

***“Organophosphine Catalyzed Intramolecular  
Hydroacylation and  $\delta'$  [C(Sp<sup>3</sup>) – H] Functionalization of  
Activated Ynones.”***

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*A dissertation submitted for the partial fulfilment of  
MS degree in Science*



**Department of Chemical Sciences**

**Indian Institute of Science Education and Research (IISER) Mohali**

**November 2018**

*Dedicated*

*To*

*My Parents*

*Who have been my inspiration to lead a successful life*

## Certificate of Examination

This is to certify that the dissertation titled “*Organophosphine Catalyzed Intramolecular Hydroacylation and  $\delta'$  [C( $Sp^3$ ) – H] Functionalization of Activated Ynones*” submitted by Mr. Raju Hazra (Reg. No. MP15008) for the partial fulfilment of MS degree programme of the Institute, has been examined by the thesis committee duly appointed by the Institute. The committee finds the work done by the candidate satisfactory and recommends that the report be accepted.

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## Declaration

The work presented in this dissertation has been carried out by me under the supervision of **Dr. S. S. V. Rama Sastry** at the Department of Chemical Sciences, Indian Institute of Science Education and Research Mohali.

This work has not been submitted in part or in full for a degree, a diploma, or a fellowship to any other university or institute. Whenever contributions of others are involved, every effort is made to indicate this clearly, with due acknowledgment of collaborative research and discussions. This thesis is a bonafied record of original work done by me and all sources listed within have been detailed in the bibliography.

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## Acknowledgement

Without acquiring any help from others, nobody succeeds in any field. I would like to acknowledge all people, who directly or indirectly contributed to my thesis work. I am very fortunate to have **Dr. S.S.V. Rama Sastry** as my MS thesis Supervisor. In many occasions, he has given valuable suggestions that directed me towards right path and motivated me for learning new entity. His understanding about people, positive approach towards problem, his enormous conviction and intellectual ideas make him best human being. I am feeling blessed for submitting my thesis under his supervision.

I would like to thanks my thesis committee members Dr. R. Vijaya Anand and Dr. Sugumar Venkataramani for their valuable inputs and support.

My sincere thanks to Dr. Jagdeep Grover, Mr. Raghu, Dr. Vivek Anand, Mr. Bishnu, Mr. Rajendra and Mr. Siddheshwar for helping me during the project work. I cannot avoid my other lab members, Sonu, Uttam, Bara, Prashant, Kaushlendra, Lona, Atanu, Pinku and Shivangi who helped me in some or other way throughout my project work. They made my life pleasant with lively consenting environment.

I am thankful to IISER Mohali for providing me the instrumental and other infrastructural facilities during the course of my project.

At last, I would like to thank my parents, brother and my friends for their motivation to accomplish my work.

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## Notations and Abbreviations

cm	Centimeter
$\delta$	Chemical shift
CDCl <sub>3</sub>	Chloroform-D
J	Coupling constant
Cy	Cyclohexyl
DCE	Dichloroethane
DCM	Dichloromethane
Et <sub>2</sub> O	Diethyl ether
DME	Dimethoxyethane
DMF	<i>N,N</i> -Dimethyl formamide
DMSO	Dimethyl sulfoxide
d	Doublet
dd	Doublet of doublet
ddd	Doublet of doublet of doublet
dt	Doublet of triplets
EWG	Electron withdrawing group
°C	Degree celsius
dr	Diastereomeric ratio
EtOAc	Ethylacetate
equiv	Equivalents
FT-IR	Fourier transform infrared spectroscopy
Hz	Hertz
h	Hour(s)
<i>i</i> -Pr	<i>iso</i> -Propyl

m.p.	Melting point
mg	Milligram(s)
mL	Milliliter(s)
mmol	Millimole(s)
min	Minute(s)
m	Multiplet
NHC	<i>N</i> -heterocyclic carbene
NMR	Nuclear Magnetic Resonance
Q	Quartet
R <sub>f</sub>	Retention factor
rt	Room temperature
s	Singlet
sept	Septet
<i>tert</i>	Tertiary
<sup>t</sup> Bu	<i>tert</i> -Butyl
TMS	Tetramethylsilane
t	Triplet
td	Triplet of doublets
tt	Triplet of triplet

## Abstract

We present an organophosphine catalyzed MBH-type reaction of activated ynone and the outcome is the hydroacylation of  $\alpha, \beta$ -ynone, which leads to the formation of cyclopentadione-fused arenes and heteroarenes. In addition, we also present an organophosphine catalyzed intramolecular aldol reaction of keto-ynone, which is actually an organophosphine catalyzed  $\delta$ [C(sp<sup>3</sup>)-H]-functionalization of  $\alpha, \beta$ -ynone, leading to the formation of 3-ethynyl-3-hydroxyindanones. Both the methodology occurs at mild conditions and is tolerant to a variety of functional groups and hence we are able to synthesize a series of compound having different type of functional groups with good to excellent yield.

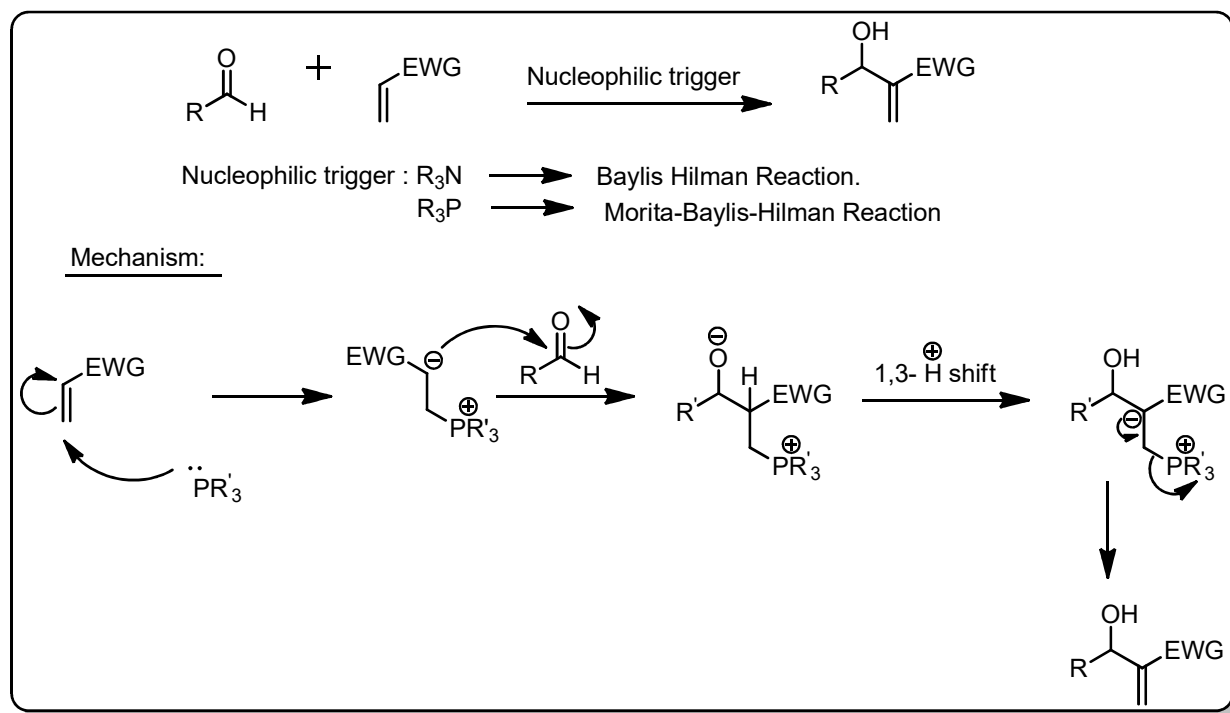
# *Chapter 1*

## **1.1 General introduction to phosphine chemistry and MBH reaction.**

Organophosphorus compounds have been widely used in organic synthesis, for example, phosphonium ylides in the Wittig reaction and transition metal catalyzed reaction in which phosphines act as ligands. There are very few reports on reactions in which phosphines act as a catalyst,<sup>1-4</sup> for example in Morita-Baylis-Hilman(MBH) reaction phosphine act as a catalyst. **(scheme 1.1).**

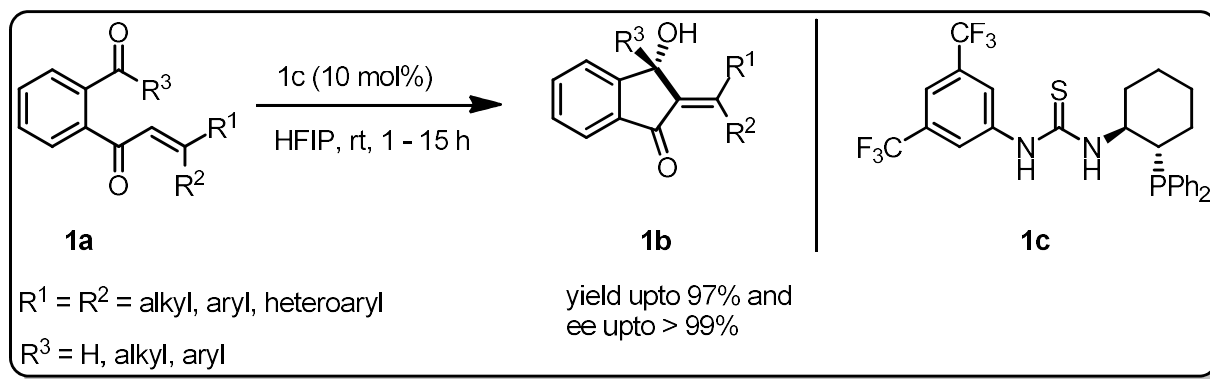
MBH reaction is nothing but a C-C bond forming reaction between the  $\alpha$ - position of an activated alkene and an aldehyde, more generally a Carbon electrophile in presence of a nucleophilic trigger.





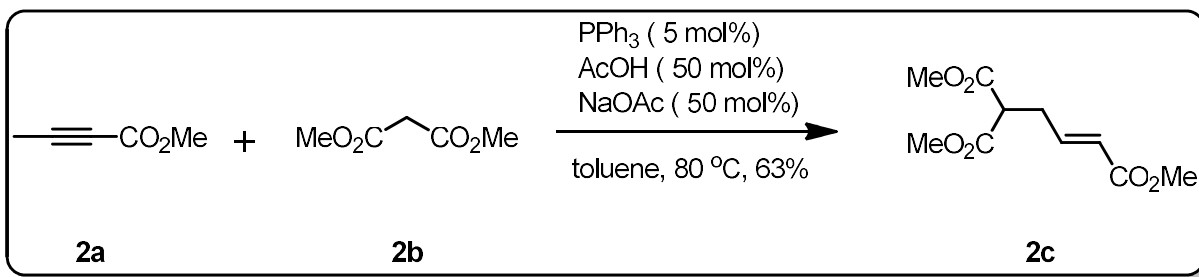
**Scheme 1.1**

Recently our group has developed organophosphine catalyzed intramolecular MBH reaction of  $\beta$ ,  $\beta$ -disubstituted enone with high yield and enantiomeric excess (**scheme 1.2**).<sup>5</sup> In this chemical transformation catalytic amount of chiral phosphine (**1c**) react with highly disubstituted enone (**1a**) to furnish the product (**1b**) in good to excellent yield with good to excellent enantiomeric excess (**scheme 1.2**).



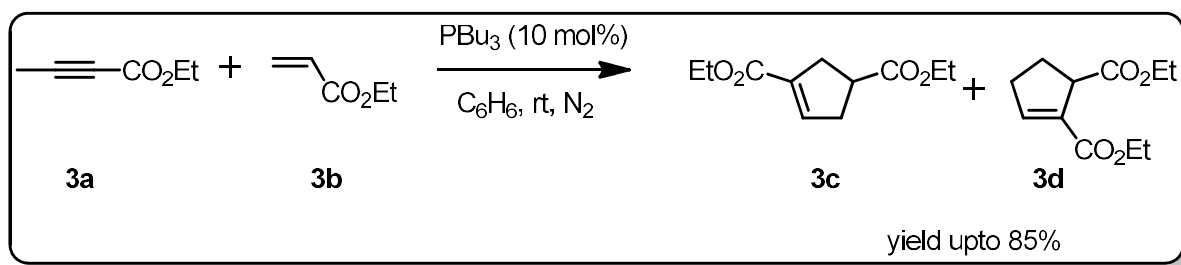
**Scheme 1.2**

So far, it was reported that nucleophilic tertiary phosphine adds to the double bond of an electron deficient alkene first and finally eliminates from the reaction product after a series of transformations. The tertiary phosphine plays the role of a catalyst. But there are very rare reports where nucleophilic tertiary phosphine adds to the triple bond of an electron deficient alkyne first and later elimination from the reaction product leads to the target product.<sup>6-8</sup> Trost first reported the phosphine-catalyzed  $\gamma$ - addition of nucleophiles to 2- alkynoate ( **Scheme 1.3**).<sup>9</sup>



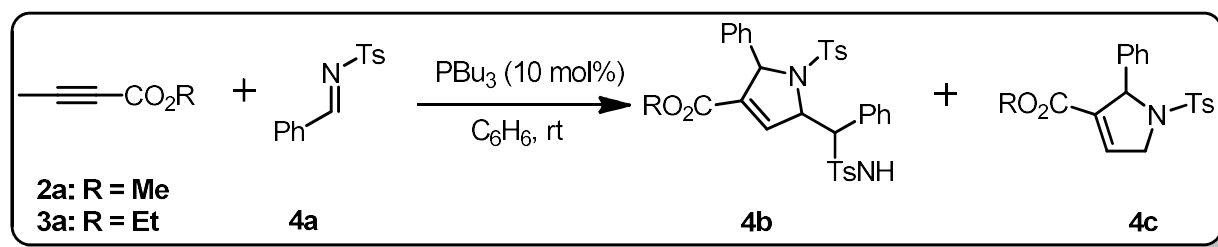
**Scheme 1.3**

Further Xiyan Lu Group develop various phosphine catalyzed [3+2] cycloaddition reaction of alkyne moiety with alkene.<sup>10-11</sup> Treatment of (**3a**) (1 mmol) with ethyl acrylate (2 mmol) in presence of 10 mol% tributylphosphine in dry benzene at room temperature under nitrogen atmosphere gave cycloadduct (**3c**) and (**3d**) in higher yield and regioselectivity (**scheme 1.4**).



**Scheme 1.4**

Instead of ethyl acrylate, they substituted electrophile with imines. Herein, treatment of 2-butynoate with *N*-tosylimines in dry benzene in presence of catalytic amount of tributylphosphine at room temperature furnish the corresponding [3+2] cycloadduct as the major product (**4b**) and small amount of adduct (**4c**), (scheme 1.5).



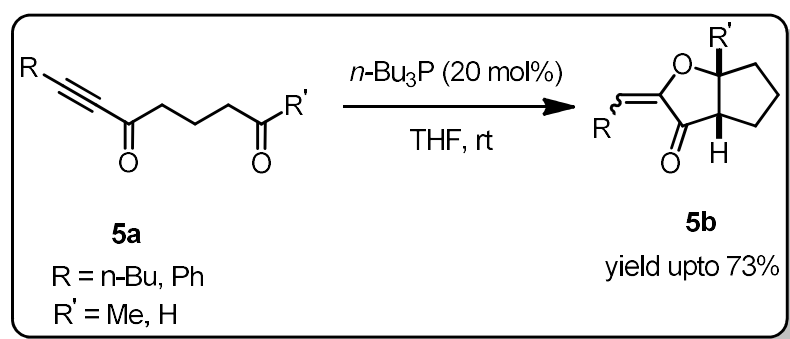
Scheme 1.5

## Chapter 2

### Results and Discussions.

In literature reports we have seen that there are very few reports of organophosphine catalyzed ynone chemistry, and within these very few reports, there are very few research group who reported organophosphine-catalyzed  $[C(sp^3-H)]$ - functionalization of ynones. For example, Tomita, Fu, and Ramachary recently reported organophosphine catalyzed  $\alpha$ - $[C(sp^3-H)]$  functionalization of ynones for the synthesis of cyclopentannulated compounds.

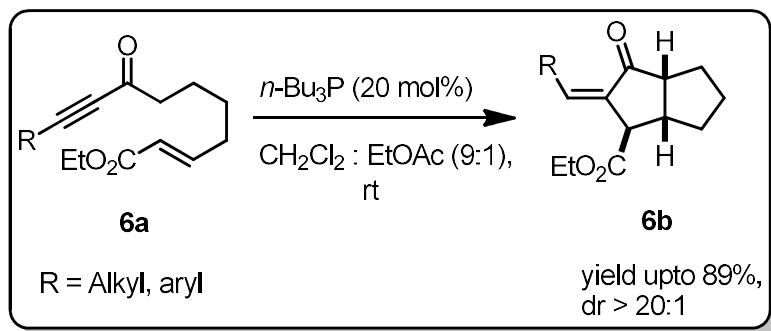
In Tomita's<sup>12</sup> approach, they have described that an unexpected *tri-n*-butylphosphine catalyzed intramolecular zipper cyclization of yne-diones (**5a**) where bicyclic ketone with five-membered ring fused with five-membered ring (**5b**) were obtained with high diastereoselectivity from yne-diones (Scheme 2.1).



Scheme 2.1

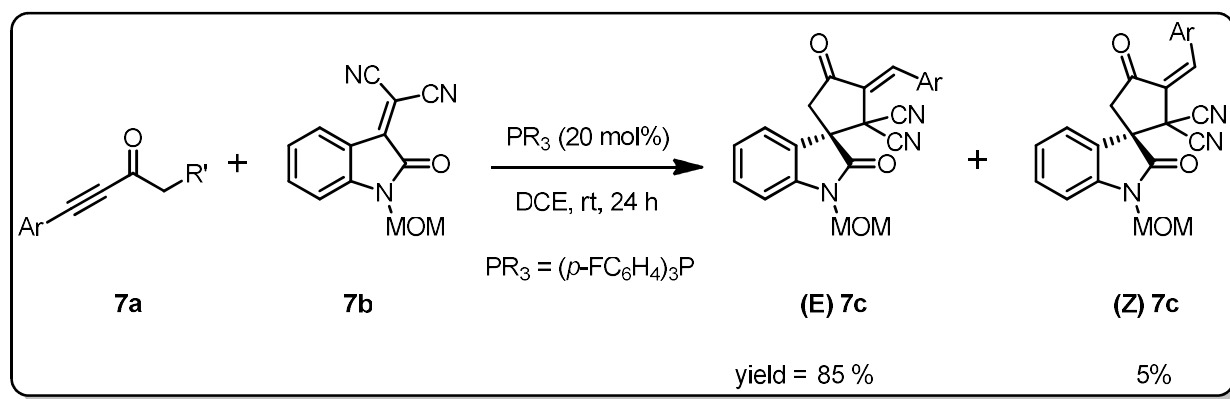
G. C. Fu<sup>13</sup> also developed an intramolecular organophosphine catalyzed  $[C(sp^3-H)]$ -functionalization of ynones in order to synthesize cyclopentannulated compounds. There is a little

bit difference between Tomita's and Fu's design. Fu modified the substrate (**5a**), here he used  $\alpha, \beta$ -unsaturated ester instead of carbonyl moiety. Herein, because of this modification they got diquinanes with high yield and diastereomeric ratio (**Scheme 2.2**).



**Scheme 2.2**

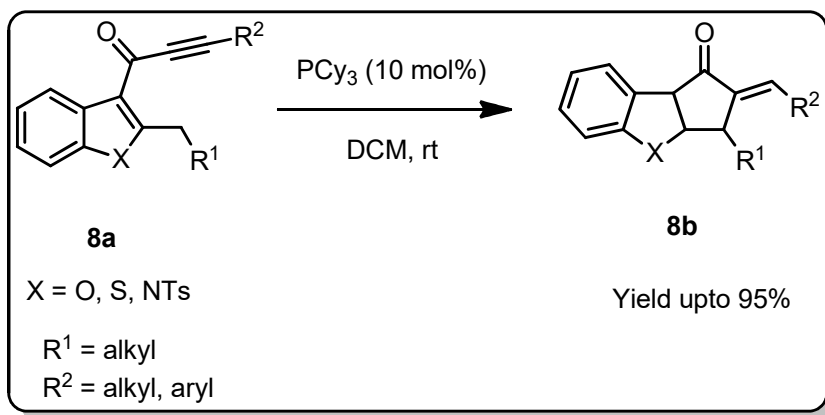
Ramachary<sup>14</sup> developed stereoselective synthesis of spirooxindoles through Tomita zipper cyclization. Here, Ramachary applied intermolecular  $[\text{C}(\text{sp}^3\text{-H})]$ -functionalization of ynones and further reaction with oxindole derivative leads to the target product spirooxindoles. In this reaction there is possibility of formation of two products *E* and *Z* isomer, but *E* – isomer formed as predominant product (**Scheme 2.3**).



**Scheme 2.3**

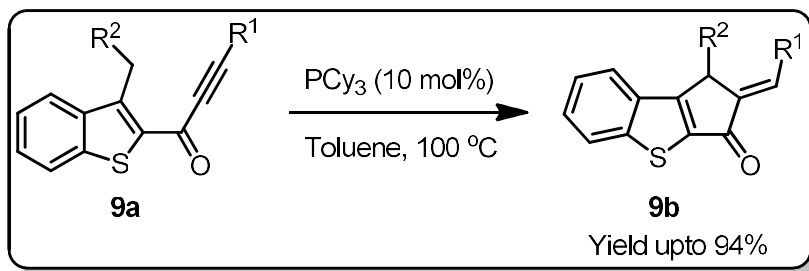
So far, we have noticed that organophosphine catalyzed  $\alpha$ - $[\text{C}(\text{sp}^3)\text{-H}]$  functionalization of ynones. However, to the best of our knowledge, there is no report in literature of  $\gamma$ - $[\text{C}(\text{sp}^3)\text{-H}]$

functionalization of ynonees. Herein, our group first reported<sup>15</sup> organophosphine catalyzed unprecedented  $\gamma$ -[C(sp<sup>3</sup>)-H] functionalization of ynone in order to synthesize cyclopentannulated heteroarenes. At first, phosphine react with ynone (**8a**) in conjugate fashion to furnish the allenolate intermediate which take up acidic  $\gamma$  proton and further carbocyclization and elimination of phosphine leads to the cyclopentannulated product (**8b**), (Scheme 2.4).



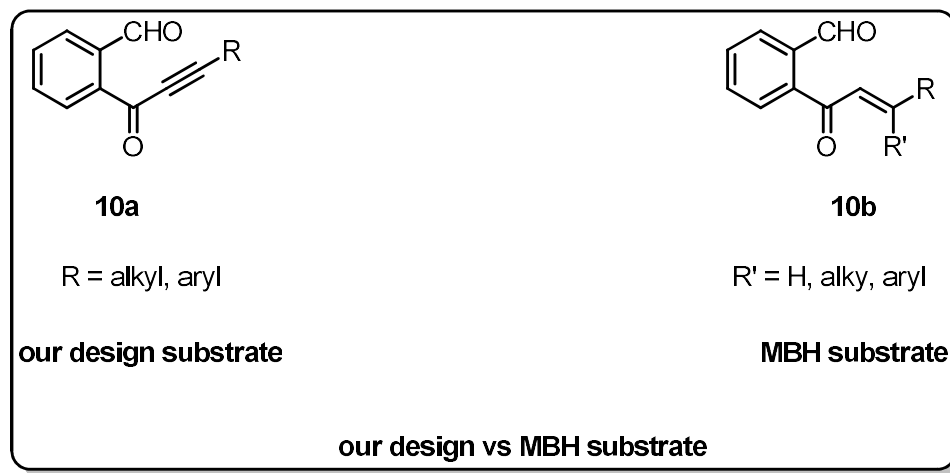
Scheme 2.4

Later on, we slightly modified the design where ynone moiety is on bottom and alkyl moiety is on top. On the basis of this design we are able to make substrate scope with benzothiophene core only. This is also organophosphine catalyzed  $\gamma$ -[C(sp<sup>3</sup>)-H] functionalization of ynone with benzothiophenes.<sup>16</sup> The previous optimization condition PCy<sub>3</sub> (10 mol%), DCM, rt, was unable to furnish the product. A brief optimization of reaction condition has performed and found that the reaction of the ynone (**9a**) with PCy<sub>3</sub> in toluene at 100 °C furnish the desired product (**9b**) in excellent yield with remarkable stereoselectivity (Scheme 2.5).



Scheme 2.5

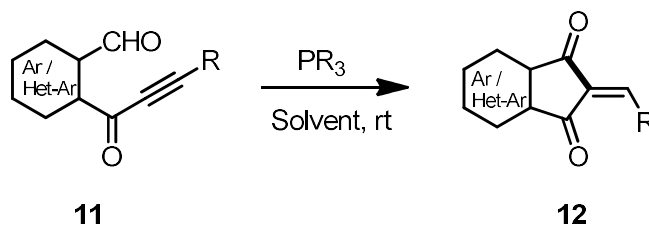
So far, we have seen that in literature, there are very few reports of activated ynone chemistry catalyzed by organophosphine among them our group has described organophosphine catalyzed  $\gamma$ -[C(sp<sup>3</sup>)-H] functionalization of ynones. Based on earlier reports we designed a substrate which is almost similar to intramolecular Morita-Baylis-Hilman(MBH) substrate. The only difference is in our design activated alkyne present to the ortho position of aldehyde whereas in MBH substrate activated alkene present to the ortho position of aldehyde (**Figure 2.1**).



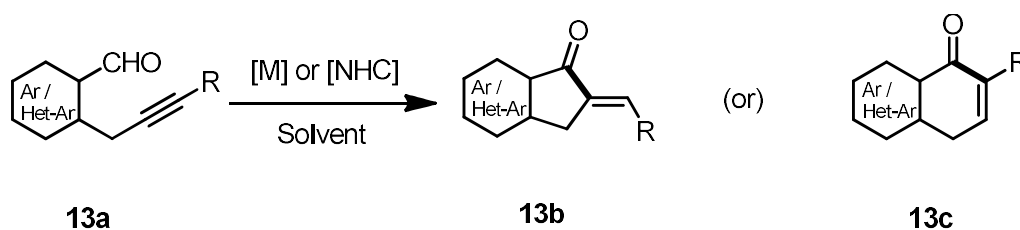
**Figure 2.1**

Typically, MBH reaction is a C-C bond forming reaction between an activated alkene and a carbon electrophile. Whereas, activated alkenes are typical substrate of MBH reaction, we were curious about the activated alkynes under the typical MBH set up. Herein, we disclose an organophosphine catalyzed intramolecular MBH-type reaction of  $\alpha$ ,  $\beta$ -ynones that provides direct access to 1,3-cyclopenta fused arenes and heteroarenes. The overall transformation originally represents hydroacylation of  $\alpha$ ,  $\beta$ -ynones catalyzed by organophosphine (**Scheme 2.6a**). So far, the hydroacylation of activated or unactivated alkynes is reported by either transition metal complexes<sup>17</sup> or N-heterocyclic carbenes(NHCs)<sup>18</sup> (**Scheme 2.6b**).

Scheme 2.6a : Organophosphine catalyzed hydroacylation of ynones.

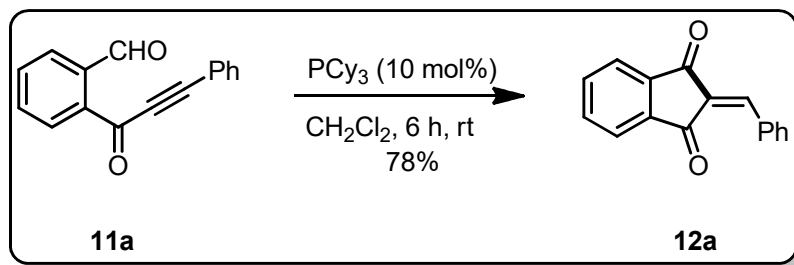


Scheme 2.6b : Metal or NHC catalyzed hydroacylation of alkynes.



Scheme 2.6

The aforementioned reaction was studied with the model substrate **11a**<sup>19</sup>, in which the  $\alpha,\beta$ -ynone and aldehyde functionalities are present in ortho to each other. Surprisingly, reaction of **11a** with 10 mol% of  $\text{PCy}_3$  at room temperature furnished an unexpected product **12a**<sup>20</sup> in 78% yield (Scheme 2.7). If we look at the product carefully, it is nothing but an indane derivative and hence, we can say that the reaction is an unusual approach for the synthesis of densely functionalized indanes. There are several bioactive natural products, which possess Indane<sup>21</sup> framework and hence this is an important attractive strategy to access those kind of natural products.



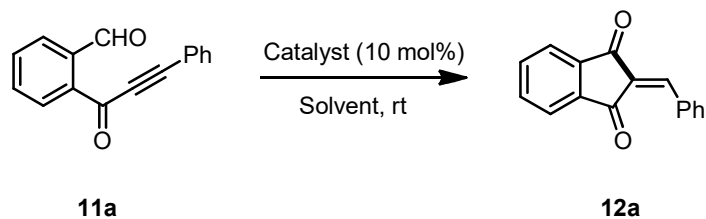
Scheme 2.7



However, to further increase the yield of the reaction, the optimization studies were carried out with different phosphines and in different solvents (**Table 2.1**). During screening of phosphines, an enhanced improvement in the yield of **12a** was observed with PPh<sub>3</sub> (**entry 4**). Further solvent screening with PPh<sub>3</sub> did not give any significant improvement in the yield (**entries 5-10**). We also verified that the reaction is working well in aqueous condition as well and interestingly the product **12a** is forming in high yield, 88%, even in presence of water (**entry 9**).<sup>15,22</sup> Even the reaction is working in brine solution also and furnishing the **12a** in excellent yield, 91% (**entry 10**).

On the other hand, well known and most successful catalysts in Baylis-Hilman chemistry, such as, 1,4-diazabicyclo[2.2.2]octane (DABCO) and  $\beta$ -isocupreidine ( $\beta$ -ICD) failed to generate even trace amount of the expected product (**entries 11 and 12**).

**Table 2.1. Optimization of reaction parameters.<sup>a</sup>**

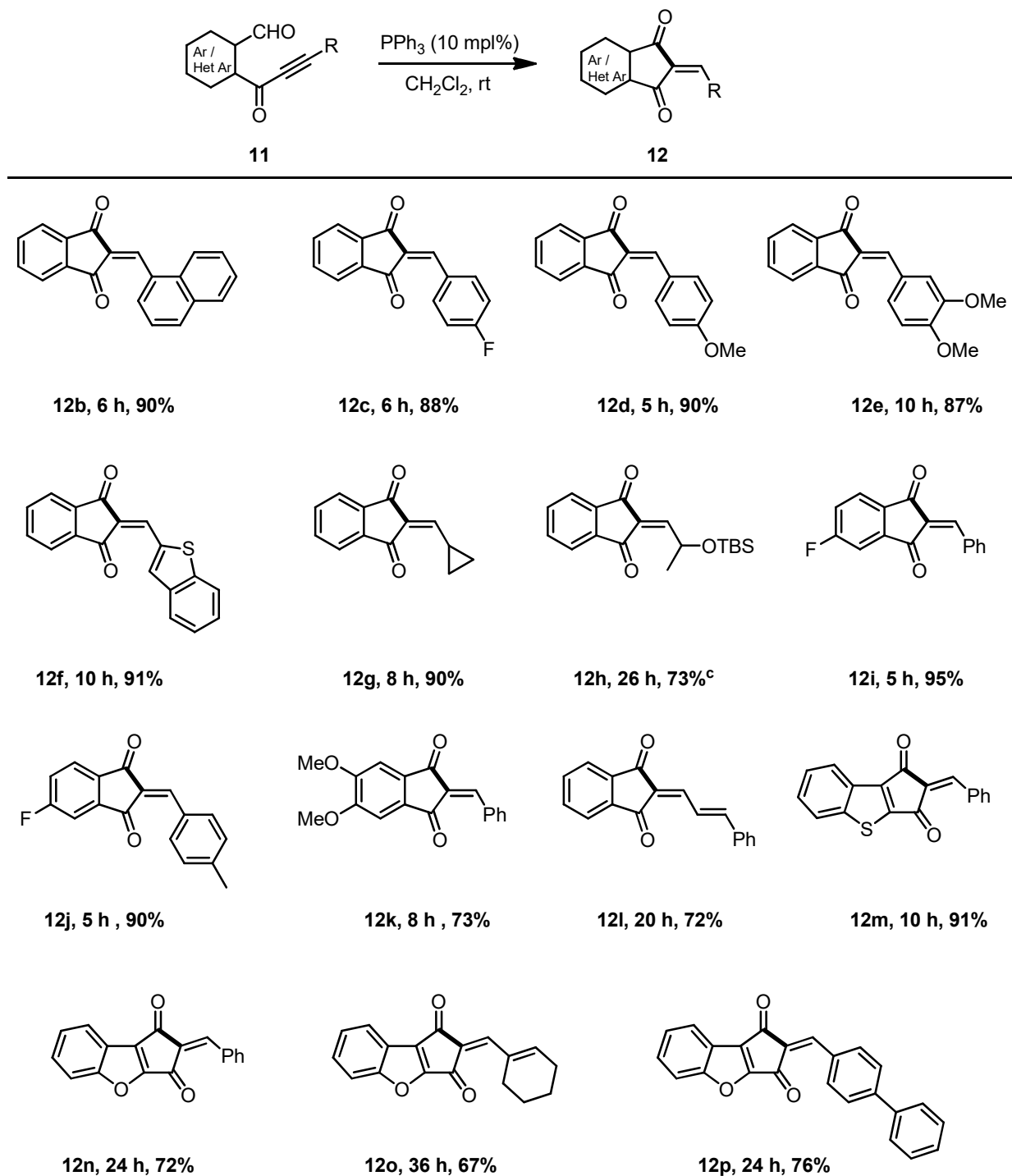


Entry	Catalyst (10 mol%)	Solvent	Time (h)	Yield (%)
1	PCy <sub>3</sub>	CH <sub>2</sub> Cl <sub>2</sub>	6	78
2	PMe <sub>2</sub> Ph	CH <sub>2</sub> Cl <sub>2</sub>	8	48
3	PEtPh <sub>2</sub>	CH <sub>2</sub> Cl <sub>2</sub>	4	72
<b>4</b>	<b>PPh<sub>3</sub></b>	<b>CH<sub>2</sub>Cl<sub>2</sub></b>	<b>5</b>	<b>92</b>
5	PPh <sub>3</sub>	CH <sub>3</sub> CN	3	76
6	PPh <sub>3</sub>	Toluene	12	82
7	PPh <sub>3</sub>	CH <sub>3</sub> O <sup>t</sup> Bu	4	70
8	PPh <sub>3</sub>	2-Me-THF	72	79
9	PPh <sub>3</sub>	H <sub>2</sub> O : THF (1:1)	40	88
10	PPh <sub>3</sub>	Brine	8	91
11	DABCO	CH <sub>2</sub> Cl <sub>2</sub>	48	–
12	β-ICD	CH <sub>2</sub> Cl <sub>2</sub>	12	–

<sup>a</sup>Reaction Conditions : A mixture of **11a** (0.1 mmol) and a catalyst (0.01 mmol) in a solvent were stirred at room temperature until **11a** disappeared (monitored by TLC). Isolated yields are reported.

Hence, 10 mol% of the cheap and readily available PPh<sub>3</sub> was considered as the catalyst for the conversion of **11a** to **12a** in dichloromethane solvent. After that, to understand the scope of the reaction, we applied the optimized conditions to synthesize various substrates (**Table 2.2**).

**Table 2.2. Substrate Scope : Cyclopentannulated Arenes and Heteroarenes<sup>a,b</sup>**

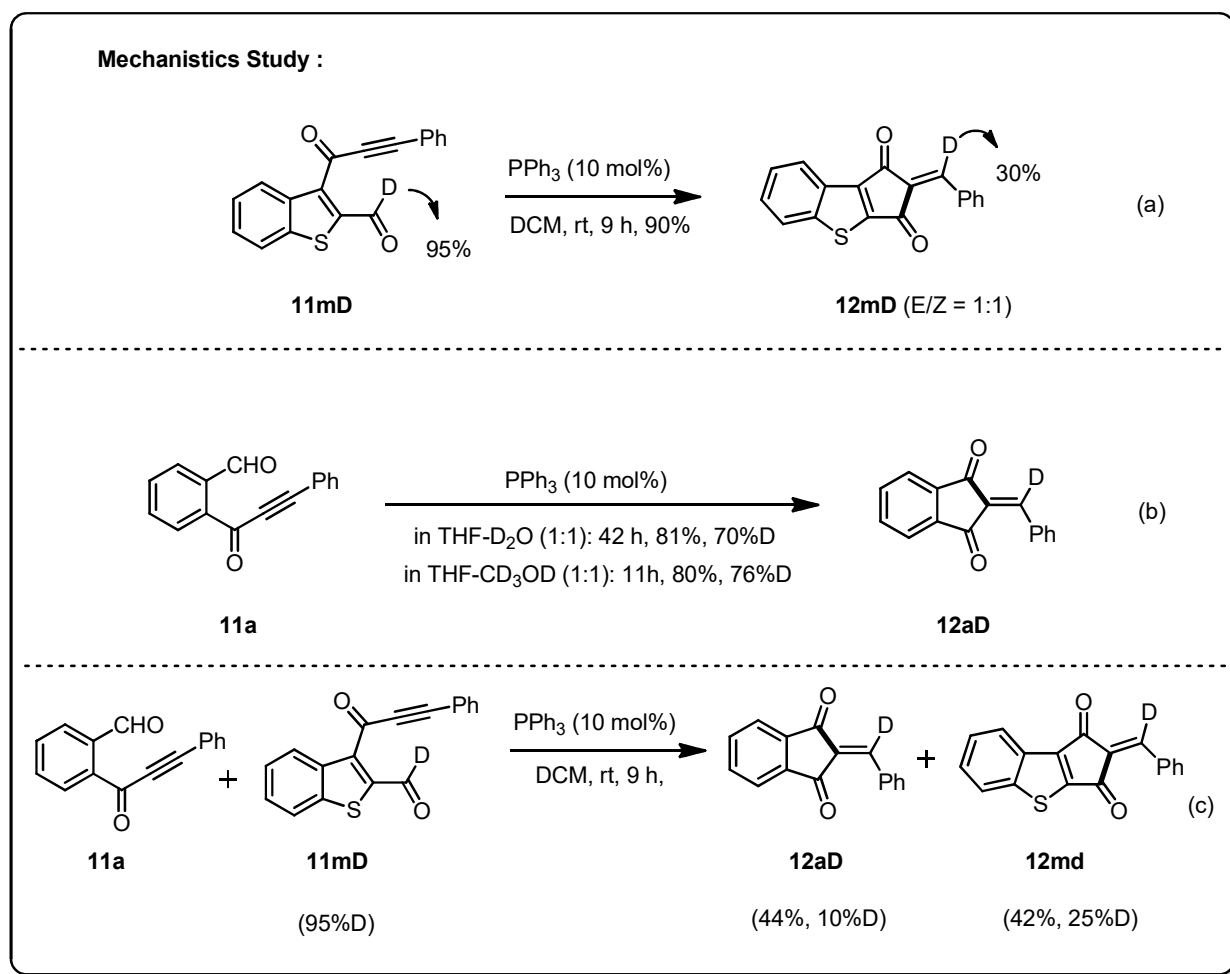


<sup>a</sup>Reaction Conditions: A mixture of **11** (0.1 mmol) and  $\text{PPh}_3$  (0.01 mmol) in DCM (1 ml) were stirred at room temperature until **11** disappeared (monitored by TLC). <sup>b</sup>Isolated Yields are reported. <sup>c</sup>At 40 °C.

We have synthesized a wide range of 2-alkylidene and 2-arylidene-1,3-indanediones possessing both electron donating and electron withdrawing groups in good to excellent yield, 67% - 91%, (**Table 2.2**). The ynones with alkyl groups also able to furnish the corresponding indanediones in good yields (**12g & 12h**). Not only ynones, enynone-containing substrates were also furnished the respective indanedione under the same optimized conditions, for example, **12i** and **12o** were obtained in 72% and 67% yields respectively. We didn't stop here, to further check the generality of this method we have synthesized functionalized 1,3-cyclopentadione-fused benzothiophenes (**12m**) and benzofurans (**12n, o & p**) in good to excellent yields.

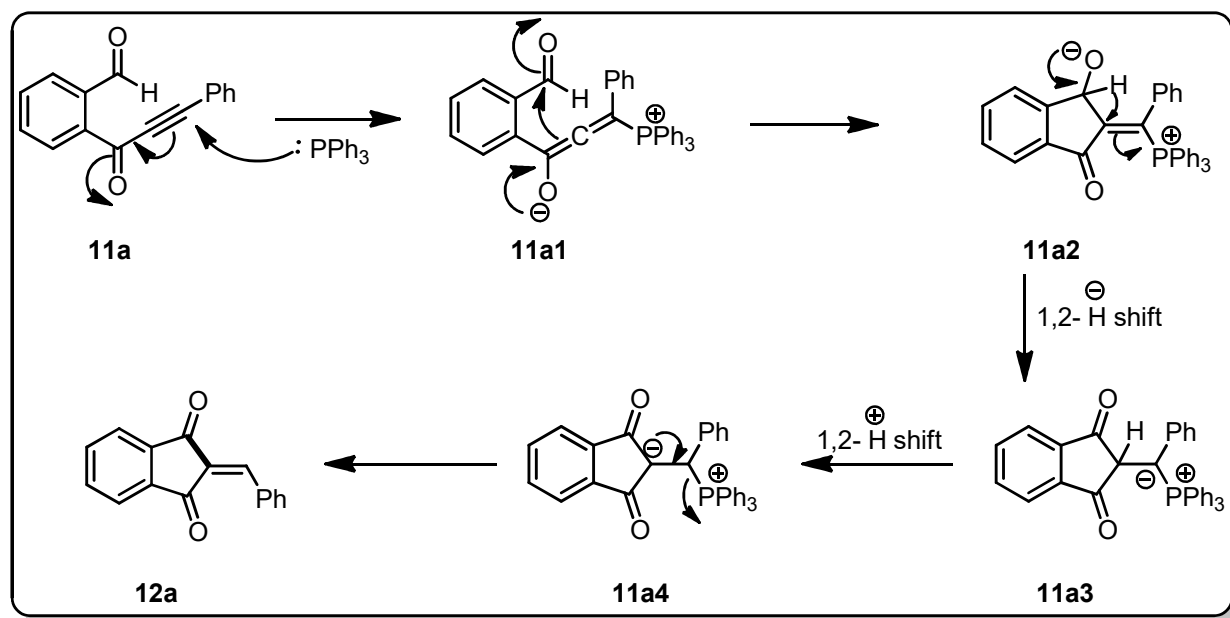
Next, we turned our attention to understand the mechanism of the phosphine catalyzed hydroacylation reaction (**Scheme 2.8**). To prove the mechanism of the reaction we prepared the parent substrate **11mD**, which possess deuterated functionality (95%D). We subjected this deuterated starting compound under optimized condition (**Scheme 2.8a**) and interestingly, in the product **12mD** the deuterium incorporation decreased to 30%, which indicate that in the course of reaction the transformation of **11mD** to **12mD** may involve intermolecular proton transfer with solvent which dominate over intramolecular proton transfer. This hypothesized proton transfer with the solvent environment was further demonstrated when **11a** was subjected under optimized condition in the presence of deuterated solvents (**Scheme 2.8b**), where 'D'-incorporation in the product **12a** was identified as 70% in THF-D<sub>2</sub>O (1:1) mixture and 76% in THF-CD<sub>3</sub>OD (1:1) mixture, but not 100%. This experiment demonstrates that in the course of reaction both intramolecular and intermolecular proton transfer are involved but intermolecular proton transfer process predominate over the intramolecular proton transfer process.

A deuterium scrambling experiment between **11a** and **11mD** was also performed (**Scheme 2.8c**) and the outcome of the experiment was observed in the products **12aD** and **12mD** with 10% and 25% 'D'-incorporation respectively, which suggests that the aldehydic proton is lost in the solvent environment during the transformation, and due to intermolecularity of the proton transfer step it again re-enters in the system and that's why we observed 10% 'D'-incorporation in the product **12aD**.



**Scheme 2.8**

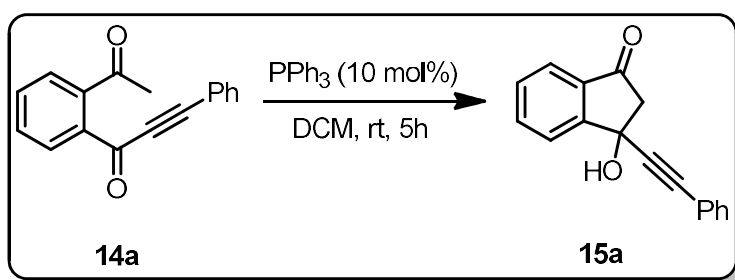
Based on the experimental evidence, a plausible mechanism is proposed for that hydroacylation reaction (**Scheme 2.9**). At first, phospha-Michael addition take place to form the allenolate intermediate **11a1**. The allenolate intermediate undergo intramolecular aldol reaction to provide the zwitterionic species **11a2** which, then transform to ylide **11a3** through 1,2-hydride shift. The ylide **11a3** undergo 1,2-proton shift or proton exchange with solvent to provide the zwitterionic species **11a4** which then eliminate the phosphine to yield the expected product **12a**.



Scheme 2.9

So far we have seen that, the hydroacylation reaction of the model substrate **11a** in which activated ynone and aldehyde are in ortho to each other. Having inspired from this hydroacylation reaction we thought about another model substrate **14a** in which keto group having  $\alpha$ -proton present to the ortho position of activated ynone instead of aldehyde functionality.

Hence, we prepared the substrate **14a** and subjected under the reaction conditions described in **Table 2.2** and surprisingly an unexpected product **15a** was isolated in 43% yield (**Scheme 2.10**).



Scheme 2.10

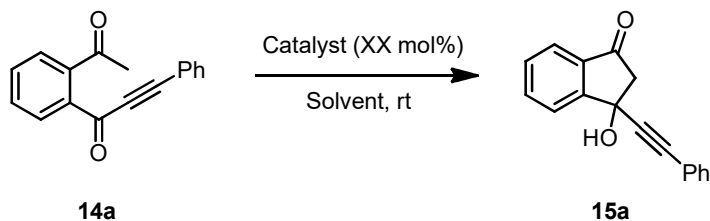
Basically, in this reaction transformation the product obtained is aldol product. Hence the salient feature of this transformation is that it involves an unprecedented *organocatalytic*  $\delta^1\text{C}(sp^3)\text{-H}$ -

**functionalization of  $\alpha$ ,  $\beta$ -ynones.** To the best of our knowledge, this study also demonstrates a phosphine-catalyzed intramolecular aldol reaction of keto-ynones.<sup>23</sup>

However, to further increase the yield of the reaction a brief optimization studies was carried out in different kind of phosphine and in different solvent (**Table 2.3**). By applying the optimized conditions described in **Table 2.2** we isolated the product **15a** in 43% yield. After increasing the mol% of PPh<sub>3</sub> and changing the solvent DCM to toluene no change in yield observed. Keeping the solvent, toluene, fixed we changed the catalyst from PPh<sub>3</sub> (20 mol%) to PBu<sub>3</sub> (20 mol%) and herein we observed the increase in yield of **15a** (**entry 3**), but no significant change in yield was observed even with 1 eq. of PBu<sub>3</sub>. Then we changed the phosphines, yet no improvement of yield was observed. So till now, PBu<sub>3</sub> (20 mol%) is working better than any other phosphines, but yield is poor. Hence, we kept the catalyst, PBu<sub>3</sub> (20 mol%), constant and started the changing solvents. During solvent screening, we observed the comparable yield of **15a** in DCM, acetonitrile and in trifluoroethanol (**entry 9-11**). After that we decided to move towards the amide solvent and a significant increase in the yield of **15a** was observed, in formamide it is 51% and in *N,N*-dimethylacetamide the yield is 61% (**entry 12 & 13**), but still yield is not very good. Then we thought about alcohol solvents and first alcohol solvent used was isopropanol. A remarkable increase in yield (82%) of **15a** was observed (**entry 14**). In methanol and ethanol yields decreased compared to isopropanol (**entry 15 & 6**). We tried the reaction in isopropanol solvent at 0 °C, but no change in yield was observed, yield was same like at room temperature. Then we tried the alcohol *tert*-butanol and surprisingly yield of **15a** increased to 87% (**entry 18**). We decreased the catalyst loading from 20 mol% to 10mol% keeping the solvent *tert*-butanol fixed, but yield is poor (62%), even after 24 hours also no improvement of yield was observed.

Herein, having a brief look at the optimization table, we can conclude that, under 20 mol% PBu<sub>3</sub> in *tert*-butanol at room temperature, **14a** furnished the expected product **15a** in excellent yield (87%) (**entry 18**) and this is our optimized conditions.

**Table 2.3. Optimization of reaction parameters.<sup>a</sup>**



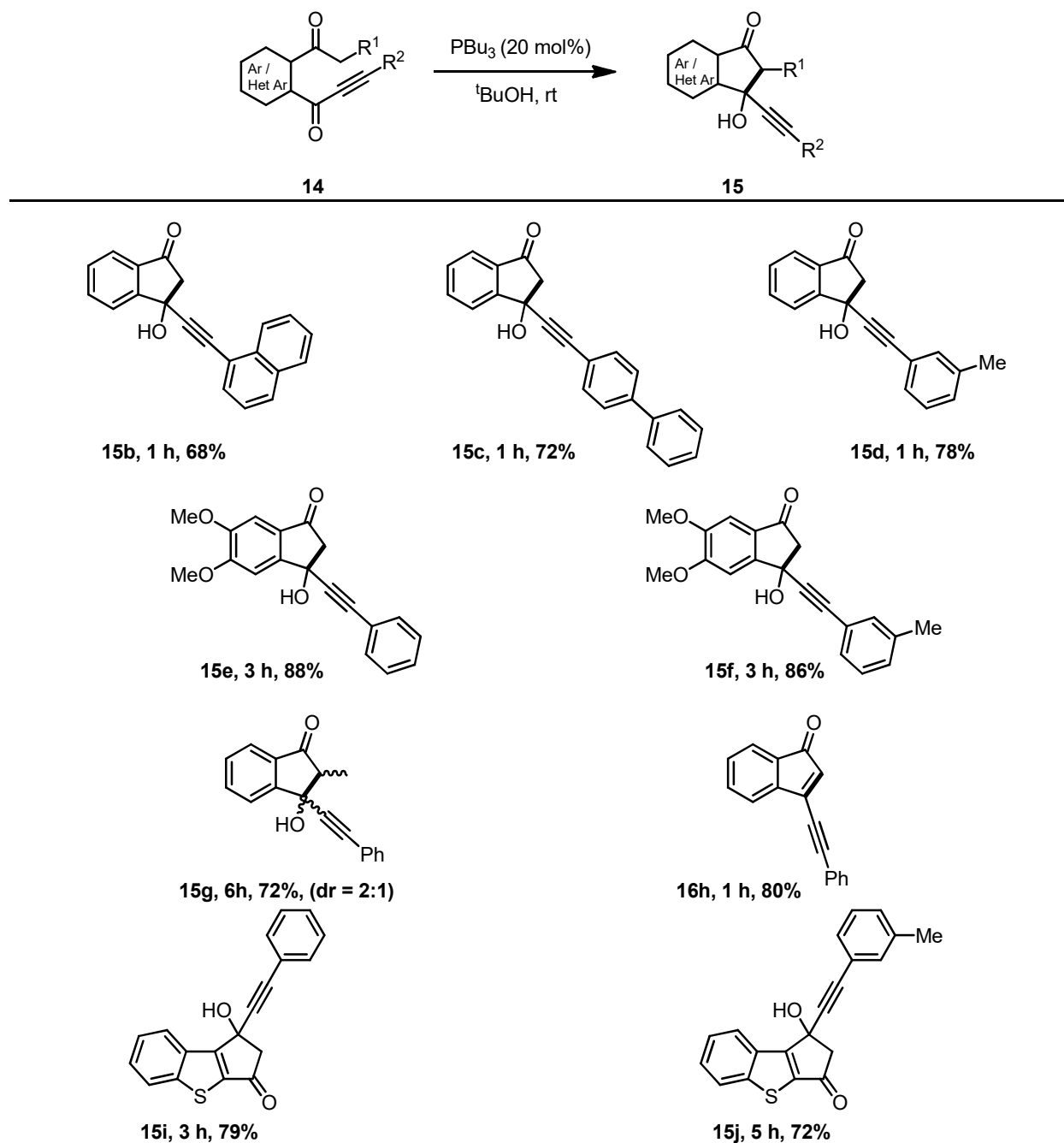
Entry	Catalyst (XX mol%)	Solvent	Time (h)	Yield (%)
1	PPh <sub>3</sub> (10)	CH <sub>2</sub> Cl <sub>2</sub>	5	43
2	PPh <sub>3</sub> (20)	Toluene	24	25
3	PBu <sub>3</sub> (20)	Toluene	3	44
4	PBu <sub>3</sub> (1 eq.)	Toluene	2	48
5	PCy <sub>3</sub> (20)	Toluene	24	21
6	EtPPh <sub>2</sub> (20)	Toluene	24	36
7	PBu <sub>3</sub> (20)	EtOAc	24	NR
8	PBu <sub>3</sub> (20)	THF	24	trace
9	PBu <sub>3</sub> (20)	F <sub>3</sub> CCH <sub>2</sub> OH	2	45
10	PBu <sub>3</sub> (20)	CH <sub>2</sub> Cl <sub>2</sub>	4	44
11	PBu <sub>3</sub> (20)	CH <sub>3</sub> CN	1	45
12	PBu <sub>3</sub> (20)	HCONH <sub>2</sub>	3	51
13	PBu <sub>3</sub> (20)	MeCONMe <sub>2</sub>	1	61
<b>14</b>	<b>PBu<sub>3</sub> (20)</b>	<b>Isopropanol</b>	<b>1</b>	<b>82</b>
15	PBu <sub>3</sub> (20)	CH <sub>3</sub> OH	1	74
16	PBu <sub>3</sub> (20)	CH <sub>3</sub> CH <sub>2</sub> OH	1	77
<b>17</b>	<b>PBu<sub>3</sub> (20)</b>	<b>Isopropanol (0 °C)</b>	<b>1</b>	<b>82</b>
<b>18</b>	<b>PBu<sub>3</sub> (20)</b>	<b><i>tert</i>-butanol</b>	<b>1</b>	<b>87</b>
19	PBu <sub>3</sub> (10)	<i>tert</i> -butanol	24	62

<sup>a</sup>Reaction Conditions: A mixture of **14a** (0.1 mmol) and a catalyst (XX mol%) in a solvent (1 ml) was stirred at room temperature until **14a** disappeared (monitored by TLC). Isolated yields are reported.

To understand the scope and generality of this methodology, we have prepared a branch of substrates applying the optimized conditions (**Table 2.4**).



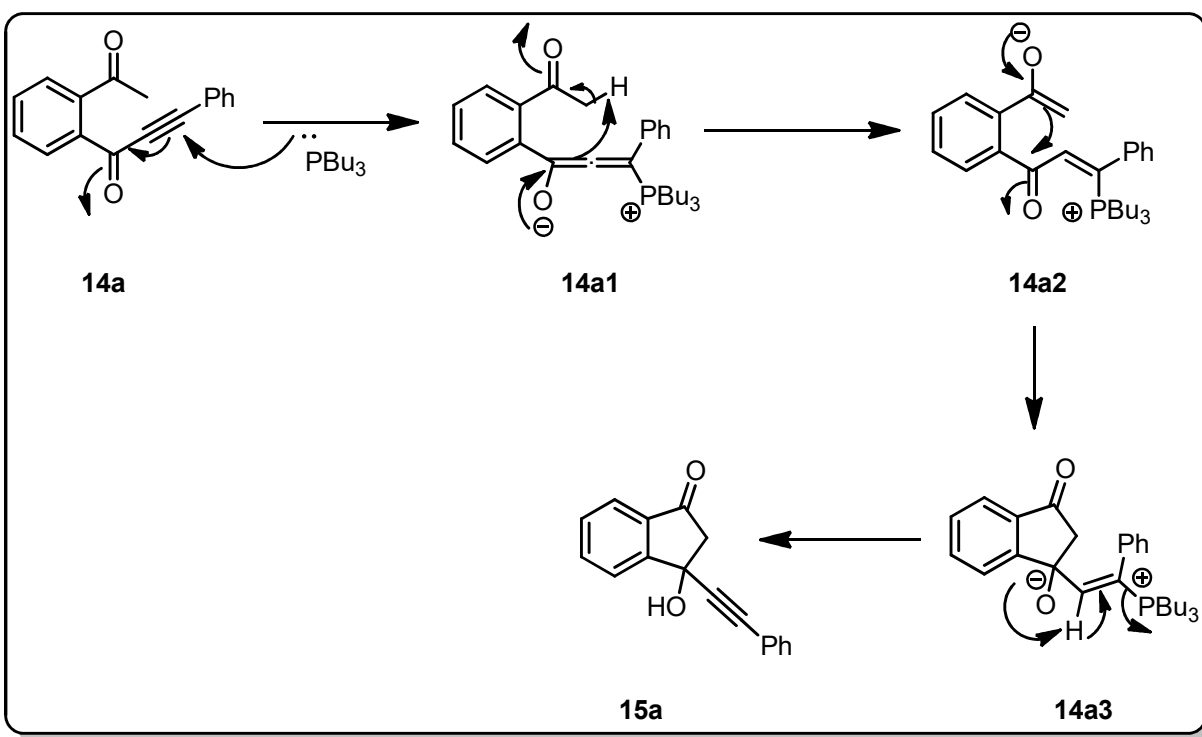
**Table 2.4. Substrate scope: 3-Ethynyl-3-hydroxyindanones<sup>a,b</sup>**



<sup>a</sup>Reaction Conditions: A mixture of **14** (0.1 mmol) and  $\text{PBu}_3$  (0.02 mmol) in *tert*-butanol was stirred at rt until **14** disappeared (monitored by TLC). <sup>b</sup>Isolated yields are reported.

Subsequent evaluation of a variety of substrates under optimized conditions we have prepared a branch of 3-ethynyl-3-hydroxyindanones (**15b-15j**) in good to excellent yield (68-88%). Apart from that, we have also synthesized the heteroarene-fused 3-ethynyl-3-hydroxyindanones by this method, otherwise, which would take a multistep synthetic pathway. As a significant extension of this methodology,  $\delta'$ -branched substrate **14g** (when  $R^1 = \text{Me}$ ,  $R^2 = \text{Ph}$ ) generated **15g** containing two contiguous stereogenic centres in 72 % yield and 2:1 dr, while **14h** (when  $R^1 = R^2 = \text{Ph}$ ) formed straightaway the ynenone **16h** in 80% yield, here the product (**15h**) generated from **14h**, undergo dehydration in situ to give the corresponding  $\beta$ -hydroxyketone (**16h**).

Based on the outcome of the reaction, we proposed a plausible mechanism of this transformation (Scheme 2.11). Initially, Michael addition of phosphine to **14a** generate the allenolate intermediate **14a1**, which undergo  $\delta'$ -proton abstraction to furnish the enolate **14a2**. Then, intramolecular aldol reaction of **14a2** produce the zwitterionic alkoxide intermediate **14a3**. The vinylic proton next to the electrophilic carbon is acidic enough and hence alkoxide intermediate **14a3** undergo intramolecular proton abstraction and removal of phosphine ultimately generate the corresponding product **15a**. The salient feature of this transformation is that, it is a *organocatalytic  $\delta'$ [C( $sp^3$ )-H]-functionalization of  $\alpha, \beta$ -ynones*.

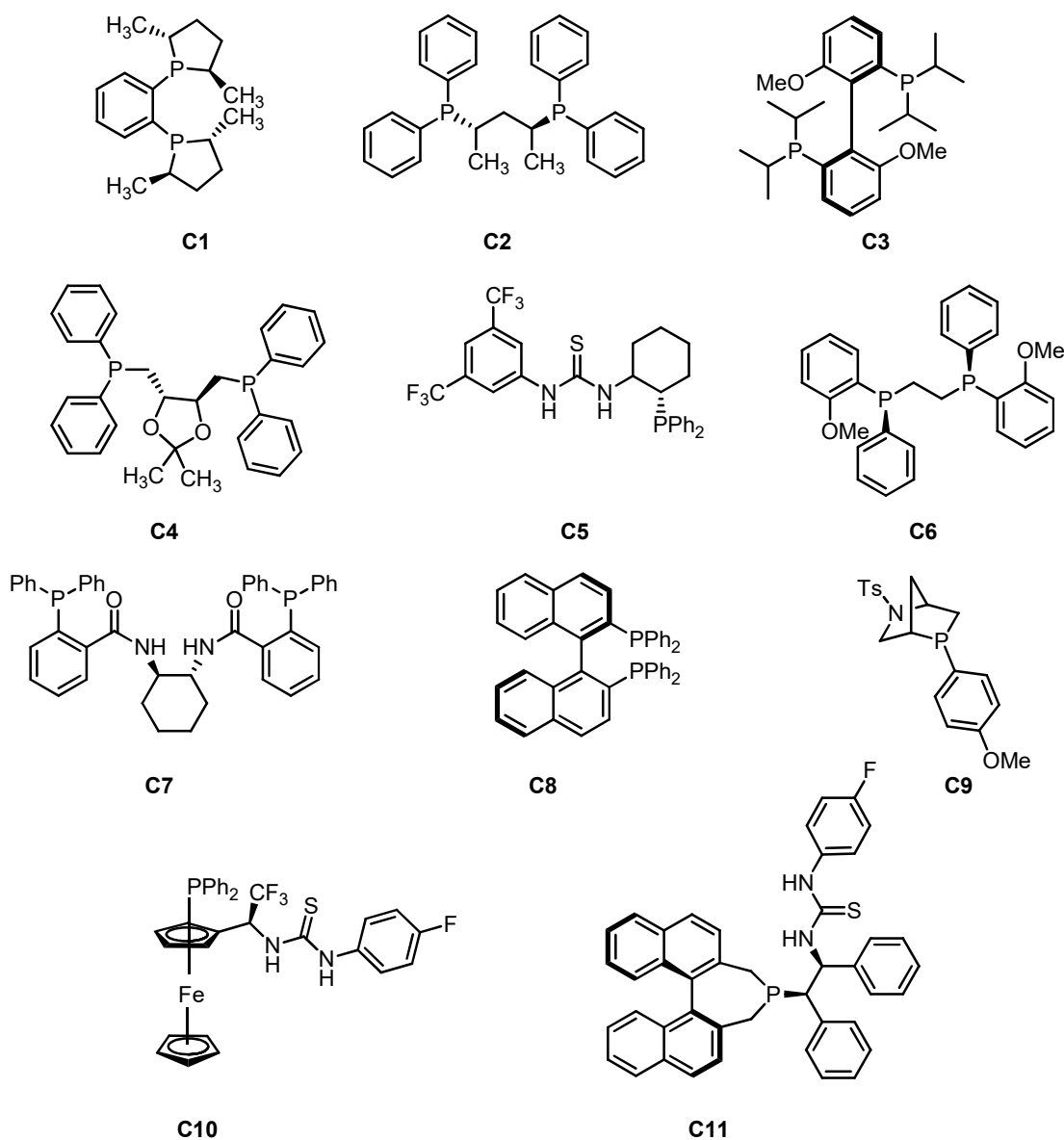


Scheme 2.11

If we look at the product 3-ethynyl-3hydroxyindanones (**15**) we can notice that in the compound stereogenic centre/centres present. So, we thought about the enantiomeric version of this methodology. To develop the enantiomeric version, we have performed an exhaustive chiral catalyst (**Fig. 2.2**) screening on the substrate (**14a**) under a variety of conditions. Some of the results are presented here (**Table 2.5**).

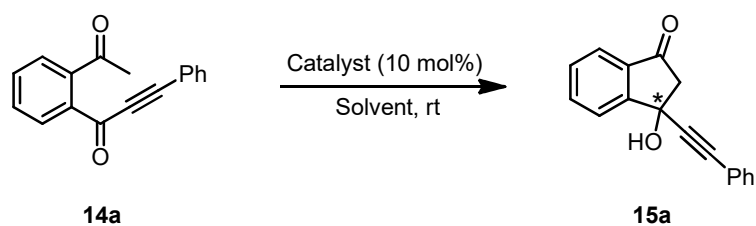
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**List of Chiral Catalysts:**



**Figure 2.2**

Table 2.5. Chiral Catalysts Screening.<sup>a</sup>



Entry	Catalyst (10 mol%)	Solvent	Time	%yield	%ee
1	C1	<i>tert</i> -Butanol	1/2 h	89	1
2	C2	<i>tert</i> -Butanol	1 h	55	0
3	C2	MeCONMe <sub>2</sub>	4 d	25	8
4	C2	CH <sub>2</sub> Cl <sub>2</sub>	4 d	43	8
5	C3	<i>tert</i> -Butanol	4 d	NR <sup>b</sup>	ND <sup>c</sup>
6	C4	<i>tert</i> -Butanol	4 d	NR	ND
7	C5	<i>tert</i> -Butanol	4 d	NR	ND
8	C6	<i>tert</i> -Butanol	1 h	55	2
9	C6	MeCONMe <sub>2</sub>	4 d	32	6
10	C6	CH <sub>2</sub> Cl <sub>2</sub>	4 d	52	2
<b>11</b>	<b>C6</b>	<b>Toluene</b>	<b>4 d</b>	<b>21</b>	<b>24</b>
12	C7	<i>tert</i> -Butanol	24	40	3
13	C7	Toluene	4 d	26	7
<b>14</b>	<b>C7</b>	<b>CH<sub>2</sub>Cl<sub>2</sub></b>	<b>4 d</b>	<b>41</b>	<b>16</b>
15	C8	<i>tert</i> -Butanol	24 h	25	8
16	C8	Toluene	4 d	27	12
17	C8	CH <sub>2</sub> Cl <sub>2</sub>	4 d	50	0
18	C8	Trifluoroethanol	24 h	53	5
19	C8	Acetonitrile	24 h	29	3
20	C8	THF/ <sup>t</sup> BuOH (1:1)	24 h	47	4
21	C9	<i>tert</i> -Butanol	4 d	NR	ND
22	C10	<i>tert</i> -Butanol	4 d	NR	ND
23	C11	<i>tert</i> -Butanol	4 d	NR	ND

<sup>a</sup>Reaction Conditions: A mixture of **14a** (0.1 mmol) and catalyst (0.01 mmol) in a solvent (1 ml) was stirred at room temperature. <sup>b</sup>No reaction, <sup>c</sup>Not determined.

**HPLC conditions:** The enantiomeric excess was determined by HPLC analysis using Daicel Chiralpak AD Column (9:1 n-Hexane/2-Propanol, 1.0 mL/min, 254 nm,  $\tau_{\text{major}} = 10.6$  min,  $\tau_{\text{minor}} = 11.6$  min).

During chiral catalyst screening, we observed that with **C1** catalyst in *tert*-butanol solvent **14a** is producing **15a** in excellent yield but the product was racemic (**entry 1**). As we moved further, we observed that **C2** catalyst is also working in *t*-butanol solvent. Then we screened the solvent and we got 8% ee both in DCM and *N, N*-dimethylacetamide, but yields are poor. Catalyst **C6** is also working well under optimized condition described in Table **2.4**. Then further solvent screening increased the % ee (**entry 8-10**), and when we used toluene as a solvent, we got the 24% ee (**entry 11**) but yield is less. Catalyst **C7** also gave some extent of ee under optimized condition as well as on changing the solvent (**entry 12-13**). Catalyst **C7** gave 16% ee with 41% yield in DCM solvent after 4 days (**entry 14**). Further catalyst and solvent screening did not give any significant results.

## Chapter 3

### Experimental Sections and Supporting Information.

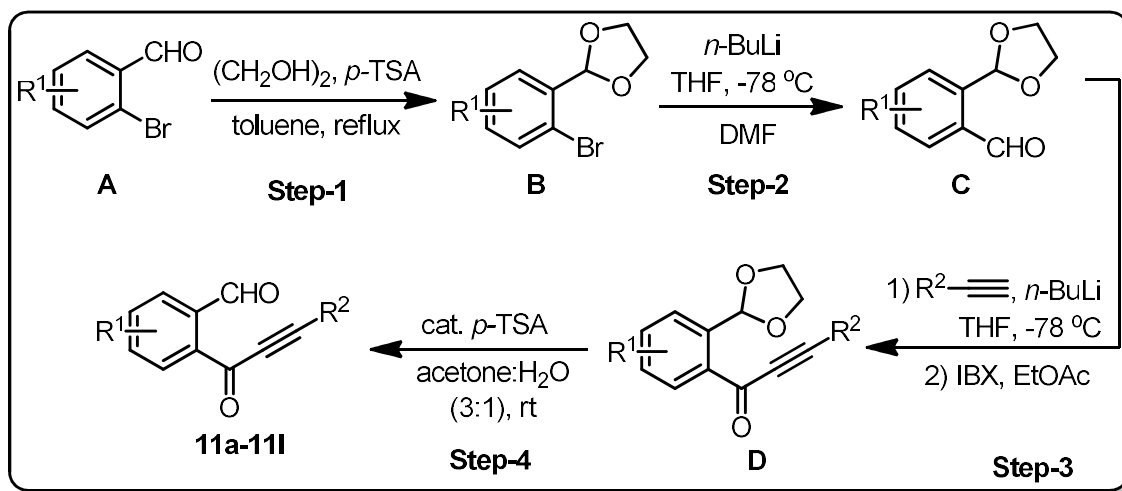
#### 3.1 General Experimental Methods:

All the starting compounds and catalysts employed in this study were procured from Sigma-Aldrich and were used without further purification. For thin layer chromatography (TLC), silica aluminium foils with fluorescent indicator 254 nm (from Aldrich) were used and compounds were visualized by irradiation with UV light and/or by treatment with a solution of *p*-anisaldehyde (23 mL), conc. H<sub>2</sub>SO<sub>4</sub> (35 mL), and acetic acid (10 mL) in ethanol (900 mL) followed by heating. Column chromatography was performed using SD Fine silica gel 100-200 mesh (approximately 15–20 g per 1 g of the crude product). Dry THF was obtained by distillation over sodium and stored over sodium wire. IR spectra were recorded on a Perkin–Elmer FT IR spectrometer as thin films or KBr pellet, as indicated, with  $\nu_{\text{max}}$  in inverse centimetres. Melting points were recorded on a digital melting point apparatus Stuart SMP30. <sup>1</sup>H NMR and <sup>13</sup>C NMR spectra were recorded on a 400 MHz Bruker Biospin Avance III FT-NMR spectrometer. NMR shifts are reported as delta ( $\delta$ ) units in parts per million (ppm) and coupling constants (*J*) are reported in Hertz (Hz). The following abbreviations are utilized to describe peak patterns when appropriate: br=broad, s=singlet, d=doublet, t=triplet, q=quartet and m=multiplet. Proton chemical shifts are given in  $\delta$  relative to tetramethylsilane ( $\delta$  0.00 ppm) in CDCl<sub>3</sub> or in (CD<sub>3</sub>)<sub>2</sub>SO ( $\delta$  2.50 ppm) or in (CD<sub>3</sub>)<sub>2</sub>CO ( $\delta$  2.05 ppm). Carbon chemical shifts are internally referenced to the deuterated solvent signals in CDCl<sub>3</sub> ( $\delta$  77.1 ppm) or in (CD<sub>3</sub>)<sub>2</sub>SO ( $\delta$  39.5 ppm) or in (CD<sub>3</sub>)<sub>2</sub>CO at  $\delta$  29.9 and 206.7. Single crystal X-ray analysis was carried on a Rigaku XtaLAB mini X-ray diffractometer. High resolution mass spectra were recorded on a Waters QTOF mass spectrometer.

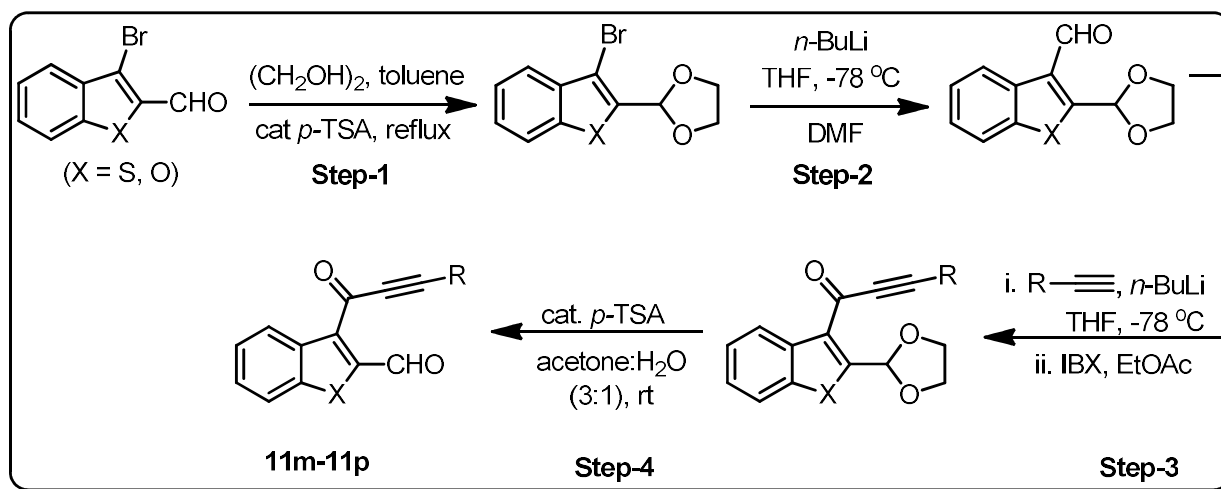
## Supporting Information:

### General Procedure 1: Synthesis of ynones-aldehydes 11

All ynone-aldehydes were synthesized according to literature report.<sup>23</sup>



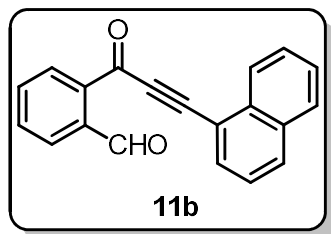
**Scheme 3.1.** Synthesis of ynone-aldehyde 11a-l.



**Scheme 3.2.** Synthesis of ynone-aldehyde 11m-11p

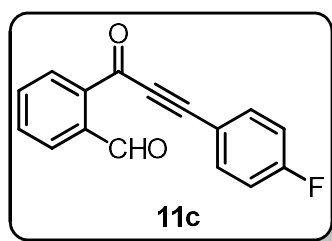
### 2-(3-(Naphthalen-1-yl)propioloyl)benzaldehyde (11b).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as orange solid. M.P = 90-91 °C.  $R_f$  = 0.4 (hexane/EtOAc = 9/1). **IR** (thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  2189, 1776, 1695, 1632, 1294, 1220, 986, 774.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  10.63 (s, 1H), 8.46 (d,  $J$  = 7.3 Hz, 1H), 8.40 (d,  $J$  = 8.3 Hz, 1H), 8.05-7.98 (m, 3H), 7.95 (d,  $J$  = 8.1 Hz, 1H), 7.83-7.75 (m, 2H), 7.71-7.67 (m, 1H), 7.62 (t,  $J$  = 7.4 Hz, 1H), 7.55 (t,  $J$  = 7.9 Hz, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )**:  $\delta$  192.1, 178.3, 138.7, 137.4, 133.7, 133.6, 133.4, 133.1, 132.9, 132.1, 131.9, 128.7, 128.5, 127.9, 127.1, 125.6, 125.2, 117.1, 92.9, 92.3. **HRMS (ESI)**:  $m/z$  calcd for  $\text{C}_{20}\text{H}_{13}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 285.0916. Found: 285.0904.



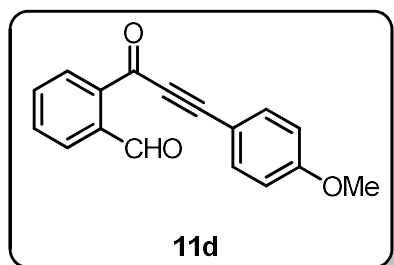
### 2-(3-(4-Fluorophenyl)propioloyl)benzaldehyde (11c).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as pale yellow solid. M. P = 116-118 °C.  $R_f$  = 0.5 (hexane/EtOAc = 4/1). **IR** (thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  2190, 1688, 1623, 750.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  10.60 (s, 1H), 8.33-8.31 (m, 1H), 7.98-7.95 (m, 1H), 7.79-7.69 (m, 4H), 7.16 (t,  $J$  = 8.5 Hz, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )**:  $\delta$  192.0, 178.2, 164.3 (d,  $J$  = 253.3 Hz, 1C), 138.3, 137.4, 135.6 (d,  $J$  = 9.1 Hz, 2C), 133.5, 132.8, 131.9, 128.5, 116.4 (d,  $J$  = 22.1 Hz, 2C), 115.7 (d,  $J$  = 3.2 Hz, 1C), 93.4, 87.5 (d,  $J$  = 0.9 Hz, 1C).  **$^{19}\text{F}$  NMR (376.5 MHz,  $\text{CDCl}_3$ )**:  $\delta$  -105.0. **HRMS (ESI)**:  $m/z$  calcd for  $\text{C}_{16}\text{H}_{10}\text{FO}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 253.0665. Found: 253.0654.



### 2-(3-(4-Methoxyphenyl)propioloyl)benzaldehyde (11d).

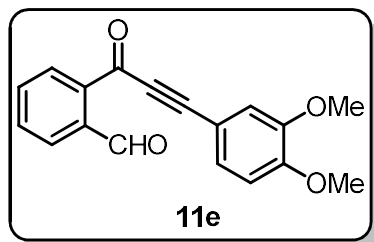
This compound was prepared by following the general procedure 1 (Scheme 3.1) and isolated as pale yellow solid. M.P = 112-114 °C.  $R_f$  = 0.5 (hexane/EtOAc = 4/1). **IR** (thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  2922, 1697, 1624, 1510, 1255.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  10.6 (s, 1H), 8.32 (d,  $J$  = 7.9 Hz, 1H), 7.96 (dd,  $J$  = 7.3 and 1.4 Hz, 1H), 7.79-7.71 (m, 2H), 7.66 (d,  $J$  = 8.7 Hz, 2H), 6.97 (d,  $J$  = 8.7 Hz, 2H), 3.89 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )**:  $\delta$  192.2, 178.3, 162.2, 138.8, 137.4, 135.4(2C), 133.2, 132.8, 131.8, 128.4, 114.6(2C), 111.3, 96.0, 87.9, 55.5. **HRMS (ESI)**:  $m/z$  calcd for  $\text{C}_{17}\text{H}_{13}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 265.0865. Found: 265.0854.





### 2-(3-(3,4-Dimethoxyphenyl)propioloyl)benzaldehyde (11e).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as brown solid. M.P = 137-139 °C.  $R_f$  = 0.3 (hexane/EtOAc = 4/1).

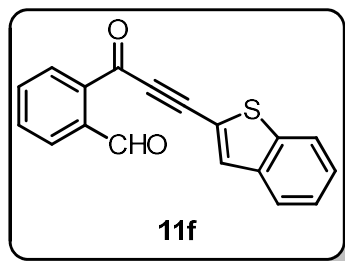


**IR (thin film, neat):** 2928, 2184, 1694, 1628, 1593, 1514, 1254, 1236, 1138, 1021.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.59 (s, 1H), 8.32 (d,  $J$  = 8.3 Hz, 1H), 7.96 (d,  $J$  = 7.2 Hz, 1H), 7.79-7.71 (m, 2H), 7.36 (d,  $J$  = 8.3 Hz, 1H), 7.17 (s, 1H), 6.92 (d,  $J$  = 8.3 Hz, 1H), 3.97 (s, 3H), 3.94 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$

192.2, 178.3, 152.2, 149.0, 138.7, 137.4, 133.2, 132.8, 131.8, 128.4, 128.0, 115.4, 111.3, 111.2, 96.0, 87.7, 56.1, 56.0. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_4$  ( $\text{M}+\text{H}$ ) $^+$ : 295.0970. Found: 295.0957.

### 2-(3-(Benzo[b]thiophen-2-yl)propioloyl)benzaldehyde (11f)

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as

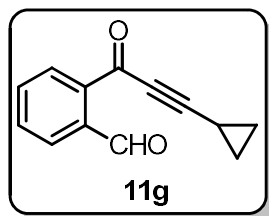


yellow solid. M.P = 148-150 °C.  $R_f$  = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  2923, 2853, 2184, 1694, 1620, 1592, 1269, 987, 738.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.56 (s, 1H), 8.32 (d,  $J$  = 7.4 Hz, 1H), 7.98 (d,  $J$  = 7.2 Hz, 1H), 7.89-7.85 (m, 3H), 7.82-7.74 (m, 2H), 7.53-7.44 (m, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$

192.0, 177.8, 142.0, 138.5, 138.1, 137.5, 134.7, 133.6, 132.9, 132.0, 128.6, 127.2, 125.4, 124.9, 122.3, 119.1, 92.9, 88.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_2\text{S}$  ( $\text{M}+\text{H}$ ) $^+$ : 291.0480. Found: 291.0447.

### 2-(3-Cyclopropylpropioloyl)benzaldehyde (11g).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as pale

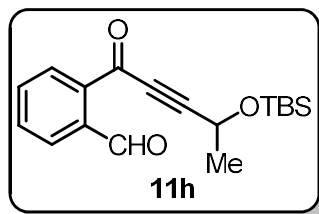


yellow oil.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  2924, 2209, 1696, 1633, 1266, 916.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.51 (s, 1H), 8.19-8.17 (m, 1H), 7.93-7.91 (m, 1H), 7.72-7.69 (m, 2H), 1.59 - 1.55 (m, 1H), 1.12- 1.06 (m, 4H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  192.2, 178.2, 138.7, 137.3, 133.1, 132.7, 131.8, 128.3, 102.9, 76.5,

10.2(2C), 0.1. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{13}\text{H}_{11}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 199.0759. Found: 199.0750.

#### 2-(4-((*tert*-Butyldimethylsilyl)oxy)pent-2-ynoyl)benzaldehyde (11h).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as



yellow oil.  $R_f = 0.5$  (hexane/EtOAc = 9/1). **IR (thin film, neat):**

$\nu_{\max}/\text{cm}^{-1}$  2210, 1699, 1645, 1254, 838.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**

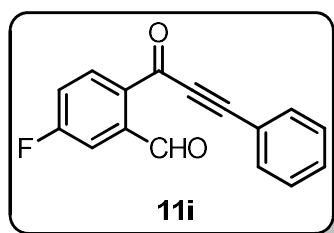
$\delta$  10.52 (s, 1H), 8.26-8.22 (m, 1H), 7.95-7.91 (m, 1H), 7.75-7.70 (m, 2H), 4.80 (q,  $J = 6.6$  Hz, 1H), 1.58 (d,  $J = 6.6$  Hz, 3H), 0.95 (s, 9H), 0.19 (s, 3H), 0.17 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  192.0,

178.2, 137.9, 137.4, 133.4, 132.7, 132.2, 128.4, 97.6, 81.6, 59.0, 25.6(3C), 24.5, 18.1, -4.7, -4.9.

**HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{25}\text{O}_3\text{Si}$  ( $\text{M}+\text{H}$ ) $^+$ : 317.1573. Found: 317.1558.

#### 4-Fluoro-2-(3-phenylpropioloyl)benzaldehyde (11i).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as pale



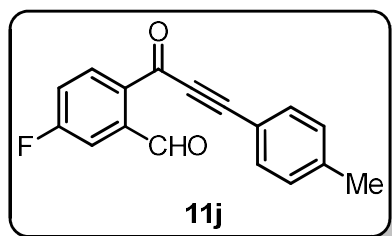
yellow solid. M.P = 82-84 °C.  $R_f = 0.4$  (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2195, 1699, 1627, 1580, 755.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.6 (s, 1H), 8.41 (dd,  $J = 8.6, 5.12$  Hz, 1H),

7.70 (d,  $J = 7.28$  Hz, 2H), 7.63 (dd,  $J = 8.6, 2.4$  Hz, 1H), 7.57-7.53 (m, 1H), 7.48-7.40 (m, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.6,

176.9, 165.4 (d,  $J = 257.2$  Hz, 1C), 140.4 (d,  $J = 7.3$  Hz, 1C), 135.1 (d,  $J = 8.8$  Hz, 1C), 134.5 (d,  $J = 3.4$  Hz, 1C), 133.2(2C), 131.4, 128.8(2C), 119.5 (d,  $J = 21.9$  Hz, 1C), 119.3, 115.7 (d,  $J = 23.3$  Hz, 1C), 94.7, 87.3.  **$^{19}\text{F}$  NMR (376.5 MHz,  $\text{CDCl}_3$ ):**  $\delta$  -103.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{16}\text{H}_{10}\text{FO}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 253.0665. Found: 253.0653.

#### 4-Fluoro-2-(3-(*p*-tolyl)propioloyl)benzaldehyde (11j).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as pale



yellow solid. M.P = 131-133 °C.  $R_f = 0.5$  (hexane/EtOAc = 4/1).

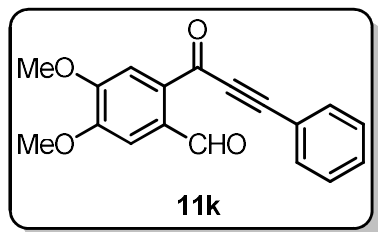
**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2923, 2195, 1690, 1625, 1580,

755.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.5 (s, 1H), 8.40 (dd,  $J = 8.5$  and  $5.2$  Hz, 1H), 7.64-5.59 (m, 3H), 7.43 ( $J = 8.1, 2.6$  Hz, 1H), 7.27 (d,  $J = 7.5$  Hz, 2H), 2.45 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.7, 176.9, 165.3 (d,  $J = 257.1$  Hz, 1C), 142.4, 140.4 (d,  $J = 7.1$  Hz, 1C), 135.0 (d,  $J = 8.8$  Hz, 1C), 134.8 (d,  $J = 3.0$  Hz, 1C), 133.3(2C), 129.7(2C), 119.53(d,  $J = 21.9$  Hz, 1C), 116.3,

115.6 (d,  $J = 23.3$  Hz, 1C), 95.6, 87.3, 21.9.  **$^{19}\text{F}$  NMR (376.5 MHz,  $\text{CDCl}_3$ ):**  $\delta$  -102.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{17}\text{H}_{12}\text{FO}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 267.0821. Found: 267.0809.

#### 4,5-Dimethoxy-2-(3-phenylpropioloyl)benzaldehyde (11k).

This compound was prepared following the general procedure 1 (Scheme 3.1) and isolated as



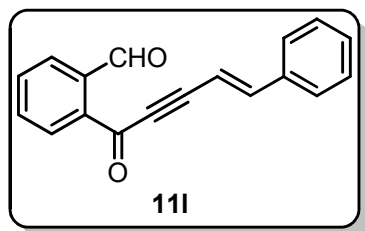
brown solid. M.P = 147-149 °C.  $R_f$  = 0.4 (hexane/EtOAc = 4/1).

**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2197, 1680, 1630, 1585, 1519, 1292, 1120.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.63 (s, 1H), 7.79 (s, 1H), 7.67 (d,  $J$  = 7.1 Hz, 2H), 7.55-7.51 (m, 2H), 7.45 (t,  $J$  = 7.2 Hz, 2H), 4.08 (s, 3H), 4.03 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  191.0, 177.2, 152.7, 152.0, 133.1(2C), 132.7, 131.7, 131.2, 128.9(2C), 119.8, 114.0,

109.9, 93.9, 88.0, 56.4, 56.3. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_4$  ( $\text{M}+\text{H}$ ) $^+$ : 295.0970. Found: 295.0956.

#### (*E*)-2-(5-Phenylpent-4-en-2-ynoyl)benzaldehyde (11l).

This compound was prepared following the general procedure 1 (Scheme 3.1) and was isolated as



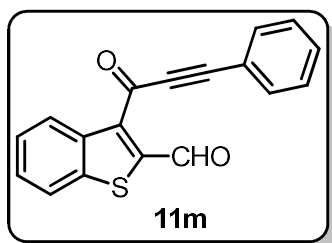
pale brown solid. M.P = 64-66 °C.  $R_f$  = 0.3 (hexane/EtOAc = 9/1).

**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2924, 2175, 1694, 1631, 1603, 1573, 1284, 1254, 939, 689.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.57 (s, 1H), 8.28 (d,  $J$  = 7.3 Hz, 1H), 7.95 (d,  $J$  = 7.8 Hz, 1H), 7.78-7.71 (m, 2H), 7.527.50 (m, 2H), 7.43-7.39 (m, 5H), 6.41 (d,  $J$  = 16.3 Hz, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  192.2, 178.2,

149.0, 138.5, 137.4, 134.9, 133.3, 132.8, 131.9, 130.4, 129.0(2C), 128.4, 127.2(2C), 104.8, 94.5, 89.6. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{13}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 261.0916. Found: 261.0905.

#### 3-(3-Phenylpropioloyl)benzo[*b*]thiophene-2-carbaldehyde (11m).

This compound was prepared following the general procedure 1 (Scheme 3.2) and isolated as pale



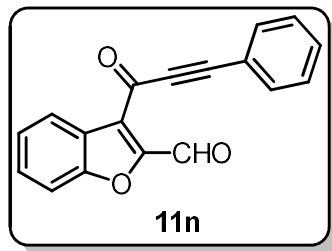
yellow solid. M.P = 130-132 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR**

**(thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2191, 1665, 1628, 1495, 1116, 756.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  10.8 (s, 1H), 8.70-8.67 (m, 1H), 7.98-7.96 (m, 1H), 7.69-7.67 (m, 2H), 7.61-7.59 (m, 2H), 7.56-7.54 (m, 1H), 7.49-7.45 (m, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  185.4,

172.0, 148.3, 141.2, 139.6, 137.1, 133.4(2C), 131.7, 128.9(2C), 128.5, 126.5, 126.1, 123.1, 119.2, 95.7, 90.3. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_2\text{S}$  ( $\text{M}+\text{H}$ ) $^+$ : 291.0480. Found: 291.9993.

### 3-(3-Phenylpropioloyl)benzofuran-2-carbaldehyde (11n).

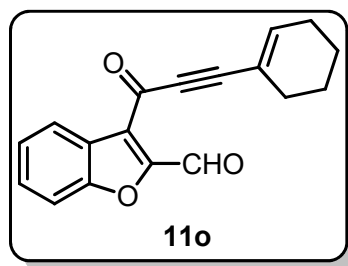
This compound was prepared following the general procedure 1 (Scheme 3.2) and was isolated as pale yellow solid. M.P = 133-135 °C.  $R_f$  = 0.5 (hexane/EtOAc = 8/2).



**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2177, 1672, 1608, 1447, 1252, 1164, 1013.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 10.72 (s, 1H), 8.46 (d,  $J$  = 7.9 Hz, 1H), 7.74-7.69 (m, 3H), 7.65-7.61 (m, 1H), 7.59-7.55 (m, 1H), 7.53-7.47 (m, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 180.9, 171.0, 155.0, 152.8, 133.2(2C), 131.7, 129.8, 129.0(2C), 127.1, 125.8, 124.1, 123.7, 119.1, 112.8, 94.6, 89.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 275.0708. Found: 275.0721.

### 3-(3-(Cyclohex-1-en-1-yl)propioloyl)benzofuran-2-carbaldehyde (11o).

This compound was prepared following the general procedure 1 (Scheme 3.2) and isolated as pale yellow semi-solid.  $R_f$  = 0.6 (hexane/EtOAc = 7/3).

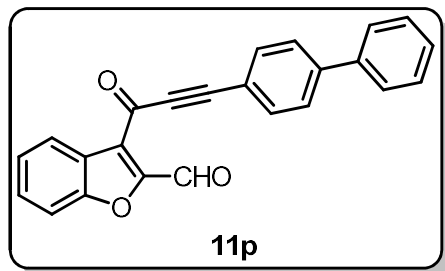


**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2933, 2182, 1682, 1611, 1546, 1446, 1190.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 10.65 (s, 1H), 8.38 (d,  $J$  = 7.9 Hz, 1H), 7.67-7.65 (m, 2H), 7.61-7.57 (m, 1H), 7.48 (d,  $J$  = 7.5 Hz, 1H), 2.31-2.25 (m, 4H), 1.74-1.67 (m, 4H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 181.0, 171.0, 154.9, 152.6, 145.0, 129.7, 127.3, 125.6,

124.2, 123.9, 118.7, 112.7, 97.1, 88.1, 27.9, 26.4, 21.8, 20.9. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 279.1021. Found: 279.1038.

### 3-(3-([1,1'-Biphenyl]-4-yl)propioloyl)benzofuran-2-carbaldehyde (11p).

This compound was prepared following the general procedure 1 (Scheme 3.2) and isolated as pale yellow solid. M.P = 144-146 °C.  $R_f$  = 0.6 (hexane/EtOAc = 8/2).



**IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2193, 1606, 1447, 1389, 1160, 997.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 10.71 (s, 1H), 8.46 (d,  $J$  = 8.0 Hz, 1H), 7.77 (d,  $J$  = 8.3 Hz, 2H), 7.70-7.67 (m, 3H), 7.63-7.59 (m, 3H), 7.54-7.47 (m, 3H), 7.43-7.39 (m, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 180.9, 171.0, 155.0, 152.8, 144.6, 139.5, 133.8(2C), 129.9, 129.1(2C), 128.5, 127.6(2C), 127.2(2C), 127.1, 125.8, 124.2, 123.8, 117.7, 112.9, 94.8, 90.3. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{24}\text{H}_{15}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 351.1021. Found: 351.1043.

## General procedure 2: Screening of reaction parameters for 12.

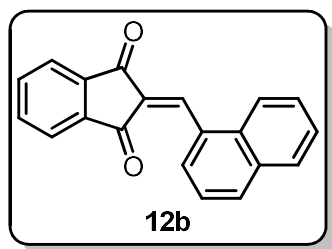
An oven dried 5 mL glass vial was charged with **11a** (0.1 mmol). A solvent (1.0 mL) and catalyst (0.01 mmol) were introduced at room temperature. Stirring was continued until **11a** disappeared as monitored by TLC. Then the reaction was quenched with water and extracted with DCM (2 x 1 mL). The organic extracts were combined, dried over anhydrous sodium sulfate and concentrated. The crude product was purified by silica gel flash chromatography using hexane/ethyl acetate as eluent, to afford **12a**.<sup>24</sup>

## General procedure 3: Evaluating the substrate scope for 12.

To an oven dried 5 mL glass vial, **11** (0.1 mmol), DCM (1.0 mL) and triphenylphosphine (0.01 mmol) were introduced at room temperature (rt) and stirring continued at rt until **1** disappeared as monitored by TLC. Then the reaction was quenched with water and extracted using DCM (2 x 1 mL). The organic extracts were combined, dried over anhydrous sodium sulfate and concentrated. The crude product was purified by silica gel flash chromatography using hexane/ethyl acetate as eluent, to afford **12**.

### 2-(Naphthalen-1-ylmethylene)-1*H*-indene-1,3(2*H*)-dione (**12b**).

Following the general procedure 3, 20 mg of **11b** afforded 18 mg (90% yield) of **12b** as yellow

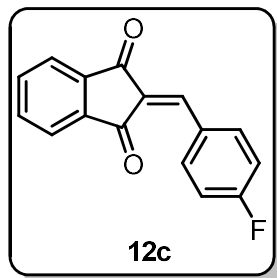


solid. M.P = 173-174 °C.  $R_f$  = 0.4 (hexane/EtOAc = 8/2). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  1693, 1615, 1356, 1226, 770, 728. **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):**  $\delta$  8.82 (s, 1H), 8.78 (d,  $J$  = 7.3 Hz, 1H), 8.28 (d,  $J$  = 8.4 Hz, 1H), 8.09-8.06 (m, 2H), 8.04-8.02 (m, 1H), 7.95 (d,  $J$  = 8.0 Hz, 1H), 7.86-7.84 (m, 2H), 7.68-7.63 (m, 2H), 7.59 (t,  $J$  = 7.6

Hz, 1H). **<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):**  $\delta$  190.2, 188.7, 143.1, 142.5, 140.0, 135.4, 135.3, 133.6, 133.5, 132.7, 132.1, 130.0, 129.1, 128.6, 127.6, 126.3, 125.1, 123.6, 123.4(2C). **HRMS (ESI):**  $m/z$  calcd for: C<sub>20</sub>H<sub>13</sub>O<sub>2</sub> (M+H)<sup>+</sup>: 285.0916. Found: 285.0902.

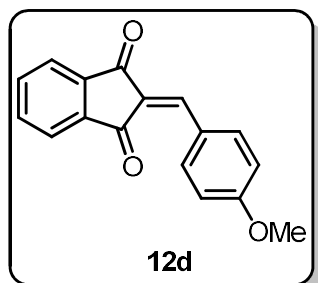
### 2-(4-Fluorobenzylidene)-1*H*-indene-1,3(2*H*)-dione (**12c**).

Following the general procedure 3, 20 mg of **11c** afforded 17 mg (88% yield) of **12c** as pale yellow solid. M.P = 179-182 °C.  $R_f$  = 0.5 (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2917, 1692, 1588, 733.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.57-8.54 (m, 2H), 8.04-8.01 (m, 2H), 7.87-7.83 (m, 3H), 7.21 (t,  $J$  = 8.5 Hz, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.2, 189.1, 165.6 (d,  $J$  = 256.0 Hz), 145.5, 142.4, 140.0, 136.9 (d,  $J$  = 9.3 Hz, 2C), 135.4, 135.3, 129.6 (d,  $J$  = 2.9 Hz), 128.6 (d,  $J$  = 2.3 Hz), 123.4, 123.3, 116.1 (d,  $J$  = 21.7 Hz, 2C).  **$^{19}\text{F}$  NMR (376.5 MHz,  $\text{CDCl}_3$ ):**  $\delta$  -103.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{16}\text{H}_{10}\text{FO}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 253.0665. Found: 253.0656.



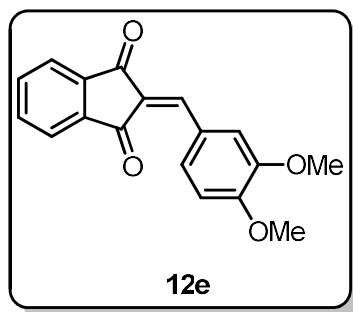
### 2-(4-Methoxybenzylidene)-1*H*-indene-1,3(2*H*)-dione (**12d**).

Following the general procedure 3, 20 mg of **11d** afforded 18 mg (90% yield) of **12d** as pale yellow solid. M.P = 155-156 °C.  $R_f$  = 0.5 (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2924, 1684, 1464, 757.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.57 (d,  $J$  = 8.8 Hz, 2H), 8.01-7.99 (m, 2H), 7.87 (s, 1H), 7.82-7.79 (m, 2H), 7.03 (d,  $J$  = 8.9 Hz, 2H), 3.93 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.9, 189.6, 164.1, 146.9, 142.4, 139.9, 137.2(2C), 135.1, 134.9, 126.6, 126.5, 123.1(2C), 114.4(2C), 55.6. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{17}\text{H}_{13}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 265.0865. Found: 265.0878.



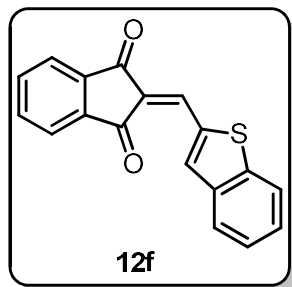
### 2-(3,4-Dimethoxybenzylidene)-1*H*-indene-1,3(2*H*)-dione (**12e**).

Following the general procedure 3, 30 mg of **11e** afforded 28 mg (93% yield) of **12e** as yellow solid. M.P = 206-208 °C.  $R_f$  = 0.3 (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2920, 1703, 1678, 1566, 1517, 1248, 1161, 1145, 739.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.87 (s, 1H), 8.00-7.99 (m, 2H), 7.84 (s, 1H), 7.81-7.79 (m, 2H), 7.75 (d,  $J$  = 8.4 Hz, 1H), 6.97 (d,  $J$  = 8.4 Hz, 1H), 4.10 (s, 3H), 4.00 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.8, 189.8, 154.0, 148.8, 147.5, 142.4, 139.9, 135.1, 134.9, 131.4, 126.9, 126.5, 123.1, 123.0, 115.4, 110.7, 56.1(2C). **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_4$  ( $\text{M}+\text{H}$ ) $^+$ : 295.0970. Found: 295.0955.



### 2-(Benzo[*b*]thiophen-2-ylmethylene)-1*H*-indene-1,3(2*H*)-dione (**12f**)

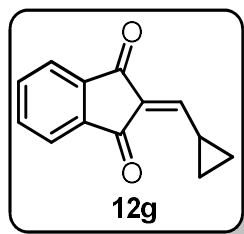
Following the general procedure 3, 20 mg of **11f** afforded 19 mg (95 % yield) of **12f** as yellow



solid. m.p. = 188-189 °C.  $R_f$  = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2921, 2851, 1722, 1687, 1608, 1585, 1356, 731, 722.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.30 (s, 1H), 8.08 (s, 1H), 8.04-8.00 (m, 2H), 7.92 (d,  $J$  = 8.1 Hz, 2H), 7.85-7.80 (m, 2H), 7.51-7.48 (m, 1H), 7.44-7.40 (m, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.0, 189.1, 145.7, 142.2, 140.5, 139.0, 138.7, 137.2, 137.0, 135.4, 135.2, 128.0, 126.8, 125.5, 125.2, 123.3, 123.2, 122.7. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_2\text{S}$  ( $\text{M}+\text{H}$ ) $^+$ : 291.0480. Found: 291.0466.

### 2-(Cyclopropylmethylene)-1*H*-indene-1,3(2*H*)-dione (**12g**).

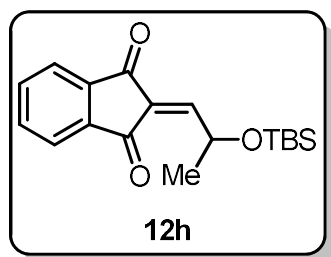
Following the general procedure 3, 20 mg of **11g** afforded 18 mg (90% yield) of **12g** as pale yellow



solid. M.P = 157-160 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2926, 1687, 735.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 7.97-7.94 (m, 2H), 7.80-7.77 (m, 2H), 6.66 (d,  $J$  = 11.7 Hz, 1H), 3.33-3.24 (m, 1H), 1.40-1.34 (m, 2H), 1.02-0.98 (m, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  191.1, 189.2, 160.2, 141.9, 139.9, 135.1, 135.0, 129.7, 123.3, 123.0, 14.3, 12.9(2C). **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{13}\text{H}_{11}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 199.0759. Found: 199.0739.

### 2-(2-((*tert*-Butyldimethylsilyl)oxy)propylidene)-1*H*-indene-1,3(2*H*)-dione (**12h**).

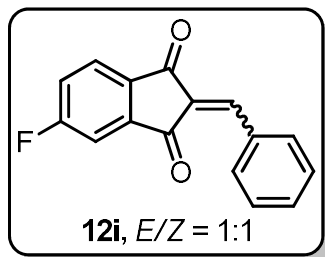
Following the general procedure 3, 100 mg of **11h** afforded 73 mg (73 % yield) of **12h** as orange



solid. M.P = 42-44 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2956, 2930, 2857, 1737, 1698, 1656, 1348, 737.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.02-7.96 (m, 2H), 7.86-7.81 (m, 2H), 7.24 (d,  $J$  = 7.9 Hz, 1H), 5.81-5.74 (m, 1H), 1.37 (d,  $J$  = 6.4 Hz, 3H), 0.90 (s, 9H), 0.09 (s, 3H), 0.04 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  189.8, 189.0, 155.8, 141.9, 140.8, 135.54, 135.53, 128.4, 123.5, 123.3, 64.6, 25.7(3C), 23.4, 18.1, -4.6, -4.7. **HRMS (ESI):**  $m/z$  calcd for:  $\text{C}_{18}\text{H}_{25}\text{O}_3\text{Si}$  ( $\text{M}+\text{H}$ ) $^+$ : 317.1573. Found: 317.1560.

### 2-Benzylidene-5-fluoro-1*H*-indene-1,3(2*H*)-dione (**12i**).

Following the general procedure 3, 30 mg of **11i** afforded 28.5 mg (95% yield) of **12i** as pale

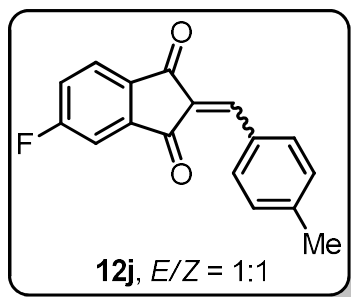


yellow solid. M.P = 172-174 °C. *R*<sub>f</sub> = 0.5 (hexane/EtOAc = 4/1). **IR** (thin film, neat):  $\nu_{\text{max}}/\text{cm}^{-1}$  1678, 1595, 750. **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>):  $\delta$  8.45 (d, *J* = 7.8 Hz, 2H), 8.06-8.02 (m, 1H), 7.906 (s, 1H), 7.65-7.62 (m, 1H), 7.59-7.47 (m, 4H). **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>):  $\delta$  189.1, 187.7, 167.2 (d, *J* = 258.1 Hz, 1C), 147.49, 145.2 (d, *J* = 8.9

Hz, 1C), 138.7 (d, *J* = 2.0 Hz, 1C), 134.3 (2C), 133.5, 132.9, 128.9, 128.8(2C) 126.1 (d, *J* = 9.4 Hz, 1C), 123.0 (d, *J* = 23.9 Hz, 1C), 110.1 (d, *J* = 18.2 Hz, 1C). **<sup>19</sup>F NMR** (376.5 MHz, CDCl<sub>3</sub>):  $\delta$  -99.2. **HRMS (ESI)**: *m/z* calcd for C<sub>16</sub>H<sub>10</sub>FO<sub>2</sub> (M+H)<sup>+</sup>: 253.0665. Found: 253.1108.

### 5-Fluoro-2-(4-methylbenzylidene)-1*H*-indene-1,3(2*H*)-dione (**12je**).

Following the general procedure 3, 30 mg of **11j** afforded 27 mg (90% yield) of **12j** as pale yellow



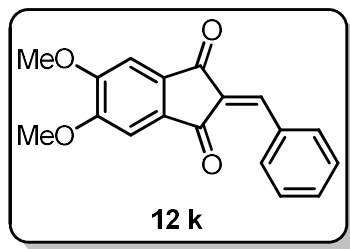
solid. M.P = 157-159 °C. *R*<sub>f</sub> = 0.5 (hexane/EtOAc = 4/1). **IR** (thin film, neat):  $\nu_{\text{max}}/\text{cm}^{-1}$  2927, 1676, 1592, 1274, 750. **<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>):  $\delta$  8.39 (d, *J* = 7.3 Hz, 2H), 8.05-8.01 (m, 1H), 7.879 (s, 1H), 7.64-7.61 (m, 1H), 7.48 (td, *J* = 8.6 and 2.3 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 2.47 (s, 3H). **<sup>13</sup>C NMR** (100 MHz, CDCl<sub>3</sub>):  $\delta$  189.3 (d, *J* = 2.2 Hz, 1C), 188.9, 167.1 (d, *J* = 257.6, 1C), 147.59,

145.2 (d, *J* = 8.6 Hz, 1C), 145.0, 138.6 (d, *J* = 2.2 Hz, 1C), 134.6(2C), 130.5, 129.7(2C), 128.0, 125.9 (d, *J* = 3.5 Hz, 1C), 122.8 (d, *J* = 23.7 Hz, 1C), 110.0 (d, *J* = 23.1 Hz, 1C), 22.0. **<sup>19</sup>F NMR** (376.5 MHz, CDCl<sub>3</sub>):  $\delta$  -99.6. **HRMS (ESI)**: *m/z* calcd for C<sub>17</sub>H<sub>12</sub>FO<sub>2</sub> (M+H)<sup>+</sup>: 267.0821. Found: 267.0811.



### 2-Benzylidene-5,6-dimethoxy-1*H*-indene-1,3(2*H*)-dione (**12k**).

Following the general procedure 3, 20 mg of **11k** afforded 14.6 mg (73 % yield) of **12k** as pale



yellow solid. M.P =188-189 °C.  $R_f$  = 0.4 (hexane/EtOAc = 4/1). **IR**

(thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  1717, 1668, 1581, 1497, 1312, 775.  **$^1\text{H}$  NMR** (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.40 (dd,  $J$  = 7.2 and 1.8 Hz, 2H),

7.72(s, 1H), 7.52-7.49 (m, 3H), 7.36 (d,  $J$  = 1.0 Hz, 2H), 4.03 (s,

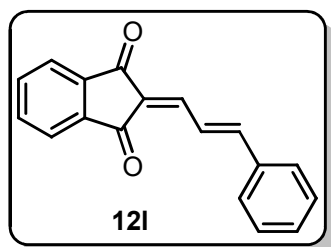
6H).  **$^{13}\text{C}$  NMR** (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  189.5, 188.3, 155.6, 155.5,

143.7, 138.0, 135.2, 133.7(2C), 133.2, 132.4, 129.5, 128.6(2C), 103.8, 103.6, 56.74, 56.71. **HRMS**

(ESI):  $m/z$  calcd for:  $\text{C}_{18}\text{H}_{15}\text{O}_4$  ( $\text{M}+\text{H}$ ) $^+$  295.0970. Found: 295.0958.

### 2-(3-Phenylallylidene)-1*H*-indene-1,3(2*H*)-dione (**12l**).

Following the general procedure 3, 95 mg of **11l** afforded 68.4 mg (72% yield) of **12l** as yellow



solid. M.P = 161-162 °C.  $R_f$  = 0.3 (hexane/EtOAc = 9/1). **IR** (thin

film, neat):  $\nu_{\max}/\text{cm}^{-1}$  2924, 1720, 1691, 1611, 1587, 1494, 1368,

1215, 1156, 989, 733.  **$^1\text{H}$  NMR** (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.47 (dd

$J$  = 15.5 Hz and 12.0 Hz, 1H), 8.01-7.99 (m, 2H), 7.83-7.81 (m,

2H), 7.717.66 (m, 3H), 7.48-7.45 (m, 3H), 7.37 (d,  $J$  = 15.5 Hz,

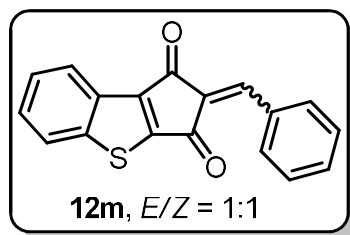
1H).  **$^{13}\text{C}$  NMR** (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  190.6, 190.1, 151.2, 144.7, 142.2, 140.8, 135.5, 135.2,

135.0, 130.9, 129.0(2C), 128.7(2C), 127.9, 123.6, 123.2, 123.0. **HRMS** (ESI):  $m/z$  calcd for

$\text{C}_{18}\text{H}_{13}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 261.0915. Found: 261.0907.

### 2-Benzylidene-1*H*-benzo[*b*]cyclopenta[*d*]thiophene-1,3(2*H*)-dione (**12m**).

Following the general procedure 3, 20 mg of **11m** afforded 18.2 mg (91% yield) of **12m** as pale



yellow solid. M.P =165-167 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR**

(thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  2918, 1729, 1679, 1463, 755.  **$^1\text{H}$  NMR**

(400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.53-8.48 (m, 1H), 8.40-8.35 (m, 2H), 8.01

(q,  $J$  = 4.2 Hz, 1H), 7.76 (d,  $J$  = 10.4 Hz, 1H), 7.64-7.61 (m, 2H),

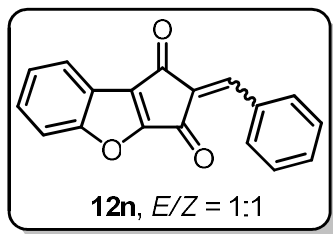
7.55-7.51 (m, 3H).  **$^{13}\text{C}$  NMR** (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  189.9, 189.1,

145.7, 142.2, 140.5, 139.1, 138.7, 137.2, 137.0, 135.4, 135.2, 128.0, 126.8, 125.5, 125.2, 123.3,

123.2, 122.7. **HRMS** (ESI):  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_2\text{S}$  ( $\text{M}+\text{H}$ ) $^+$ : 291.0480. Found: 291.1102.

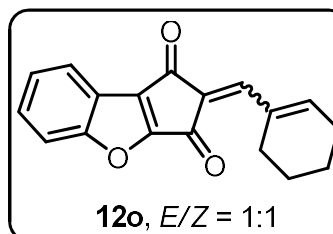
### 2-Benzylidene-1*H*-cyclopenta[*b*]benzofuran-1,3(2*H*)-dione (**12n**).

Following the general procedure 3, 25 mg of **11n** afforded 18 mg (72% yield) of **12n** as pale yellow solid. M.P = 193-195 °C.  $R_f$  = 0.5 (hexane/EtOAc = 8/2). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3060, 1688, 1618, 1439, 1372, 1195.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 8.31-8.29 (m, 2H), 8.06 (d,  $J$  = 7.8 Hz, 1H), 7.78 (s, 1H), 7.74-7.71 (m, 1H), 7.63 (t,  $J$  = 7.8 Hz, 1H), 7.55-7.50 (m, 4H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 182.1, 178.5, 169.6, 161.6, 143.4, 138.9, 135.8, 133.4(2C), 132.5, 132.3, 130.2, 128.7(2C), 126.2, 123.8, 120.0, 113.7. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{11}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 275.0708. Found: 275.0726.



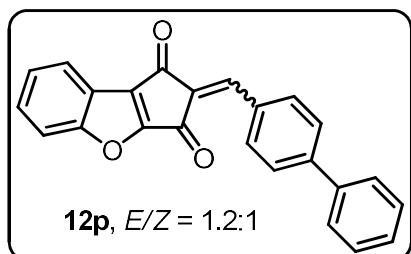
### 2-(Cyclohex-1-en-1-ylmethylene)-1*H*-cyclopenta[*b*]benzofuran-1,3(2*H*)-dione (**12o**).

Following the general procedure 3, 22 mg of **11o** afforded 15 mg (67% yield) of **12o** as pale yellow solid. m.p. = 159-161 °C.  $R_f$  = 0.6 (hexane/EtOAc = 7/3). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2926, 1689, 1600, 1409, 1278, 1073.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 8.43-8.40 (m, 1H), 7.96-7.94 (m, 1H), 7.58-7.56 (m, 2H), 7.21 (s, 1H), 6.81-6.79 (m, 1H), 2.726-2.722 (m, 2H), 2.38-2.35 (m, 2H), 1.74-1.70 (m, 2H), 1.68-1.63 (m, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 184.9, 182.9, 158.9, 149.1, 148.4, 147.2, 145.9, 136.6, 131.0, 129.1, 128.8, 126.8, 125.9, 123.9, 28.1, 27.8, 22.4, 21.1. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 279.1021. Found: 279.1007.



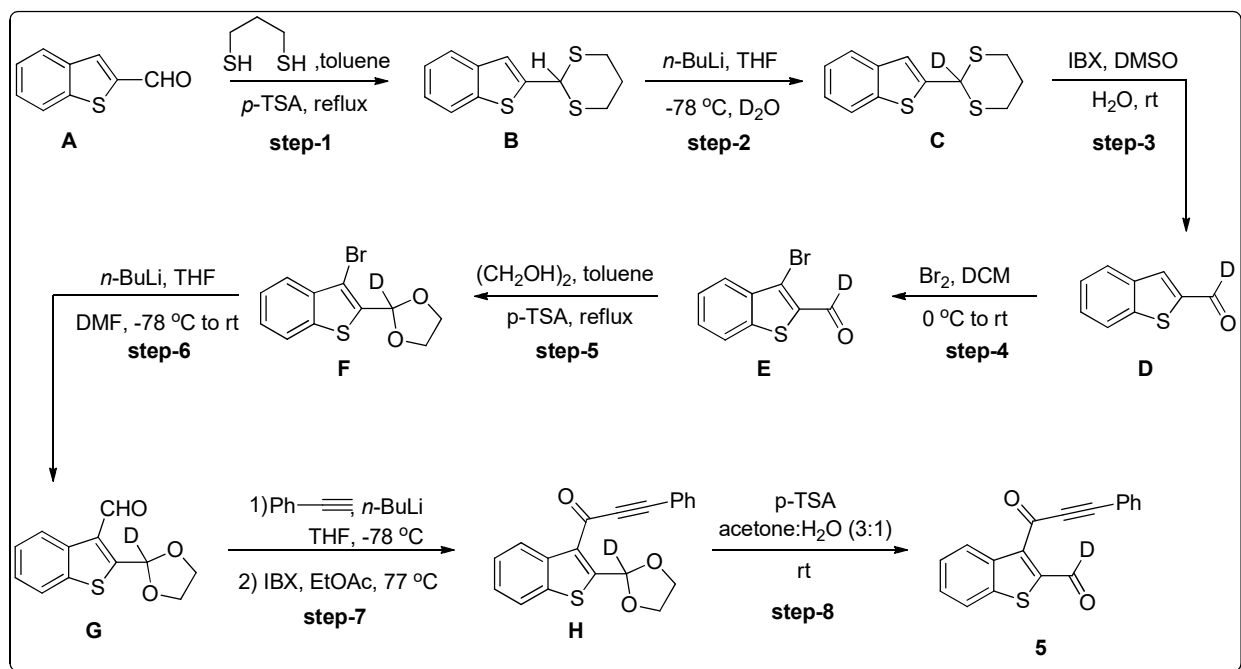
### 2-([1,1'-Biphenyl]-4-ylmethylene)-1*H*-cyclopenta[*b*]benzofuran-1,3(2*H*)-dione (**12p**).

Following the general procedure 3, 25 mg of **11p** afforded 19 mg (76% yield) of **12p** as pale yellow solid. M.P = 181-183 °C.  $R_f$  = 0.6 (hexane/EtOAc = 8/2). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3057, 1678, 1598, 1482, 1306, 1017.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 8.39 (d,  $J$  = 8.1 Hz, 2H), 8.06 (d,  $J$  = 7.7 Hz, 1H), 7.81 (s, 1H), 7.75-7.73 (m, 3H), 7.68-7.60 (m, 3H), 7.54-7.47 (m, 3H), 7.427.39 (m, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):** 182.3, 178.7, 169.7, 167.5, 161.7, 145.0, 142.9, 139.9, 135.8, 134.3, 134.2, 133.3, 131.6, 130.3, 129.0(2C), 128.3, 127.4, 127.3(2C), 126.2, 123.9, 120.4, 113.8. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{24}\text{H}_{15}\text{O}_3$  ( $\text{M}+\text{H}$ ) $^+$ : 351.1021. Found: 351.1039.



### General procedure 4: Synthesis of 3-(3-Phenylpropioloyl)benzo[*b*]thiophene-2-carbaldehyde-*d* (**11nD**).

The synthesis of deuterated ynone aldehyde **11nD** (~95%D) was accomplished in eight steps starting from benzo[*b*]thiophene-2-carbaldehyde (**Scheme 3.3**).



**Scheme 3.3**

**A representative procedure for step-1:** In an oven dried RB flask, benzo[*b*]thiophene-2-carbaldehyde (1.0 g, 6.17 mmol), propane-1,3-dithiol (8.0 mmol, 0.86 mL) and *p*-TSA (0.16 mmol, 27 mg) were dissolved in toluene (6.0 mL). The reaction mixture was refluxed in a Dean-Stark set-up for 2 h until the completion consumption of starting material (by TLC). Upon completion, the reaction mixture was quenched by adding saturated aq. NaHCO<sub>3</sub> solution and extracted with EtOAc. The combined organic layers were dried over Na<sub>2</sub>SO<sub>4</sub>, and concentrated under reduced pressure. The crude product was purified by silica gel column chromatography using 10% ethyl acetate/hexane as an eluent to afford the **B** in near quantitative yield.

**A representative procedure for step-2:** To a solution of **B** (1.0 g, 4 mmol) in anhydrous THF (7 mL) at -78 °C, was added *n*-BuLi (1.6 M in hexane, 3.2 mL, 5.2 mmol) and stirring was

continued at  $-78^{\circ}\text{C}$  for 40 minutes. Following this, the reaction mixture was warmed to  $0^{\circ}\text{C}$  and  $\text{D}_2\text{O}$  (0.25 mL) was added and stirring continued for 1 h. The reaction mixture was quenched with saturated aq.  $\text{NH}_4\text{Cl}$  solution and extracted with ethyl acetate. The organic layer was dried and the residue was chromatographed on silica to give **C**.

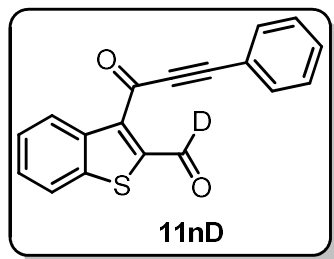
**A representative procedure for step-3:** IBX (2.2g, 7.9 mmol) was dissolved in DMSO (4.0 mL) with vigorous stirring for approximately 30 min at ambient temperature. This solution was then added to a solution of **C** (1.0 g, 3.9 mmol) in DMSO/ $\text{H}_2\text{O}$  (4:1, 3.0 mL) and stirred at room temperature. The reaction was monitored by TLC until complete consumption of starting material was observed. The mixture was quenched by addition of saturated aqueous  $\text{Na}_2\text{S}_2\text{O}_3$  (5 mL). Following extraction with ether (2x5 mL), the organic phase was washed with water, dried over anhydrous sodium sulfate, and concentrated. Final purification was done by column chromatography (silica gel) to furnish the desired aldehyde **D**.

**A representative procedure for step-4:** To a stirred solution of **D** (500 mg, 3.0 mmol) in DCM (7.0 mL) at  $0^{\circ}\text{C}$ , was added molecular bromine (0.23 mL, 4.6 mmol). After 15 min of addition, the reaction was warmed to room temperature and continued overnight. Upon completion, the mixture was quenched by addition of saturated aqueous  $\text{Na}_2\text{S}_2\text{O}_3$  (5.0 mL) and extracted with DCM. The organic layer was dried and the residue chromatographed on silica to give 3-bromobenzo[*b*]thiophene-2-carbaldehyde-*d* **E**.

**Representative procedures for step-5 to step-8:** The same procedure was followed as described in Scheme 3.2.

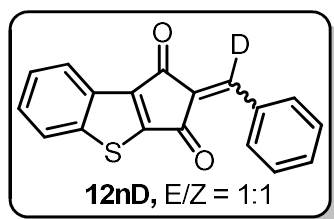
### 3-(3-Phenylpropioloyl)benzo[*b*]thiophene-2-carbaldehyde-*d* (11nD).

This compound was prepared following the general procedure 4 and isolated as orange solid. M.P = 112-114 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2889, 2191, 1772, 1649, 1490, 1276, 750.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):** 10.81 (s, 0.05H), 8.69-8.67 (m, 1H), 7.96-7.94 (m, 1H), 7.67 (d,  $J$  = 7.8 Hz, 2H), 7.61-7.54 (m, 3H), 7.48- 7.44 (m, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  185 (t,  $J$  = 30.2 Hz, CD), 172.0, 148.3, 141.2, 139.6, 137.1, 133.4(2C), 131.7, 129(2C), 128.4, 126.5, 126.1, 123.1, 119.2, 95.7, 90.3. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_8\text{DO}_2\text{S}(\text{M-H})^+$ : 290.0386, Found: 290.0374.



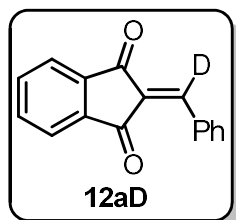
### 2-Benzylidene-1*H*-benzo[*b*]cyclopenta[*d*]thiophene-1,3(2*H*)-dione-*d* (12nD).

Following the general procedure 3, 25 mg of **11nD** afforded 24 mg (96% yield) of **12nD** as pale yellow solid. M.P = 180-182 °C.  $R_f$  = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2919, 1710, 1677, 1612, 1504, 1463, 1449, 737.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.51- 8.47 (m, 1H), 8.39-8.35 (m, 2H), 8.02- 7.99 (m, 1H), 7.75 (s, 0.70H), 7.65-7.60 (m, 2H), 7.54-7.52 (m, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  184.2, 183.4, 159.0, 155.5, 148.9, 147.5 (t,  $J$  = 7.8 Hz, CD), 143.0, 133.7, 132.8, 132.4, 131.2, 129.2, 128.7(2C), 127.1, 126.1, 126.0, 124.1. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{10}\text{DO}_2\text{S}(\text{M+H})^+$ : 292.0542. Found: 292.0536.



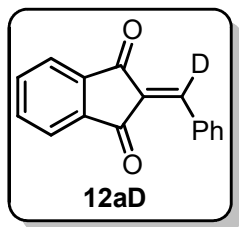
### 2-Benzylidene-1*H*-indene-1,3(2*H*)-dione (12aD, THF/ $\text{D}_2\text{O}$ ).

Following the general procedure 3, 20 mg of **11a** afforded 16 mg (80% yield) of **12aD** as light yellow solid. M.P = 142-144 °C.  $R_f$  = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2924, 1723, 1689, 1586, 1261, 801, 737, 685.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.50 (d,  $J$  = 7.0 Hz, 2H), 8.04 (d,  $J$  = 4.5 Hz, 2H), 7.93 (s, 0.03H), 7.85- 7.83 (m, 2H), 7.59-7.53 (m, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  190.3, 189.1, 147.0, 142.5, 140.1, 135.4, 135.2, 134.2(2C), 131.1 (t,  $J$  = 5.5 Hz, CD), 129.2, 129.1, 128.8(2C), 123.4(2C). **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{16}\text{H}_{10}\text{DO}_2(\text{M+H})^+$ : 236.0822. Found: 236.0809.



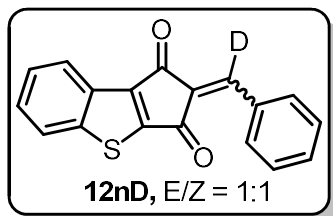
### 2-Benzylidene-1*H*-indene-1,3(2*H*)-dione (12aD, THF/MeOH-*d*<sub>4</sub>).

Following the general procedure 3, 20 mg of **11a** afforded 16 mg (80% yield) of **12aD** as light yellow solid. M.P = 152-153 °C. *R*<sub>f</sub> = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  2924, 1724, 1690, 1607, 1586, 1351, 1209, 738, 684. **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):**  $\delta$  8.50-8.47 (m, 2H), 8.06-8.01 (m, 2H), 7.93 (s, 0.24H), 7.86-7.82 (m, 2H), 7.60-7.52 (m, 3H). **<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):**  $\delta$  190.3, 189.1, 147.0, 142.5, 140.1, 135.4, 135.2, 134.2(2C), 133.1 (t, *J* = 5.5 Hz, CD), 129.2 129.1, 128.8(2C), 123.4(2C). **HRMS (ESI):** *m/z* calcd for C<sub>16</sub>H<sub>10</sub>DO<sub>2</sub> (M+H)<sup>+</sup>: 236.0822. Found: 236.0809.



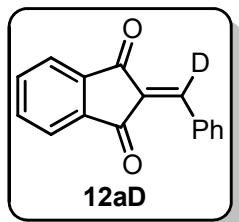
### 2-Benzylidene-1*H*-benzo[*b*]cyclopenta[*d*]thiophene-1,3(2*H*)-dione-*d* (12nD) in *D*-scrambling experiment.

Following the general procedure-3, 25 mg of **11nD** afforded 10.5 mg (42% yield) of **12nD** as pale yellow solid (~25%D). M.P = 180-182 °C. *R*<sub>f</sub> = 0.5 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  2919, 1710, 1677, 1612, 1504, 1463, 1449, 737. **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):**  $\delta$  8.51- 8.47 (m, 1H), 8.39- 8.35 (m, 2H), 8.02- 7.99 (m, 1H), 7.75 (s, 0.70H), 7.65-7.60 (m, 2H), 7.54-7.52 (m, 3H). **<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):**  $\delta$  184.2, 183.4, 159.0, 155.5, 148.9, 147.5 (t, *J* = 7.8 Hz, CD), 143.0, 133.7, 132.8, 132.4, 131.2, 129.2, 128.7(2C), 127.1, 126.1, 126.0, 124.1. **HRMS (ESI):** *m/z* calcd for C<sub>18</sub>H<sub>10</sub>DO<sub>2</sub>S (M+H)<sup>+</sup>: 292.0542. Found: 292.0536.



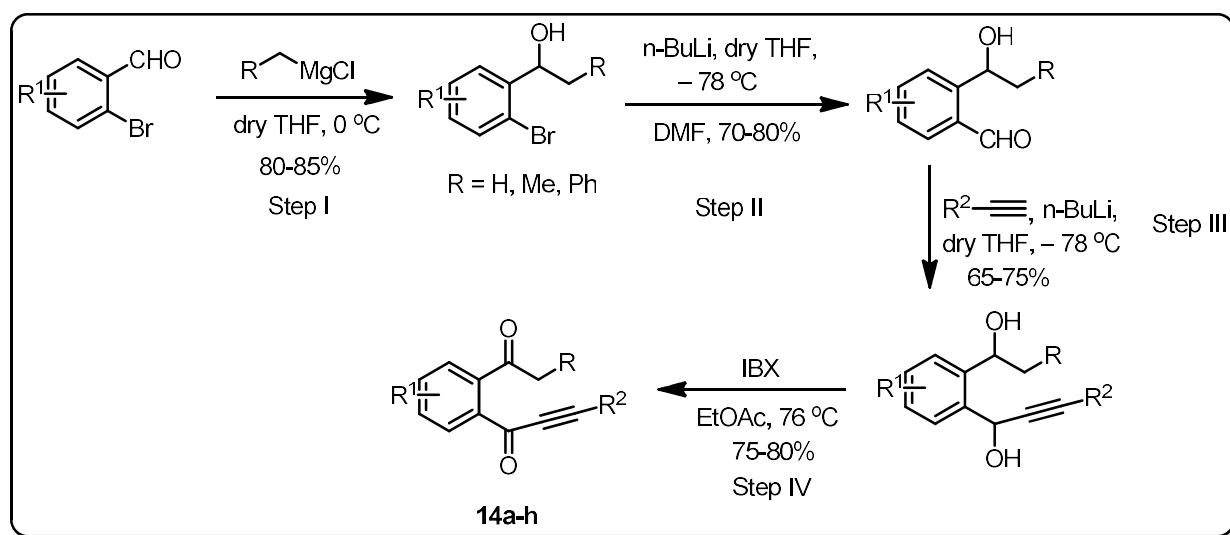
### 2-Benzylidene-1*H*-indene-1,3(2*H*)-dione (12aD) in *D*-scrambling experiment.

Following the general procedure-3, 25 mg of **11a** afforded 11 mg (44% yield) of **12aD** as light yellow solid (~10%D). M.P = 152-153 °C. *R*<sub>f</sub> = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\text{max}}/\text{cm}^{-1}$  2924, 1724, 1690, 1607, 1586, 1351, 1209, 738, 684. **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):**  $\delta$  8.50-8.47 (m, 2H), 8.06-8.01 (m, 2H), 7.93 (s, 0.24H), 7.86-7.82 (m, 2H), 7.60-7.52 (m, 3H). **<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>):**  $\delta$  190.3, 189.1, 147.0, 142.5, 140.1, 135.4, 135.2, 134.2(2C), 133.1 (t, *J* = 5.5 Hz, CD), 129.2 129.1, 128.8(2C), 123.4(2C). **HRMS (ESI):** *m/z* calcd for C<sub>16</sub>H<sub>10</sub>DO<sub>2</sub> (M+H)<sup>+</sup>: 236.0822. Found: 236.0809.



### General procedure 5: Synthesis of keto-ynones (14a-14h).

These ketoynones were synthesized by following four step straightforward procedure. The Grignard addition to the aldehyde functionality followed by n-BuLi/DMF mediated substitution of bromine with an aldehyde afforded xx. n-BuLi mediated alkynylation with appropriate alkynes deliver corresponding ynols, which upon subsequent IBX oxidation afford the desired ketoynone (Scheme 3.4).



Scheme 3.4

**Representative procedure for step-I:** To a 50 mL RB flask equipped with magnetic stir bar was added the 2-bromo aldehyde (500 mg, 2.7 mmol), anhydrous THF (5.0 ml) under N<sub>2</sub> atmosphere and stirred at 0 °C for 2-3 minutes. Methyl, ethyl or benzyl magnesium chloride (3.24 mmol) was added dropwise to the above solution and stirring was continued for 1 h. The reaction mixture was quenched with dil. HCl and extracted twice with EtOAc. The combined organic layers were dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>, concentrated and purified by silica gel column chromatography.

**Representative procedure for step-II:** To a 25 mL long neck RB flask equipped with magnetic stir bar was added 2-bromo alcohol (500 mg, 2.48 mmol), anhydrous THF (5.0 mL) under N<sub>2</sub> atmosphere and stirred at -78 °C for 5 mins. n-BuLi (1.6 M in hexane, 3.41 mL, 5.46 mmol) was added drop wise to the above solution and stirring was continued for 1 h. Dry DMF

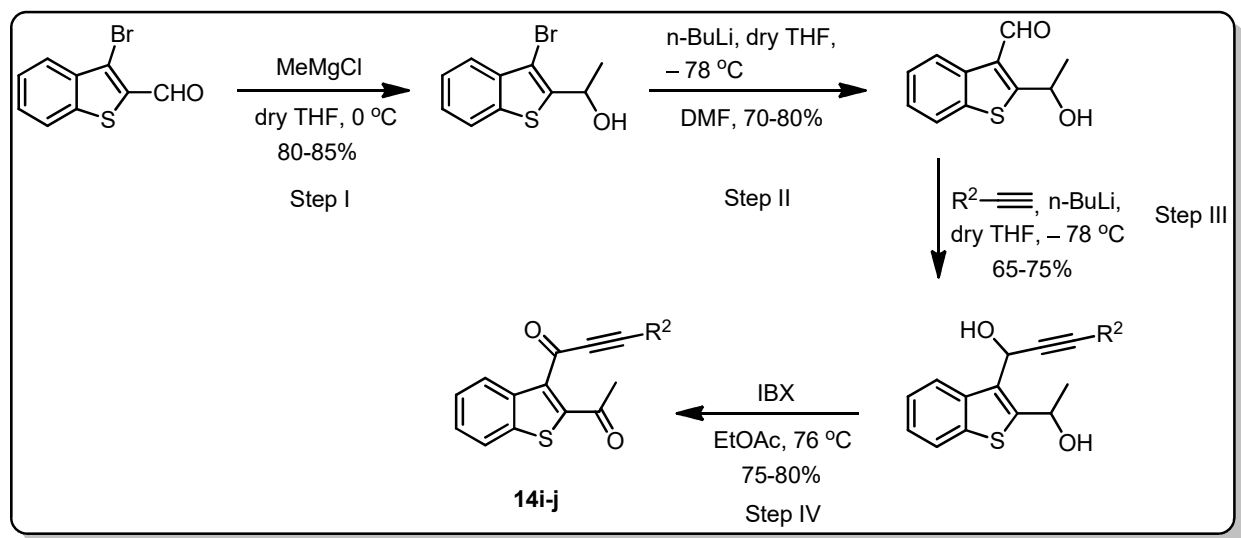
(0.4 ml, 5 mmol) was introduced into the reaction mixture at the same temperature and stirred for 1 h. The reaction mixture was quenched with sat. aq.  $\text{NH}_4\text{Cl}$  solution and extracted with EtOAc. The combined organic layers were dried over anhydrous  $\text{Na}_2\text{SO}_4$ , concentrated and purified using silica gel column chromatography.

**Representative procedure for step-III:** To a 25 mL long neck RB flask equipped with magnetic stir bar was added alkyne (4.4 mmol), anhydrous THF (5.0 mL) under  $\text{N}_2$  atmosphere and stirred at  $-78^\circ\text{C}$  for 5 minutes.  $n\text{-BuLi}$  (1.6 M in hexane, 2.75 mL, 4.4 mmol) was added drop wise to the above solution and stirring was continued for 1 h. The hydroxyaldehyde (300 mg, 2.0 mmol) was then introduced to the reaction mixture at the same temperature and stirred for 1 h. The reaction mixture was quenched with sat. aq.  $\text{NH}_4\text{Cl}$  solution and extracted with EtOAc. The combined organic layers were dried over anhydrous  $\text{Na}_2\text{SO}_4$ , concentrated and purified using silica gel column chromatography.

**Representative procedure for step-IV:** To a 50 mL RB flask equipped with stir bar was added ynone (425 mg, 1.68 mmol) and dissolved in EtOAc (10 ml). IBX (1.0 g, 3.7 mmol) was then introduced and refluxed at  $78^\circ\text{C}$  for 4-5 h. After completion of the reaction, the reaction mixture was filtered through celite pad. The filtrate was concentrated and purified using column chromatography.

#### General procedure 6: Synthesis of keto-ynone (14i-j)

These ketoynone were prepared by following the same aforementioned protocol as described for the preparation of ketoynone appended to the phenyl backbone (Scheme 3.5).

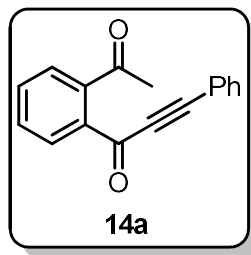


Scheme 3.5



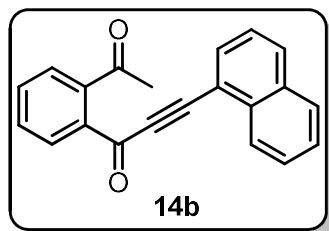
### 1-(2-acetylphenyl)-3-phenylprop-2-yn-1-one (14a).

This compound was prepared following the general procedure 5 and isolated as pale yellow viscous oil.  $R_f = 0.4$  (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3062, 2198, 1701, 1636, 1594, 1569, 1489, 1286, 1245, 1210, 1012, 758, 689.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.23 (dd,  $J = 7.5$ , 1H), 7.69-7.59 (m, 4H), 7.54-7.50 (m, 1H), 7.46-7.42 (m, 2H), 7.4 (dd,  $J = 7.5$ , 1H), 2.55 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  204.1, 178.1, 143.2, 135.2, 133.5, 133.1(2C), 131.5, 131.1, 129.8, 128.7(2C), 126.5, 119.7, 94.2, 87.0, 30.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{17}\text{H}_{13}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 249.0916, Found: 249.0907.



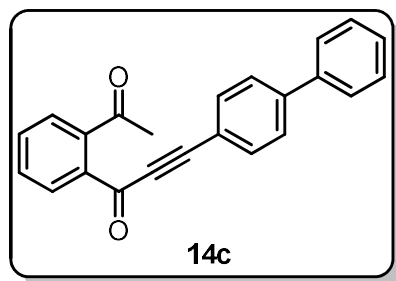
### 1-(2-acetylphenyl)-3-(naphthalen-1-yl)prop-2-yn-1-one (14b).

This compound was prepared by following the general procedure 5 and isolated as pale yellow liquid.  $R_f = 0.5$  (Hexane/EtOAc = 10/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2926, 2187, 1771, 1697, 1633, 1285, 759.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.38 (d,  $J = 8.2$  Hz, 1H), 8.33 (dd,  $J = 7.1$  and 0.9 Hz, 1H), 8.01 (d,  $J = 9.3$  Hz, 1H), 7.96-7.91 (m, 2H), 7.71-7.63 (m, 3H), 7.62-7.58 (m, 1H), 7.55-7.51 (m, 1H), 7.43 (dd,  $J = 7.4$  and 1.3 Hz, 1H), 2.59 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  204.0, 178.1, 143.2, 135.4, 133.6, 133.5, 133.4, 133.0, 131.8, 131.5, 129.9, 128.6, 127.8, 127.0, 126.6, 125.7, 125.2, 117.3, 92.6, 91.7, 30.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{21}\text{H}_{14}\text{O}_2\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 321.0891. Found: 321.0887.



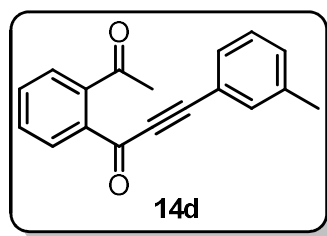
### 3-([1,1'-biphenyl]-4-yl)-1-(2-acetylphenyl)prop-2-yn-1-one (14c).

This compound was prepared by following the general procedure 5 and isolated as pale yellow liquid.  $R_f = 0.5$  (Hexane/EtOAc = 10/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2924, 2852, 2195, 1701, 1634, 1485, 1006.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.25 (dd,  $J = 7.4$  and 0.9 Hz, 1H), 7.77-7.75 (m, 2H), 7.70-7.63 (m, 6H), 7.50 (t,  $J = 7.1$  Hz, 2H), 7.44-7.39 (m, 2H), 2.56 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  204.1, 178.0, 143.9, 143.3, 139.7, 135.2, 133.7(2C), 133.5, 131.5, 129.8, 129.0(2C), 128.3, 127.4(2C), 127.1(2C), 126.5, 118.4, 94.3, 87.7, 30.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{23}\text{H}_{16}\text{O}_2\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 347.1048. Found: 347.1034.



### 1-(2-acetylphenyl)-3-(*m*-tolyl)prop-2-yn-1-one (14d).

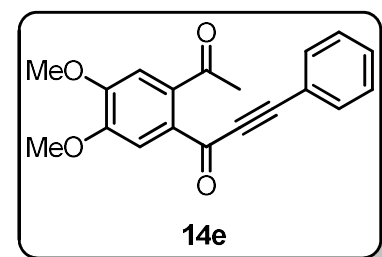
This compound was prepared by following the general procedure 5 and isolated as pale



yellow liquid.  $R_f = 0.5$  (Hexane/EtOAc = 10/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2955, 2924, 2190, 1742, 1730, 1465.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.23 (dd,  $J = 7.4$  and  $0.8$  Hz, 1H), 7.68-7.59 (m, 2H), 7.49-7.47 (m, 2H), 7.38 (dd,  $J = 7.4$  and  $1.0$  Hz, 1H), 7.33-7.31 (m, 2H), 2.54 (s, 3H), 2.39 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  204.1, 178.0, 143.2, 138.6, 135.2, 133.6, 133.4, 132.0, 131.5, 130.3, 129.8, 128.6, 126.5, 119.5, 94.6, 86.7, 30.4, 21.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 263.1072. Found: 263.1077.

### 1-(2-Acetyl-4,5-dimethoxyphenyl)-3-phenylprop-2-yn-1-one (14e).

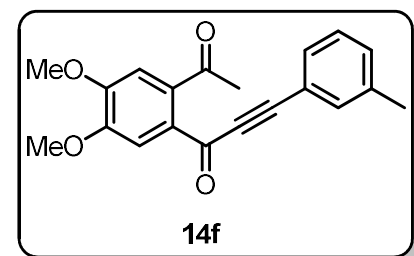
This compound was prepared following the general procedure 5 and isolated as white solid.



M.P = 138-140 °C.  $R_f = 0.4$  (hexane/EtOAc = 7/3). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2936, 2195, 1696, 1630, 1592, 1563, 1515, 1463, 1350, 1285, 1196, 1159, 1076.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.68 (s, 1H), 7.65-7.63 (m, 2H), 7.52-7.48 (m, 1H), 7.447.41 (m, 2H), 6.84 (s, 1H), 4.02 (s, 3H), 3.98 (s, 3H), 2.50 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  203.9, 176.6, 153.2, 149.3, 137.9, 133.0(2C), 131.0, 128.8(2C), 128.1, 119.8, 113.5, 109.5, 93.8, 87.2, 56.4, 56.2, 30.7. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{19}\text{H}_{16}\text{O}_4\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 331.0947. Found: 331.0937.

### 1-(2-Acetyl-4,5-dimethoxyphenyl)-3-(*m*-tolyl)prop-2-yn-1-one (14f).

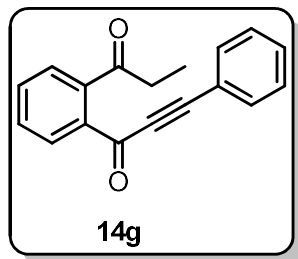
This compound was prepared following the general procedure 5 and isolated as white solid.



M.P = 131-133 °C.  $R_f = 0.5$  (hexane/EtOAc = 7/3). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2936, 2195, 1696, 1630, 1592, 1563, 1515, 1463, 1350, 1285, 1196, 1159, 1076.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.67 (s, 1H), 7.44 (s, 2H), 7.32-7.29 (m, 2H), 6.83 (s, 1H), 4.01 (s, 3H), 3.96 (s, 3H), 2.49 (s, 3H), 2.37 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  203.9, 176.6, 153.1, 149.2, 138.6, 137.9, 133.4, 132.0, 130.1, 128.7, 128.2, 119.6, 113.5, 109.5, 94.2, 86.9, 56.4, 56.2, 30.7, 21.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{20}\text{H}_{18}\text{O}_4\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 345.1103. Found: 345.1119.

### 3-Phenyl-1-(2-propionylphenyl)prop-2-yn-1-one (14g).

This compound was prepared by following the general procedure-10 and isolated as pale

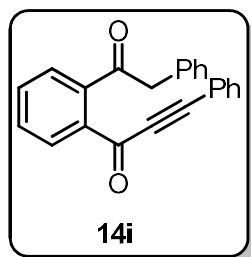


brown liquid.  $R_f = 0.6$  (Hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  2978, 2199, 1702, 1636, 1490, 1302, 1209, 1012, 995, 759, 688.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.26-8.24 (m, 1H), 7.68-7.57 (m, 4H), 7.52-7.48 (m, 1H), 7.44-7.41 (m, 2H), 7.33-7.31 (m, 1H), 2.75 (q,  $J = 7.2$  Hz, 2H), 1.26 (t,  $J = 7.2$  Hz, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  207.5, 178.0, 143.6, 135.0, 133.6,

133.2(2C), 131.8, 131.1, 129.6, 128.8(2C), 126.5, 119.8, 94.3, 86.9, 36.6, 8.5. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 263.1072. Found: 263.1065.

### 3-Phenyl-1-(2-(2-phenylacetyl)phenyl)prop-2-yn-1-one (14h).

This compound was prepared following the general procedure 5 and isolated as white solid.

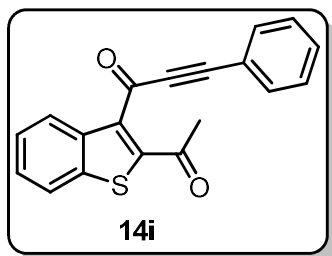


M.P = 100-102 °C.  $R_f = 0.5$  (hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3064, 2198, 1703, 1634, 1596, 1568, 1489, 1443, 1307, 1291, 1210, 1013, 995, 756, 688.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.33-8.31 (m, 1H), 7.72- 7.70 (m, 2H), 7.62-7.60 (m, 2H), 7.56-7.52 (m, 1H), 7.48-7.44 (m, 2H), 7.34-7.27 (m, 5H), 7.20-7.18 (m, 1H), 4.10 (s, 2H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  204.2, 177.8, 143.0, 134.6, 133.9,

133.7, 133.2(2C), 132.0, 131.2, 130.0(2C), 129.6, 128.8(2C), 128.5(2C), 127.0(2C), 119.7, 94.6, 86.7, 50.0. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{23}\text{H}_{16}\text{O}_2\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 347.1048. Found: 347.1038.

### 1-(2-acetylbenzo[b]thiophen-3-yl)-3-phenylprop-2-yn-1-one (14i).

This compound was prepared following the general procedure 6 and isolated as pale yellow solid.

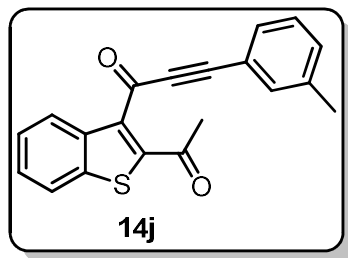


M.P = 124-126 °C.  $R_f = 0.4$  (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3060, 2194, 1684, 1646, 1504, 1459, 1428, 1356, 1279, 1228, 1146, 1121, 758.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.26-8.23 (m, 1H), 7.93-7.90 (m, 1H), 7.61 (d,  $J = 7.3$  Hz, 2H), 7.57-7.53 (m, 2H), 7.50 (d,  $J = 7.5$  Hz, 1H), 7.42 (t,  $J = 7.7$  Hz, 2H), 2.72 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  193.1, 175.4, 144.9, 139.8,

137.6, 136.8, 133.3(2C), 131.3, 128.7(2C), 127.6, 126.2(2C), 125.0, 122.7(2C), 119.6, 94.5, 89.1, 30.4. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{19}\text{H}_{12}\text{O}_2\text{SNa}$  ( $\text{M}+\text{Na}$ ) $^+$ : 327.0456, Found: 327.0450.

### 1-(2-Acetylbenzo[*b*]thiophen-3-yl)-3-(*m*-tolyl)prop-2-yn-1-one (**14j**).

This compound was prepared following the general procedure 6 and isolated as pale brown



solid. M.P = 82-84 °C.  $R_f$  = 0.4 (hexane/EtOAc = 9/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3058, 2919, 2185, 1680, 1627, 1501, 1117, 735.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  8.24-8.22 (m, 1H), 7.90-7.88 (m, 1H), 7.55-7.50 (m, 2H), 7.42-7.40 (m, 2H), 7.30-7.28 (m, 2H), 2.71 (s, 3H), 2.36 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  193.1, 175.5, 144.8, 139.8, 138.6, 137.7, 136.8, 133.7, 132.3, 130.5, 128.6, 127.6, 126.2, 125.0, 122.7, 119.3, 95.0, 89.0, 30.4, 21.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{20}\text{H}_{14}\text{O}_2\text{SNa}$  ( $\text{M}+\text{Na}$ ) $^+$ : 341.0613. Found: 341.0620.

### General procedure 7: Screening of reaction parameters.

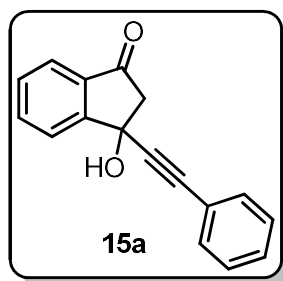
An oven dried 5 mL glass vial was charged with **14a** (0.1 mmol). Solvent (1 mL) and catalyst (0.02 mmol) were introduced. Stirring continued until **14a** disappeared as monitored by TLC. Then the reaction was quenched with water and extracted. The organic extracts were combined dried over anhydrous sodium sulphate and concentrated. The crude product was purified by silica gel flash chromatography using hexane/ethyl acetate as eluent, to afford **15a**.

### General procedure 8: Evaluating the substrate scope.

An oven dried 5 mL glass vial was charged with **14** (0.1 mmol). *t*-BuOH (1 mL) and tributyl phosphine (0.02 mmol) were introduced at rt until **14** disappeared as monitored by TLC. Then the reaction was quenched with water and extracted using ethyl acetate. The organic extracts were combined dried over anhydrous sodium sulphate and concentrated. The crude product was purified by silica gel flash chromatography using hexane/ethyl acetate as eluent, to afford **15**.

### 3-hydroxy-3-(phenylethynyl)-2,3-dihydro-1H-inden-1-one (**15a**).

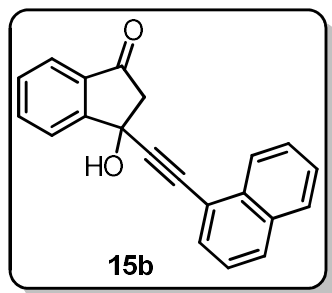
Following the general procedure 8, 20 mg of **14a** afforded 19 mg (95% yield) of **15a** as brown



viscous oil.  $R_f = 0.25$  (hexane/EtOAc = 4/1). IR (thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  3398, 2924, 2293, 1721, 1604, 1490, 1463, 1288, 1236, 1039, 757, 691.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.91 (d,  $J = 7.7$  Hz, 1H), 7.80-7.75 (m, 2H), 7.56 (t,  $J = 7.4$  Hz, 1H), 7.45-7.43 (m, 2H), 7.36-7.31 (m, 3H), 3.30 (ABq,  $\Delta\nu_{\text{AB}} = 35.5$  Hz,  $J_{\text{AB}} = 18.7$  Hz, 2H), 3.06 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.9, 155.5, 135.9, 134.8, 131.7(2C), 130.1, 128.9, 128.4(2C), 124.8, 123.4, 121.8, 89.7, 85.8, 69.9, 54.3. HRMS (ESI):  $m/z$  calcd for  $\text{C}_{17}\text{H}_{13}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 249.0916, Found: 249.0927.

### 3-hydroxy-3-(naphthalen-1-ylethynyl)-2,3-dihydro-1H-inden-1-one (**15b**).

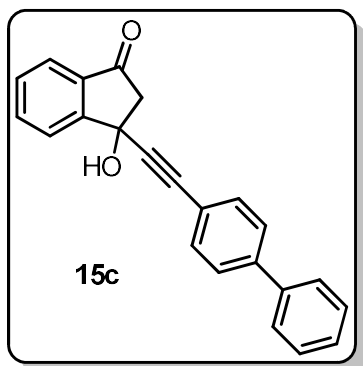
This compound was isolated as yellow oil. Following the general procedure 8, 35 mg of **14b** afforded 23.8 mg of **15b** (68% yield).  $R_f = 0.5$  (Hexane/EtOAc = 5/1).



IR (thin film, neat):  $\nu_{\max}/\text{cm}^{-1}$  3394, 2925, 2216, 1710, 1592, 1032, 761.  $^1\text{H}$  NMR (400 MHz,  $(\text{CD}_3)_2\text{SO}$ ):  $\delta$  8.26-8.22 (m, 1H), 8.03 (d,  $J = 7.6$  Hz, 1H), 7.98 (d,  $J = 8.1$  Hz, 2H), 7.88 (t,  $J = 7.4$  Hz, 1H), 7.82-7.80 (m, 1H), 7.71 (dd,  $J = 7.5$  and 3.6 Hz, 1H), 7.67-7.64 (m, 1H), 7.63-7.57 (m, 2H), 7.51 (t,  $J = 7.8$  Hz, 1H), 6.90 (s, 1H), 3.46 (d,  $J = 18.5$  Hz, 1H), 3.09 (d,  $J = 18.5$  Hz, 1H).  $^{13}\text{C}$  NMR (100 MHz,  $(\text{CD}_3)_2\text{SO}$ ):  $\delta$  202.3, 157.0, 136.4, 134.6, 133.2, 132.9, 130.9, 130.3, 129.7, 128.9, 127.7, 127.2, 126.0, 125.86, 125.83, 123.0, 119.6, 97.4, 82.2, 69.2, 54.6. HRMS (ESI):  $m/z$  calcd for  $\text{C}_{21}\text{H}_{15}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 299.1072. Found: 299.1058.

### 3-([1,1'-biphenyl]-4-ylethynyl)-3-hydroxy-2,3-dihydro-1H-inden-1-one (**15c**).

This compound was isolated as yellow oil. Following the general procedure 8, 30 mg of **14c**

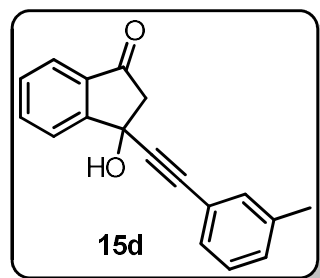


afforded 21.6 mg of **15c** (72% yield).  $R_f = 0.5$  (Hexane/EtOAc = 5/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3398, 2946, 2930, 2221, 1728, 1610, 1641, 1240, 758.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.94 (d,  $J = 7.5$  Hz, 1H), 7.85 (t,  $J = 7.2$  Hz, 1H), 7.69 (dd,  $J = 8.3$  and 3.8 Hz, 5H), 7.60 (t,  $J = 7.2$  Hz, 1H), 7.53 (d,  $J = 8.1$  Hz, 1H), 7.49-7.45 (m, 2H), 7.40-7.36 (m, 2H), 6.77 (s, 1H), 3.32 (d,  $J = 18.5$  Hz, 1H), 3.01 (d,  $J = 18.5$  Hz, 1H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  201.8, 155.5, 141.7, 140.1, 135.9, 134.8, 132.1(3C), 130.1,

128.9(2C), 127.8, 127.0(3C), 124.8, 123.4, 120.6, 90.3, 85.7, 69.9, 54.3. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{23}\text{H}_{17}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 325.1229. Found: 325.1265.

### 1-(2-acetylphenyl)-3-(m-tolyl)prop-2-yn-1-one (**15d**).

This compound was isolated as pale yellow oil. Following the general procedure 8, 30 mg of

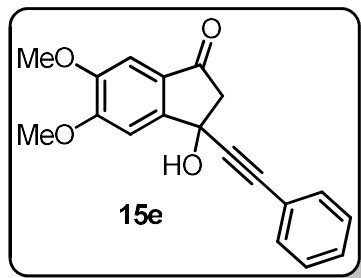


**14d** afforded 23.4 mg of **15d** (78% yield).  $R_f = 0.3$  (Hexane/EtOAc = 4/1). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3396, 2956, 2924, 2226, 1722, 1603, 1640.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.91 (td,  $J = 7.6$  and 0.8 Hz, 1H), 7.80-7.75 (m, 2H), 7.56 (dt,  $J = 7.4$  and 0.7 Hz, 1H), 7.27-7.16 (m, 4H), 3.29 (ABq,  $J_{AB} = 18.6$  Hz, 2H), 3.00 (bs, 1H), 2.33 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  201.9, 155.5, 138.1, 135.9, 134.8, 132.3, 130.1,

129.8, 128.8, 128.2, 124.8, 123.3, 121.5, 89.3, 86.0, 69.9, 54.3, 21.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{15}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 263.1072. Found: 263.1080.

### 3-Hydroxy-5,6-dimethoxy-3-(phenylethynyl)-2,3-dihydro-1*H*-inden-1-one (15e).

Following the general procedure 8, 20 mg of **14e** afforded 17.6 mg (88% yield) of **15e** as pale

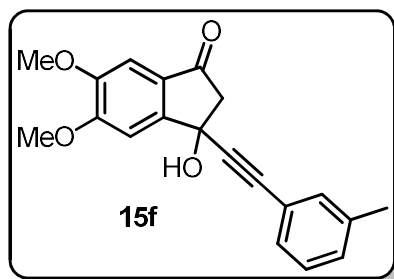


brown oil.  $R_f = 0.5$  (hexane/EtOAc = 6/4). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3443, 2923, 2851, 2227, 1703, 1594, 1499, 1461, 1298, 1214.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.44-7.42 (m, 2H), 7.37-7.28 (m, 4H), 7.16 (s, 1H), 4.04 (s, 3H), 3.94 (s, 3H), 3.40, 3.15 (ABq,  $J_{AB}=18.5$  Hz, 2H) 3.29 (s, 1H).  **$^{13}\text{C}$**

**NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  200.6, 156.2, 151.3, 150.6, 131.7(2C), 128.9, 128.4(2C), 128.1, 121.9, 105.5, 103.5, 89.9, 85.4, 69.7, 56.5, 56.3, 54.7. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{19}\text{H}_{17}\text{O}_4$  ( $\text{M}+\text{H}$ ) $^+$ : 309.1127. Found: 309.1112.

### 3-Hydroxy-5,6-dimethoxy-3-(*m*-tolylethynyl)-2,3-dihydro-1*H*-inden-1-one (15f).

Following the general procedure 8, 20 mg of **14f** afforded 17.2 mg (86% yield) of **15f** as pale

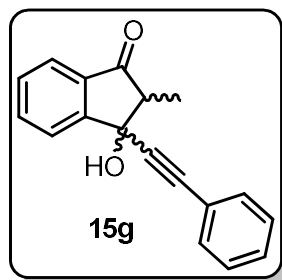


yellow solid. M.P = 121-122 °C.  $R_f = 0.5$  (hexane/EtOAc = 6/4). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3360, 2926, 2853, 2232, 1709, 1596, 1501, 1460, 1300, 1217.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.28-7.15 (m, 6H), 4.05 (s, 3H), 3.95 (s, 3H), 3.15 (ABq,  $J_{AB}=18.5$  Hz, 3H), 2.33 (s, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  200.5, 156.2, 151.3, 150.6, 138.1, 132.2, 129.8, 128.8, 128.3, 128.1, 121.6, 105.5, 103.4, 89.5,

85.6, 69.7, 56.5, 56.3, 54.7, 21.2. **HRMS (ESI):**  $m/z$  calcd for  $\text{C}_{20}\text{H}_{18}\text{O}_4\text{Na}$  ( $\text{M}+\text{Na}$ ) $^+$ : 345.1103. Found: 345.1107.

### 3-Hydroxy-2-methyl-3-(phenylethynyl)-2,3-dihydro-1*H*-inden-1-one (15g).

This compound was isolated as pale brown oil. Following the general procedure 8, 100 mg of

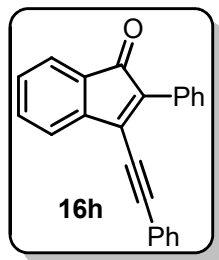


**14g** afforded 71.7 mg of **15g** (72% yield).  $R_f = 0.5$  (Hexane/EtOAc = 7/3). **IR (thin film, neat):**  $\nu_{\max}/\text{cm}^{-1}$  3193, 3067, 2960, 2934, 1721, 1605, 1466, 1289, 1227, 1146, 1095, 757, 693.  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):**  $\delta$  7.89 (d,  $J = 7.7$  Hz, 1H), 7.78-7.68 (m, 2H), 7.54-7.50 (m, 1H), 7.40-7.38 (m, 2H), 7.35-7.26 (m, 3H), 3.16 (s, 1H), 3.00 (q,  $J = 7.4$  Hz, 1H), 1.51 (d,  $J = 7.4$  Hz, 3H).  **$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ):**  $\delta$  203.8, 154.5, 135.7, 134.2, 131.8(2C), 130.0, 129.0, 128.4(2C), 124.6, 123.5, 122.0, 89.4, 87.7, 75.3, 56.8, 12.2. **HRMS**

**(ESI):**  $m/z$  calcd for  $\text{C}_{18}\text{H}_{14}\text{O}_2$  ( $\text{M}+\text{H}$ ) $^+$ : 311.1072. Found: 311.1056.

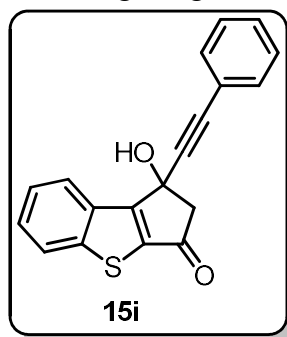
### 2-Phenyl-3-(phenylethynyl)-1H-inden-1-one (16h).

Following the general procedure 8, 20 mg of **14h** afforded 16 mg (80% yield) of **16h** as pale yellow solid. M.P = 98-100 °C.  $R_f$  = 0.7 (hexane/EtOAc = 9/1). IR (**thin film, neat**):  $\nu_{\max}/\text{cm}^{-1}$  3059, 2918, 2188, 1712, 1698, 1599, 1493, 1456, 1368, 1069, 753, 688.  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.10 (d,  $J$  = 7.3 Hz, 2H), 7.64-7.61 (m, 2H), 7.56-7.48 (m, 4H), 7.46-7.39 (m, 5H), 7.36-7.32 (m, 1H).  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  196.2, 143.5, 136.2, 135.9, 134.2, 132.2(2C), 131.1, 130.0, 129.9, 129.3, 129.0(2C), 128.8, 128.7(2C), 128.3(2C), 122.6, 122.2, 120.7, 108.4, 83.9. HRMS (ESI):  $m/z$  calcd for  $\text{C}_{23}\text{H}_{15}\text{O}$  ( $\text{M}+\text{H}$ ) $^+$ : 307.1123. Found: 307.1122.



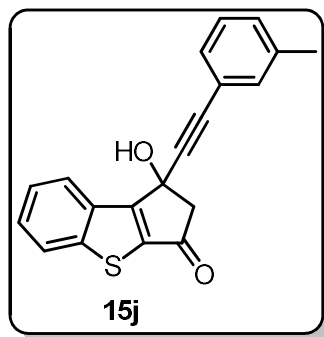
### 1-Hydroxy-1-(phenylethynyl)-1H-benzo[b]cyclopenta[d]thiophen-3(2H)-one (15i).

Following the general procedure 8, 20 mg of **14i** afforded 15.8 mg (79% yield) of **15i** as pale brown solid. M.P = 127-129 °C.  $R_f$  = 0.15 (hexane/EtOAc = 9/1). IR (**thin film, neat**):  $\nu_{\max}/\text{cm}^{-1}$  3392, 2922, 2231, 1708, 1596, 1520, 1489, 1268, 1245, 1038, 755, 732.  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.31-8.29 (m, 1H), 7.97-7.95 (m, 1H), 7.59-7.54 (m, 2H), 7.44 (d,  $J$  = 7.9 Hz, 2H), 7.38-7.31 (m, 3H), 3.61 (ABq,  $J_{AB}$  = 18.2 Hz, 2H), 3.14 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  193.5, 162.2, 148.7, 141.3, 131.9(2C), 131.8(2C), 129.1, 128.5, 128.4, 125.7, 124.6(2C), 121.5, 88.0, 86.3, 67.5, 58.5. HRMS (ESI):  $m/z$  calcd for  $\text{C}_{19}\text{H}_{11}\text{O}_2\text{S}$  ( $\text{M}-\text{H}$ ) $^+$ : 303.0480. Found: 303.0467.



### 1-Hydroxy-1-(*m*-tolylethynyl)-1H-benzo[b]cyclopenta[d]thiophen-3(2H)-one (15j).

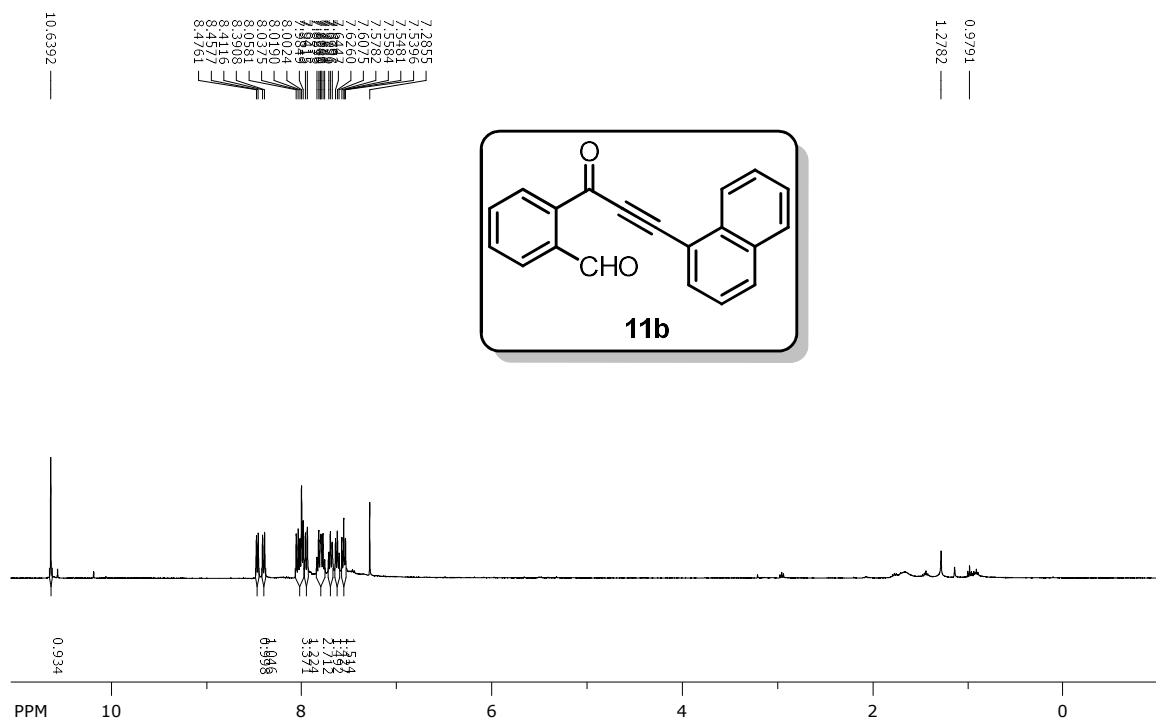
Following the general procedure 8, 20 mg of **14j** afforded 14.4 mg (72% yield) of **15j** as pale brown solid. M.P = 111-113 °C.  $R_f$  = 0.5 (hexane/EtOAc = 4/1). IR (**thin film, neat**):  $\nu_{\max}/\text{cm}^{-1}$  3433, 2925, 2854, 2232, 1711, 1595, 1520, 1426, 1271, 1246, 1094, 1041.  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.31-8.29 (m, 1H), 7.97-7.94 (m, 1H), 7.59-7.54 (m, 2H), 7.26-7.16 (m, 4H), 3.73, 3.48 (ABq,  $J_{AB}$  = 18.2 Hz, 2H), 3.27 (s, 1H), 2.32 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  193.7, 162.4, 148.7, 141.2, 138.2, 132.3, 131.9, 130, 128.9, 128.5, 128.3, 125.7, 124.6, 124.5, 121.4, 87.7, 86.5, 67.5, 58.6, 21.2. HRMS (ESI):  $m/z$  calcd for  $\text{C}_{20}\text{H}_{13}\text{O}_2\text{S}$  ( $\text{M}-\text{H}$ ) $^+$ : 317.0637. Found: 317.0625.

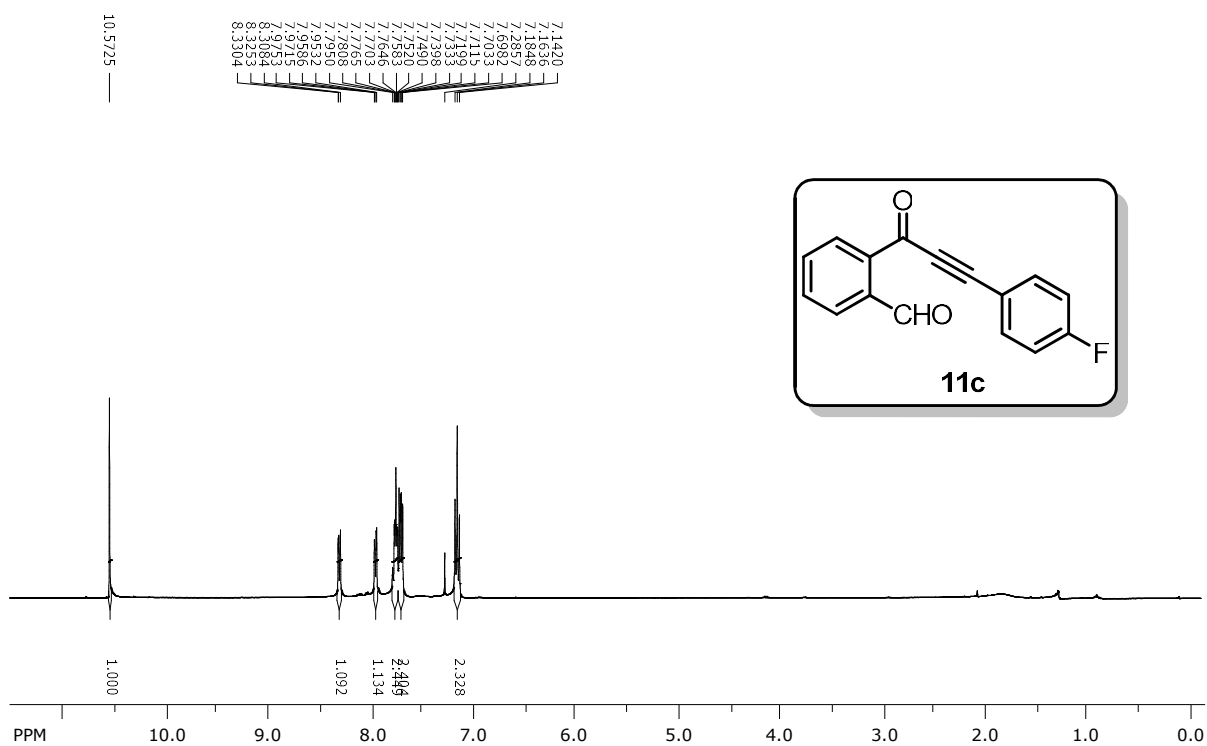
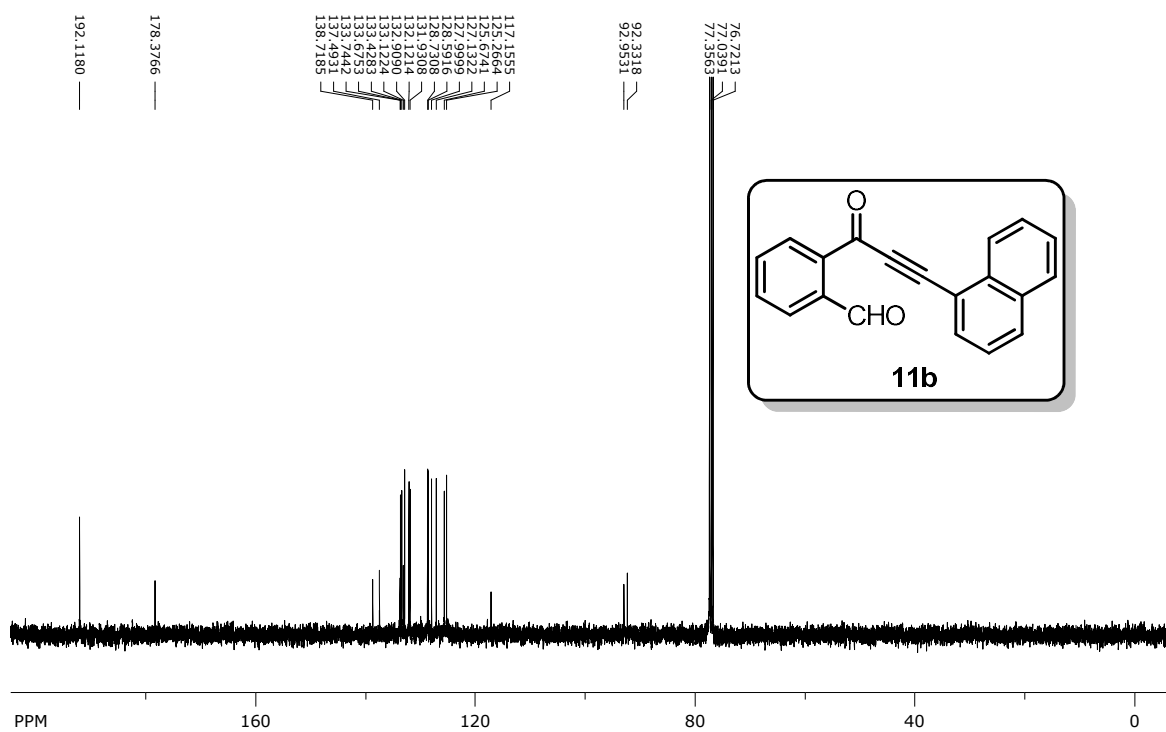


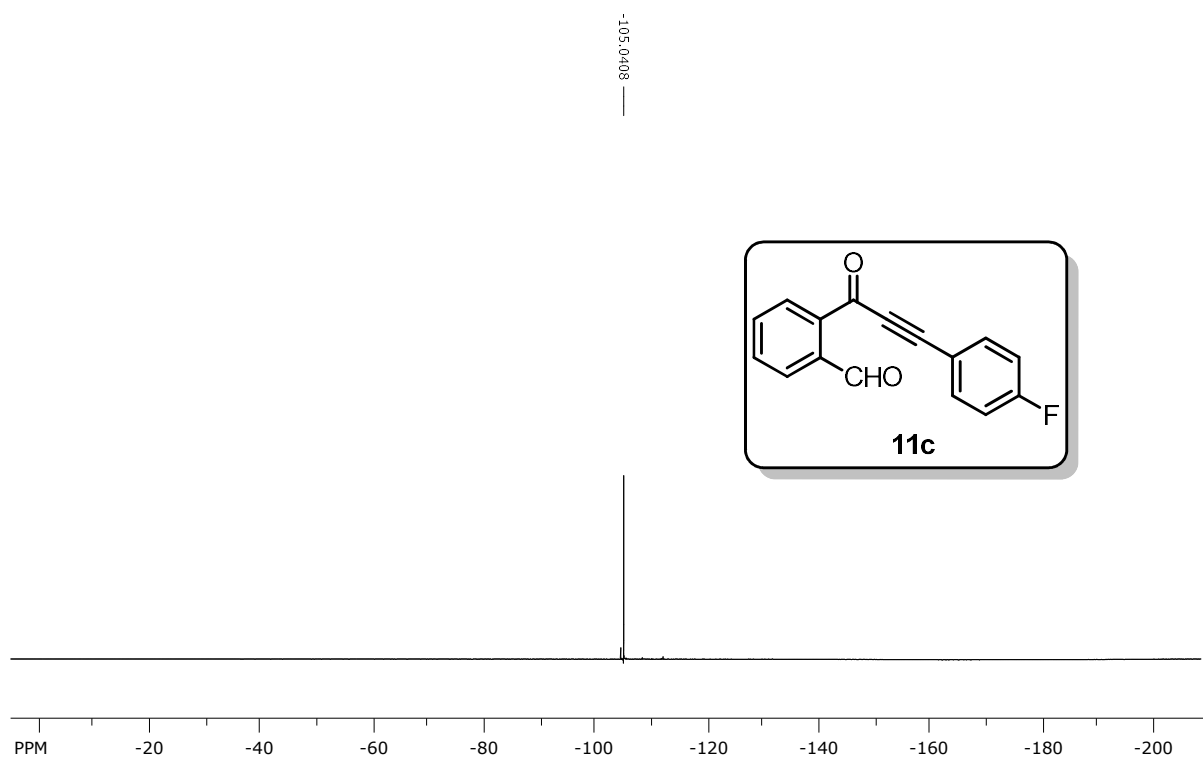
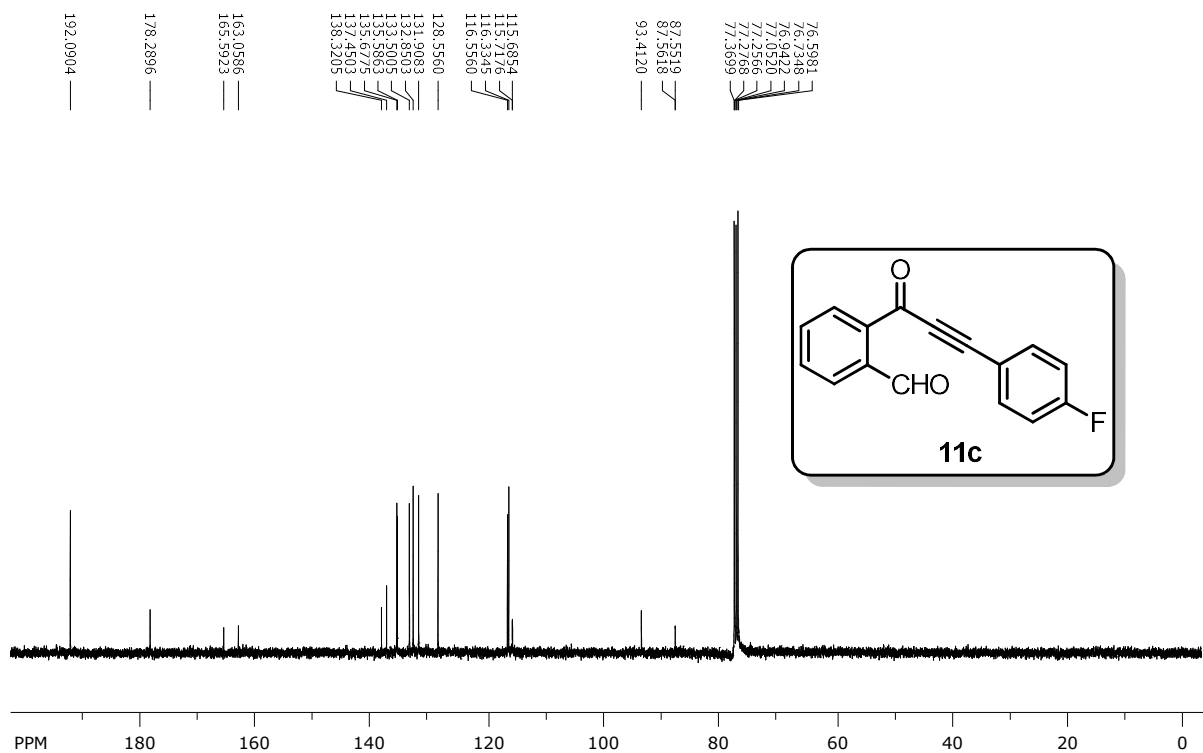


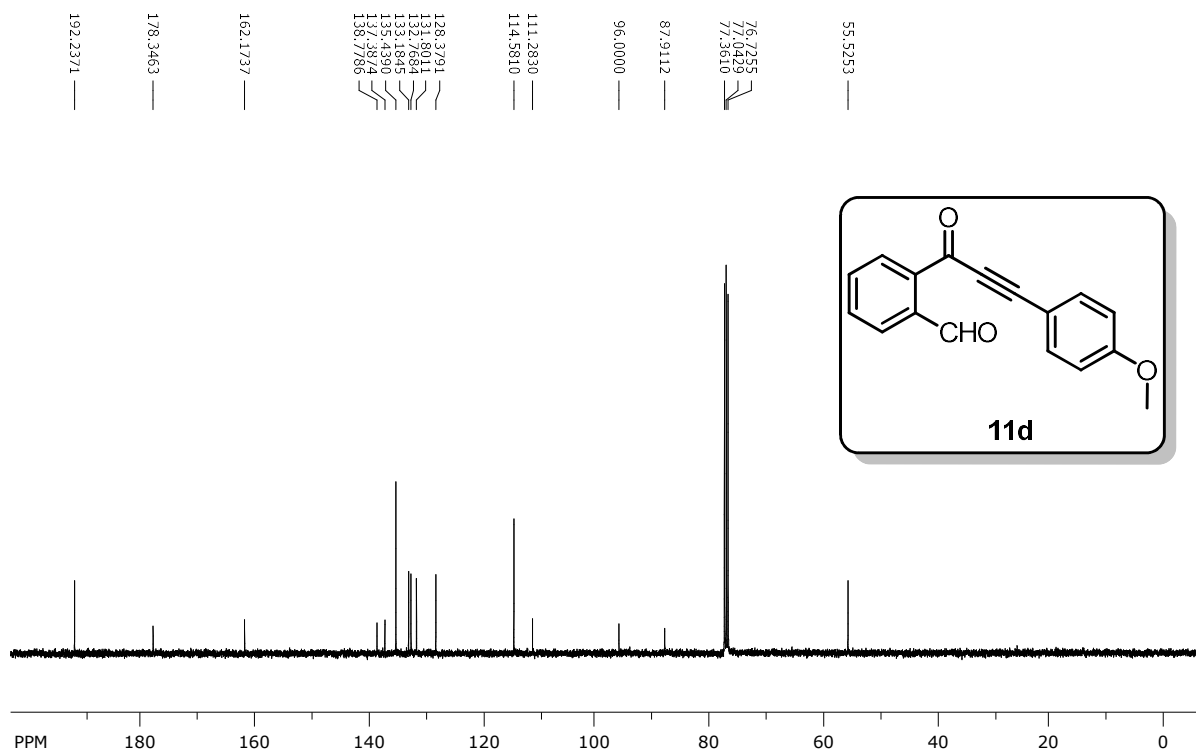
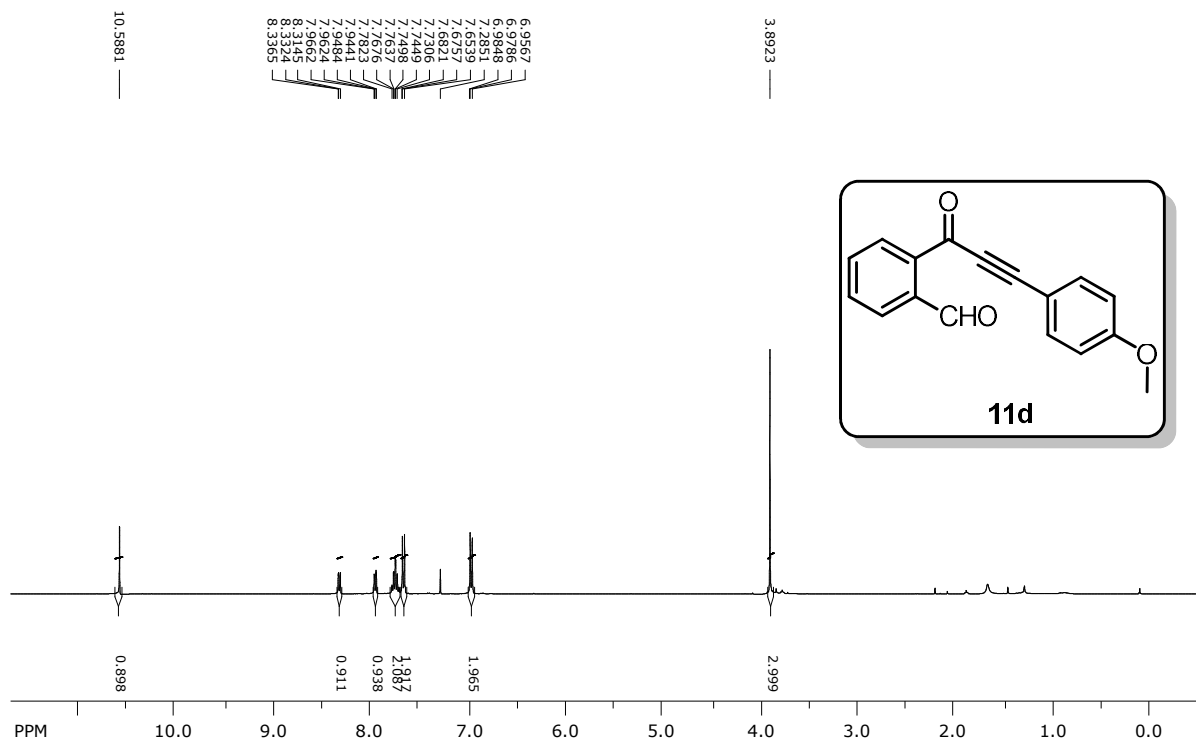
## Copies of $^1\text{H}$ and $^{13}\text{C}$ -NMR spectra of all the new compounds reported in this study

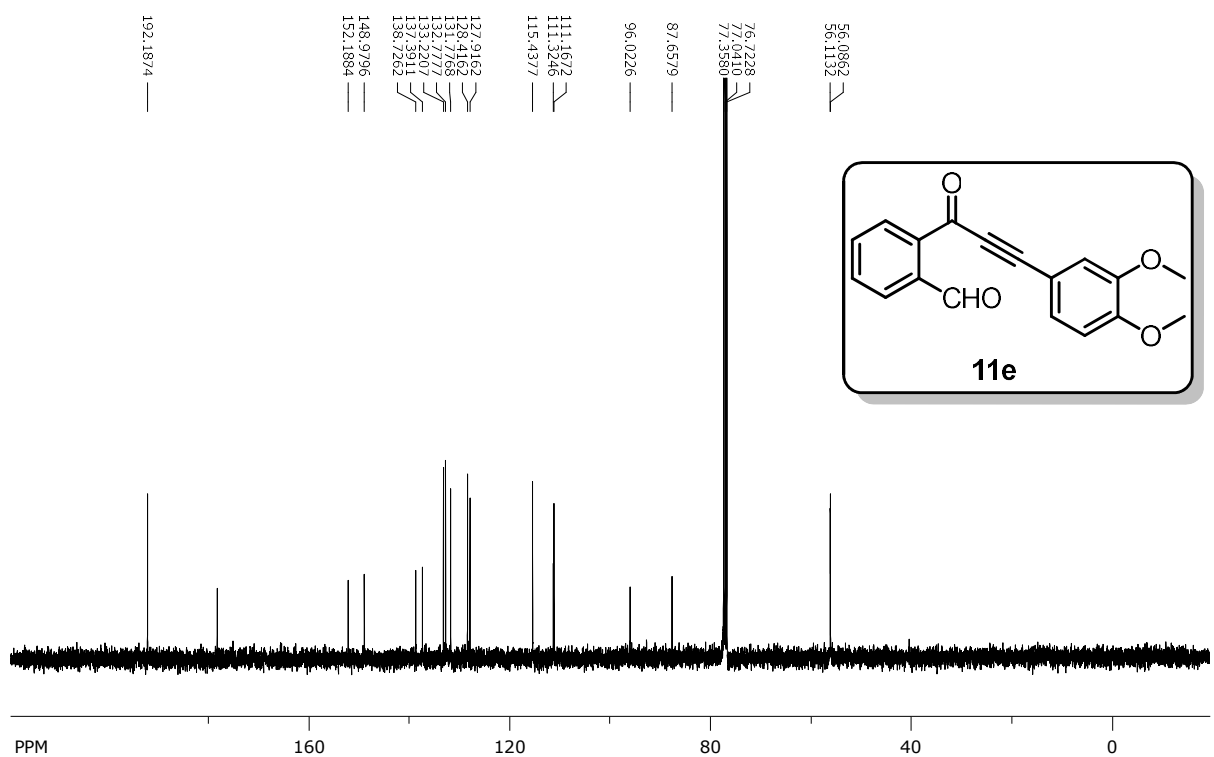
(Note: In general, in a  $^1\text{H}$  NMR spectrum recorded in  $\text{CDCl}_3$  and  $\text{DMSO}-d_6$ , a peak at around  $\delta$  1.6 and 3.33 refers to moisture respectively in the solvent/sample and a peak at about  $\delta$  1.2 refers to oil/grease present in the sample. In a  $^{13}\text{C}$  NMR spectrum recorded in  $\text{CDCl}_3$ , a peak at about  $\delta$  29.7 usually represents oil/grease)

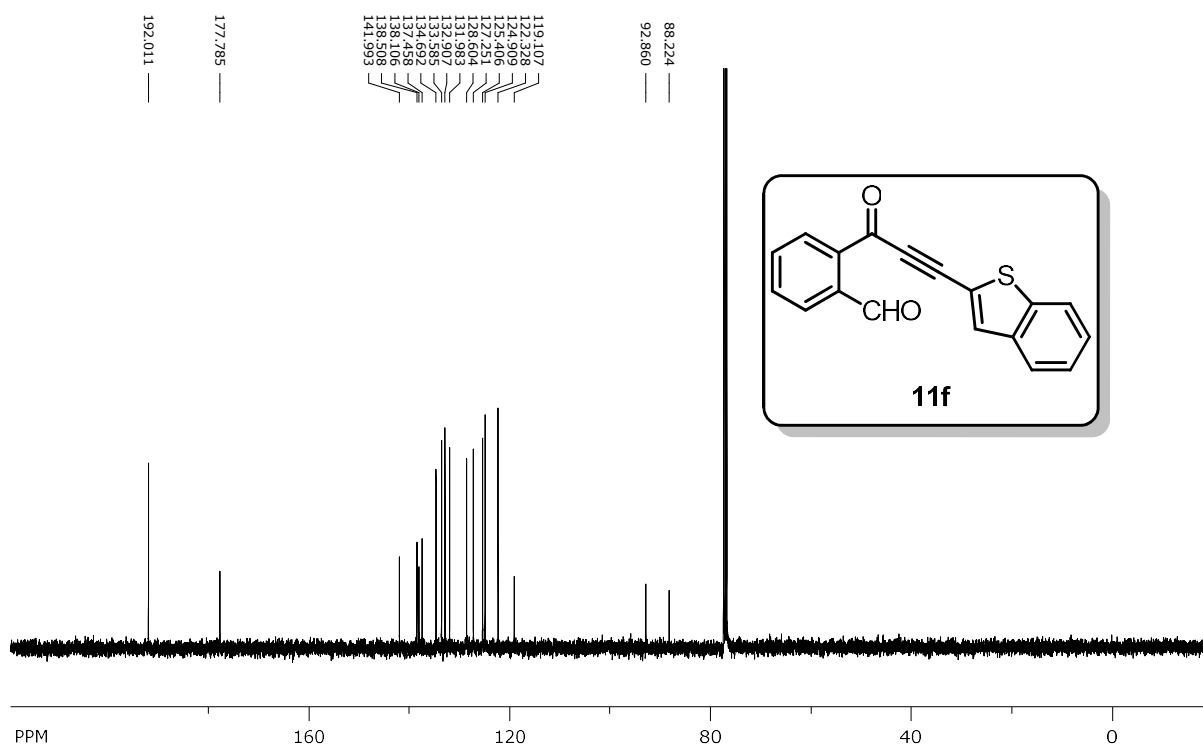
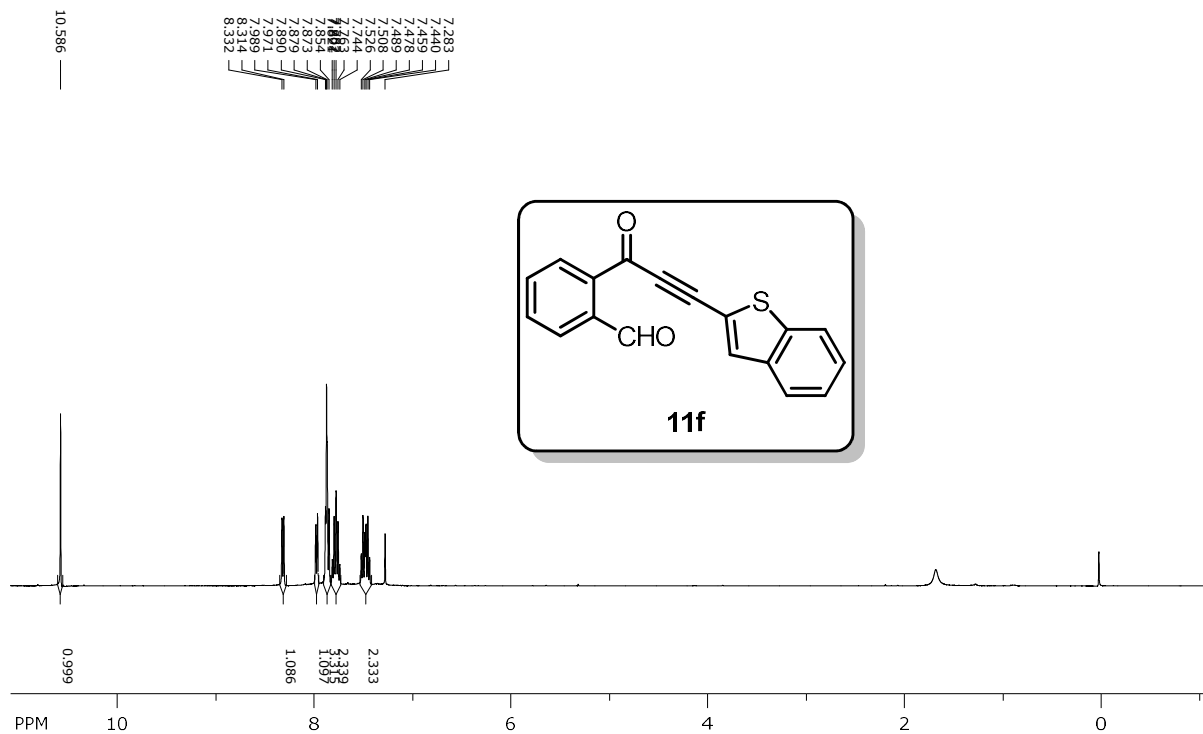


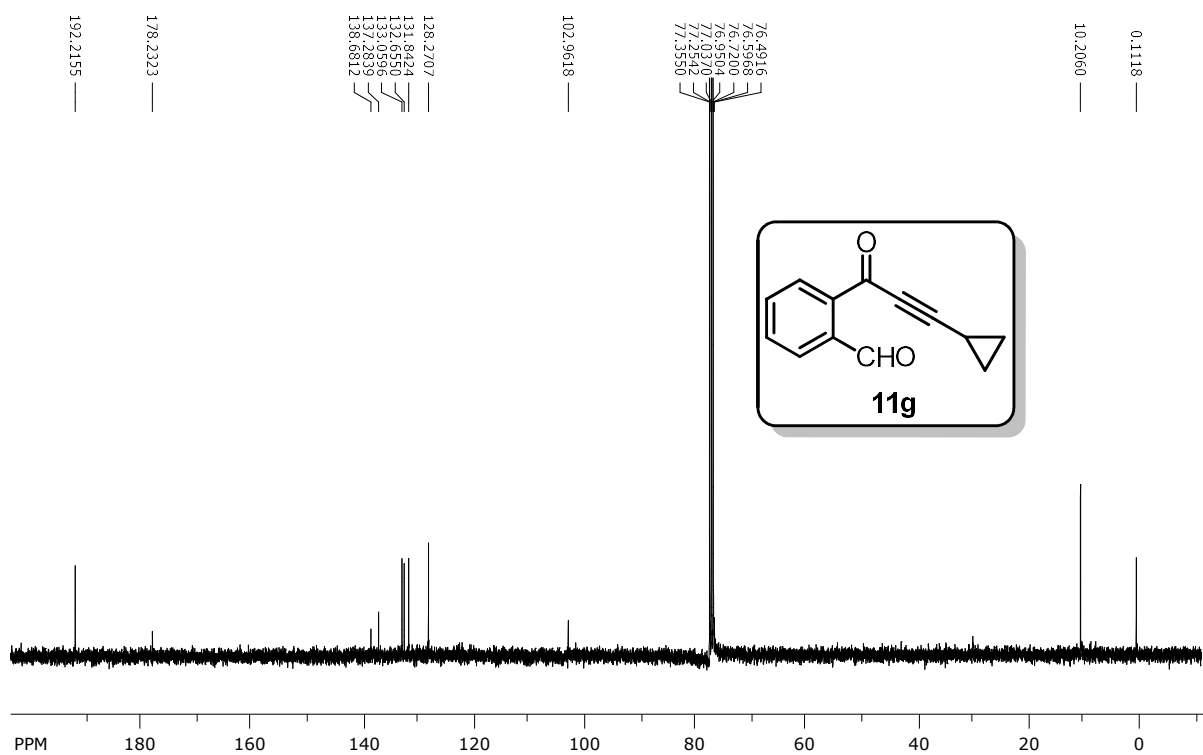
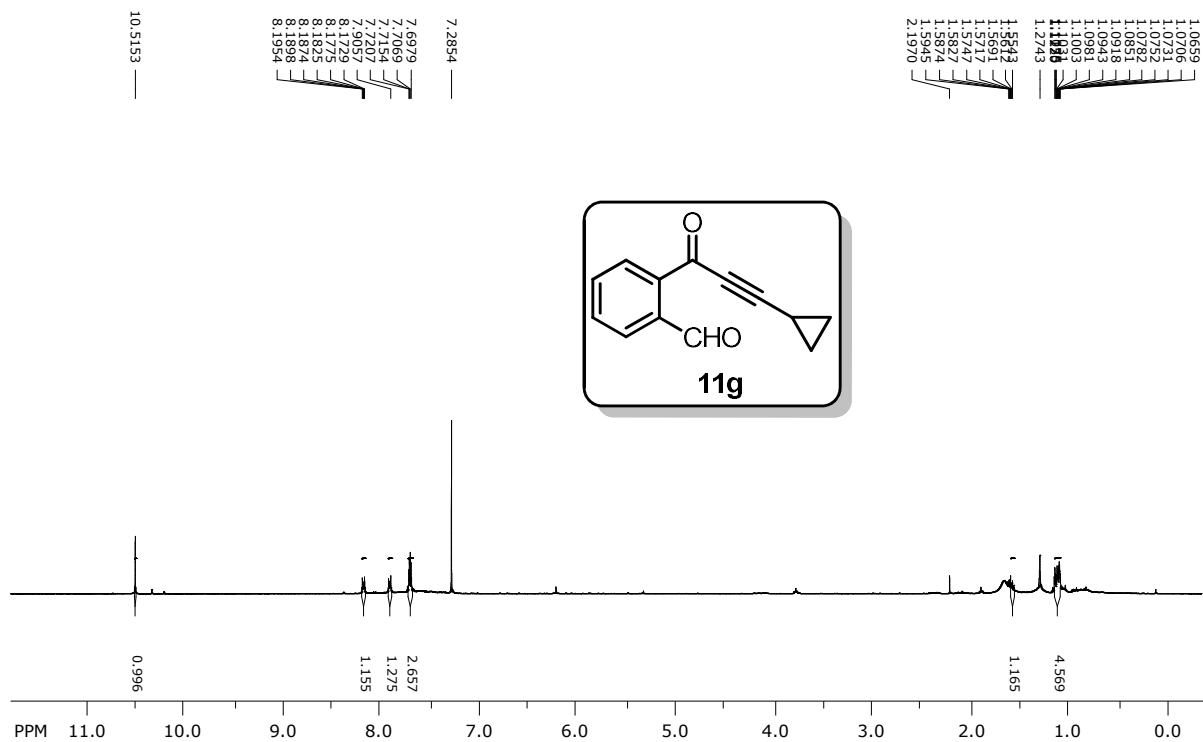






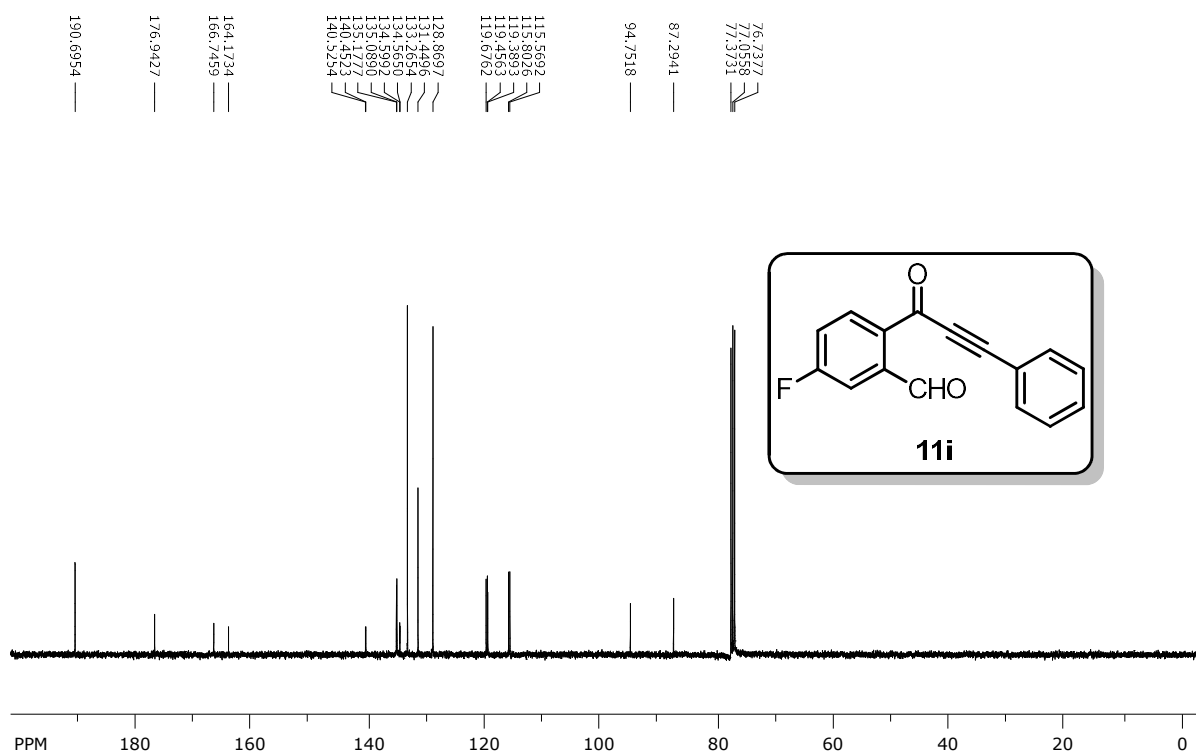
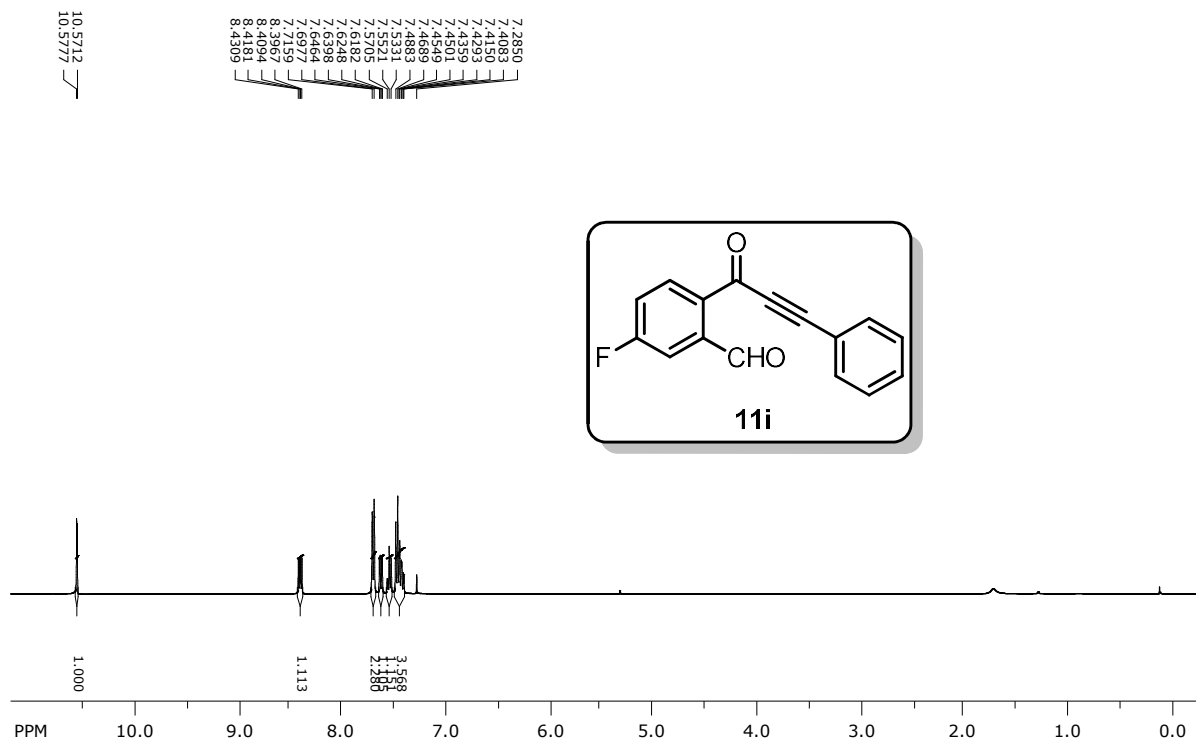


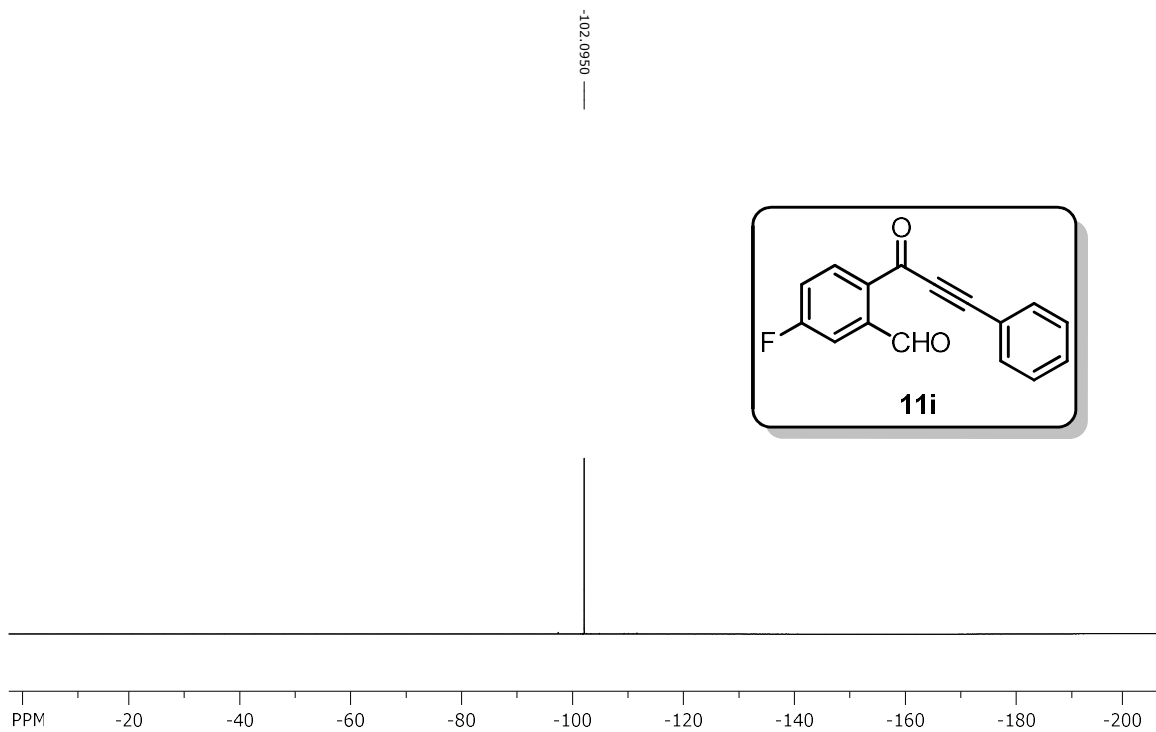


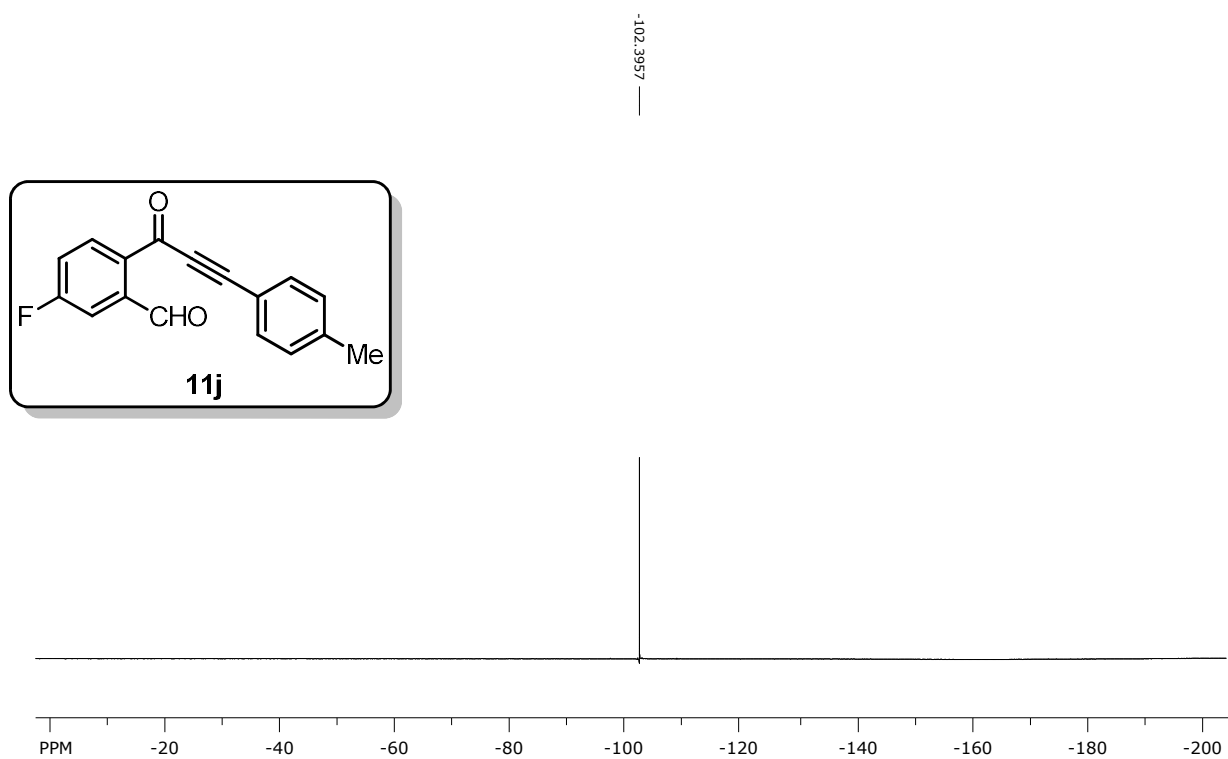
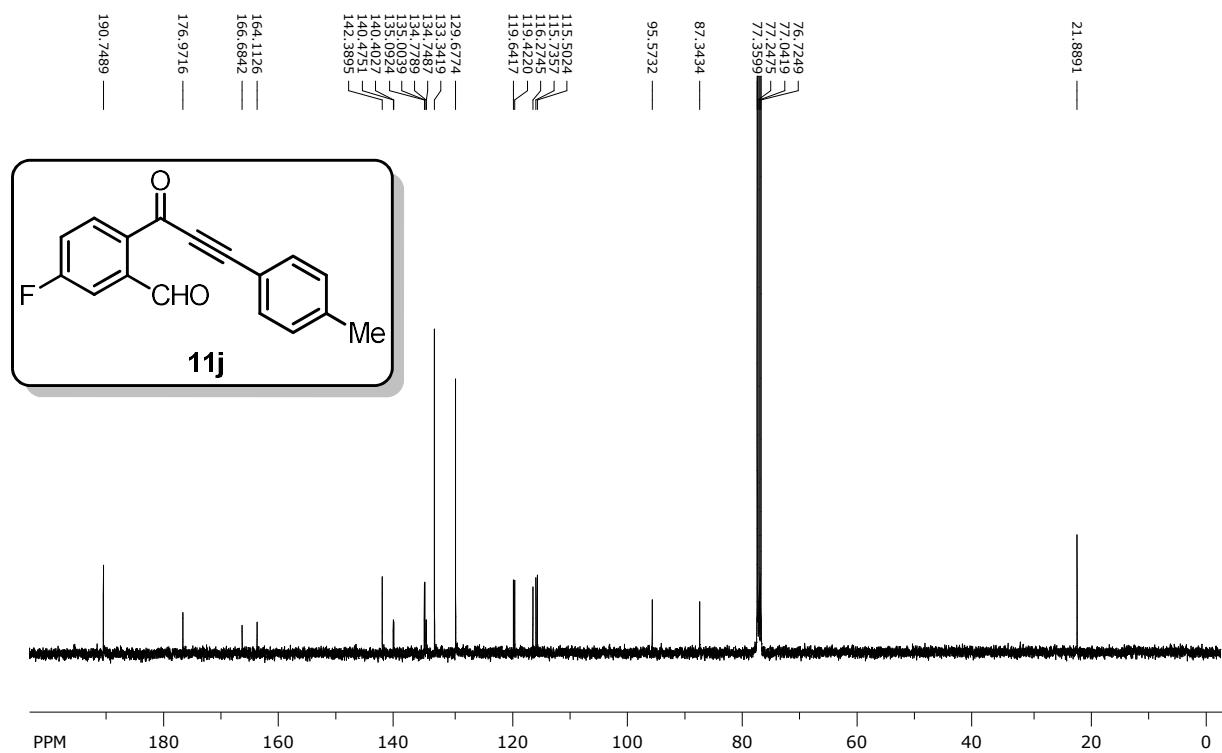


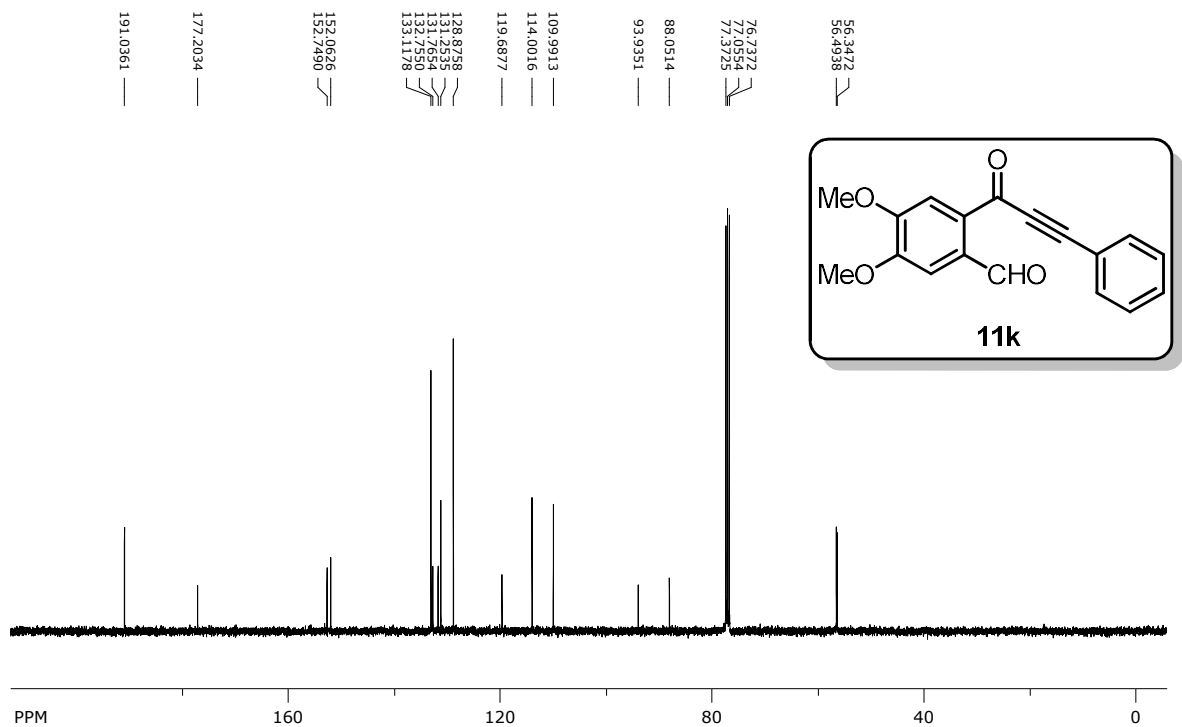
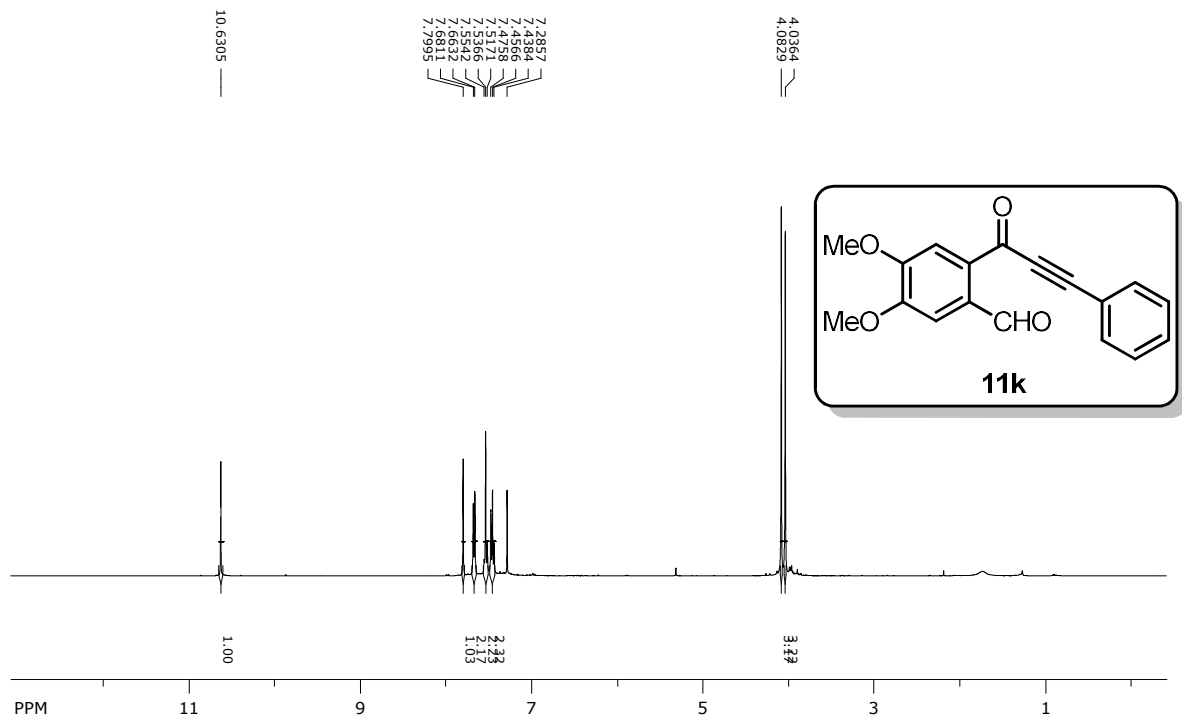


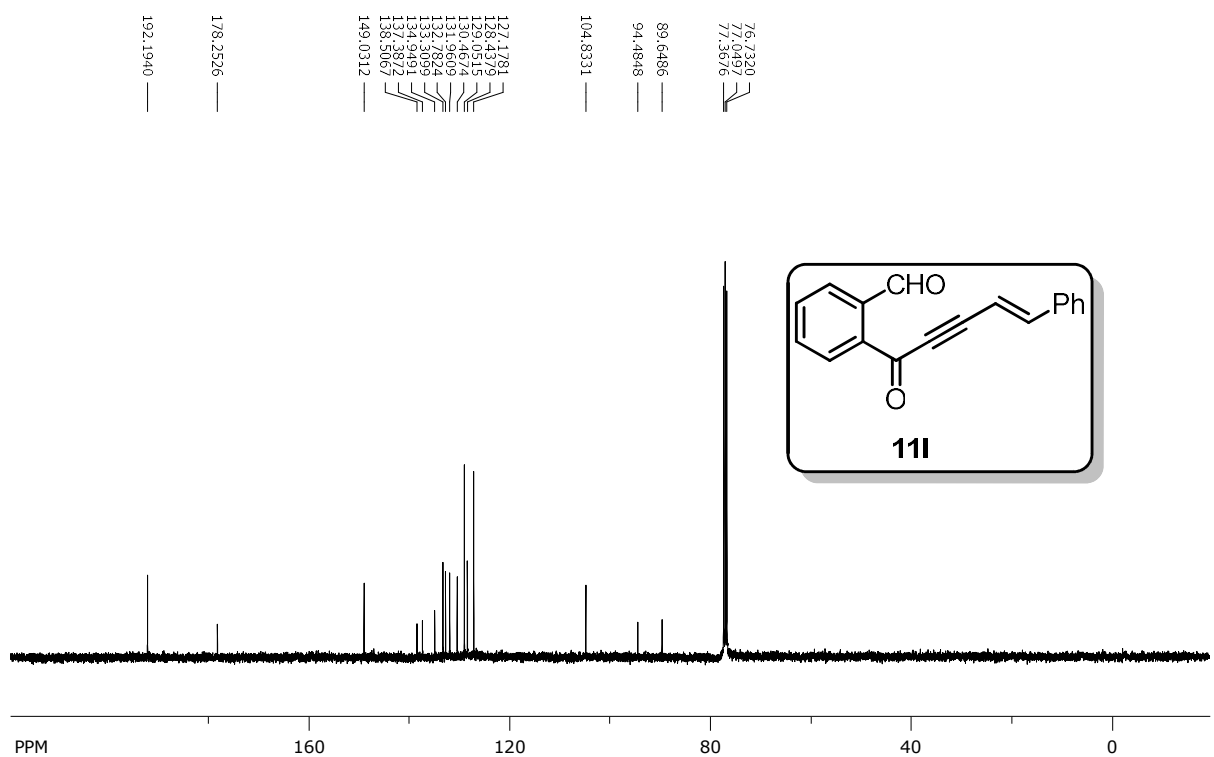
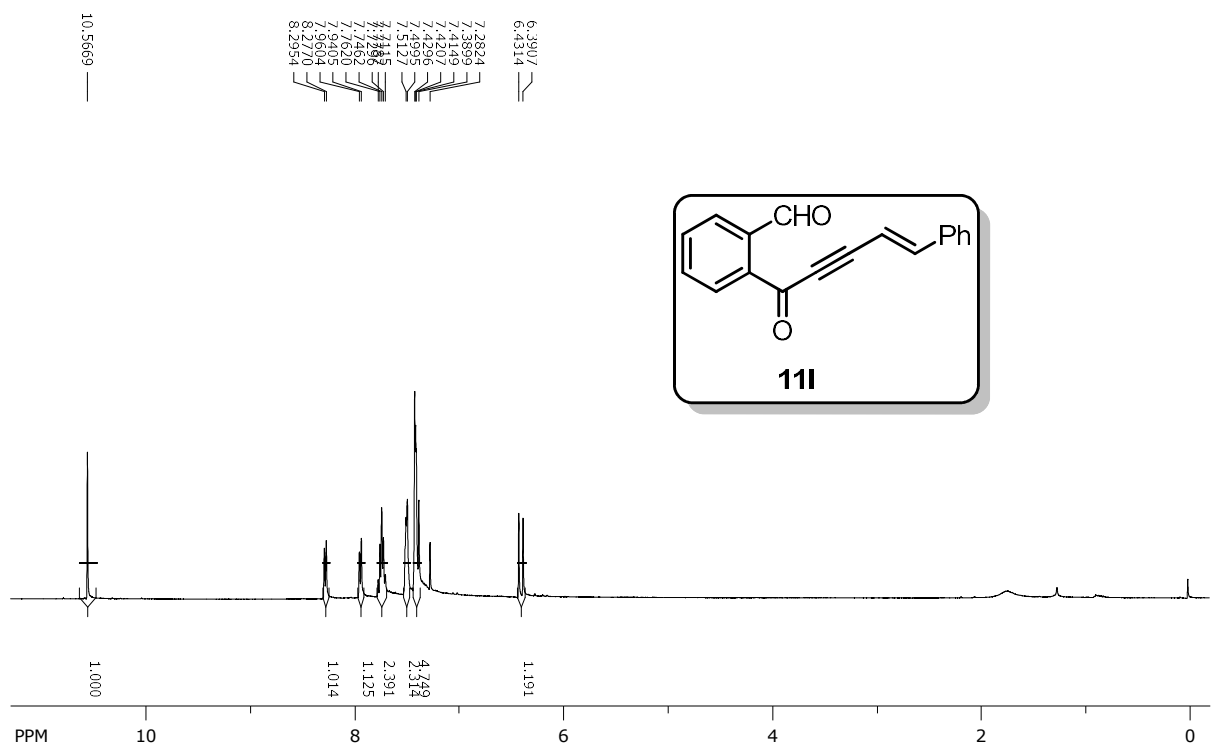


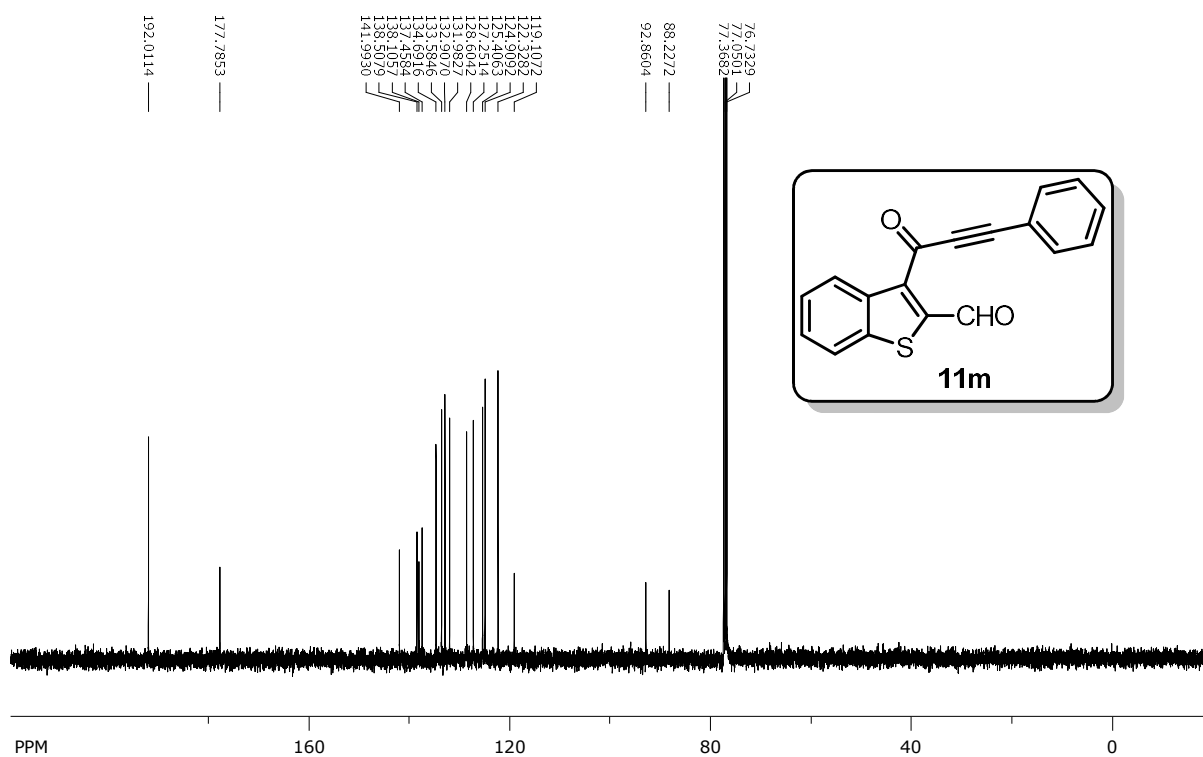
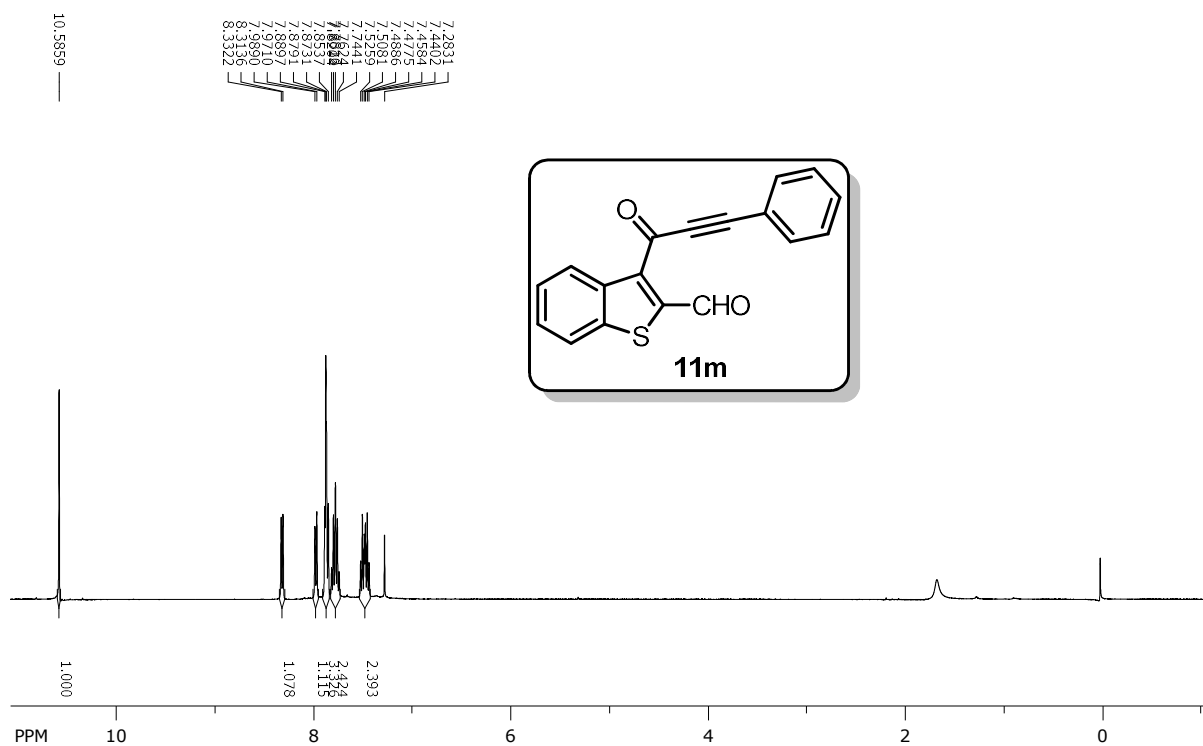


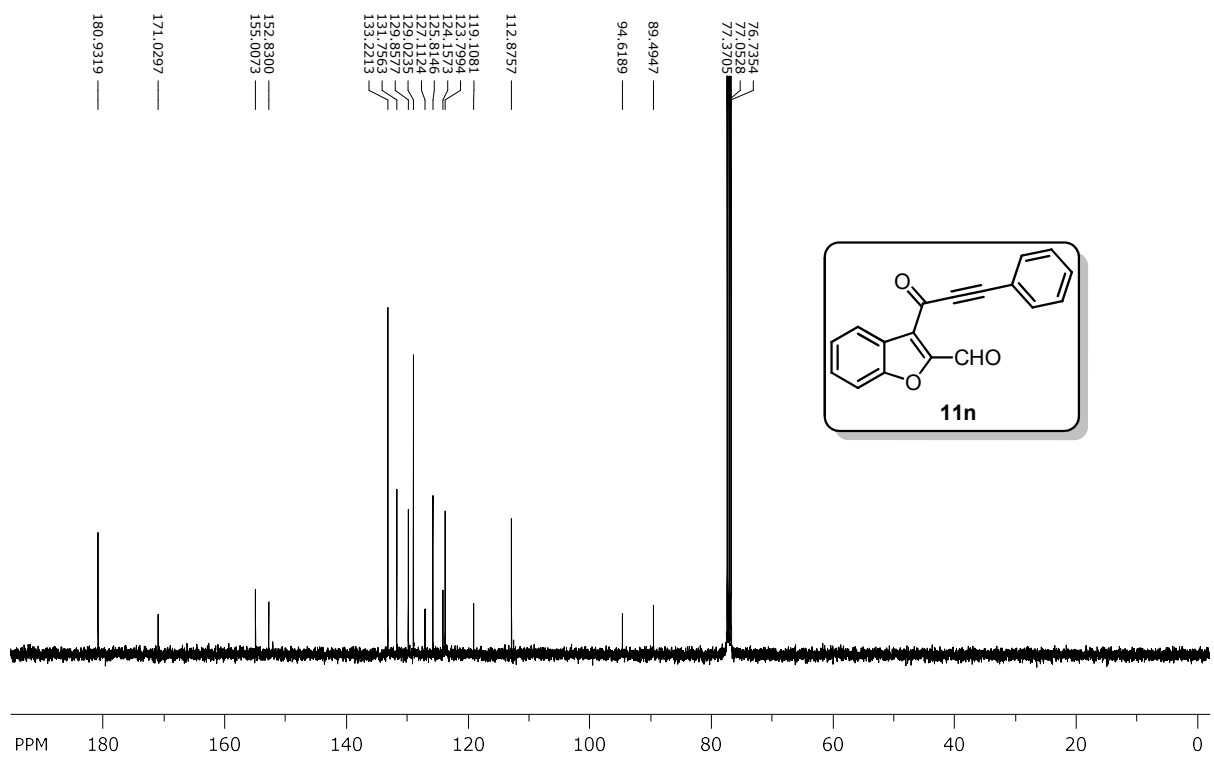
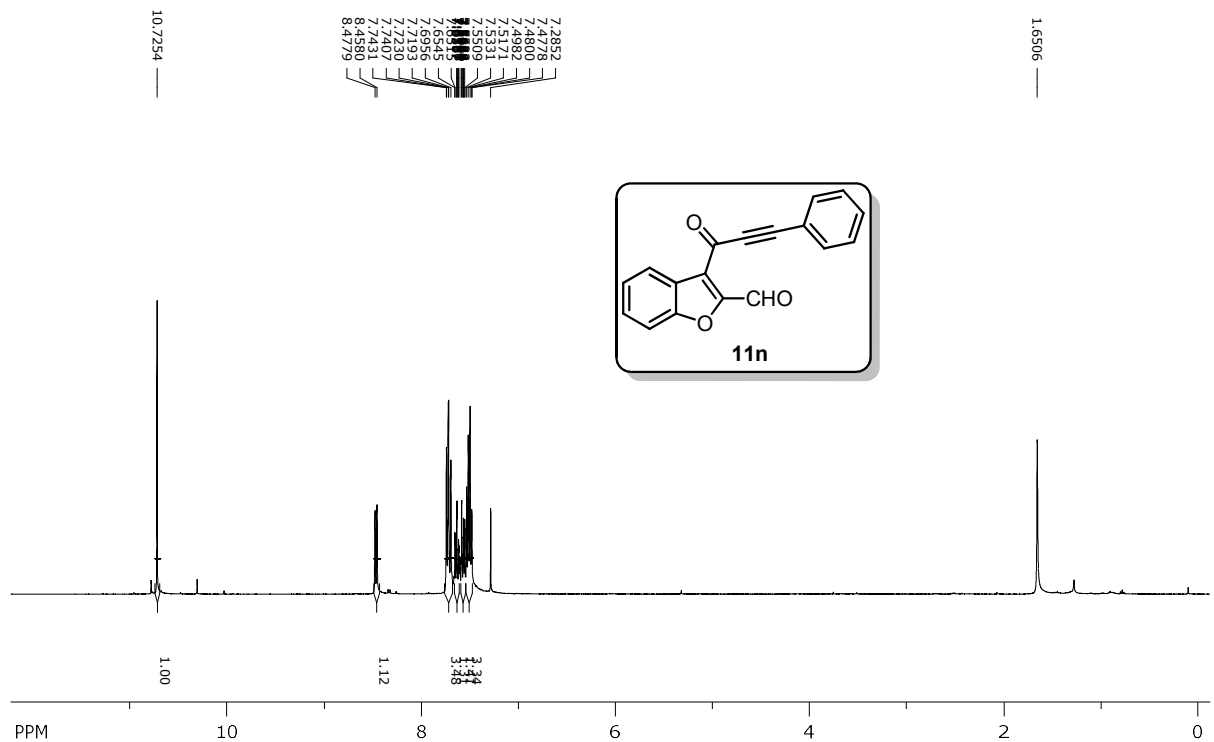


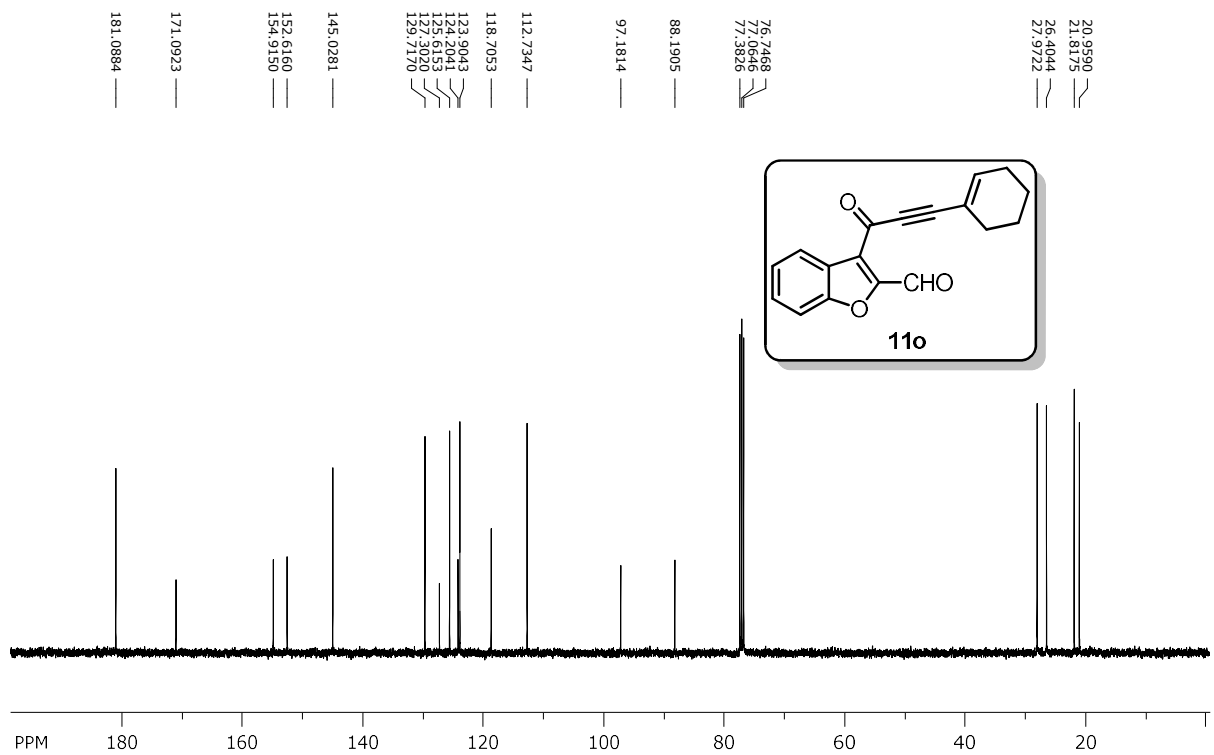
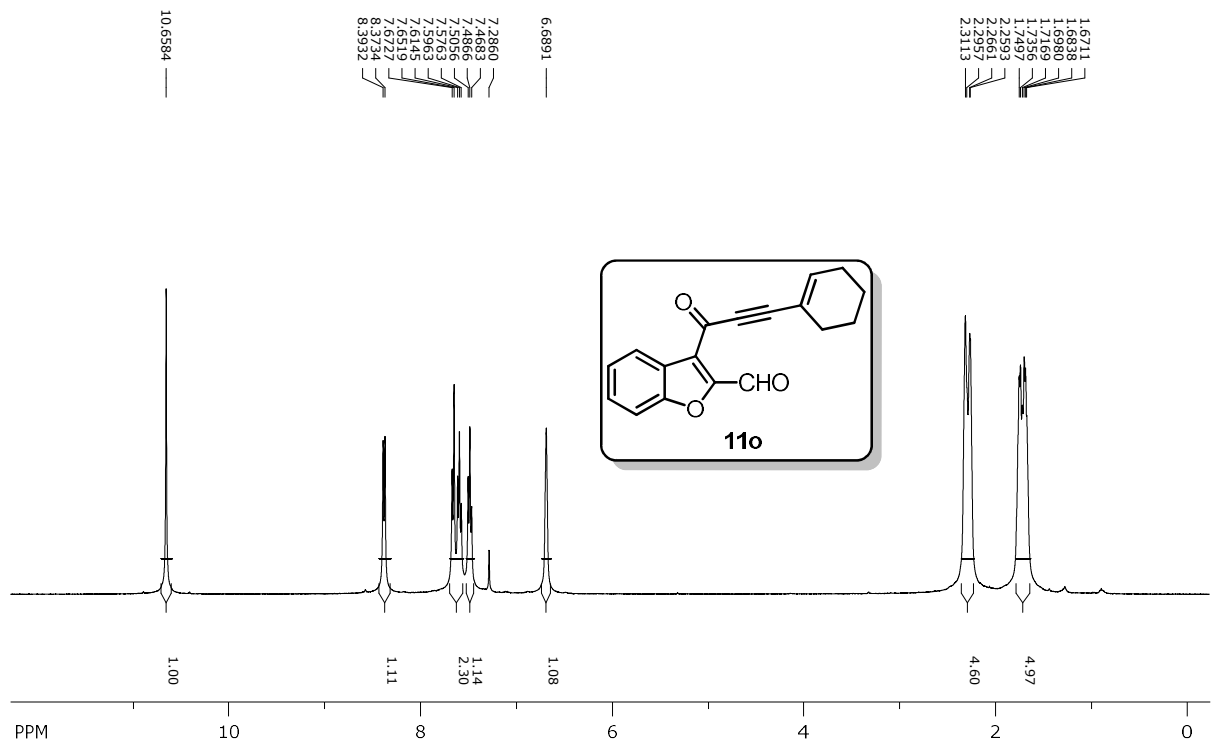




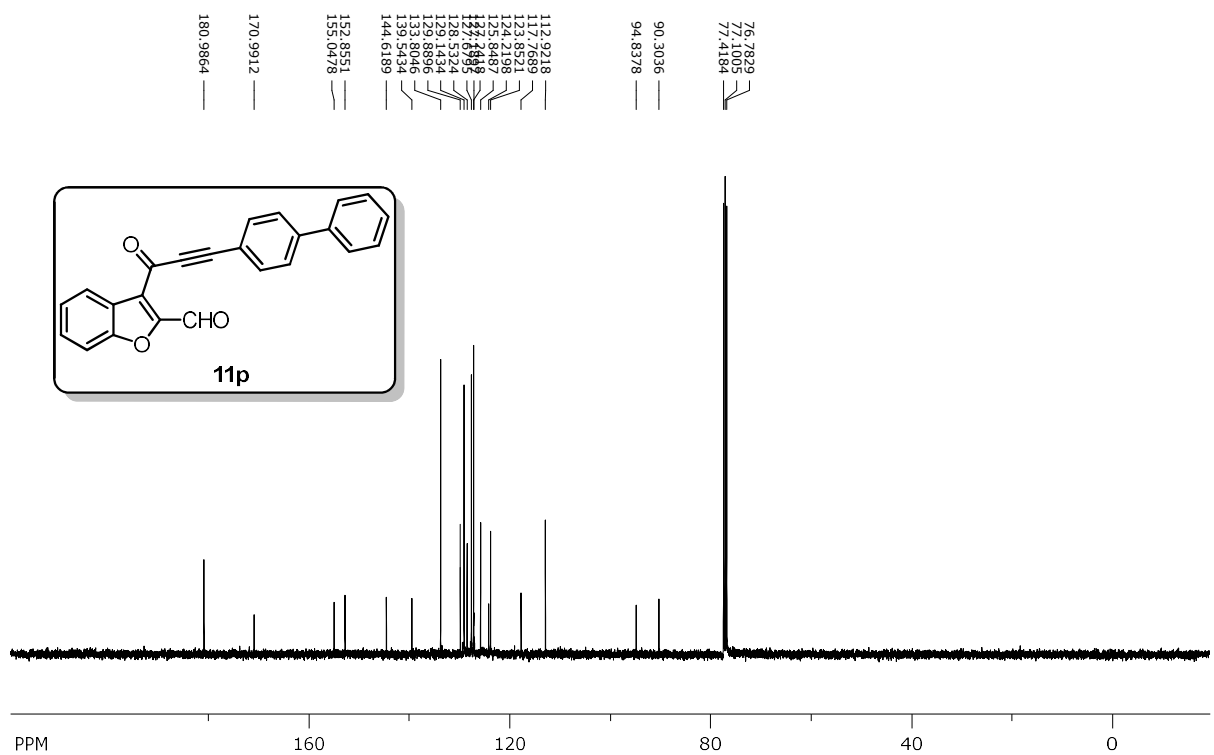
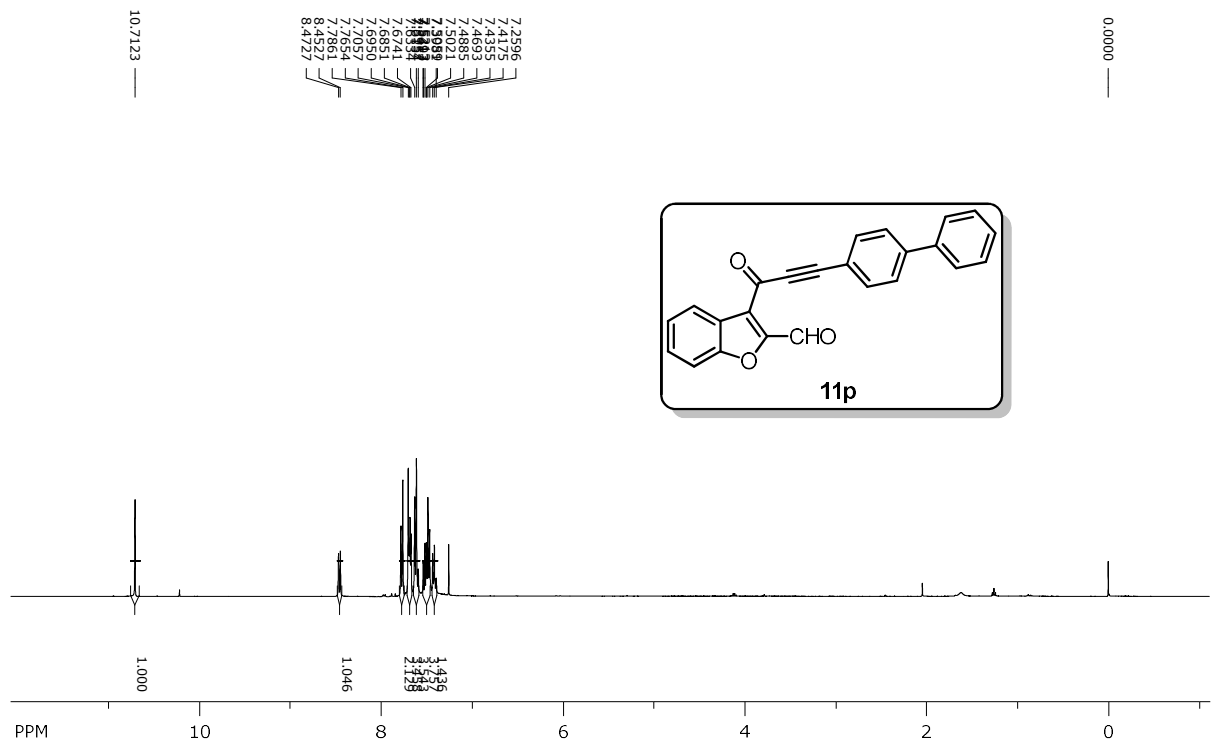




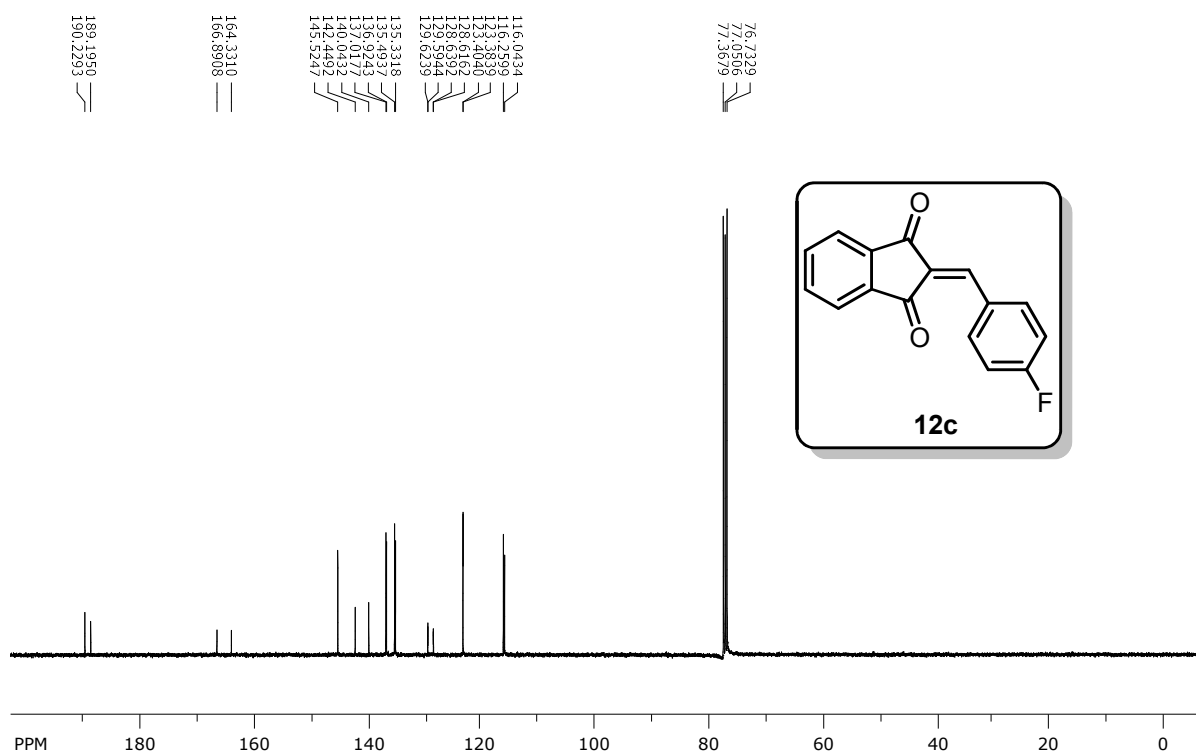
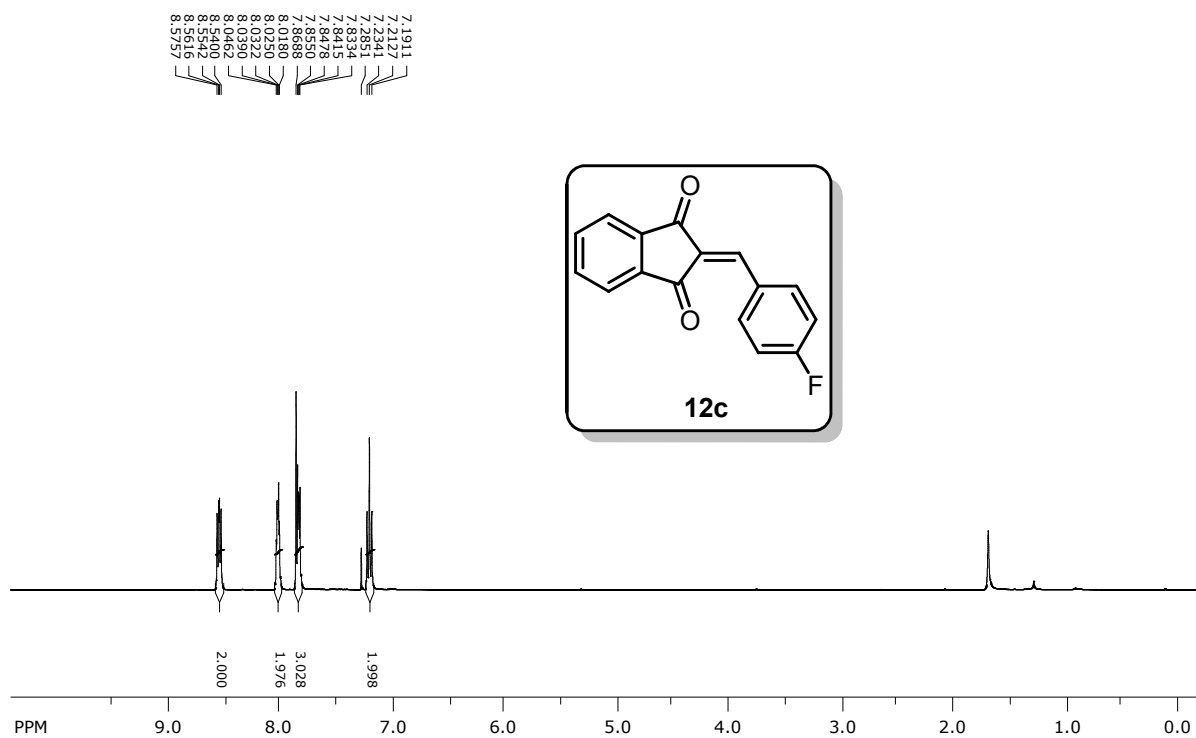


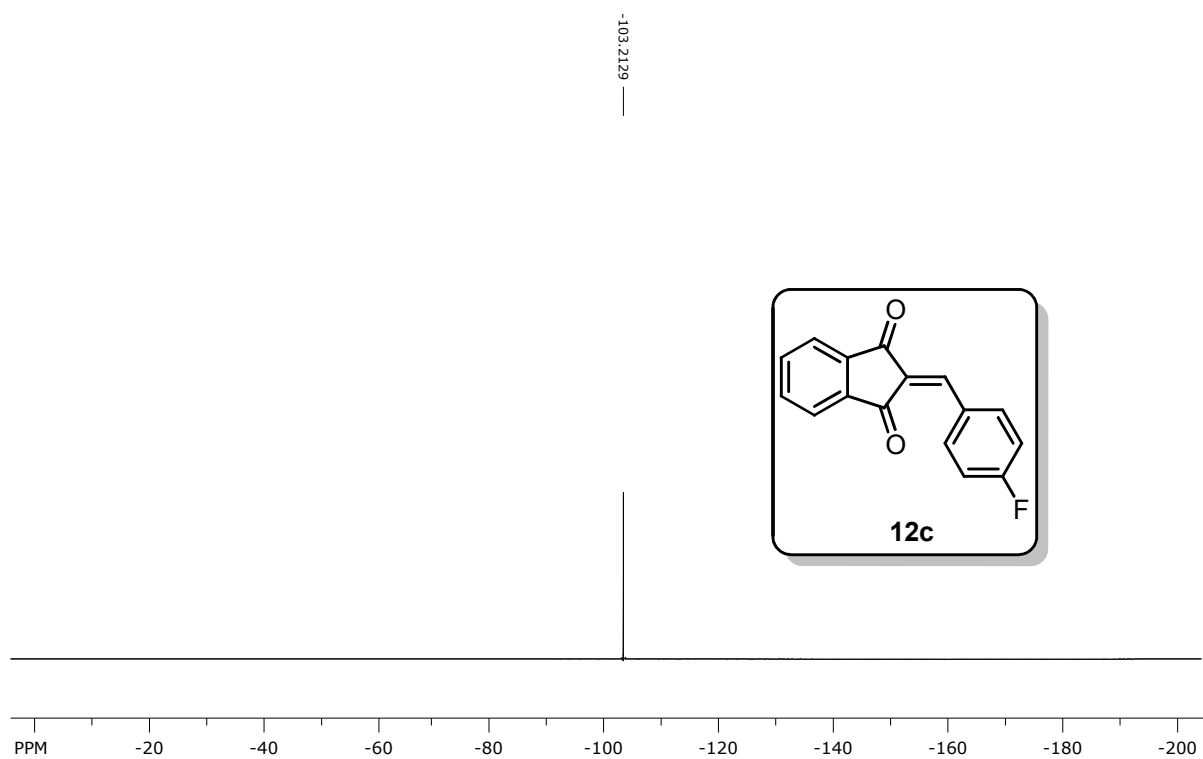


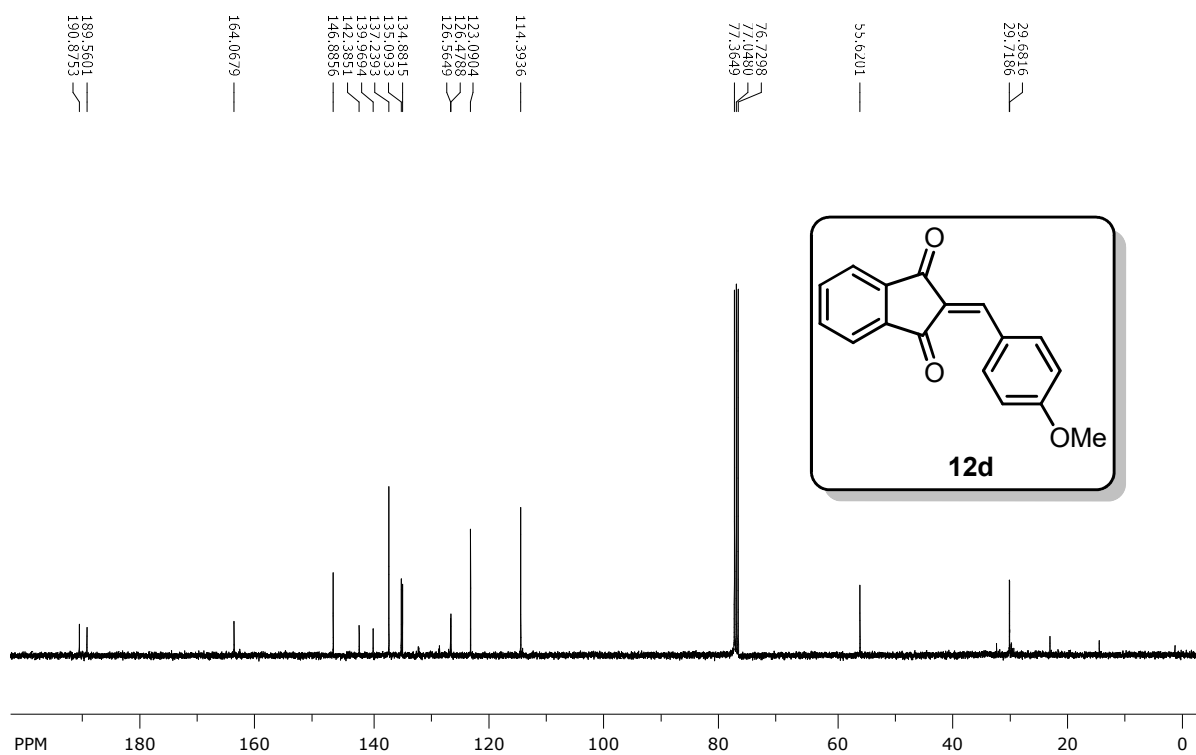
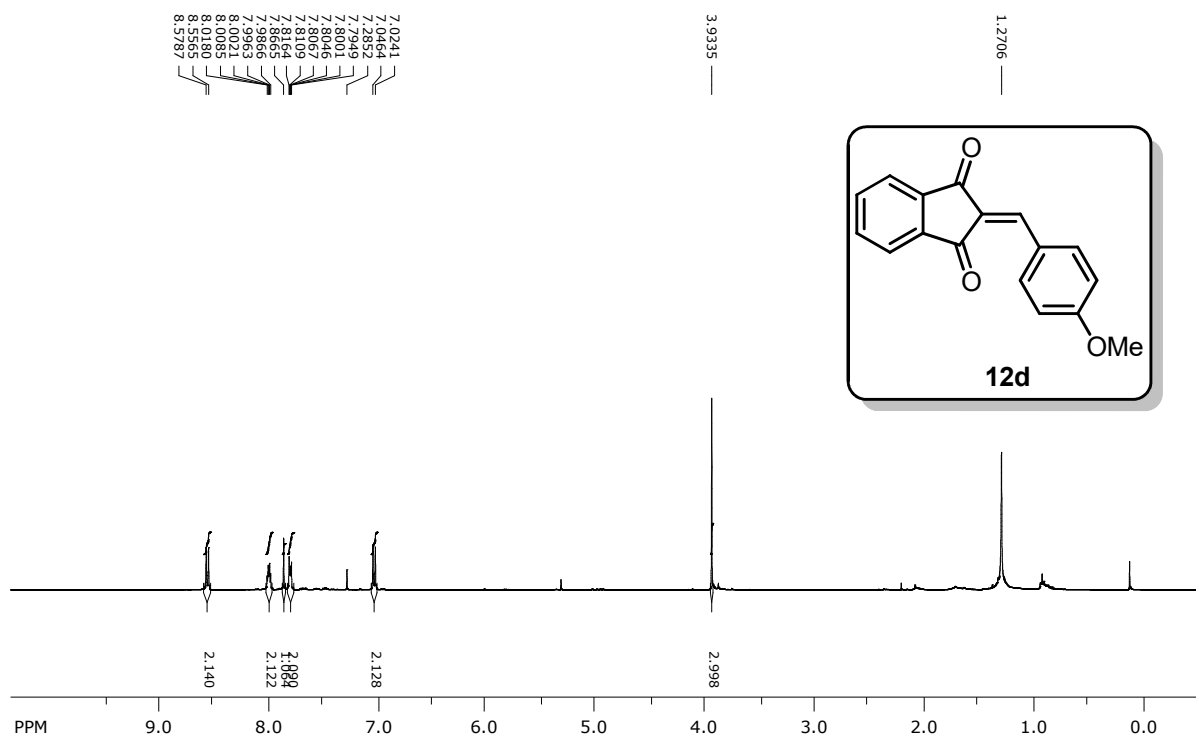


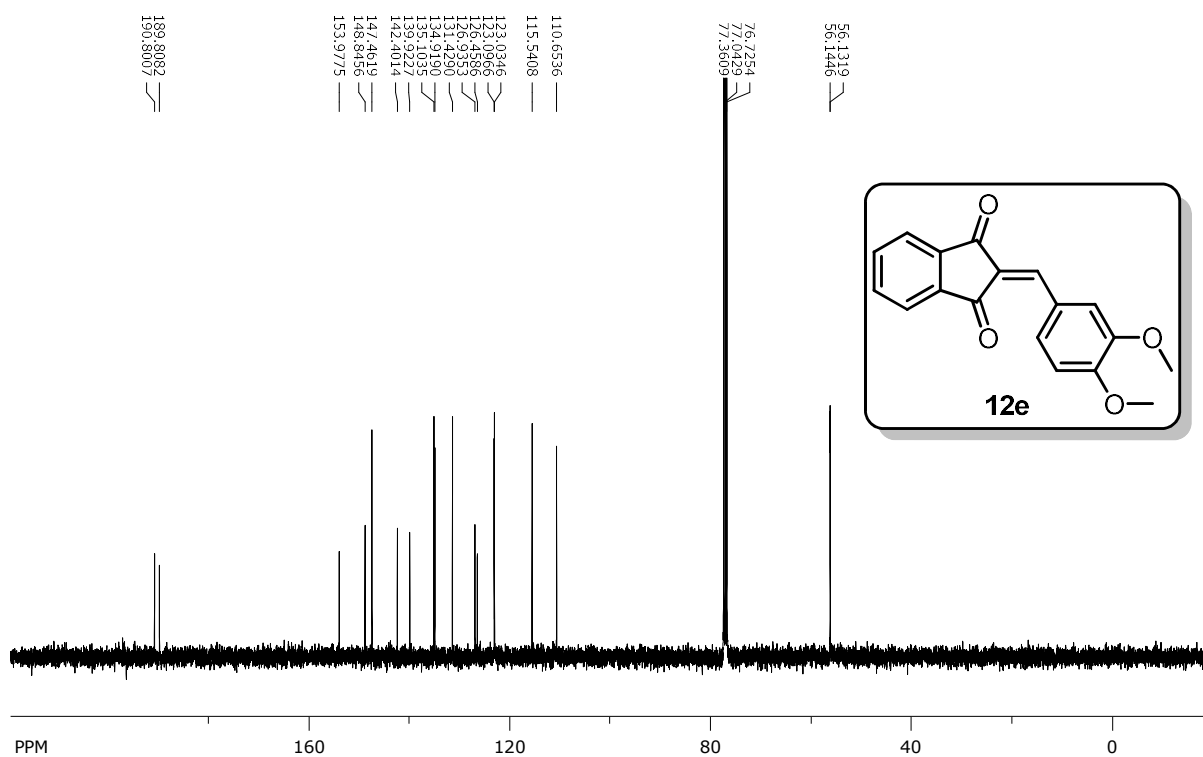
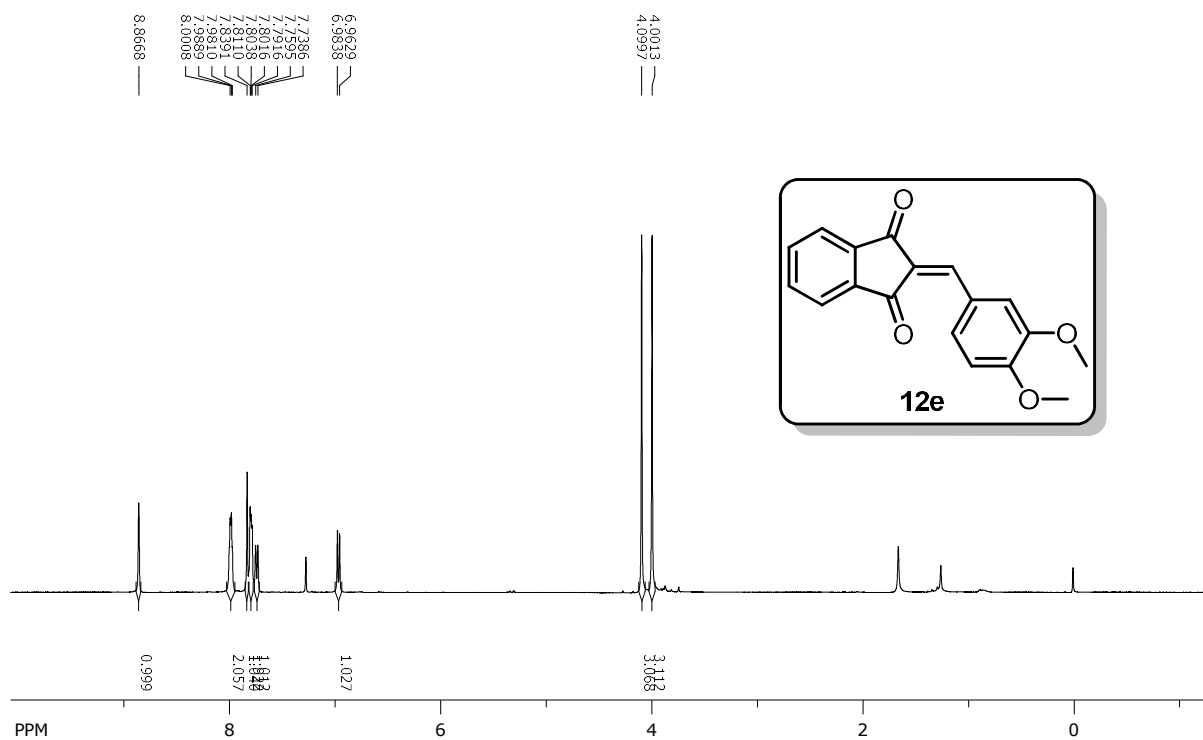


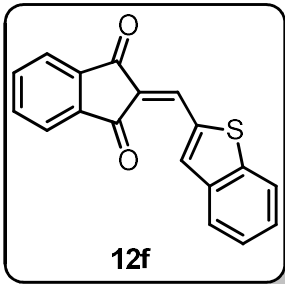
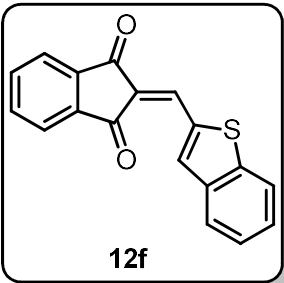






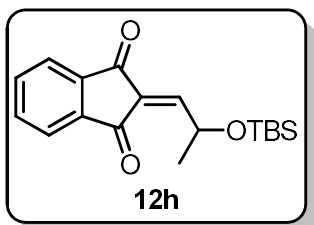
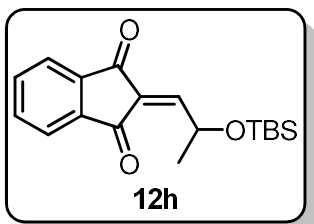


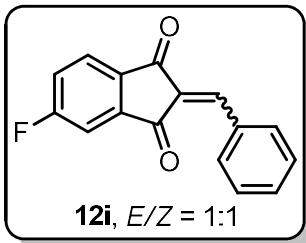
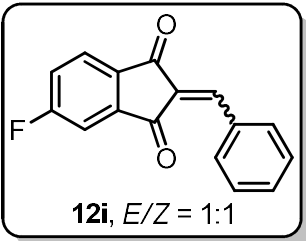


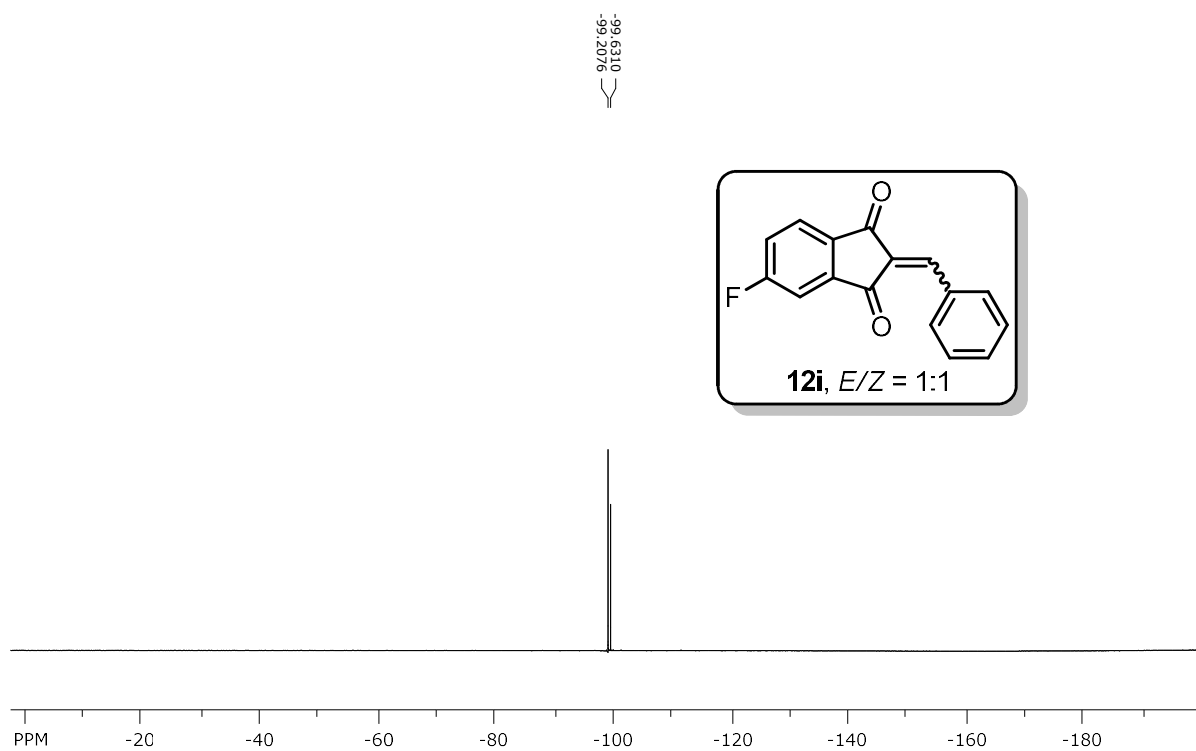


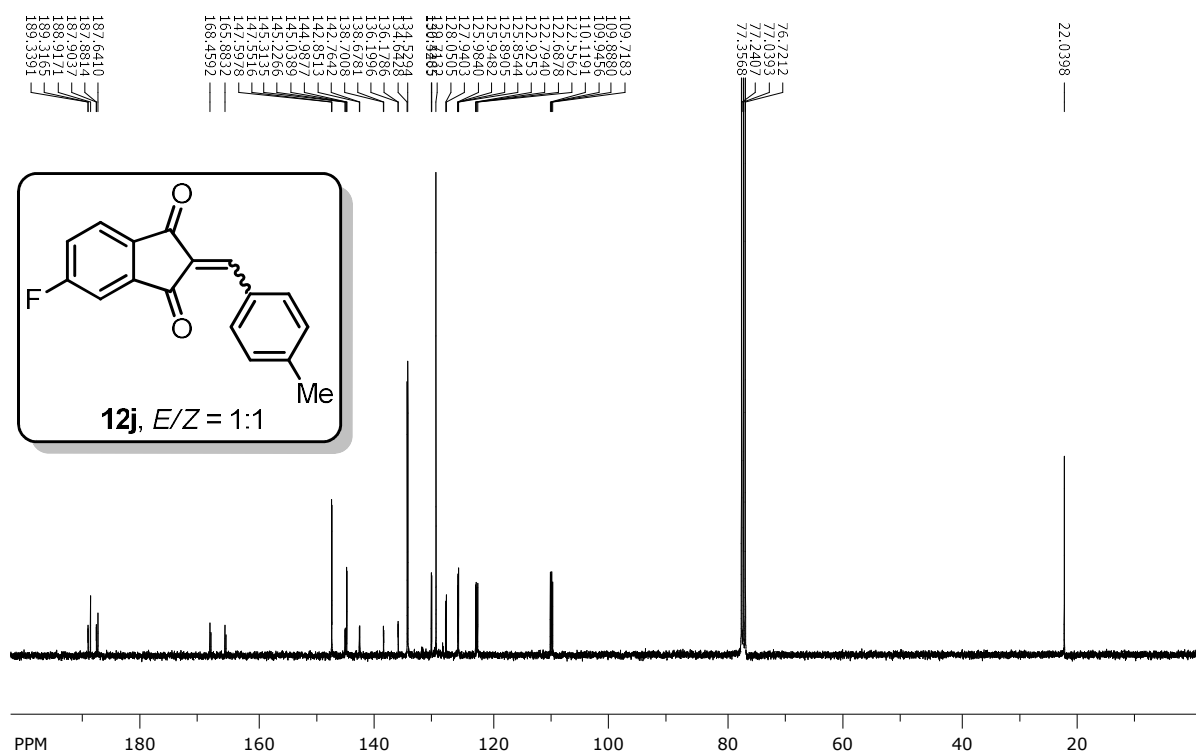
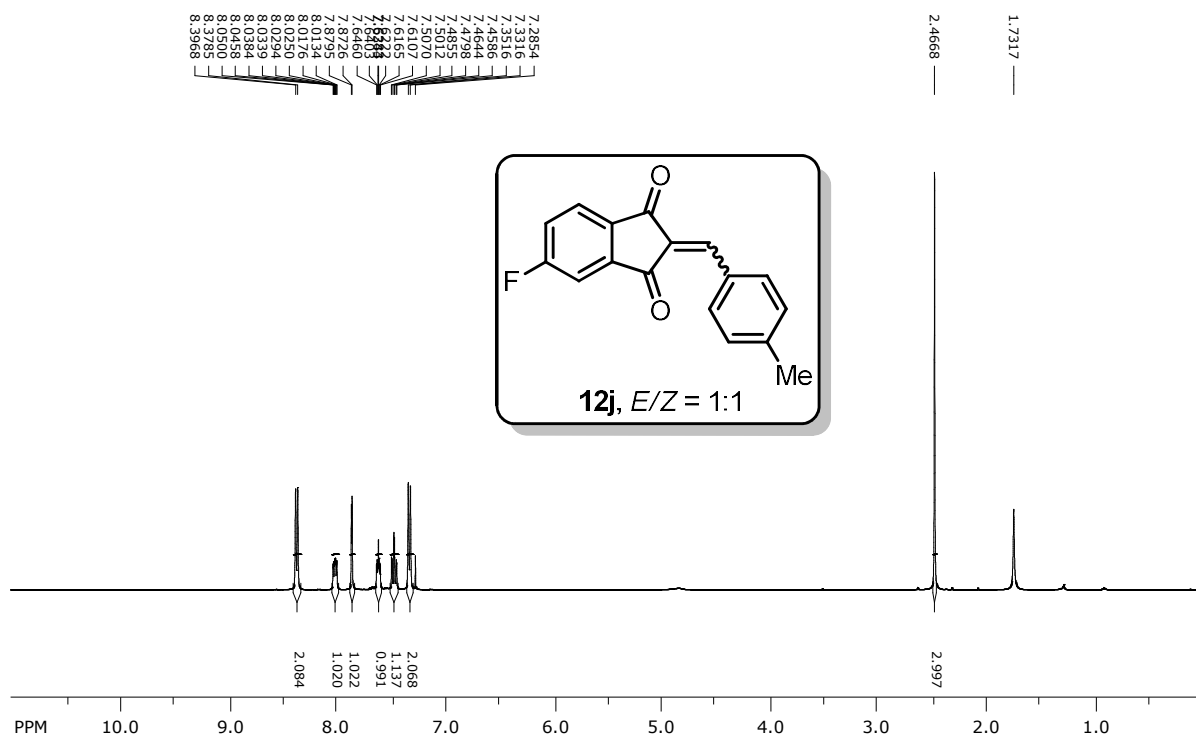


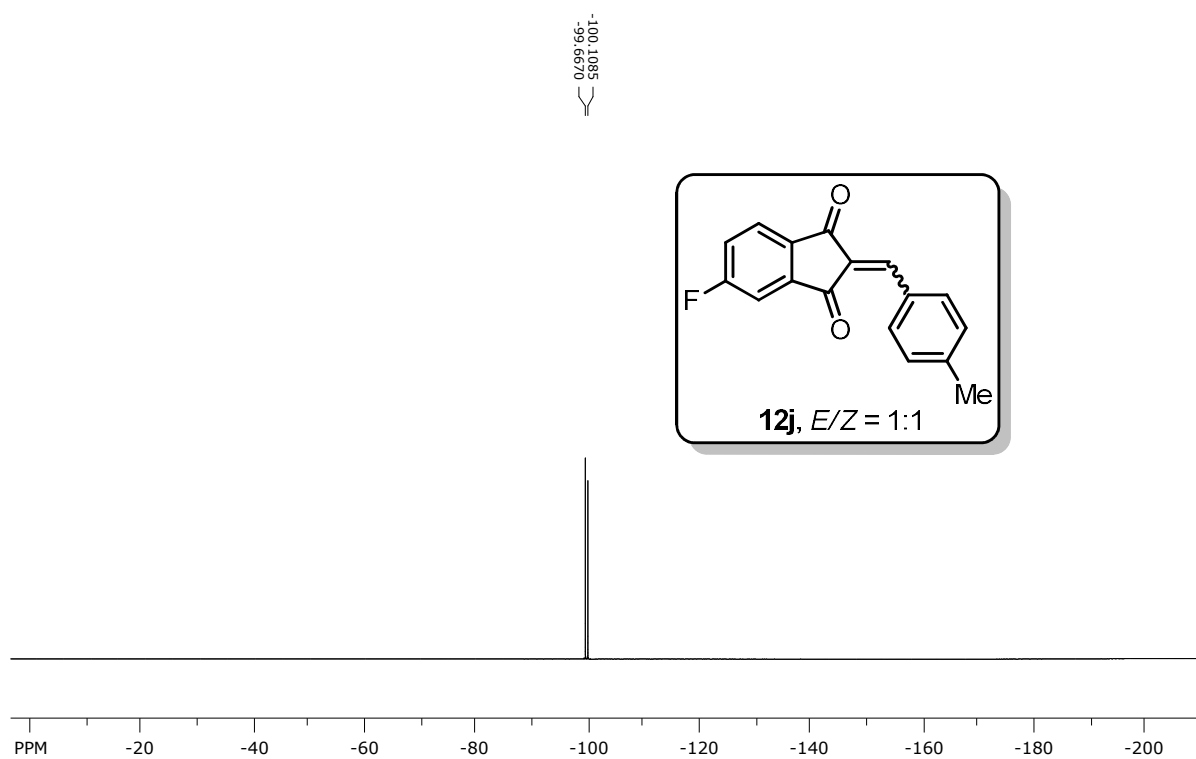


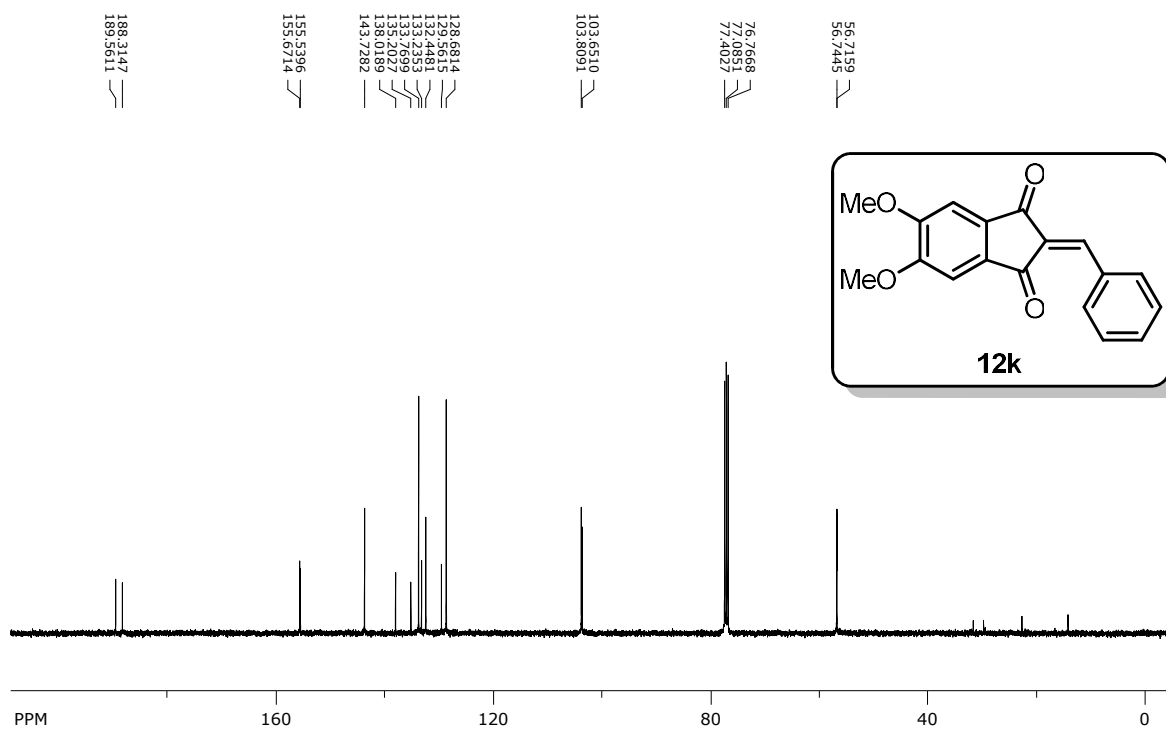
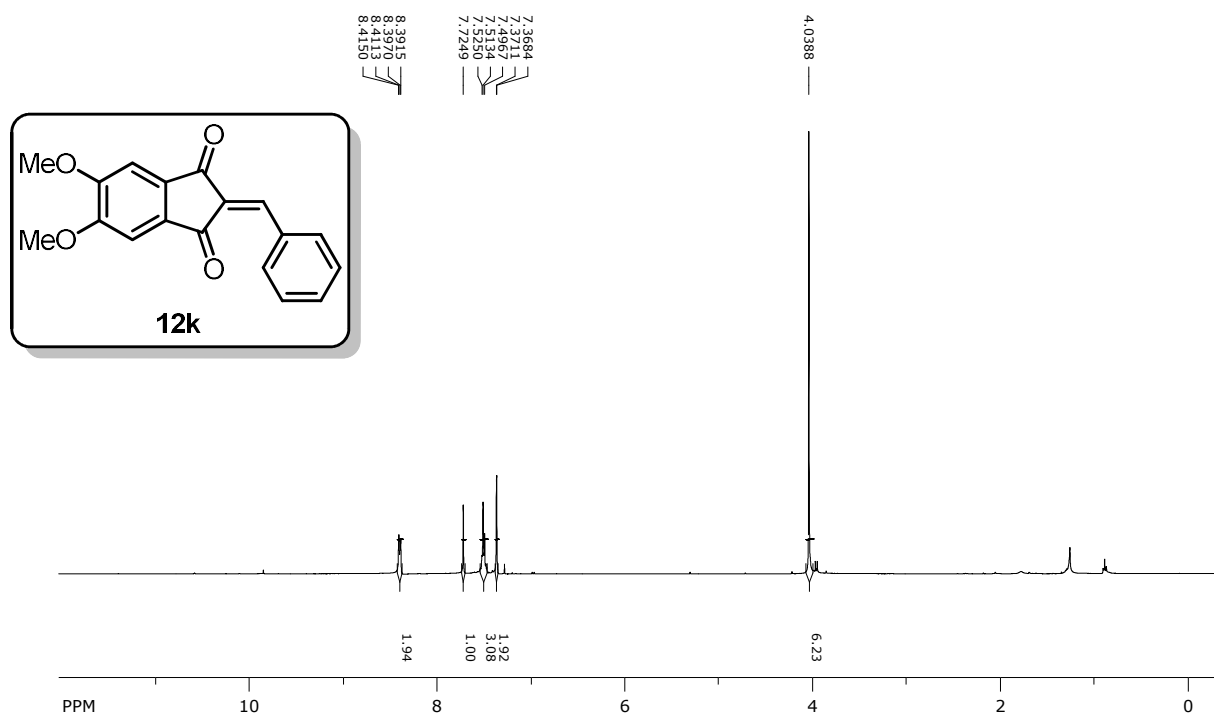


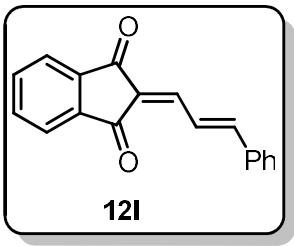
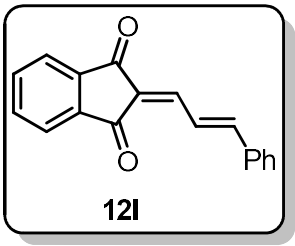


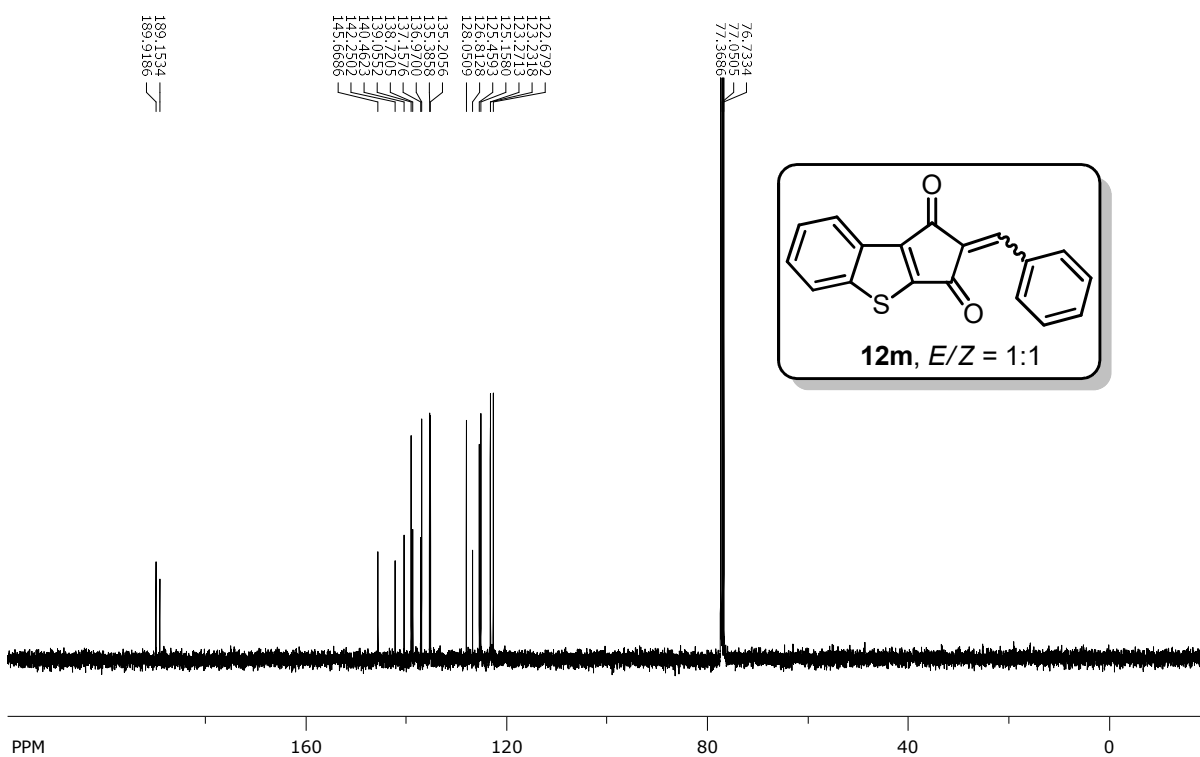
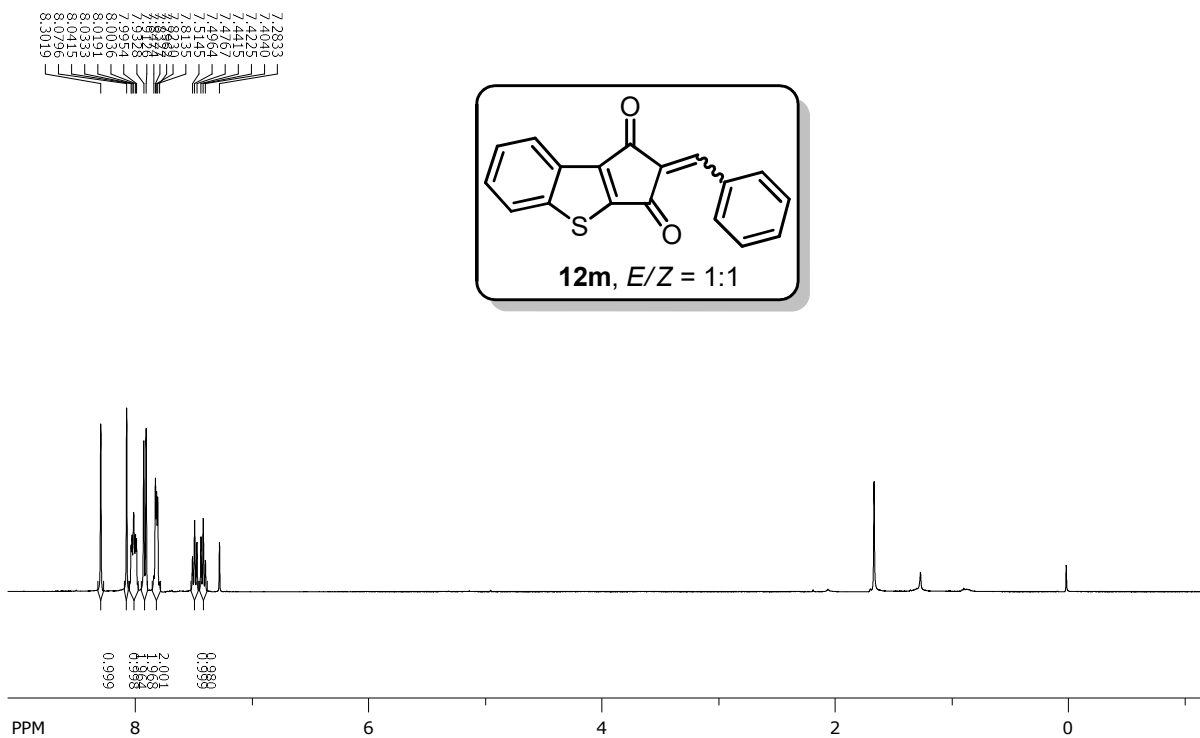




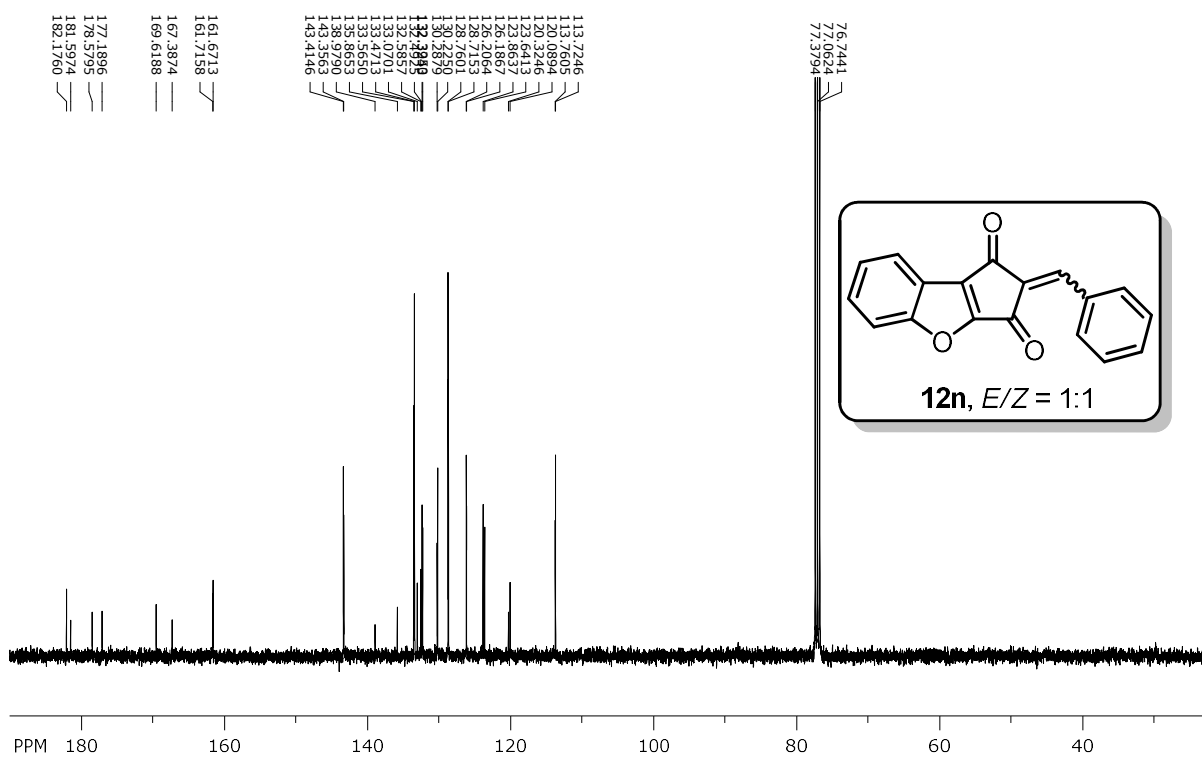
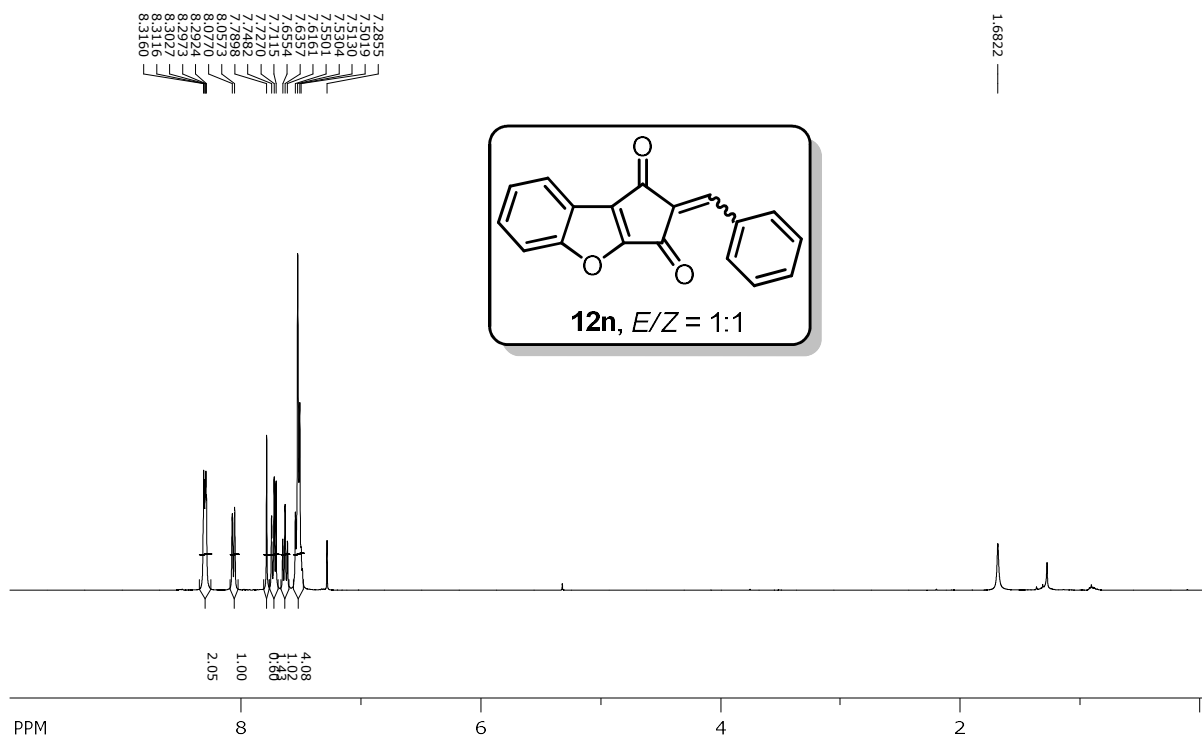


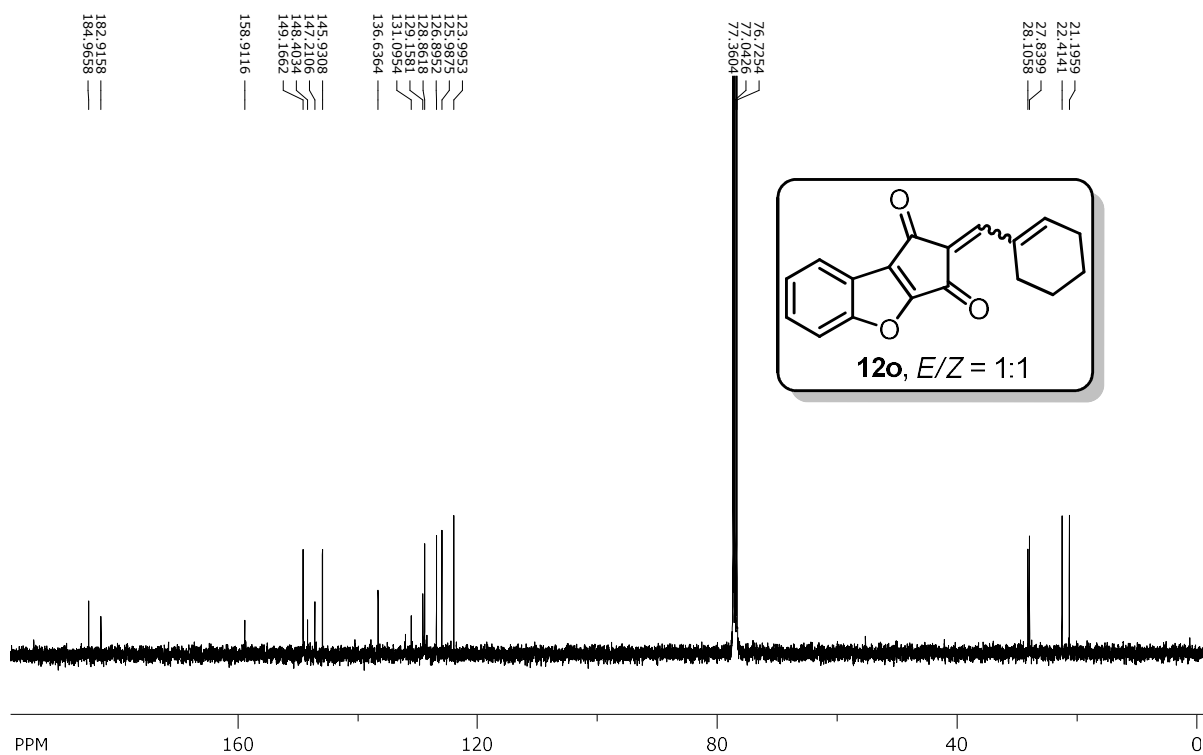
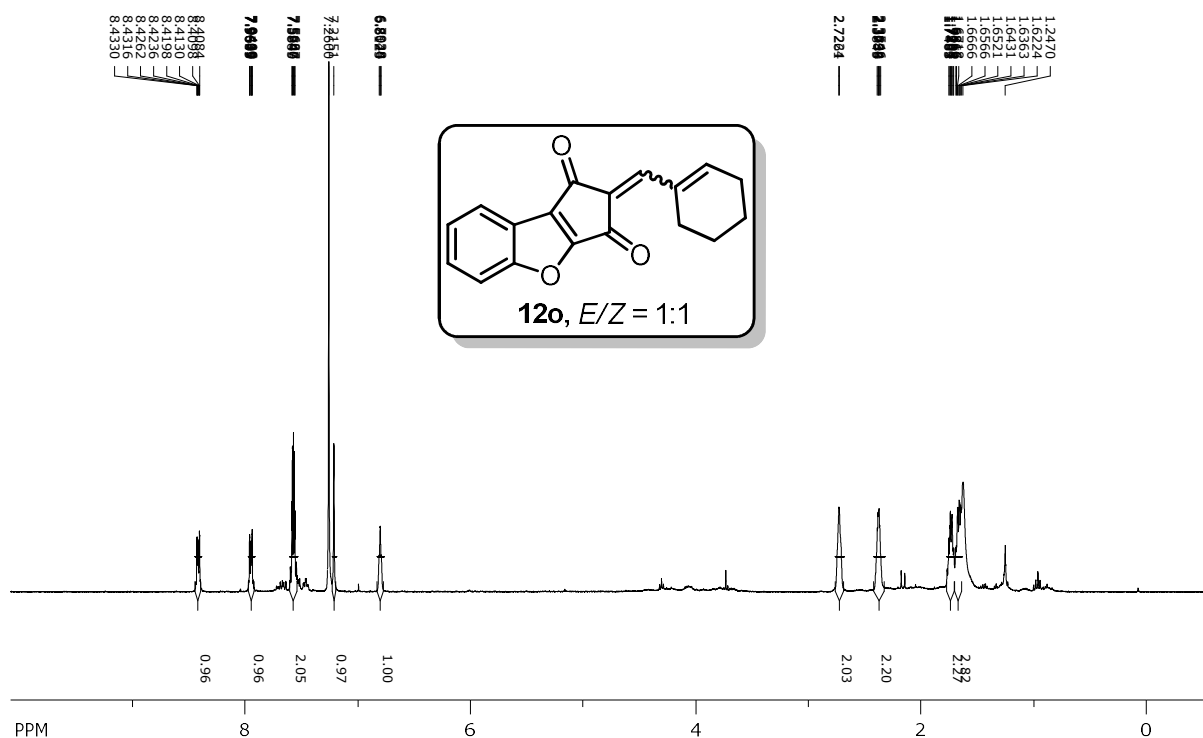


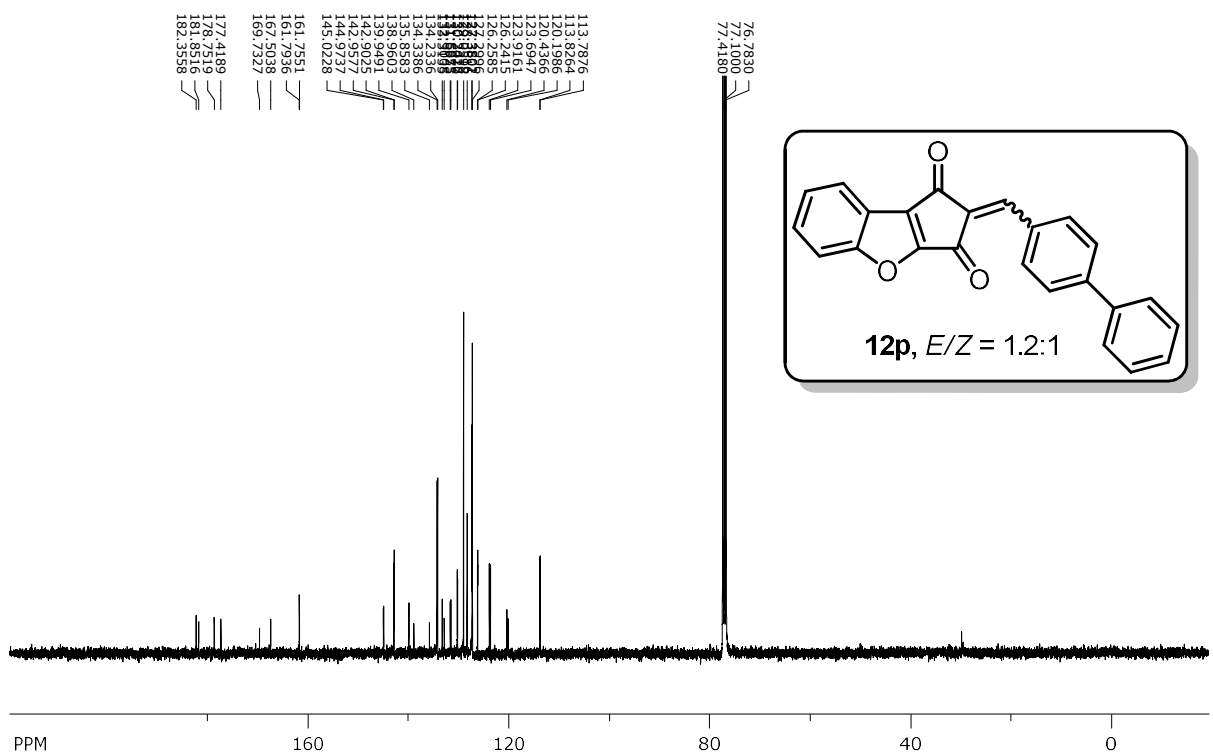


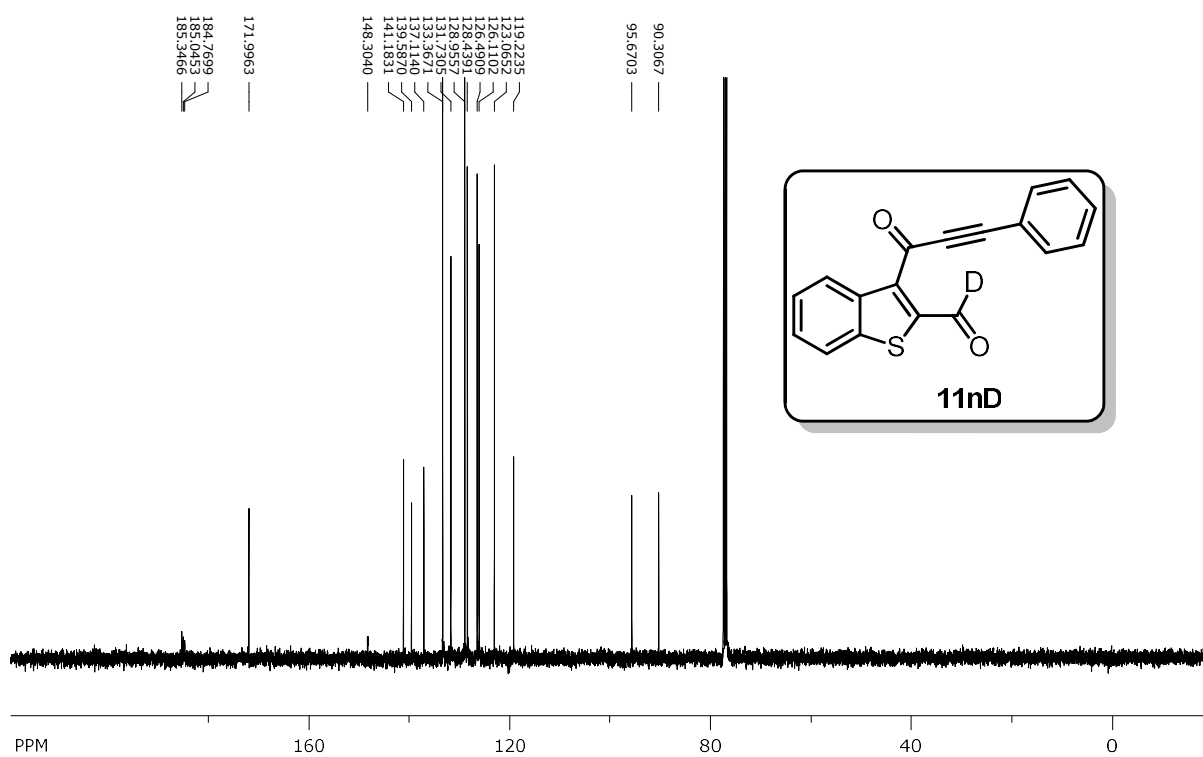
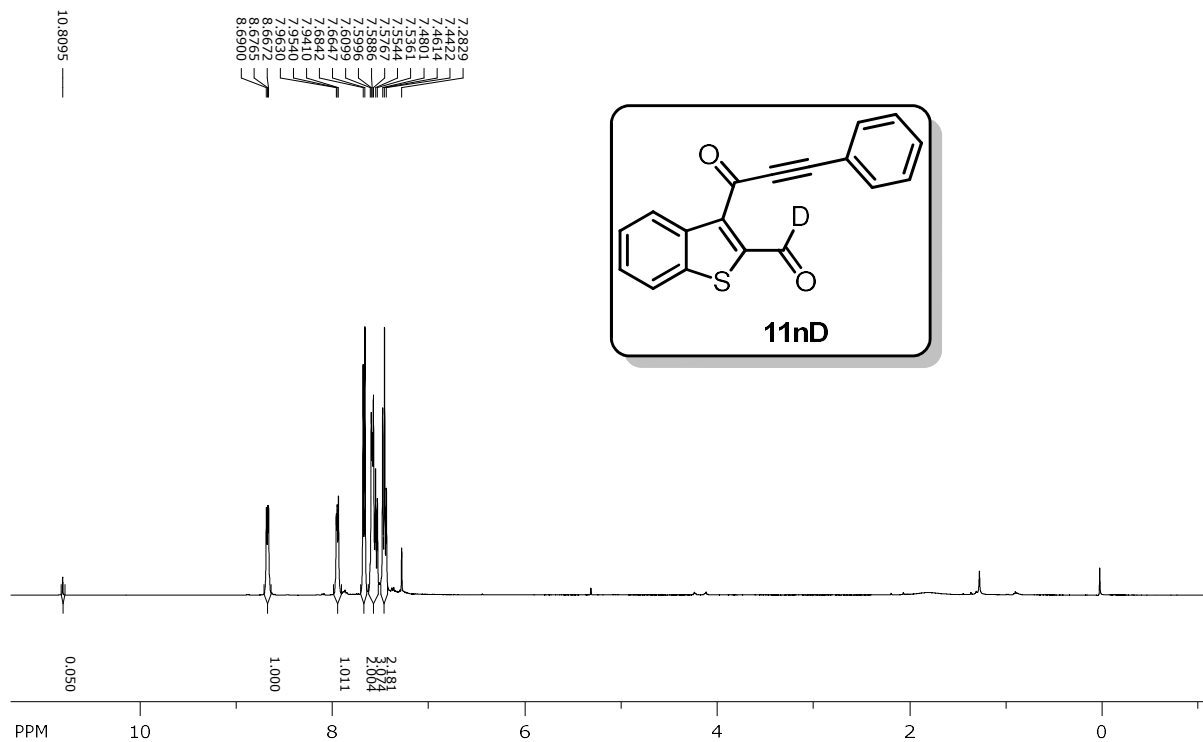




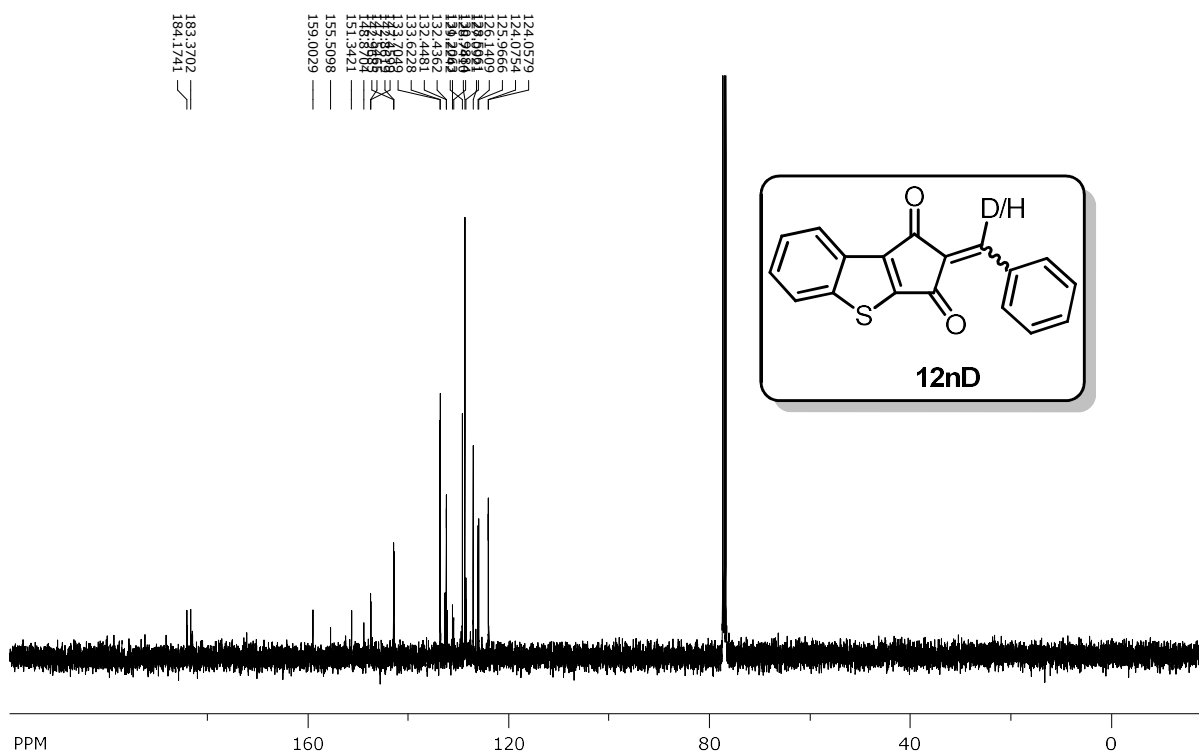
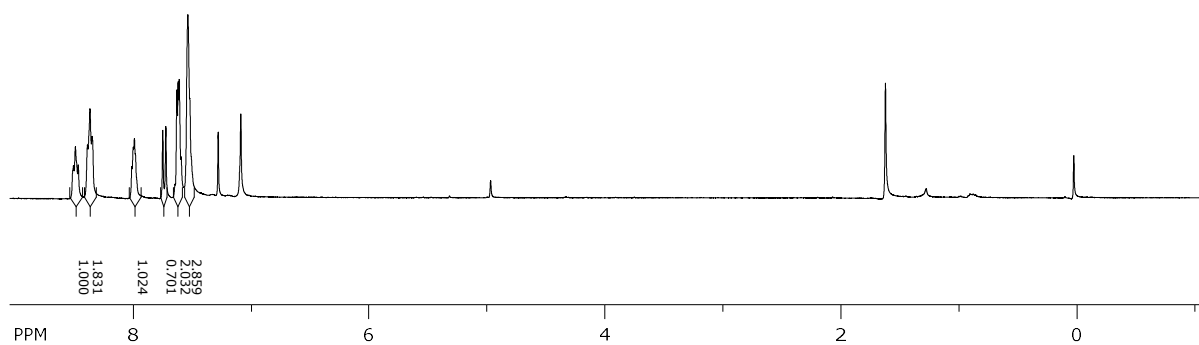
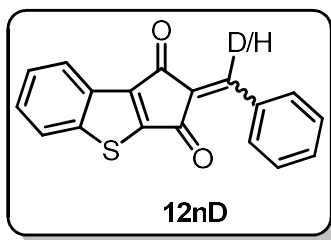


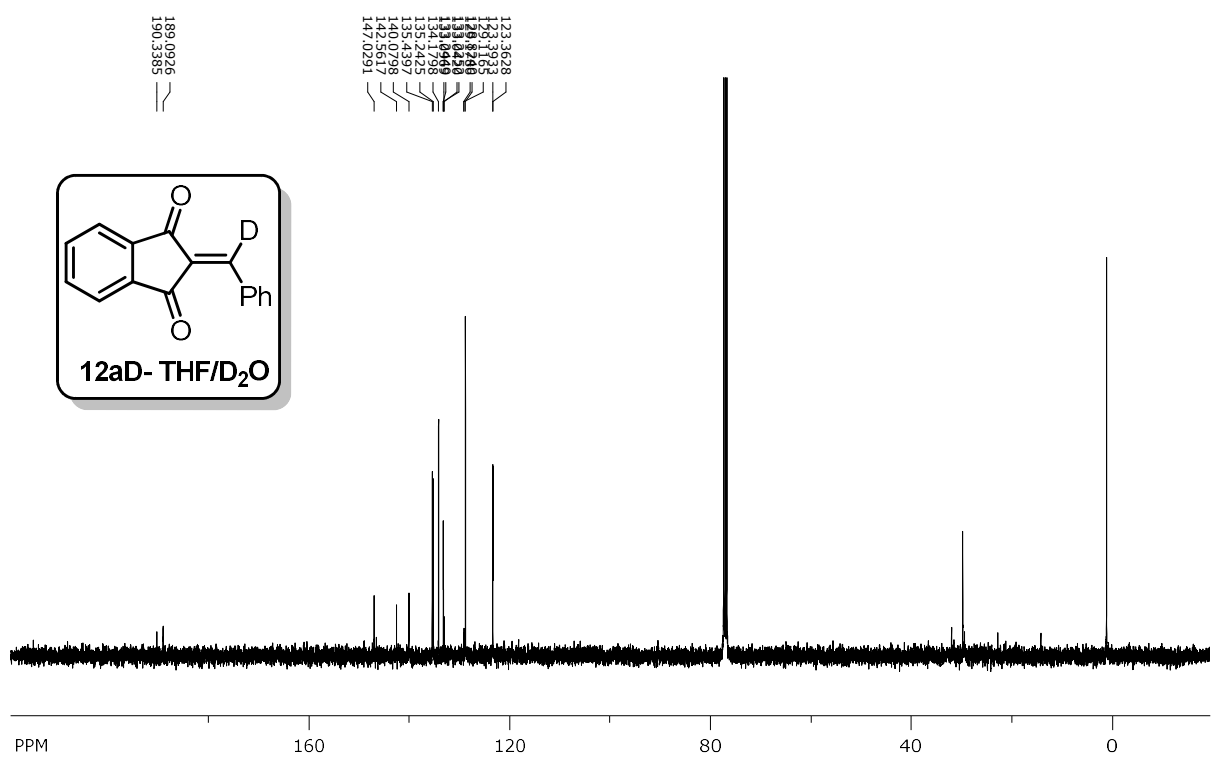
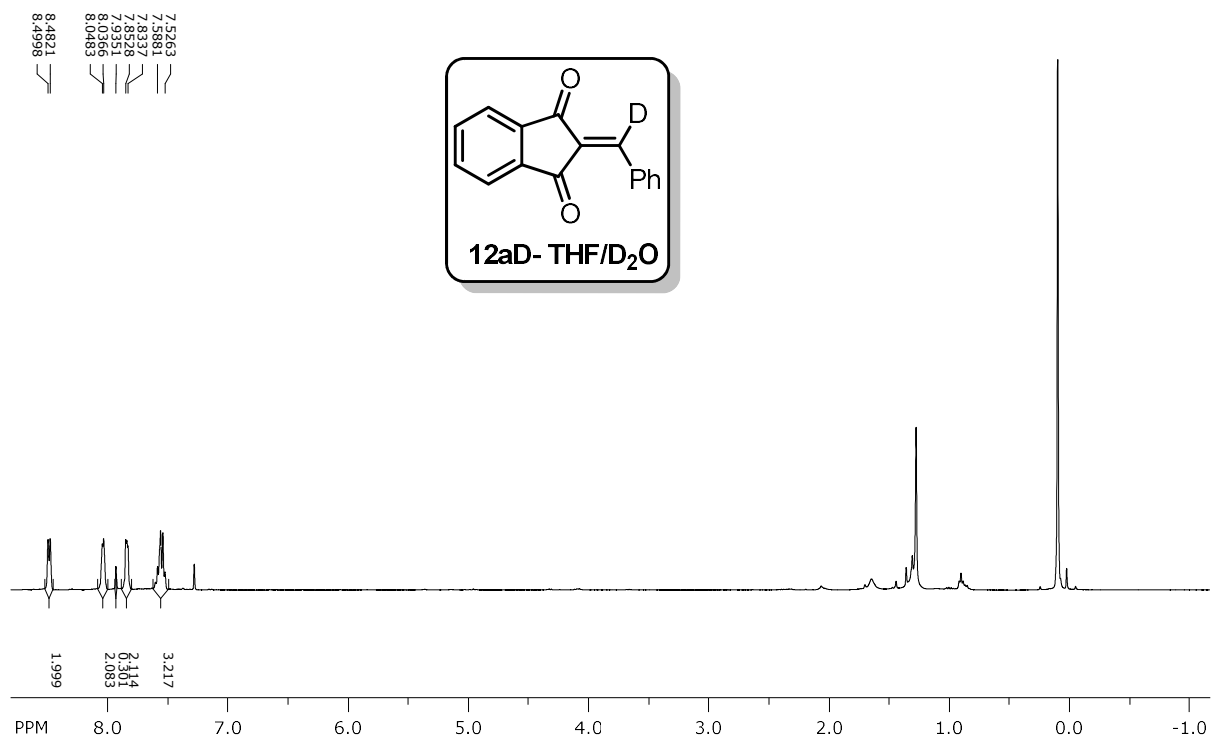


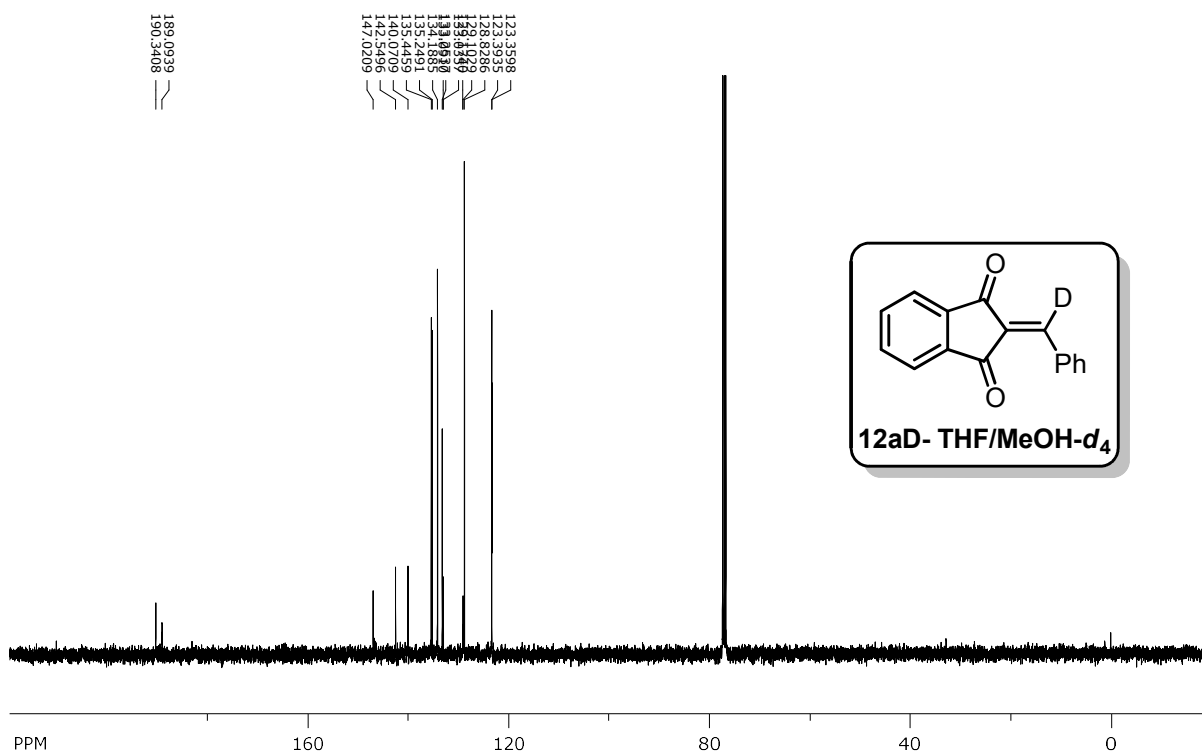
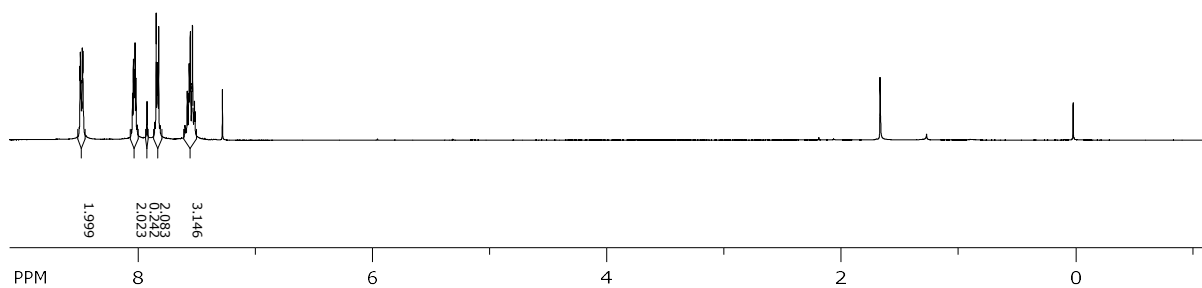
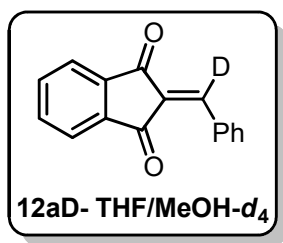


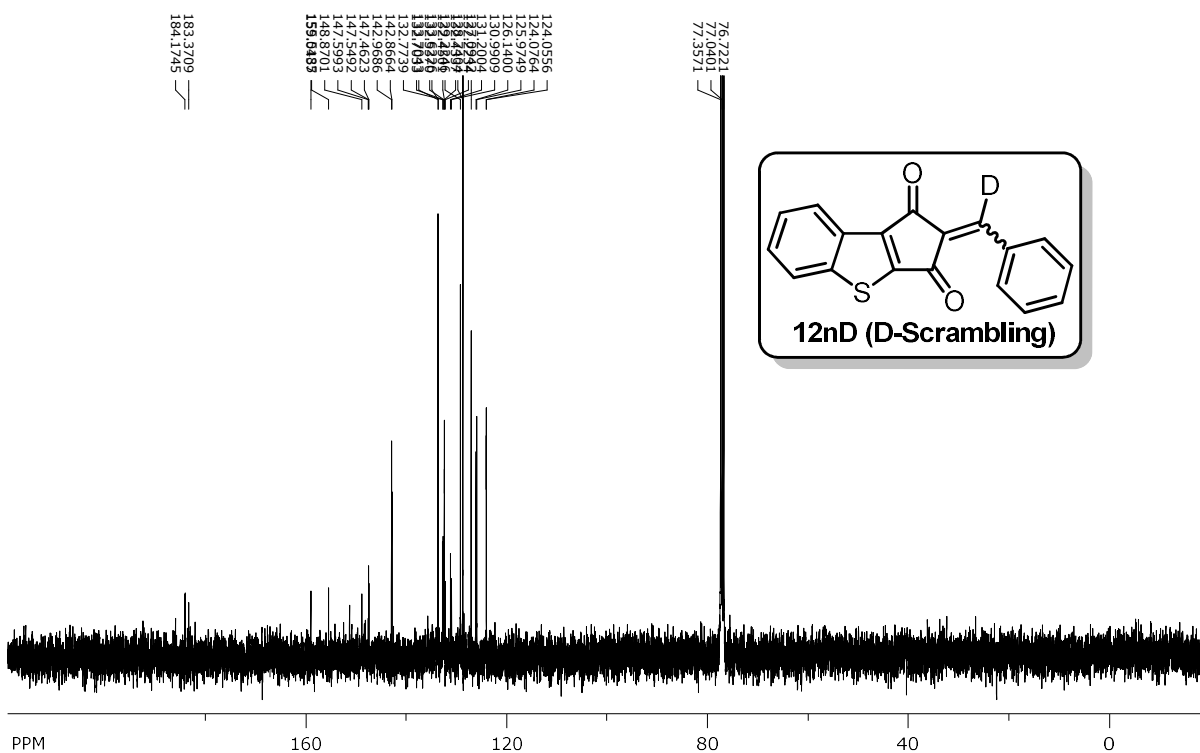
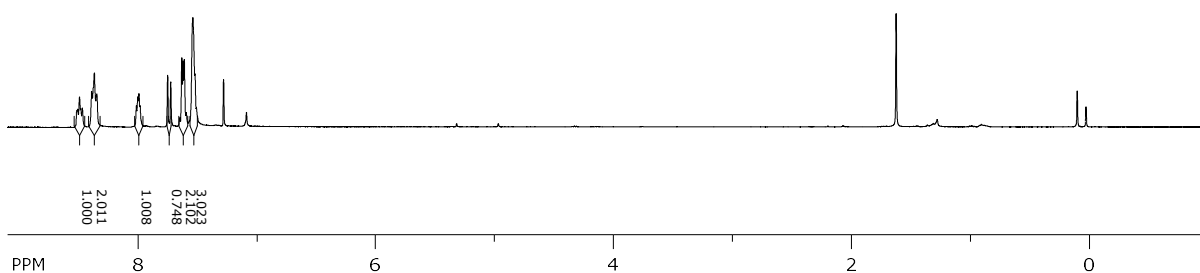
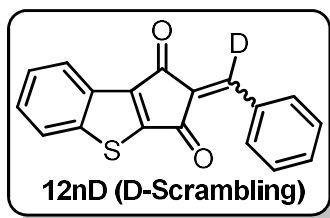


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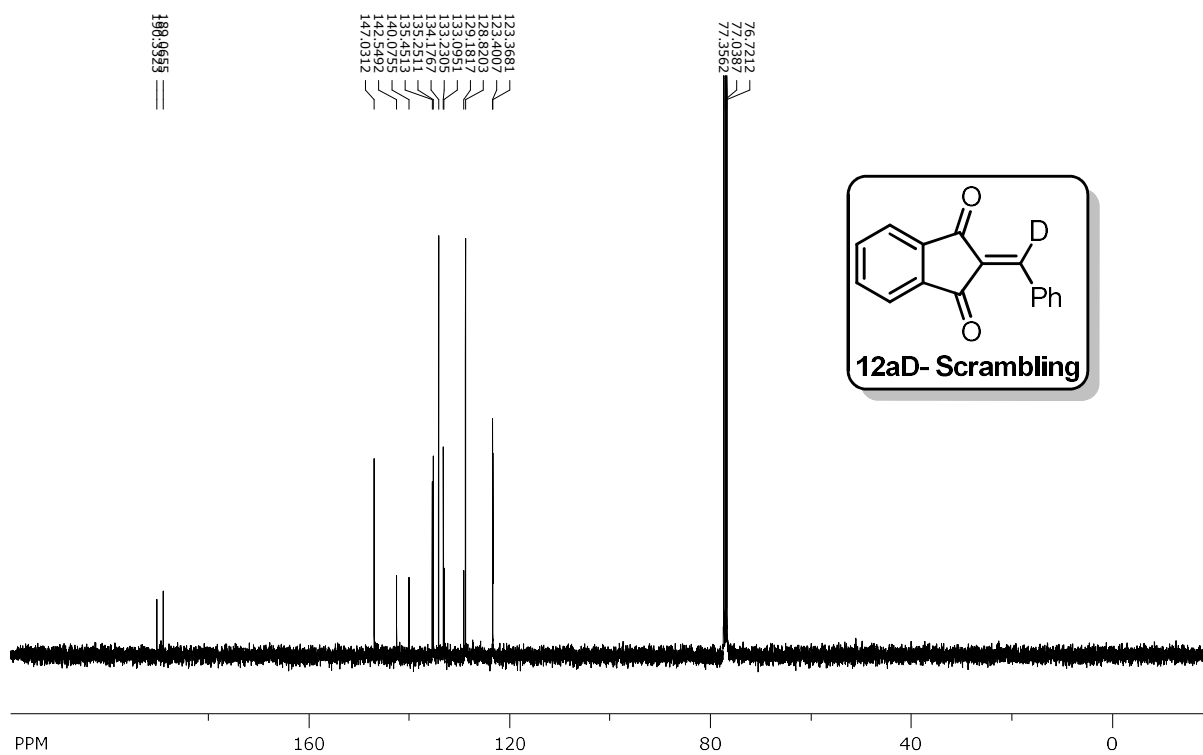
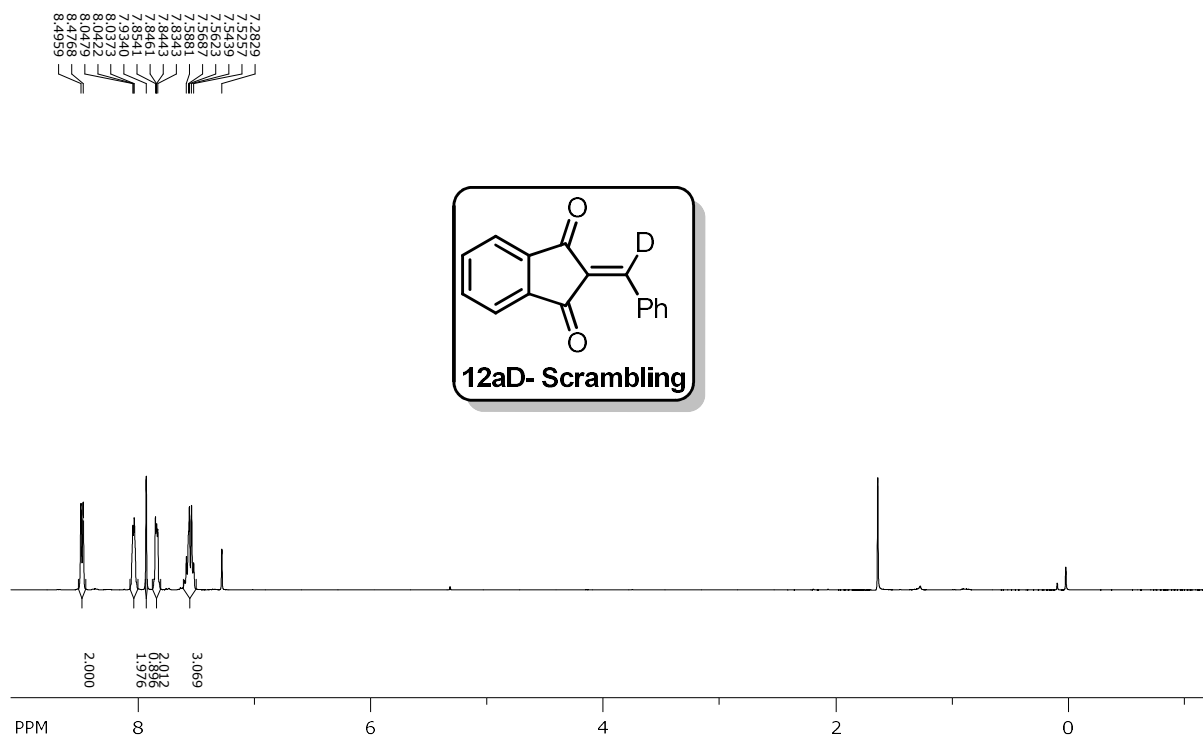




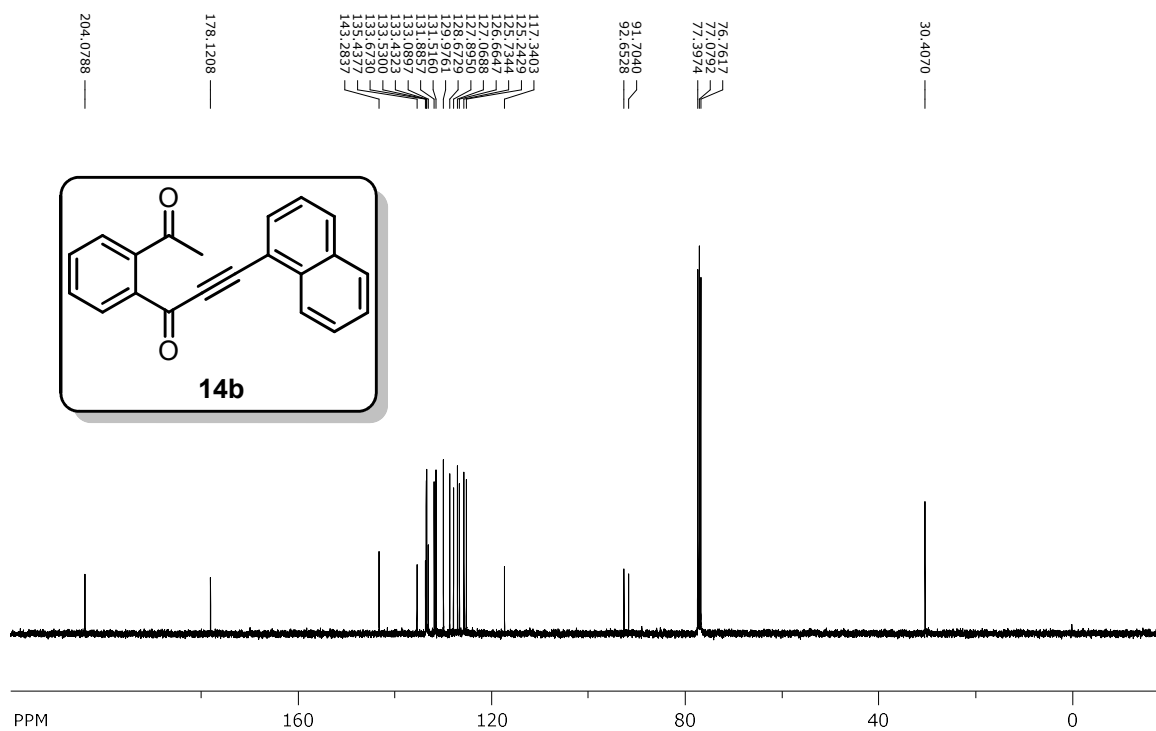
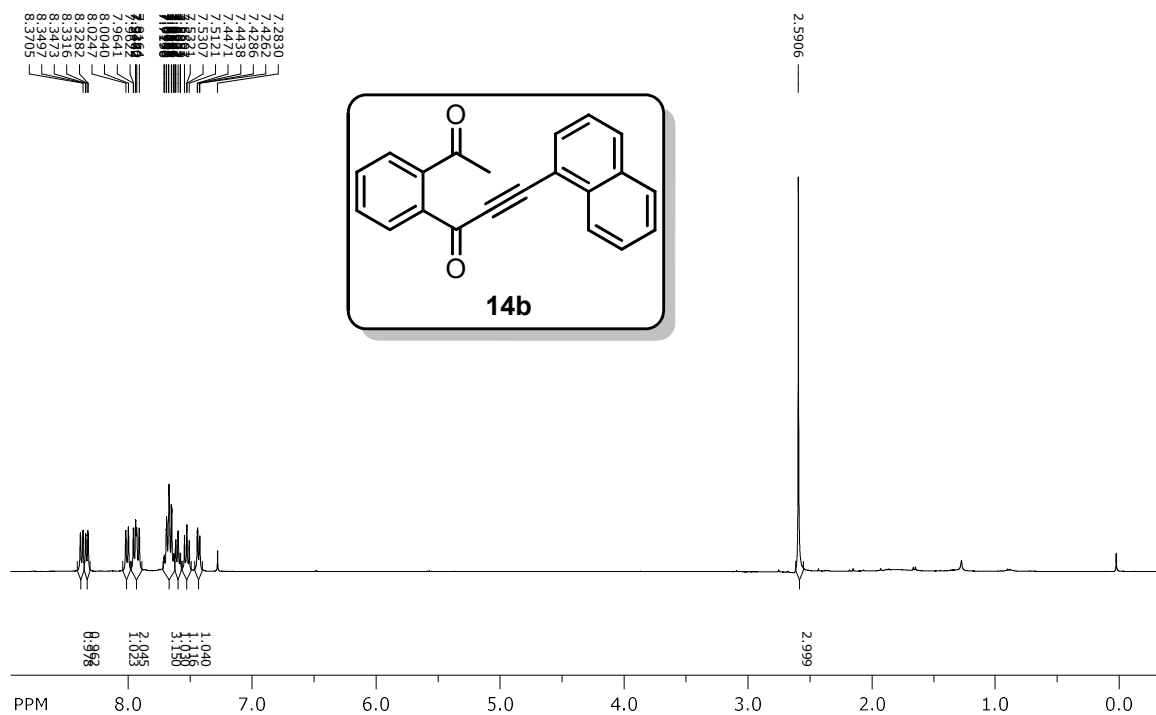


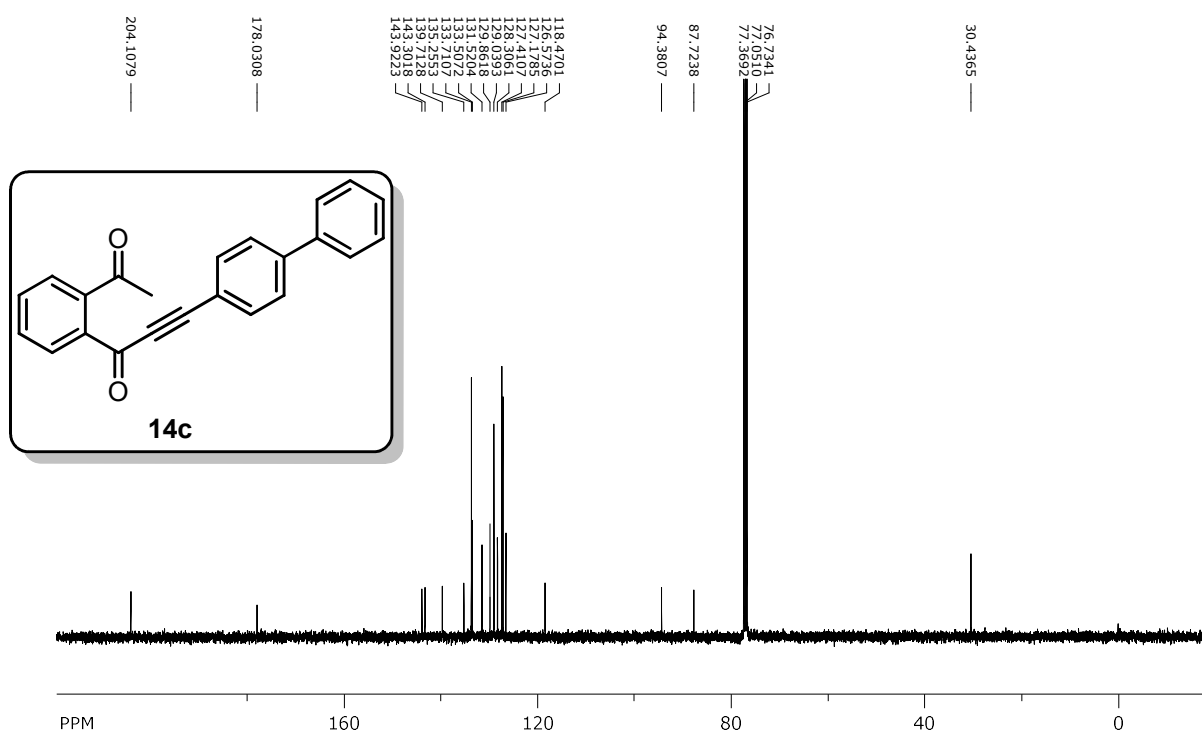
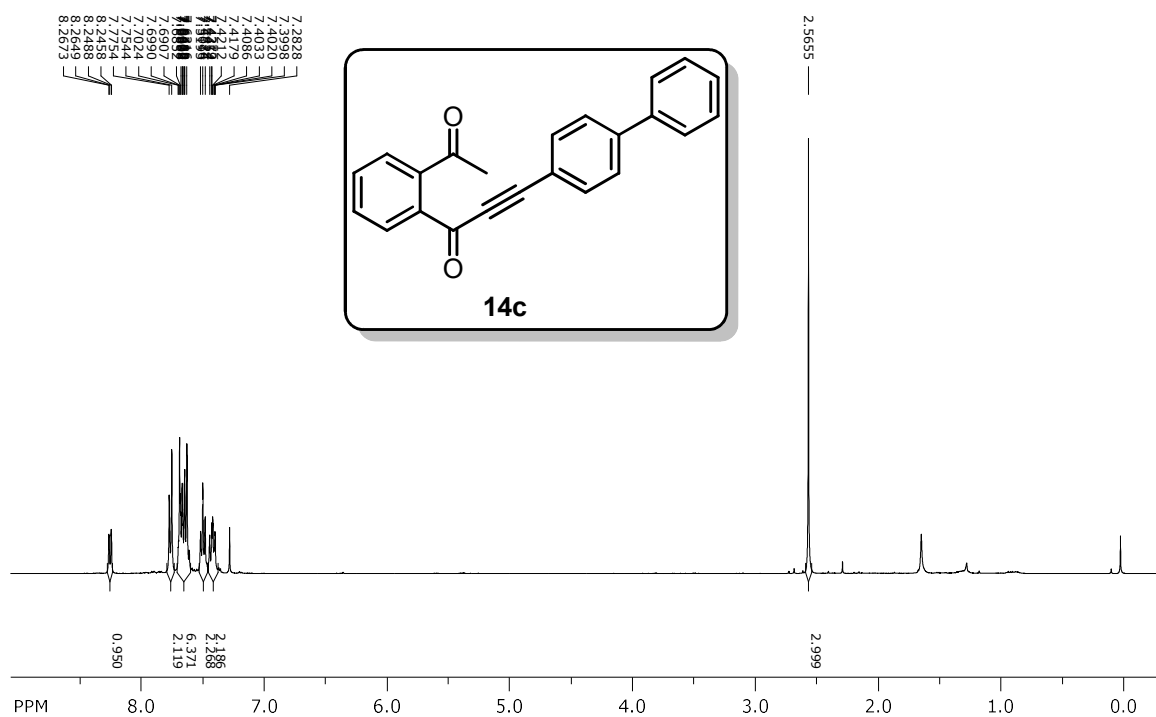


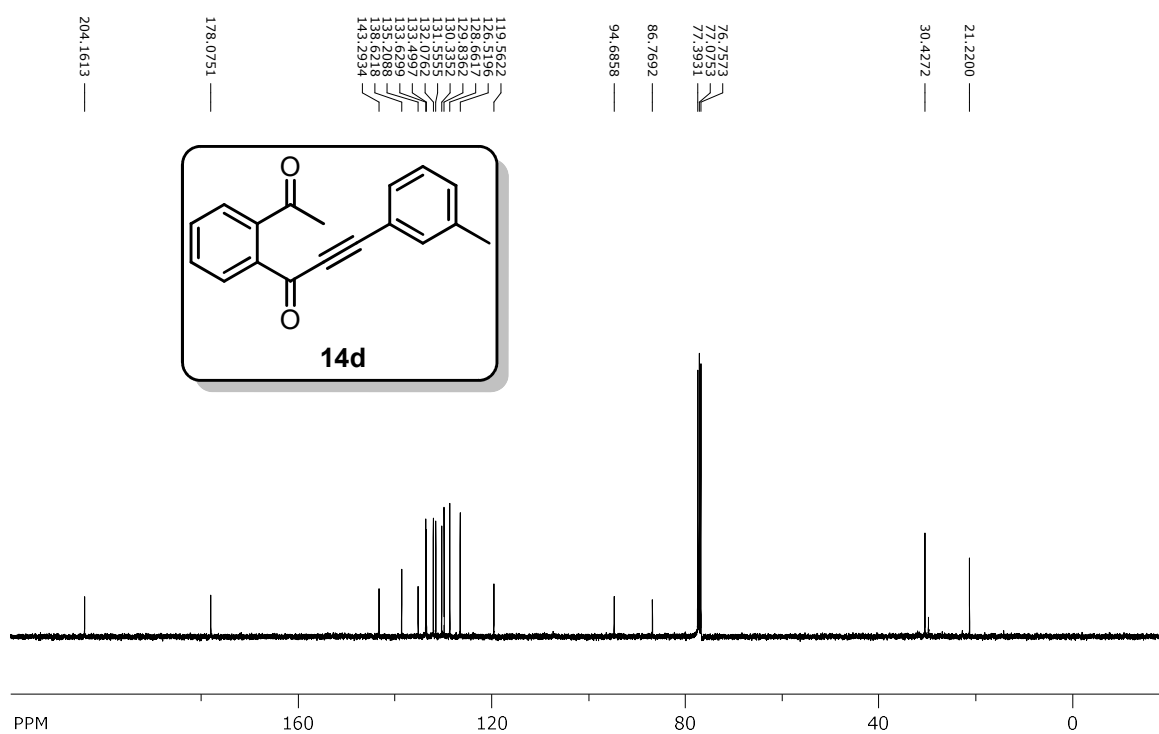
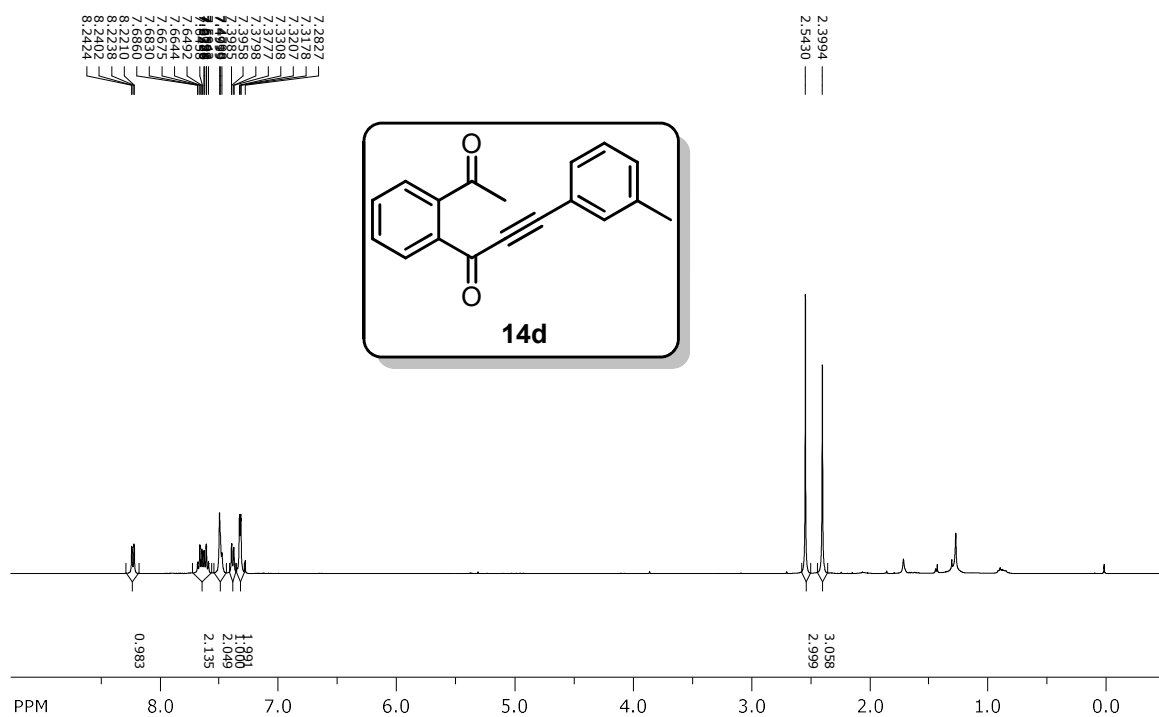


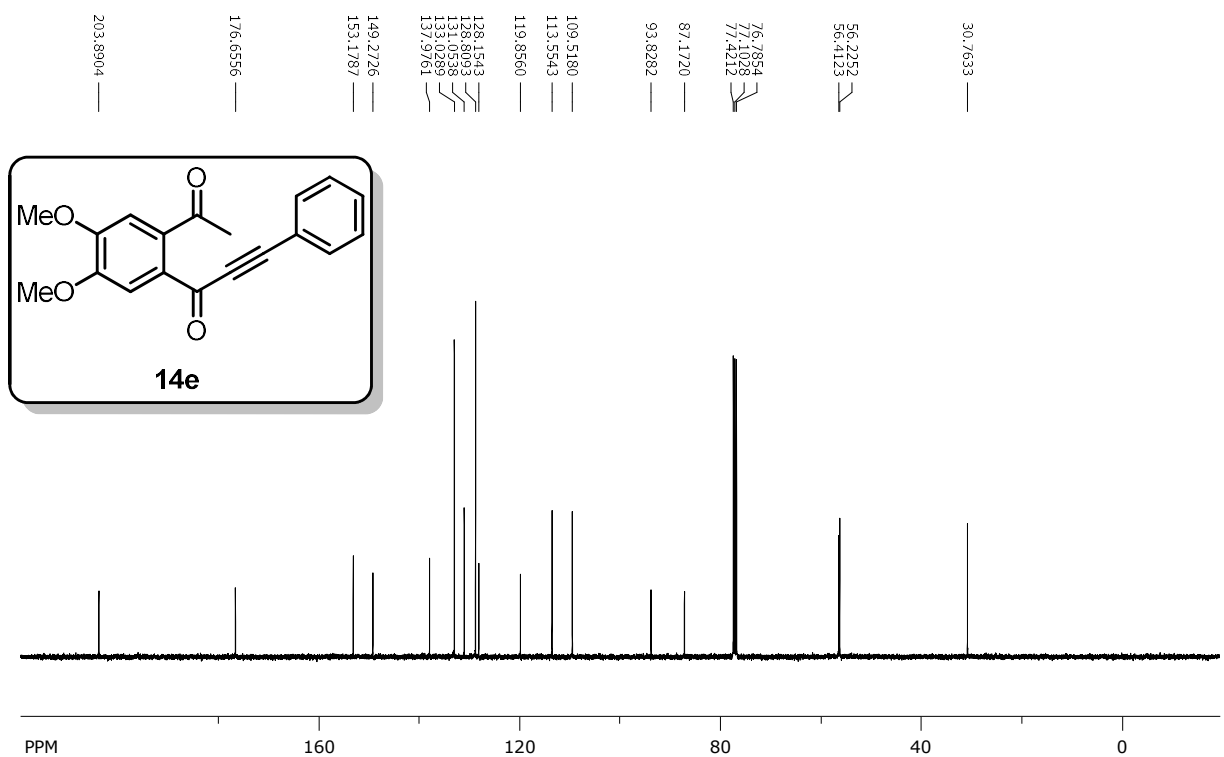
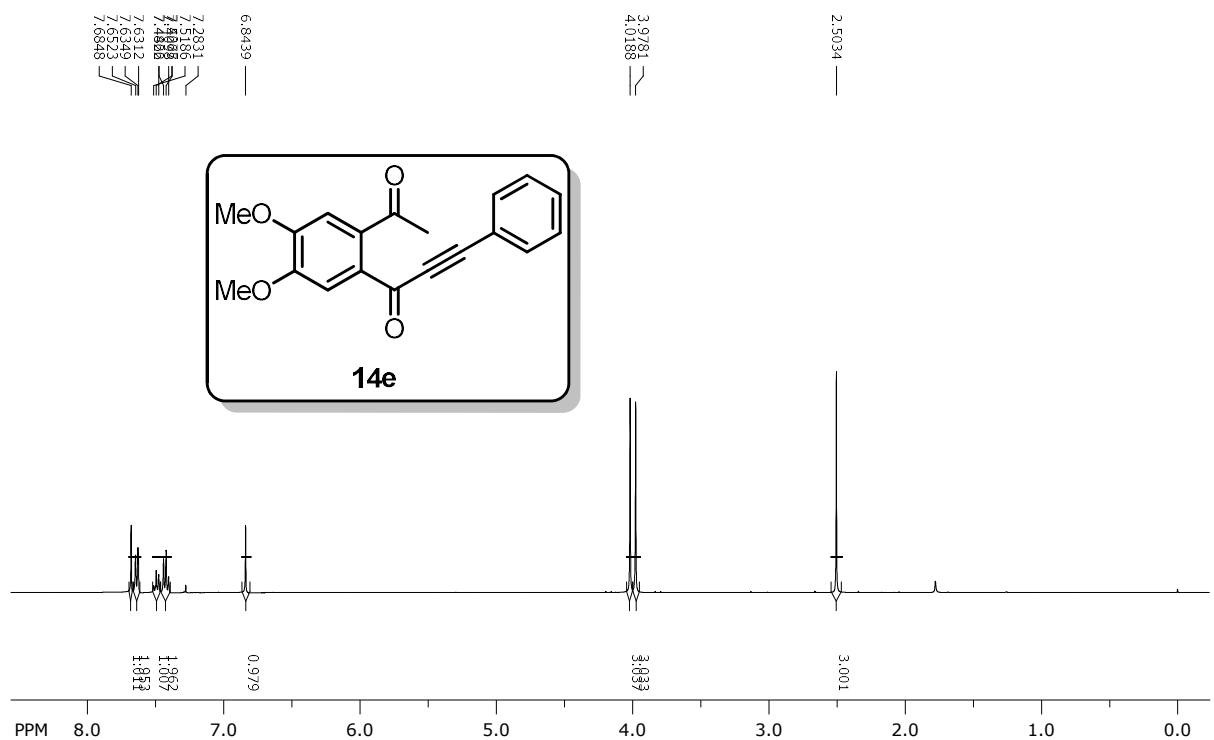


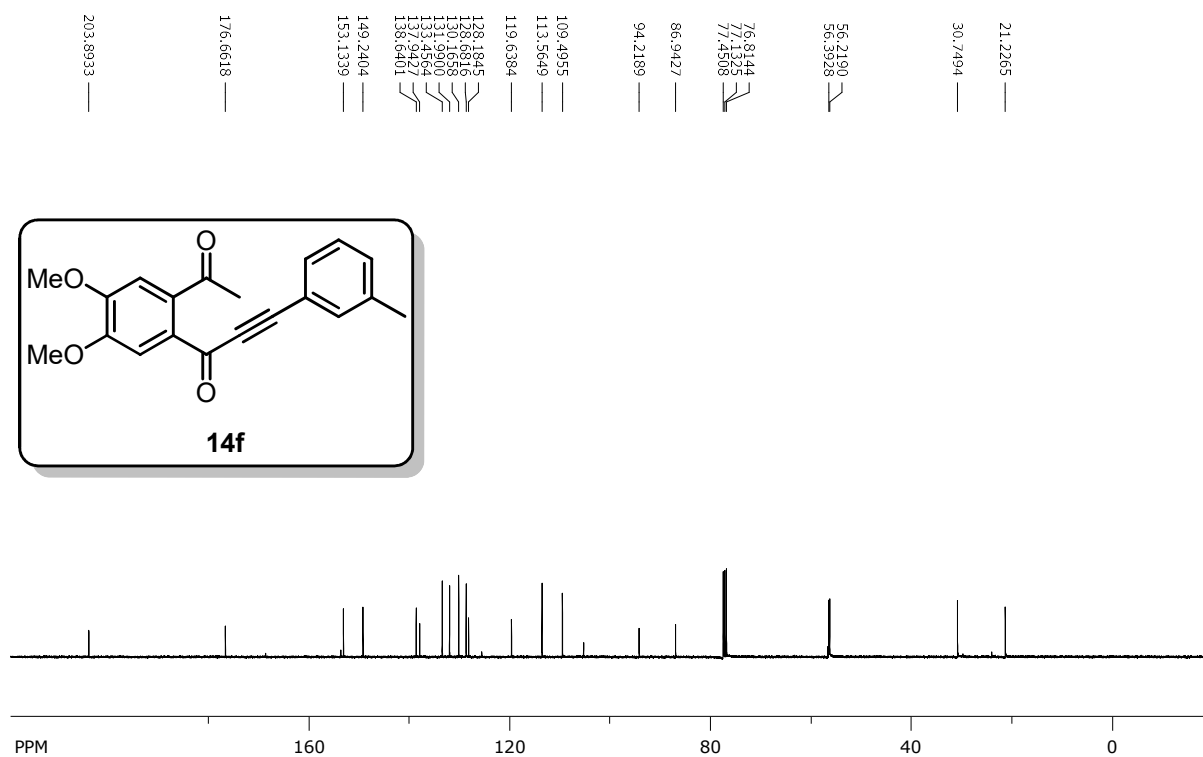


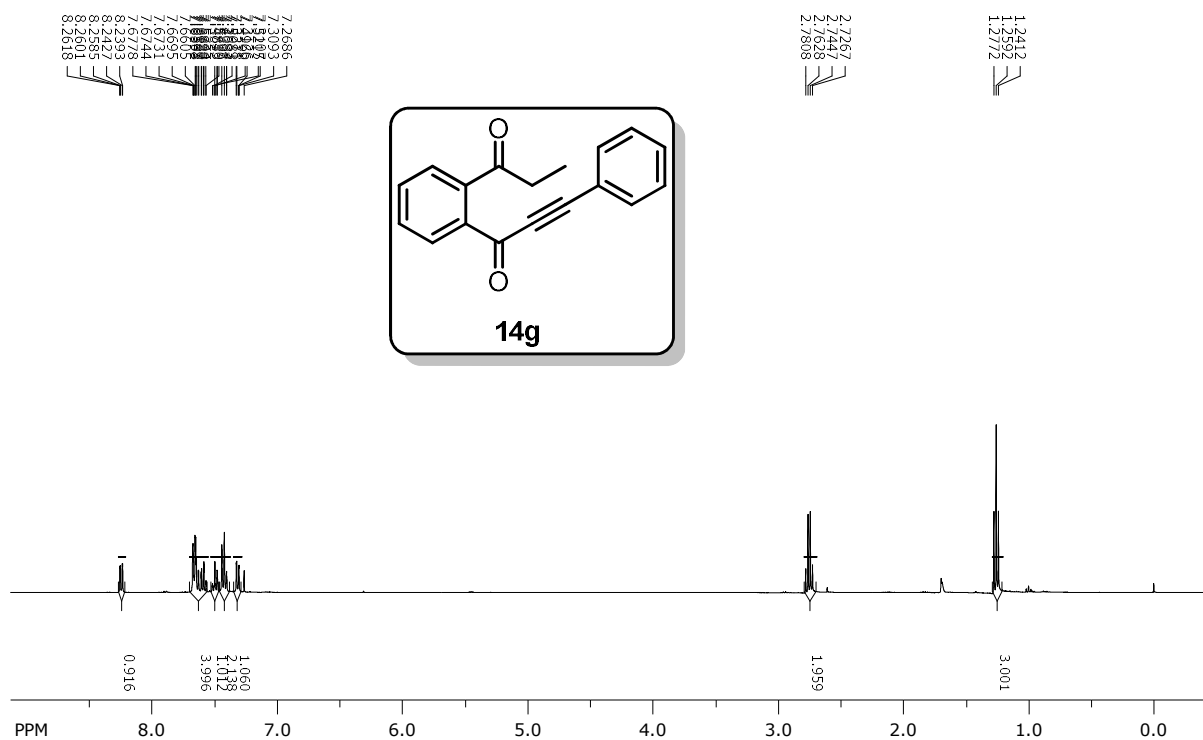




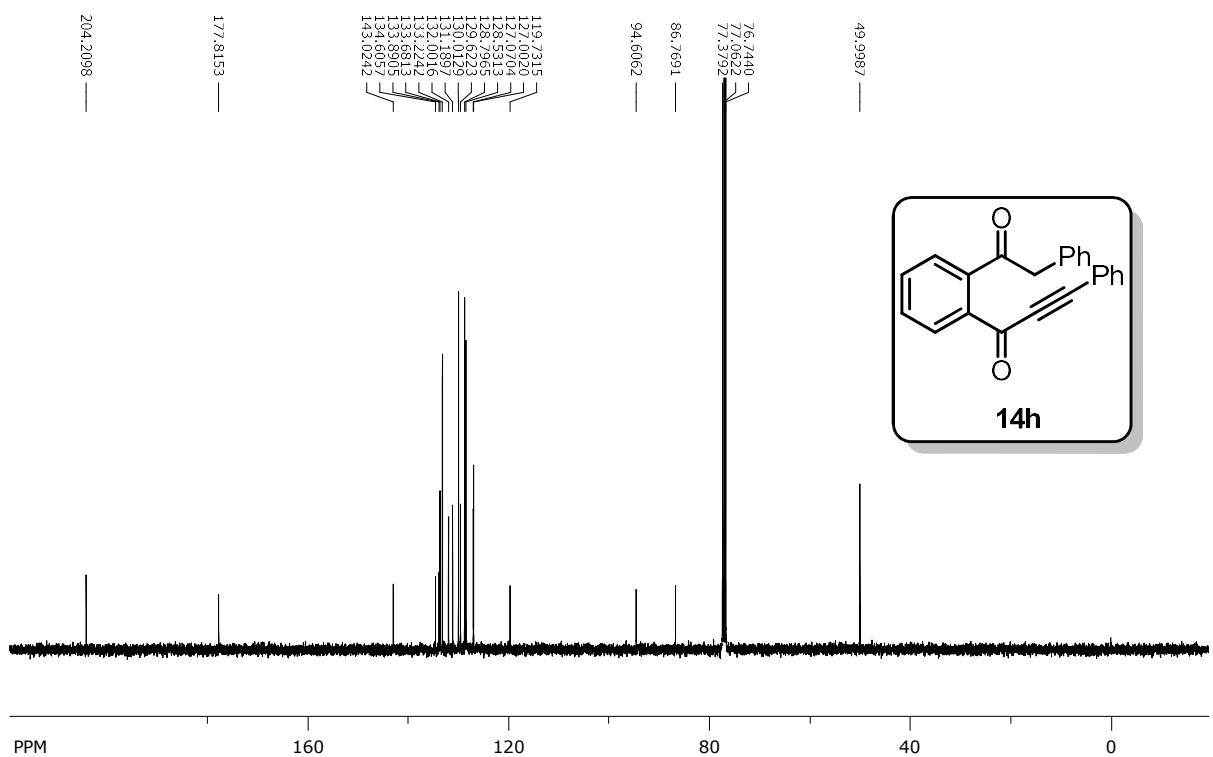
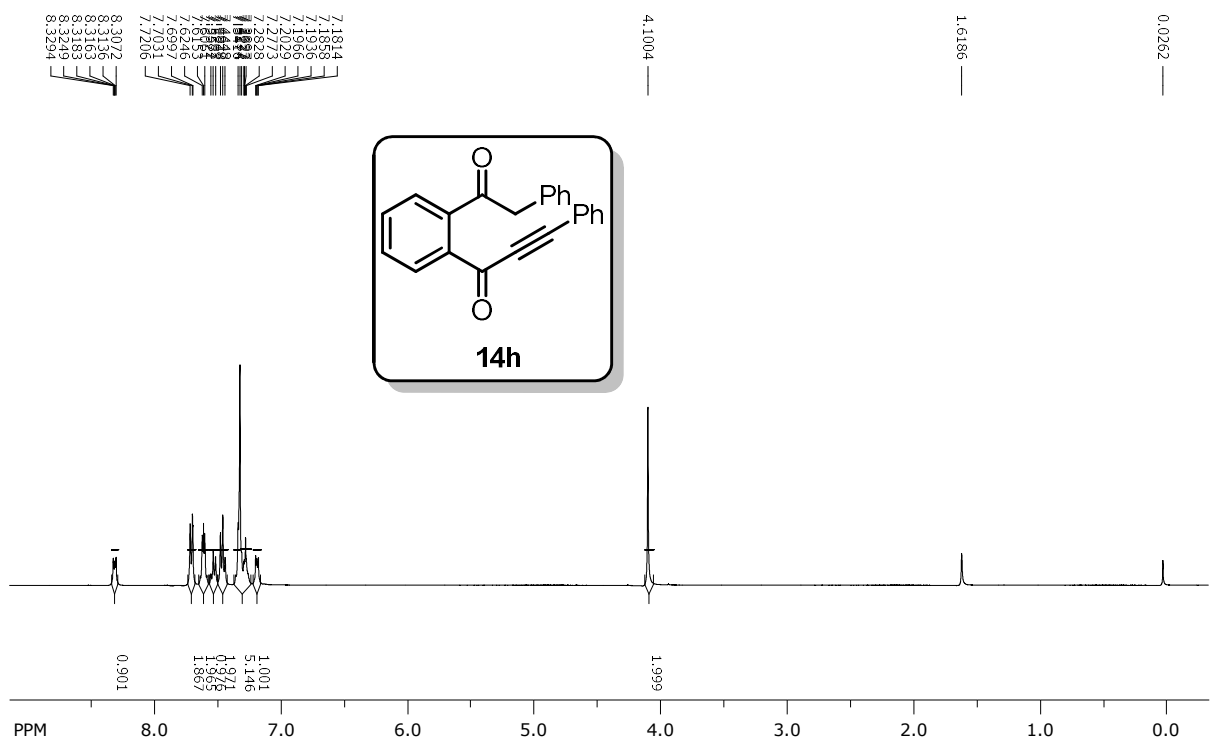


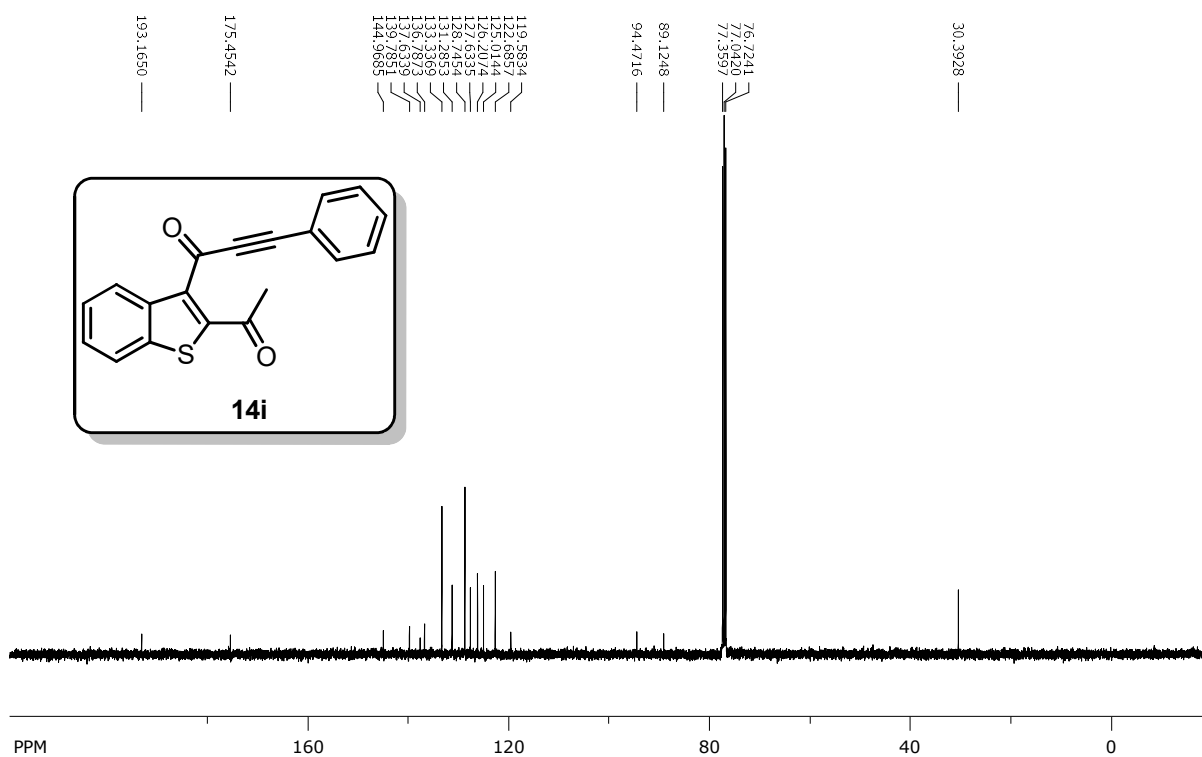
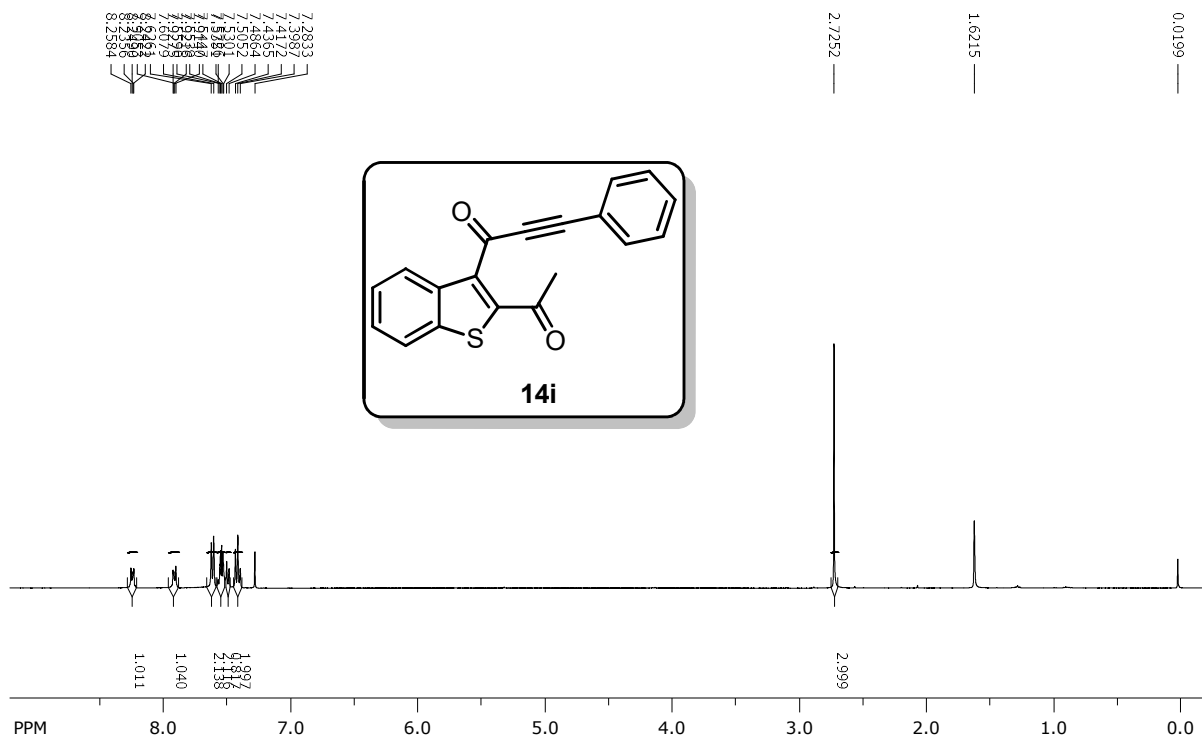


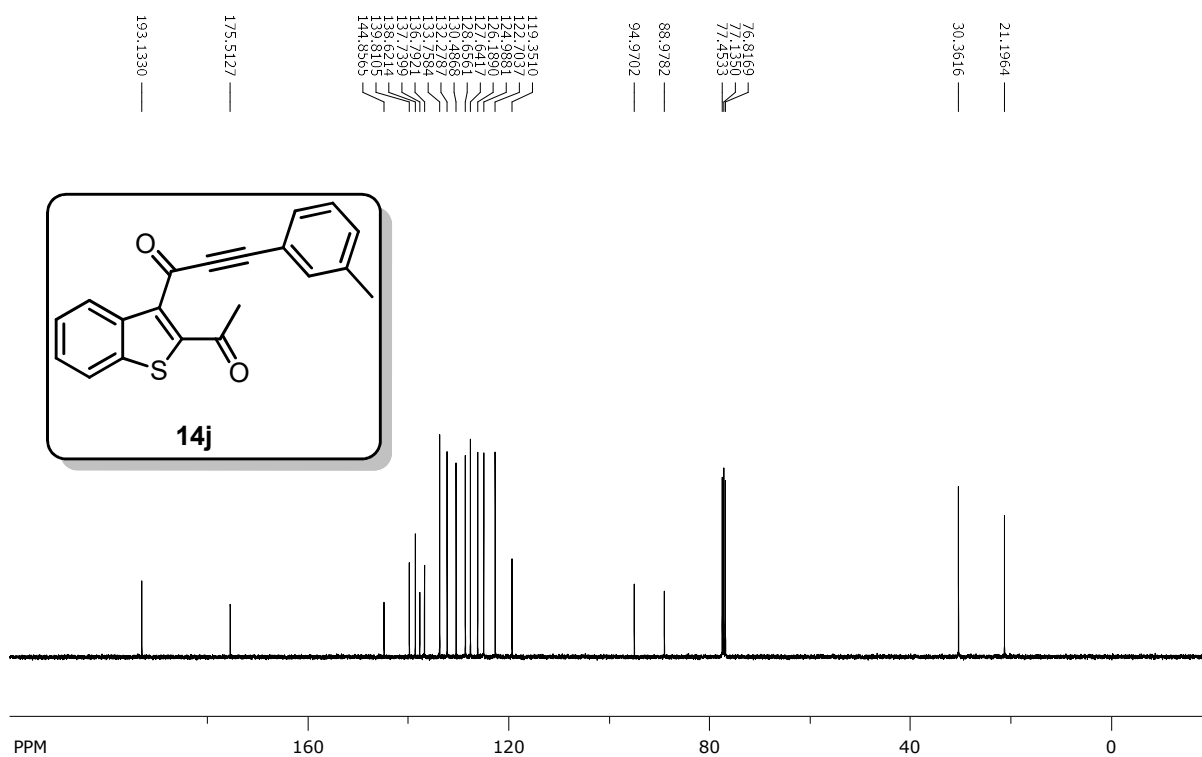
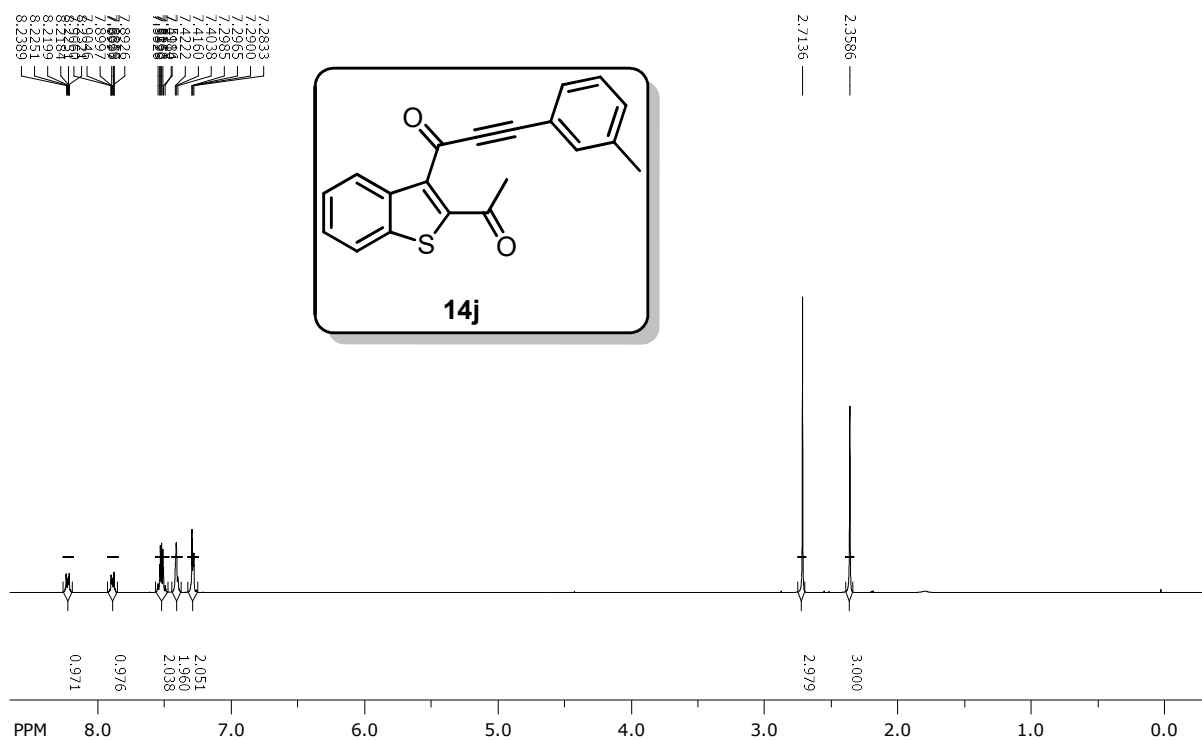


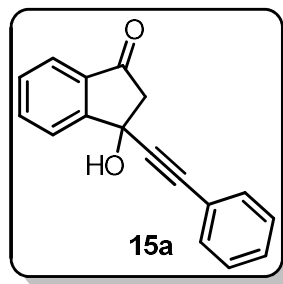
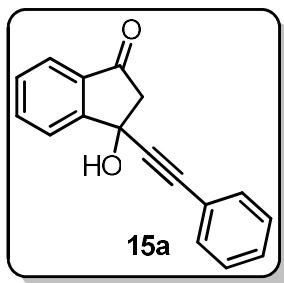




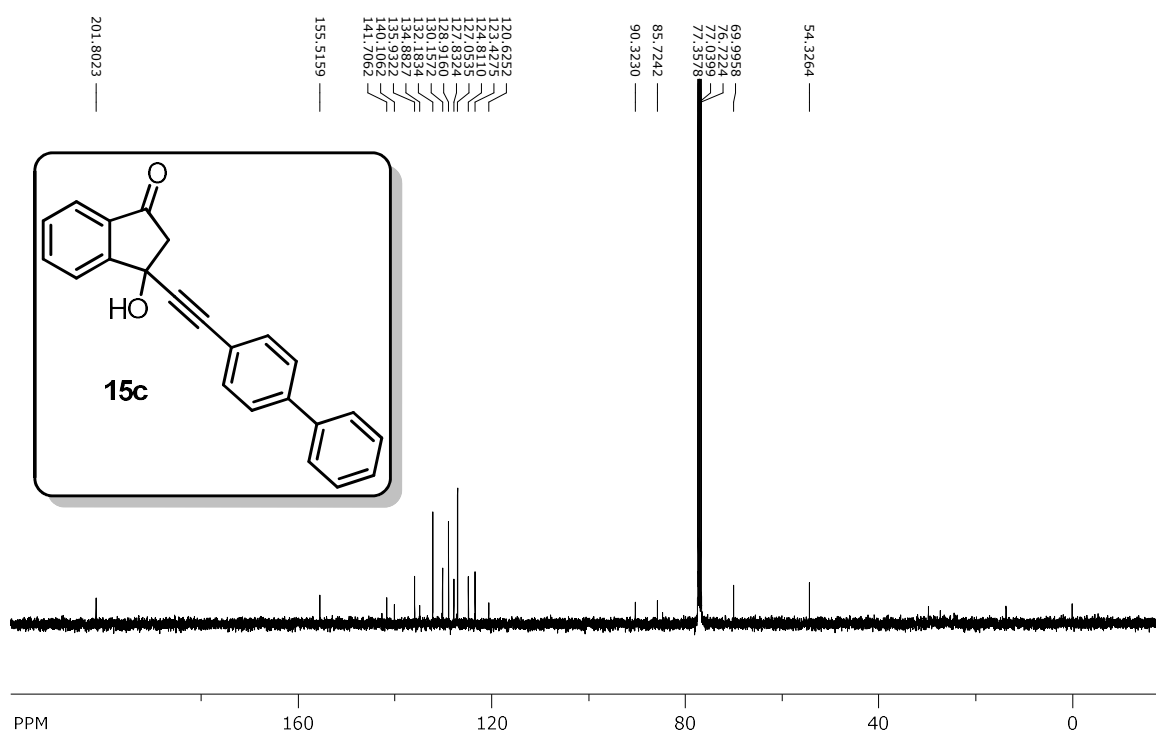
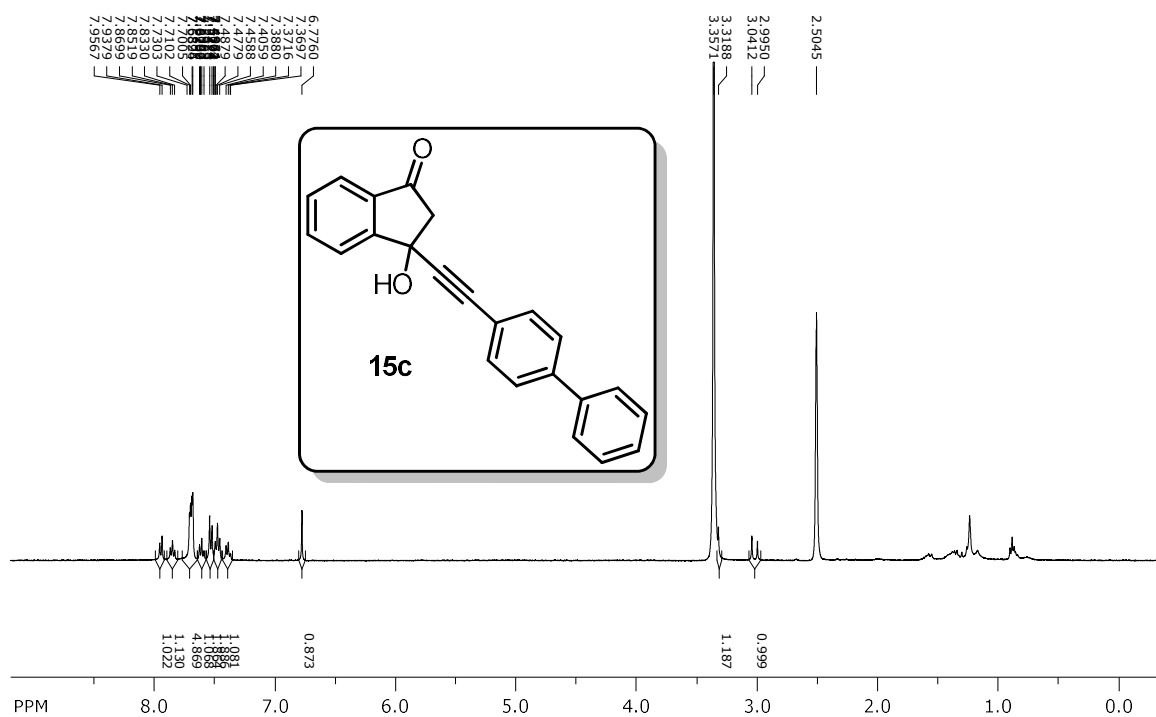


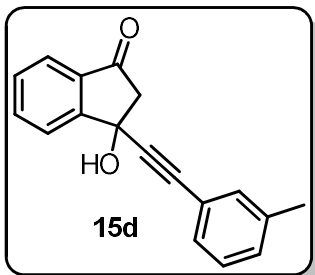
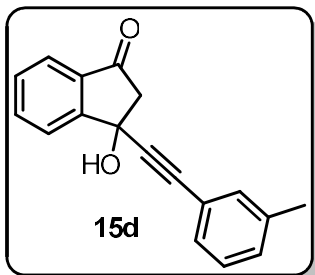


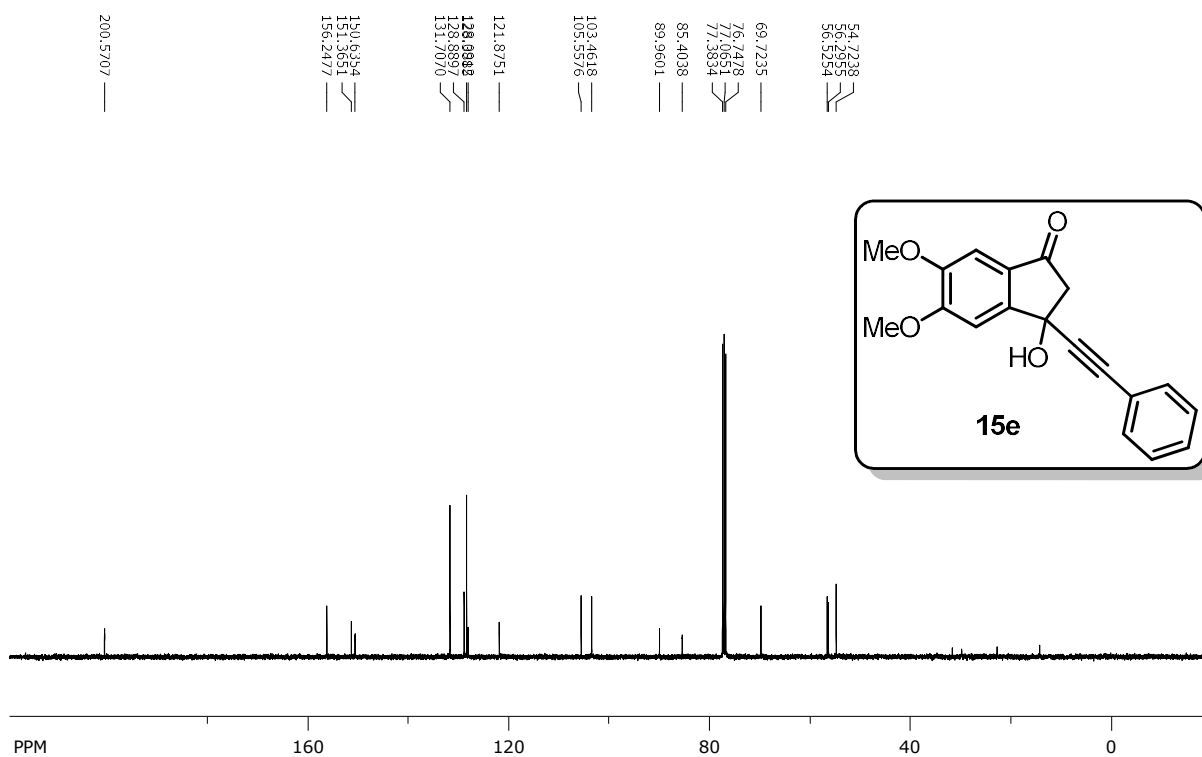
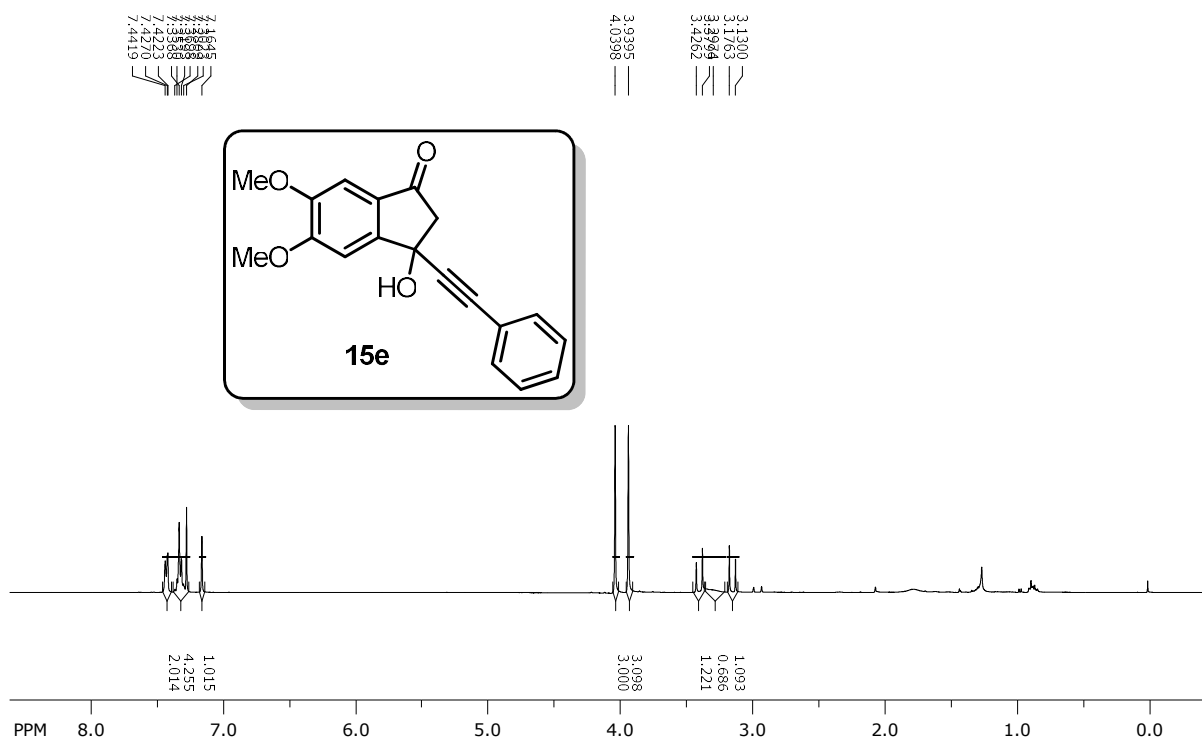




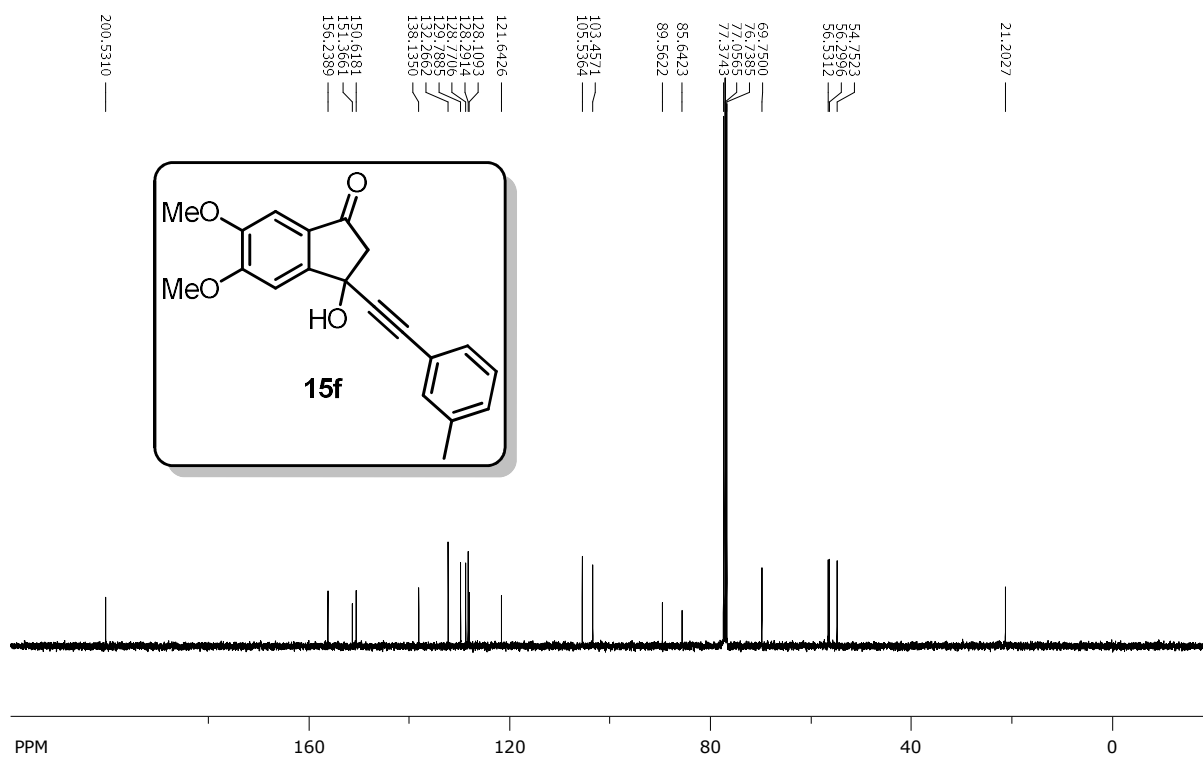
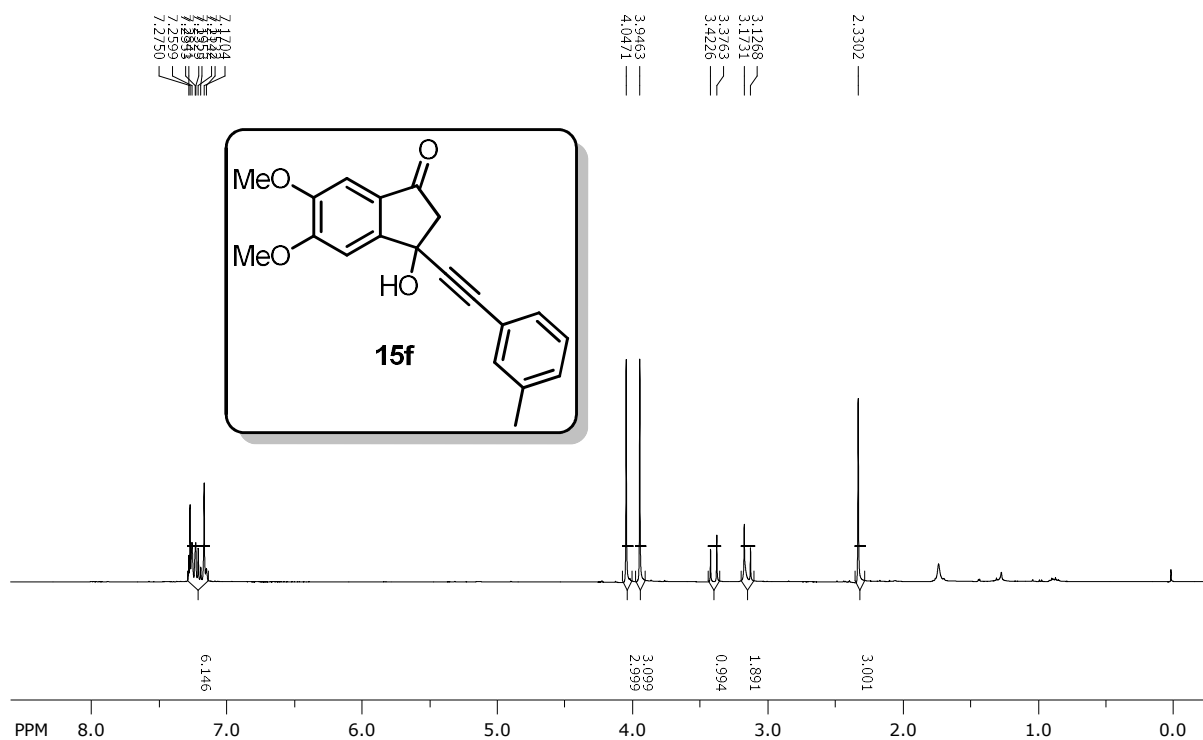


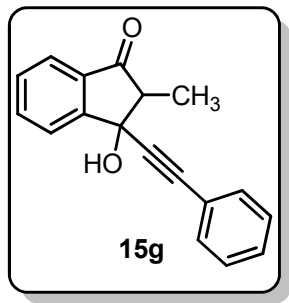
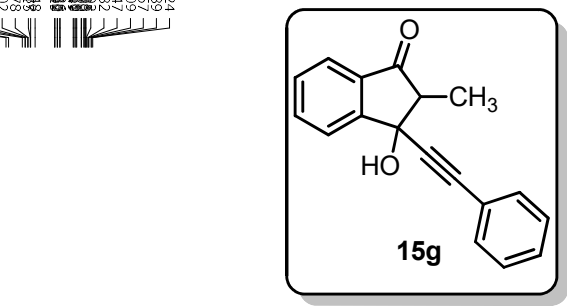




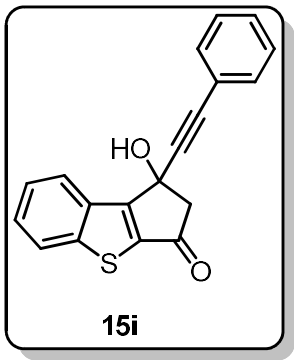
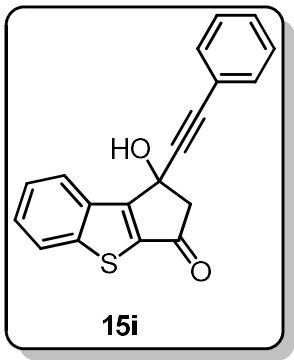


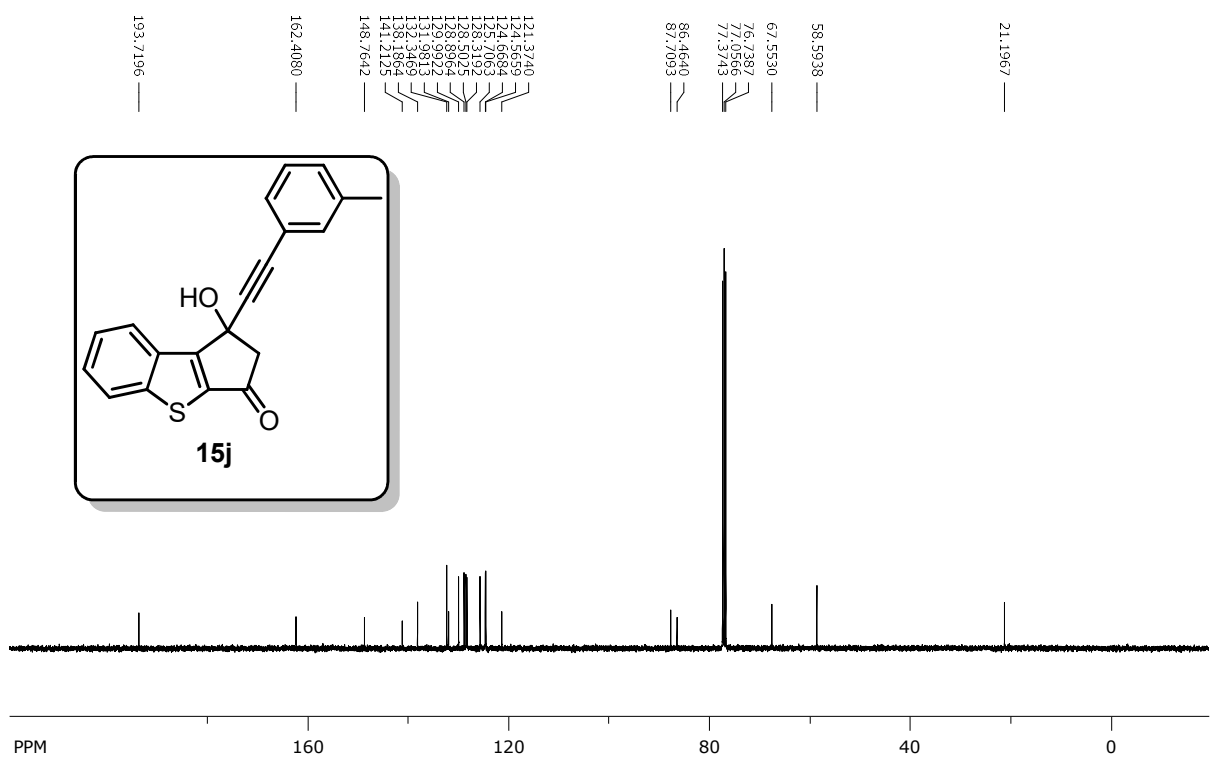
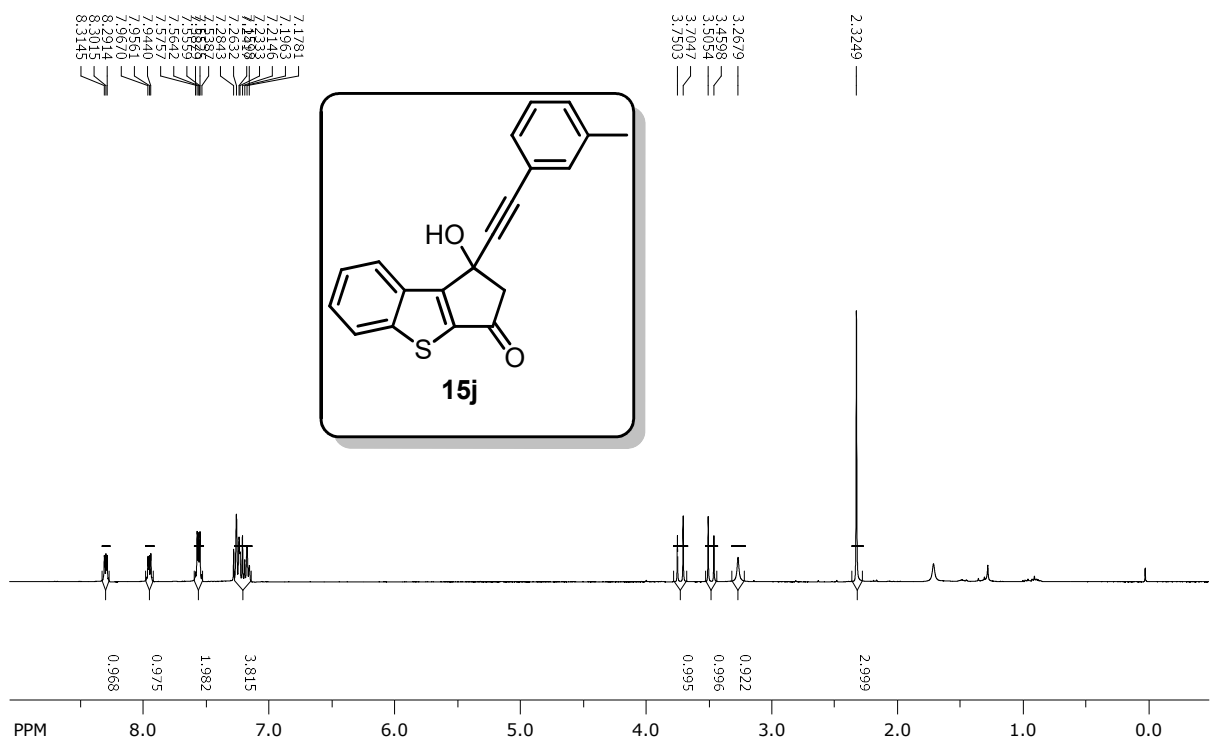












## *Conclusion*

We have demonstrated organophosphine catalyzed intramolecular hydroacylation of activated ynones. This is basically intramolecular MBH type reaction of  $\alpha, \beta$ -ynones, which provides access to a variety of cyclopenta-fused arenes and heteroarenes. This transformation happens at mild condition and tolerant to a variety of functional groups. Furthermore, we have also developed an organophosphine catalyzed intramolecular  $\delta'$ -[C(sp<sup>3</sup>)-H]-functionalization of activated ynones which provides direct access to aldol product 3-ethynyl-3-hydroxyindanones. To the best of our knowledge, this study demonstrate a phosphine catalyzed aldol reaction of keto-ynones. This transformation take place at mild condition and due to tolerant to a variety of functional groups, we were able to synthesized a series of 3-ethynyl-3-hydroxyindanones having different type of functional group.

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## List of Publications:

- "Organophosphine Catalyzed Intramolecular Hydroacylation of Activated Alkynes." Atanu Mondal; **Raju Hazra**; Jagdeep Grover; Raghu Moluguri; S.S.V Ramasastry\*. *ACS Catal.* **2018**, 8, 2748-2753.
- "Organocatalytic  $\gamma$ -[ C(Sp<sup>3</sup>)-H ] Functionalization of Ynones: An Unusual Approach for the Cyclopentannulation of Benzothiophenes." Jagdeep Grover<sup>†</sup>; Raghu Moluguri<sup>†</sup>; **Raju Hazra**; Atanu Mondal; S.S.V Ramasastry\*. *Synthesis* **2018**, 50, 1462-1470 [ <sup>†</sup> These authors contributed equally to this work].
- "1,6-Hydroolefination and Cascade Cyclization of p-Quinone Methides with Unactivated Olefins: Total Synthesis of (±)-Isopaucifloral F." Abhijeet Jadhav<sup>†</sup>; Yogesh Pankhade<sup>†</sup>; **Raju Hazra**; Ramasamy Vijaya Anand\*. *J. Org. Chem.* **2018**, 83, 10107-10119 [ <sup>†</sup> These authors contributed equally to this work ].