Supplementary Information

Easy access to medium-sized lactones through metal carbene migratory insertion enabled 1,4-palladium shift

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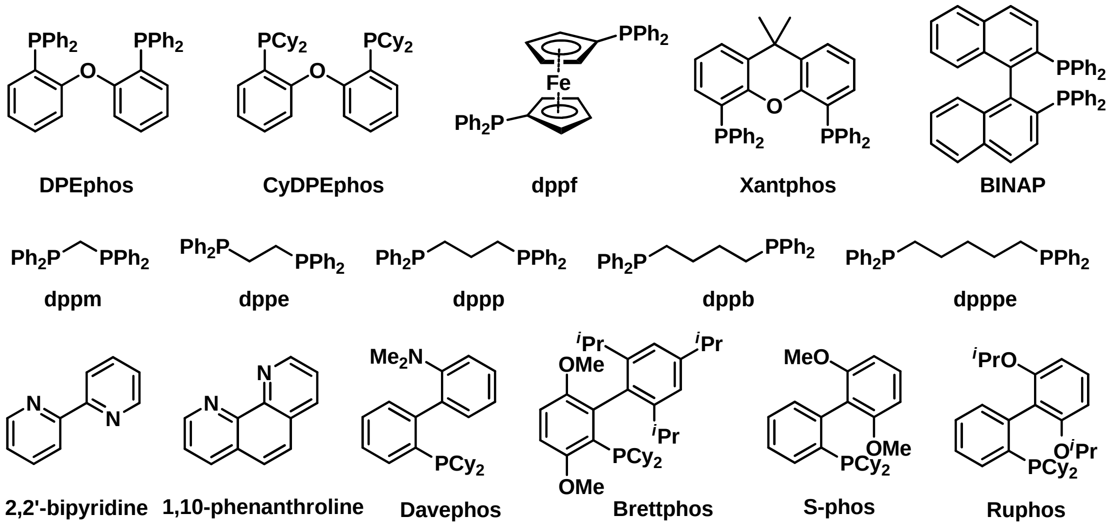
Supplementary Methods

General information

Chemicals were purchased from commercial suppliers and used without further purification unless otherwise stated. Solvents were dried by Innovative Technology Solvent Purification System. Reaction progress was monitored by thin layer chromatography (TLC) and components were visualized by observation under UV light at 254nm. Flash column chromatography was performed using silica gel 60 (200-300 mesh). ^{1}H, ^{13}C and ^{19}F NMR spectra were recorded on Bruker-BioSpin AVANCE III HD and JNM-ECZ600S spectrometer. Chemical shifts are reported parts per million (ppm) referenced to $CDCl_3$ (δ 7.26 ppm), tetramethylsilane (TMS, δ 0.00 ppm), DMSO-d_6 (δ 2.50 ppm), CD_3CN (δ 1.94 ppm) for ^{1}H NMR; $CDCl_3$ (δ 77.00 ppm), DMSO-d_6 (δ 40.00 ppm), CD_3CN (δ 118.0 ppm) for ^{13}C NMR. Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet; d = doublet; t = triplet; q = quartet; p = pentet; m = multiplet; br = broad), coupling constant (Hz), integration. Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm). HRMS were obtained on Thermo Scientific LTQ Orbitrap XL and Bruker Impact II UHR-TOF.

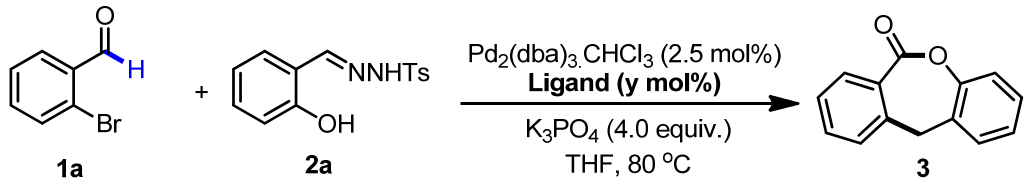
Optimization of the reaction conditions



Optimization of the reaction conditions for seven-membered lactone in terms of 2-bromobenzaldehyde.

An oven-dried reaction tube containing a stirring bar was charged with Pd precatalyst (**x** mol%), ligand (**y** mol%), base (**z** equiv.) and **2a** (0.4 mmol, 116 mg). After evacuating and back filling with dry argon, the procedure was repeated for three times, anhydrous solvent (2.0 mL) and **1a** (0.2 mmol, 37 mg) were added via syringe. The mixture was stirred at 80 ^{o}C for 24 h. The crude mixture was cooled to room temperature. EtOAc was added to the mixture. The mixture was filtered through celite. The solvents were evaporated and the crude products were determined via ^{1}H NMR using mesitylene as internal standard.

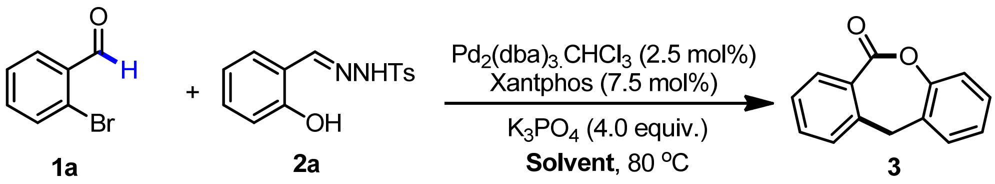
Supplementary Table 1. Screening of ligands[a]



Entry	Ligand (y mol%)	3 (%)[b]
1	DPEphos (7.5)	5
2	dppe (7.5)	52[c]
3	dppf (7.5)	49[c]
4	Tri-2-furylphosphine (15)	0
5	Tri-*o*-tolylphosphine (15)	0
6	**Xantphos (7.5)**	**77**
7	dppp (7.5)	67
8	dpppe (7.5)	35
9	BINAP (7.5)	2
10	dppb (7.5)	57
11	dppm (7.5)	0
12	CyDPEphos (7.5)	0

[a] Reaction condition: **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd_2(dba)_3.CHCl_3$ (2.5 mol%), **Ligand (y mol%)**, K_3PO_4 (4.0 equiv) in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 24h.
[b] NMR yields were determined using mesitylene as internal standard. [c] Isolated yield.

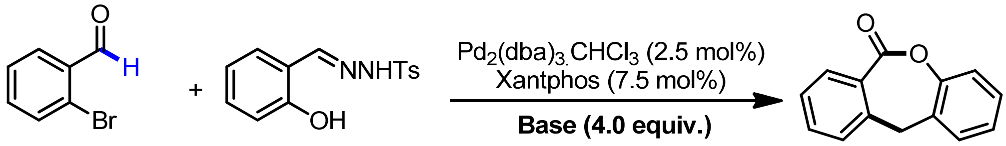
Supplementary Table 2. Screening of solvents[a]



Entry	Solvent	3 (%)[b]
1	MeCN	1
2	Toluene	0.2
3	DMF	trace
4	Dioxane	77
5	DCE	NP
6	PhCl	NP
7	MTBE	NP
8	DME	NP

[a] Reaction condition: **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd_2(dba)_3.CHCl_3$ (2.5 mol%), Xantphos (7.5 mol%), K_3PO_4 (4.0 equiv) in **solvent** (2.0 mL), stirring under atmosphere of Argon at 80 °C for 24h.
[b] NMR yields were determined using mesitylene as internal standard.

Supplementary Table 3. Screening of bases[a]

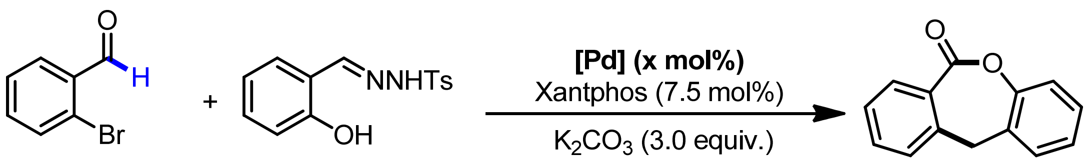


1a 0.2 mmol; 2a 0.4 mmol; 3

Entry	Base (4.0 equiv.)	3 (%)[b]
1	Cs_2CO_3	0
2	KOAc	5
3	LiO^tBu	0
4	NaOMe	5
5	Na_2CO_3	0
6	$NaHCO_3$	0
7	NaOAc	0
8	**K_2CO_3**	**80 (74)[c,d]**

[a] Reaction condition: **1a** (0.2 mmol), **2a** (0.4 mmol), $Pd_2(dba)_3$.$CHCl_3$ (2.5 mol%), Xantphos (7.5 mol%), **base (4.0 equiv)** in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 24h.
[b] NMR yields were determined using mesitylene as internal standard. [c] Isolated yield. [d] 12h.

Supplementary Table 4. Screening of palladium sources[a]



1a; 2a; 3

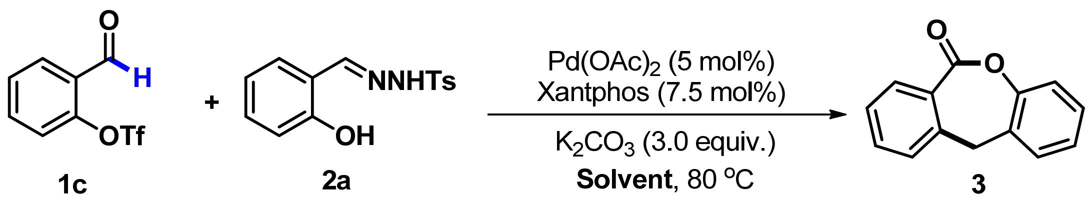
Entry	[Pd] (x mol%)	3 (%)[b]
1	**$Pd(OAc)_2$ (5)**	**76 (76)[c]**
2	$PdCl_2$ (5)	73 (73)[c]
3	$(\eta^3\text{-}C_3H_5)_2Pd_2Cl_2$ (2.5)	84 (75)[c]
4	$Pd(MeCN)_2Cl_2$ (5)	(69)[c]
5	$Pd(SMe_2)_2Cl_2$ (5)	(61)[c]

[a] Reaction condition: **1a** (0.2 mmol), **2a** (0.4 mmol), **[Pd] (x mol%)**, Xantphos (7.5 mol%), K_2CO_3 (3.0 equiv.) in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 12h.
[b] NMR yields were determined using mesitylene as internal standard. [c] Isolated yield.

Optimization of the reaction conditions for seven-membered lactone in terms of 2-formylphenyl trifluoromethanesulfonate.

An oven-dried reaction tube containing a stirring bar was charged with Pd precatalyst (**x** mol%), ligand (7.5 mol%), base (3.0 equiv.) and **2a** (0.4 mmol, 116 mg). After evacuating and back filling with dry argon, the procedure was repeated for three times, anhydrous solvent (2.0 mL) and **1c** (0.2 mmol, 51 mg) were added via syringe. The mixture was stirred at 80 °C for 12 h. The crude mixture was cooled to room temperature. Decane (0.2 mmol, 1.0 equiv., 39 μL) was added via microsyringe followed by 5 mL of EtOAc. An aliquot was filtered through a plug of silica and celite and analyzed by GC.

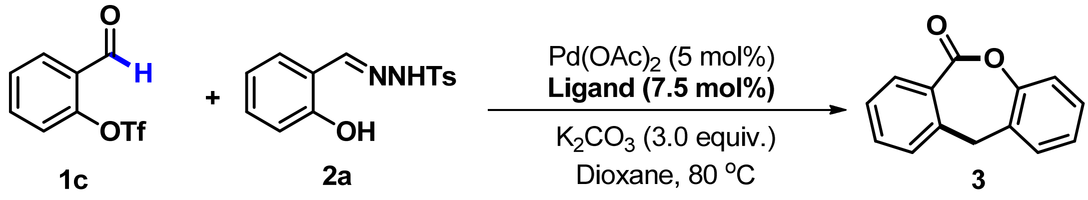
Supplementary Table 5. Screening of solvents[a]



Entry	Solvent	3 (%)[b]
1	THF	53
2	Dioxane	63

[a]Reaction condition: **1c** (0.2 mmol), **2a** (0.4 mmol), Pd(OAc) (5 mol%), Xantphos (7.5 mol%), K_2CO_3 (3.0 equiv) in **solvent** (2.0 mL), stirring under atmosphere of Argon at 80 °C for 12h.
[b] GC yields were determined using decane as internal standard.

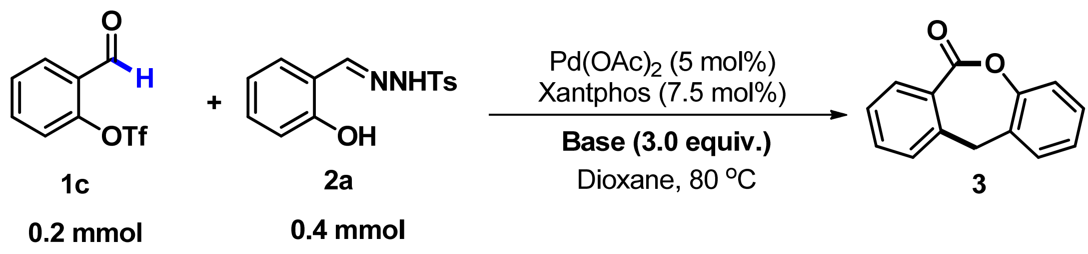
Supplementary Table 6. Screening of ligands[a]



Entry	Ligand	3 (%)[b]
1	Xantphos	63
2	dppm	trace
3	dppe	18
4	dppp	29
5	dppb	15
6	dpppe	15
7	dppf	22
8	BINAP	trace
9	DPEphos	trace
10	CyDPEphos	trace

[a] Reaction condition: **1c** (0.2 mmol), **2a** (0.4 mmol), Pd(OAc) (5 mol%), **Ligand** (7.5 mol%), K_2CO_3 (3.0 equiv) in dioxane (2.0 mL), stirring under atmosphere of Argon at 80 °C for 12h.
[b] GC yields were determined using decane as internal standard.

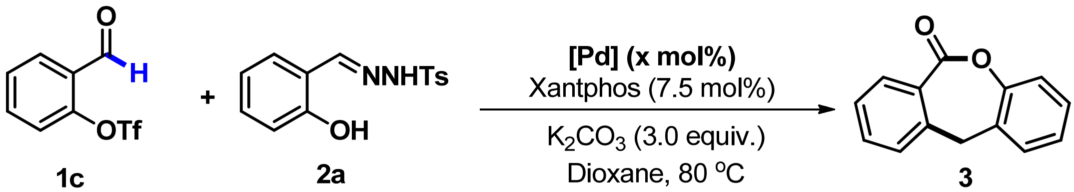
Supplementary Table 7. Screening of bases[a]



Entry	Base	3 (%)[b]
1	K_3PO_4	53
2	Cs_2CO_3	15
3	LiO^tBu	5
4	KOAc	trace
5	NaOMe	trace
6	K_2CO_3	63

[a] Reaction condition: **1c** (0.2 mmol), **2a** (0.4 mmol), Pd(OAc) (5 mol%), Xantphos (7.5 mol%), **base** (3.0 equiv) in dioxane (2.0 mL), stirring under atmosphere of Argon at 80 °C for 12h.
[b] GC yields were determined using decane as internal standard.

Supplementary Table 8. Screening of palladium sources[a]



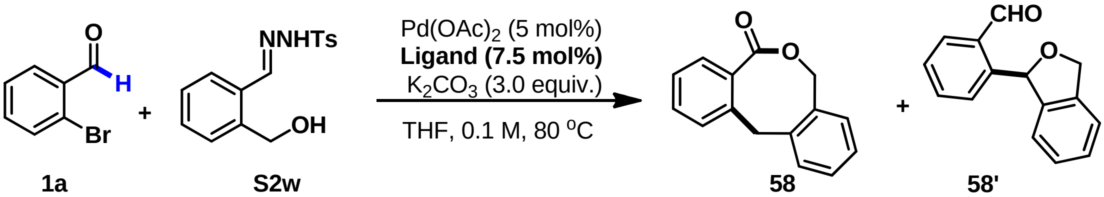
Entry	[Pd] (x mol%)	3 (%)[b]
1	$Pd(OAc)_2$ (5)	63
2	$PdCl_2$ (5)	52
3	$Pd(TFA)_2$ (5)	76
4	**(η-$C_3H_5)_2Pd_2Cl_2$ (2.5)**	**85(80)[c]**
5	$Pd(MeCN)_2Cl_2$ (5)	85(79)[c]
6	$Pd_2(dba)_3.CHCl_3$ (2.5)	78

[a] Reaction condition: **1c** (0.2 mmol), **2a** (0.4 mmol), **[Pd] (x mol%)**, Ligand (7.5 mol%), K_2CO_3 (3.0 equiv) in dioxane (2.0 mL), stirring under atmosphere of Argon at 80 °C for 12h. [b] GC yields were determined using decane as internal standard. [c] isolated yield.

Optimization of the reaction conditions for eight-membered lactone.

An oven-dried reaction tube containing a stirring bar was charged with Pd precatalyst (5 mol%), ligand (7.5 mol%), base (3.0 equiv.) and **S2w** (0.4 mmol). After evacuating and back filling with dry argon, the procedure was repeated for three times, anhydrous solvent (2.0 mL) and **1a/ 1b/ 1c** (0.2 mmol) were added via syringe. The mixture was stirred at 80 °C for 10 h. The crude mixture was cooled to room temperature. EtOAc was added to the mixture. The mixture was filtered through celite. The solvents were evaporated and the crude products were determined via ^{1}H NMR using dibromomethane as internal standard.

Supplementary Table 9. Screening of ligands[a]

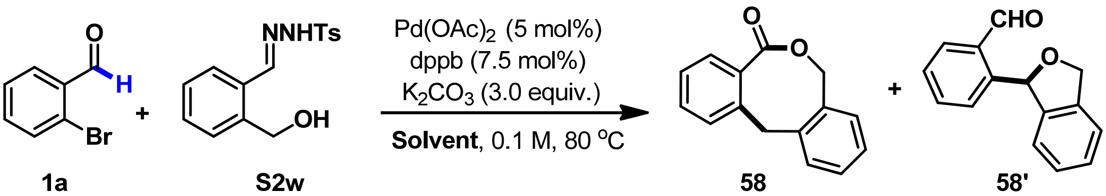


1a **S2w** **58** **58'**

Entry	Ligand (7.5 mol%)	58 (%)[b]	58' (%)[b]
1	Xantphos	15	trace
2	DPEphos	27	8
3	P-(2-furyl)$_3$	-	-
4	Ruphos	trace	-
5	S-phos	trace	-
6	**dppb**	**47(30)[c]**	**7**
7	dppf	-	-
8	PPh_3	12	trace
9	BINAP	-	-
10	Brettphos	14	-
11	Davephos	12	-
12	P-(*o*-tolyl)$_3$	19	-
13	P-(*p*-$C_6H_5CF_3$)$_3$	14	-
14	P(Cy)$_3$.HBF_4	10	-
12	2,2'-bipyridine	-	-
13	1,10-phenanthroline	-	-

[a] Reaction condition: **1a** (0.2 mmol), **S2w** (0.4 mmol), Pd(OAc)$_2$ (5 mol%), **Ligand** (7.5 mol%), K_2CO_3 (3.0 equiv.) in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 10 h. [b] NMR yields were determined using dibromomethane as internal standard. [c] Isolated yield.

Supplementary Table 10. Screening of solvents[a]

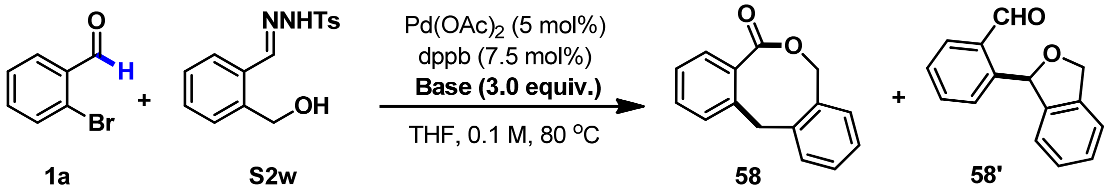


1a **S2w** **58** **58'**

Entry	Solvent	58 (%)[b]	58' (%)[b]
1	Toluene	45	8
2	DMF	-	-
3	Dioxane	23	-
4	Acetonitrile	trace	-
5	DME	44	7
6	$PhCF_3$	46	9
7	**THF**	**47**	**7**

[a] Reaction condition: **1a** (0.2 mmol), **S2w** (0.4 mmol), Pd(OAc)$_2$ (5 mol%), dppb (7.5 mol%), K_2CO_3 (3.0 equiv.) in **solvent** (2.0 mL), stirring under atmosphere of Argon at 80 °C for 10 h.
[b] NMR yields were determined using dibromomethane as internal standard.

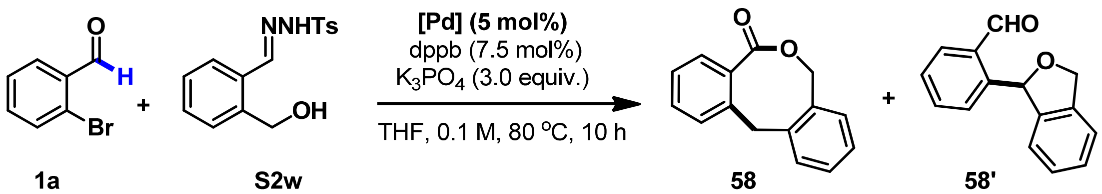
Supplementary Table 11. Screening of bases[a]



Entry	Base	58 (%)[b]	58' (%)[b]
1	$NaHCO_3$	trace	-
2	Na_2CO_3	trace	-
3	**K_3PO_4**	**56 (44)[c]**	**10**
4	Cs_2CO_3	36	6
5	LiO^tBu	-	-
6	KOH	37	9
7	KH_2PO_4	trace	-
8	K_3PO_4 (4.0 equiv.)	52	10
9	KOAc	31	14

[a] Reaction condition: **1a** (0.2 mmol), **S2w** (0.4 mmol), $Pd(OAc)_2$ (5 mol%), dppb (7.5 mol%), **Base (3.0 equiv.)** in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 10 h.
[b] NMR yields were determined using dibromomethane as internal standard. [c] Isolated yield.

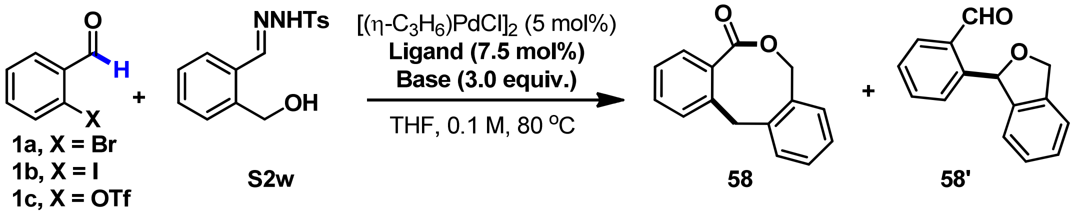
Supplementary Table 12. Screening of palladium sources[a]



Entry	[Pd] (5 mol%)	58 (%)[b]	58' (%)[b]
1	$Pd(PPh_3)_2Cl_2$	38	8
2	$PdCl_2$	38	9
3	**$[(\eta\text{-}C_3H_6)PdCl]_2$**	**72 (64)[c]**	**6**
4	$Pd(TFA)_2$	-	-
5	$Pd(OAc)_2$	56 (44)[c]	9
6	$Pd(dba)_2$	44	12

[a] Reaction condition: **1a** (0.2 mmol), **S2w** (0.4 mmol), **[Pd] (5 mol%)**, dppb (7.5 mol%), K_3PO_4 (3.0 equiv.) in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 10 h.
[b] NMR yields were determined using dibromomethane as internal standard. [c] Isolated yield.

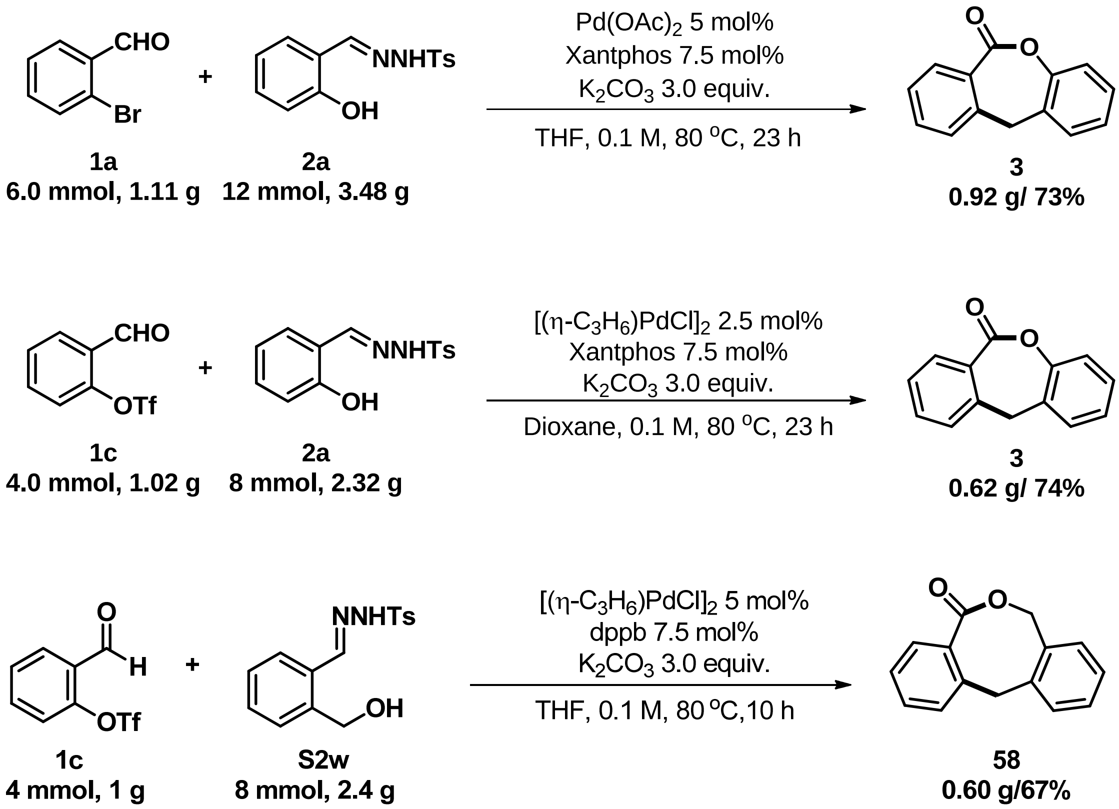
Supplementary Table 13. Final screening: achieving optimal conditions[a]



Entry	X	Ligand	Base	58 (%)[b]	58' (%)[b]
1	Br	dppb	K_2CO_3	74 (64)[c]	8
2	Br	dppb	Cs_2CO_3	23	5
3	I	dppb	K_3PO_4	trace	-
4	Cl	dppb	K_3PO_4	-	-
5	OTf	dppb	K_3PO_4	75 (71)[c]	7
6	**OTf**	**dppb**	**K_2CO_3**	**85 (76)[c]**	**7 (5)[c]**
7	OTf	dppm	K_2CO_3	40	10
8	OTf	dppe	K_2CO_3	40	9
9	OTf	dppp	K_2CO_3	72	10
10	OTf	dpppe	K_2CO_3	54	9
11[d]	OTf	dppb	K_2CO_3	78 (71)[c]	15 (11)[c]

[a] Reaction condition: **1a/ 1b/ 1c** (0.2 mmol), **S2w** (0.4 mmol), [(η-C_3H_6)PdCl]$_2$ (5 mol%), **Ligand (7.5 mol%)**, **Base(3.0 equiv.)** in THF (2.0 mL), stirring under atmosphere of Argon at 80 °C for 10 h. [b] NMR yields were determined using dibromomethane as internal standard. [c] Isolated yield.
[d] [(η-C_3H_6)PdCl]$_2$ (2.5 mol%), dppb (7.5 mol%) for 16 h.

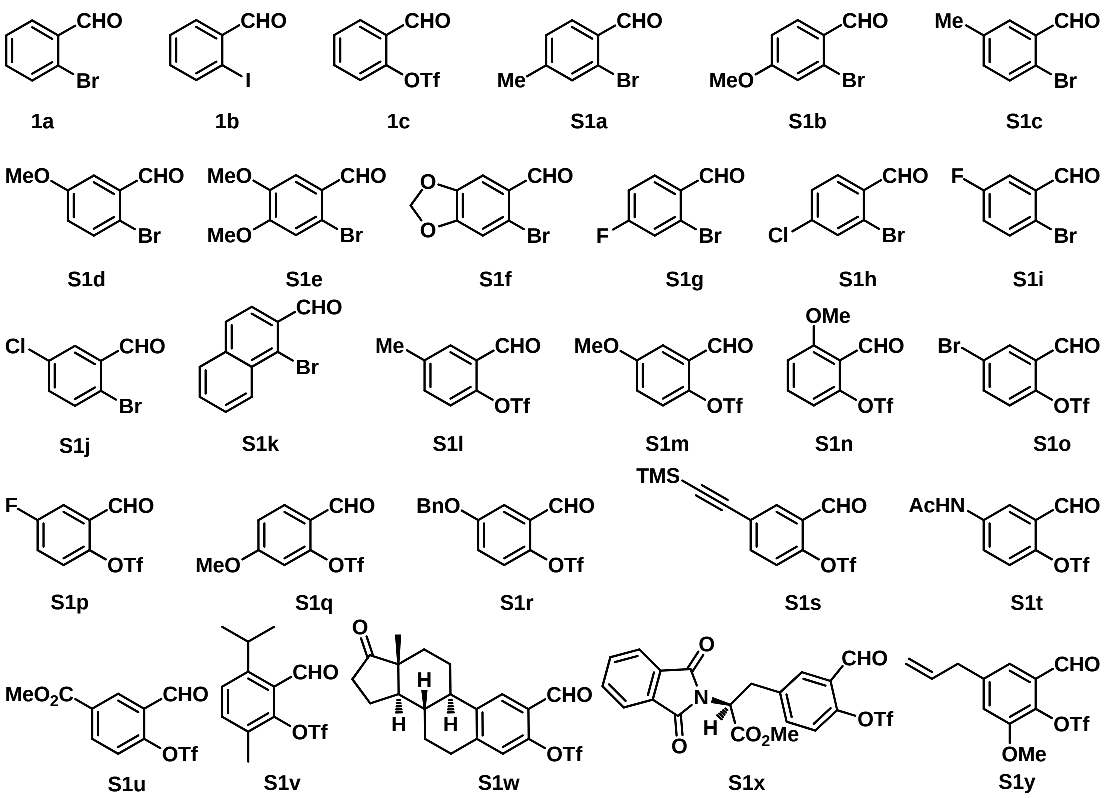
Gram-scale synthesis



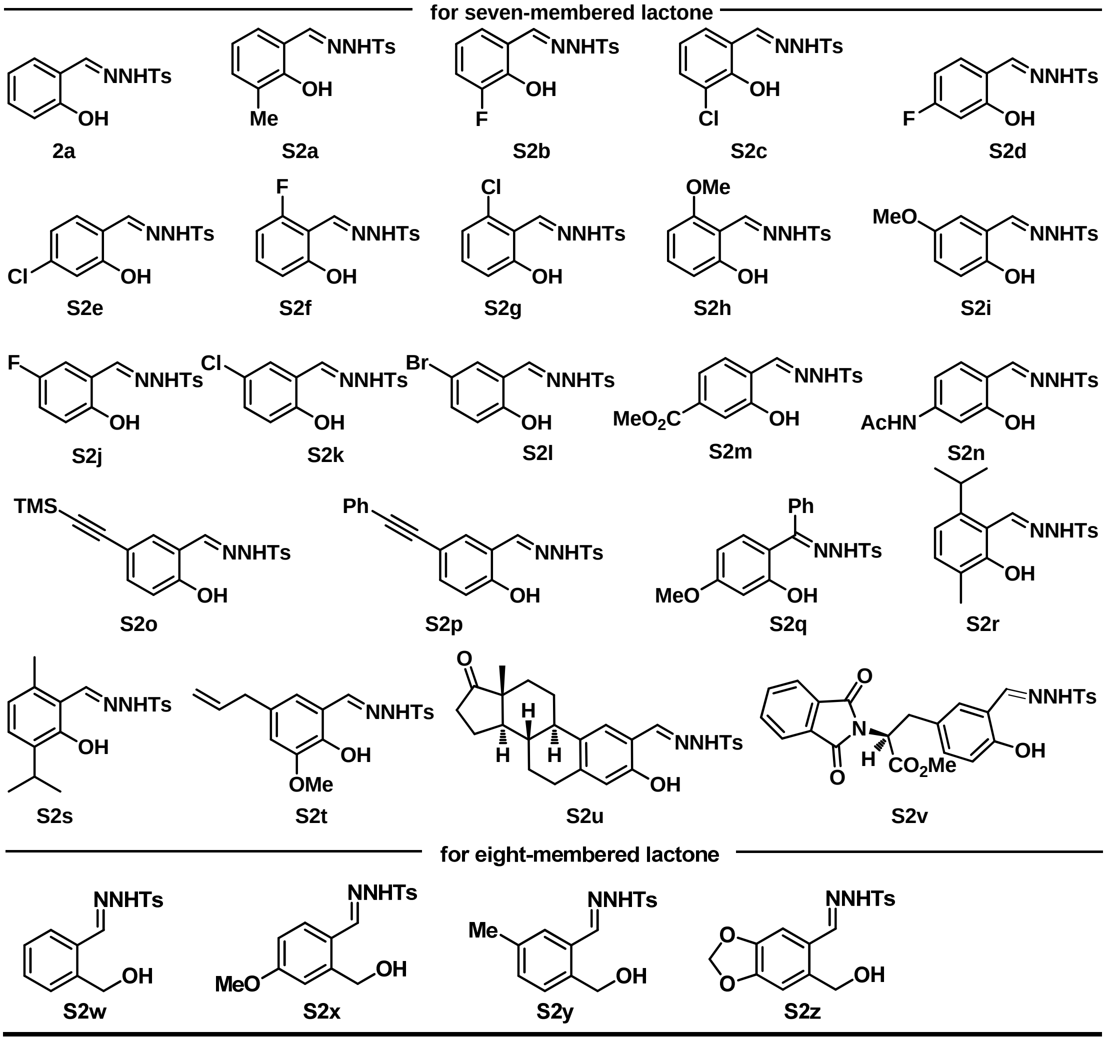
Supplementary Figure 1. Gram-scale synthesis. Synthesis of lactones under optimal reaction conditions.

Substrates involved in the manuscript

Aldehyde derivatives:



N-tosylhydrazone:

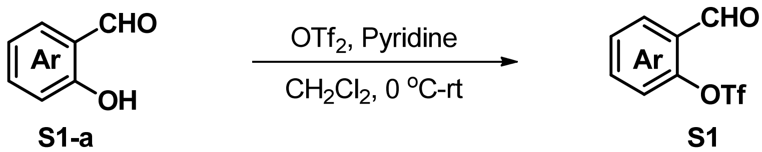


Supplementary Figure 2. Substrates involved in the manuscript.

Procedures for the preparation of substrates

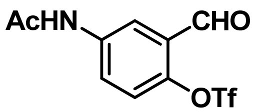
The salicylaldehyde analogues with substituents on the aromatic ring **S1s-a**[1], **S1t-a** (paracitamol)[2], **S1u-a** (methylparaben)[3,4], **S1v-a** (thymol)[3,4], **S1w-a** (estrone)[5], **S1x-a** (methyl N-Phth-L-tyrosinate)[5] were prepared according to the reference. The other salicylaldehyde analogues were commercial available.

5.1 General procedure for the synthesis S1[6]



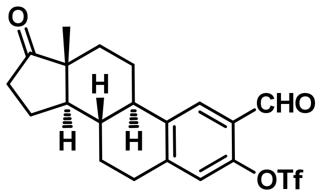
To a solution of salicylaldehyde (2.44 g, 20 mmol) in CH_2Cl_2 (60 mL) were successively added pyridine (4.8 mL, 60 mmol) and Tf_2O (5.0 mL, 30 mmol) at 0 °C. After being stirred for 3 h at room temperature, the reaction was stopped by adding saturated aqueous $NaHCO_3$ at 0 °C. The crude products were extracted with CH_2Cl_2 (x 4) and the combined organic extracts were washed with 1 M aqueous HCl (x1), brine, dried (Na_2SO_4), and concentrated in vacuo. The residue was purified by column chromatography (silica gel, PE/EtOAc = 10/1) to give **1c** (4.63 g, 91%) as a colorless oil.

4-Acetamido-2-formylphenyl trifluoromethanesulfonate (S1t)



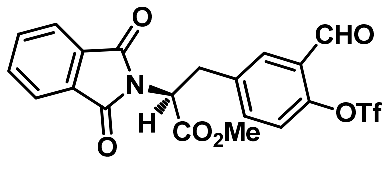
Yield 70%, slightly yellow solid; R_f = 0.30 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (600 MHz, DMSO-*d₆*)** δ 10.48 (s, 1H), 10.04 (s, 1H), 8.28 (d, *J* = 2.4 Hz, 1H), 7.95 (dd, J_1 = 9.0 Hz, J_2 = 3.0 Hz, 1H), 7.54 (d, J = 9.0 Hz, 1H), 2.09 (s, 3H); **^{13}C NMR (151 MHz, DMSO-d_6)** δ 189.2, 169.6, 143.0, 140.6, 128.8, 125.9, 123.9, 122.9, 122.8, 118.7 (q, J = 320.7 Hz), 24.5; **^{19}F NMR (376 MHz, DMSO-d_6)** δ -73.1; **HRMS (ESI)** m/z calcd for $C_{10}H_9F_3NO_5S^+$ $(M+H)^+$ 312.01480, found 312.01489.

(8S,9R,13R,14R)-2-Formyl-13-methyl-17-oxo-7,8,9,11,12,13,14,15,16,17-decahydro-6H-cyclopenta[a]phenanthren-3-yl trifluoromethanesulfonate (S1w)



Yield 80%, White solid; R_f = 0.40 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (600 MHz, CDCl$_3$)** δ 10.11 (s, 1H), 7.85 (s, 1H), 7.07 (s, 1H), 3.03-2.93 (m, 2H), 2.47 (q, J = 9.0 Hz, 2H), 2.30 (dd, J_1 = 10.8 Hz, J_2 = 3.6 Hz, 1H), 2.15-2.02 (m, 3H), 1.96 (d, J = 13.8 Hz, 1H), 1.65-1.44 (m, 6H), 0.88 (s, 3H); **^{13}C NMR (151 MHz, CDCl$_3$)** δ 219.9, 186.4, 147.4, 146.5, 141.1, 128.1, 125.8, 122.2, 118.4 (q, J = 320.9 Hz), 50.1, 47.6, 43.7, 37.3, 35.6, 31.2, 29.7, 25.6, 25.4, 21.4, 13.6; **^{19}F NMR (376 MHz, CDCl$_3$)** δ -72.9; **HRMS (ESI)** m/z calcd for $C_{20}H_{22}F_3O_5S^+$ $(M+H)^+$ 431.11346, found 431.11340.

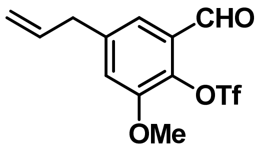
(S)-Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-(3-formyl-4-(((trifluoromethyl)sulfonyl)oxy)phenyl)propanoate (S1x)



Yield 81%, White solid; R_f = 0.40 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (600 MHz, CDCl$_3$)** δ 10.09 (s, 1H), 7.79-7.76 (m, 3H), 7.70-7.69 (m, 2H), 7.53 (dd, J_1 = 8.4 Hz, J_2 = 1.8 Hz, 1H), 7.24 (d, J = 8.4 Hz, 1H), 5.15 (q, J = 5.4 Hz, 1H), 3.74 (s, 3H), 3.68 (dd, J_1 =

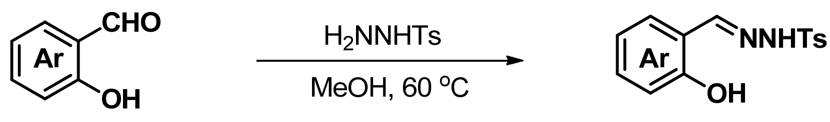
14.4 Hz, J_2 = 5.4 Hz, 1H), 3.58 (dd, J_1 = 14.4 Hz, J_2 = 10.8 Hz, 1H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 186.2, 168.6, 167.2, 148.4, 138.4, 136.1, 134.4, 131.3, 131.2, 128.2, 123.6, 122.5, 118.4 (q, J = 327.4 Hz,), 53.0, 52.3, 34.0; **^{19}F NMR (376 MHz, $CDCl_3$)** δ -72.9; **HRMS (ESI)** m/z calcd for $C_{20}H_{15}F_3NO_8S^+$ $(M+H)^+$ 486.04650, found 486.04681.

4-Allyl-2-formyl-6-methoxyphenyl trifluoromethanesulfonate (S1y)



Yield 87%, White solid; R_f = 0.50 (petroleum ether : ethyl acetate = 20 : 1); **^{1}H NMR (600 MHz, $CDCl_3$)** δ 10.15 (s, 1H), 7.30 (d, J = 2.4 Hz, 1H), 7.12 (d, J = 2.4 Hz, 1H), 5.94-5.87 (m, 1H), 5.15-5.10 (m, 2H), 3.92 (s, 3H), 3.42 (d, J = 7.2 Hz, 2H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 186.7, 151.4, 141.9, 137.3, 135.3, 129.0, 120.9, 118.7, 118.5 (q, J = 318.9 Hz), 117.4, 56.3, 39.6; **^{19}F NMR (376 MHz, $CDCl_3$)** δ -72.9; **HRMS (ESI)** m/z calcd for $C_{12}H_{12}F_3O_5S^+$ $(M+H)^+$ 325.03521, found 325.03506.

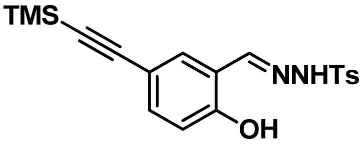
5.2 General procedure for the synthesis of *N*-tosylhydrazones used for seven-membered lactones[7]



S1-a S2

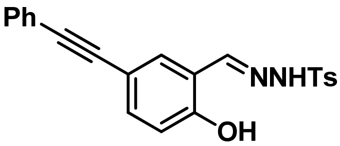
Salicylaldehyde (4.8 mL, 44 mmol) was dissolved in methanol (30 mL), then $TsNHNH_2$ (7.44 g, 40 mmol) was added to the reaction mixture. The resulting mixture was heated at 60 ^{o}C for 2 h. After cooling to room temperature, the precipitates were filtered and washed by petroleum ether, and then kept in desiccator under vacuum to afford pure product **2a** (10.4 g, 90%).

N'-(2-hydroxy-5-((trimethylsilyl)ethynyl)benzylidene)-4-methylbenzenesulfonohydrazide (S2o)



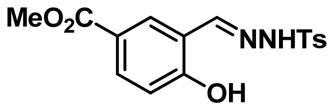
Yield 87%, white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 10.33 (s, 1H), 8.36 (s, 1H), 7.88 (s, 1H), 7.84 (d, *J* = 8.0 Hz, 2H), 7.38-7.34 (m, 3H), 7.26-7.25 (m, 1H), 6.86 (d, *J* = 8.8 Hz, 1H), 2.42 (s, 3H), 0.22 (s, 9H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 158.0, 150.9, 145.1, 135.6, 134.7, 134.1, 130.1, 127.8, 117.2, 116.9, 114.5, 103.9, 93.1, 21.6, -0.1; **HRMS (ESI)** m/z calcd for $C_{19}H_{23}N_2O_3SSi^+$ $(M+H)^+$ 387.11932, found 387.11972.

N'-(2-hydroxy-5-(phenylethynyl)benzylidene)-4-methylbenzenesulfonohydrazide (S2p)



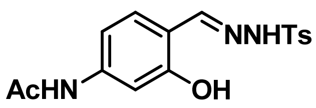
Yield 89%, white solid; R_f= 0.50 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 10.35 (s, 1H), 8.32-8.28 (m, 1H), 7.92 (s, 1H), 7.85 (d, *J* = 8.4 Hz, 2H), 7.49-7.47 (m, 2H), 7.43 (dd, J_1 = 8.8 Hz, J_2 = 2.0 Hz, 1H), 7.36-7.32 (m, 6H), 6.92 (d, *J* = 8.8 Hz, 1H), 2.42 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 158.0, 151.1, 145.1, 135.3, 134.3, 134.1, 131.4, 130.1, 128.4, 128.2, 127.9, 123.1, 117.5, 117.0, 114.6, 88.4, 88.2, 21.7; **HRMS (ESI)** m/z calcd for $C_{22}H_{19}N_2O_3S^+$ $(M+H)^+$ 391.11109, found 391.11127.

Methyl 4-hydroxy-3-((2-tosylhydrazono)methyl)benzoate (S2m)



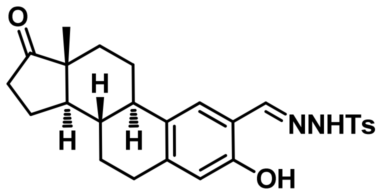
Yield 65%, white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 1 : 1); **^{1}H NMR (400 MHz, DMSO-d_6)** δ 11.63 (s, 1H), 11.09 (s, 1H), 8.22 (s, 1H), 8.14 (d, J = 2.0 Hz, 1H), 7.83 (dd, J_1 = 8.8 Hz, J_2 = 2.0 Hz, 1H), 7.76 (d, J = 8.4 Hz, 2H), 7.43 (d, J = 8.4 Hz, 2H), 6.97 (d, J = 8.8 Hz, 1H), 3.83 (s, 3H), 2.37 (s, 3H); **^{13}C NMR (101 MHz, DMSO-d_6)** δ 166.2, 160.8, 144.4, 144.2, 136.5, 132.9, 130.3, 128.7, 127.6, 121.3, 120.1, 116.9, 52.4, 21.54; **HRMS (ESI)** m/z calcd for $C_{16}H_{17}N_2O_5S^+$ $(M+H)^+$ 349.08527, found 349.08502.

N-(3-hydroxy-4-((2-tosylhydrazono)methyl)phenyl)acetamide (S2n)



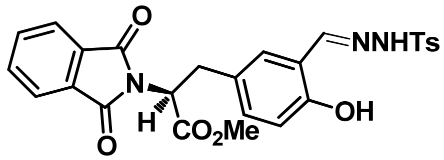
Yield 78%, white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 1 : 3); **^{1}H NMR (400 MHz, DMSO-d_6)** δ11.43 (s, 1H), 9.92 (s, 1H), 9.81 (s, 1H), 8.14 (s, 1H), 7.74 (d, J = 8.0 Hz, 2H), 7.66 (d, J = 2.4 Hz, 1H), 7.49 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.42 (d, J = 8.0 Hz, 2H), 6.78 (d, J = 8.8 Hz, 1H), 2.36 (s, 3H), 1.99 (s, 3H); **^{13}C NMR (101 MHz, DMSO-d_6)** δ 168.3, 152.8, 145.5, 144.1, 136.5, 132.0, 130.3, 127.6, 123.6, 119.5, 117.6, 117.0, 24.3, 21.6; **HRMS (ESI)** m/z calcd for $C_{16}H_{18}N_3O_4S^+$ $(M+H)^+$ 348.10125, found 348.10110.

N'-(((8*S*,9*R*,13*R*,14*R*)-3-hydroxy-13-methyl-17-oxo-7,8,9,11,12,13,14,15,16,17-decahydro-6H-cyclopenta[*a*]phenanthren-2-yl)methylene)-4-methylbenzenesulfonohydrazide (S2u)



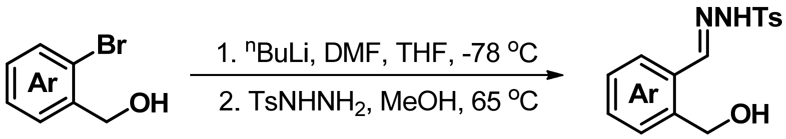
Yield 62%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 9.99 (s, 1H), 8.34 (s, 1H), 7.97 (s, 1H), 7.82 (d, *J* = 8.4 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 2H), 7.01 (s, 1H), 6.67 (s, 1H), 2.88-2.85 (m, 2H), 2.52 (dd, J_1 = 19.2 Hz, J_2 = 8.8 Hz, 1H), 2.40 (s, 3H), 2.33-1.93 (m, 6H), 1.66-1.35 (m, 6H), 0.89 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 221.7, 155.6, 152.4, 144.6, 141.5, 134.4, 131.2, 129.9, 127.9, 127.8, 116.6, 115.0, 50.2, 48.0, 43.4, 38.0, 35.9, 31.4, 29.4, 26.2, 25.8, 21.6, 21.5, 13.7. **HRMS (ESI)** m/z calcd for $C_{26}H_{31}N_2O_4S^+$ $(M+H)^+$ 467.19990, found 467.20020.

(S)-Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-(4-hydroxy-3-((2-tosylhydrazono)methyl)phenyl)propanoate (S2v)



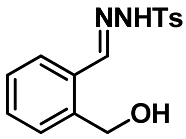
Yield 86%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (400 MHz, DMSO-*d*$_6$)** δ 11.41 (s, 1H), 10.06 (s, 1H), 8.04 (s, 1H), 7.86 (s, 4H), 7.73 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 8.0 Hz, 2H), 7.32 (d, *J* = 1.2 Hz, 1H), 7.02 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 5.22 (dd, J_1 = 11.2 Hz, J_2 = 4.8 Hz, 1H), 3.70 (s, 3H), 3.40 (d, *J* = 4.8 Hz, 1H), 3.25-3.19 (m, 1H), 2.38 (s, 3H); **^{13}C NMR (101 MHz, DMSO-*d*$_6$)** δ 169.6, 167.5, 155.7, 146.2, 144.1, 136.3, 135.6, 132.4, 131.1, 130.3, 128.2, 128.1, 127.7, 124.1, 119.4, 116.7, 53.3, 53.2, 33.6, 21.6; **HRMS (ESI)** m/z calcd for $C_{26}H_{24}N_3O_7S^+$ $(M+H)^+$ 522.13295, found 522.13330.

5.3 General procedure for the synthesis of *N*-tosylhydrazones used for eight-membered lactones



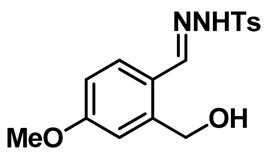
^{n}BuLi (2.5 equiv, 50 mmol) was added slowly to a solution of (2-bromoaryl)methanol (20 mmol) in 20 mL of dry THF at -78 °C. The resulting mixture was stirred at that temperature for 30 minutes and dry DMF (2.0 equiv) was added to the solution dropwise. After stirring at -78 °C for another 30 minutes, the reaction flask was taken out from the low-temperature bath and stirred for 10 minutes in an ice-bath. The conversion of starting into product could be checked by TLC. The reaction was then quenched by adding 10 mL of aq. solution of ammonium chloride. 20 mL of ethyl acetate was added and reaction mixture was stirred at room temperature for 15 minutes. It was then filtered via a short pad of celite and the filtrate was extracted by ethyl acetate (3 X 25 mL). The combined ethyl acetate layers were washed with brine, dried over anhydrous Na_2SO_4 and solvent was removed under reduced pressure. The residue thus obtained was dissolved in DCM and passed through a short pad of silica gel using DCM as eluent. The solvent was removed under reduced pressure. The residue was then dissolved in methanol (20 mL), $TsNHNH_2$ was added and the mixture was heated at 65 °C for 1 h. The reaction flask was then cooled to room temperature during which white precipitate appeared (In case if precipitate didn't appeare petroleum ether could be added). The precipitate was then filtered, and washed with DCM to get pure *N*-tosylhydrzones.

N'-(2-(hydroxymethyl)benzylidene)-4-methylbenzenesulfonohydrazide (S2w)



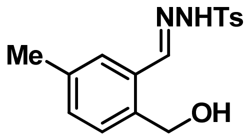
Yield 68%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 1 : 1); **^{1}H NMR (400 MHz, DMSO-*d$_6$*)** δ 11.43 (s, 1H), 8.19 (s, 1H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 7.6 Hz, 1H), 7.45-7.40 (m, 3H), 7.35 (t, *J* = 7.6 Hz, 1H), 7.28 (t, *J* = 7.2 Hz, 1H), 5.21 (t, *J* = 5.2 Hz, 1H), 4.54 (d, *J* = 5.2 Hz, 2H), 2.36 (s, 3H); **^{13}C NMR (101 MHz, DMSO-*d$_6$*)** δ 146.8, 144.0, 141.3, 136.6, 131.4, 130.2, 130.1, 128.4, 127.8, 127.7, 127.3, 61.7, 21.5.

N'-(2-(hydroxymethyl)-4-methoxybenzylidene)-4-methylbenzenesulfonohydrazide (S2x)



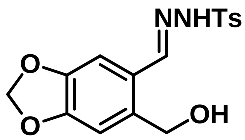
Yield 64%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 1 : 2); **^{1}H NMR (400 MHz, DMSO-*d$_6$*)** δ 11.20 (br s, 1H), 8.08 (s, 1H), 7.76 (d, *J* = 8.0 Hz, 2H), 7.51 (d, *J* = 8.8 Hz, 1H), 7.40 (d, *J* = 8.4 Hz, 2H), 7.04 (d, *J* = 2.4 Hz, 1H), 6.84 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 5.24 (br s, 1H), 4.53 (d, *J* = 2.8 Hz, 2H), 3.77 (s, 3H), 2.36 (s, 3H); **^{13}C NMR (101 MHz, DMSO-*d$_6$*)** δ 160.9, 147.1, 143.9, 143.5, 136.6, 130.1, 129.8, 127.8, 123.7, 113.3, 112.9, 61.7, 55.7, 21.5; **HRMS (ESI)** m/z calcd for $C_{16}H_{19}N_2O_4S^+$ $(M+H)^+$ 335.10600, found 335.10626.

***N'*-(2-(hydroxymethyl)-5-methylbenzylidene)-4-methylbenzenesulfonohydrazide (S2y)**



Yield 77%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 1 : 1); **^{1}H NMR (600 MHz, DMSO-*d₆*)** δ 11.43 (s, 1H), 8.15 (s, 1H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 8.4 Hz, 2H), 7.39 (s, 1H), 7.31 (d, *J* = 7.8 Hz, 1H), 7.16 (dd, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 5.15 (t, *J* = 5.4 Hz, 1H), 4.49 (d, *J* = 5.4 Hz, 2 H), 2.35 (s, 3H), 2.28 (s, 3H); **^{13}C NMR (101 MHz, DMSO-d_6)** δ 146.9, 144.0, 138.5, 136.8, 136.6, 131.3, 130.8, 130.2, 128.6, 127.8, 127.7, 61.6, 21.5, 21.1; **HRMS (ESI)** m/z calcd for $C_{16}H_{19}N_2O_3S^+$ $(M+H)^+$ 319.11109, found 319.11136.

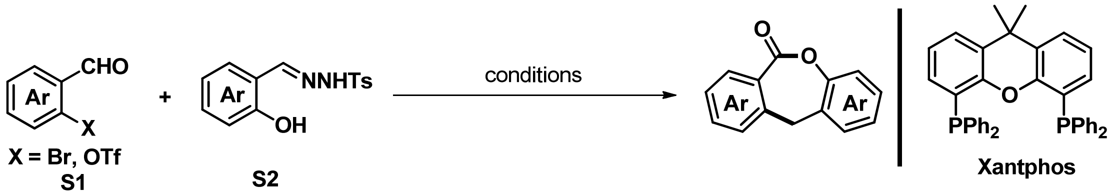
***N'*-((6-(hydroxymethyl)benzo[*d*][1,3]dioxol-5-yl)methylene)-4-methylbenzenesulfonohydrazide (S2z)**



Yield 63%, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 1 : 2); **^{1}H NMR (600 MHz, DMSO-d_6)** δ 11.28 (s, 1H), 8.11 (s, 1H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 7.8 Hz, 2H), 7.10 (s, 1H), 6.95 (s, 1H), 6.03 (s, 2H), 5.20 (t, *J* = 5.4 Hz, 1H), 4.44 (d, *J* = 5.4 Hz, 2 H), 2.36 (s, 3H); **^{13}C NMR (151 MHz, DMSO-d_6)** δ 149.1, 147.0, 146.0, 143.9, 136.9, 136.6, 130.1, 127.8, 125.4, 108.9, 105.5, 101.9, 61.1, 21.5; **HRMS (ESI)** m/z calcd for $C_{16}H_{17}N_2O_5S^+$ $(M+H)^+$ 349.08527, found 349.08563.

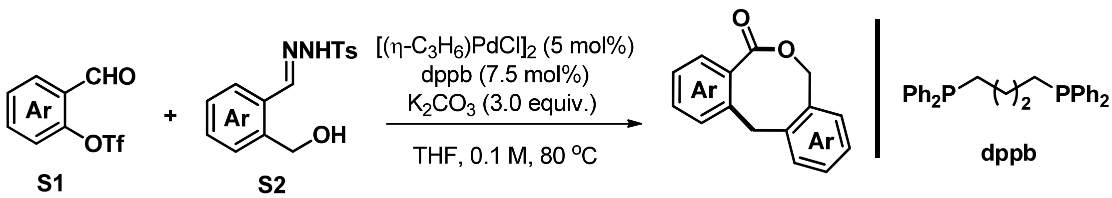
General procedure for the synthesis of lactones

General procedure for the synthesis of seven-membered lactones



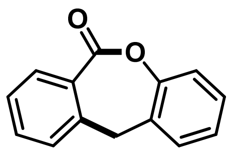
An oven-dried reaction tube containing a stirring bar was charged with $Pd(OAc)_2$ (5 mol%) or $[(\eta\text{-}C_3H_6)PdCl]_2$ (2.5 mol%), Xantphos (7.5 mol%), K_2CO_3 (3.0 equiv.), *N*-tosylhydrazone S**2** (0.4 mmol) and S**1** (if solid) (0.2 mmol). After evacuating and back filling with dry argon, the procedure was repeated for three times, solvent THF or dioxane (2.0 mL) and **S1** (if liquid) (0.2 mmol) were added via syringe. The mixture was stirred at 80 ^{o}C. When the reaction was completed, the crude mixture was cooled to room temperature. The mixture was filtered through a short pad of celite. After removing the solvent under reduced pressure, the residual was purified by column chromatography on silica gel.

General procedure for the synthesis of eight-membered lactones



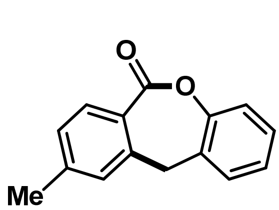
An oven-dried schlenk tube containing a stirring bar was charged with $[(\eta\text{-}C_3H_6)PdCl]_2$ (5 mol%), *N*-tosylhydrazone **S2** (0.4 mmol, 2 equiv), bis(diphenylphosphanyl)butane (dppb) (7.5 mol%), K_2CO_3 (3.0 equiv) and 2-formylaryl trifluoromethanesulfonate **S1** (0.2 mmol, in case it is solid). After evacuating and back filling with dry argon, the procedure was repeated for three times. 2-formylaryl trifluoromethanesulfonate **S1** (0.2 mmol, in case it is liquid) and tetrahydrofuran (THF) (2.0 mL) were added *via* syringe. The mixture was stirred at 80 ^{o}C for 10 hours. The crude mixture was cooled to room temperature. The mixture was filtered through a short pad of celite. After removing the solvent under reduced pressure, the residual was purified by silica gel column chromatography to obtain the eight-membered lactone compound.

Dibenzo[*b*,*e*]oxepin-6(11*H*)-one (3)



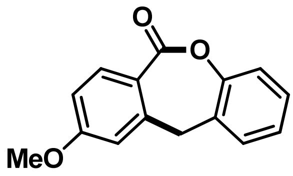
Yield 76% (32.0 mg) from *o*-bromobenzaldehyde for 10 h; Yield 80% (34.1 mg) from 2-formylphenyl trifluoromethanesulfonate for 9 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (d, *J* = 8.0 Hz, 1H), 7.45 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.33 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.27-7.19 (m, 4H), 7.14-7.09 (m, 1H), 4.00 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 150.7, 142.6, 133.4, 132.7, 132.6, 128.2, 128.1, 128.0, 127.4, 127.1, 125.8, 120.7, 37.4.

9-Methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (4)



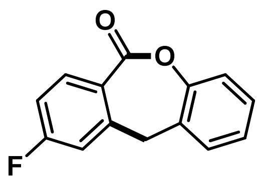
Yield 82% (37.0 mg) for 16 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.79 (d, *J* = 8.0 Hz, 1H), 7.26-7.18 (m, 3H), 7.13-7.07 (m, 3H), 3.95 (s, 2H), 2.35 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 150.8, 144.4, 142.5, 132.9, 132.7, 128.2, 128.1, 128.0, 127.8, 125.8, 125.1, 120.7, 37.4, 21.5; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_2^+$ $(M+H)^+$ 225.09101, found 225.09140.

9-Methoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (5)



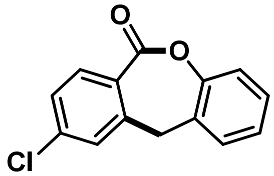
Yield 84% (40.5 mg) from 2-bromo-4-methoxybenzaldehyde for 16 h; Yield 65% (31.6 mg) from 2-formyl-5-methoxyphenyl trifluoromethanesulfonate for 6 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.88 (d, *J* = 8.8 Hz, 1H), 7.26-7.18 (m, 3H), 7.14-7.09 (m, 1H), 6.81 (dd, J_1 = 8.8 Hz, J_2 =2.4 Hz, 1H), 6.75 (d, *J* = 2.4 Hz, 1H), 3.96 (s, 2H), 3.83 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.8, 163.4, 150.9, 144.7, 135.3, 132.4, 128.12, 128.09, 125.7, 120.7, 120.1, 112.61, 112.57, 55.4, 37.8; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_3^+$ $(M+H)^+$ 241.08592, found 241.08603.

9-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (6)



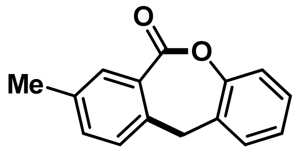
Yield 80% (38.2 mg) for 11 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.94-7.90 (m, 1H), 7.31-7.22 (m, 5H), 7.27-7.22 (m, 3H), 7.16-7.12 (m, 1H), 7.04-6.96 (m, 2H), 3.99 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.28 (d, *J* = 257.2 Hz), 165.1, 150.7, 145.4 (d, *J* = 8.7 Hz), 135.7, 135.6, 131.9, 128.3 (d, *J* = 18.7 Hz), 126.0, 124.3 (d, *J* = 3.1 Hz), 120.8, 114.7 (d, *J* = 21.8 Hz), 114.3 (d, *J* = 22.4 Hz), 37.3 (d, *J* = 1.0 Hz); **^{19}F NMR (376 MHz, CDCl$_3$)** δ -104.4; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06566.

9-Chlorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (7)



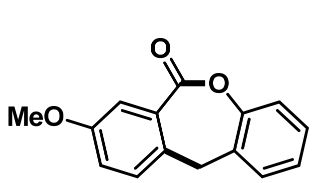
Yield 67% (32.8 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.83 (d, *J* = 8.0 Hz, 1H), 7.31-7.22 (m, 5H), 7.17-7.12 (m, 1H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.1, 150.6, 144.0, 139.5, 134.3, 131.8, 128.4, 128.3, 127.8, 127.3, 126.5, 126.1, 120.8, 37.1; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03671.

8-Methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (8)



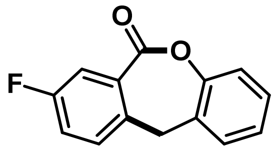
Yield 73% (33.0 mg), white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.69 (s, 1H), 7.26-7.07 (m, 6H), 3.94 (s, 2H), 2.31 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.3, 150.7, 139.7, 137.3, 134.1, 132.98, 132.92, 128.04, 127.96, 127.7, 127.1, 125.8, 120.6, 36.9, 20.7. **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_2^+$ $(M+H)^+$ 225.09101, found 225.09117.

8-Methoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (9)



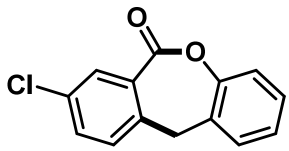
Yield 79% (37.9 mg) from 2-bromo-5-methoxybenz aldehyde for 12 h; Yield 71% (34.2 mg) from 2-formyl-4-methoxy phenyltrifluoromethanesulfonate for 18 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.40 (d, *J* = 1.4 Hz, 1H), 7.24-7.08 (m, 5H), 7.00-6.98 (m, 1H), 3.93 (s, 2H), 3.78 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.0, 158.7, 150.6, 135.1, 133.2, 128.7, 128.4, 128.0, 125.8, 120.6, 120.3, 116.3, 55.5, 36.5; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_3^+$ $(M+H)^+$ 241.08592, found 241.08545.

8-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (10)



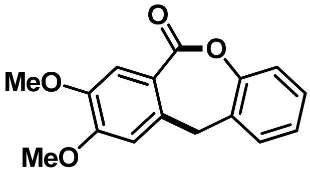
Yield 65% (30.0 mg) for 14 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.58 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 7.26-7.21 (m, 4H), 7.17-7.11 (m, 2H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 164.8 (d, *J* = 2.6 Hz), 161.6 (d, *J* = 248.0 Hz), 150.4, 138.6 (d, *J* = 3.4 Hz), 132.5, 129.7, 129.6, 129.0 (d, *J* = 7.6 Hz), 128.2 (d, *J* = 16.9 Hz), 126.0, 120.8, 120.3 (d, *J* = 21.5 Hz), 119.3 (d, *J* = 23.7 Hz), 36.6; **^{19}F NMR (376 MHz, CDCl$_3$)** δ -114.3; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06554.

8-Chlorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (11)



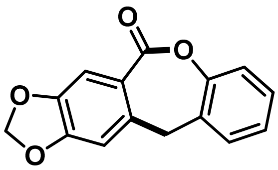
Yield 65% (32.1 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.85 (d, *J* = 2.0 Hz, 1H), 7.40 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 7.26-7.20 (m, 4H), 7.16-7.11 (m, 1H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 164.8, 150.4, 140.9, 133.3, 133.2, 132.3, 132.1, 129.5, 128.6, 128.4, 128.2, 126.1, 120.7, 36.7; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03674.

8,9-Dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (12)



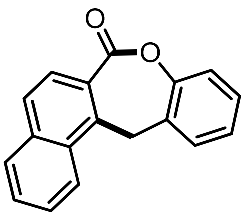
Yield 67% (36.0 mg) for 9 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.41 (s, 1H), 7.27-7.20 (m, 3H), 7.15-7.10 (m, 1H), 6.72 (s, 1H), 3.95 (s, 5H), 3.87 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.8, 153.0, 150.9, 148.0, 137.1, 133.0, 128.0, 127.9, 125.7, 120.7, 119.4, 114.9, 109.8, 56.09, 56.07, 37.2; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_4^+$ $(M+H)^+$ 271.09649, found 271.09689.

[1,3]Dioxolo[4',5':4,5]benzo[1,2-*e*]benzo[*b*]oxepin-5(11*H*)-one (13)



Yield 75% (38.4 mg) for 12 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.31 (s, 1H), 7.24-7.21 (m, 3H), 7.14-7.09 (m, 1H), 6.70 (s, 1H), 5.98 (s, 2H), 3.89 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.4, 151.7, 150.8, 146.9, 138.9, 132.8, 128.1, 127.9, 125.8, 121.0, 120.6, 112.1, 107.4, 102.0, 37.2; **HRMS (ESI)** m/z calcd for $C_{15}H_{11}O_4^+$ $(M+H)^+$ 255.06519, found 255.06525.

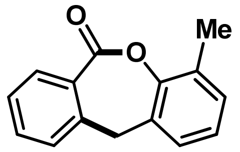
Benzo[*b*]naphtho[1,2-*e*]oxepin-7(13*H*)-one (14)



Yield 55% (28.9 mg) for 12 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 20 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.39 (d, J = 8.4 Hz, 1H), 7.87-7.82 (m, 2H), 7.77 (d, J = 8.8 Hz, 1H), 7.69-7.59 (m, 2H), 7.35 (dd, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.26-7.18 (m, 2H), 7.09 (td, J_1 = 7.2 Hz, J_2 = 1.6 Hz, 1H), 4.44 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ

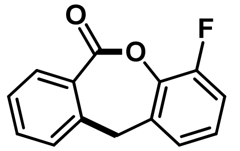
166.8, 151.2, 140.7, 135.6, 132.3, 129.0, 128.8, 128.2, 128.1, 128.0, 127.6, 127.4, 127.2, 125.7, 125.3, 124.0, 120.3, 30.4; **HRMS (ESI)** m/z calcd for $C_{18}H_{13}O_2^+$ $(M+H)^+$ 261.09101, found 261.09131.

4-Methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (15)



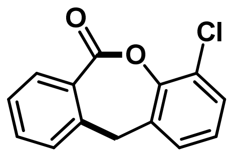
Yield 74% (33.3 mg) for 22 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (d, *J* = 8.0 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J* = 7.6 Hz, 1H), 7.08-6.98 (m, 3H), 3.96 (s, 2H), 2.37 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.9, 149.1, 142.9, 133.3, 132.8, 132.6, 130.0, 129.7, 128.0, 127.3, 127.1, 125.6, 125.5, 37.5, 16.4; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_2^+$ $(M+H)^+$ 225.09101, found 225.09082.

4-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (16)



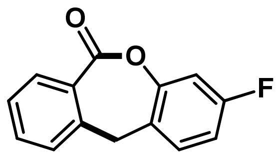
Yield 58% (26.6 mg) for 5 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.91 (d, *J* = 8.0 Hz, 1H), 7.49 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.27 (d, *J* = 7.6 Hz, 1H), 7.09-6.88 (m, 3H), 4.03 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 164.9, 153.1 (d, *J* = 252.8 Hz), 142.1, 138.4 (d, *J* = 11.5 Hz), 135.3, 133.7, 133.0, 127.6, 127.5 (d, *J* = 38.6 Hz), 126.2 (d, *J* = 7.6 Hz), 122.9 (d, *J* = 3.7 Hz), 115.4 (d, *J* = 18.7 Hz), 37.3 (d, *J* = 2.3 Hz); **^{19}F NMR (376 MHz, $CDCl_3$)** δ -128.9; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06569.

4-Chlorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (17)



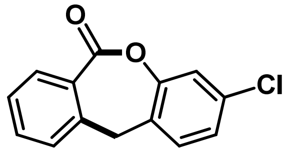
Yield 60% (29.4 mg) for 6 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.92 (d, *J* = 7.6 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.29-7.26 (m, 2H), 7.15 (d, *J* = 7.6 Hz, 1H), 7.06-7.03 (m, 1H), 4.02 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 164.5, 146.8, 142.1, 134.8, 133.7, 132.9, 129.0, 127.7, 127.4, 127.3, 126.4, 126.3, 126.0, 37.5; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03621.

3-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (18)



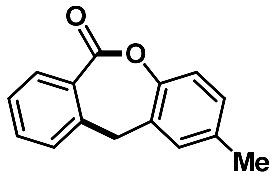
Yield 60% (27.7 mg) for 10 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.89 (dd, J_1 = 8.0, J_2 = 1.2 Hz, 1H), 7.48 (td, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H), 7.34 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.26-7.19 (m, 2H), 6.97 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 6.83 (td, J_1 = 8.4 Hz, J_2 = 2.8 Hz, 1H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.4, 161.8 (d, *J* = 248.1 Hz), 151.2 (d, *J* = 11.6 Hz), 142.4, 133.6, 132.8, 128.8 (d, *J* = 9.3 Hz), 128.5 (d, *J* = 3.5 Hz), 127.7, 127.6, 127.1, 112.6 (d, *J* = 21.3 Hz), 108.7 (d, *J* = 24.9 Hz), 36.8; **^{19}F NMR (376 MHz, CDCl$_3$)** δ -113.2; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06551.

3-Chlorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (19)



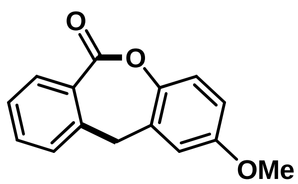
Yield 66% (32.3mg) for 6 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.88 (d, *J* = 8.0 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 1H), 7.26-7.18 (m, 3H), 7.09 (dd, J_1 = 8.0, J_2 =2.0 Hz, 1H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.3, 151.0, 142.1, 133.6, 133.2, 132.8, 131.2, 128.9, 127.72, 127.66, 127.1, 125.9, 121.2, 36.9; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03674.

2-Methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (20)



Yield 82% (37.0 mg) for 6 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.88 (d, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 7.2 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J* = 7.6 Hz, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 7.05 (s, 1H), 7.00 (d, *J* = 8.4 Hz, 1H), 3.94 (s, 2H), 2.29 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.4, 148.5, 142.6, 135.6, 133.3, 132.7, 132.3, 128.6, 128.5, 128.1, 127.4, 127.1, 120.3, 37.4, 20.6.

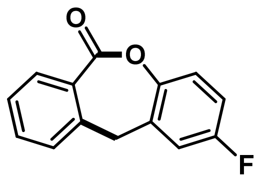
2-Methoxydibenzo[b,e]oxepin-6(11H)-one (21)



Yield 53% (25.5 mg) for 6 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (dd, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.46 (td, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H), 7.33 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.25 (d, *J* =

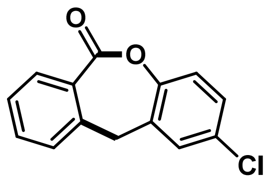
6.4 Hz, 1H), 7.14 (d, J = 8.8 Hz, 1H), 6.77 (d, J = 2.8 Hz, 1H), 6.71 (dd, J_1 = 8.8 Hz, J_2 = 3.2 Hz, 1H), 3.95 (s, 2H), 3.77 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.5, 157.1, 144.4, 142.4, 133.8, 133.3, 132.8, 128.1, 127.5, 127.2, 121.5, 113.4, 112.4, 55.6, 37.7; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_3^+$ $(M+H)^+$ 241.08592, found 241.08601.

2-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (22)



Yield 86% (39.3 mg) for 3 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.90 (dd, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.48 (td, J_1= 7.6 Hz,, J_2 = 1.2 Hz, 1H), 7.35 (td, J_1 = 7.6 Hz, J_2= 0.8 Hz, 1H), 7.26 (d, J = 7.6 Hz, 1H), 7.18 (dd, J_1 = 8.8 Hz, J_2 = 4.8 Hz, 1H), 6.97 (dd, J_1 = 8.4 Hz, J_2 = 3.2 Hz, 1H), 6.89 (td, J_1= 8.4 Hz, J_2 = 3.2 Hz, 1H), 3.97 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ165.7, 159.8 (d, J = 246.5 Hz), 146.7 (d, J = 2.9 Hz), 141.9, 134.5 (d, J = 8.1 Hz), 133.5, 132.9, 127.8, 127.7, 127.2, 122.1 (d, J = 8.9 Hz), 114.8 (d, J = 23.9 Hz), 114.44 (d, J = 23.3 Hz), 37.30 (d, J = 0.9 Hz); **^{19}F NMR (376 MHz, CDCl$_3$)** δ -116.6; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06558.

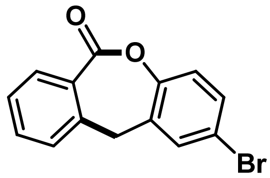
2-Chlorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (23)



Yield 77% (37.6 mg) for 3 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.89 (d, J = 7.6 Hz, 1H), 7.48 (td, J_1 = 7.2 Hz, J_2 = 0.8 Hz, 1H), 7.35 (t, J = 7.6 Hz, 1H), 7.27-7.14 (m, 4H), 3.96 (s, 2H); **^{13}C NMR (101 MHz,**

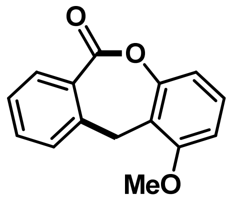
$CDCl_3$) δ 165.5, 149.2, 141.7, 134.2, 133.6, 132.8, 130.8, 128.0, 127.72, 127.67, 127.2, 122.0, 37.1; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03653.

2-Bromodibenzo[*b*,*e*]oxepin-6(11*H*)-one (24)



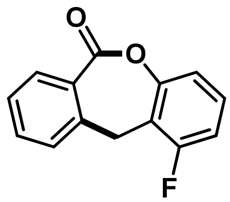
Yield 62% (35.8 mg) for 5 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (dd, J_1 = 7.6 Hz, J_2 = 1.0 Hz, 1H), 7.48 (td, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 7.41-7.25 (m, 4H), 7.10 (d, J = 8.4 Hz, 1H), 3.96 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.4, 149.8, 141.8, 134.7, 133.6, 132.8, 131.0, 130.9, 127.8, 127.7, 127.2, 122.4, 118.5, 37.1; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}BrO_2^+$ $(M+H)^+$ 288.98587, found 288.98636.

1-Methoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (25)



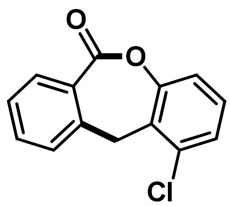
Yield 58% (28.1 mg) for 4 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.90 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.44 (td, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 7.31 (td, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.24 (d, J = 7.6 Hz, 1H), 7.05 (t, J = 7.6 Hz, 1H), 6.83-6.80 (m, 2H), 3.98 (s, 2H), 3.86 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.7, 150.7, 142.8, 139.6, 134.4, 133.3, 132.8, 128.0, 127.4, 127.2, 126.1, 119.3, 111.1, 56.0, 37.3; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_3^+$ $(M+H)^+$ 241.08592, found 241.08583.

1-Fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (26)



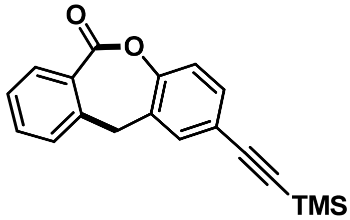
Yield 64% (29.4 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (dd, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 7.48 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.37-7.30 (m, 2H), 7.16 (td, J_1 = 8.0 Hz, J_2 = 6.4 Hz, 1H), 7.04 (d, *J* = 8.4 Hz, 1H), 6.91 (t, *J* = 8.8 Hz, 1H), 4.06 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.4, 158.96 (d, *J* = 247.5 Hz), 151.8 (d, *J* = 5.9 Hz), 141.6, 133.6, 132.9, 128.2, 127.9 (d, *J* = 9.7 Hz), 127.7, 127.6, 120.8 (d, *J* = 20.3 Hz), 116.4 (d, *J* = 3.5 Hz), 112.6 (d, *J* = 22.5 Hz), 28.4 (d, *J* = 3.9 Hz); **^{19}F NMR (376 MHz, $CDCl_3$)** δ -119.6; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}FO_2^+$ $(M+H)^+$ 229.06593, found 229.06546.

1-Chlorodibenzo[b,e]oxepin-6(11H)-one (27)



Yield 59% (29.1 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (d, *J* = 7.6 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 7.37-7.33 (m, 2H), 7.21-7.09 (m, 3H), 4.22 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.2, 151.6, 141.5, 133.7, 132.7, 132.3, 131.4, 128.0, 127.8, 127.5, 126.6, 119.5, 32.8; **HRMS (ESI)** m/z calcd for $C_{14}H_{10}ClO_2^+$ $(M+H)^+$ 245.03638, found 245.03622.

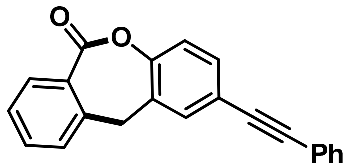
2-((Trimethylsilyl)ethynyl)dibenzo[*b*,*e*]oxepin-6(11*H*)-one (28)



Yield 67% (41.3 mg) from 2-bromobenzaldehyde for 5 h; Yield 86% (52.6 mg) from 2-formylphenyl trifluoromethanesulfonate for 5 h, white solid; R_f = 0.50

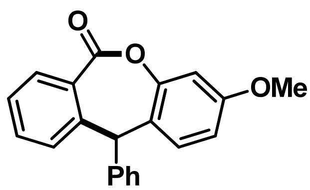
(petroleum ether : ethyl acetate = 100 : 1); **^{1}H NMR (600 MHz, $CDCl_3$, TMS)** δ 7.86 (dd, J_1 = 7.8 Hz, J_2 =1.8 Hz, 1H), 7.45 (td, J_1 = 7.8 Hz, J_2 =1.2 Hz, 1H), 7.38 (d, J = 2.4 Hz, 1H), 7.34-7.29 (m, 2H), 7.23 (d, J = 7.8 Hz, 1H), 7.14 (d, J = 8.4 Hz, 1H), 3.95 (s, 2H), 0.23 (s, 9H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 165.5, 150.6, 142.0, 133.5, 132.7, 132.7, 131.8, 131.7, 127.8, 127.6, 127.2, 120.8, 120.7, 103.7, 94.8, 37.1, -0.2. **HRMS (ESI)** m/z calcd for $C_{19}H_{19}O_2Si^+$ $(M+H)^+$ 307.11488, found 307.11478.

2-(Phenylethynyl)dibenzo[*b*,*e*]oxepin-6(11*H*)-one (29)



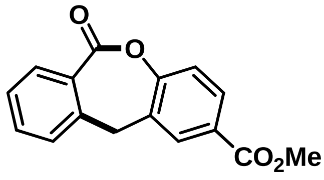
Yield 81% (50.3 mg) for 6 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 25 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (d, J = 7.2 Hz, 1H), 7.51-7.44 (m, 4H), 7.39-7.33 (m, 5H), 7.26 (d, J = 7.2 Hz, 1H), 7.20 (d, J = 8.4 Hz, 1H), 3.99 (s, 2H); **^{13}C NMR (100 MHz, $CDCl_3$)** δ 165.7, 150.4, 142.0, 133.6, 132.8, 132.7, 131.5, 131.4, 131.3, 128.43, 128.35, 127.9, 127.6, 127.2, 122.8, 120.93, 120.90, 89.8, 88.1, 37.2. **HRMS (ESI)** m/z calcd for $C_{22}H_{15}O_2^+$ $(M+H)^+$ 311.10666, found 311.10690.

(S)-3-methoxy-11-phenyldibenzo[b,e]oxepin-6(11H)-one (30)



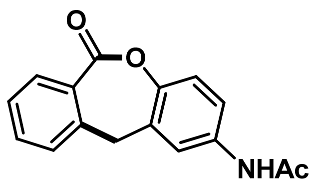
Yield 42% (26.7 mg) for 10 h, colorless oil; R_f = 0.30 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.83-7.81 (m, 2H), 7.54-7.47 (m, 4H), 7.40-7.29 (m, 3H), 6.84-6.82 (m, 1H), 6.72 (s, 1H), 6.34-6.32 (m, 2H), 3.68 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 160.6, 150.8, 146.4, 136.7, 135.4, 129.30, 129.27, 128.7, 128.6, 127.8, 124.8, 122.0, 121.9, 120.0, 106.2, 102.5, 100.9, 88.4, 55.2.

Methyl 6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepine-2-carboxylate (31)



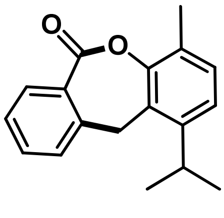
Yield 37% (20.2 mg) from 2-bromobenzaldehyde for 5 h; Yield 37% (19.8 mg) from 2-formylphenyl trifluoromethanesulfonate for 8 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.98 (d, *J* = 1.6 Hz, 1H), 7.93-7.88 (m, 2H), 7.49 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.36 (t, *J* = 7.6 Hz, 1H), 7.30-7.27 (m, 2H), 4.06 (s, 2H), 3.90 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.0, 165.2, 154.1, 141.9, 133.7, 132.8, 132.7, 129.9, 127.71, 127.69, 127.6, 127.3, 120.9, 52.3, 37.2; **HRMS (ESI)** m/z calcd for $C_{16}H_{13}O_4^+$ $(M+H)^+$ 269.08084, found 269.08090.

N-(6-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetamide (32)



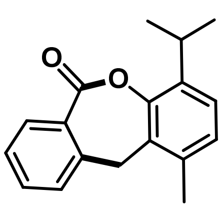
Yield 44% (23.5 mg) for 6 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 1 : 1); **^{1}H NMR (400 MHz, DMSO-d_6)** δ 10.03 (s, 1H), 7.76 (d, *J* = 7.2 Hz, 1H), 7.71 (d, *J* = 2.4 Hz, 1H), 7.57 (t, *J* = 7.2 Hz, 1H), 7.48 (d, *J* = 7.6 Hz, 1H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.34 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.18 (d, *J* = 8.8 Hz, 1H), 4.05 (s, 2H), 2.03 (s, 3H); **^{13}C NMR (101 MHz, DMSO-d_6)** δ 168.8, 165.9, 145.9, 143.4, 137.5, 134.1, 133.9, 132.6, 128.2, 128.04, 127.98, 121.1, 119.1, 118.8, 36.6, 24.4; **HRMS (ESI)** m/z calcd for $C_{16}H_{14}NO_3^+$ $(M+H)^+$ 268.09682, found 268.09711.

1-Isopropyl-4-methyldibenzo[b,e]oxepin-6(11H)-one (33)



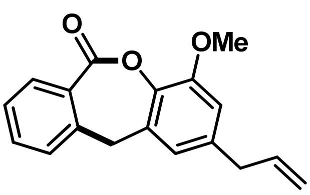
Yield 52% (27.8 mg) for 6 h, colorless oil; R_f = 0.30 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.91 (d, J = 7.6 Hz, 1H), 7.46 (td, J_1 = 7.6, J_2 = 1.2 Hz, 1H), 7.34-7.26 (m, 2H), 7.02 (m, 2H), 4.07 (s, 2H), 3.32 (hept, J = 6.8 Hz, 1H), 2.35 (s, 3H), 1.26 (d, J = 7.2 Hz, 6H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.1, 149.3, 143.3, 133.4, 133.3, 132.6, 130.9, 129.0, 128.2, 127.4, 127.3, 127.2, 122.1, 31.8, 29.2, 23.7, 16.3; **HRMS (ESI)** m/z calcd for $C_{18}H_{19}O_2^+$ $(M+H)^+$ 267.13796, found 267.13745.

4-Isopropyl-1-methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (34)



Yield 50% (26.8 mg) for 11 h, colorless oil; R_f = 0.30 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.90 (dd, J_1 = 7.6 Hz, J_2 = 1.0 Hz, 1H), 7.45 (td, J_1 = 7.6, J_2 = 1.2 Hz, 1H), 7.34-7.27 (m, 2H), 7.02 (d, J = 7.6 Hz, 1H), 6.95 (d, J = 8.0 Hz, 1H), 4.01 (s, 2H), 3.46 (hept, J = 6.8 Hz, 1H), 2.41 (s, 3H), 1.22 (d, J = 6.8 Hz, 6H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.3, 148.4, 143.1, 138.0, 133.3, 132.5, 132.4, 131.9, 128.1, 127.38, 127.36, 126.9, 124.3, 32.7, 27.4, 22.9, 19.2; **HRMS (ESI)** m/z calcd for $C_{18}H_{19}O_2^+$ $(M+H)^+$ 267.13796, found 267.13748.

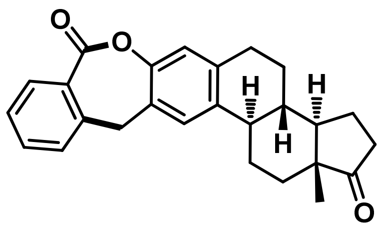
2-Allyl-4-methoxydibenzo[b,e]oxepin-6(11H)-one (35)



Yield 64% (36.0 mg) from 2-bromobenzaldehyde for 4 h; Yield 37% (20.7 mg) from 2-formylphenyl trifluoromethanesulfonate for 6 h, white solid; R_f = 0.30

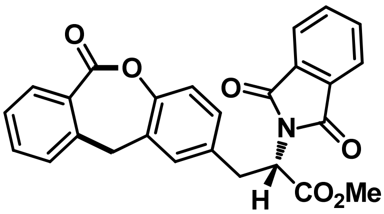
(petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.90 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.24 (d, *J* = 7.6 Hz, 1H), 6.66 (s, 1H), 6.64 (s, 1H), 5.96-5.86 (m, 1H), 5.12-5.07 (m, 2H), 3.95 (s, 2H), 3.85 (s, 3H), 3.31 (d, *J* = 6.4 Hz, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.9, 150.5, 142.8, 138.3, 137.8, 136.7, 134.1, 133.2, 132.8, 128.0, 127.4, 127.2, 119.2, 116.3, 111.2, 55.9, 39.9, 37.4; **HRMS (ESI)** m/z calcd for $C_{18}H_{17}O_3^+$ $(M+H)^+$ 281.11722, found 281.11765.

(3*aR*,3*bS*,14*bR*,16*aR*)-3b,16a-dimethyl-3,3a,3b,4,5,13,14b,15,16,16a-decahydro-1H-benzo[*e*]cyclopenta[7,8]phenanthro[2,3-*b*]oxepine-1,8(2*H*)-dione (36)



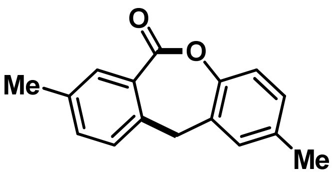
Yield 64% (49.4 mg) from 2-bromobenzaldehyde for 16 h; Yield 77% (59.5 mg) from 2-formylphenyl trifluoromethanesulfonate for 11 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.86 (d, *J* = 7.2 Hz, 1H), 7.45 (dt, J_1 = 7.6 Hz, J_2 = 0.9 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J* = 7.6 Hz, 1H), 7.17 (s, 1H), 6.96 (s, 1H), 3.95 (s, 2H), 2.86-2.84 (m, 2H), 2.54-2.41 (m, 2H), 2.25-1.95 (m, 5H), 1.67-1.36 (m, 6H), 0.89 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 220.7, 166.4, 148.4, 142.7, 137.3, 136.6, 133.3, 132.6, 129.7, 128.1, 127.3, 127.0, 125.0, 120.6, 50.2, 47.8, 43.9, 37.9, 37.4, 35.7, 31.4, 28.9, 26.2, 25.8, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{26}H_{27}O_3^+$ $(M+H)^+$ 387.19547, found 387.19577.

(*S*)-Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-(6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-2-yl) propanoate (37)



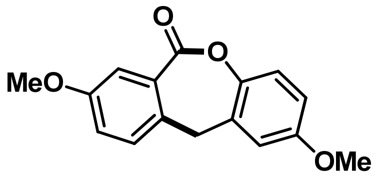
Yield 77% (68.8 mg) from 2-bromobenzaldehyde for 5 h; Yield 81% (71.8 mg) from 2-formylphenyl trifluoromethanesulfonate for 4 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.81 (d, *J* = 7.2 Hz, 1H), 7.74-7.68 (m, 4H), 7.39 (t, *J* = 7.2 Hz, 1H), 7.28 (t, *J* = 7.2 Hz, 1H), 7.11-7.01 (m, 4H), 5.12 (dd, J_1 = 10.8 Hz, J_2 = 5.6 Hz, 1H), 3.95-3.77 (m, 5H), 3.57-3.45 (m, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 169.0, 167.3, 165.9, 149.4, 142.3, 134.4, 134.1, 133.3, 132.7, 132.6, 131.3, 128.5, 128.4, 127.8, 127.2, 126.9, 123.4, 120.7, 52.9, 52.8, 37.2, 33.8; **HRMS (ESI)** m/z calcd for $C_{26}H_{20}NO_6^+$ $(M+H)^+$ 442.12851, found 442.12897.

2,8-Dimethyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (38)



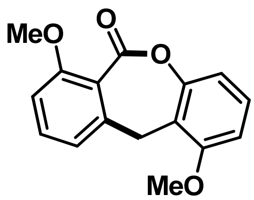
Yield 74% (35.3 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.68 (s, 1H), 7.26-7.24 (m, 1H), 7.14-6.97 (m, 4H), 3.90 (s, 2H), 2.31 (s, 3H), 2.28 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.7, 148.5, 139.8, 137.2, 135.5, 134.1, 133.0, 132.6, 128.5, 128.4, 127.8, 127.0, 120.3, 36.9, 20.7, 20.6; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_2^+$ $(M+H)^+$ 239.10666, found 239.10661.

2,8-Dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (39)



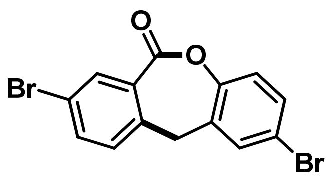
Yield 74% (40 mg) for 12 h, white solid; R_f = 0.3 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.39 (d, *J* = 2.8 Hz, 1H), 7.14 (t, *J* = 8.4 Hz, 2H), 6.99 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 6.75 (d, *J* = 2.8 Hz, 1H), 6.69 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 3.88 (s, 2H), 3.78 (s, 3H), 3.76 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.4, 158.7, 157.0, 144.3, 134.9, 134.3, 128.7, 128.5, 121.4, 120.2, 116.3, 113.2, 112.2, 55.6, 55.5, 36.7; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_4^+$ $(M+H)^+$ 271.09649, found 271.09668.

1,7-Dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (40)



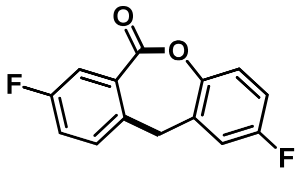
Yield 37% (20.0 mg) for 26 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.32 (t, *J* = 8.0 Hz, 1H), 7.11 (t, *J* = 8.0 Hz, 1H), 6.87-6.80 (m, 3H), 6.66 (d, *J* = 8.4 Hz, 1H), 3.95 (s, 2H), 3.84 (s, 6H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 162.9, 159.5, 156.0, 151.5, 144.8, 133.0, 127.4, 121.8, 118.9, 117.0, 112.7, 110.3, 107.5, 56.1, 56.0, 28.1; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_4^+$ $(M+H)^+$ 271.09649, found 271.09671.

2,8-Dibromodibenzo[*b*,*e*]oxepin-6(11*H*)-one (41)



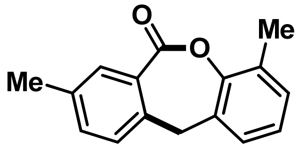
Yield 42 % (31 mg) for 5 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 20 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.00 (s, 1H), 7.59 (d, *J* = 8.0 Hz, 1H), 7.39 (s, 1H), 7.34 (d, *J* = 8.8 Hz, 1H), 7.15 (d, *J* = 8.0 Hz, 1H), 7.10 (d, *J* = 8.8 Hz, 1H), 3.92 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 164.0, 149.5, 140.6, 136.4, 135.4, 134.1, 131.3, 131.0, 129.4, 128.9, 122.5, 121.4, 118.8, 36.5; **HRMS (ESI)** m/z calcd for $C_{14}H_8Br_2NaO_2^+$ $[M+Na]^+$ 388.8783, found 388.8773.

2,8-Difluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (42)



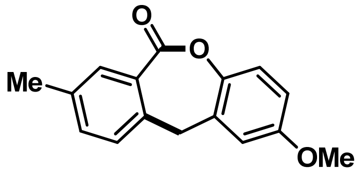
Yield 63% (31 mg) for 10 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.59 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 7.27-7.16 (m, 3H), 7.00-6.89 (m, 2H), 3.96 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 164.5 (d, *J* = 2.2 Hz), 161.7 (d, *J* = 247.8 Hz), 159.8 (d, *J* = 245.9 Hz), 146.4 (d, *J* = 2.8 Hz), 137.9 (d, *J* = 3.3 Hz), 134.4 (d, *J* = 8.3 Hz), 129.4 (d, *J* = 7.4 Hz), 129.1 (d, *J* = 7.6 Hz), 122.2 (d, *J* = 8.8 Hz), 120.5 (d, *J* = 21.5 Hz), 119.4 (d, *J* = 23.6 Hz), 114.8 (d, *J* = 14.8 Hz), 114.6 (d, *J* = 14.0 Hz), 36.4; **^{19}F NMR (376 MHz, CDCl$_3$)** δ -113.8, -116.2; **HRMS (ESI)** m/z calcd for $C_{14}H_9F_2O_2^+$ $(M+H)^+$ 247.05651, found 247.05618.

4,8-Dimethyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (43)



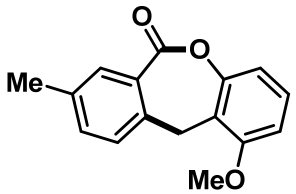
Yield 60% (29.0 mg) for 29 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.71 (s, 1H), 7.26-7.24 (m, 1H), 7.14 (d, *J* = 8.0 Hz, 1H), 7.07-6.97 (m, 3H), 3.93 (s, 2H), 2.37 (s, 3H), 2.32 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.3, 149.1, 140.0, 137.2, 134.1, 133.1, 132.9, 130.0, 129.6, 127.6, 127.1, 125.53, 125.45, 37.0, 20.7, 16.4; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_2^+$ $(M+H)^+$ 239.10666, found 239.10674.

2-Methoxy-8-methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (44)



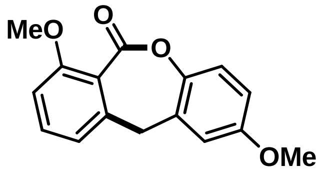
Yield 71% (36.2 mg) for 7 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.69 (s, 1H), 7.26-7.24 (m, 1H), 7.15-7.12 (m, 2H), 6.76 (d, *J* = 2.8 Hz, 1H), 6.69 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 3.90 (s, 2H), 3.76 (s, 3H), 2.32 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.8, 157.0, 144.4, 139.5, 137.3, 134.1, 134.0, 133.0, 127.7, 127.1, 121.4, 113.3, 112.3, 55.5, 37.2, 20.7; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_3^+$ $(M+H)^+$ 255.10157, found 255.10164.

1-Methoxy-8-methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (45)



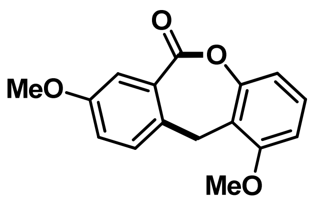
Yield 92% (47.2 mg) for 4 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.71 (s, 1H), 7.24 (dd, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.13 (d, *J* = 7.6 Hz, 1H), 7.04 (t, *J* = 8.0 Hz, 1H), 6.82-6.79 (m, 2H), 3.93 (s, 2H), 3.85 (s, 3H), 2.31 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 166.0, 150.7, 139.9, 139.5, 137.2, 134.7, 134.0, 133.0, 127.6, 127.1, 126.0, 119.2, 110.9, 55.9, 36.9, 20.7; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_3^+$ $(M+H)^+$ 255.10157, found 255.10127.

2,7-Dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (46)



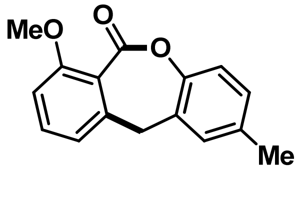
Yield 62% (33.9 mg) for 8 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.33 (t, *J* = 8.0 Hz, 1H), 7.10 (d, *J* = 8.4 Hz, 1H), 6.86-6.81 (m, 2H), 6.74-6.68 (m, 2H), 3.85 (s, 5H), 3.76 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 163.3, 159.6, 156.7, 144.24, 144.22, 134.0, 133.1, 121.0, 118.6, 116.8, 113.3, 112.3, 110.5, 56.1, 55.6, 37.4; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_4^+$ $(M+H)^+$ 271.09649, found 271.09625.

1,8-Dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (47)



Yield 70% (38 mg) for 7 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.40 (d, *J* = 2.4 Hz, 1H), 7.14 (d, *J* = 8.4 Hz, 1H), 7.04 (t, *J* = 8.0 Hz, 1H), 6.97 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 6.80 (d, *J* = 7.6 Hz, 2H), 3.91 (s, 2H), 3.85 (s, 3H), 3.77 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.7, 158.6, 150.7, 139.4, 135.3, 135.0, 128.54, 128.46, 126.1, 120.2, 119.1, 116.2, 110.9, 55.9, 55.4, 36.3; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_4^+$ $(M+H)^+$ 271.09649, found 271.09683.

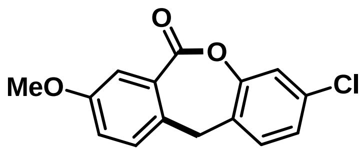
7-Methoxy-2-methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (48)



Yield 65% (33.0 mg) for 10 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.32 (t, *J* = 8.0 Hz, 1H), 7.07- 6.97 (m, 3H), 6.82 (t,

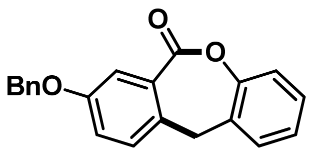
J = 8.4 Hz, 2H), 3.84 (s, 5H), 2.27 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 163.2, 159.5, 148.3, 144.5, 135.1, 133.1, 132.5, 128.5, 128.4, 119.9, 118.5, 116.8, 110.4, 56.1, 37.1, 20.6; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_3^+$ $(M+H)^+$ 255.10157, found 255.10165.

3-Chloro-8-methoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (49)



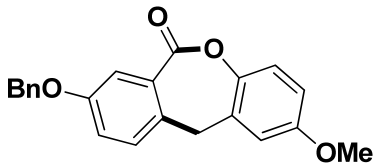
Yield 60% (33 mg) for 12 h, white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.38 (d, J = 2.4 Hz, 1H), 7.23 (s, 1H), 7.16 (t, J = 7.6 Hz, 2H), 7.09 (d, J = 8.0 Hz, 1H), 7.01 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 3.90 (s, 2H), 3.80 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.3, 158.8, 150.9, 134.5, 133.0, 131.8, 128.7, 128.5, 128.4, 125.9, 121.2, 120.5, 116.4, 55.6, 36.0; **HRMS (ESI)** m/z calcd for $C_{15}H_{12}ClO_3^+$ $(M+H)^+$ 275.04695, found 275.04706.

8-(Benzyloxy)dibenzo[*b*,*e*]oxepin-6(11*H*)-one (50)



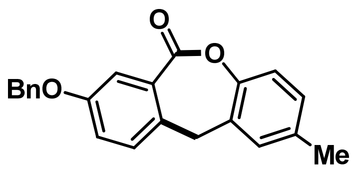
Yield 73% (46.7 mg) for 6 h, light yellow solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.87 (d, J = 8.4 Hz, 1H), 7.40-7.33 (m, 5H), 7.25-7.19 (m, 3H), 7.14-7.09 (m, 1H), 6.89-6.84 (m, 2H), 5.09 (s, 2H), 3.95 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.8, 162.6, 150.9, 144.7, 135.8, 135.3, 132.3, 128.7, 128.3, 128.13, 128.11, 127.5, 125.8, 120.7, 120.3, 113.5, 113.2, 70.1, 37.8; **HRMS (ESI)** m/z calcd for $C_{21}H_{17}O_3^+$ $(M+H)^+$ 317.11722, found 317.11731.

8-(Benzyloxy)-2-methoxydibenzo[*b,e*]oxepin-6(11*H*)-one (51)



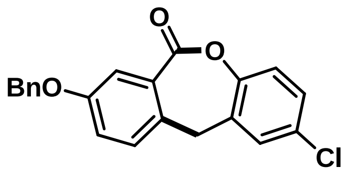
Yield 88% (61 mg) for 5 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.86 (d, *J* = 8.6 Hz, 1H), 7.39-7.33 (m, 5H), 7.13 (d, *J* = 8.8 Hz, 1H), 6.88 (dd, J_1 = 8.7 Hz, J_2 = 2.4 Hz, 1H), 6.83-6.75 (m, 1H), 6.77 (d, *J* = 2.8 Hz, 1H), 6.70 (dd, J_1 = 8.9 Hz, J_2 = 2.9 Hz, 1H), 5.08 (s, 2H), 3.90 (s, 2H), 3.76 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 162.4, 157.0, 144.6, 144.4, 135.8, 135.3, 133.4, 128.6, 128.2, 127.4, 121.4, 120.3, 113.5, 113.3, 113.2, 112.4, 70.1, 55.5, 37.9; **HRMS (ESI)** m/z calcd for $C_{22}H_{19}O_4^+$ $(M+H)^+$ 347.12779, found 347.12796.

8-(Benzyloxy)-2-methyldibenzo[*b,e*]oxepin-6(11*H*)-one (52)



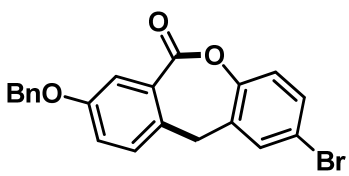
Yield 67 % (44 mg) for 9 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.87 (d, *J* = 8.6 Hz, 1H), 7.40-7.33 (m, 5H), 7.10 (d, *J* = 8.2 Hz, 1H), 7.05 (s, 1H), 7.00 (d, *J* = 8.2 Hz, 1H), 6.88 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 6.83 (d, *J* = 2.0 Hz, 1H), 5.09 (s, 2H), 3.91 (s, 2H), 2.29 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 162.5, 148.7, 144.8, 135.8, 135.5, 135.3, 132.0, 128.67, 128.63, 128.5, 128.3, 127.5, 120.4, 113.5, 113.1, 70.1, 37.8, 20.7; **HRMS (ESI)** m/z calcd for $C_{22}H_{19}O_3^+$ $(M+H)^+$ 331.13287, found 331.13297.

8-(Benzyloxy)-2-chlorodibenzo[*b,e*]oxepin-6(11*H*)-one (53)



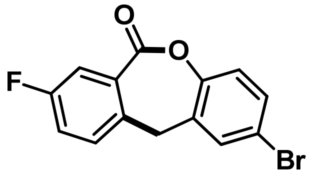
Yield 90 % (63 mg) for 8 h, white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.88 (d, *J* = 8.8 Hz, 1H), 7.41-7.34 (m, 5H), 7.23 (s, 1H), 7.18-7.13 (m, 2H), 6.90 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 6.83 (d, *J* = 2.0 Hz, 1H), 5.10 (s, 2H), 3.92 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.1, 162.7, 149.4, 143.9, 135.7, 135.4, 134.0, 130.7, 128.7, 128.3, 127.9, 127.4, 122.0, 119.9, 113.6, 113.5, 70.1, 37.4; **HRMS (ESI)** m/z calcd for $C_{21}H_{16}ClO_3^+$ $(M+H)^+$ 351.07825, found 351.07843.

8-(Benzyloxy)-2-bromodibenzo[*b,e*]oxepin-6(11*H*)-one (54)



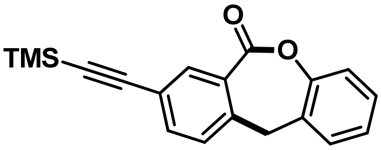
Yield 65 % (51 mg) for 5 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.87 (d, *J* = 8.8 Hz, 1H), 7.41-7.30 (m, 7H), 7.09 (d, *J* = 8.8 Hz, 1H), 6.90 (dd, J_1 = 8.4 Hz, J_2 = 2.0 Hz, 1H), 6.83 (d, *J* = 2.0 Hz, 1H), 5.10 (s, 2H), 3.92 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 165.1, 162.7, 150.0, 143.9, 135.7, 135.5, 134.4, 131.0, 130.9, 128.7, 128.3, 127.5, 122.5, 119.9, 118.4, 113.6, 113.5, 70.2, 37.4; **HRMS (ESI)** m/z calcd for $C_{21}H_{16}BrO_3^+$ $(M+H)^+$ 395.02773, found 395.02777.

2-Bromo-8-fluorodibenzo[*b*,*e*]oxepin-6(11*H*)-one (55)



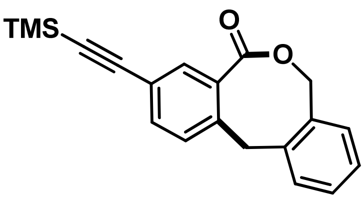
Yield 65% (40 mg) for 6 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.58 (d, *J* = 7.6 Hz, 1H), 7.40-7.09 (m, 5H), 3.94 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 164.1 (d, *J* = 2.2 Hz), 161.7 (d, *J* = 249.0 Hz), 149.5, 137.7 (d, *J* = 3.2 Hz), 134.5, 131.2, 130.9, 129.3 (d, *J* = 7.6 Hz), 129.1 (d, *J* = 7.6 Hz), 122.5, 120.6 (d, *J* = 21.4 Hz), 119.4 (d, *J* = 23.8 Hz), 118.7, 36.2; **HRMS (ESI)** m/z calcd for $C_{14}H_9BrFO_2^+$ $(M+H)^+$ 306.97645, found 306.97629.

8-((Trimethylsilyl)ethynyl)dibenzo[b,e]oxepin-6(11H)-one (56)



Yield 70% (43.0 mg) for 12 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (600 MHz, $CDCl_3$, TMS)** δ 7.98 (d, *J* = 1.8 Hz, 1H), 7.51 (dd, J_1 = 7.8 Hz, J_2 =1.8 Hz, 1H), 7.24-7.19 (m, 4H), 7.13-7.10 (m, 1H), 3.98 (s, 2H), 0.22 (s, 9H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 165.3, 150.5, 142.4, 136.2, 132.1, 128.3, 128.24, 128.19, 127.2, 126.0, 122.9, 120.7, 103.0, 96.0, 37.3, -0.2. **HRMS (ESI)** m/z calcd for $C_{19}H_{19}O_2Si^+$ $(M+H)^+$ 307.11488, found 307.11453.

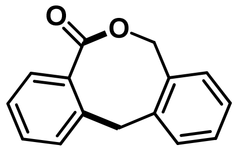
3-((Trimethylsilyl)ethynyl)-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (57)



Yield 51% (33 mg), white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.71 (s, 1H), 7.56 (d, *J* = 7.6 Hz, 1H), 7.37-7.22 (m, 4H), 7.08 (d, *J* = 7.2 Hz, 1H), 5.15 (s, 2H), 4.13 (s, 2H), 0.27 (s, 9H);

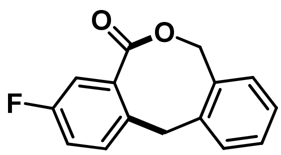
^{13}C NMR (101 MHz, CDCl$_3$) δ 171.6, 136.4, 135.2, 134.4, 133.6, 132.5, 131.2, 130.22, 130.17, 129.3, 128.5, 127.2, 122.8, 103.2, 96.1, 71.5, 40.1, -0.2; **HRMS (ESI)** m/z calcd for $C_{20}H_{21}O_2Si^+$ $(M+H)^+$ 321.13053, found 321.13077.

7,12-Dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (58)



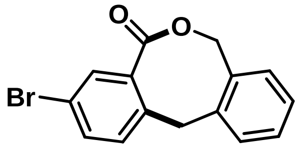
Yield 76% (34 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.47 (d, *J* = 7.6 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 1H), 7.24 (t, *J* = 7.6 Hz, 1H), 7.20-7.15 (m, 3H), 7.10-7.07 (m, 1H), 6.93 (d, *J* = 7.6 Hz, 1H), 5.01 (s, 2H), 4.00 (s, 2H); **^{13}C NMR (151 MHz, CDCl$_3$)** δ 172.2, 136.5, 133.9, 133.4, 132.0, 131.8, 129.8, 129.8, 128.8, 128.1, 127.3, 127.2, 126.7, 71.1, 39.7; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_2^+$ $[M + H]^+$ 225.09101 , found 225.09116.

3-Fluoro-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (59)



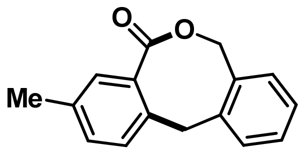
Yield 70% (34 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.35-7.13 (m, 6H), 7.07 (d, *J* = 7.2 Hz, 1H), 5.16 (s, 2H), 4.10 (s, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 171.1 (d, , *J* = 2.6 Hz), 161.6 (d, *J* = 248.3 Hz), 136.6, 133.9 (d, *J* = 7.5 Hz), 133.5, 132.1 (d, *J* = 7.8 Hz), 130.3 (d, *J* = 3.6 Hz), 130.2, 129.3, 129.5, 127.2, 119.2 (d, *J* = 21.3 Hz), 114.7 (d, *J* = 23.6 Hz), 71.6, 39.4; **^{19}F NMR (376 MHz, CDCl$_3$)** δ -113.6; **HRMS (ESI)** m/z calcd for $C_{15}H_{12}FO_2^+$ $(M+H)^+$ 243.08158, found 243.08176.

3-Bromo-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (60)



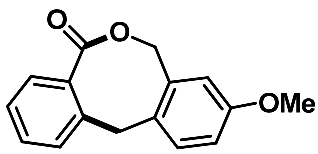
Yield 51% (31 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (600 MHz, $CDCl_3$)** δ 7.72 (d, *J* = 1.8 Hz, 1H), 7.58 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 7.32 (td, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 7.28 (d, *J* = 7.2 Hz, 1H), 7.22 (td, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 7.19 (d, *J* = 7.8 Hz, 1H), 7.08 (d, *J* = 7.2 Hz, 1H), 5.16 (s, 2H), 4.09 (s, 2H); **^{13}C NMR (151 MHz, $CDCl_3$)** δ 170.9, 136.1, 135.1, 134.1, 133.5, 133.4, 131.8, 130.5, 130.2, 129.3, 128.5, 127.2, 121.2, 71.6, 39.7; **HRMS (ESI)** m/z calcd for $C_{15}H_{11}BrNaO_2{}^+$ (M + Na)$^+$ 324.9835, found 324.9831.

3-Methyl-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (61)



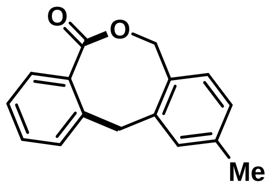
Yield 84% (40 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.38 (s, 1H), 7.32-7.25 (m, 3H), 7.20-7.16 (m, 2H), 7.03 (d, *J* = 6.8 Hz, 1H), 5.13 (s, 2H), 4.08 (s, 2H), 2.36 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 172.8, 137.4, 137.1, 133.8, 132.9, 132.1, 131.3, 130.04, 130.02, 129.1, 128.4, 128.1, 126.9, 71.5, 39.7, 20.8; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_2{}^+$ (M+H)$^+$ 239.10666, found 239.10683.

9-Methoxy-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (62)



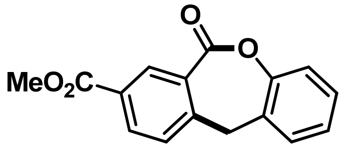
Yield 64% (32 mg), white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.57 (d, *J* = 7.6 Hz, 1H), 7.46 (t, d, *J* = 7.6 Hz, 1H), 7.36 (t, d, *J* = 7.6 Hz, 1H), 7.28 (d, *J* = 7.6 Hz, 1H), 7.22 (d, *J* = 8.4 Hz, 1H), 6.83 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 6.61 (d, J = 2.0 Hz, 1H), 5.09 (s, 2H), 4.07 (s, 2H), 3.77 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 172.7, 158.3, 134.99, 134.91, 132.2, 132.1, 131.2, 130.0, 129.0, 127.7, 127.4, 114.4, 113.6, 71.4, 55.3, 39.3; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_3^+$ $(M+H)^+$ 255.10157, found 255.10168.

10-Methyl-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-5-one (63)



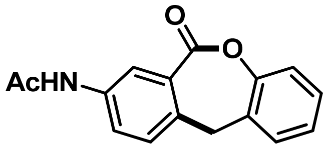
Yield 73% (35 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (600 MHz, CDCl$_3$)** δ 7.57 (dd, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 7.45 (td, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 7.35 (td, J_1 = 7.2 Hz, J_2 = 0.6 Hz, 1H), 7.30 (d, J = 7.2 Hz, 1H), 7.13 (s, 1H), 7.01 (d, J = 7.2 Hz, 1H), 6.94 (d, J = 7.2 Hz, 1H), 5.10 (s, 2H), 4.08 (s, 2H), 2.36 (s, 3H); **^{13}C NMR (151 MHz, CDCl$_3$)** δ 172.7, 139.0, 136.5, 134.3, 132.3, 132.0, 130.9, 130.7, 130.0, 128.4, 127.6, 127.45, 127.41, 71.4, 40.1, 20.9; **HRMS (ESI)** m/z calcd for $C_{16}H_{15}O_2^+$ $(M+H)^+$ 239.10666, found 239.10678.

Methyl 6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepine-8-carboxylate (64)



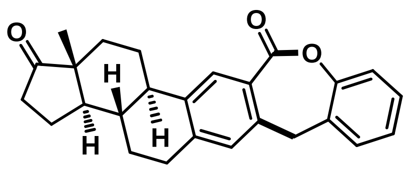
Yield 36% (19.4 mg) for 4 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 8.55 (d, J = 1.2 Hz, 1H), 8.12 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H), 7.37 (d, J = 8.0 Hz, 1H), 7.28-7.24 (m, 3H), 7.17-7.12 (m, 1H), 4.06 (s, 2H), 3.91 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 165.6, 165.2, 150.5, 147.0, 134.2, 134.1, 131.7, 129.8, 128.5, 128.4, 128.3, 127.5, 126.1, 120.8, 52.4, 37.4; **HRMS (ESI)** m/z calcd for $C_{16}H_{13}O_4^+$ $(M+H)^+$ 269.08084, found 269.08075.

N-(6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-8-yl)acetamide (65)



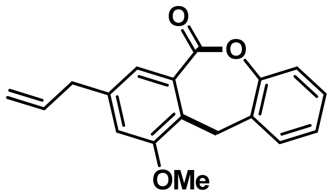
Yield 34% (18.4 mg) for 4 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 8.00 (dd, J_1 = 8.4 Hz, J_2 = 2.0 Hz, 1H), 7.87 (s, 1H), 7.75 (d, J = 2.0 Hz, 1H), 7.26-7.19 (m, 4H), 7.12 (td, J_1 = 6.8 Hz, J_2 = 2.0 Hz, 1H), 3.96 (s, 2H), 2.19 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 168.8, 166.1, 150.5, 138.2, 137.5, 132.7, 128.2, 128.13, 128.1, 126.0, 125.2, 123.4, 120.7, 36.8, 24.4; **HRMS (ESI)** m/z calcd for $C_{16}H_{14}NO_3^+$ $(M+H)^+$ 268.09682, found 268.09698.

(2*aR*,5*aR*,5*bS*,16*bR*)-2a-Methyl-2,2a,5,5a,6,7,9,16b-octahydro-1H-benzo[*b*]cyclopenta[7,8]phenanthro[2,3-e]oxepine-3,15(4*H*,5*bH*)-dione (66)



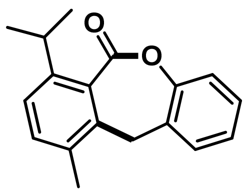
Yield 70% (54.6 mg) for 10 h, white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.82 (s, 1H), 7.25-7.18 (m, 3H), 7.14-7.09 (m, 1H), 6.99 (s, 1H), 3.94 (dd, J_1 = 34.4 Hz, J_2 = 13.6 Hz, 2H), 2.97-2.84 (m, 2H), 2.53-2.43 (m, 2H), 2.23-1.95 (m, 5H), 1.66-1.37 (m, 6H), 0.87 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 220.5, 166.4, 150.8, 143.0, 139.9, 139.3, 132.9, 130.1, 128.1, 128.0, 127.7, 125.8, 125.2, 120.7, 50.3, 47.8, 43.9, 37.7, 37.0, 35.7, 31.3, 29.3, 26.0, 25.5, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{26}H_{27}O_3^+$ $(M+H)^+$ 387.19547, found 387.19522.

8-Allyl-10-methoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (67)



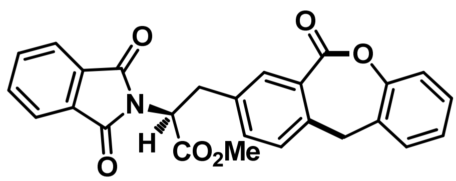
Yield 75% (42.4 mg) for 10 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.28-7.19 (m, 4H), 7.12-7.07 (m, 1H), 6.85 (s, 1H), 5.94-5.84 (m, 1H), 5.11-5.07 (m, 2H), 4.05 (s, 2H), 3.87 (s, 3H), 3.35 (d, *J* = 6.4 Hz, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.3, 154.7, 151.2, 140.1, 136.3, 133.0, 129.28, 129.26, 128.4, 127.8, 125.6, 123.8, 120.4, 116.7, 115.2, 56.1, 39.9, 27.2; **HRMS (ESI)** m/z calcd for $C_{18}H_{17}O_3^+$ $(M+H)^+$ 281.11722, found 281.11737.

7-Isopropyl-10-methyldibenzo[*b*,*e*]oxepin-6(11*H*)-one (68)



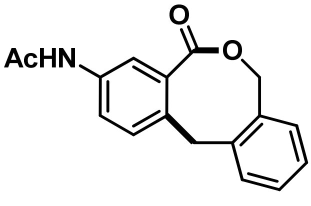
Yield 52% (27.6 mg) for 9 h, white solid; R_f = 0.45 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.24-7.13 (m, 5H), 7.06 (td, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 3.90 (s, 2H), 3.40-3.29 (m, 1H), 2.42 (s, 3H), 1.20 (d, *J* = 7.2 Hz, 6H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.2, 150.9, 147.7, 140.3, 133.1, 132.8, 130.1, 128.0, 127.7, 127.6, 125.2, 124.5, 119.6, 32.1, 29.9, 24.0, 19.4; **HRMS (ESI)** m/z calcd for $C_{18}H_{19}O_2^+$ $(M+H)^+$ 267.13796, found 267.13785.

(S)-Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-(6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-8-yl)propanoate (69)



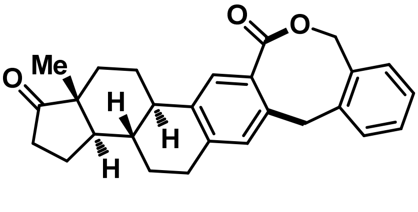
Yield 64% (57.3 mg) for 10 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.77-7.74 (m, 1H), 7.71-7.68 (m, 2H), 7.31 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H), 7.20-7.06 (m, 3H), 5.10 (dd, J_1 = 10.4 Hz, J_2 = 5.2 Hz, 1H), 3.94-3.86 (m, 1H), 3.76 (s, 2H), 3.61-3.48 (m, 1H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 169.0, 167.4, 165.6, 150.5, 141.2, 136.3, 134.2, 133.7, 133.2, 132.4, 131.4, 128.1, 128.0, 127.6, 125.7, 123.5, 120.6, 53.0, 52.7, 37.0, 34.0; **HRMS (ESI)** m/z calcd for $C_{26}H_{20}NO_6^+$ $(M+H)^+$ 442.12851, found 442.12909.

***N*-(5-oxo-7,12-dihydro-5*H*-dibenzo[*c,f*]oxocin-3-yl)acetamide (70)**



Yield 70% (39 mg), white solid; R_f = 0.40 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (600 MHz, DMSO-*d*$_6$)** δ 10.16 (s, 1H), 7.84 (d, *J* = 2.4 Hz, 1H), 7.66 (dd, J_1 = 8.4 Hz, J_2 = 1.8 Hz, 1H), 7.38 (d, *J* = 7.2 Hz, 1H), 7.34-7.31 (m, 2H), 7.22 (td, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 7.17 (d, *J* = 6.6 Hz, 1H), 5.13 (s, 2H), 4.01 (s, 2H), 2.05 (s, 3H); **^{13}C NMR (151 MHz, DMSO-*d*$_6$)** δ 172.1, 169.1, 139.1, 137.4, 134.4, 132.9, 131.1, 130.7, 129.5, 129.1, 128.9, 127.3, 122.8, 117.9, 71.3, 38.9, 24.5; **HRMS (ESI)** m/z calcd for $C_{17}H_{16}NO_3^+$ $(M+H)^+$ 282.11247, found 282.11264.

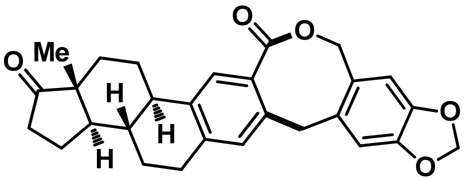
(3*aR*,3*bS*,15*bR*,17*aR*)-17a-Methyl-3,3a,4,5,7,12,15b,16,17,17a-decahydrobenzo[*c*] cyclopenta[7,8]phenanthro[2,3-f]oxocine-1,14(2*H*,3*bH*)-dione (71)



Yield 72% (58 mg), white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.50 (s, 1H), 7.31-7.27 (m, 2H), 7.19 (td, J_1 = 6.8 Hz, J_2 = 1.6 Hz, 1H), 7.06 (d, *J* = 7.4 Hz, 1H), 7.02 (s, 1H), 5.16 (s, 2H), 4.08 (s, 2H), 2.91-2.87 (m, 2H), 2.55-2.43 (m, 2H), 2.31-2.26 (m, 1H), 2.20-1.97 (m, 4H), 1.61-1.41 (m, 6H), 0.90 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ

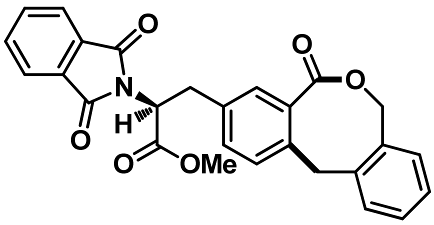
220.4, 173.0, 141.3, 139.5, 137.2, 133.9, 131.9, 130.7, 130.1, 129.8, 129.1, 128.3, 126.9, 125.0, 71.6, 50.4, 47.8, 44.0, 39.8, 37.9, 35.7, 31.4, 29.3, 26.2, 25.6, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{27}H_{29}O_3^+$ $(M+H)^+$ 401.21112, found 401.21170.

(2*aS*,2*bR*,5*aR*,7*aR*)-5a-Methyl-2,2a,3,4,5a,6,7,7a,11,17-decahydro-[1,3]dioxolo[4',5':4,5]benzo[1,2-*c*]cyclopenta[7,8]phenanthro[2,3-*f*]oxocine-5,9(1*H*,2*bH*)-dione (72)



Yield 78% (69 mg), white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (600 MHz, CDCl$_3$)** δ 7.49 (s, 1H), 7.00 (s, 1H), 6.77 (s, 1H), 6.55 (s, 1H), 5.95 (s, 2H), 5.06 (s, 2H), 3.98 (s, 2H), 2.92-2.88 (m, 2H), 2.55-2.43 (m, 2H), 2.31-2.26 (m, 1H), 2.20-197 (m, 4H), 1.66-1.41 (m, 6H), 0.91 (s, 3H); **^{13}C NMR (151 MHz, CDCl$_3$)** δ 220.5, 173.0, 147.8, 146.1, 141.4, 139.4, 132.2, 131.0, 130.5, 129.7, 127.2, 125.1, 110.7, 108.8, 101.3, 71.3, 50.3, 47.8, 44.0, 39.5, 37.8, 35.7, 31.4, 29.3, 26.1, 25.6, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{28}H_{29}O_5^+$ $(M+H)^+$ 445.20095, found 445.20068.

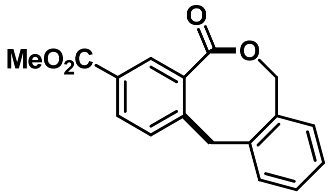
Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-(5-oxo-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocin-3-yl)propanoate (73)



Yield 78% (71 mg), white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (600 MHz, CDCl$_3$)** δ 7.70 (q, J = 3.0 Hz, 2H), 7.65 (q, J = 3.0 Hz, 2H), 7.33 (q, J = 1.8 Hz, 1H), 7.26-7.24 (m, 2H), 7.19 (d, J = 6.6 Hz, 1H), 7.14 (td, J_1 = 7.8 Hz, J_2 = 1.2 Hz, 1H), 7.09 (d, J = 7.8 Hz, 1H), 6.97 (d, J =

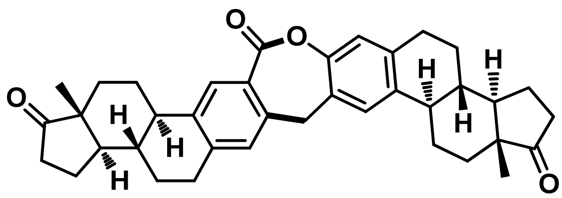
7.2 Hz, 1H), 5.09 (q, J = 5.4 Hz, 1H), 4.93-4.85 (m, 2H), 4.02-3.94 (m, 2H), 3.75 (s, 3H), 3.59 (dd, J_1 = 14.4 Hz, J_2 = 5.4 Hz, 1H), 3.51 (dd, J_1 = 14.4 Hz, J_2 = 10.8 Hz, 1H), **^{13}C NMR (151 MHz, $CDCl_3$)** δ 172.0, 168.8, 167.2, 136.7, 136.5, 134.2, 133.7, 132.8, 132.6, 132.5, 131.3, 130.4, 130.1, 129.1, 128.3, 128.1, 126.9, 123.4, 71.2, 52.90, 52.88, 39.6, 34.1; **HRMS (ESI)** m/z calcd for $C_{27}H_{22}NO_6^+$ $(M+H)^+$ 456.14416, found 456.14447.

Methyl 5-oxo-7,12-dihydro-5*H*-dibenzo[*c*,*f*]oxocine-3-carboxylate (74)



Yield 54% (30 mg), white solid; R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.26 (d, J = 1.6 Hz, 1H), 8.12 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H), 7.40 (d, J = 8.0 Hz, 1H), 7.35-7.30 (m, 2H), 7.23 (td, J_1 = 7.2 Hz, J_2 = 2.0 Hz, 1H), 7.07 (d, J = 7.6 Hz, 1H), 5.14 (s, 2H), 4.18 (s, 2H), 3.93 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 171.5, 165.7, 139.2, 135.9, 133.6, 133.1, 132.6, 130.4, 130.3, 129.6, 129.3, 129.1, 128.5, 127.3, 71.5, 52.4, 40.2; **HRMS (ESI)** m/z calcd for $C_{17}H_{15}O_4^+$ $(M+H)^+$ 283.09649, found 283.09698.

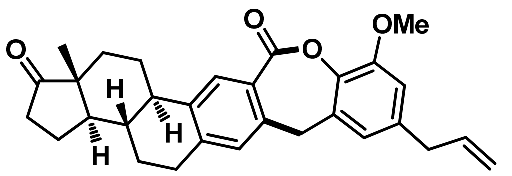
(3*aR*,5*aR*,11*aS*,11*bR*,14*aR*,16*aR*,21*aS*,21*bR*)-3a,14a-Dimethyl-1,3a,4,5,5a,11,11a,12,13,14a,15,16,16a,18,20,21,21a,21b-octadecahydrocyclopenta[7,8]phenanthro[2,3-*b*]cyclopenta[7,8]phenanthro[2,3-*e*]oxepine-3,7,14(2*H*,10*H*,11b*H*)-trione (75)



Yield 74% (83.6 mg) for 21 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz,**

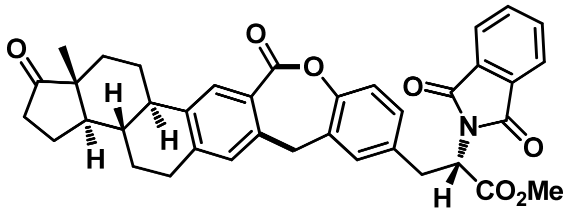
CDCl$_3$) δ 7.80 (s, 1H), 7.15 (s, 1H), 6.98 (s, 1H), 6.95 (s, 1H), 3.89 (dd, J_1 = 38.4 Hz, J_2 = 11.6 Hz, 2H), 2.92-2.82 (m, 4H), 2.53-2.41 (m, 4H), 2.24-1.94 (m, 10H), 1.64-1.36 (m, 12H), 0.89 (s, 3H), 0.87 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 220.7, 220.5, 166.7, 148.6, 142.8, 140.0, 139.1, 137.2, 136.5, 130.0, 129.9, 127.6, 125.3, 124.9, 120.6, 50.22, 50.19, 47.8, 47.7, 43.9, 43.8, 37.9, 37.7, 36.9, 35.73, 35.69, 31.4, 31.3, 29.3, 28.9, 26.2, 26.0, 25.8, 25.5, 21.4, 13.69, 13.65; **HRMS (ESI)** m/z calcd for $C_{38}H_{43}O_4^+$ $(M+H)^+$ 563.31559, found 563.31580.

(2*aR*,5*aR*,5*bS*,16*bR*)-11-Allyl-13-methoxy-2a-methyl-2,2a,5,5a,6,7,9,16b-octahydro-1H-benzo[b]cyclopenta[7,8]phenanthro[2,3-*e*]oxepine-3,15(4H,5*bH*)-dione (76)



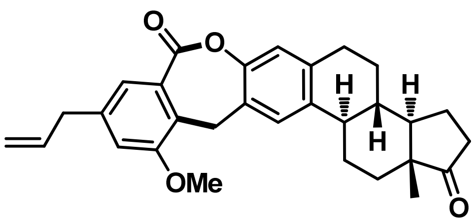
Yield 43% (38.8 mg) for 8 h, white solid; R_f = 0.50 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.83 (s, 1H), 6.97 (s, 1H), 6.64 (s, 1H), 6.62 (s, 1H), 5.96-5.86 (m, 1H), 5.12- 5.07 (m, 2H), 3.93 (s, 2H), 3.84 (s, 3H), 3.31 (d, J = 6.4 Hz, 2H), 2.97-2.84 (m, 2H), 2.53-2.42 (m, 2H), 2.23-1.94 (m, 5H), 1.66-1.39 (m, 6H), 0.87 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 220.5, 166.2, 150.6, 142.8, 140.1, 139.2, 138.2, 138.0, 136.7, 134.4, 130.2, 127.7, 125.2, 119.1, 116.3, 111.2, 56.0, 50.3, 47.8, 43.9, 39.9, 37.8, 37.0, 35.7, 31.3, 29.3, 26.0, 25.5, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{30}H_{33}O_4^+$ $(M+H)^+$ 457.23734, found 457.23764.

(*S*)-Methyl 2-(1,3-dioxoisoindolin-2-yl)-3-((2*aR*,5*aR*,5*bS*,16*bR*)-2a-methyl-3,15-dioxo-2,2a,3,4,5,5a,5b,6,7,9,15,16b-dodecahydro-1H-benzo[*b*]cyclopenta[7,8]phenanthro[2,3-*e*]oxepin-11-yl)propanoate (77)



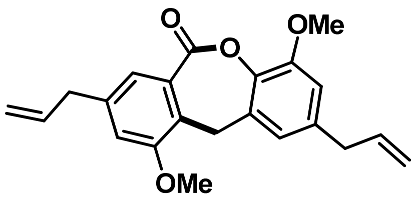
Yield 64% (79.2 mg) for 5 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.80-7.70 (m, 5H), 7.08-6.97 (m, 3H), 6.91 (d, *J* = 6.8 Hz, 1H), 5.15-5.10 (m, 1H), 3.95-3.77 (m, 5H), 3.58-3.45 (m, 2H), 2.97-2.92 (m, 2H), 2.53-2.37 (m, 2H), 2.22-1.94 (m, 5H), 1.66-1.36 (m, 6H), 0.87 (d, *J* = 2.4 Hz, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 220.4, 169.1, 167.4, 166.2, 149.6, 142.9, 139.6, 139.2, 134.3, 134.2, 132.92, 132.90, 131.4, 129.98, 129.97, 128.5, 128.4, 128.3, 128.2, 127.62, 127.58, 125.1, 123.5, 120.82, 120.78, 52.9, 52.82, 52.76, 50.2, 47.8, 43.8, 37.7, 36.9, 35.7, 33.8, 31.3, 29.3, 26.0, 25.4, 21.4, 13.7; **HRMS (ESI)** m/z calcd for $C_{38}H_{36}NO_7^+$ $(M+H)^+$ 618.24863, found 618.24878.

(3*aR*,5*aR*,16*aS*,16*bR*)-10-Allyl-8-methoxy-3a-methyl-3a,4,5,5a,15,16,16a,16b-octahydro-1H-benzo[*e*]cyclopenta[7,8]phenanthro[2,3-*b*]oxepine-3,12(2*H*,7*H*)-dione (78)



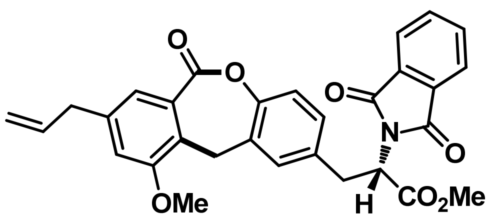
Yield 42% (39.0 mg) for 17 h, white solid; R_f = 0.15 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.27 (s, 1H), 7.16 (s, 1H), 6.93 (s, 1H), 6.84 (s, 1H), 5.93-5.83 (m, 1H), 5.11-5.06 (m, 2H), 4.04-3.95 (m, 2H), 3.87 (s, 3H), 3.34 (d, J = 6.8 Hz, 2H), 2.84 (dd, J_1 = 8.8 Hz, J_2 = 4.0 Hz, 2H), 2.54-2.43 (m, 2H), 2.22-1.96 (m, 5H), 1.67-1.48 (m, 6H), 0.90 (s, 3H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 220.8, 166.7, 154.6, 149.0, 140.0, 137.0, 136.34, 136.31, 130.1, 129.4, 125.3, 123.8, 120.3, 116.6, 115.2, 56.1, 50.3, 47.9, 44.0, 39.9, 37.9, 35.8, 31.5, 29.0, 27.1, 26.8, 26.2, 25.8, 21.5, 13.8; **HRMS (ESI)** m/z calcd for $C_{30}H_{33}O_4^+$ $(M+H)^+$ 457.23734, found 457.23749.

2,8-Diallyl-4,10-dimethoxydibenzo[*b*,*e*]oxepin-6(11*H*)-one (79)



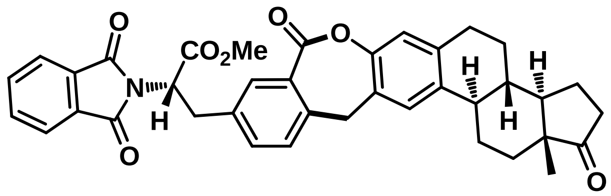
Yield 53% (37.5 mg) for 13 h, white solid; R_f = 0.25 (petroleum ether : ethyl acetate = 20 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.30 (s, 1H), 6.84 (s, 1H), 6.67 (s, 1H), 6.61 (s, 1H), 5.96-5.83 (m, 2H), 5.12-5.06 (m, 4H), 4.00 (s, 2H), 3.87 (s, 3H), 3.83 (s, 3H), 3.32 (dd, J_1 = 11.4 Hz, J_2 = 6.8 Hz, 4H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 154.7, 150.3, 140.0, 138.4, 138.0, 136.8, 136.3, 134.4, 129.5, 129.3, 124.0, 119.6, 116.6, 116.2, 115.2, 111.0, 56.1, 55.9, 40.0, 39.9, 27.1; **HRMS (ESI)** m/z calcd for $C_{22}H_{23}O_4^+$ $(M+H)^+$ 351.15909, found 351.15933.

(*S*)-Methyl 3-(8-allyl-10-methoxy-6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-2-yl)-2-(1,3-dioxoisoindolin-2-yl)propanoate (80)



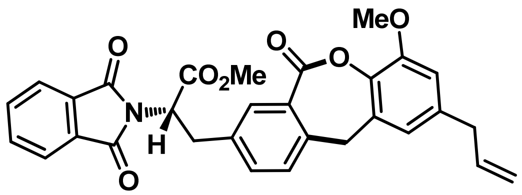
Yield 52% (53.8 mg) for 5 h, white solid; R_f = 0.18 (petroleum ether : ethyl acetate = 5 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.77-7.67 (m, 4H), 7.22 (s, 1H), 7.09 (s, 1H), 7.01-6.97 (m, 2H), 6.80 (s, 1H), 5.93-5.83 (m, 1H), 5.15-5.06 (m, 3H), 3.91 (s, 2H), 3.84 (s, 3H), 3.77 (s, 3H), 3.57-3.45 (m, 2H), 3.33 (d, *J* = 6.8 Hz, 2H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 169.1, 167.4, 166.2, 154.6, 150.0, 140.0, 136.2, 134.2, 134.1, 133.1, 131.4, 129.1, 129.0, 128.8, 128.1, 123.7, 123.4, 120.4, 116.6, 115.2, 56.0, 52.9, 39.9, 33.8, 27.0; **HRMS (ESI)** m/z calcd for $C_{30}H_{26}NO_7^+$ $(M+H)^+$ 512.17038, found 512.17053.

(*S*)-methyl 2-(1,3-dioxoisoindolin-2-yl)-3-((3*aR*,3*bS*,14*bR*,16*aR*)-16a-methyl-1,8-dioxo-2,3,3a,3b,4,5,8,13,14b,15,16,16a-dodecahydro-1H-benzo[*e*]cyclopenta[7,8]phenanthro[2,3-*b*]oxepin-10-yl)propanoate (81)



Yield 31% (38.2 mg) for 28 h, white solid; R_f = 0.20 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, CDCl$_3$)** δ 7.79-7.68 (m, 5H), 7.31-7.27 (m, 1H), 7.12-7.10 (m, 2H), 6.90 (d, *J* = 3.6 Hz, 1H), 5.10 (dd, J_1 = 10.4 Hz, J_2 = 5.2 Hz, 1H), 3.85 (s, 2H), 3.76 (s, 3H), 3.61-3.49 (m, 2H), 2.83 (d, *J* = 4.8 Hz, 2H), 2.53-2.34 (m, 2H), 2.21-1.94 (m, 5H), 1.66-1.33 (m, 6H), 0.88 (s, 3H); **^{13}C NMR (101 MHz, CDCl$_3$)** δ 220.7, 169.0, 167.4, 165.9, 148.4, 141.3, 137.2, 136.6, 136.2, 134.2, 133.6, 133.2, 131.5, 129.5, 128.3, 127.6, 125.0, 123.6, 120.58, 120.56, 53.0, 52.8, 50.3, 47.8, 43.9, 37.9, 37.0, 35.8, 33.9, 31.4, 28.9, 26.2, 25.8, 21.5, 13.7; **HRMS (ESI)** m/z calcd for $C_{38}H_{36}NO_7^+$ $(M+H)^+$ 618.24863, found 618.24884.

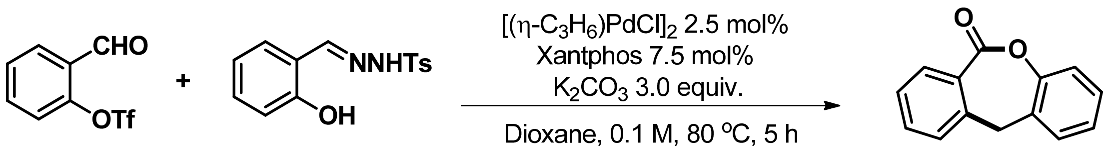
(*S*)-Methyl 3-(2-allyl-4-methoxy-6-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-8-yl)-2-(1,3-dioxoisoindolin-2-yl)propanoate (82)



Yield 47% (48.1 mg) for 11 h, white solid; R_f = 0.24 (petroleum ether : ethyl acetate = 3 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.79-7.69 (m, 5H), 7.30 (dd, J_1 = 8.0 Hz, J_1 = 1.6 Hz, 1H), 7.11 (d, J = 8.0 Hz, 1H), 6.60 (d, J = 1.2 Hz, 2H), 5.94-5.84 (m, 1H), 5.12-5.06 (m, 3H), 3.84 (s, 2H), 3.82 (s, 3H), 3.76 (s, 3H), 3.61-3.48 (m, 2H), 3.29 (d, J = 6.8 Hz, 2H).; **^{13}C NMR (101 MHz, $CDCl_3$)** δ 169.0, 167.4, 165.4, 150.5, 141.4, 138.2, 137.8, 136.7, 136.3, 134.2, 133.9, 133.5, 133.4, 131.5, 128.2, 127.7, 123.6, 119.2, 116.3, 111.2, 55.9, 53.0, 52.8, 39.9, 37.0, 34.0; **HRMS (ESI)** m/z calcd for $C_{30}H_{26}NO_7^+$ $(M+H)^+$ 512.17038, found 512.17078.

Deuterium-labeling experiments

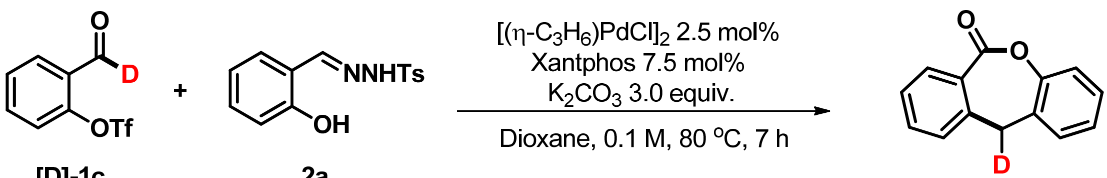
In the presence of D_2O:



1c **0.2 mmol** **2a** **2.0 equiv.** **3** **23.3 mg/ 55%**

An oven-dried reaction tube containing a stirring bar was charged with [(η-C_3H_6)PdCl]$_2$ (2.5 mol%), Xantphos (7.5 mol%), K_2CO_3 (3.0 equiv.) and **2a** (0.4 mmol, 116 mg). After degassed and filled with dry argon repeated three times, dioxane (2.0 mL), **1c** (0.2 mmol, 51 mg) and D_2O (10.0 equiv.) were added via syringe. The mixture was stirred at 80 ^{o}C for 5 h. The crude mixture was cooled to room temperature. EtOAc was added to the mixture. The reaction mixture was filtered through a short pad of celite. After removing the solvent under reduced pressure, the residual was purified by silica gel column chromatography to obtain the seven-membered lactone (**3**).

8.2 [D]-1c instead of 1c:



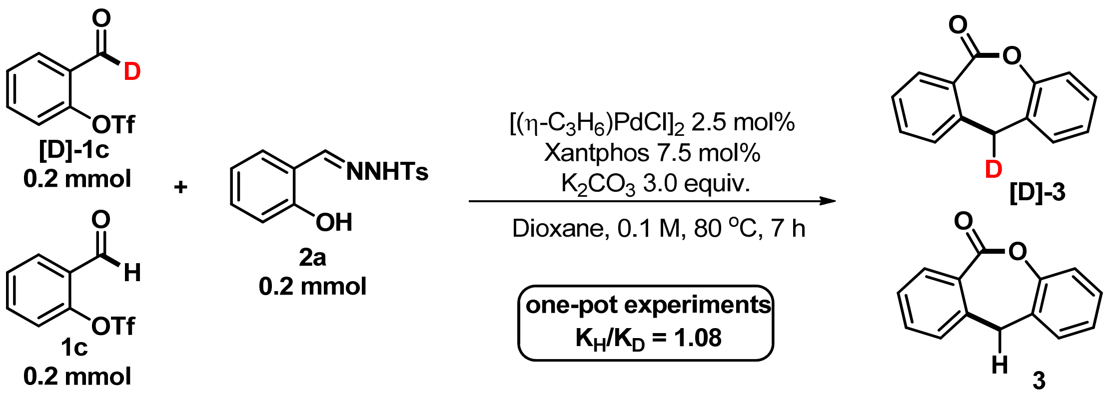
[D]-1c **0.2 mmol** **2a** **2.0 equiv.** **[D]-3** **31.7 mg/ 75%**

Following the general procedure for the synthesis of seven-membered lactone, the reaction was generate the deuterated product (**[D]-3**) in 75% yield. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.89 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.46 (td, J_1 = 7.6 Hz, J_2 = 1.2

Hz, 1H), 7.32 (td, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.27-7.19 (m, 4H), 7.15-7.10 (m, 1H), 3.99 (s, 1H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 166.1, 150.6, 142.5, 133.4, 132.7, 132.6, 128.13, 128.10, 128.0, 127.4, 127.1, 125.8, 120.7, 37.4, 37.1 (t, J = 20.0 Hz).

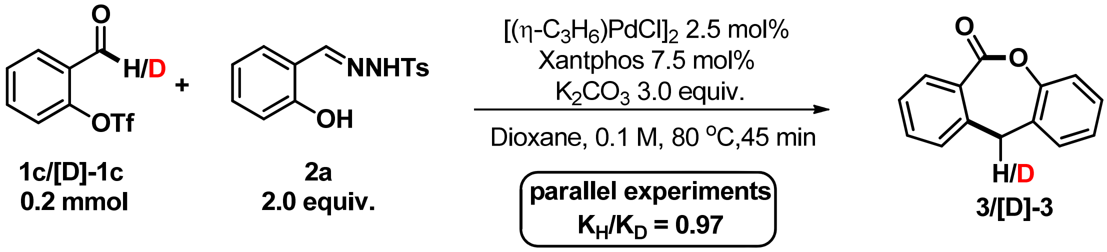
Kinetic isotope effect experiment:

a) One-pot experiment



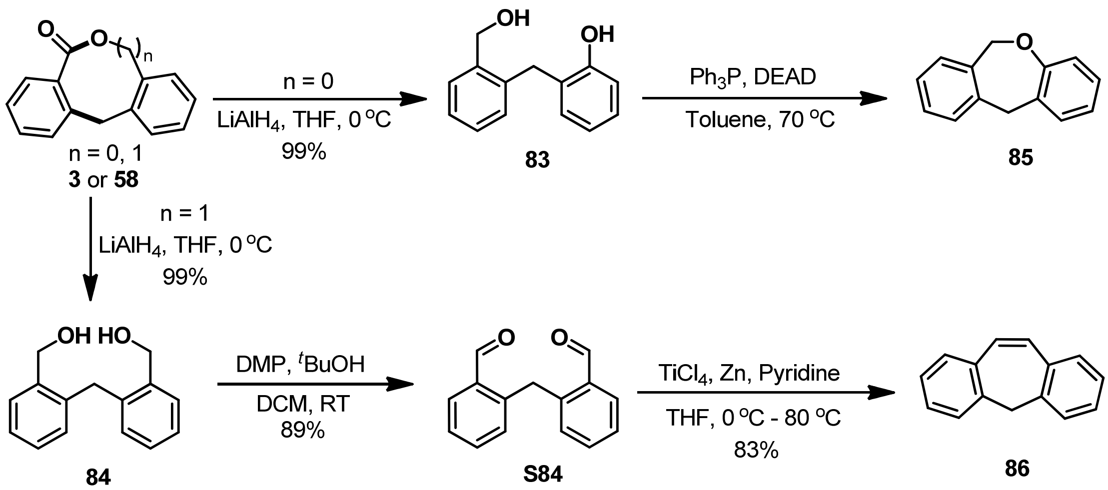
One-pot experiment was conducted using 0.2 mmol **1c**, 0.2 mmol **[D]-1c,** 0.2 mmol **2a** as the substrates. Following the general procedure for the synthesis of seven-membered lactone, the reaction was stopped after 7 h. The crude mixture was cooled to room temperature. EtOAc was added to the mixture. The reaction mixture was filtered through a short pad of celite. After removing the solvent under reduced pressure, the residual was purified by silica gel column chromatography to obtain the seven-membered lactone (**3**/**[D]-3**) compound. The KIE value (K_H/K_D = 0.96) was determined on the basis of ^{1}H NMR analysis.

b) Parallel experiments



Parallel experiments were conducted using **1c** and **[D]-1c** as substrates. Following the general procedure for the synthesis of seven-membered lactone, the two reactions were stopped after 45 min. The crude mixture was cooled to room temperature. EtOAc was added to the mixture. The mixture was filtered through Celite. The solvents were evaporated and the yields of the products (**3/[D]-3**) were estimated by GC using *n*-decane as the internal standard. KIE = 8.5/8.8 = 0.97 was obtained.

Representative synthetic application



To a mixture of $LiAlH_4$ (1.01 equiv) in 3 mL of THF at 0 °C, a solution of **3** (161 mg, 0.76 mmol) in 7 mL of THF was added slowly. The reaction mixture was stirred for 4 h and carefully quenched with 2 mL of aq. NH_4Cl solution. 15 mL of EtOAc and 3 mL of 10% aq. NaOH solution were added sequentially and stirred for another 15 minutes at room temperature. The resulting mixture was then filtered. The filtrate was extracted with EtOAc (3×15 mL). The combined EtOAc layer was washed with 5 mL of 10% aq. HCl, brine and dried over Na_2SO_4. The solvent was removed under reduced pressure. The residues were purified by column chromatography on silica gel to get product (**83**) (162 mg, 99%) as a white solid. R_f = 0.5 (petroleum ether : ethyl acetate = 2 : 1); **^{1}H NMR (400 MHz, CD_3CN)** δ 7.11 (s, 1H), 7.00-6.79 (m, 1H), 6.82-6.80 (m, 2H), 6.73-6.65 (m, 3H), 6.44-6.40 (m, 2H), 4.29 (d, *J* = 4.8 Hz, 2H), 3.60 (s, 2H), 3.20 (t, *J* = 4.8 Hz, 1H); **^{13}C NMR (101 MHz, CD_3CN)** δ 155.3, 139.5, 139.3, 131.4, 130.2, 128.6, 128.20, 128.15, 127.4, 126.8, 120.4, 115.9, 62.8, 32.2; **HRMS (ESI)** m/z calcd for $C_{14}H_{15}O_2^+$ $(M+H)^+$ 215.10666, found 215.10617.

Compound **85** was prepared from **83** using the literature procedure.[8] Diol **84** (128.4 mg, 0.60 mmol), triphenylphosphine (165.2 mg, 0.63 mmol) in toluene (6 mL) solution of diethyl diazene-1,2-dicarboxylate (95 µL, 0.60 mmol) was added dropwise at room temperature, the reaction mixture was stirred under argon 6 hours at 70 ^{o}C. The solvent of the reaction mixture was evaporated, and the residue was purified by column chromatography to give compound **85** (116.8 mg, 98%) as light yellow liquid; R_f = 0.7 (petroleum ether : ethyl acetate = 50 : 1); **^{1}H NMR (400 MHz, CD_3CN)** δ 7.06-6.97 (m, 1H), 6.87 (d, *J* = 7.2 Hz, 1H), 6.82 (t, *J* = 7.2 Hz, 1H), 6.58 (t, *J* = 7.2 Hz, 1H), 6.48 (d, *J* = 8.4 Hz, 1H), 5.04 (s, 1H), 3.98 (s, 1H); **^{13}C NMR (101 MHz, CD_3CN)** δ 157.3, 141.3, 136.6, 131.6, 129.4, 128.8, 128.7, 128.4, 127.7, 126.1, 121.9, 120.0, 70.6, 38.6.

To a mixture of $LiAlH_4$ (2.5 equiv) in 3 mL of THF at 0 °C, a solution of **58** (150 mg, 0.66 mmol) in 7 mL of THF was added slowly. The reaction mixture was stirred for 3 h and carefully quenched with 2 mL of aq. NH_4Cl solution. 15 mL of EtOAc and 3 mL of 10% aq. NaOH solution were added sequentially and stirred for another 15 minutes at room temperature. The resulting mixture was then filtered. The filtrate was extracted with EtOAc (3×15 mL). The combined EtOAc layer was washed with 5 mL of 10% aq. HCl, brine and dried over Na_2SO_4. The solvent was removed under reduced pressure and the residual solid was washed and filtered again using DCM. The pure compound **84** (150 mg, 99%) was obtained as a white solid. R_f = 0.3 (petroleum ether : ethyl acetate = 1 : 1); **^{1}H NMR (600 MHz, DMSO-*d$_6$*)** δ 7.43 (d, J = 7.2 Hz, 2H), 7.21 (td, J_1 = 7.2 Hz, J_2 = 0.6 Hz, 2H), 7.14 (td, J_1 = 7.2 Hz, J_2 = 0.6 Hz, 2H), 6.84 (d, J = 7.2 Hz, 2H), 5.13 (t, J = 5.4 Hz, 2H), 4.47 (d, J = 5.4 Hz, 4H), 3.98 (s, 2H); **^{13}C NMR (151 MHz, DMSO-*d$_6$*)** δ 140.7, 137.7, 129.3, 127.4, 127.2, 126.5, 61.2, 34.0; **HRMS (ESI)** m/z calcd for $C_{15}H_{17}O_2^+$ $(M+H)^+$ 229.12231, found 229.12238.

Compound **S84** was prepared from **84** using an oxidation method described in literature.[9] To a stirred mixture of **84** (160 mg, 0.7 mmol) in dichloromethane (10 mL) at room temperature was added sequentially *tert*-butyl alcohol (10 equiv) and Desse-Martin periodinane (3 equiv). After stirring for 5 h, saturated aqueous sodium hydrogen carbonate (5 mL) and saturated aqueous sodium thiosulfate (5 mL) were added to the mixture, which was extracted with dichloromethane (2×20 mL). The organic layer was washed with brine and dried over Na_2SO_4. The solvent was evaporated under reduced pressure and the residue was purified by silica gel column to get **S84** (140 mg, 89% yield) as colourless liquid; R_f = 0.3 (petroleum ether : ethyl acetate = 10 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 10.16 (s, 2H), 7.84 (d, *J* = 7.2 Hz, 2H), 7.46-7.37 (m, 4H), 7.01 (d, *J* = 7.6 Hz, 2H), 4.88 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 192.5, 141.9, 133.7, 133.6, 132.8, 130.8, 126.8, 34.6; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}O_2^+$ $(M+H)^+$ 225.09101, found 225.09125.

Compound **86** was prepared from **S84** using the literature procedure.[10] In a two-neck round-bottom flask containing **S84** (60 mg, 0.27 mmol) and zinc dust (6.0 equiv) in dry THF (10 mL) was added pyridine (12.0 equiv). The stirred mixture was cooled to 0 °C and titanium(IV) chloride (3.0 equiv) was added dropwise. The mixture was then heated at 80 °C for 6 h before being cooled to room temperature and quenched with saturated aqueous $NaHCO_3$ solution. It was then filtered through a pad of celite. The filtrate was extracted with DCM (2×20 mL), washed brine and dried over Na_2SO_4. Evaporation of the solvent under reduced pressure and purification of the crude product by column chromatography afforded **86** (43 mg, 83%) as white solid; R_f = 0.6 (petroleum ether : ethyl acetate = 20 : 1); **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.35-7.29 (m, 6H), 7.22 (td, J_1 = 7.2 Hz, J_2 = 1.6 Hz, 2H), 7.05 (s, 2H); 3.76 (s, 2H); **^{13}C NMR (101 MHz, $CDCl_3$)** δ 138.1, 135.1, 131.5, 128.4, 128.1, 127.8, 126.0, 41.6; **HRMS (ESI)** m/z calcd for $C_{15}H_{13}^+$ $(M+H)^+$ 193.10118, found 193.10083

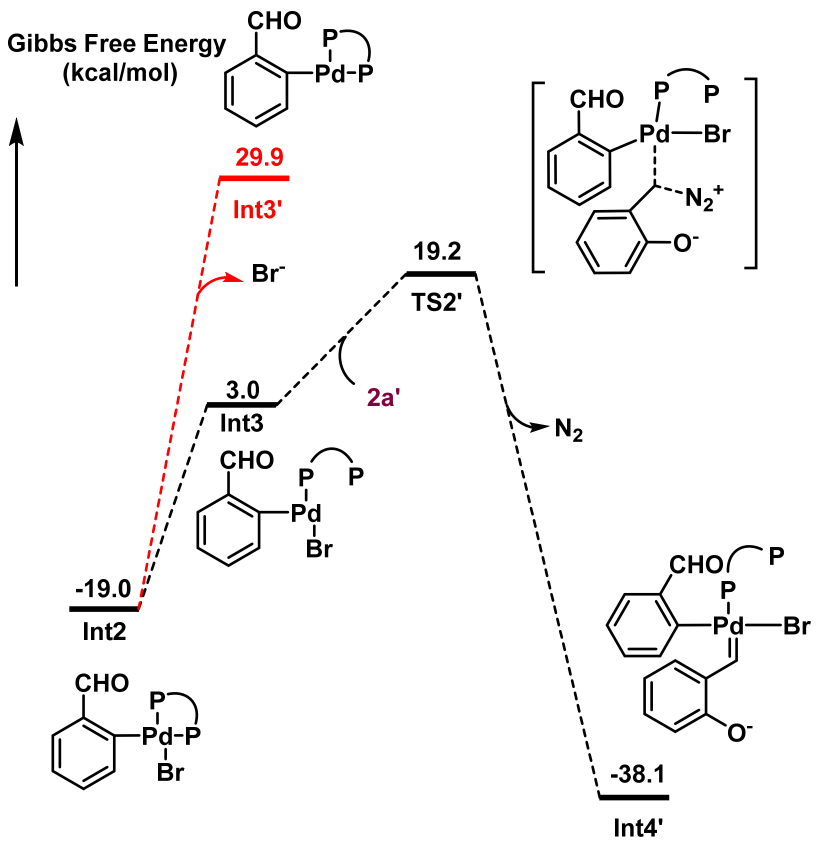
Computational details

The geometries were optimized by hybrid functional B3LYP[11-12] with the LANL2DZ[13-15] effective core potential for Pd and Br, and 6-31G* basis set for the rest atoms. The same level calculation of vibrational frequency was carried out to check the stationary point or transition state as minima or saddle point, and to obtain the thermodynamic corrections. Single point energy was performed by meta-GGA hybrid functional M06[16] with def2-TZVP[17] basis set for all atoms. Solvation energy was obtained by SMD[18] continuum solvation model in 1,4-Dioxane solution. The changes in Gibbs free energy with single point and solvation energy are reported in the content. All the calculations were performed in Gaussian09 package.[19]

Pathway for ligand dissociation

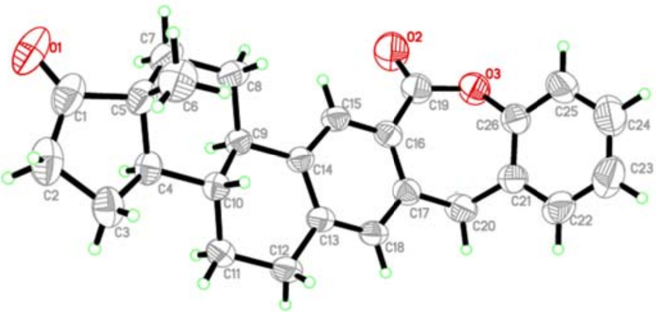
Following one reviewer's suggestion, the possibility of the pathway through attack of **2a'** to **Int2** was further explored. However, all attempts to locate an intermediate with one Pd-P opened with **2a'** failed, presumably because the steric hindrance of ligands prevents the binding of **2a'** to the metal center.

In order to compare with the favorable pathway already shown in the manuscript, we further explored another two possible reaction pathways. As can be seen from the following Fig. SII-1, the direct dissociation of Br^- anion from **Int2** to **Int3'** is energetically unfavorable as this process requires the energy of 48.9 kcal/mol. Another process involves the dissociation of one arm of the bidentated ligand to form **Int3** without counter anion exchange, followed by the reaction of **Int3** with **2a'** leading to dediazonation**.** Such a process is energetically unfavorable as it needs to overcome a large barrier of 38.2 kcal/mol relative to **Int2**. All in all, these two pathways are not favored compared to the one shown in Figure 3 in the manuscript.



Supplementary Figure 3. Reaction Energy Profiles of Ligand Dissociation Calculated at M06/def2-TZVP//B3LYP/6-31G(d)(LANL2DZ) Level.

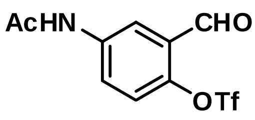
Crystal data and structure refinement for 66



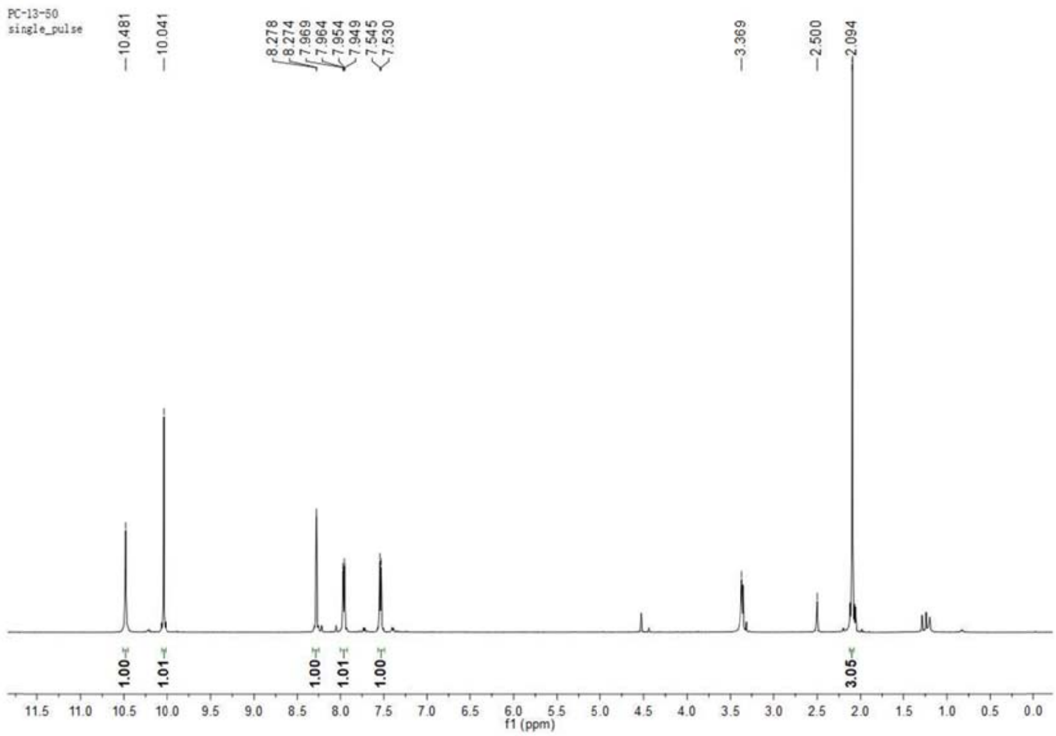
Supplementary Figure 4. X-ray structure of **66**. The thermal ellipsoid was drawn at the 50% probability level.

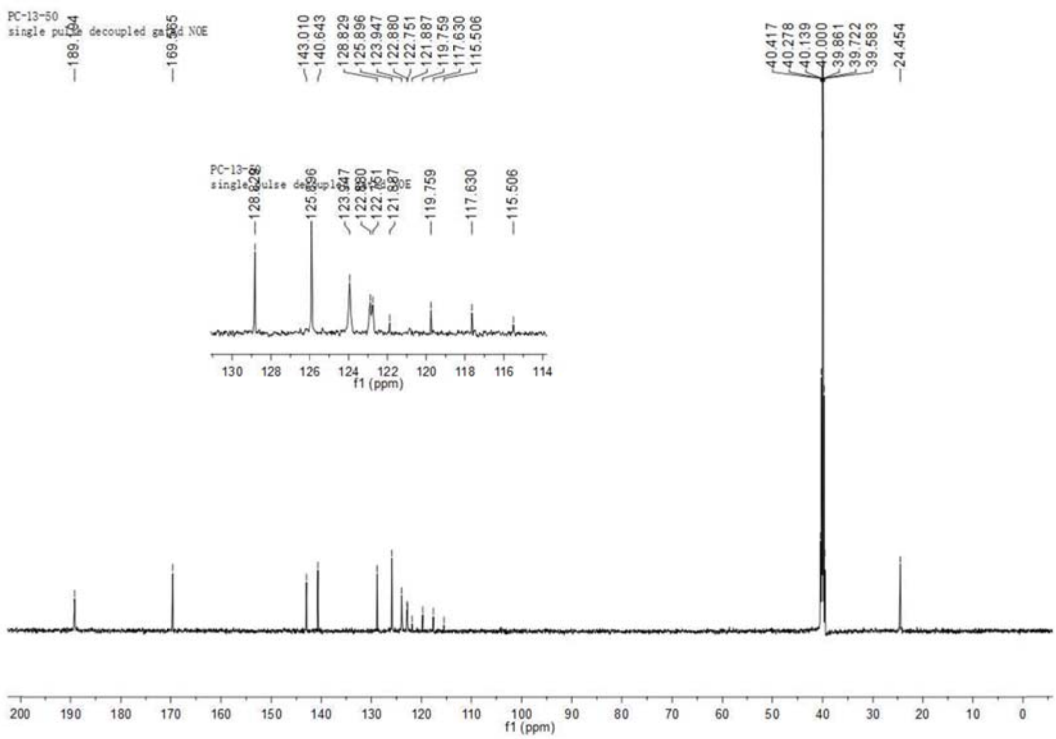
Empirical formula	$C_{26}H_{26}O_3$
Formula weight	386.47
Temperature	293(2) K
Wavelength	0.71073 A
Crystal system, space group	Orthorhombic, P212121
Unit cell dimensions	a = 9.841(2) Å alpha = 90 deg.
	b = 13.449(3) Å beta = 90 deg.
	c = 15.601(3) Å gamma = 90 deg.
Volume	2064.8(7) $Å^3$
Z, Calculated density	4, 1.243 Mg/m^3
Absorption coefficient	0.080 mm^{-1}
F(000)	824
Crystal size	0.90 x 0.45 x 0.30 mm
Theta range for data collection	2.88 to 27.48 deg.
Limiting indices	-12<=h<=12, -17<=k<=16, -20<=l<=20

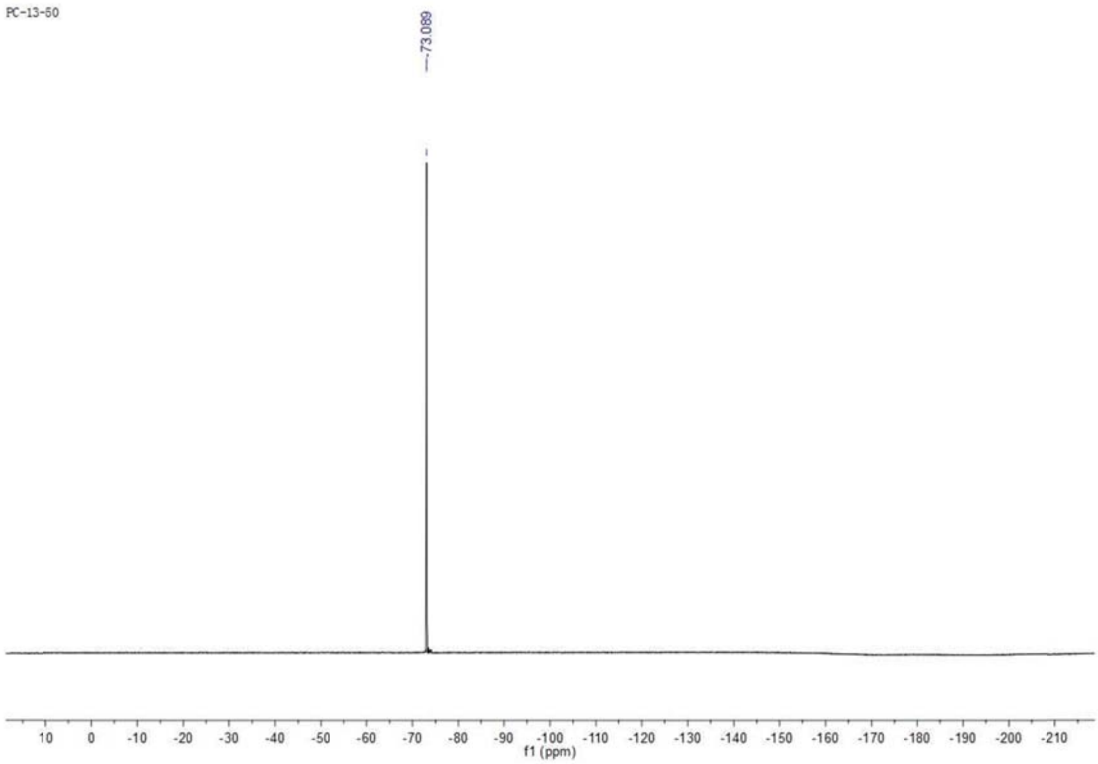
Reflections collected / unique	16011 / 4666 [R(int) = 0.0219]
Completeness to theta = 27.48	98.7 %
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	4666 / 0 / 264
Goodness-of-fit on F^2	1.077
Final R indices [I>2sigma(I)]	R_1 = 0.0370, wR_2 = 0.1000
R indices (all data)	R_1 = 0.0383, wR_2 = 0.1012
Absolute structure parameter	1.4(11)
Largest diff. peak and hole	0.160 and -0.157 e.A^{-3}


AcHN
CHO
OTf

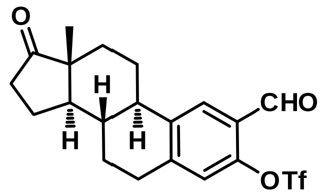
S1t


PC-13-50
single_pulse
10.481
10.041
8.278
8.274
7.969
7.964
7.954
7.949
7.545
7.530
3.369
2.500
2.094
1.00
1.01
1.00
1.01
1.00
3.05
f1 (ppm)

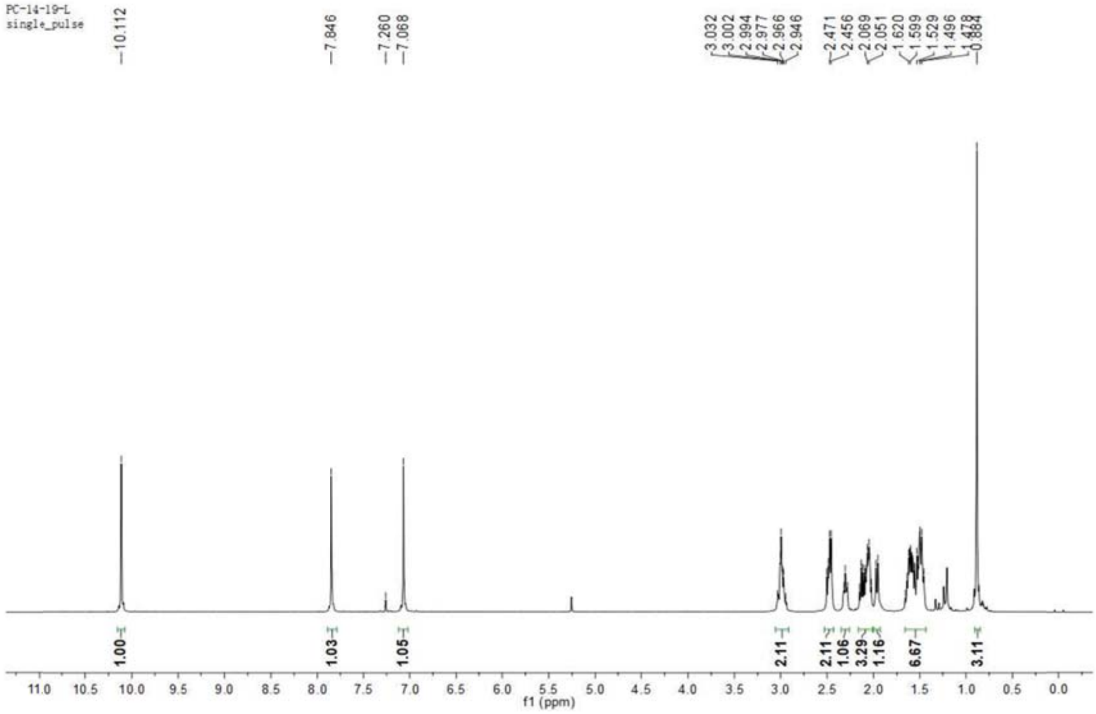

PC-13-50
single pulse decoupled gated NOE
169.565
143.010
140.643
128.829
125.896
123.947
122.880
122.751
121.887
119.759
117.630
115.506
40.417
40.278
40.139
40.000
39.861
39.722
39.583
24.454
PC-13-50
125.896
123.947
122.880
122.751
121.887
119.759
117.630
115.506
f1 (ppm)
f1 (ppm)

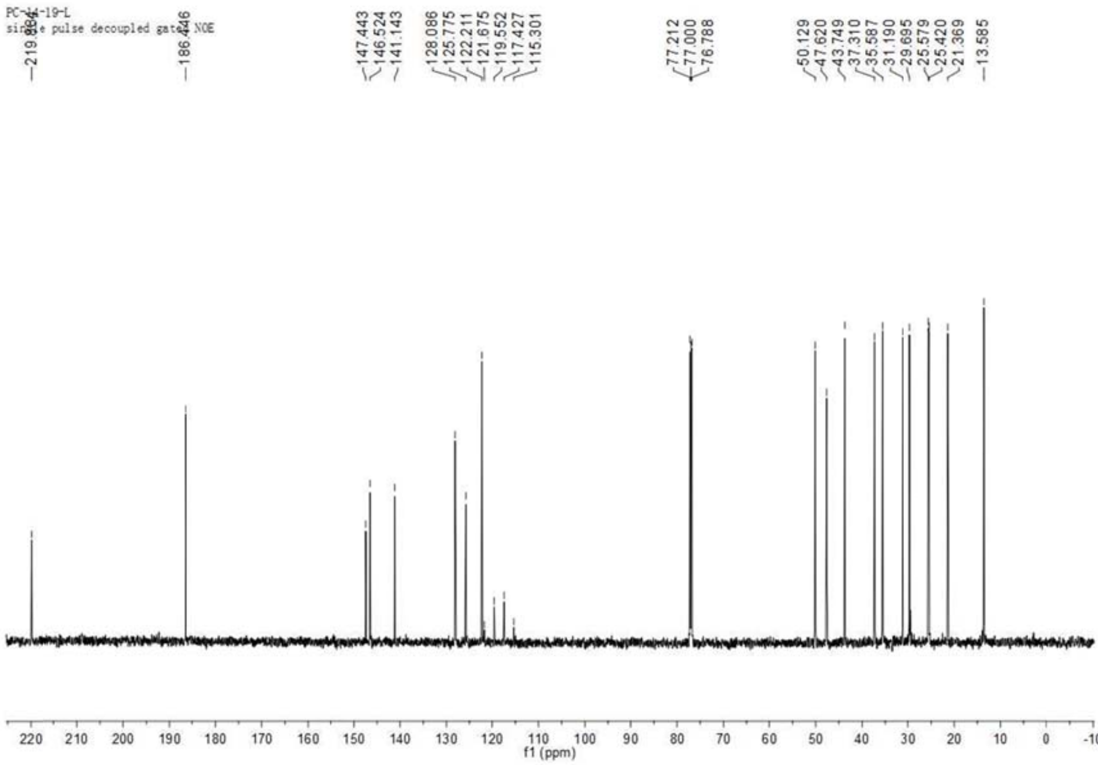


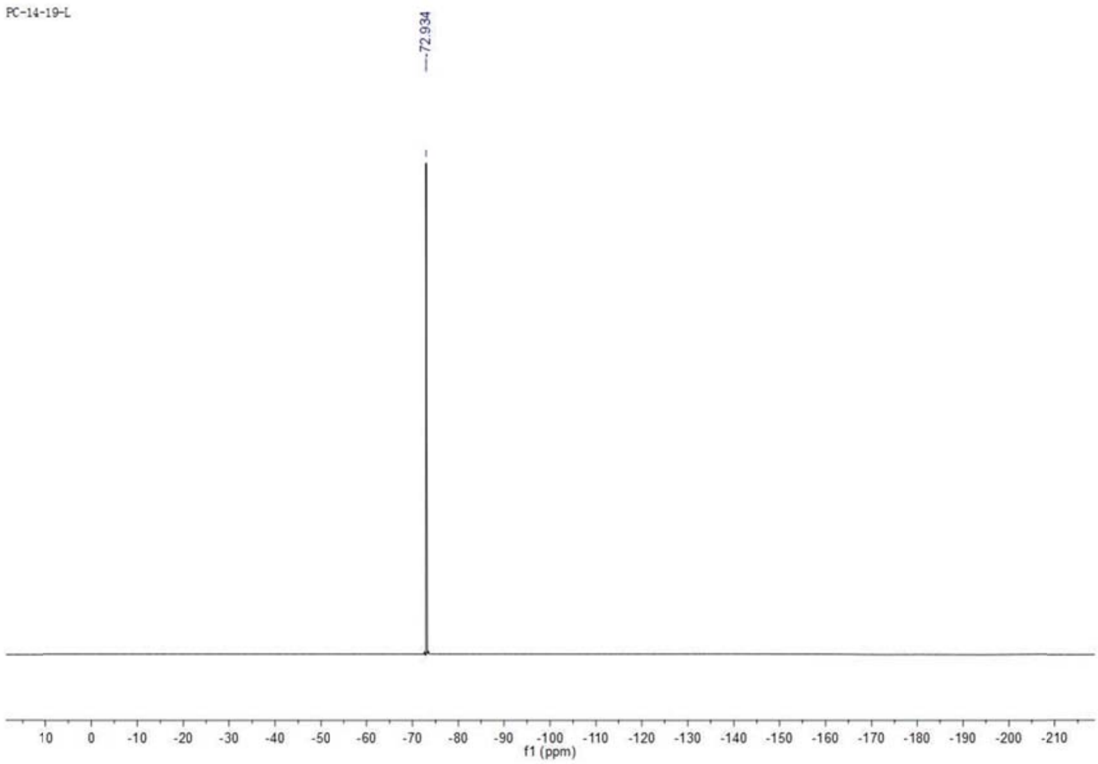
Supplementary Figure 5 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound S1t.


O
H
H
H
CHO
OTf

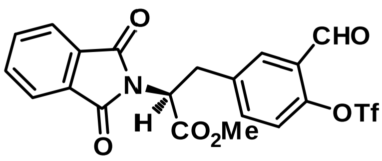
S1w


PC-14-19-L
single_pulse
10.112
7.846
7.260
7.068
3.032
3.002
2.994
2.977
2.966
2.946
2.471
2.456
2.069
2.051
1.620
1.599
1.529
1.496
0.884
1.00
1.03
1.05
2.11
2.11
1.06
3.29
1.16
6.67
3.11
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

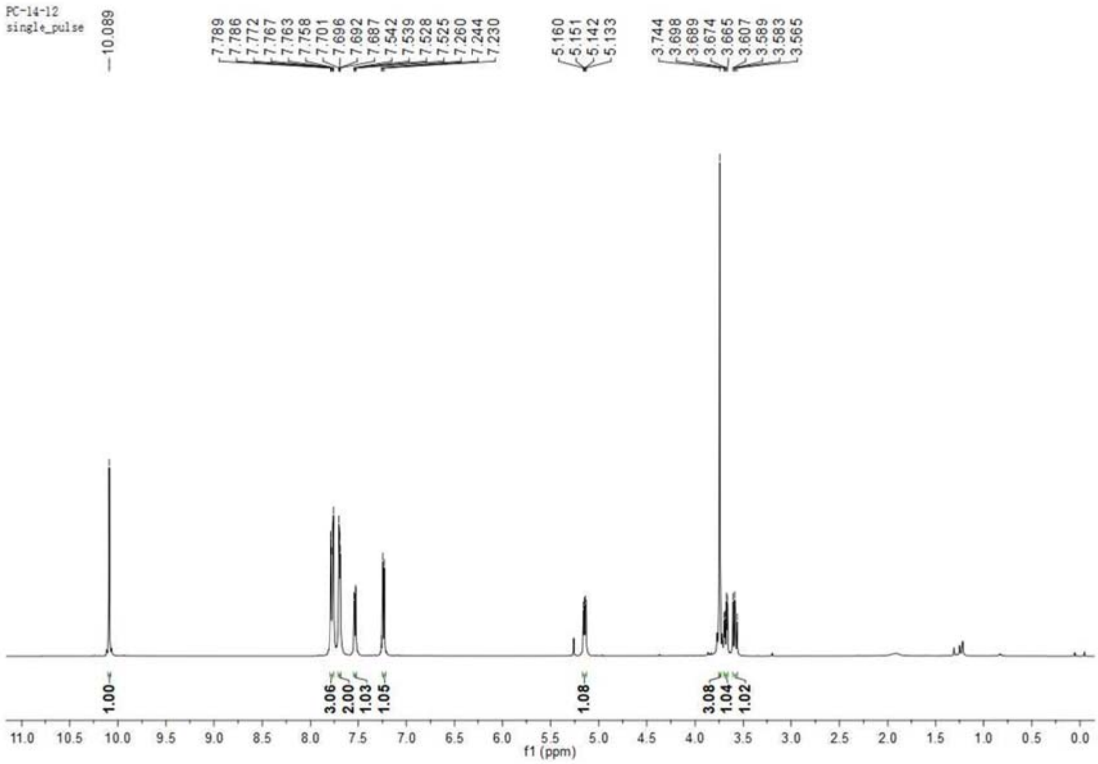

PC-14-19-L
single pulse decoupled gated NOE
186.446
147.443
146.524
141.143
128.086
125.775
122.211
121.675
119.552
117.427
115.301
77.212
77.000
76.788
50.129
47.620
43.749
37.310
35.587
31.190
29.695
25.579
25.420
21.369
13.585
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

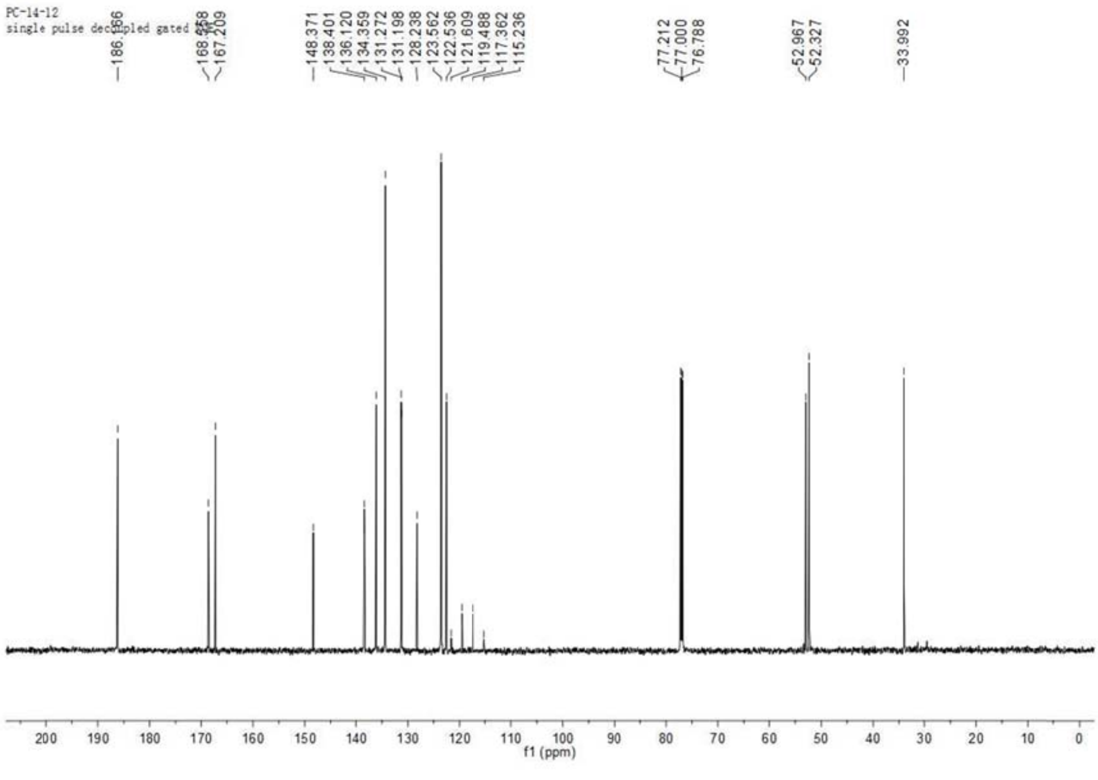


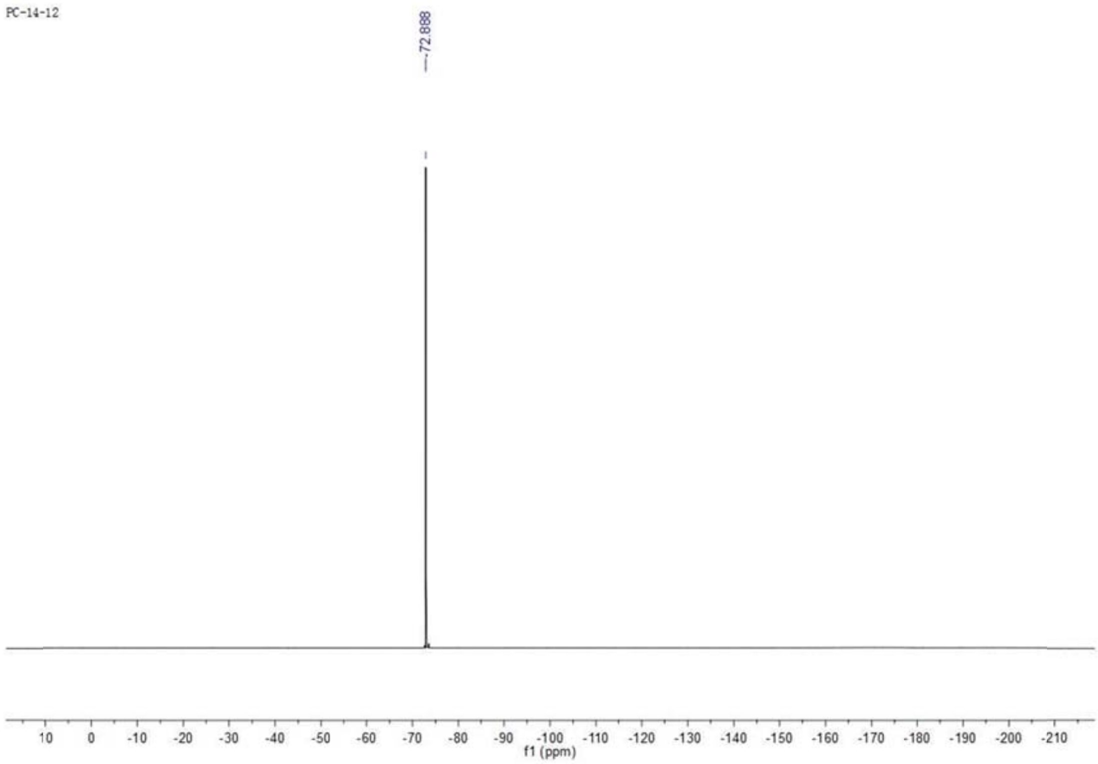
Supplementary Figure 6 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound S1w.


CHO
OTf
N
H
CO2Me
O
O

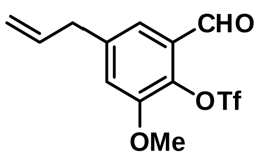
S1x


PC-14-12
single_pulse
10.089
7.789
7.786
7.772
7.767
7.763
7.758
7.701
7.696
7.692
7.687
7.542
7.539
7.528
7.525
7.260
7.244
7.230
5.160
5.151
5.142
5.133
3.744
3.698
3.689
3.674
3.665
3.607
3.589
3.583
3.565
1.00
3.06
2.00
1.03
1.05
1.08
3.08
1.04
1.02
f1 (ppm)

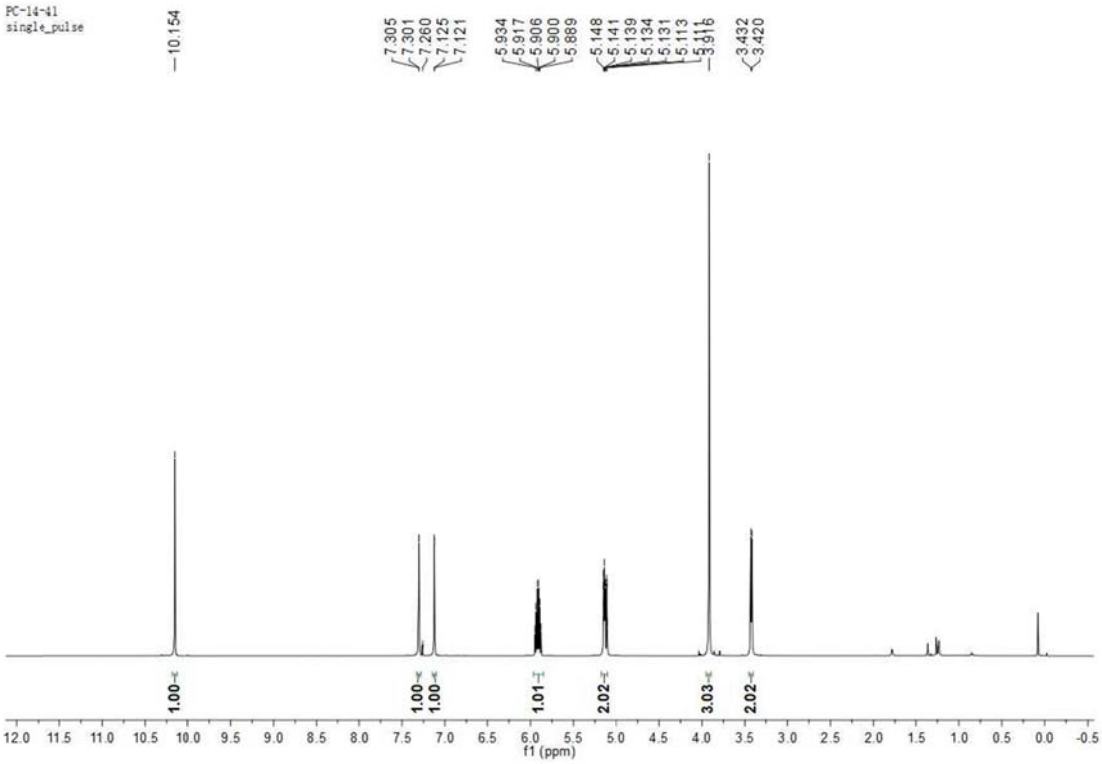

PC-14-12
single pulse decoupled gated
186.156
168.558
167.209
148.371
138.401
136.120
134.359
131.272
131.198
128.238
123.562
122.536
121.609
119.488
117.362
115.236
77.212
77.000
76.788
52.967
52.327
33.992
f1 (ppm)

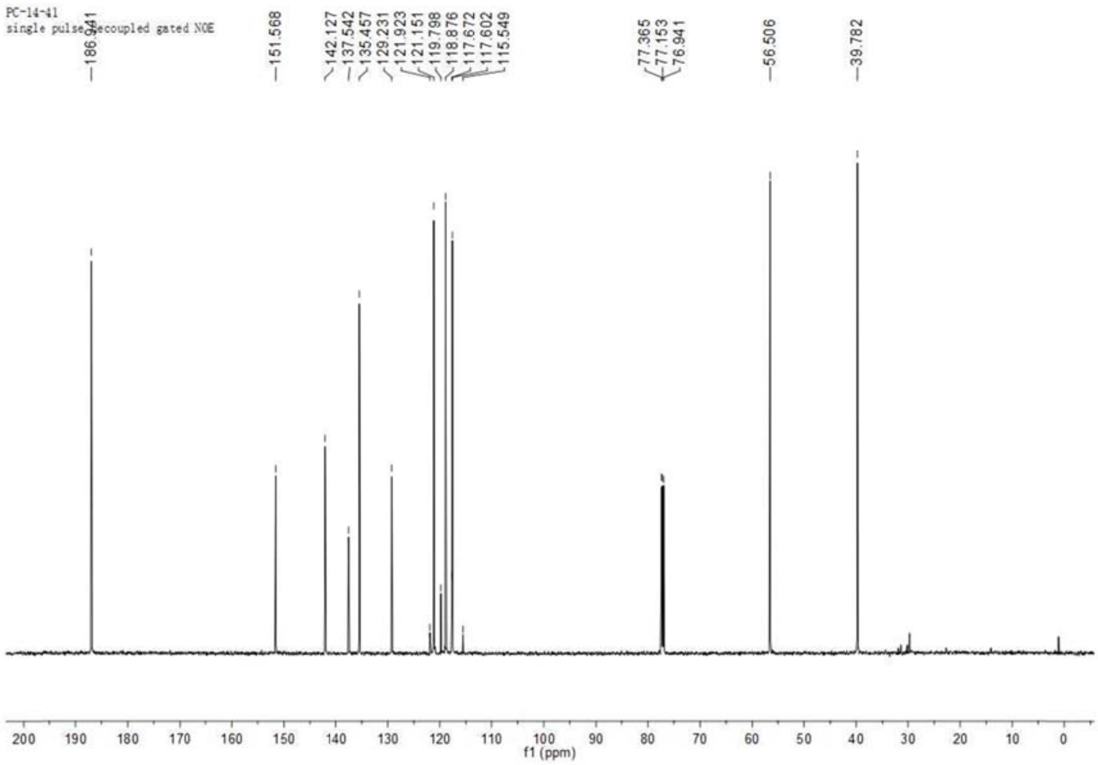


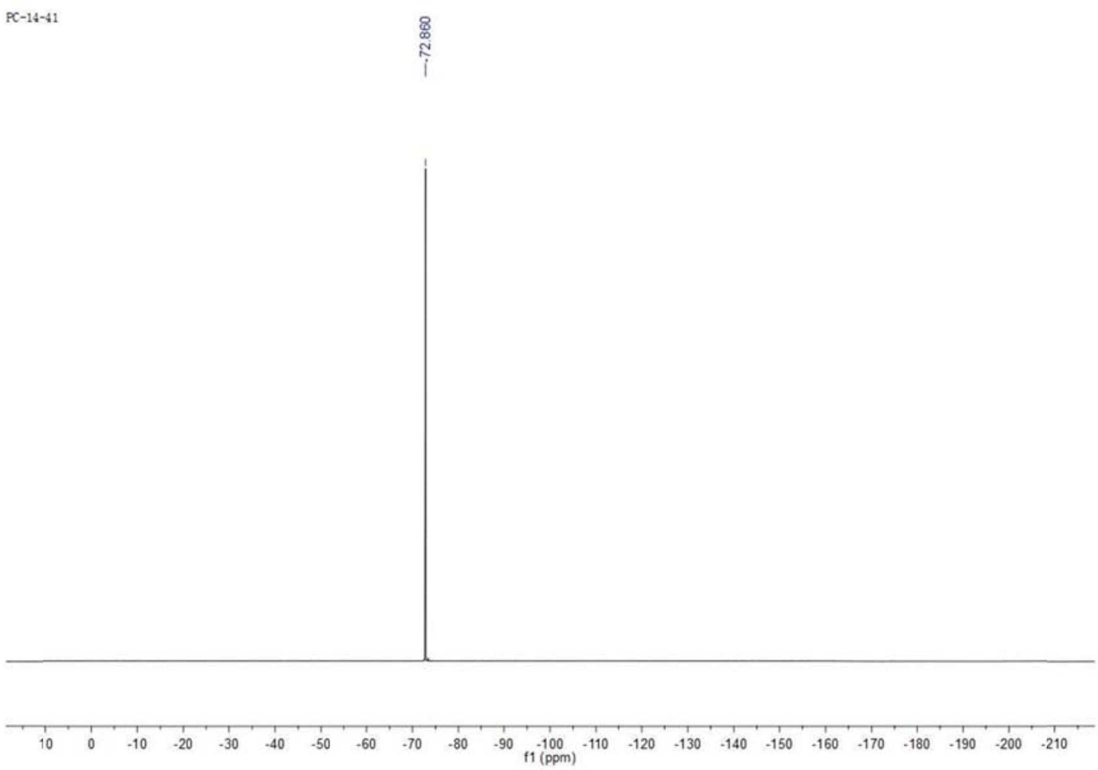
Supplementary Figure 7 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound S1x


CHO
OTf
OMe

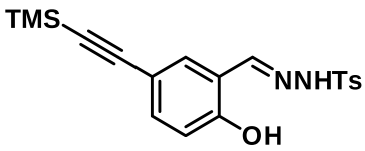
S1y


PC-14-41
single_pulse
10.154
7.305
7.301
7.260
7.125
7.121
5.934
5.917
5.906
5.900
5.889
5.148
5.141
5.139
5.134
5.131
5.113
5.111
3.916
3.432
3.420
1.00
1.00
1.00
1.01
2.02
3.03
2.02
f1 (ppm)

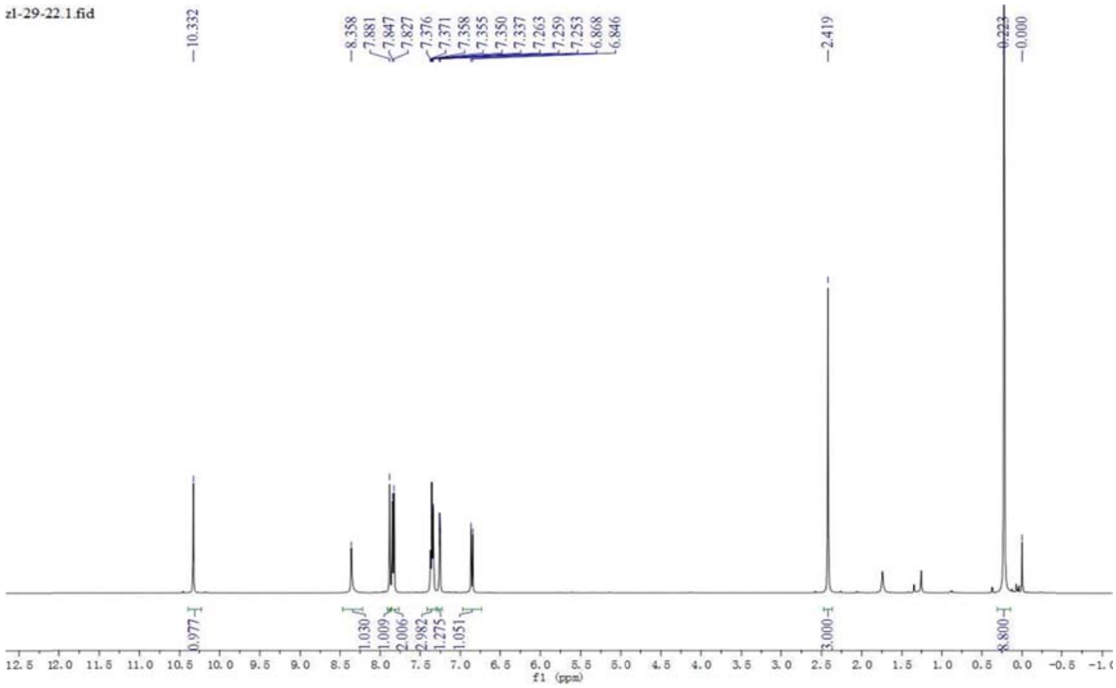

PC-14-41
single pulse decoupled gated NOE
186.941
151.568
142.127
137.542
135.457
129.231
121.923
121.151
119.798
118.876
117.672
117.602
115.549
77.365
77.153
76.941
56.506
39.782
f1 (ppm)

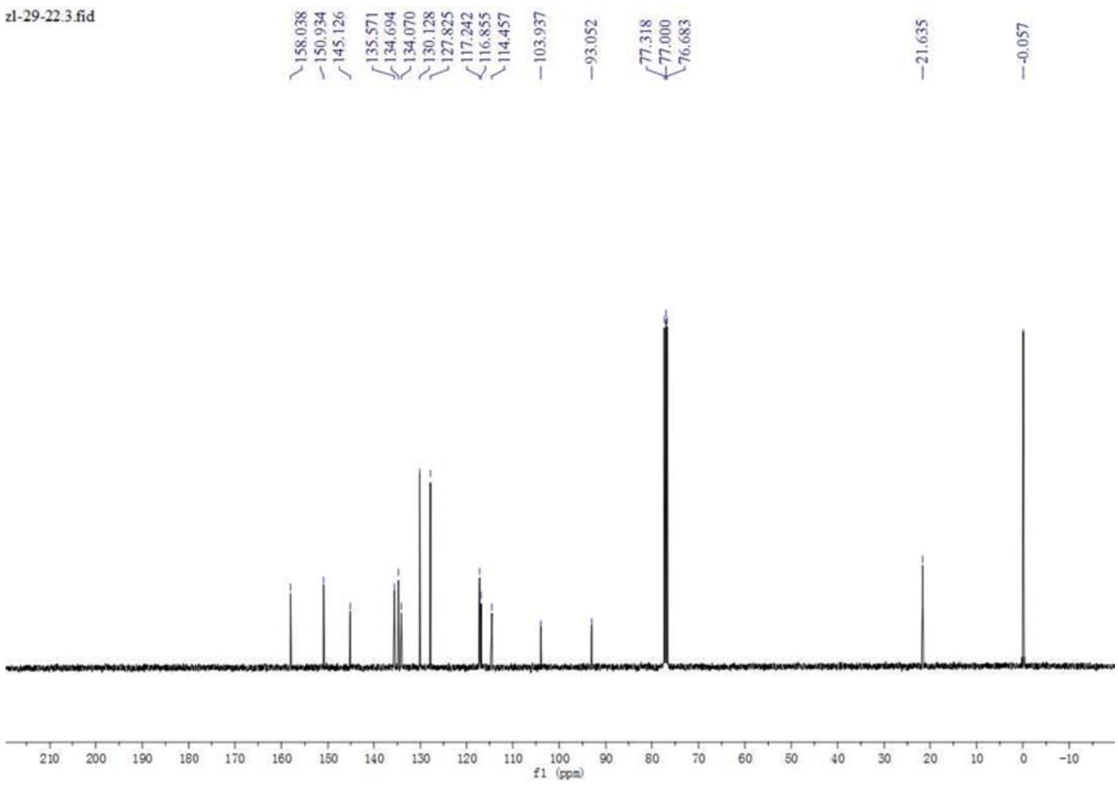


Supplementary Figure 8 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound S1y

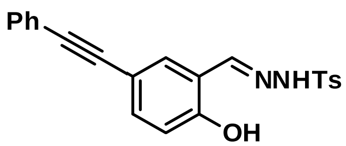


S2o

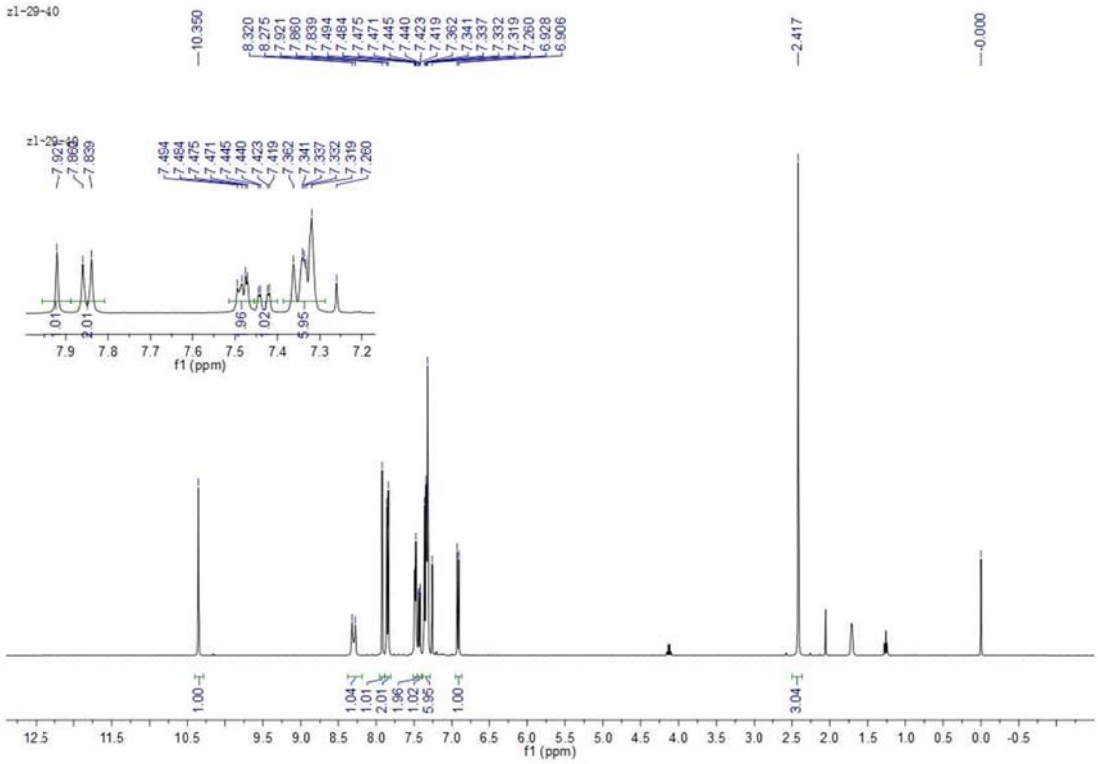


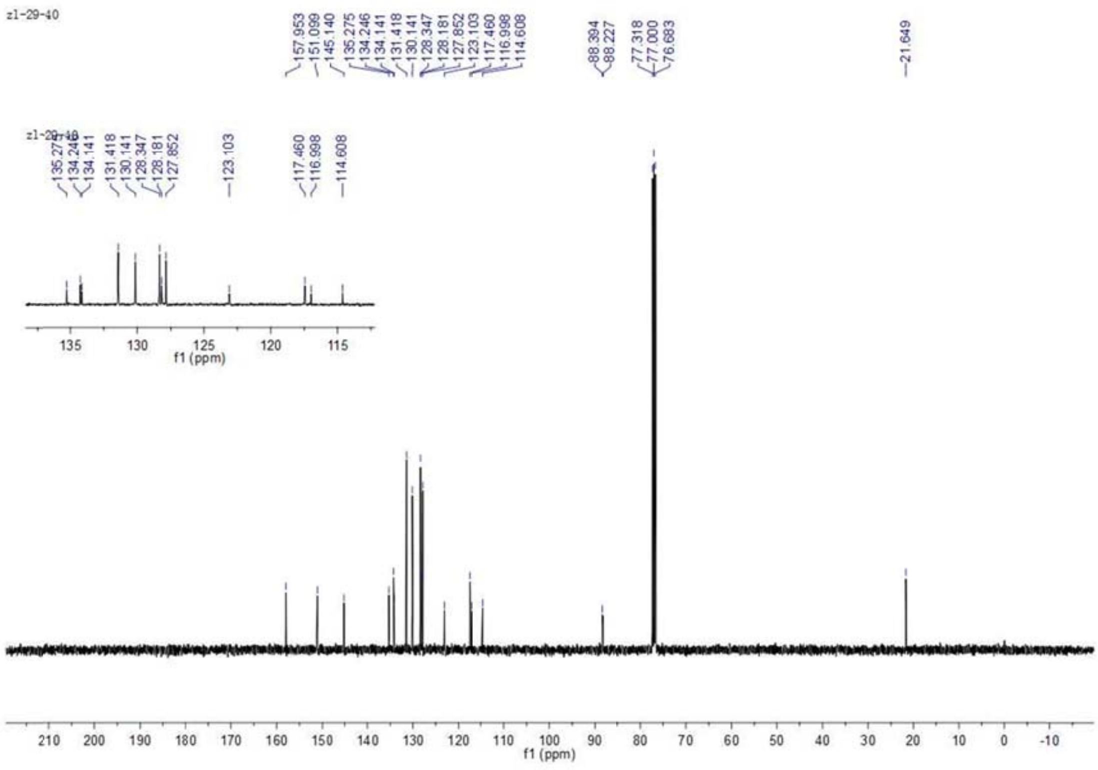


Supplementary Figure 9 ^{1}H NMR and ^{13}C NMR spectra for compound S2o

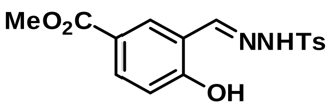


S2p

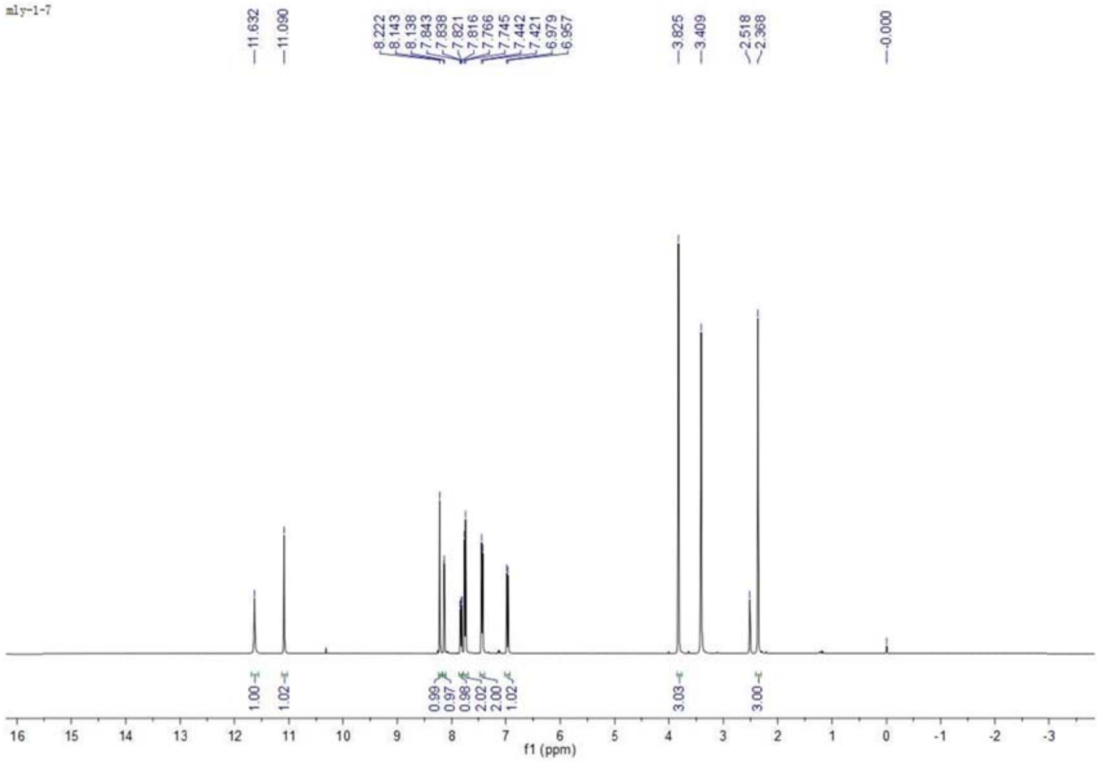


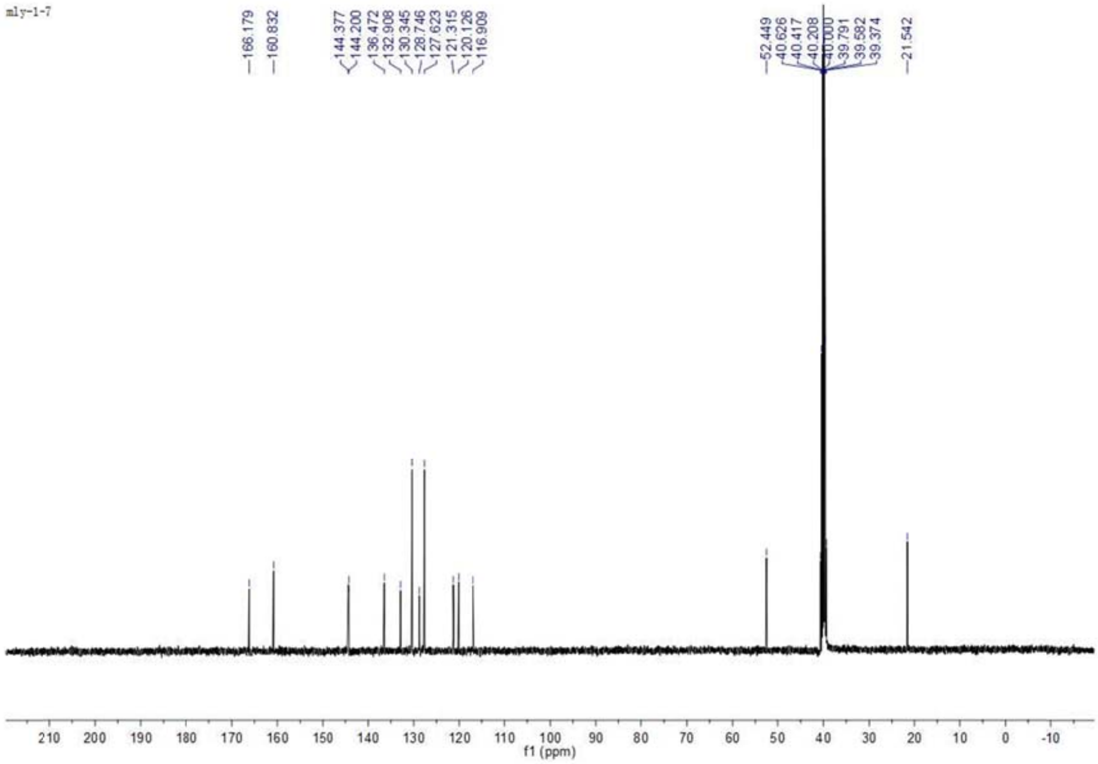


Supplementary Figure 10 ^{1}H NMR and ^{13}C NMR spectra for compound S2p

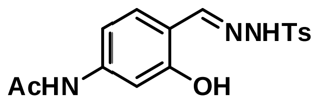


S2m

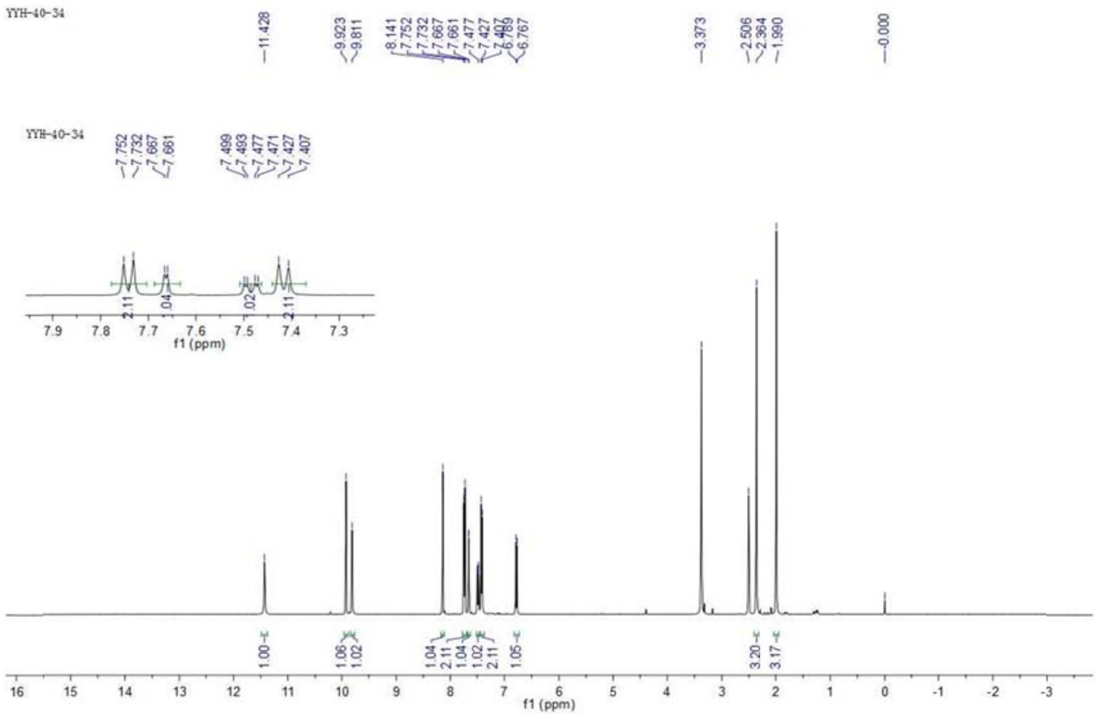


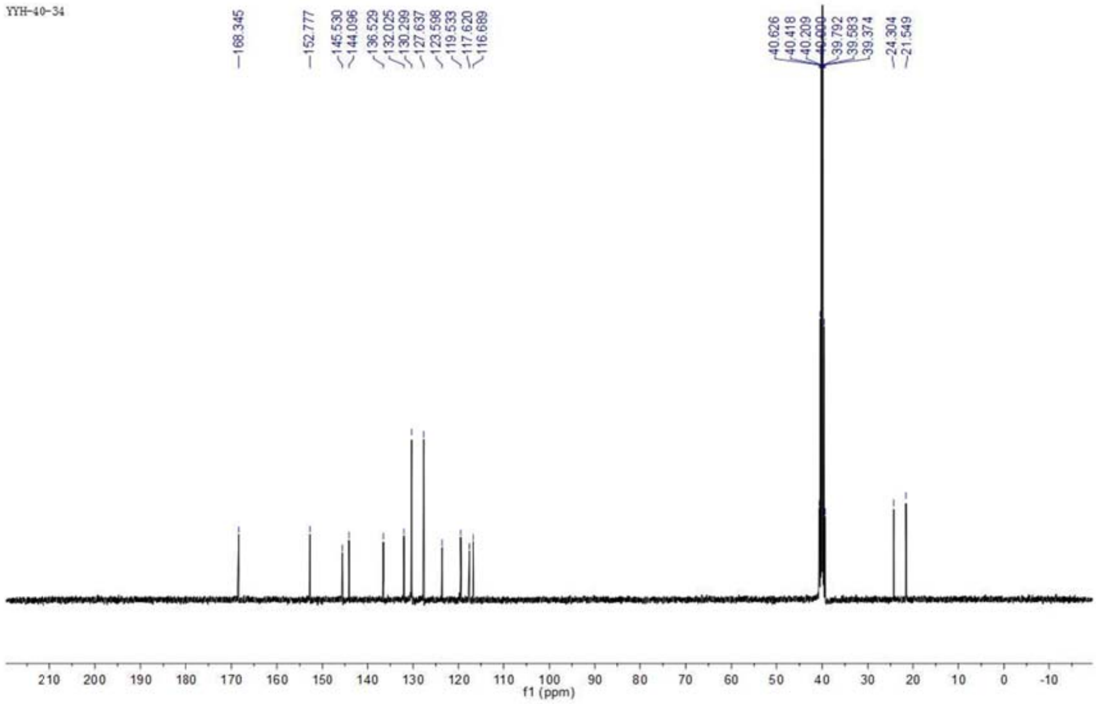


Supplementary Figure 11 ^{1}H NMR and ^{13}C NMR spectra for compound S2m

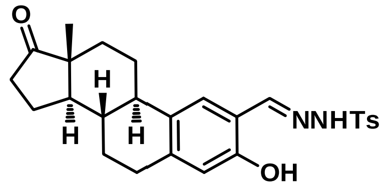


S2n

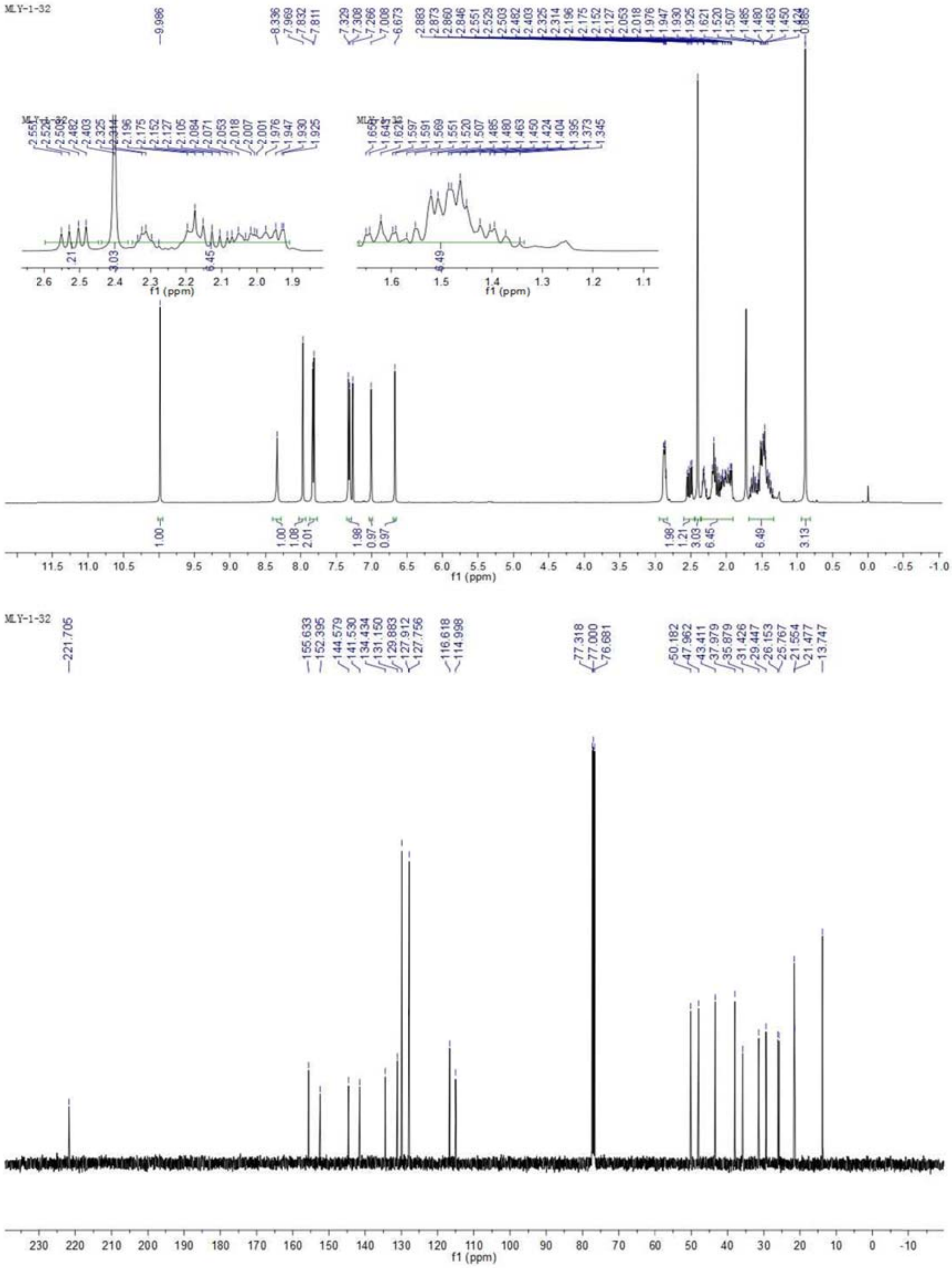




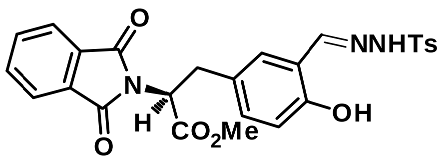
Supplementary Figure 11 ^{1}H NMR and ^{13}C NMR spectra for compound S2n



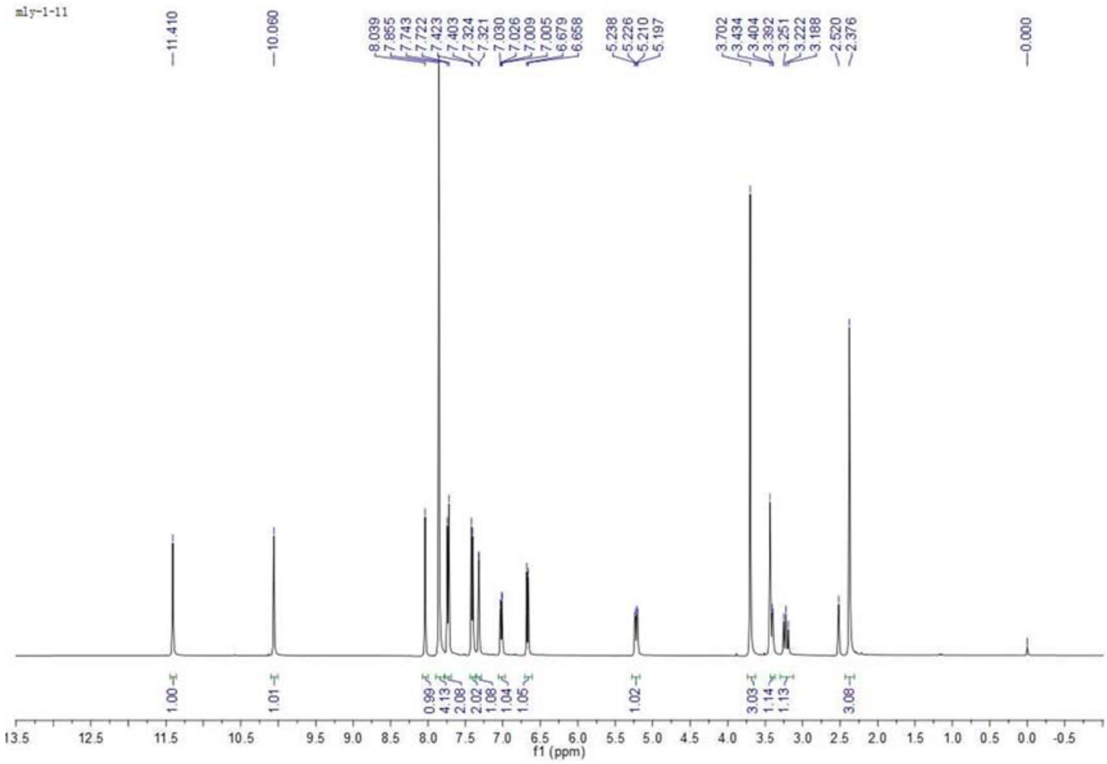
S2u

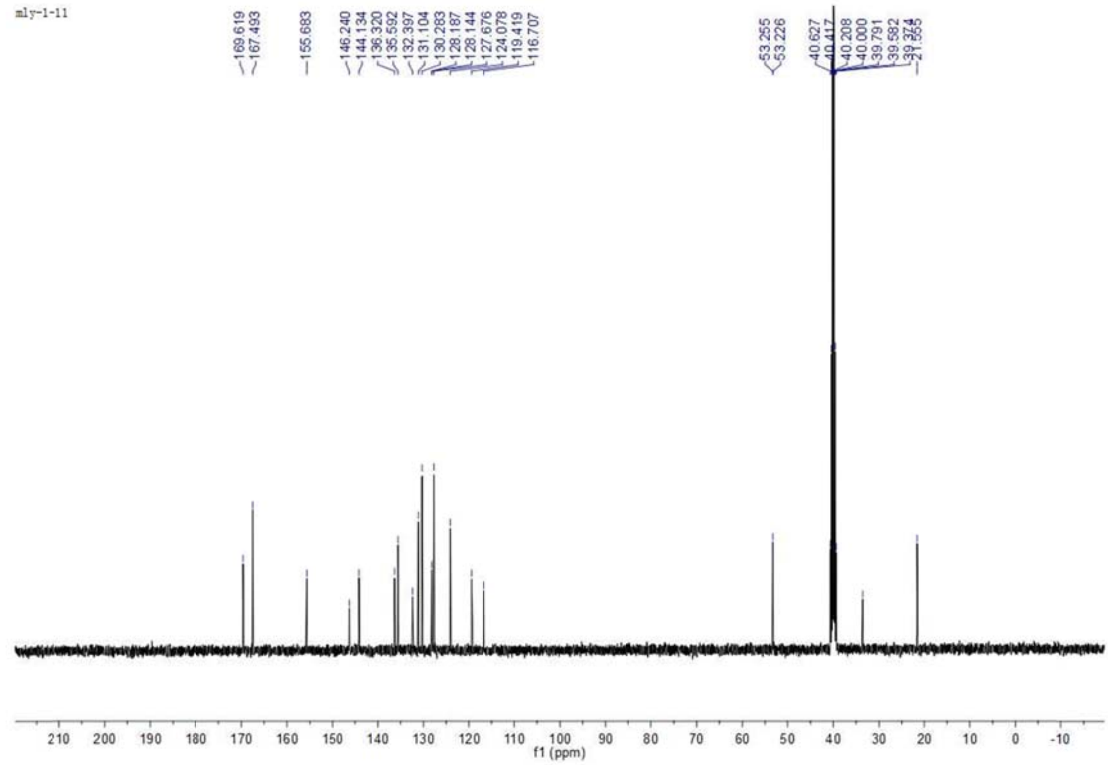


Supplementary Figure 12 ^{1}H NMR and ^{13}C NMR spectra for compound S2u

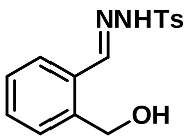


S2v

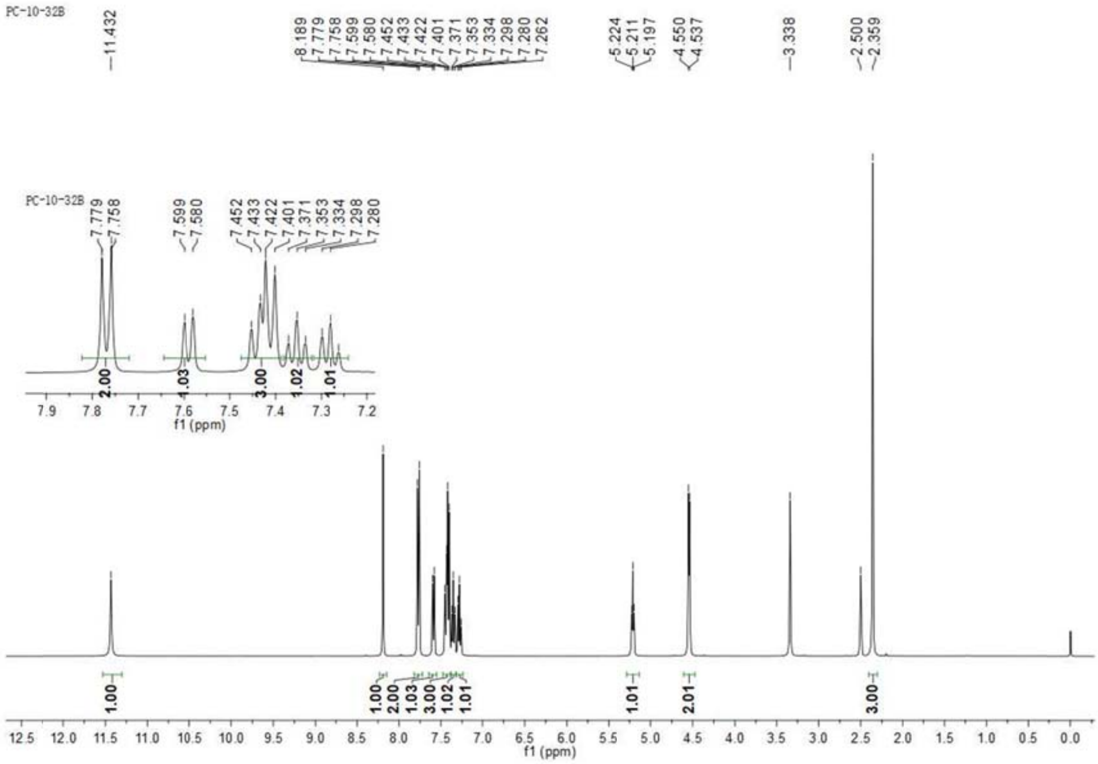


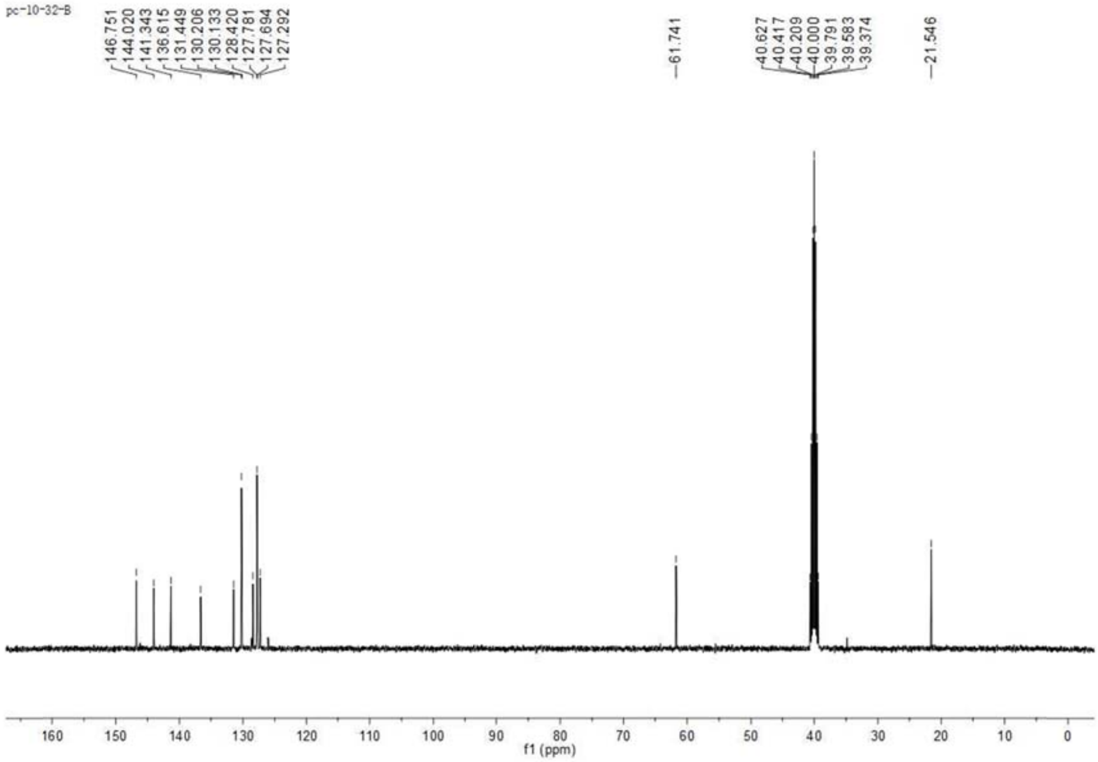


Supplementary Figure 13 ^{1}H NMR and ^{13}C NMR spectra for compound S2v

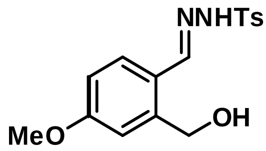


S2w

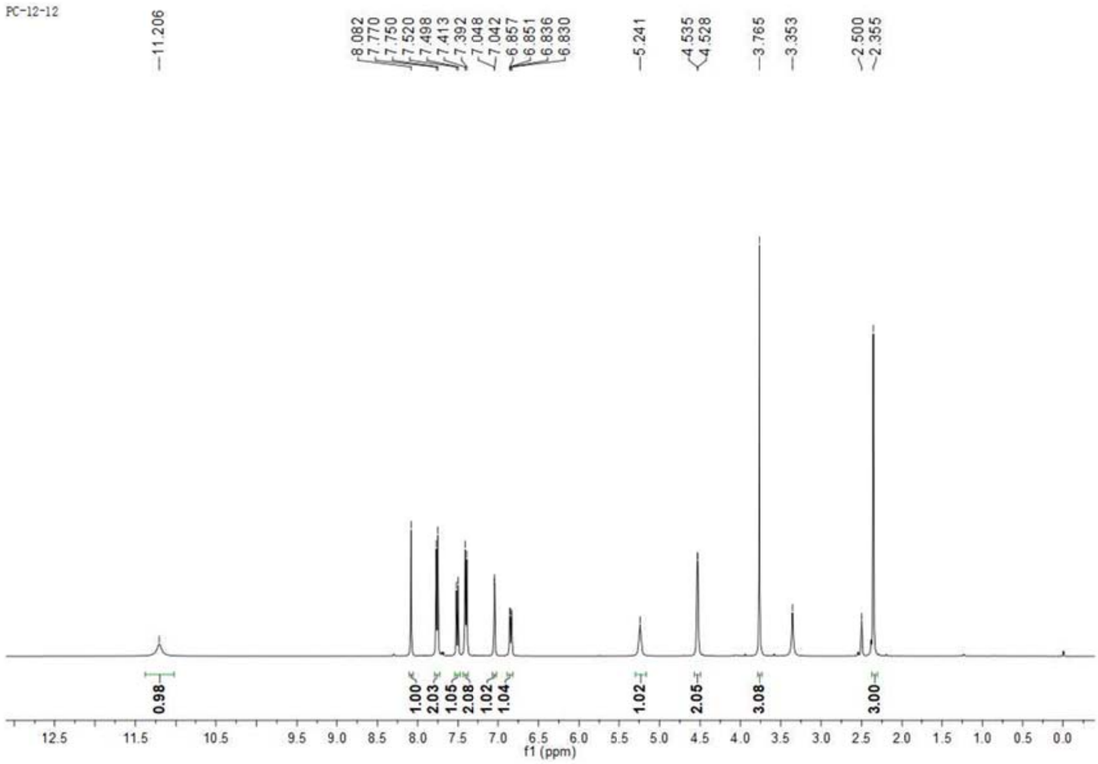


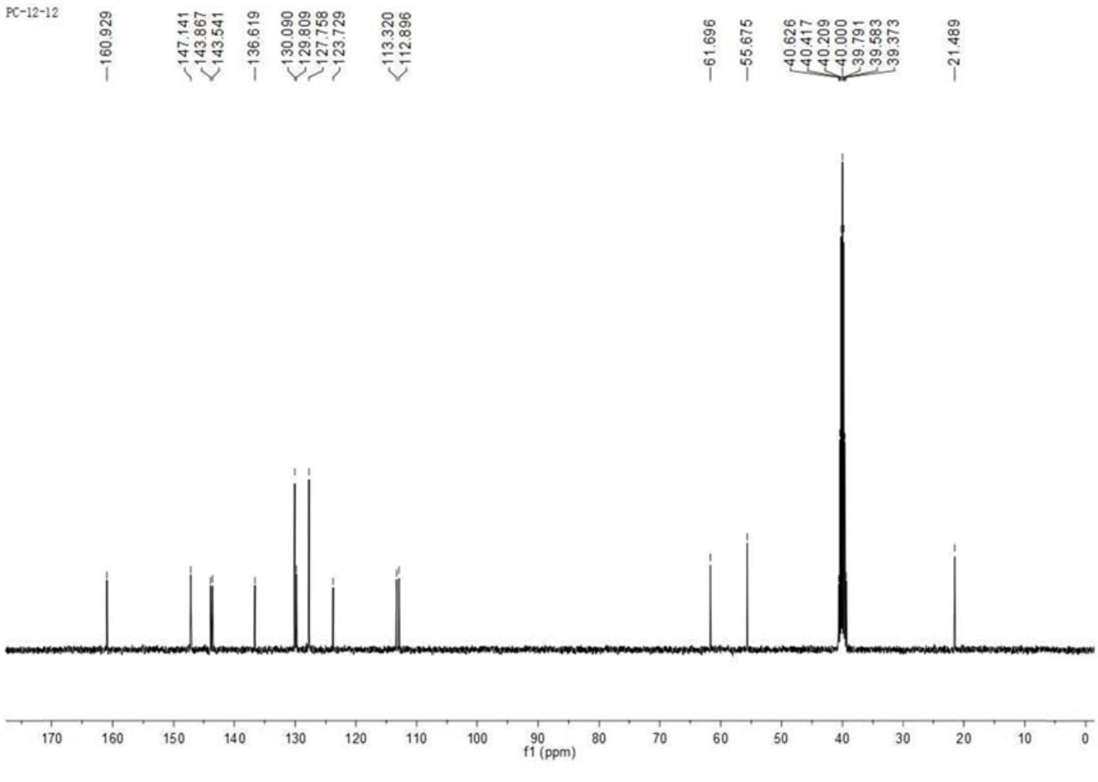


Supplementary Figure 14 ^{1}H NMR and ^{13}C NMR spectra for compound S2w

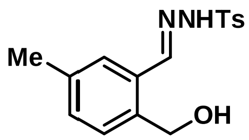


S2x

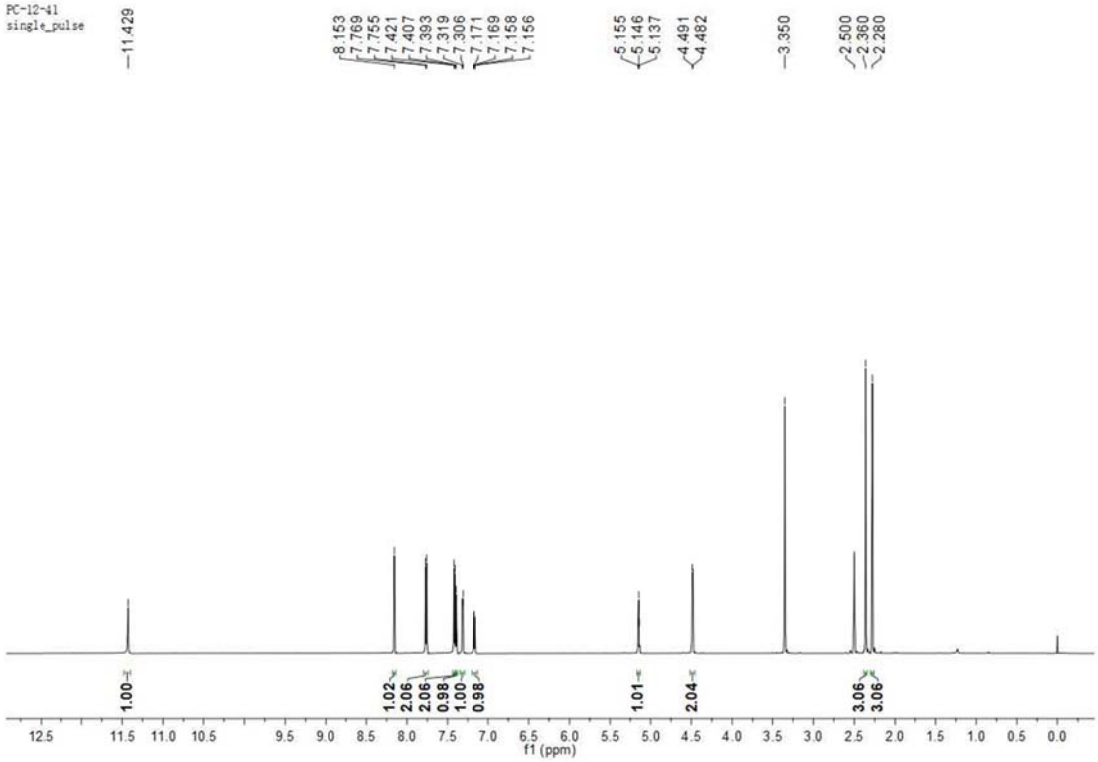


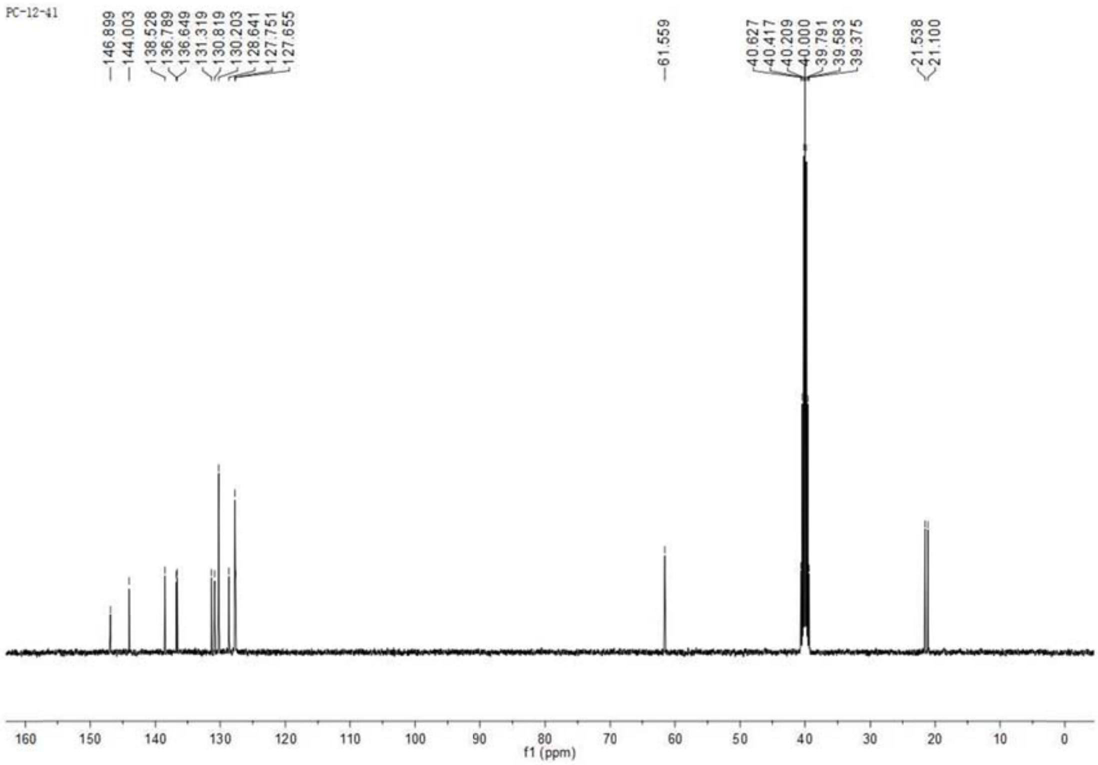


Supplementary Figure 15 ^{1}H NMR and ^{13}C NMR spectra for compound S2x

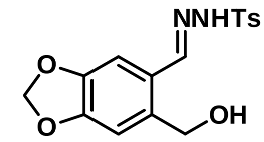


S2y

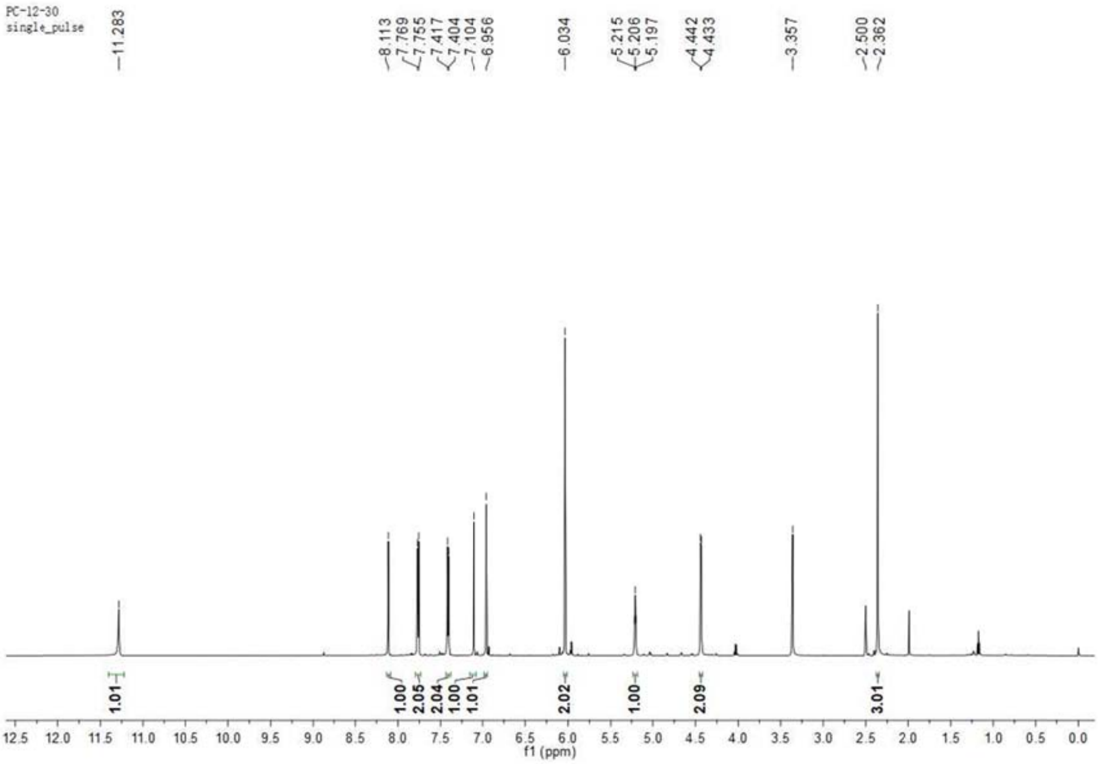


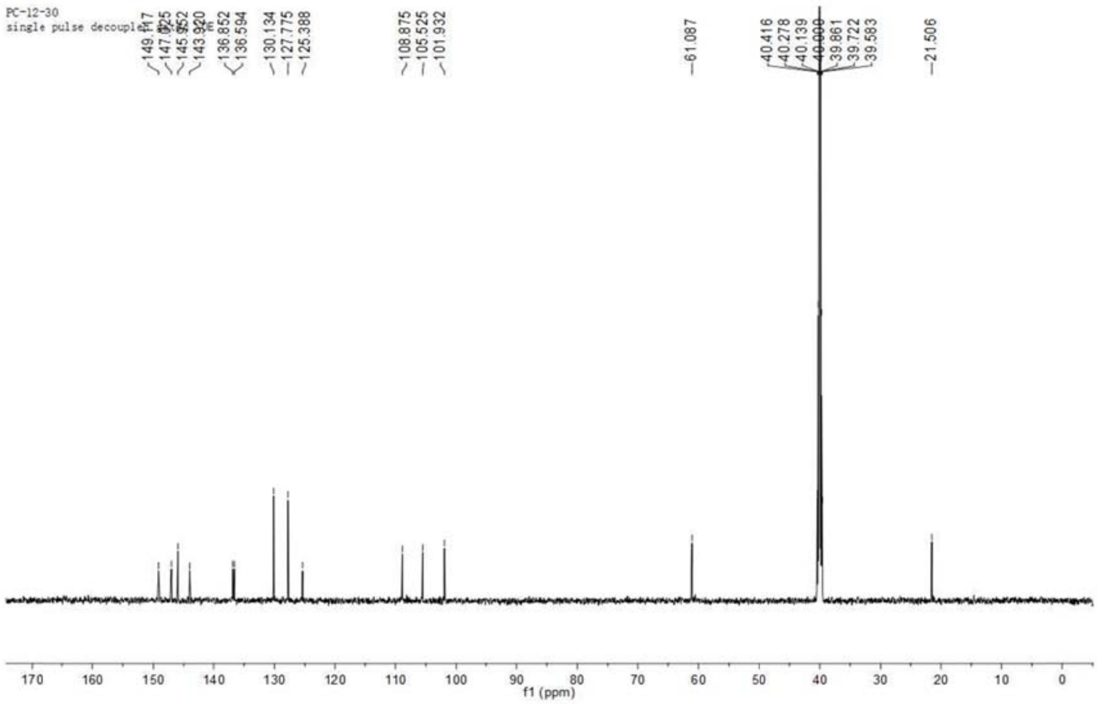


Supplementary Figure 16 ^{1}H NMR and ^{13}C NMR spectra for compound S2y

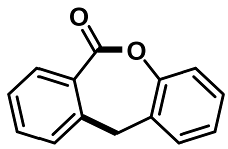


S2z

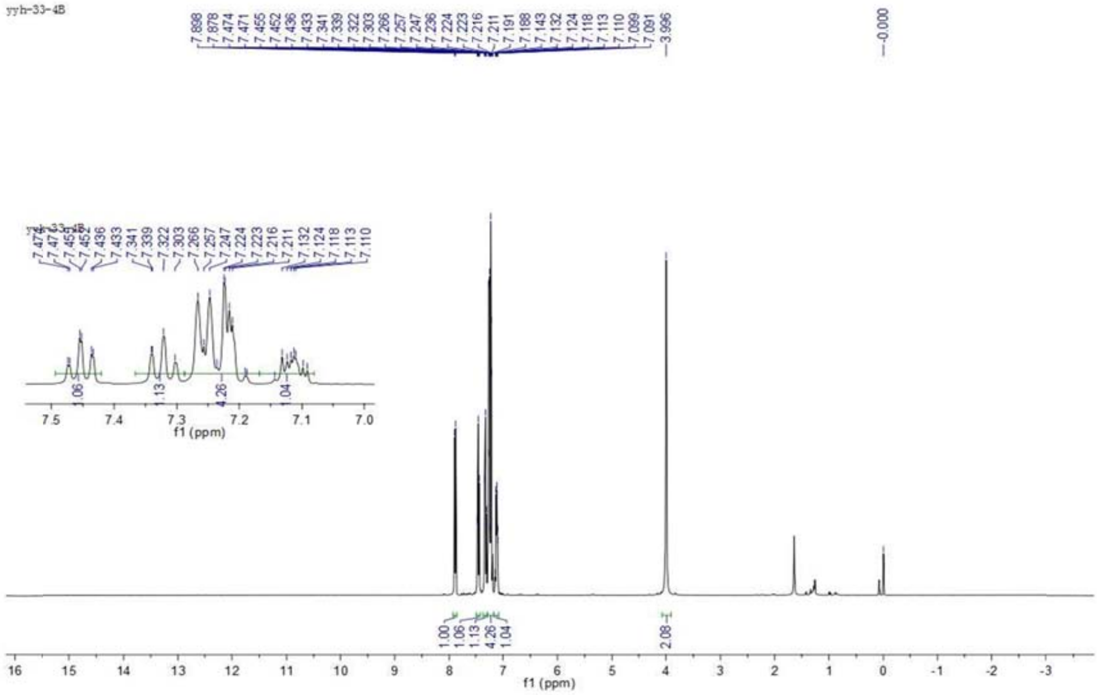


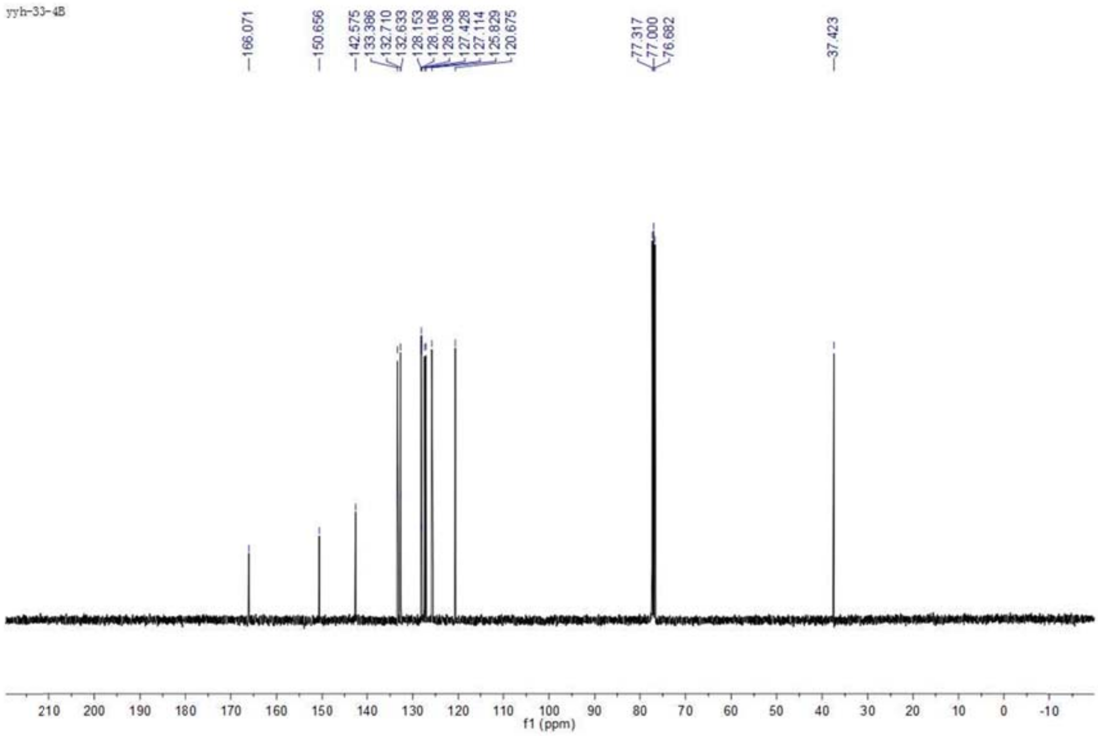


Supplementary Figure 17 ^{1}H NMR and ^{13}C NMR spectra for compound S2z

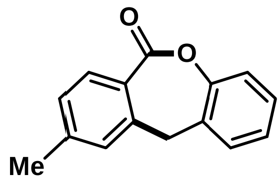


3

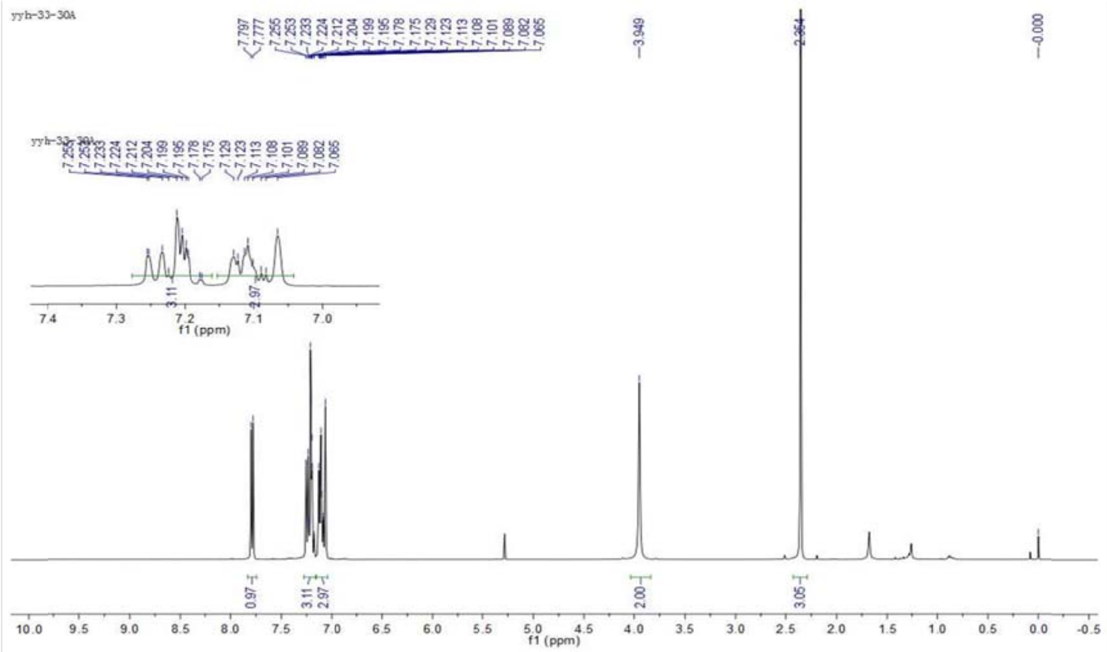


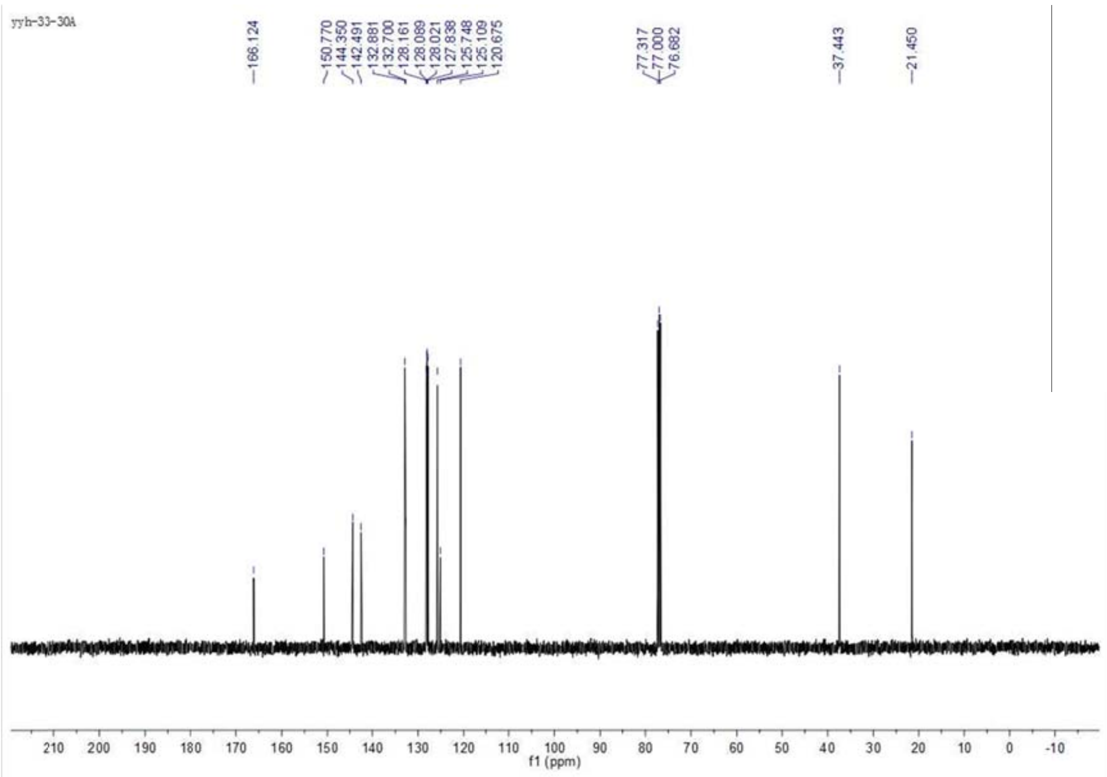


Supplementary Figure 18 ^{1}H NMR and ^{13}C NMR spectra for compound 3

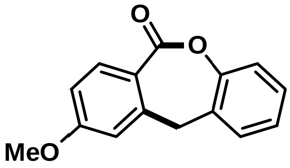


4

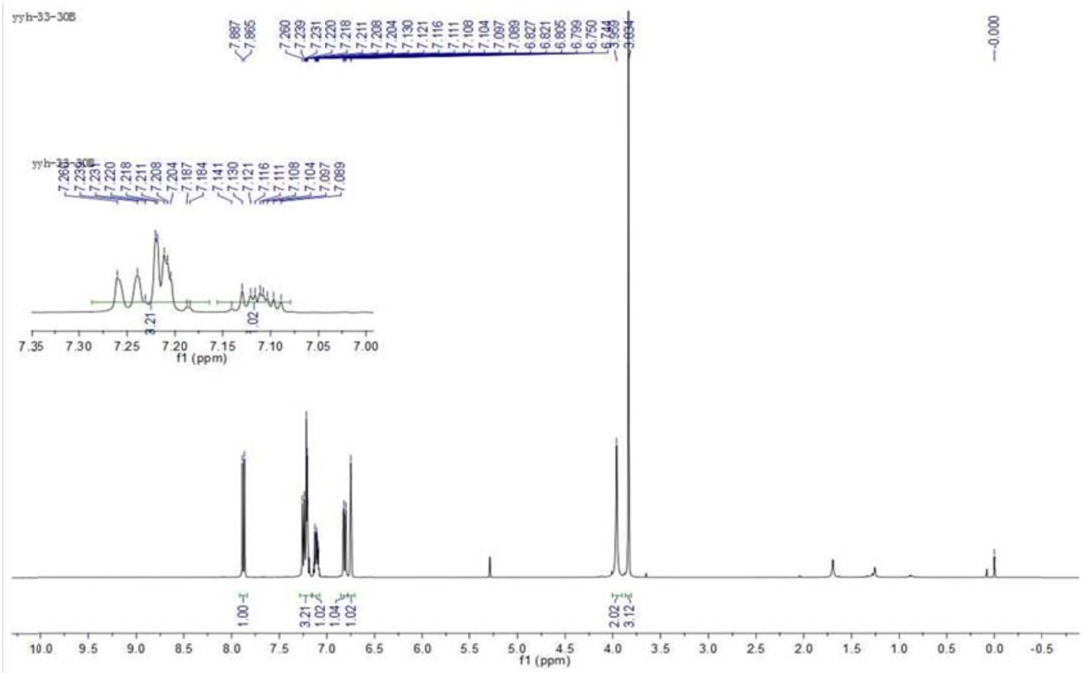


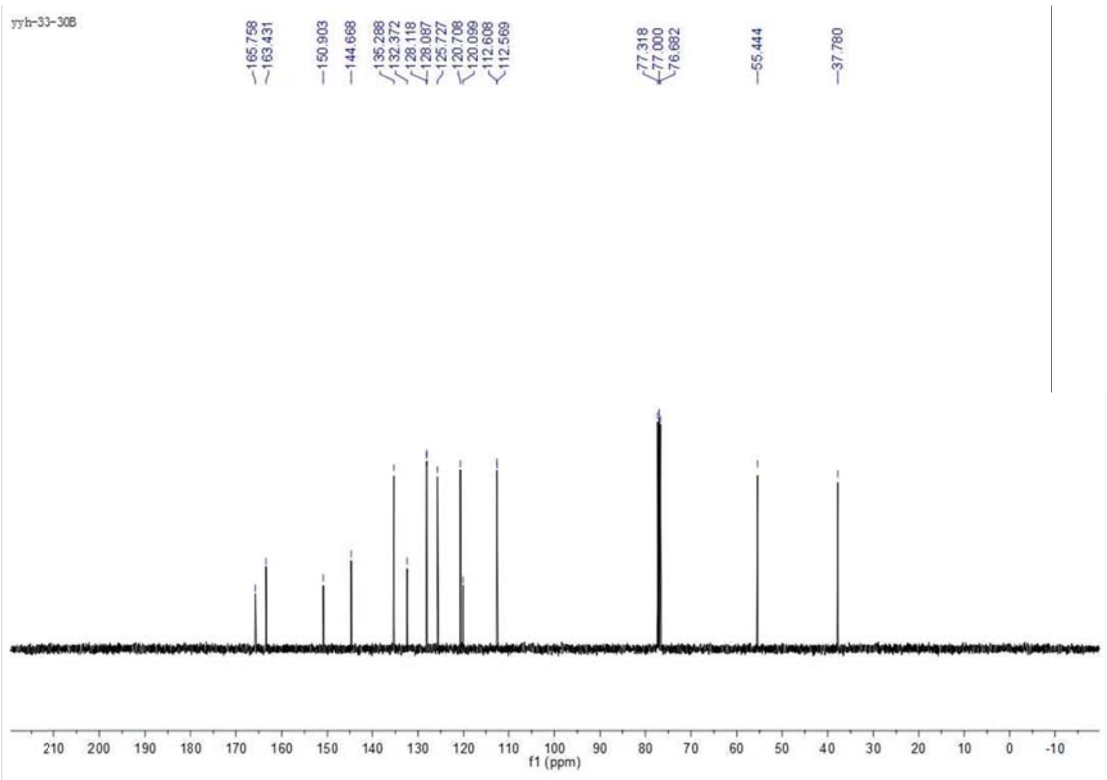


Supplementary Figure 19 ^{1}H NMR and ^{13}C NMR spectra for compound 4

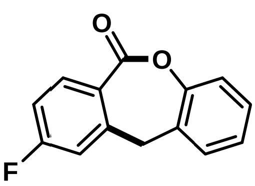


5

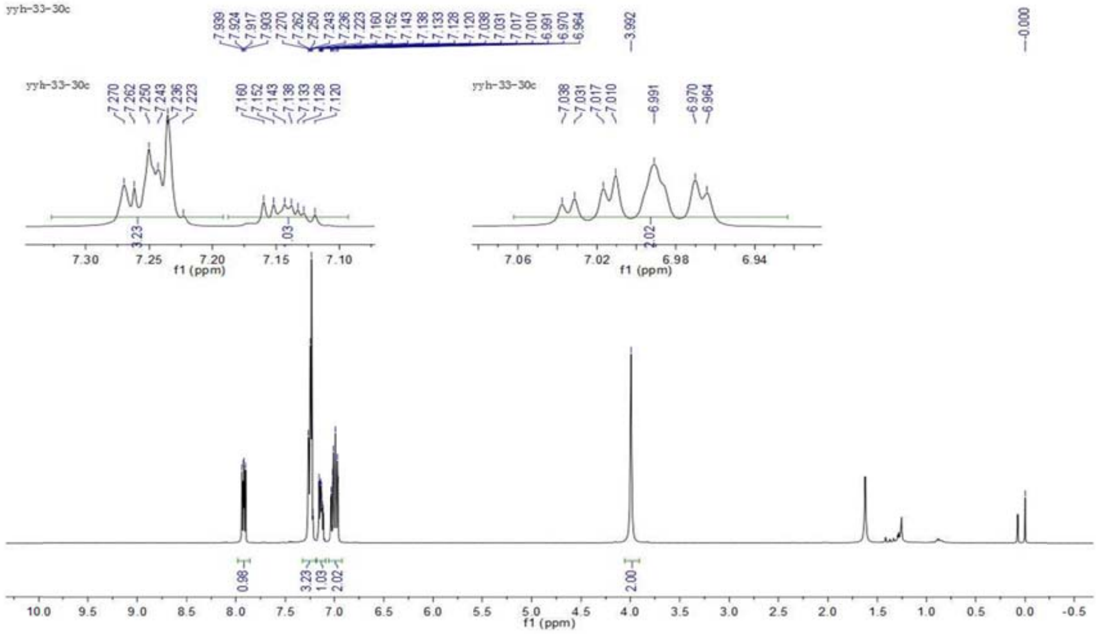


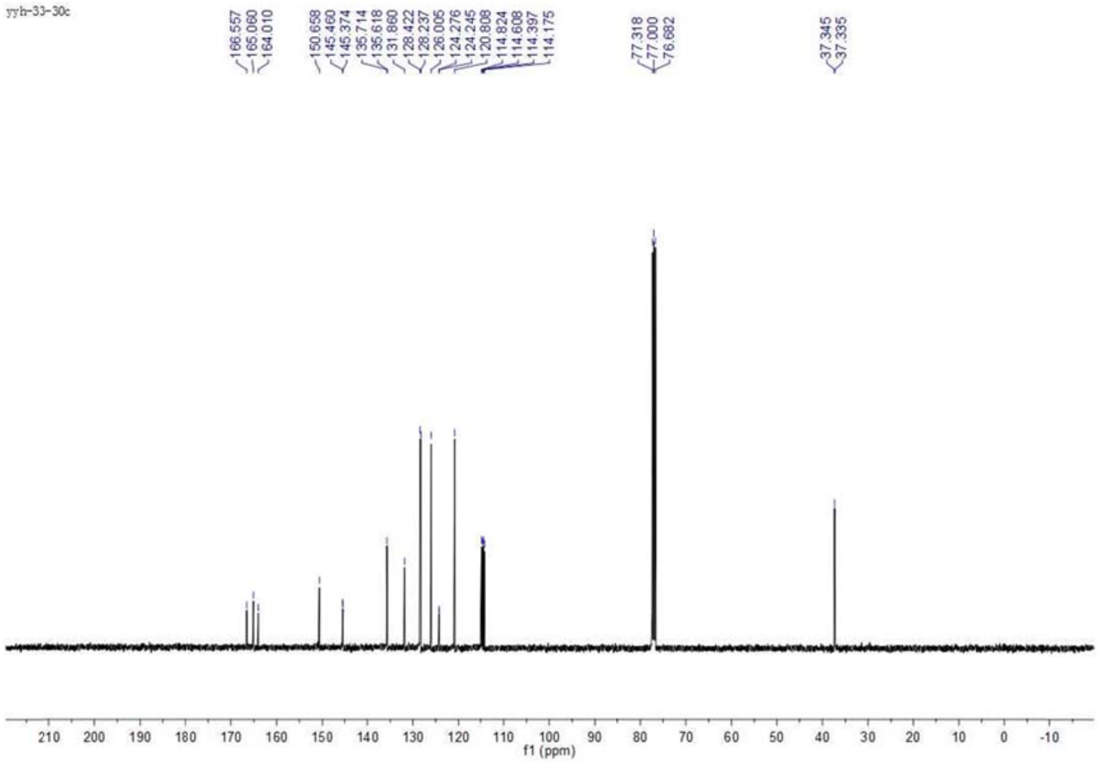


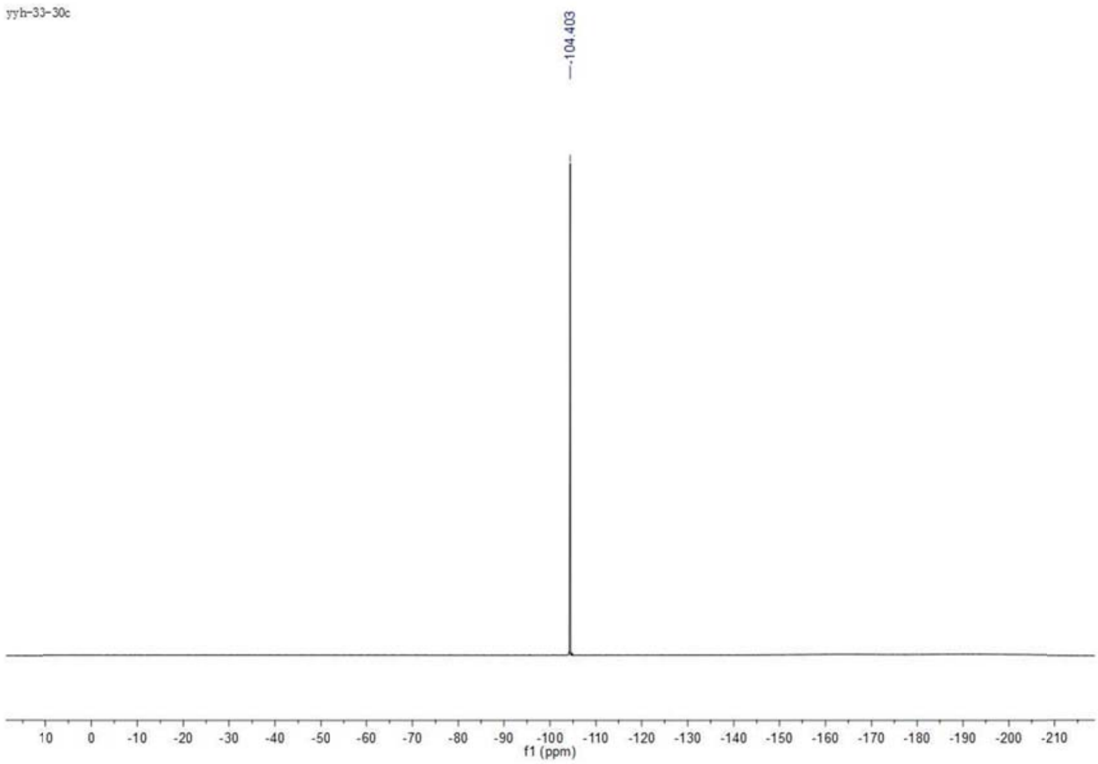
Supplementary Figure 20 ^{1}H NMR and ^{13}C NMR spectra for compound 5


O
O
F

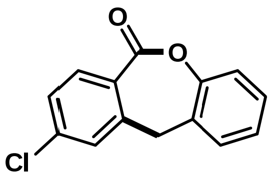
6


yyh-33-30c
7.939
7.924
7.917
7.903
7.270
7.262
7.250
7.243
7.236
7.223
7.160
7.152
7.143
7.138
7.133
7.128
7.120
7.038
7.031
7.017
7.010
6.991
6.970
6.964
3.992
0.000
0.98
3.23
1.03
2.02
2.00
f1 (ppm)

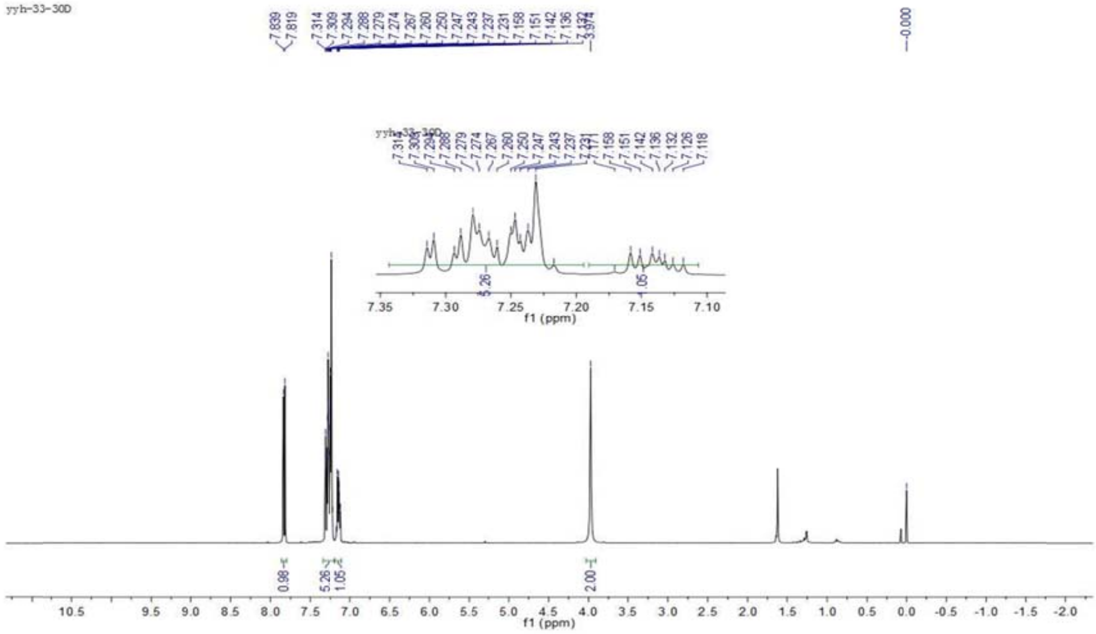

yyh-33-30c
166.557
165.060
164.010
150.658
145.460
145.374
135.714
135.618
131.860
128.422
128.237
126.005
124.276
124.245
120.808
114.824
114.608
114.397
114.175
77.318
77.000
76.682
37.345
37.335
f1 (ppm)

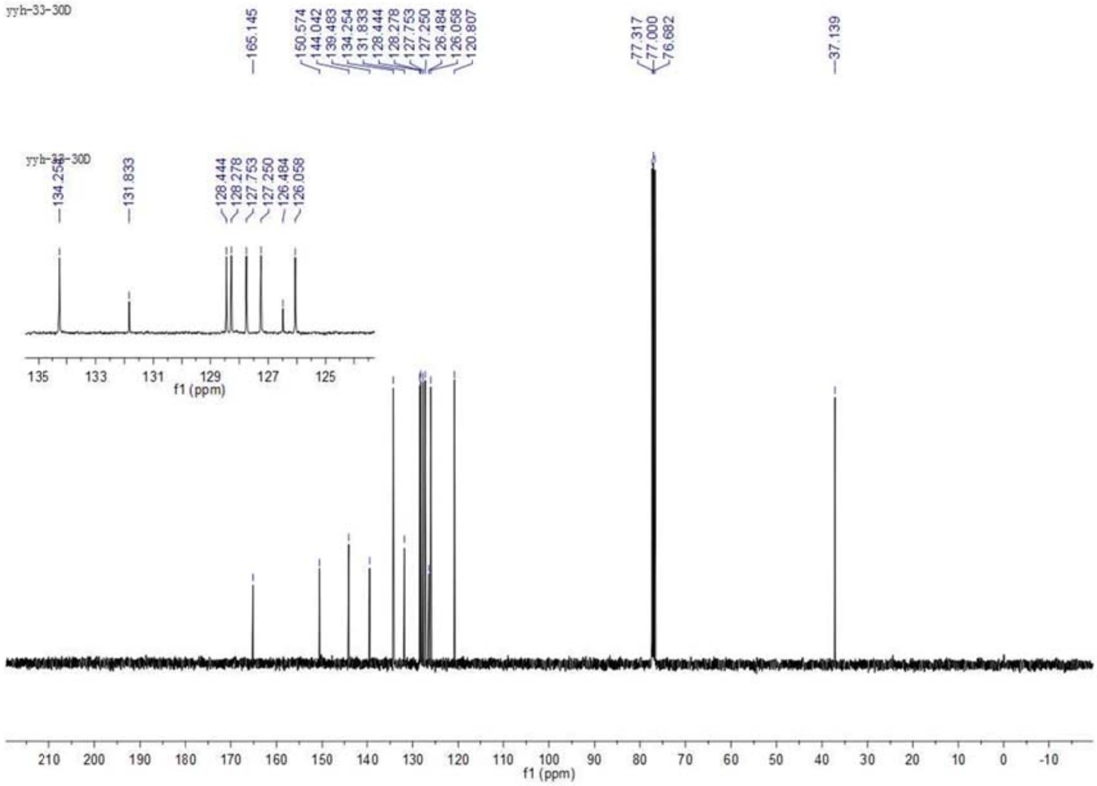


Supplementary Figure 21 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 6

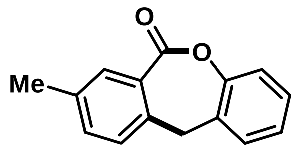


7

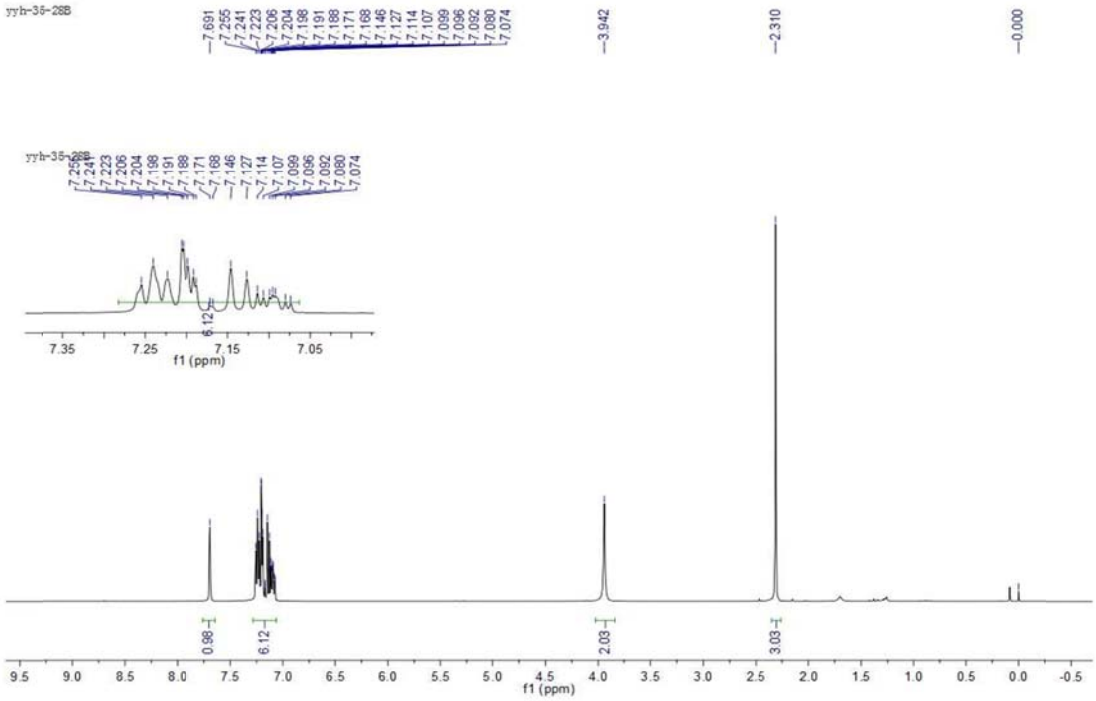


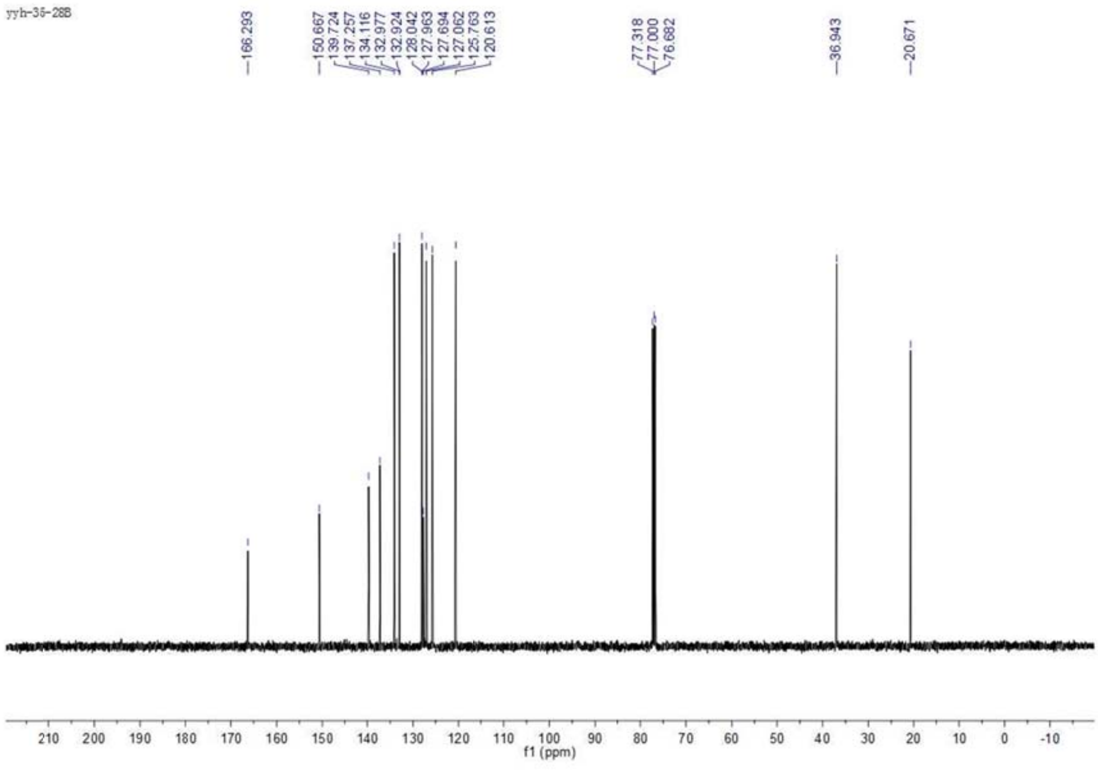


Supplementary Figure 22 ^{1}H NMR and ^{13}C NMR spectra for compound 7

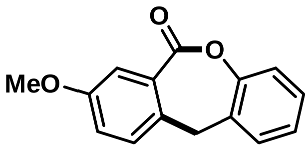


8

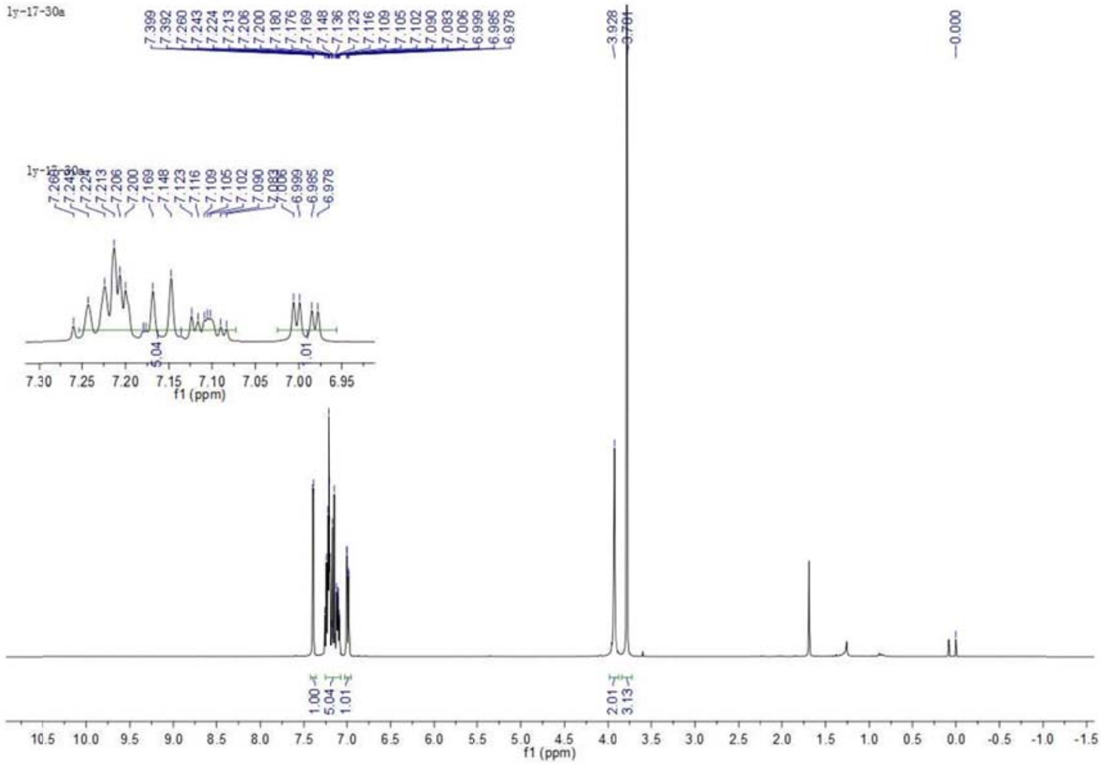


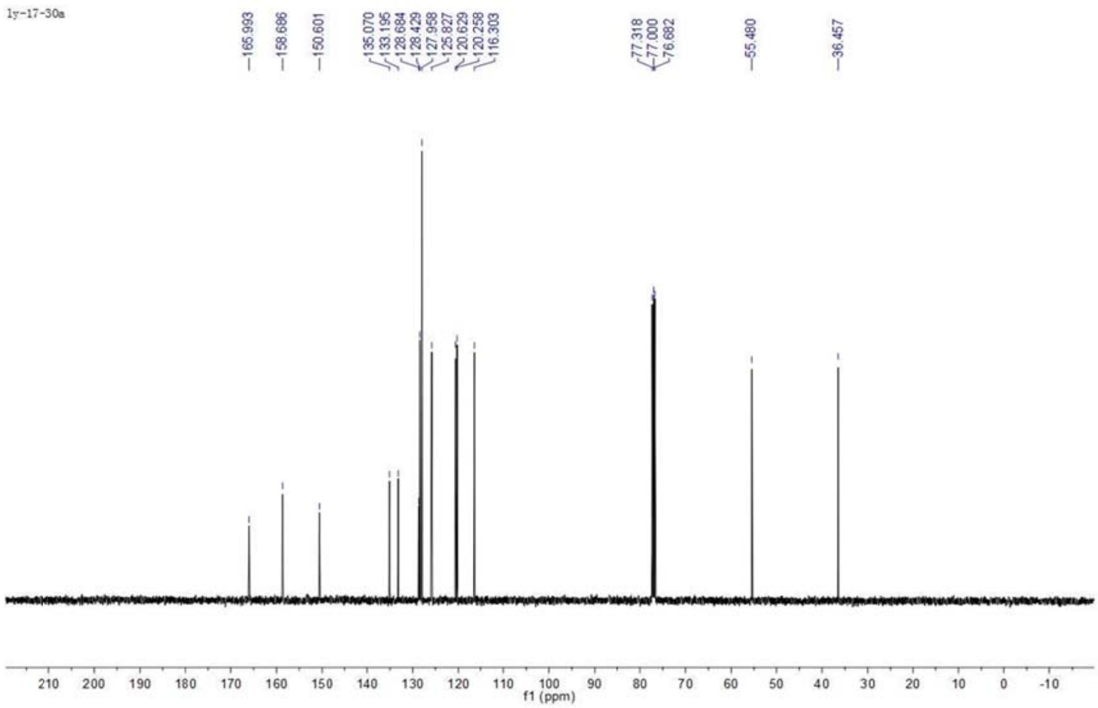


Supplementary Figure 23 ^{1}H NMR and ^{13}C NMR spectra for compound 8

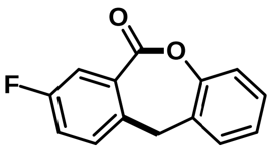


9

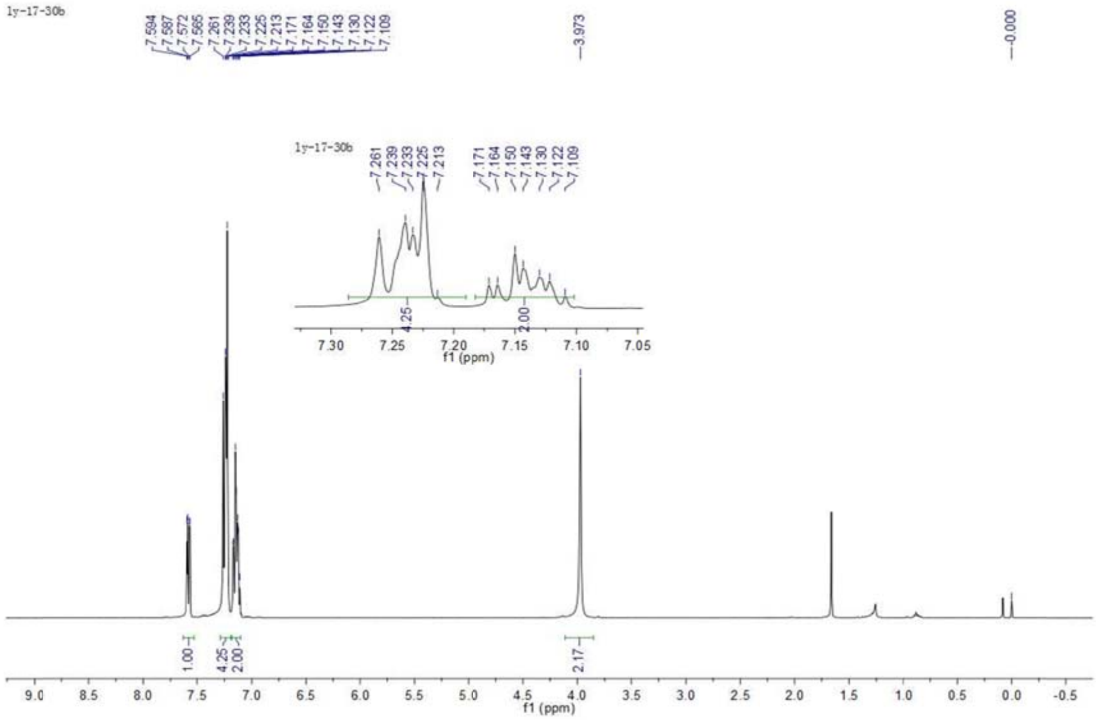


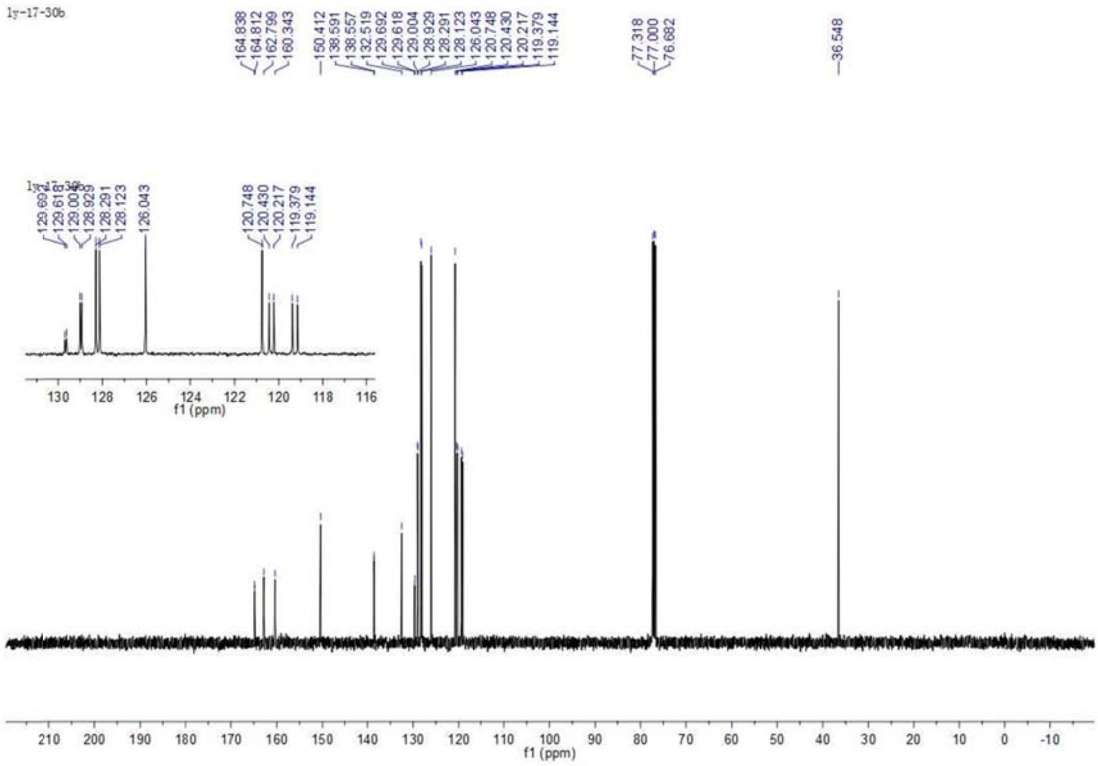


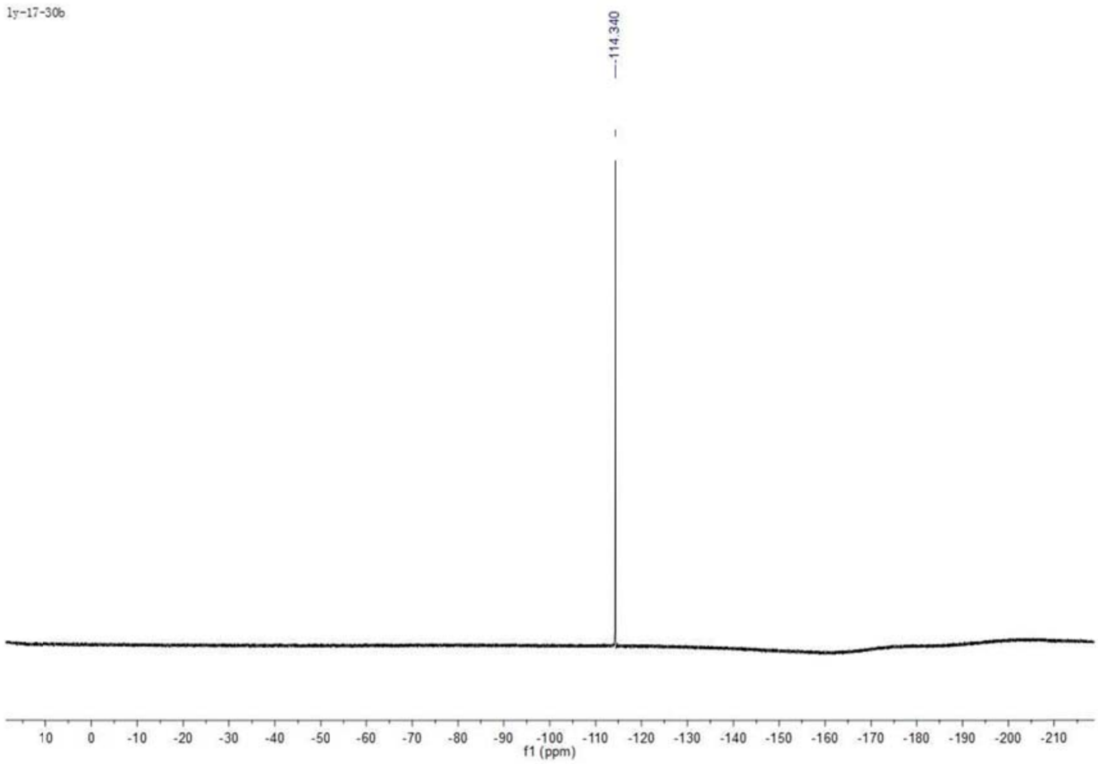
Supplementary Figure 24 ^{1}H NMR and ^{13}C NMR spectra for compound 9



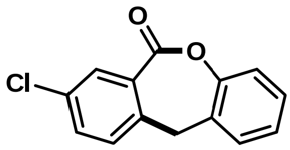
10



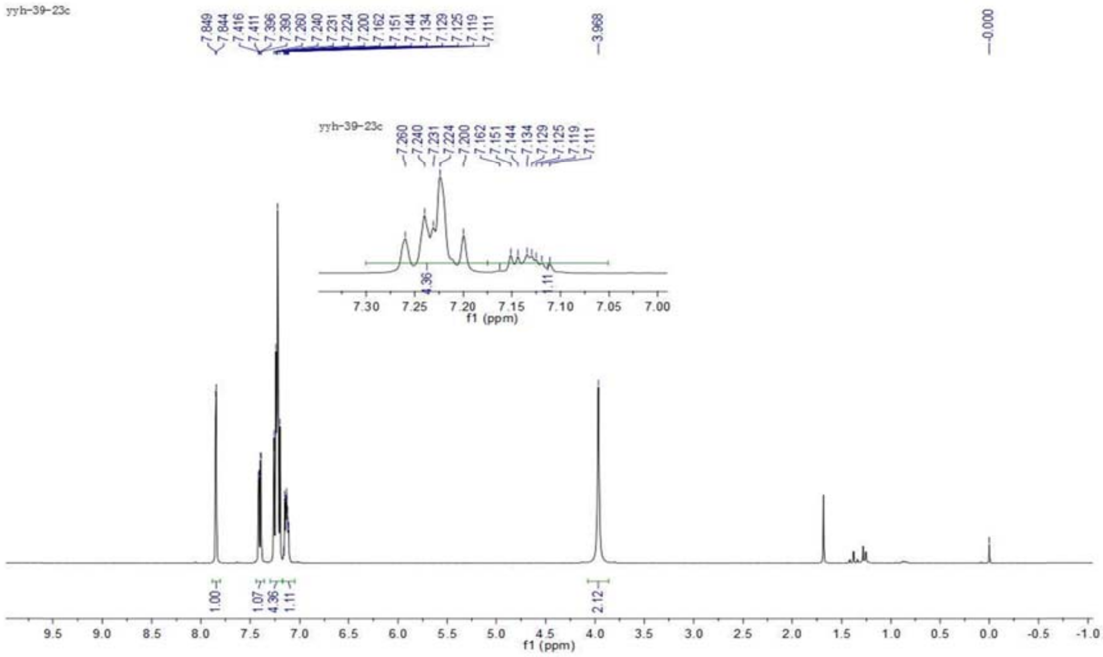


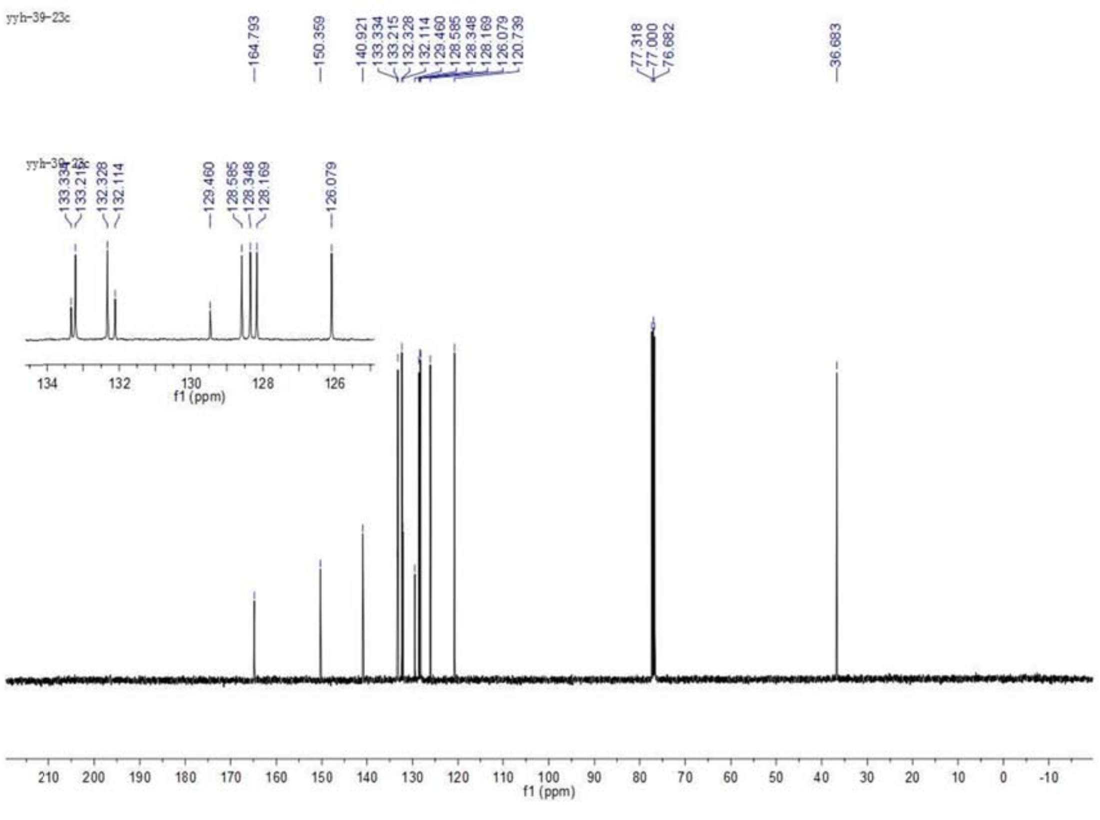


Supplementary Figure 25 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 10

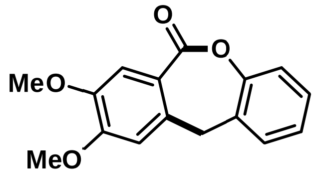


11

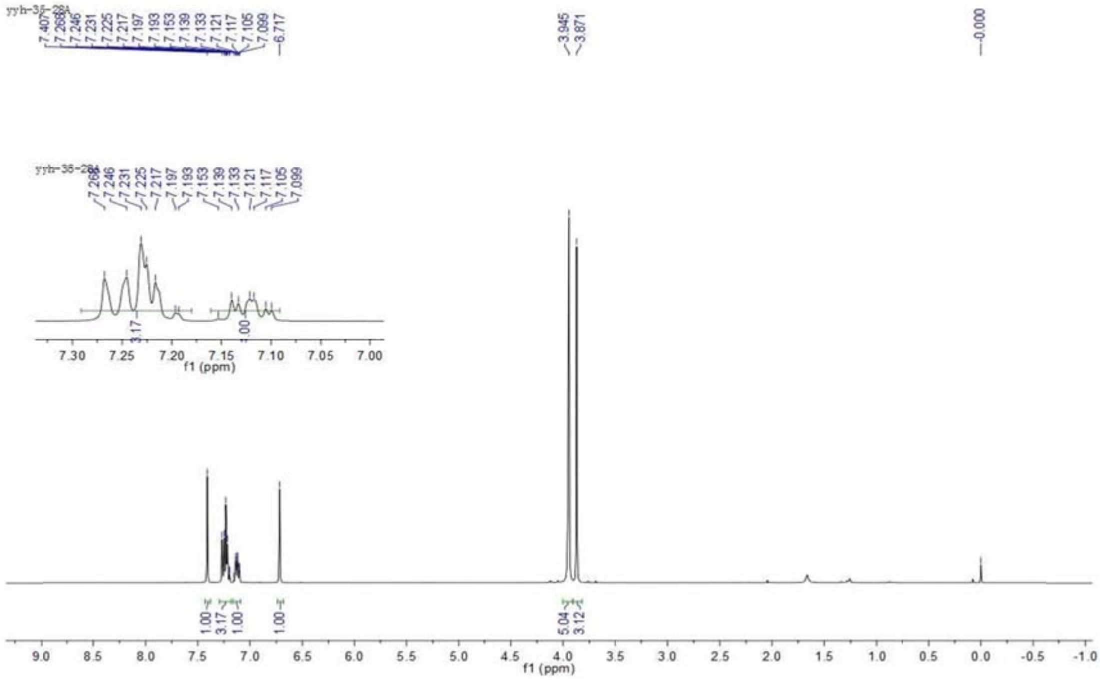


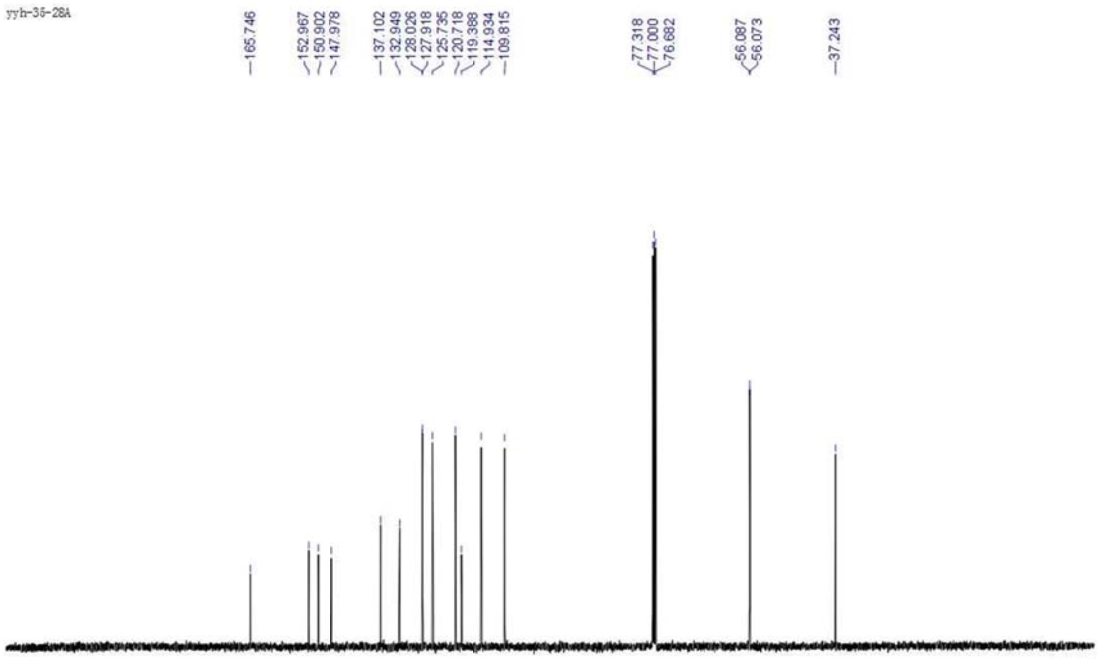


Supplementary Figure 26 ^{1}H NMR and ^{13}C NMR spectra for compound 11

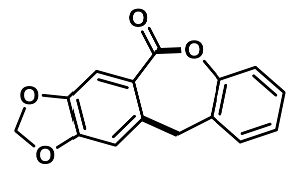


12

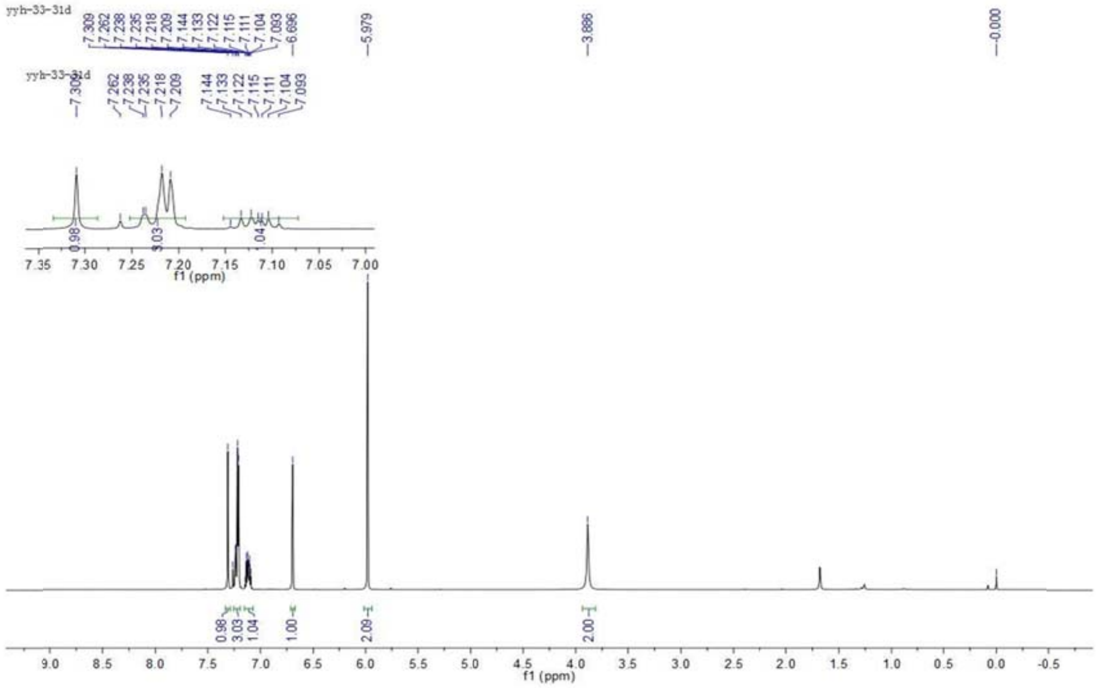


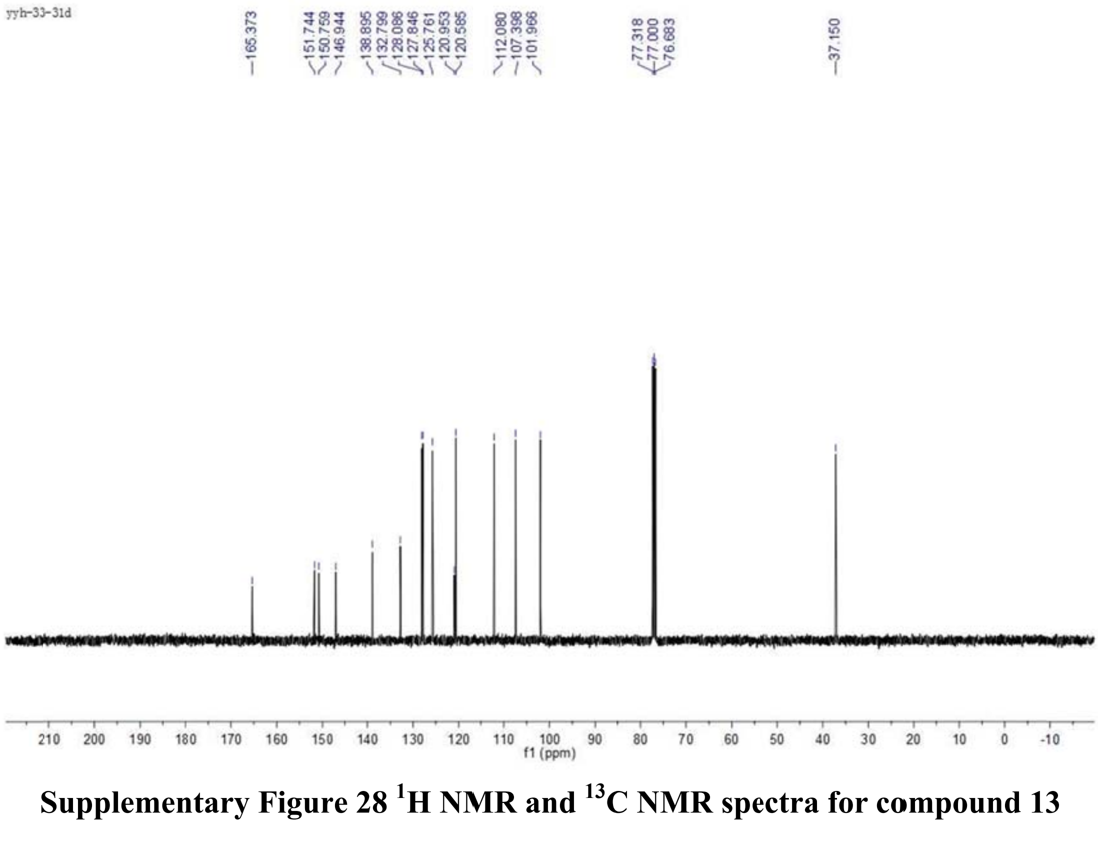


Supplementary Figure 27 ^{1}H NMR and ^{13}C NMR spectra for compound 12

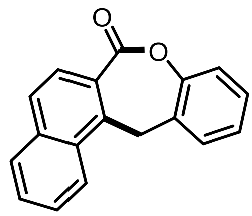


13

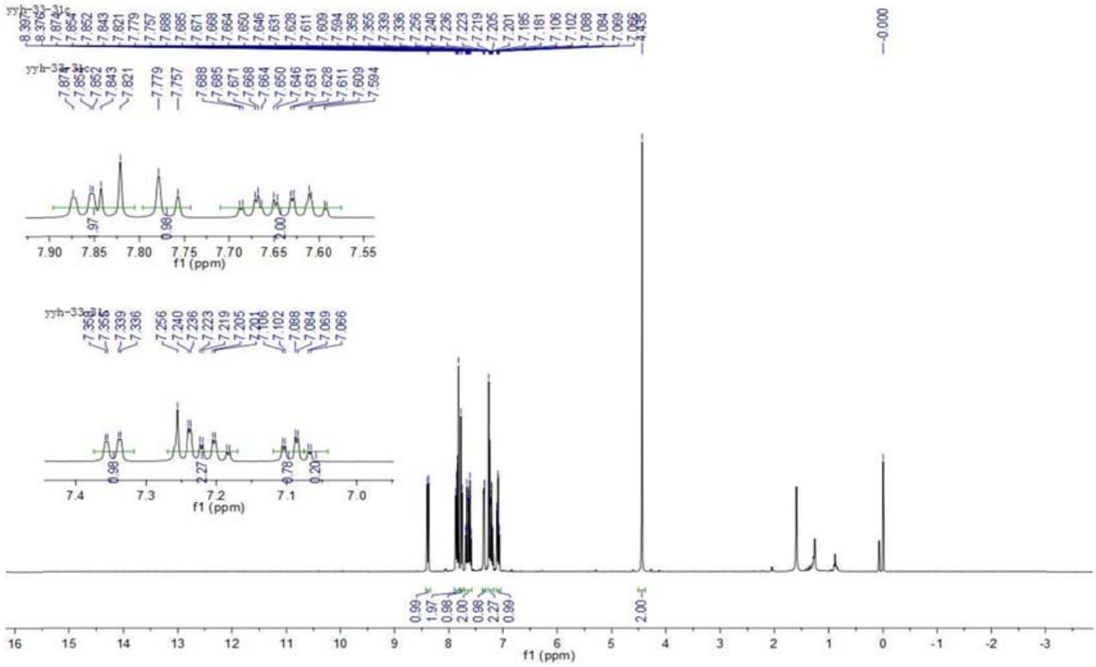


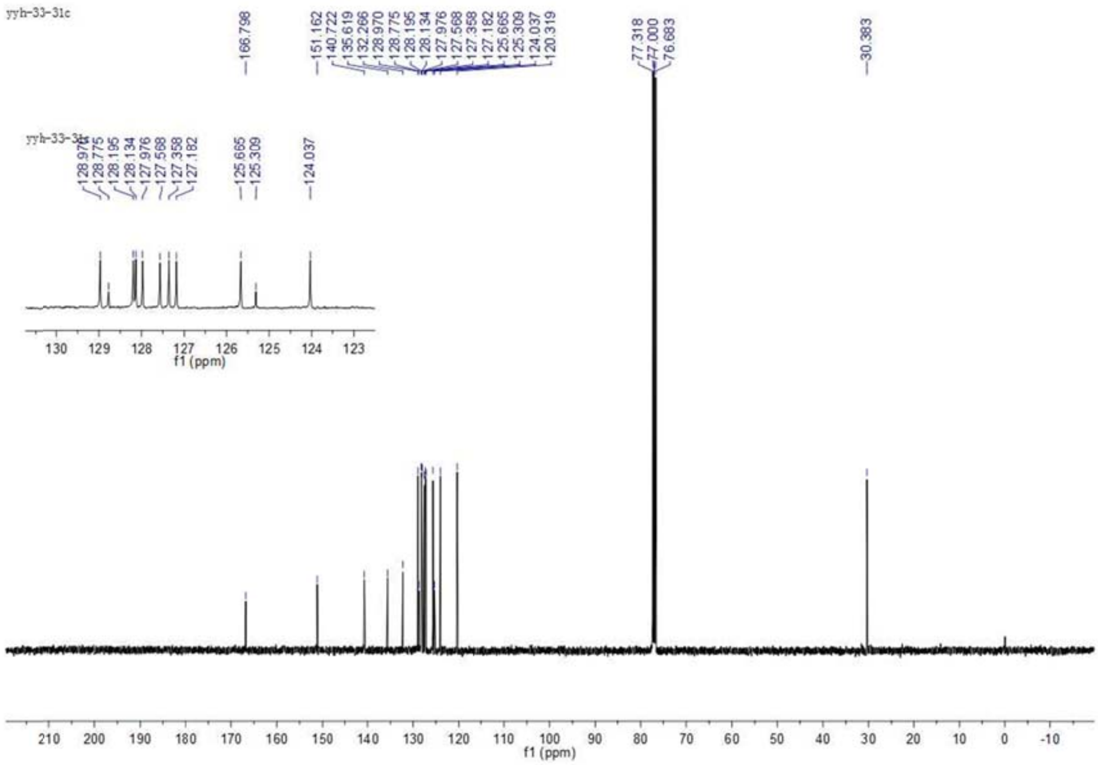


Supplementary Figure 28 ^{1}H NMR and ^{13}C NMR spectra for compound 13

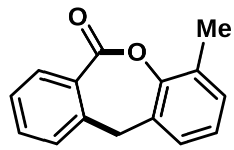


14

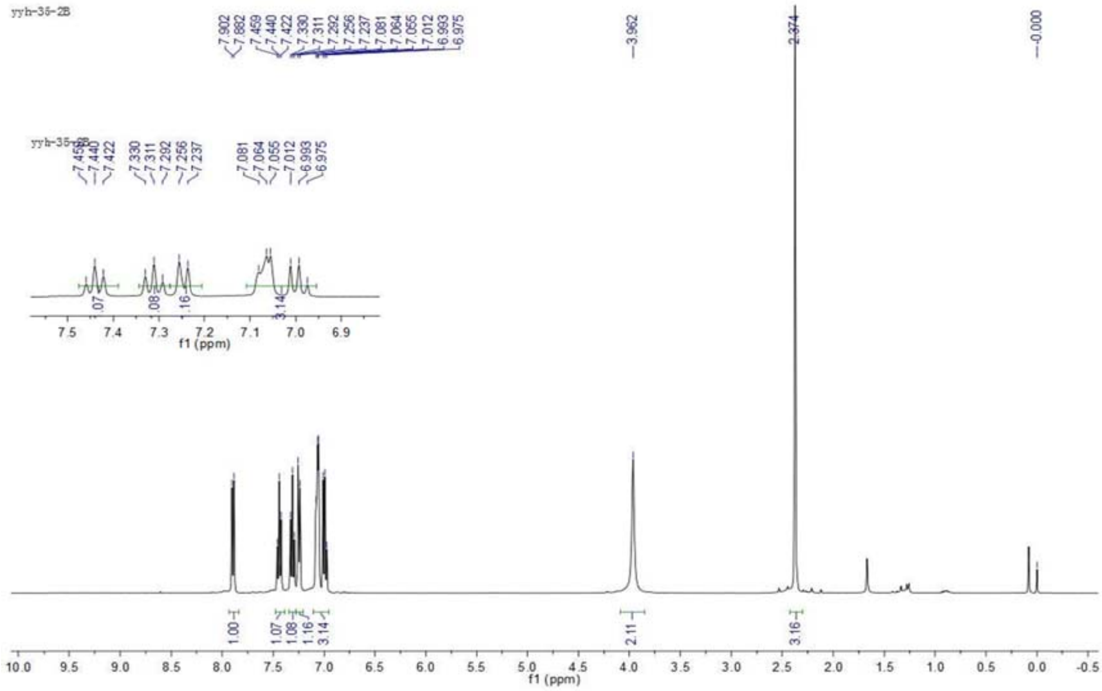


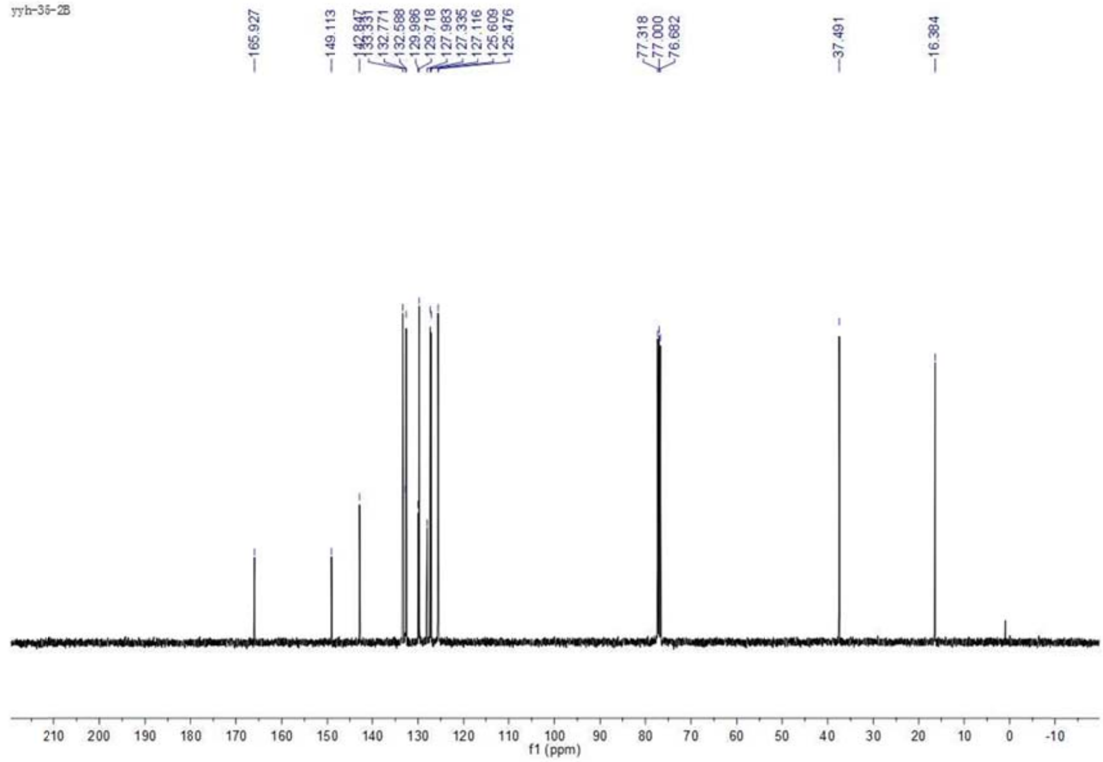


Supplementary Figure 29 ^{1}H NMR and ^{13}C NMR spectra for compound 14

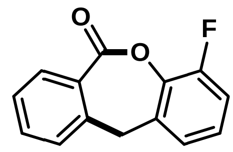


15

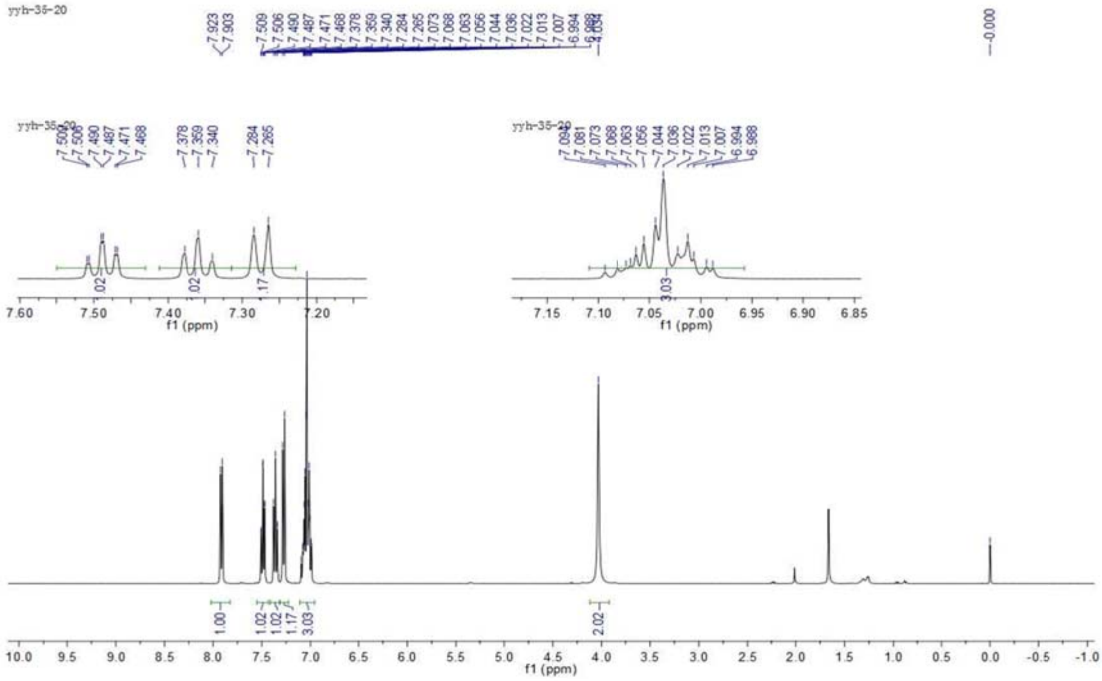


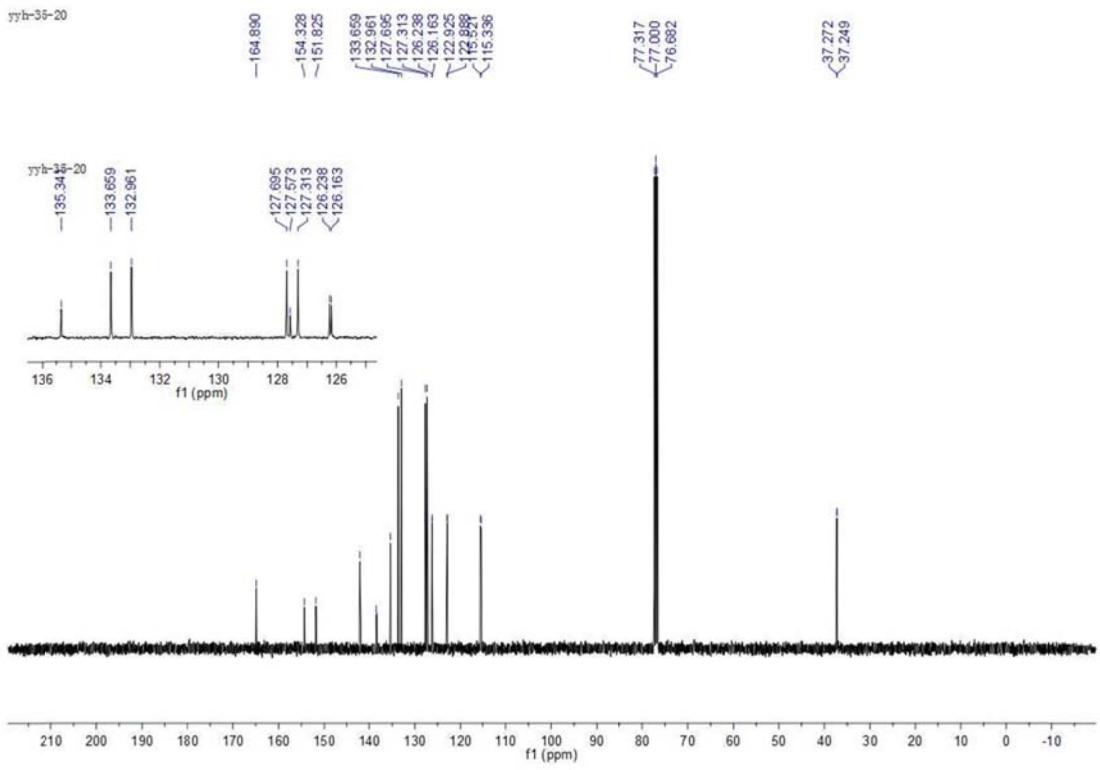


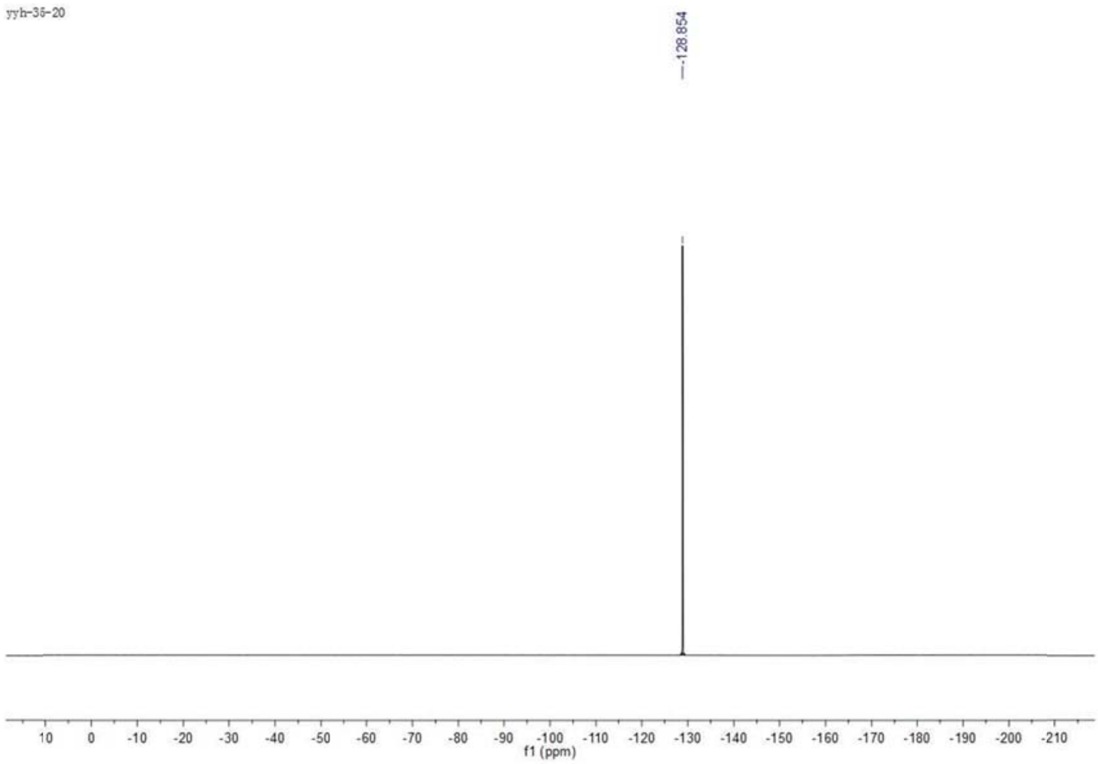
Supplementary Figure 30 ^{1}H NMR and ^{13}C NMR spectra for compound 15


O
O
F

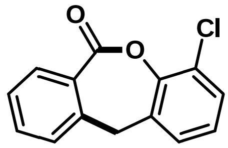
16


yyh-35-20
7.923
7.903
7.509
7.506
7.490
7.487
7.471
7.468
7.378
7.359
7.340
7.284
7.265
7.073
7.068
7.063
7.056
7.044
7.036
7.022
7.013
7.007
6.994
6.988
4.034
0.000
1.00
1.02
1.02
1.17
3.03
2.02
f1 (ppm)

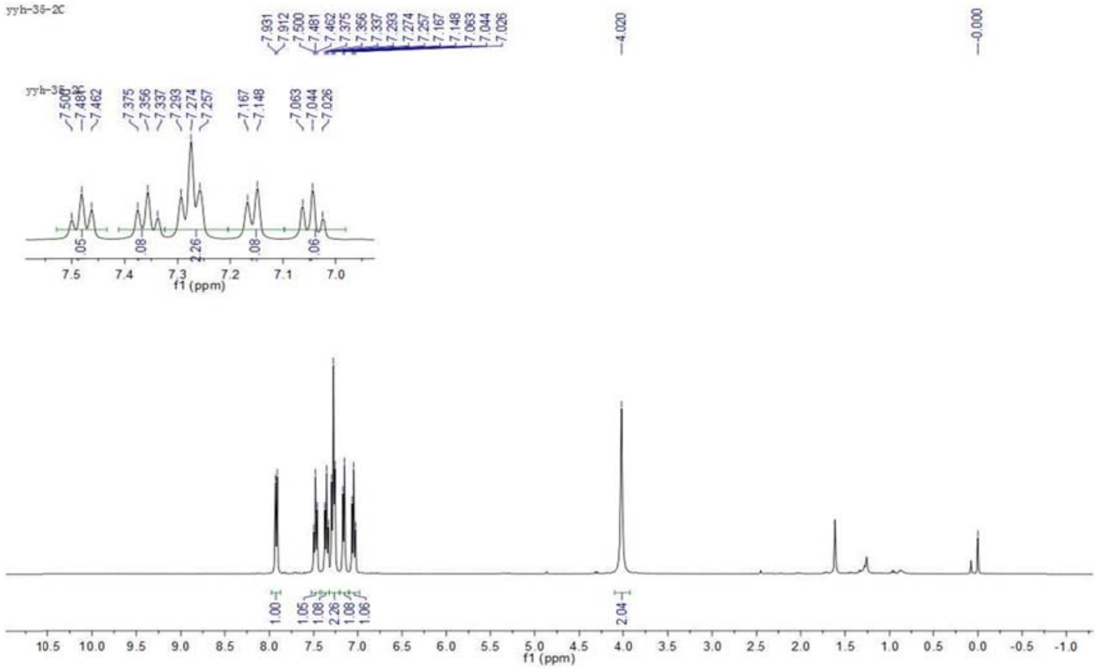

yyh-35-20
164.890
154.328
151.825
133.659
132.961
127.695
127.313
126.238
126.163
122.925
122.888
115.521
115.336
77.317
77.000
76.682
37.272
37.249
135.341
127.573
f1 (ppm)

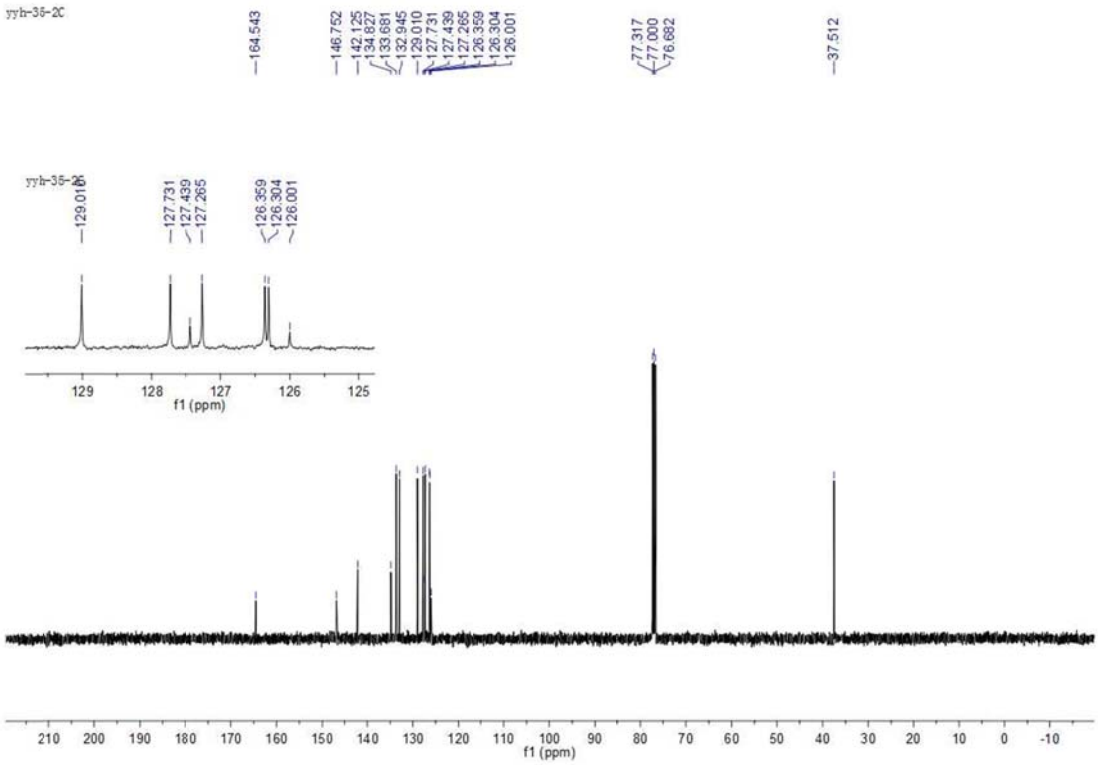


Supplementary Figure 31 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 16

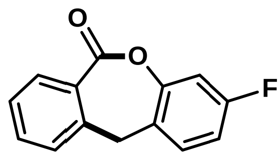


17

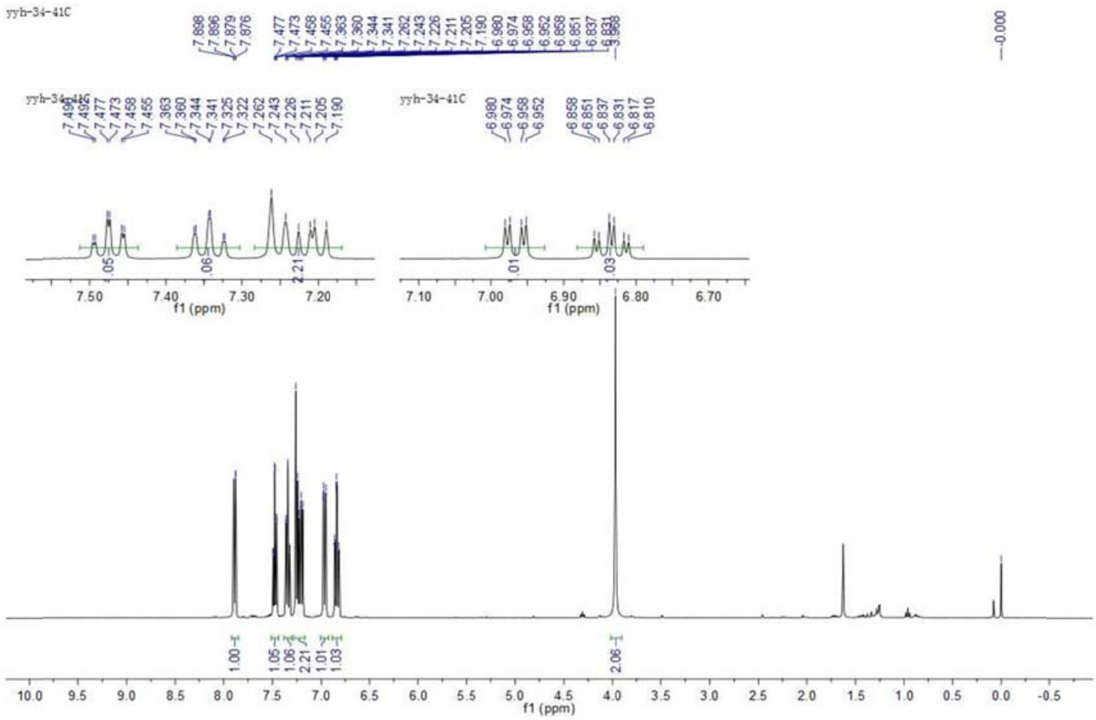


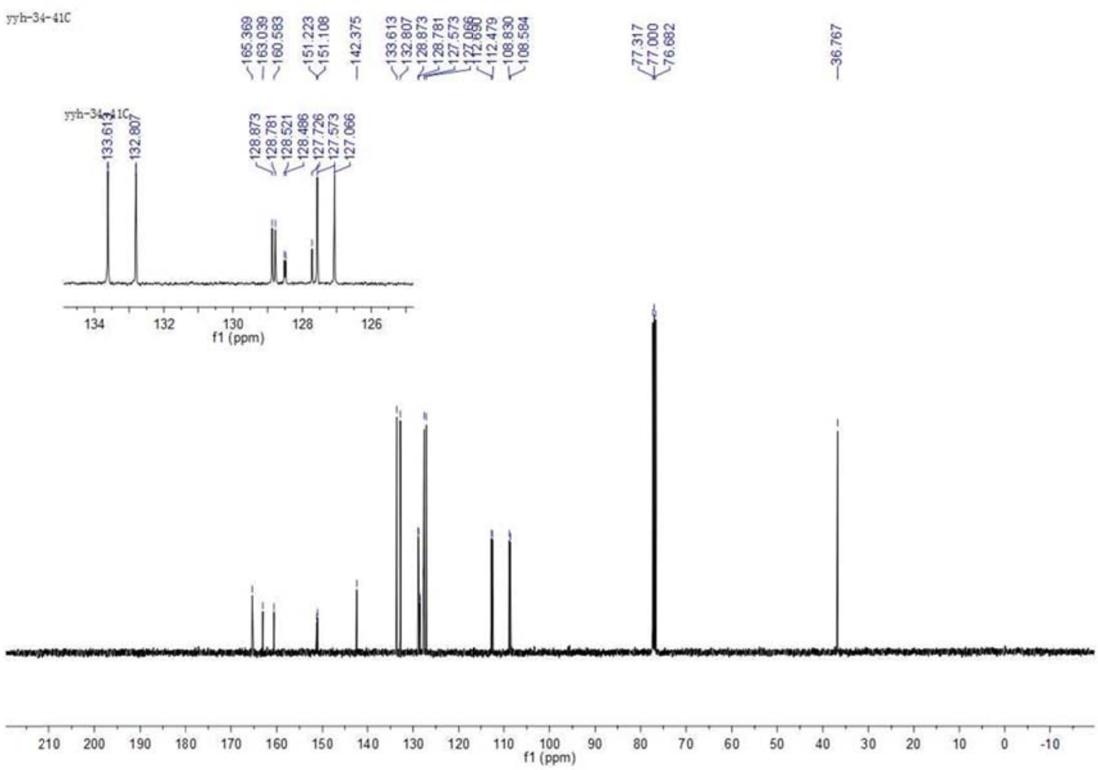


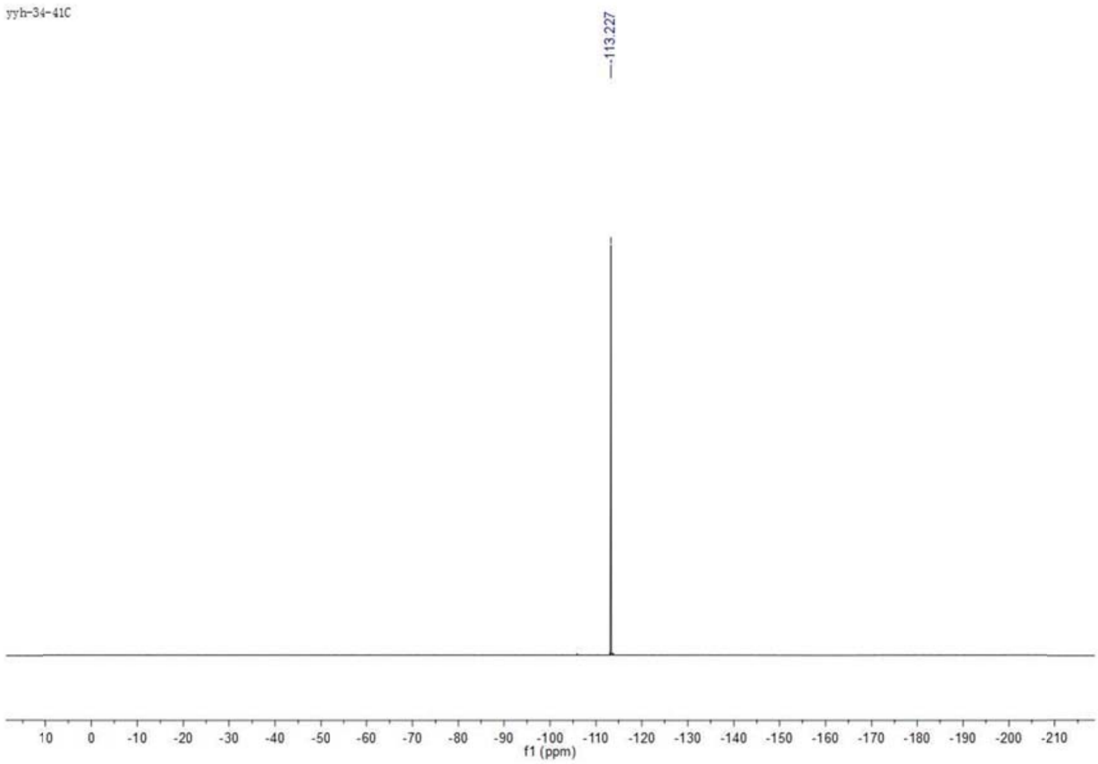
Supplementary Figure 32 ^{1}H NMR and ^{13}C NMR spectra for compound 17


O
O
F

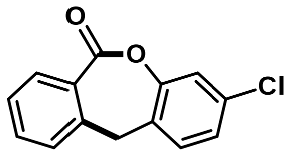
18


yyh-34-41C
7.898
7.896
7.879
7.876
7.477
7.473
7.458
7.455
7.363
7.360
7.344
7.341
7.262
7.243
7.226
7.211
7.205
7.190
6.980
6.974
6.958
6.952
6.858
6.851
6.837
6.831
3.958
-0.000
1.00
1.05
1.06
2.21
1.01
1.03
2.06
f1 (ppm)

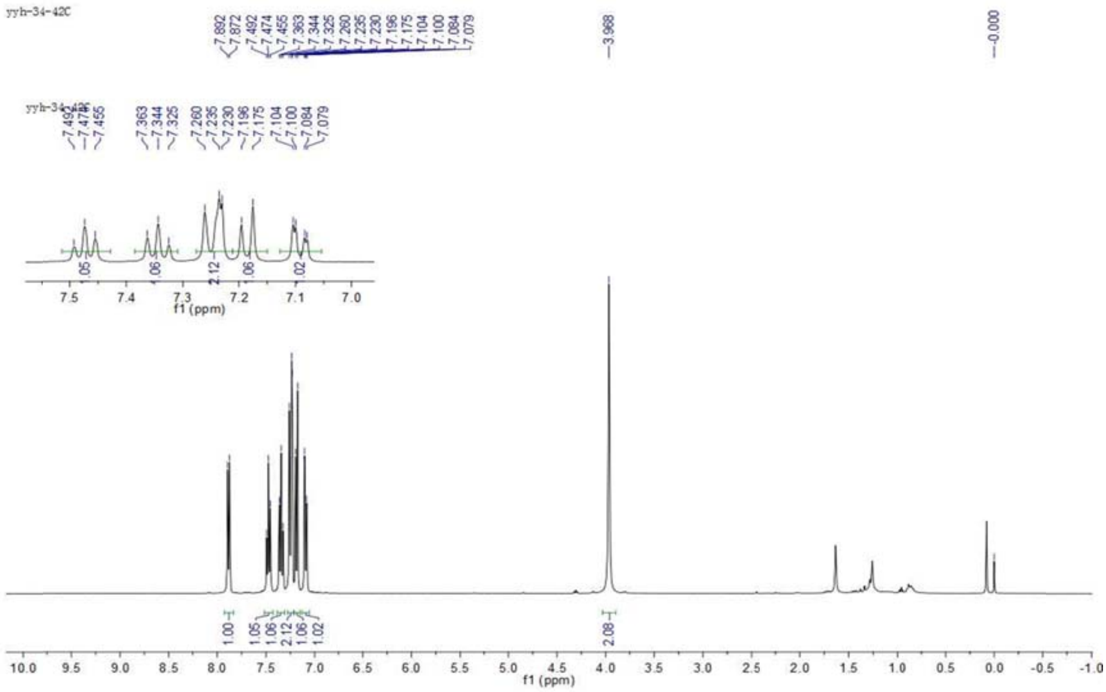

yyh-34-41C
165.369
163.039
160.583
151.223
151.108
142.375
133.613
132.807
128.873
128.781
127.573
127.066
112.690
112.479
108.830
108.584
77.317
77.000
76.682
36.767
128.521
128.486
127.726
f1 (ppm)

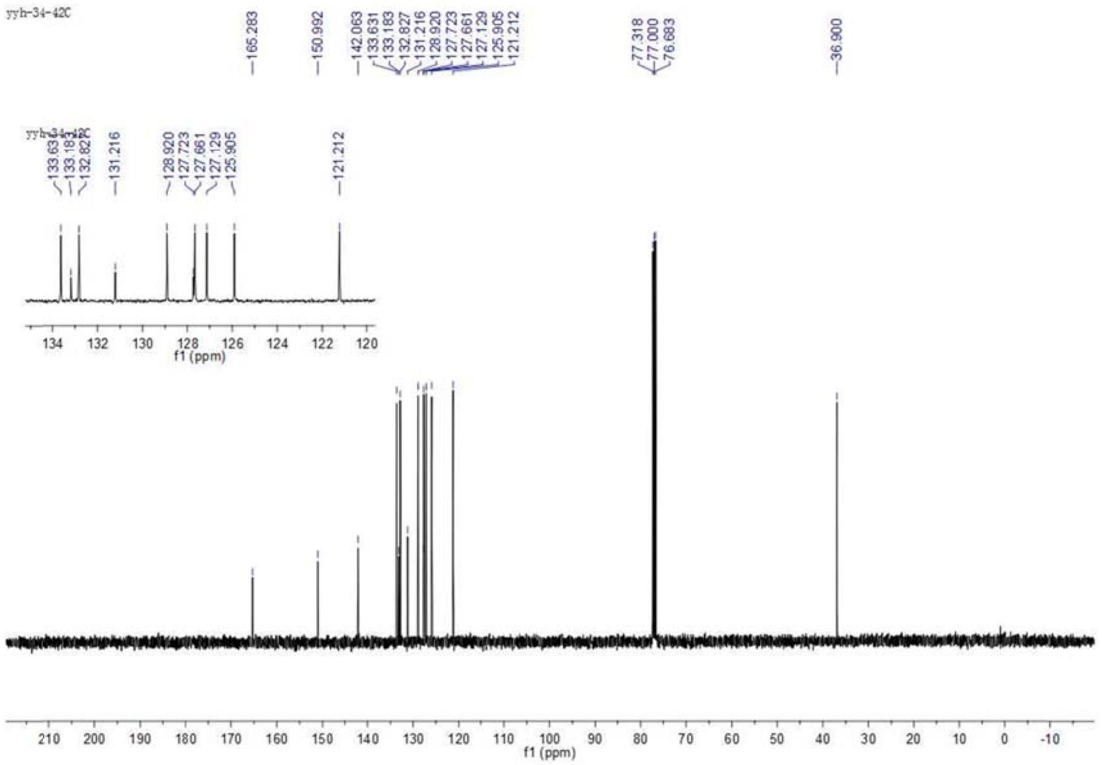


Supplementary Figure 33 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 18

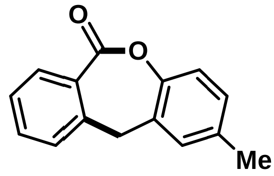


19





Supplementary Figure 34 ^{1}H NMR and ^{13}C NMR spectra for compound 19



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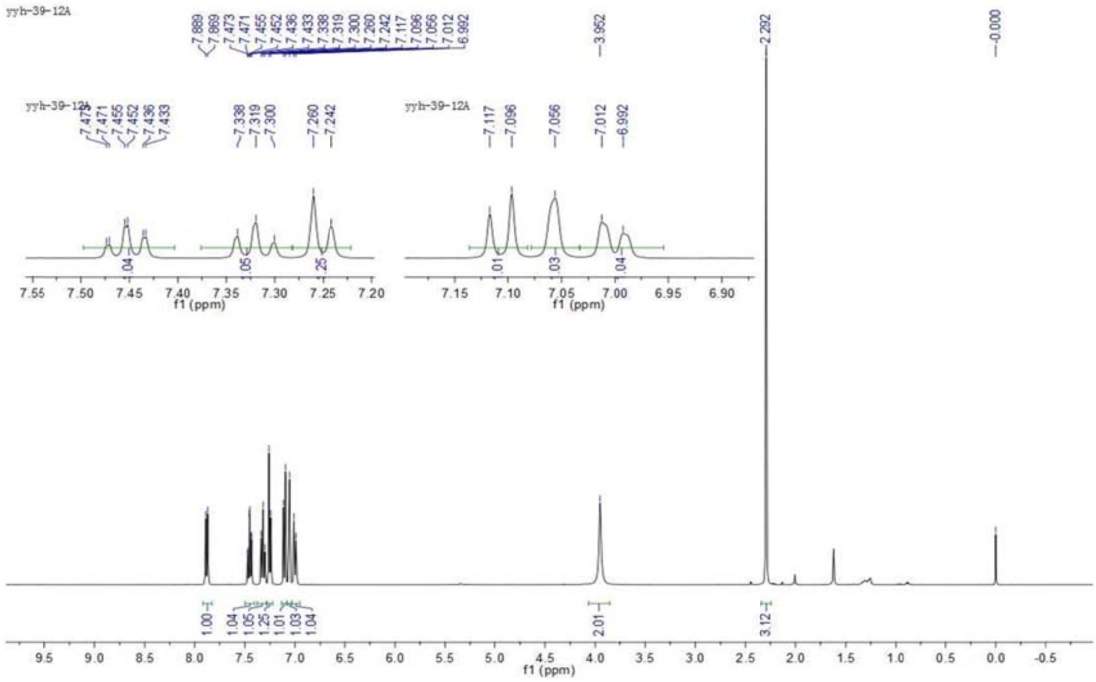
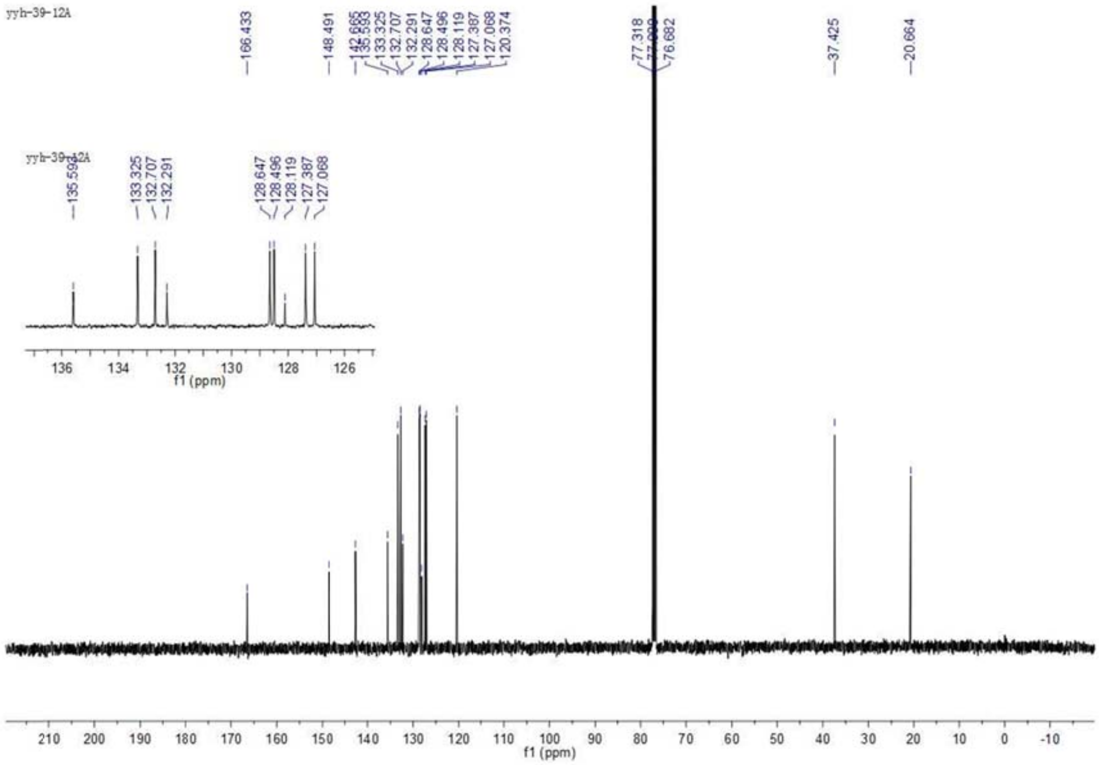
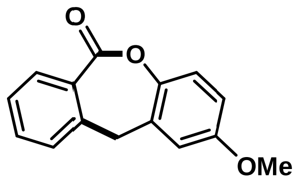




Supplementary Figure 35 ^{1}H NMR and ^{13}C NMR spectra for compound 20



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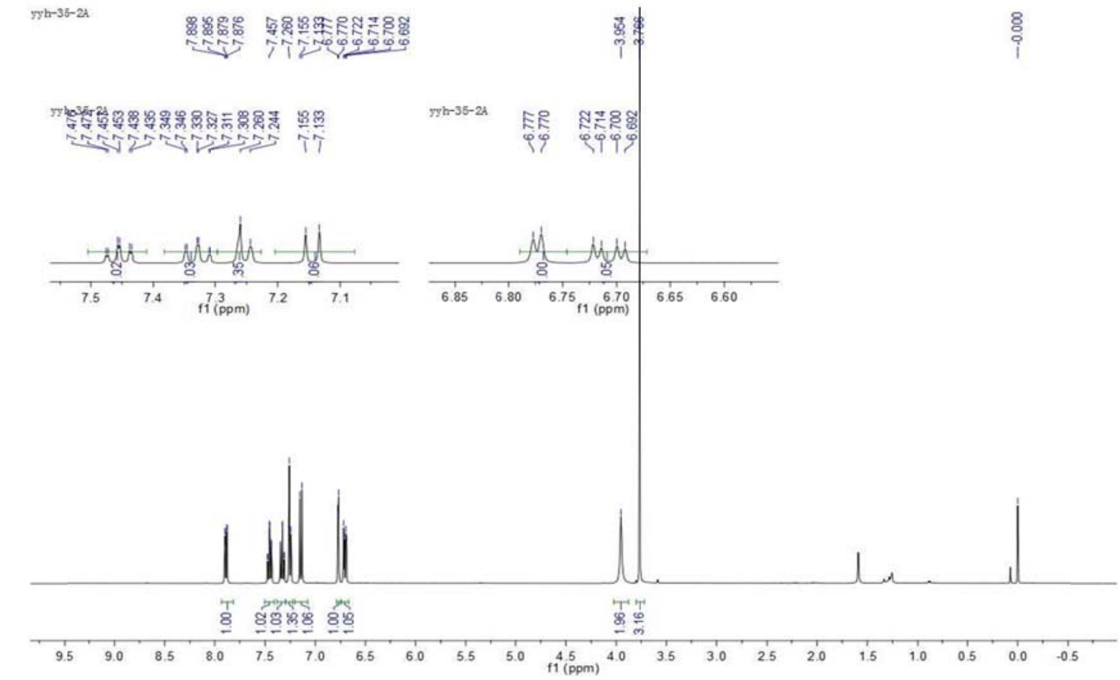
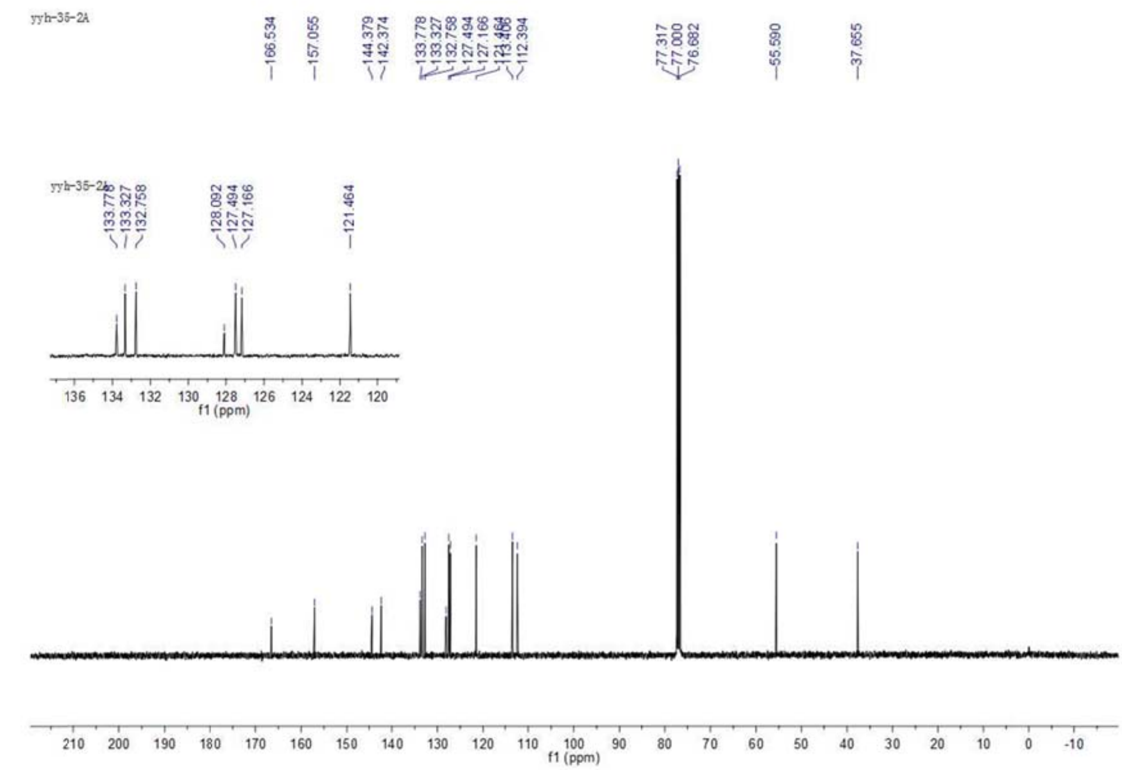
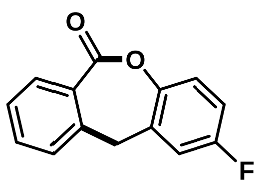




Supplementary Figure 36 ^{1}H NMR and ^{13}C NMR spectra for compound 21



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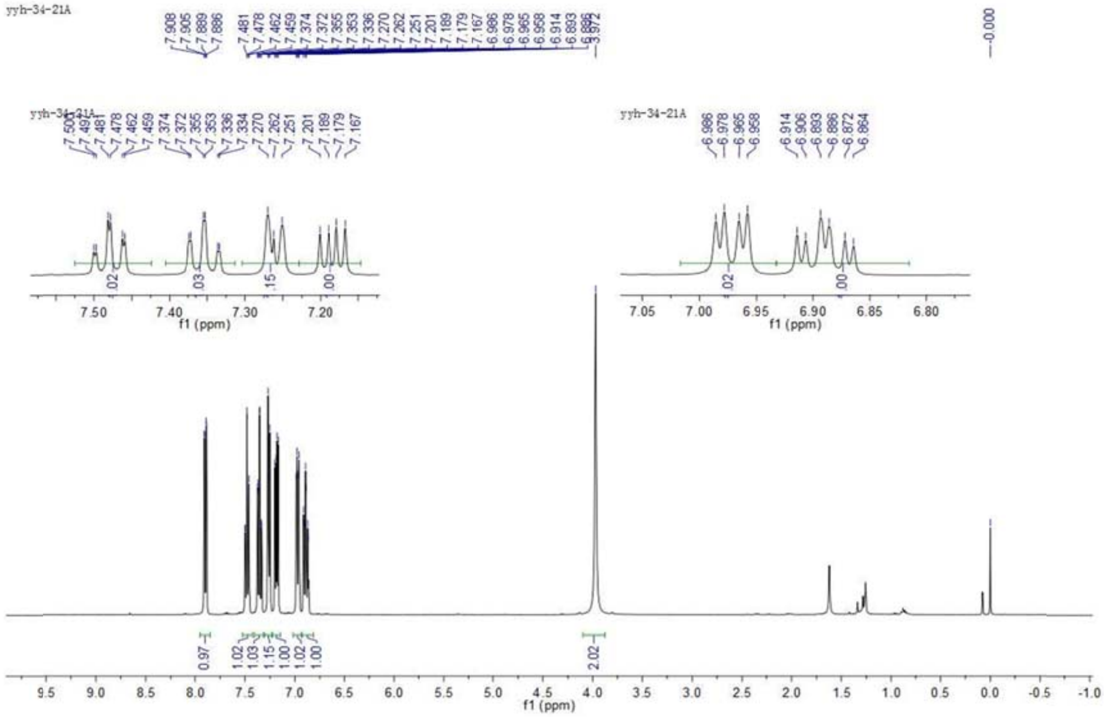
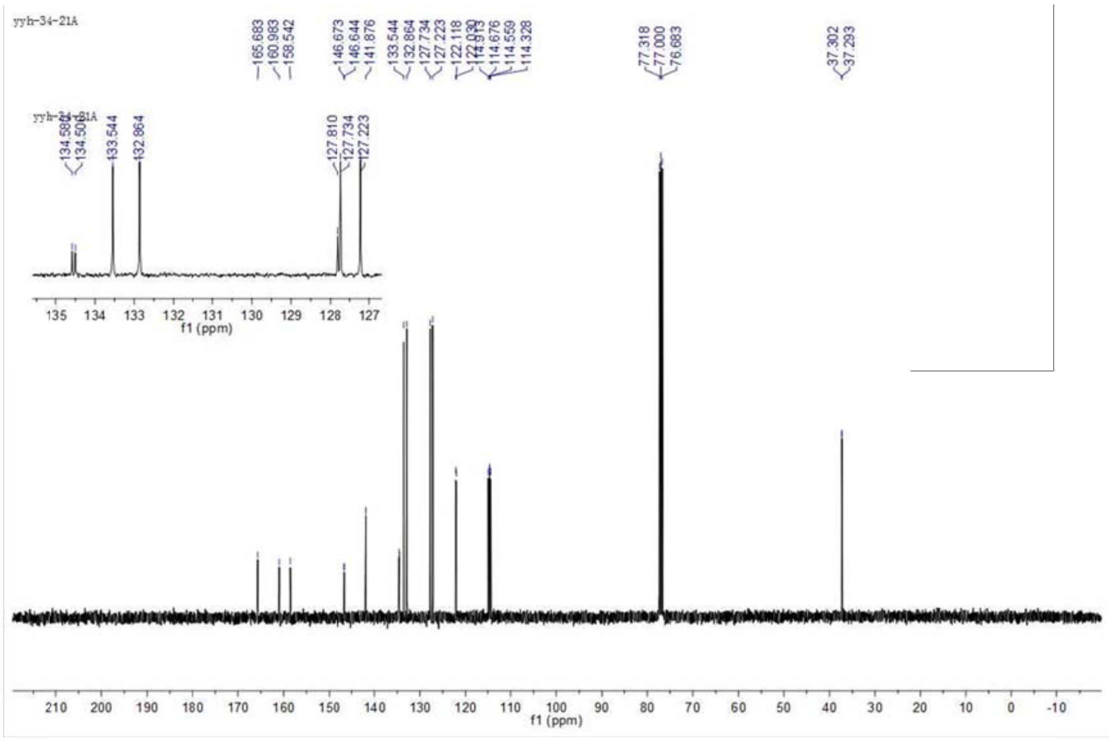
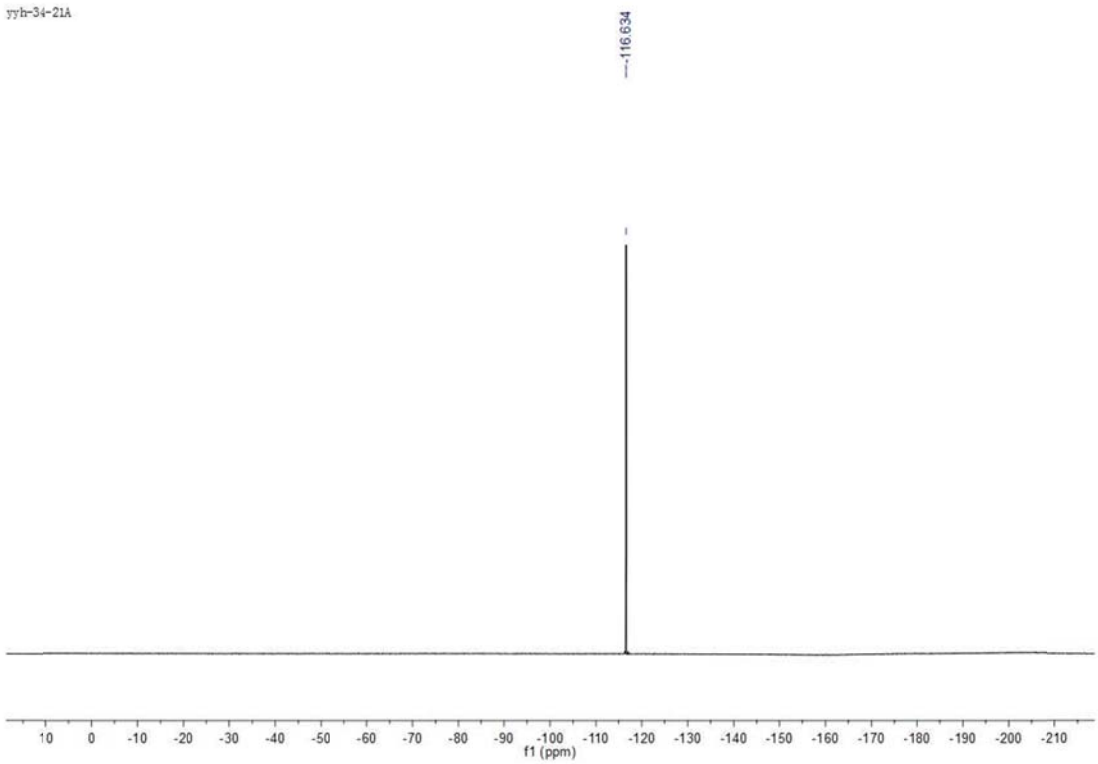
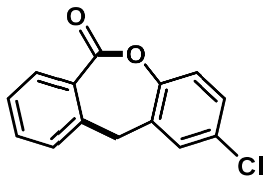






Supplementary Figure 37 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 22



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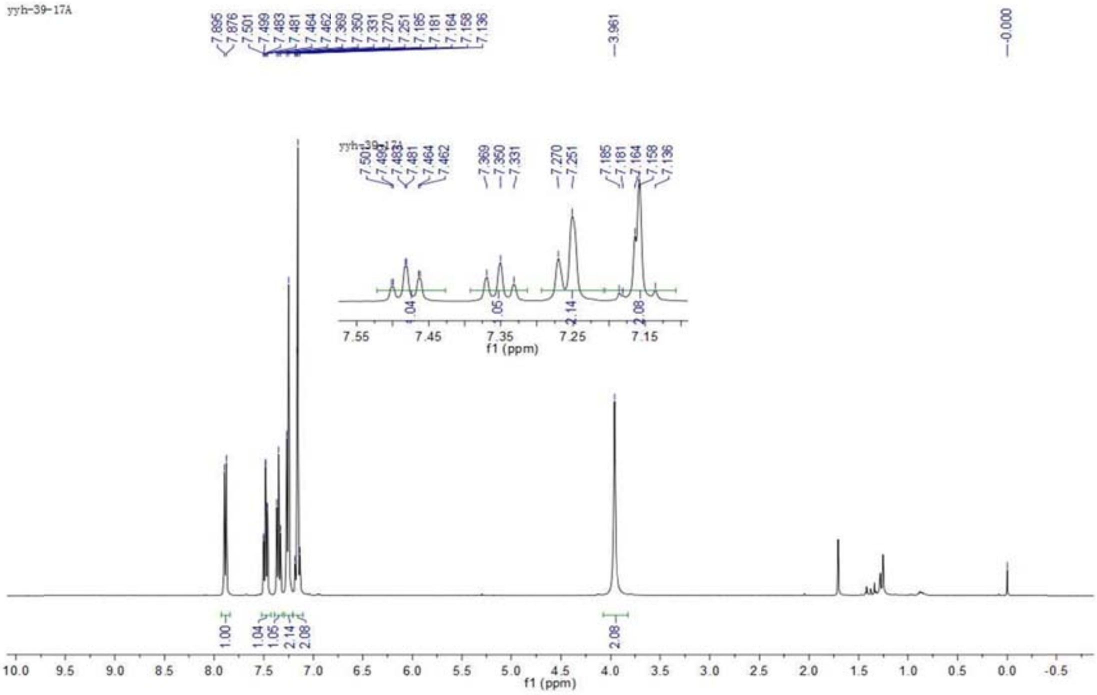
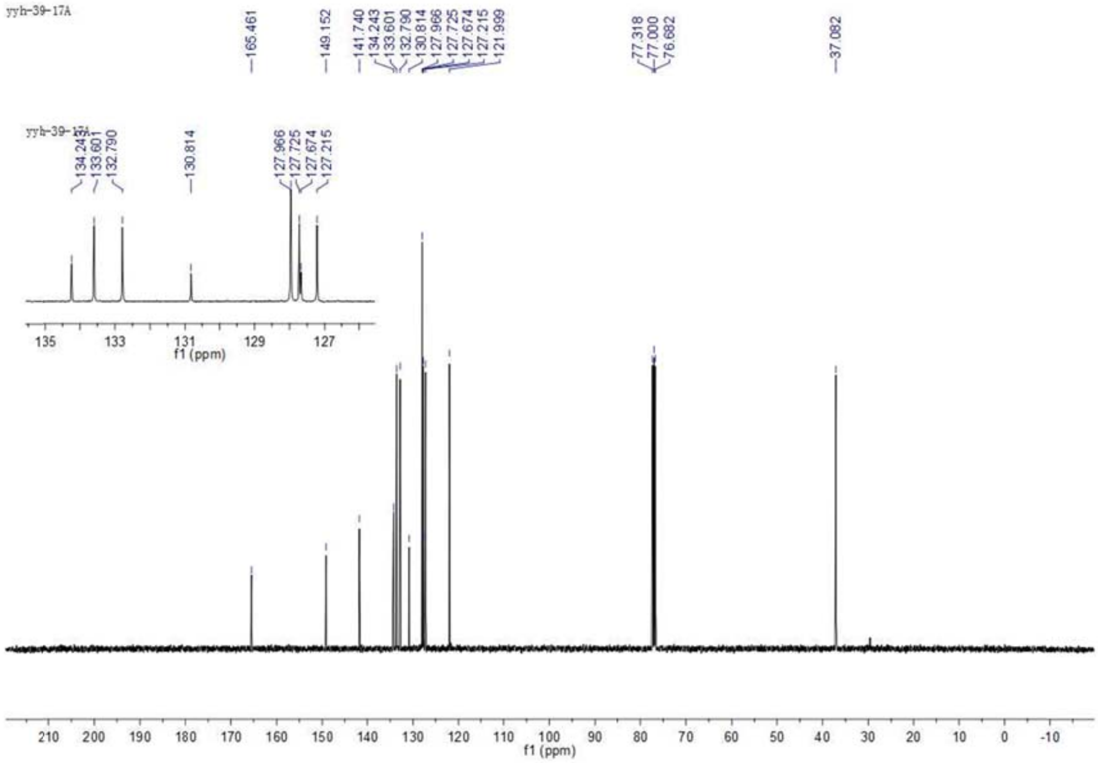
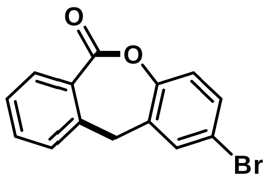




Supplementary Figure 38 ^{1}H NMR and ^{13}C NMR spectra for compound 23



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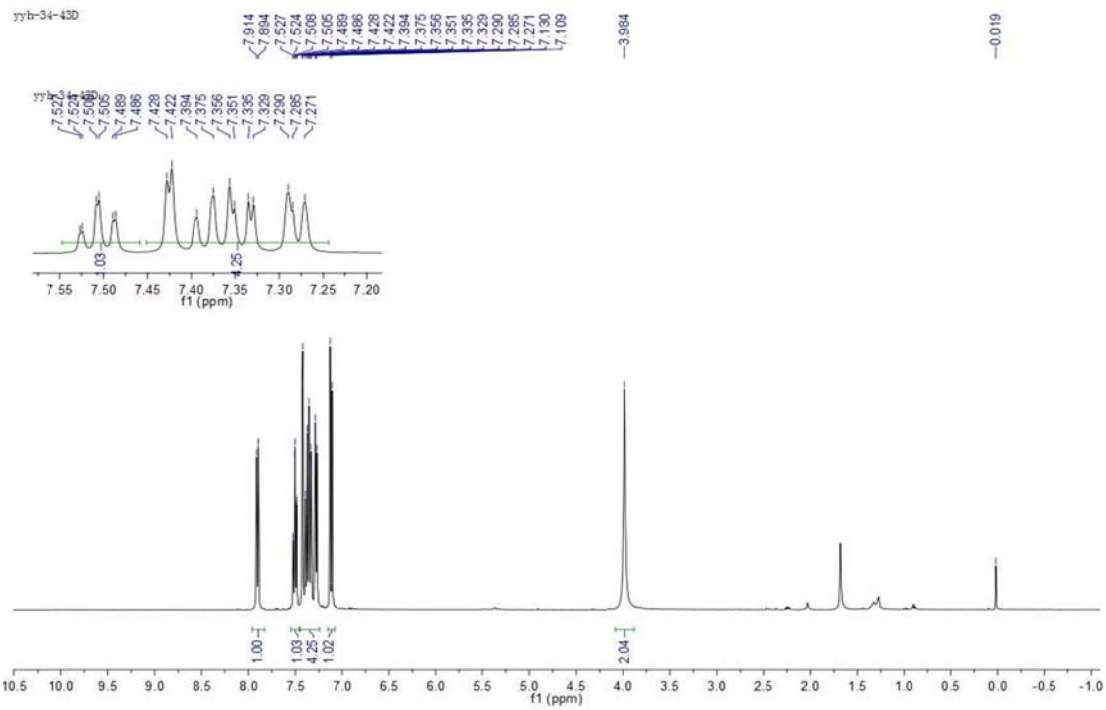
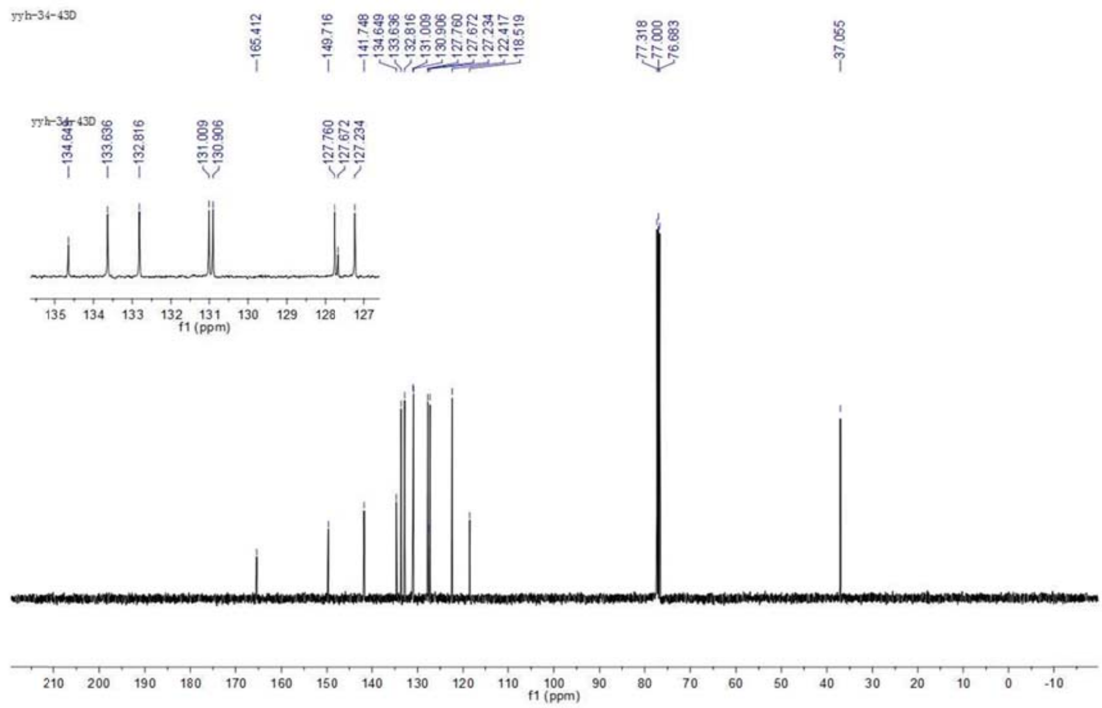
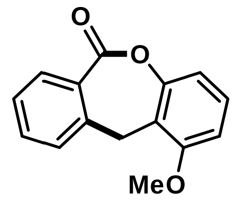




Supplementary Figure 39 ^{1}H NMR and ^{13}C NMR spectra for compound 24



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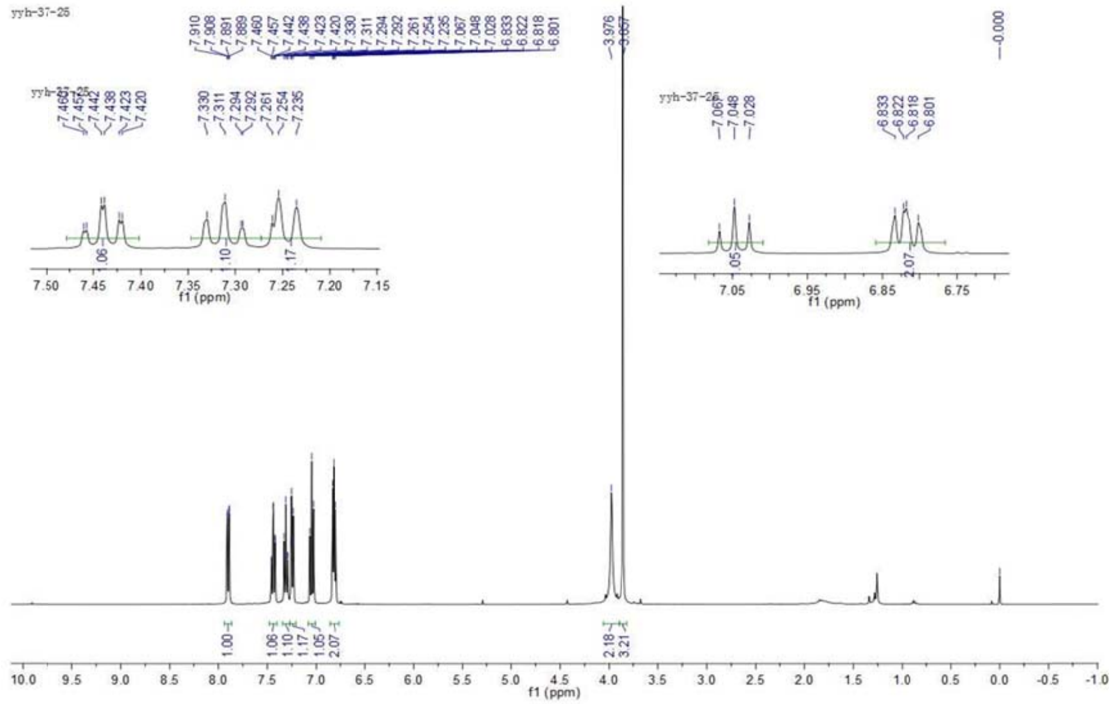
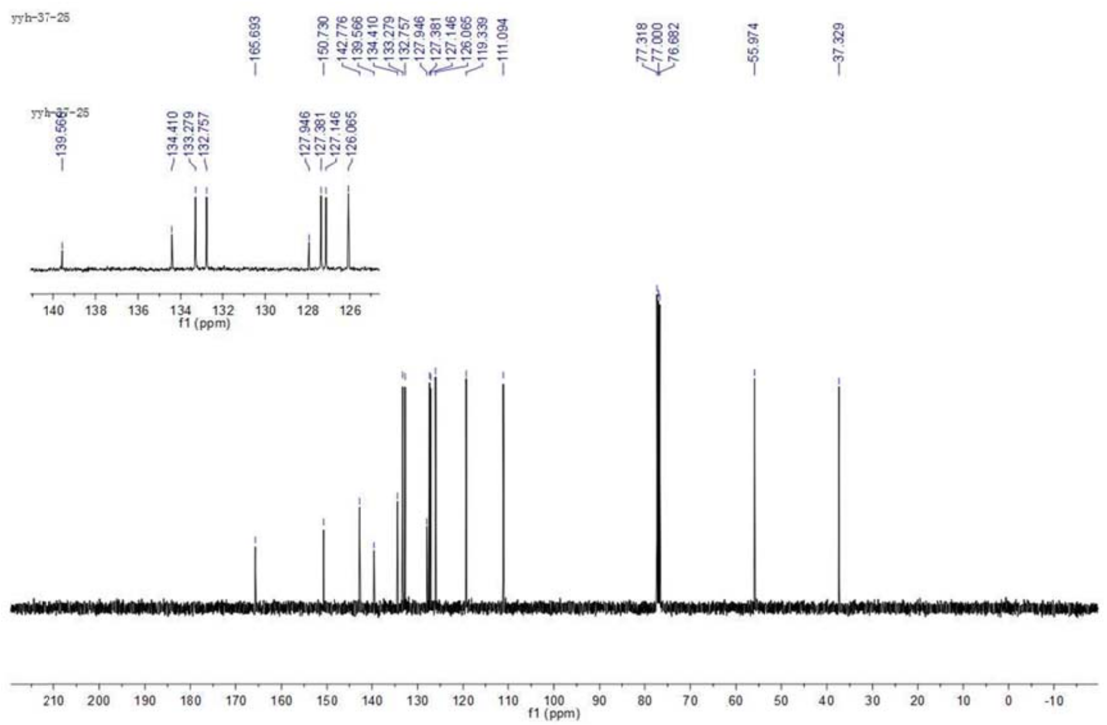
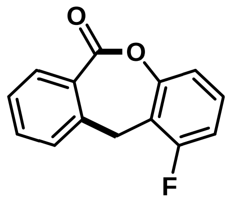
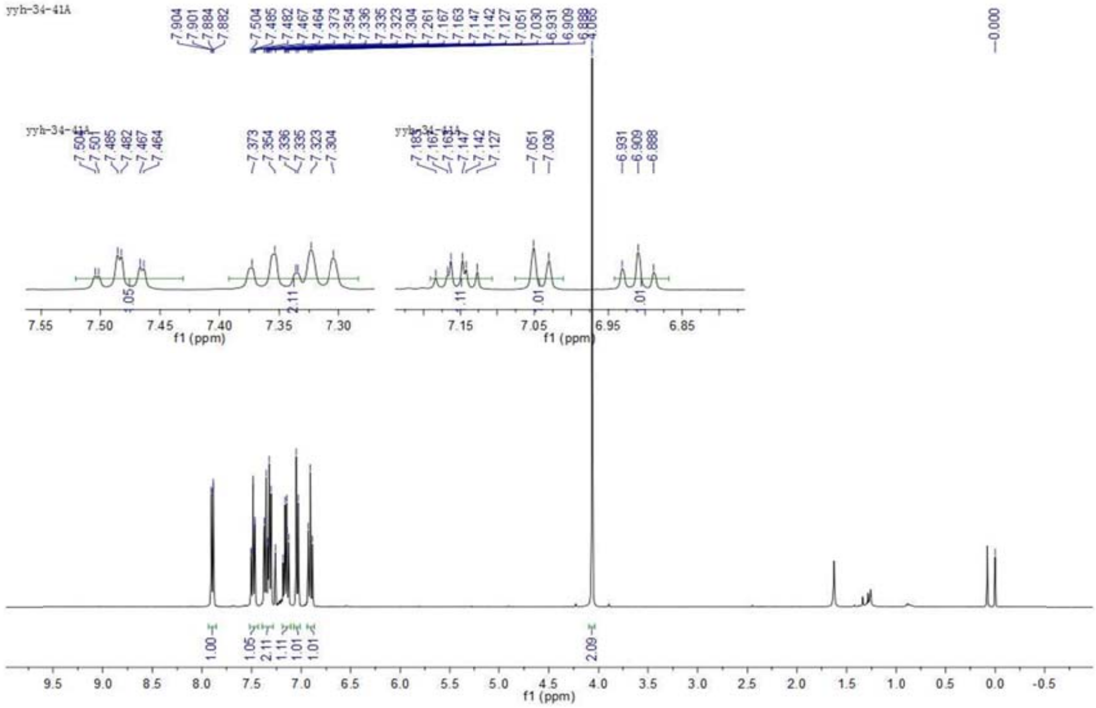


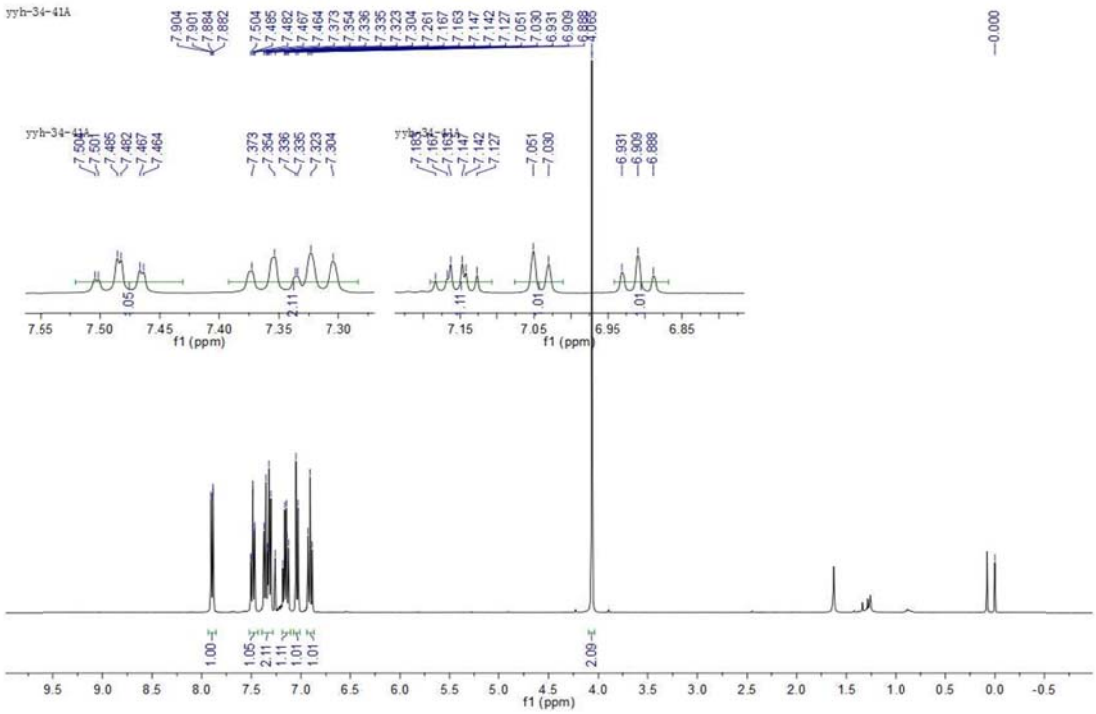


Supplementary Figure 40 ^{1}H NMR and ^{13}C NMR spectra for compound 25


O
O
F

26


yyh-34-41A
7.904
7.901
7.884
7.882
7.504
7.485
7.482
7.467
7.464
7.373
7.354
7.336
7.335
7.323
7.304
7.261
7.167
7.163
7.147
7.142
7.127
7.051
7.030
6.931
6.909
6.888
4.065
0.000
1.05
2.11
1.11
1.01
1.01
1.00
2.09
f1 (ppm)


yyh-34-41A
7.904
7.901
7.884
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7.464
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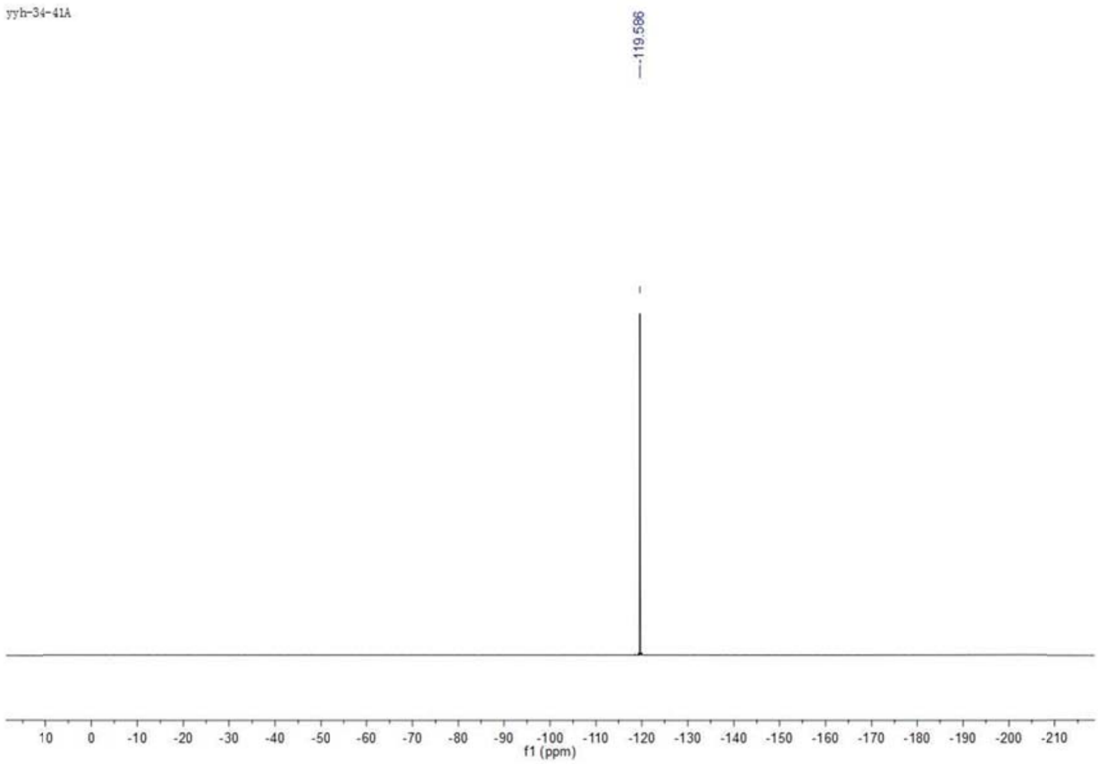
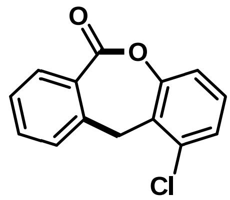
7.336
7.335
7.323
7.304
7.261
7.167
7.163
7.147
7.142
7.127
7.051
7.030
6.931
6.909
6.888
4.065
0.000
1.05
2.11
1.11
1.01
1.01
1.00
2.09
f1 (ppm)



Supplementary Figure 41 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 26



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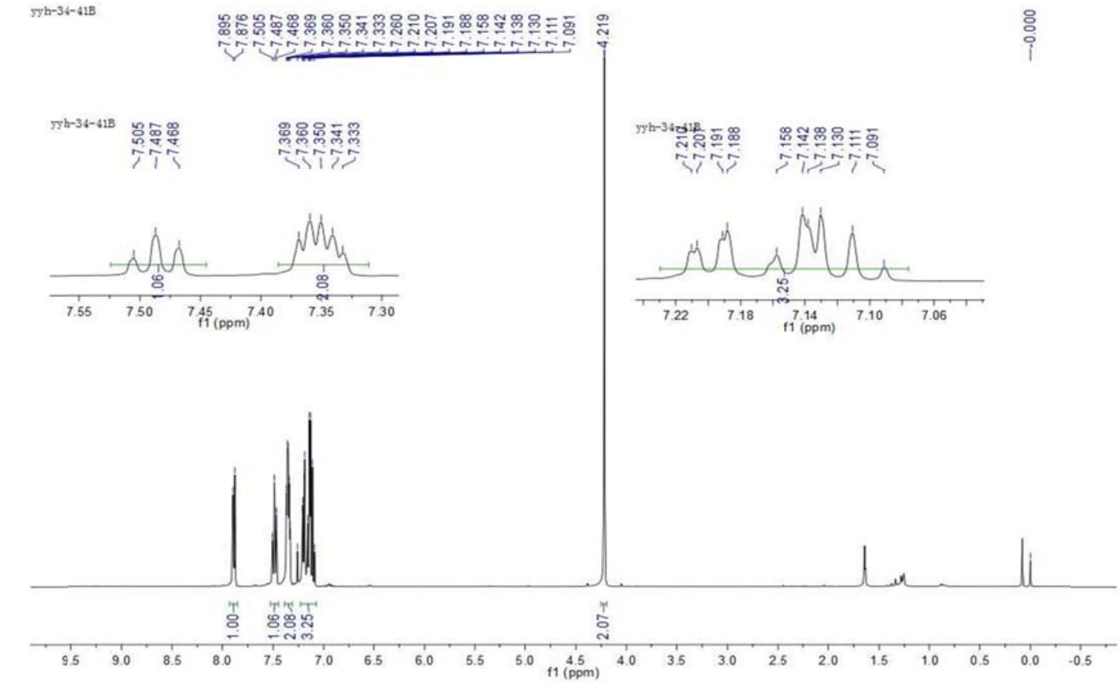
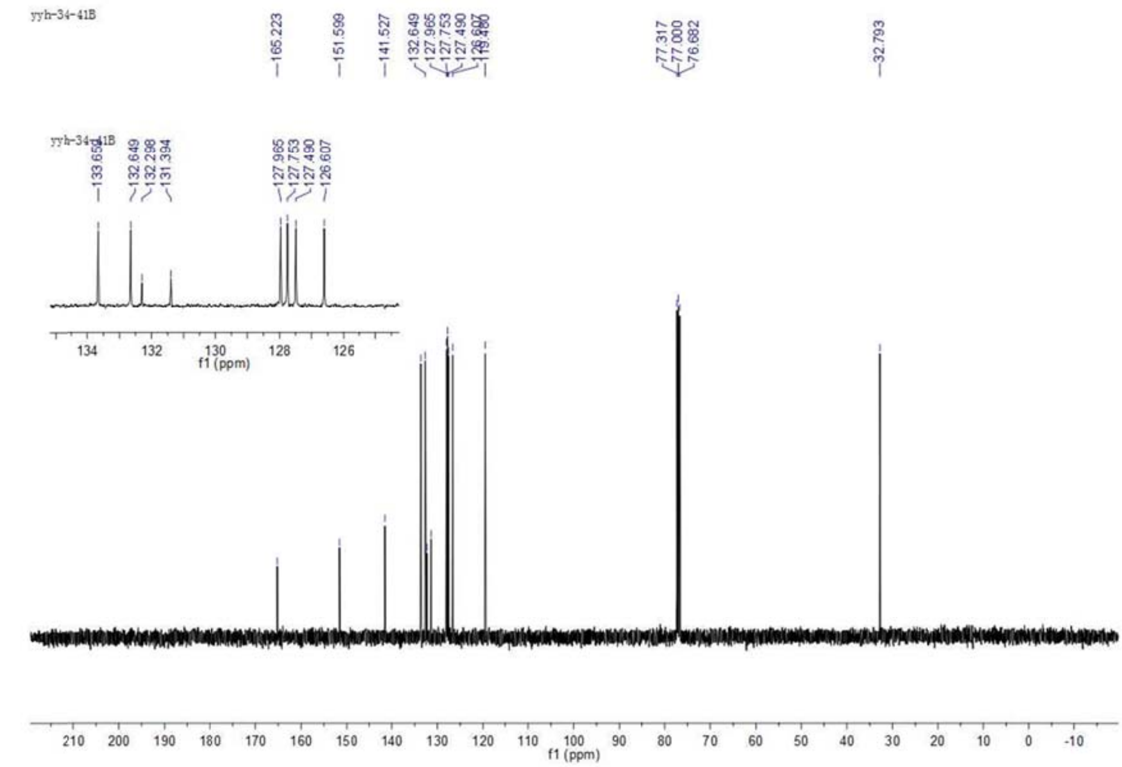
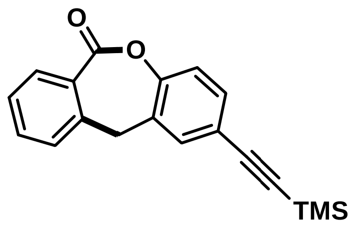




Supplementary Figure 42 ^{1}H NMR and ^{13}C NMR spectra for compound 27



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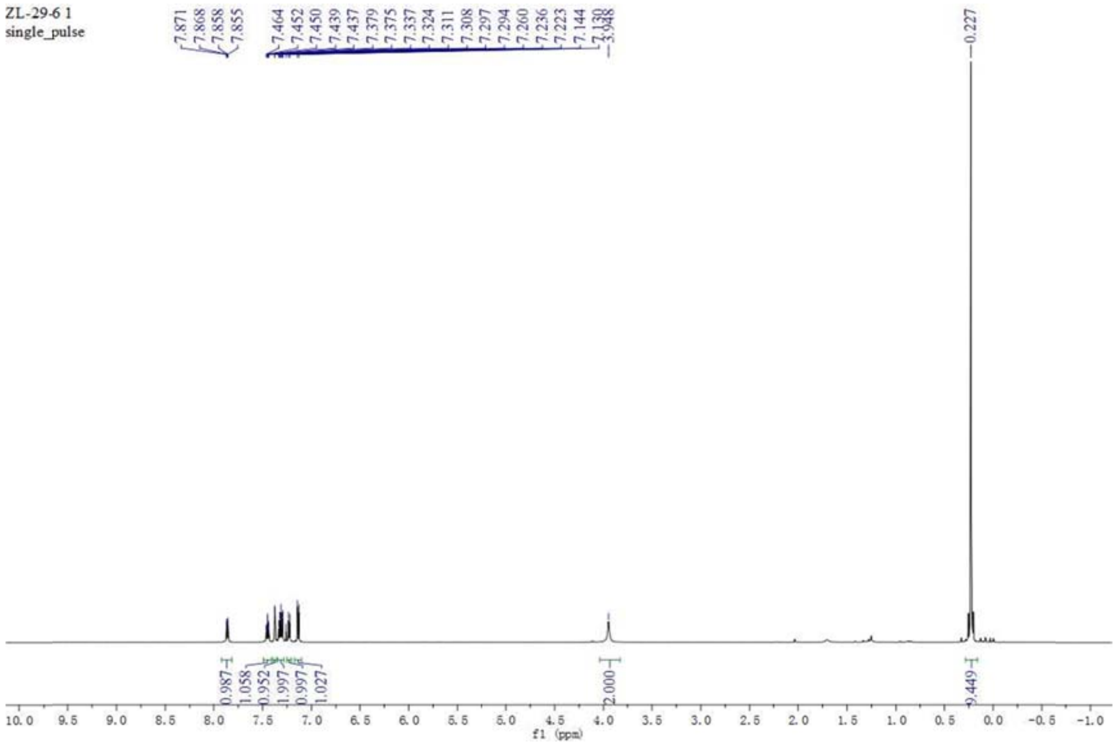
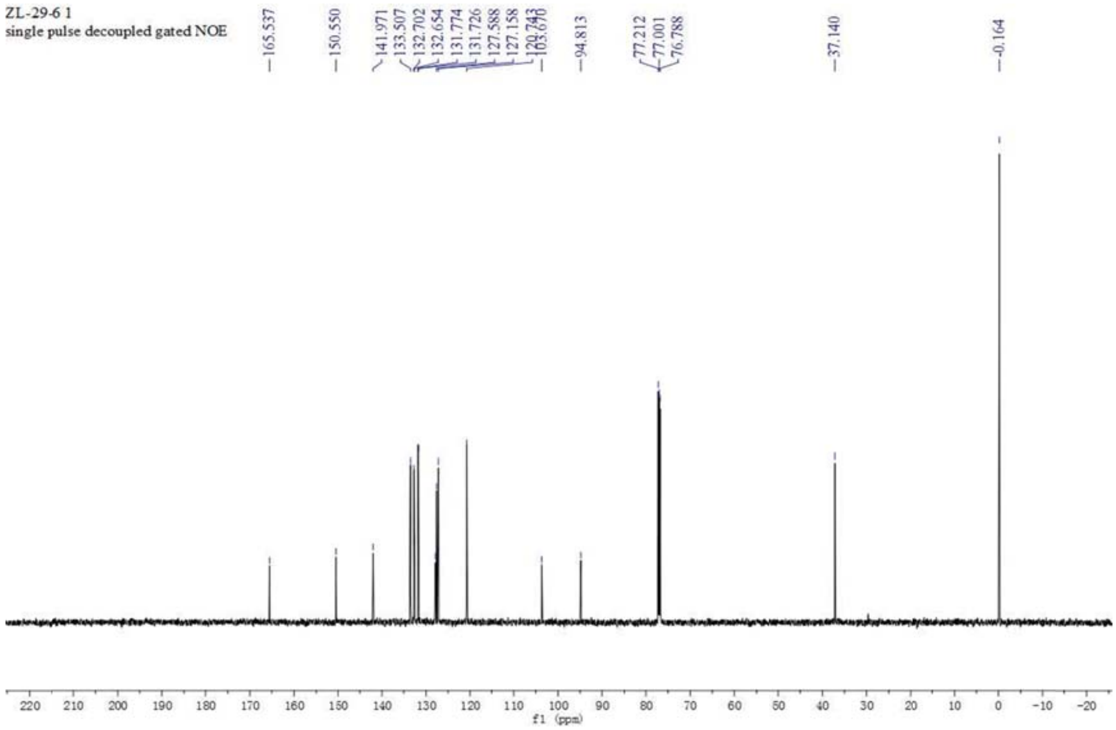
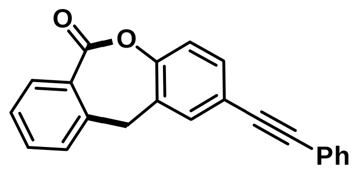




Supplementary Figure 43 ^{1}H NMR and ^{13}C NMR spectra for compound 28



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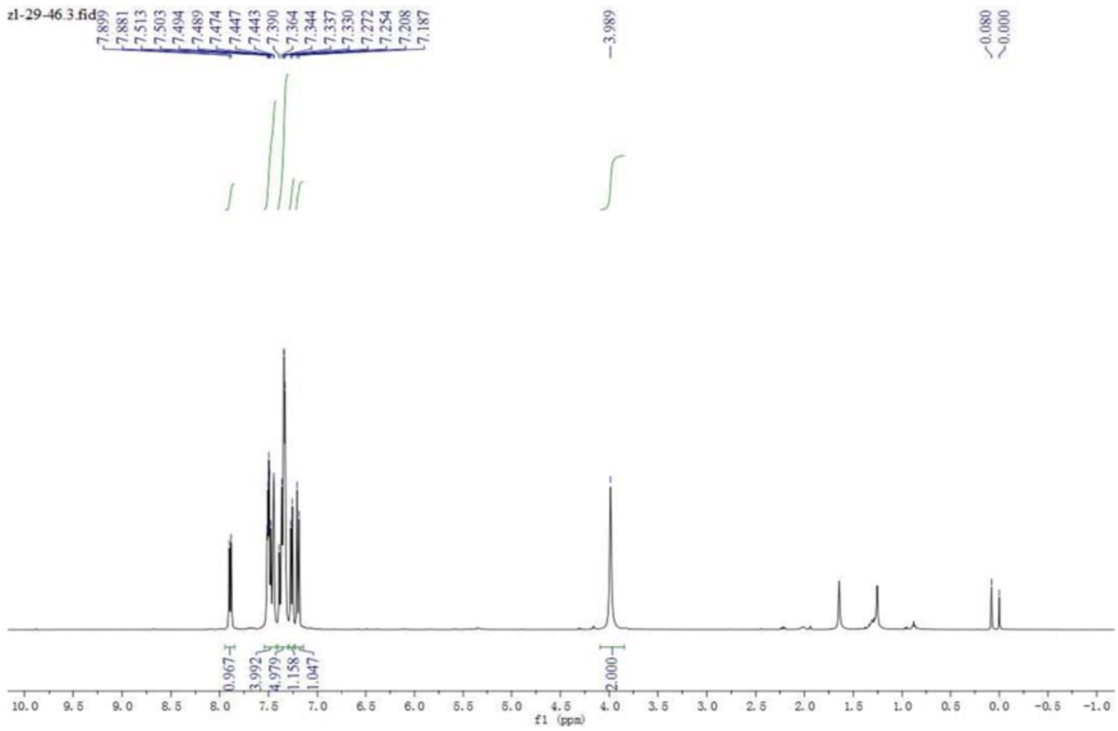
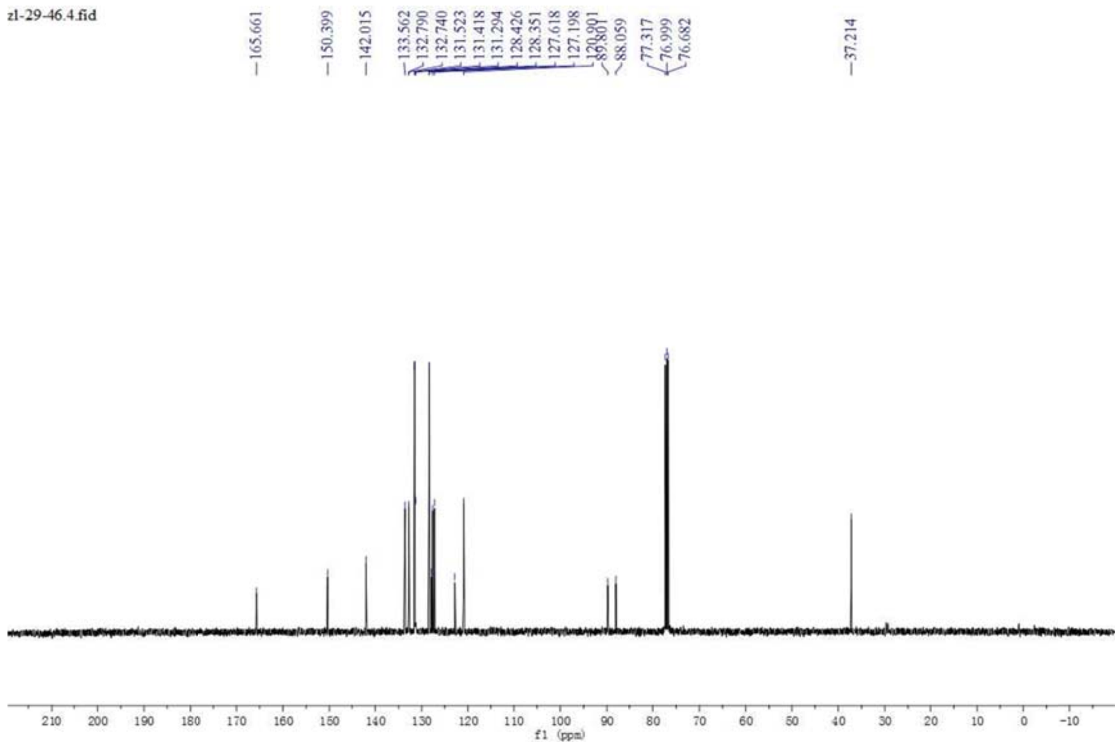
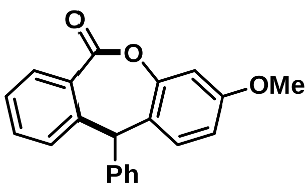




Supplementary Figure 44 ^{1}H NMR and ^{13}C NMR spectra for compound 29



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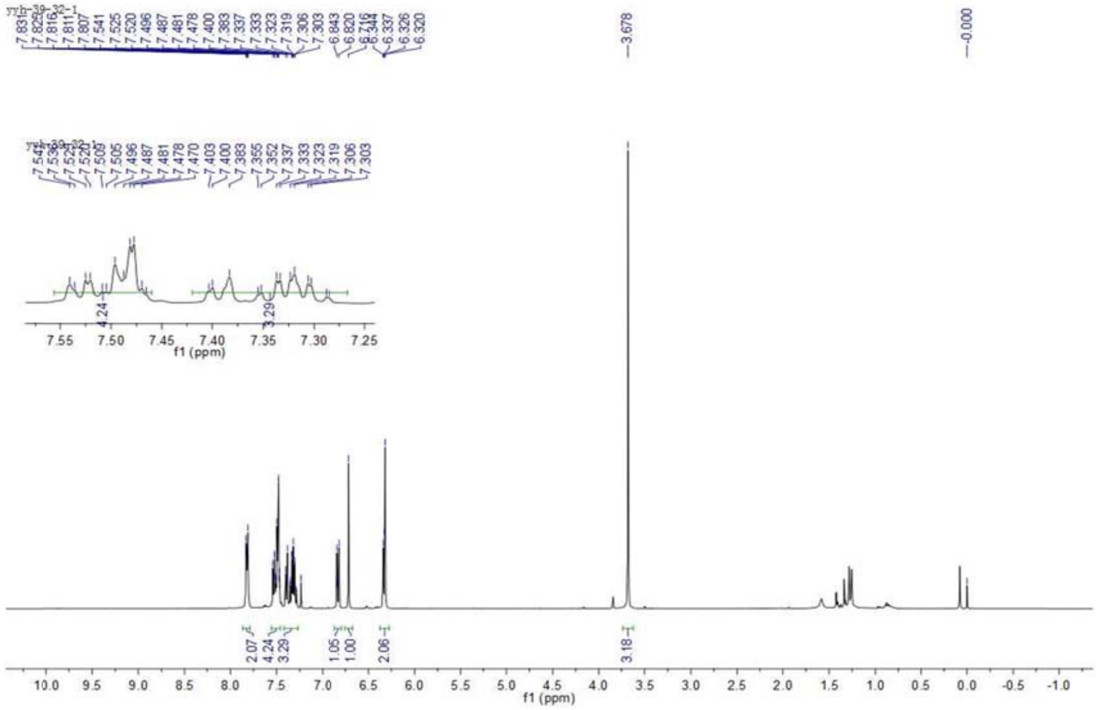
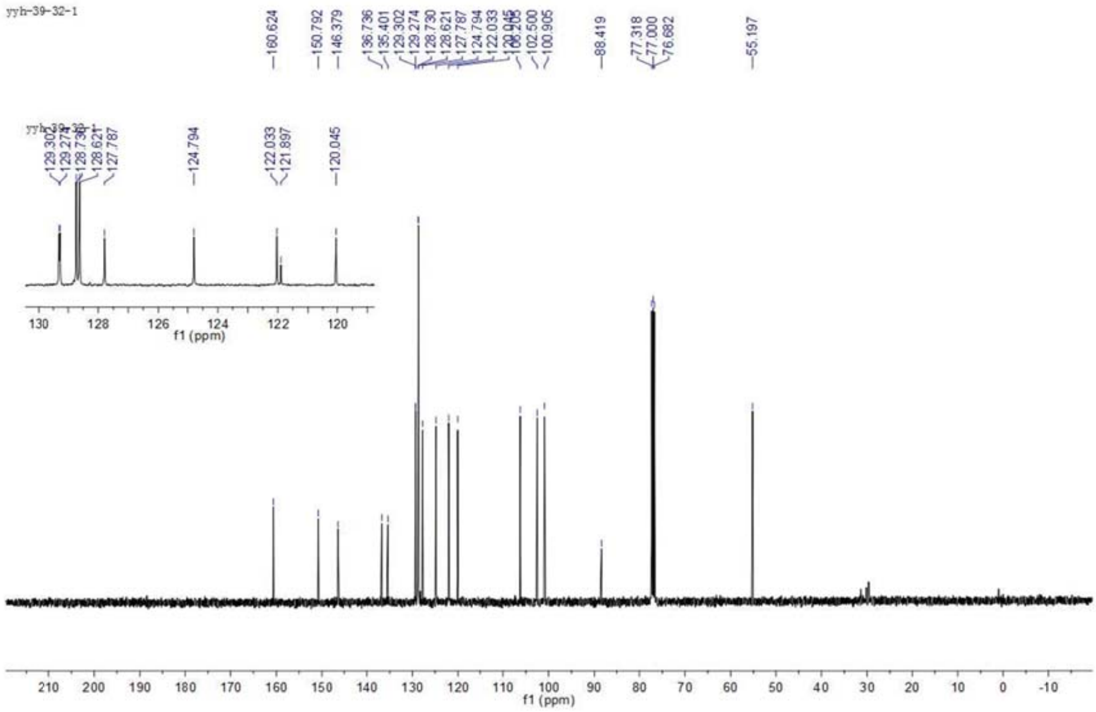
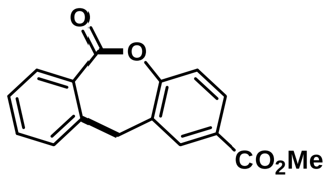




Supplementary Figure 45 ^{1}H NMR and ^{13}C NMR spectra for compound 30



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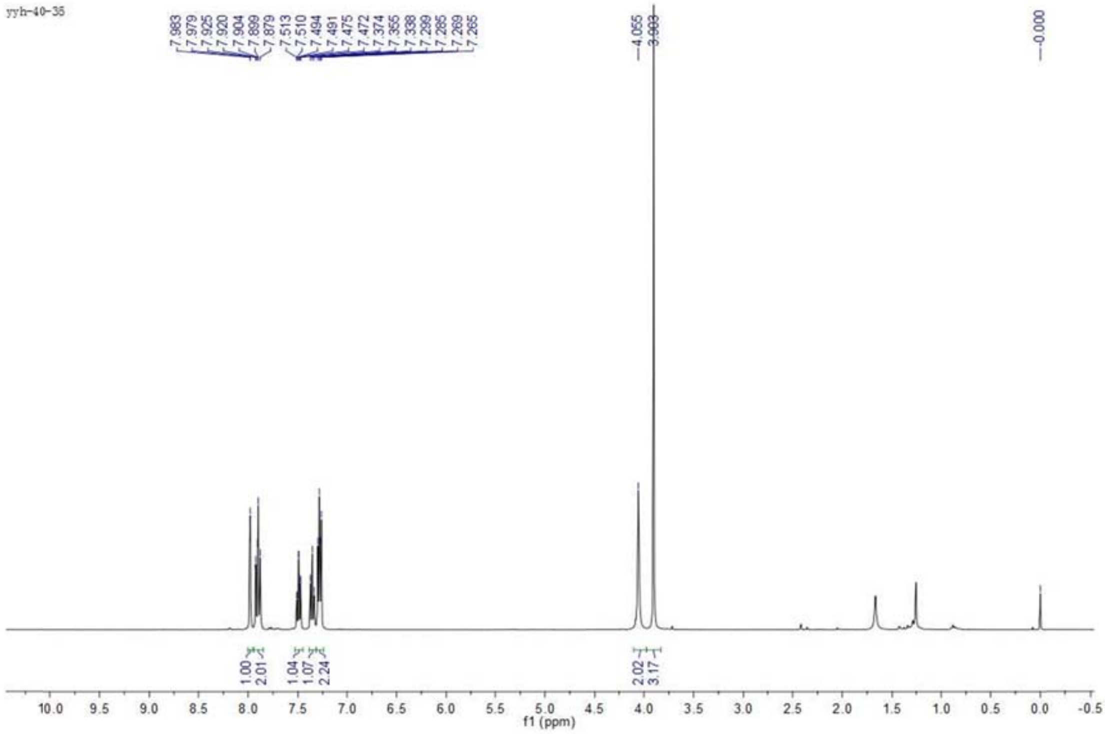
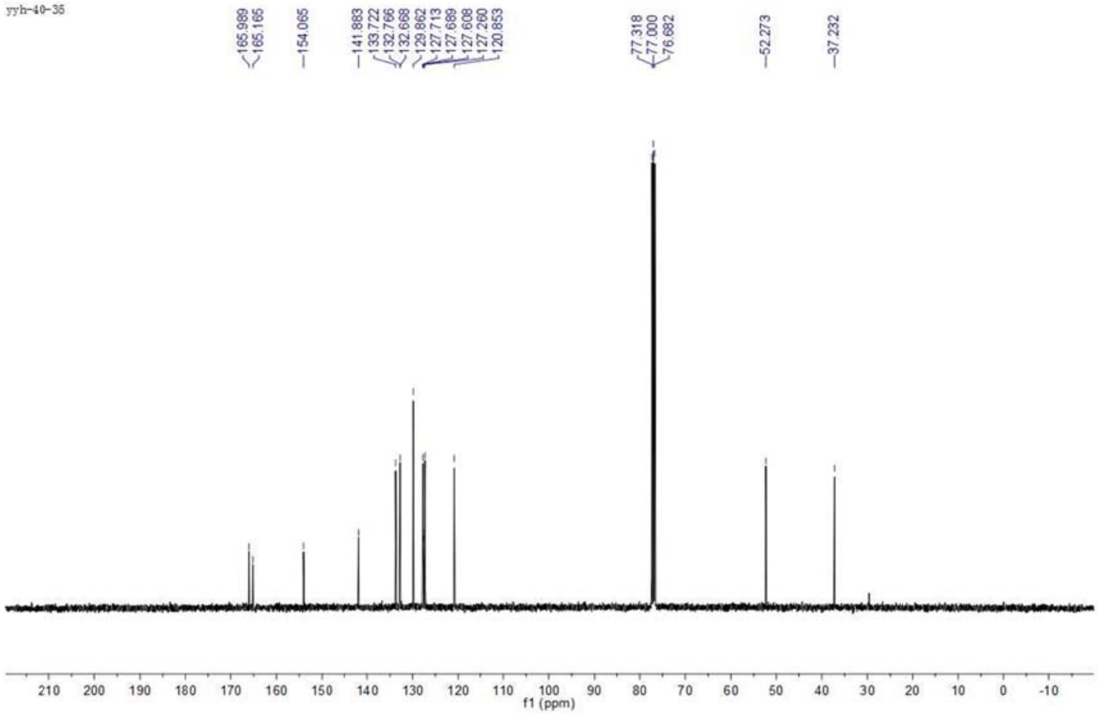
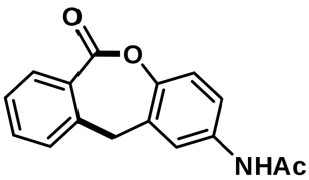




Supplementary Figure 46 ^{1}H NMR and ^{13}C NMR spectra for compound 31



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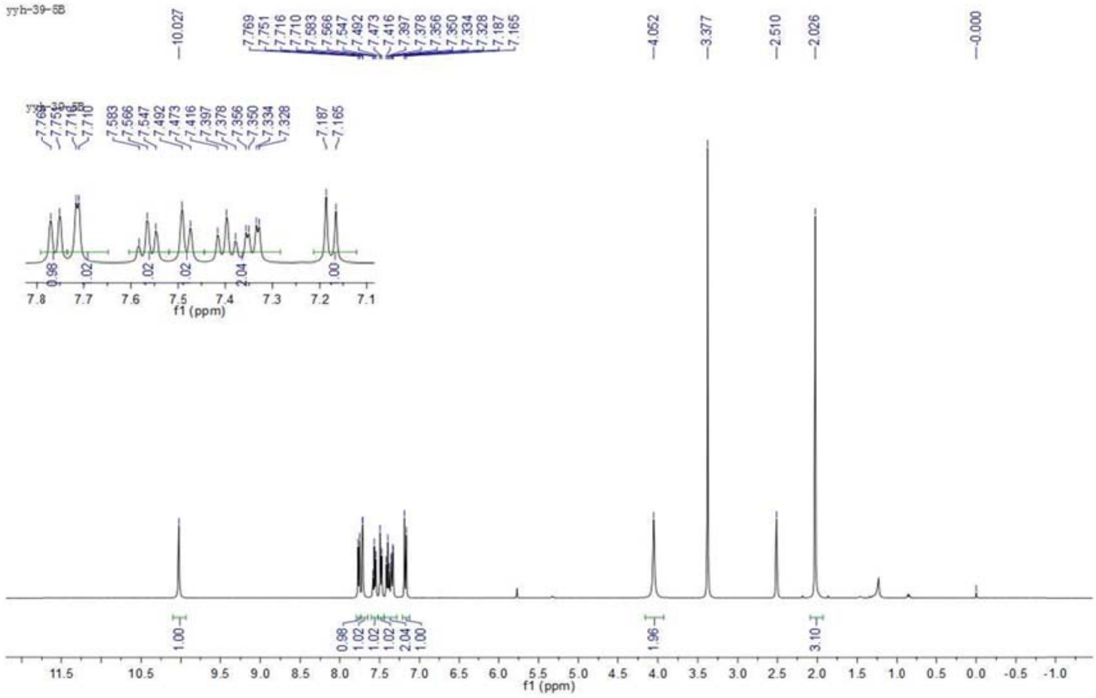
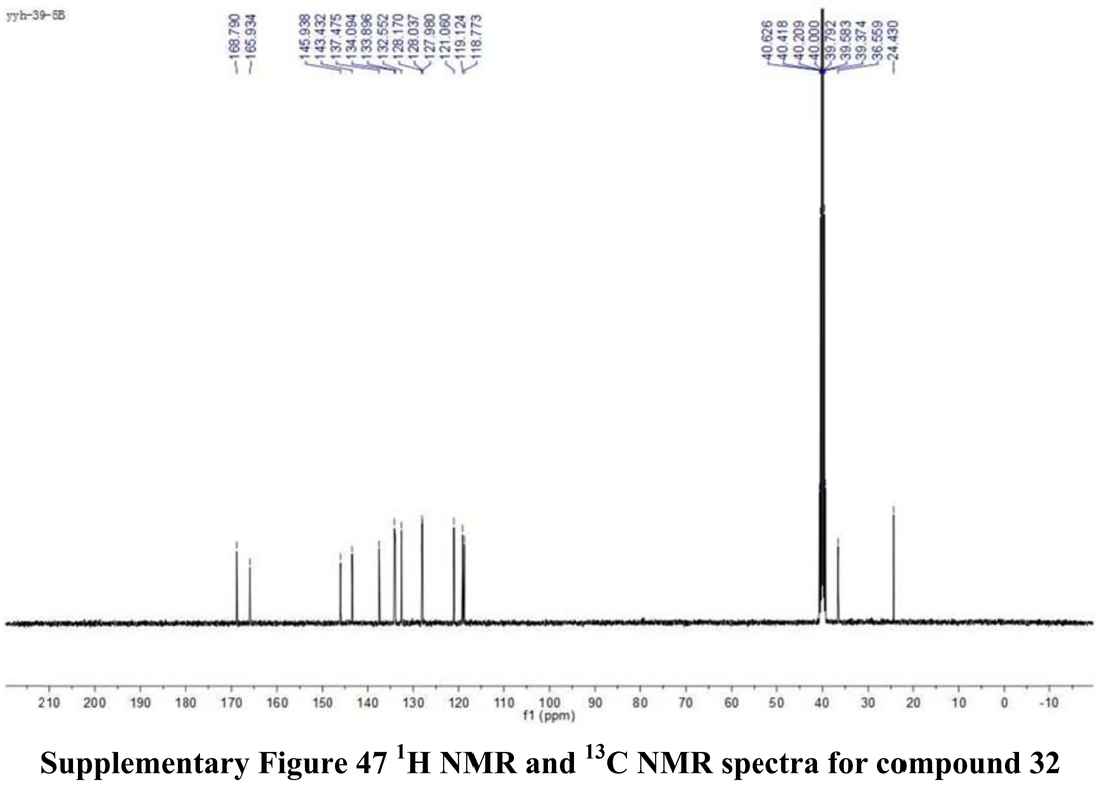
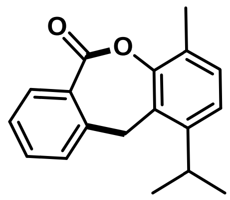




Supplementary Figure 47 ^{1}H NMR and ^{13}C NMR spectra for compound 32



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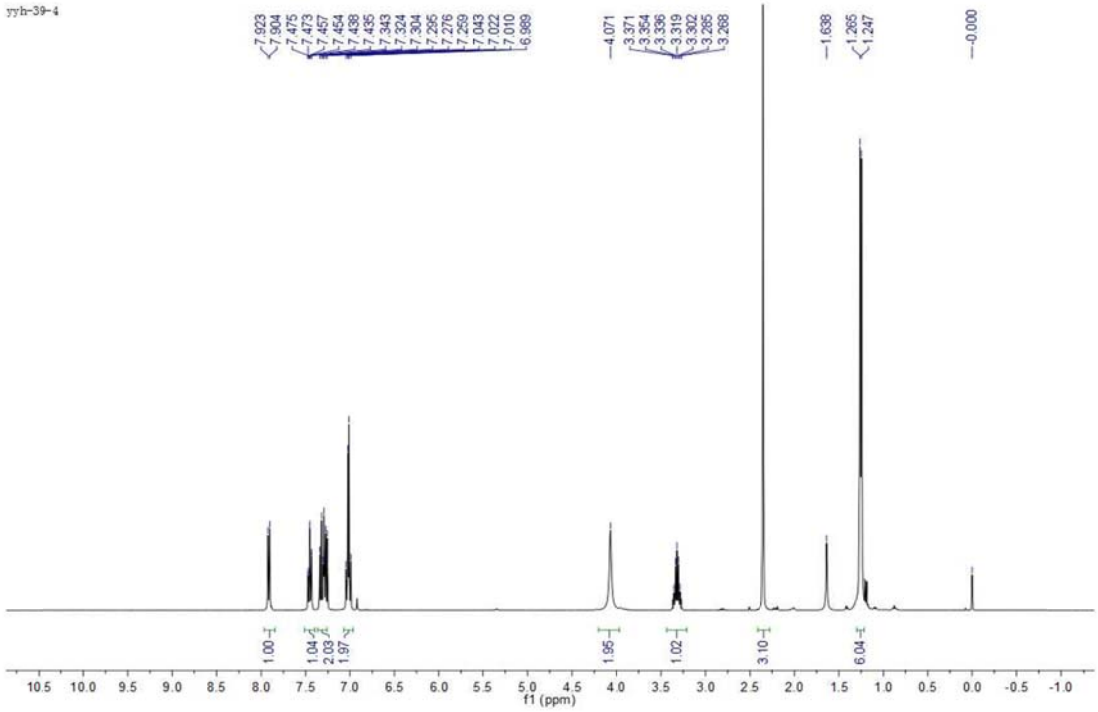
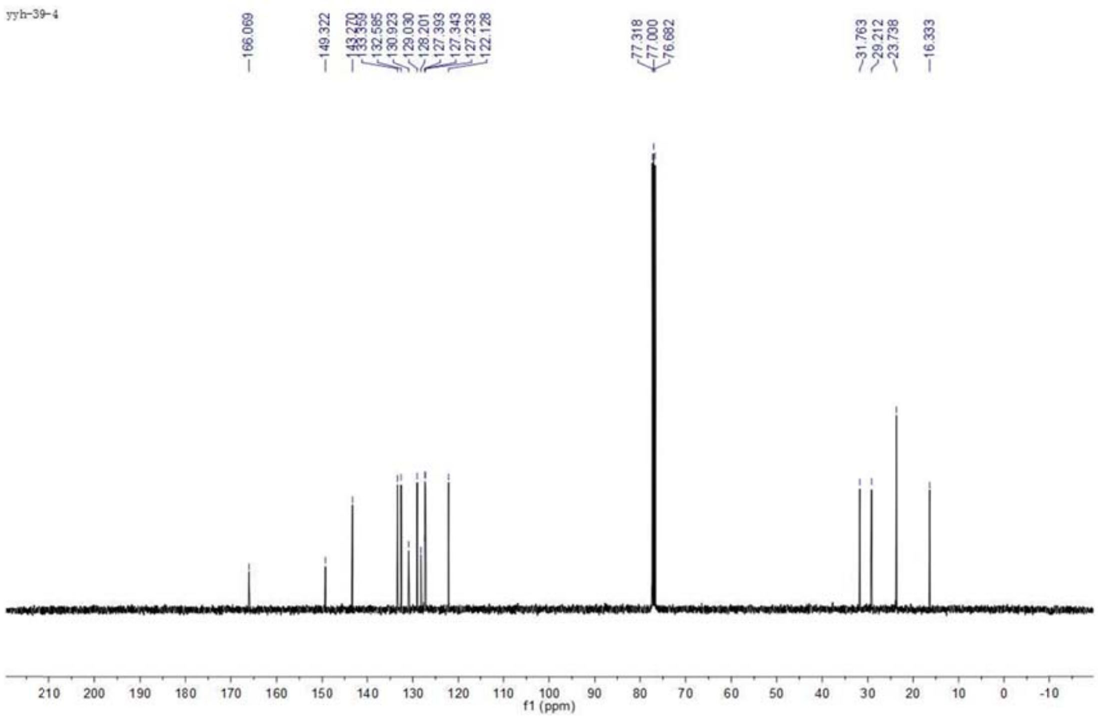
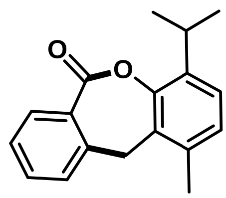




Supplementary Figure 48 ^{1}H NMR and ^{13}C NMR spectra for compound 33



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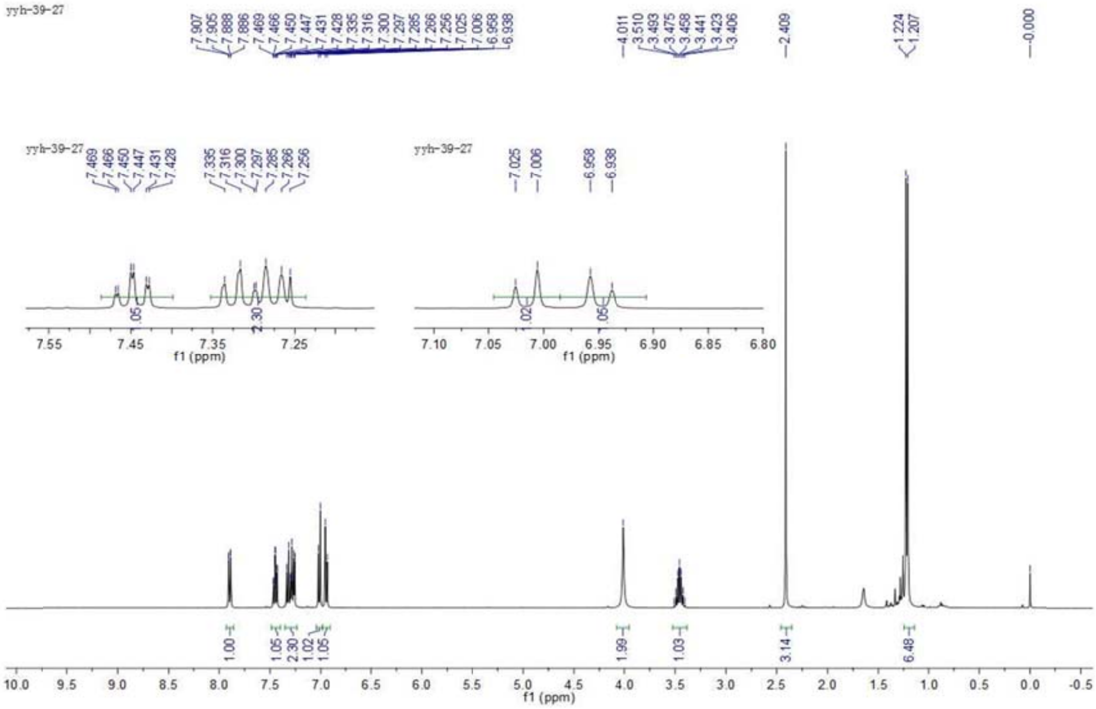
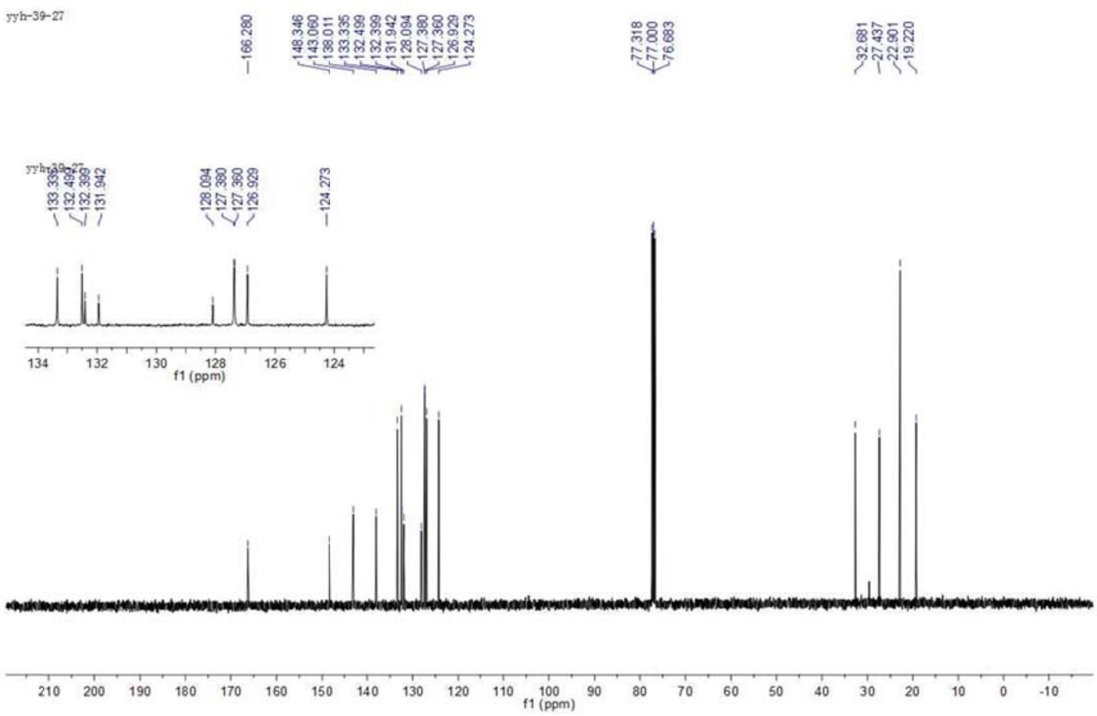
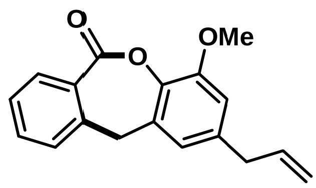




Supplementary Figure 49 ^{1}H NMR and ^{13}C NMR spectra for compound 34



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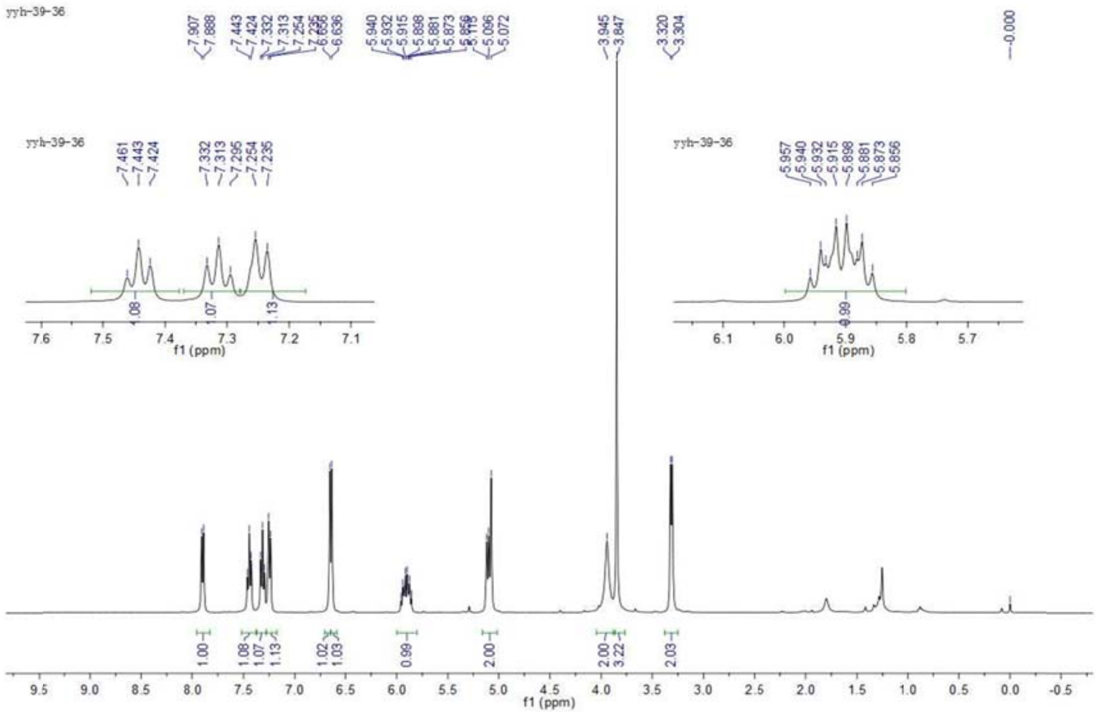
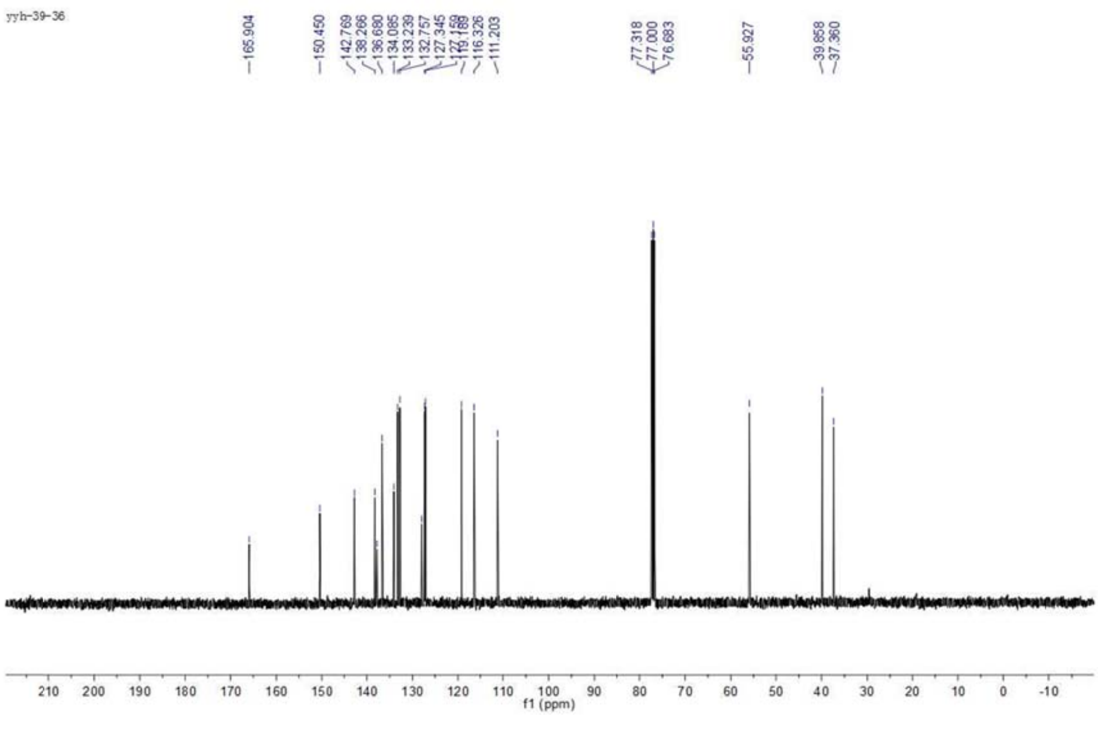
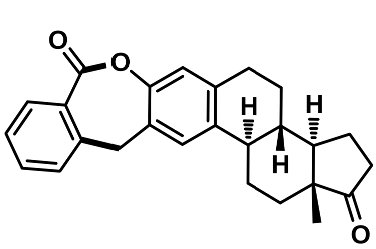




Supplementary Figure 50 ^{1}H NMR and ^{13}C NMR spectra for compound 35



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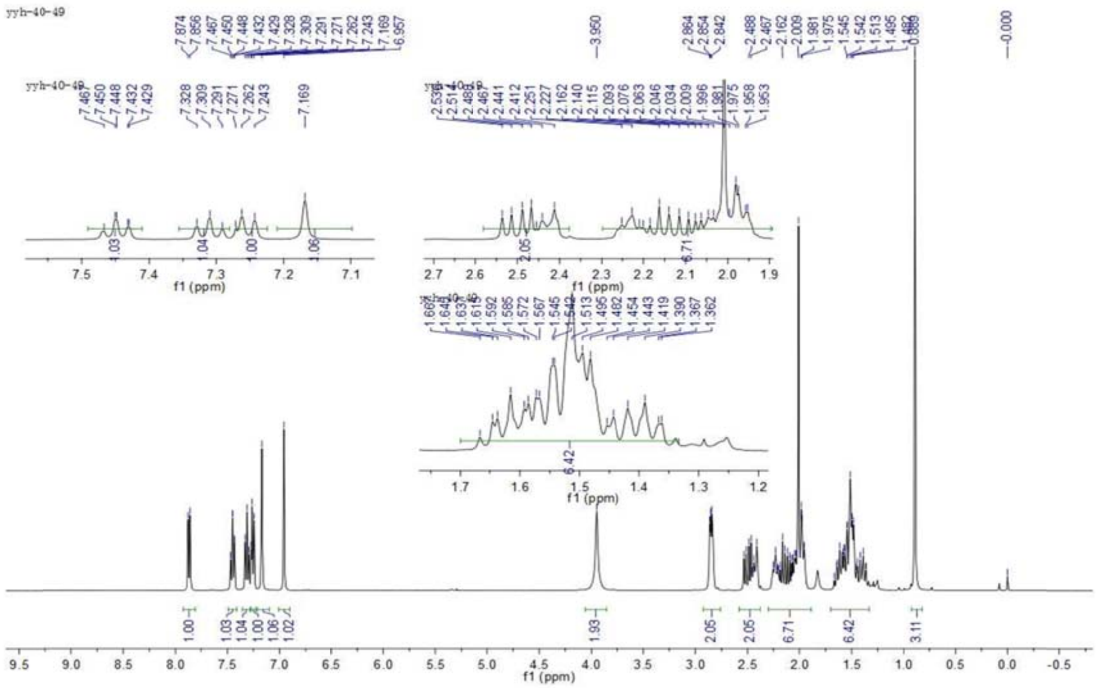
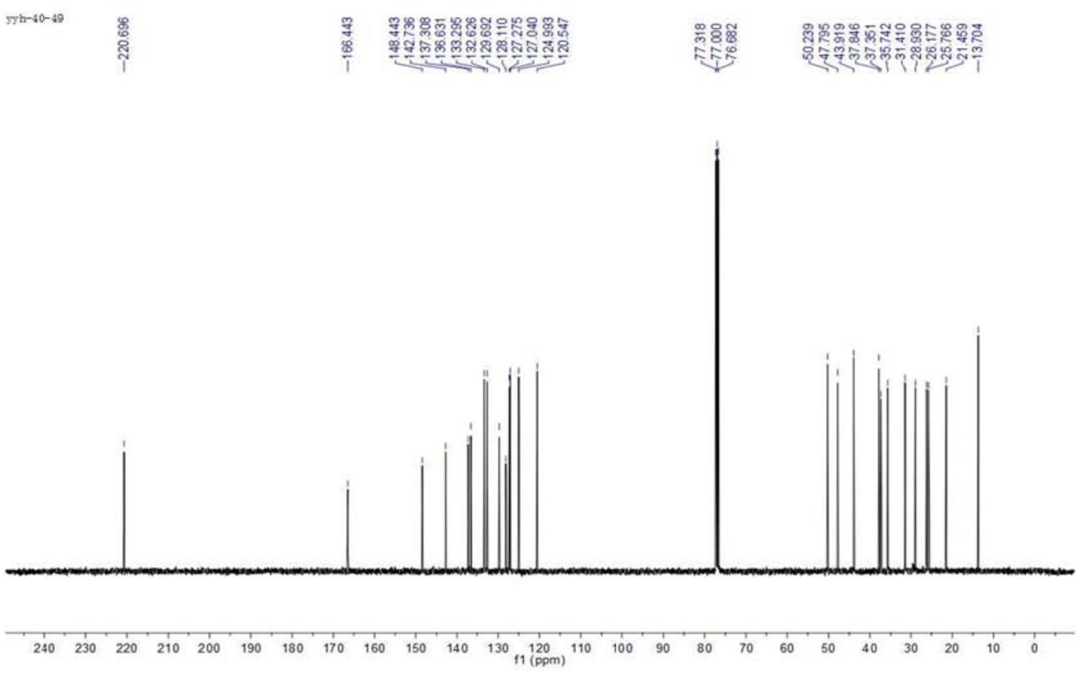
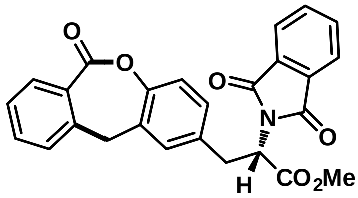




Supplementary Figure 51 ^{1}H NMR and ^{13}C NMR spectra for compound 36



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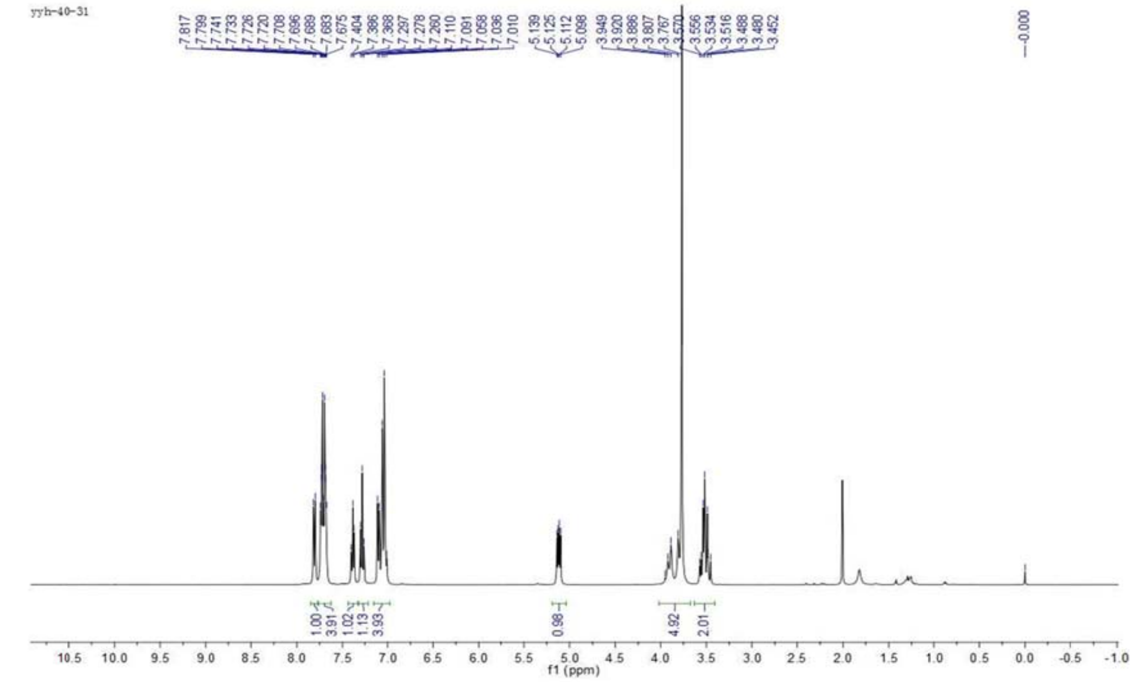
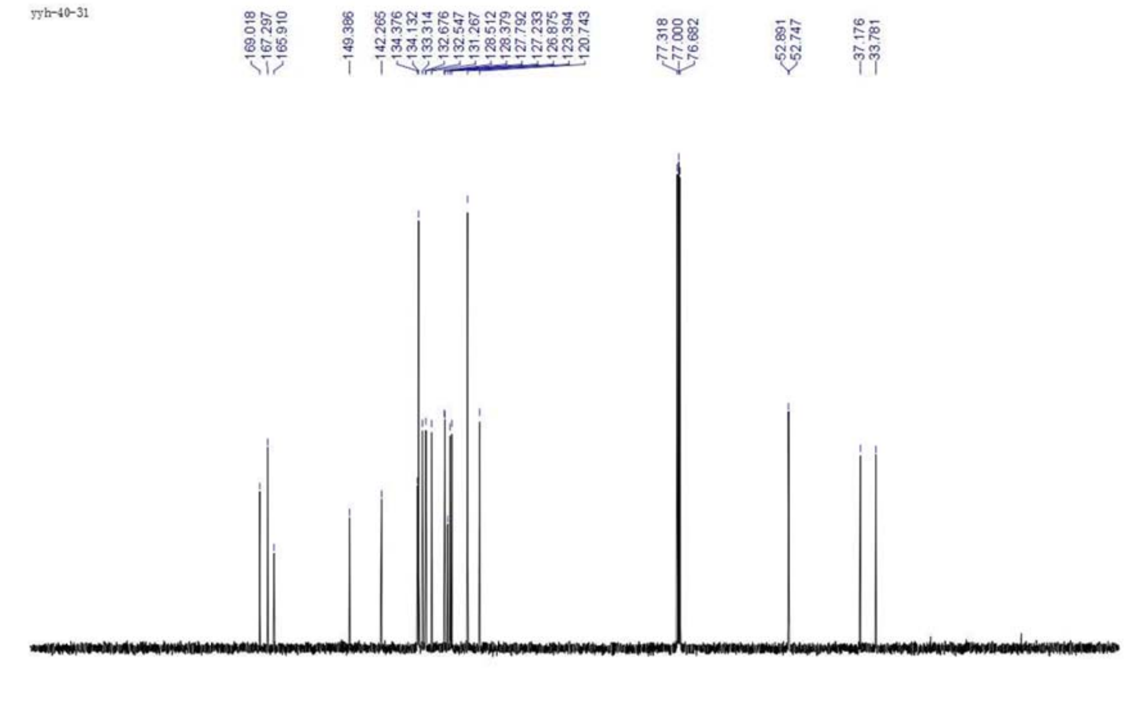
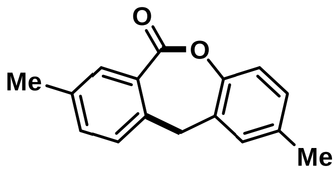




Supplementary Figure 52 ^{1}H NMR and ^{13}C NMR spectra for compound 37



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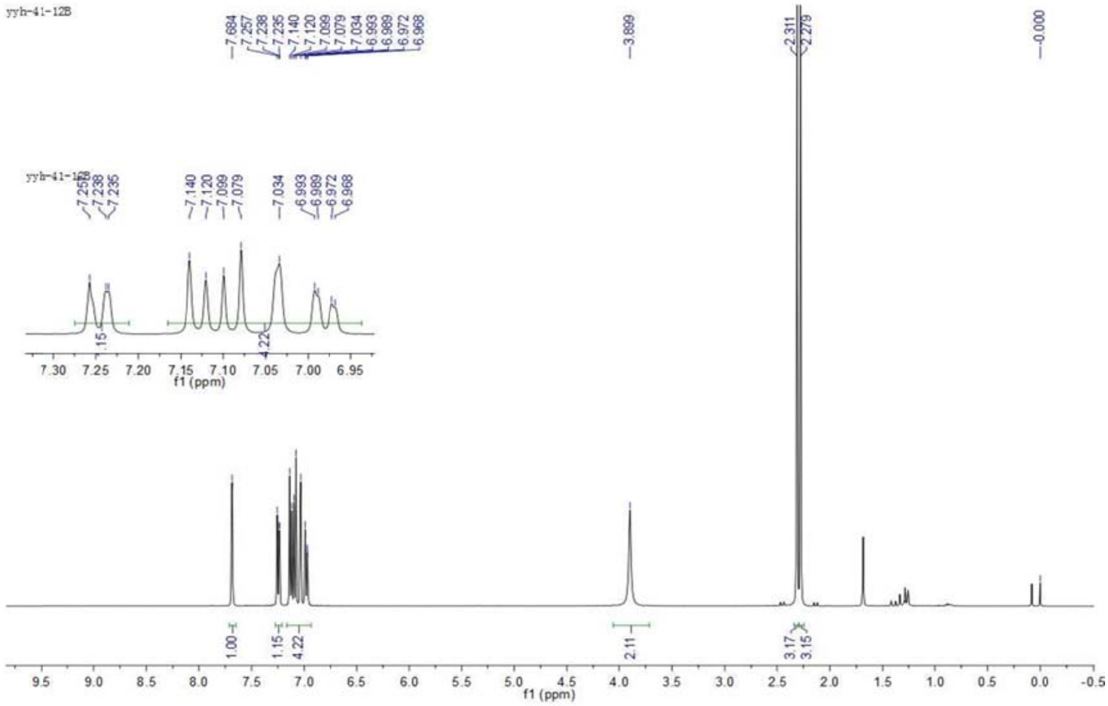
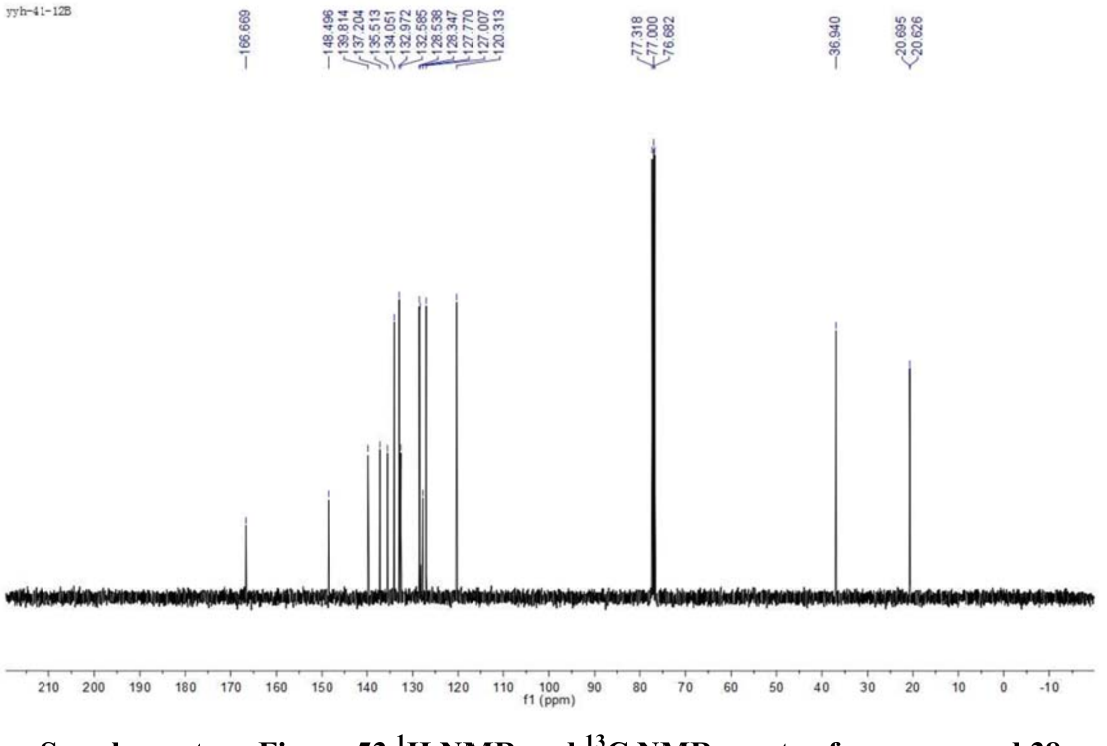
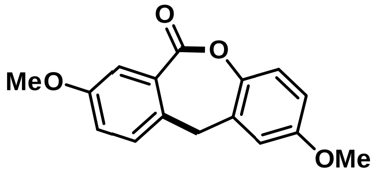




Supplementary Figure 53 ^{1}H NMR and ^{13}C NMR spectra for compound 38



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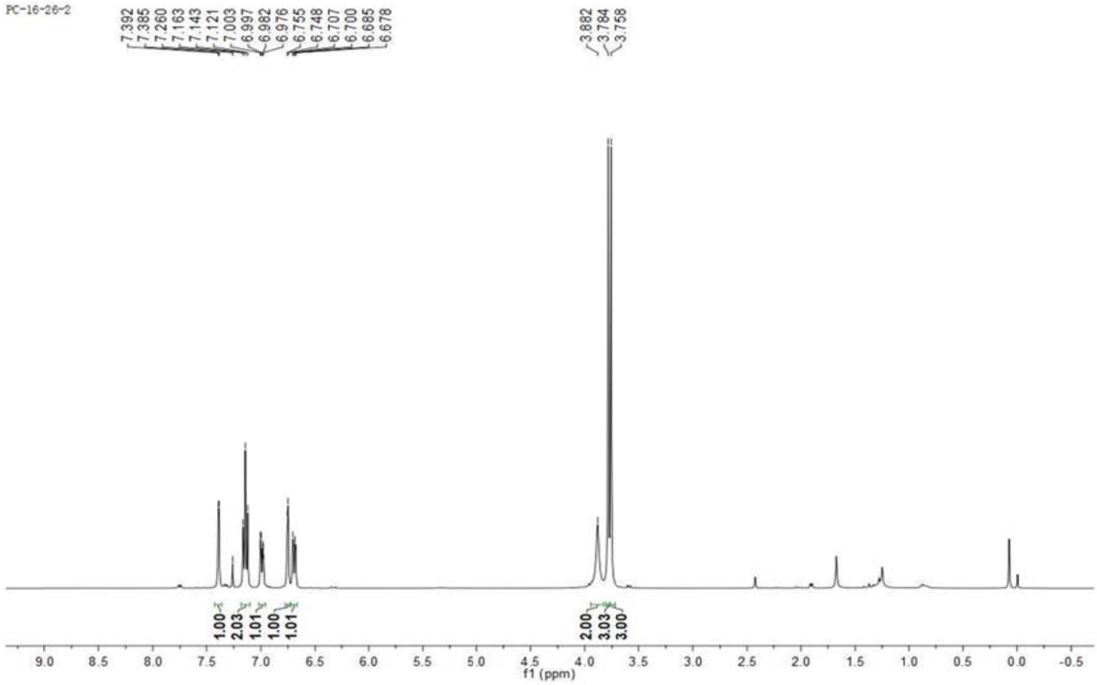
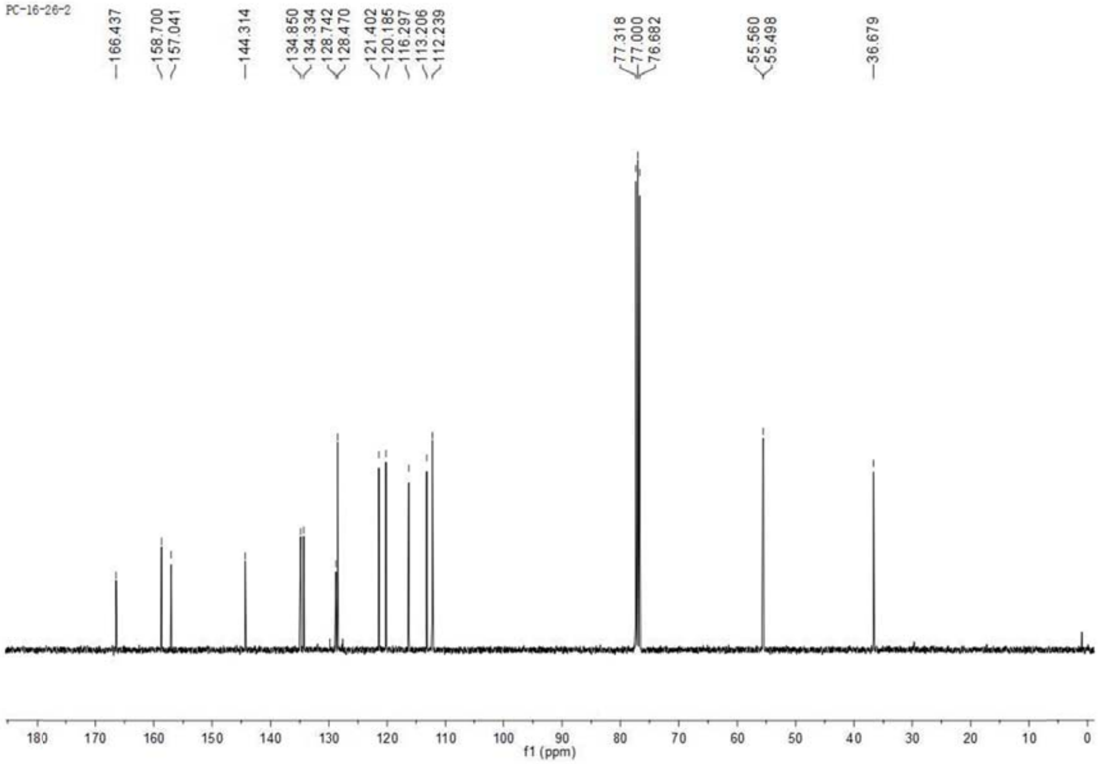
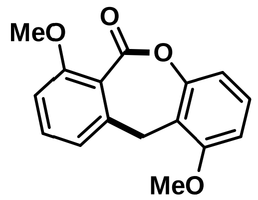




Supplementary Figure 54 ^{1}H NMR and ^{13}C NMR spectra for compound 39



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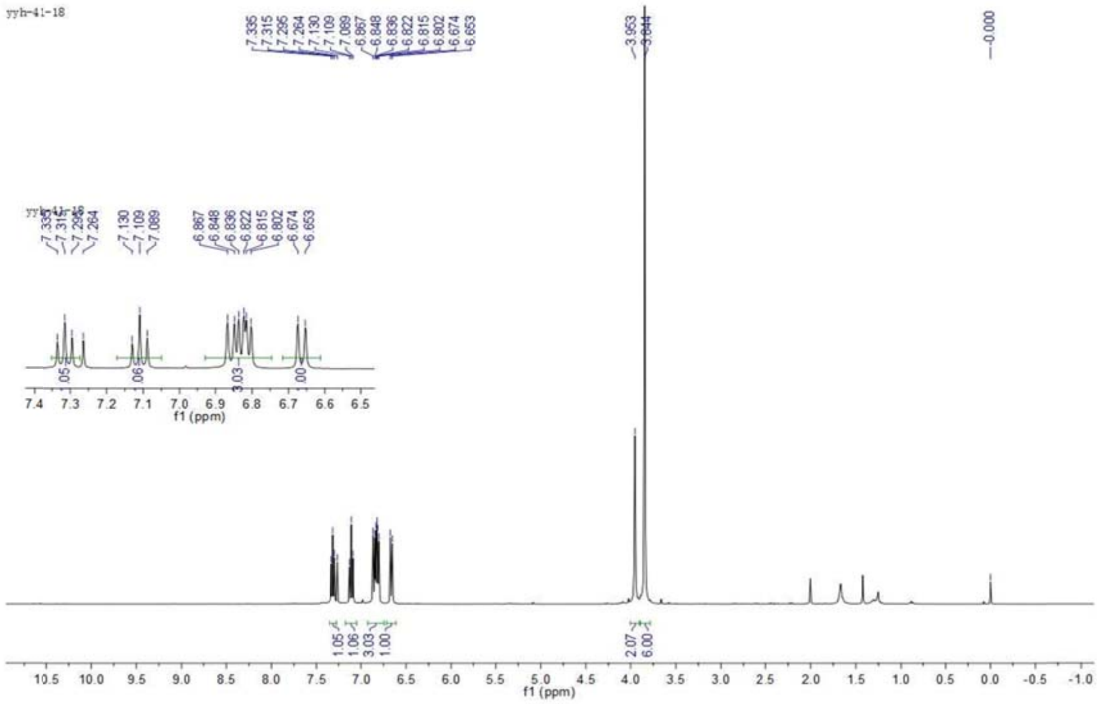
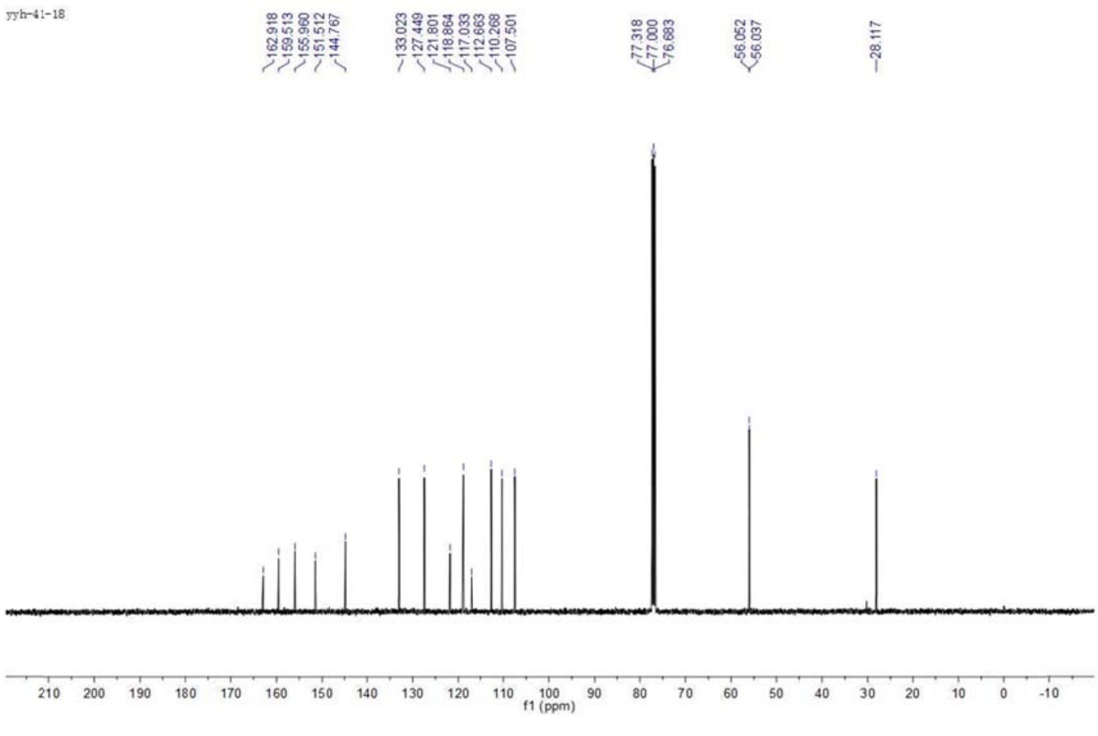
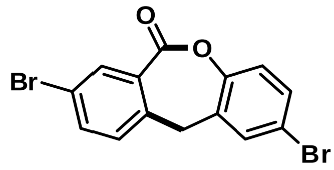




Supplementary Figure 55 ^{1}H NMR and ^{13}C NMR spectra for compound 40



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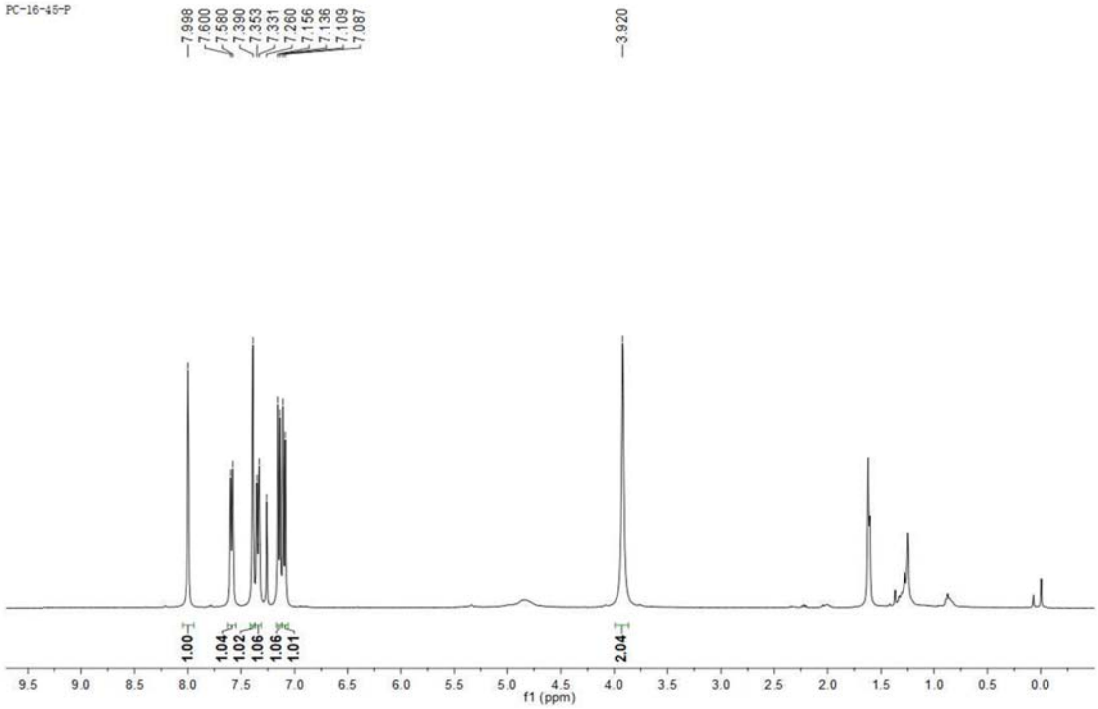
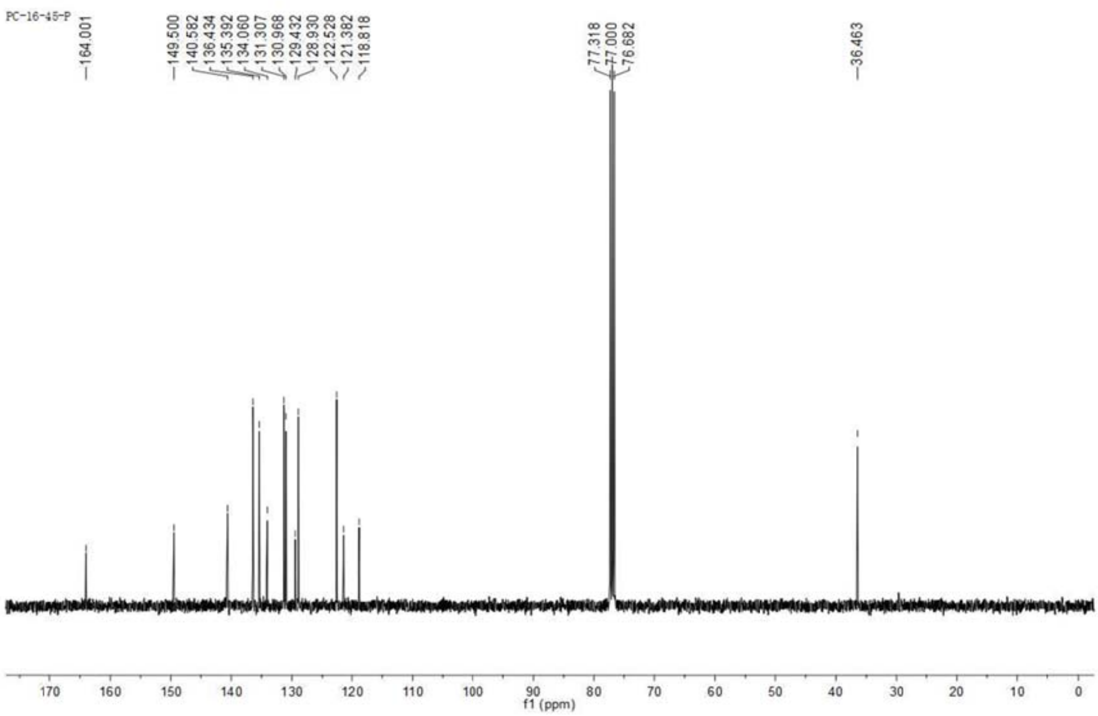
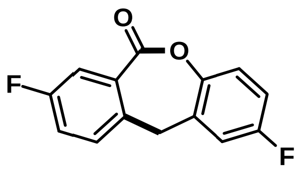
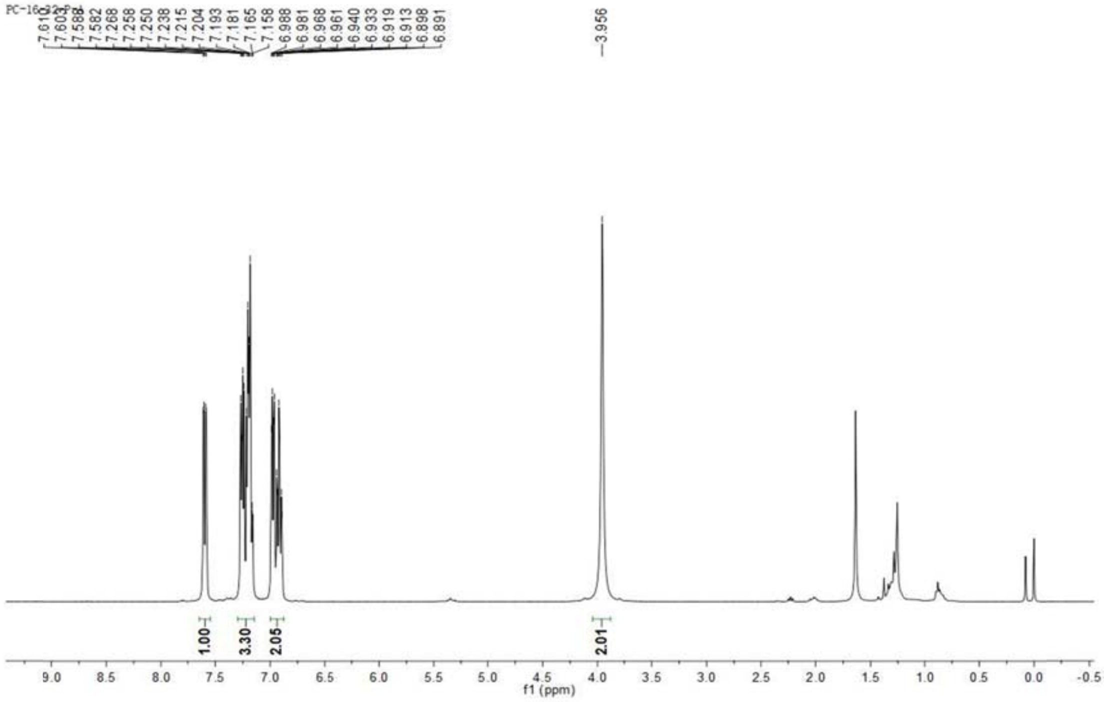


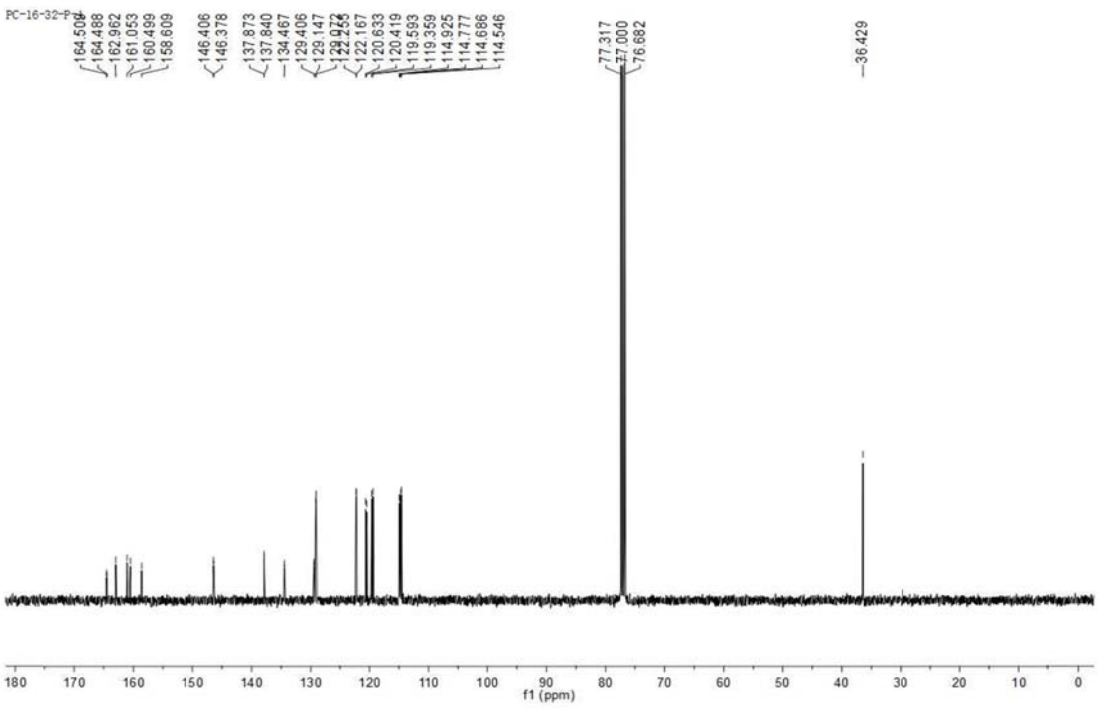


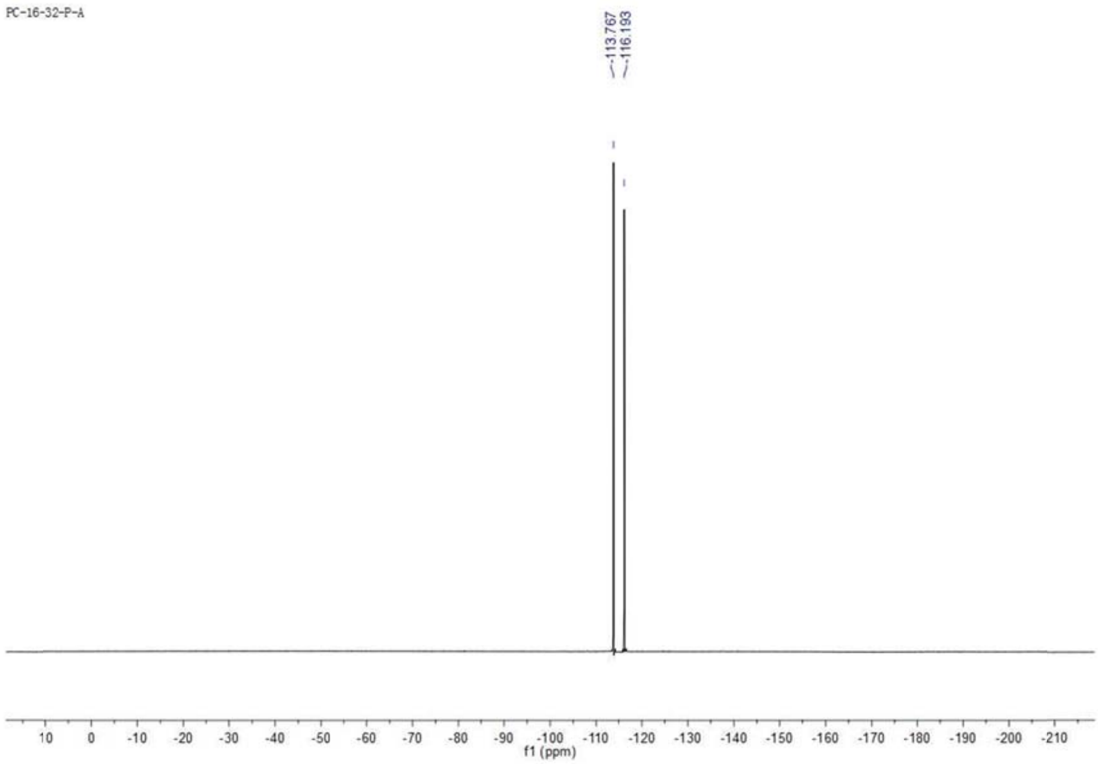
Supplementary Figure 56 ^{1}H NMR and ^{13}C NMR spectra for compound 41



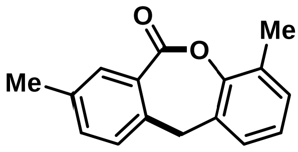
42



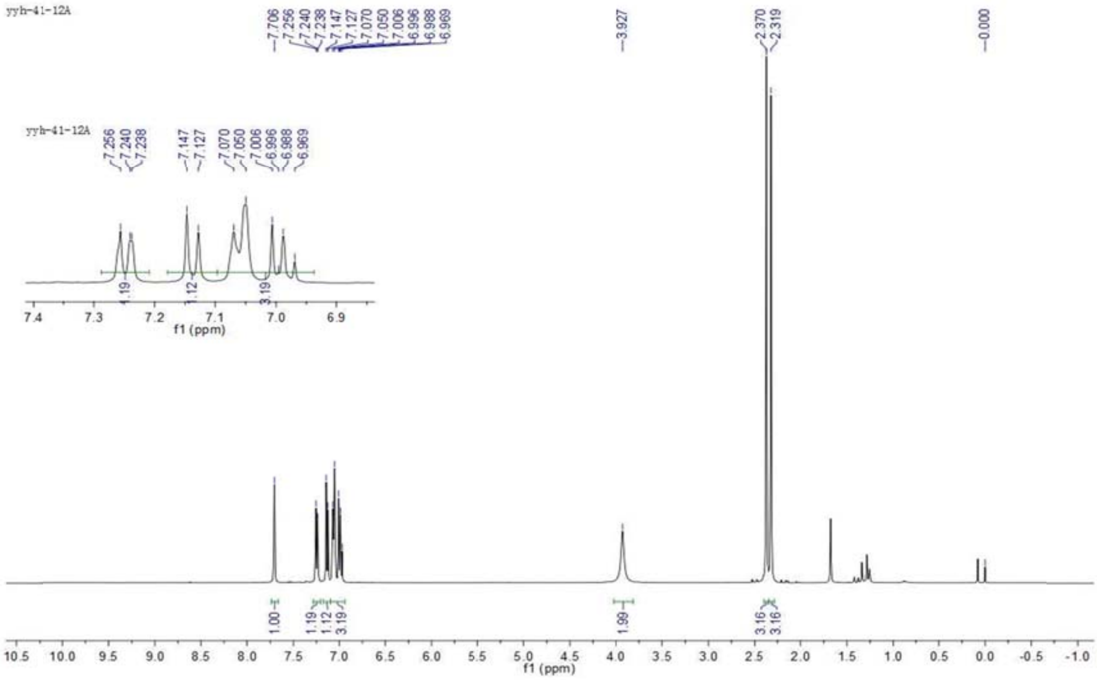


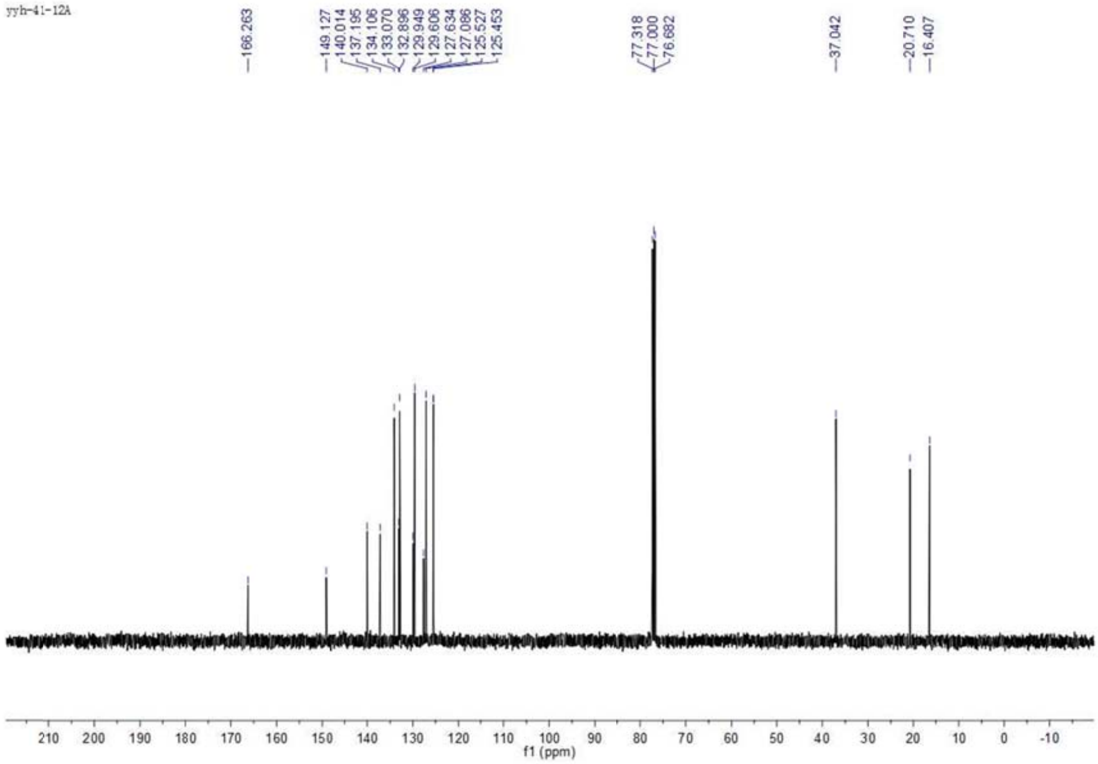


Supplementary Figure 57 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 42

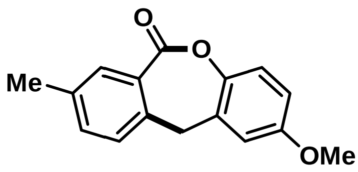


43

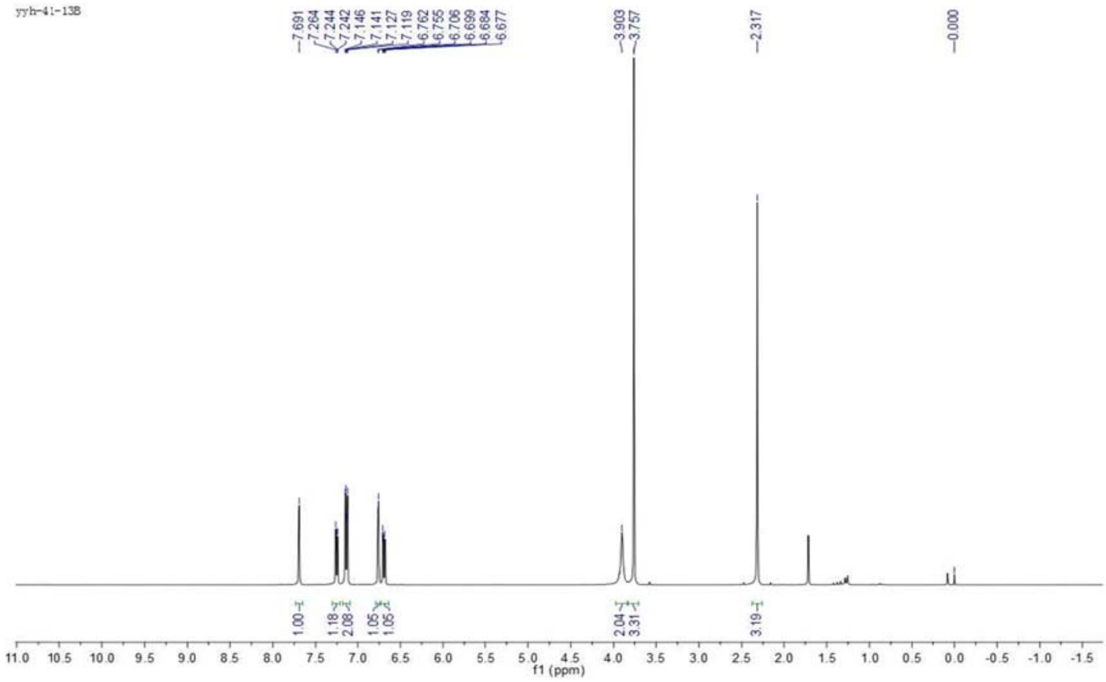


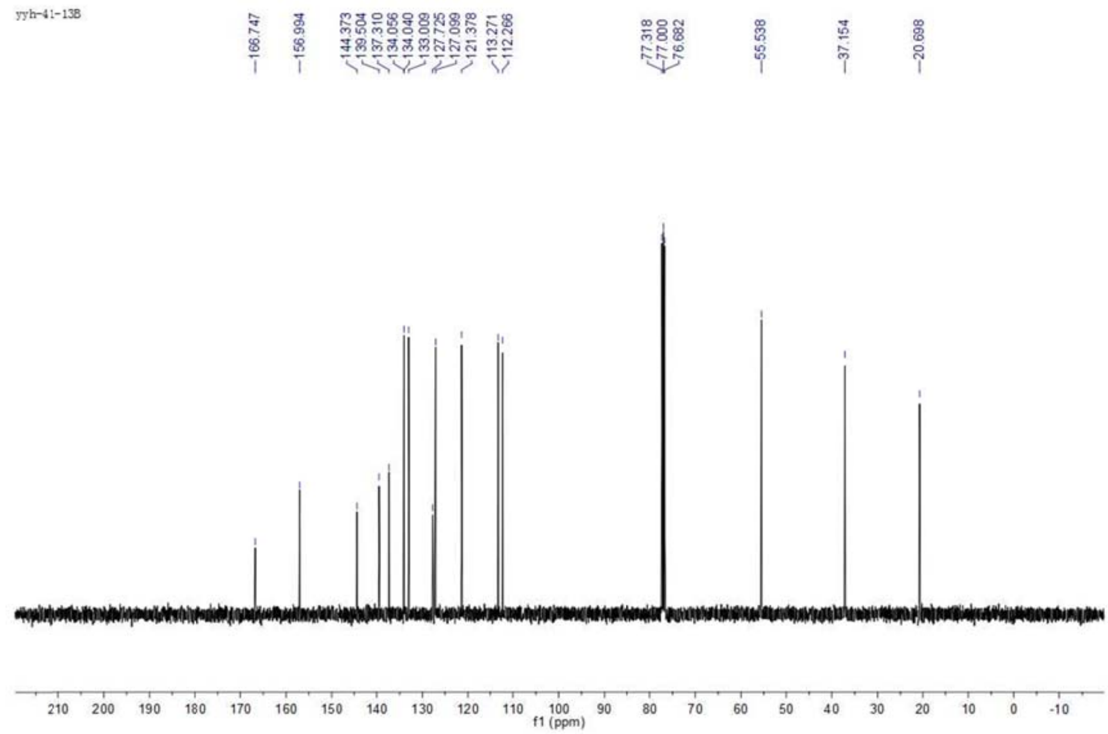


Supplementary Figure 58 ^{1}H NMR and ^{13}C NMR spectra for compound 43

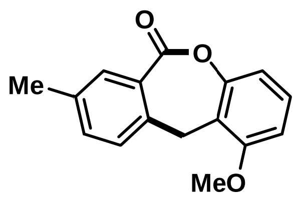


44

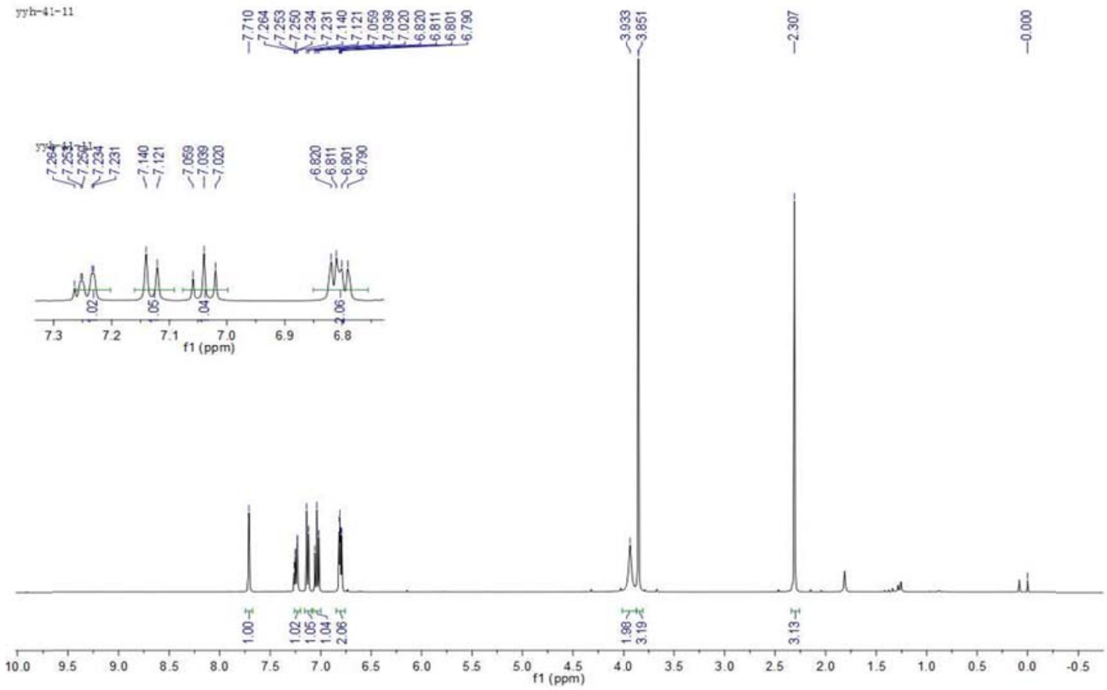


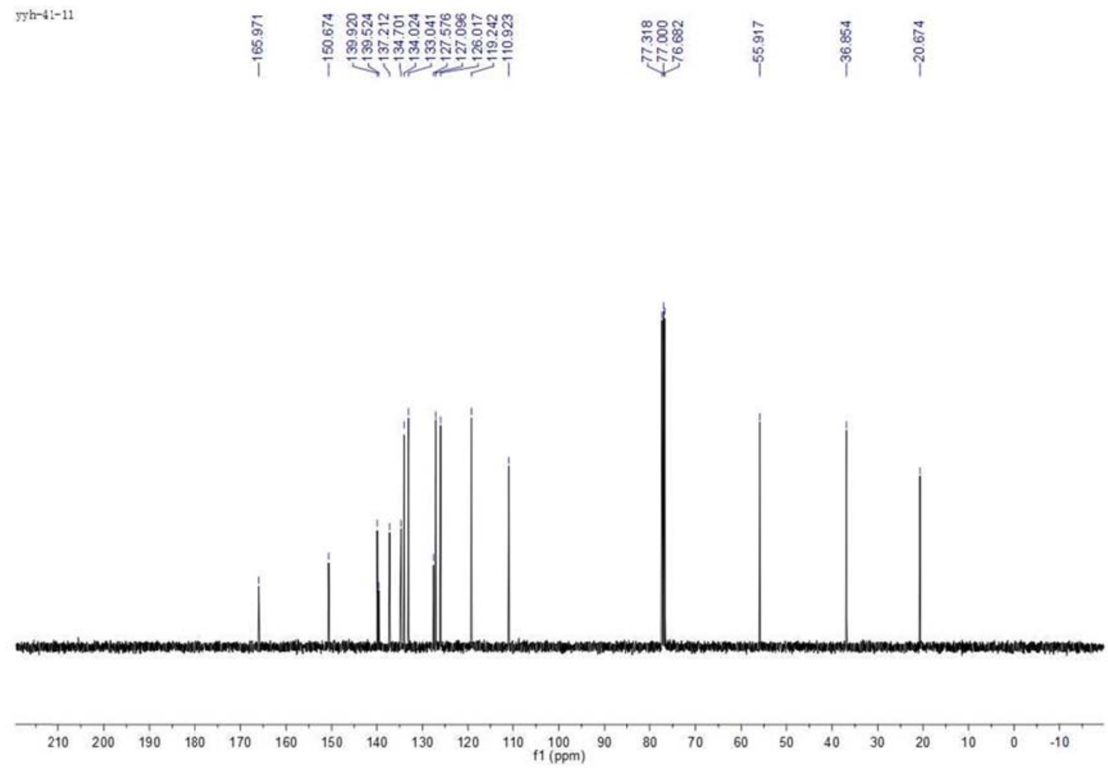


Supplementary Figure 59 ^{1}H NMR and ^{13}C NMR spectra for compound 44

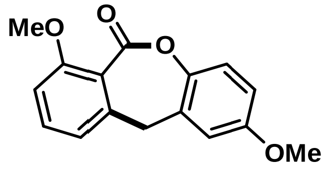


45

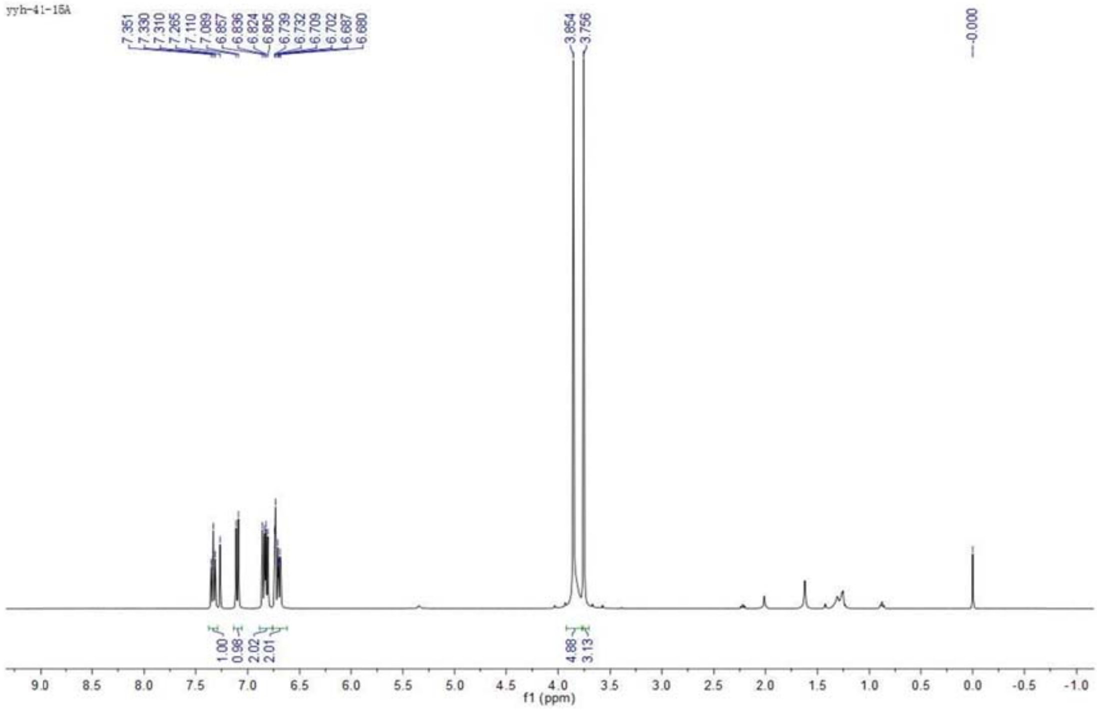


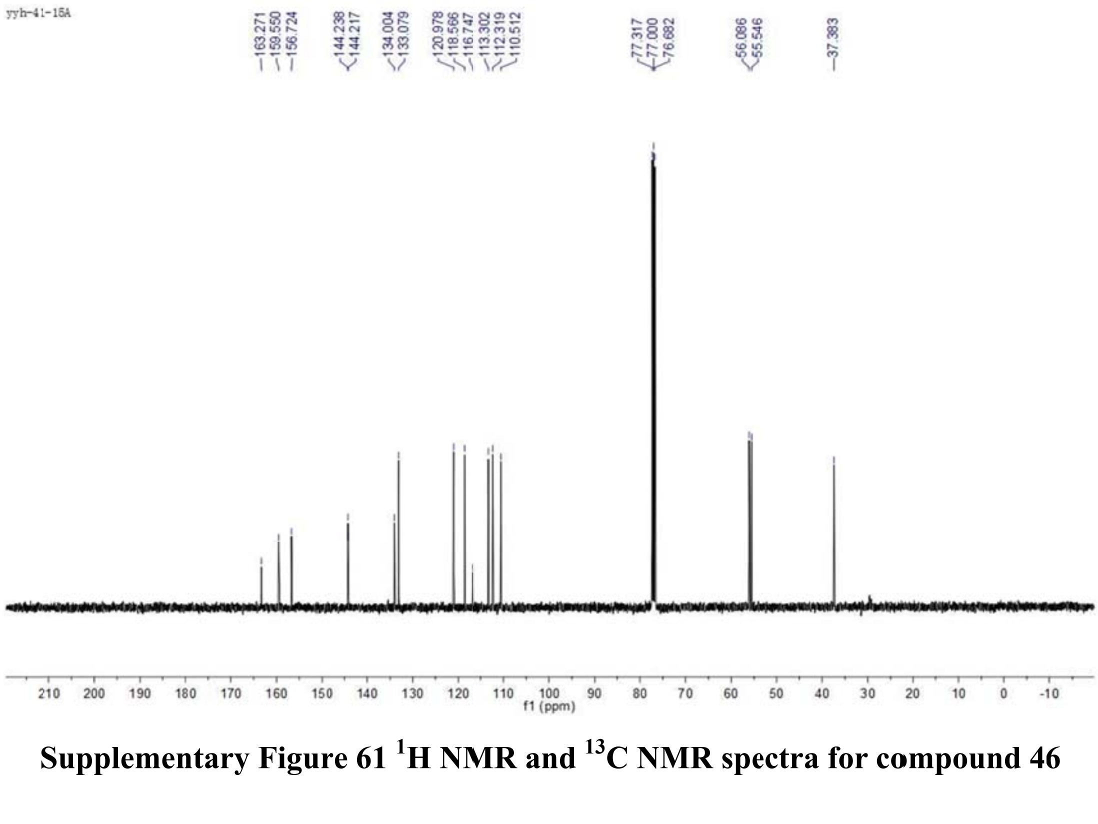


Supplementary Figure 60 ^{1}H NMR and ^{13}C NMR spectra for compound 45

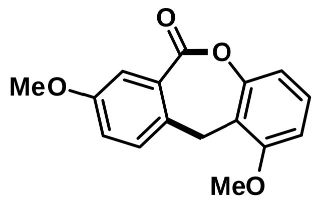


46

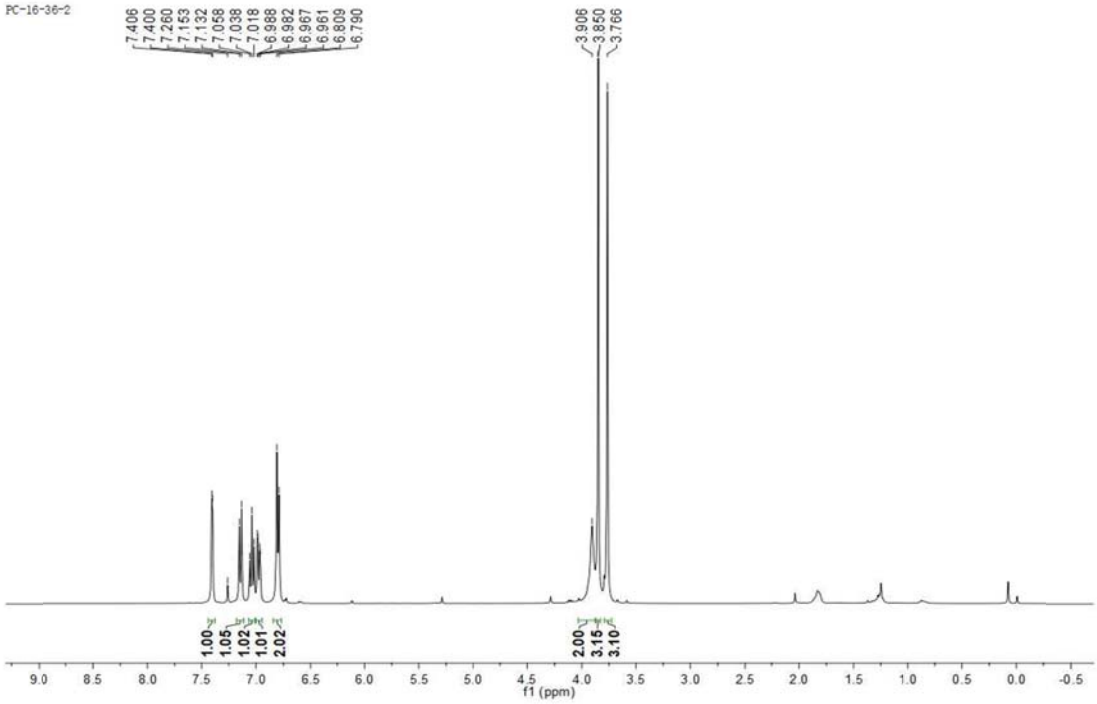


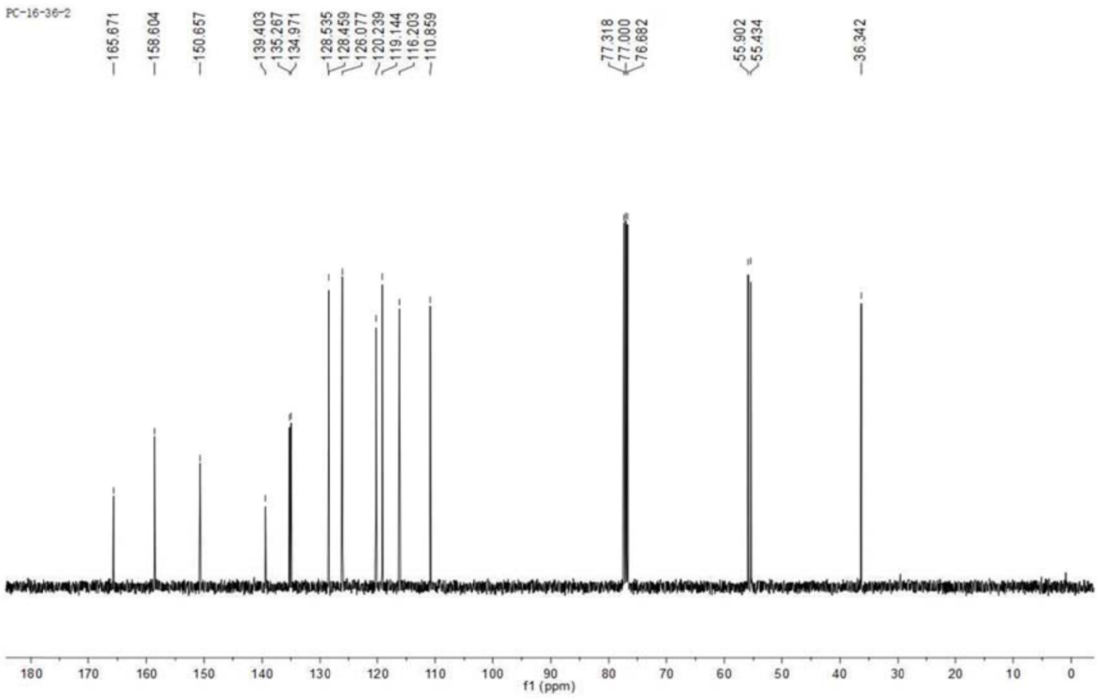


Supplementary Figure 61 ^{1}H NMR and ^{13}C NMR spectra for compound 46

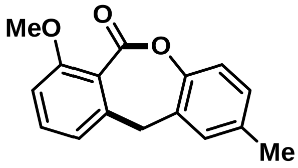


47

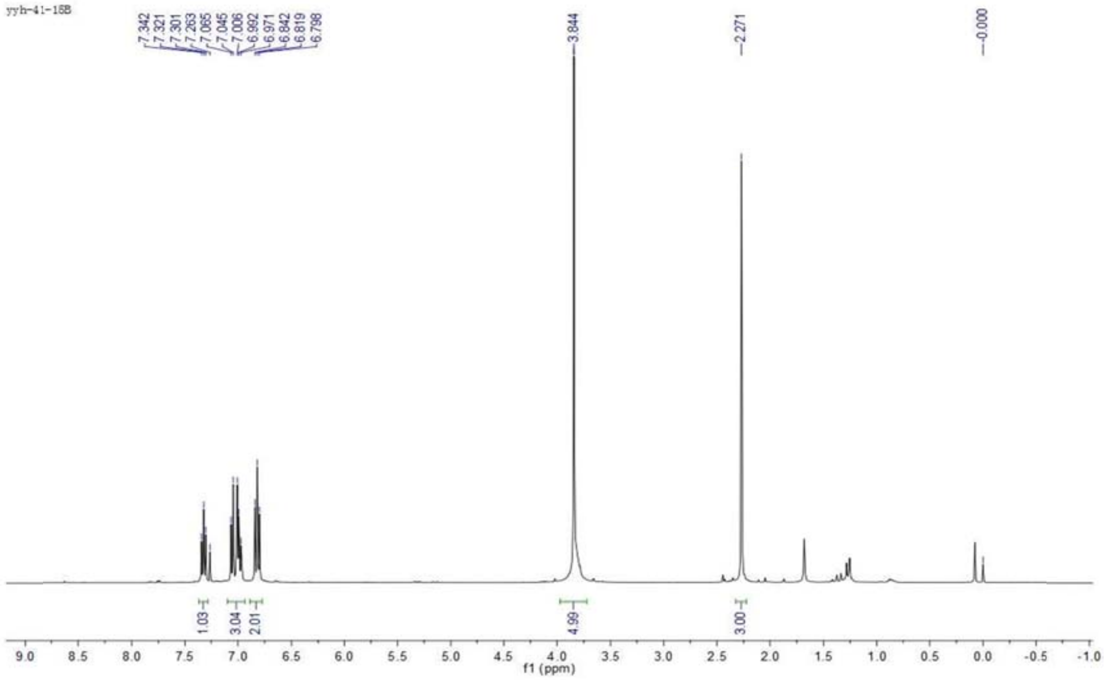


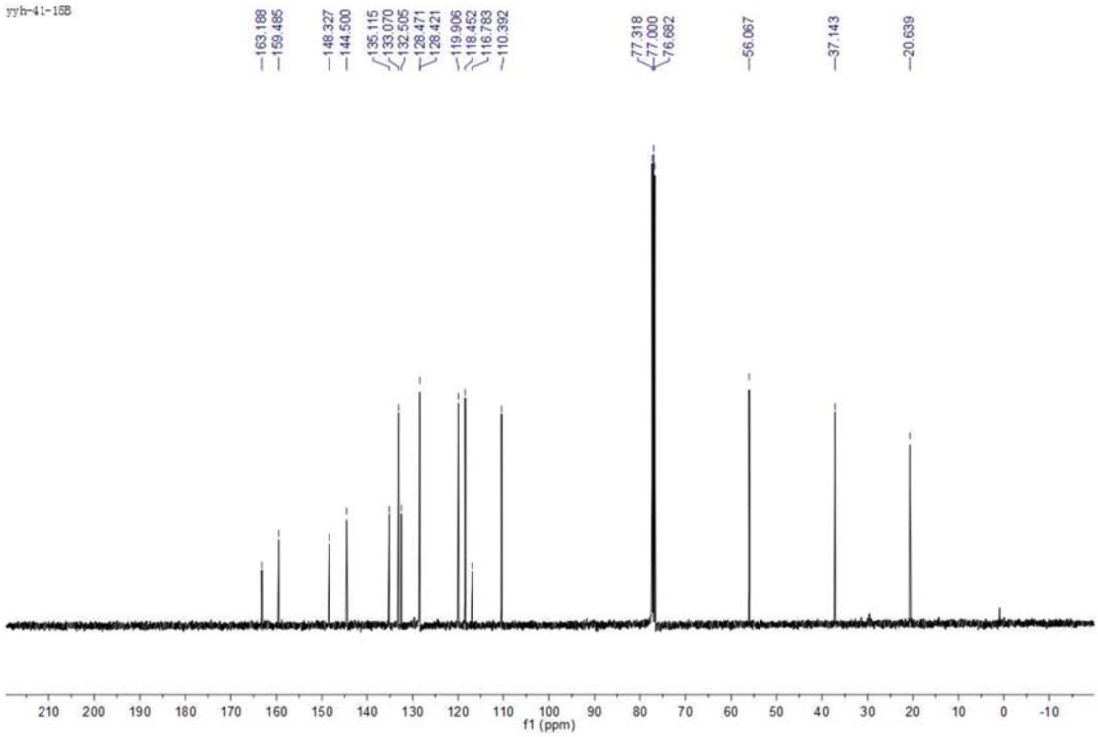


Supplementary Figure 62 ^{1}H NMR and ^{13}C NMR spectra for compound 47

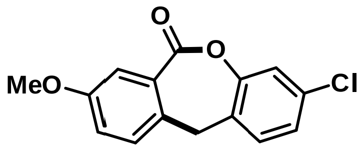


48

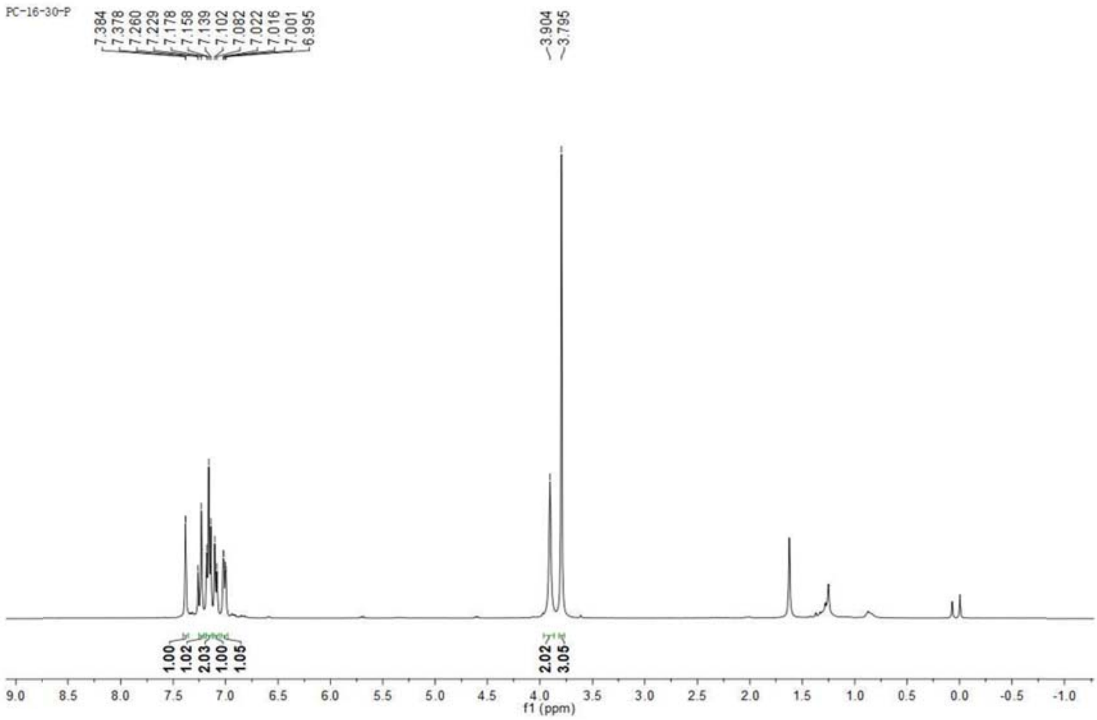


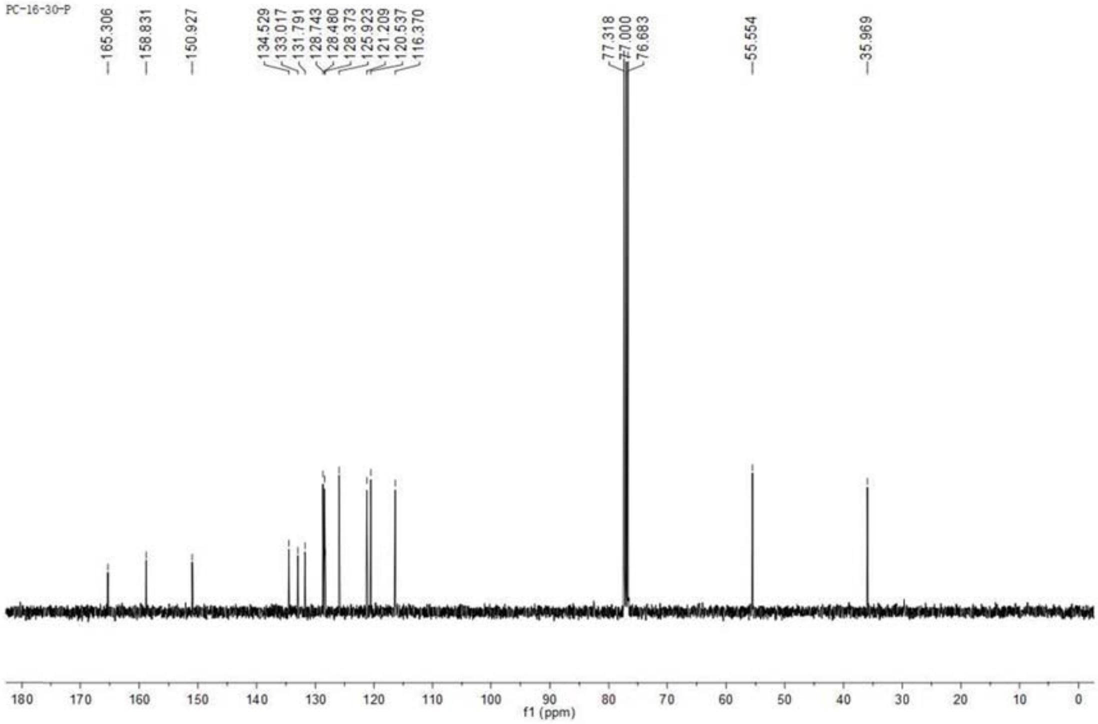


Supplementary Figure 63 ^{1}H NMR and ^{13}C NMR spectra for compound 48

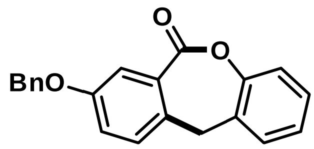


49





Supplementary Figure 64 ^{1}H NMR and ^{13}C NMR spectra for compound 49



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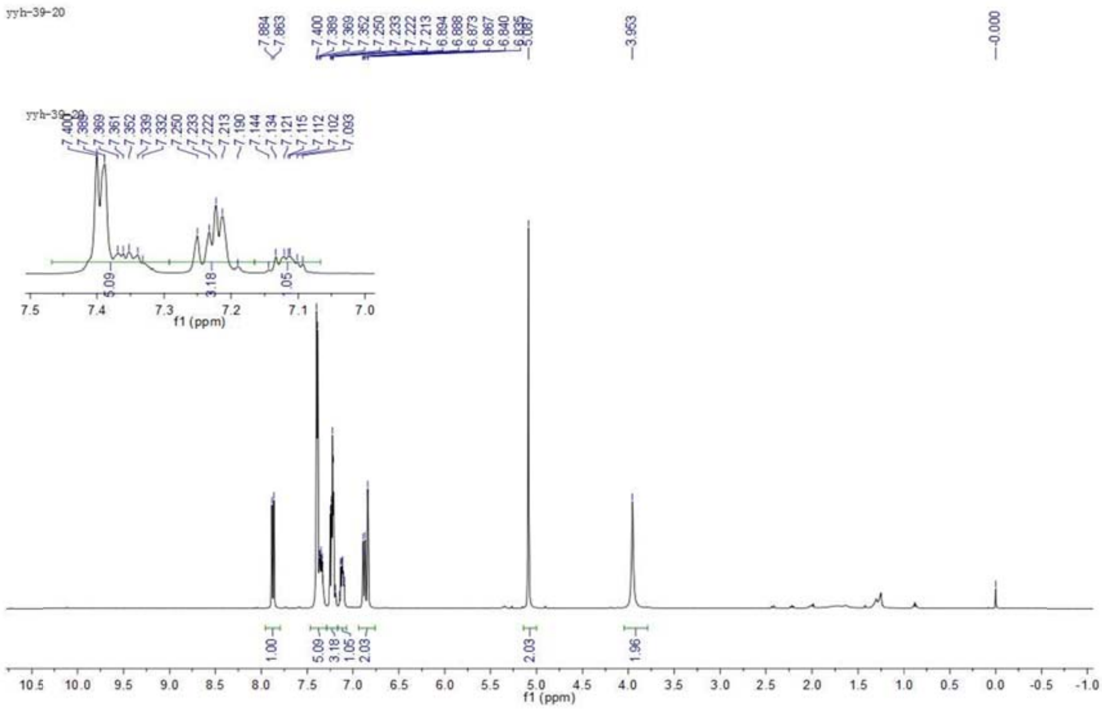
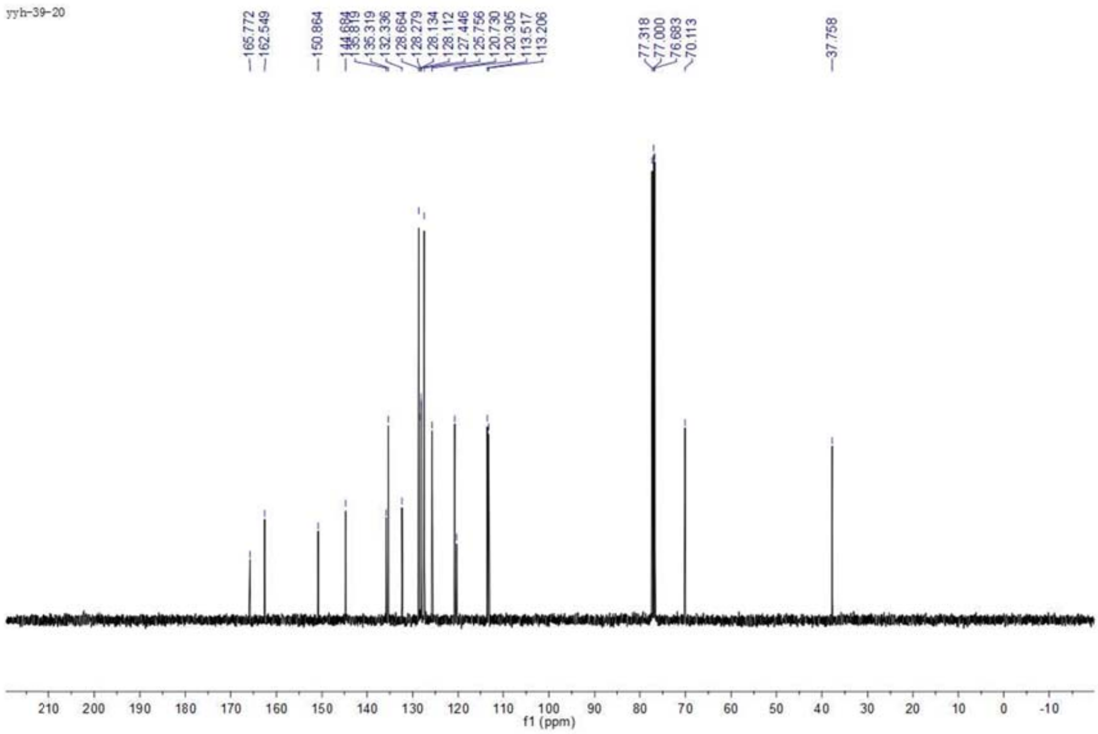
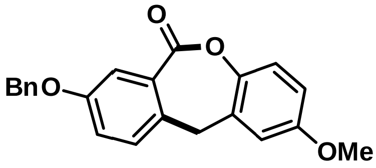
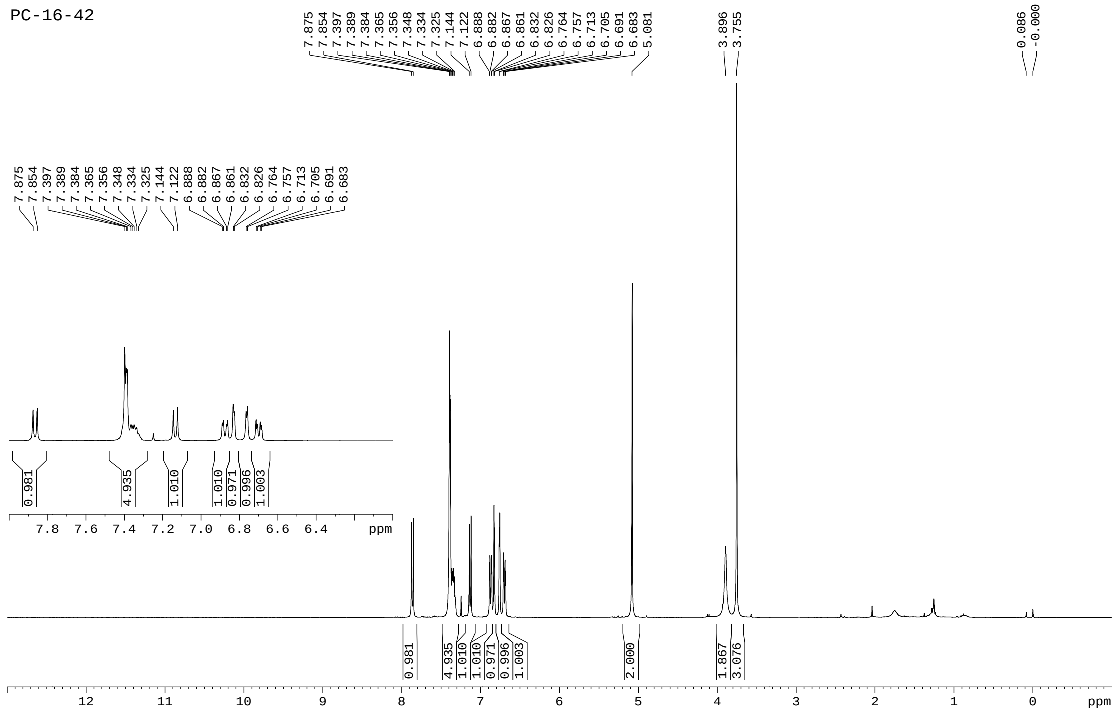


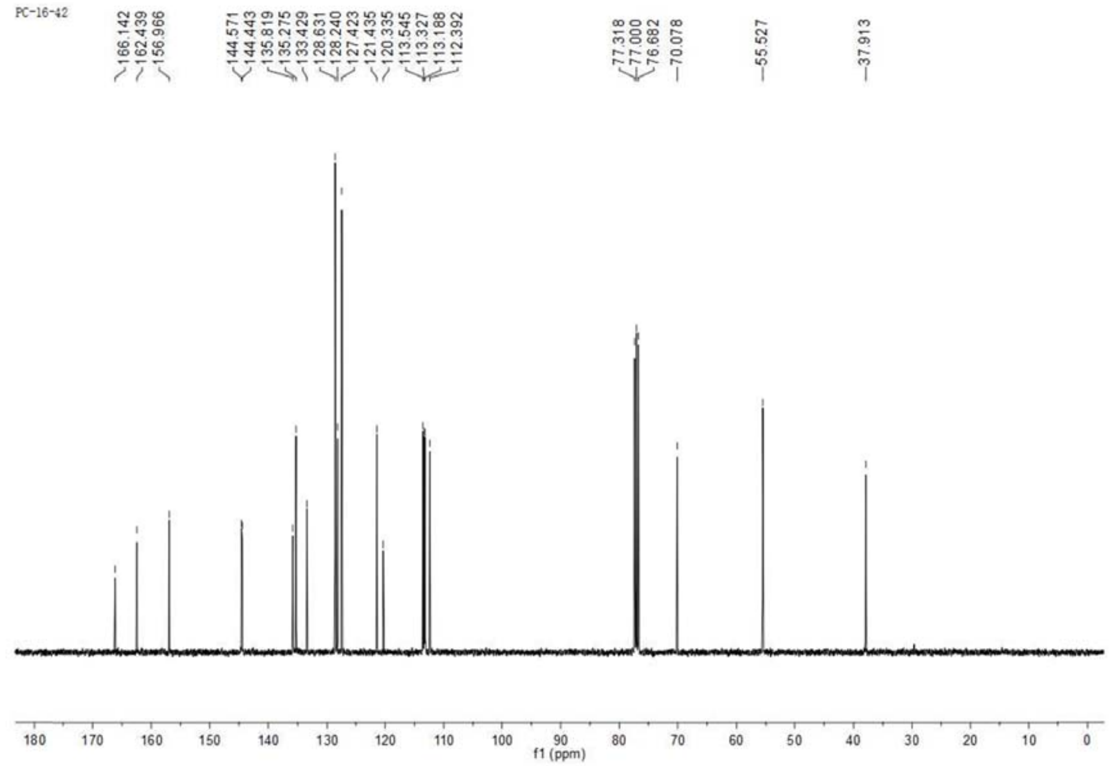


Supplementary Figure 65 ^{1}H NMR and ^{13}C NMR spectra for compound 50

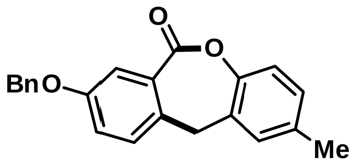


51

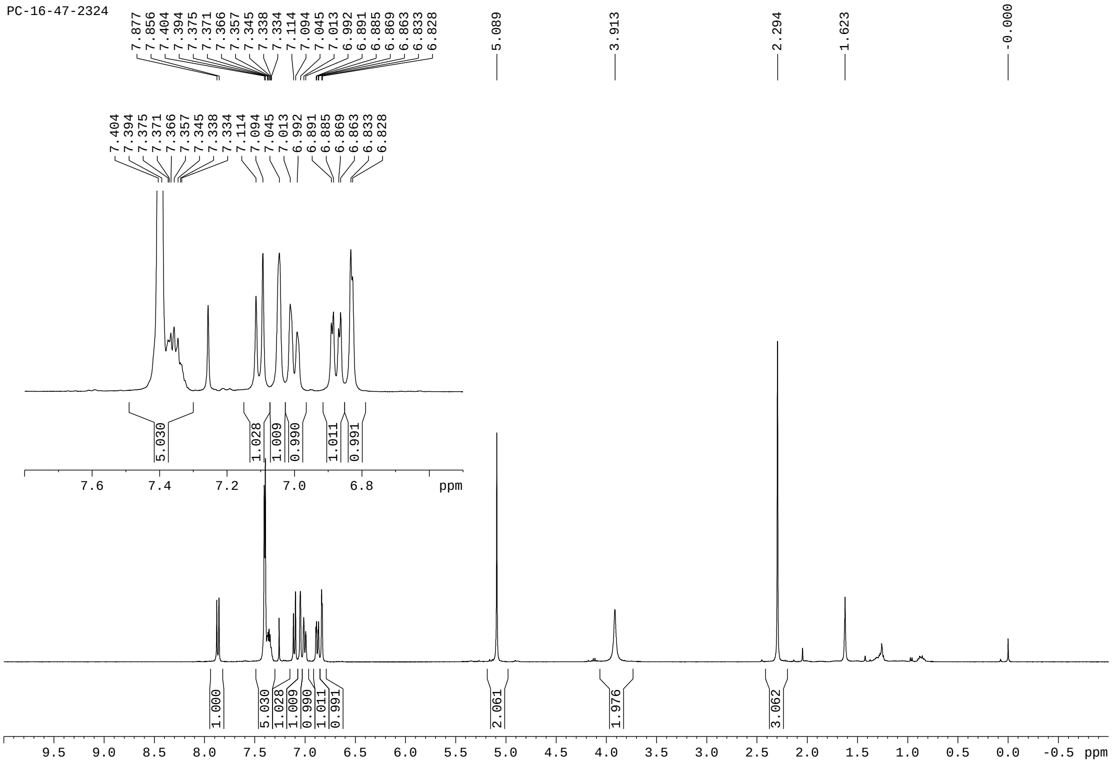


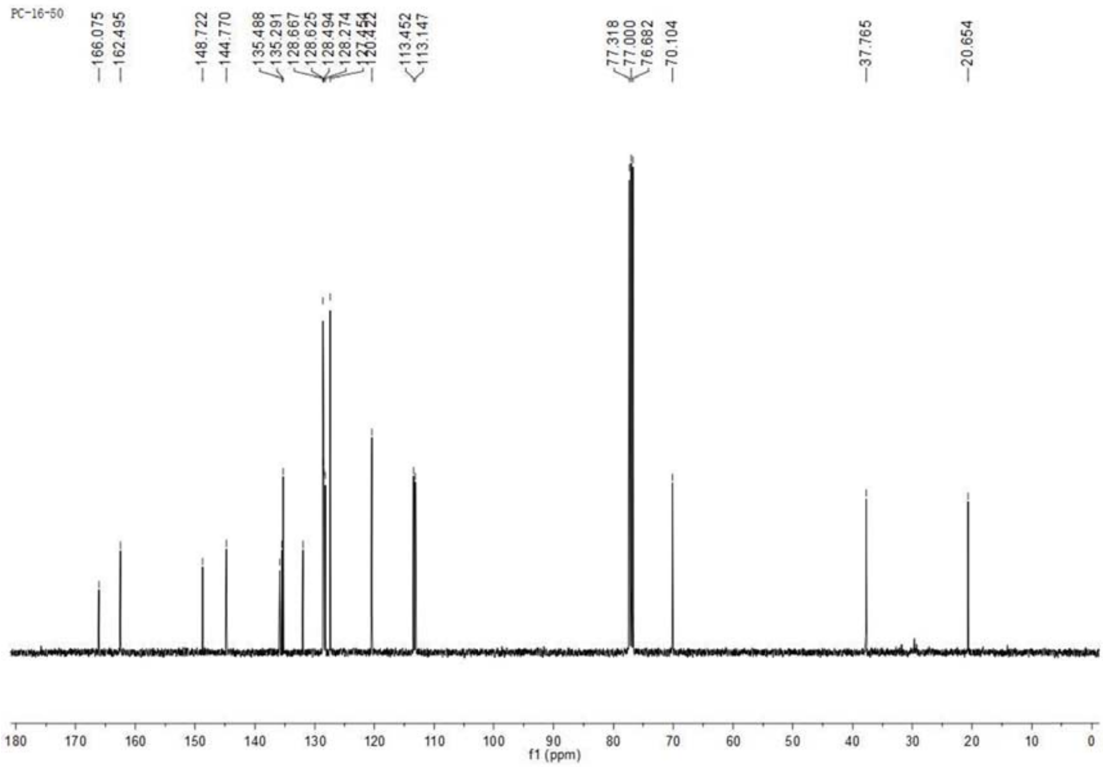


Supplementary Figure 66 ^{1}H NMR and ^{13}C NMR spectra for compound 51

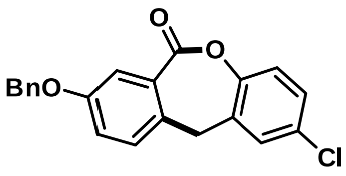


52





Supplementary Figure 67 ^{1}H NMR and ^{13}C NMR spectra for compound 52



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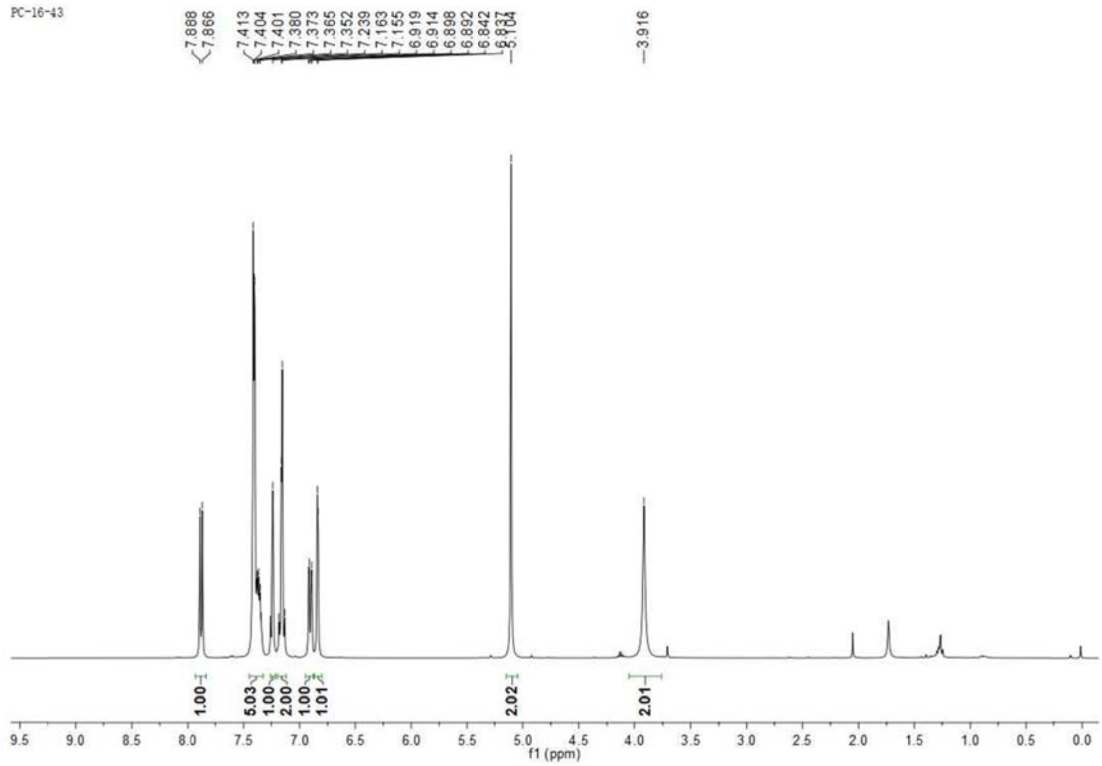
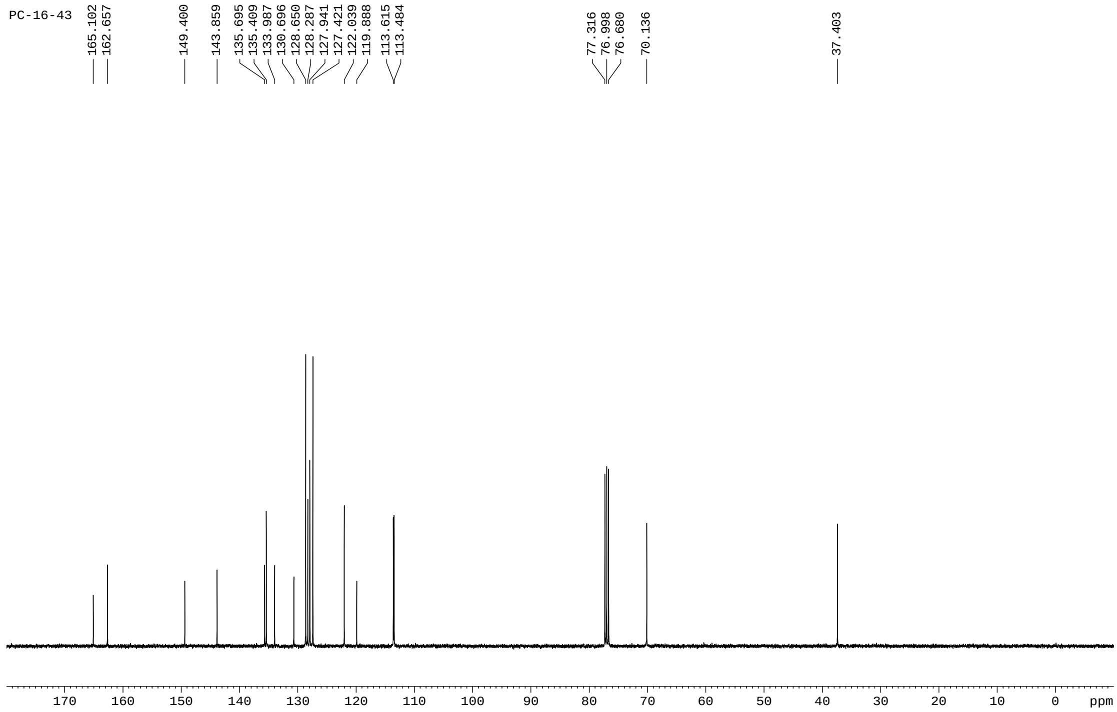
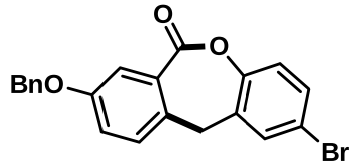
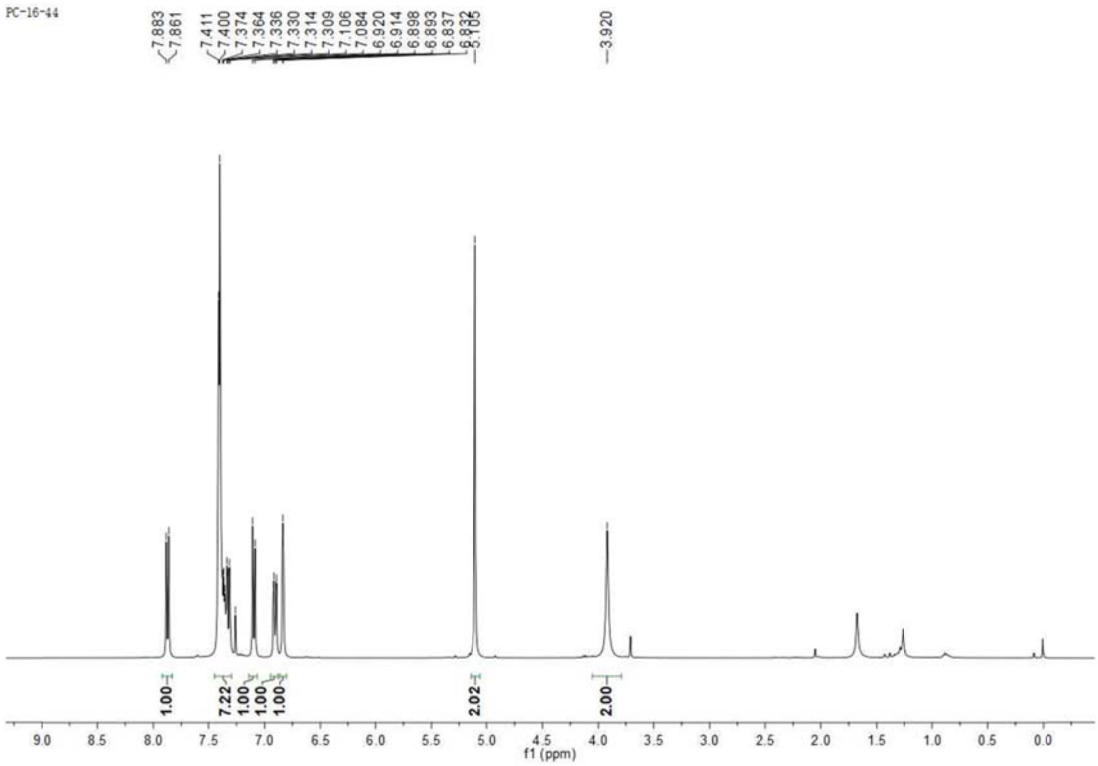


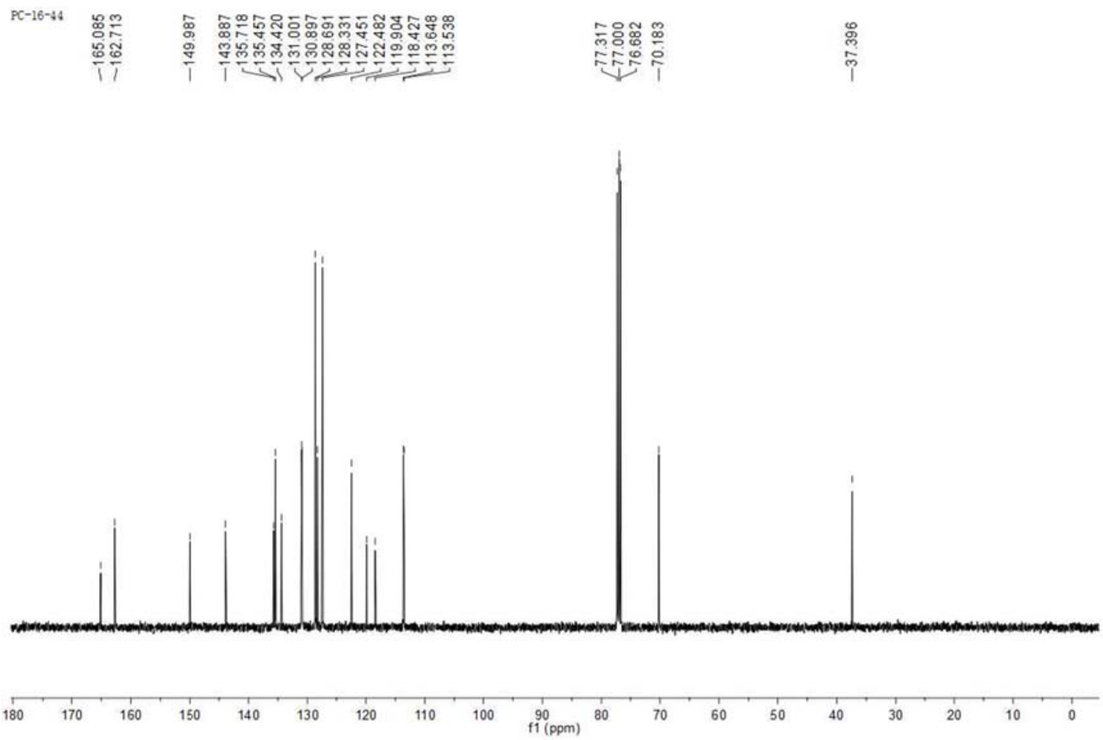


Supplementary Figure 68 ^{1}H NMR and ^{13}C NMR spectra for compound 53

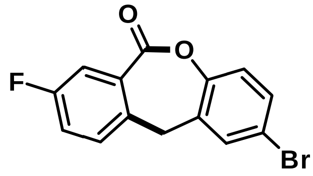


54

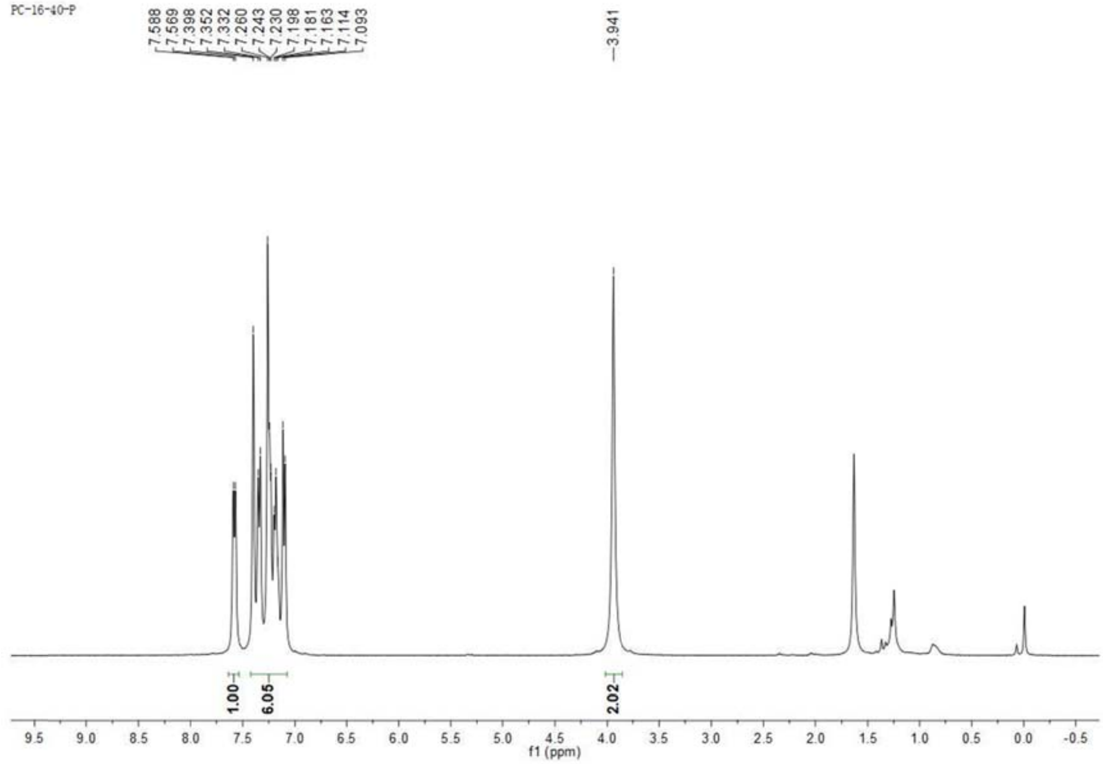


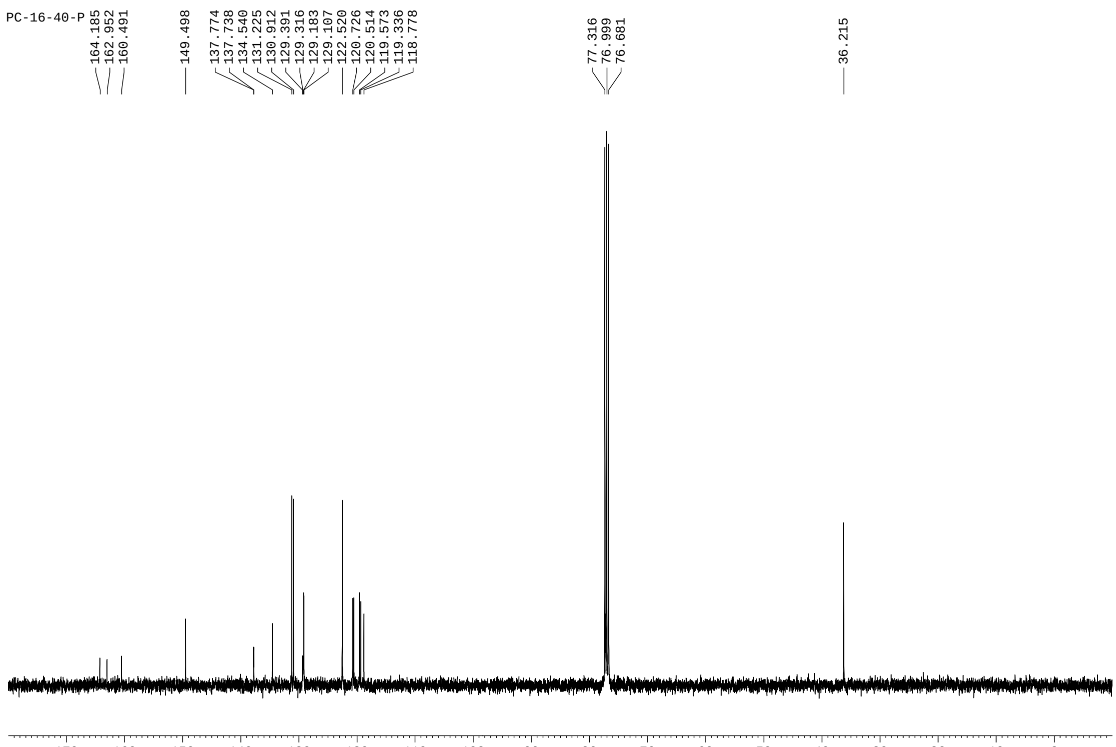


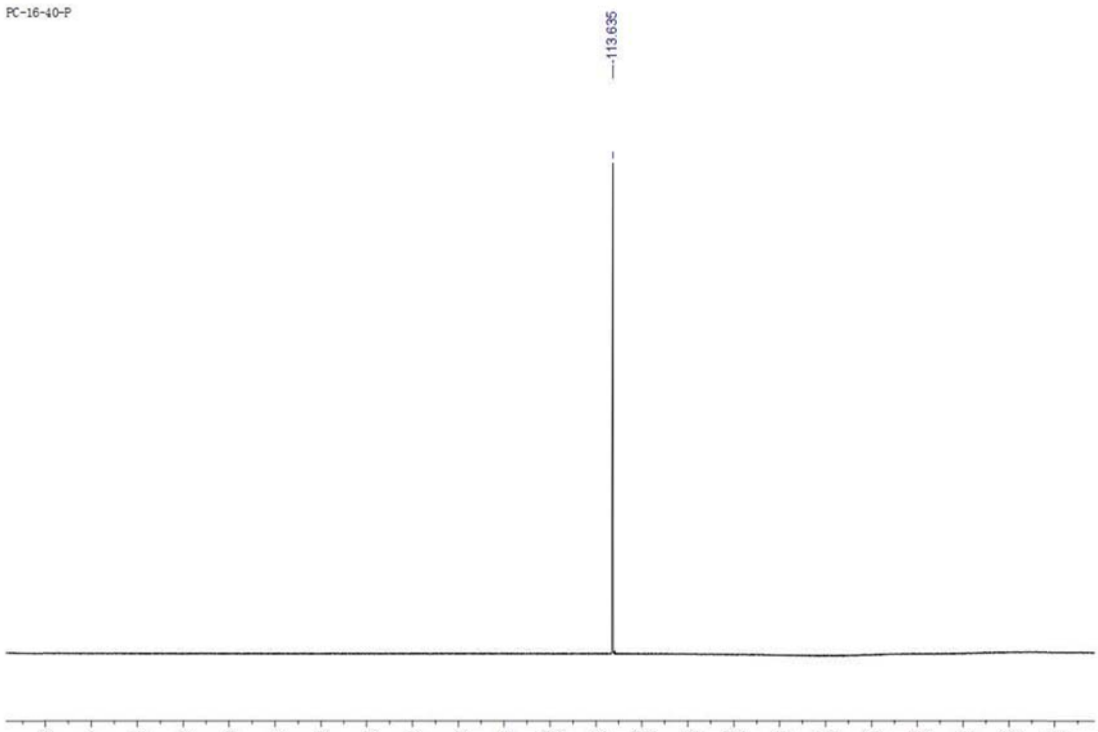
Supplementary Figure 69 ^{1}H NMR and ^{13}C NMR spectra for compound 54


O
O
F
Br

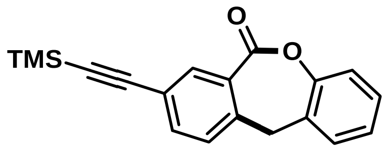
55


PC-16-40-P
7.588
7.569
7.398
7.352
7.332
7.260
7.243
7.230
7.198
7.181
7.163
7.114
7.093
3.941
1.00
6.05
2.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

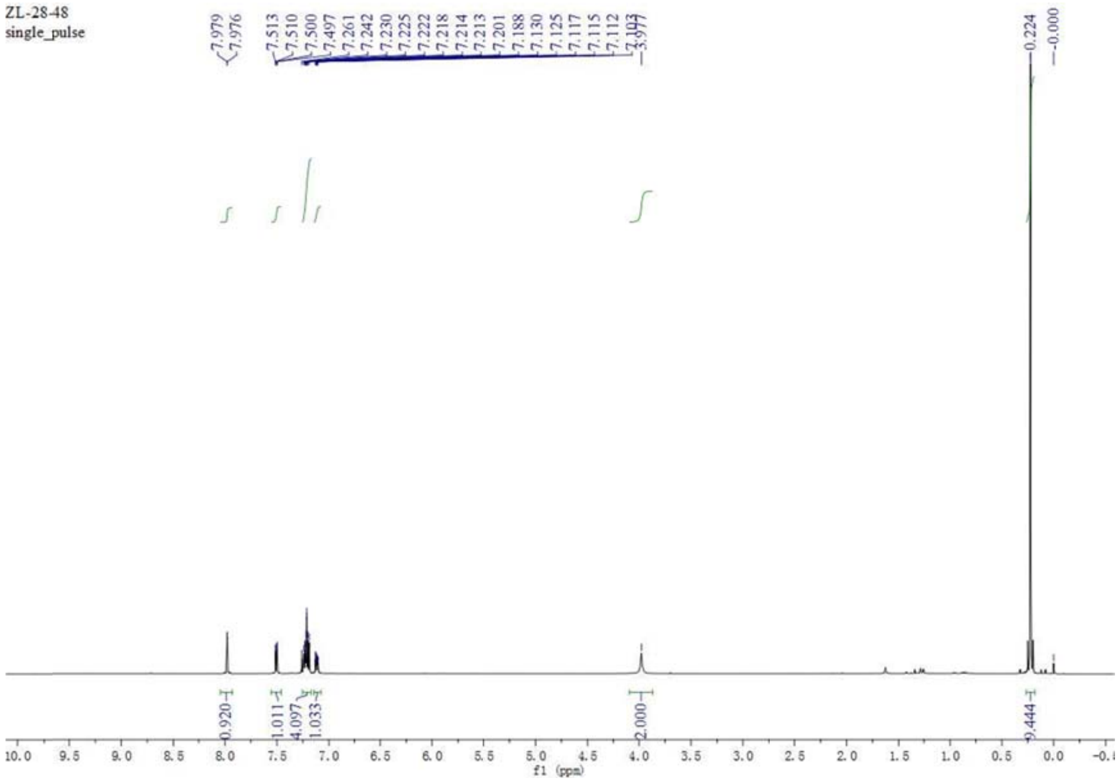

PC-16-40-P
164.185
162.952
160.491
149.498
137.774
137.738
134.540
131.225
130.912
129.391
129.316
129.183
129.107
122.520
120.726
120.514
119.573
119.336
118.778
77.316
76.999
76.681
36.215
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

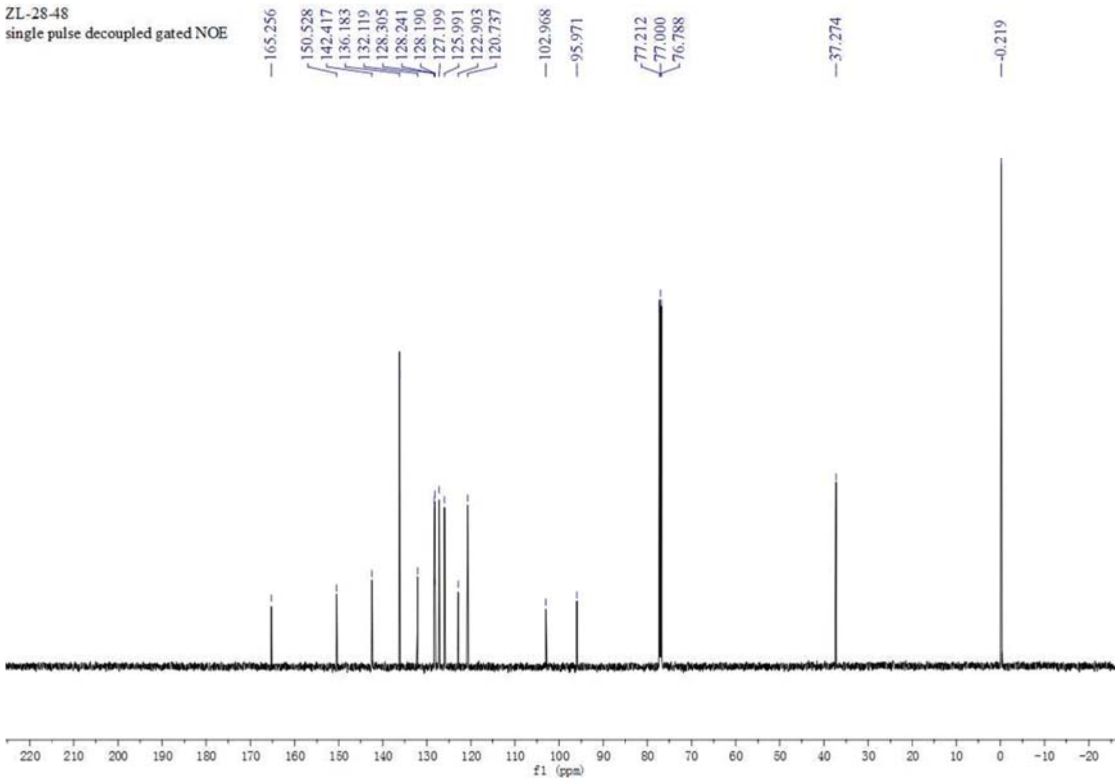


Supplementary Figure 70 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 55

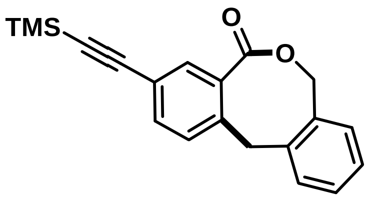


56

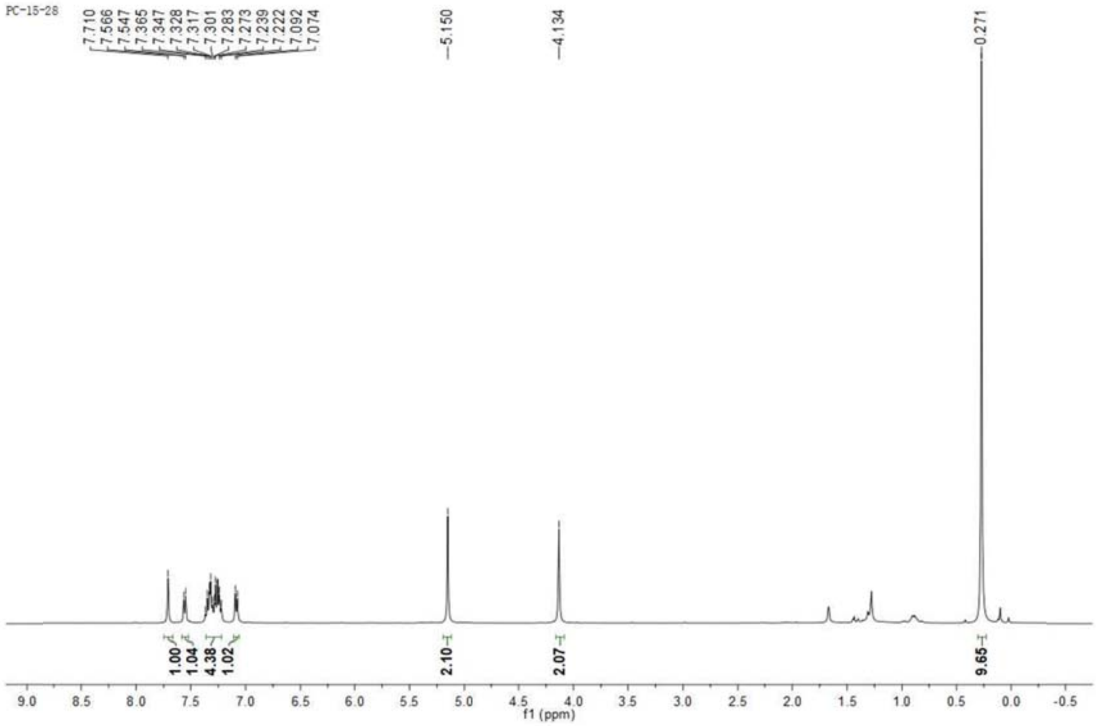


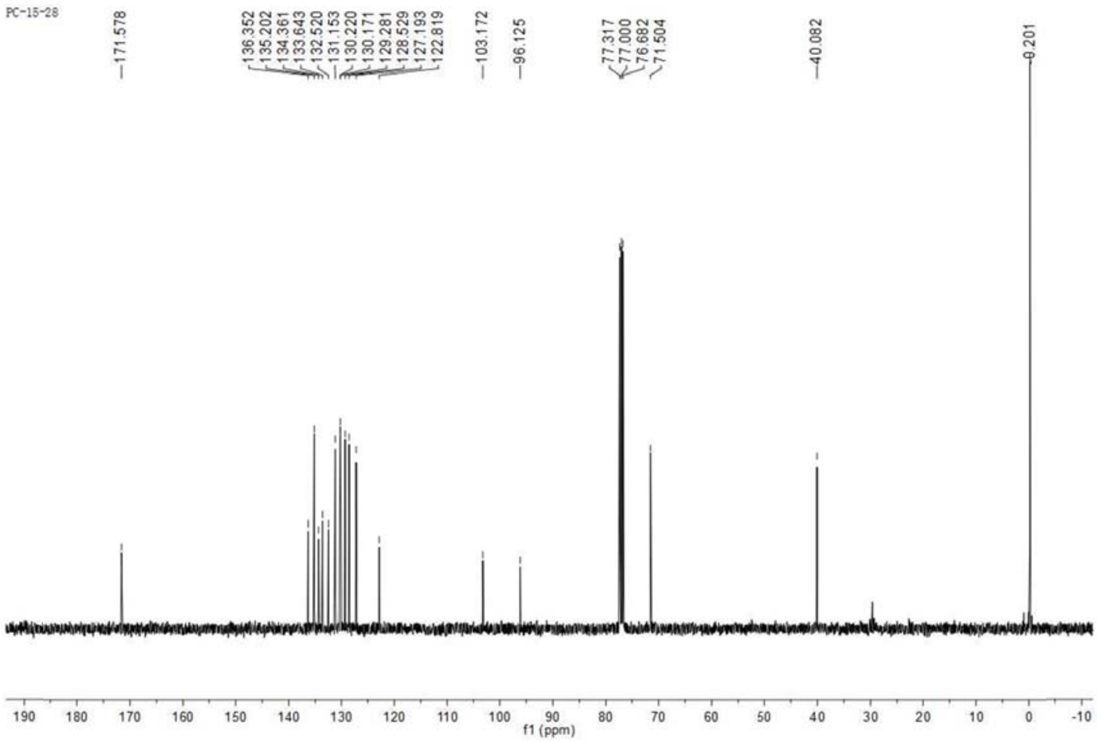


Supplementary Figure 71 ^{1}H NMR and ^{13}C NMR spectra for compound 56

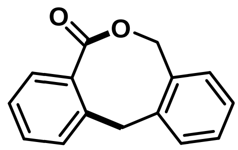


57

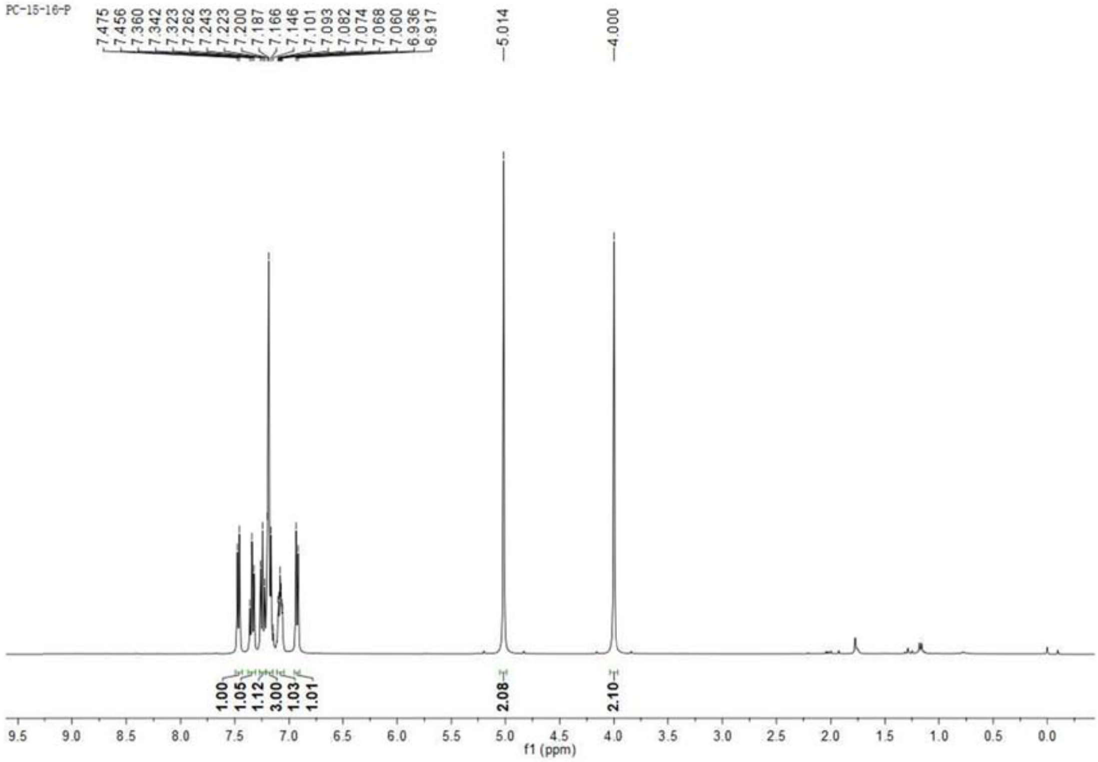


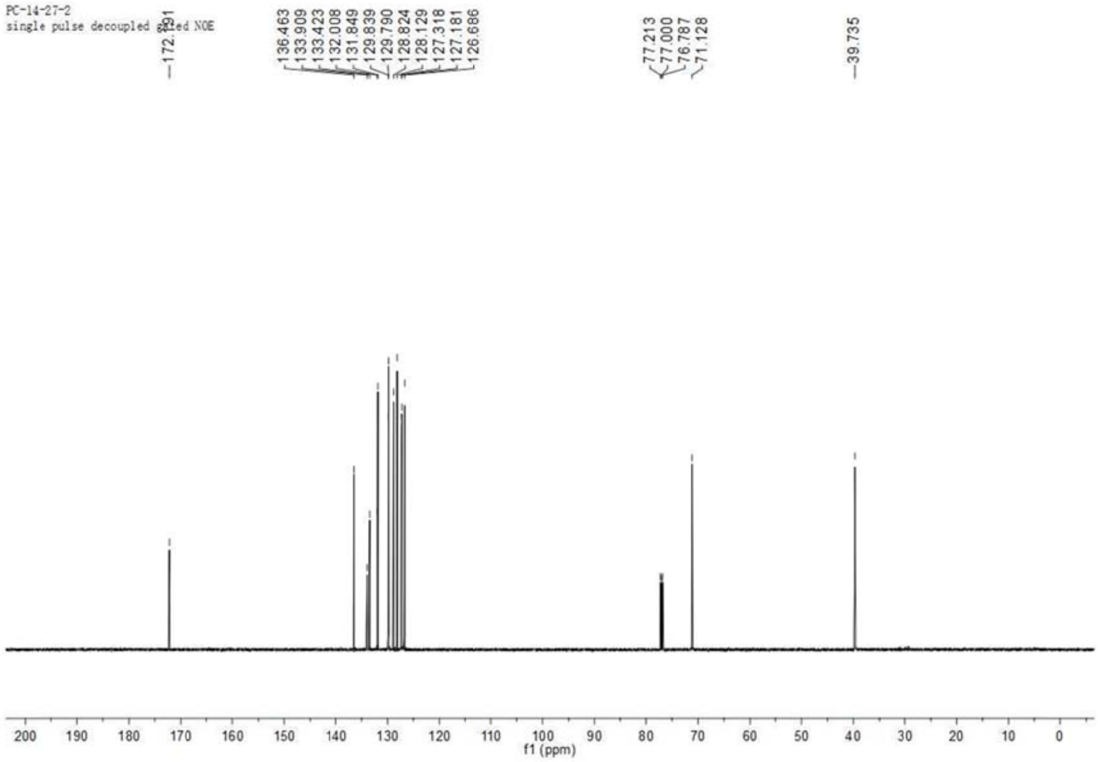


Supplementary Figure 72 ^{1}H NMR and ^{13}C NMR spectra for compound 57

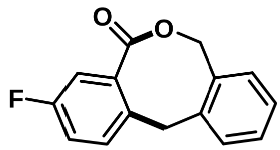


58

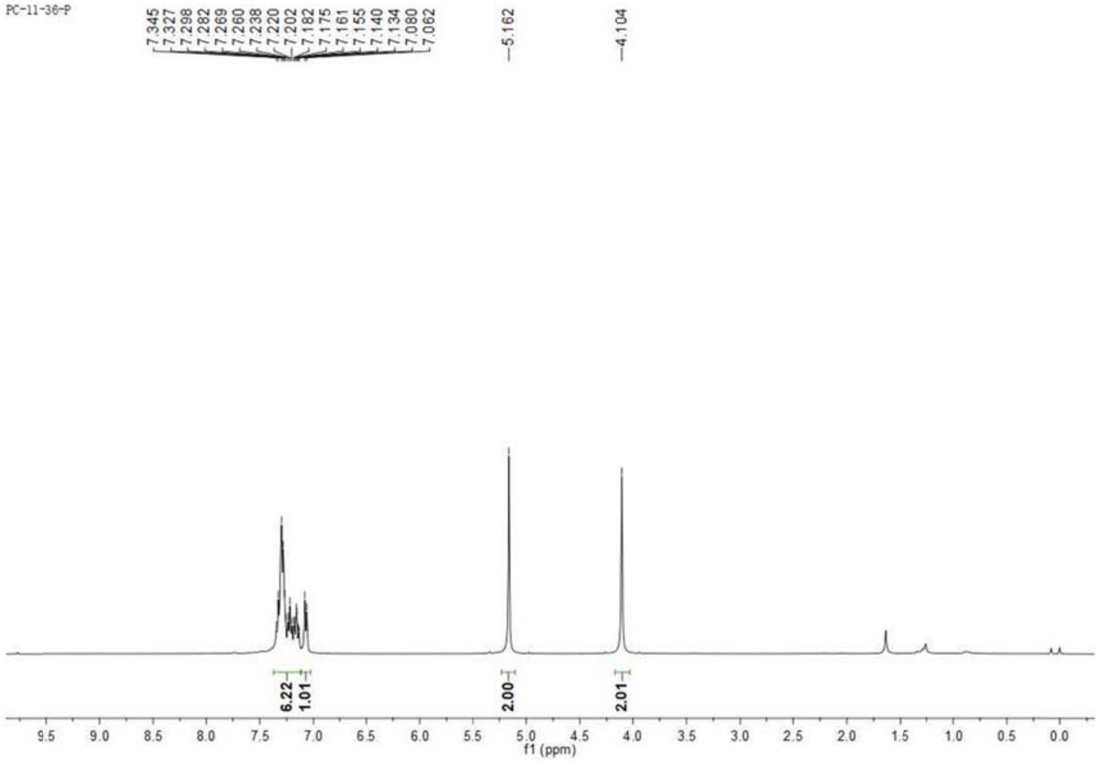


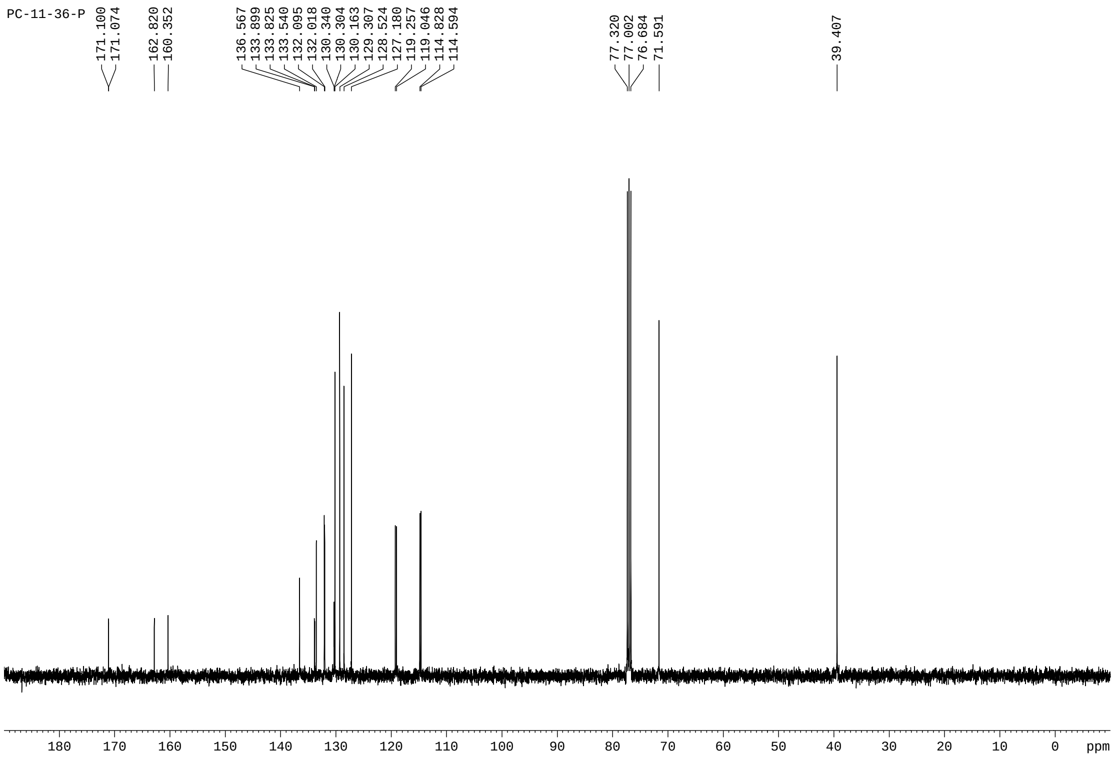


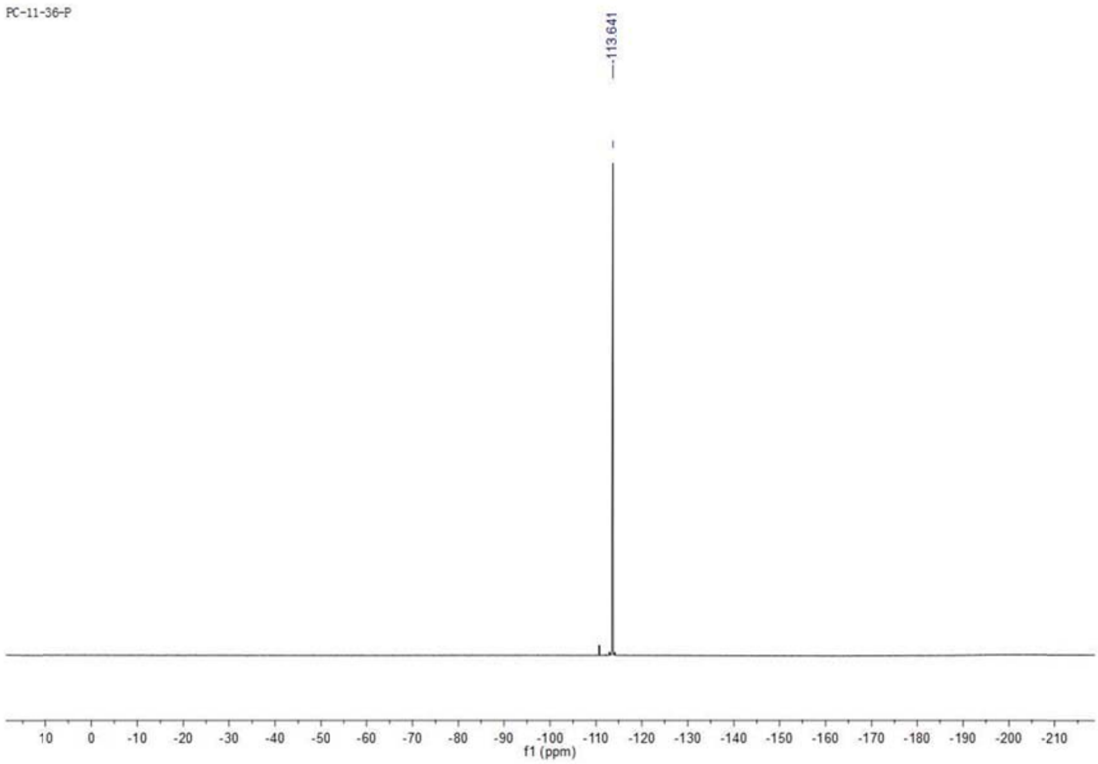
Supplementary Figure 73 ^{1}H NMR and ^{13}C NMR spectra for compound 58



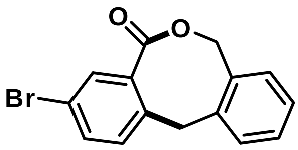
59


PC-11-36-P
7.345
7.327
7.298
7.282
7.269
7.260
7.238
7.220
7.202
7.182
7.175
7.161
7.155
7.140
7.134
7.080
7.062
5.162
4.104
6.22
1.01
2.00
2.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

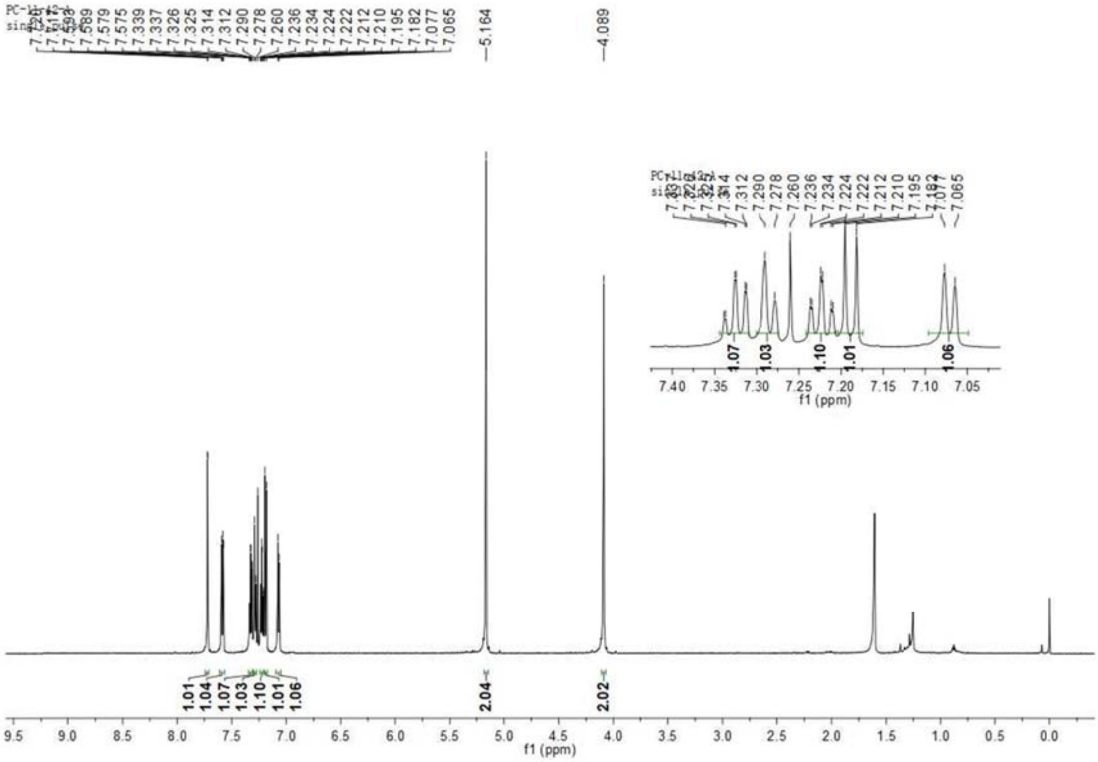

PC-11-36-P
171.100
171.074
162.820
160.352
136.567
133.899
133.825
133.540
132.095
132.018
130.340
130.304
130.163
129.307
128.524
127.180
119.257
119.046
114.828
114.594
77.320
77.002
76.684
71.591
39.407
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

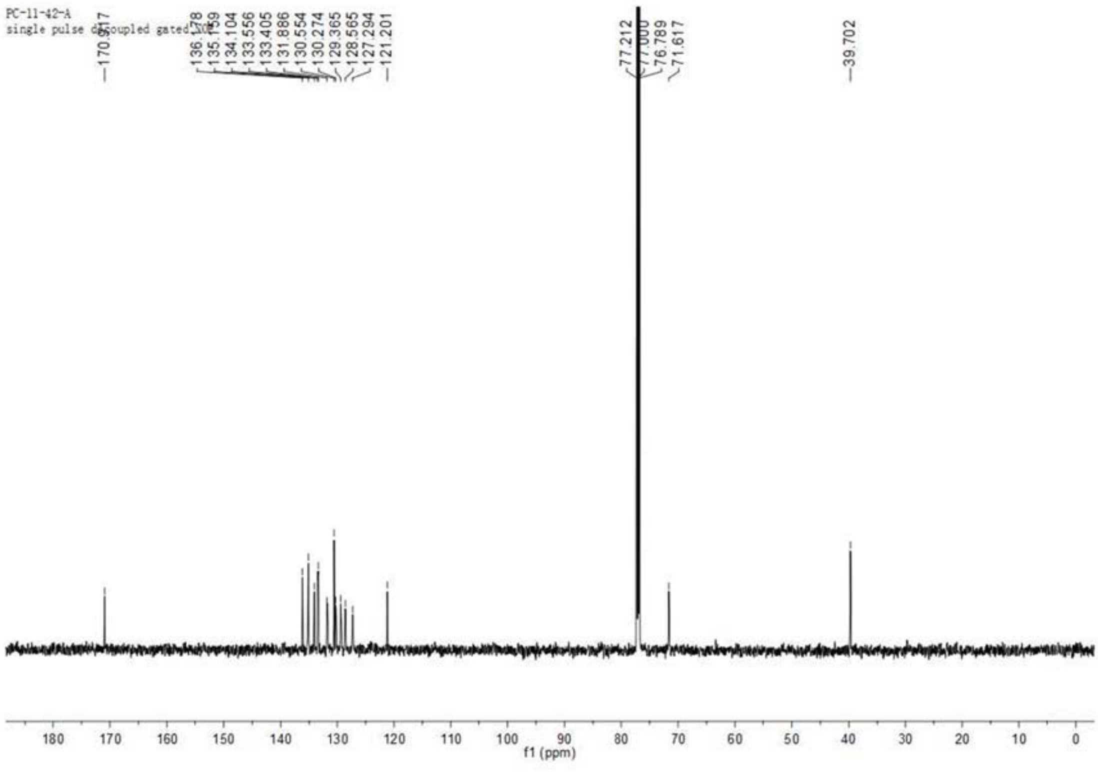


Supplementary Figure 74 ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra for compound 59

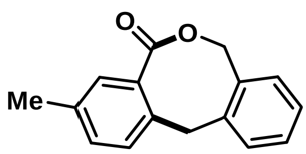


60

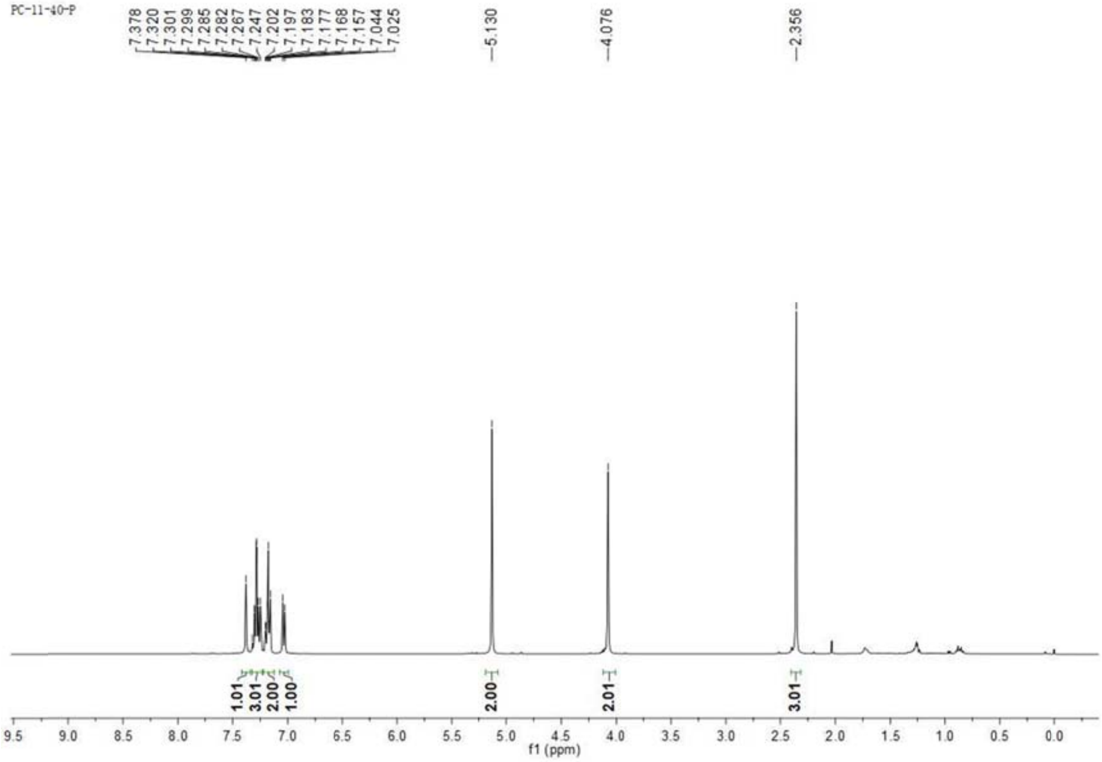


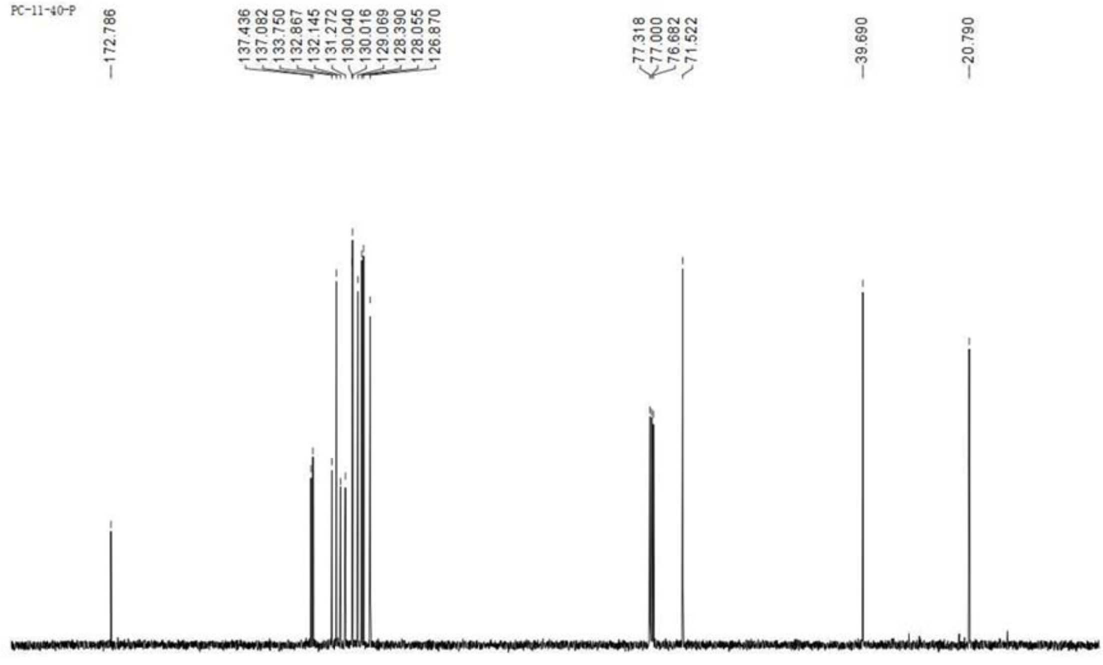


Supplementary Figure 75 ^{1}H NMR and ^{13}C NMR spectra for compound 60

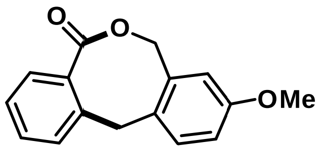


61

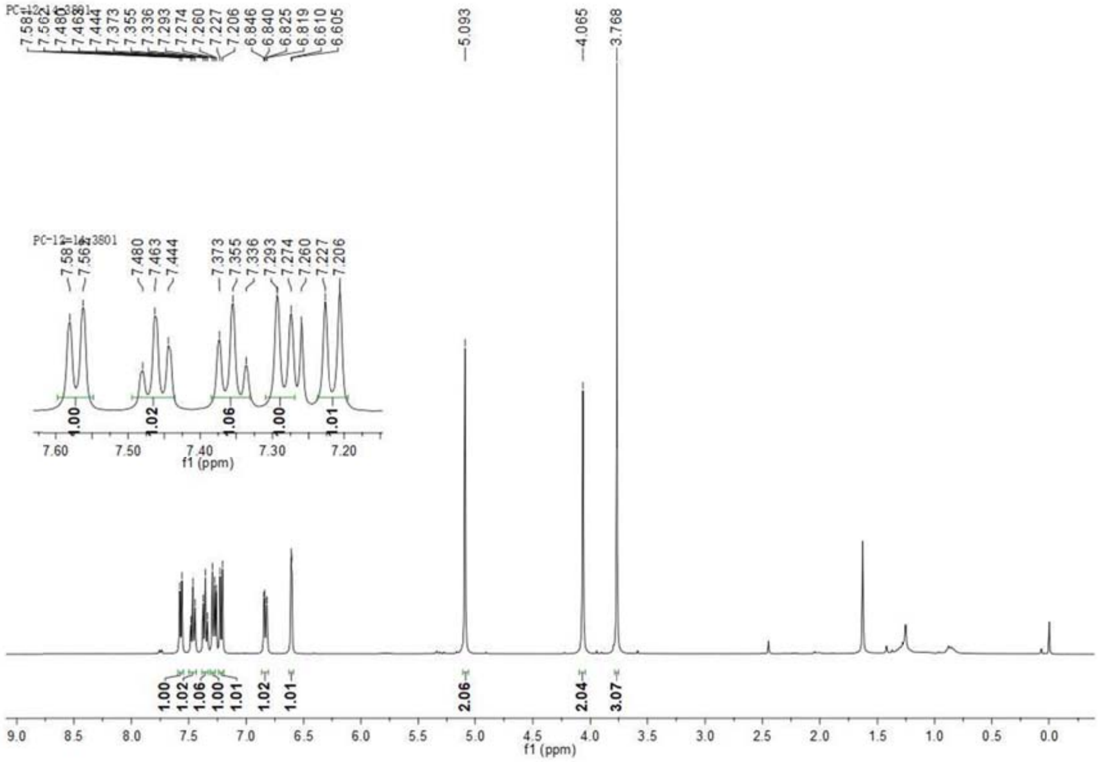


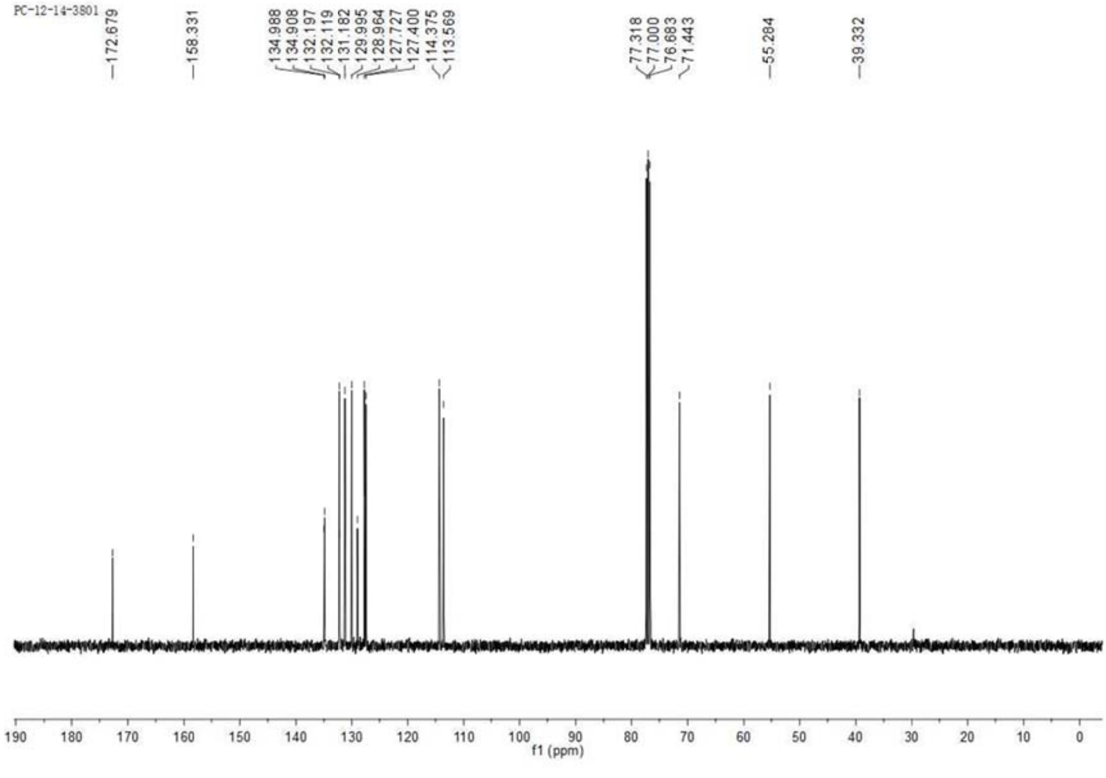


Supplementary Figure 76 ^{1}H NMR and ^{13}C NMR spectra for compound 61

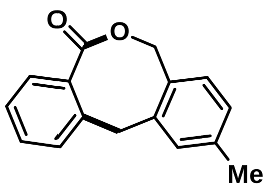


62





Supplementary Figure 77 ^{1}H NMR and ^{13}C NMR spectra for compound 62



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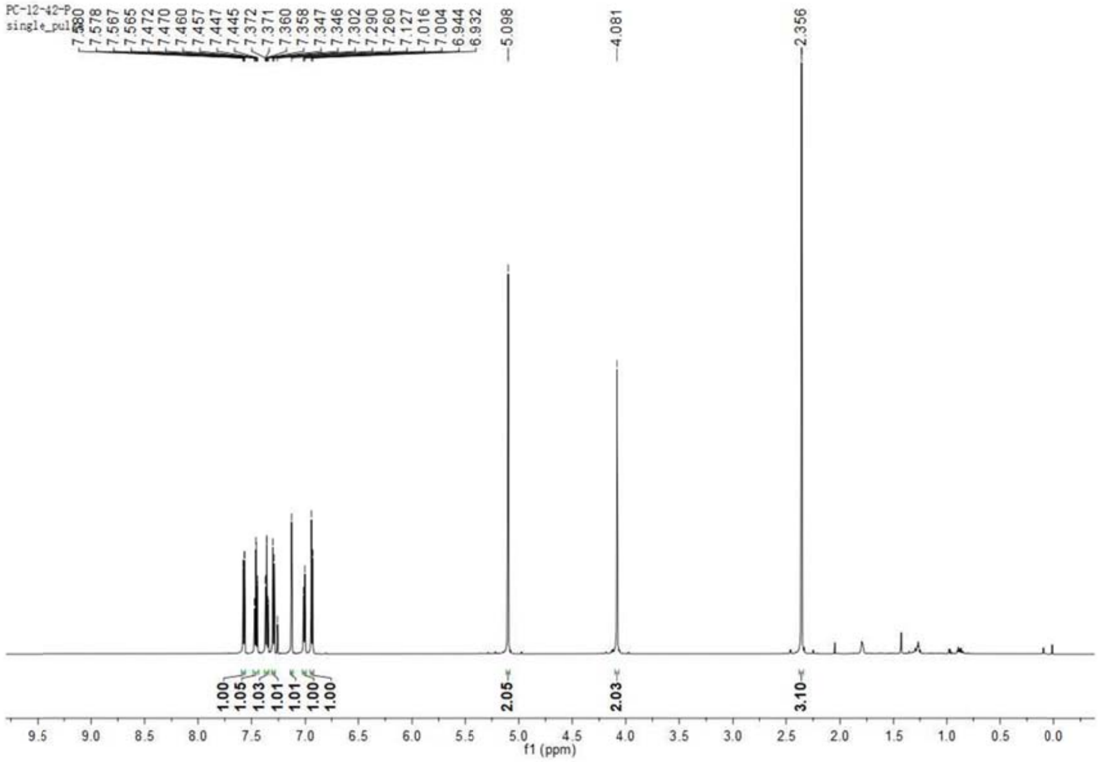
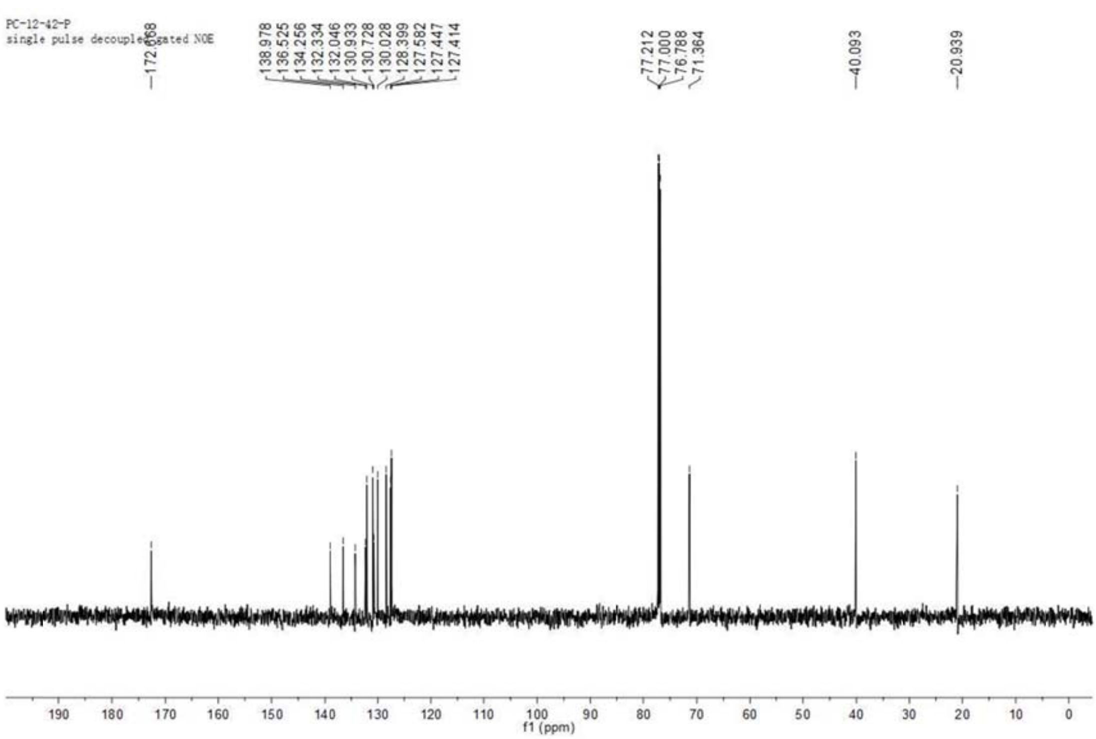
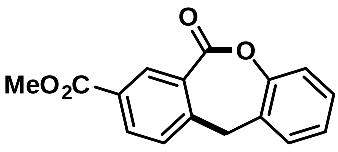




Supplementary Figure 78 ^{1}H NMR and ^{13}C NMR spectra for compound 63



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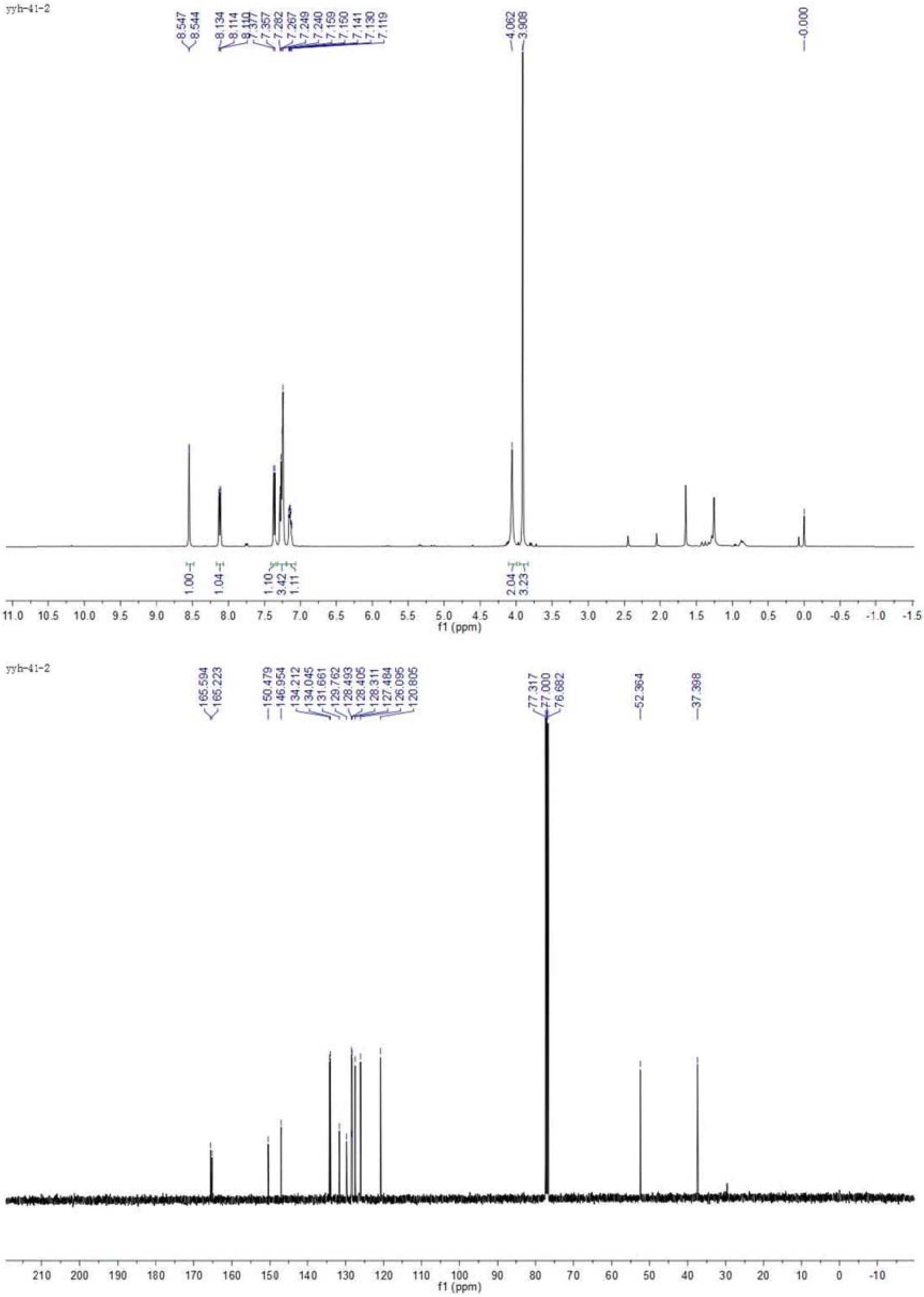
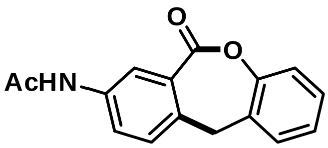


Supplementary Figure 79 ^{1}H NMR and ^{13}C NMR spectra for compound 64



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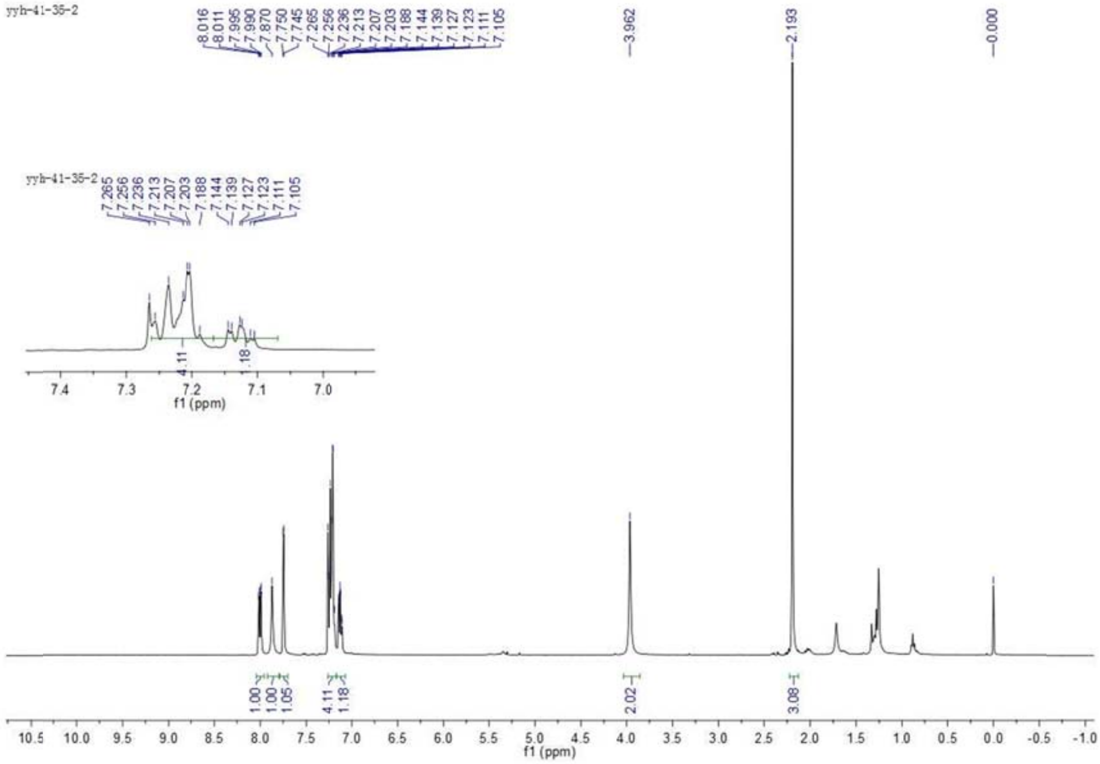
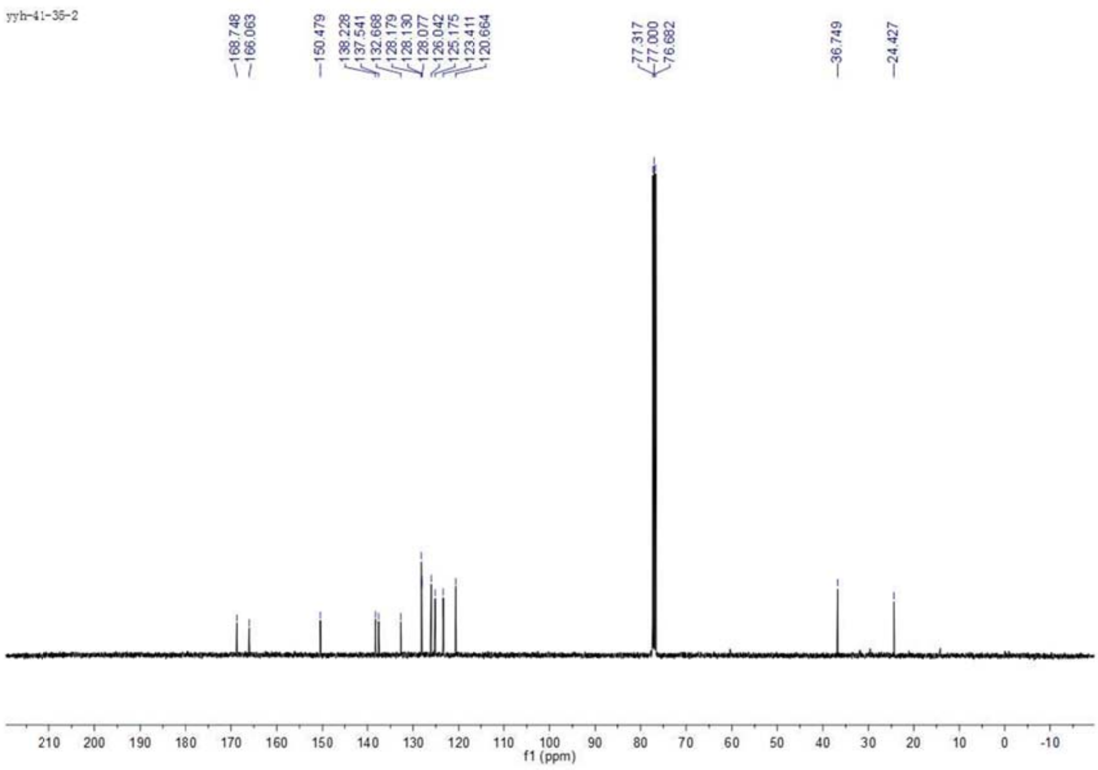
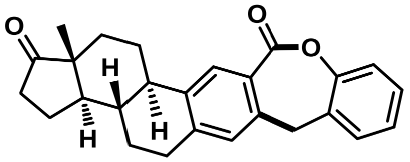




Supplementary Figure 80 ^{1}H NMR and ^{13}C NMR spectra for compound 65



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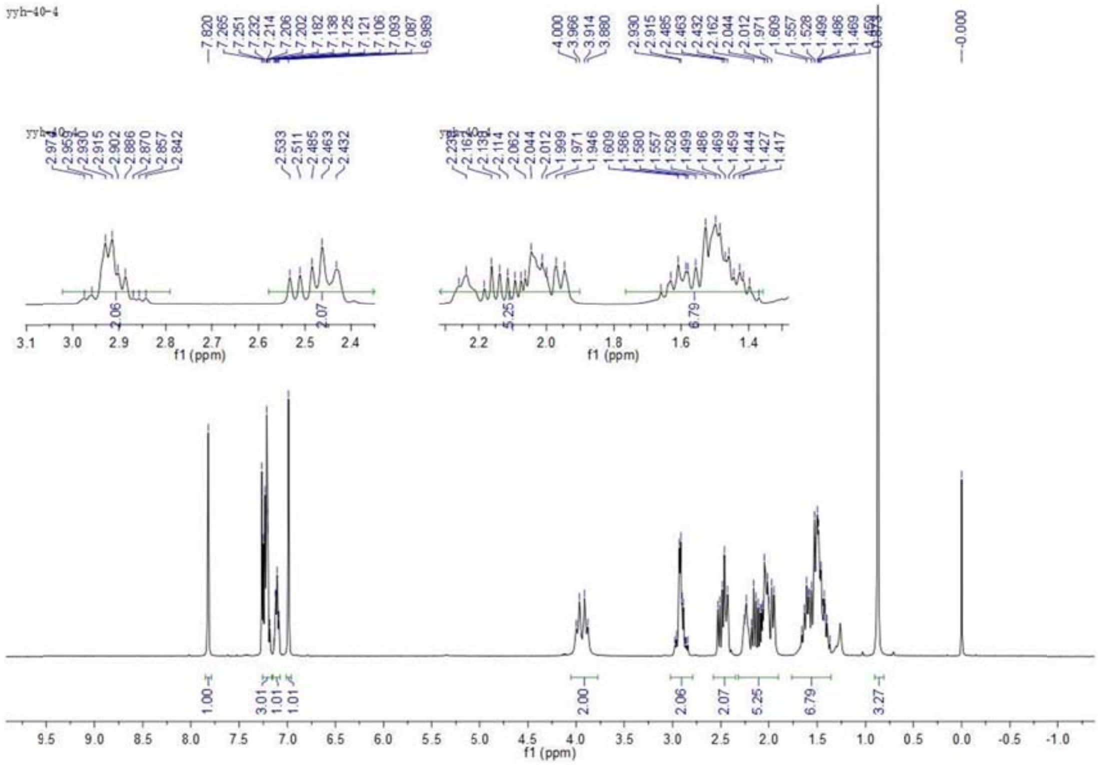
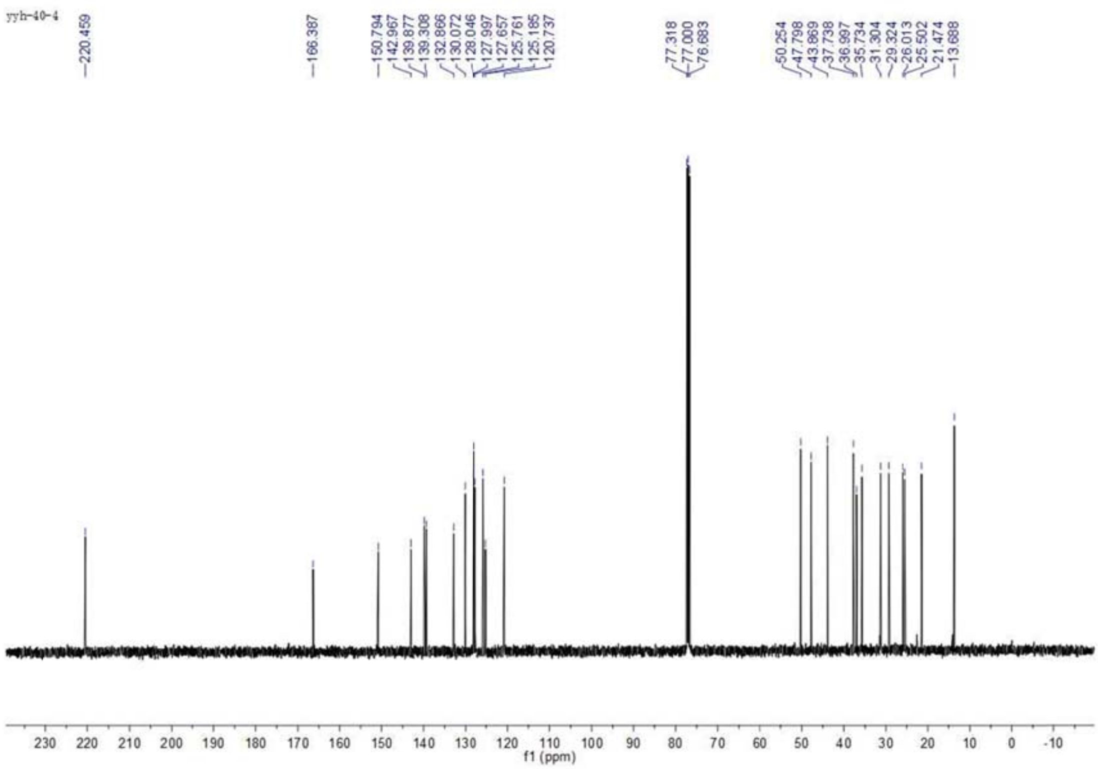
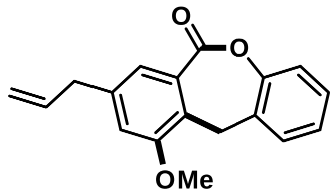




Supplementary Figure 81 ^{1}H NMR and ^{13}C NMR spectra for compound 66



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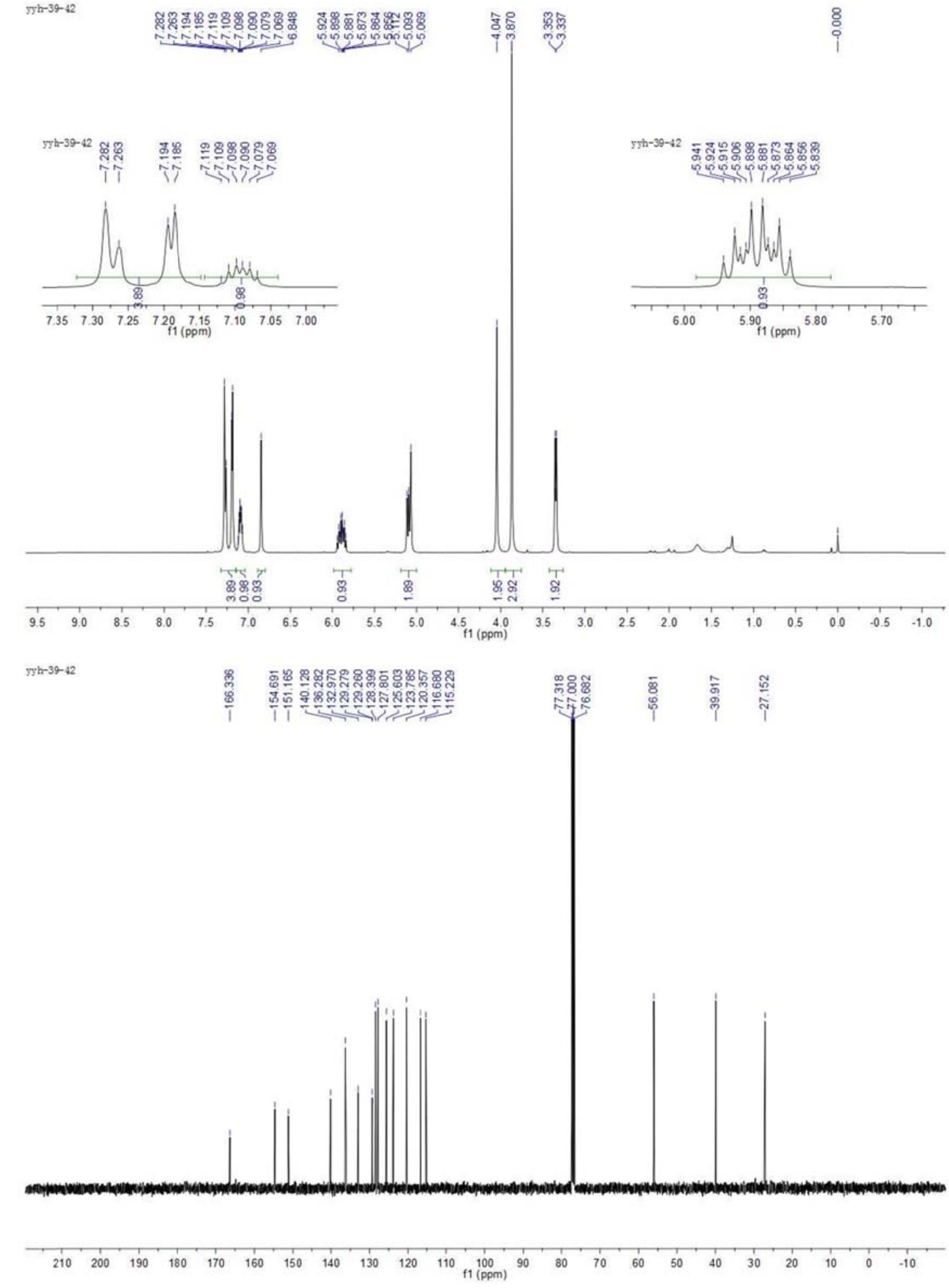
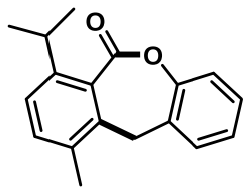


Supplementary Figure 82 ^{1}H NMR and ^{13}C NMR spectra for compound 67



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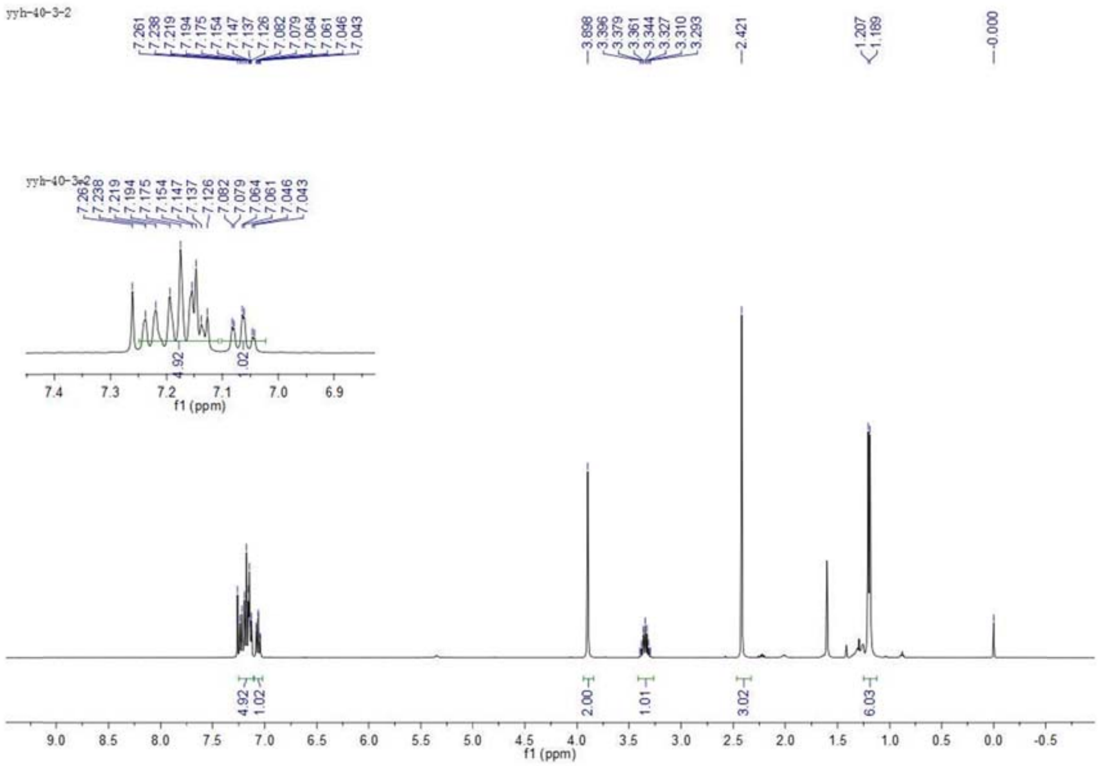
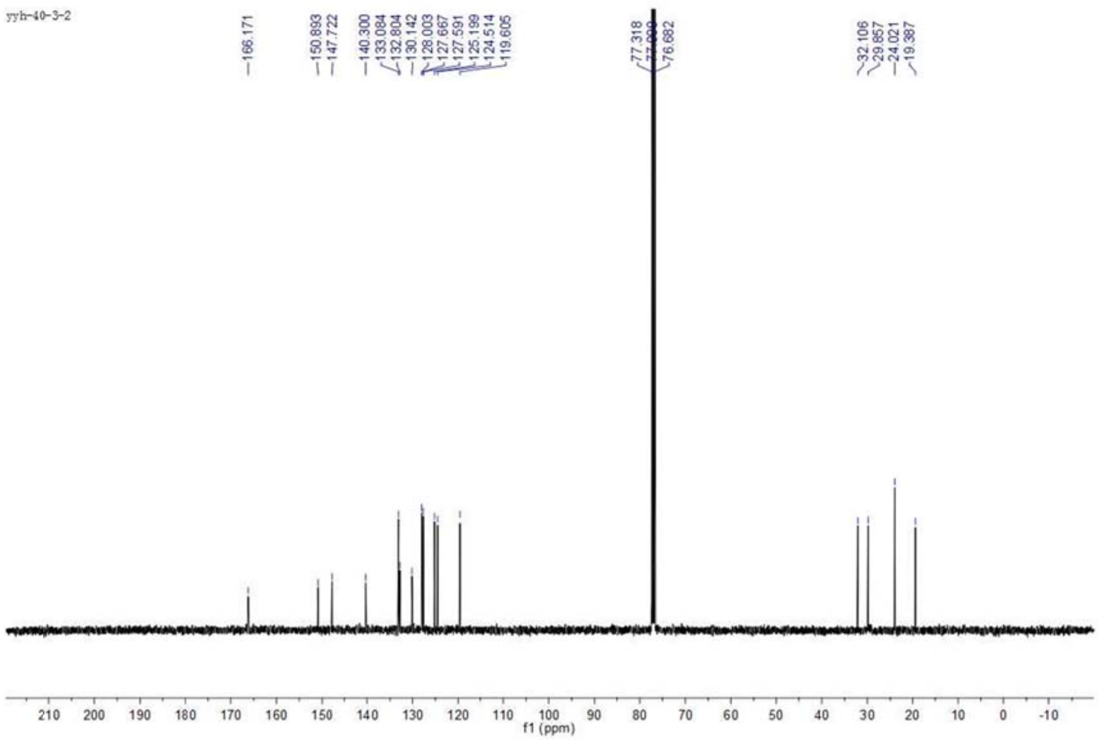
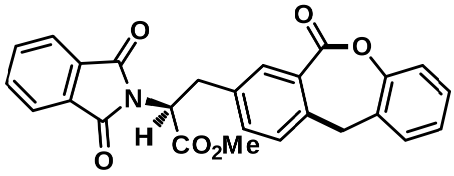




Supplementary Figure 83 ^{1}H NMR and ^{13}C NMR spectra for compound 68



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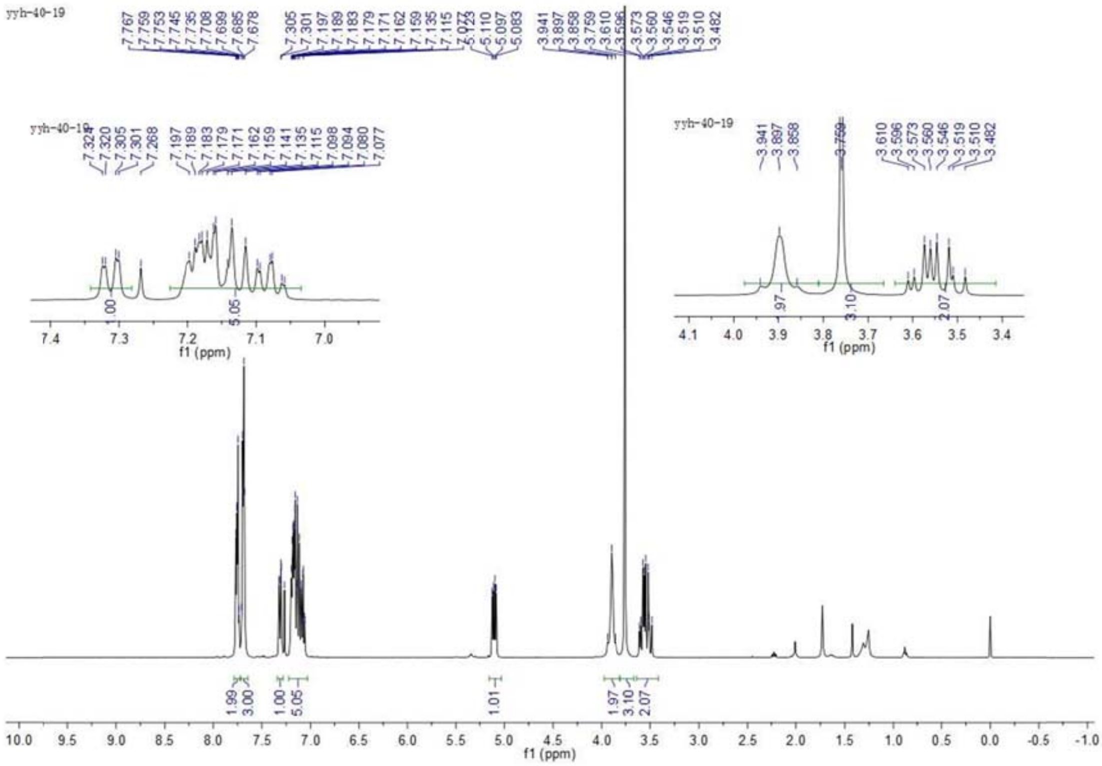
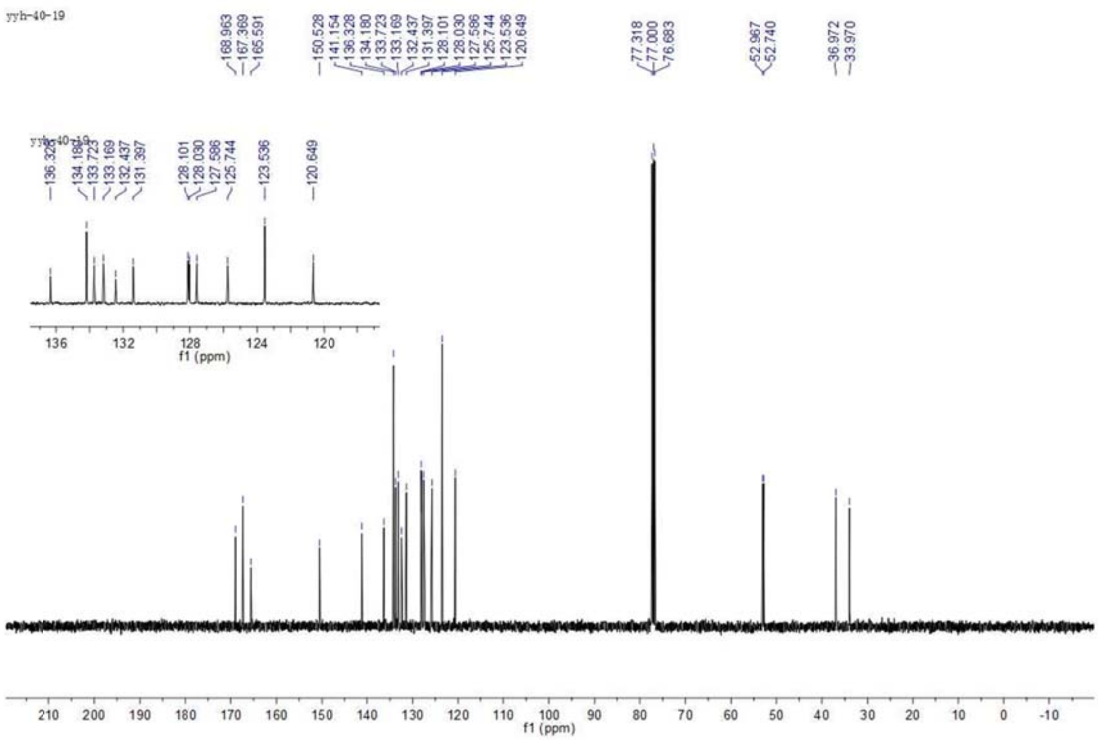
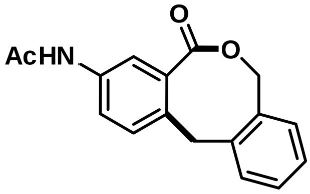




Supplementary Figure 84 ^{1}H NMR and ^{13}C NMR spectra for compound 69



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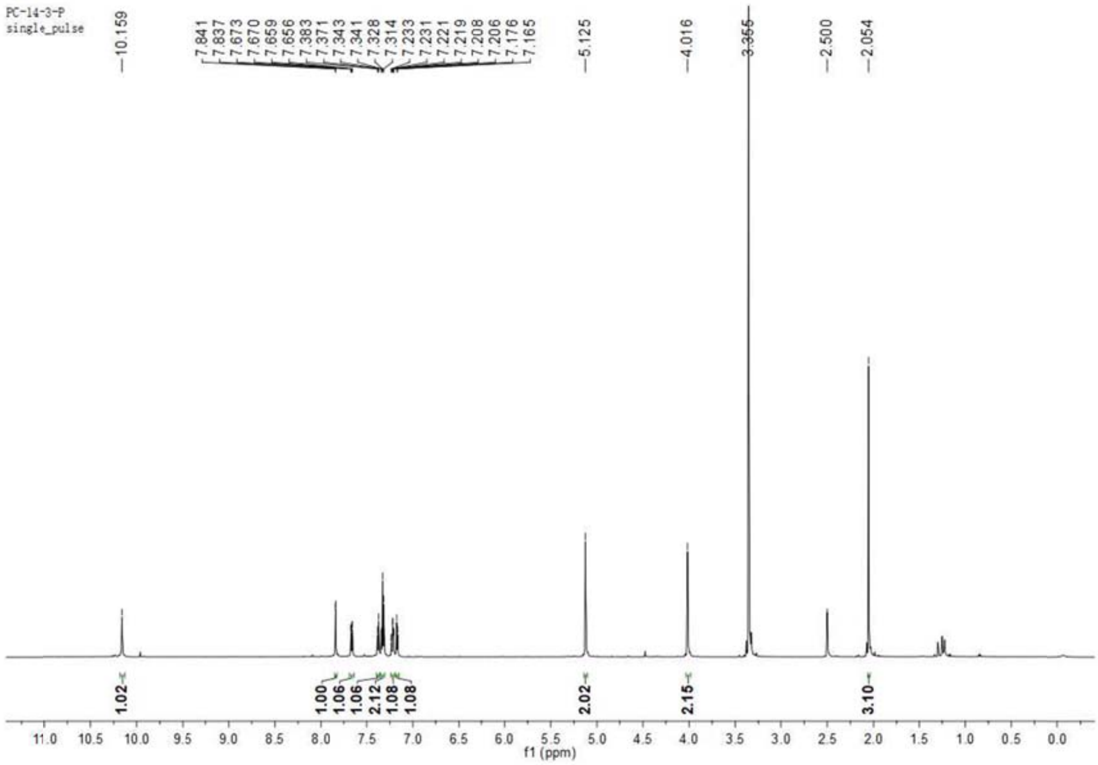
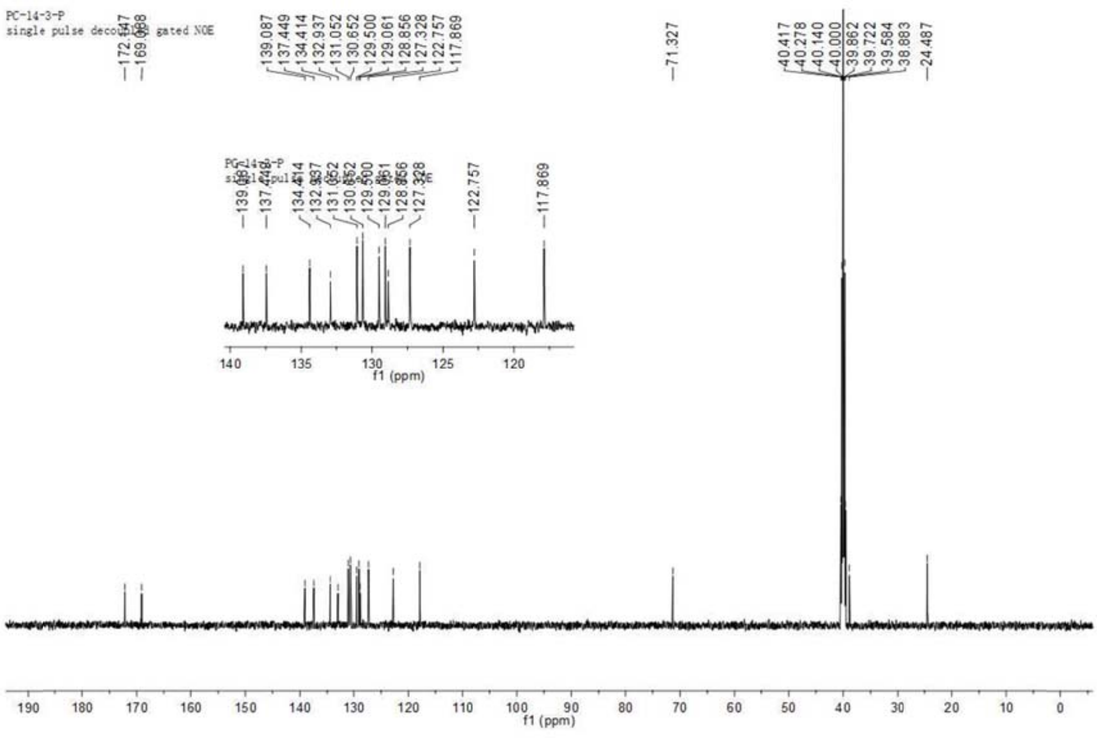
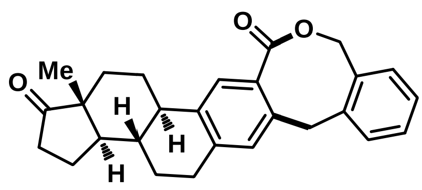




Supplementary Figure 85 ^{1}H NMR and ^{13}C NMR spectra for compound 70



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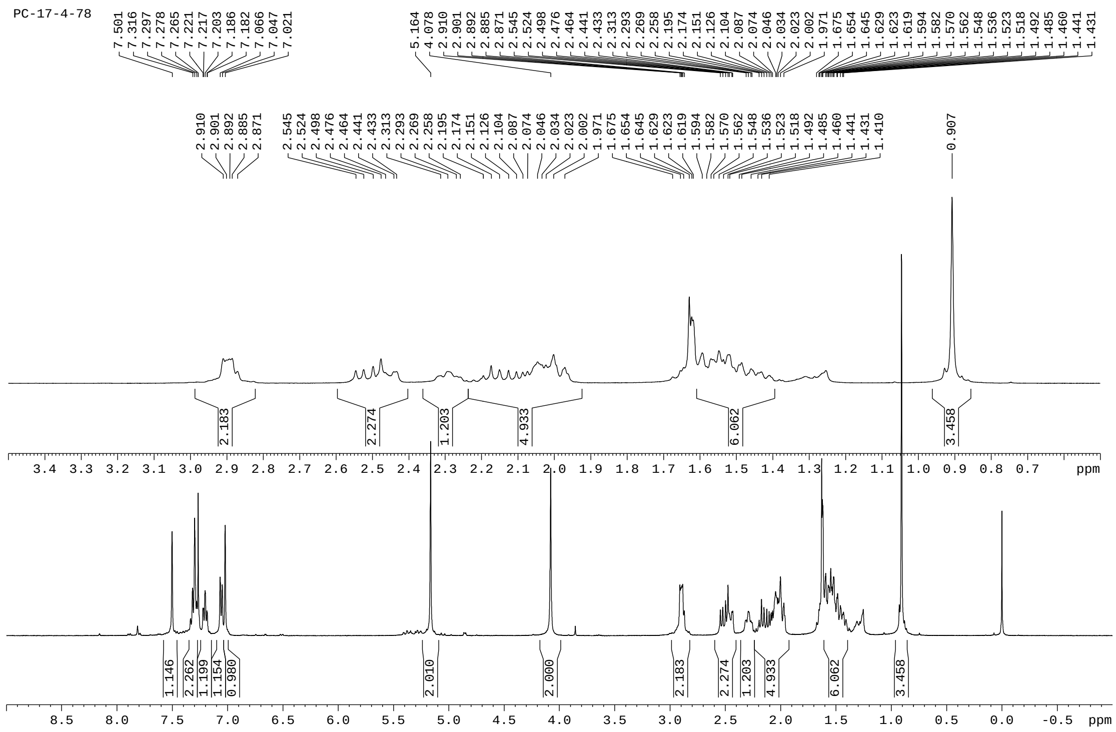
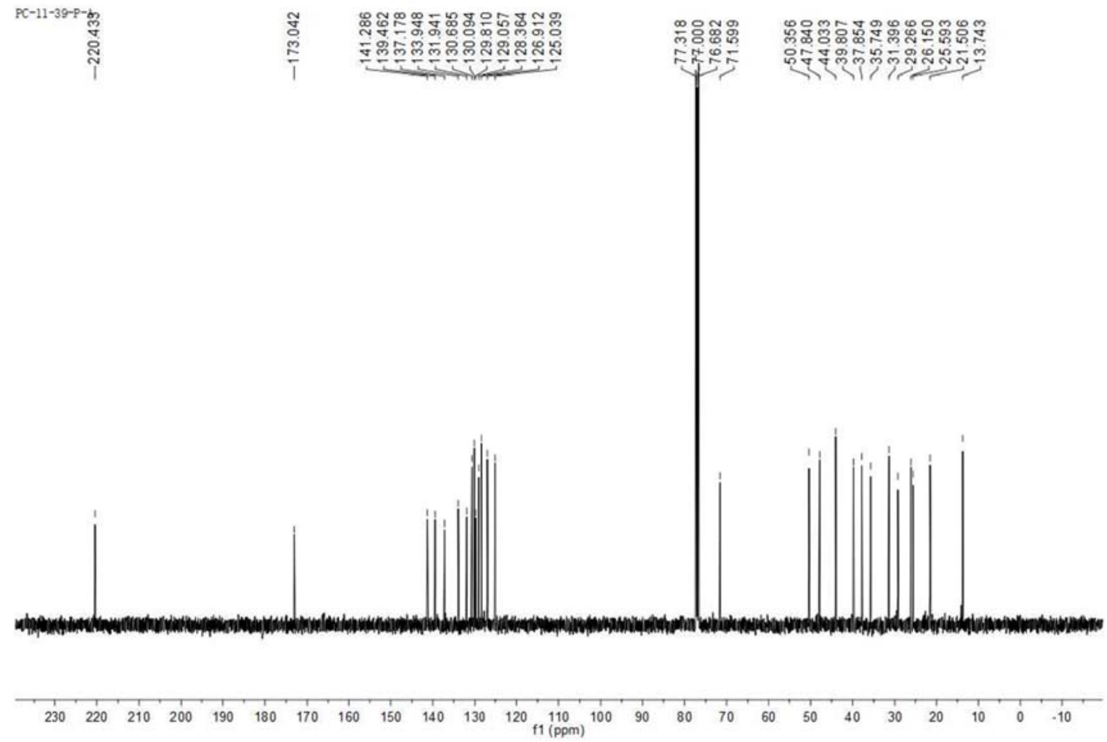
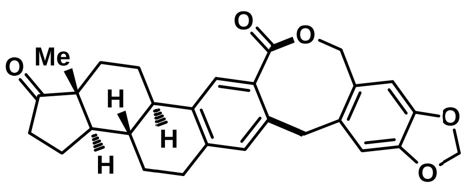




Supplementary Figure 86 ^{1}H NMR and ^{13}C NMR spectra for compound 71



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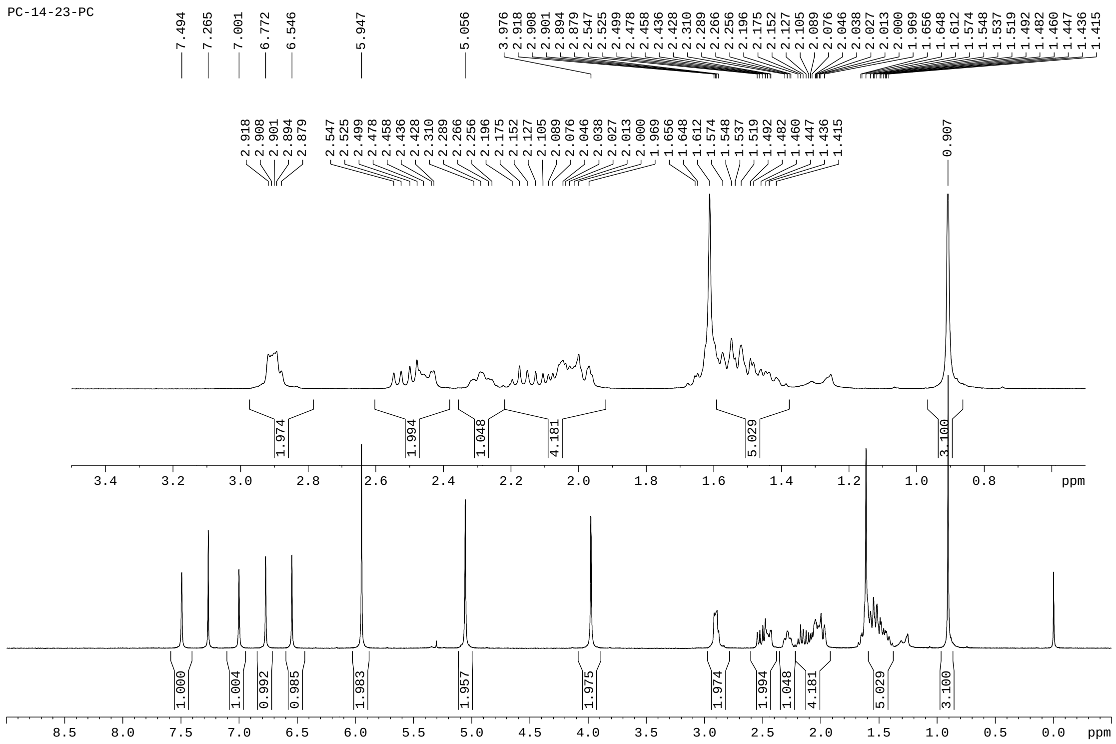
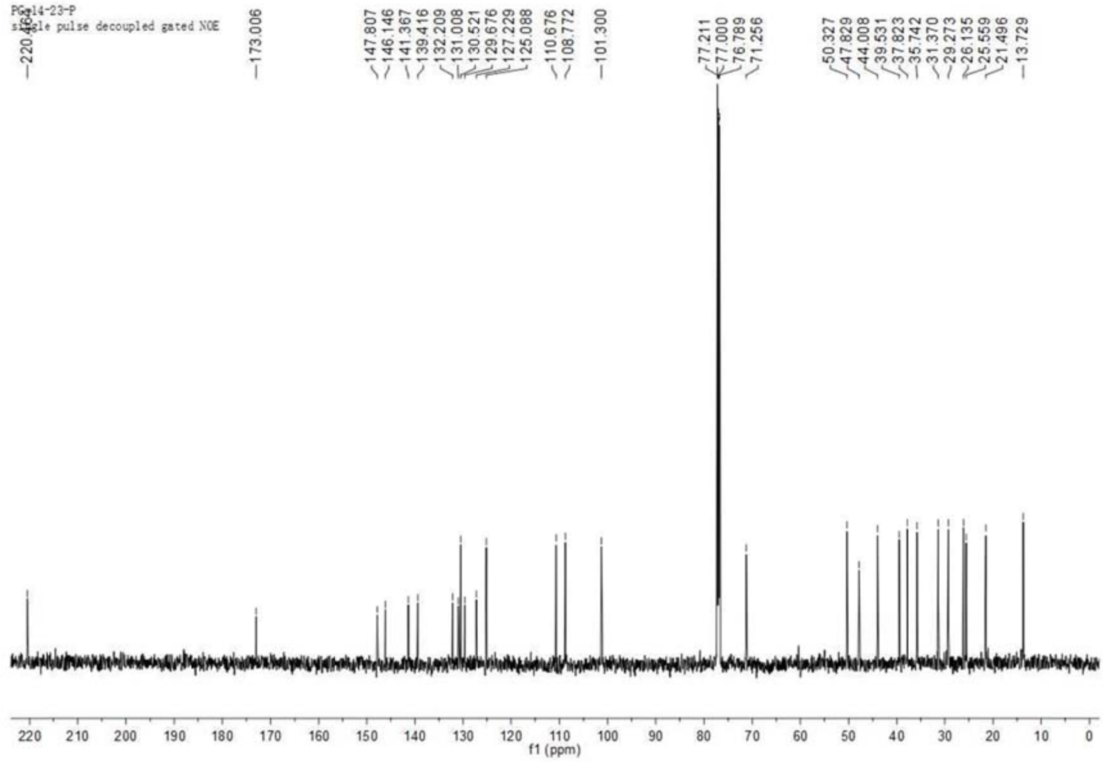
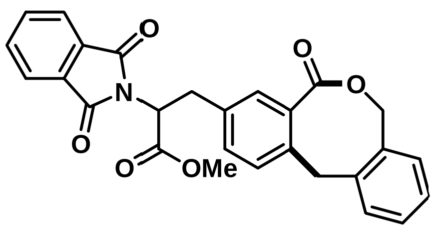




Supplementary Figure 87 ^{1}H NMR and ^{13}C NMR spectra for compound 72



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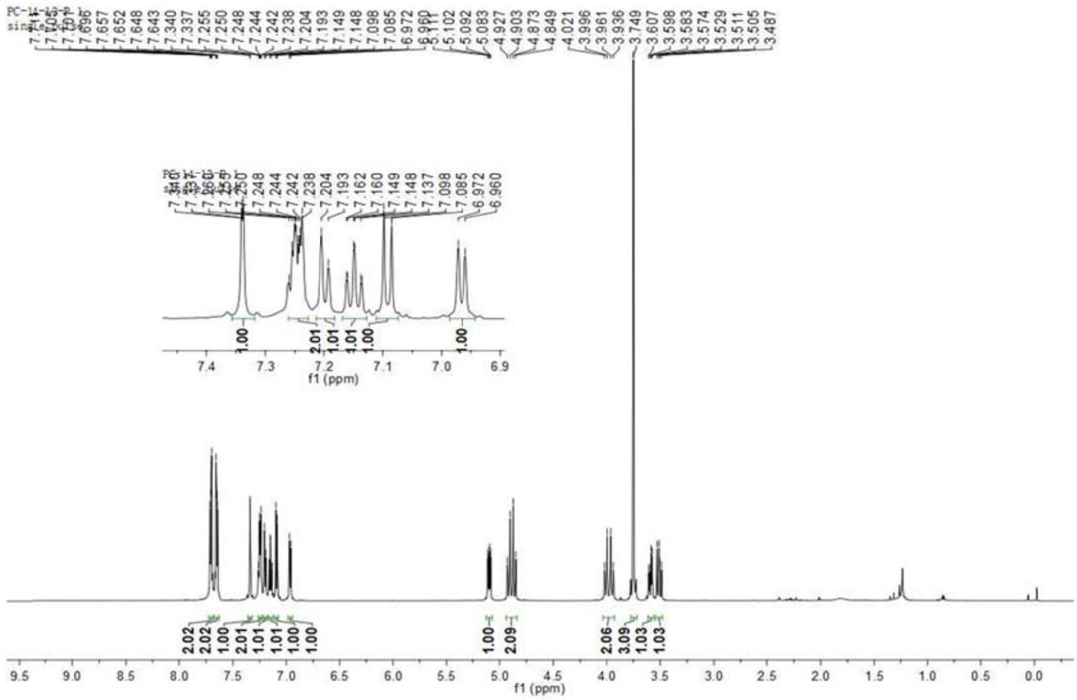
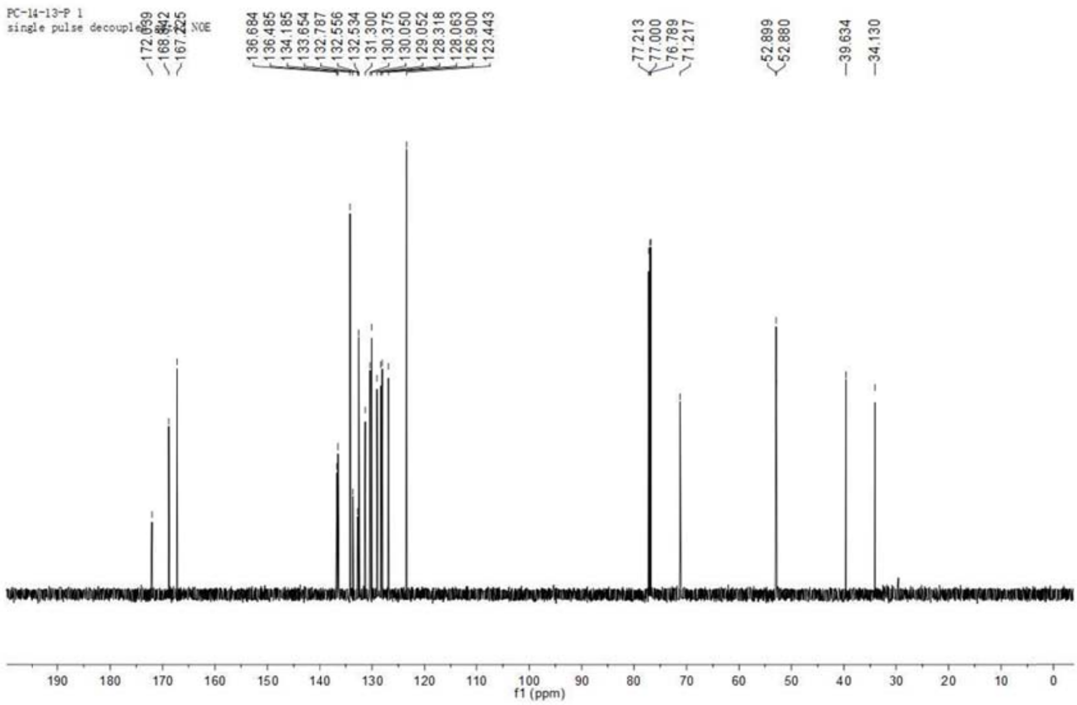
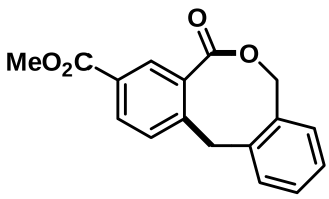




Supplementary Figure 88 ^{1}H NMR and ^{13}C NMR spectra for compound 73



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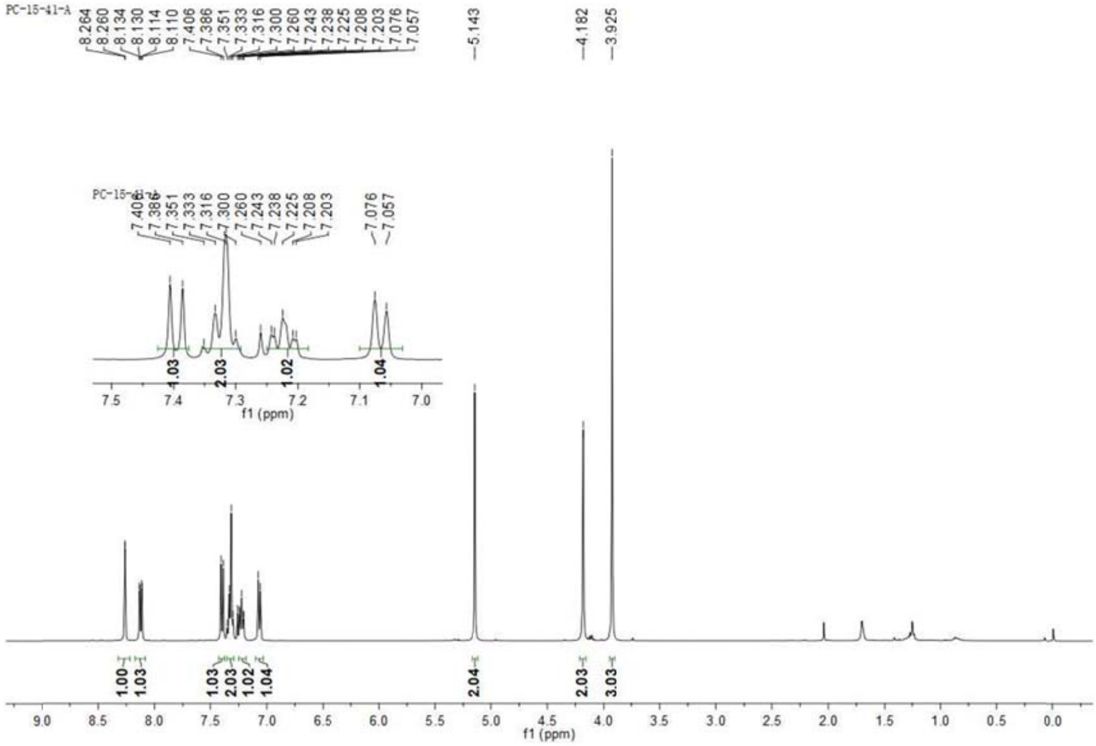
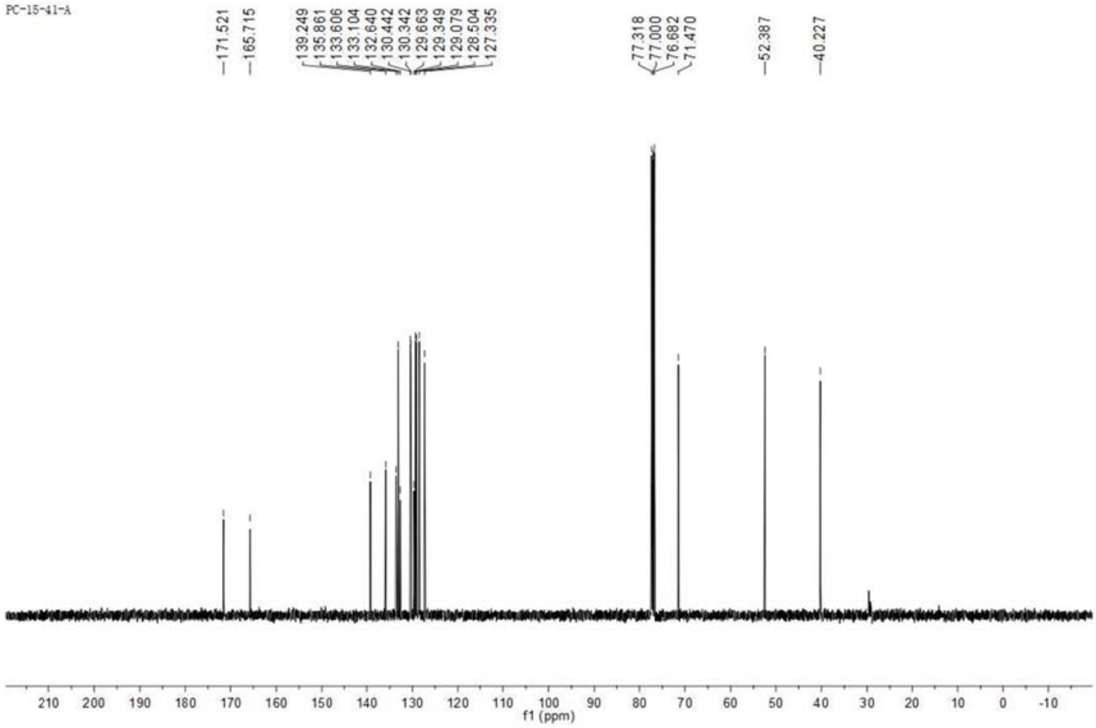
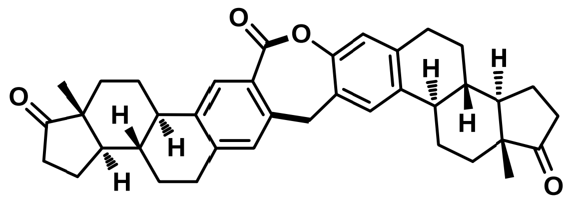




Supplementary Figure 89 ^{1}H NMR and ^{13}C NMR spectra for compound 74



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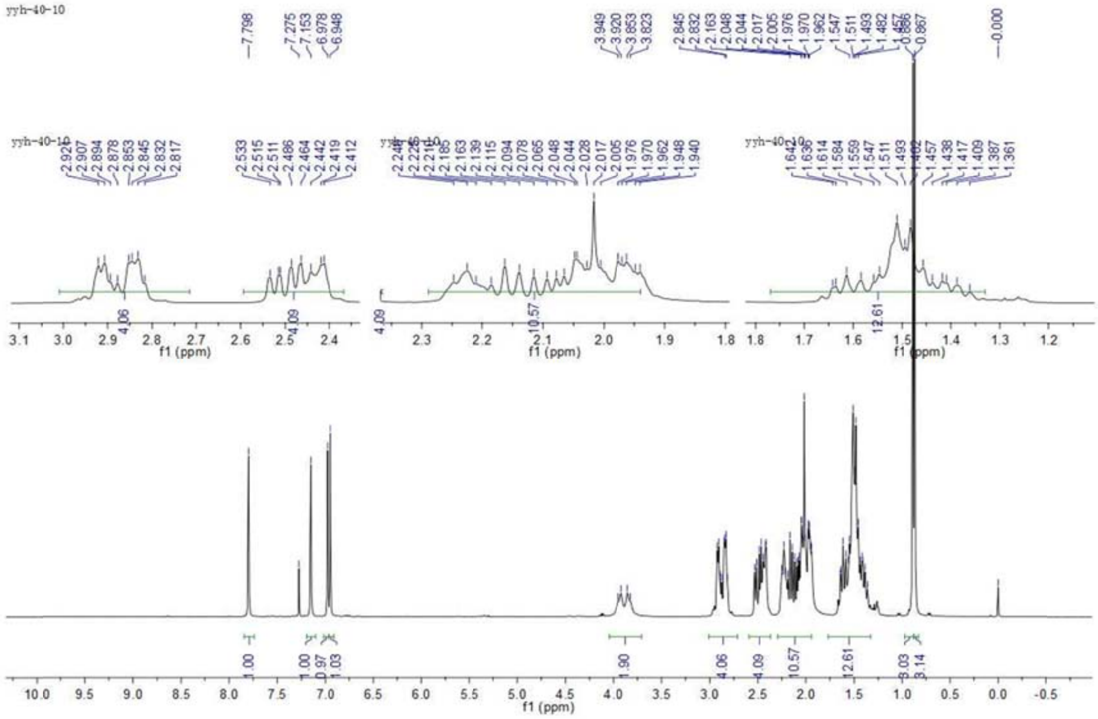
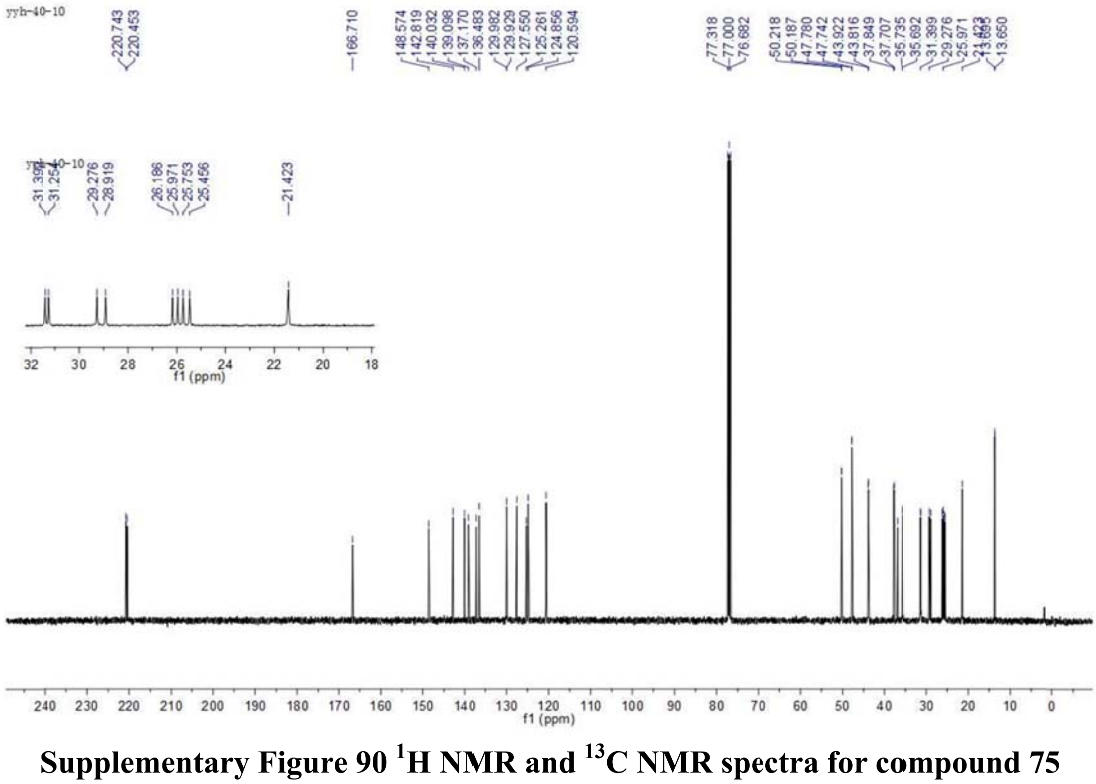
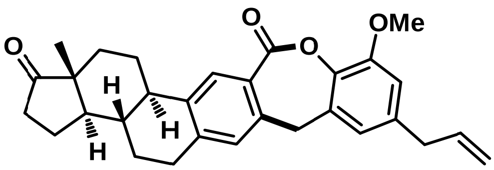




Supplementary Figure 90 ^{1}H NMR and ^{13}C NMR spectra for compound 75



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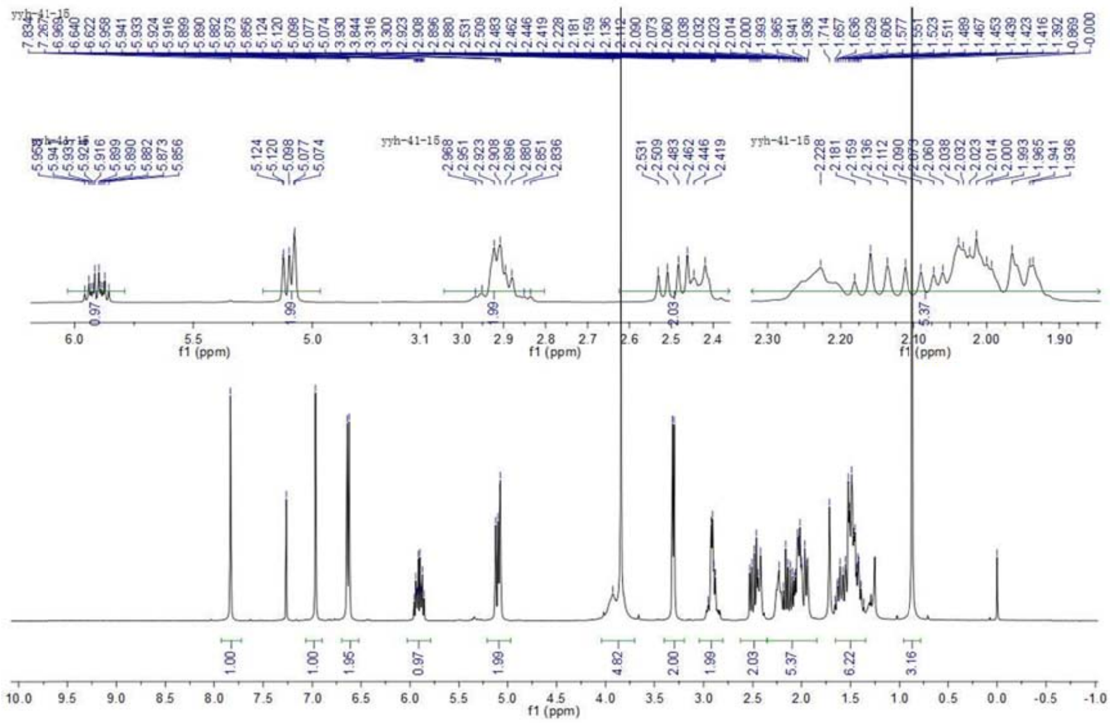
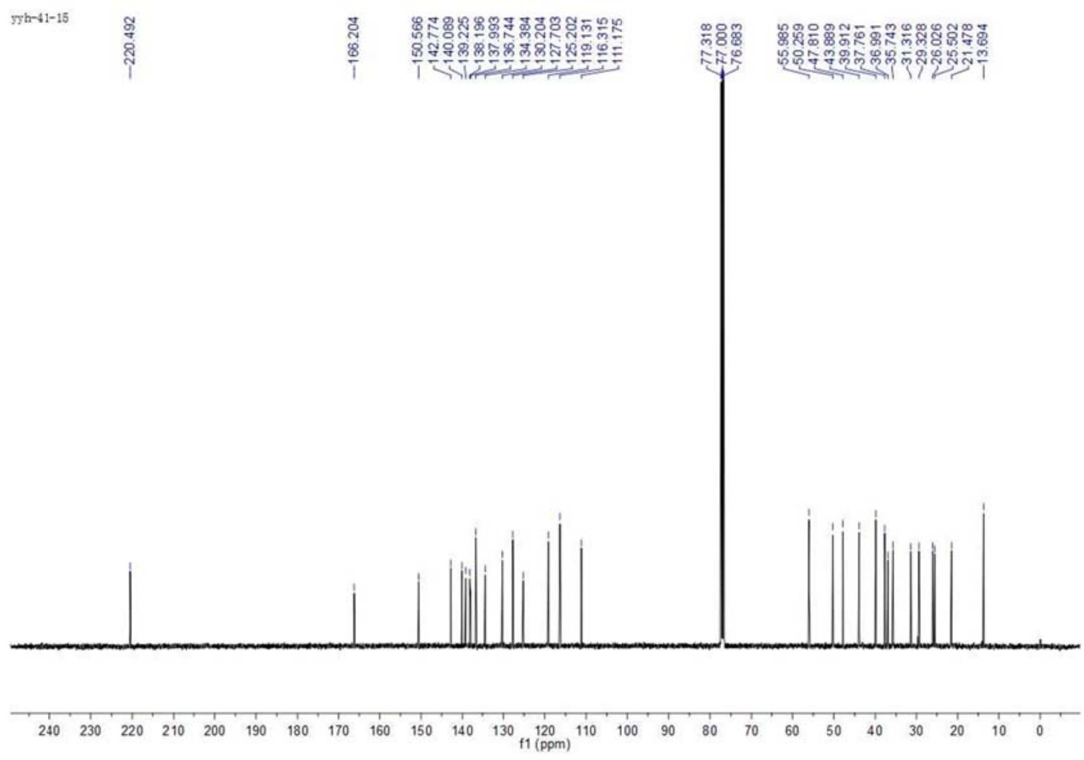
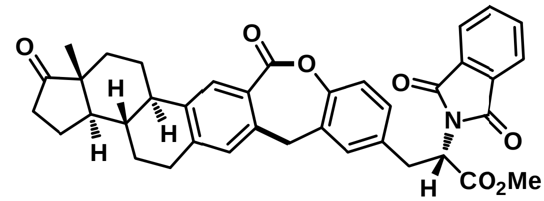




Supplementary Figure 91 ^{1}H NMR and ^{13}C NMR spectra for compound 76



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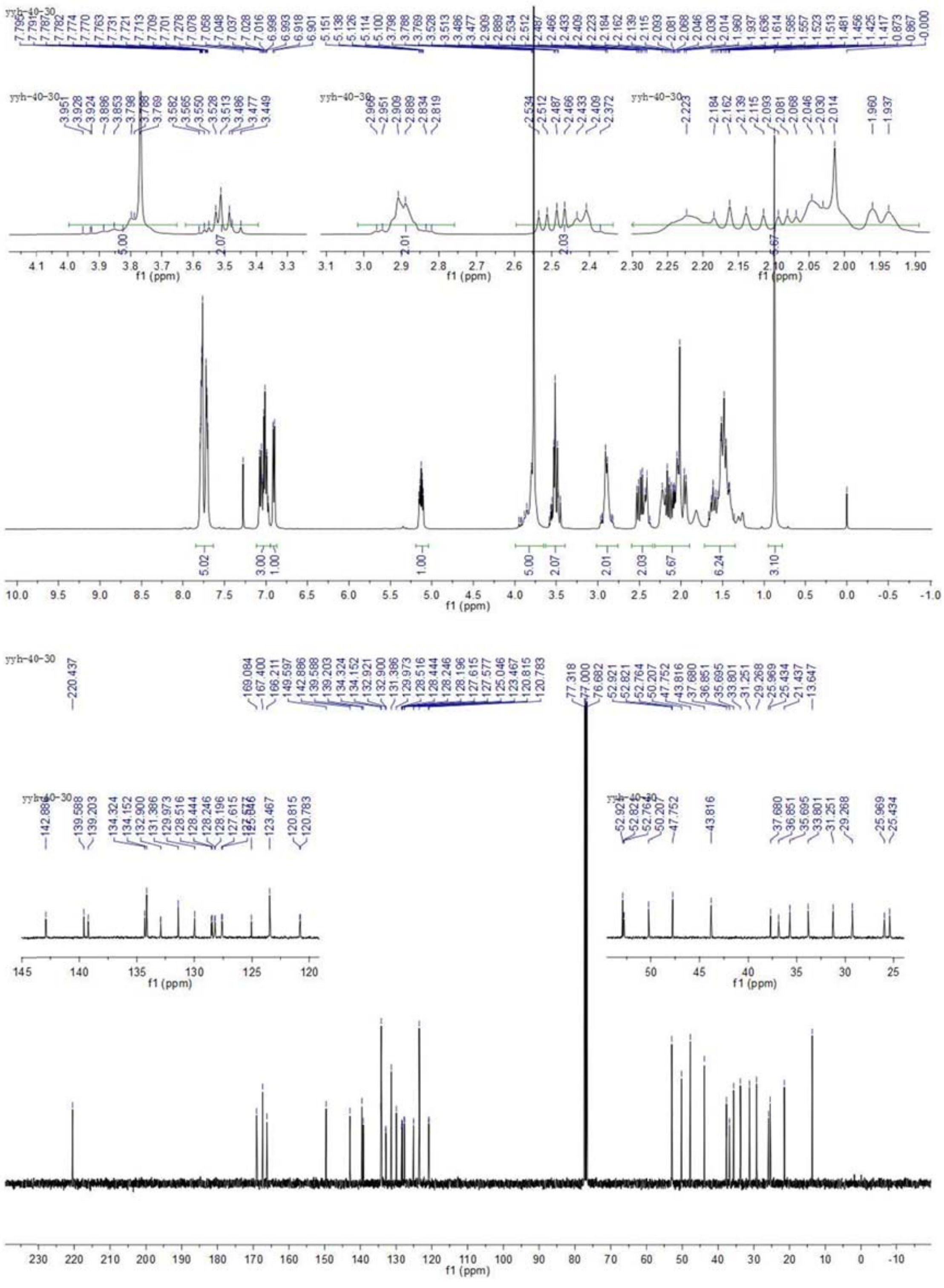
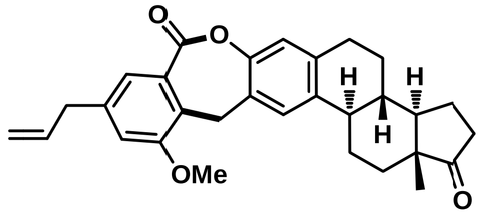


Supplementary Figure 92 ^{1}H NMR and ^{13}C NMR spectra for compound 77



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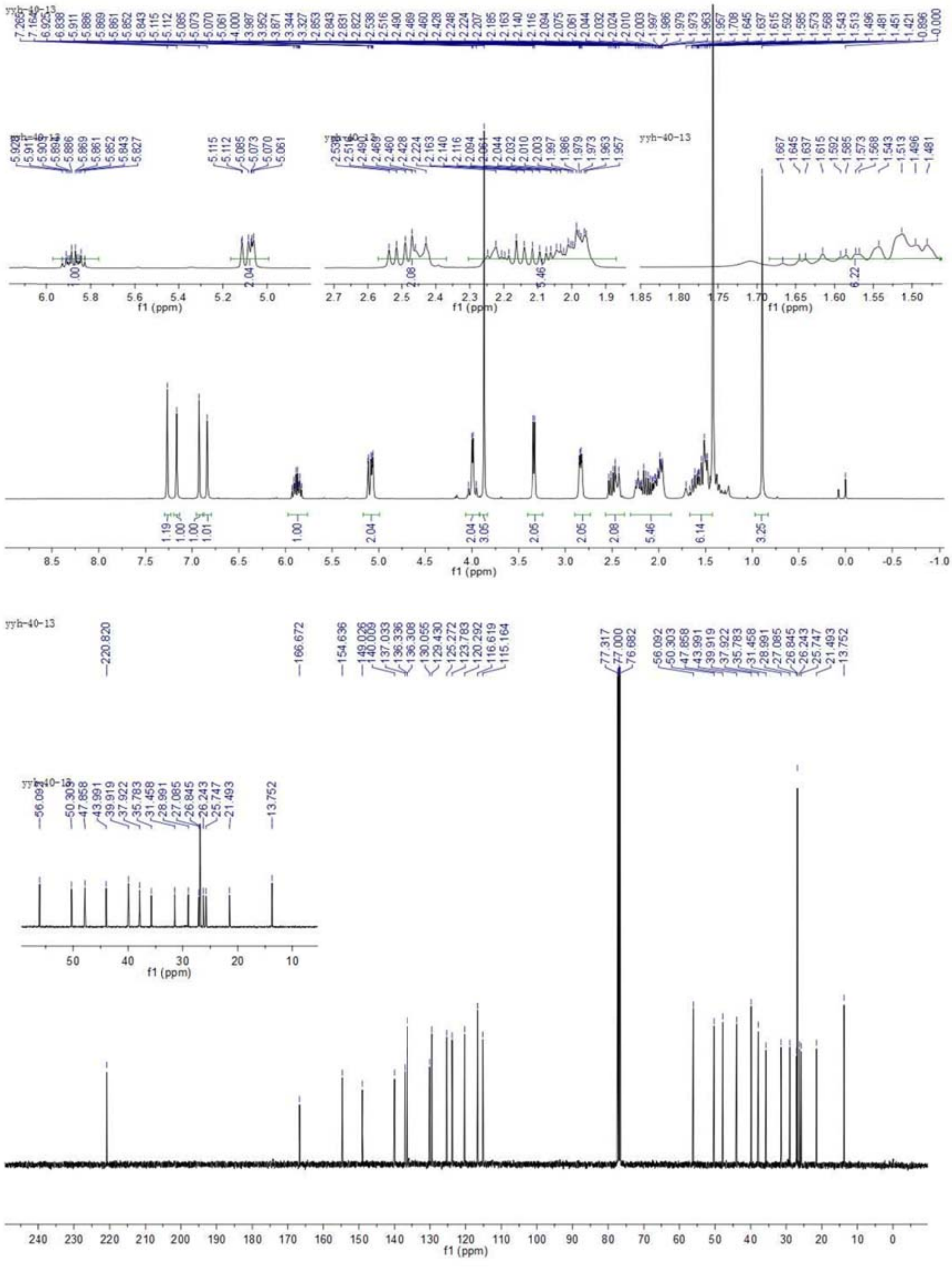
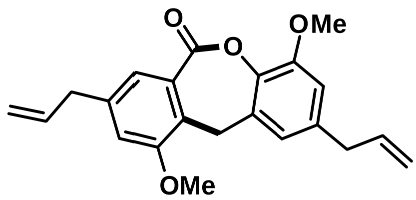


Supplementary Figure 93 ^{1}H NMR and ^{13}C NMR spectra for compound 78



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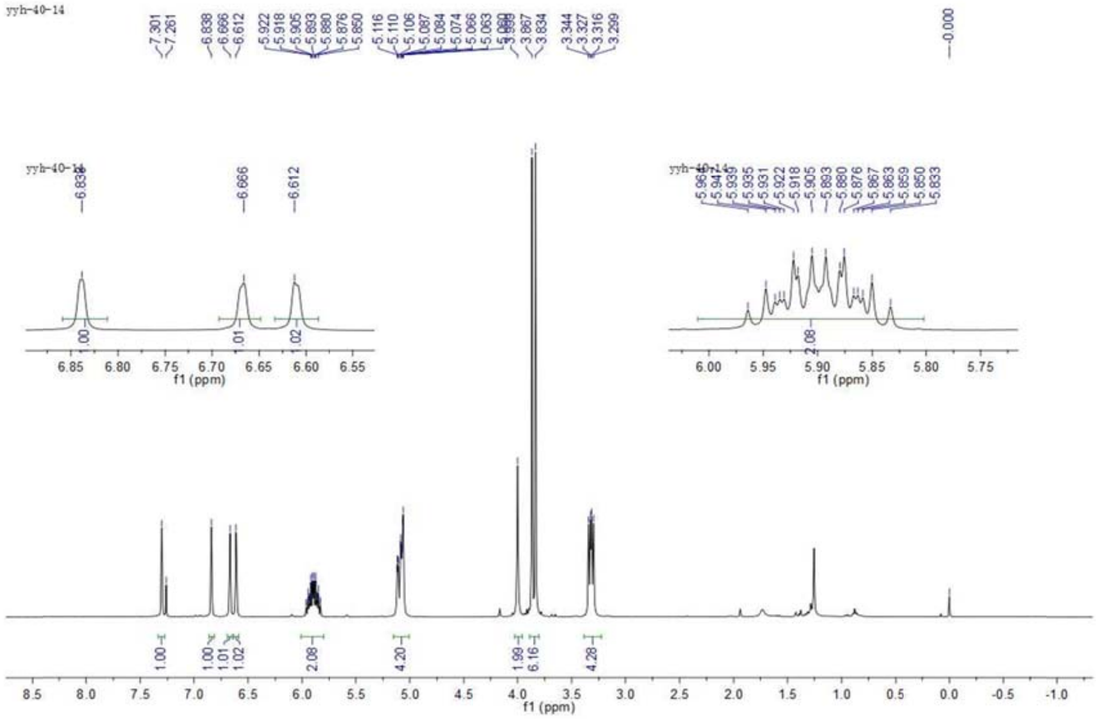
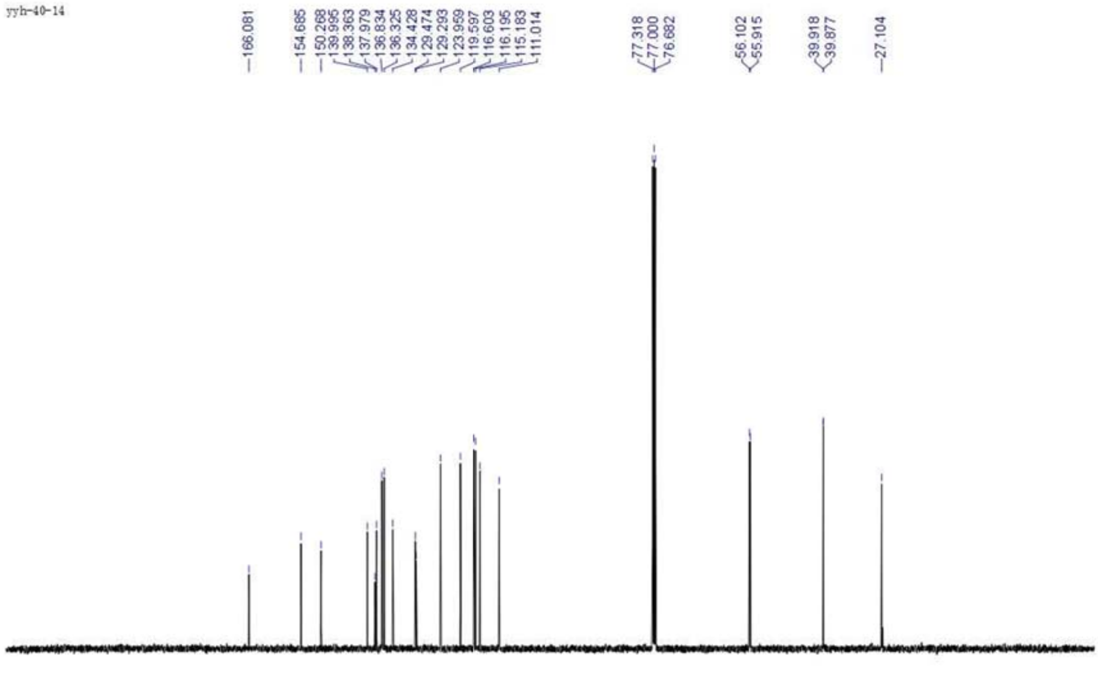
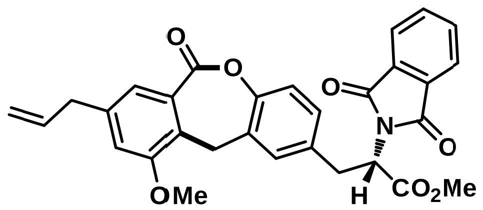




Supplementary Figure 94 ^{1}H NMR and ^{13}C NMR spectra for compound 79



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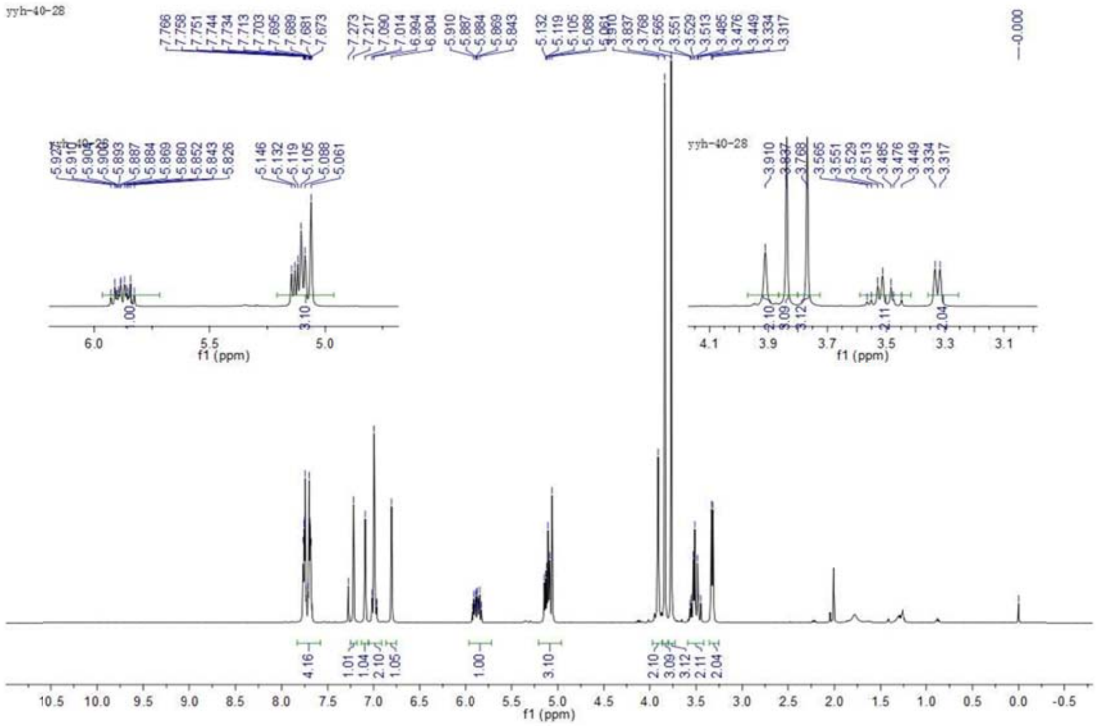
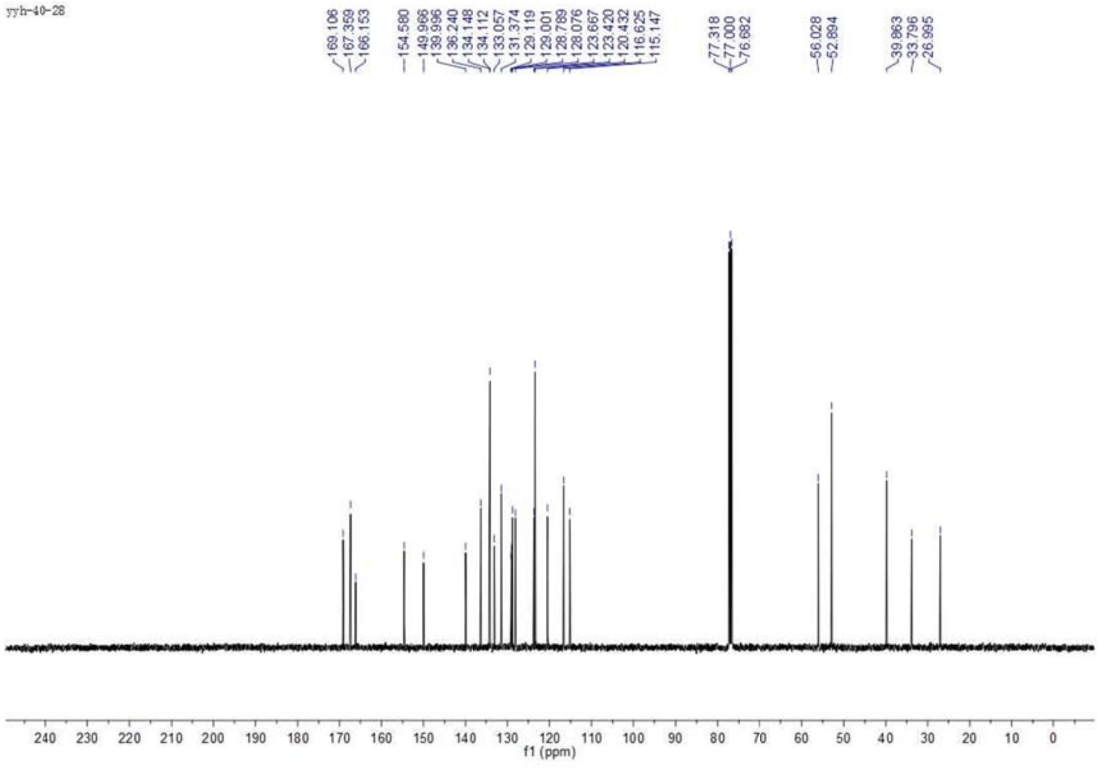
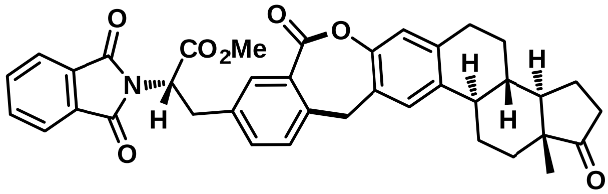




Supplementary Figure 95 ^{1}H NMR and ^{13}C NMR spectra for compound 80



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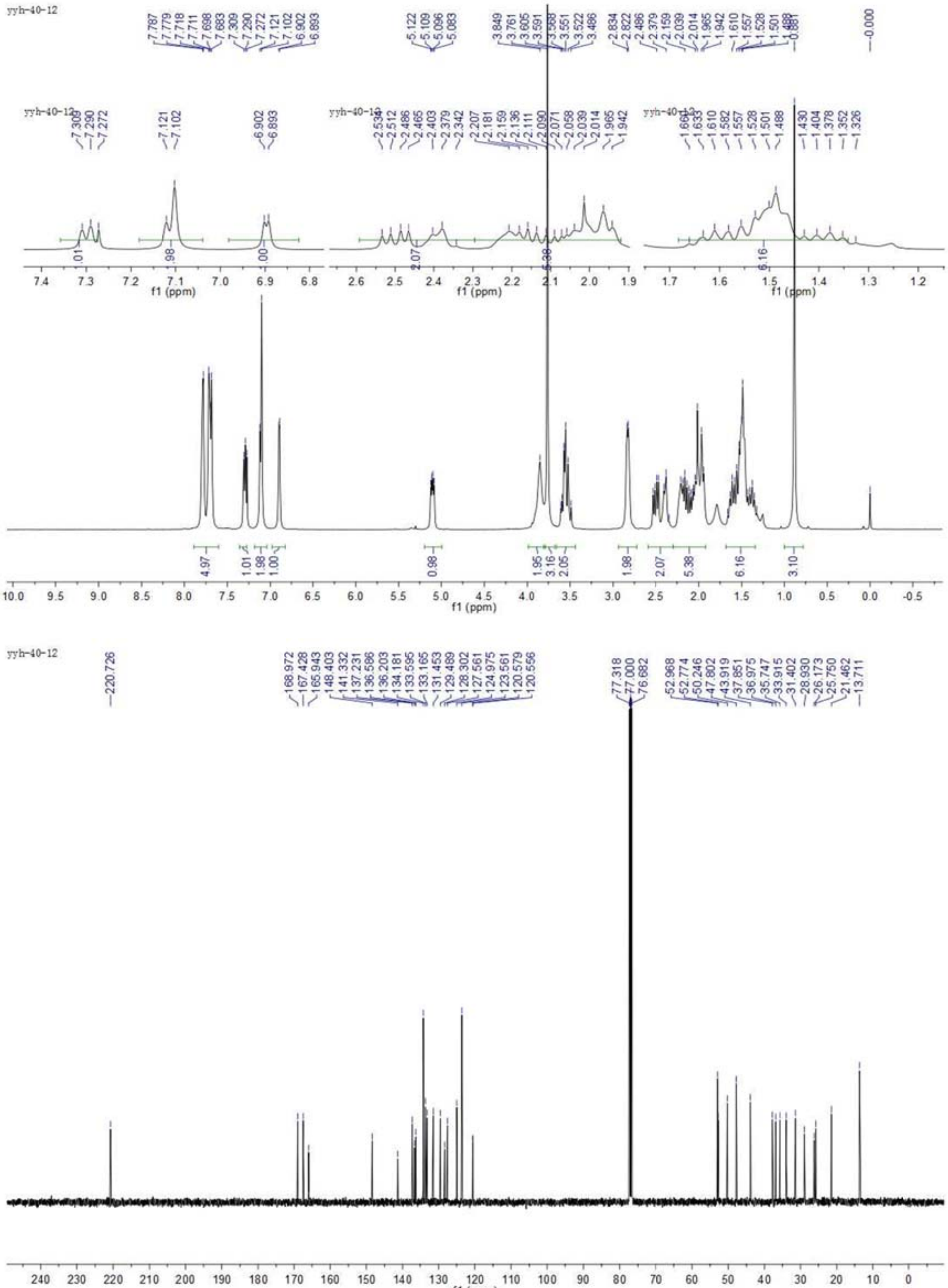
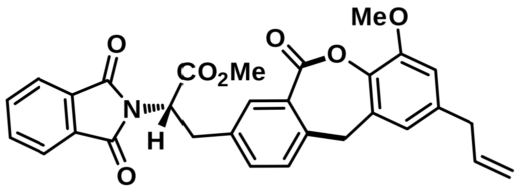


Supplementary Figure 96 ^{1}H NMR and ^{13}C NMR spectra for compound 81



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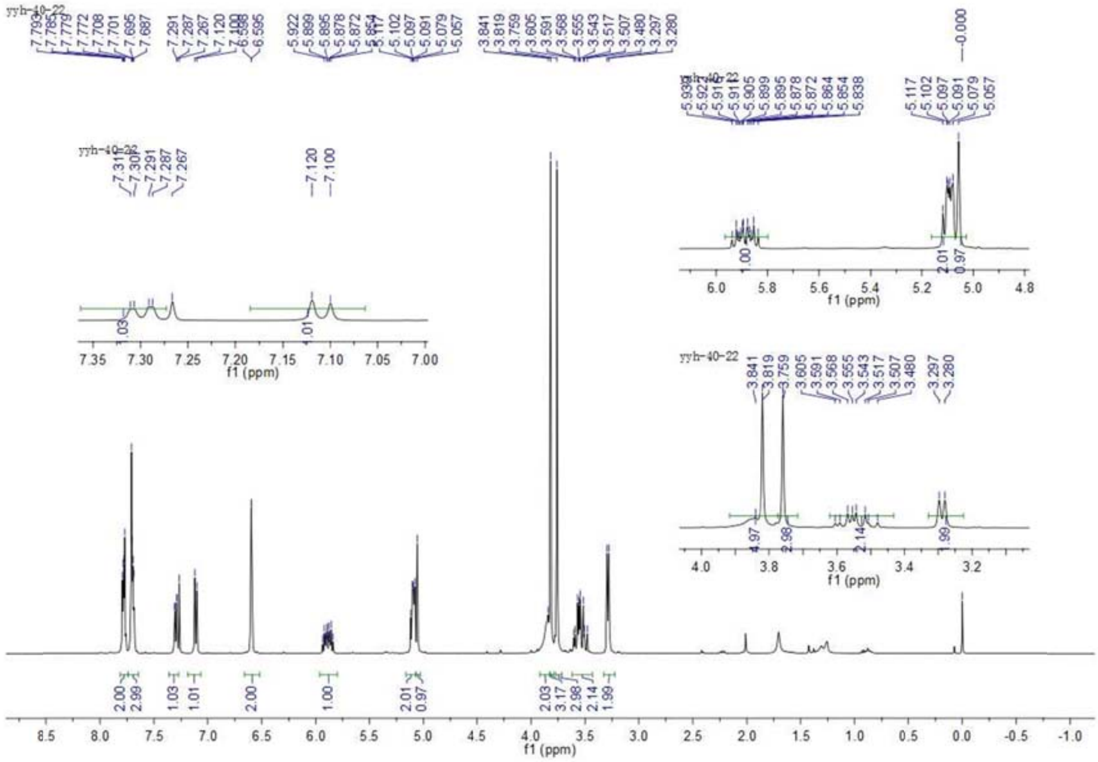
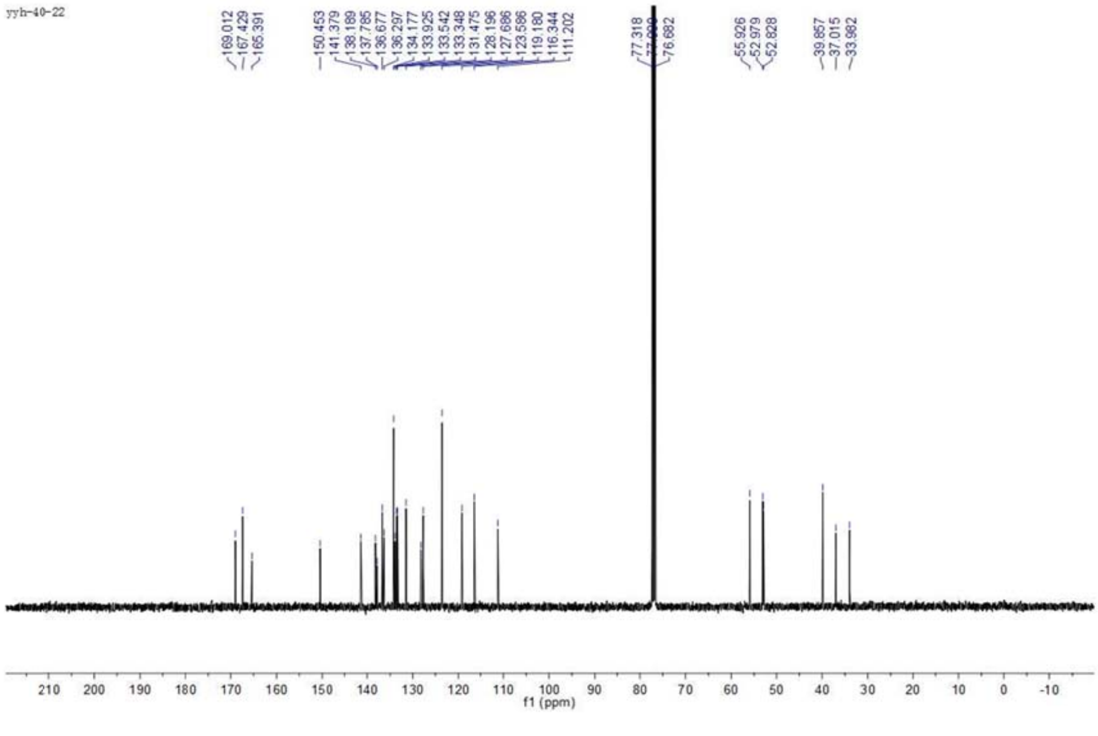
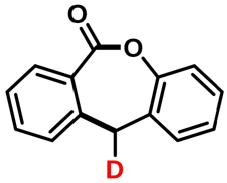
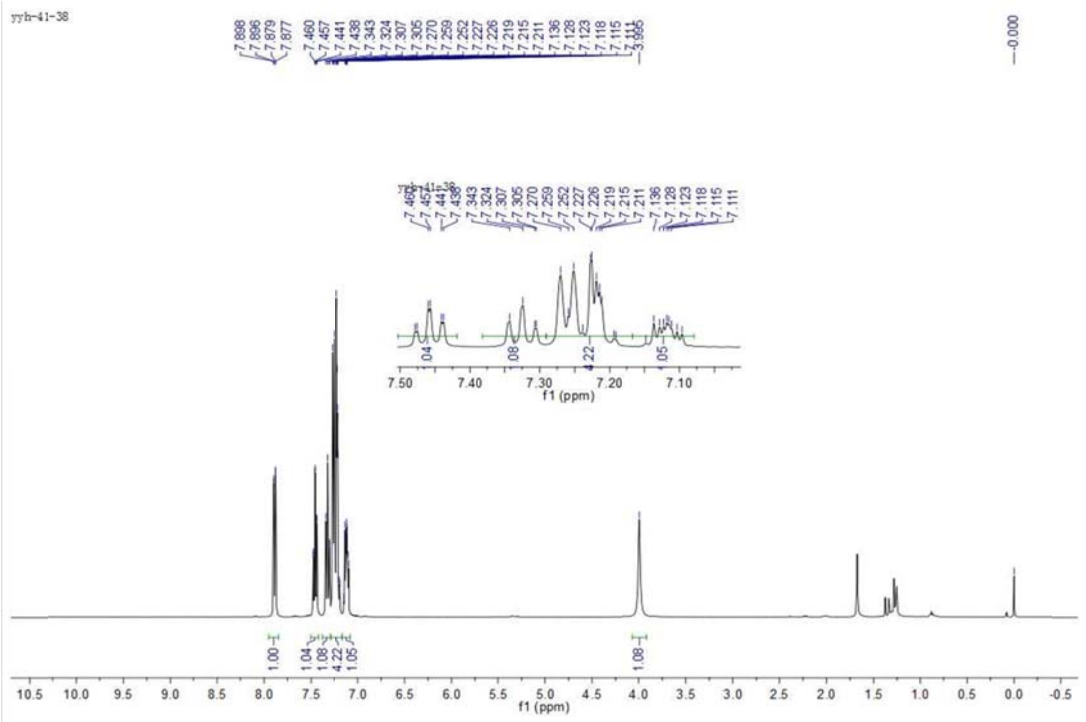


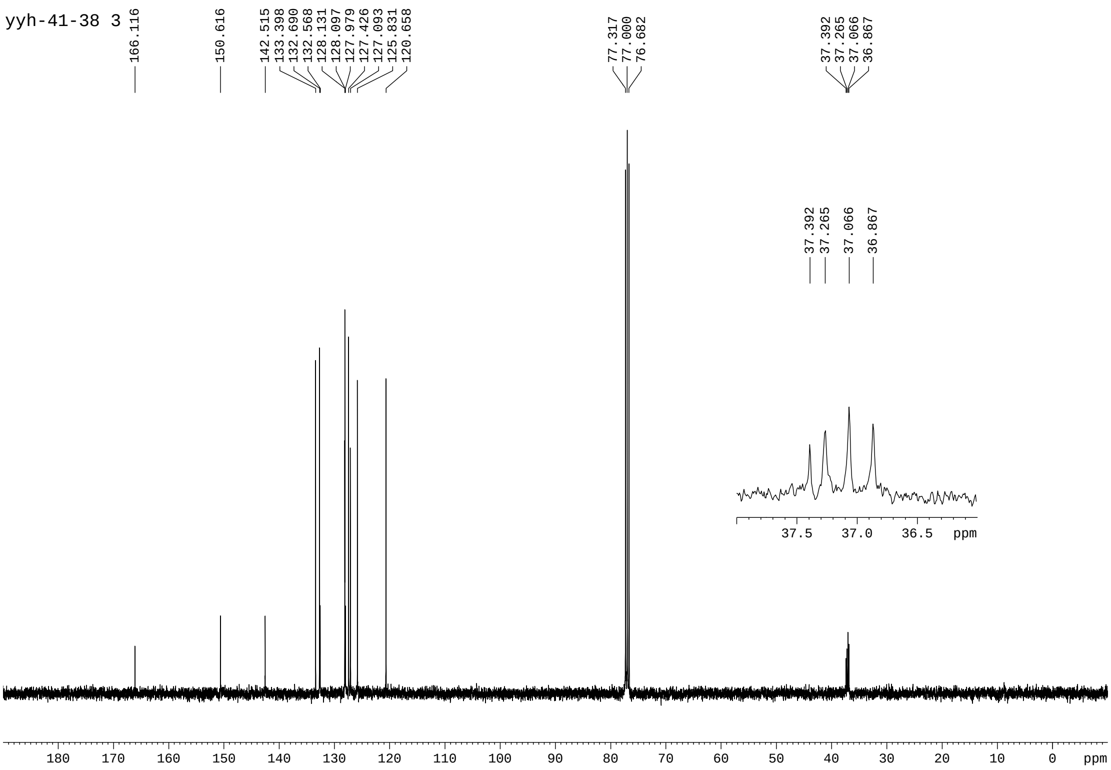


Supplementary Figure 97 ^{1}H NMR and ^{13}C NMR spectra for compound 82

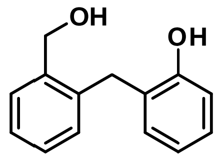


[D]-3





Supplementary Figure 98 ^{1}H NMR and ^{13}C NMR spectra for compound [D]-3



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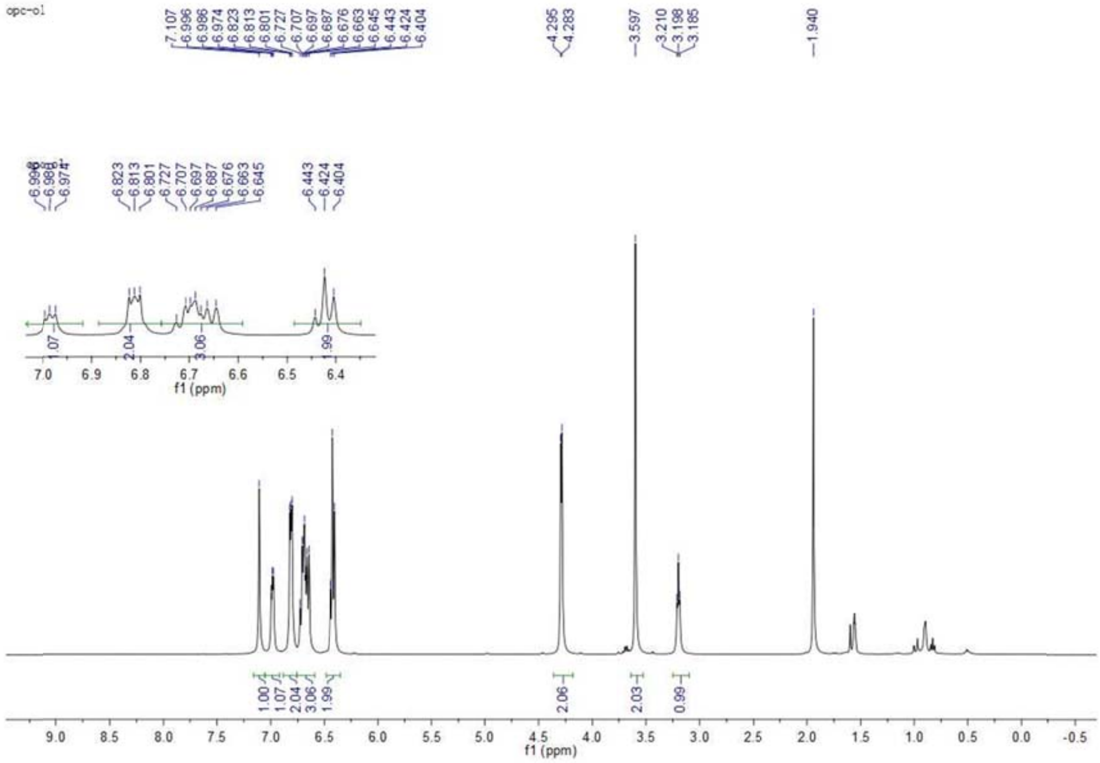
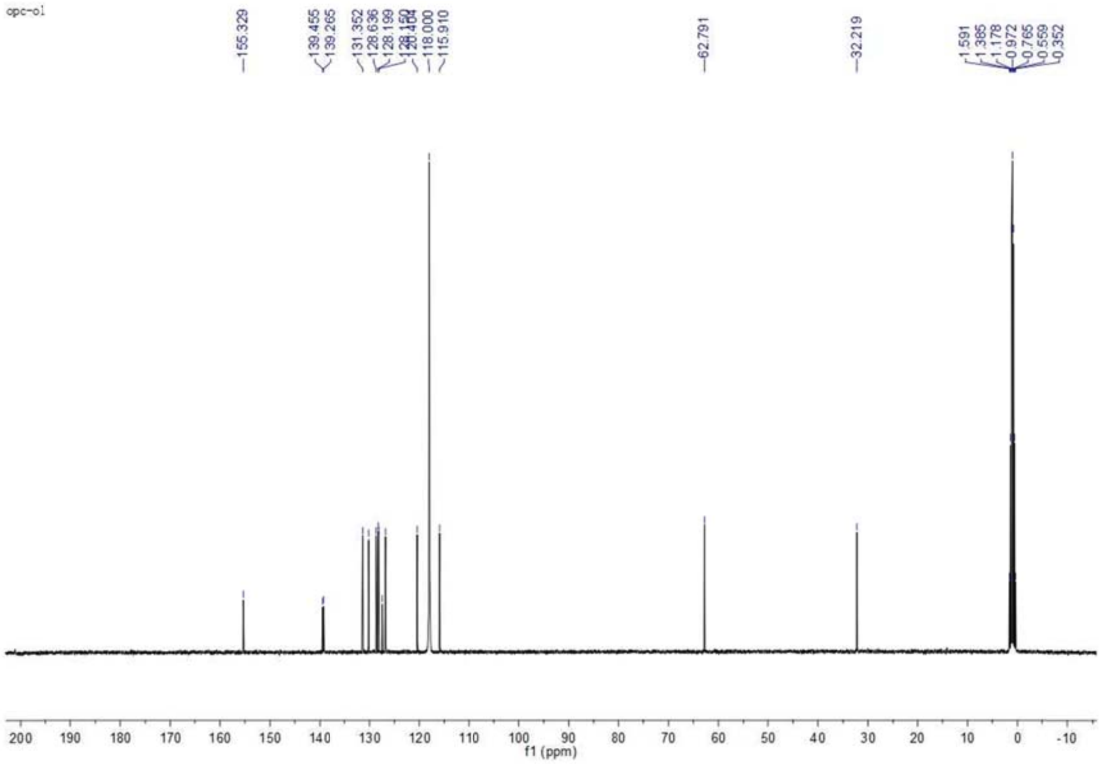
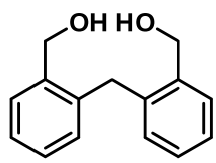




Supplementary Figure 99 ^{1}H NMR and ^{13}C NMR spectra for compound 83



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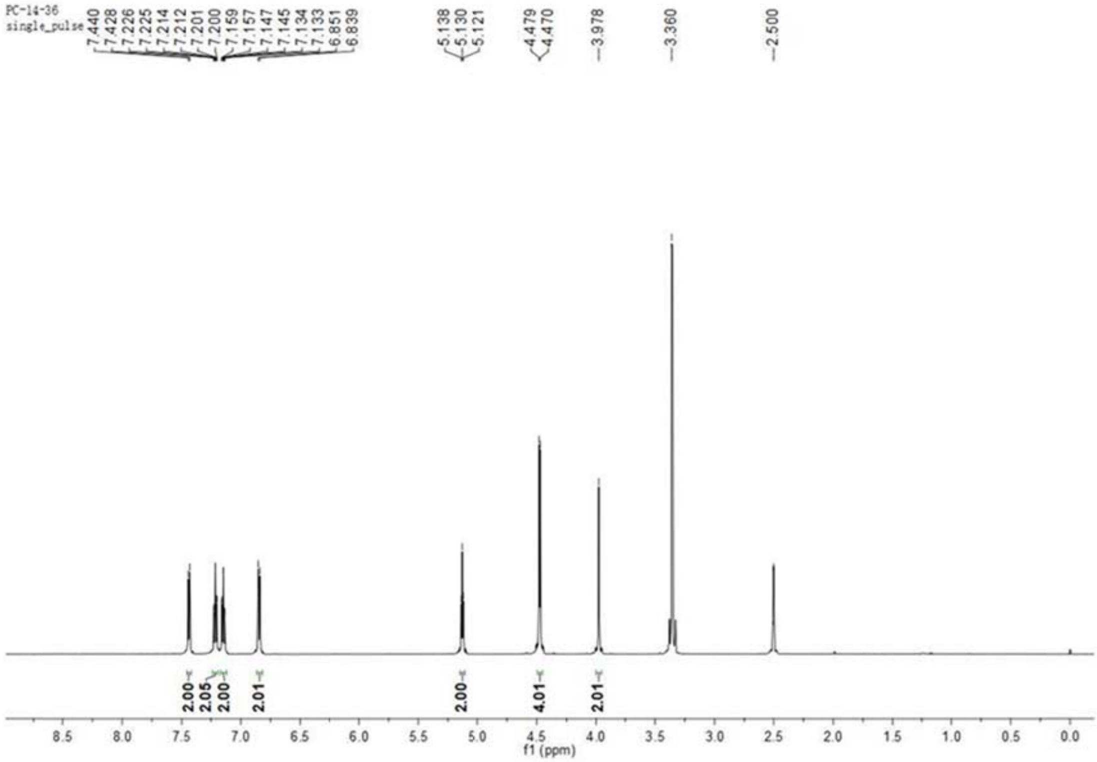
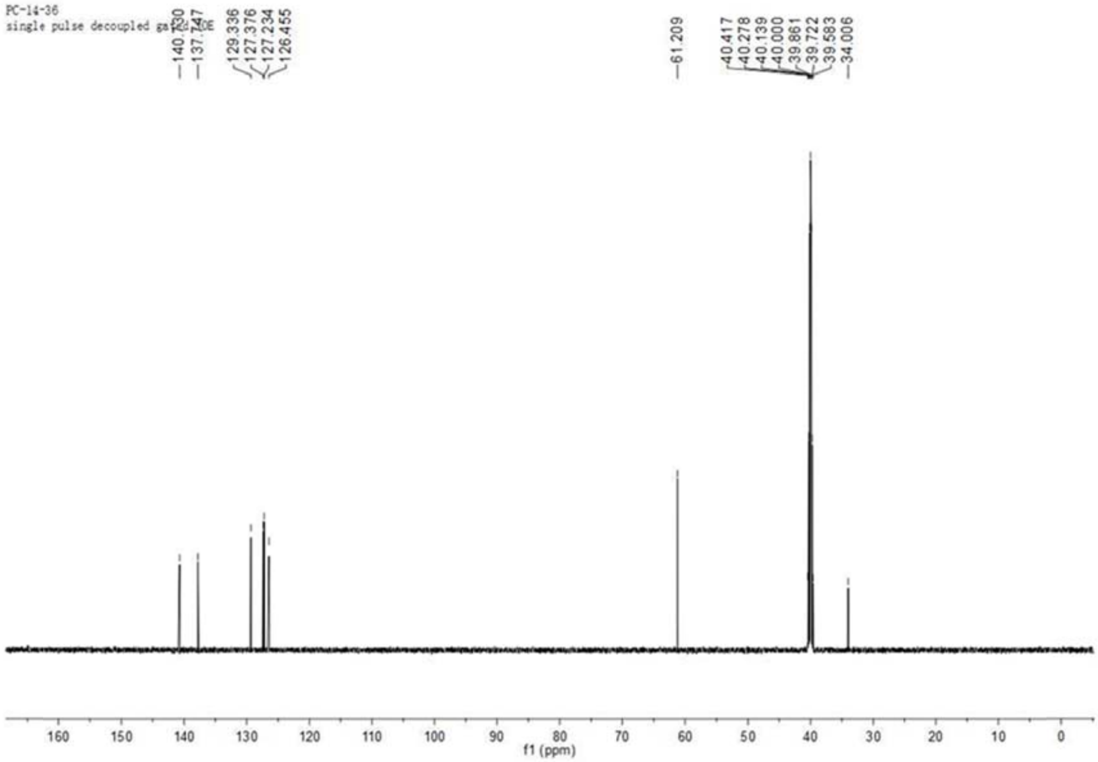
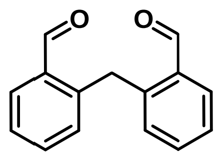
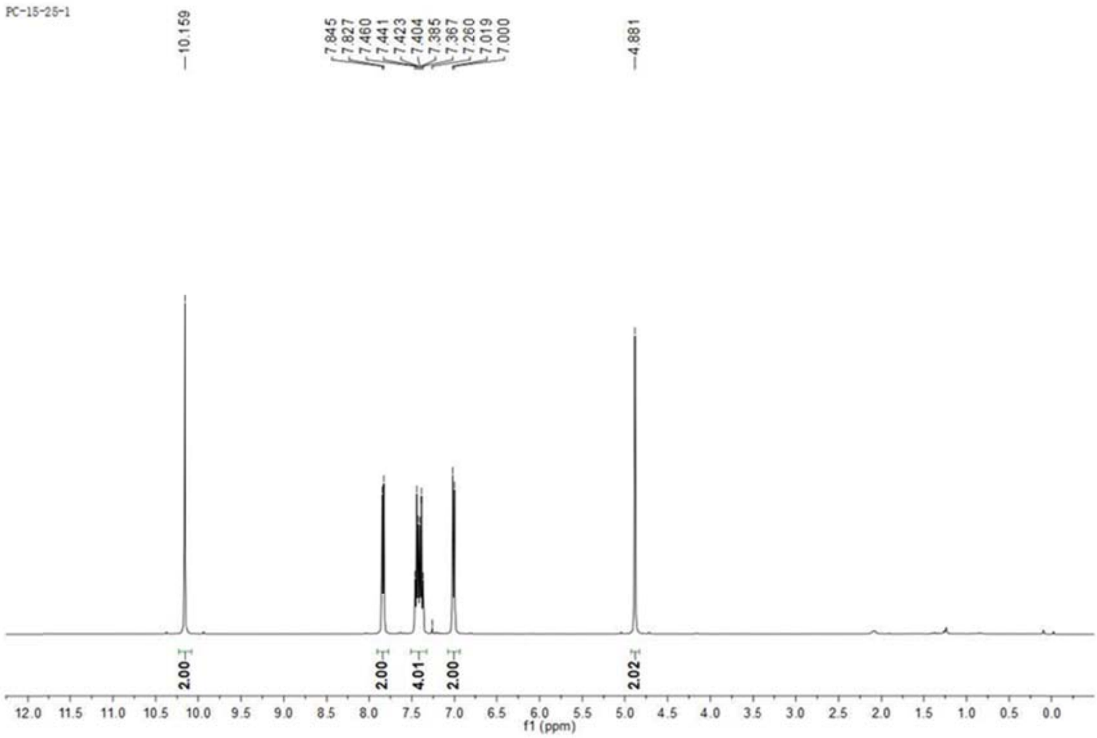


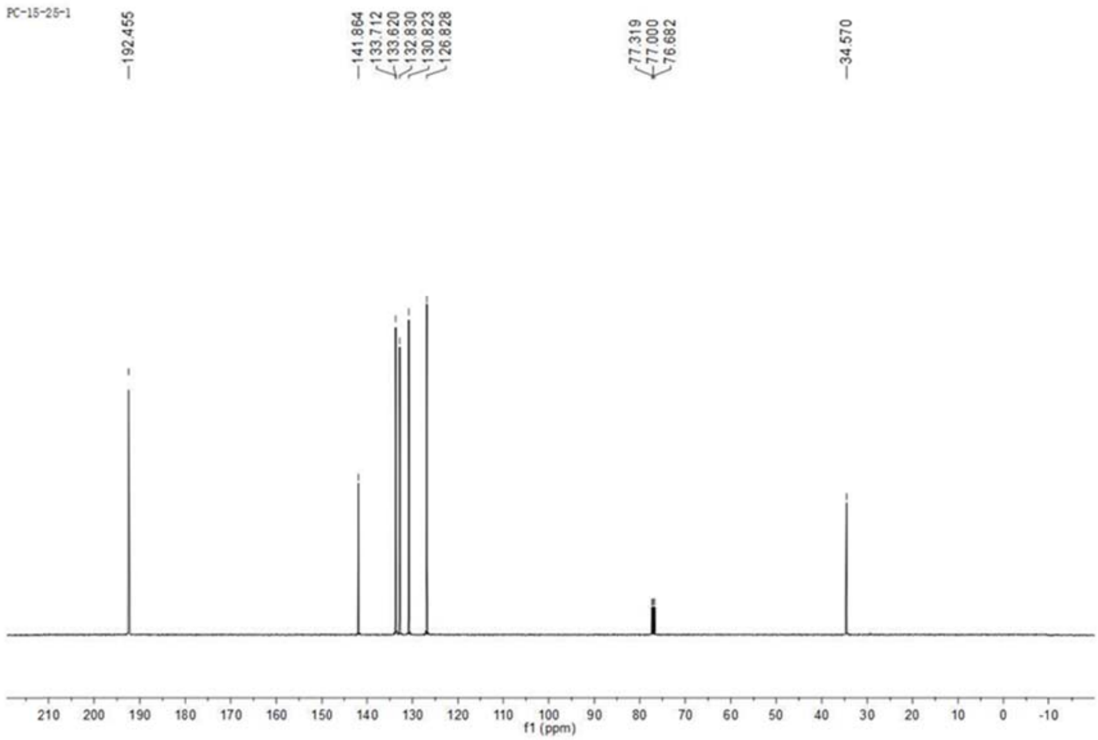


Supplementary Figure 100 ^{1}H NMR and ^{13}C NMR spectra for compound 84

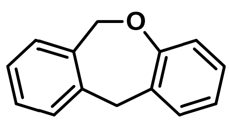


S84





Supplementary Figure 101 ^{1}H NMR and ^{13}C NMR spectra for compound S84



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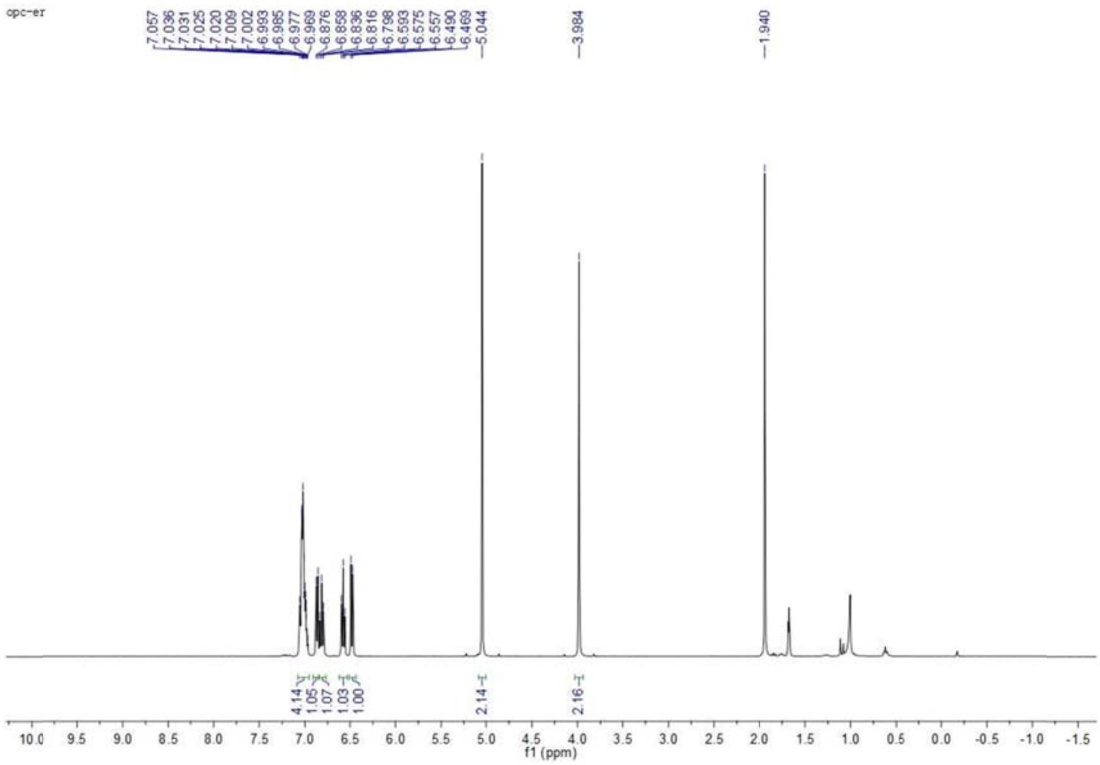
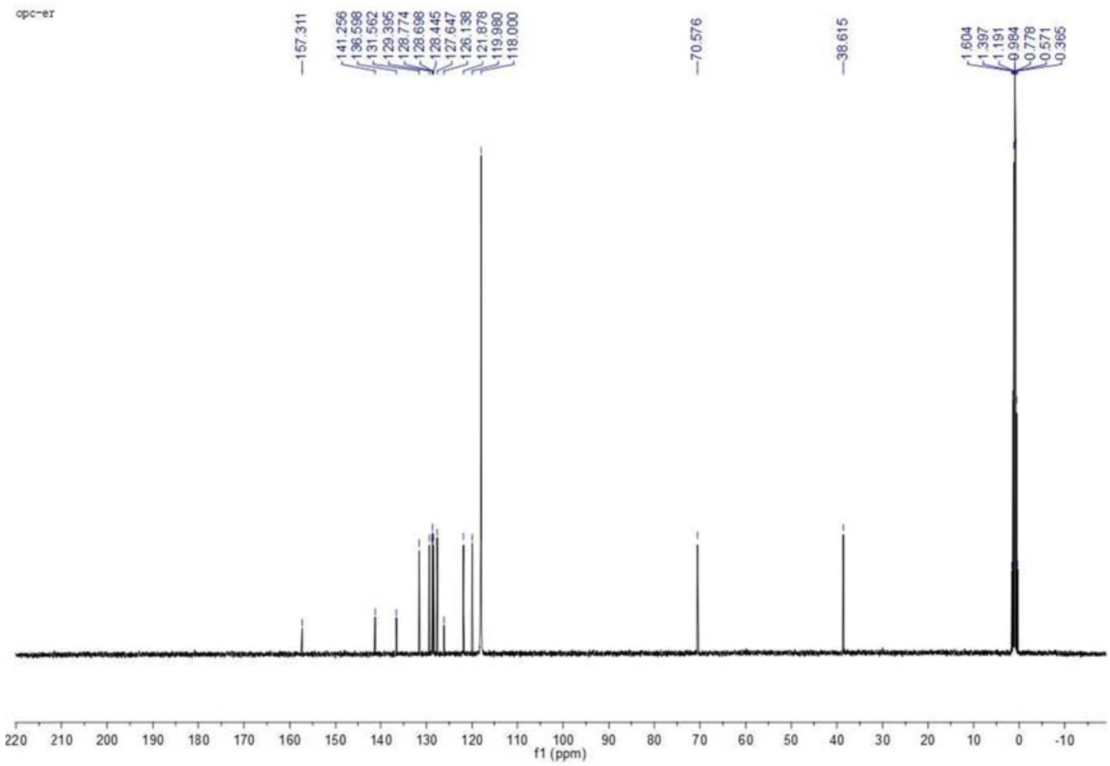
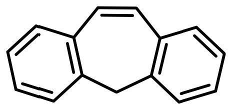
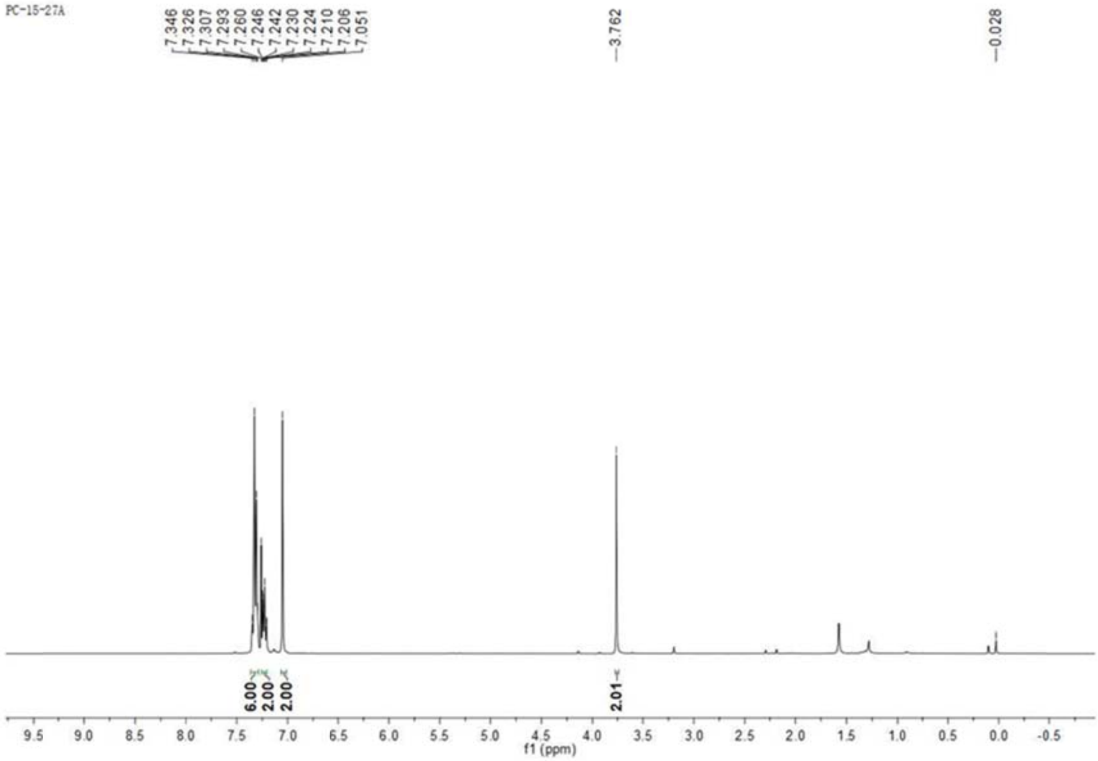


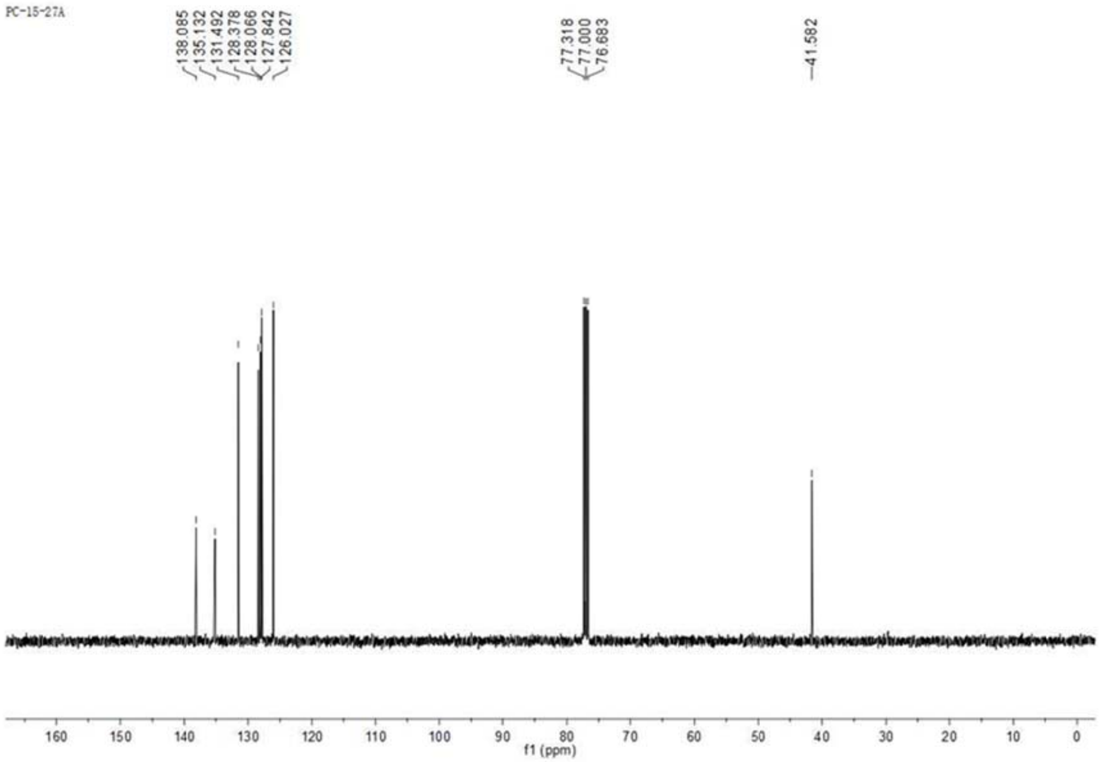


Supplementary Figure 102 ^{1}H NMR and ^{13}C NMR spectra for compound 85



86





Supplementary Figure 102 ^{1}H NMR and ^{13}C NMR spectra for compound 86

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