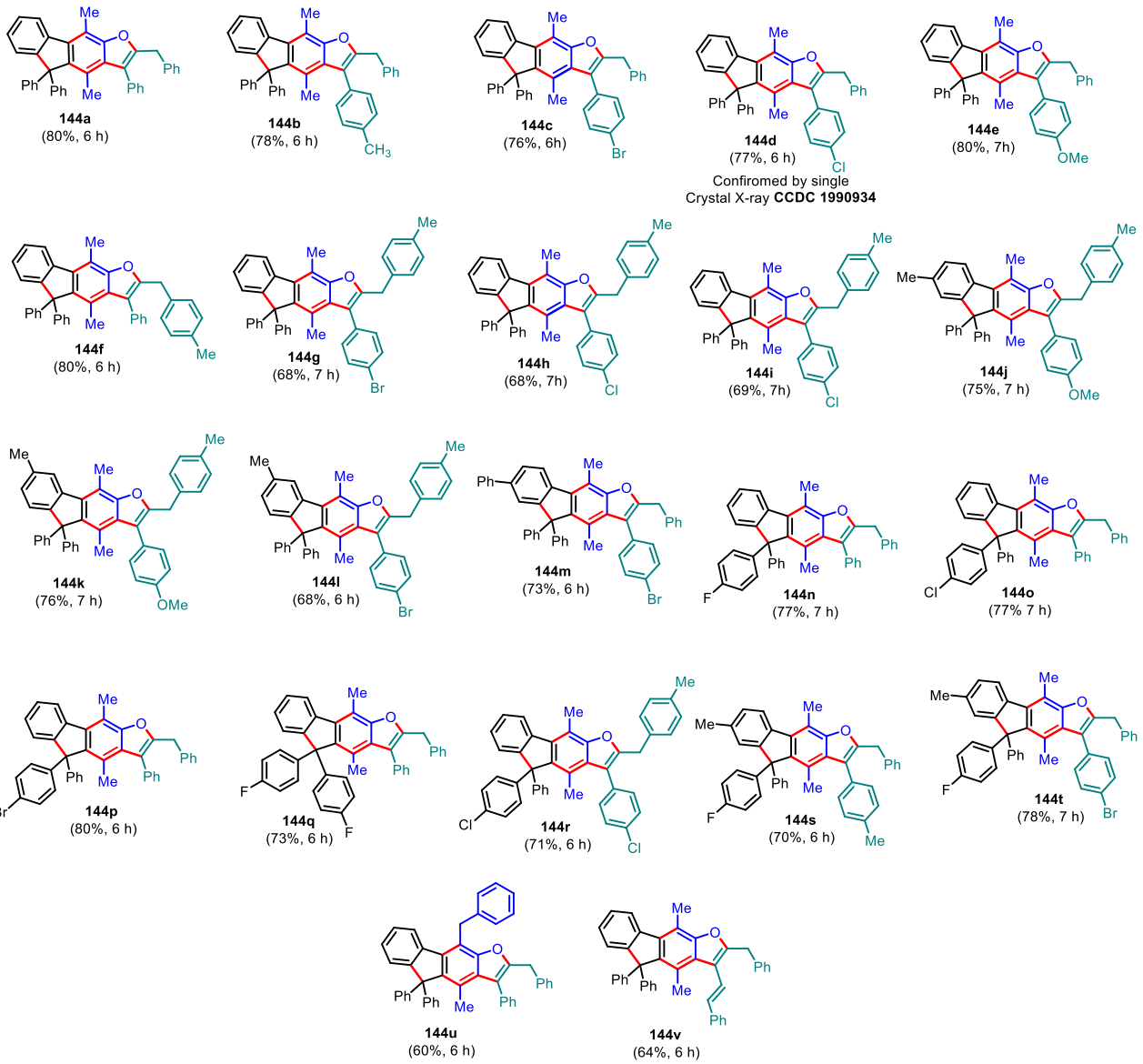


4.3b SCOPE OF THE REACTION

After establishing the typical reaction conditions for the annulation of propargyl alcohols with 1,3-diketone to produce fluoreno[3,2-*b*]furan, we were excited to investigate the flexibility of this approach in terms of substrates **1**, **72b**, and **96** (Table 2). To begin, we chose a number of *sec*-propargyl alcohols (**96**) with various benzylic aryl ring replacements (such as 4-methyl, 4-bromo, 4-chloro, and 4-methoxy groups) and treated them with **1a** and **72b** under typical reaction conditions. In all situations, this reaction produced good yields of the respective fluorenofurans **144b**-**144e**. In supplement to NMR and mass data, single-crystal X-ray data[16] was used to augment the structural conformation of compound **144d**. Next, we exposed that changes on the acetylenic aryl ring (**144f),** as well as both aryl rings of alcohol **96**, had no discernible inhibitory effect on the reaction of **1a** and **72b** to yield **144g**-**144i**. Later, by treating *tert*-propargyl alcohols (**1**) with various *sec*-propargyl alcohols (**96**) and diketone **72b**, we investigated the scope of substitutions on the alkynyl-phenyl ring, which resulted in the creation of corresponding fluorenofurans **144j**-**144m** in 68-76 % yields. These reaction conditions tolerated substitutions on the propargylic aryl rings of *tert*-propargyl alcohol (**1**), resulting in high yields of fluorenofurans **144n**-**144t** with an unsymmetrical quaternary center at C5 (stereogenic centre). The related product **144u** was produced in 60% yield by treating 3-benzylpentane-2,4-dione (**72h**) with **1a** and **96b** under typical annulation conditions. We were able to incorporate a styryl group on the third position in compound **144v** by treating **72b** and **96a** with 1,3,5-triphenylpent-1-en-4-yn-3-ol.

Table 2. Substrate scope of annulation reaction.[a]





[a] Reaction conditions: A mixture of **1** (0.35 mmol), **72** (0.45 mmol), 10 mol% Ca(OTf)2, 5 mol% Bu_4NPF_6 was refluxed in 1,2- DCE for 2-3 h, then **96a** (0.42 mmol) was added to the reaction mixture, after formation of alkylated product (40-60 min) DABCO (1.05 mmol) along with acetonitrile was introduced to the reaction mixture and refluxed for 2-3 h.

4.3c Data for Single X-Ray Crystal Structure 144d.

We used the vapor diffusion crystallization method to grow crystal for **144d** wherein the compound was dissolved in chloroform at elevated temperatures to make a saturated solution in a small vial which was then placed in a closed bottle with *n*-hexane as the other solvent.

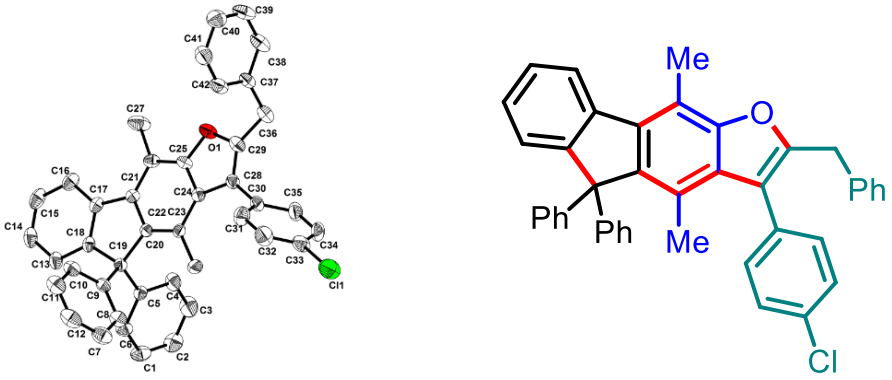


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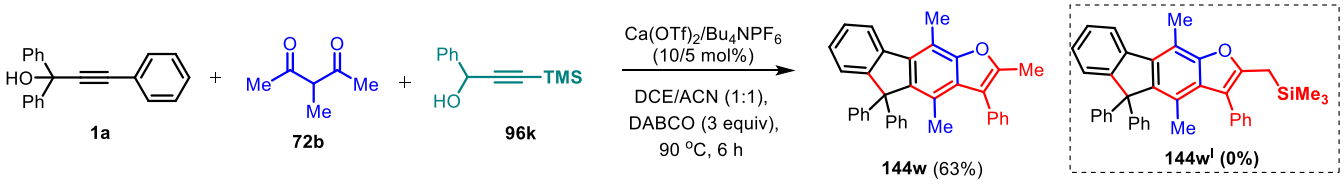
Figure 2. ORTEP representation of compound **144d** and thermal ellipsoids are drawn with 50% probability.

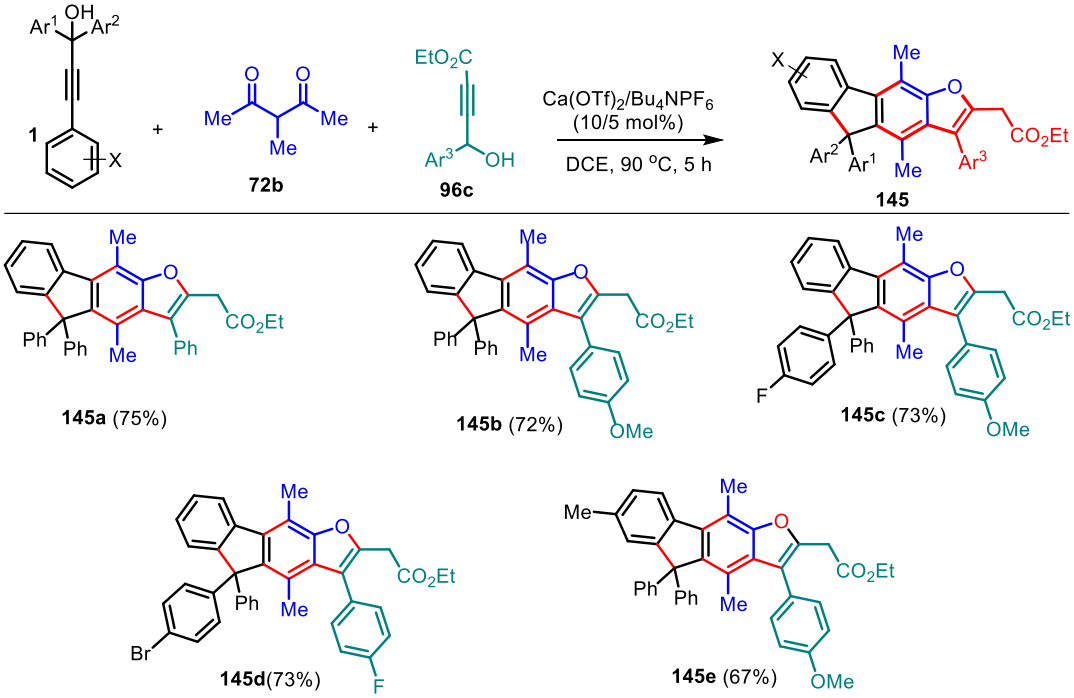
Under standard conditions, the reaction of **1a** and **72b** with 1-phenyl-3-(trimethylsilyl) prop-2-yn-1-ol (**96k**) gave the fluorenofuran **144w**, but not **144w′**, as expected. (Scheme 5). This could be due to the presence of fluoride ion (from the additive) in the process, which has a strong affinity for the silyl group, resulting in desilylation **144w**[24].



Scheme 5. Synthesis of 5H-fluoreno[3,2-*b*]furan(**144w**) with TMS-alkyne (**96k**)

As a result of these findings, the reactivity of *sec*-propargyl alcohols (**96c**) with electron-withdrawing groups (on the alkyne side) with *tert*-propargyl alcohols (**1**) and diketones **72b** were investigated (Scheme 6). Compounds **1a**, **72b**, and **96c** were all exposed to typical reaction conditions, yielding fluorenofuran **145a** with a yield of 78%. Interestingly, we noticed that the presence of DABCO did not have any appreciable impact on the product formed *via* the addition of ester **96c** to the fluorenol intermediate (**144aa**, see the Scheme in Table 1). As a result, we duplicated the reaction conditions but in the absence of DABCO, and to our pleasant surprise, the result was a 75% yield of **145a**. Due to the presence of an ester group, the intermediate **145aa** effectively undergoes an intramolecular oxa-Michael addition

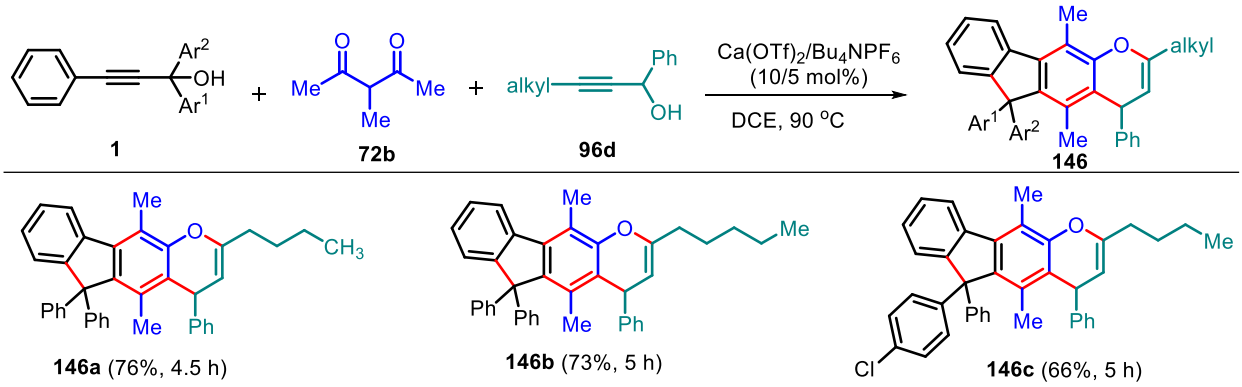
(Scheme 6) and as a result, an annulation reaction occurs without the use of any base. Similarly, the ester **96c** could produce the fluorenofurans **145b-145d** in good yields and the ester **96c** could produce the compound **145e** in good yields (Scheme 6).



[a]Reaction conditions: A mixture of **1** (0.35 mmol), **72b** (0.45 mmol), 10 mol% $Ca(OTf)_2$, 5 mol% Bu_4NPF_6 were refluxed in 1,2- DCE for 2-3 h then **96c** (0.42 mmol) was added to the reaction mixture and refluxed till the product formation (1-2 h).

Scheme 6. Ca(II)-catalyzed, annulation reaction of **1**, **72b** with propargyl esters (**96c**).[a]

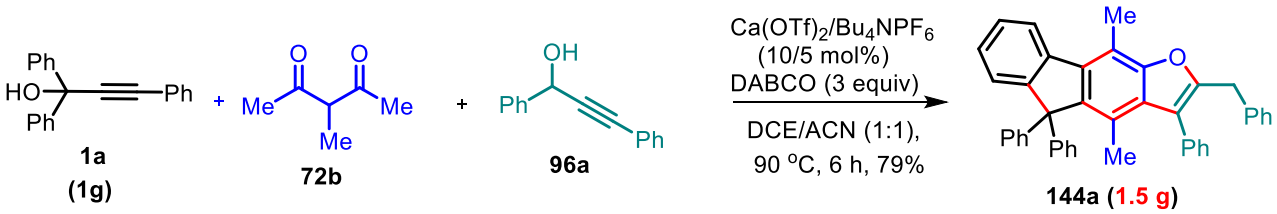
The experimental results in schemes 5 and 6 demonstrated the regioselectivity during the formation of fluorenofurans, in which the alkyne-terminus of *sec*-propargyl alcohol **96d** (Scheme 5, 6) and **144** (Table 2) are aryl and ester groups, respectively. We then investigated the regioselectivity of *sec*-propargyl alcohols with alkylgroups on the alkyne-terminus (Scheme 7). As a result, the substrates **1a**, **72b**, and 1-phenylhept-2-yn-1-ol (**96d**) were refluxed in DCE for 4.5 hours with 10/5 mol% $Ca(OTf)_2/Bu_4NPF_6$ (typical reaction conditions of Scheme 6) to generate the product **146a** in 76% yield. The presence of an alkyl group on the alkyne-terminus of **96d** diverted the regioselectivity of the annulation reaction to create a fluorenopyran (rather than fluorenofuran) *via* a 6-*endo*-*dig*-cyclization pathway (refer to Scheme 10 for mechanistic details). When *tert*-propargyl alcohol **1** was made to react with **72b** and 1-phenyloct-2-yn-1-ol (**96e**) an identical type of regioselectivity was observed in the fluorenopyrans **146b** and **146c** formed (Scheme 7).



[a]Reaction conditions: A mixture of **1** (0.35 mmol), **72b** (0.45 mmol), 10 mol% $Ca(OTf)_2$, 5 mol% Bu_4NPF_6 were refluxed in 1,2- DCE for 2-3 h then **96d** (0.42 mmol) was added to the reaction mixture and refluxed till the product formation (1-2 h).

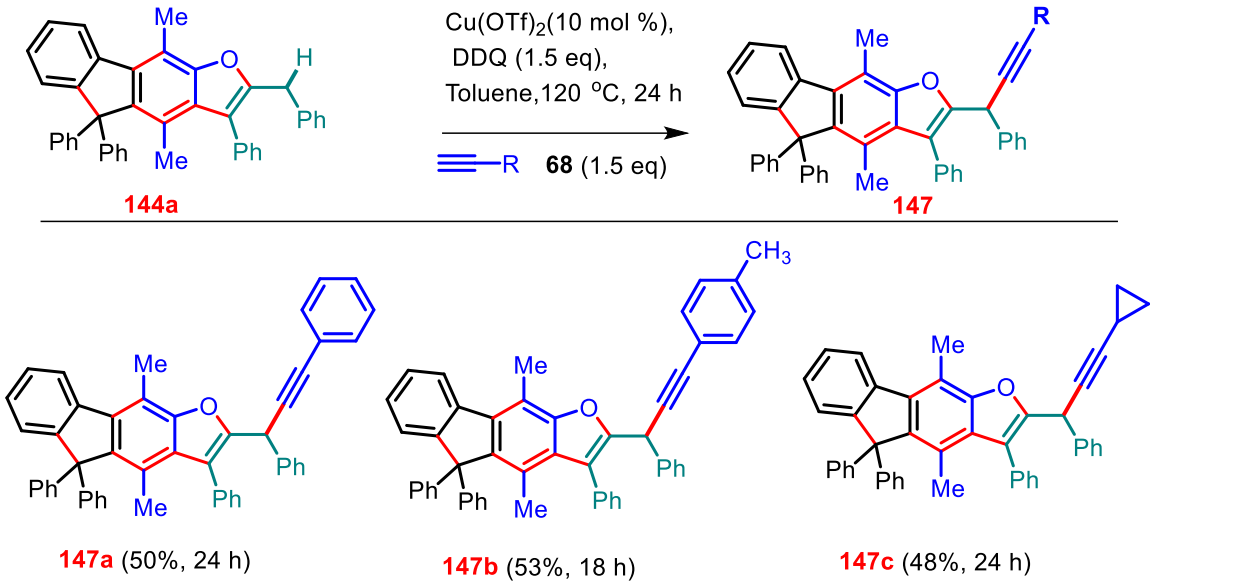
Scheme 7. Ca(II)-catalyzed, annulation reaction of **1**, **72b** with **96d** bearing alkyl groups on alkyne terminus.[a]

After studying the regioselective annulation of propargylic alcohols with 1,3-diketones, we were able to achieve a gram-scale synthesis of **144a** from **1a**, **72b**, and **96a** under typical reaction conditions (Scheme 8).



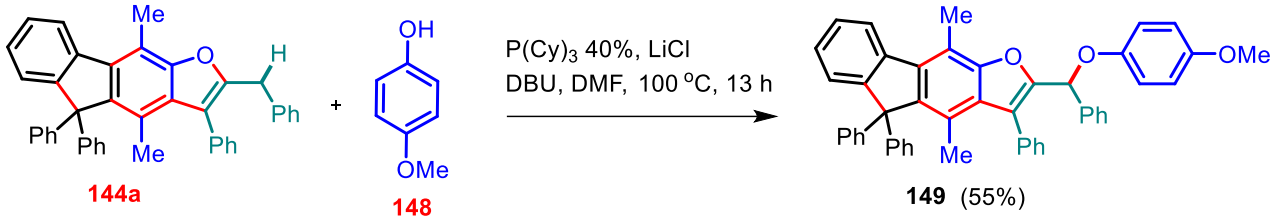
Scheme 8. Gram Scale Synthesis of **138a.**

We were interested in exploring the synthetic utility of **144a** by executing the benzylic C-H functionalization after the successful demonstration of gram-scale synthesis. After 24 hours, the dehydrogenative cross-coupling reaction of compound **144a** with phenylacetylene[17] was accelerated by copper(II), and the cross-coupled product **147a** was produced in 50% yield (Scheme 8). Similarly, **144a** was treated to copper-catalyzed benzylic C-H functionalization with p-tolylacetylene and cyclopropyl acetylene to produce **147b** and **147c**, respectively (Scheme 9).



Scheme 9. Benzylic Csp3-H functionalization of **144a**: dehydrogenative cross-coupling with an alkyne.

The following synthetic transformation was constructed to demonstrate the potentiality of **144a** by exposing it to benzylic oxidation with *p*-methoxyphenol[18] to provide the desired product. **149**(Scheme 10).



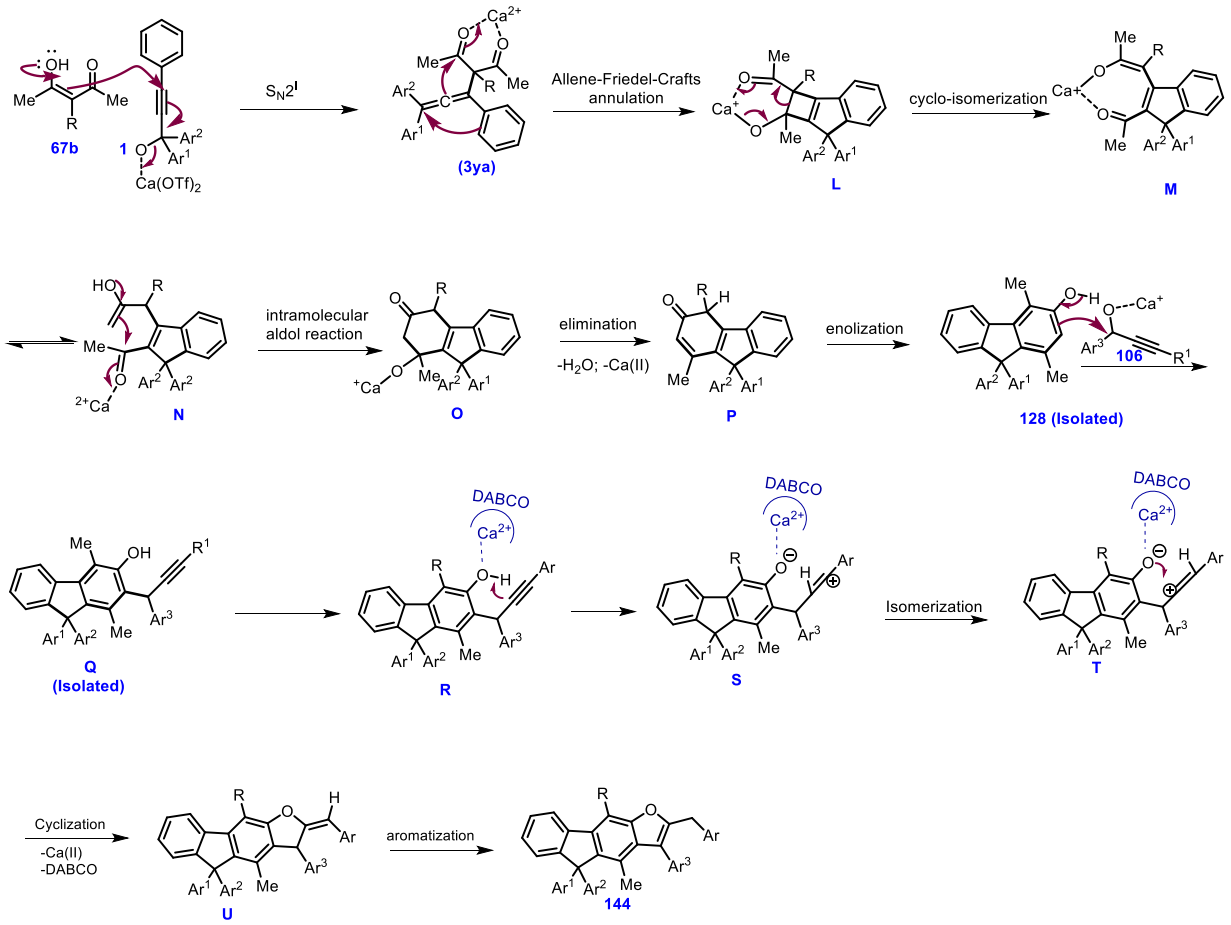
Scheme 10. Benzylic Csp3-H functionalization of **144a**: Oxidative etherification

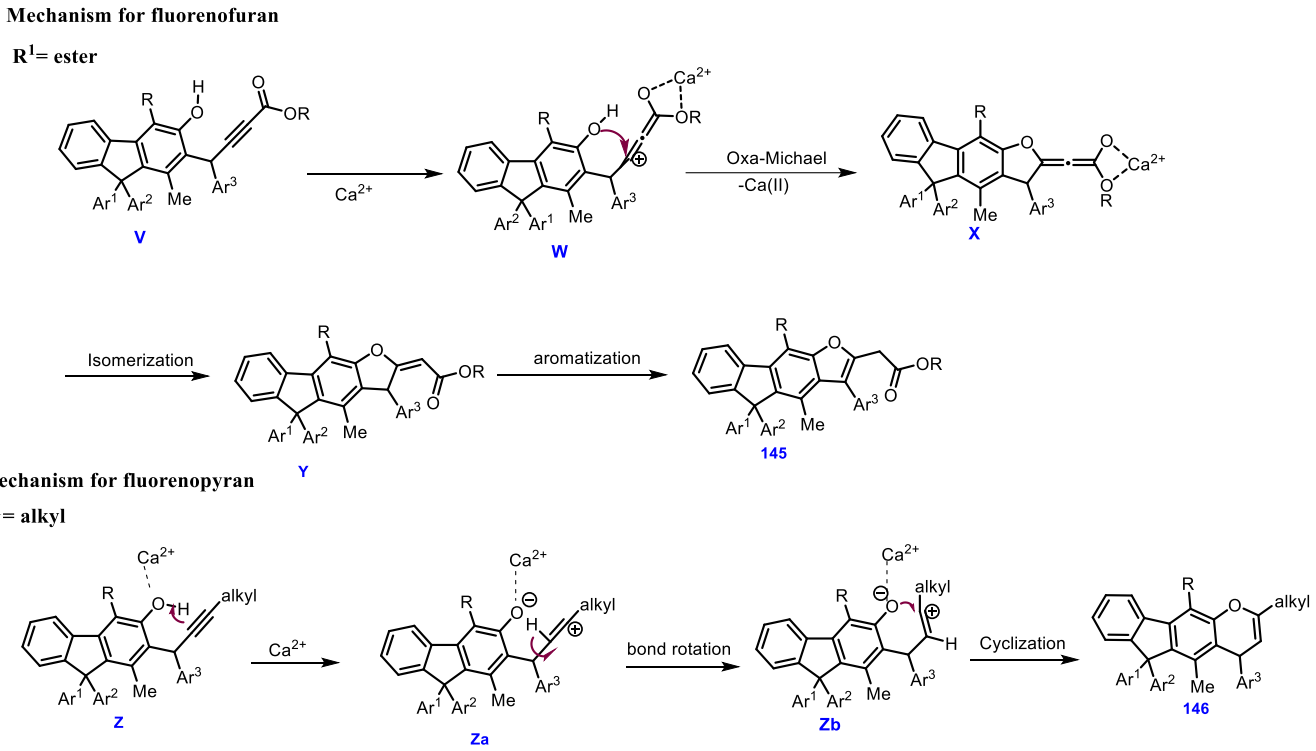
4.4 Reaction Mechanism

We hypothesized the likely reaction mechanism for this annulation reaction in Scheme 10 based on prior results acquired by us and other research groups[15,17]. The tetrasubstituted allene intermediate **3ya** is produced *via* the S_N^2 substitution process between compounds **1** and **72b** (isolated). Following the intramolecular-allene-Friedel-Crafts-Annulation reaction (I-AFCA) of **3ya**, the tricyclic molecule **L** is formed, which is easily isomerized to indene **M**. Compounds **M** and **N** exist in keto-enol tautomerism, and they undergo a calcium-catalyzed intramolecular-aldol reaction to yield tri-carbocyclic molecule **O**, which is then eliminated (**P**) and aromatized to give fluorenol **128**. (isolated). Between **128** and **96a**, calcium-catalyzed

C–C bond formation produces intermediate Q. (isolated). The nature of the R^1-group was used to define the cyclization mode. If R^1 is an aryl group (Case 1), DABCO-assisted Ca(II) raises the acidity of a nearby phenolic proton, allowing protonation of an alkyne through a tight six-membered transition state (R), resulting in the cationic molecule **S**. The steric- DABCO ligands bound to calcium limit bond rotation at this point, so the cation (S) isomerizes to **T** and enables the formation of the furan ring **U**, which eventually aromatizes to create compound **144**. In case 2, where R^1 is an ester group (V), the Lewis acidity of calcium causes charge separation on propargyl ester (W), allowing for intramolecular Oxa-Michael addition to giving compound **145aa** *via* the intermediates X, Y. If R^1 is an alkyl group (Z), the acidity of the phenolic proton increases due to the calcium and protonates the alkyne through a six-membered transition state to create the cation **Za**. The C–C bond twist provides the right orientation for cyclization to yield the pyran **146** (Zb, the positive charge is stabilized by the +I action of the alkyl groups)(Scheme 11).

Scheme 11. Reaction mechanism for the Ca(II) catalyzed regioselective synthesis of fluorenofuran





4.5 CONCLUSIONS

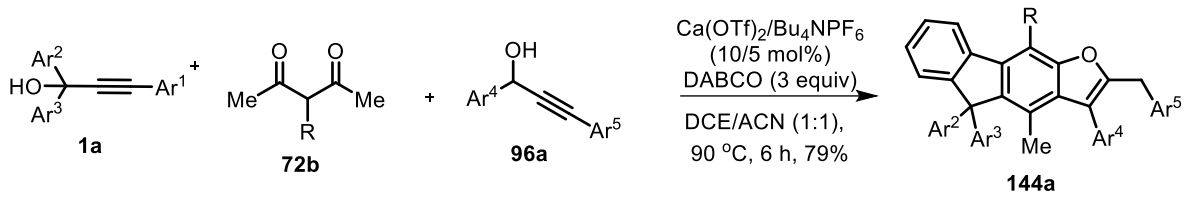
We were also able to demonstrate that functionalized 5*H*-fluoreno[3,2-*b*]furans and indeno[2,1-*g*]furans could be generated using calcium-catalyzed, cascade, and highly regioselective sequential annulation process chromenes. This method uses a three-component, one-pot reaction to create structurally challenging tetra-annulated hetero-aryls with five C-C bonds and one C-O bond. The scope of substitutions on aryl rings has been well investigated, as has the role of *sec*-propargyl alcohol in determining regioselectivity. The cyclization process with *sec*-propargyl alcohols does not require a base if the alkyne terminal is aryl-substituted; if it is an ester or an alkyl group, it requires. Further, the gram-scale synthesis and synthetic transformations of the products through C_{sp3}-H functionalization is demonstrated.

4.6 EXPERIMENTAL SECTION

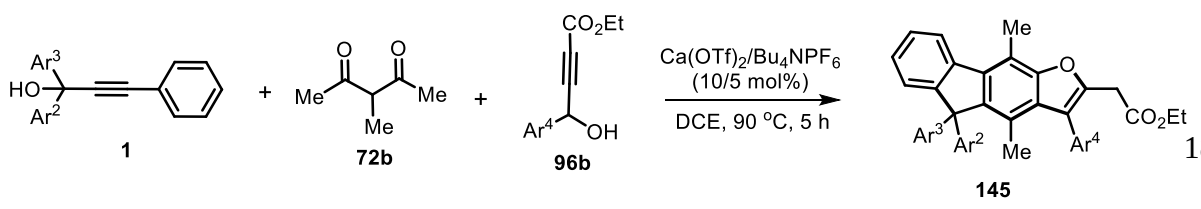
Unless otherwise noted, all reagents were used as received from commercial suppliers. Reactions were performed in flame-dried or oven-dried glassware with magnetic stirring. Reactions were monitored using thin-layer chromatography (TLC) with aluminum sheets silica gel 60 F-254 from Merck. TLC plates were visualized with UV light (25 nm), iodine treatment, or using p-anisaldehyde or $KMnO_4$ stain. Column chromatography was carried out using silica gel 60-120 mesh as the stationary phase. NMR spectra were recorded at 500 MHz and 400 MHz (1H-NMR), and $^{13}C\{1H\}$ NMR was recorded using 125 MHz and 100 MHz on

an Avance Bruker spectrometer. Chemical shifts (δ) are reported in ppm, using the residual solvent peak in $CDCl_3$ (1H: δ= 7.26 and ^{13}C: δ = 77.16 ppm) as an internal standard. The coupling constants (J) are given in Hz. HRMS were recorded using ESI-TOF techniques. Melting points were measured with LAB INDIA melting apparatus**.**

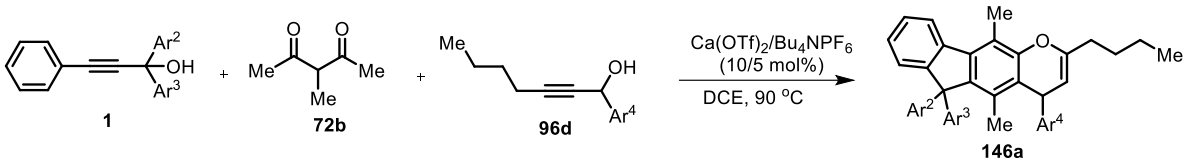
4.6a General experimental procedure for the synthesis of (144a): A mixture of tert-propargyl alcohol (1,1,3-triphenylprop-2-yn-1-ol)**1a** (0.35 mmol, 100 mg), 3-methylpentane-2,4-dione **72b** (0.45 mmol, 52 mg) and $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) was refluxed in 1,2-dichloro ethane (2 mL) at 90 °C for 2h. After the complete conversion of compound **1a** (monitored by TLC), 0.42 mmol (87 mg) of 1,3-diphenylprop-2-yn-1-ol **96a** was added to the above reaction mixture and continued to reflux for 45 minutes. After the formation new spot on TLC, DABCO (3 eq.) in acetonitrile (2 ml) was added to the reaction mixture and continued the reflux till the complete formation of the product (monitored by TLC). After completion of the reaction, the solvent was directly evaporated under reduced pressure to obtain the crude product. Then the crude product was purified by column chromatography (3-6 %, EtOAc in pet. ether) to obtain the pure product **144a** in 80% yield.



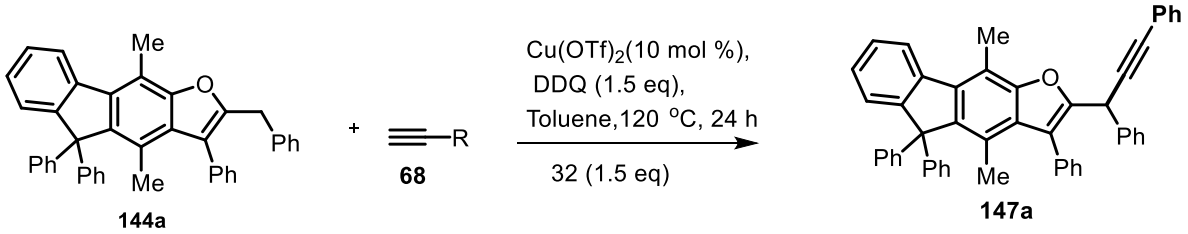
4.6b General procedure for the synthesis of fluoreno[3,2-*b*]furan (145a): A mixture of tert-propargyl alcohol (1,1,3-triphenylprop-2-yn-1-ol)**1a** (0.35 mmol, 100 mg), 3-methylpentane-2,4-dione **72b** (0.45 mmol, 52 mg) and $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) was refluxed in 1,2-DCE at 90 °C for 2h. After the complete conversion of compound **1a** (monitored by TLC), 0.42 mmol of *sec*-propargyl alcohol (ethyl 4-hydroxy-4-phenylbut-2-ynoate) **96b** (86 mg) was added to the above reaction mixture and continued to reflux for 4-5 hours. After completion of the reaction (monitored by TLC), the solvent was directly concentrated under reduced pressure to isolate the crude product which was purified by column chromatography (3-5 %, EtOAc in pet. ether) to obtain the pure compound **145a** in 75% yield.



4.6c General procedure for the synthesis of fluorenopyran (146a): A mixture of tert-propargyl alcohol (1,1,3-triphenylprop-2-yn-1-ol)**1a** (0.35 mmol, 100 mg), 3-methylpentane-2,4-dione **72b** (0.45 mmol, 52 mg) and $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) was refluxed in 1,2-DCE at 90 °C for 2 h. After the complete conversion of compound **1a** (monitored by TLC), 0.42 mmol of *sec*-propargyl alcohol **96d** (79 mg) was added to the above reaction mixture and continued to reflux for 2-4 hours. After completion of the reaction (monitored by TLC), the solvent was directly concentrated under reduced pressure to isolate the crude product, which was purified by column chromatography (3-5 %, EtOAc in pet. ether) to obtain the pure compound **146a** in 76% yield.



4.6d General experimental procedure for the synthesis of compound (147a):[18] A mixture of $Cu(OTf)_2$ (10 mol%), DDQ (0.27 mmol), toluene (2 mL), phenylacetylene **68** (0.27 mmol) and fluoreno[3,2-*b*]furan **144a** (0.18 mmol) was placed in a sealable tube. The tube was sealed and flushed with nitrogen; then the mixture was stirred at 120 °C for 24 hours. After completion of the reaction (monitor by TLC), the mixture was cooled to room temperature and flushed through a short column of silica gel with ethyl acetate. The solvent was removed under vacuum; the resultant dark purple crude was isolated and purified by flash column chromatography to obtain the pure compound **147a** in 50% yield.



4.7 SPECTRAL DATA

2-Benzyl-4,10-dimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan (***144a***).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid (155.2 mg, 80%); mp 231–232°C.^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (d, J = 7.6 Hz, 1H), 7.25-7.23 (m, 4H), 7.22-7.21 (m, 4H), 7.21-7.18 (m, 4H), 7.16-7.14 (m, 4H), 7.10-

7.05 (m, 7H), 3.87 (s, 2H), 2.81 (s, 3H), 1.55 (s, 3H) ppm.^{13}C{1H}(100 MHz, $CDCl_3$) δ 155.4, 153.7, 153.6, 144.9, 143.0, 141.1, 138.2, 135.3, 134.1, 130.9, 129.1, 128.7, 128.6, 128.1, 127.9, 127.4, 127.1, 127.1, 126.9, 126.5, 126.3, 125.5, 122.6, 119.6, 114.3, 64.7, 32.9, 16.8, 12.9 ppm. HRMS (ESI-TOF): m/z $[M + H]^+$calculated for $C_{42}H_{32}OH$: 553.2531; found: 553.2533. IR (film): ν_{max} 3019, 1490, 1295, 1108, 769 cm^{-1}.

2-Benzyl-4,10-dimethyl-5,5-diphenyl-3-(p-tolyl)-5H-fluoreno[3,2-b]furan(144b).

Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid (155.22 mg, 78%); mp: 241-243 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90 (d, J = 7.6 Hz, 1H), 7.32-7.24 (m,10H), 7.18-7.14 (m, 6H), 7.12-7.09 (m, 6H), 3.90 (s, 2H), 2.88 (s, 3H), 2.30 (s, 3H), 1.62 (s, 3H) ppm.^{13}C{1H}(100 MHz, $CDCl_3$) δ 155.3, 153.8, 153.5, 144.8, 142.9, 141.0, 135.9, 135.0, 134.1, 130.8, 129.0, 128.5, 127.9, 127.7, 127.2, 127.0, 127.0, 126.8, 126.1, 125.3, 122.5, 119.3, 114.1, 64.6, 32.4, 21.0, 16.7, 12.7 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$ calculated for $C_{43}H_{34}OH$: 567.2688; found: 567.2689. IR (film): ν_{max} 3025, 1736, 1512, 1445, 720 cm^{-1}.

2-Benzyl-3-(4-bromophenyl)-4,10-dimethyl-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144c).

Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether) the product was obtained as white solid(167.96 mg, 76%); mp: 268-270 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.84 (d, J = 7.5 Hz, 1H), 7.38 (t, J = 1.5 Hz, 1H), 7.22-7.17 (m, 8H), 7.14- 7.11(m, 5H), 7.09-7.04 (m, 8H), 3.85 (s, 2H), 2.81 (s, 3H), 1.56 (s, 3H) ppm.^{13}C{1H}(100 MHz, $CDCl_3$) δ 155.3, 153.6, 153.6, 145.0, 142.8, 140.9, 137.8, 135.4, 133.1, 132.4, 131.2, 129.0, 128.5, 127.8, 127.1, 126.9, 126.7, 126.5, 126.2, 125.9, 125.4, 122.5, 121.6, 118.3, 114.2, 64.6, 32.8, 29.7, 16.9, 12.7 ppm. HRMS (ESI-TOF):m/z$[M+Na]^+$calculated for $C_{42}H_{31}BrONa$: 653.1456;found: 653.1458. IR (film): ν_{max} 3082, 1736, 1600, 1466, 1100, 758 cm^{-1}.

2-Benzyl-3-(4-chlorophenyl)-4,10-dimethyl-5,5-diphenyl-5H-fluoreno[3,2 b]furan(144d).Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether) the product was obtained as white solid(158.62 mg, 77%); mp: 239-241 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90 (d, J = 7.6 Hz, 1H), 7.30 (d, J = 2 Hz, 1H) 7.29-7.25 (m, 7H), 7.22-7.18 (m, 7H), 7.18-7.13 (m, 6H), 3.92 (s, 3H), 2.88 (s, 3H), 1.63 (s, 3H) ppm. ^{13}C{1H}(100 MHz,

$CDCl_3$) δ 155.3, 153.7, 153.6, 145.0, 142.8, 140.9, 137.9, 135.4, 133.4, 132.6, 132.1, 129.0, 128.5, 128.3, 127.8, 127.1, 126.9, 126.8, 126.5, 126.2, 125.9, 125.4, 122.5, 118.3, 114.3, 64.6, 32.8, 16.9, 12.8 ppm. HRMS (ESI-TOF): m/z $[M + H]^+$ calculated for $C_{42}H_{31}ClOH$: 587.2141; found: 587.2143. IR (film): ν_{max} 2977, 1734, 1596, 1491, 1032, 730 cm^{-1}.

2-Benzyl-3-(4-methoxyphenyl)-4,10-dimethyl-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144e).Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), the product was obtained as white solid(163.2 mg, 80%); mp: 256-258 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.83 (d, J = 1 Hz, 1H), 7.22-7.15 (m, 7H), 7.14-7.12 (m, 5H), 7.12-7.03 (m, 8H), 6.80 (t, J = 2 Hz, 2H), 3.90 (s 2H), 3.72 (s, 3H), 2.81 (s, 3H), 1.57 (s, 3H) ppm. ^{3}C{1H}(125 MHz, $CDCl_3$) δ 158.9, 155.3, 153.6, 153.5, 144.8, 142.9, 141.0, 138.2, 135.1, 131.9, 129.0, 128.6, 128.4, 127.7, 127.2, 127.0, 126.8, 126.3, 126.2, 126.1, 126.1, 125.3, 122.5, 119.0, 114.1, 113.4, 64.6, 55.2, 32.8, 16.6, 12.7 ppm. HRMS (ESI-TOF): m/z $[M + Na]^+$ calculated for $C_{43}H_{34}O_2Na$: 605.2457; found: 605.2458. IR (film): ν_{max} 3021, 2154, 1511, 1208, 854 cm^{-1}.

4,10-Dimethyl-2-(4-methylbenzyl)-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan(144f).Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), the product was obtained as white solid(159.43 mg, 80%); mp: 200-202°C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 7.6 Hz, 1H), 7.30-7.25 (m, 7H), 7.25-7.21 (m, 3H), 7.19-7.16 (m, 6H), 7.15-7.10 (m, 6H), 3.94 (s, 2H), 2.88 (s, 3H), 2.34 (s, 3H), 1.64 (3H) ppm.^{13}C{1H}(100 MHz, $CDCl_3$) δ 155.3, 153.5, 153.5, 144.8, 142.9, 141.0, 138.2, 137.0, 135.1, 130.9, 130.7, 129.0, 128.7, 128.6, 128.5, 127.7, 127.1, 127.0, 126.8, 126.4, 126.2, 126.2, 125.4, 122.5, 119.4, 114.1, 64.6, 32.8, 21.2, 16.7, 12.8ppm. HRMS (ESI-TOF): m/z $[M + H]^+$ calculated for $C_{43}H_{34}OH$: 567.2688; found: 567.2684. IR (film): ν_{max}3021, 1596, 1491, 1219, 1109, 826, 772 cm^{-1}.

3-(4-Bromophenyl)-4,10-dimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-fluoreno[3,2-b]furan (144g). Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), the product was obtained as white solid(153.68 mg, 68%);mp: 226-228 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.96 (d, J = 7.5 Hz, 1H), 7.95-7.49 (m, 7H), 7.35-7.31 (m, 8H), 7.30-7.13 (m, 6H), 3.93 (s, 2H), 2.93 (S, 3H), 2.35 (s, 3H), 1.68 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$) δ 155.3, 153.9, 145.0, 142.8, 140.9, 136.0, 135.3, 134.8, 133.2, 132.5, 131.2, 129.2, 129.0, 128.4,

127.8, 127.1, 126.9, 126.8, 126.2, 125.9, 125.4, 122.5, 121.5, 118.2, 114.2, 64.6, 32.4, 21.0, 16.9, 14.1, 12.7ppm. HRMS (ESI-TOF): m/z [M + Na]$^+$ calculated for $C_{43}H_{33}BrONa$ 667.1615; found: 667.1617.

3-(4-chlorophenyl)-4,10-dimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144h).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether), and the product was obtained as white solid(143.65 mg, 68%);mp: 238-240 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ7.91 (d, J = 7.5 Hz, 1H), 7.31-7.29 (m, 3H), 7.28-7.25 (m, 6H), 7.22-7.21 (m, 2H), 7.19-7.14 (m, 6H), 7.13-7.09 (m, 4H), 3.89 (s, 2H), 2.88 (s, 3H), 2.30 (s, 3H), 1.62 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$) δ 155.3, 153.9, 142.8, 136.0, 134.8, 133.4, 132.1, 129.2, 129.0, 128.4, 128.2, 127.8, 127.0, 126.9, 126.2, 125.9, 125.3, 122.5 64.6, 29.7, 16.8, 12.7ppm. HRMS (ESI-TOF): m/z [M + H]$^+$ calculated for $C_{43}H_{33}ClOH$ 601.2298; found: 601.2296. IR (film): ν_{max}2922, 2852, 1758, 1589, 1447, 1090, 702 cm^{-1}.

3-(4-Methoxyphenyl)-4,10-dimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-luoreno[3,2-b]furan(144i).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(144.79 mg, 69%); mp: 248-250°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.83 (d, J = 7.5 Hz, 1H), 7.21-7.18 (m, 6H), 7.15-7.11 (m, 2H), 7.10-7.08 (m, 3H), 7.07-7.03 (m, 6H), 7.00 (d, J = 8 Hz, 2H), 6.78 (d, J = 8.5 Hz, 2H) 3.82 (s, 2H), 3.71 (s, 3H), 2.80 (s, 3H), 2.22 (s, 3H), 1.57 (s, 3H) ppm.^{13}C{1H}(125 MHz, $CDCl_3$) δ 158.9, 155.4, 153.9, 144.8, 142.9, 141.1, 135.8, 135.2, 135.1, 131.9, 129.1, 129.1, 128.5, 127.7, 127.2, 127.0, 126.7, 126.2, 126.1, 125.8, 122.5, 118.9, 114.1, 113.4, 64.6, 55.2, 32.4, 21.0, 16.6, 12.7ppm. HRMS (ESI-TOF): *m/*z [M+H]$^+$ calculated for $C_{44}H_{36}O_2H$: 597.2795; found: 597.2797.

3-(4-Methoxyphenyl)-4,7,10-trimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144j). Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(153.51 mg, 75%);mp: 250-252°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.78 (d, J = 8.5 Hz, 1H), 7.28-7.23 (m, 5H), 7.20-7.15 (m, 4H), 7.14 (d, J = 7 Hz, 2H), 7.12-7.10 (m, 3H), 7.08-7.07 (m, 4H), 6.85 (d, J = 8.5 Hz, 2H), 3.89 (s, 2H), 3.79 (s, 3H), 2.85 (s, 3H), 2.30 (s, 3H), 2.25 (s, 3H), 1.62 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ

158.9, 155.5, 153.7, 153.5, 144.7, 143.1, 138.4, 136.5, 135.8, 135.2, 131.9, 129.1(2), 128.5, 128.0, 127.7, 126.8, 126.2, 126.1, 126.0, 122.2, 118.9, 113.4, 64.5, 55.2, 32.3, 21.6, 21.0, 16.6, 12.7ppm. HRMS (ESI-TOF): m/z[M+H]$^+$calculated for $C_{45}H_{38}O_2H$: 611.2950; found: 611.2952. IR (film): ν_{max}2958, 1509, 1286, 1030, 772 cm^{-1}.

3-(4-Methoxyphenyl)-4,8,10-trimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144k). Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(155.56 mg, 76%); mp: 251-253 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.82 (d, J = 6.3 Hz, 1H), 7.27-7.24 (m, 4H), 7.20-7.17 (m, 5H), 7.16-7.13 (m, 5H), 7.12-7.08 (m, 3H), 6.96-6.94 (m, 1H), 6.86 (d, J = 9 Hz, 2H), 3.89 (s, 2H), 3.79 (s, 3H), 2.88 (s, 3H), 2.40 (s, 3H), 2.30 (s, 3H), 1.63 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 159.0, 153.9, 153.6, 152.9, 145.2, 143.3, 141.3, 136.6, 136.0, 135.3, 135.2, 132.0, 129.2, 128.6, 127.8, 127.2, 126.3, 126.3, 126.2, 125.1, 123.2, 119.0, 114.2, 113.5, 64.3, 55.3, 32.5, 21.8, 21.1, 16.7, 12.9 ppm. HRMS (ESI-TOF): m/z [M+Na]$^+$calculated for $C_{45}H_{38}O_2Na$: 633.2770, found: 633.2773.

3-(4-Bromophenyl)-4,8,10-trimethyl-2-(4-methylbenzyl)-5,5-diphenyl-5H-fluoreno[3,2-b]furan(144l).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether),and the product was obtained as yellow sticky (150.14 mg, 68%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73 (s, 1H),7.45 (d, J = 8 Hz, 2H), 7.25 (d, J = 7.6 Hz, 3H), 7.18-7.14 (m, 10H), 7.13-7.09 (m, 4H), 6.8 (d, J = 8 Hz,1H), 3.88 (s, 2H), 2.88 (s, 3H), 2.40 (s, 3H), 2.30 (s, 3H), 1.62 (s, 3H) ppm. ^{13}C{1H}(100 MHz, $CDCl_3$)δ 153.9, 153.6, 152.8, 145.4, 143.1, 141.1, 136.7, 136.1, 134.9, 133.3, 132.6, 131.3, 129.3, 129.1, 128.5, 127.9 (2), 127.8, 126.7, 126.2, 126.0, 125.1, 123.3, 121.6, 118.3, 114.3, 64.3, 32.5, 21.8, 21.1, 17.0, 12.9 ppm. HRMS (ESI-TOF): m/z [M+H]$^+$ calculated for $C_{44}H_{35}BrOH$: 659.1949; found: 659.1950.

2-Benzyl-3-(4-bromophenyl)-4,10-dimethyl-5,5,7-triphenyl-5H-fluoreno[3,2-b]furan(144m).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(143.16 mg, 73%);mp: 221-223°C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, J = 8.4 Hz, 1H), 7.46-7.42 (m, 2H), 7.40-7.37 (m, 4H), 7.28 (t, J = 7.2 Hz, 2H), 7.24-7.22 (m, 5H), 7.22-7.21 (m, 2H), 7.12-7.02 (m, 11H), 3.81 (s, 2H), 2.83 (s,

3H), 2.23 (s, 3H) ppm. $^{13}C\{1H\}$(100 MHz, $CDCl_3$)δ 156.1, 154.1, 153.7, 145.3, 142.9, 141.3, 140.3, 139.9, 136.1, 135.2, 134.9, 132.6, 131.3, 129.3, 129.2, 128.7, 128.5, 127.9, 127.1, 127.0, 126.4, 126.3, 126.1, 124.2, 122.8, 121.6, 118.3, 114.3, 64.8, 32.5, 21.1, 16.9, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+Na]^+$calculated for $C_{48}H_{35}BrONa$: 729.1769; found: 729.1770.

2-Benzyl-5-(4-fluorophenyl)-4,10-dimethyl-3,5-diphenyl-5H-fluoreno[3,2-b]furan(144n).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid(149.10 mg, 79%);mp: 225-227°C. ^1H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, J = 7.6 Hz, 1H), 7.30-7.27 (m, 4H), 7.26-7.24 (m, 6H), 7.21-7.18 (m, 4H), 7.17-7.13 (m, 7H), 7.02 (t, J = 9 Hz, 1H), 3.93 (s, 2H), 2.89 (s, 3H), 1.62 (s, 3H) ppm. $^{13}C\{1H\}$(125 MHz, $CDCl_3$)δ 155.3, 153.7, 153.5, 144.9, 142.8, 140.9, 137.9, 135.3, 132.4, 132.3, 129.0, 128.5, 128.5, 127.8, 127.0, 126.9, 126.9, 126.4, 126.2, 126.0, 125.4, 122.5, 118.4, 114.9, 114.2, 64.6, 32.8, 16.6, 12.7 ppm. HRMS (ESI-TOF): m/z$[M+H]^+$ calculated for $C_{42}H_{31}FOH$:571.2437; found: 571.2438. IR (film): ν_{max}2932, 1677, 1453, 1230, 753 cm^{-1}

2-Benzyl-5-(4-chlorophenyl)-4,10-dimethyl-3,5-diphenyl-5H-fluoreno[3,2-]furan(144o).
Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether) the product was obtained as white solid (141.88 mg, 77%); mp: 228-230 °C. ^1H NMR (500 MHz, $CDCl_3$): δ7.91(d, J = 8 Hz, 1H), 7.30-7.27 (m, 7H), 7.23-7.17 (m, 10H), 7.15-7.12 (m, 5H), 3.94 (s, 2H), 2.88 (s, 3H), 1.67 (s, 3H) ppm. $^{13}C\{1H\}$(125 MHz, $CDCl_3$)δ 155.1, 153.84, 153.87, 144.56, 142.5, 141.8, 141.1, 138.2, 135.2, 134.0, 132.1, 130.9, 128.0, 122.7, 122.7, 119.6, 114.5, 64.2, 32.9, 16.8, 12.8 ppm. HRMS (ESI-TOF): m/z$[M+H]^+$ calculated for $C_{42}H_{31}ClOH$:587.2131; found, 587.2132. IR (film): ν_{max}2962, 1623, 1398, 1060, 768 cm^{-1}.

2-Benzyl-5-(4-bromophenyl)-4,10-dimethyl-3,5-diphenyl-5H-fluoreno[3,2-b]furan(144p).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid(139.22 mg, 80%);mp: 226-228°C. ^1H NMR (500 MHz, $CDCl_3$): δ 7.91 (d, J = 7.5 Hz, 1H), 7.32-7.26 (m, 10H), 7.24-7.22 (m, 6H), 7.17-7.12 (m, 6H), 3.95 (s, 2H), 2.88 (s, 3H), 1.61 (s, 3H) ppm. $^{13}C\{1H\}$(125 MHz, $CDCl_3$)δ 154.9, 153.8 (2), 144.5, 142.5, 142.4, 141.1, 138.2, 135.2, 134.1, 131.0, 129.0, 128.7, 128.6, 128.2, 128.0, 127.5, 127.4, 127.3, 127.0, 126.5 (2), 126.2, 125.3, 122.7, 120.3, 119.6, 114.5, 64.3, 33.0,

16.8, 12.8 ppm. HRMS (ESI-TOF): m/z [M + H]$^+$ calculated for $C_{42}H_{31}BrOH$: 631.1636; found: 631.1640.

2-Benzyl-5,5-bis(4-fluorophenyl)-4,10-dimethyl-3-phenyl-5H-fluoreno[3,2-]furan (144q). Following general experimental procedure-4.6a, the crude reaction mixture was procedurepurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid (134.13 mg, 73%); mp: 239-241 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (d, J = 7.6 Hz, 1H), 7.39-7.32 (m, 7H), 7.30-7.25 (m, 3H), 7.24-7.18 (m, 7H), 6.91-6.87 (m, 4H), 3.98 (s, 2H), 2.91 (s, 3H), 1.64 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 162.5, 160.5, 155.1, 153.9, 153.8, 144.7, 140.9, 138.6, 138.6, 138.1, 135.1, 134.0, 130.9, 130.6, 130.6, 128.7, 128.6, 128.2, 127.5, 127.4, 127.3, 127.0, 126.5, 126.0, 125.5, 122.8, 119.6, 114.8, 114.7, 114.5, 63.6, 33.0, 16.7, 12.8 ppm. HRMS (ESI-TOF): m/z [M+Na]$^+$ calculated for $C_{42}H_{30}F_2Ona$: 611.2163; found: 611.2164. IR (film): ν_{max} 3025, 2360, 1597, 1502, 1225, 889, 754 cm^{-1}.

3,5-Bis(4-chlorophenyl)-4,10-dimethyl-2-(4-methylbenzyl)-5-phenyl-5H-fluoreno[3,2-b]furan(144r).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether), and the product was obtained as white solid(143.35 mg, 71%); mp: 240-242°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.91 (d, J = 7.5 Hz, 1H), 7.32-7.28 (m, 3H), 7.25-7.22 (m, 4H), 7.20-7.17 (m, 4H), 7.15-7.12 (m, 5H), 7.12-7.08 (m, 4H), 3.88 (s, 2H), 2.87 (s, 3H), 2.30 (s, 3H), 1.61 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 154.8, 154.1, 153.6, 144.5, 142.3, 141.6, 140.8, 136.0, 134.7, 133.5, 132.5, 132.1, 132.0, 130.4, 129.2, 128.8, 128.4, 128.3, 127.9, 127.3, 127.0, 126.4, 125.2, 122.6, 118.1, 114.4, 64.1, 32.4, 21.0, 16.8, 12.7 ppm. HRMS (ESI-TOF): m/z [M + Na]$^+$ calculated for $C_{43}H_{32}Cl_2Ona$: 657.1728; found: 657.1729.

2-Benzyl-5-(4-fluorophenyl)-4,7,10-trimethyl-5-phenyl-3-(p-tolyl)-5H-fluoreno[3,2-b]furan(144s).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(132.46 mg, 70%);mp: 249-251°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.82 (d, J = 6.4 Hz, 1H), 7.34 (d, J = 6.4 Hz, 2H), 7.28-7.23 (m, 7H), 7.22-7.19 (m, 4H), 7.18-7.08 (m, 7H), 6.90-6.87 (m, 3H), 3.91 (s, 2H), 2.33 (s, 3H), 2.29 (s, 3H), 1.62 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.5, 153.9, 153.7, 144.9, 143.0, 138.9 (2), 138.3, 136.9, 135.5, 134.9, 133.5, 133.5, 132.8, 130.8, 130.7, 129.3, 129.0, 128.5, 128.4,

128.3, 128.0, 126.6, 126.4, 126.0, 125.8, 122.5, 118.2, 114.7, 114.5, 114.0, 64.0, 32.5, 21.7, 21.1, 16.9, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$ calculated for $C_{44}H_{35}FOH$: 599.2750; found: 599.2752.

2-Benzyl-3-(4-bromophenyl)-5-(4-fluorophenyl)-4,7,10-trimethyl-5-phenyl-5H-fluoreno[3,2-b]furan(144t). Following general experimental procedure-4.6a, the crude reaction mixture waspurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid(163.40 mg, 78%);mp: 196-198°C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (d, J = 8 Hz, 1H), 7.46 (d, J = 7.5 Hz, 2H), 7.28-7.23 (m, 5H), 7.22-7.19 (m, 6H), 7.18-7.14 (m, 4H), 7.14-7.05 (m, 2H), 6.86 (t, J = 8.5 Hz, 1H), 3.92 (s, 2H), 2.85 (s, 3H), 2.26 (s, 3H), 1.60 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 162.4, 160.5, 155.5, 153.7, 153.6, 144.9, 143.0, 138.9, 138.9, 138.2, 138.0, 137.0, 135.6, 133.2, 132.6, 131.4, 130.8, 130.7, 129.0, 128.7, 128.6, 128.3, 128.0, 126.6, 126.5, 126.4, 126.0, 125.8, 122.5, 121.7, 118.4, 114.7, 114.6, 114.0, 64.0, 32.9, 21.7, 16.9, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+Na]^+$calculated for $C_{43}H_{32}BrFONa$: 685.1519; found: 685.1520. IR (film): ν_{max} 2915, 2360, 1504, 1224, 1030, 743 cm^{-1}.

2,10-Dibenzyl-4-methyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan(144u).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as yellow sticky (1322.67 mg, 60%). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.75 (d, J = 7.5 Hz, 1H), 7.33-7.31 (m, 4H), 7.30-7.27 (m, 7H), 7.25-7.24 (m, 5H), 7.23-7.20 (m, 3H), 7.18-7.13 (m, 8H), 7.09-7.08 (m, 1H), 4.78 (s, 2H), 3.89 (s, 2H), 1.66 (s, 3H) ppm. ^{13}C{1H}(100 MHz, $CDCl_3$)δ 155.6, 154.0, 153.9, 145.4, 143.0, 140.2, 139.7, 138.1, 135.6, 134.1, 131.0, 129.2, 128.7, 128.6, 128.5(2), 128.1, 127.9, 127.6, 127.5, 127.2, 127.1, 126.4, 126.3, 126.1, 125.5, 122.7, 119.5, 116.4, 64.7, 32.9, 32.1, 17.0 ppm. HRMS (ESI-TOF): m/z$[M + H]^+$ calculated for $C_{48}H_{36}OH$: 629.2844; found: 629.2848.

(E)-2-Benzyl-4,10-dimethyl-5,5-diphenyl-3-styryl-5H-fluoreno[3,2-b]furan (144v). Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether) the product was obtained as Yellow liquid(130.24 mg, 64%). ^{1}H NMR (500 MHz, $CDCl_3$): δ7.91(d, J = 7.5 Hz, 1H), 7.36-7.31 (m, 10H), 7.28 (d, J = 6 Hz, 2H), 7.22 (d, J = 3.5 Hz, 2H), 7.21-7.18 (m, 4H), 7.17-7.14 (m, 7H), 4.23 (s, 2H), 2.80 (s, 3H), 2.19 (s, 3H) ppm.^{13}C{1H}(100 MHz,

$CDCl_3$)δ 155.4, 153.8, 153.4, 145.2, 143.1, 141.1, 138.5, 137.4, 135.5, 132.7, 129.2, 128.8, 128.7(2), 127.9, 127.7, 127.2, 127.0(2), 126.6, 126.4(2), 126.2, 125.5, 122.6, 120.9, 117.6, 114.3, 64.7, 33.5, 17.3, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$calculated for $C_{44}H_{34}OH$: 579.2688; found: 579.2690.

2,4,10-trimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan (144w).Following general experimental procedure-4.6a, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid(105.21 mg, 63%);mp: 168-169 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.93 (d, J = 8.5 Hz, 1H), 7.32-7.30 (m, 2H), 7.29-7.26 (m, 9H), 7.18-7.17 (m, 3H), 7.15-7.19 (m, 5H), 2.92 (s, 3H), 2.31 (s, 3H), 1.63 (s, 3H) ppm.^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.5, 153.3, 152.3, 144.9, 143.0, 141.2, 134.9, 134.5, 131.1, 130.8, 129.2, 129.2, 128.0 (2), 127.8 (2), 127.3, 127.2, 127.1, 126.8, 126.6, 126.2 (2), 125.9, 125.5 (2), 122.5, 118.8, 114.0, 64.7, 16.9, 12.8, 12.5 ppm. HRMS (ESI-TOF): m/z $[M+Na]^+$calculated for $C_{36}H_{28}Ona$:499.2038; found:499.2037. IR (film): ν_{max} 3054, 1594, 1449, 1249, 1030, 720 cm^{-}.[1]

Ethyl 2-(4,10-dimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan-2-yl)acetate (145a). Following general experimental procedure-4.6b, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid (144.71 mg, 75%); mp: 149-151°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.94 (d, J = 8.5 Hz, 1H), 7.31-7.29 (m, 5H), 7.28-7.24 (m, 5H), 7.18 (t, J = 6 Hz, 3H) 7.15-7.13 (m, 5H), 4.18 (q, J = 7.5 Hz, 2H), 3.64 (s, 2H), 2.92 (s, 3H), 1.64 (s, 3H), 1.26 (t, J = 7 Hz, 3H) ppm. ^{13}C{1H}(100 MHz, $CDCl_3$)δ 169.4, 155.5, 153.9, 147.7, 145.1, 142.9, 141.1, 135.8, 133.5, 132.4, 131.3, 130.8, 129.1 (2), 128.1, 127.9 (2), 127.6, 127.2, 127.1, 126.8, 126.5, 126.4, 126.3, 125.5, 122.7, 121.6, 114.4, 64.7, 61.4, 33.2, 16.8, 14.3, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$calculated for $C_{39}H_{32}O_3H$: 549.2429; found: 549.2430. IR (film): ν_{max} 3051, 2978, 1738, 1502, 1196, 759 cm^{-1}.

Ethyl2-(3-(4-methoxyphenyl)-4,10-dimethyl-5,5-diphenyl-5H-fluoreno[3,2-b]furan-2-yl)acetate (145b). Following general experimental procedure-4.6b, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether), and the product was obtained as white solid (146.16 mg, 72%); mp: 152-154°C.^{1}H NMR (500 MHz, $CDCl_3$): δ 7.85 (d, J = 5 Hz, 1H), 7.25-7.21 (m, 4H), 7.20-7.19 (m, 2H), 7.18-7.14 (m, 3H), 7.12-7.10 (m, 2H), 7.09-7.07 (m, 4H), 6.79 (d, J = 9 Hz, 2H), 4.11 (q, J = 7 Hz, 2H),

3.72 (s, 3H), 3.57 (s, 2H), 2.84 (s, 3H), 1.58 (s, 3H), 1.20 (t, *J* = 7 Hz, 3H) ppm. $^{13}C\{1H\}$(125 MHz, $CDCl_3$)δ 169.5, 159.1, 155.5, 153.8, 147.8, 145.0, 142.9, 141.0, 135.6, 131.8, 129.1, 127.8, 127.1, 127.0, 126.5, 126.3, 125.5, 125.5, 122.7, 121.1, 114.4, 113.5, 61.3, 55.3, 33.2, 16.7, 14.3, 12.8 ppm. HRMS (ESI-TOF): m/z$[M+Na]^+$calculated for $C_{40}H_{34}O_4Na$: 601.2355; found: 601.2358. IR (film): ν_{max} 3053, 1729, 1371, 1297, 1198, 771 cm^{-1}.

Ethyl2-(5-(4-fluorophenyl)-3-(4-methoxyphenyl)-4,10-dimethyl-5-phenyl-5H-fluoreno[3,2-b]furan-2-yl)acetate (145c).Following general experimental procedure-4.6b, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as Yellow liquid (143.81 mg, 73%).^1H NMR (500 MHz, $CDCl_3$): δ 7.96 (d, *J* = 7.5 Hz, 1H), 7.31-7.29 (m, 2H), 7.28-7.24 (m, 7H), 7.21 (d, *J* =1.5 Hz, 1H), 7.19-7.18 (m, 3H), 6.19-6.87 (m, 4H), 4.22 (q, *J* = 7 Hz, 2H), 3.83 (s, 3H), 3.67 (s, 2H), 2.93 (s, 3H), 1.67 (s, 3H), 1.30 (t, *J* = 7 Hz, 3H) ppm. $^{13}C\{1H\}$(125 MHz, $CDCl_3$)δ 169.5, 162.4, 159.2, 155.3, 153.8, 147.8, 144.8, 142.8, 140.9, 138.7, 138.7, 135.5, 131.8, 130.8, 130.7, 129.0, 128.0, 127.3, 127.1, 127.0, 126.4 (2), 125.4, 125.3, 122.8, 121.1, 114.7, 114.5, 114.5, 113.6, 64.1, 61.4, 55.3, 33.1, 16.6, 14.3, 12.8 ppm. HRMS (ESI-TOF): *m/z* $[M+H]^+$calculated for $C_{40}H_{33}FO_4H$: 597.2441; found: 597.2442. IR (film): ν_{max} 2985, 1748, 1368, 1257, 1189, 741 cm^{-1}.

Ethyl2-(3-(4-methoxyphenyl)-4,7,10-trimethyl-5,5-diphenyl-5H-fluoreno[3,2-b]furan-2-yl)acetate (145d). Following general experimental procedure-4.6b, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid(132.66 mg, 67%); mp: 156-158°C. ^1H NMR (500 MHz, $CDCl_3$): δ 7.94 (d, *J* = 8.5 Hz, 1H), 7.22-7.18 (m, 4H), 7.15-7.14 (m, 3H), 7.11-7.09 (m, 5H), 7.09-7.03 (m, 2H), 6.78 (d, *J* = 8.5 Hz, 2H), 4.11 (q, *J* = 7.5 Hz, 2H), 3.27 (s, 3H), 3.56 (s, 2H), 2.81 (s, 3H), 2.19 (s, 3H), 1.56 (s, 3H), 1.20 (t, *J* = 7 Hz, 3H) ppm. $^{13}C\{1H\}$(100 MHz, $CDCl_3$)δ 159.1, 158.3, 155.7, 153.8, 147.6, 143.1, 138.4, 136.8, 135.8, 131.8, 129.9, 129.2 (2), 129.1, 128.9, 128.1 (2), 128.0, 127.9, 126.7, 126.6, 126.4, 126.2, 126.1, 126.0, 125.6, 122.4, 121.1, 113.6, 64.6, 55.3, 33.2, 21.7, 16.7, 14.3, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$calculated for $C_{41}H_{36}O_4H$: 593.2692; found: 593.2690.

Ethyl2-(5-(4-bromophenyl)-3-(4-fluorophenyl)-4,10-dimethyl-5-phenyl-5H-fluoreno[3,2-b]furan-2-yl)acetate (145e).Following general experimental procedure-4.6b, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as white solid (129.21 mg, 73%); mp: 258-260°C.^{1}H NMR (500 MHz, $CDCl_3$): δ 7.93 (d, J = 8 Hz, 1H), 7.33-7.26 (m, 6H), 7.24-7.23 (m, 3H), 7.18 (t, J = 6 Hz, 1H), 7.15-7.14 (m, 4H), 7.13-7.03 (m, 2H), 4.18 (q, J = 7.2 Hz, 2H), 3.63 (s, 2H), 2.90 (s, 3H), 1.62 (s, 3H), 1.27 (t, J = 7 Hz, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 169.3, 163.5, 154.9, 153.9, 148.1, 144.7, 142.3, 140.9, 135.8, 132.4, 131.0, 130.9, 129.3, 128.9, 128.1, 127.4, 127.2, 126.8, 126.6, 126.2, 125.3, 122.8, 120.5, 120.4, 115.3, 115.1, 114.7, 64.3, 61.5, 33.1, 16.8, 14.3, 12.8 ppm. HRMS (ESI-TOF): m/z$[M+Na]^+$ calculated for $C_{39}H_{30}BrFO_3Na$: 667.1260; found: 667.1261.

2-Butyl-5,11-dimethyl-4,6,6-triphenyl-4,6-dihydroindeno[2,1-g]chromene (146a).Following general experimental procedure-4.6c, the crude reaction mixture waspurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as Yellow liquid(142.36 mg, 76%). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, J = 7.5 Hz, 1H), 7.34-7.28 (m, 5H), 7.27-7.24 (m, 4H), 7.23-7.19 (m, 6H), 7.19-7.14 (m, 3H), 6.64 (s, 1H), 5.34 (s, 1H), 2.65 (s, 3H), 2.32-2.29 (m, 2H), 1.92 (s, 3H), 1.58-1.53 (m, 2H), 1.45-1.41 (m, 2H), 0.92 (t, J = 7.5 Hz, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.8, 153.3, 143.1, 143.0, 142.6, 140.9, 139.5, 139.4, 131.2, 129.3, 128.9, 128.6, 128.1, 127.9, 127.3, 127.1, 127.0 (2), 126.9, 126.4, 126.3, 125.4, 124.6, 123.2, 119.9, 87.5, 78.8, 65.1, 34.8, 30.8, 22.1, 18.7, 17.4, 13.7, 13.7, 12.8 ppm. HRMS (ESI-TOF): *m/*z $[M+H]^+$calculated for $C_{40}H_{36}OH$: 533.2844; found: 533.2846. IR (film): ν_{max} 2945, 1678, 1596, 1445, 1252, 1132, 1032, 850 cm^{-1}.

5,11-Dimethyl-2-pentyl-4,6,6-triphenyl-4,6-dihydroindeno[2,1-g] chromene (146b). Following general experimental procedure-4.6c, the crude reaction mixture waspurified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained aswhitesolid(140.34 mg, 73%); mp: 219-221°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95 (d, J = 7.5 Hz, 1H), 7.23-7.27 (m, 7H), 7.26-7.25 (m, 10H), 7.24-7.18 (m, 1H), 5.77 (s, 1H), 4.51 (s, 1H), 2.72 (s, 3H), 2.00-1.98 (m, 1H), 1.82-1.80 (m, 1H), 1.65-1.61 (m, 2H), 1.39 (s, 3H), 1.28-0.94 (m, 4H), 0.93 (t, J = 1.5 Hz, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 156.1, 154.6, 143.7, 142.6, 141.7, 141.0, 140.1, 139.3, 131.0, 129.2, 129.1, 128.3, 127.8, 127.7, 127.4, 127.1, 127.1, 126.9, 126.4, 126.3, 125.3, 123.7, 123.3, 118.6, 65.1, 33.9, 31.8, 25.3,

20.6, 14.1, 12.8 ppm. HRMS (ESI-TOF): m/z $[M+H]^+$calculated for $C_{41}H_{38}OH$: 547.3001; found: 547.3003.

2-Butyl-6-(4-chlorophenyl)-5,11-dimethyl-4,6-diphenyl-4,6-dihydroindeno[2,1-g]chromene (146c). Following general experimental procedure-4.6c, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained as Yellow liquid (117.21 mg, 68%). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, J = 8 Hz, 1H), 7.30-7.25 (m, 10H), 7.23-7.19 (m, 3H), 7.18-7.13 (m, 4H), 6.66 (s, 1H), 5.34 (s, 1H), 2.65 (s, 3H), 2.32-29 (m, 2H), 1.90 (s, 3H), 1.59-1.53 (m, 2H), 1.45-1.41 (m, 2H), 0.92 (t, J = 7.5 Hz, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.3, 153.5, 142.6, 142.2, 141.8, 140.9, 139.5, 139.3, 132.2, 131.1, 130.8, 130.3, 129.1, 128.7, 128.7, 128.1, 128.0, 127.4, 127.3, 127.1, 126.9, 126.5, 125.2, 124.7, 123.4, 120.0, 87.6, 78.7, 64.6, 34.8, 30.8, 22.2, 18.7, 17.4, 13.7, 12.8 ppm. (LCMS): m/z $[M+H]^+$: 567. IR (film): ν_{max} 2955, 1656, 1552, 1484, 1264, 1121, 1028, 819 cm^{-1}.

2-(1,3-diphenylprop-2-yn-1-yl)-4,10-dimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan (147a).Following general experimental procedure-4.6d, the crude reaction mixture was purified by column chromatography (silica gel, 3-5 %, EtOAc in petroleum ether) the product was obtained aswhite solid (59 mg, 50%); mp: 153-154 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.91 (d, J = 7.5 Hz, 1H), 7.49-7.45 (m, 3H), 7.41-7.34 (m, 2H), 7.33-7.32 (m, 4H), 7.30-7.27 (m, 6H), 7.27-7.24 (m, 4H), 7.21-7.16 (m, 4H), 7.14-7.11 (m, 5H), 7.06 (t, J = 5.5 Hz, 1H), 5.23 (s, 1H), 2.90 (s, 3H), 1.63 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.5, 151.9, 142.9 (2), 141.0, 138.7, 133.6, 131.9, 131.1, 130.9, 129.6, 129.2, 129.1, 129.0, 128.9, 128.7, 128.6, 128.4, 128.3, 128.2 (2), 128.1, 127.9 (2), 127.8 (2), 127.7, 127.6, 127.3, 127.2, 127.1, 126.9, 126.6, 126.3 (2), 125.5, 123.4, 122.7, 122.6, 119.4, 114.6, 87.3, 84.164.7, 36.1, 16.8, 12.9 ppm. (LCMS): m/z $[M+H]^+$: 653 ppm. IR (film): ν_{max} 2985, 1526, 1348, 748 cm^{-1}.

4,10-Dimethyl-3,5,5-triphenyl-2-(1-phenyl-3-(p-tolyl)prop-2-yn-1-yl)-5H-fluoreno[3,2-b]furan (147b).Following general experimental procedure-4.6d, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained aswhite solid(63.94 mg, 53%) ; mp: 168-170°C. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.95 (d, J = 8 Hz, 1H), 7.51 (d, J = 7.5 Hz, 2H) 7.43-7.36 (m, 6H), 7.35-7.33 (m, 9H), 7.32-7.13 (m, 10 H), 5.25 (s, 1H), 2.93 (s, 3H), 2.37 (s, 3H), 1.66 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.5, 153.8, 152.1, 145.1, 143.0, 142.9, 141.0, 138.8, 138.2,

135.8, 133.6, 131.8, 131.1, 131.0, 129.2, 129.1, 129.0, 128.9, 128.7, 128.6, 128.4, 128.1, 127.9 (3), 127.7, 127.3, 127.2, 127. 0 (2), 126.7, 126.5, 126.3 (2), 125.5, 122.7, 122.6, 120.4, 119.4, 114.7, 86.6, 84.2, 77.4, 64.8, 36.1, 21.5, 16.8, 12.9 ppm. (LCMS): m/z $[M+H]^+$: 667. IR (film): ν_{max} 2924, 1491, 1218, 772, 698 cm^{-1}.

2-(3-Cyclopropyl-1-phenylprop-2-yn-1-yl)-4,10-dimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-b]furan (147c). Following general experimental procedure-4.6d, the crude reaction mixture was purified by column chromatography (silica gel, 3-6 %, EtOAc in petroleum ether) the product was obtained aswhite solid (53.56 mg, 48%);mp: 158-160°C.^{1}H NMR (500 MHz, $CDCl_3$): δ 7.92 (d, J = 8 Hz, 1H), 7.40-7.35 (m, 3H), 7.32-7.25 (m, 10H), 7.24-7.13 (m, 10H), 4.95 (s, 1H), 2.88 (s, 3H), 1.60 (s, 3H), 1.29-1.26 (m, 2H), 0.88-0.85 (m, 1H), 0.76-0.74 (m, 1H), 0.74-0.68 (m, 1H) ppm.^{13}C{1H}(125 MHz, $CDCl_3$)δ 155.5, 153.7, 152.5, 145.0, 143.0, 142.9 (2), 141.0, 139.2, 135.6, 133.7, 131.1, 130.9 (2), 129.1(2), 128.7, 128.6, 128.5, 128.3, 128.1, 128.0, 127.9, 127.9 (2), 127.8, 127.6, 127.2, 127.1, 127.0, 126.9, 126.6, 126.3 (2), 125.5, 122.7, 122.6, 119.0, 114.6, 87.3, 72.9, 64.7, 35.4, 16.8, 12.9, 8.3 ppm. (LCMS): m/z $[M+H]^+$: 617.

Experimental procedure for the synthesis of (149):[19] A mixture of compound **144a** (0.1 mmol), 4-methoxy phenol (**148**) (0.18 mmol), tricyclohexylphosphane (PCy_3, 40 mol%), and lithium chloride (5.0 eq.) was taken into a sealed tube. The tube was evacuated and re-filled with nitrogen for 3 cycles then, anhydrous DMF (2.0 mL) and DBU (2.5 eq.) were added. The tube was placed into a preheated oil bath at 100 °C for 14 h. After the completion of the reaction, the mixture was cooled to ambient temperature and diluted with EtOAc and water. The organic layer was separated, and the aqueous layer was further extracted with EtOAc (~10 mL×3). The combined organic layers were dried over Na_2SO_4 and evaporated under reduced pressure. The crude product was purified by flash column chromatography on silica gel (60-120 mesh), using 6-7%, EtOAc in pet ether to afford the pure product **149** in 55% yield.

2-((4-Methoxyphenoxy)(phenyl)methyl)-4,10-dimethyl-3,5,5-triphenyl-5H-fluoreno[3,2-]furan (149).white solid mp: 201-203°C; (67.15 mg, 55%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05-7.99 (m, 3H), 7.53 (d, J = 7.6 Hz, 1H), 7.43 (t, J = 8 Hz, 2H), 7.38-7.29 (m, 10H), 7.26-7.23 (m, 8H), 6.80 (t, J = 1.6 Hz, 4H), 4.61 (s, 1H), 3.79 (s, 3H), 3.01 (s, 3H), 1.68 (s, 3H) ppm. ^{13}C{1H}(125 MHz, $CDCl_3$)δ 183.7, 155.7, 154.6, 153.3, 152.7, 148.4, 147.2, 144.9, 141.4, 140.9, 139.0, 138.5, 136.5, 132.0, 131.7, 131.3, 130.3, 128.9, 128.7, 128.0, 127.9,

127.5, 127.4, 127.2, 127.0, 126.8 (2), 126.7, 126.3, 125.5, 125.4, 125.1, 124.5, 124.3, 123.1, 122.2, 114.9, 113.9, 113.7, 63.6, 54.7, 28.6, 15.8, 11.7 3 ppm. (LCMS): m/z $[M+H]^+$: 675. IR (film): ν_{max} 2920, 2850, 1736, 1642, 1361, 797 cm^{-1}.

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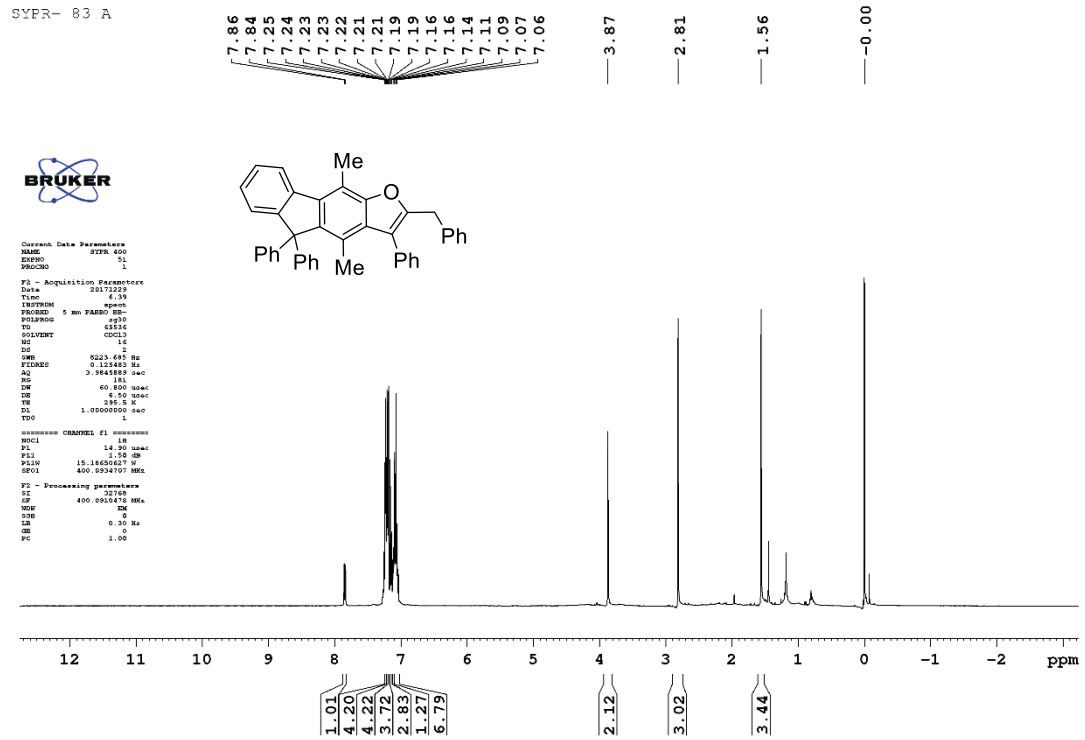
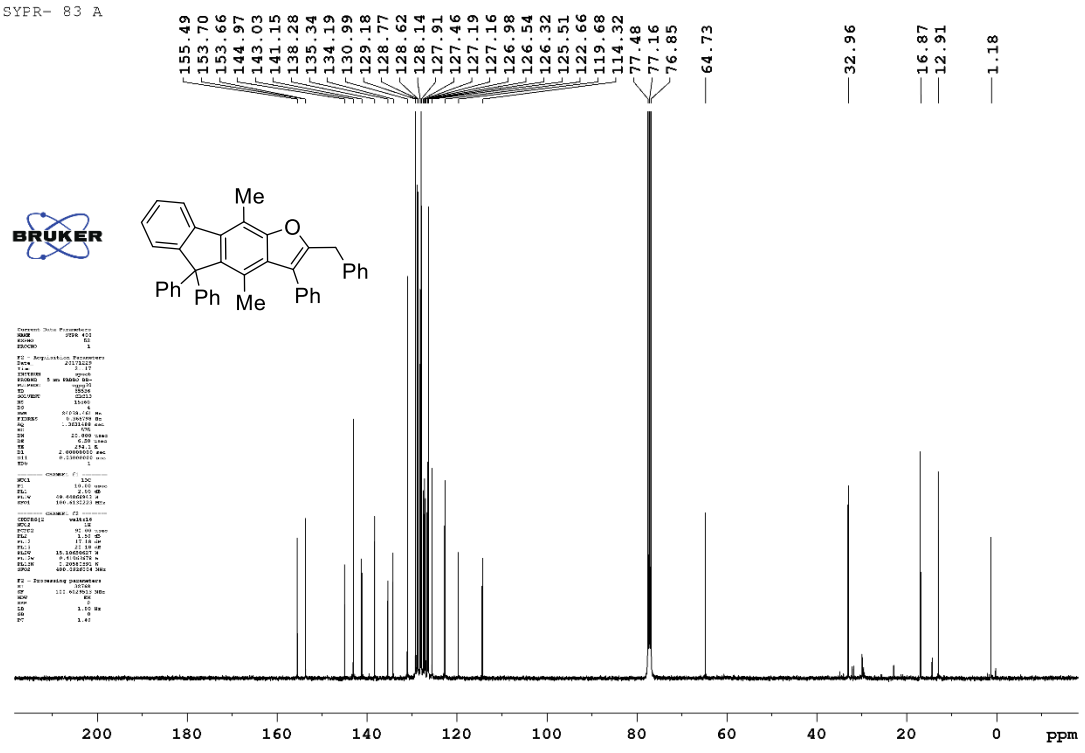
4.8a Crystal data and structure refinement for 129d.

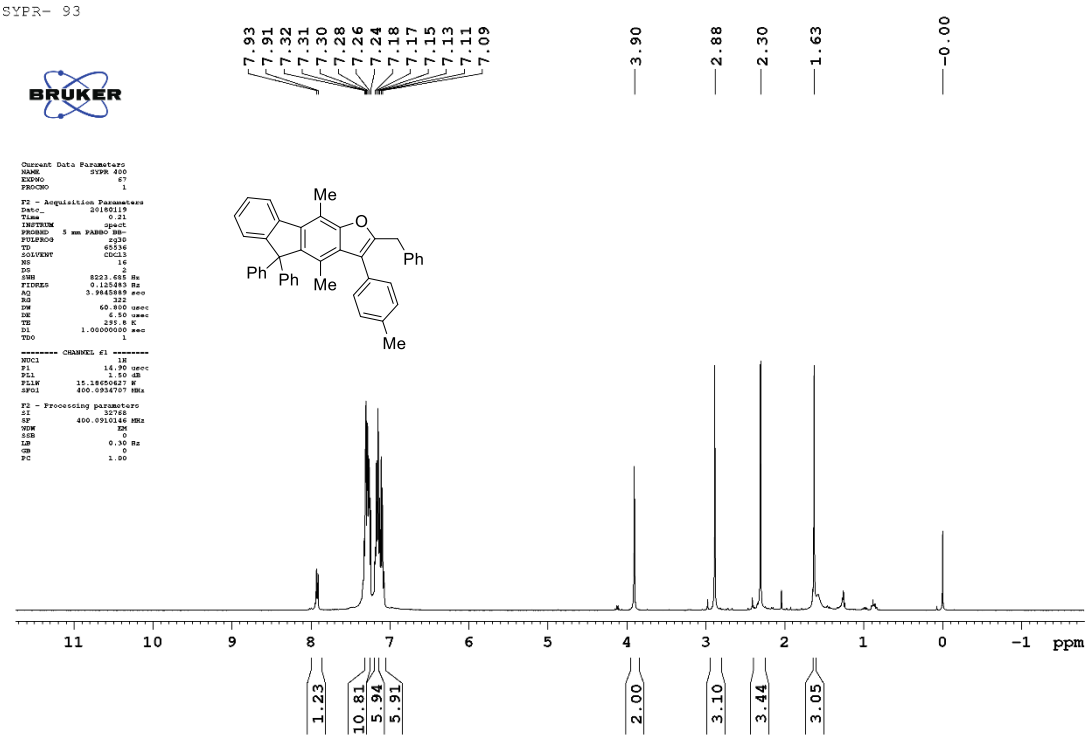
Identification code	shelx-97
Empirical formula	$C_{42}H_{31}ClO$
Formula weight	1169.20
Temperature	297 K
Wavelength	0.71073 Å
Crystal system	'Monoclinic'
Space group	P2(1)
Unit cell dimensions	a = 8.9086(10) Å α = 90.00.
	b = 23.856(3) Å β = 90.076(6).
	c = 14.701(2) Å γ = 90.00.

Volume	3124.4(7)
Z	2
Density (calculated)	1.243 Mg/m3
Absorption coefficient	0.155 mm-1
F(000)	1222.0
Crystal size	0.24 x 0.22 x 0.20 mm3
Theta range for data collection	2.29 to 24.99 °.
Index ranges	-10<=h<=10,-28<=k<=28,-17<=l<=17
Reflections collected	11026
Independent reflections	8060 [R(int) = 0.0503]
Max. and min. transmission	0.963 and 0.969
restraints / parameters	1 / 798
Goodness-of-fit on F^2	1.023
Final R indices [I>2sigma(I)]	R1 = 0.0503, wR2 = 0.1222
R indices (all data)	R1 = 0.0824, wR2 = 0.1101

4.9 SPECTRAL COPIES



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7.11
7.09
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2.30
1.63
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O
Ph
Ph
Ph
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Me
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8
7
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5
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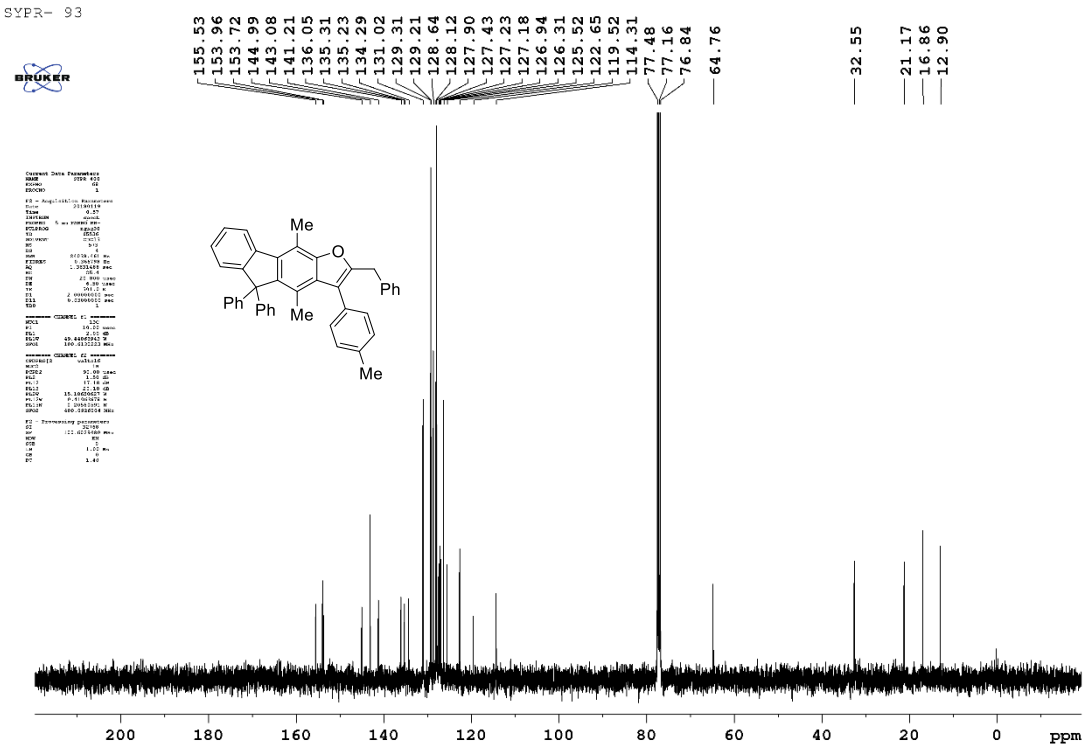
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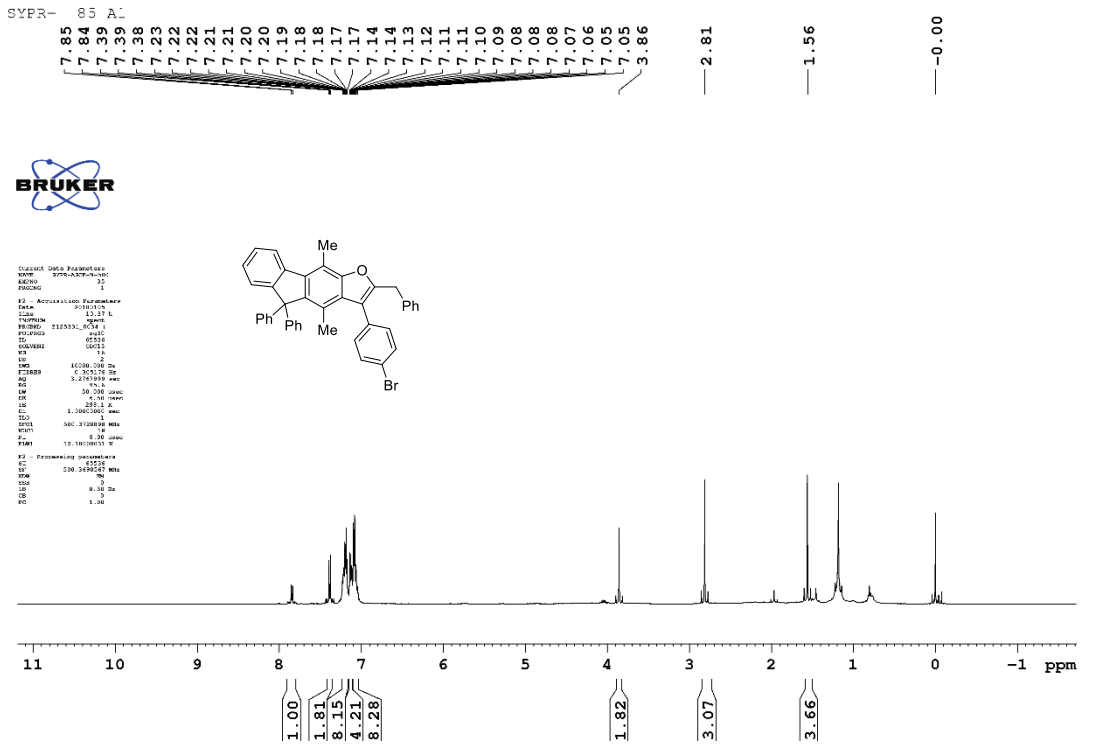
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2.81
1.56
-0.00
BRUKER
Me
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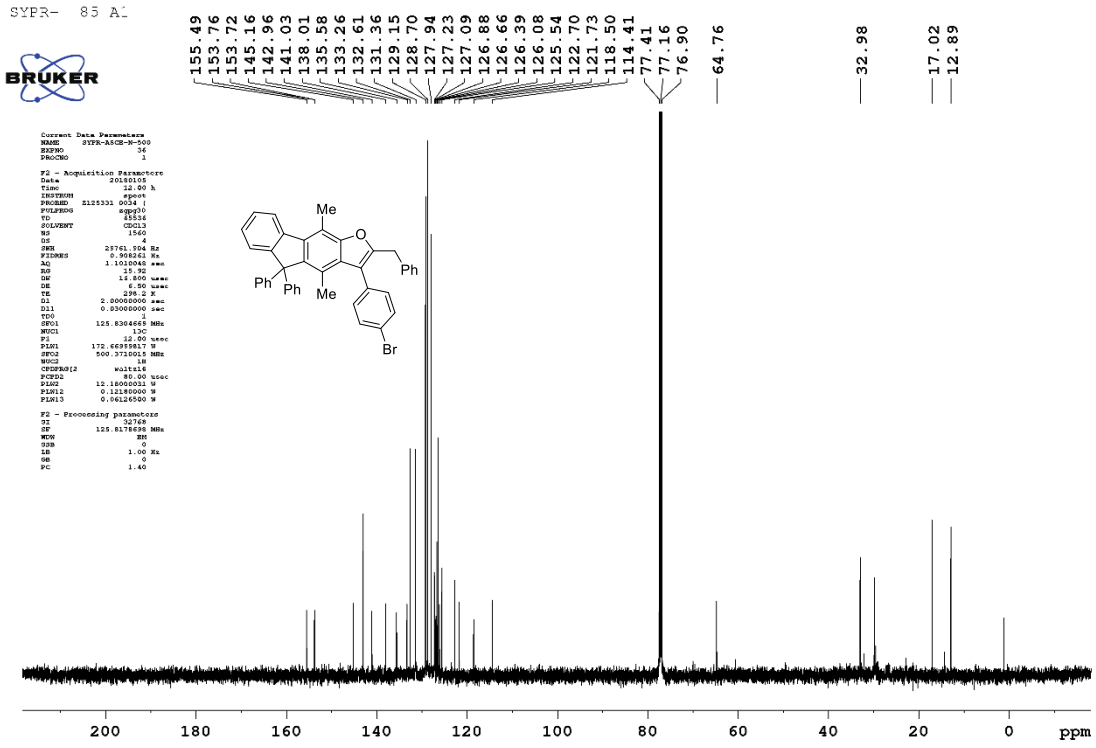
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17.02 12.89
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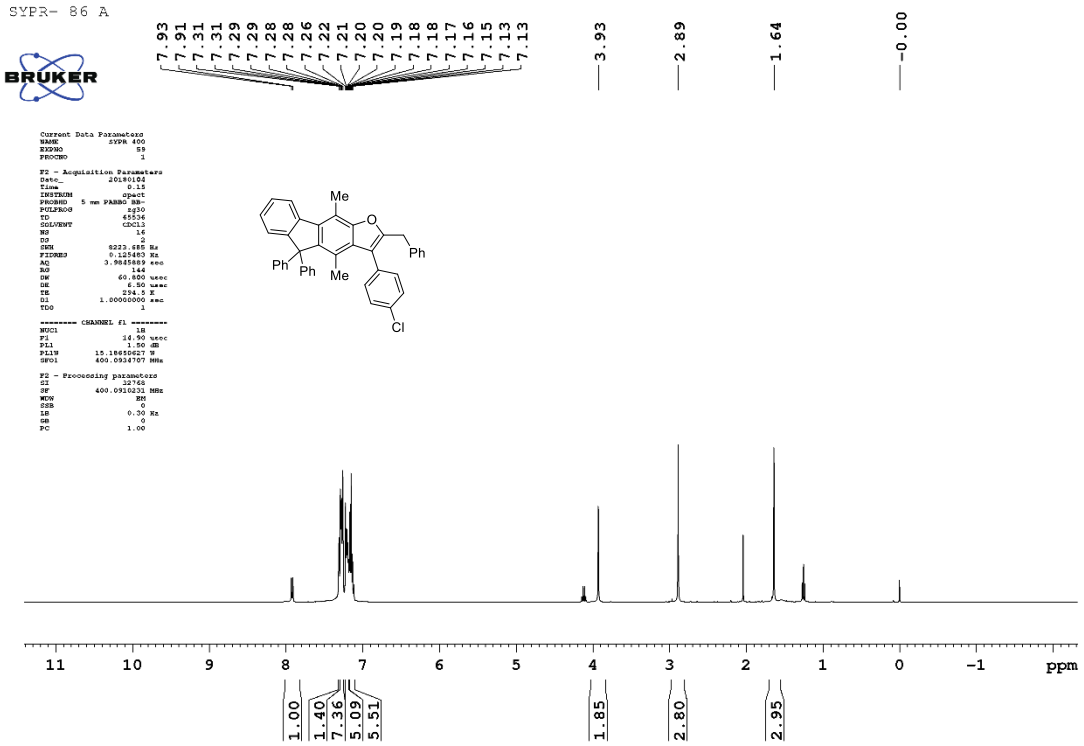
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7.26
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7.21
7.20
7.20
7.19
7.18
7.18
7.17
7.16
7.15
7.13
3.93
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1.64
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Ph
Ph
Me
Cl
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9
8
7
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5
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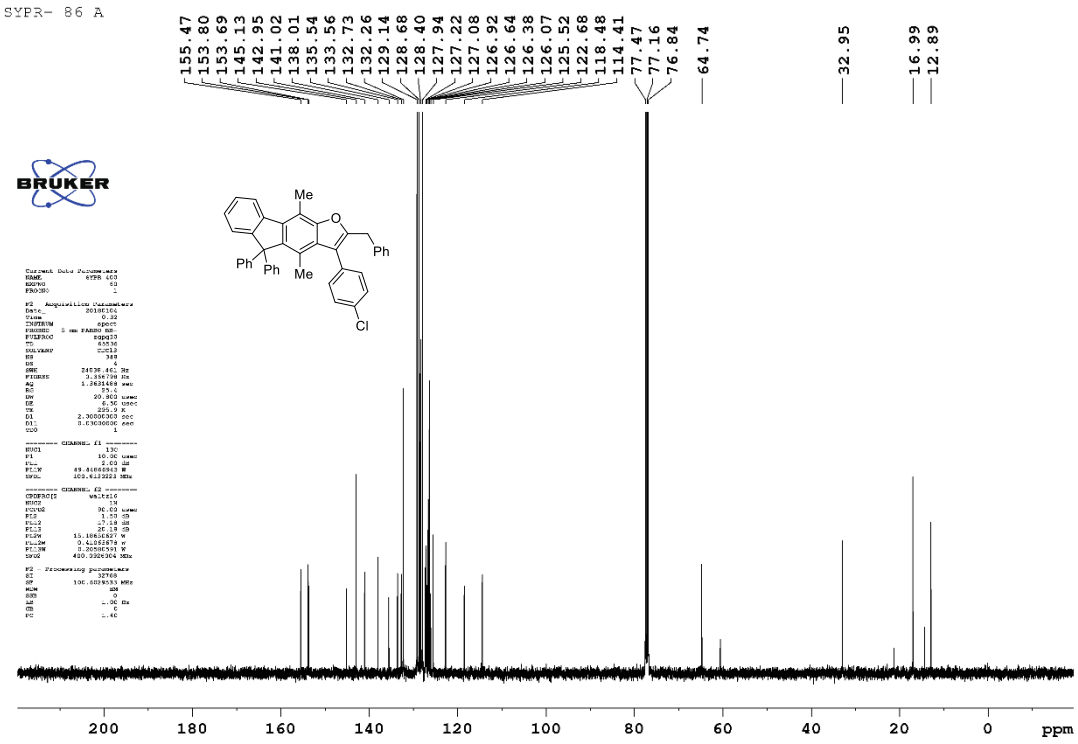
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153.80
153.69
145.13
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141.02
138.01
135.54
133.56
132.73
132.26
129.14
128.68
128.40
127.94
127.22
127.08
126.92
126.64
126.38
126.07
125.52
122.68
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16.99
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Ph
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Cl
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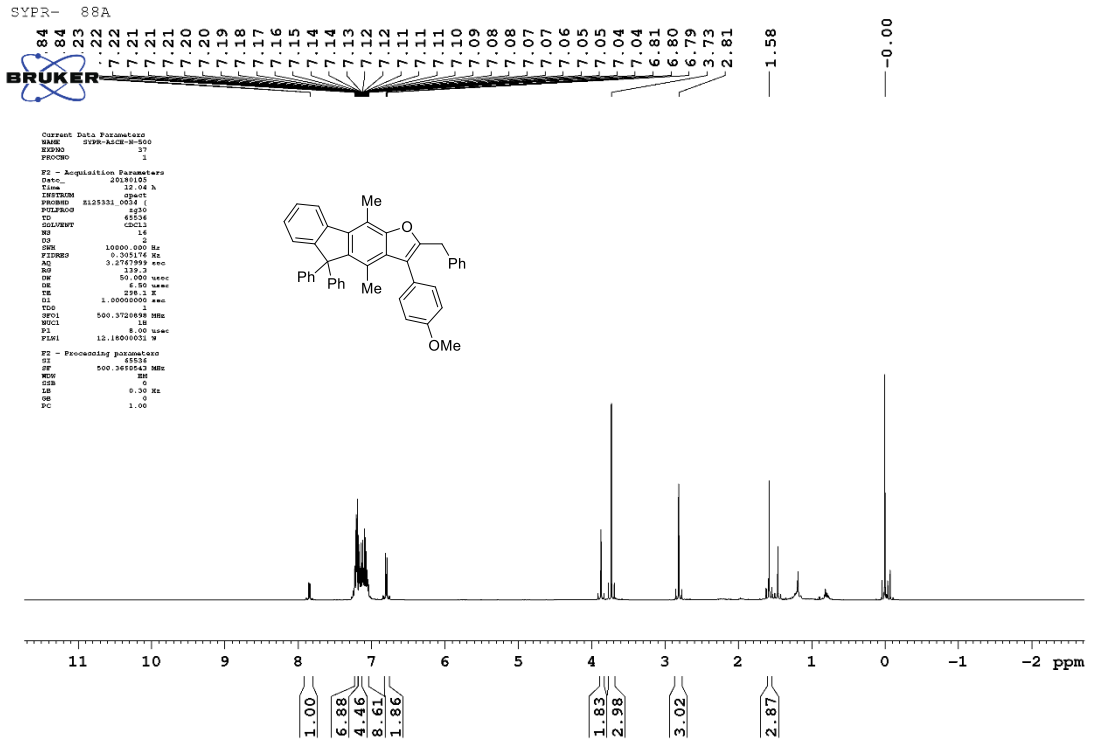
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Me
O
Ph
Ph
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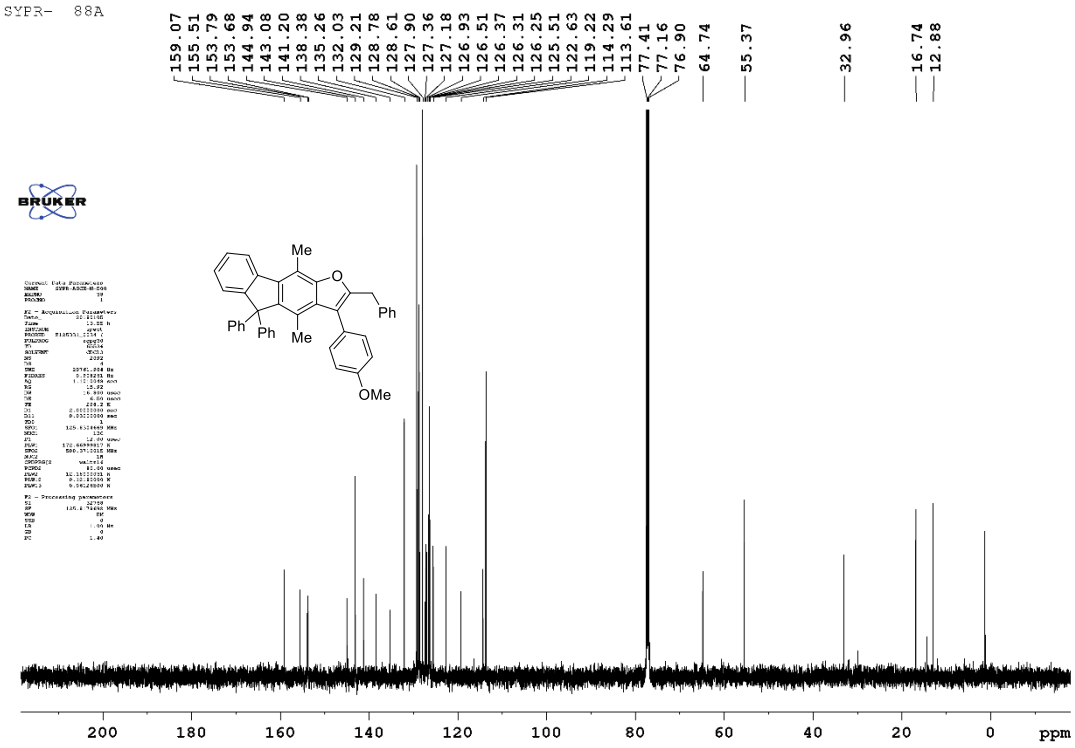
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Ph
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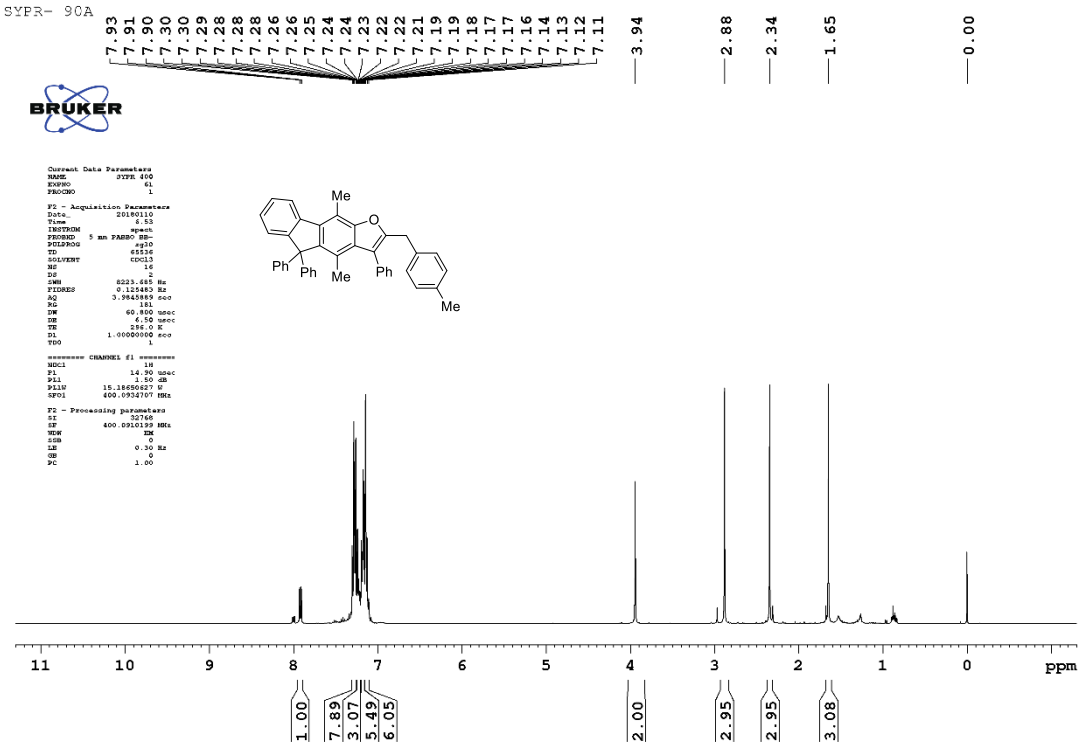
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3.94
2.88
2.34
1.65
0.00
BRUKER
Me
O
Ph
Ph
Me
Ph
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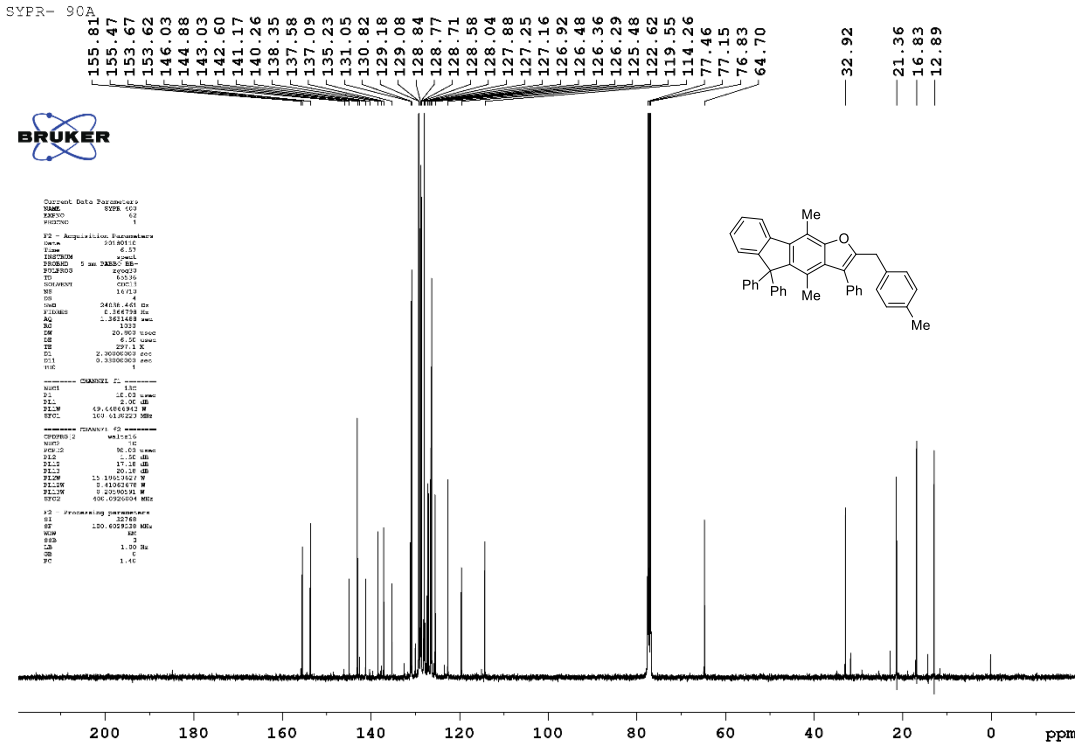
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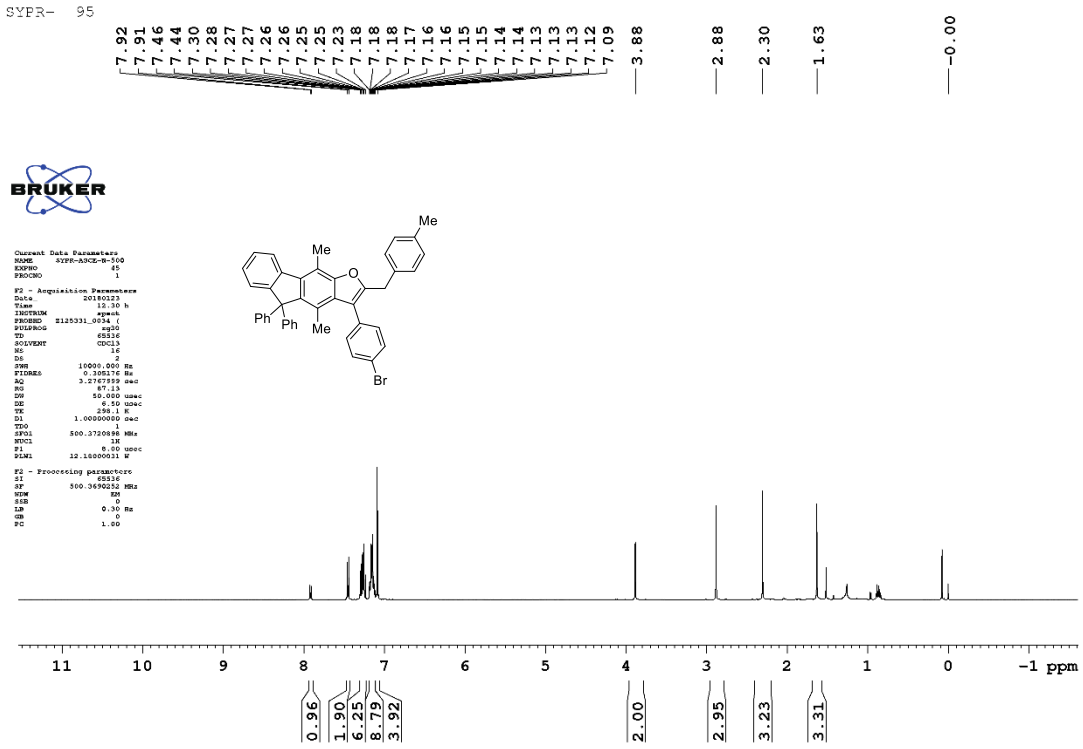
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4
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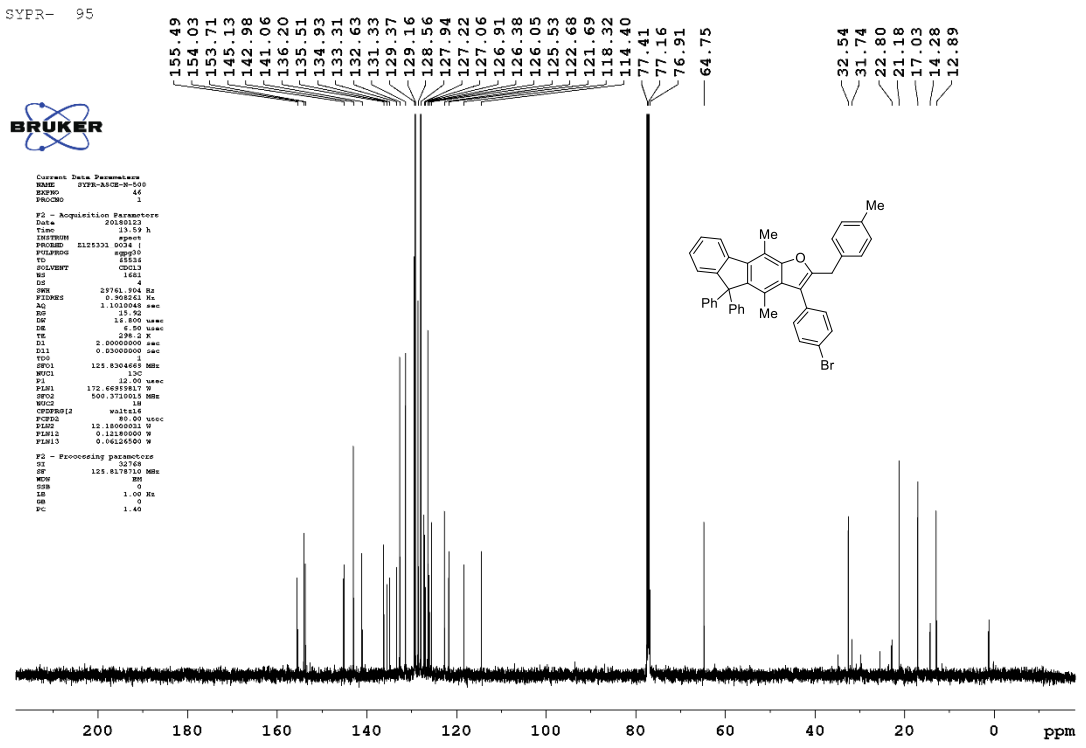
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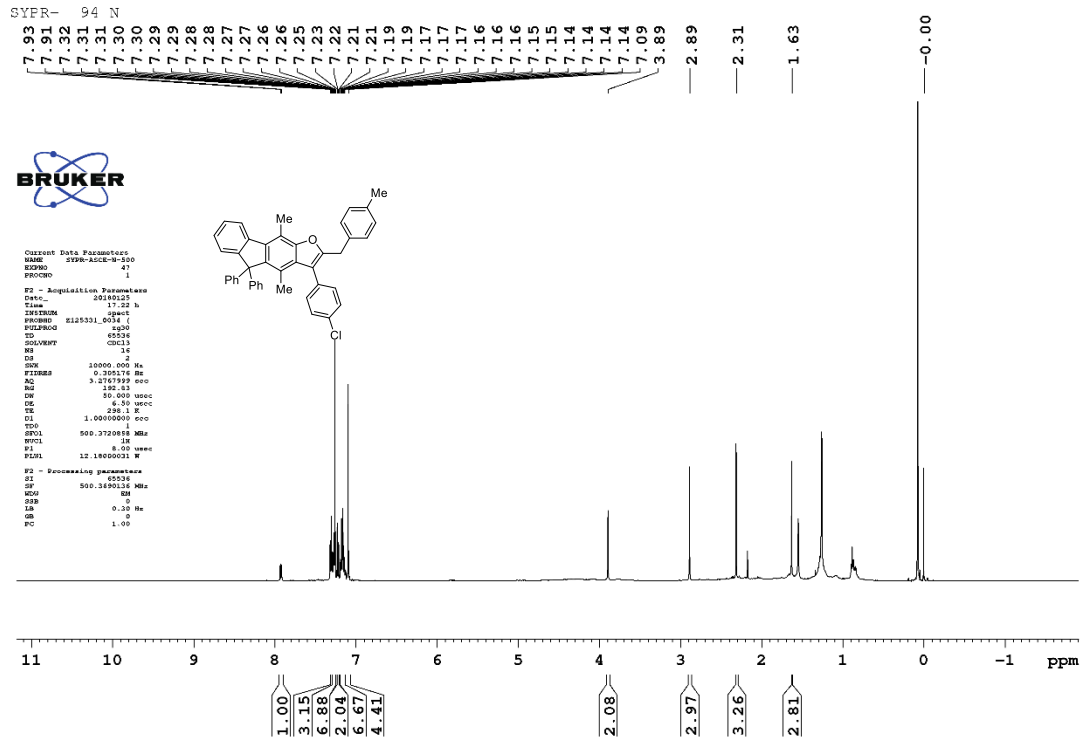
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BRUKER
Me
Me
O
Ph
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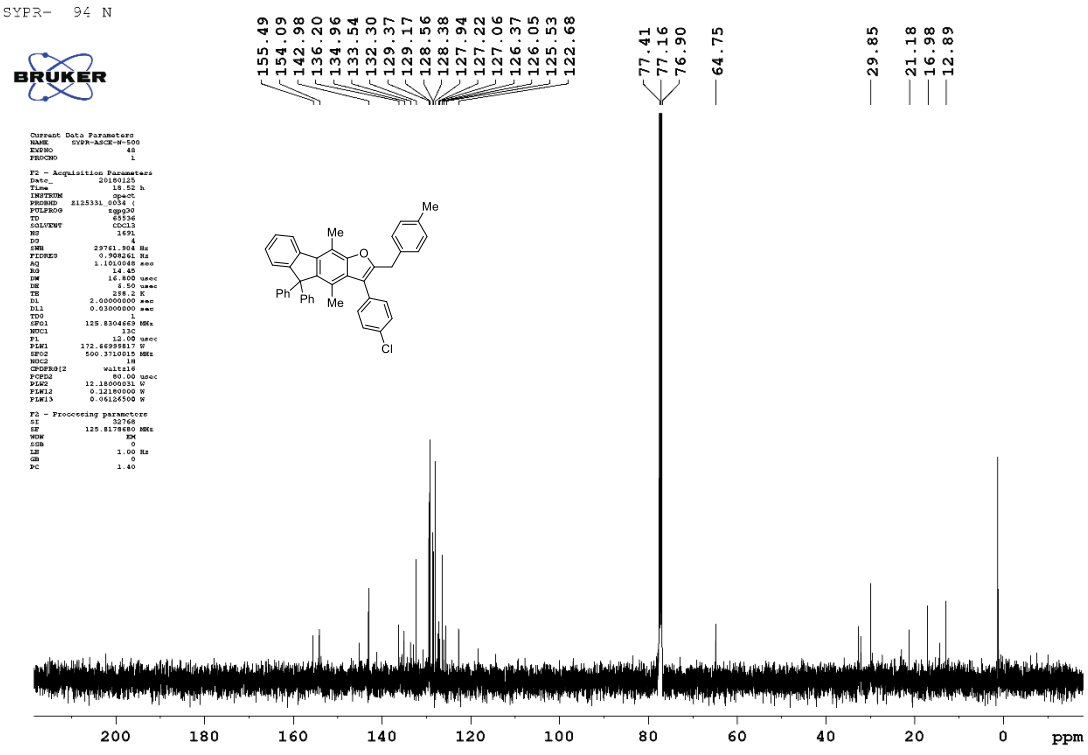
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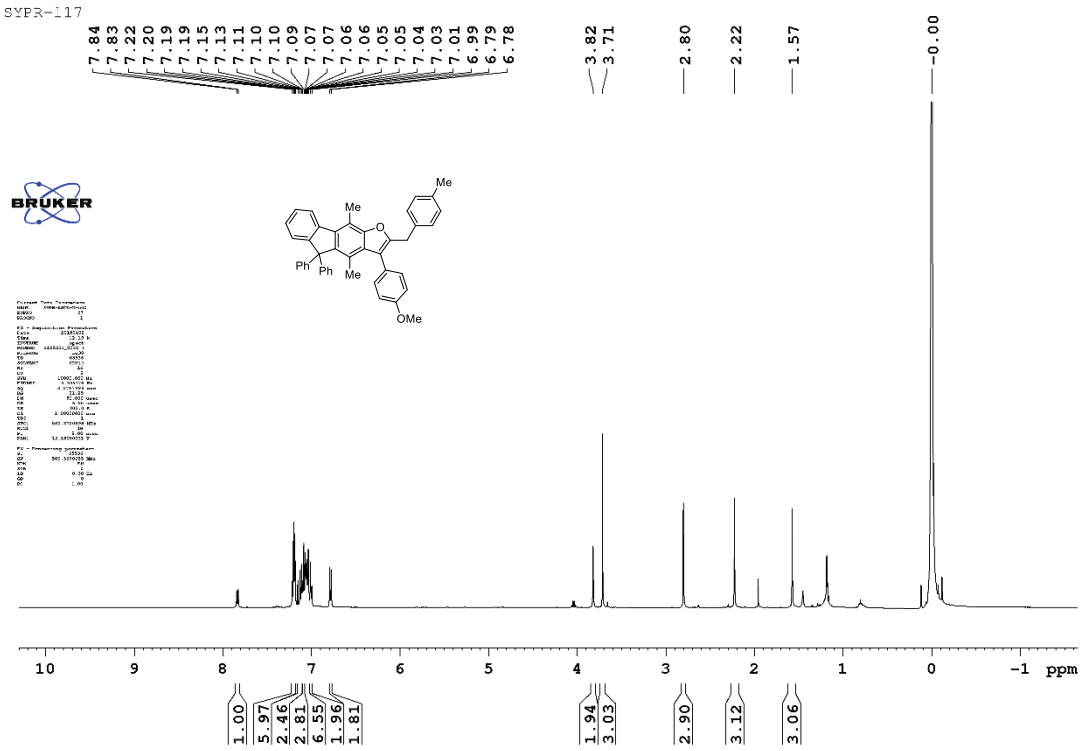
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3
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−1
ppm
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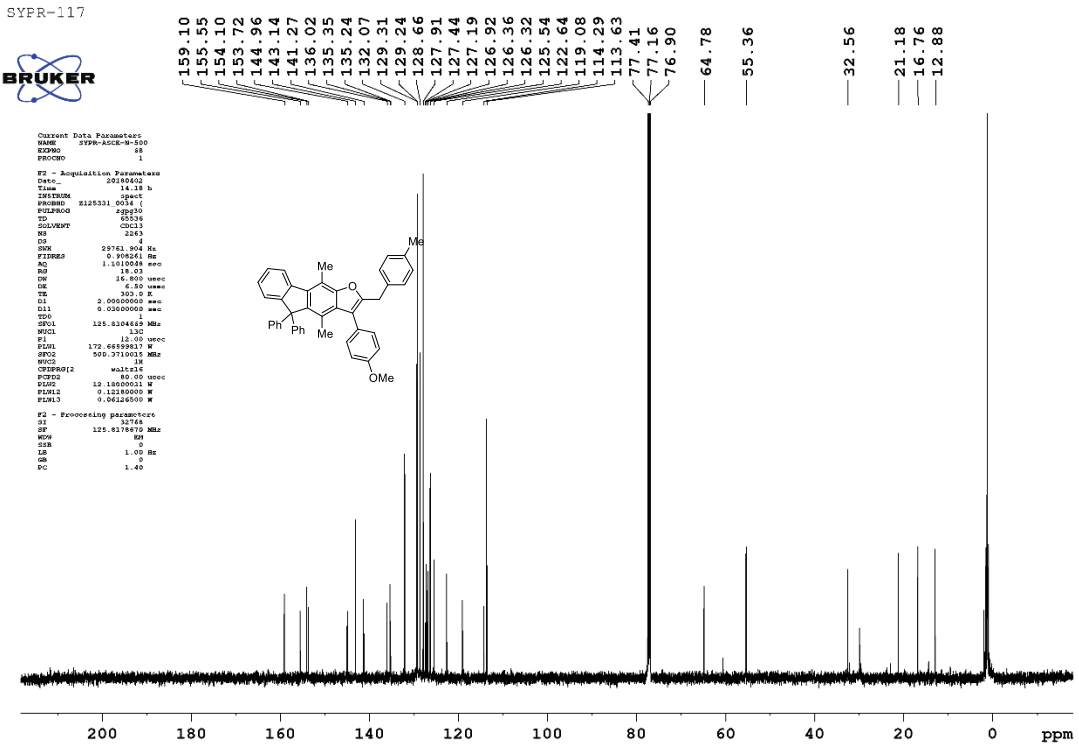
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135.24
132.07
129.31
129.24
128.66
127.91
127.44
127.19
126.92
126.36
126.32
125.54
122.64
119.08
114.29
113.63
77.41
77.16
76.90
64.78
55.36
32.56
21.18
16.76
12.88
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Me
Ph
Ph
Me
OMe
200
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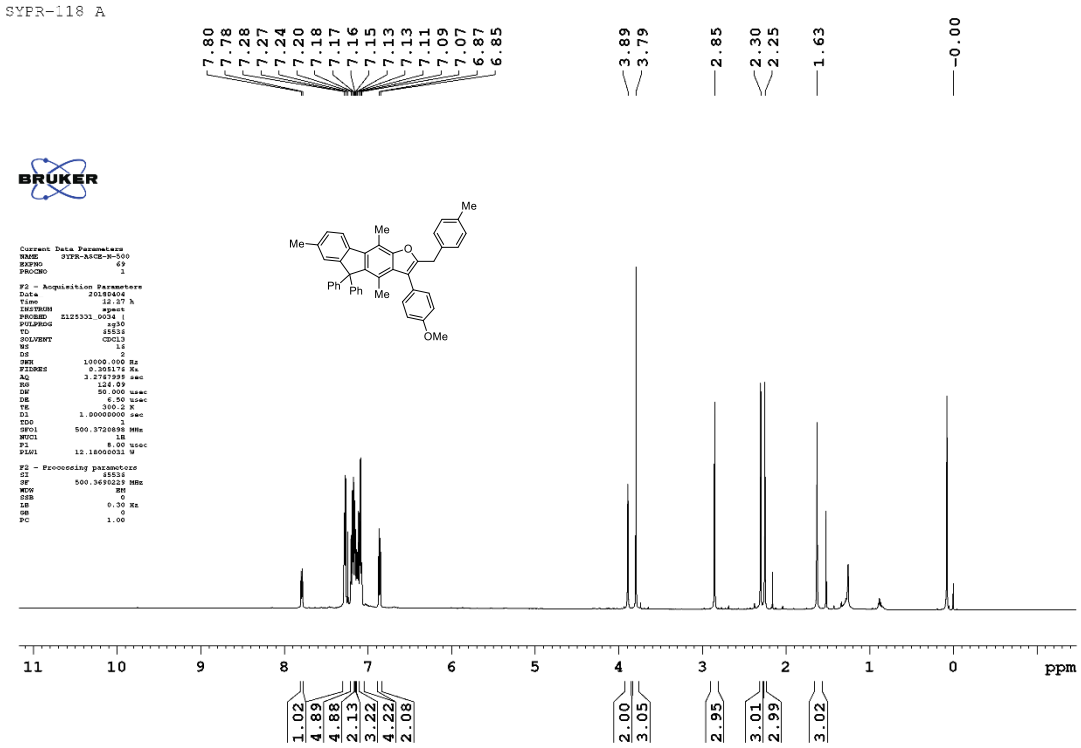
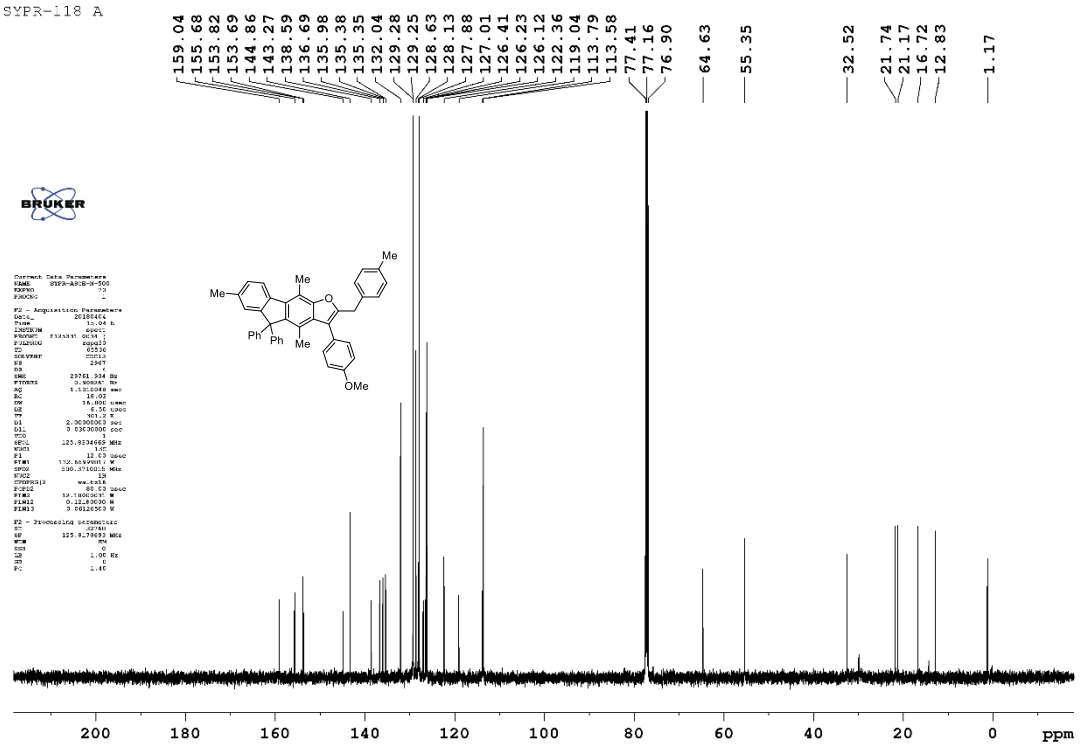
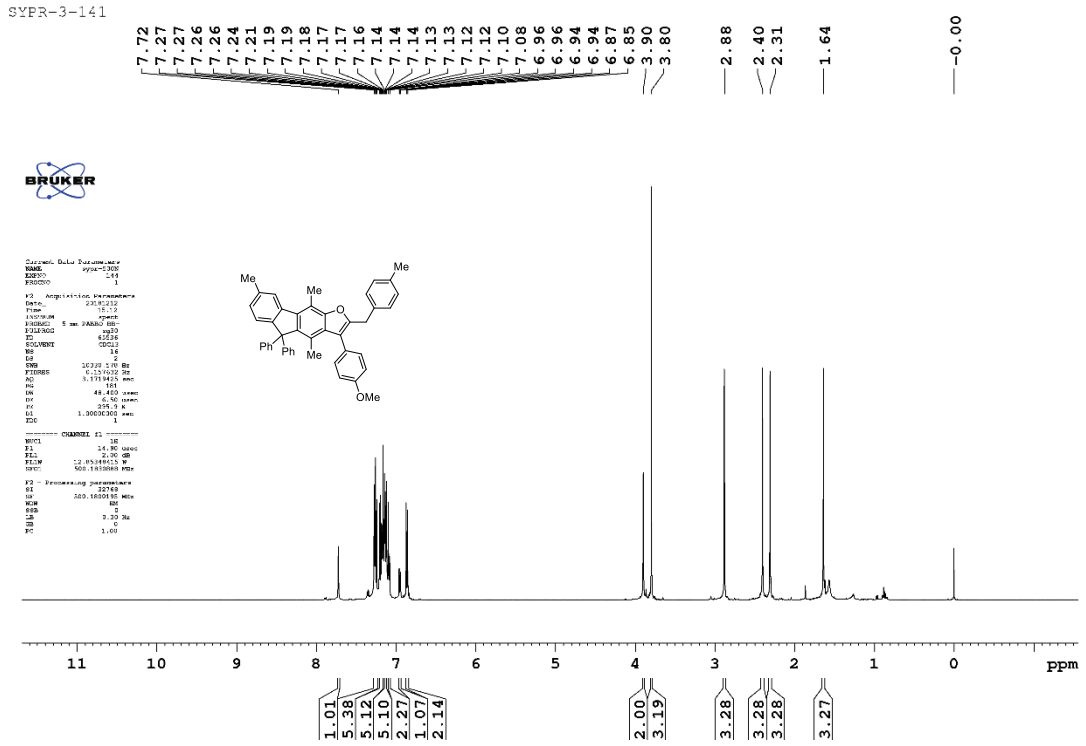
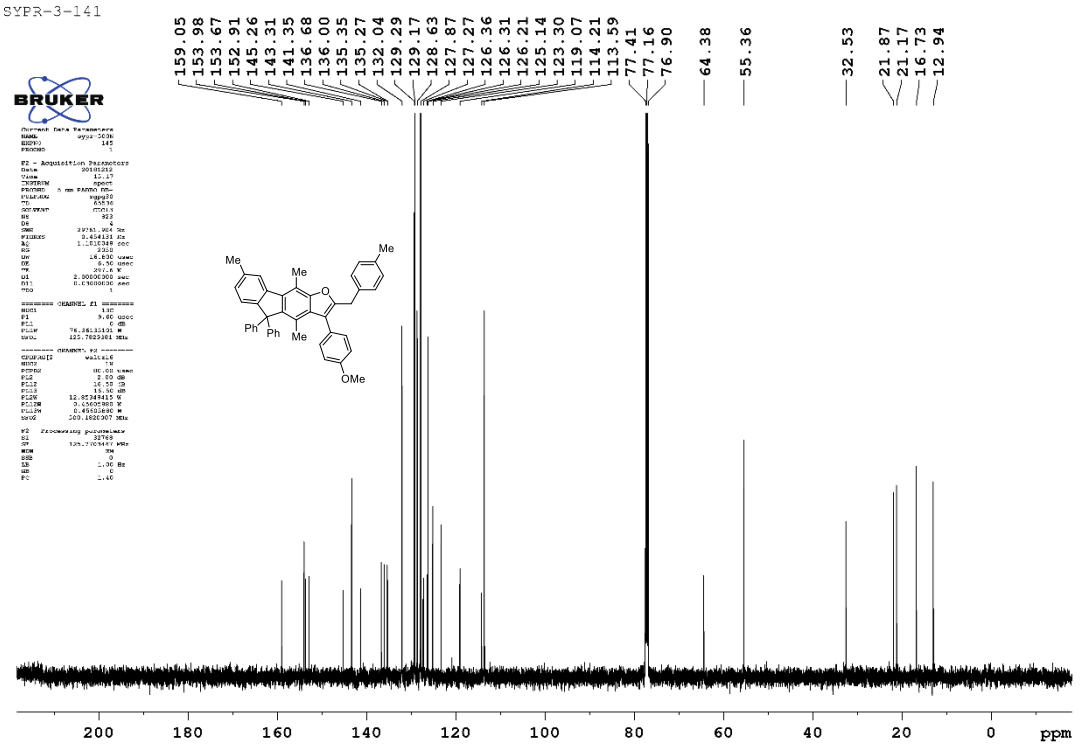
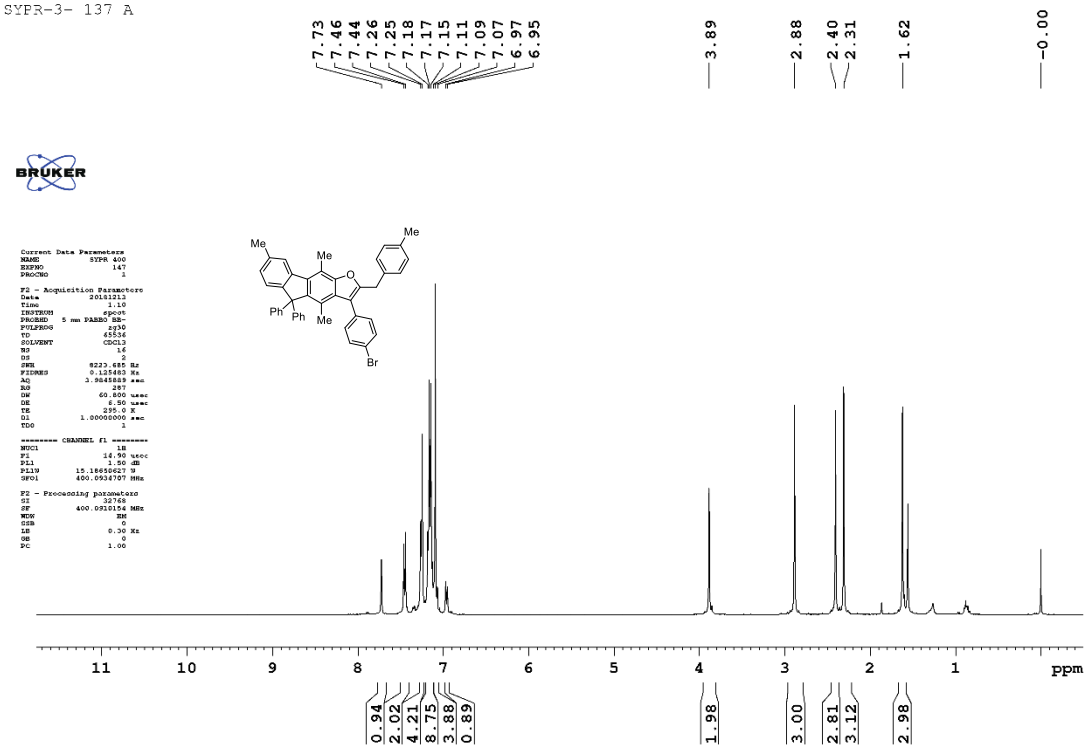
140
120
100
80
60
40
20
0
ppm

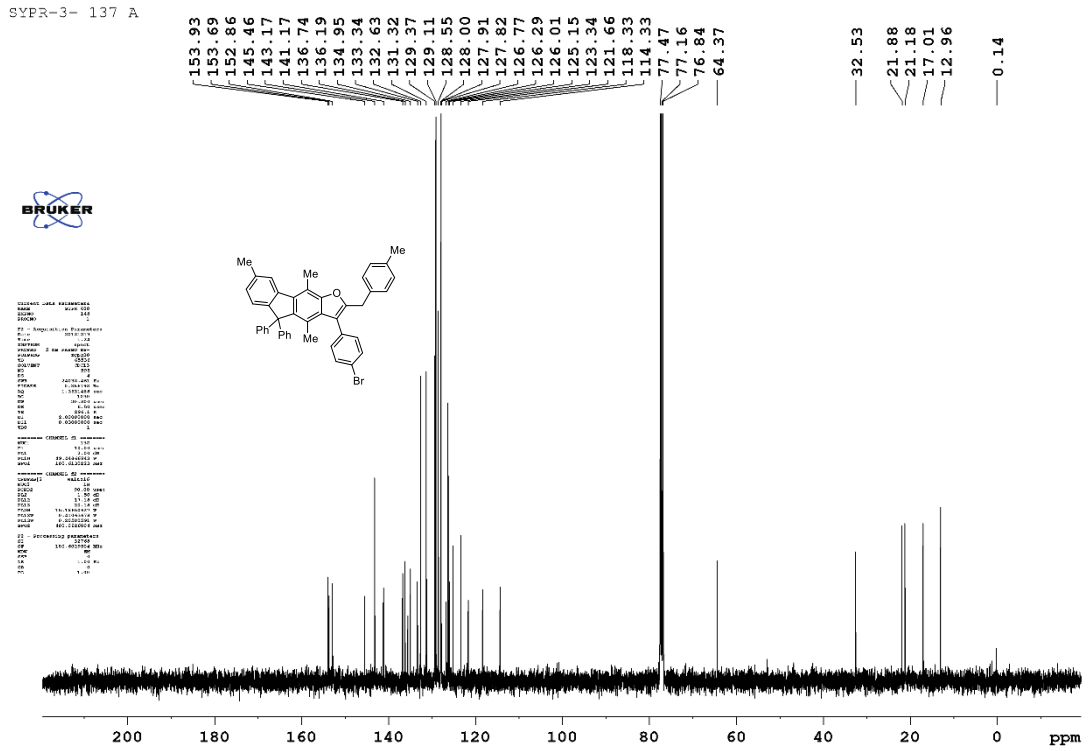

SYPR-118 A
7.80
7.78
7.28
7.27
7.24
7.20
7.18
7.17
7.16
7.15
7.13
7.13
7.11
7.09
7.07
6.87
6.85
3.89
3.79
2.85
2.30
2.25
1.63
0.00
BRUKER
Me
Me
Ph
Ph
Me
Me
OMe
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.02
4.89
4.88
2.13
3.22
4.22
2.08
2.00
3.05
2.95
3.01
2.99
3.02

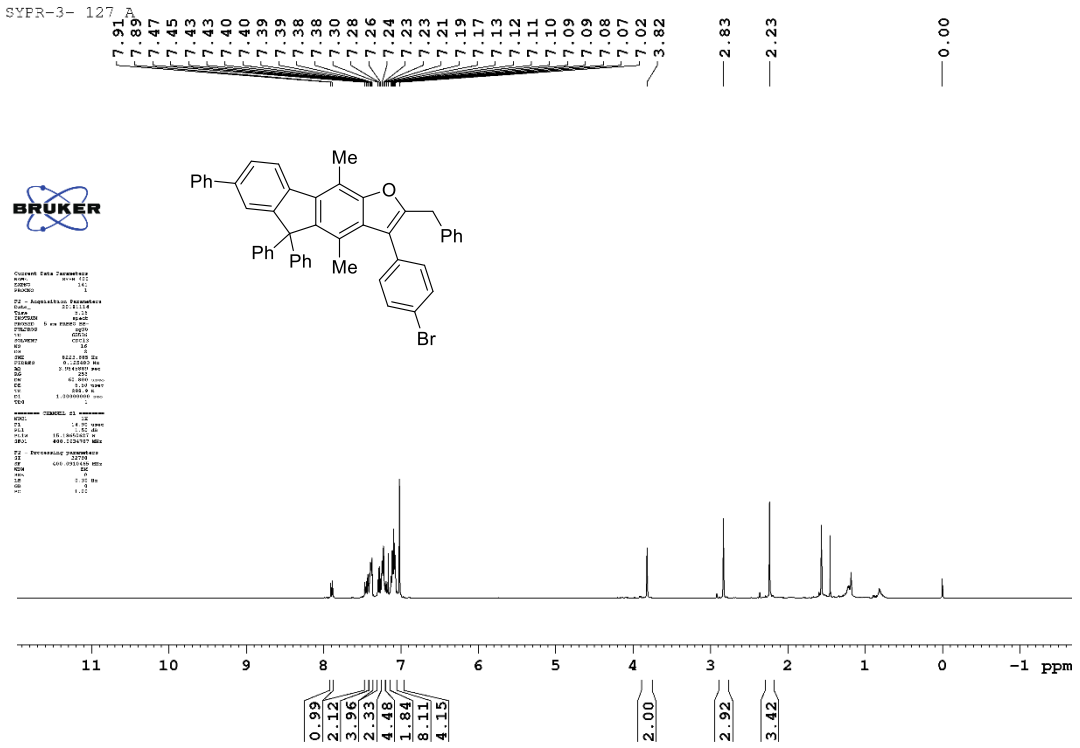

SYPR-118 A
159.04
155.68
153.82
153.69
144.86
143.27
138.59
136.69
135.98
135.38
135.35
132.04
129.28
129.25
128.63
128.13
127.88
127.01
126.41
126.23
126.12
122.36
119.04
113.79
113.58
77.41
77.16
76.90
64.63
55.35
32.52
21.74
21.17
16.72
12.83
1.17
BRUKER
Me
Me
Ph
Ph
Me
Me
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm

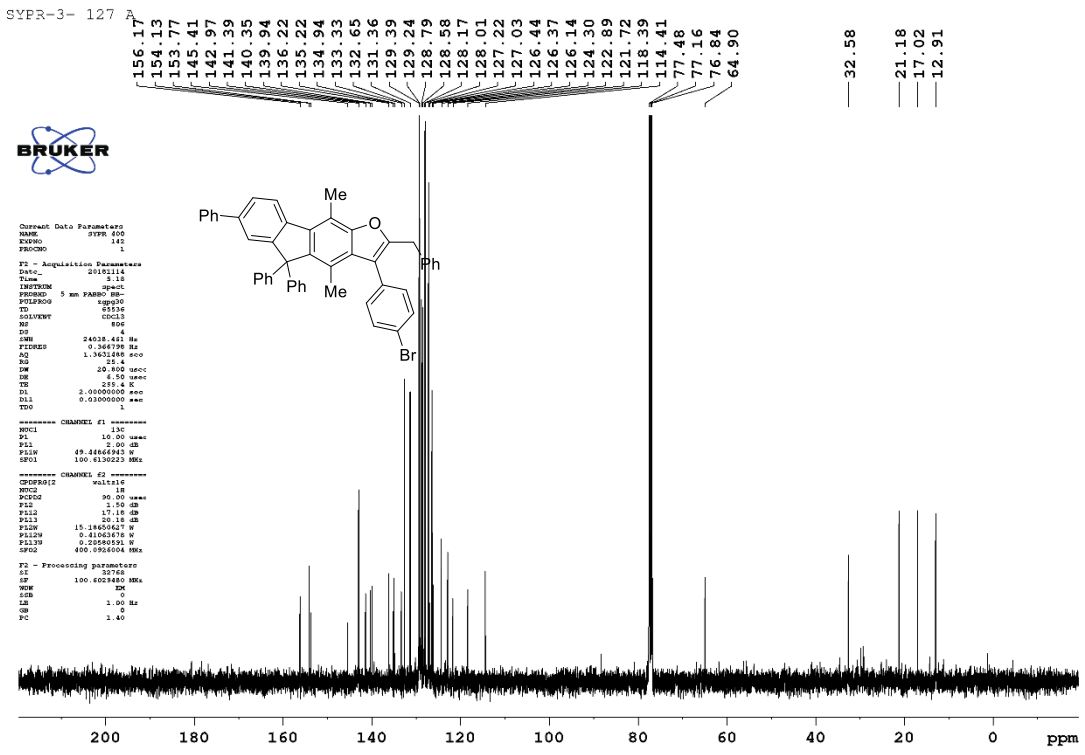

SYPR-3-141
7.72
7.27
7.27
7.26
7.26
7.24
7.21
7.19
7.19
7.18
7.17
7.17
7.16
7.14
7.14
7.14
7.13
7.12
7.12
7.10
7.08
6.96
6.96
6.94
6.94
6.87
6.85
3.90
3.80
2.88
2.40
2.31
1.64
0.00
BRUKER
Me
Me
Me
Ph
Ph
Me
OMe
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.01
5.38
5.12
5.10
2.27
1.07
2.14
2.00
3.19
3.28
3.28
3.28
3.27

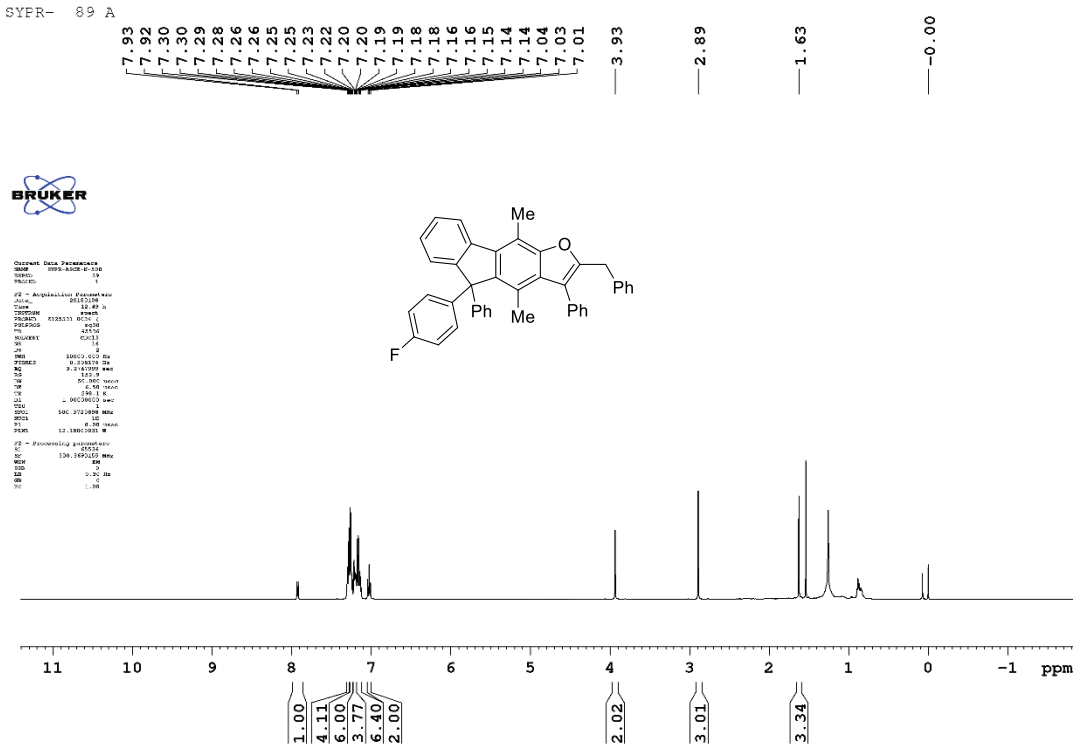

SYPR-3-141
159.05
153.98
153.67
152.91
145.26
143.31
141.35
136.68
136.00
135.35
135.27
132.04
129.29
129.17
128.63
127.87
127.27
126.36
126.31
126.21
125.14
123.30
119.07
114.21
113.59
77.41
77.16
76.90
64.38
55.36
32.53
21.87
21.17
16.73
12.94
BRUKER
Me
Me
Me
Ph
Ph
Me
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm

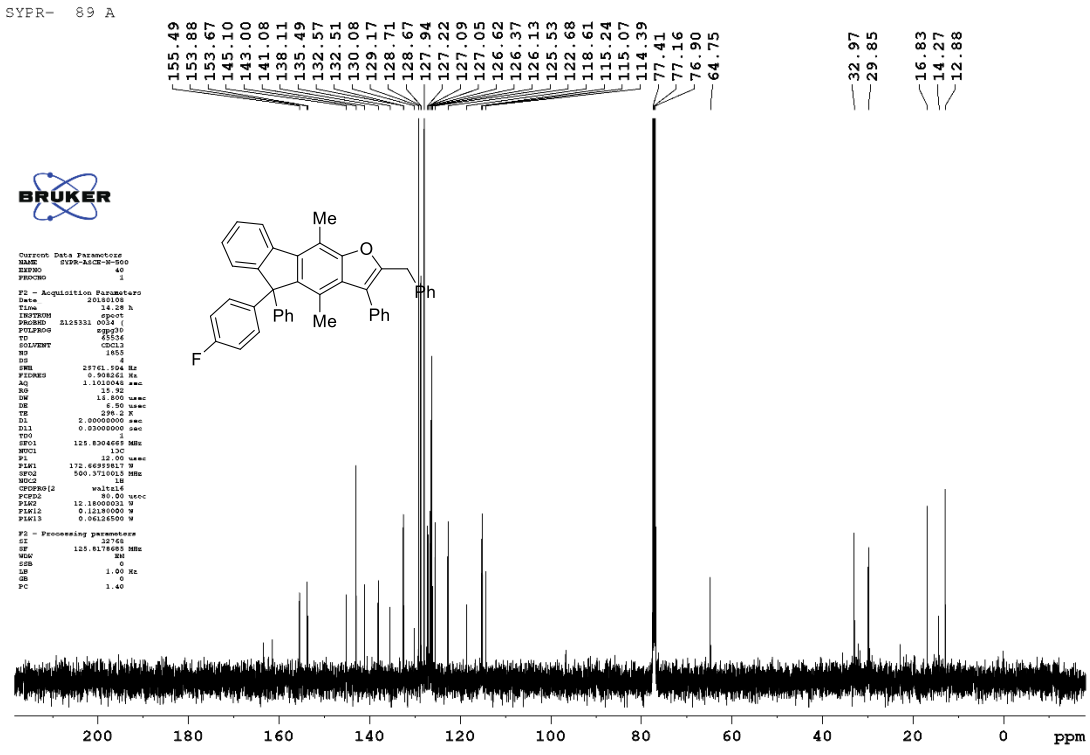

SYPR-3- 137 A
7.73
7.46
7.44
7.26
7.25
7.18
7.17
7.15
7.11
7.09
7.07
6.97
6.95
3.89
2.88
2.40
2.31
1.62
0.00
BRUKER
Me
Me
Me
Ph
Ph
Me
Br
11
10
9
8
7
6
5
4
3
2
1
ppm
0.94
2.02
4.21
8.75
3.88
0.89
1.98
3.00
2.81
3.12
2.98

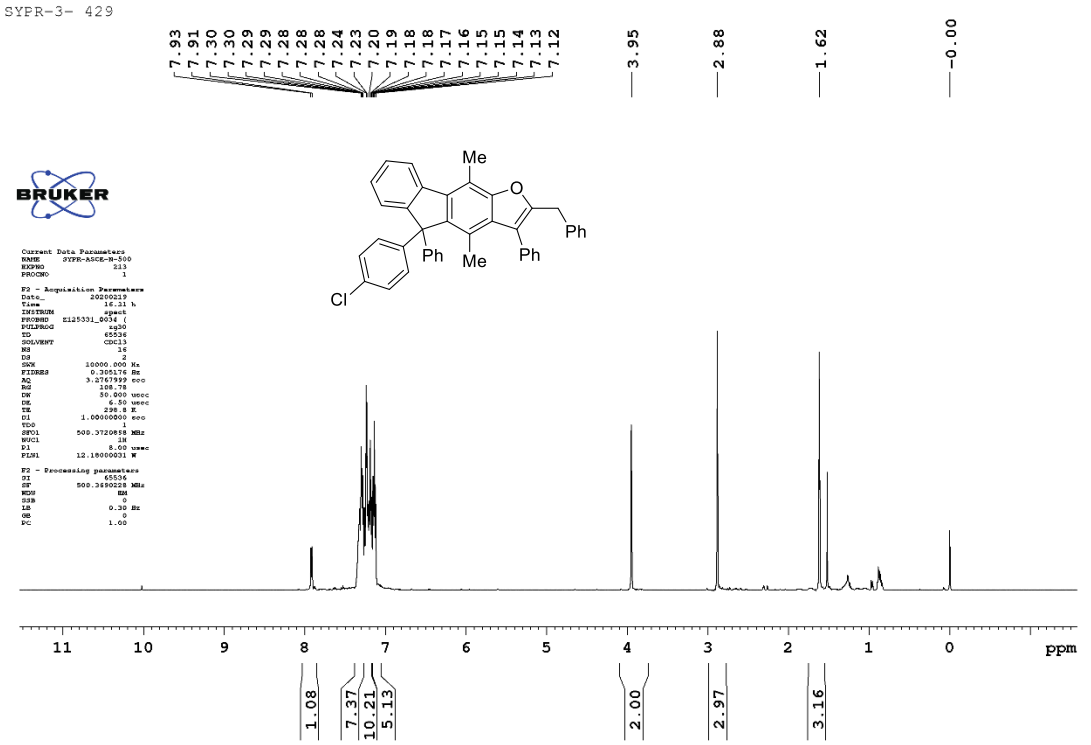

SYPR-3- 137 A
153.93
153.69
152.86
145.46
143.17
141.17
136.74
136.19
134.95
133.34
132.63
131.32
129.37
129.11
128.55
128.00
127.91
127.82
126.77
126.29
126.01
125.15
123.34
121.66
118.33
114.33
77.47
77.16
76.84
64.37
32.53
21.88
21.18
17.01
12.96
0.14
BRUKER
Me
Me
Me
Ph
Ph
Me
Br
200
180
160
140
120
100
80
60
40
20
0
ppm

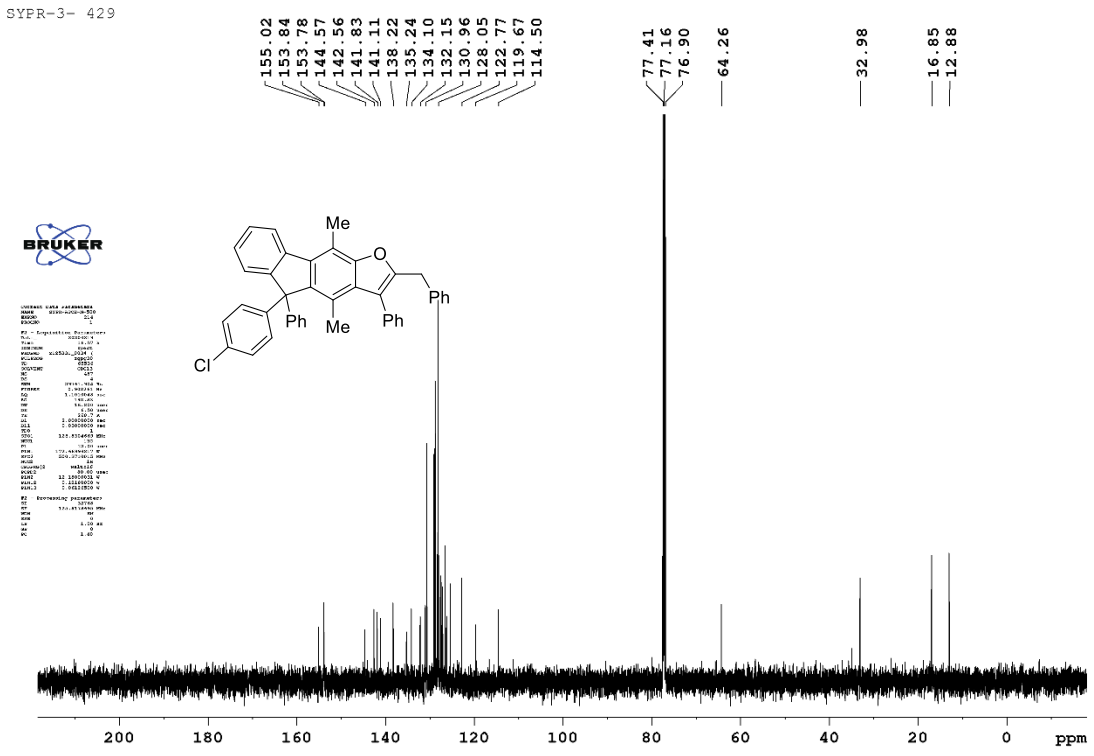

SYPR-3- 127 A
7.91 7.89 7.47 7.45 7.43 7.43 7.40 7.40 7.39 7.39 7.38 7.38 7.30 7.28 7.26 7.24 7.23 7.23 7.21 7.19 7.17 7.13 7.12 7.11 7.10 7.09 7.09 7.08 7.07 7.02 3.82 2.83 2.23 0.00
Me
Ph
O
Ph
Ph
Ph
Me
Br
11 10 9 8 7 6 5 4 3 2 1 0 -1 ppm
0.99 2.12 3.96 2.33 4.48 1.84 8.11 4.15 2.00 2.92 3.42

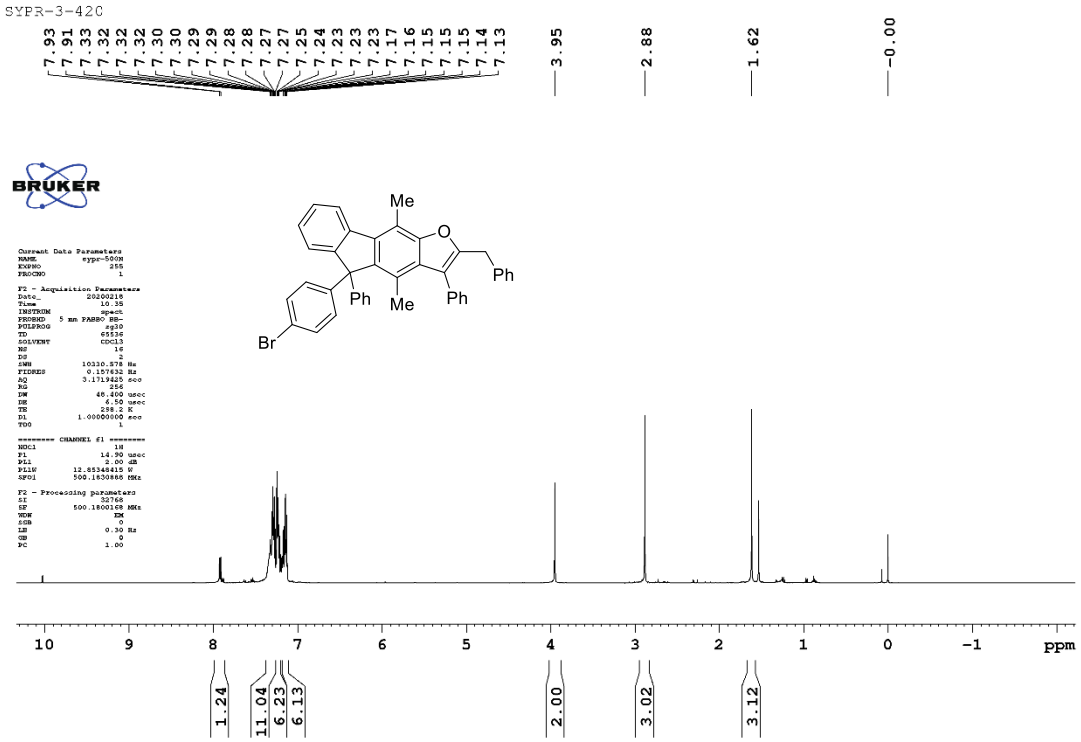

SYPR-3- 127 A
156.17 154.13 153.77 145.41 142.97 141.39 140.35 139.94 136.22 135.22 134.94 133.33 132.65 131.36 129.39 129.24 128.79 128.58 128.17 128.01 127.22 127.03 126.44 126.37 126.14 124.30 122.89 121.72 118.39 114.41 77.48 77.16 76.84 64.90 32.58 21.18 17.02 12.91
Me
Ph
O
Ph
Ph
Ph
Me
Br
200 180 160 140 120 100 80 60 40 20 0 ppm

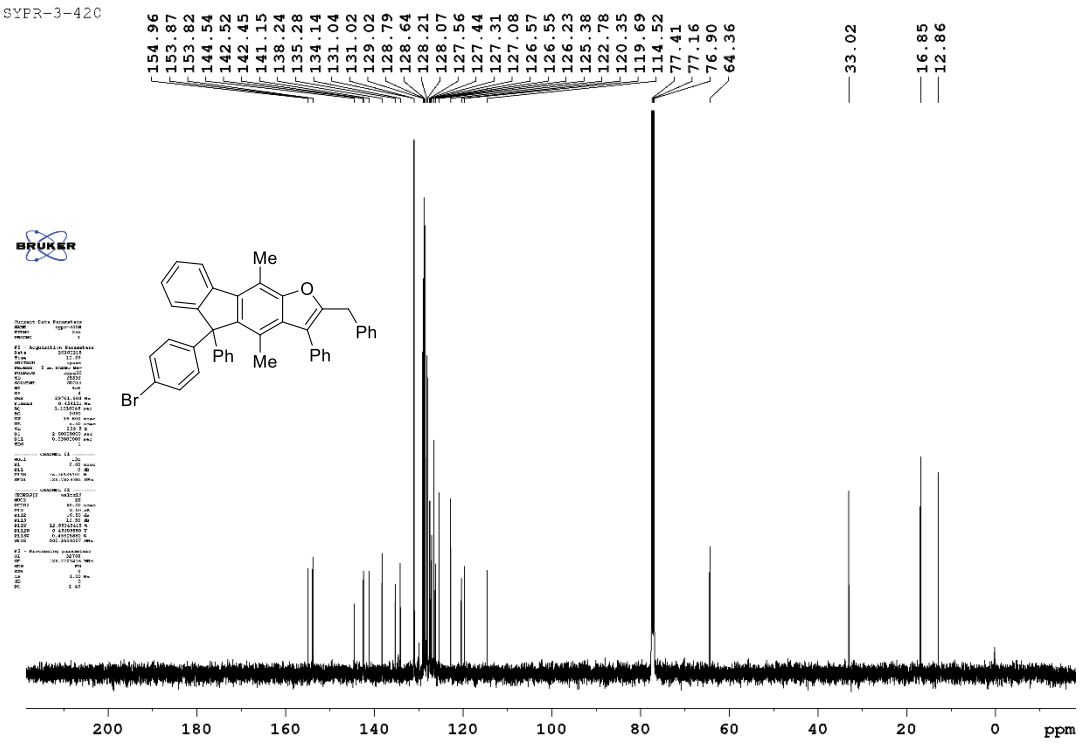

SYPR- 89 A
7.93
7.92
7.30
7.30
7.29
7.28
7.26
7.26
7.25
7.25
7.23
7.22
7.20
7.20
7.19
7.19
7.18
7.18
7.16
7.16
7.15
7.14
7.14
7.04
7.03
7.01
3.93
2.89
1.63
0.00
BRUKER
Me
O
Ph
Ph
Me
Ph
F
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.00
4.11
6.00
3.77
6.40
2.00
2.02
3.01
3.34

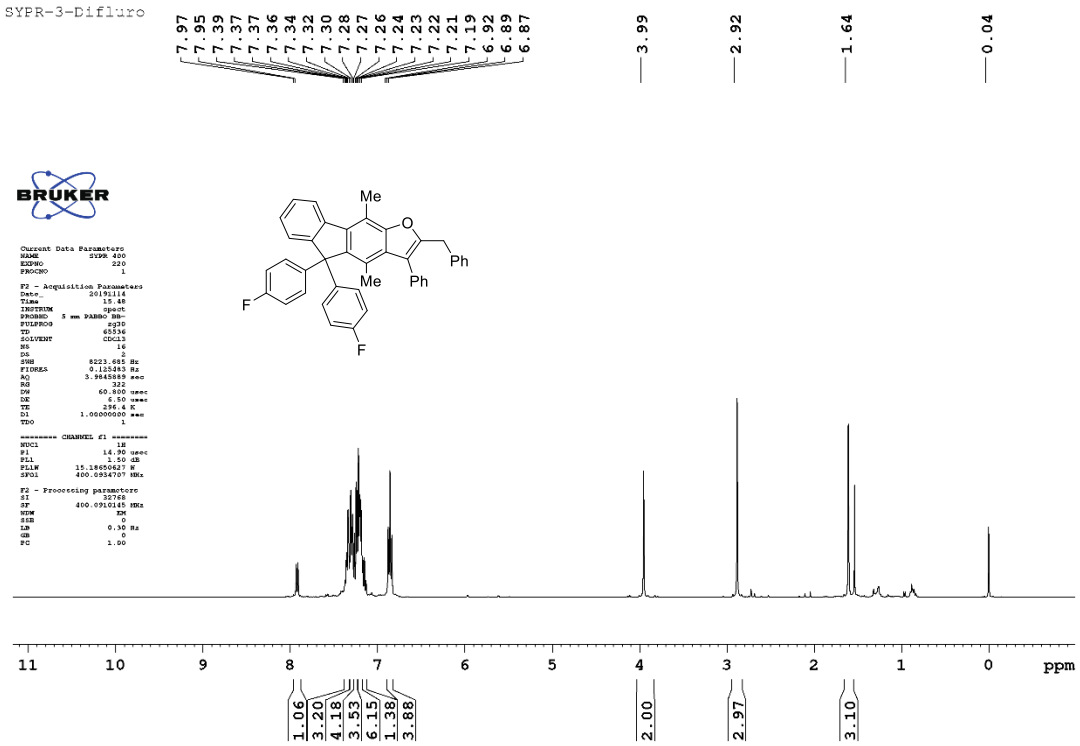

SYPR- 89 A
155.49
153.88
153.67
145.10
143.00
141.08
138.11
135.49
132.57
132.51
130.08
129.17
128.71
128.67
127.94
127.22
127.09
127.05
126.62
126.37
126.13
125.53
122.68
118.61
115.24
115.07
114.39
77.41
77.16
76.90
64.75
32.97
29.85
16.83
14.27
12.88
BRUKER
Me
O
Ph
Ph
Me
Ph
F
200
180
160
140
120
100
80
60
40
20
0
ppm

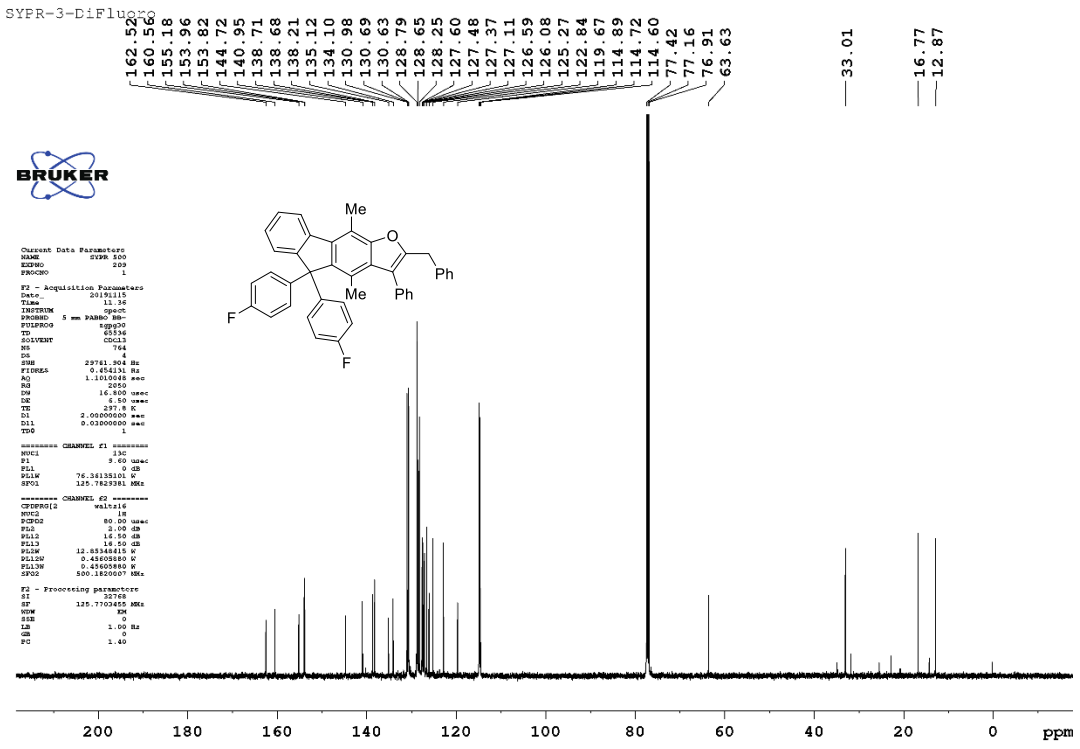

SYPR-3- 429
7.93
7.91
7.30
7.30
7.29
7.29
7.28
7.28
7.28
7.24
7.23
7.20
7.19
7.18
7.18
7.17
7.16
7.15
7.15
7.14
7.13
7.12
3.95
2.88
1.62
0.00
Me
O
Ph
Ph
Me
Ph
Cl
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.08
7.37
10.21
5.13
2.00
2.97
3.16

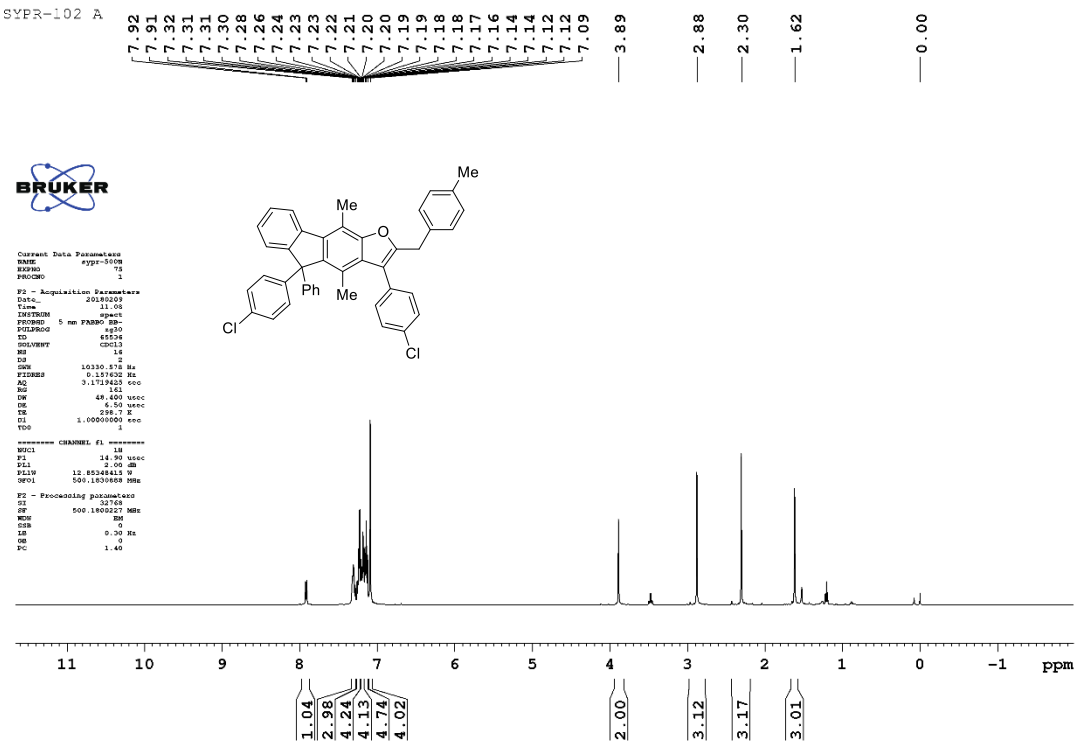

SYPR-3- 429
155.02
153.84
153.78
144.57
142.56
141.83
141.11
138.22
135.24
134.10
132.15
130.96
128.05
122.77
119.67
114.50
77.41
77.16
76.90
64.26
32.98
16.85
12.88
Me
O
Ph
Ph
Me
Ph
Cl
200
180
160
140
120
100
80
60
40
20
0
ppm

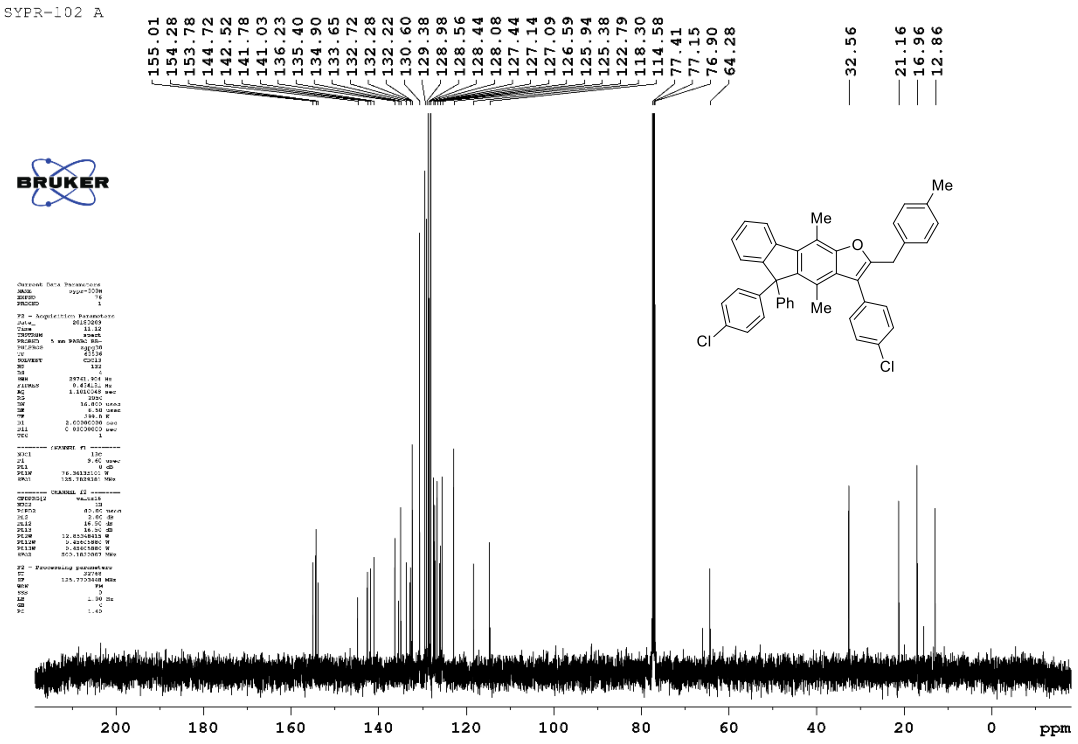

SYPR-3-42C
7.93
7.91
7.33
7.32
7.32
7.32
7.30
7.30
7.29
7.29
7.28
7.28
7.27
7.27
7.25
7.24
7.23
7.23
7.23
7.17
7.16
7.15
7.15
7.15
7.14
7.13
3.95
2.88
1.62
0.00
BRUKER
Me
O
Ph
Ph
Me
Ph
Br
1.24
11.04
6.23
6.13
2.00
3.02
3.12
10
9
8
7
6
5
4
3
2
1
0
-1
ppm

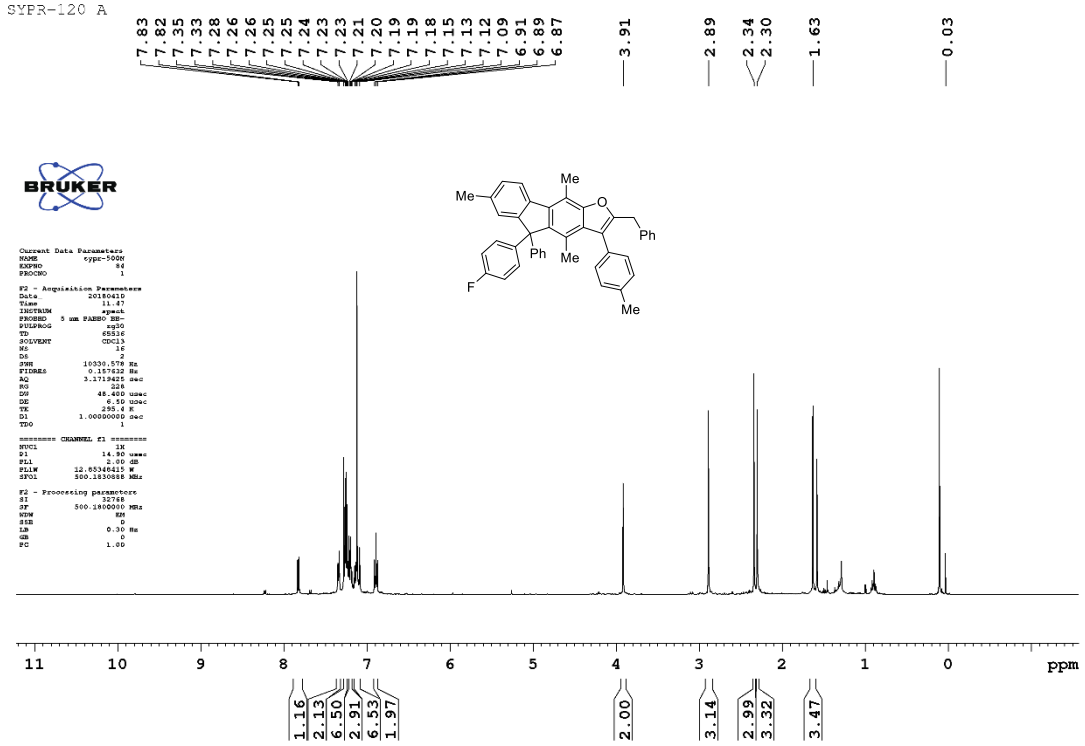

SYPR-3-42C
154.96
153.87
153.82
144.54
142.52
142.45
141.15
138.24
135.28
134.14
131.04
131.02
129.02
128.79
128.64
128.21
128.07
127.56
127.44
127.31
127.08
126.57
126.55
126.23
125.38
122.78
120.35
119.69
114.52
77.41
77.16
76.90
64.36
33.02
16.85
12.86
BRUKER
Me
O
Ph
Ph
Me
Ph
Br
200
180
160
140
120
100
80
60
40
20
0
ppm

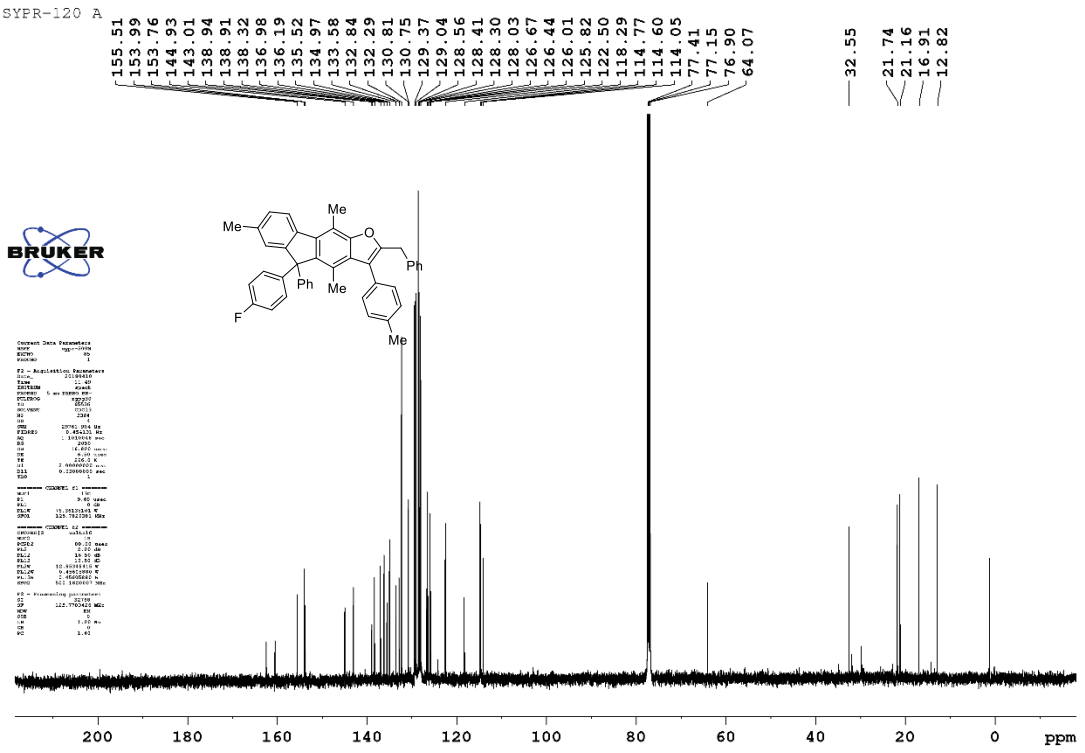

SYPR-3-Difluro
7.97
7.95
7.39
7.37
7.37
7.36
7.34
7.32
7.30
7.28
7.27
7.26
7.24
7.23
7.22
7.21
7.19
6.92
6.89
6.87
3.99
2.92
1.64
0.04
BRUKER
Me
O
Ph
Me
Ph
F
F
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.06
3.20
4.18
3.53
6.15
1.38
3.88
2.00
2.97
3.10

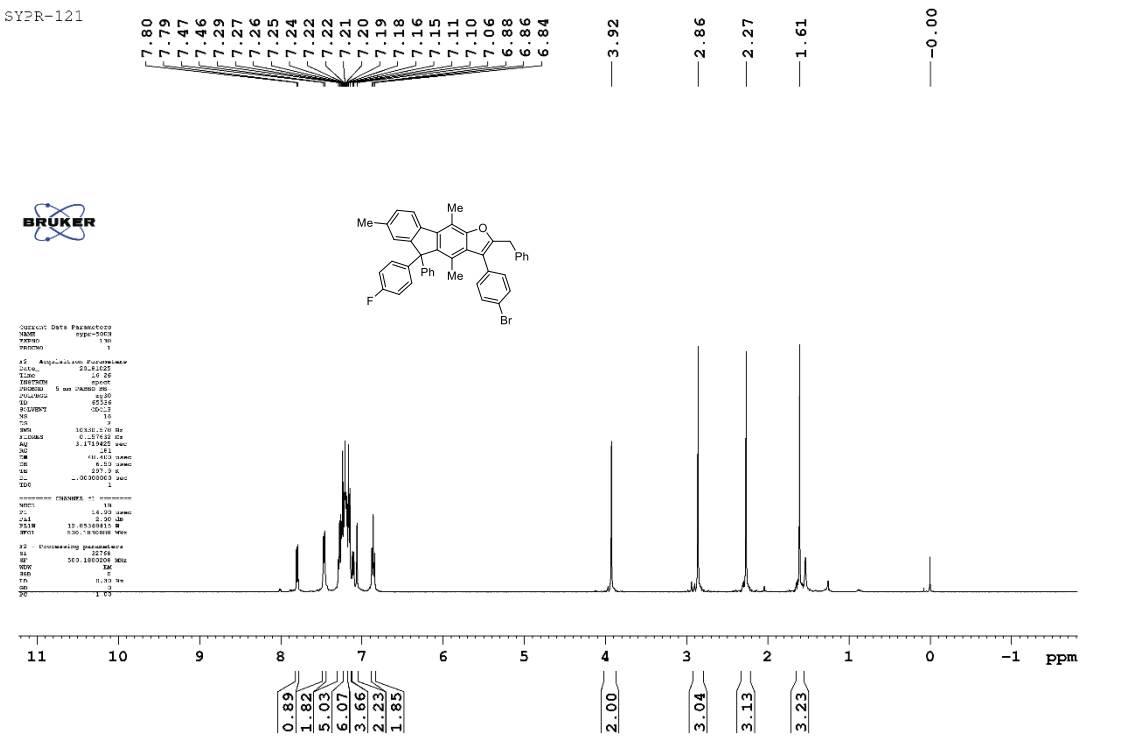

SYPR-3-DiFluoro
162.52
160.56
155.18
153.96
153.82
144.72
140.95
138.71
138.68
138.21
135.12
134.10
130.98
130.69
130.63
128.79
128.65
128.25
127.60
127.48
127.37
127.11
126.59
126.08
125.27
122.84
119.67
114.89
114.72
114.60
77.42
77.16
76.91
63.63
33.01
16.77
12.87
BRUKER
Me
O
Ph
Me
Ph
F
F
200
180
160
140
120
100
80
60
40
20
0
ppm

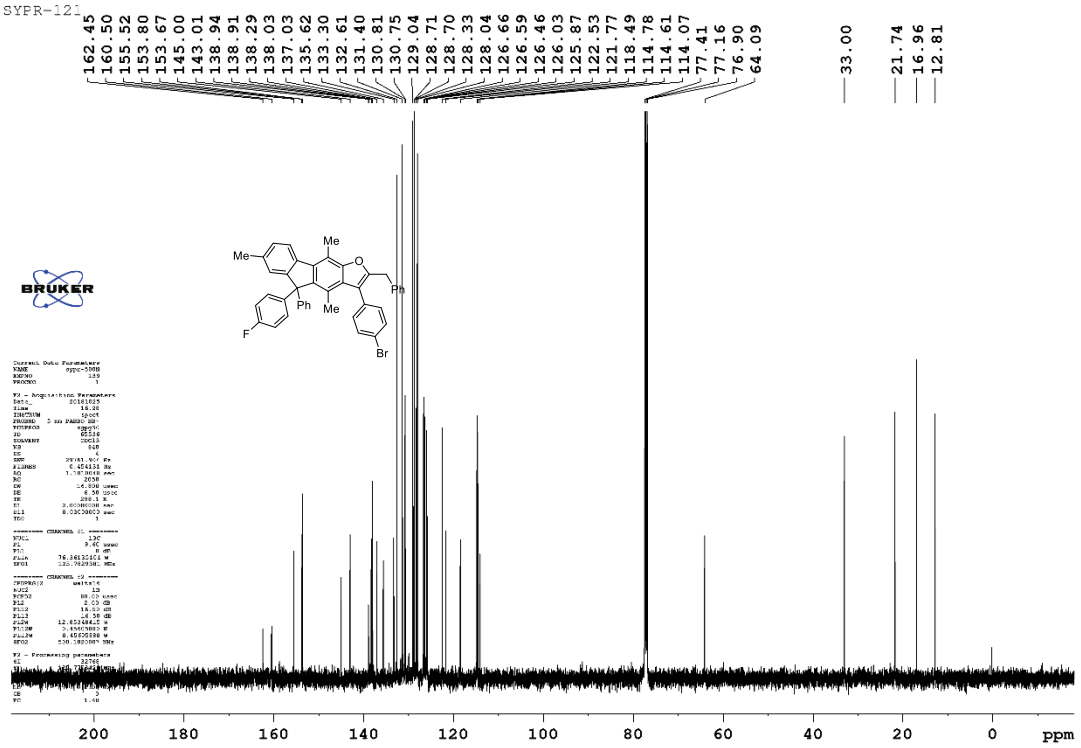

SYPR-102 A
7.92
7.91
7.32
7.31
7.31
7.30
7.28
7.26
7.24
7.23
7.23
7.22
7.21
7.20
7.20
7.19
7.19
7.18
7.18
7.17
7.16
7.14
7.14
7.12
7.12
7.09
3.89
2.88
2.30
1.62
0.00
BRUKER
Me
Me
O
Ph
Me
Cl
Cl
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
1.04
2.98
4.24
4.13
4.74
4.02
2.00
3.12
3.17
3.01

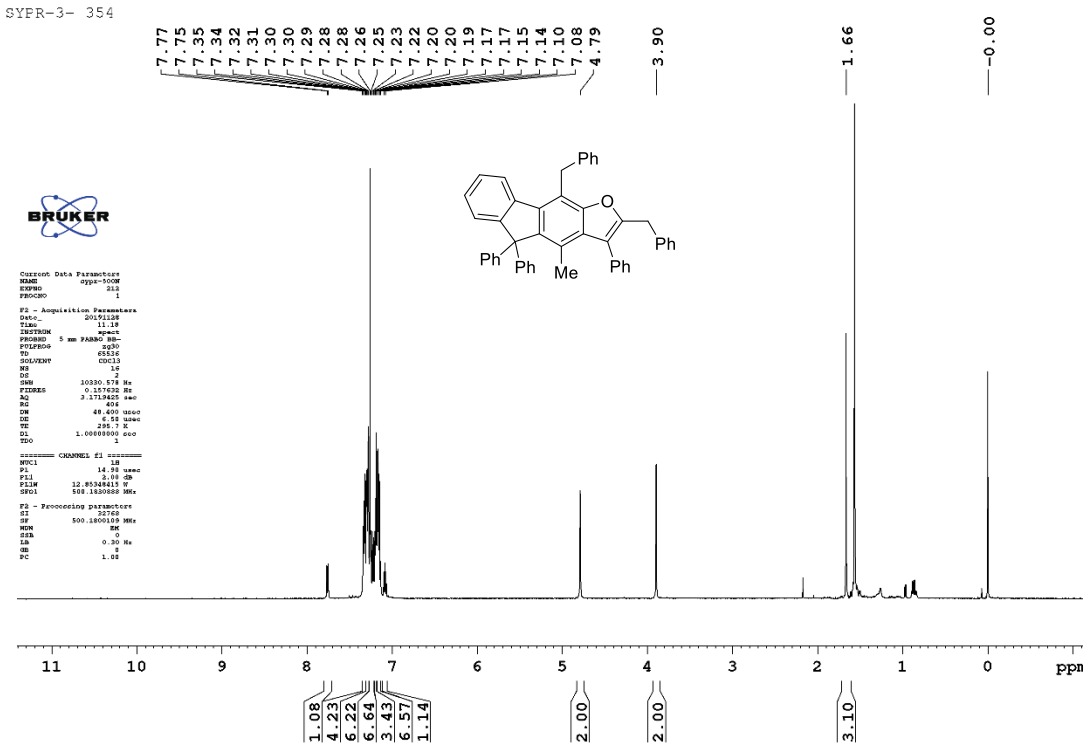

SYPR-102 A
155.01
154.28
153.78
144.72
142.52
141.78
141.03
136.23
135.40
134.90
133.65
132.72
132.28
132.22
130.60
129.38
128.98
128.56
128.44
128.08
127.44
127.14
127.09
126.59
125.94
125.38
122.79
118.30
114.58
77.41
77.15
76.90
64.28
32.56
21.16
16.96
12.86
BRUKER
Me
Me
O
Ph
Me
Cl
Cl
200
180
160
140
120
100
80
60
40
20
0
ppm

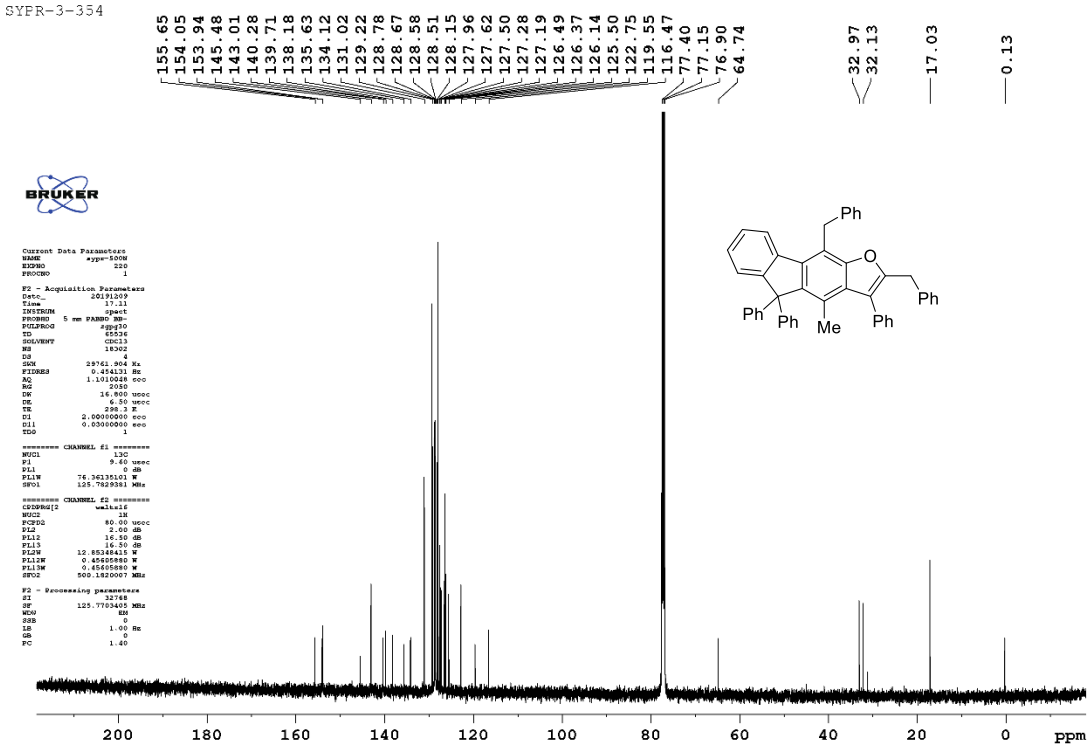

SYPR-120 A
7.83
7.82
7.35
7.33
7.28
7.26
7.26
7.25
7.25
7.24
7.23
7.23
7.21
7.20
7.19
7.19
7.18
7.15
7.13
7.12
7.09
6.91
6.89
6.87
3.91
2.89
2.34
2.30
1.63
0.03
BRUKER
Me
Me
O
Ph
Ph
Me
F
Me
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.16
2.13
6.50
2.91
6.53
1.97
2.00
3.14
2.99
3.32
3.47

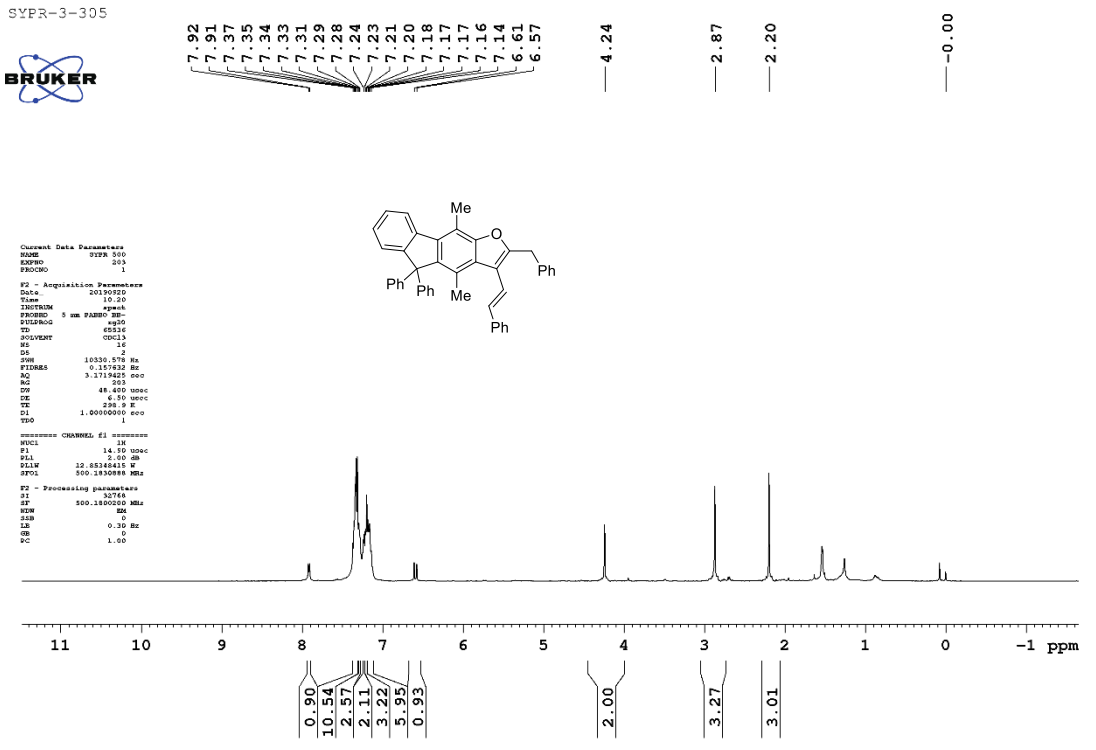

SYPR-120 A
155.51
153.99
153.76
144.93
143.01
138.94
138.91
138.32
136.98
136.19
135.52
134.97
133.58
132.84
132.29
130.81
130.75
129.37
129.04
128.56
128.41
128.30
128.03
126.67
126.44
126.01
125.82
122.50
118.29
114.77
114.60
114.05
77.41
77.15
76.90
64.07
32.55
21.74
21.16
16.91
12.82
BRUKER
Me
Me
O
Ph
Ph
Me
F
Me
200
180
160
140
120
100
80
60
40
20
0
ppm

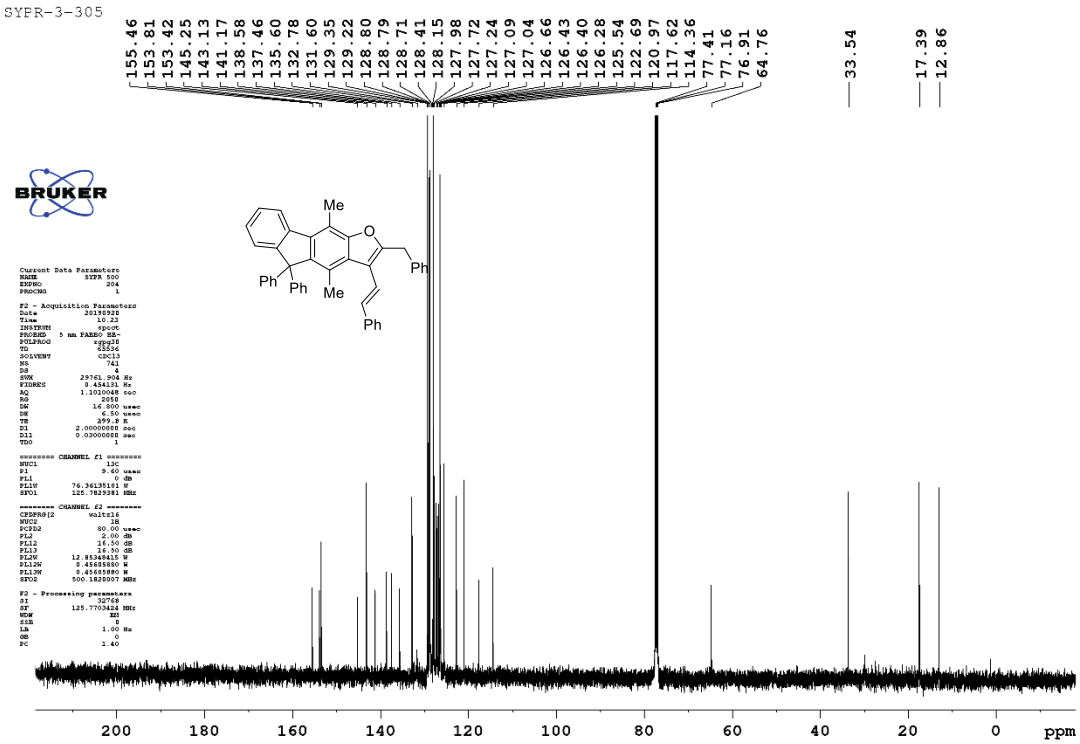

SYPR-121
7.80
7.79
7.47
7.46
7.29
7.27
7.26
7.25
7.24
7.22
7.22
7.21
7.20
7.19
7.18
7.16
7.15
7.11
7.10
7.06
6.88
6.86
6.84
3.92
2.86
2.27
1.61
0.00
BRUKER
Me
Me
O
Ph
Ph
Me
F
Br
11
10
9
8
7
6
5
4
3
2
1
0
−1
ppm
0.89
1.82
5.03
6.07
3.66
2.23
1.85
2.00
3.04
3.13
3.23

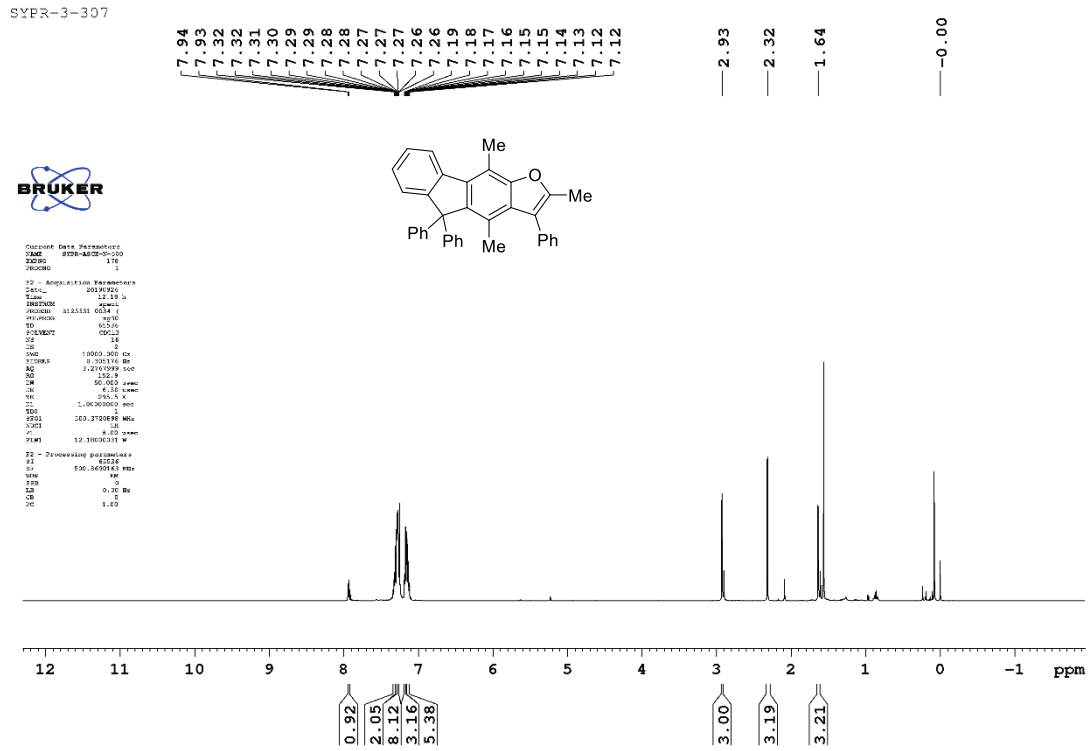

SYPR-121
162.45
160.50
155.52
153.80
153.67
145.00
143.01
138.94
138.91
138.29
138.03
137.03
135.62
133.30
132.61
131.40
130.81
130.75
129.04
128.71
128.70
128.33
128.04
126.66
126.59
126.46
126.03
125.87
122.53
121.77
118.49
114.78
114.61
114.07
77.41
77.16
76.90
64.09
33.00
21.74
16.96
12.81
BRUKER
Me
Me
O
Ph
Ph
Me
F
Br
200
180
160
140
120
100
80
60
40
20
0
ppm

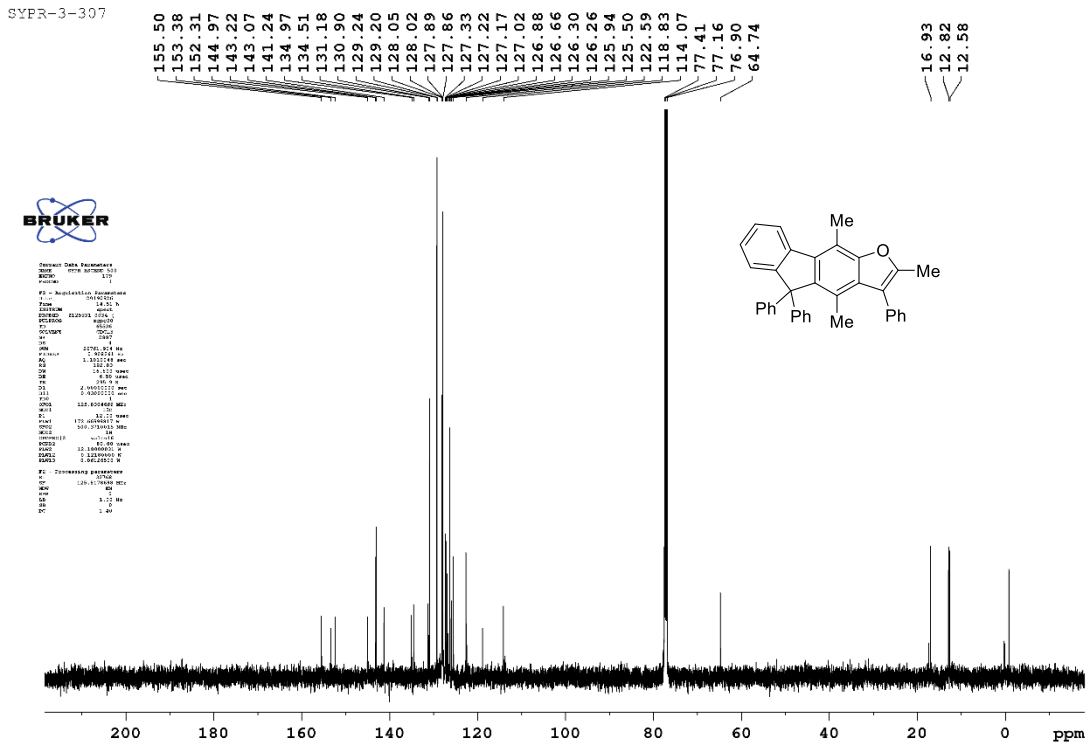

SYPR-3- 354
7.77 7.75 7.35 7.34 7.32 7.31 7.30 7.30 7.29 7.28 7.28 7.26 7.25 7.23 7.22 7.20 7.20 7.19 7.17 7.17 7.15 7.14 7.10 7.08 4.79
3.90
1.66
0.00
Ph
O
Ph
Ph
Ph
Ph
Me
11 10 9 8 7 6 5 4 3 2 1 0 ppm
1.08 4.23 6.22 6.64 3.43 6.57 1.14
2.00
2.00
3.10

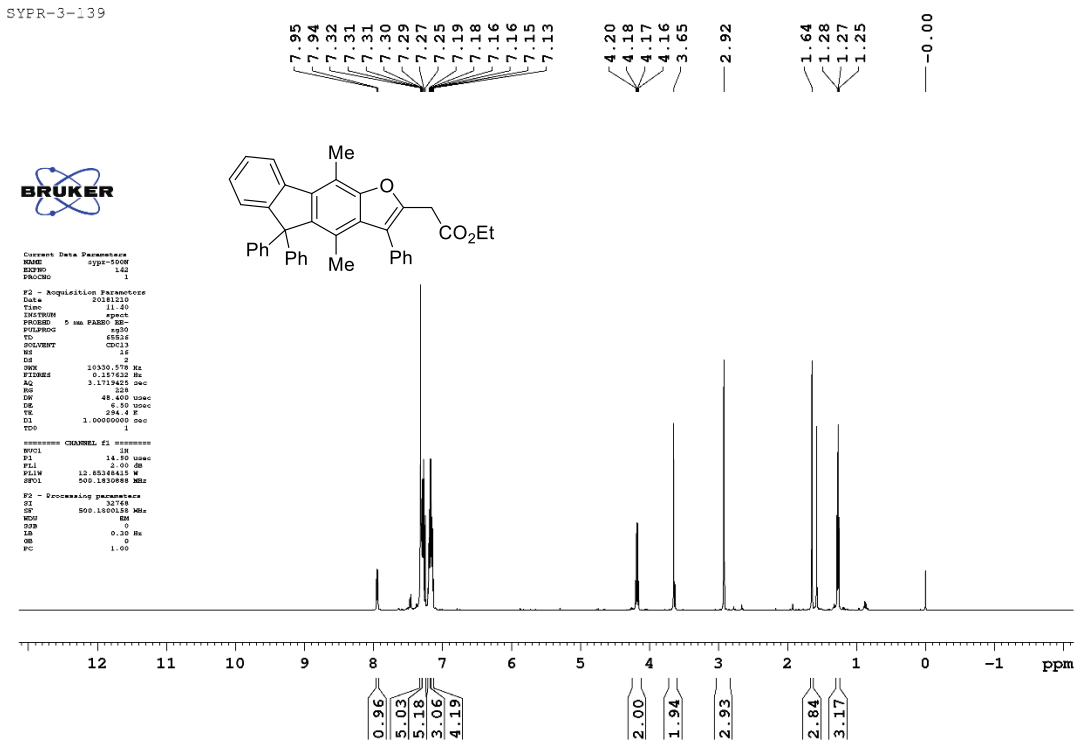

SYPR-3-354
155.65 154.05 153.94 145.48 143.01 140.28 139.71 138.18 135.63 134.12 131.02 129.22 128.78 128.67 128.58 128.51 128.15 127.96 127.62 127.50 127.28 127.19 126.49 126.37 126.14 125.50 122.75 119.55 116.47 77.40 77.15 76.90 64.74
32.97 32.13
17.03
0.13
Ph
O
Ph
Ph
Ph
Ph
Me
200 180 160 140 120 100 80 60 40 20 0 ppm

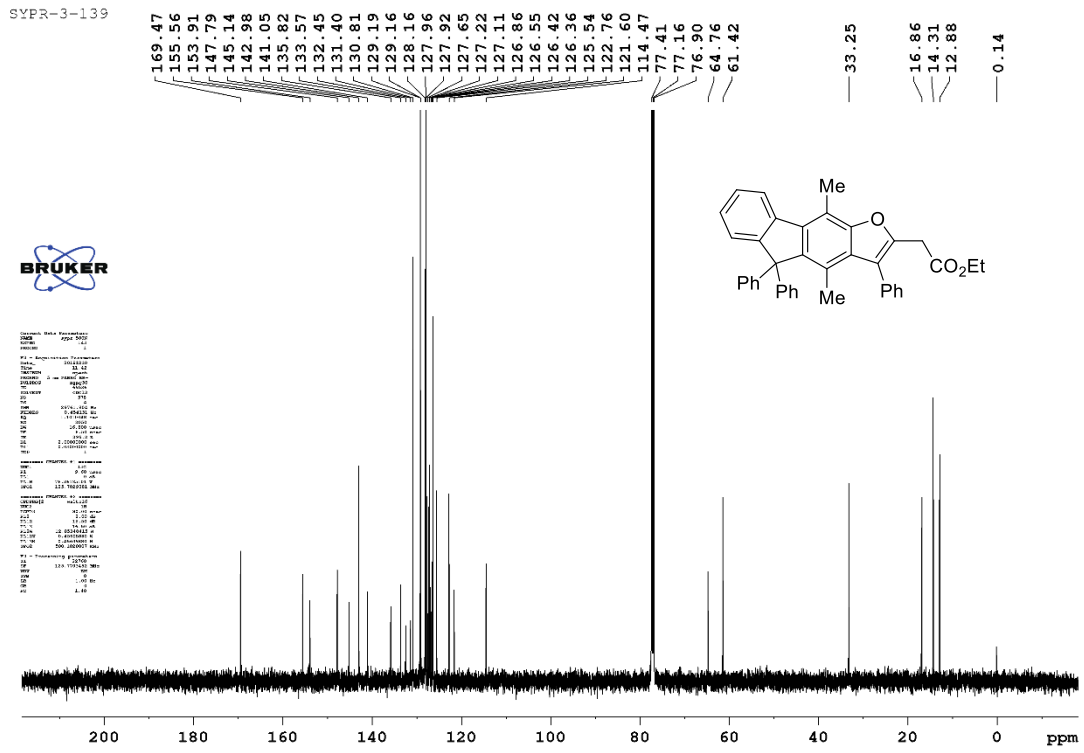

SYPR-3-305
7.92
7.91
7.37
7.35
7.34
7.33
7.31
7.29
7.28
7.24
7.23
7.21
7.20
7.18
7.17
7.17
7.16
7.14
6.61
6.57
4.24
2.87
2.20
-0.00
Me
O
Ph
Ph
Ph
Me
Ph
11
10
9
8
7
6
5
4
3
2
1
0
-1 ppm
0.90
10.54
2.57
2.11
3.22
5.95
0.93
2.00
3.27
3.01

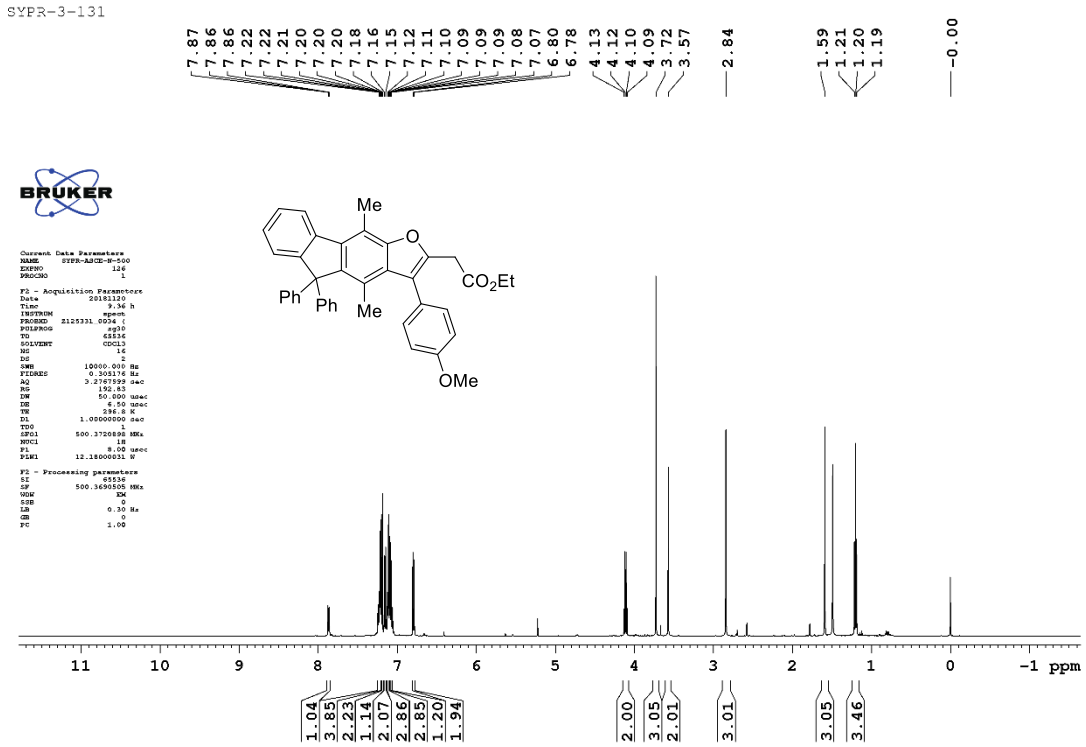

SYPR-3-305
155.46
153.81
153.42
145.25
143.13
141.17
138.58
137.46
135.60
132.78
131.60
129.35
129.22
128.80
128.79
128.71
128.41
128.15
127.98
127.72
127.24
127.09
127.04
126.66
126.43
126.40
126.28
125.54
122.69
120.97
117.62
114.36
77.41
77.16
76.91
64.76
33.54
17.39
12.86
Me
O
Ph
Ph
Ph
Me
Ph
200
180
160
140
120
100
80
60
40
20
0
ppm

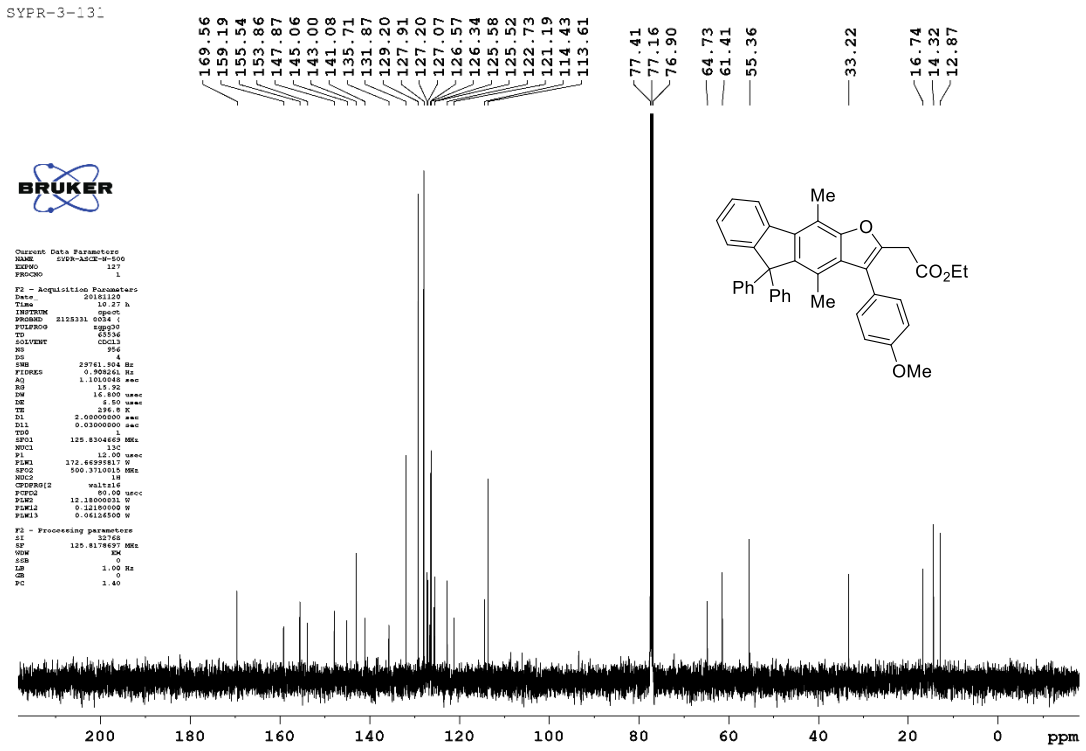

SYPR-3-307
7.94 7.93 7.32 7.32 7.31 7.30 7.29 7.29 7.28 7.28 7.27 7.27 7.27 7.26 7.26 7.19 7.18 7.17 7.16 7.15 7.15 7.14 7.13 7.12 7.12
2.93
2.32
1.64
-0.00
Me
O
Me
Ph
Ph
Me
Ph
BRUKER
12 11 10 9 8 7 6 5 4 3 2 1 0 -1 ppm
0.92 2.05 8.12 3.16 5.38 3.00 3.19 3.21

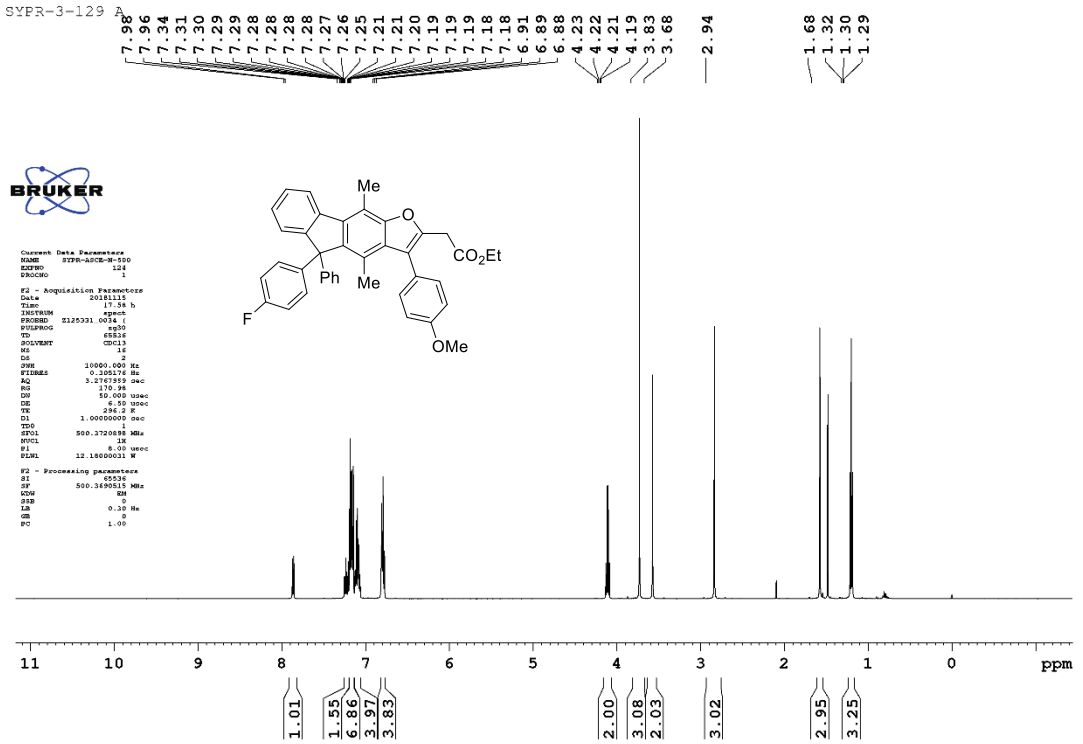

SYPR-3-307
155.50 153.38 152.31 144.97 143.22 143.07 141.24 134.97 134.51 131.18 130.90 129.24 129.20 128.05 128.02 127.89 127.86 127.33 127.22 127.17 127.02 126.88 126.66 126.30 126.26 125.94 125.50 122.59 118.83 114.07 77.41 77.16 76.90 64.74
16.93 12.82 12.58
Me
O
Me
Ph
Ph
Me
Ph
BRUKER
200 180 160 140 120 100 80 60 40 20 0 ppm

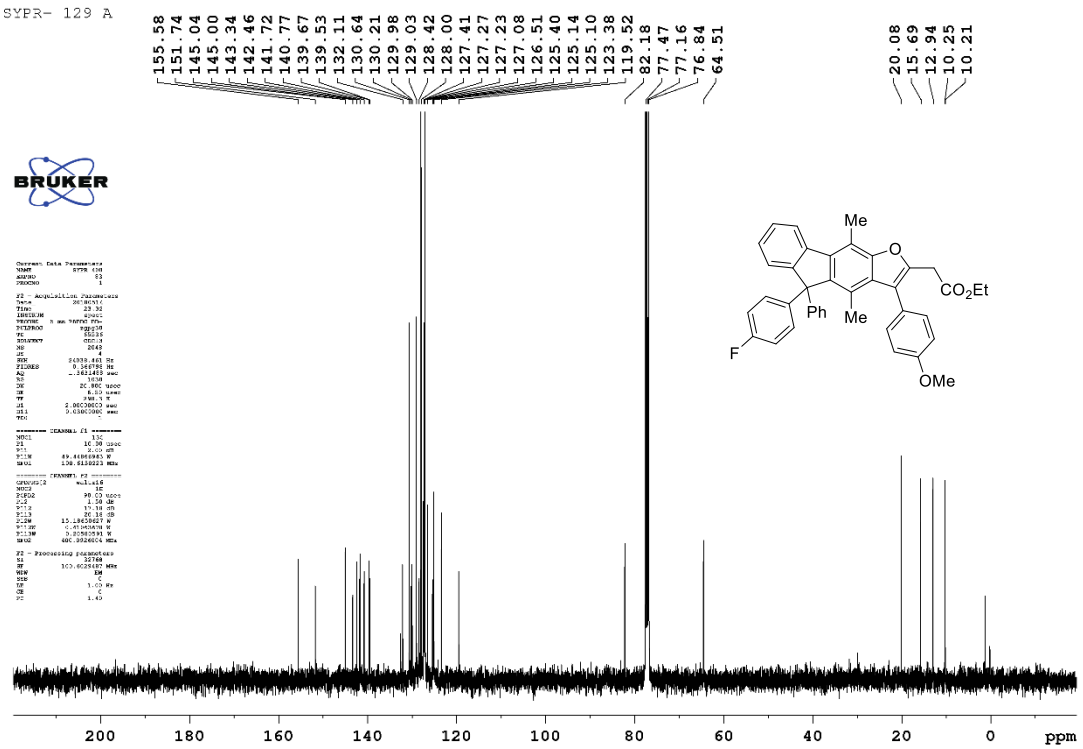

SYPR-3-139
7.95
7.94
7.32
7.31
7.31
7.30
7.29
7.27
7.25
7.19
7.18
7.16
7.16
7.15
7.13
4.20
4.18
4.17
4.16
3.65
2.92
1.64
1.28
1.27
1.25
-0.00
Me
O
CO2Et
Ph
Ph
Me
Ph
BRUKER
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
ppm
0.96
5.03
5.18
3.06
4.19
2.00
1.94
2.93
2.84
3.17

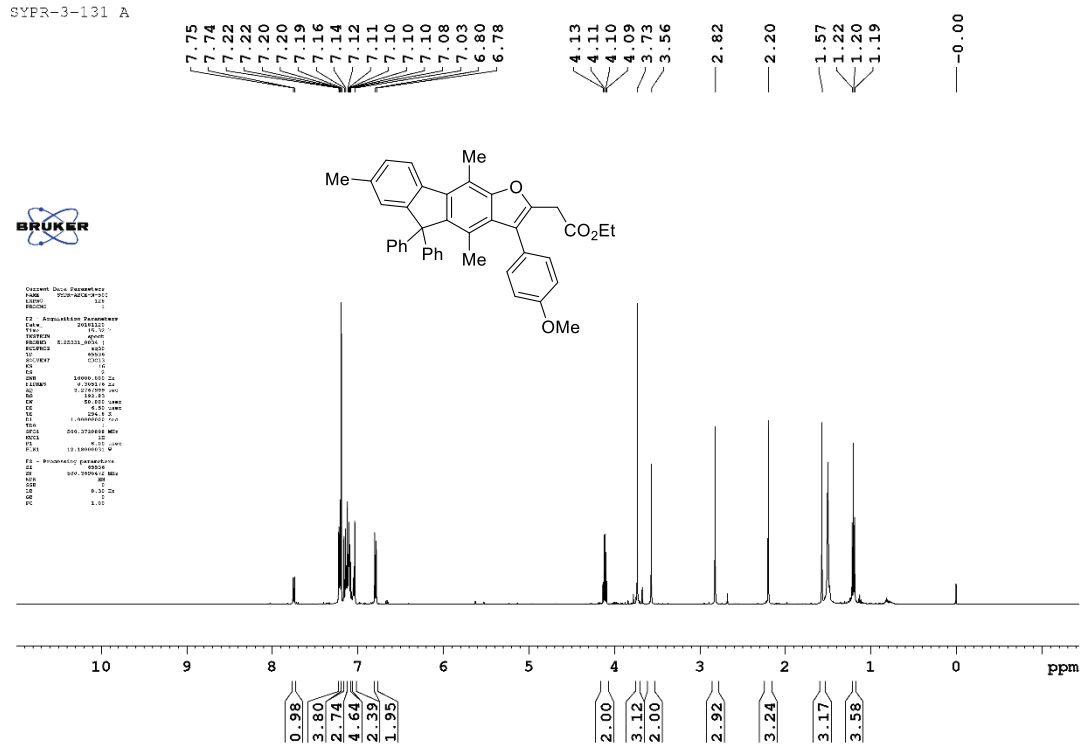

SYPR-3-139
169.47
155.56
153.91
147.79
145.14
142.98
141.05
135.82
133.57
132.45
131.40
130.81
129.19
129.16
128.16
127.96
127.92
127.65
127.22
127.11
126.86
126.55
126.42
126.36
125.54
122.76
121.60
114.47
77.41
77.16
76.90
64.76
61.42
33.25
16.86
14.31
12.88
0.14
Me
O
CO2Et
Ph
Ph
Me
Ph
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm

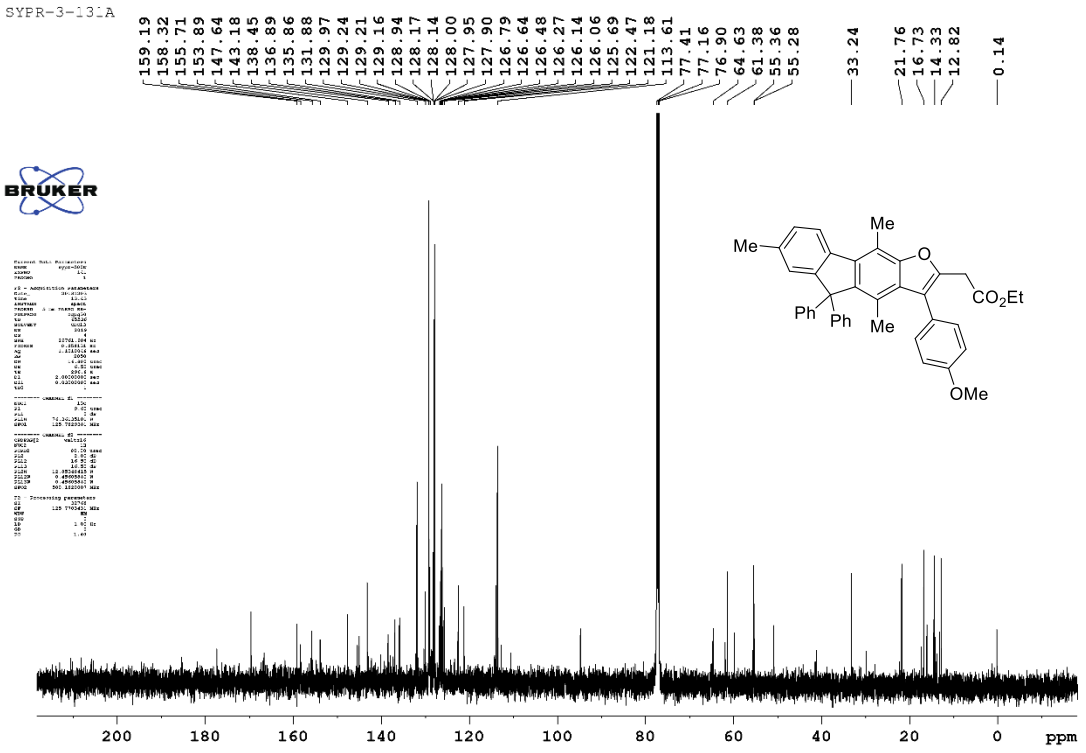

SYPR-3-131
7.87
7.86
7.86
7.22
7.22
7.21
7.20
7.20
7.20
7.18
7.16
7.15
7.12
7.11
7.10
7.09
7.09
7.09
7.08
7.07
6.80
6.78
4.13
4.12
4.10
4.09
3.72
3.57
2.84
1.59
1.21
1.20
1.19
0.00
BRUKER
Me
O
CO2Et
Ph
Ph
Me
OMe
11
10
9
8
7
6
5
4
3
2
1
0
-1 ppm
1.04
3.85
2.23
1.14
2.07
2.86
2.85
1.20
1.94
2.00
3.05
2.01
3.01
3.05
3.46

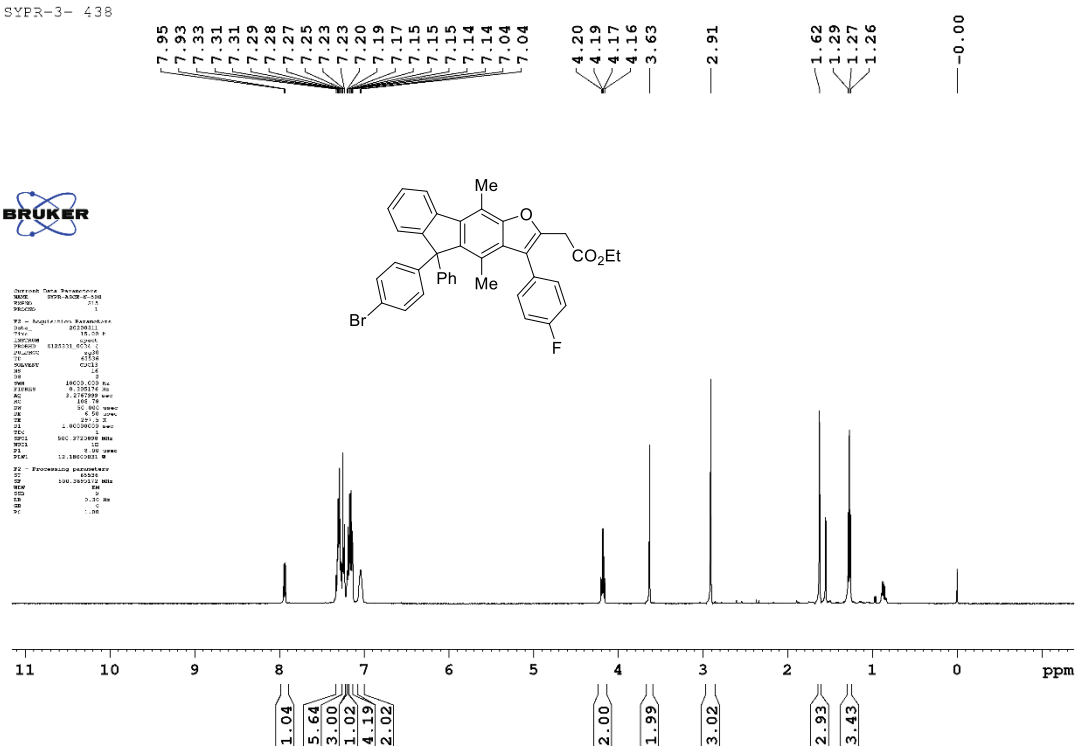

SYPR-3-131
169.56
159.19
155.54
153.86
147.87
145.06
143.00
141.08
135.71
131.87
129.20
127.91
127.20
127.07
126.57
126.34
125.58
125.52
122.73
121.19
114.43
113.61
77.41
77.16
76.90
64.73
61.41
55.36
33.22
16.74
14.32
12.87
BRUKER
Me
O
CO2Et
Ph
Ph
Me
OMe
200
180
160
140
120
100
80
60
40
20
0
ppm

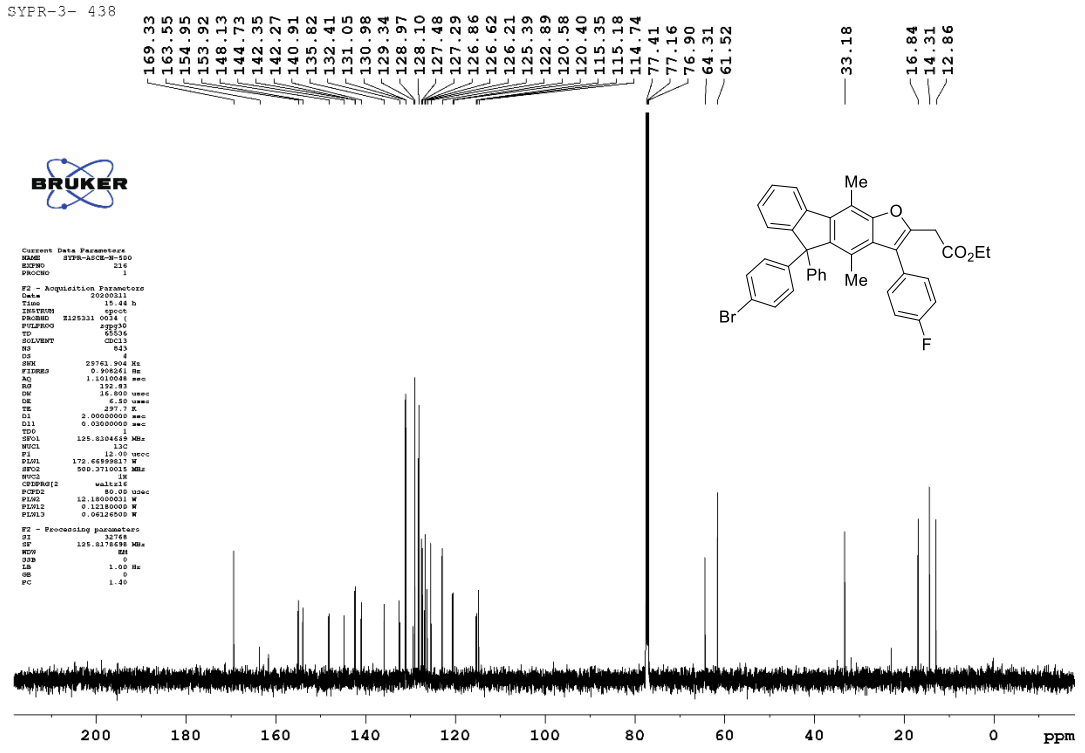

SYPR-3-129 A
7.98 7.96 7.34 7.31 7.30 7.29 7.29 7.28 7.28 7.28 7.27 7.26 7.25 7.21 7.21 7.20 7.19 7.19 7.19 7.18 7.18 6.91 6.89 6.88
4.23 4.22 4.21 4.19 3.83 3.68
2.94
1.68 1.32 1.30 1.29
BRUKER
Me
O
CO2Et
Ph
Me
F
OMe
11 10 9 8 7 6 5 4 3 2 1 0 ppm
1.01 1.55 6.86 3.97 3.83 2.00 3.08 2.03 3.02 2.95 3.25

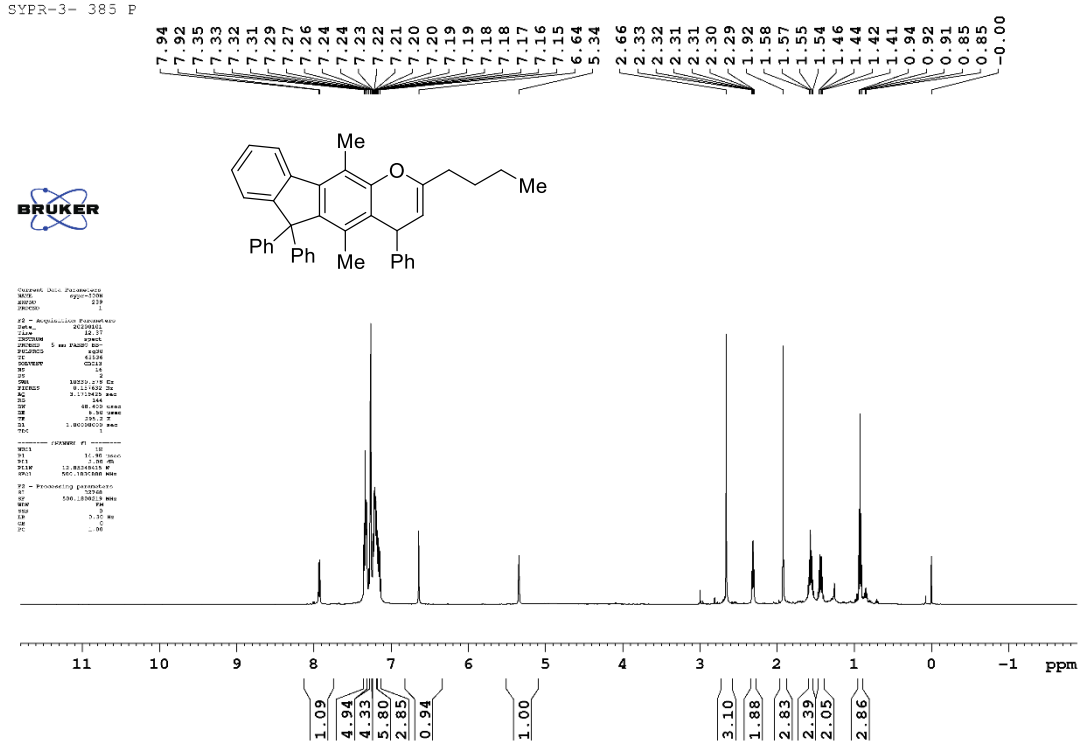

SYPR- 129 A
155.58 151.74 145.04 145.00 143.34 142.46 141.72 140.77 139.67 139.53 132.11 130.64 130.21 129.98 129.03 128.42 128.00 127.41 127.27 127.23 127.08 126.51 125.40 125.14 125.10 123.38 119.52 82.18 77.47 77.16 76.84 64.51
20.08 15.69 12.94 10.25 10.21
BRUKER
Me
O
CO2Et
Ph
Me
F
OMe
200 180 160 140 120 100 80 60 40 20 0 ppm

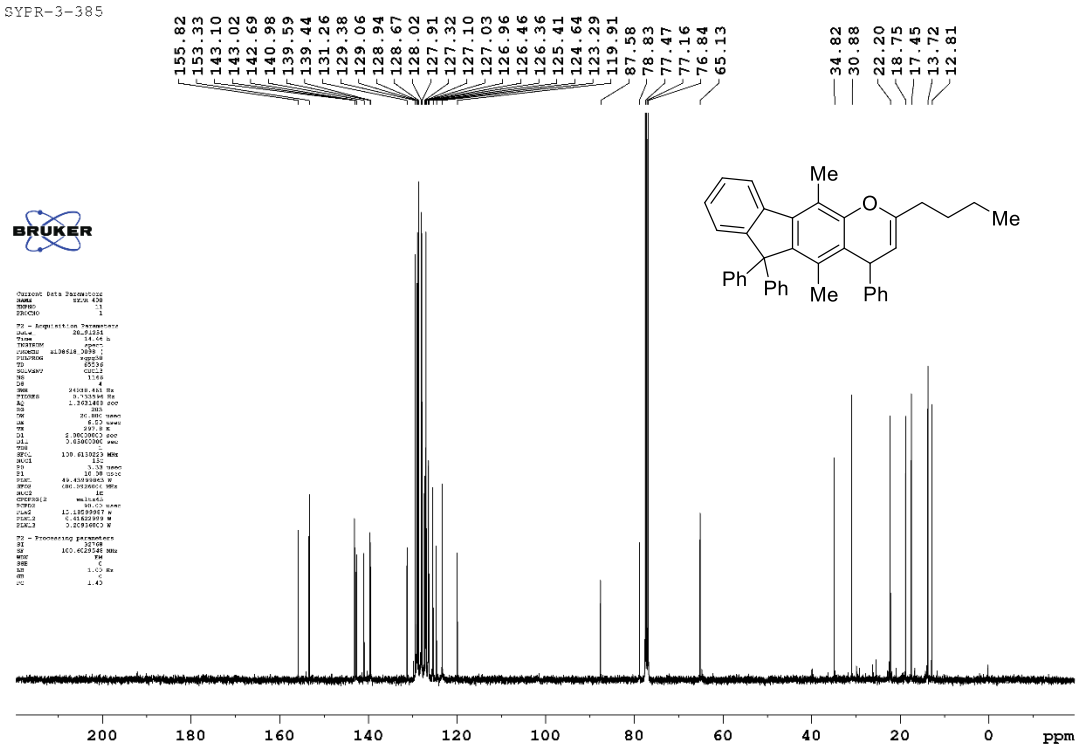

SYPR-3-131 A
7.75
7.74
7.22
7.22
7.20
7.20
7.19
7.16
7.14
7.12
7.11
7.10
7.10
7.10
7.08
7.03
6.80
6.78
4.13
4.11
4.10
4.09
3.73
3.56
2.82
2.20
1.57
1.22
1.20
1.19
0.00
Me
Me
O
CO2Et
Ph
Ph
Me
OMe
BRUKER
10
9
8
7
6
5
4
3
2
1
0
ppm
0.98
3.80
2.74
4.64
2.39
1.95
2.00
3.12
2.00
2.92
3.24
3.17
3.58

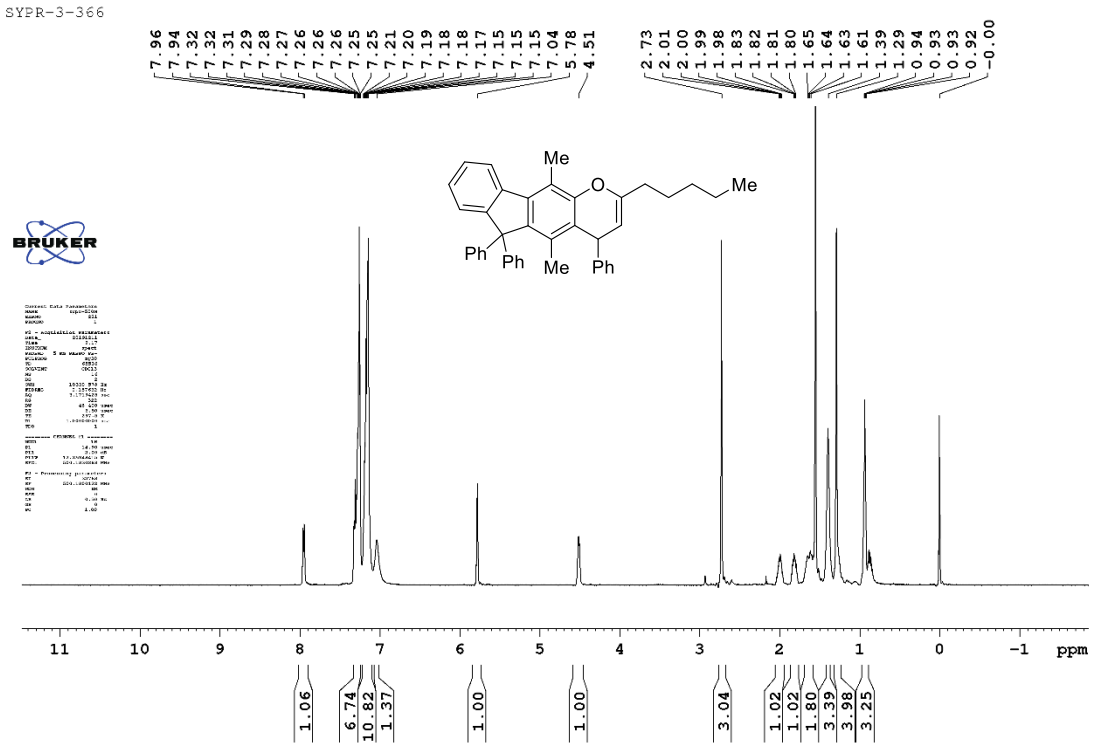

SYPR-3-131A
159.19
158.32
155.71
153.89
147.64
143.18
138.45
136.89
135.86
131.88
129.97
129.24
129.21
129.16
128.94
128.17
128.14
128.00
127.95
127.90
126.79
126.64
126.48
126.27
126.14
126.06
125.69
122.47
121.18
113.61
77.41
77.16
76.90
64.63
61.38
55.36
55.28
33.24
21.76
16.73
14.33
12.82
0.14
Me
Me
O
CO2Et
Ph
Ph
Me
OMe
BRUKER
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3- 438
7.95
7.93
7.33
7.31
7.31
7.29
7.28
7.27
7.25
7.23
7.23
7.20
7.19
7.17
7.15
7.15
7.15
7.14
7.14
7.04
7.04
4.20
4.19
4.17
4.16
3.63
2.91
1.62
1.29
1.27
1.26
0.00
BRUKER
Me
O
CO2Et
Ph
Me
Br
F
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.04
5.64
3.00
1.02
4.19
2.02
2.00
1.99
3.02
2.93
3.43


SYPR-3- 438
169.33
163.55
154.95
153.92
148.13
144.73
142.35
142.27
140.91
135.82
132.41
131.05
130.98
129.34
128.97
128.10
127.48
127.29
126.86
126.62
126.21
125.39
122.89
120.58
120.40
115.35
115.18
114.74
77.41
77.16
76.90
64.31
61.52
33.18
16.84
14.31
12.86
BRUKER
Me
O
CO2Et
Ph
Me
Br
F
200
180
160
140
120
100
80
60
40
20
0
ppm


SYPR-3- 385 P
7.94 7.92 7.35 7.33 7.32 7.31 7.29 7.27 7.26 7.24 7.24 7.23 7.22 7.21 7.20 7.20 7.19 7.19 7.18 7.18 7.17 7.16 7.15 6.64 5.34 2.66 2.33 2.32 2.31 2.30 2.29 1.92 1.58 1.57 1.55 1.54 1.46 1.44 1.42 1.41 0.94 0.92 0.91 0.85 0.85 -0.00
Me
O
Me
Ph
Ph
Me
Ph
BRUKER
11 10 9 8 7 6 5 4 3 2 1 0 -1 ppm
1.09 4.94 4.33 5.80 2.85 0.94 1.00 3.10 1.88 2.83 2.39 2.05 2.86


SYPR-3-385
155.82 153.33 143.10 143.02 142.69 140.98 139.59 139.44 131.26 129.38 129.06 128.94 128.67 128.02 127.91 127.32 127.10 127.03 126.96 126.46 126.36 125.41 124.64 123.29 119.91 87.58 78.83 77.47 77.16 76.84 65.13
34.82 30.88 22.20 18.75 17.45 13.72 12.81
Me
O
Me
Ph
Ph
Me
Ph
BRUKER
200 180 160 140 120 100 80 60 40 20 0 ppm


SYPR-3-366
7.96 7.94 7.32 7.32 7.31 7.29 7.28 7.27 7.26 7.26 7.26 7.25 7.25 7.21 7.20 7.19 7.18 7.18 7.17 7.15 7.15 7.15 7.04 5.78 4.51
2.73 2.01 2.00 1.99 1.98 1.83 1.82 1.81 1.80 1.65 1.64 1.63 1.61 1.39 1.29 0.94 0.93 0.93 0.92 -0.00
Me
O
Me
Ph
Ph
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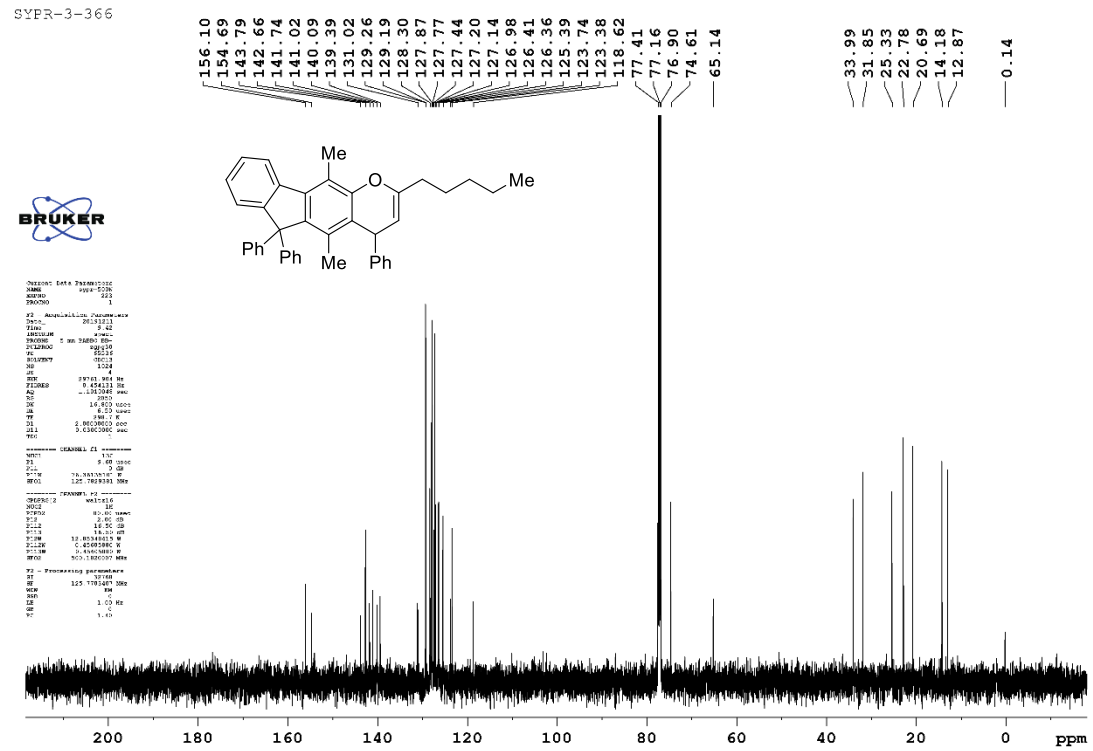
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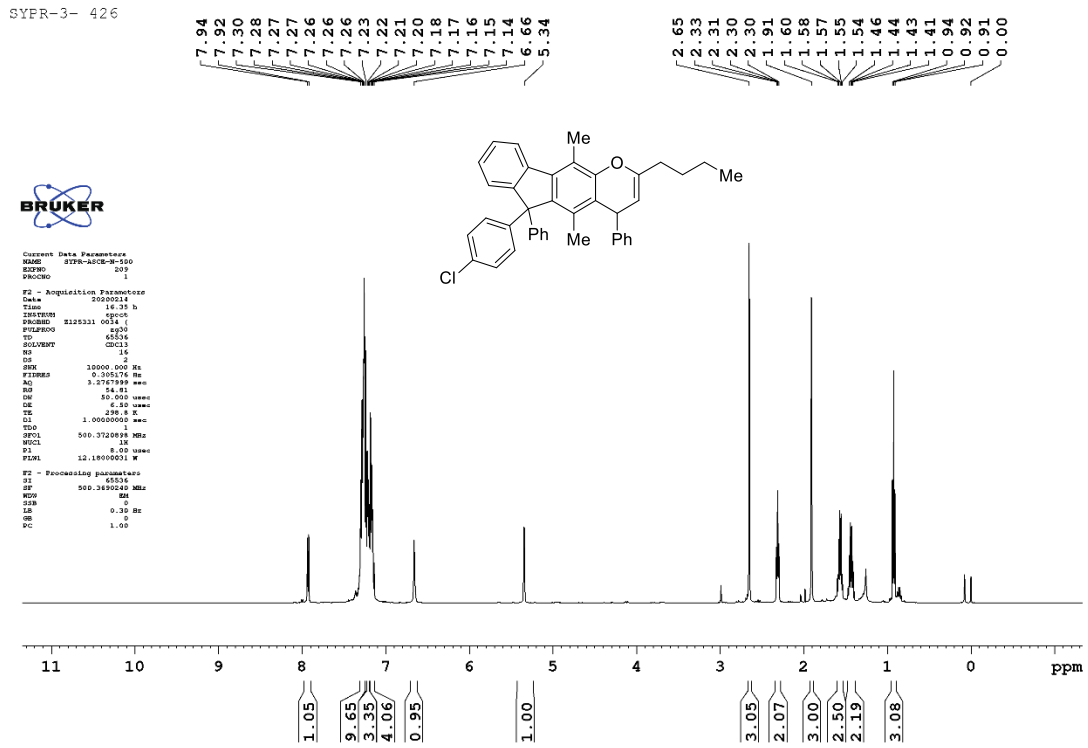
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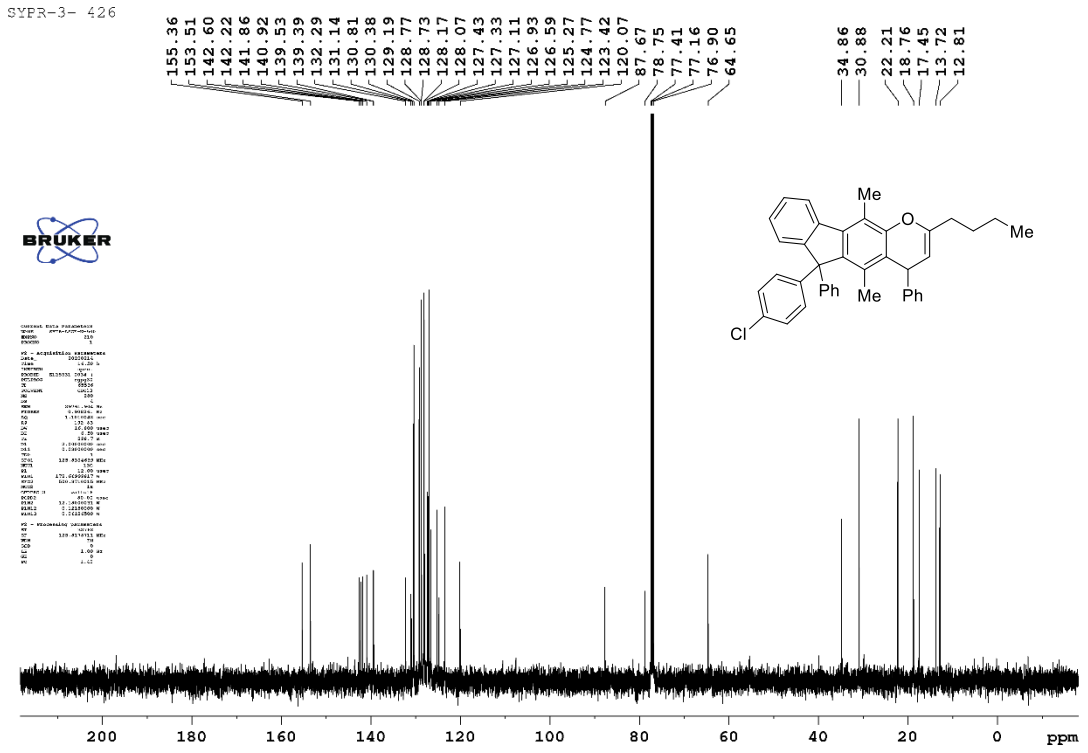
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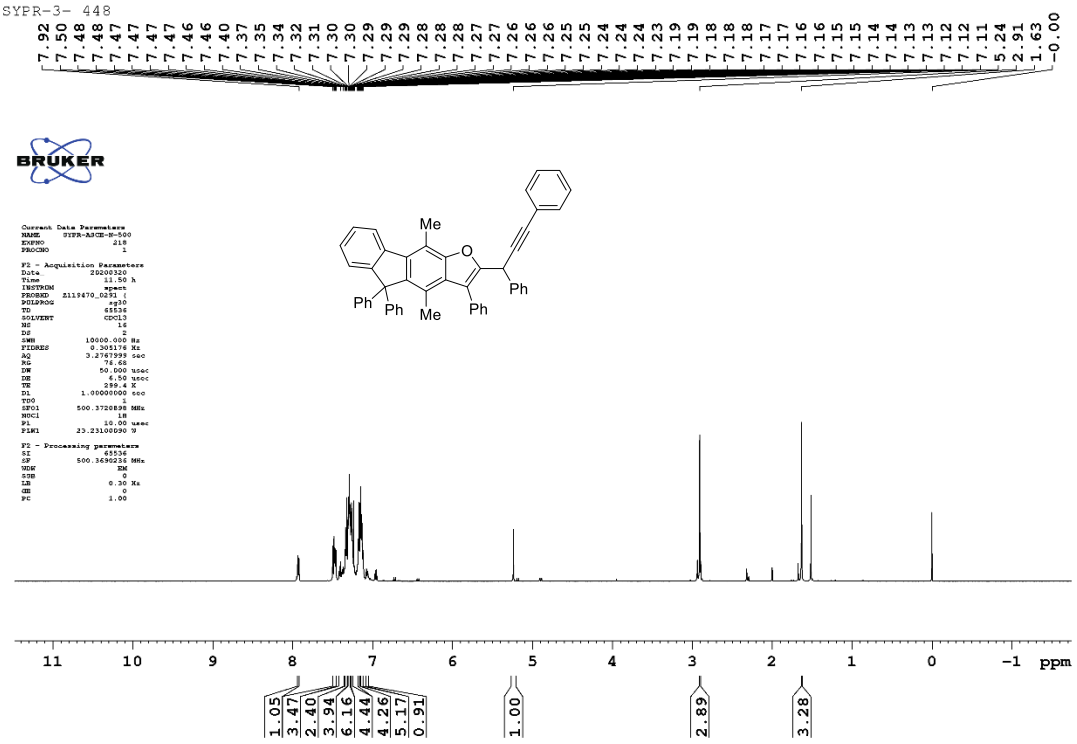
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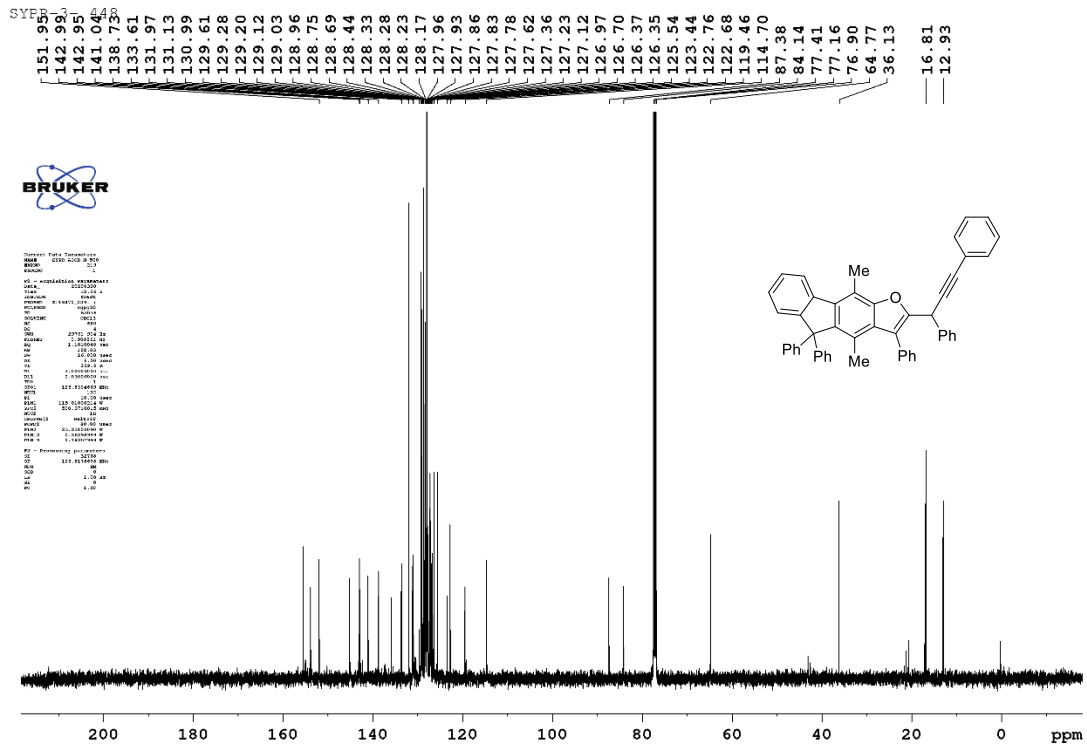
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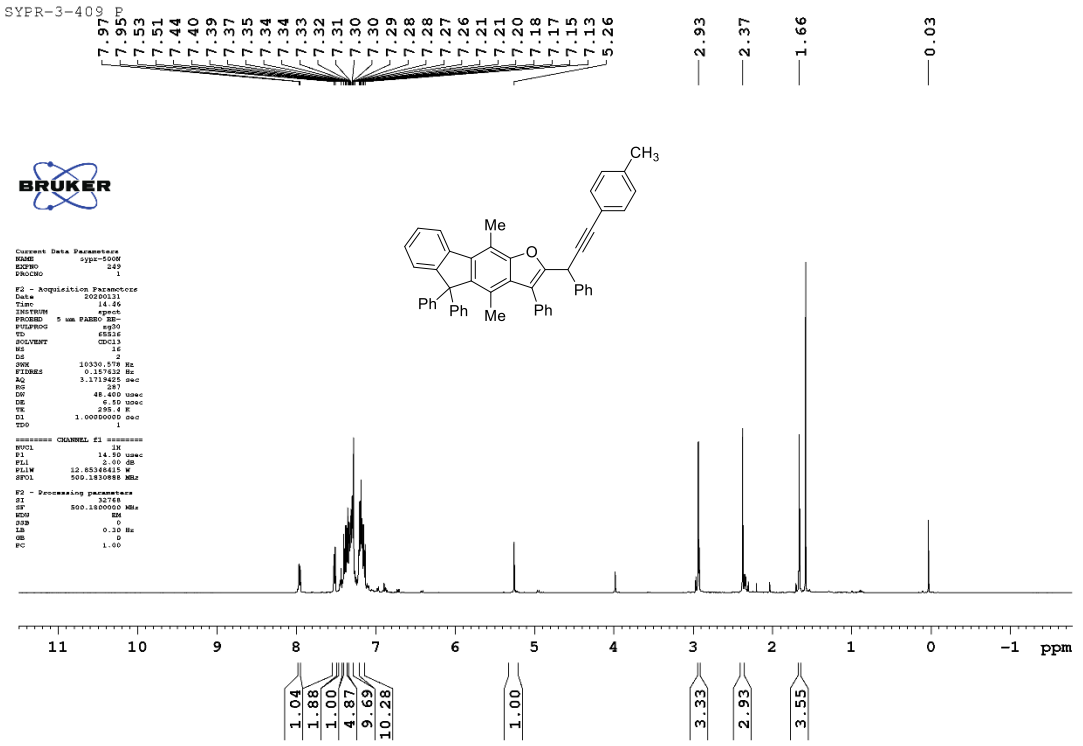
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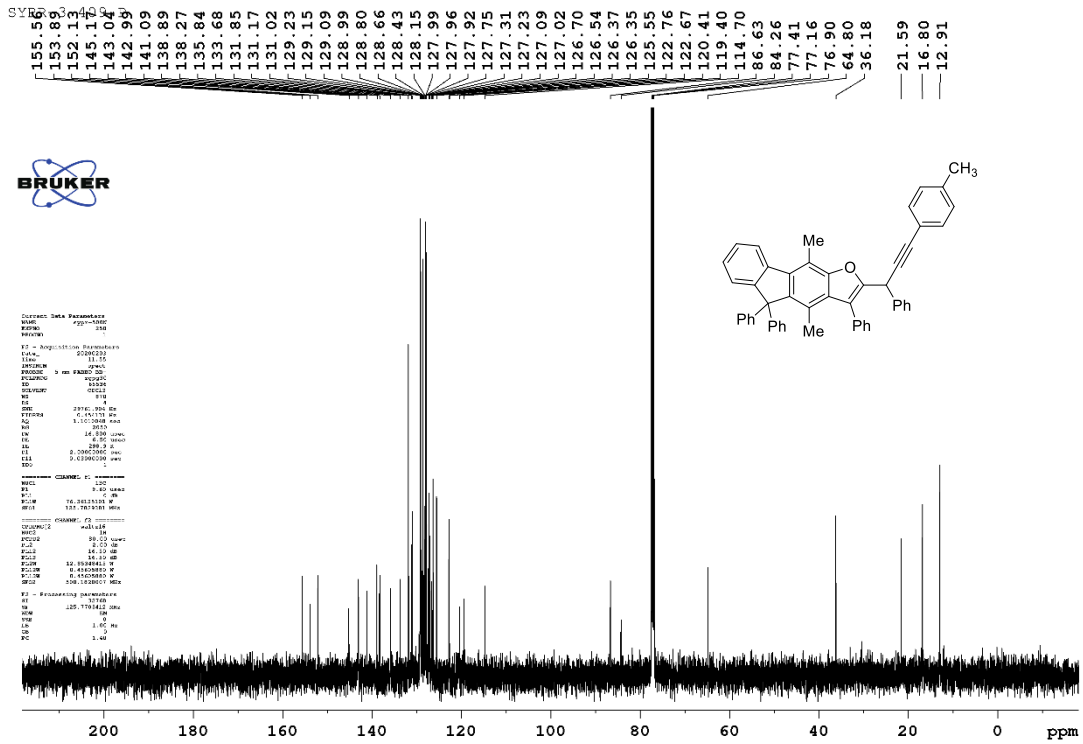
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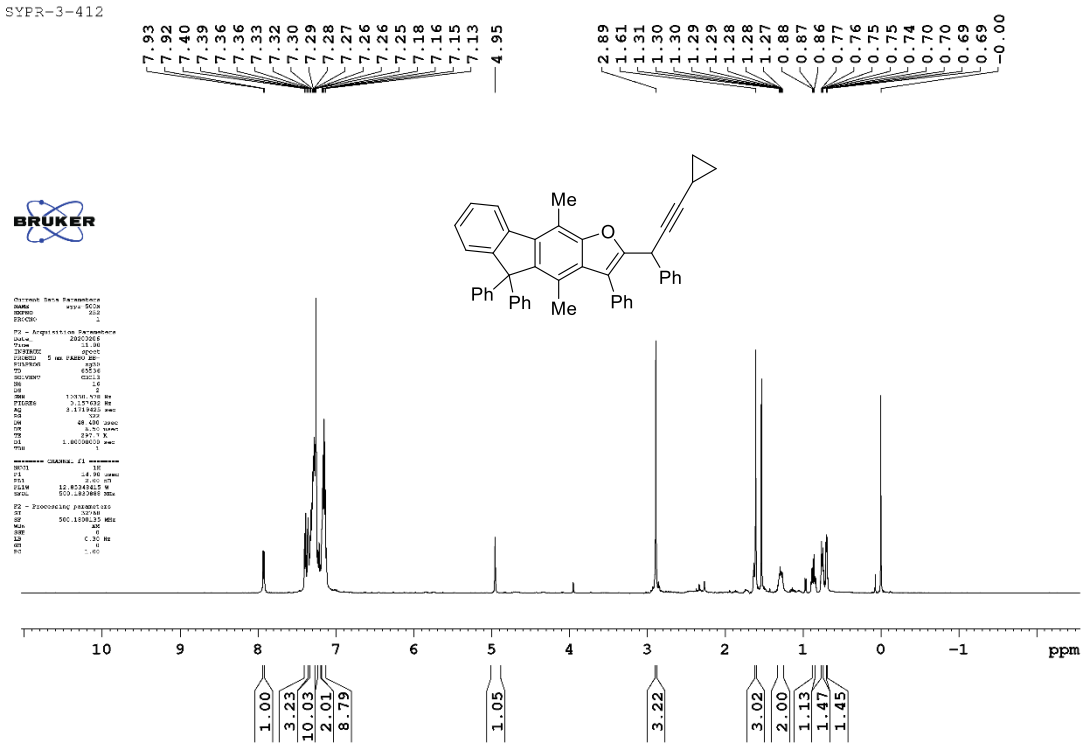
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BRUKER
Me
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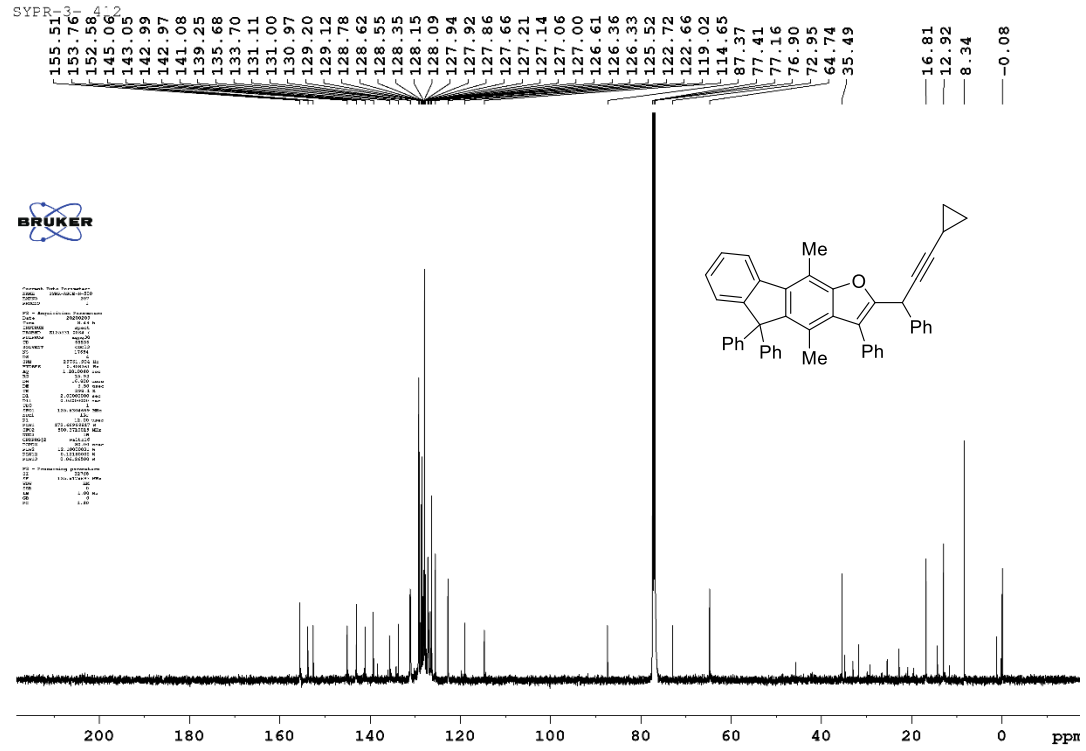
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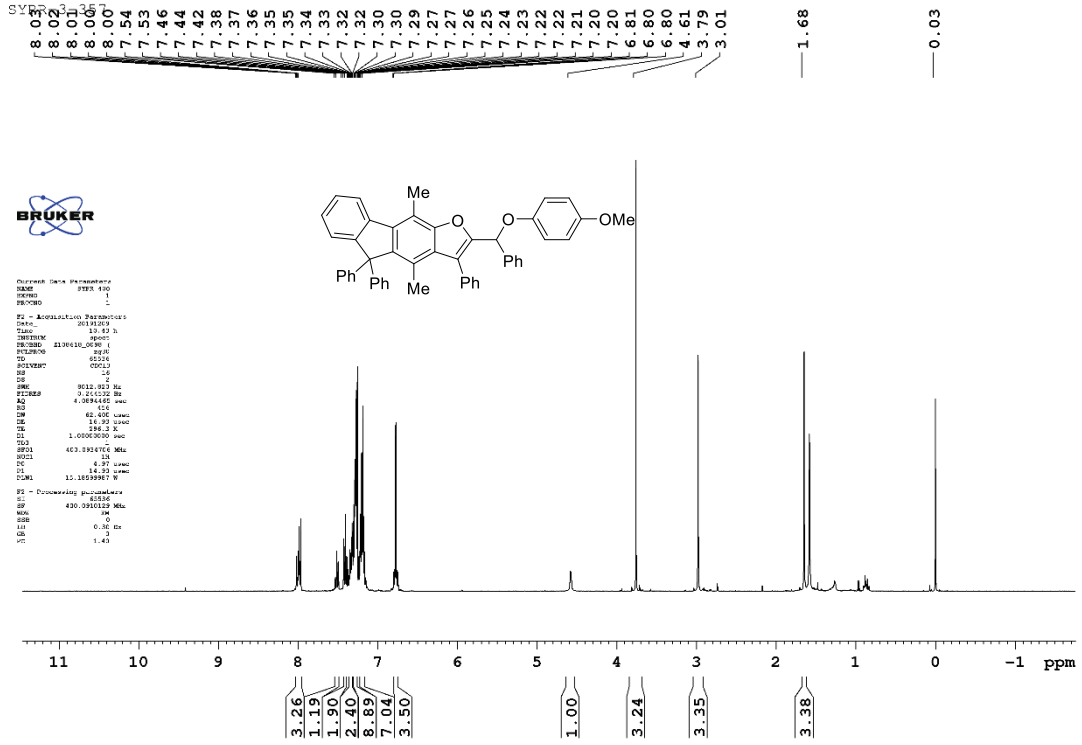
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1.68
0.03
BRUKER
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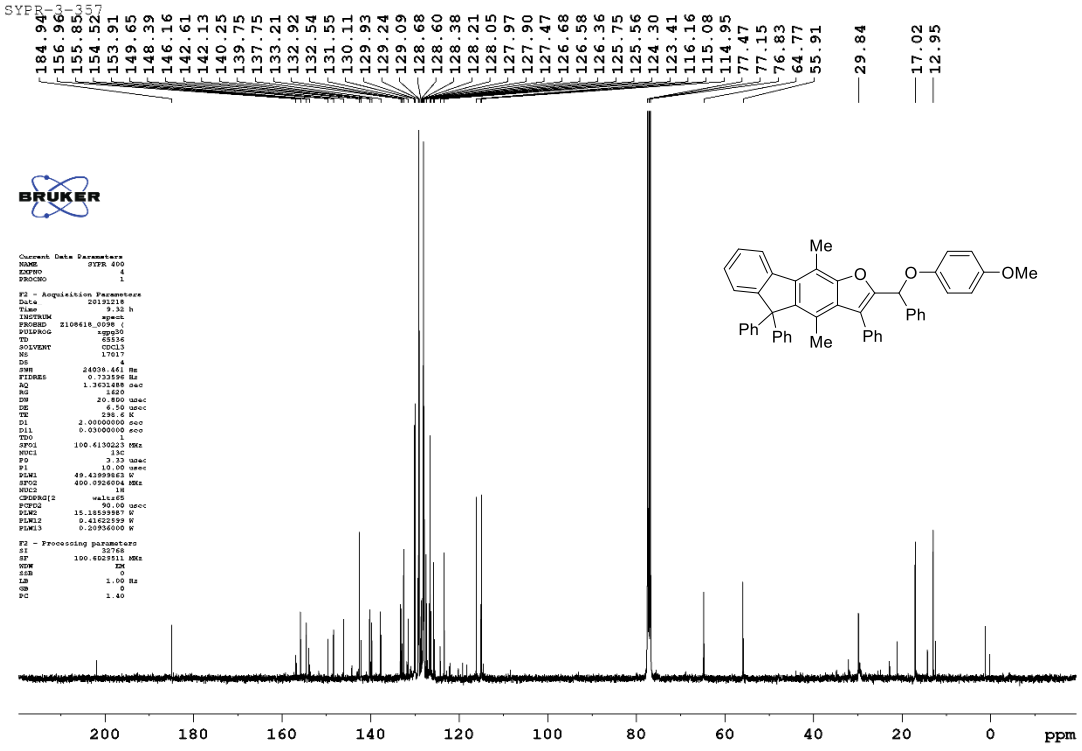
3.38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29.84
17.02 12.95
BRUKER
Me
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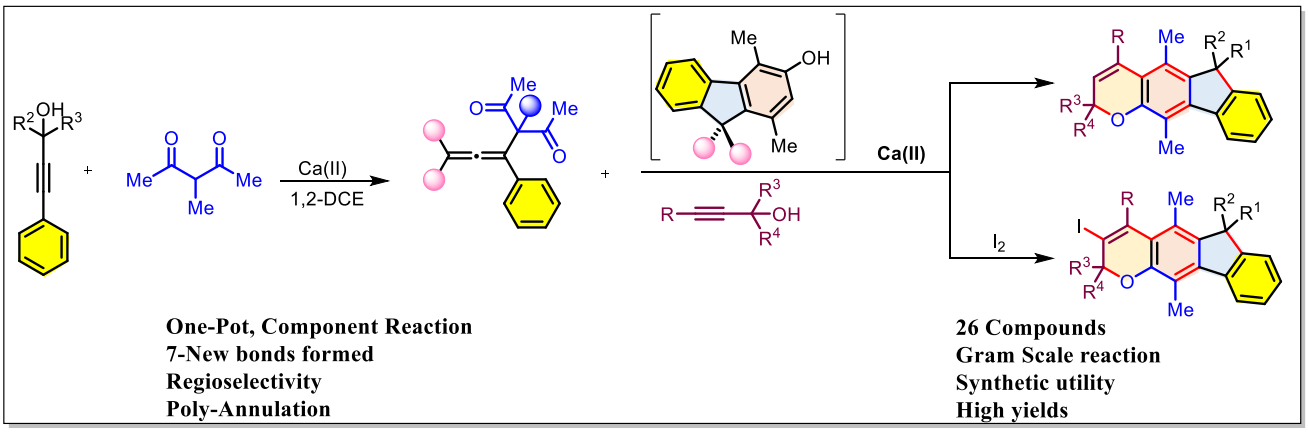
Synthesis and in-situ cyclization of tetrasubstituted allenes to access tetracyclic fluorenopyrans



Adv. Synth. Catal. **2018**, 360, 4422

5.1 PROPOSAL FOR THE SYNTHESIS OF FLUORENOPYRAN

As mentioned before, ynol **1** and diketone **72b** react in the presence of calcium-catalyst to give allene intermediate **3ya**, which further cyclizes to produce fluorenol **128**. At this stage, we presume that if we can add *tert*-propargyl alcohol to the fluorenol **128**, it can form a C-O bond due to the hard-hard interactions over the C-C bond, to give ether compound **IX**. Once **IX** is formed, further it may undergo Claisen or [3,3]-rearrangement of ether to give allene intermediate followed by a 6-endo-trig-cyclization or 5-*endo-dig*-cyclization possibilities

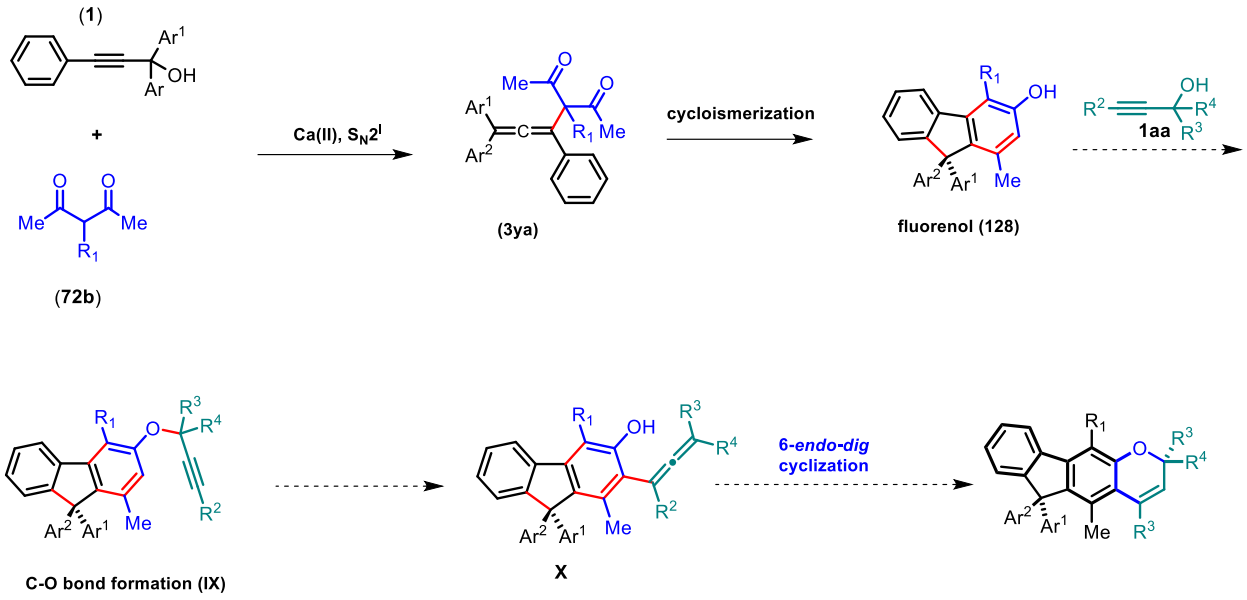


Figure 1. Conceptualization of highly regioselective synthesis of fluorenopyran.

When we look at the literature for chromene chemistry, we found that similar kinds of polycyclic molecules are abundant in natural products and are of great importance in chemical biology and material science. Synthesis of these complex molecules from simple acyclic starting materials is always challenging and demanding. For example, chromenes as an important class of heterocyclic compounds from both pharmaceutical and biological point of view.[1] As a result, the synthesis of chromenes has been attracted the attention of many synthetic chemists.[2] Similarly, chromene is a useful carbocyclic moiety found in a wide variety of bioactive natural and synthetic compounds.[3] Due to their unique features, such as good charge transporters with high chemical stability, these moieties are frequently utilized in material science, light-emitting diodes (OLEDs), and dyes sensitized solar cells (DSSC).[4] Some of these tetracyclic frameworks, such as Gnetuhainins S,[7] and Parvifolol A.[8,9] were created by nature to use as a combination of fluorenyl and pyran scaffolds (Figure 2). When it

comes to the laboratory synthesis, very few reports are available for indeno[1,2-*c*]chromenes,[5,6] but none for the indeno[1,2-*g*]chromenes, except a patent.[10] According to this patent, these compounds exhibited excellent photochromic properties and are used in many types of plastics and especially for ophthalmic purposes.

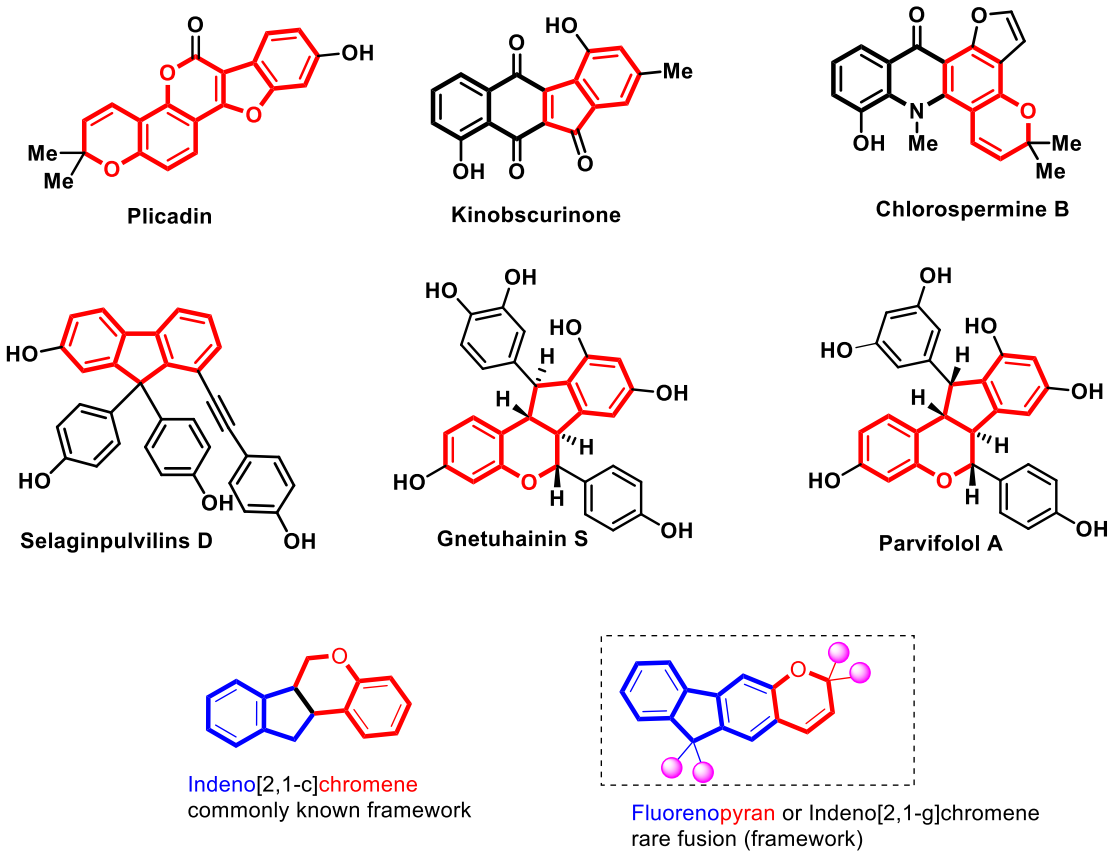


Figure 2.Representative structures of natural polycyclic frameworks embedded with chromene, indene and fluorene

5.2 RESULTS AND DISCUSSION

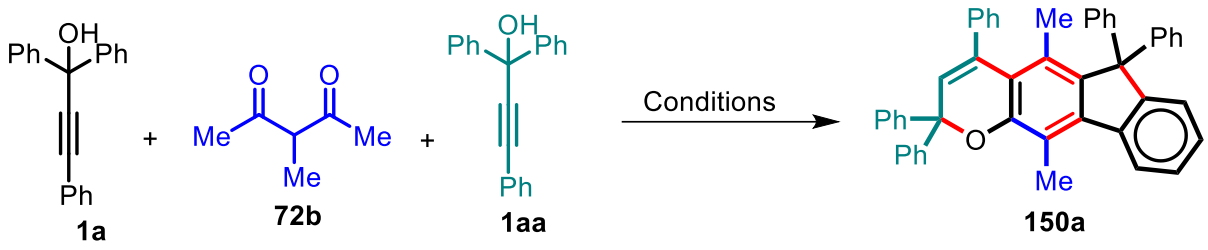
However, difficulties such as a multi-step method, various protection, and deprotection strategies, less yield, and longer reaction periods have been found in the reported synthesis of these polycyclic moieties green synthetic methods are in short supply in modern synthetic chemistry, so various protocols have been developed and are being followed.[11] One of them is a one-pot, multicomponent reaction (MCR) approach.[12] Because of the potential use of fluorenopyrans and the rarity of synthetic procedures, we present the first one-pot, multicomponent annulation of acyclic propargyl alcohols and 2-methyl-1,3-diketones into tetracyclic fluorenopyrans utilizing calcium-catalysis.[13] Our concept for fluorenopyran synthesis is that fluorene and pyrans are very well privileged scaffolds, thus we proposed

combining them into a single (hybrid) molecule such that the properties of both molecules can reinforce one another in the hybrid structure. We proposed a preliminary investigation on acidochromism for selected compounds to evaluate this. Our main concern while designing a synthetic methodology for this particular compounds is, to include as many green synthetic protocols as possible.

5.3 Optimization Studies

To test our hypothesis, we stirred a mixture of propargyl alcohol (**1a**, 2 equiv.), 3-methylpentane-2,4-dione (**72b**, 1.3 equiv.), and 10 mol % $Ca(OTf)_2/Bu_4NPF_6$ in 1,2-DCE for 15 h at room temperature, discovering that the desired flurenopyran (**150a**) was formed in 10% along with other inseparable mixtures. After the formation of the fluorenol intermediate, (**128**), the second part of **1a** was added to the same flask to enhance the production of the **150a** (monitored by TLC). As expected, the yield of the product was increased to 25% (entry 1, Table 1). This prompted us to experiment with alternative conditions to improve the reaction yield. We refluxed the reaction in DCE at 90 ^oC and found that the yield of **150a** was raised to 67%. (entry 2). Assuming that increasing the reaction temperature would enhance the yield of **150**, the reaction was refluxed in a higher boiling solvent, toluene (120 ^oC), but the yield was only 40%. (entry 3). The reaction could not initiate in a protic solvent like ethanol at reflux, but solvent-free conditions gave a moderate yield of 48% at 110 ^oC (entries 4, 5). DCE was shown to be better at reflux conditions than the other solvent systems investigated, therefore it was selected as the best solvent. A few more experiments were carried out to reduce catalyst loadings, and it was determined that 10 mol% $Ca(OTf)_2$/5 mol% Bu_4NPF_6 provided 70% of **150a** in 4 h (entry 6).To examine the importance of the catalyst, we performed the reaction without catalyst/additive (entry 10), without Ca(II) (entry 9), and without additive (entry 8). These results inferred to us that the combination of both is mandated as the mixture undergo a ligand metathesis to yield more soluble and more acidic Ca(II) salt.[14] KPF_6 was proved as a bad choice of additive along with a Ca(II) (entry 11). Other acid catalysts such as $Mg(OTf)_2$, $FeCl_3$, and *p*-TSA were found to be less effective (entries 12-14). Finally, entry 6 turned out to be the optimum condition for the formation of **150a**.

Table 1. Optimization studies for the synthesis of fluorenopyran



Entry	Catalyst (mol%)	Reaction conditions[a]	Yield (%)[b]
1	$Ca(OTf)_2$/ Bu_4NPF_6 (10/10)	DCE, rt, 15 h	25
2	$Ca(OTf)_2$/ Bu_4NPF_6 (10/10)	DCE, 90 °C, 4 h	67
3	$Ca(OTf)_2$/ Bu_4NPF_6 (10/5)	Toluene, 120 °C, 8h	40
4	$Ca(OTf)_2$/ Bu_4NPF_6 (10/5)	EtOH, 90 °C, 8 h	nr
5	$Ca(OTf)_2$/ Bu_4NPF_6 (10/5)	Neat, 110 °C, 8 h	48
6[c]	**$Ca(OTf)_2$/ Bu_4NPF_6 (10/5)**	**DCE, 90 °C, 4 h**	**70**
7	$Ca(OTf)_2$/ Bu_4NPF_6 (5/10)	DCE, 90 °C, 4 h	53
8	$Ca(OTf)_2$, (10)	DCE, 90 °C, 12 h	nr
9	Bu_4NPF_6, (10)	DCE, 90 °C, 12 h	nr
10	No catalyst, no additive	DCE, 90 °C, 12 h	nr
11	$Ca(OTf)_2$/ KPF_6 (10/5)	DCE, 90 °C, 4 h	10
12	$Mg(OTf)_2$/Bu_4NPF_6 (10/5)	DCE, 90 °C, 12 h	26
13	PTSA (10)	DCE, 90 °C, 4.5 h	60
14	$FeCl_3$ (10)	DCE, 90 °C, 12 h	15

1a (1 equiv., 1.2 equiv.), **72b** (1.3 equiv.), were used; [b]Isolated yields;[c]Optimum conditions; DCE: 2-dichloroethane; rt: room temperature; nr=no reaction; OTf= trifluoromethanesulfonate

5.3a Characterization of Compound 150a

Isolated compound **150a** was fully characterized using ^{1}H NMR, ^{13}C NMR, HRMS, IR, melting point & single-crystal XRD. Characteristic Pyran proton shows a sharp peak in proton NMR at 6.20 ppm and aromatic CH proton shows in proton NMR at 7.92-7.09 ppm. The quaternary center was characterized by ^{13}C NMR signal present at 64.7 ppm and HRMS data also confirms the molecular weight of the compound **150a**. Single-crystal X-ray data was collected for compound **150a** which confirms the core structure of flurenopyran moiety (Figure 2)

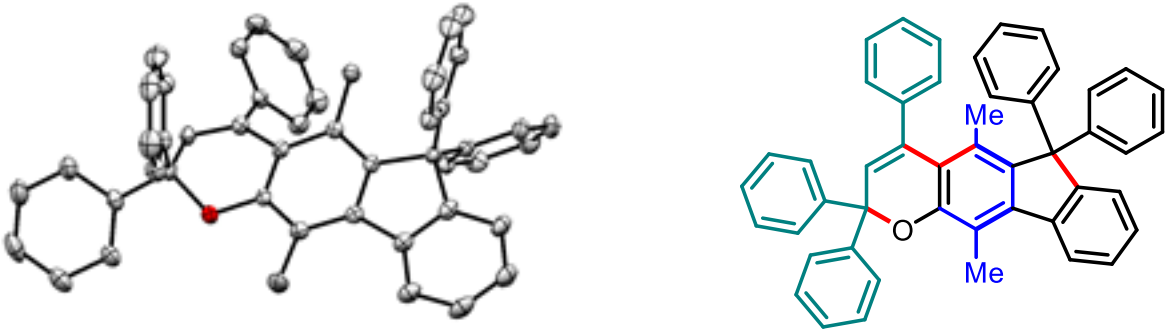


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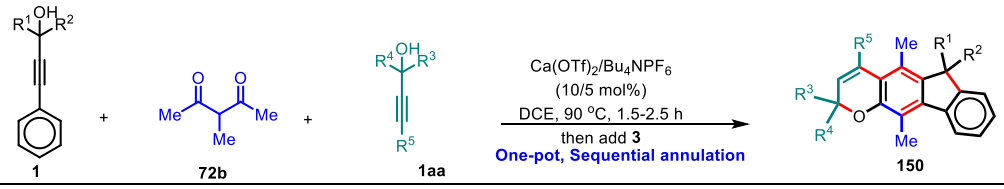
Figure 2. Single crystal X-Ry structure of **150a**

5.3b SCOPE OF THE REACTION

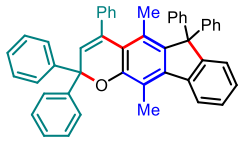
After successful optimization of reaction conditions for the regioselective, one-pot annulation of propargyl alcohol **1a** and 2-methyl acetylacetone to generate fluorenopyran **150a** (Table 2), we explored the flexibility of this reaction using different substrates. Correspondingly, **1a** and **72b** were refluxed in 1,2-DCE with 10 mol% Ca(II)/5 mol% Bu_4NPF_6 until the starting materials were consumed (as determined by TLC), after which propargyl alcohol **1b** was added to the reaction pot and the reaction was continued until completion to isolate the fluorenopyran **150b** in a 67 % yield. Other propargyl alcohols **1c-1f** were also treated with **1a** and **72b** under typical reaction conditions to demonstrate the diversity at the quaternary-C2-center and yielded good yields of flurenopyrans **150a-150e**. Compared to **150a**, the yields of **150b**, **150c,** and **150d** were somewhat lesser, this could be because the phenyl ring at the C2 center has a halogen substitution. Surprisingly, **150a** had a yield that was comparable to **150e** (diphenyl versus dimethyl at C2). By using **150h** & **1i** (*p*-tolyl and cyclopropyl groups) as the second alcoholic partners, the scope of substitutions at C4 was established, and the related polycyclic products **150f-150h** were synthesized in good yields. We also investigated the

potential of 1,1-diphenyl-3-(p-tolyl)prop-2-yn-1-ol (**1b**) with **72b** and other propargylic partners **1** to produce the fluorenopyrans **150j-150n** in modest yields. Following these findings, we planned to construct a spirocyclic quaternary center at the C2 position of compound **150** by using cyclic propargyl alcohol (**1**) second addition. To synthesize indeno[2,1-*g*]chromene **150o, 1a** and diketone **72b** were annulated under standard conditions, and then fluorenyl propargyl alcohol(**1aa**) was added after the production of flurenol, and the reaction has proceeded. As shown in Table 2, the additional fluorenopyrans **150p & 150q** having a spirocyclic 9-fluorenyl moiety at the C2 center were also synthesized in good yields. The reaction could not progress beyond the synthesis of fluorenol when 1-(phenylethynyl)cyclohexan-1-ol(**1ab**) was utilized as the second propargylic partner because the 1-(phenylethynyl)cyclohexan-1-ol underwent Rupe elimination.[15]

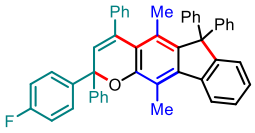
Table 2. substrate scope of the Ca(II)-catalyzed synthesis of fluorenopyrans.[a]



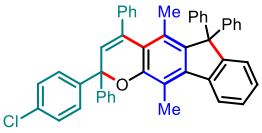
1 + 72b + 1aa → 150



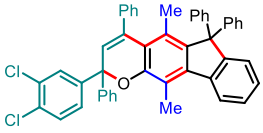
150a, 70%, 4 h



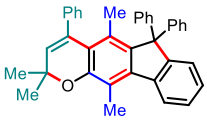
150b, 67%, 4 h



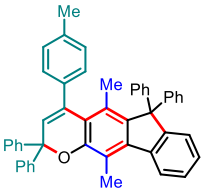
150c, 65%, 3.5 h



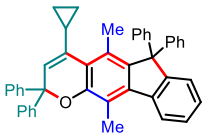
150d, 63%, 4.5 h



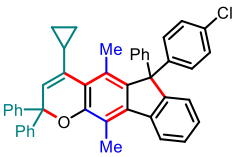
150e 71%, 3.5 h



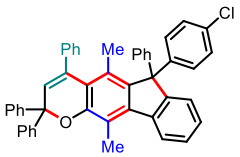
150f, 70%, 4 h



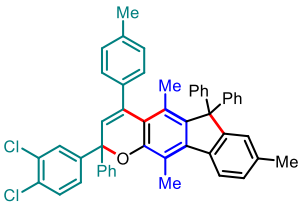
150g, 69%, 3.5 h



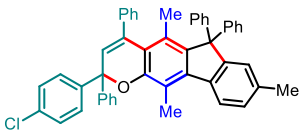
150h, 65%, 3.5 h



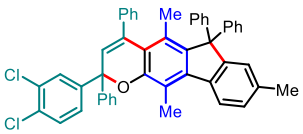
150i, 66%, 4 h



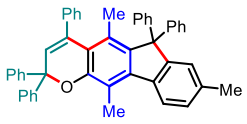
150j, 68%, 4 h



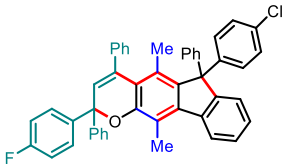
150k, 66%, 4.2 h



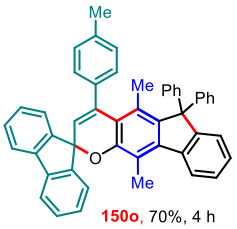
150l, 68%, 4 h



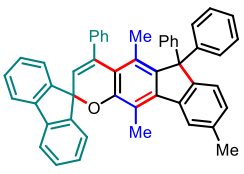
150m, 73%, 4 h



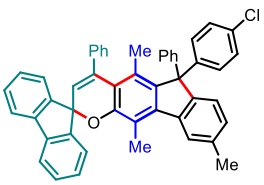
150n, 63%, 4 h



150o, 70%, 4 h



150p, 71%, 4 h

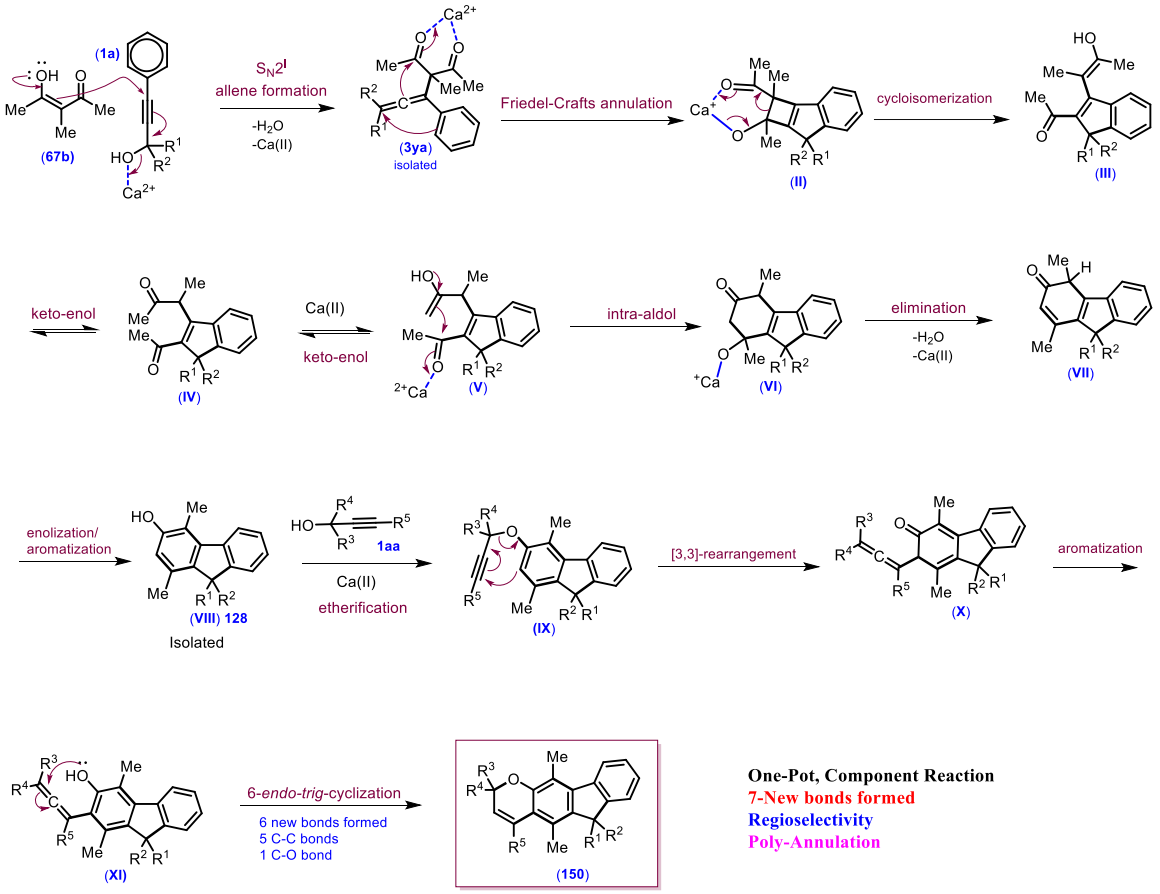


150q, 72%, 4 h

[a]Reaction conditions: A mixture of **1** equiv. 1, 1.3 equiv. **72b**, 10 mol% $Ca(OTf)_2$/5 mol% Bu_4NPF_6 were refluxed in 1,2- dichloroethane for 1.5-2.5 h then 1.2 equiv. of **1aa** was added

5.3c Reaction Mechanism

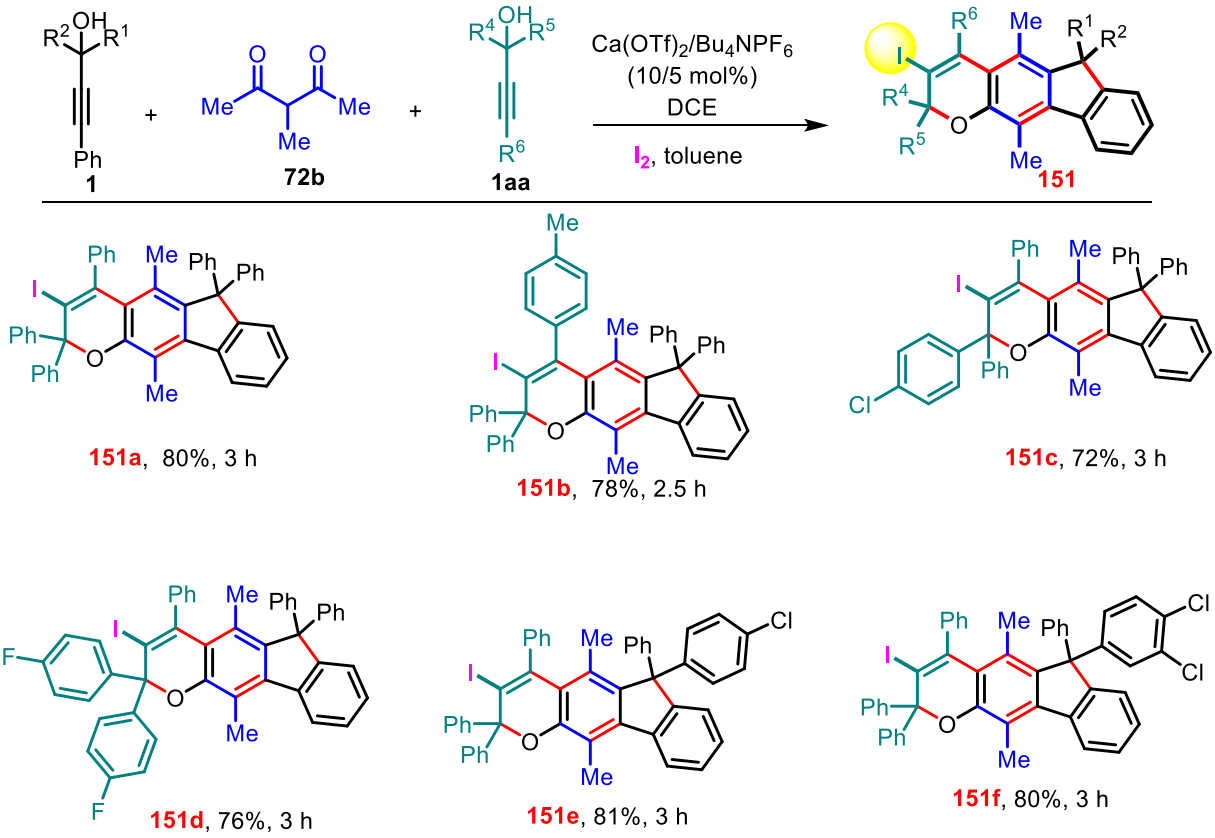
A plausible mechanism for the Ca(II) catalyzed regioselective synthesis of flurenopyran derivatives is described in Scheme 2. Initially the activated propargyl alcohol (1) interacts with the enol form of diketone **72b** *via* the S_N2^I process, yielding the tetra-substituted allene intermediate. (**3ya**)[16] (*isolated and confirmed*). An intra-molecular Allene-Friedel-Crafts annulation of (**3ya**) gives the tricarbocyclic compound (**II**), which further cycloisomerizes to the indene (**III**) in the presence of Ca(II). Later enol (**III**) undergo tautomerism to give diketone **IV**. Then a Ca(II)-catalyzed intramolecular aldol condensation of diketone **IV** through enol **V** gives annulated-**VI**, followed by elimination provides tricyclic ketone **VII**[17a,17b]. Aromatization of **VII** gives fluorenol **VIII**[17c] (*isolated and characterized*), which forms ether **IX** with the second propargyl alcohol partner (**1**). Finally, Claisen or [3,3]-rearrangement [18] of ether **IX** yields allene intermediate (**X**), which then cyclizes through a *6-endo dig* fashion to provide the fluorenpopyran **150**.



Scheme 1. Plausible reaction mechanism

A detailed examination of propargylic ether (**IX**) in the reaction mechanism (Scheme 2) revealed that molecular iodine can be used to activate the triple bond, resulting in intramolecular iodocyclization (Table 3) and the formation of iodo-fluorenopyrans.[18] We planned our experiment based on this assumption: **1a** and **72b** were exposed to typical reaction conditions to create fluorenol (**VIII**), then the reaction was brought to room temperature and **1a** was introduced as the second alcoholic partner together with molecular iodine and 2 mL of toluene.[19] Probably, the iodocyclization went smoothly, yielding 3-iodo flurenopyran **151a** in 80% yield (Table 3). This result prompted us to test the protocol's universality by combining other propargyl alcohols **1** and **1aa** with diketone **72b**. As a result, we were able to obtain the corresponding 3-iodo-fluorenopyrans **151b-151f** in good to excellent yields as depicted in Table 3.

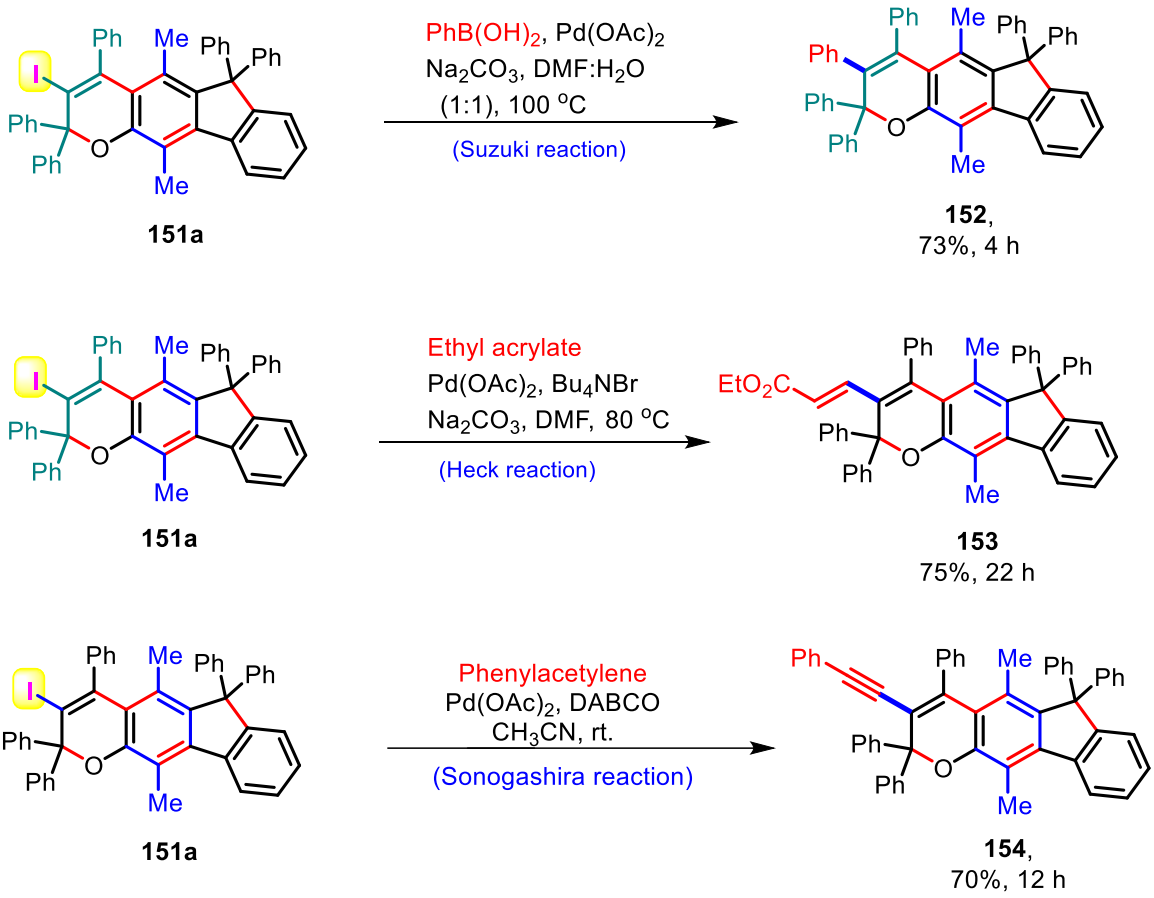
Table 3. Ca(II)-catalyzed, one-pot, 4-component Iodo-cycloisomerization reaction.[a]



[a]Reaction conditions: A mixture of 1 equiv. **1**, 1.3 equiv. **72b**, 10 mol% $Ca(OTf)_2$, 5 mol% Bu_4NPF_6 were refluxed in 1,2- dichloroethane for 2 h then the reaction was brought to rt and added 1.2 equiv. of 1aa and 2 equiv. of iodine in toluene and continued the reaction at rtuntill completion.

5.3d Synthetic transformations of 151a

We were excited to demonstrate the synthetic utility of these iodo compounds in cross-coupling processes after developing a simple 4-component synthesis of 3-iodo-fluorenopyrans (Scheme 3). Therefore, the first cross-coupling was executed with phenylboronic acid and iodide **151a** under Suzuki conditions[20] [5 mol% $Pd(OAc)_2$, Na_2CO_3, DMF:H_2O (1:1), 100 °C] to yield the cross-coupled product **152** in 73% yield. Another transformation of **151a** was achieved with ethyl acrylate under Heck conditions[21] [$Pd(OAc)_2$, Bu_4NBr, Na_2CO_3, DMF, 80 °C] to furnish the acrylate compound **153** in 75% yield. The third reaction was performed with phenylacetylene under Sonogashira conditions[22] [($Pd(OAc)_2$, DABCO, CH_3CN, r.t.] and furnished the alkyne **154** in 70% yield (Scheme 3).



Scheme 2. Synthetic transformation of **151a**

5.4 Acidochromic Properties:

Acidochromism is the change in colour of chromophores caused by the interaction of acids; this feature has been investigated in depth in recent years due to its usefulness in the sensor sector.[24] We opted to investigate the acidochromic characteristics of a few compounds because they are known to have interesting electronic/physical properties. The compound's absorption spectrum **150a** (5,11-dimethyl-2,2,4,6,6-pentaphenyl-2,6-dihydroindeno[2,1-g]chromene) were recorded in chloroform solution ($1x10^{-4}$ M) and showed strong absorption maxima at 254 nm, 309 nm, 321 nm and weak absorption at 348 nm as shown in Figure 2. The concentration of the proton was modulated by the addition of aliquots of trifluoroacetic acid (0.3 mL), upon gradual addition of aliquots of TFA to the solution, the lower wavelength band at 309 nm and 321 nm showed a gradual decrease in the intensity, and redshift was observed. A new broad peak appeared in the visible region around 512 nm. The change in the color of the solution was observed from colorless to maroon, which is due to the protonation of pyran segment **150a1** that generates a highly conjugated fluorenone **150a2** by ring-opening of pyran[23] as shown in Scheme 4.

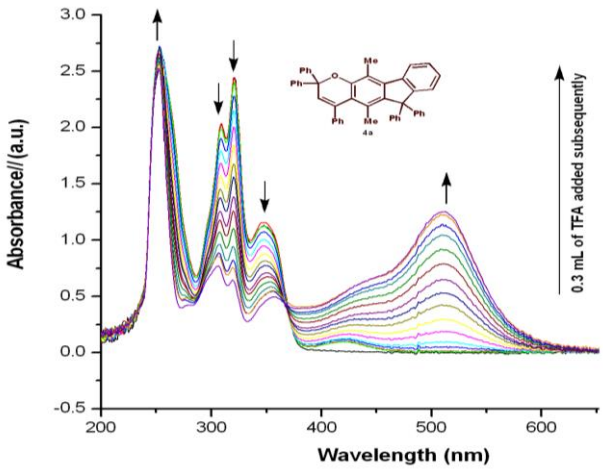
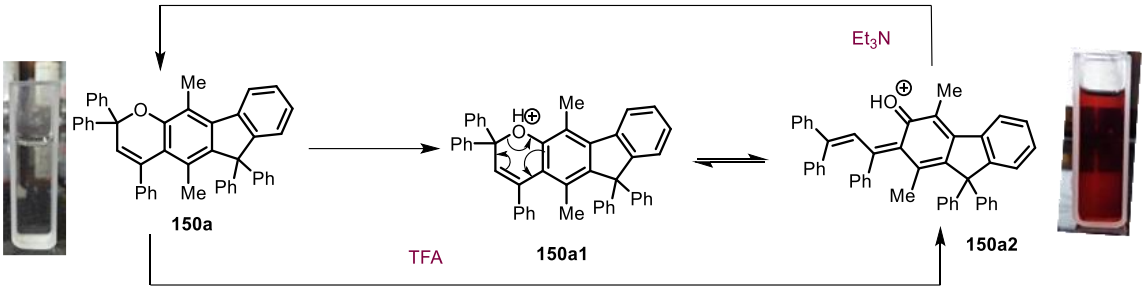


Figure 3. Absorption spectra of compound **135a** measured in chloroform solution with different amounts of TFA

The solution turned colorless again by the addition of triethylamine (NEt_3) and further addition of acid to this solution lead to a maroon color solution (Scheme 4), which confirms the reversible switch in the reaction. The observation of two isosbestic points in absorption spectra suggests the presence of the neutral and protonated forms in equilibrium.[25]



Scheme 3. Protonation-deprotonationequilibrium of the compound **144a** in presence of TFA

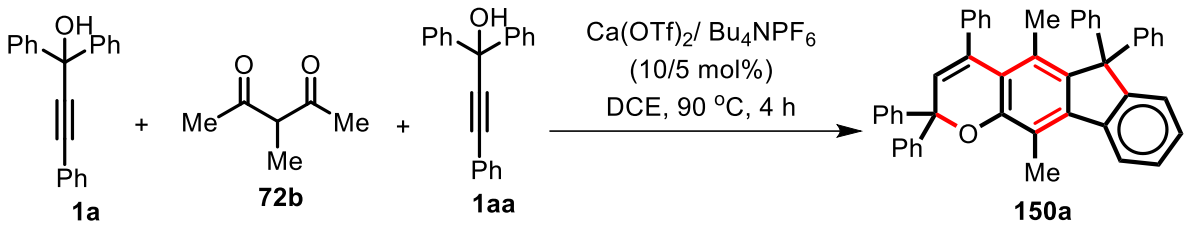
5.5 Conclusions

we established an operationally affordable technique for the synthesis of sophisticated polycyclic compounds, fluorenopyrans, and 3-iodo-fluorenopyrans utilising a calcium(II) catalyst and simple acyclic propargyl alcohols and 3-methylpentane-2,4-dione. Isolation and characterization of key intermediates supported the proposed reaction mechanism. Wide substrate scope, the formation of seven new bonds (3-contiguous C-C bonds) in one pot, *via* the sequential Allene-Friedel-Crafts cyclization/cycloisomerization, intramolecular aldol reaction, Claisen rearrangement, iodocyclization, and 6-*endo dig* cyclization to get the desired products are some of the highlights of the synthesis. Acidochromic properties of selected compounds suggested that these compounds can be useful candidates in material applications.

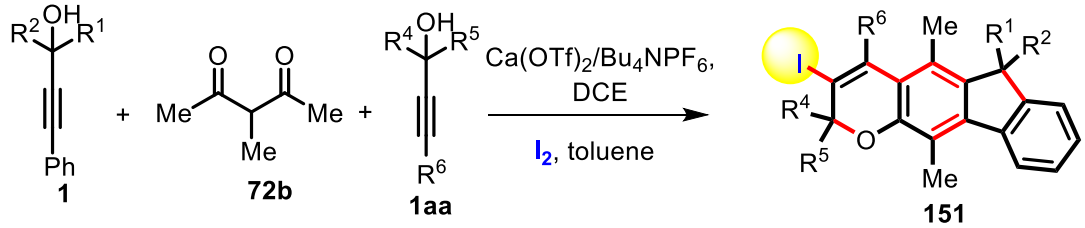
5.6 EXPERIMENTAL SECTION

5.6a General information: Unless otherwise noted, all reagents were used as received from commercial suppliers. Reactions were performed in flame-dried or oven-dried glassware with magnetic stirring. Reactions were monitored using thin-layer chromatography (TLC) with aluminium sheets silica gel 60 F254 from Merck. TLC plates were visualized with UV light (254 nm), iodine treatment or using p-anisaldehyde or KMNO4 stain. Column chromatography was carried out using silica gel 60-120 mesh as stationary phase. NMR spectra were recorded at 500 MHz and 400 MHz (H) and at 125 MHz and 100 MHz (C), respectively on the Avance Bruker spectrometer. Chemical shifts (δ) are reported in ppm, using the residual solvent peak in CDCl3 (H: δ = 7.26 and C: δ = 77.0 ppm) as internal standard, and coupling constants (J) are given in Hz. HRMS were recorded using ESI-TOF techniques. Melting points were measured with the LABINDIA mepa melting apparatus.

5.6bTypical experimental procedure for the synthesis of flurenopyran (150a): A mixture of propargyl alcohol **1a** (0.35 mmol, 100 mg) and dione **72b** (0.45 mmol, 52 mg) were refluxed in 1,2-DCE at 90 °C in presence of $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) for 2 h. Then 0.42 mmol (119 mg) of propargyl alcohol **1aa** was added to the reaction mixture and continued till completion of the reaction (monitored by TLC). After completion of the reaction, the crude product was purified by silica gel column chromatography (3-5 %, EtOAc in pet ether) to obtain the desired product **150a** in 70% yield.

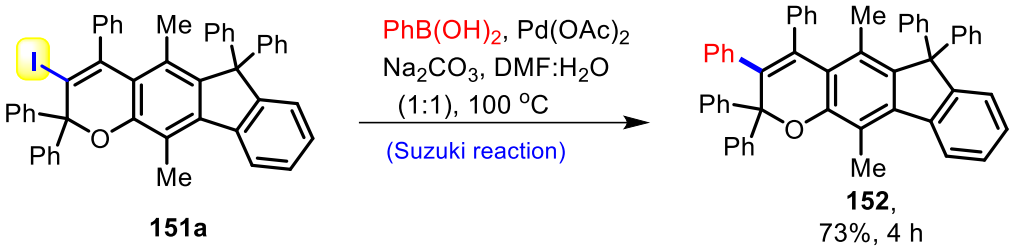


5.6c Typical experimental procedure for the synthesis of 3-iodo-flurenopyran (151a): A mixture of propargyl alcohol **1a** (0.35 mmol, 100 mg) and dione **72b** (0.45 mmol, 42.15 mg) was refluxed in 1,2-DCE at 90 °C in presence of $Ca(OTf)_2/Bu_4NPF_6$ (10/5 mol%) for 2 h. Then reaction mixture was brought to room temperature and 0.42 mmol (119 mg) of propargyl alcohol **1aa** along with 1.42 mmol (180 mg) of I_2 and 1 mL of toluene were added to to it and continue at room temperature till completion of the reaction (monitored by TLC). After completion of the reaction, the reaction mixture was diluted with saturated $Na_2S_2O_8$ solution, extracted with EtOAc (thrice), the combined organic layers were washed with brine solution and dried over anhydrous Na_2SO_4. The solvent was removed under reduced pressure and the crude product was purified by silica gel column chromatography (3-5 %, EtOAc in pet ether) to obtain the desired product **151a** in 80% yield.



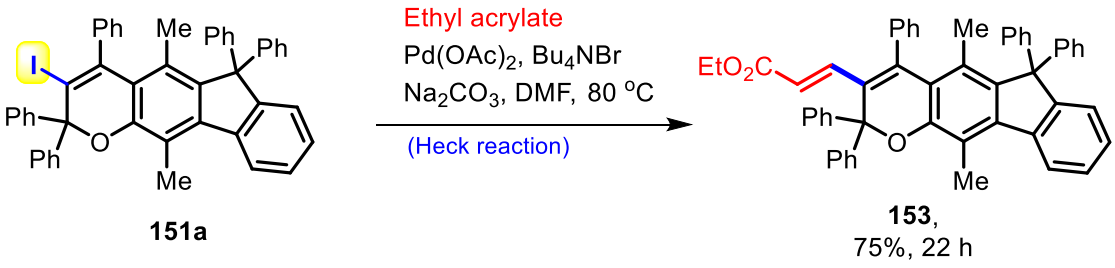
5.6d Typical experimental procedure for the Suzuki cross coupling reaction (152): $PhB(OH)_2$ (41.1 mg, 0.33 mmol) was added to a solution of 3-iodo flurenopyran **151a** (203 mg, 0.27 mmol) in 3.0 mL of DMF/H_2O (2:1) containing Na_2CO_3 (1 equiv) and stirred at room

temperature for 5 min. Then $Pd(OAc)_2$ (5 mol %) was added and the flask was flushed with N_2, sealed and allowed to stir at 100 °C for 4 h. The resulting mixture was filtered off, washed and filtrate was extracted with diethyl ether. The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure and the residue was purified by column chromatography (4-6%, EtOAc in pet ether) with silica gel to give the product in **152** in 73% yield.



151a **152**, 73%, 4 h

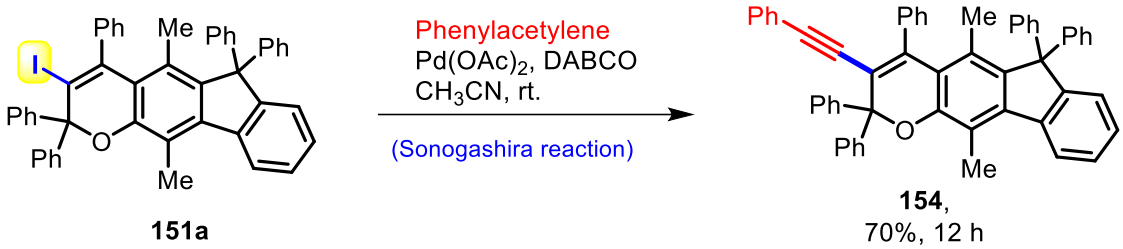
5.6e Typical experimental procedure for the Heck cross coupling reaction (153): Ethyl acrylate (47.9 mg, 0.47 mmol), was added to a solution of 3-iodo-flurenopyran **151a** (173 mg, 0.23 mmol) in DMF (1.8 mL) containing K_2CO_3 (2.5 equiv.) and Bu_4NBr (1 equiv.) and stirred at room temperature for 5 min. $Pd(OAc)_2$ (5 mol %) was then added and the flask was flushed with N_2, sealed, and allowed to stir at 80 °C for 22 h. The resulting mixture was filtered off, washed and filtrate was extracted with diethyl ether. The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4. The solvent was evaporated under reduced pressure and the residue was purified by column chromatography (4-6%, EtOAc in pet ether) with silica gel to give product **153** in 75% yield.



151a **153**, 75%, 22 h

5.6f Typical experimental procedure for the Sonogashira cross coupling reaction (154): Solution of $Pd(OAc)_2$ (2 mol%) in acetonitrile (1 mL) was added to a mixture of phenyl acetylene (45 mg, 0.45 mmol), 3-iodo-flurenopyran **151a** (168 mg, 0.22 mmol), DABCO (3 equiv), and MeCN (4 mL). Then mixture was stirred under N_2 at room temperature for 12 h. The resulting mixture was filtered off, washed and filtrate was extracted with diethyl ether. The combined organics were washed with brine and dried over anhydrous Na_2SO_4. The

solvent was evaporated under reduced pressure and the residue was purified by column chromatography (4-6%, EtOAc in pet ether) with silica gel to give product **154** in 70% yield.



151a

154, 70%, 12 h

5.7. Crystal data and structure refinement for 150a.

Identification code:	**150a**	
Empirical formula	$C_{48}H_{36}O$	
Formula weight	628.28	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group	P-1	
Unit cell dimensions	a = 10.944(2) Å	a= 69.944(8)°.
	b = 11.879(2) Å	b= 89.614(9)°.
	c = 16.351(3) Å	g = 64.991(8)°.
Volume	1785.6(5) $Å^3$	
Z	53	
Density (calculated)	1.430 Mg/m^3	
Absorption coefficient	0.132 mm^{-1}	
F(000)	795	
Theta range for data collection	2.29 to 25.00°.	
Index ranges	-13<=h<=13, -14<=k<=14, -19<=l<=19	
Reflections collected	58927	
Independent reflections	6287 [R(int) = 0.0713]	
Completeness to theta = 25.00°	99.9 %	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	6287 / 0 / 446	

Goodness-of-fit on F^2	1.376
Final R indices [I>2sigma(I)]	R1 = 0.0943, wR2 = 0.3116
R indices (all data)	R1 = 0.1198, wR2 = 0.3330
Largest diff. peak and hole	1.847 and -0.306 e. $Å^{-3}$
X-ray diffractometer	Bruker APEX II QUAZAR
CCDC	**1842703**

5.8 SPECTRAL DATA

5,11-dimethyl-2,2,4,6,6-pentaphenyl-2,6-dihydroindeno[2,1-g]chromene (150a): Following general experimental procedure 5.6b; yield: 156 mg (70%) as white solid; mp 297-298 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.91 (d, J = 8 Hz, 1H), 7.55 (d, J = 7.6 Hz, 4H), 7.31-7.22 (m, 13H), 7.16- 7.09 (m, 11H), 6.20 (s, 1H), 2.82 (s, 3H), 1.21 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.9, 152.3, 144.5, 143.9, 142.4, 141.3, 140.6, 140.1, 139.1, 130.9, 130.5, 128.9, 128.2, 127.9, 127.6, 127.3, 127.2, 127.1, 127.1, 127.1, 126.9, 126.1, 125.1, 123.2, 119.3, 82.2, 64.7, 20.6, 12.8 ppm. HRMS (ESI): m/z calcd. for $C_{48}H_{36}O[M+H]^+$: 629.2844; found 629.2844.

2-(4-fluorophenyl)-5,11-dimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g] chromene (150b): Following general experimental procedure 5.6b; yield: 153 mg (67%) as yellow solid; mp 214-216 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (d, J = 7.2 Hz, 1H), 7.90-7.86 (m, 1H), 7.81-7.79 (m, 1H), 7.64-7.60 (m, 1H), 7.57-7.52 (m, 5H), 7.36-7.28 (m, 17H), 7.17 (d, J = 10.4 Hz, 2H), 6.15 (s, 1H), 2.84 (s, 3H), 1.25 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 160.8, 155.9, 152.1, 144.4, 144.1, 142.4, 142.3, 141.1, 140.6, 140.3, 139.4, 132.7, 132.6, 132.5, 130.6, 129.9, 128.9, 128.4, 128.3, 128.1, 127.8, 127.7, 127.6, 127.4, 127.2, 127.1, 126.9, 126.9, 126.2, 126.2, 125.2, 123.2, 123.2, 119.2, 115.6, 115.4, 114.9, 114.7, 81.9, 64.8, 20.6, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{35}FO$ $[M+H]^+$:647.2750; found: 647.2752.

2-(4-chlorophenyl)-5,11-dimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1- g]chromene (150c): Following general experimental procedure 5.6b; yield: 152 mg (65%) as white solid; mp 252-254 ºC. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.91 (d, J = 8 Hz, 1H), 7.65 (d , J = 1.5 Hz, 11 1H), 7.52 (t, J = 1 Hz, 3H), 7.33 (d, J = 2 Hz, 2H), 7.31 (d, J = 8 Hz, 2H), 7.28 (d,J = 3 Hz, 2H), 7.25-7.24 (m, 2H), 7.18-7.15 (m, 4H), 7.13 (d, J = 2 Hz, 2H), 7.13 (d, J = 3 Hz, 2H),

7.11-7.10 (m, 3H), 7.09-7.07 (m, 4H), 6.10 (s, 1H), 2.80 (s, 3H), 2.16 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.9, 151.8, 144.8, 144.3, 143.4, 142.3, 142.2, 140.9, 140.5, 140.4, 140.0, 132.1, 131.4, 130.8, 130.0, 129.4, 129.2, 128.9, 128.9, 128.3, 128.2, 127.7, 127.6, 127.5, 127.3, 127.1, 127.0, 126.8, 126.6, 126.3, 126.2, 125.2, 123.3, 123.1, 119.2, 81.5, 64.8, 20.6, 12.8 ppm. HRMS(ESI-TOF): m/z calcd. for C48H35ClO $[M+Na]^+$:685.2273; found 685.2257.

2-(3,4-dichlorophenyl)-5,11-dimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g] chromene (150d): Following general experimental procedure 5.6b; yield: 155 mg (63%) as white solid; mp 260-261°C. 1H NMR (CDCl3, 500 MHz): δ 7.95 (d, J = 8 Hz, 1H), 7.56 (d, J = 7.5 Hz, 2H), 7.51 (d, J = 8.5 Hz, 2H), 7.36-7.27 (m, 6H), 7.19 (d, J = 5 Hz, 5H), 7.16-7.11 (m, 11H), 6.11 (s, 1H), 2.84 (s, 3H), 1.25 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 100 MHz): δ 156, 152.1, 144.2, 144.1, 143, 142.4, 142.3, 141, 140.5, 140.3, 139.6, 133.2, 130.7, 130.2, 129.8, 129.7, 129, 128.9, 128.7, 128.7, 128.6, 128.6, 128.5, 128.4, 128.4, 128.3, 128.2, 128.1, 127.7, 127.6, 127.5, 127.4, 127.3, 127.1, 127.1, 127, 126.9, 126.3, 126.2, 125.2, 123.3, 123.2,119.2, 81.9, 64.8, 20.6, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{34}Cl_2O$ $[M+H]^+$:697.2064; found: 697.2077.

2,2,5,11-tetramethyl-4,6,6-triphenyl-2,6-dihydroindeno[2,1-g]chromene(150e): Following general experimental procedure 5.6b; yield: 126 mg (71%) as white solid; mp 263-265°C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.98 (d, J = 8Hz, 1H), 7.34-7.28 (m, 7H), 7.22-7.16 (m, 11H), 7.07-7.05 (m, 2H), 5.74 (s, 1H), 2.74 (s, 3H), 1.54 (s, 6H), 1.31 (s, 3H) ppm. 13C NMR (CDCl3, 125 MHz): δ 155.9, 152.8, 143.4, 142.6, 142.1, 140.9, 139.8, 136.9, 132.1, 130.4, 129.1, 128.1, 127.6, 127.1, 127.1, 126.9, 126.6, 126.2, 125.2, 123.1, 122.4, 119.8, 64.4, 26.4, 20.7, 12.5 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{38}H_{32}O[M+H]^+$:505.2531; found: 505.2528.

5,11-dimethyl-2,2,6,6-tetraphenyl-4-(p-tolyl)-2,6-dihydroindeno[2,1-g]chromene (150f): Following general experimental procedure 5.6b; yield: 159 mg (70%) as white solid; mp 270-272°C. 1H NMR (CDCl3, 400 MHz): δ 7.97 (d, J = 8.4 Hz, 1H), 7.60 (d, J = 8 Hz, 4H), 7.36-7.27 (m, 8H), 7.20-7.12 (m, 13H), 7.01 (d, J = 8 Hz, 2H), 6.25 (s, 1H), 2.89 (s, 3H), 2.32 (s, 12 3H), 1.31 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 152.4, 144.6, 143.8, 142.5, 140.7, 139.1, 138.4, 136.8, 130.6, 130.5, 129.1, 128.9, 127.9, 127.6, 127.3, 127.2, 127.1,

127.1, 126.9, 126.1, 125.2, 123.3, 123.2, 119.3, 82.3, 64.8, 21.1, 20.6, 12.9 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{49}H_{38}O[M+H]^+$:643.3000; found: 643.3000.

4-cyclopropyl-5,11-dimethyl-2,2,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g]chromene (150g): Following general experimental procedure 5.6b; yield:144 mg (69%) as yellow solid; mp 236-237°C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.80 (d, J = 7.5 Hz, 1H), 7.36-7.34 (m, 4H), 7.20 (t, J = 1 Hz, 1H), 7.19 (d, J = 1.5 Hz, 2H), 7.18-7.17 (m, 3H), 7.15-7,10 (m, 3H), 7.06-7.02 (m, 10H), 5.76 (s, 1H), 2.68 (s, 3H), 2.00 (s, 3H), 0.82-0.76 (m, 1H), 0.71-0.67 (m, 2H), 0.59-0.56 (m, 2H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 155.9, 151.4, 144.9, 143.6, 142.8, 140.7, 139.6, 139.5, 130.0, 129.1, 127.8, 127.7, 127.1, 127.1, 126.9, 126.1, 125.1, 125.1, 124.8, 123.1, 119.2, 81.9, 64.8, 19.9, 15.5, 12.8, 10.1 ppm. HRMS (ESITOF): m/z calcd. for $C_{45}H_{36}O[M+H]^+$:593.2844; found: 593.2844.

6-(4-chlorophenyl)-4-cyclopropyl-5,11-dimethyl-2,2,6-triphenyl-2,6-dihydroindeno[2,1-g]chromene (150h): Following general experimental procedure 5.6b; yield: 122 mg (65%) as white solid; mp 240-241°C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.80 (d, J = 7.6 Hz, 1H), 7.35 (d, J = 8 Hz, 4H), 7.19-7.13 (m, 8H), 7.08-7.06 (m, 4H), 7.04-6.99 (m, 6H), 5.90 (s, 1H), 2.67 (s, 3H), 1.47 (s, 3H), 0.80-0.76 (m, 1H), 0.72-0.70 (m, 2H), 0.59-0.54 (m, 2H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): 155.4, 151.6, 144.9, 144.8, 143.2, 142.3, 141.5, 140.6, 139.5, 139.4, 131.9, 130.5, 130.1, 129.8, 128.9, 128.2, 127.8, 127.2, 127.1, 126.9, 126.3, 125.2, 125.1, 124.9, 123.2, 119.3, 82.1, 64.3, 19.5, 15.5, 12.8, 10.1, 10.1 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{45}H_{35}ClO$ $[M+H]^+$:627.2454; found: 627.2459.

6-(4-chlorophenyl)-5,11-dimethyl-2,2,4,6-tetraphenyl-2,6-dihydroindeno[2,1- g]chromene (150i): Following general experimental procedure 5.6b; yield: 138 mg (66%) as white solid; mp 256-257 °C. 1H NMR (CDCl3, 500 MHz): δ 7.97 (d, J = 8 Hz, 1H), 7.61 (d, J = 7.5 Hz, 4H), 7.37-7.05 (m, 23H), 6.28 (s, 1H), 2.89 (s, 3H), 1.28 (s, 3H) ppm. 13C NMR (CDCl3, 125 MHz): δ 155.5, 152.5, 144.5, 144.4, 143.4, 142.1, 141.3, 141.2, 140.6, 140.1, 139.1, 132.1, 131.1, 130.4, 128.8, 128.3, 128.1, 127.8, 127.4, 127.3, 127.2, 13 127.2, 127.1, 127.1, 127.1, 126.4, 125.1, 123.4, 123.3, 119.5, 82.3, 64.3, 20.6, 12.9 ppm. HRMS (ESI-TOF): m/z calcd. for C48H35ClO $[M+H]^+$:663.2454; found: 663.2456.

2-(3,4-dichlorophenyl)-5,8,11-trimethyl-2,6,6-triphenyl-4-(p-tolyl)-2,6-dihydroindeno [2,1-g] chromene (150j): Following general experimental procedure 5.6b; yield: 166 mg (68%) as yellow solid; mp 246-247 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.81 (d, J =8.5 Hz, 1H), 7.67 (d, J = 1 Hz, 1H), 7.54-7.53 (m, 2H), 7.36-7.33 (m, 3H), 7.29-7.28 (m, 2H), 7.18-7.10 (m, 12H), 7.06 (d, J = 8 Hz, 2H), 7.00 (d, 2H), 6.08 (s, 1H), 2.80 (s, 3H), 2.29 (s, 3H), 2.28 (s, 3H), 1.26 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.2, 151.8, 145.1, 144.1, 142.5, 142.5, 139.9, 138.1, 137.9, 137.4, 137.2, 132.2, 131.4, 130.8, 129.9, 129.3, 128.9, 128.8, 128.1, 127.7, 127.7, 127, 126.9, 126.7, 126.2, 126.2, 125.8, 123.1, 122.7, 118.7, 81.5, 64.7, 21.6, 21.1, 20.6, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{50}H_{38}Cl_2O[M+Na]^+$:747.2197; found: 747.2197.

2-(4-chlorophenyl)-5,8,11-trimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g] hromene (150k): Following general experimental procedure 5.6b; yield:150 mg, (66%) as white solid; 262-264 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): 7.84 (d, J = 8.5 Hz, 1H), 7.59-7.57 (m, 2H), 7.54-7.53 (m, 2H), 7.37-7.34 (2H), 7.31-7.28 (m, 4H), 7.21-7.17 (m, 12H), 7.14-7.12 (m, 4H), 6.19 (s, 1H), 2.84 (s, 3H), 2.29 (s, 3H), 1.26 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.1, 152.1, 144.2, 144.1, 143.1, 142.6, 142.5, 141.1, 140.4, 139.5, 137.9, 137.3, 133.1, 131.4, 130.5, 129.9, 129.2, 128.9, 128.6, 128.6, 128.4, 128.2, 128.1, 127.9, 127.7, 127.6, 127.6, 127.4, 127.2, 127.1, 126.8, 126.2, 126.1, 125.8, 123.1, 122.7, 118.7, 81.8, 64.6, 21.6, 20.6, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{49}H_{37}ClO$ $[M+H]^+$:677.2611; found: 677.2611.

2-(3,4-dichlorophenyl)-5,8,11-trimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g]chromene (150l): Following general experimental procedure 5.6b; yield:163 mg (68%) as yellow solid; mp 251-253 °C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.81 (d, J = 8.8 Hz, 1H), 7.56 (d, J = 1.2 Hz, 2H), 7.53 (d, J = 10 Hz, 2H), 7.52-7.49 (m, 3H), 7.36-7.32 (m, 5H), 7.29-7.27 (m, 2H), 7.18-7.14 (m, 6H), 7.10 (d, J = 6.4 Hz, 5H), 6.15 (s, 1H), 2.81 (s, 3H), 2.27 (s, 3H), 1.22 (s, 3H) ppm. 13C NMR (CDCl3, 100 MHz): δ 156.1, 152.1, 144.2, 143.9, 143.1, 142.6, 142.5, 141.1, 140.4, 139.6, 137.9, 137.2, 133.1, 130.5, 129,9, 129.1, 128.9, 128.6, 128.5, 128.2, 128.1, 127.9, 127.6, 127.5, 127.4, 127.1, 127.1, 126.8, 126.5, 14 126.1, 126.1, 125.7, 122.9, 122.7, 118.7, 81.8, 64.6, 21.6, 20.5, 12.8 ppm. HRMS (ESITOF): m/z calcd. for $C_{49}H_{36}Cl_2O[M+H]^+$:711.2221; found: 711.2222.

5,8,11-trimethyl-2,2,4,6,6-pentaphenyl-2,6-dihydroindeno[2,1-g]chromene(150m):
Following general experimental procedure 5.6b; yield: 158 mg (73%) as yellow solid; mp 263-264°C. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.84 (s, 1H), 7.59 (d, J = 7.2 Hz, 2H), 7.28 (t, J = 6.8 Hz, 5H), 7.23-7.21 (m, 3H), 7.13 (d, J = 12.4 Hz, 6H), 7.10-7.06 (m, 11H), 6.17 (s, 1H), 2.79 (s, 3H), 2.23 (s, 3H), 1.19 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.1, 151.2, 143.5, 142.7, 141.6, 140.3, 139.2, 138.1, 137.1, 136.1, 129.6, 129.4, 129.1, 128.1, 127.9, 127.2, 127.1, 127.1, 126.8, 126.7, 126.6, 126.5, 126.1, 126.1, 125.9, 125.1, 124.7, 121.9, 121.7, 117.7, 81.1, 63.6, 20.5, 19.5, 11.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{49}H_{38}O[M+H]^+$:643.3000; found: 643.2996.

6-(4-chlorophenyl)-2-(4-fluorophenyl)-5,11-dimethyl-2,4,6-triphenyl-2,6-dihydroindeno [2,1 -g]chromene (150n)*:* Following general experimental procedure 5.6b; yield: 135 mg (63%) as white solid; 232-236 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.95 (d, J = 8 Hz, 1H), 7.58-7.54 (m, 4H), 7.36-7.22 (m, 6H), 7.20-7.16 (m, 9H), 7.13-7.09 (m, 4H), 7.09-7.01 (m, 3H), 6.21 (s, 1H), 2.85 (s, 3H), 1.26 (s, 3H) ppm.^{13}C NMR ($CDCl_3$, 125 MHz): δ 163.2, 160.8, 155.4, 152.3, 144.3, 143.5, 141.9, 141.2, 141.1, 140.5, 140.2, 139.3, 132.1, 130.8, 130.5, 130.4, 129.1, 128.9, 128.8, 128.7, 128.3, 128.1, 127.8, 127.5, 127.3, 127.2, 127.1, 126.9, 126.4, 125.1, 123.3, 119.4, 114.9, 114.7, 82.1, 64.3, 20.6, 12.8 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{34}ClFO$ $[M+H]^+$:681.2360; found: 681.2372.

5',11'-dimethyl-6',6'-diphenyl-4'-(p-tolyl)-6'H-spiro[fluorene-9,2'-indeno[2,1-g]chromene] (150o): Following general experimental procedure 5.6b; yield 153 mg (70%) as colorless sticky solid. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.88 (d, J = 8 Hz, 1H), 7.66 (d, J = 7.5 Hz, 2H), 7.42-7.37 (m, 4H), 7.35 (t, J = 2 Hz, 1H), 7.31 (t, J = 2 Hz, 2H), 7.29 (d, J = 2 Hz, 1H) 7.27 (d, J = 7.5 Hz, 2H) 7.24-7.23 (m, 4H), 7.22-7.20 (m, 2H), 7.20-7.14 (m, 3H), 7.05-7.00 (m, 4H), 5.94 (s, 1H), 2.50 (s, 3H), 2.29 (s, 3H), 1.44 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 154.9, 154.5, 146.5, 143.3, 143.1, 140.7, 140.6, 140.1, 139.7, 139.6, 139.5, 138.4, 137.1, 131.9, 130.5, 130.5, 130.3, 129.7, 129.6, 129.6, 129.1, 128.8, 128.1, 128.1, 128.1, 127.9, 127.5, 127.4, 126.9, 126.6, 124.9, 123.5, 120.5, 15 119.9, 84.3, 64.3, 21.1, 20.8, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{49}H_{36}O$ $[M+H]^+$:641.2844; found: 641.2840.

5',8',11'-trimethyl-4',6',6'-triphenyl-6'H-spiro[fluorene-9,2'-indeno[2,1-g]chromene] (150p): Following general experimental procedure 5.6b; yield:142 mg (71%) as white solid; mp 262-264 ºC.^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.88 (d, J = 7.6 Hz, 1H), 7.67 (d, J = 8.8 Hz, 1H), 7.42-7.37 (m, 5H), 7.34 (d, J = 1.6 Hz, 1H), 7.32 (t, J = 6.8 Hz, 3H), 7.26 (d, J = 10.4 Hz, 3H), 7.21 (t, J = 2.4 Hz, 5H), 7.19 (s, 1H), 7.17 (d, J = 8 Hz, 1H), 7.14 (d, J = 7.6 Hz, 1H), 7.02-6.96 (m, 4H), 5.92 (s, 1H), 2.50 (s, 3H), 2.27 (s, 3H), 1.44 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.0, 146.7, 142.5, 140.7, 140.2, 139.6, 138.5, 136.8, 130.6, 129.5, 129.1, 128.9, 128.1, 127.7, 127.6, 127.3, 126.9, 126.3, 125.2, 125.1, 123.3, 120.1, 119.9, 84.2, 65.1, 21.1, 20.8, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{49}H_{36}O$ $[M+H]^+$:641.2844; found: 641.2844.

6'-(4-chlorophenyl)-5',11'-dimethyl-4',6'-diphenyl-6'H-spiro[fluorene-9,2'-indeno[2,1-g]chromene] (150q): Following general experimental procedure 5.6b; yield: 188 mg (72%) as colorless sticky. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.88 (d, J = 7.5 Hz, 1H), 7.67 (d, J = 7.5 Hz, 2H), 7.42- 7.38 (m, 4H), 7.29 (t, J = 7.5 Hz, 3H), 7.26 (d, J = 3.5 2H), 7.24 (d, J = 3 Hz, 3H), 7.22 (t, J = 8 Hz, 2H), 7.20-7.17 (m, 6H), 7.15 (d, J = 10 Hz, 1H), 7.12- 7.10 (m, 2H), 5.94 (s, 1H), 2.50 (s, 3H), 1.41 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.4, 154.3, 146.6, 146.5, 143.9, 142.1, 141.4, 141.3, 140.6, 140.2, 139.7, 132.1, 130.4, 130.3, 129.6, 128.8, 128.3, 128.2, 128.1, 127.9, 127.9, 127.4, 127.2, 127.1, 127.1, 126.5, 125.1, 124.9, 123.4, 123.2, 120.3, 119.9, 84.3, 64.5, 20.8, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{33}ClO$ $[M+H]^+$:661.2298; found: 661.2297.

***3-iodo-5,11-dimethyl-2,2,4,6,6-pentaphenyl-2,6-dihydroindeno[2,1-g]chromene*(151a):** Following general experimental procedure 5.6c; yield: 213 mg (80%) as white solid; mp 200-202 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.92 (d, J = 8 Hz, 1H), 7.53 (t, J = 4 Hz, 5H), 7.34-7.24 (m, 7H), 7.19 (t, J = 10.5 Hz, 2H), 7.17-7.04 (m, 9H), 7.01-6.91 (m, 5H) 2.80 (s, 3H), 0.95 (s, 3H) ppm.^{13}C NMR (CDCl3, 100 MHz): δ 155.5, 152.1, 144.6, 144.3, 143.5, 141.9, 141.1, 140.3, 140.2, 131.9, 130.3, 130.2, 130.1, 128.8, 128.7, 128.2, 127.9, 127.7, 127.5, 127.5, 127.2, 127.1, 127.1, 127.2, 126.3, 125.3, 125.1, 123.3, 119.1, 104.3, 16 88.3, 64.2, 19.6, 12.6 ppm. HRMS (ESI-TOF): m/z calcd. for C48H35IO $[M+Na]^+$:777.1630; found 777.1626.

3-iodo-5,11-dimethyl-2,2,6,6-tetraphenyl-4-(p-tolyl)-2,6-dihydroindeno[2,1-g]chromene (151b): Following general experimental procedure 5.6c; yield: 212 mg (78%) as sticky orange solid. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.93 (t, 2H), 7.53 (t, J = 7.5 Hz, 4H), 7.42-7.40 (m, 6H), 7.34-7.32 (m, 8H), 7.15-7.09 (m, 6H), 7.01 (t, J = 8 Hz, 2H), 3.77 (s, 3H), 2.80 (s, 3H), 0.98 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 158.7, 154.7, 144.7, 142.4, 141.4, 140.4, 140.3, 136.7, 132.6, 131.3, 129.7, 129.3, 128.8, 128.8, 128.7, 128.6, 128.4, 128.3, 128.3, 128.1, 127.9, 127.6, 127.5, 127.1, 126.1, 125.4, 125.4, 125.2, 124.1, 123.2, 118.7, 113.1, 103.8, 88.3, 64.7, 29.7, 19.7, 12.6 ppm. HRMS (ESITOF): m/z calcd. for $C_{49}H_{37}IO$ $[M+K]^+$:807.1526; found: 807.1774.

2-(4-chlorophenyl)-3-iodo-5,11-dimethyl-2,4,6,6-tetraphenyl-2,6-dihydroindeno[2,1-g]chromene (151c): Following general experimental procedure 5.6c; yield: 201 mg (72%) as yellow solid; mp 245-247 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.94-7.91 (m, 2H), 7.72-7.79 (m, 3H), 7.65-7.52 (m, 1H), 7.54-7.47 (m, 7H), 7.36-7.31 (m, 6H), 7.13- 7.10 (m, 6H), 7.03-7.01 (m, 3H), 2.80 (s, 3H), 0.97 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.1, 151.7, 145.2, 144.2, 144.1, 143.3, 142.2, 140.5, 140.2, 133.9, 132.6, 131.5, 130.7, 130.6, 130.2, 130.1, 129.9, 129.8, 129.7, 129.4, 129.1, 128.8, 128.7, 128.6, 128.4, 128.2, 128.1, 127.7, 127.6, 127.1, 126.2, 126.1, 125.2, 125.1, 123.3, 118.7, 103.2, 87.8, 64.6, 19.7, 12.6 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{34}ClIO$ $[M+H]^+$:789.1421; found: 789.1415.

2,2-bis(4-fluorophenyl)-3-iodo-5,11-dimethyl-4,6,6-triphenyl-2,6-dihydroindeno[2,1-g]chromene (151d): Following general experimental procedure 5.6c; yield:212 mg (76%) as yellow sticky solid.^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.93 (d, J = 7.5 Hz, 1H), 7.62-7.59 (m, 1H), 7.57 (d, J = 7.5 Hz, 3H), 7.51-7.49 (m, 3H), 7.40-7.39 (m, 3H), 7.29 (d, J = 3 Hz, 2H), 7.28 (d, J = 2 Hz, 3H), 7.22-7.17 (m, 1H), 7.13-7.10 (m, 5H), 7.08-7.02 (m, 5H), 2.80 (s, 3H), 0.99 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 163.4, 161.5, 156.1, 151.6, 144.1, 142.2, 140.3, 140.3, 131.8, 130.6, 130.5, 130.1, 129.7, 128.8, 128.5, 128.5, 128.4, 127.7, 127.6, 127.6, 127.1, 126.2, 125.2, 123.3, 115.1, 115.1, 114.6, 114.4, 103.5, 87.5, 64.7, 17 19.6, 12.6 ppm. HRMS(ESI-TOF): m/z calcd. for $C_{48}H_{33}F_2IO$ $[M+H]^+$:791.1622; found: 791.1617.

6-(4-chlorophenyl)-3-iodo-5,11-dimethyl-2,2,4,6-tetraphenyl2,6-dihydroindeno[2,1-g]chromene (151e): Following general experimental procedure 5.6c; yield:201 mg (81%) as yellow sticky solid. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.81-7.78 (m, 2H), 7.52- 7.50 (m, 1H), 7.49-7.45 (m, 3H), 7.43-7.42 (m, 4H), 7.40-7.30 (m, 12H), 7.15-7.11 (m, 4H), 7.02-7.00 (m,

2H), 2.80 (s, 3H), 0.97 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.1, 151.7, 145.2, 144.2, 144.1, 143.3, 142.2, 140.5, 140.2, 133.9, 133.7, 133.5, 132.7, 131.5, 130.7, 130.6, 130.2, 130.1, 129.9, 129.8, 129.8, 129.4, 129.1, 129.1, 128.8, 128.8, 128.7, 128.7, 128.5, 128.5, 128.4, 128.2, 128.1, 127.7, 127.7, 127.6, 127.6, 127.5, 127.1, 126.2, 126.2, 125.2, 125.1, 123.3, 118.8, 103.2, 87.8, 64.6, 19.7, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{34}ClIO$ $[M+H]^+$:789.1421; found: 789.1415.

6-(3,4-dichlorophenyl)-3-iodo-5,11-dimethyl-2,2,4,6-tetraphenyl-2,6-dihydroindeno[2,1-g] chromene (151f): Following general experimental procedure 5.6c; yield: 187 mg (80%) as yellow sticky solid. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.54-7.52 (m, 1H), 7.35-7.28 (m, 4H), 7.25-7.21(m, 7H), 7.18-7.11 (m, 5H), 7.09-7.05 (m, 5H), 6.98-6.96 (m, 2H), 6.94-6.91 (m, 2H), 2.80 (s, 3H), 0.95 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 155.5, 152.1, 144.9, 144.6, 144.6, 144.3, 143.5, 141.9, 141.2, 140.3, 140.3, 131.9, 130.4, 130.2, 128.9, 128.6, 128.3, 127.9, 127.7, 127.5, 127.5, 127.3, 127.2, 127.1, 126.3, 125.1, 123.4, 119.1,104.3, 88.3, 64.2, 19.7, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{48}H_{33}Cl_2IO$: 823.1031; found: 823.1025.

5,11-dimethyl-2,2,3,4,6,6-hexaphenyl-2,6-dihydroindeno[2,1-g]chromene (152): Following experimental procedure 5.6d; yield: 68 mg (73%) as white solid; 260-262 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.89 (d, J = 7.5 Hz, 1H), 7.51-7.49 (m, 5H), 7.31-7.29 (m, 4H), 7.25 (d, J = 7 Hz, 3H), 7.22 (d, J = 7.5 Hz, 3H), 7.19-7.16 (m, 4H), 7.14-7.10 (m, 4H), 7.07-7.03 (m, 6H), 7.0-6.96 (m, 4H), 2.77 (s, 3H), 1.53 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.1, 151.9, 145.1, 144.7, 144.3, 144.1, 142.3, 140.4, 140.3, 130.5, 130.2, 128.8, 128.8, 127.9, 127.6, 127.6, 127.5, 127.4, 127.4, 127.2, 127.1, 126.1, 125.2, 123.2, 18 118.8, 104.1, 88.2, 64.6, 19.7, 12.6 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{54}H_{40}O$ $[M+Na]^+$: 727.2976; found: 727.2977.

Ethyl3-(5,11-dimethyl-2,2,4,6,6-pentaphenyl-2,6-dihydroindeno[2,1-g]chromen-3-yl)acrylate (153): Following experimental procedure 5.6e; yield: 72 mg (75%) as yellow solid; mp 173-174°C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.92 (d, J = 8 Hz, 1H), 7.40-7.31 (m, 6H), 7.28- 7.20 (m, 11H), 7.10-6.99 (m, 12H), 5.01 (d, J = 16.5 Hz, 1H), 4.01-3.97 (q, J = 7 Hz, 2H), 2.75 (s, 3H), 1.58 (s, 3H), 1.12 (t, J = 9 Hz, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 167.1, 156.1, 153.1, 144.2, 143.5, 142.5, 142.3, 141.8, 141.2, 140.3, 139.1, 132.9, 132.1, 130.6, 129.1, 128.8, 127.9, 127.8, 127.6, 127.6, 127.1, 126.1, 126.1, 125.2, 125.1, 123.4,

121.3, 118.6, 87.3, 64.6, 59.9, 19.4, 14.1, 12.5 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{53}H_{42}O_3$ $[M+H]^+$:727.3212; found: 727.3214.

5,11-dimethyl-2,2,4,6,6-pentaphenyl-3-(phenylethynyl)-2,6-dihydroindeno[2,1-g]chromene (154): Following experimental procedure 5.6f; yield 67 mg (70%) as white solid; mp 115-116°C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.89 (d, J = 7.5 Hz, 1H), 7.53-7.49 (m, 6H), 7.36-7.28 (m, 9H), 7.24 (dd, J1 = 3 Hz, J1 = 1.5 Hz,4H), 7.18-7.16 (m, 5H), 7.06-7.03 (m, 6H), 6.98 (d, J = 1 Hz, 4H), 2.77 (s, 3H), 1.25 (s, 3H) ppm. ^{13}C NMR ($CDCl_3$, 125 MHz): δ 156.1, 151.9, 145.1, 144.7, 144.3, 144.1, 142.3, 140.4, 132.5, 130.5, 130.2, 129.2, 128.8, 128.8, 128.4, 128.3, 127.9, 127.7, 127.6, 126.5, 127.4, 127.4, 127.1, 126.1, 125.2, 123.2, 121.8, 118.8, 104.1, 88.2, 81.5, 73.9, 64.7, 19.7, 12.7 ppm. HRMS (ESI-TOF): m/z calcd. for $C_{56}H_{40}O$ $[M+Na]^+$:751.2976; found: 751.2978.

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5.9.1 SPECTRAL COPIES

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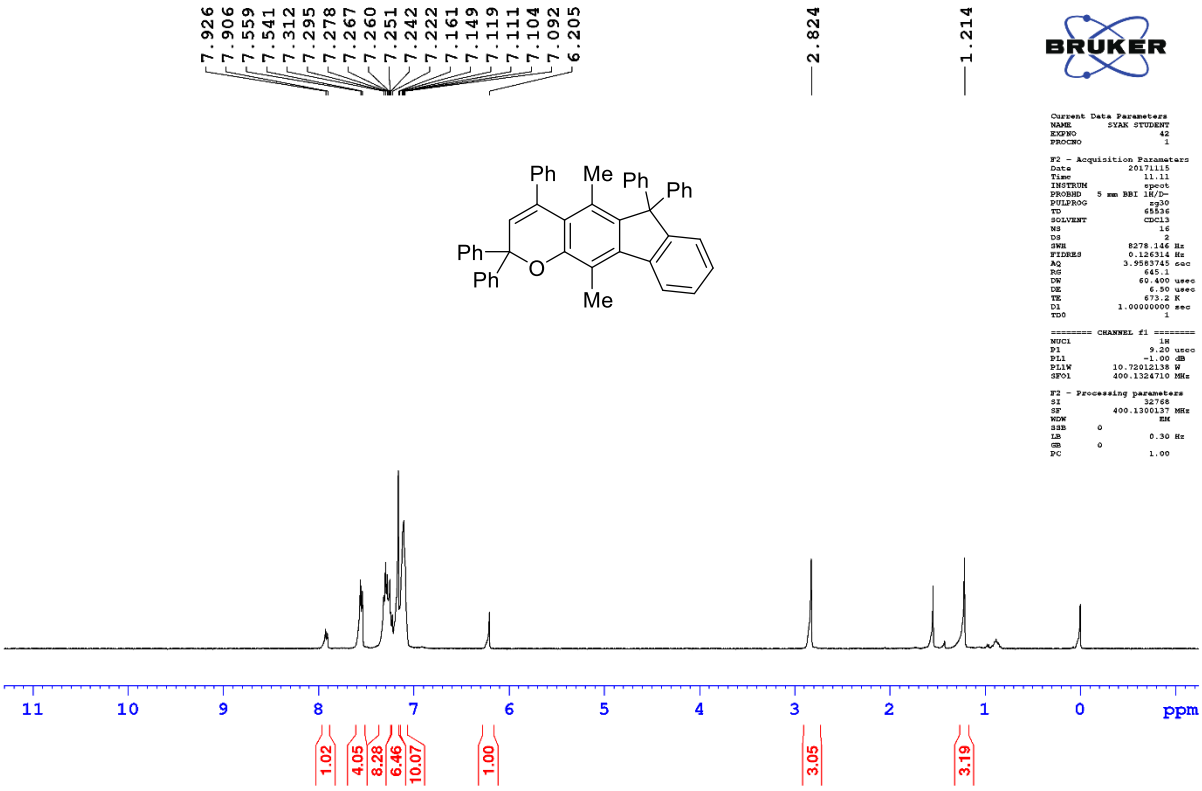

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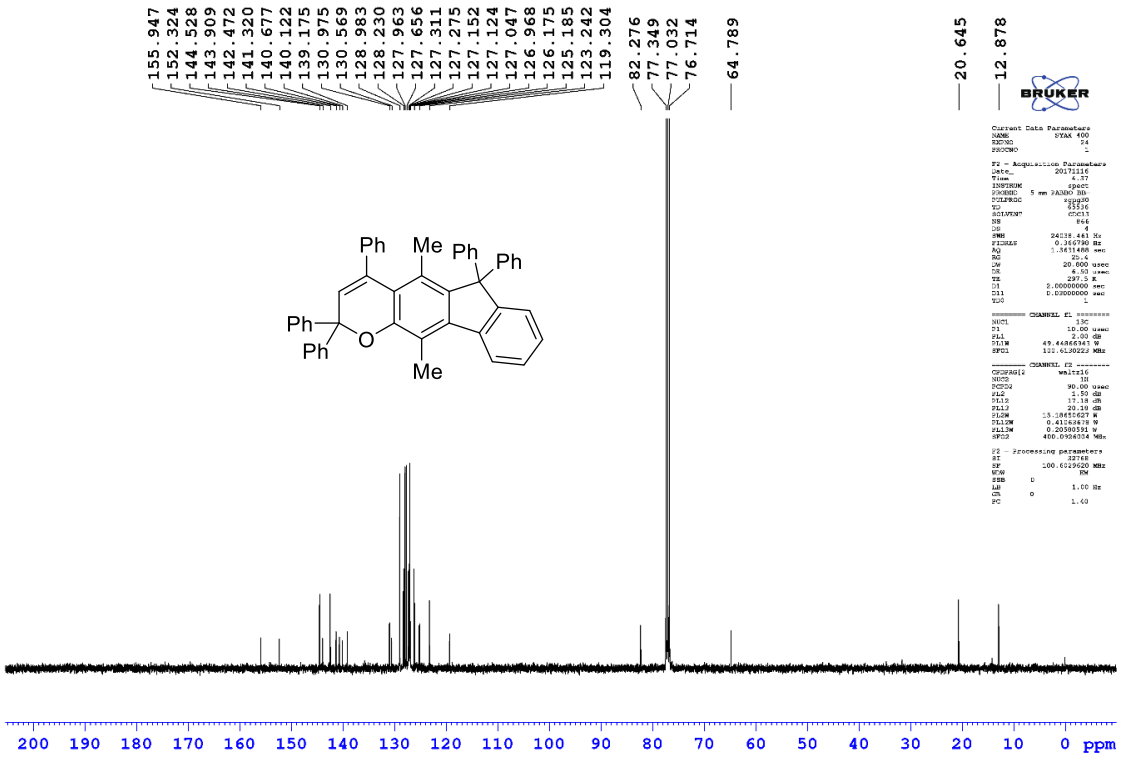

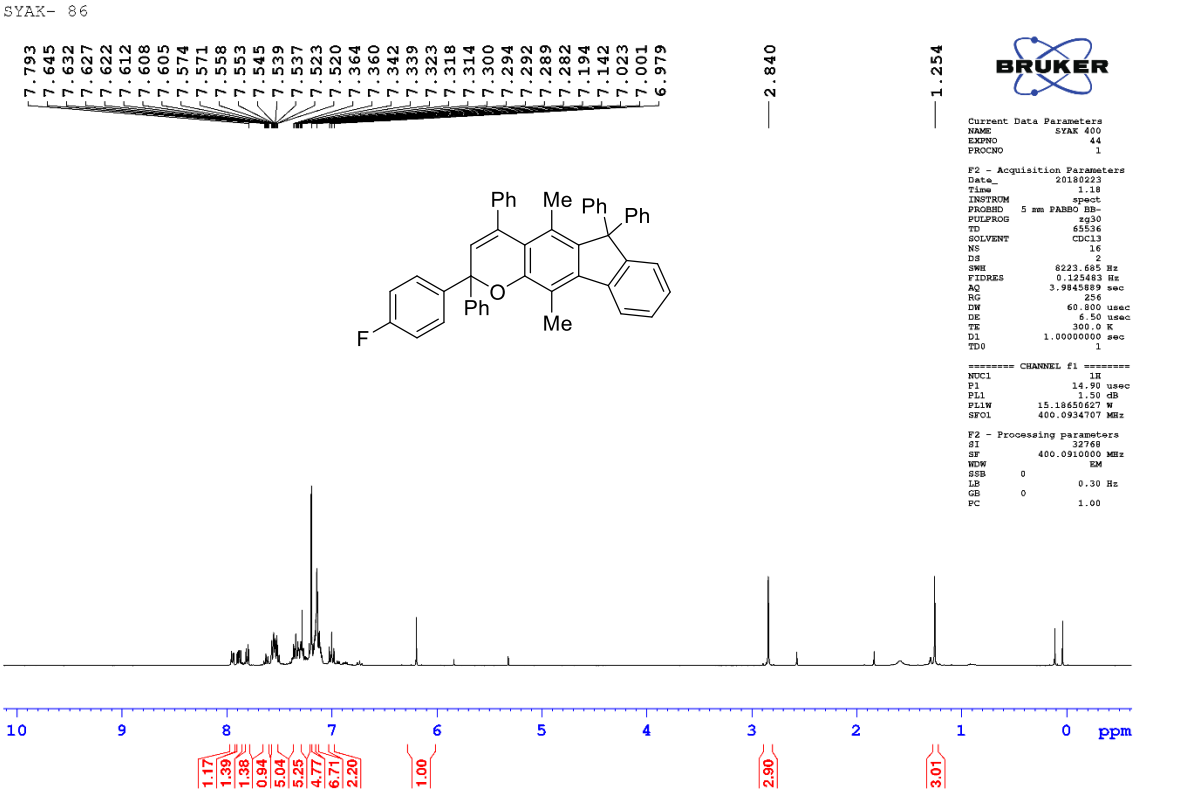
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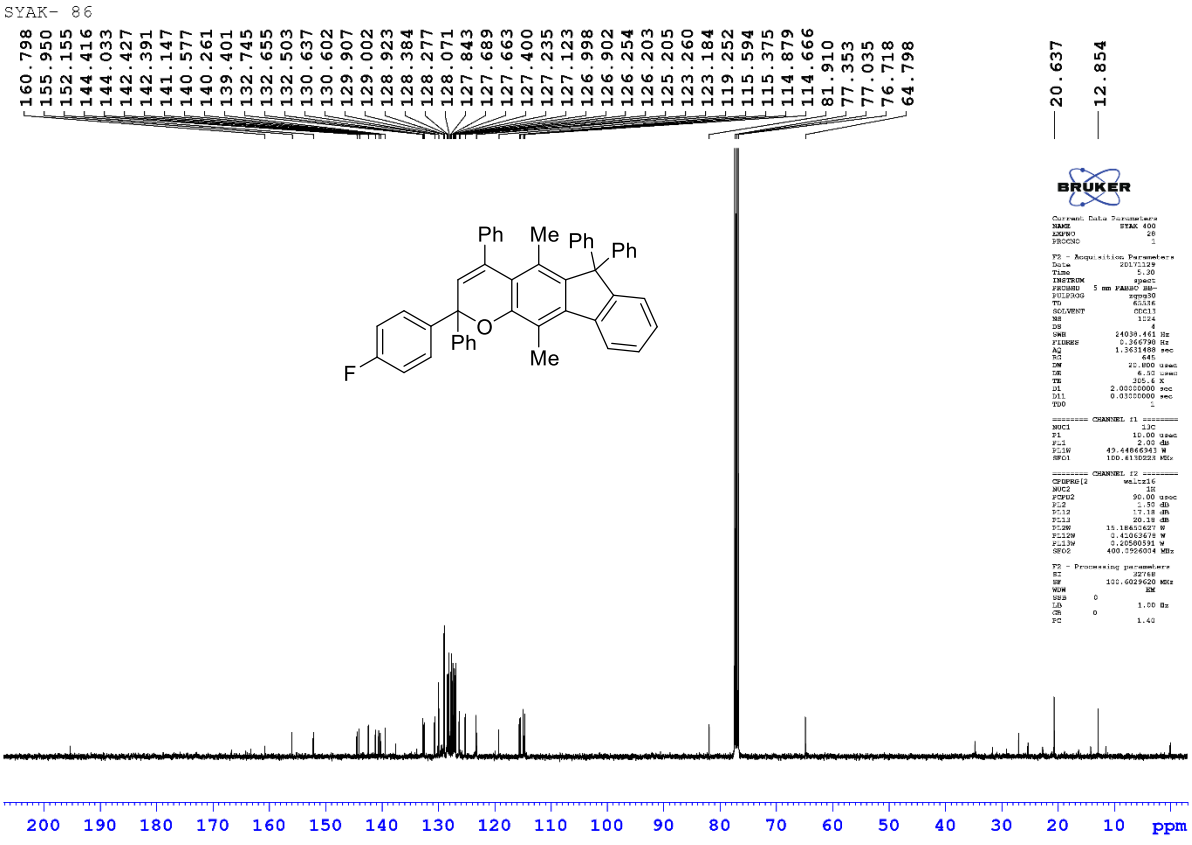
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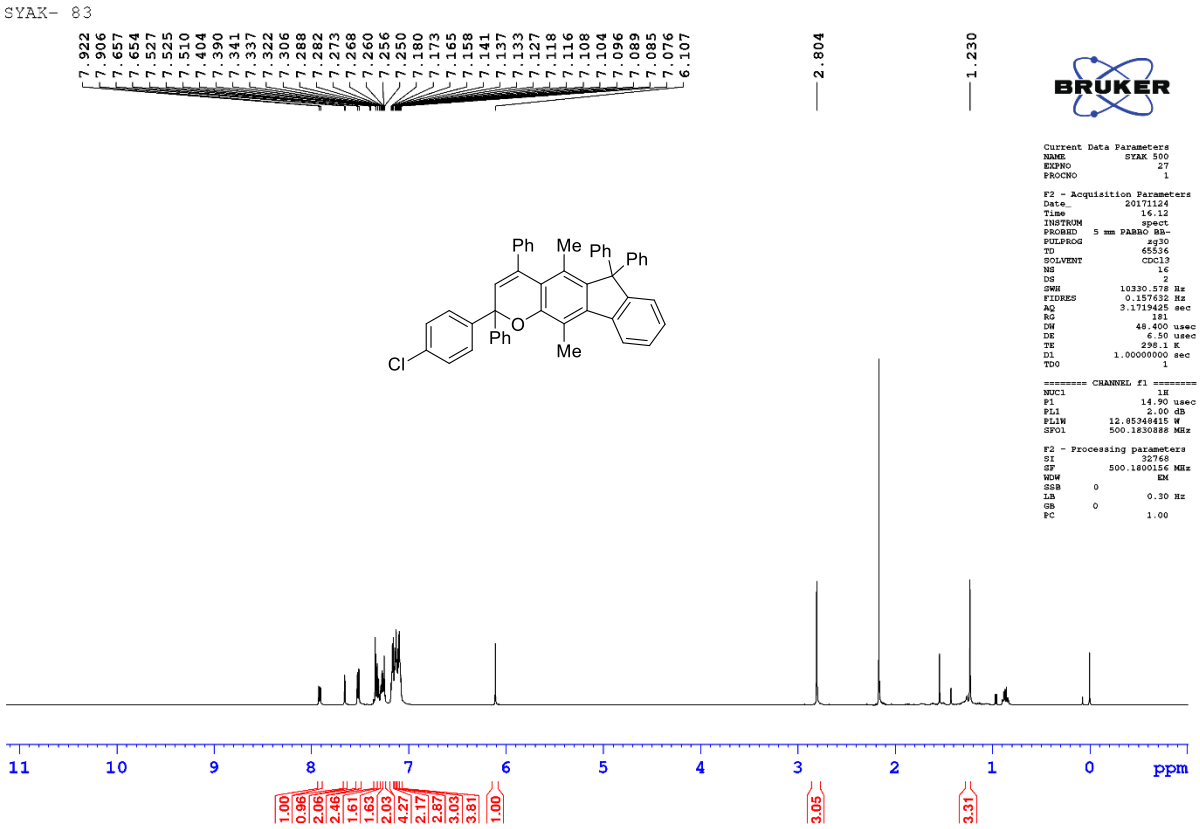
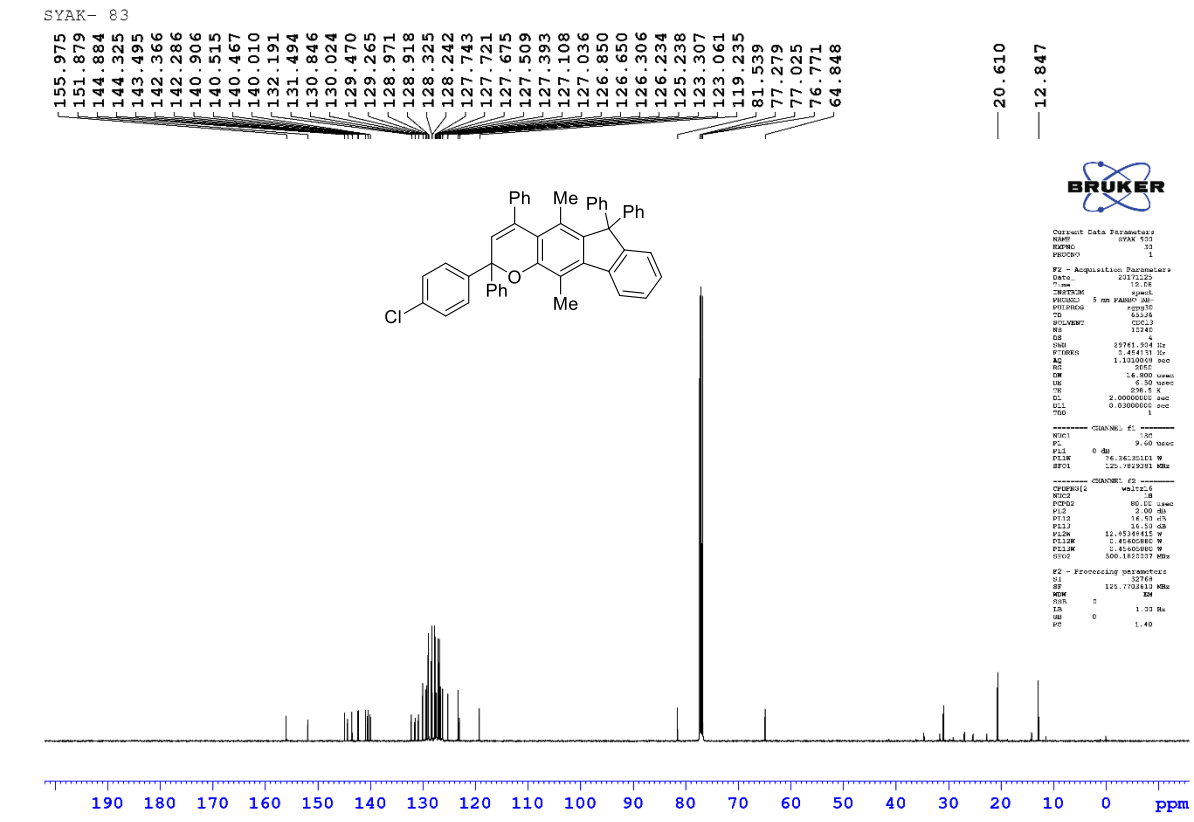
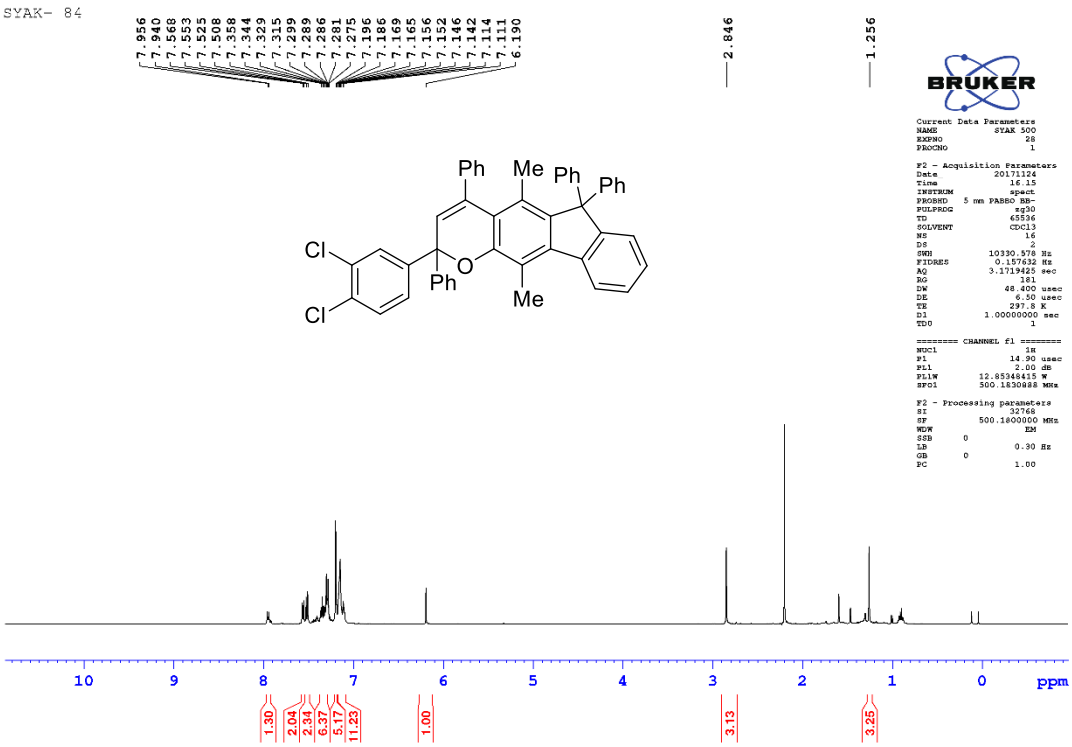
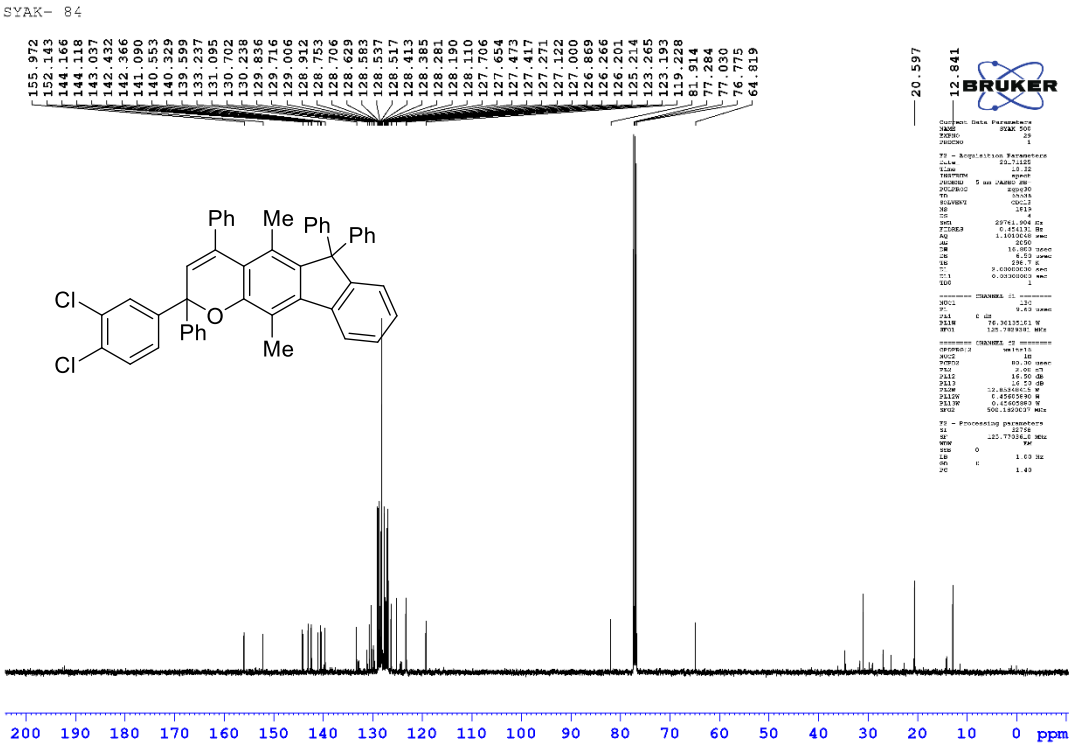
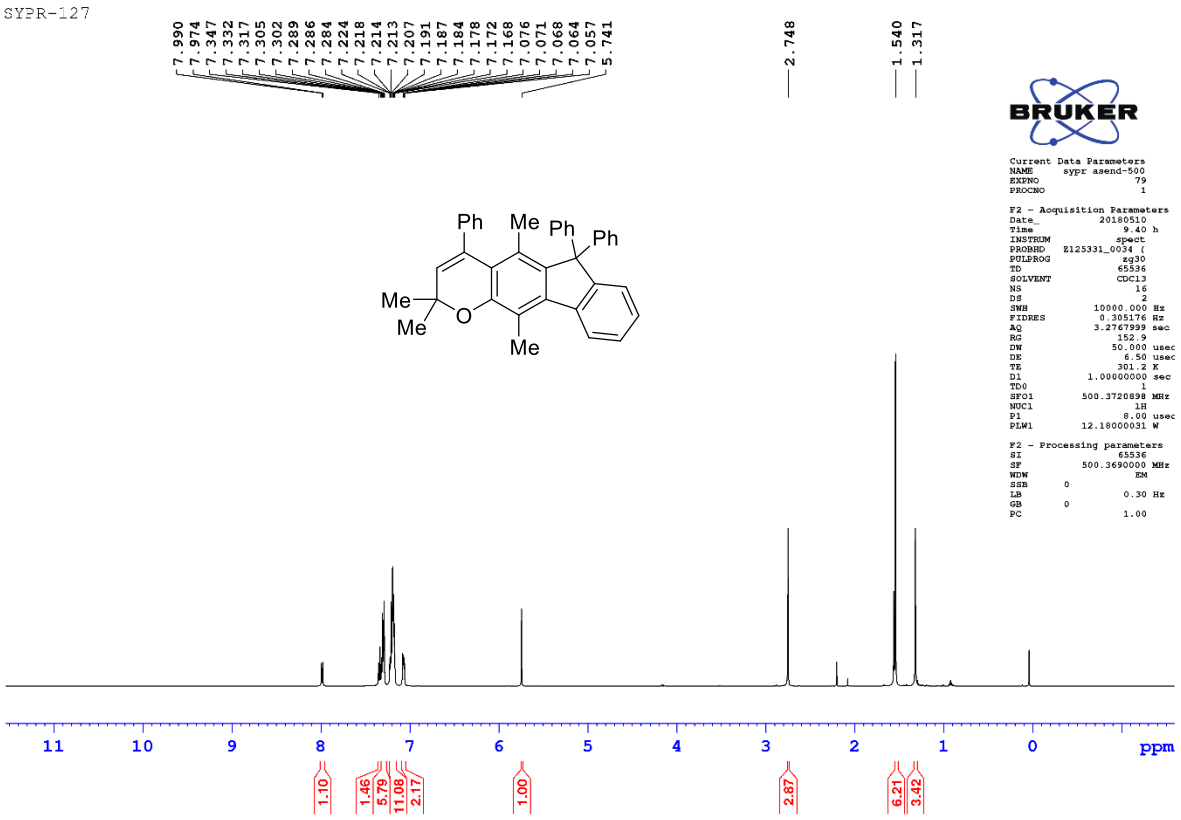
126.254
126.203
125.205
123.260
123.184
119.252
115.594
115.375
114.879
114.666
81.910
77.353
77.035
76.718
64.798
20.637
12.854
Ph
Me
Ph
Ph
O
Ph
Me
F
BRUKER
Current Data Parameters
NAME SYAK 400
EXPNO 26
PROCNO 1
F2 - Acquisition Parameters
Date_ 20171129
Time 5.30
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 1024
DS 4
SWH 24038.461 Hz
FIDRES 0.366790 Hz
AQ 1.3631488 sec
RG 645
DW 20.800 usec
DE 6.50 usec
TE 305.6 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 0.20500391 W
SFO2 400.0926034 MHz
F2 - Processing parameters
SI 32768
SF 100.6029620 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

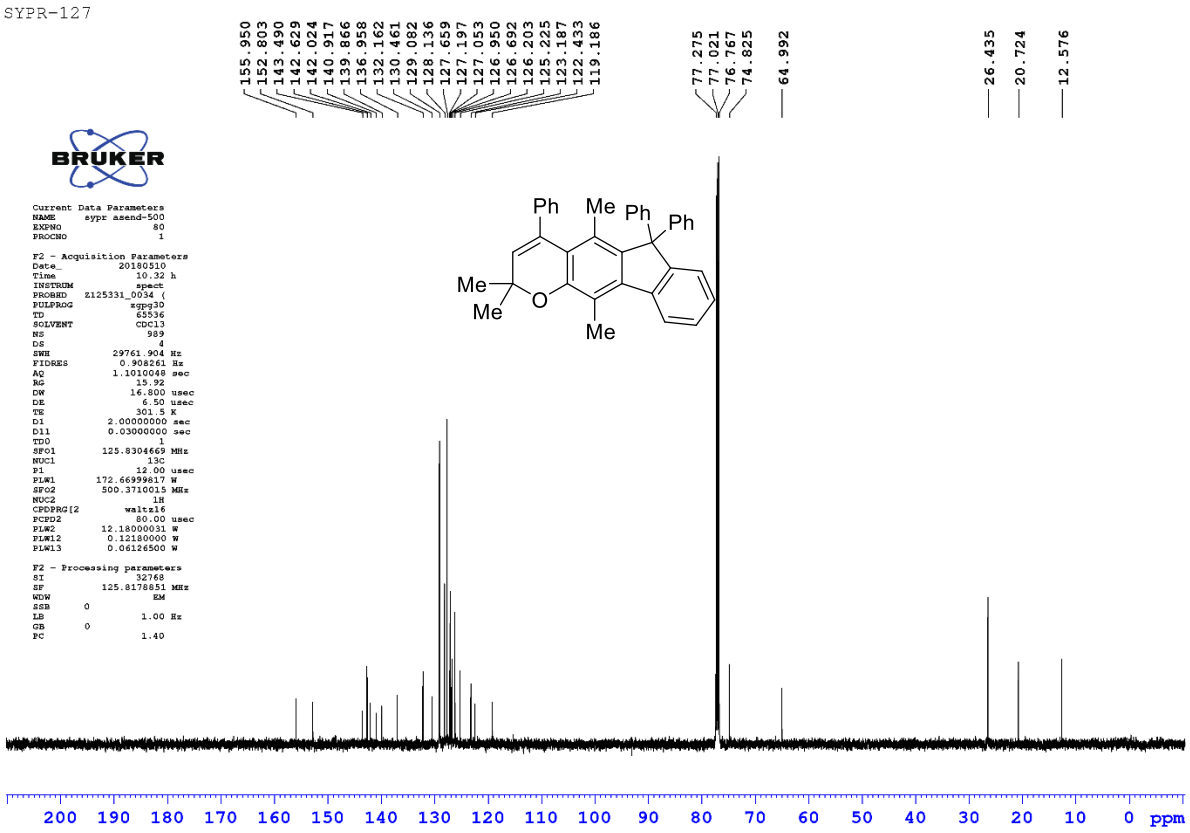

SYAK- 83
7.922
7.906
7.657
7.654
7.527
7.525
7.510
7.404
7.390
7.341
7.337
7.322
7.306
7.288
7.282
7.273
7.268
7.260
7.256
7.250
7.180
7.173
7.165
7.158
7.141
7.137
7.133
7.127
7.118
7.116
7.108
7.104
7.096
7.089
7.085
7.076
6.107
2.804
1.230
BRUKER
Ph
Me
Ph
Ph
Ph
O
Me
Cl
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.00
0.96
2.06
2.46
1.61
1.63
2.03
4.27
2.17
2.87
3.03
3.81
1.00
3.05
3.31

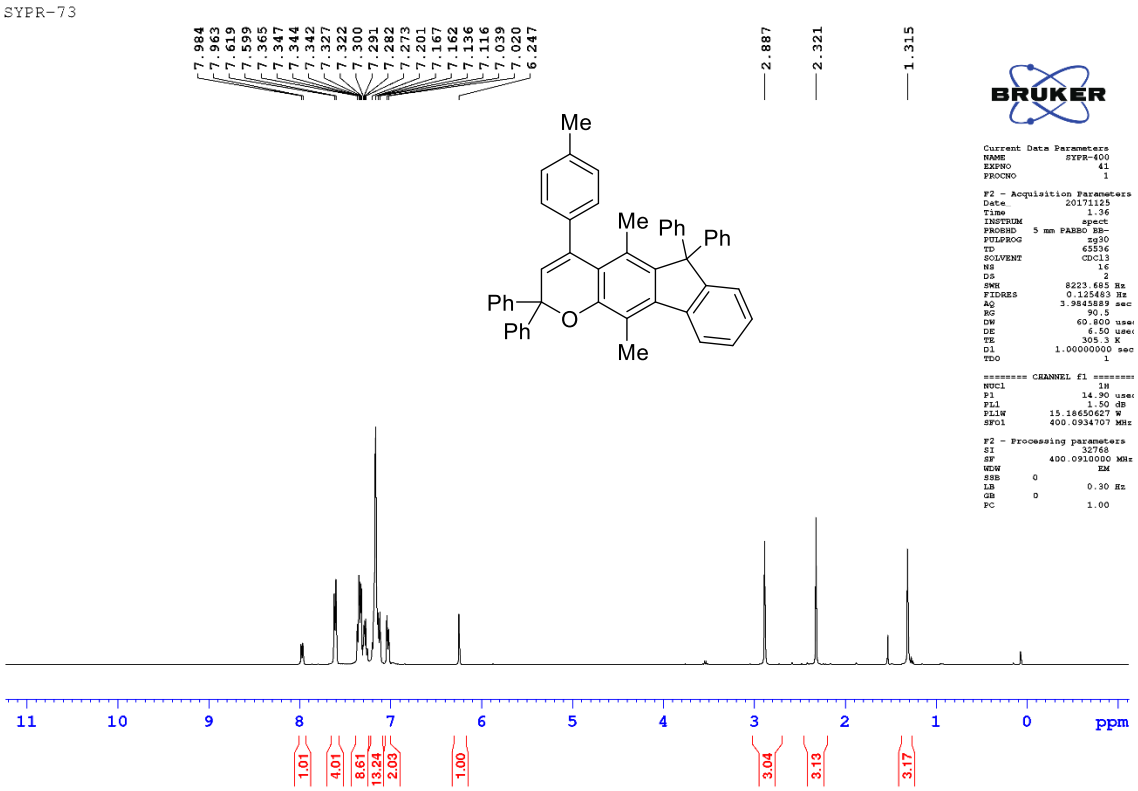

SYAK- 83
155.975
151.879
144.884
144.325
143.495
142.366
142.286
140.906
140.515
140.467
140.010
132.191
131.494
130.846
130.024
129.470
129.265
128.971
128.918
128.325
128.242
127.743
127.721
127.675
127.509
127.393
127.108
127.036
126.850
126.650
126.306
126.234
125.238
123.307
123.061
119.235
81.539
77.279
77.025
76.771
64.848
20.610
12.847
BRUKER
Ph
Me
Ph
Ph
Ph
O
Me
Cl
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

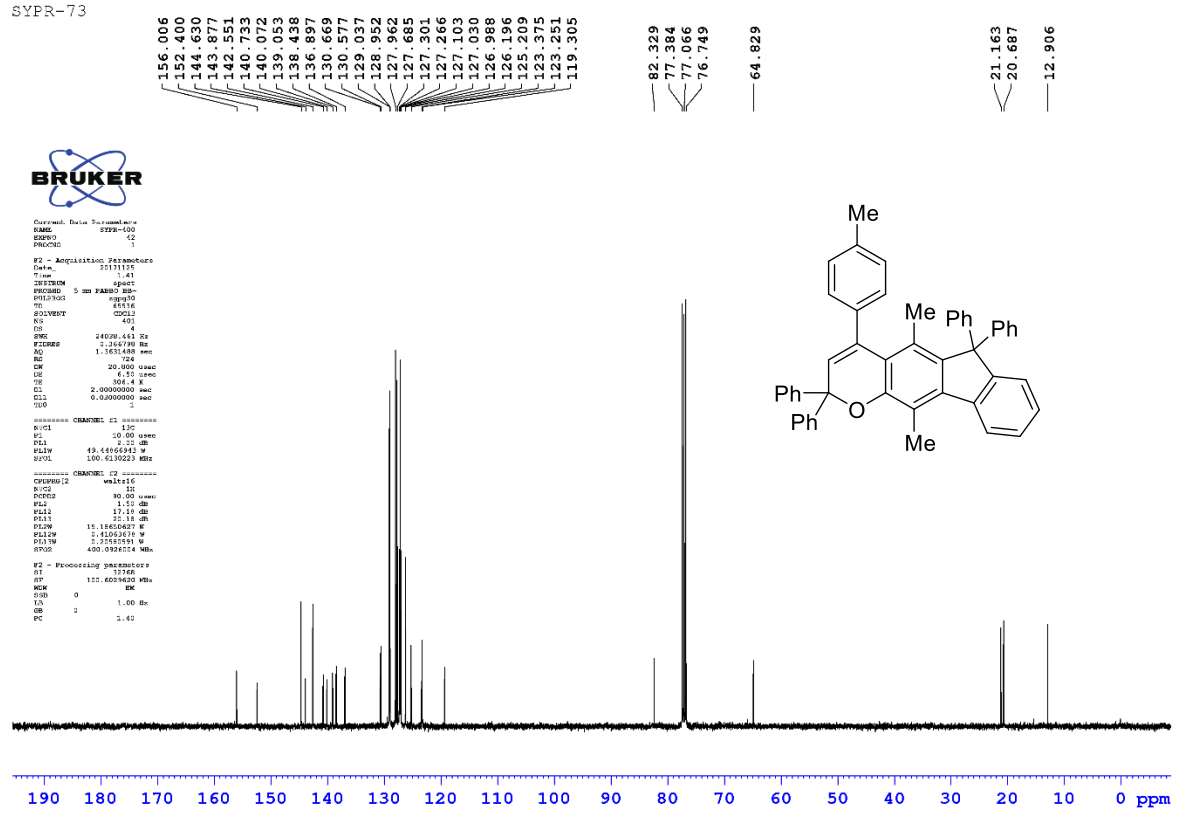

SYAK- 84
7.956
7.940
7.568
7.553
7.525
7.508
7.358
7.344
7.329
7.315
7.299
7.289
7.286
7.281
7.275
7.196
7.186
7.169
7.165
7.156
7.152
7.146
7.142
7.114
7.111
6.190
2.846
1.256
Ph
Me
Ph
Ph
Cl
Cl
O
Ph
Me
BRUKER
Current Data Parameters
NAME SYAK 500
EXPNO 28
PROCNO 1
F2 - Acquisition Parameters
Date 20171124
Time 16.15
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 181
DW 48.400 usec
DE 6.50 usec
TE 297.8 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 14.90 usec
PL1 2.00 dB
PL1W 12.85348415 W
SFO1 500.1830988 MHz
F2 - Processing parameters
SI 32768
SF 500.1800000 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
10
9
8
7
6
5
4
3
2
1
0
ppm
1.30
2.04
2.34
6.37
5.17
11.23
1.00
3.13
3.25


SYAK- 84
155.972
152.143
144.166
144.118
143.037
142.432
142.366
141.090
140.553
140.329
139.599
133.237
131.095
130.702
130.238
129.836
129.716
129.006
128.912
128.753
128.706
128.629
128.583
128.537
128.517
128.413
128.385
128.281
128.190
128.110
127.706
127.654
127.473
127.417
127.271
127.122
127.000
126.869
126.266
126.201
125.214
123.265
123.193
119.228
81.914
77.284
77.030
76.775
64.819
20.597
12.841
Ph
Me
Ph
Ph
Cl
Cl
O
Ph
Me
BRUKER
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

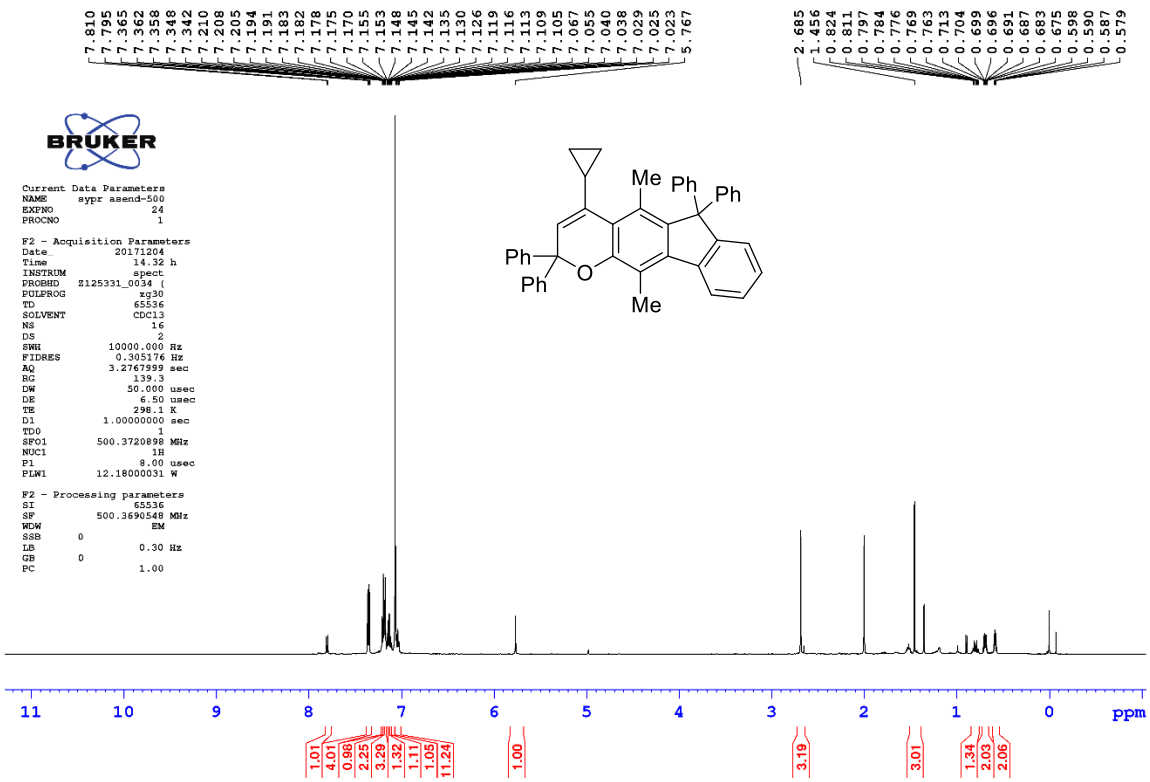

SYPR-127
7.990
7.974
7.347
7.332
7.317
7.305
7.302
7.289
7.286
7.284
7.224
7.218
7.214
7.213
7.207
7.191
7.187
7.184
7.178
7.172
7.168
7.076
7.071
7.068
7.064
7.057
5.741
2.748
1.540
1.317
Ph
Me
Ph
Ph
Me
Me
O
Me
Current Data Parameters
NAME sypr asend-500
EXPNO 79
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180510
Time 9.40 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 301.2 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
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.10
1.46
5.79
11.08
2.17
1.00
2.87
6.21
3.42


SYPR-127
155.950
152.803
143.490
142.629
142.024
140.917
139.866
136.958
132.162
130.461
129.082
128.136
127.659
127.197
127.053
126.950
126.692
126.203
125.225
123.187
122.433
119.186
77.275
77.021
76.767
74.825
64.992
26.435
20.724
12.576
Ph
Me
Ph
Ph
Me
Me
O
Me
Current Data Parameters
NAME sypr asend-500
EXPNO 80
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180510
Time 10.32 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG xgpg30
TD 65536
SOLVENT CDCl3
NS 989
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 15.92
DW 16.800 usec
DE 6.50 usec
TE 301.5 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 125.8178851 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

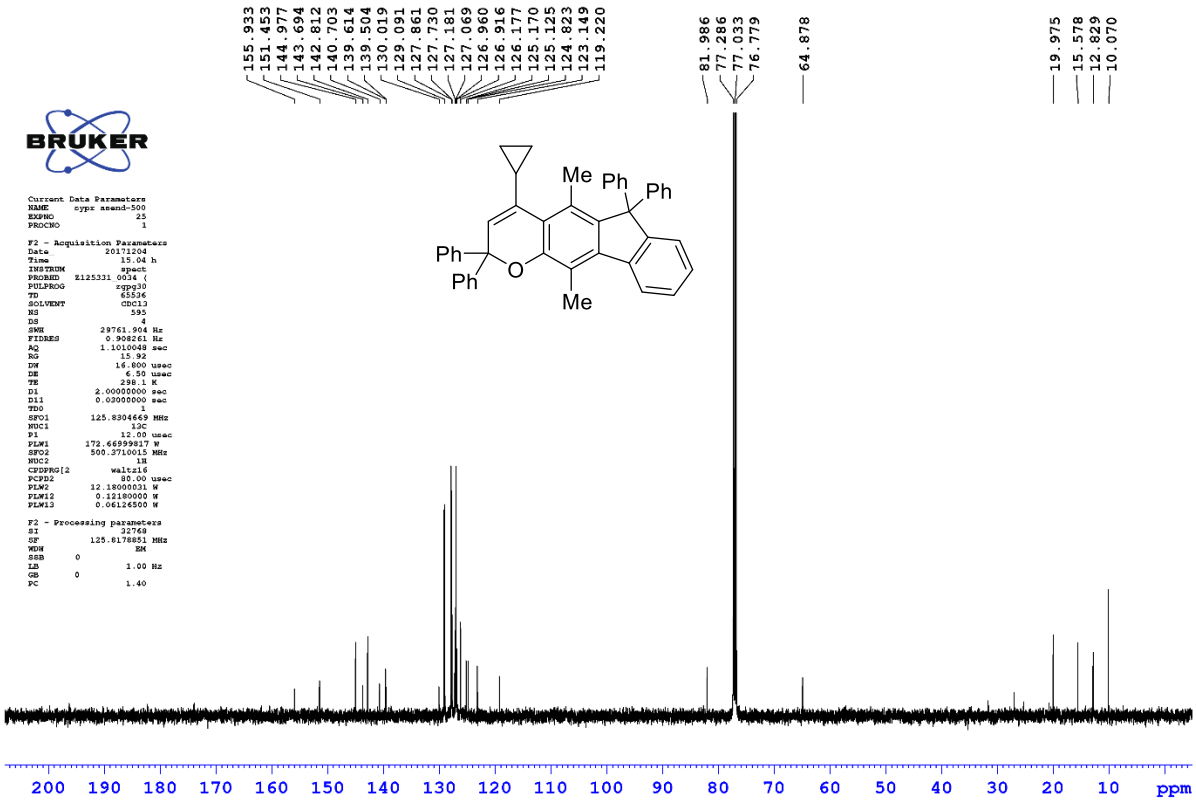

SYPR-73
7.984
7.963
7.619
7.599
7.365
7.347
7.344
7.342
7.327
7.322
7.300
7.291
7.282
7.273
7.201
7.167
7.162
7.136
7.116
7.039
7.020
6.247
2.887
2.321
1.315
Me
Me
Ph
Ph
Ph
Ph
O
Me
BRUKER
Current Data Parameters
NAME SYPR-400
EXPNO 41
PROCNO 1
F2 - Acquisition Parameters
Date_ 20171125
Time 1.36
INSTRUM 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 90.5
DW 60.800 use
DE 6.50 use
TE 305.3 K
D1 1.00000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 1H
P1 14.90 use
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
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.01
4.01
8.61
13.24
2.03
1.00
3.04
3.13
3.17


SYPR-73
156.006
152.400
144.630
143.877
142.551
140.733
140.072
139.053
138.438
136.897
130.669
130.577
129.037
128.952
127.962
127.685
127.301
127.266
127.103
127.030
126.988
126.196
125.209
123.375
123.251
119.305
82.329
77.384
77.066
76.749
64.829
21.163
20.687
12.906
BRUKER
Current Data Parameters
NAME SYPR-400
EXPNO 42
PROCNO 1
F2 - Acquisition Parameters
Date_ 20171125
Time 1.41
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 401
DS 4
SWH 24038.461 Hz
FIDRES 2.366798 Hz
AQ 1.1631488 sec
RG 724
DW 20.800 usec
DE 6.50 usec
TE 304.4 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
======== CHANNEL f1 ========
NUC1 13C
P1 10.00 usec
PL1 2.00 dB
PL1W 49.44666943 W
SFO1 100.6130223 MHz
======== CHANNEL f2 ========
CPDPRG[2 waltz16
NUC2 1H
PCPD2 90.00 usec
PL2 1.50 dB
PL12 17.19 dB
PL13 22.18 dB
PL2W 15.18650627 W
PL12W 2.41063676 W
PL13W 1.22585791 W
SFO2 400.0932674 MHz
F2 - Processing parameters
SI 32768
SF 100.6228430 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
Me
Me
Ph
Ph
Ph
Ph
O
Me
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

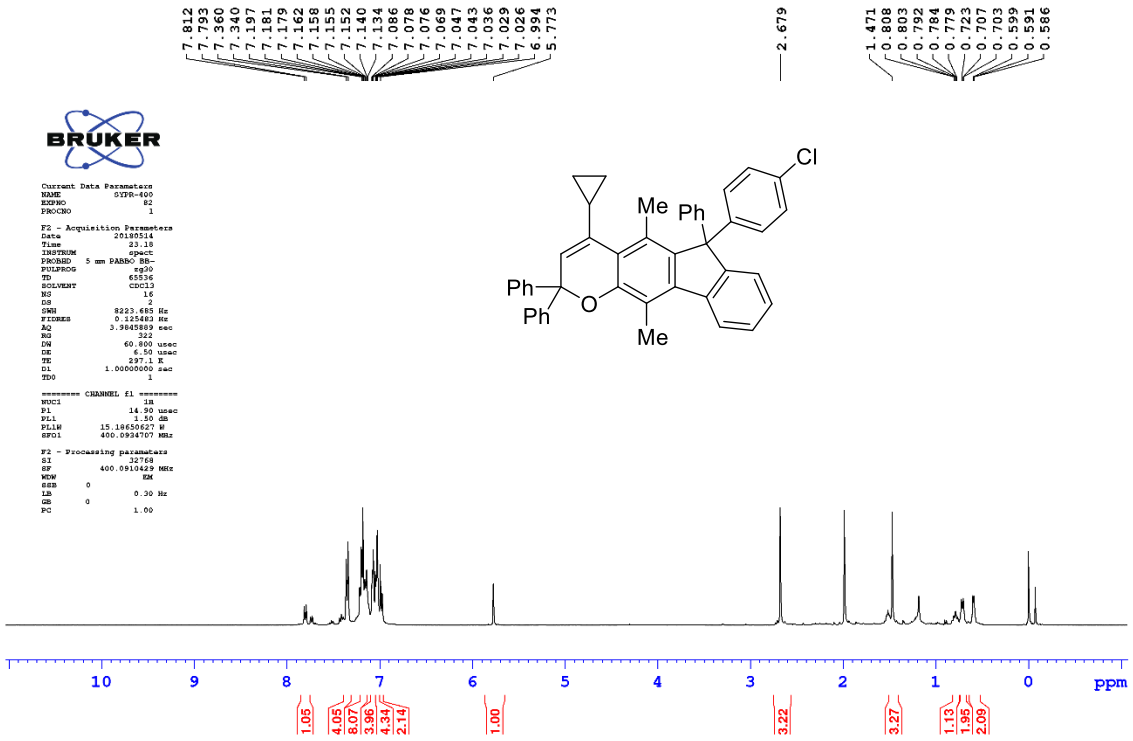
SYPR- 72P



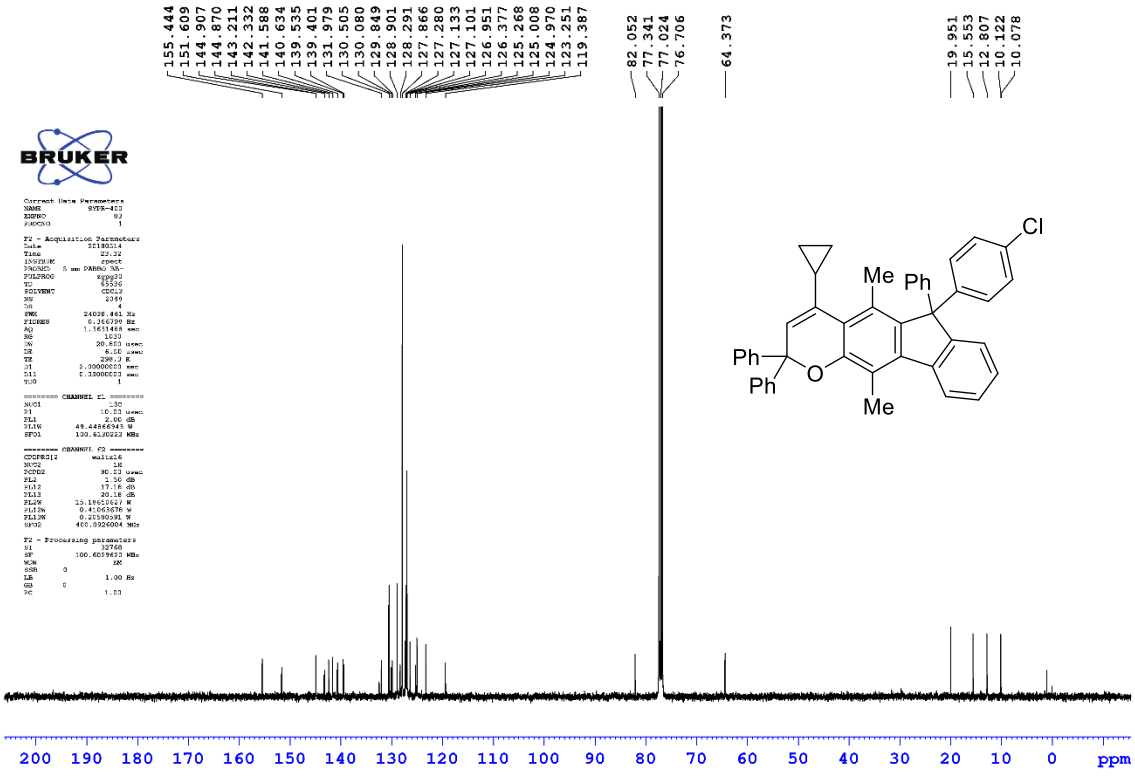
SYPR- 72P

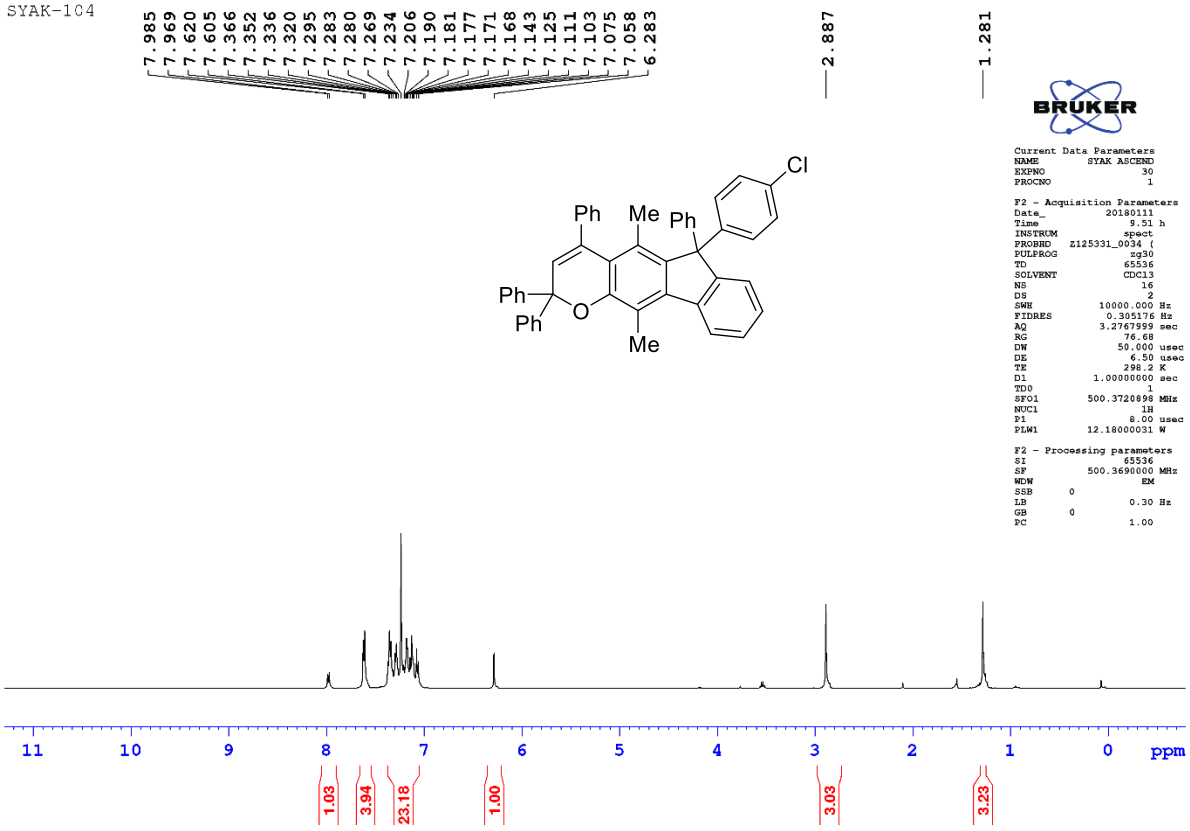


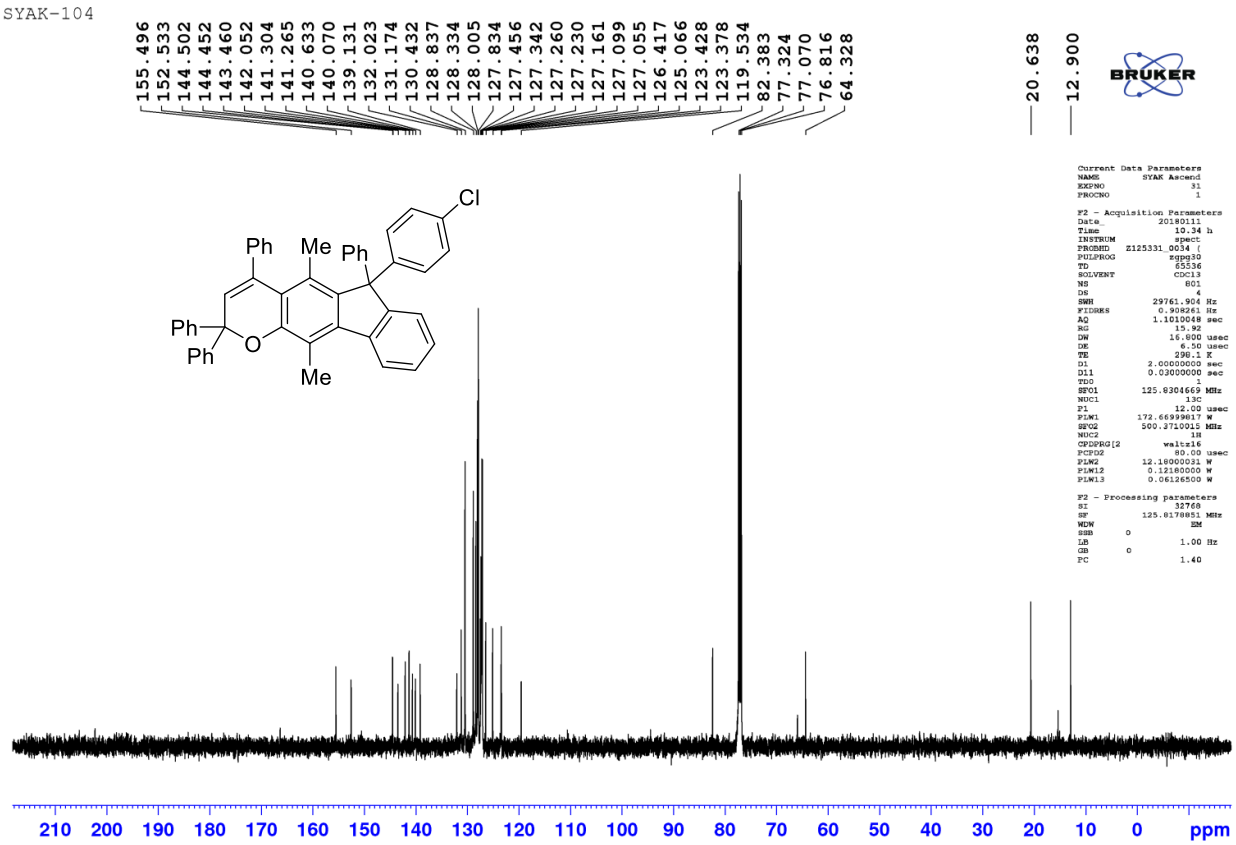
SYPR- 129 A



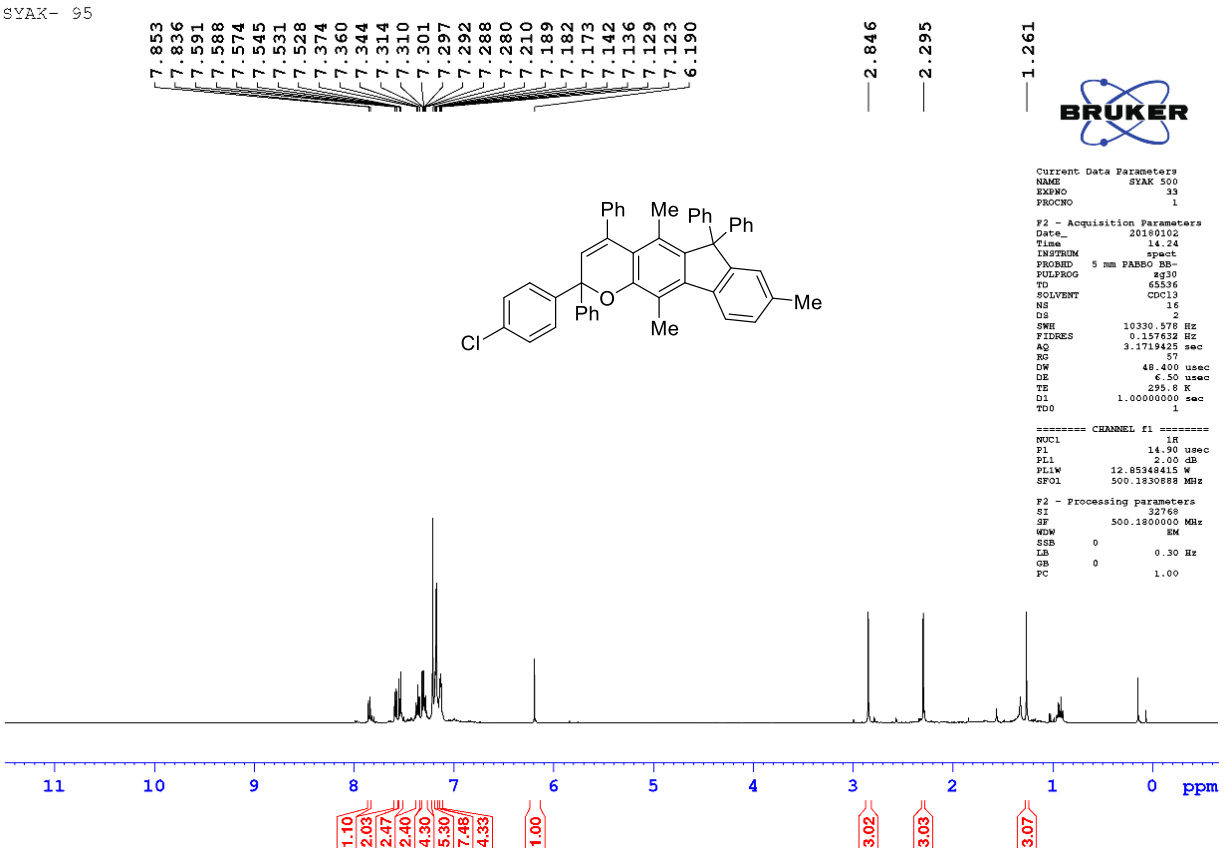
SYPR- 129 A



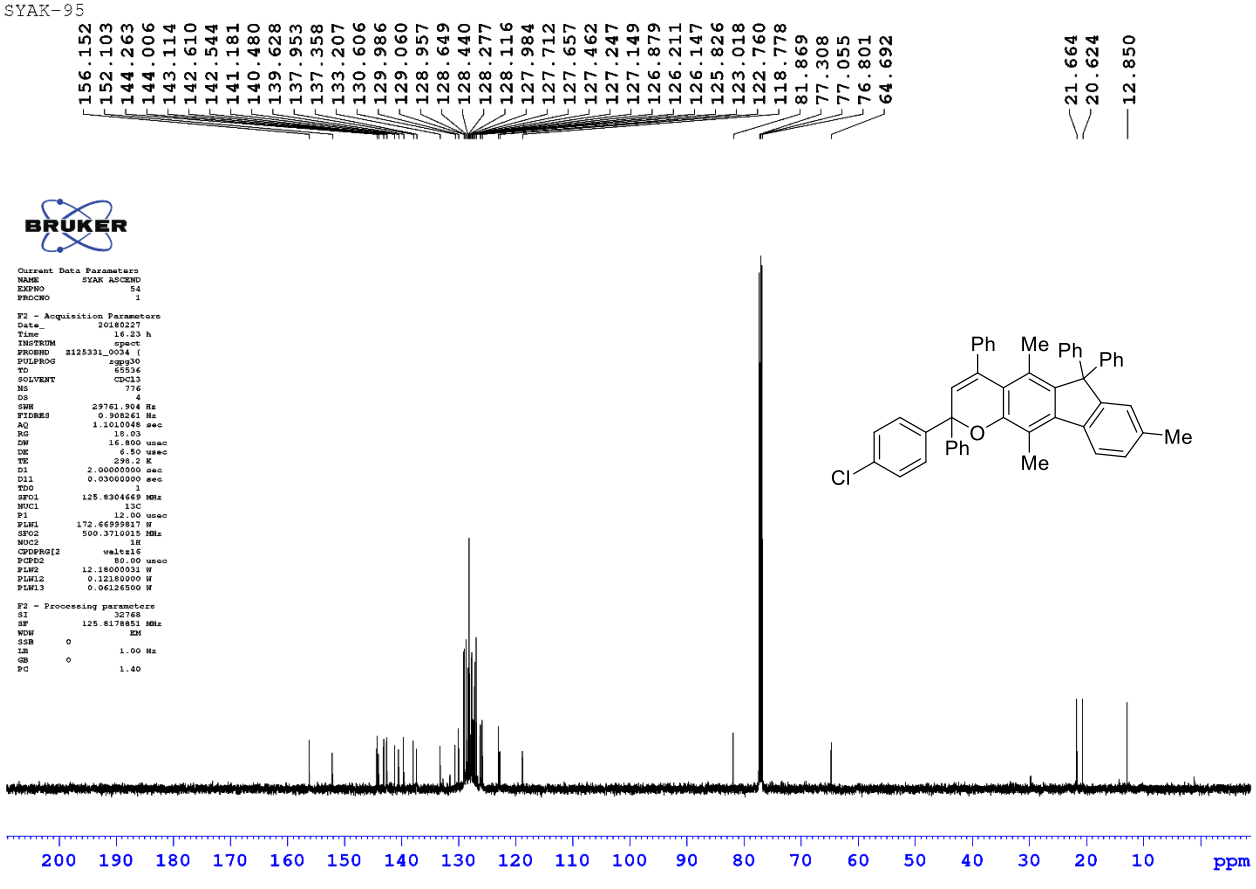

SYAK-104
7.985
7.969
7.620
7.605
7.366
7.352
7.336
7.320
7.295
7.283
7.280
7.269
7.234
7.206
7.190
7.181
7.177
7.171
7.168
7.143
7.125
7.111
7.103
7.075
7.058
6.283
2.887
1.281
Cl
Ph
Me
Ph
Ph
O
Ph
Me
BRUKER
Current Data Parameters
NAME SYAK ASCEND
EXPNO 30
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180111
Time 9.51 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 298.2 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
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.03
3.94
23.18
1.00
3.03
3.23

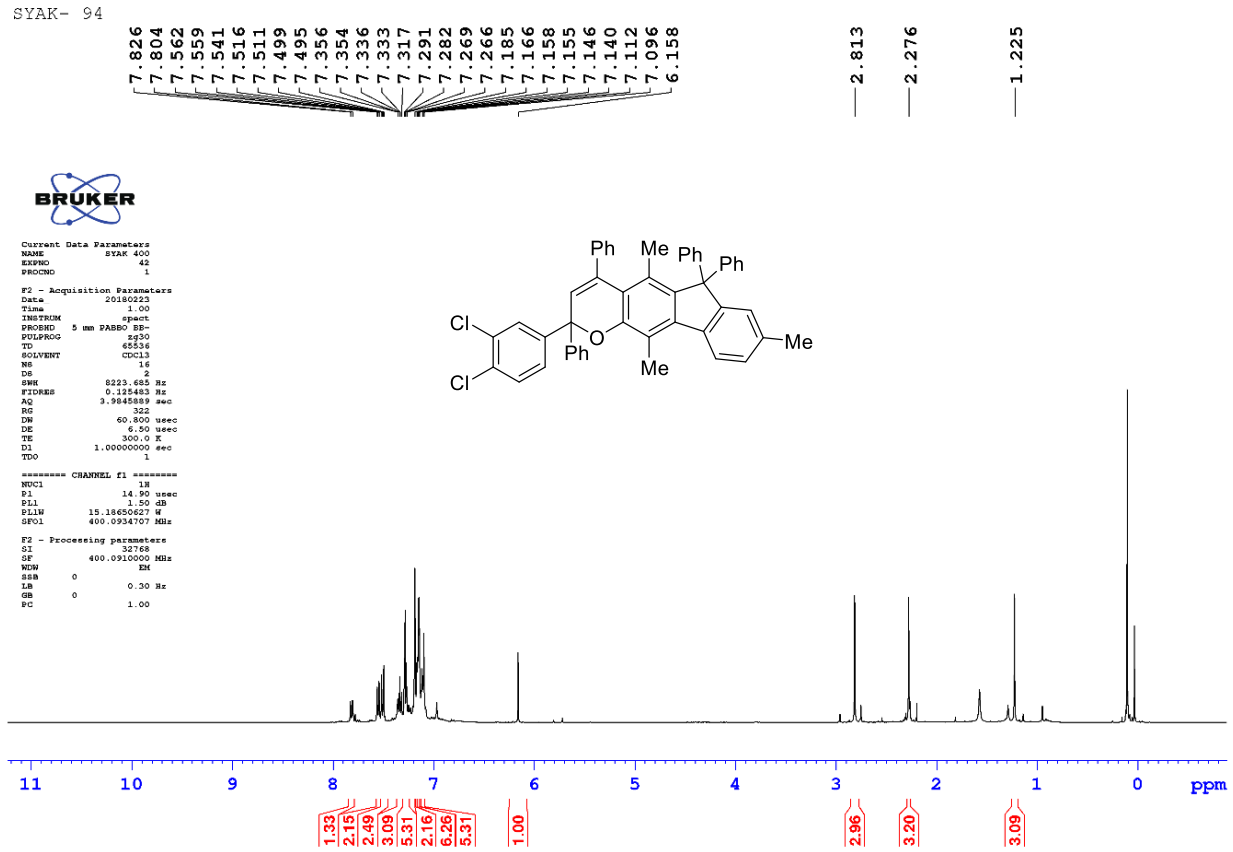

SYAK-104
155.496
152.533
144.502
144.452
143.460
142.052
141.304
141.265
140.633
140.070
139.131
132.023
131.174
130.432
128.837
128.334
128.005
127.834
127.456
127.342
127.260
127.230
127.161
127.099
127.055
126.417
125.066
123.428
123.378
119.534
82.383
77.324
77.070
76.816
64.328
20.638
12.900
Cl
Ph
Me
Ph
Ph
O
Ph
Me
BRUKER
Current Data Parameters
NAME SYAK Ascend
EXPNO 31
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180111
Time 10.34 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 801
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 15.92
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 125.8178851 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

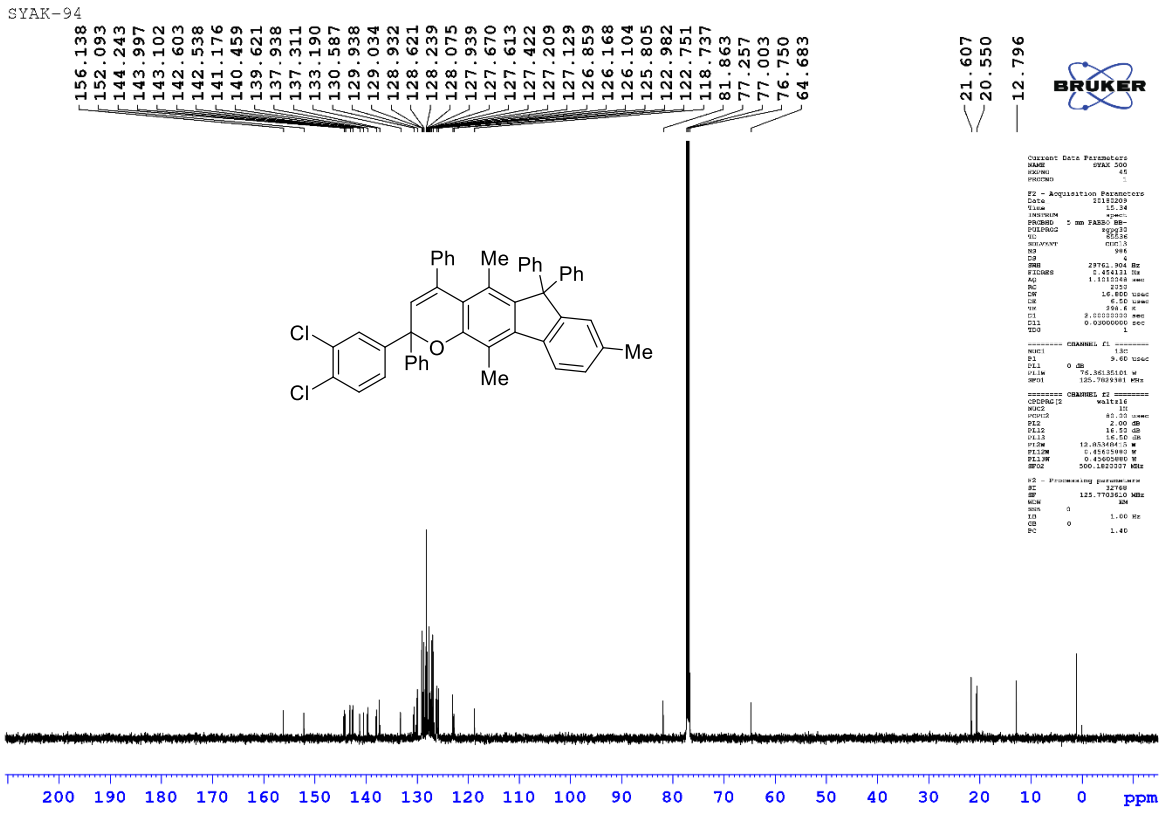
SYAK- 95



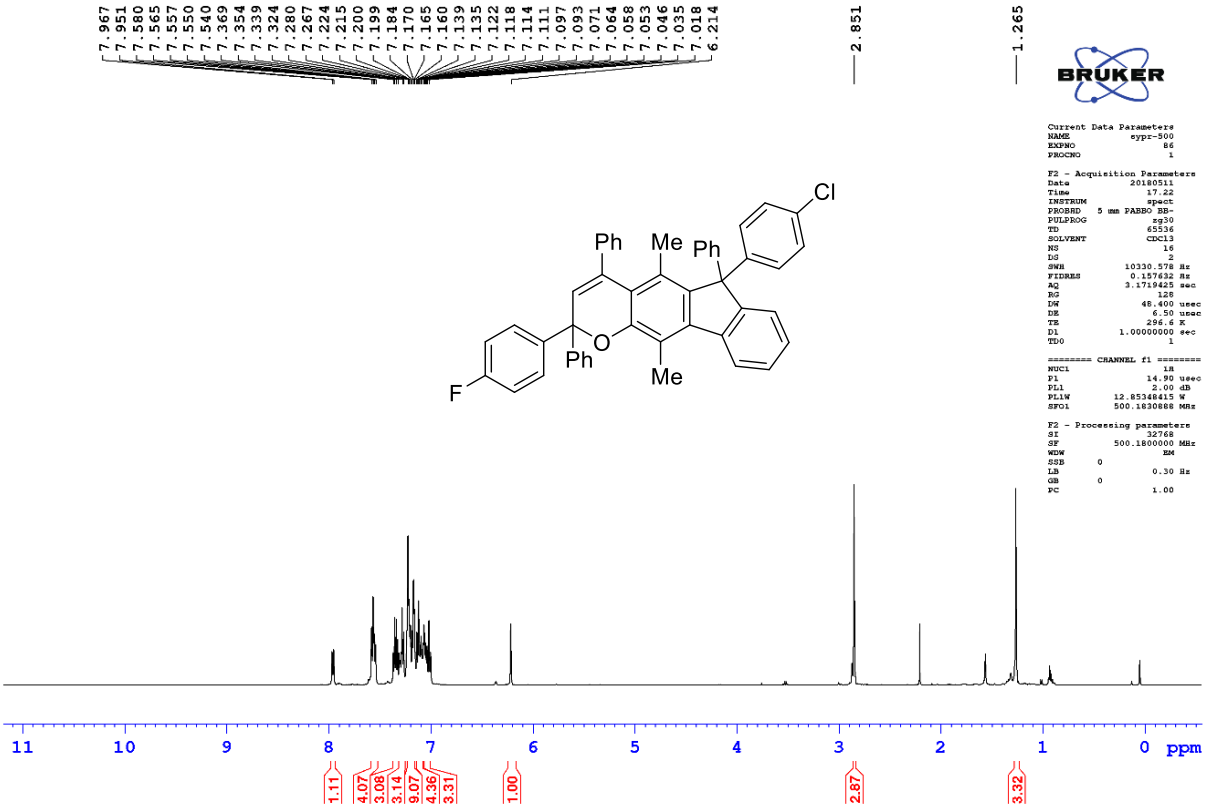
SYAK-95



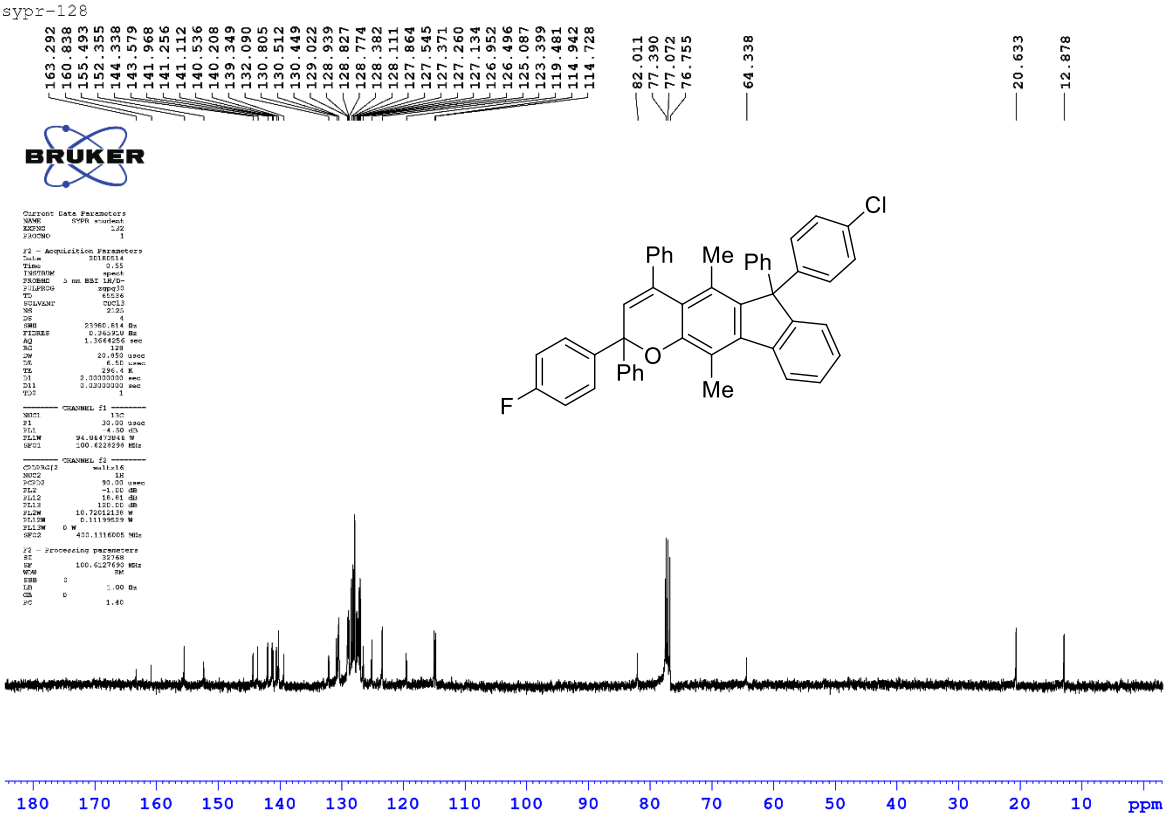

SYAK- 94
7.826
7.804
7.562
7.559
7.541
7.516
7.511
7.499
7.495
7.356
7.354
7.336
7.333
7.317
7.291
7.282
7.269
7.266
7.185
7.166
7.158
7.155
7.146
7.140
7.112
7.096
6.158
2.813
2.276
1.225
BRUKER
Ph
Me
Ph
Ph
Cl
O
Me
Cl
Ph
Me
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.33
2.15
2.49
3.09
5.31
2.16
6.26
5.31
1.00
2.96
3.20
3.09

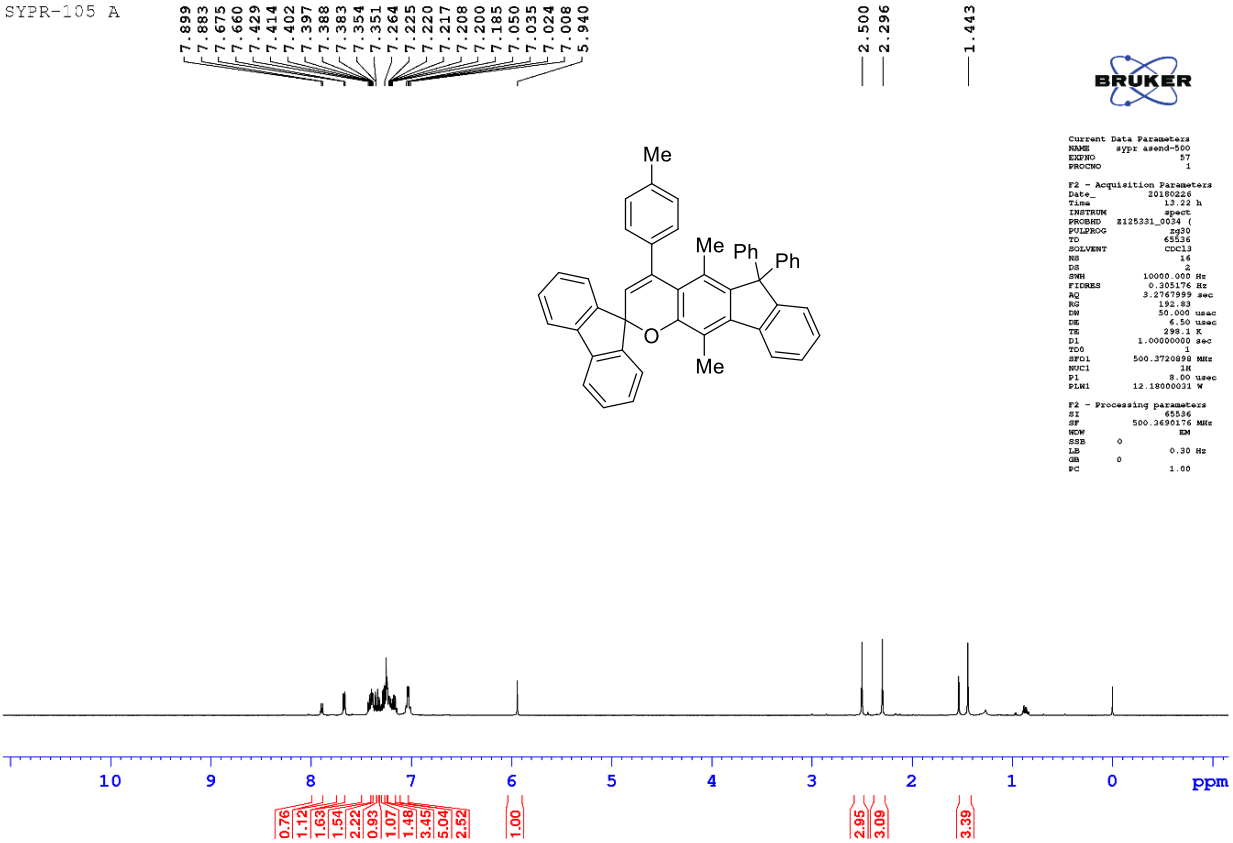

SYAK-94
156.138
152.093
144.243
143.997
143.102
142.603
142.538
141.176
140.459
139.621
137.938
137.311
133.190
130.587
129.938
129.034
128.932
128.621
128.239
128.075
127.939
127.670
127.613
127.422
127.209
127.129
126.859
126.168
126.104
125.805
122.982
122.751
118.737
81.863
77.257
77.003
76.750
64.683
21.607
20.550
12.796
BRUKER
Ph
Me
Ph
Ph
Cl
O
Me
Cl
Ph
Me
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

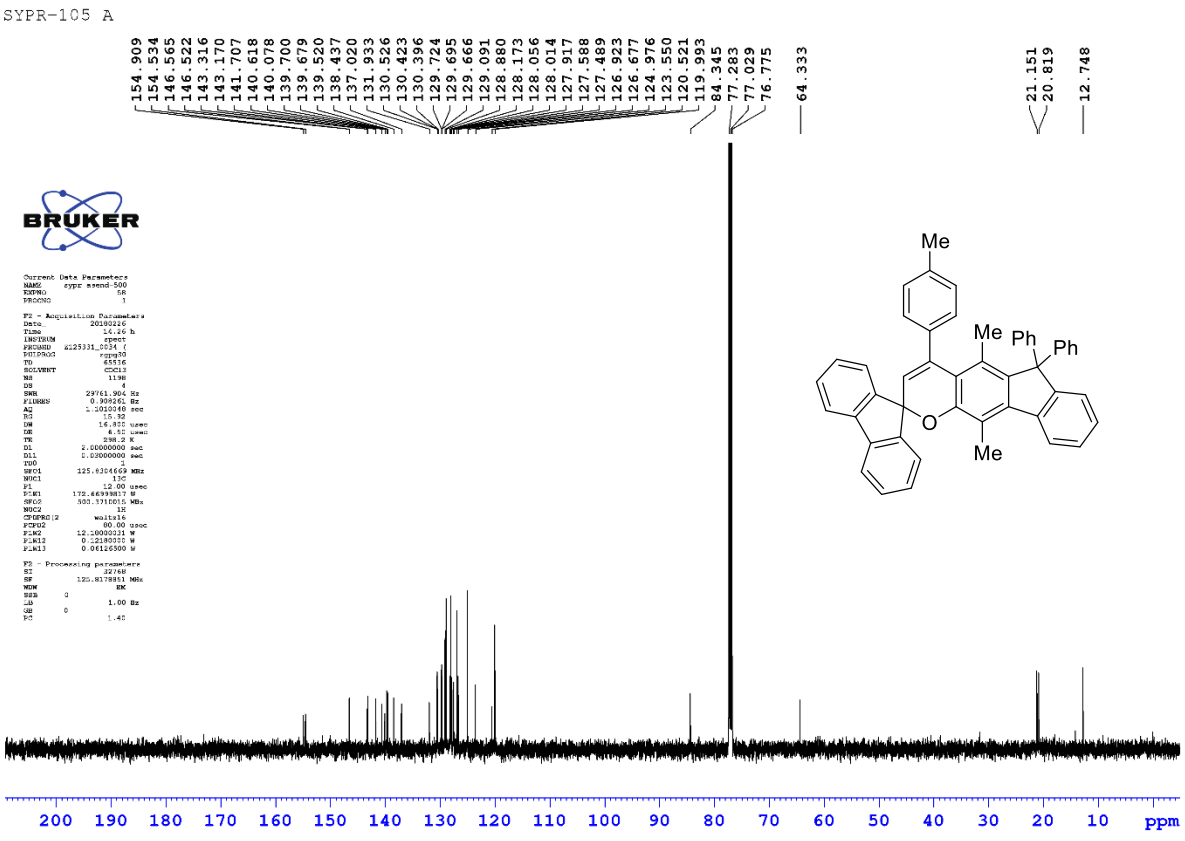
SYPR-128

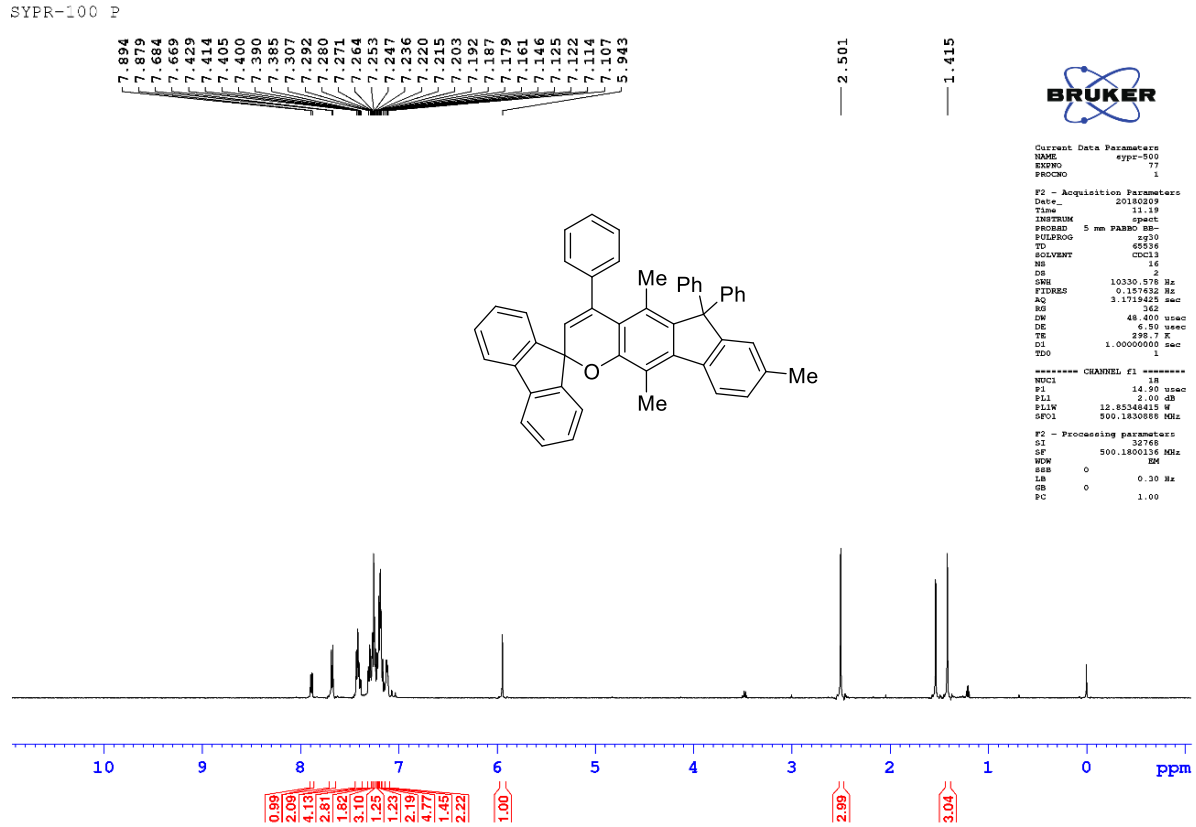


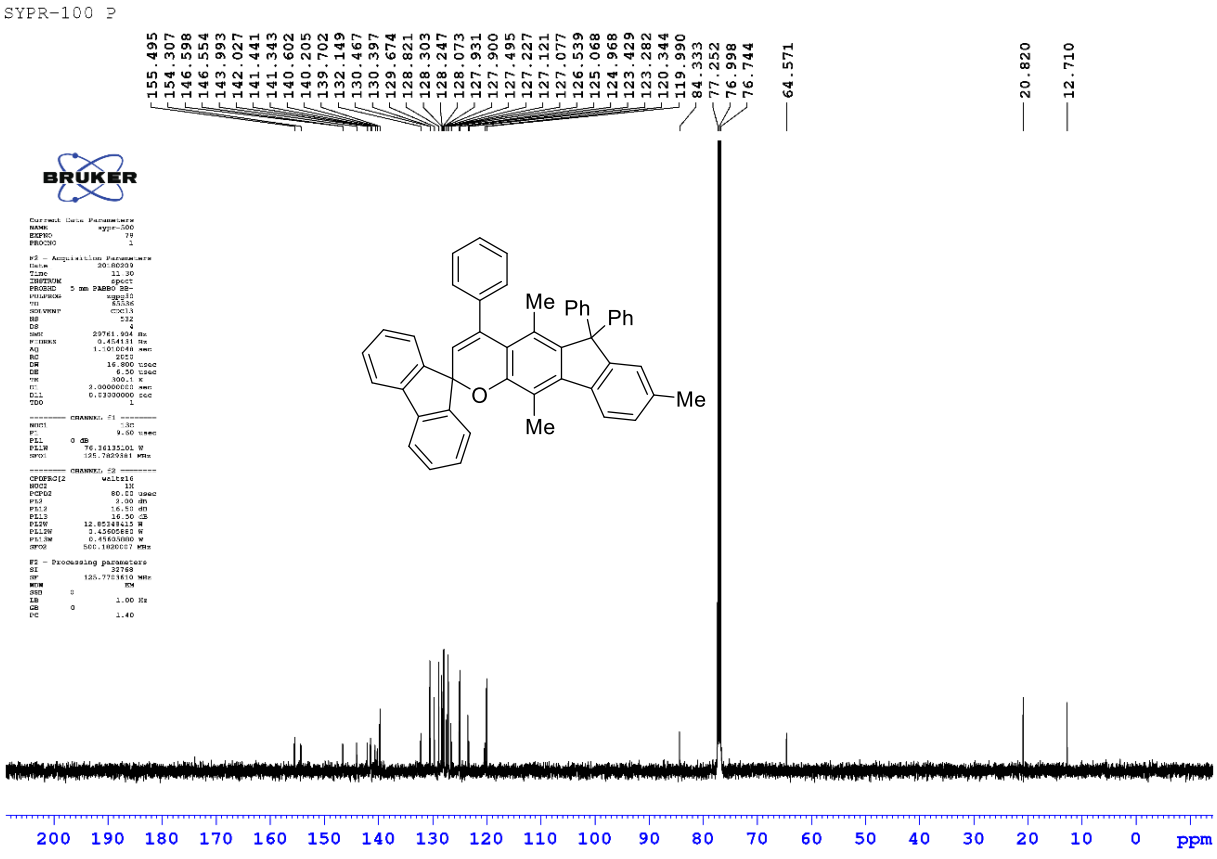
sypr-128



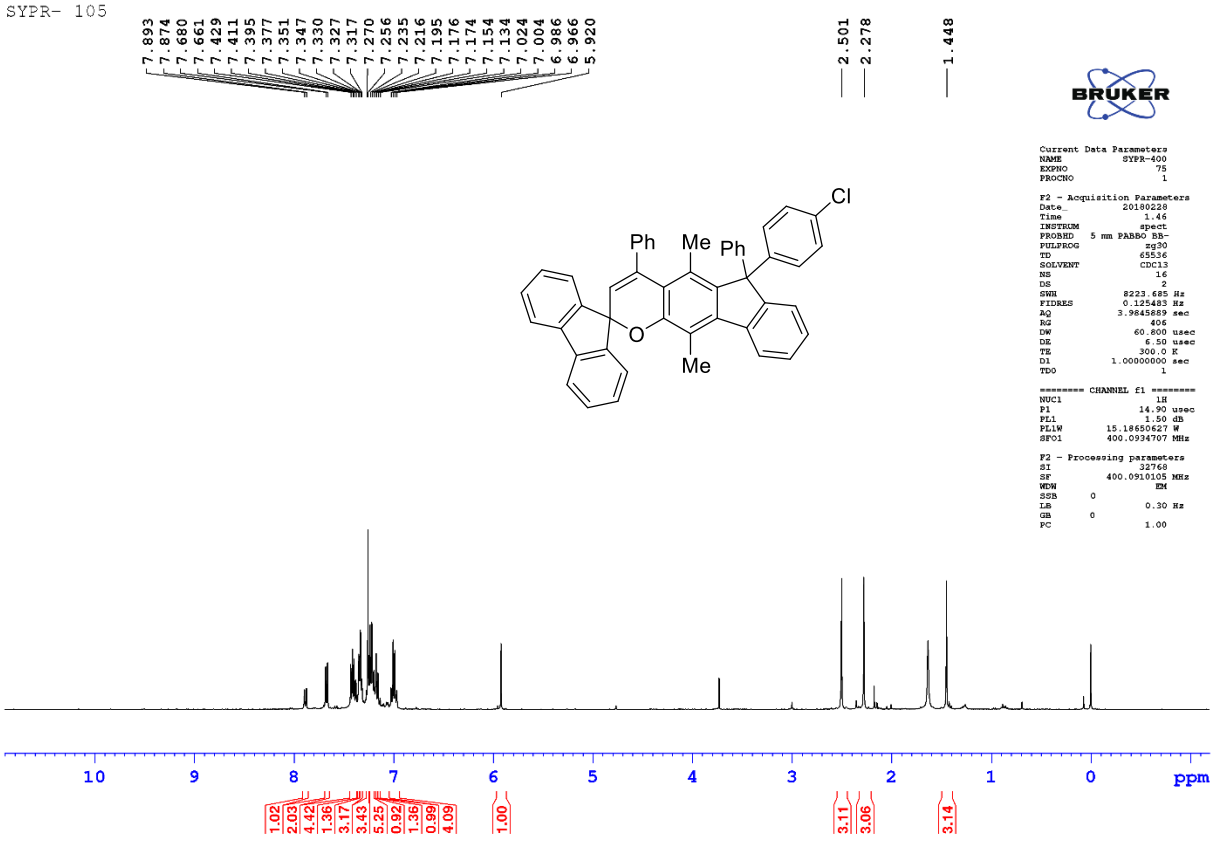

SYPR-105 A
7.899
7.883
7.675
7.660
7.429
7.414
7.402
7.397
7.388
7.383
7.354
7.351
7.264
7.225
7.220
7.217
7.208
7.200
7.185
7.050
7.035
7.024
7.008
5.940
2.500
2.296
1.443
BRUKER
Me
Me
Ph
Ph
O
Me
Current Data Parameters
NAME sypr asend-500
EXPNO 57
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180226
Time 13.22 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 192.83
DW 50.000 usec
DE 6.50 usec
TE 299.1 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 500.3690176 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 1.00
10
9
8
7
6
5
4
3
2
1
0
ppm
0.76
1.12
1.63
1.54
2.22
0.93
1.07
1.48
3.45
5.04
2.52
1.00
2.95
3.09
3.39


SYPR-105 A
154.909
154.534
146.565
146.522
143.316
143.170
141.707
140.618
140.078
139.700
139.679
139.520
138.437
137.020
131.933
130.526
130.423
130.396
129.724
129.695
129.666
129.091
128.880
128.173
128.056
128.014
127.917
127.588
127.489
126.923
126.677
124.976
123.550
120.521
119.993
84.345
77.283
77.029
76.775
64.333
21.151
20.819
12.748
BRUKER
Current Data Parameters
NAME sypr asend-500
EXPNO 58
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180226
Time 14.26 h
INSTRUM spect
PROBHD Z125331_0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 1198
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010240 sec
RG 15.92
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 172.46999817 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 125.8178851 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
Me
Me
Ph
Ph
O
Me
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

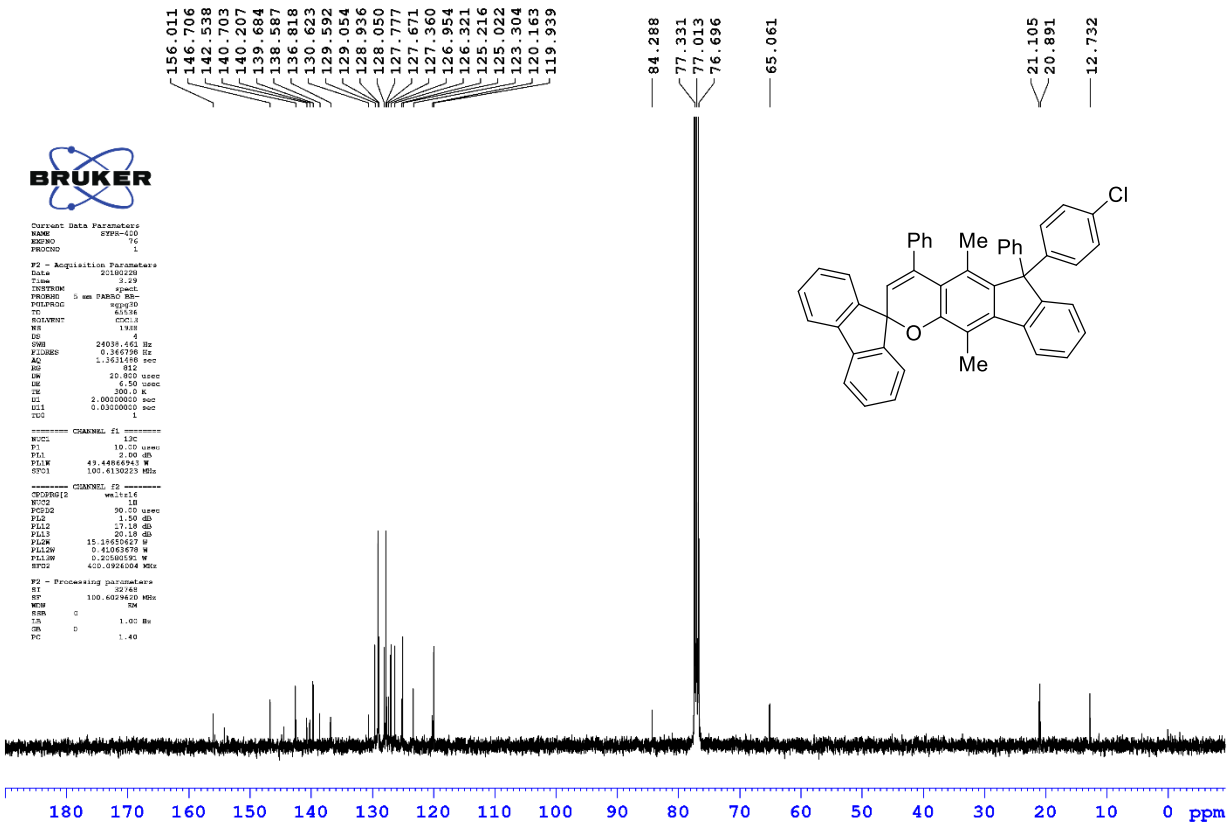

SYPR-100 P
7.894
7.879
7.684
7.669
7.429
7.414
7.405
7.400
7.390
7.385
7.307
7.292
7.280
7.271
7.264
7.253
7.247
7.236
7.220
7.215
7.203
7.192
7.187
7.179
7.161
7.146
7.125
7.122
7.114
7.107
5.943
2.501
1.415
BRUKER
Me
Ph
Ph
O
Me
Me
10
9
8
7
6
5
4
3
2
1
0
ppm
0.99
2.09
4.13
2.81
1.82
3.10
1.25
1.23
2.19
4.77
1.45
2.22
1.00
2.99
3.04


SYPR-100 P
155.495
154.307
146.598
146.554
143.993
142.027
141.441
141.343
140.602
140.205
139.702
132.149
130.467
130.397
129.674
128.821
128.303
128.247
128.073
127.931
127.900
127.495
127.227
127.121
127.077
126.539
125.068
124.968
123.429
123.282
120.344
119.990
84.333
77.252
76.998
76.744
64.571
20.820
12.710
BRUKER
Me
Ph
Ph
O
Me
Me
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

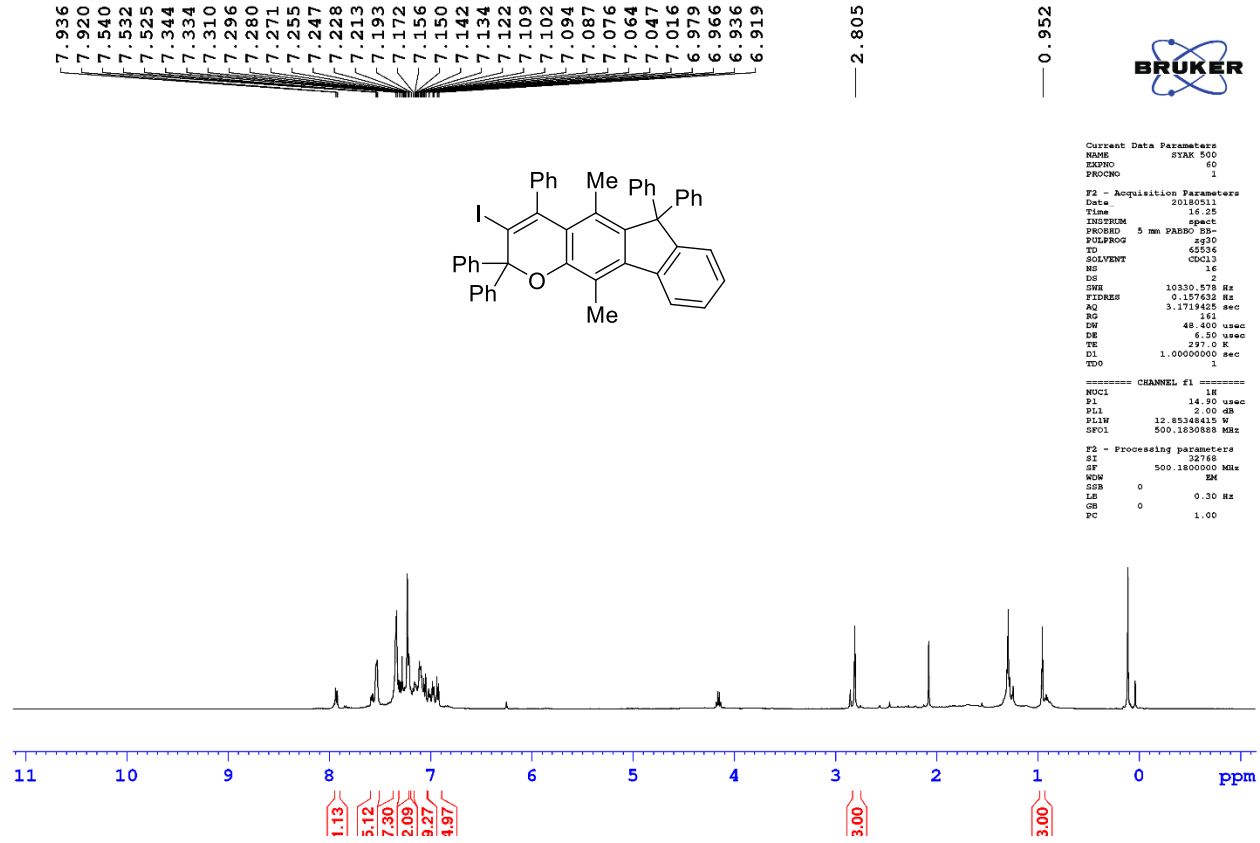
SYPR- 105



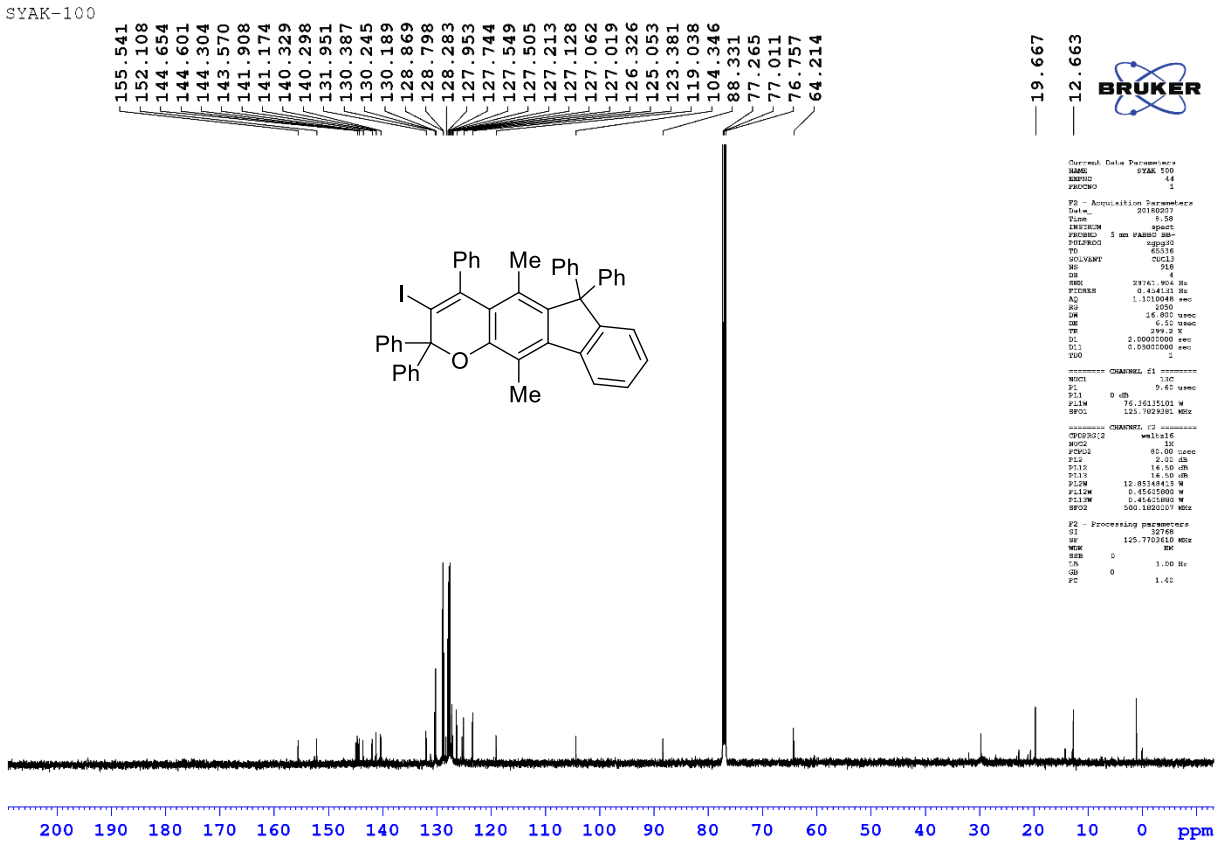
SYPR- 105

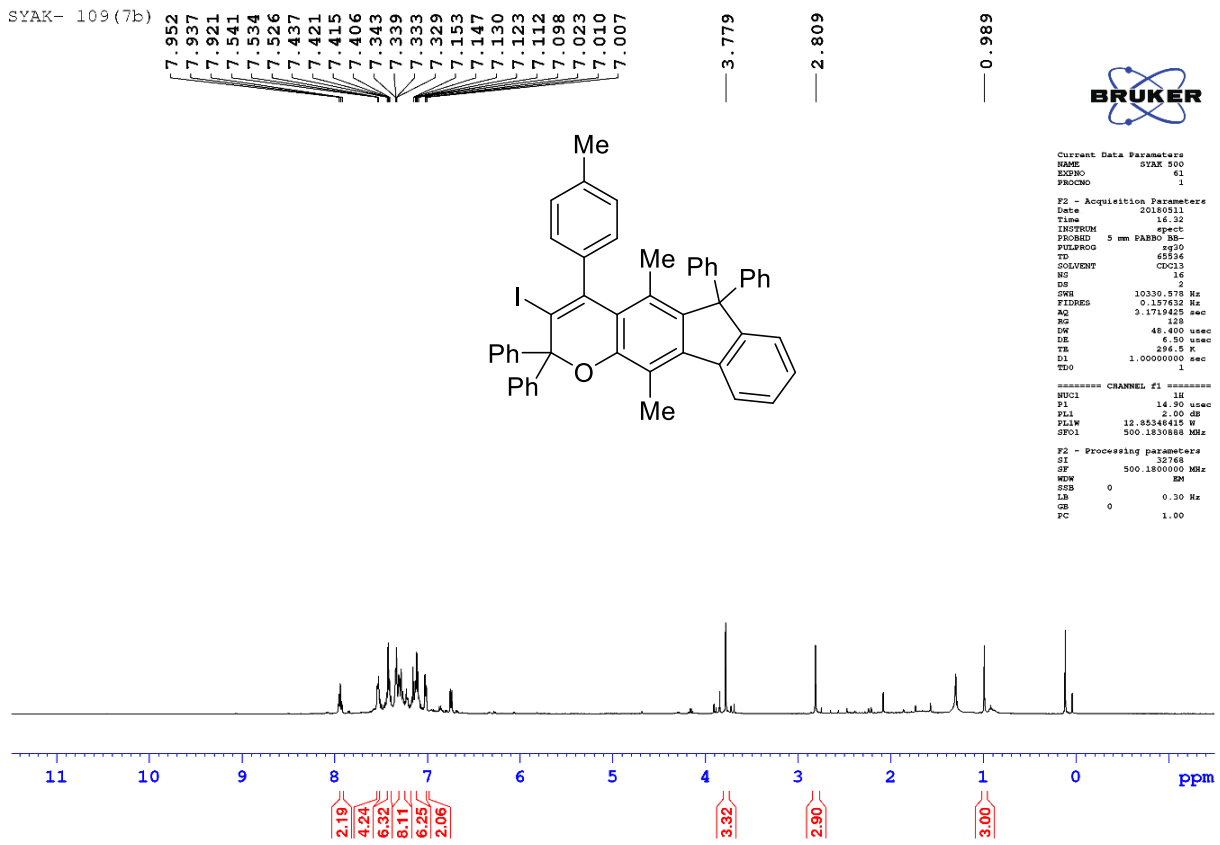


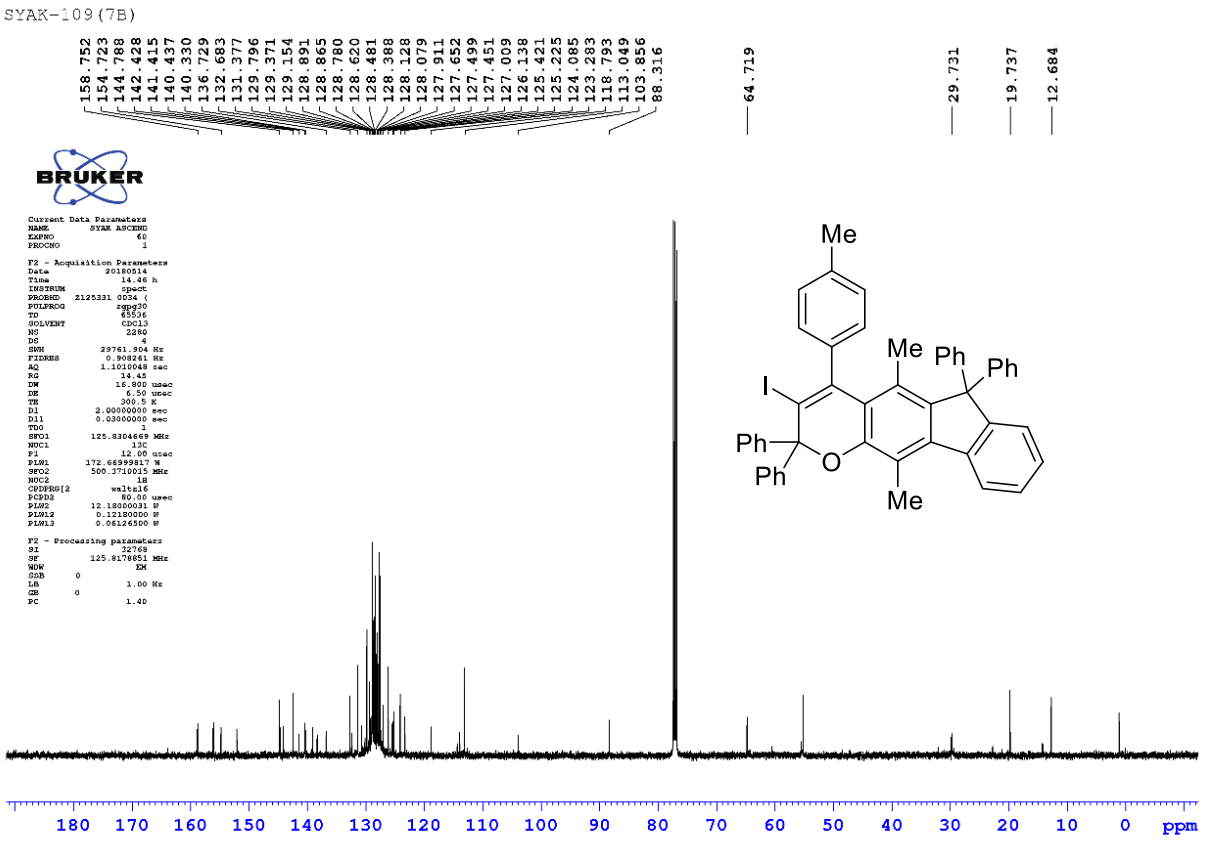
SYAK- 100 (7a)

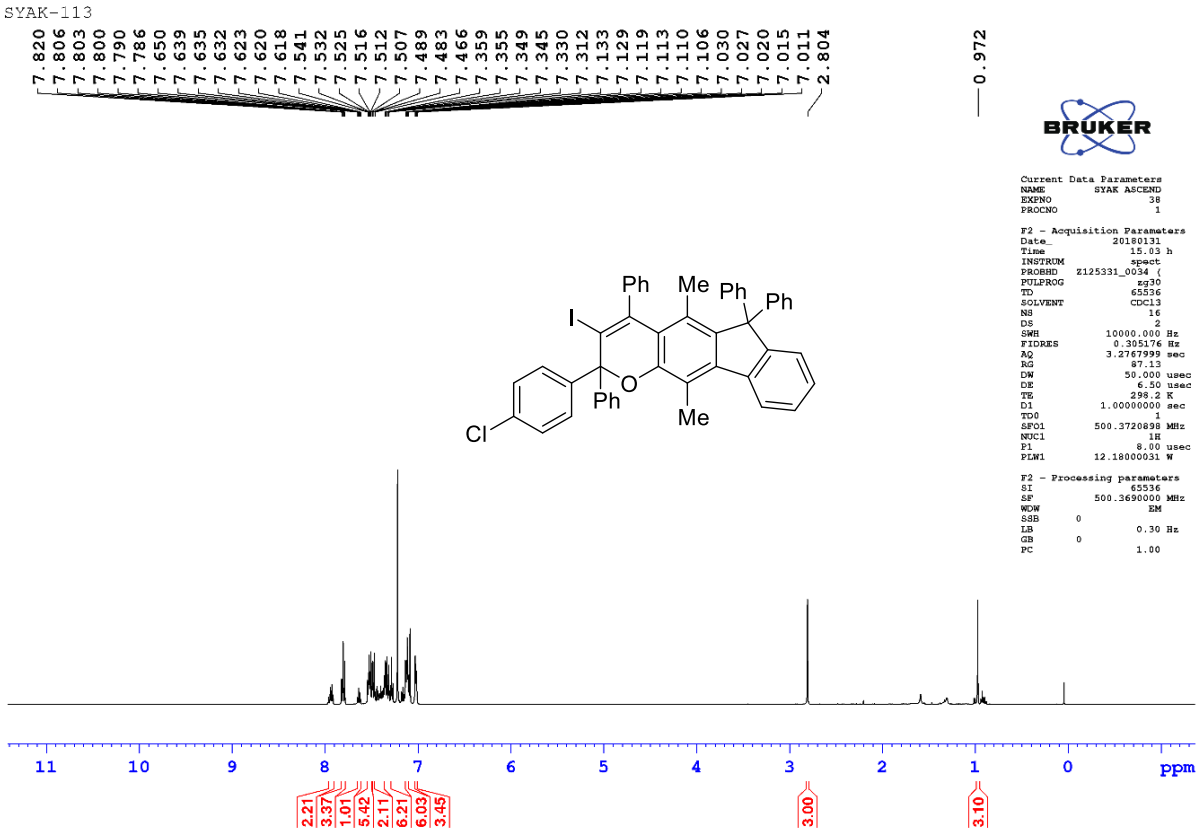


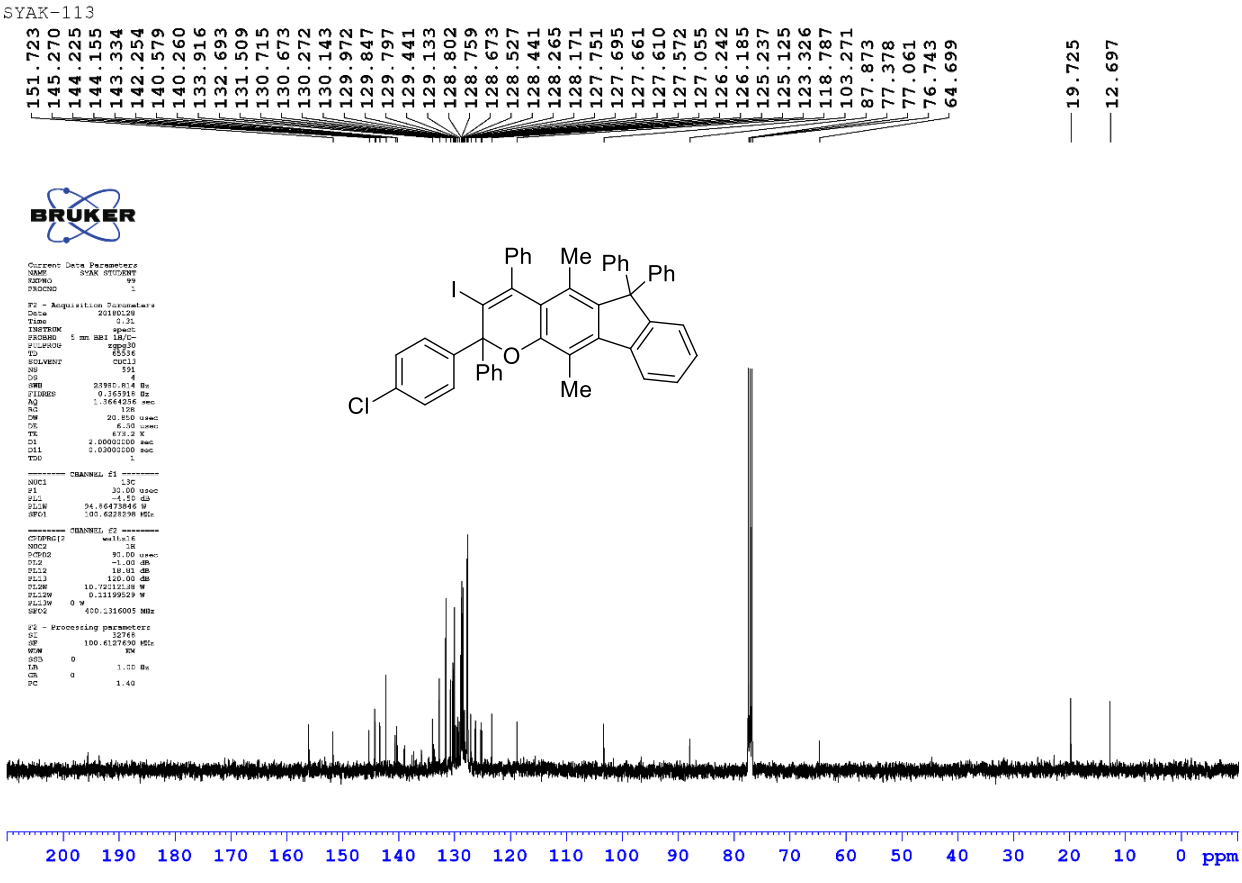
SYAK-100

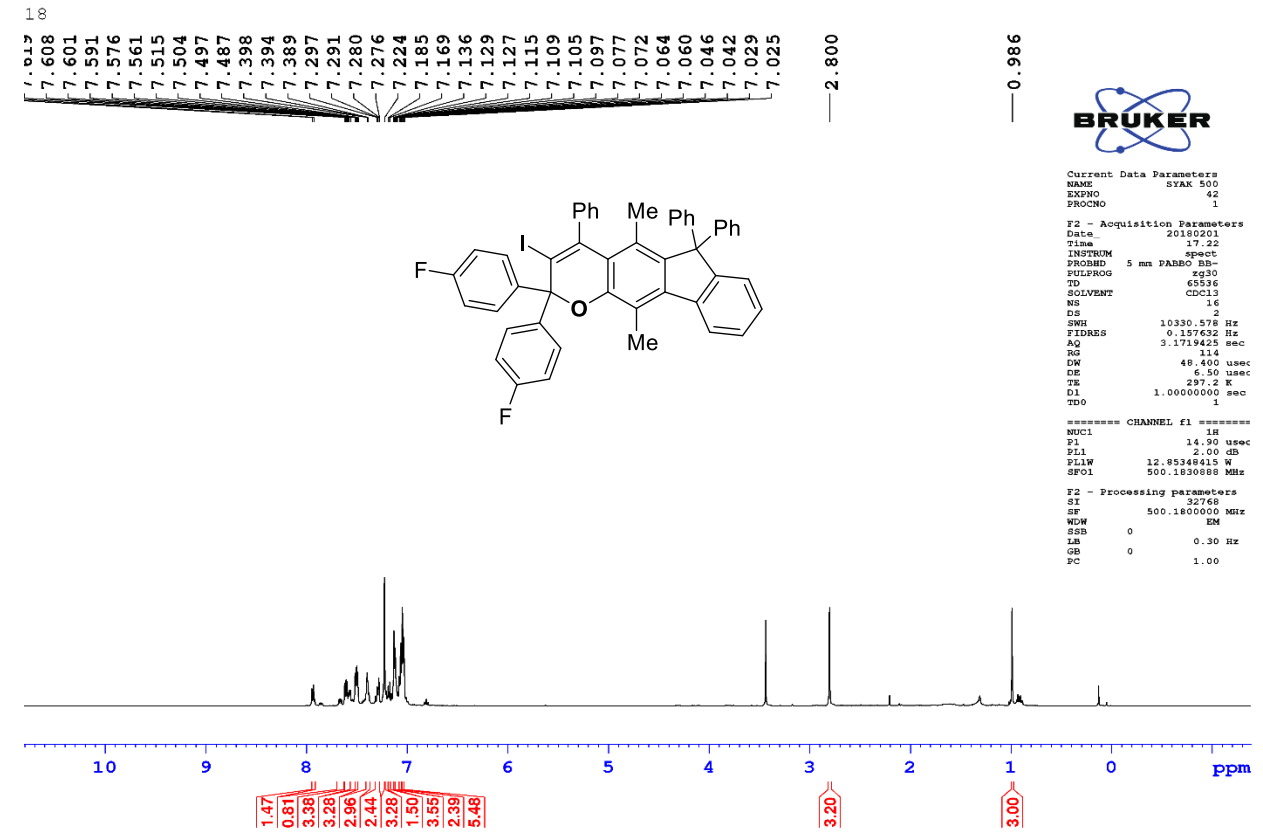


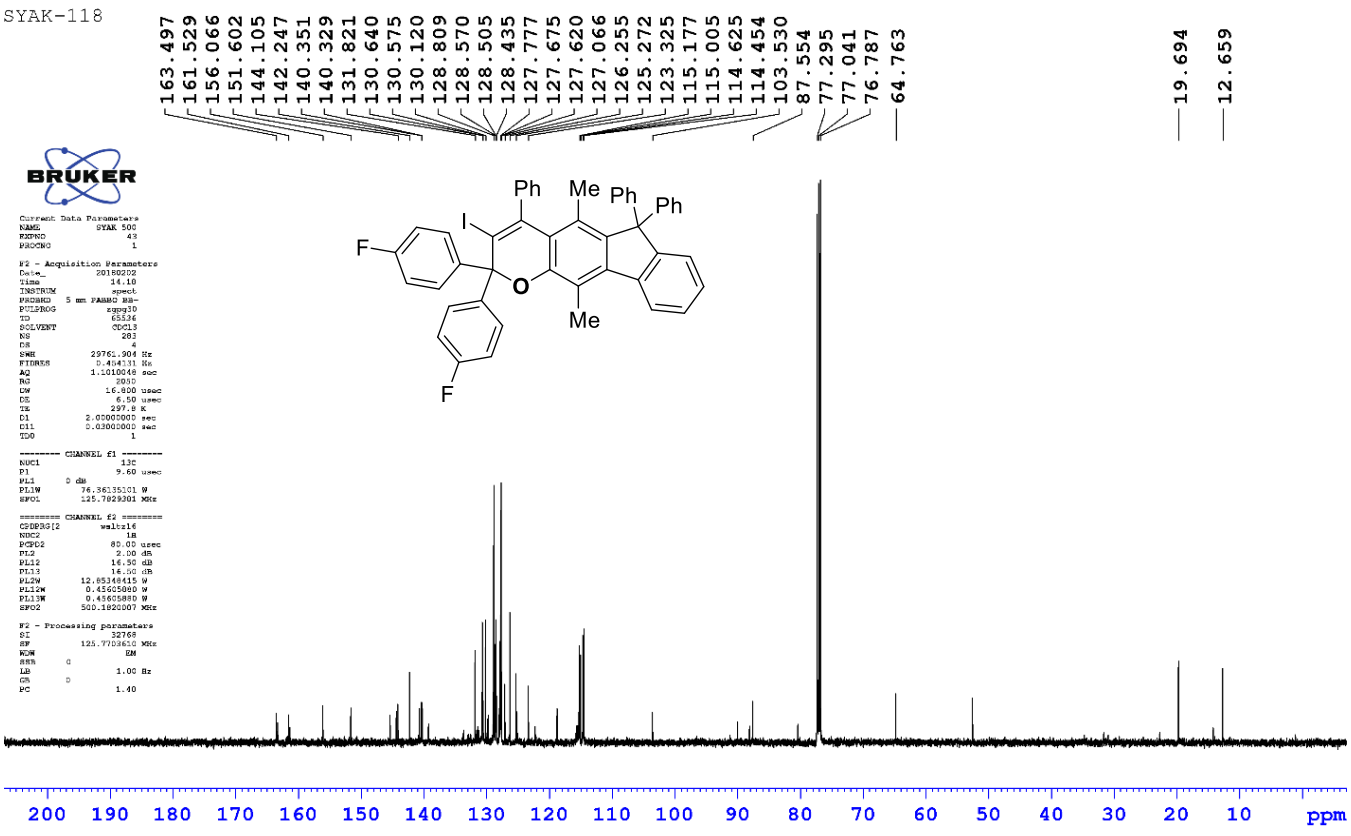

SYAK- 109(7b)
7.952
7.937
7.921
7.541
7.534
7.526
7.437
7.421
7.415
7.406
7.343
7.339
7.333
7.329
7.153
7.147
7.130
7.123
7.112
7.098
7.023
7.010
7.007
3.779
2.809
0.989
BRUKER
Me
Me
Ph
Ph
I
Ph
Ph
O
Me
Current Data Parameters
NAME SYAK 500
EXPNO 61
PROCNO 1
F2 - Acquisition Parameters
Date 20180511
Time 16.32
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 120
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 12.85346415 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
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.19
4.24
6.32
8.11
6.25
2.06
3.32
2.90
3.00


SYAK-109(7B)
158.752
154.723
144.788
142.428
141.415
140.437
140.330
136.729
132.683
131.377
129.796
129.371
129.154
128.891
128.865
128.780
128.620
128.481
128.388
128.128
128.079
127.911
127.652
127.499
127.451
127.009
126.138
125.421
125.225
124.085
123.283
118.793
113.049
103.856
88.316
64.719
29.731
19.737
12.684
BRUKER
Current Data Parameters
NAME SYAK ASCEND
EXPNO 60
PROCNO 1
F2 - Acquisition Parameters
Date 20180514
Time 14.46 h
INSTRUM spect
PROBHD Z125331 0034 (
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 2280
DS 4
SWH 29761.904 Hz
FIDRES 0.908261 Hz
AQ 1.1010048 sec
RG 14.45
DW 16.800 usec
DE 6.50 usec
TE 300.5 K
D1 2.00000000 sec
D11 0.03000000 sec
TD0 1
SFO1 125.8304669 MHz
NUC1 13C
P1 12.00 usec
PL1 172.66999817 W
SFO2 500.3710015 MHz
NUC2 1H
CPDPRG[2 waltz16
PCPD2 80.00 usec
PL2 12.18000031 W
PL12 0.12180000 W
PL13 0.06126500 W
F2 - Processing parameters
SI 32768
SF 125.8178851 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
Me
Me
Ph
Ph
I
Ph
Ph
O
Me
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


SYAK-113
7.820
7.806
7.803
7.800
7.790
7.786
7.650
7.639
7.635
7.632
7.623
7.620
7.618
7.541
7.532
7.525
7.516
7.512
7.507
7.489
7.483
7.466
7.359
7.355
7.349
7.345
7.330
7.312
7.133
7.129
7.119
7.113
7.110
7.106
7.030
7.027
7.020
7.015
7.011
2.804
0.972
BRUKER
Current Data Parameters
NAME SYAK ASCEND
EXPNO 38
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180131
Time 15.03 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 87.13
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
Ph
Me
Ph
Ph
I
O
Ph
Cl
Me
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.21
3.37
1.01
5.42
2.11
6.21
6.03
3.45
3.00
3.10


SYAK-113
151.723
145.270
144.225
144.155
143.334
142.254
140.579
140.260
133.916
132.693
131.509
130.715
130.673
130.272
130.143
129.972
129.847
129.797
129.441
129.133
128.802
128.759
128.673
128.527
128.441
128.265
128.171
127.751
127.695
127.661
127.610
127.572
127.055
126.242
126.185
125.237
125.125
123.326
118.787
103.271
87.873
77.378
77.061
76.743
64.699
19.725
12.697
BRUKER
Ph
Me
Ph
Ph
I
O
Ph
Cl
Me
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


18
7.608
7.601
7.591
7.576
7.561
7.515
7.504
7.497
7.487
7.398
7.394
7.389
7.297
7.291
7.280
7.276
7.224
7.185
7.169
7.136
7.129
7.127
7.115
7.109
7.105
7.097
7.077
7.072
7.064
7.060
7.046
7.042
7.029
7.025
2.800
0.986
Ph
Me
Ph
Ph
I
F
O
Me
F
BRUKER
Current Data Parameters
NAME SYAK 500
EXPNO 42
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180201
Time 17.22
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 114
DW 48.400 usec
DE 6.50 usec
TE 297.2 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
10
9
8
7
6
5
4
3
2
1
0
ppm
1.47
0.81
3.38
3.28
2.96
2.44
3.28
1.50
3.55
2.39
5.48
3.20
3.00


SYAK-118
163.497
161.529
156.066
151.602
144.105
142.247
140.351
140.329
131.821
130.640
130.575
130.120
128.809
128.570
128.505
128.435
127.777
127.675
127.620
127.066
126.255
125.272
123.325
115.177
115.005
114.625
114.454
103.530
87.554
77.295
77.041
76.787
64.763
19.694
12.659
BRUKER
Current Data Parameters
NAME SYAK 500
EXPNO 43
PROCNO 1
F2 - Acquisition Parameters
Date_ 20180202
Time 14.10
INSTRUM spect
PROBHD 5 mm PABBO BB-
PULPROG zgpg30
TD 65536
SOLVENT CDCl3
NS 283
DS 4
SWH 29761.904 Hz
FIDRES 0.454131 Hz
AQ 1.1010048 sec
RG 3080
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 125.7829301 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 0.45605980 W
PL13W 0.45605880 W
SFO2 500.1820007 MHz
F2 - Processing parameters
SI 32768
SF 125.7705650 MHz
WDW EM
SSB 0
LB 1.00 Hz
GB 0
PC 1.40
Ph
Me
Ph
Ph
I
F
O
Me
F
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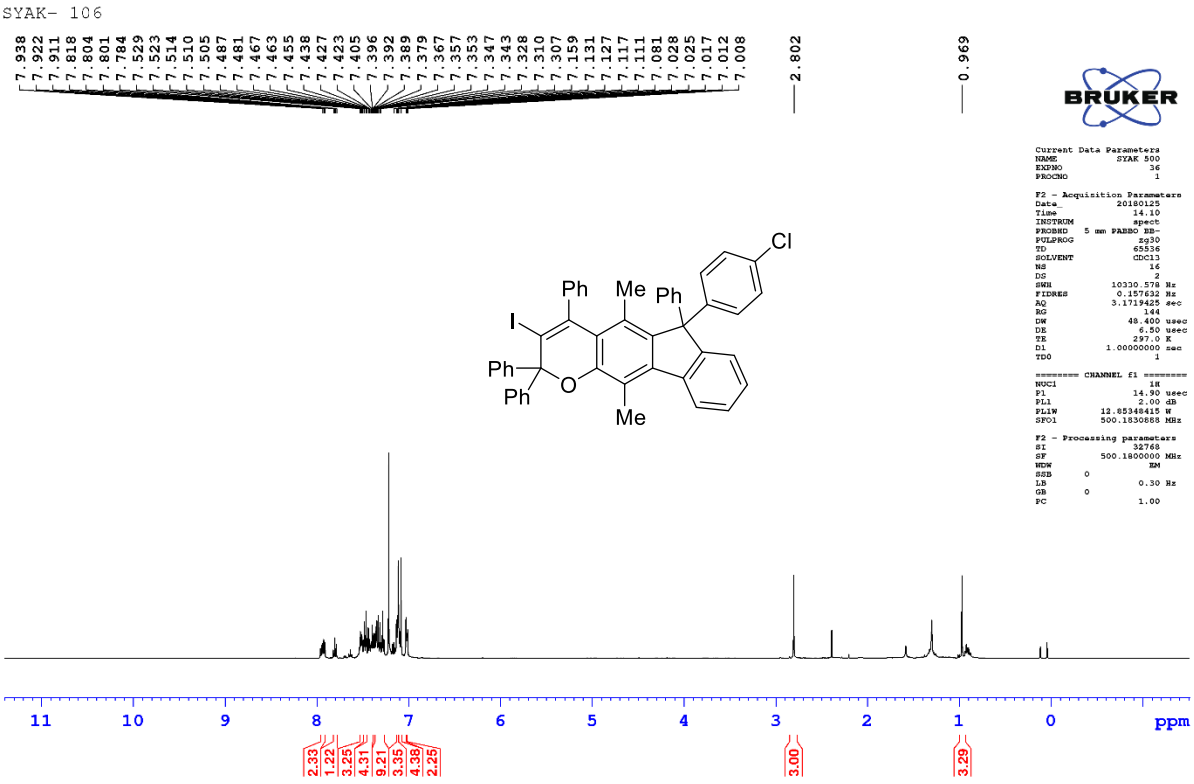
ppm


SYAK- 106
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SOLVENT CDCl3
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RG 144
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DE 6.50 usec
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GB 0
PC 1.00
Cl
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Me
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I
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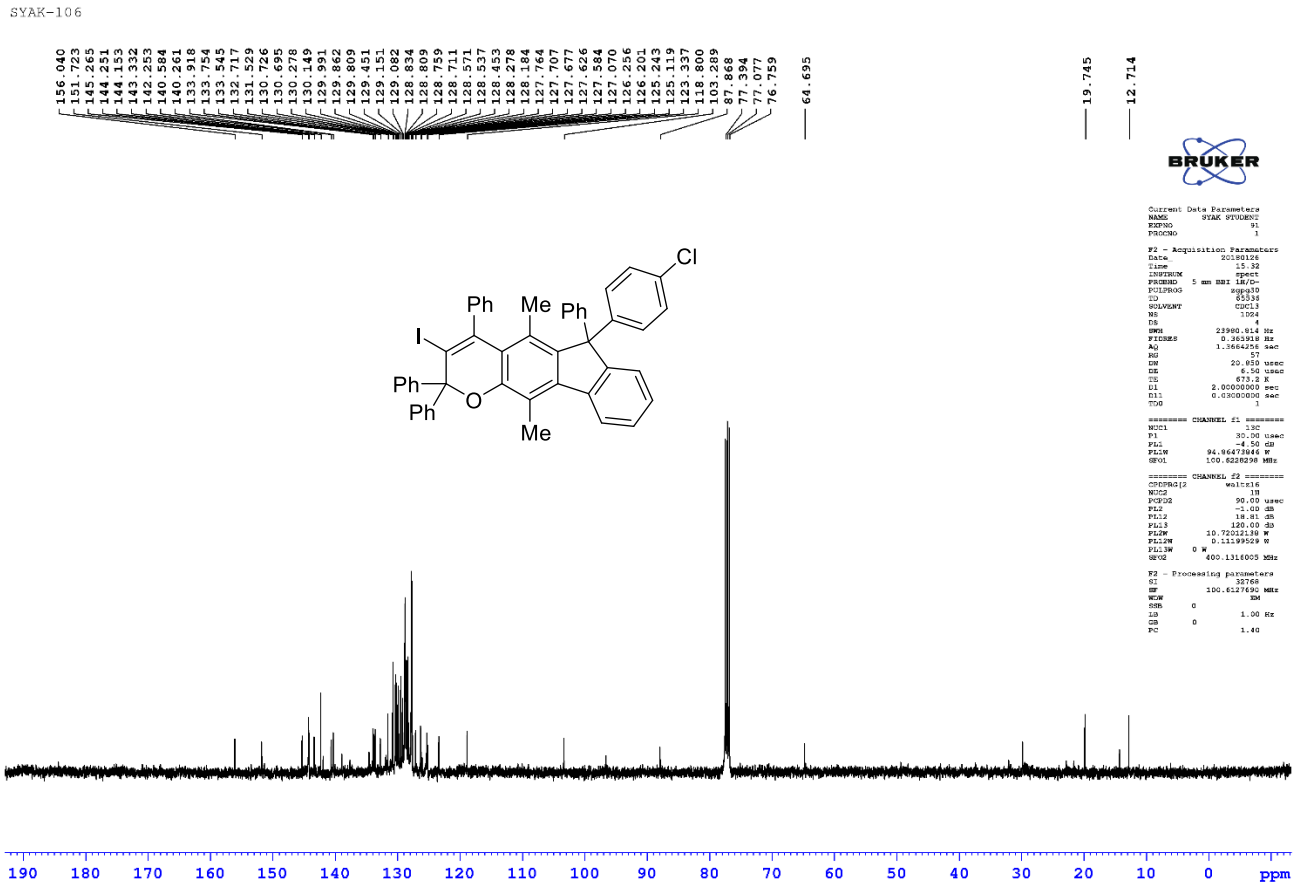
3.00
3.29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DS 4
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D11 0.03000000 sec
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P1 30.00 usec
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NUC2 1H
PCPD2 90.00 usec
PL2 -1.00 dB
PL12 18.81 dB
PL13 120.00 dB
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PL12W 0.11199529 W
PL13W 0 W
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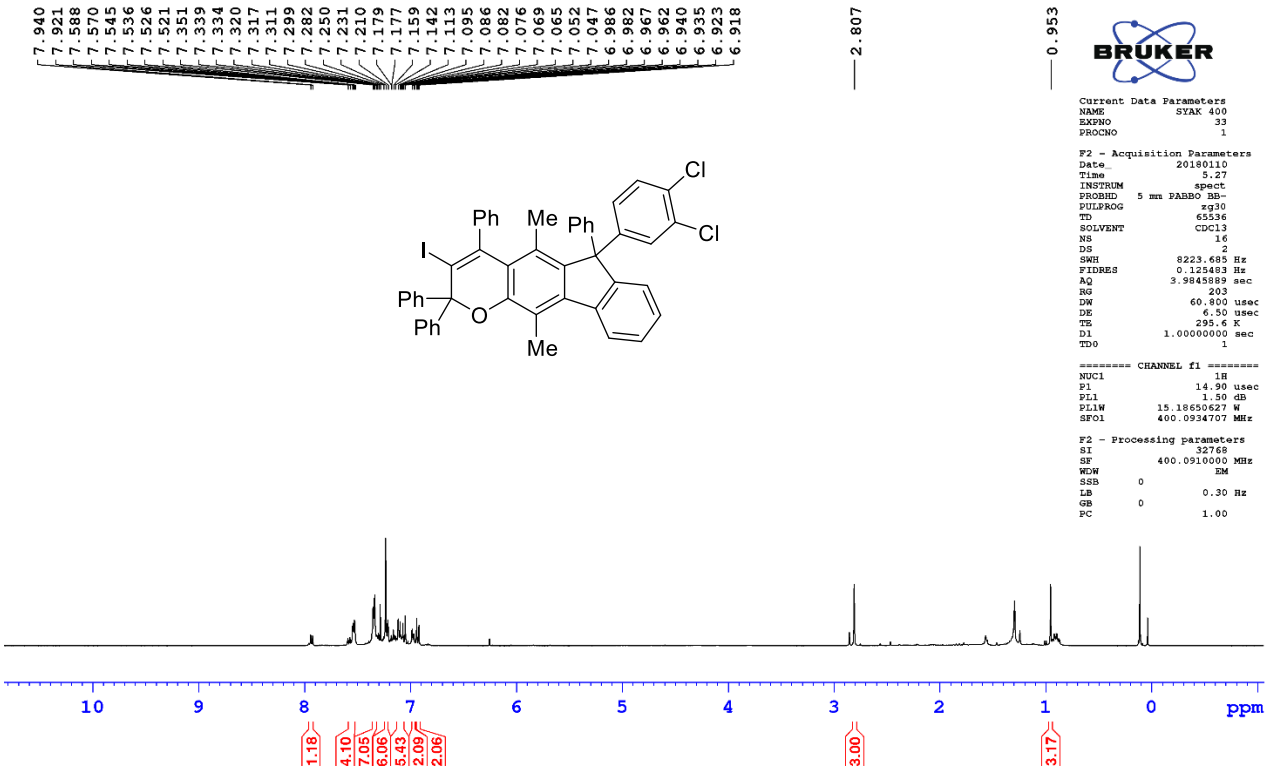
SYAK- 103 A



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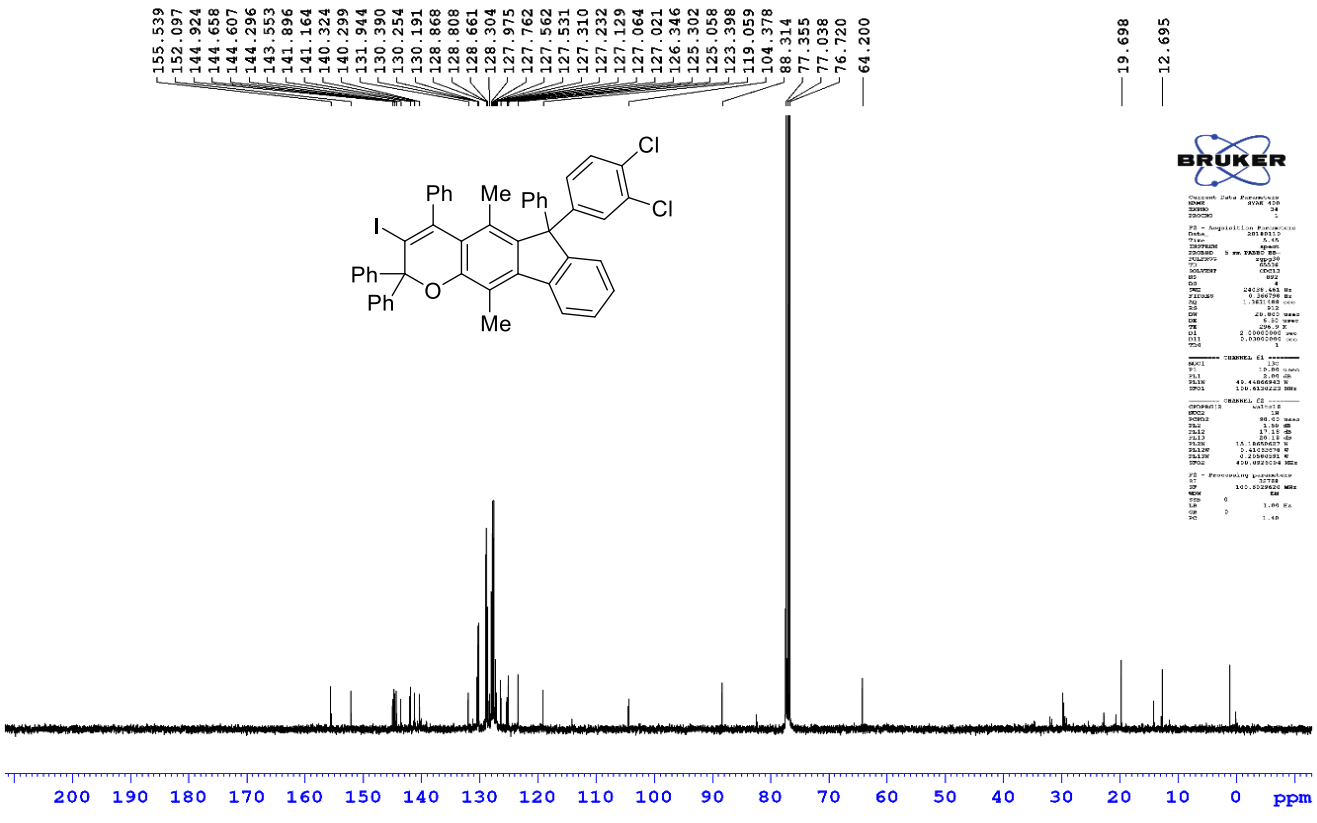

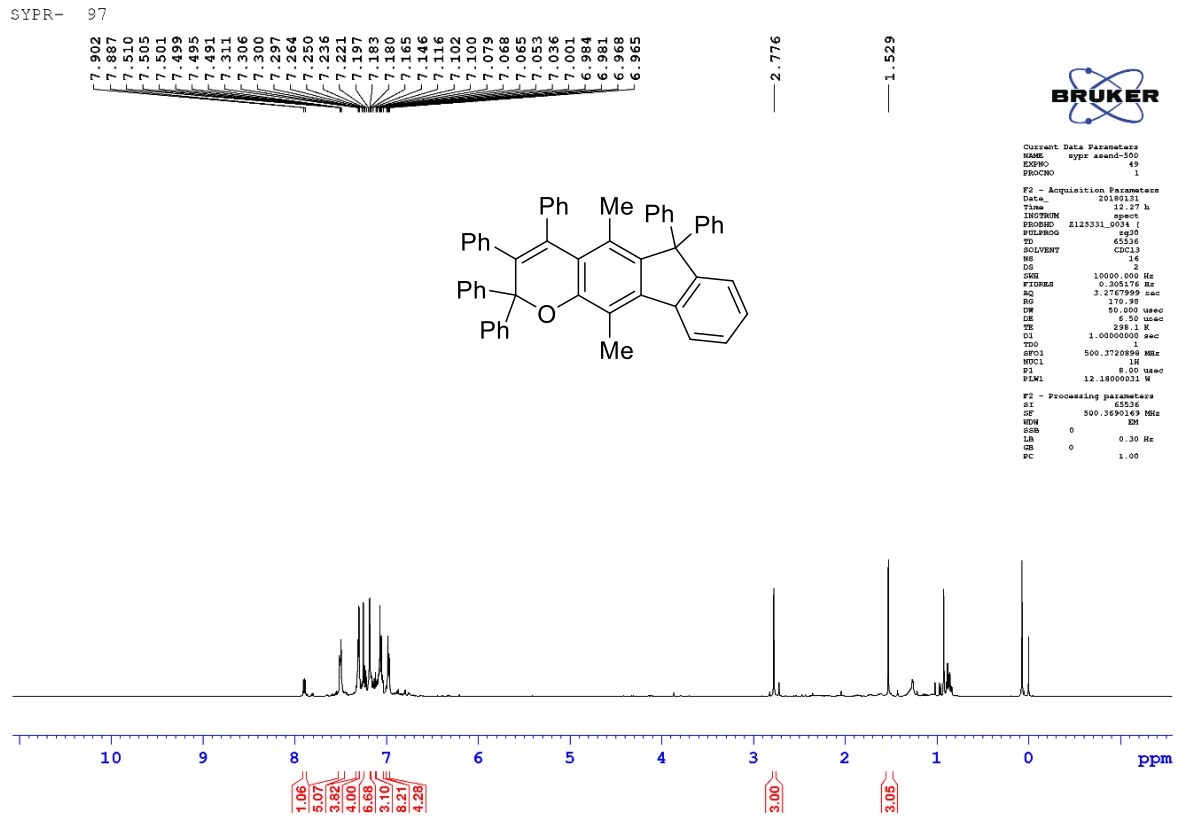
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7.053
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PROCNO 1
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RG 170.98
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DE 6.50 usec
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SFO1 500.3720898 MHz
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PC 1.00
10
9
8
7
6
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4
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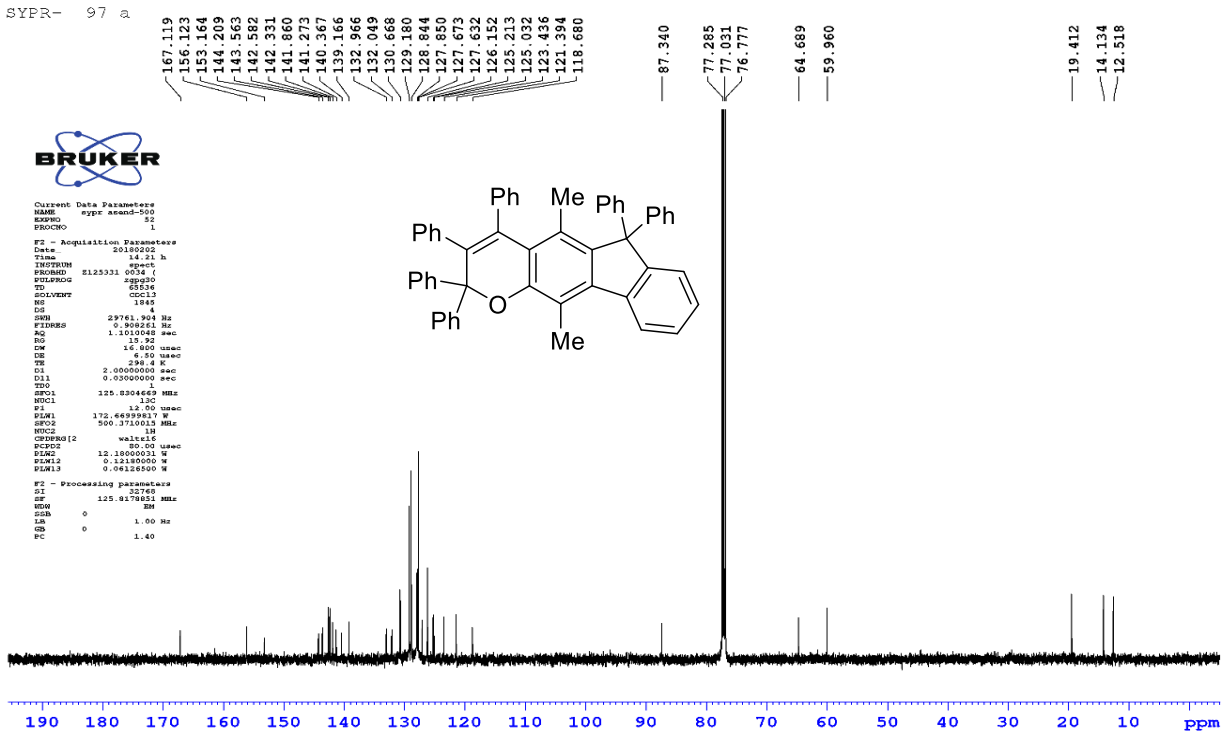
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PROCNO 1
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FIDRES 0.908261 Hz
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P1 12.50 usec
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PLW13 0.06126500 W
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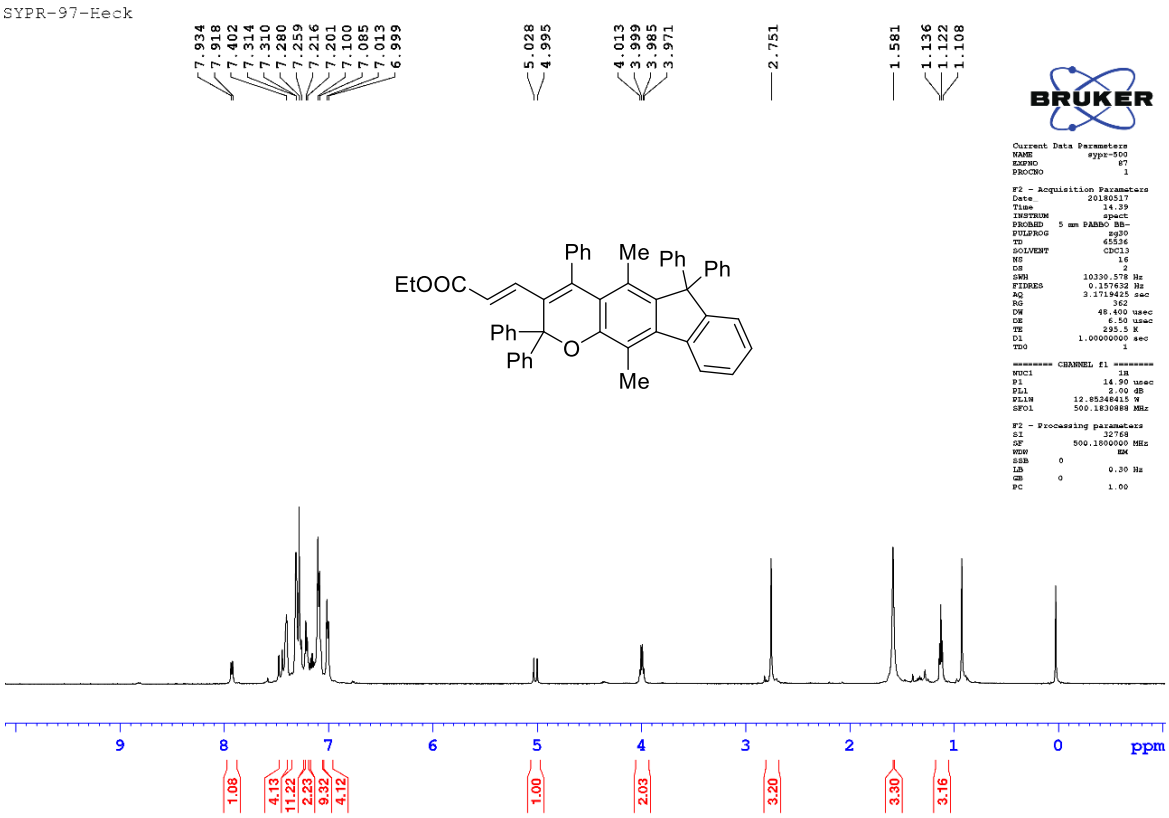
ppm

SYPR-97-Heck



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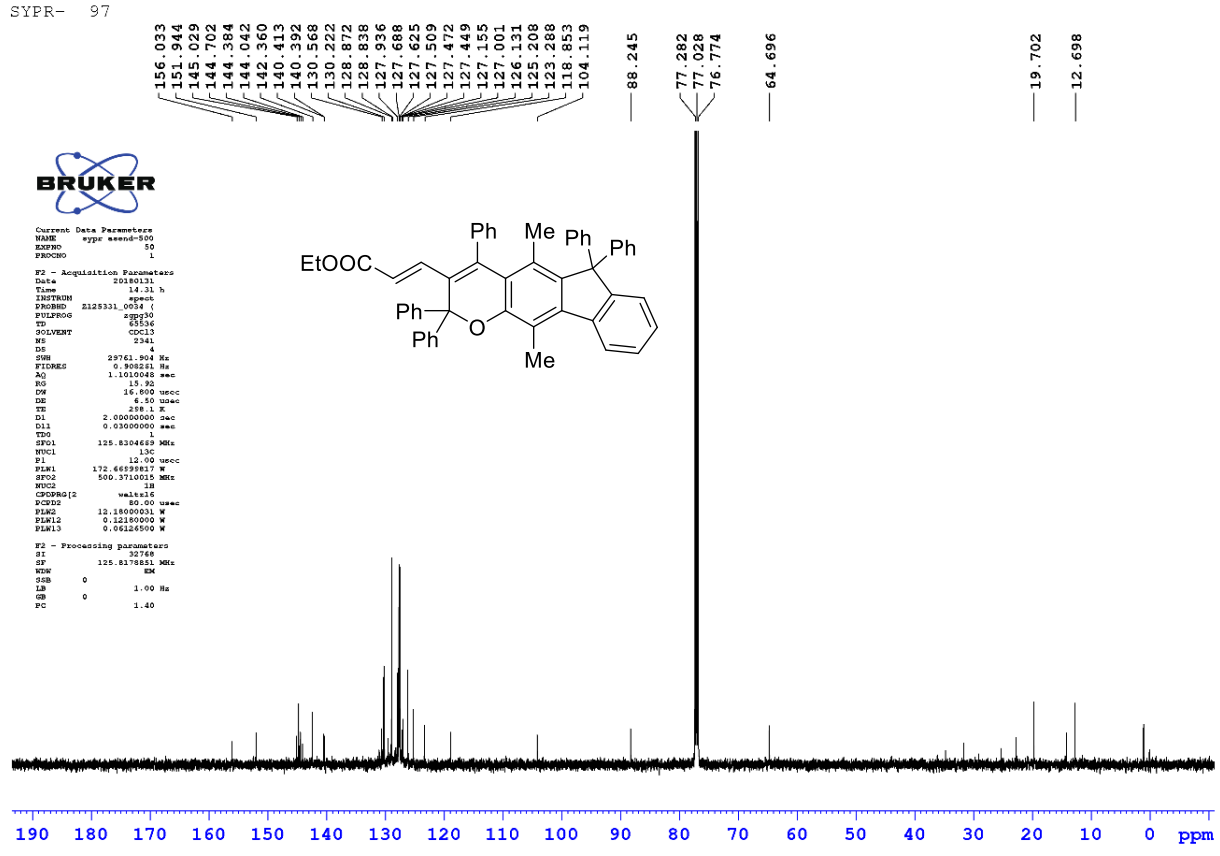

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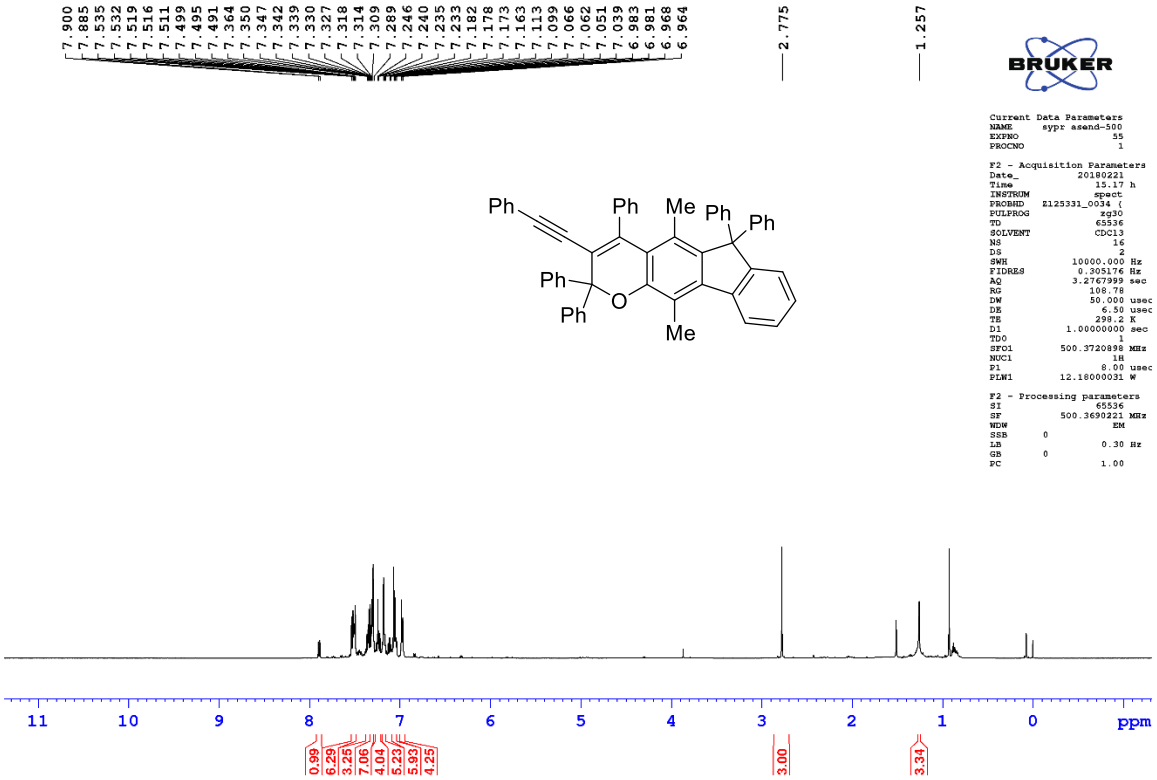

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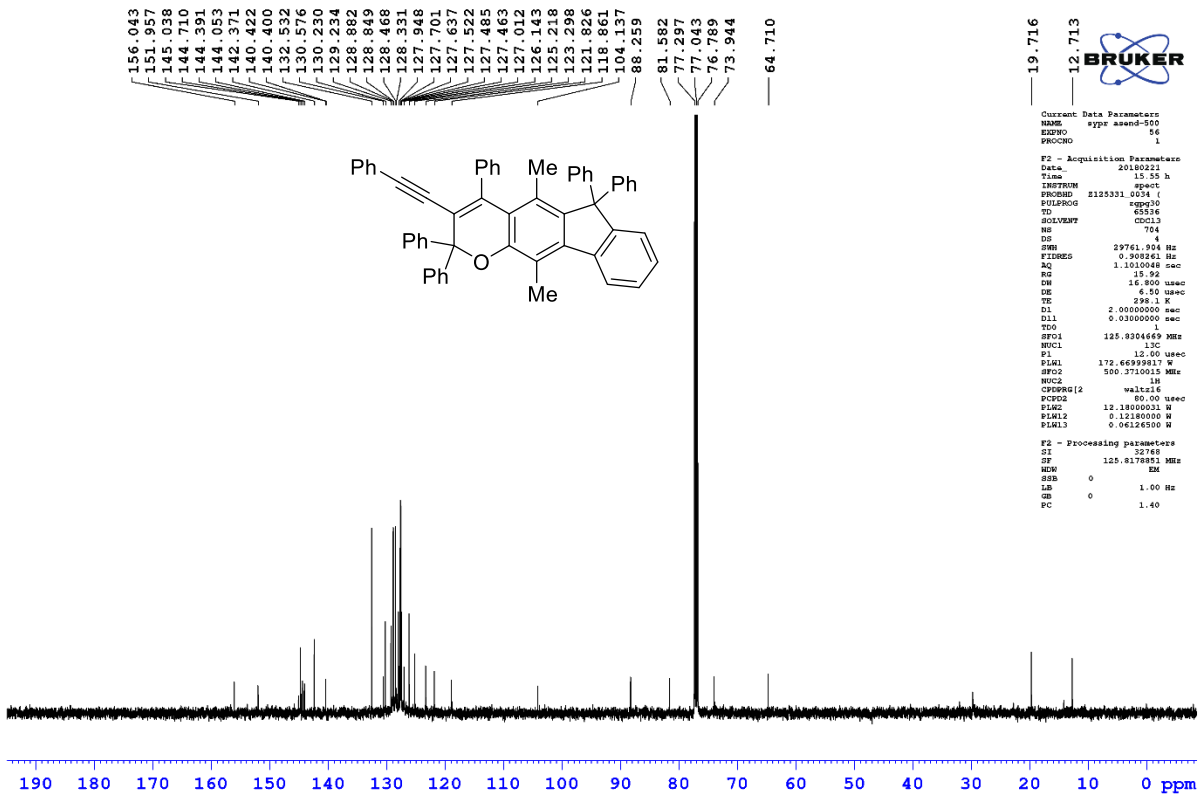

List of Publications

1. Stereoselective Sulfenylation of Oxindole-derived Propargyl Alcohols: Calcium catalyzed, Solvent-Free Synthesis of Sulfenylated-3-Alkenyloxindoles, T. Khan, **P. Rajesh,** D. Arun, S. Yaragorla, ***Org. Biomol. Chem.,* 2021,***19,*** 10201**.**

2. Calcium-Catalyzed Intramolecular Hydroamination-Deacylation Reaction of in situ formed *β*-Amino Allenes, S. Yaragorla, D. Sneha Latha. **P. Rajesh,** ***Adv. Synth. Catal.* 2021,** *363,* 5486**.**

3. Calcium-catalyzed formal [3 + 2] annulation of C, N-diacyliminium ions with nucleophilic phenols: a diversity oriented synthesis of 3-aminofurans. **Rajesh P**., A. I. Almansour, N. Arumugam, and S. Yaragorla. ***Org. Biomol. Chem.* 2021,** *19,* 1060.

4. In Situ Generation of Allenes and their Application to One-Pot Assembly of Functionalized Fluoreno[3,2-b]furans by Calcium- Catalyzed, Regioselective, 3-Component Reactions. S Yaragorla, **Rajesh.** P ***Eur. J. Org. Chem.* 2020,** 7243.

5. Brønsted acid promoted Thermal-Ring-Rearrangement of Fluorenopyrans to 2-(1H-inden-3-yl)-9H-fluoren-3-ols bearing two all-carbon-quaternary centres. T Khan, **P Rajesh**, D Praveen, K. V. Jovan Jose, S Yaragorla. ***Eur. J. Org. Chem.* 2020,** 2199.

6. An efficient Benzannulation protocol for the synthesis of 9,9-Diphenyl-9*H*-fluorenols using Intramolecular Allene Friedel–Crafts Annulation. S Yaragorla, **P Rajesh**. ***Eur. J. Org. Chem.* 2019,** 5740.

7. Regiospecific formal [3+ 2] annulation of tert-propargyl alcohols with acyclic1, 3-diketones via the cycloisomerization of homoallenyl ketones. S Yaragorla, **P Rajesh.** ***Org. Biomol. Chem*. 2019,** *17,* 1924.

8. Ca (II)-Mediated Regioselective One-pot Sequential Annulation of Acyclic compounds to Polycyclic Fluorenopyrans. S Yaragorla, **P Rajesh**, A Pareek, A Kumar. ***Adv. Synth. Catal*. 2018,** *360,* 4422.

9. Highly Regioselective Synthesis of Oxindolyl-Pyrroles and Quinolines via a One-Pot, Sequential Meyer–Schuster Rearrangement, Anti-Michael Addition/$C_{(sp^3)}$–H Functionalization, and Azacyclization. S Yaragorla, R Dada, **P Rajesh**, M Sharma. ***ACS omega* 2018,** *3,* 2934.

Calcium-catalyzed in-situ synthesis and cyclization reactions of tetrasubstituted allenes

by Rajesh Pallava

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Submission ID: 1802200280
File name: Rajesh-Thesis.docx (4.23M)
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Character count: 68283

Calcium-catalyzed in-situ synthesis and cyclization reactions of tetrasubstituted allenes

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University of Hyderabad
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School of Chemistry
University of Hyderabad

Intramolecular Allene Friedel-Crafts Annulation ", European Journal of Organic Chemistry, 2019
Publication

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5 Srinivasarao Yaragorla, P. Rajesh. " Regiospecific formal [3 + 2] annulation of -propargyl alcohols with acyclic 1,3-diketones the cycloisomerization of homoallenyl ketones ", Organic & Biomolecular Chemistry, 2018 — 1 %
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6 Srinivasarao Yaragorla, P. Rajesh, Abhishek Pareek, Ankit Kumar. "Ca(II)-Mediated Regioselective One-pot Sequential Annulation of Acyclic compounds to Polycyclic Fluorenopyrans", Advanced Synthesis & Catalysis, 2018 — 1 %
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University of Hyderabad
Hyderabad-500 046, India.

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7 Srinivasarao Yaragorla, Rajesh P. "Regiospecific formal [3+2] Annulation of tert-Propargyl alcohols with acyclic 1,3-diketones via the Cycloisomerization of homoallenyl ketones", Organic & Biomolecular Chemistry, 2018 — 1 %
Publication

Our publication
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Internet Source

Submitted to Alfaisal University

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11	Bingyu Yan, Yang Fu, Hui Zhu, Zhiyuan Chen. " Synthesis of Divergent Benzo[ ]fluorenones through Cycloaromatization Reactions of 1,5-Enynols and 1,5-Diynols ", The Journal of Organic Chemistry, 2019 Publication	<1%
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13	Eiji Yoneda, Takayuki Kaneko, Shi-Wei Zhang, Kiyotaka Onitsuka, Shigetoshi Takahashi. "Ruthenium-Catalyzed Cyclic Carbonylation of Allenyl Alcohols. Selective Synthesis of γ- and δ-Lactones", Organic Letters, 2000 Publication	<1%

14	Srinivasarao Yaragorla, Ravikrishna Dada, Abhishek Pareek, Garima Singh. " A calcium catalysed regioselective (5- dig) tandem process for the synthesis of fully substituted furans ", RSC Advances, 2016 Publication	<1 %
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