Supporting Information

Sulfonyl radical-enabled 6-*endo-trig* cyclization for regiospecific synthesis of unsymmetrical diaryl sulfones

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Context

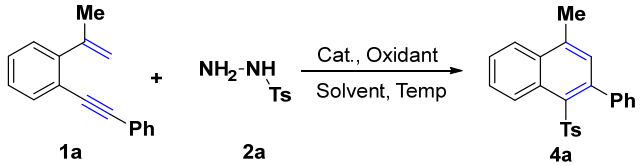
Experimental

General Information

^{1}H NMR (^{13}C NMR) spectra were measured on a Bruker DPX 400 MHz spectrometer in $CDCl_3$ (DMSO-d_6) with chemical shift (δ) given in ppm relative to TMS as internal standard [(s = singlet, d = doublet, t = triplet, brs = broad singlet, m = multiplet), coupling constant (Hz)]. HRMS (ESI) was determined by using microTOF-QII HRMS/MS instrument (BRUKER). X-Ray crystallographic analysis was performed with a Siemens SMART CCD and a Siemens P4 diffractometer.

Condition optimization

Table 1 Screening of Optimal Conditions for Forming **4a**[a]



Entry	Oxidant (eq.)	Cat.(mol%)	Additive (eq.)	Solvent	Yield [b](%)
1	DTBP (4.0)			DCE	29
2	DTBP (4.0)			1,4-dioxane	18
3	DTBP (4.0)			DMF	trace
4	DTBP (4.0)			MeCN	34
5	DTBP (4.0)	$FeCl_2$ (10)		MeCN	38
6	DTBP (5.0)	$FeCl_2$ (10)		MeCN	43
7	DTBP (6.0)	$FeCl_2$ (10)		MeCN	40
8	DTBP (5.0)	$Cu(OTf)_2$ (10)		MeCN	30
9	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)		MeCN	50
10	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (1.0)	MeCN	66
11	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	77
12	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	^{t}BuOLi (0.5)	MeCN	ND[c]
13	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	Cs_2CO_3 (0.5)	MeCN	30
14	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	Et_3N (0.5)	MeCN	45
15	DTBP (5.0)	$FeCl_2$ (10) / $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	68[d]
16	TBPB (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	trace
17	DCP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	trace
18	TBHP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	ND
19	TBHP (5.0)	TBAI (10)	DBU (0.5)	MeCN	ND
20	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	67[e]
21	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	57[f]
22	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	DBU (0.5)	MeCN	70[g]

[a]Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), *p*-toluenesulfonyl hydrazine (**2a**, 0.4 mmol, 2.0 equiv.), solvent (1.0 mL), air, 100 °C. [b]Isolated yield based on **1a**. [c] Not detected. [d]Use of 4 Å MS (100 mg). [e]The mol ratio of **1a**:**2a** was in 1:3. [f]The reaction was at 90 °C. [g]The reaction was at 110 °C.

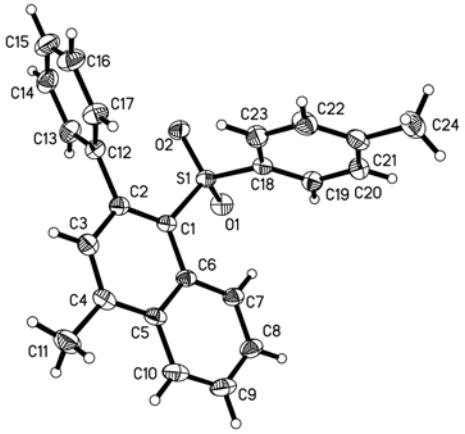
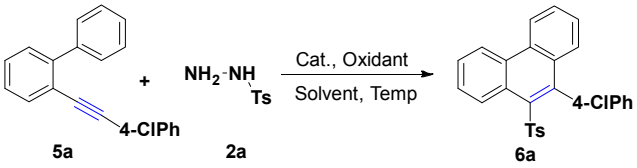


Figure 1 The ORTEP Drawing of **4a** (Thermal ellipsoids are set at 30% probability level)

Table 2 Screening of Optimal Conditions for Forming **6a**[a]



Entry	Oxidant (eq.)	Cat. (mol %)	Solvent	Additive (eq.)	T (°C)	Yield[b](%)
1	DTBP (5.0)	$FeCl_2$ (10)/ $Cu(OTf)_2$ (10)	MeCN	DBU (0.5)	100	15
2	DTBP (5.0)	$Cu(OTf)_2$ (10)	MeCN	DBU (0.5)	100	18
3	DTBP (5.0)	$Cu(OTf)_2$ (10)	MeCN		100	25
4	DTBP (5.0)	$FeCl_2$(10)	MeCN		100	20
5	DTBP (5.0)	$Cu(OTf)_2$ (10)	MeCN		120	34
6	DTBP (5.0)	$Cu(OTf)_2$(10)	DCE		120	39
7	DTBP (5.0)	$Cu(OTf)_2$(10)	1,4-dioxane		120	18
8	DTBP (5.0)	$Cu(OTf)_2$(10)	toluene		120	28
9	DTBP (5.0)	$Cu(OTf)_2$(10)	DMF		120	trace
10	DTBP (5.0)	$FeCl_3$(10)	DCE		120	18
11	DTBP (5.0)	$Pd(OAc)_2$(10)	DCE		120	trace
12	DTBP (5.0)	CuI(10)	DCE		120	25
13	DTBP (5.0)	$Cu(OAc)_2$(10)	DCE		120	28
14	DTBP (5.0)	$Co(acac)_2$(10)	DCE		120	22
15	DTBP (5.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	41[c]
16	DTBP (6.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	50[c]
16	TBHP (6.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	10[c]
17	TBPB (6.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	15[c]
19	BPO (6.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	12[c]
20	DPO (6.0)	$Cu(OTf)_2$(10)	DCE	4Å MS	120	ND[c]
21	TBHP (5.0)	TBAI (10)	DCE	4Å MS	120	ND[c]

[a]Reaction conditions: **5a** (0.2 mmol, 1 equiv), *p*-toluenesulfonyl hydrazine (**2a**, 0.8 mmol, 4.0 equiv.), solvent (1.0 mL), air, for 12 h.

[b]Isolated yield based on **5a**. [c]4Å MS (100 mg). ND = Not detected

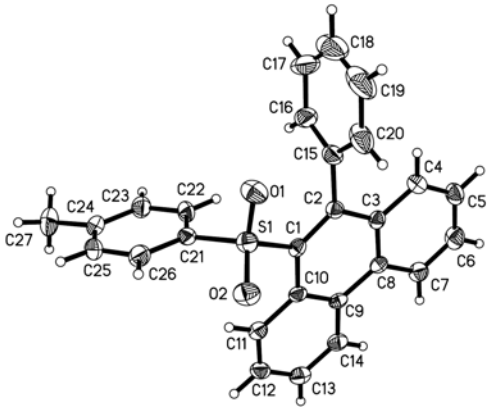
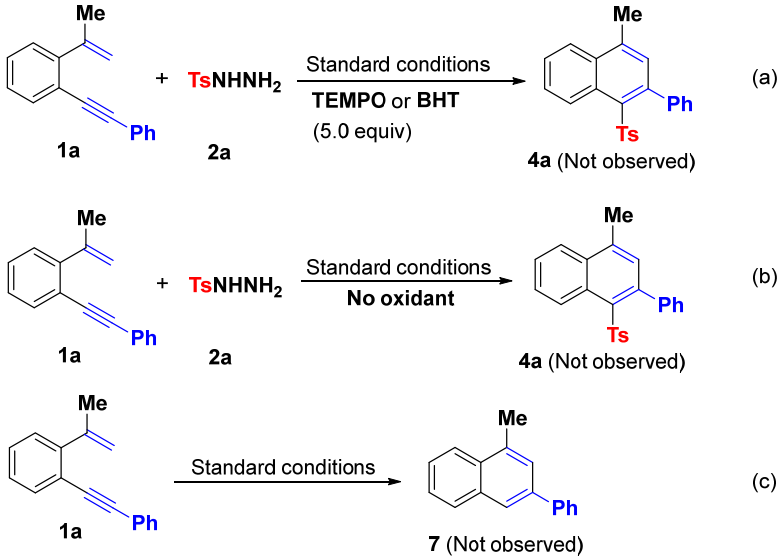


Figure 2 The ORTEP Drawing of **6n** (Thermal ellipsoids are set at 30% probability level)



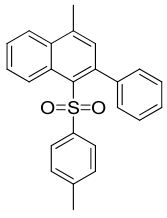
Scheme 1 Control experiments

General Procedure for the Synthesis of Products 4

Example for the synthesis of **4a**:

1-(Phenylethynyl)-2-(prop-1-en-2-yl)benzene **1a** (44 mg, 0.2 mmol, 1.0 equiv), tosylhydrazide (**2a**, 75 mg, 0.4 mmol, 2.0 equiv), $Cu(OTf)_2$ (7.0 mg, 10 mol%), $FeCl_2$ (2.5 mg, 10 mol%), and MeCN (1.0 mL) were introduced in a 10-mL reaction tube, DBU (15.2 mg, 0.5 equiv) and DTBP (146.2 mg, 1.0 mmol, 5.0 equiv) were then successively added and sealed. The mixture stirred at 100 °C until complete consumption of the starting material **1a**. After completion of the reaction, the reaction mixture was concentrated in vacuum. The crude product was purified by flash column chromatography (petroleum ether/ethyl acetate) to afford the desired product **4a**.

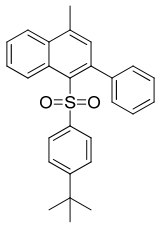
*4-Methyl-2-phenyl-1-tosylnaphthalene (**4a**)*



Yellow solid, mp 150-151 °C; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.14–9.06 (m, 1H), 8.09–8.00 (m, 1H),

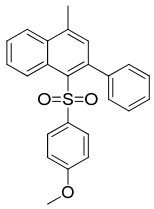
7.63–7.56 (m, 2H), 7.51–7.45 (m, 2H), 7.35–7.28 (m, 3H), 7.26–7.23 (m, 2H), 7.19 (s, 1H), 7.07 (d, J = 8.0 Hz, 2H), 2.72 (d, J = 0.8 Hz, 3H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.7, 143.0, 141.4, 141.0, 140.4, 132.6, 131.8, 131.0, 130.1, 129.2, 129.0, 127.8, 127.3, 127.2, 126.6, 126.5, 124.6, 21.5, 20.0; HRMS (APCI-TOF) *m/z* Calcd. For $C_{24}H_{21}O_2S$, 373.1262 $[M+H]^+$, found 373.1263.

*1-((4-(tert-Butyl)phenyl)sulfonyl)-4-methyl-2-phenylnaphthalene (**4b**)*



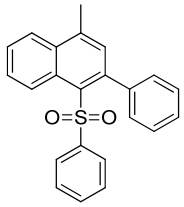
Yellow solid, mp 185-186 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.18 (d, J = 8.4 Hz, 1H), 8.07 (m, 1H), 7.66–7.58 (m, 2H), 7.47 (m, 2H), 7.30–7.24 (m, 5H), 7.23–7.18 (m, 2H), 7.17 (s, 1H), 2.72 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 155.84, 143.39, 141.32, 140.70, 140.27, 132.58, 132.10, 130.93, 130.19, 129.08, 127.76, 127.38, 127.16, 126.59, 126.48, 126.46, 125.50, 124.57, 35.01, 31.02, 19.93; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{27}O_2S$ 415.1732 $[M+H]^+$, found 415.1728.

*1-((4-Methoxyphenyl)sulfonyl)-4-methyl-2-phenylnaphthalene (**4c**)*



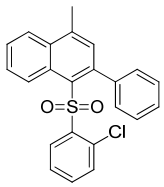
White solid, mp 208-209 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.18–9.11 (m, 1H), 8.09–8.03 (m, 1H), 7.61 (m, 2H), 7.53–7.48 (m, 2H), 7.36–7.30 (m, 3H), 7.25–7.22 (m, 2H), 7.17 (d, J = 0.8 Hz, 1H), 6.76–6.70 (m, 2H), 3.77 (s, 3H), 2.71 (d, J = 0.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.45, 143.3, 141.5, 140.2, 135.5, 132.6, 132.3, 131.0, 130.0, 129.0, 128.8, 127.7, 127.4, 127.2, 126.4, 124.6, 113.7, 55.5, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{21}O_3S$ 389.1211 $[M+H]^+$, found 389.1212.

*4-Methyl-2-phenyl-1-(phenylsulfonyl)naphthalene (**4d**)*



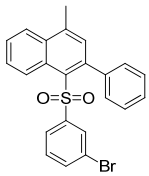
Yellow solid, mp 188-189 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.17–9.12 (m, 1H), 8.12–8.07 (m, 1H), 7.67–7.59 (m, 4H), 7.47–7.24 (m, 9H), 2.76 (d, J = 0.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.9, 143.8, 141.2, 140.6, 132.6, 132.2, 131.5, 131.0, 130.1, 129.1, 128.5, 127.8, 127.4, 127.3, 126.5, 126.5, 126.4, 124.6, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{23}H_{19}O_2S$ 359.1106 $[M+H]^+$, found 359.1107.

*1-((2-Chlorophenyl)sulfonyl)-4-methyl-2-phenylnaphthalene (**4e**)*



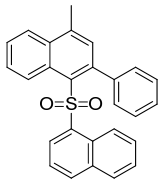
White solid, mp 181-182 ºC;^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.34–9.18 (m, 1H), 8.18–8.07 (m, 1H), 7.72–7.55 (m, 3H), 7.29–7.17 (m, 8H), 7.06 (t, J = 7.6 Hz, 1H), 2.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 142.3, 141.1, 140.5, 140.1, 133.0, 132.5, 131.9, 131.0, 130.7, 130.1, 129.6, 129.5, 127.7, 127.6, 127., 126.5, 126.5, 126.2, 124.6, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{23}H_{18}ClO_2S$ 393.0716 $[M+H]^+$, found 393.0718.

*1-((3-Bromophenyl)sulfonyl)-4-methyl-2-phenylnaphthalene (**4f**)*



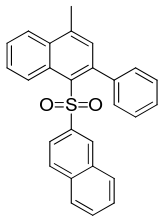
Yellow solid, mp 111-112 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.19–9.14 (m, 1H), 8.11–8.07 (m, 1H), 7.65 (m, 2H), 7.57 (t, J = 1.6 Hz, 1H), 7.49 (m, 1H), 7.43 (m, 1H), 7.37–7.27 (m, 3H), 7.19–7.10 (m, 4H), 2.74 (d, J = 0.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 145.5, 143.6, 141.0, 140.5, 135.2, 132.6, 131.3, 130.8, 130.1, 130.0, 129.7, 129.3, 128.0, 127.7, 127.5, 126.7, 126.2, 125.2, 124.7, 122.4, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{23}H_{18}BrO_2S$ 437.0211 $[M+H]^+$, found 437.0212.

*4-Methyl-1-(naphthalen-1-ylsulfonyl)-2-phenylnaphthalene (**4g**)*



Yellow solid, mp 172-173 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.25 (m, 1H), 8.30–7.98 (m, 2H), 7.97–7.36 (m, 8H), 7.36–7.00 (m, 6H), 2.73 (d, J = 5.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 145.3, 143.2, 143.1, 141.2, 140.7, 139.1, 132.9, 131.8, 130.9, 130.6, 129.9, 129.2, 129.2, 128.4, 128.2, 127.9, 127.4, 127.4, 127.0, 126.8, 126.6, 126.2, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{21}O_2S$ 409.1262 $[M+H]^+$, found 409.1270.

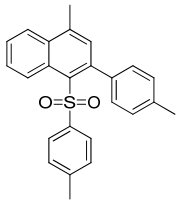
*4-Methyl-1-(naphthalen-2-ylsulfonyl)-2-phenylnaphthalene (**4h**)*



Yellow solid, mp 145-146 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.24 (d, J = 8.4 Hz, 1H), 8.35–7.98 (m, 2H), 7.98–7.42 (m, 9H), 7.42–6.98 (m, 5H), 2.72 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.7, 141.1, 140.6, 140.5, 134.5, 132.6, 131.8, 131.7, 130.9, 130.2, 129.3, 129.2, 128.8, 128.6, 128.0, 127.9, 127.7, 127.5, 127.3,

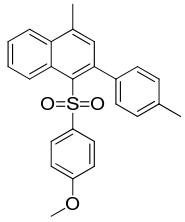
127.2, 126.5, 126.4, 124.6, 121.9, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{21}O_2S$ 409.1262 $[M+H]^+$, found 409.1250.

*4-Methyl-2-(p-tolyl)-1-tosylnaphthalene (**4j**)*



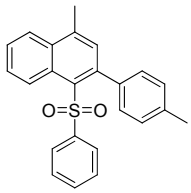
Yellow solid, mp 189-190 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.09 (m, 1H), 8.10–8.04 (m, 1H), 7.65–7.57 (m, 2H), 7.51 (d, J = 8.4 Hz, 2H), 7.24–7.05 (m, 7H), 2.74 (s, 3H), 2.43 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.8, 142.9, 141.0, 140.3, 138.5, 137.0, 132.5, 131.75, 131.2, 130.1, 129.1, 128.9, 128.1, 127.7, 126.6, 126.4, 126.4, 124.6, 21.5, 21.3, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{25}H_{23}O_2S$ 387.1419 $[M+H]^+$, found 387.1428.

*1-((4-Methoxyphenyl)sulfonyl)-4-methyl-2-(p-tolyl)naphthalene (**4k**)*



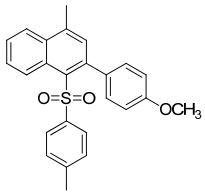
White solid, mp 153-154 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.17–9.08 (m, 1H), 8.04 (m, 1H), 7.63–7.49 (m, 4H), 7.15 (m, 5H), 6.78–6.68 (m, 2H), 3.77 (d, J = 4.0 Hz, 3H), 2.70 (d, J = 3.6 Hz, 3H), 2.40 (d, J = 4.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.5, 143.5, 140.1, 138.6, 136.9, 135.6, 132.6, 132.3, 131.2, 130.1, 128.9, 128.8, 128.1, 127.7, 126.5, 126.4, 124.6, 113.6, 55.5, 21.3, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{25}H_{23}O_3S$ 403.1368 $[M+H]^+$, found 403.1386.

*4-Methyl-1-(phenylsulfonyl)-2-(p-tolyl)naphthalene (**4l**)*



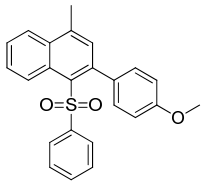
Yellow solid, mp 210-211 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.10–9.04 (m, 1H), 8.08–8.03 (m, 1H), 7.62–7.54 (m, 4H), 7.41–7.36 (m, 1H), 7.29–7.27 (m, 1H), 7.19 (m, 1H), 7.15–7.10 (m, 4H), 2.72 (d, J = 0.4 Hz, 3H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 144.0, 140.5, 138.3, 137.1, 132.5, 132.1, 131.5, 131.1, 130.2, 129.0, 128.4, 128.1, 127.8, 126.5, 126.4, 126.4, 124.6, 21.3, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{21}O_2S$ 373.1262 $[M+H]^+$, found 373.1258.

*2-(4-Methoxyphenyl)-4-methyl-1-tosylnaphthalene (**4m**)*



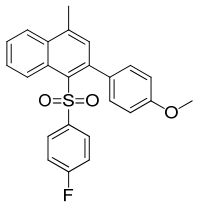
White solid, mp 155-156 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.11 (m, 1H), 8.08–8.01 (m, 1H), 7.63–7.55 (m, 2H), 7.42 (d, J = 8.4 Hz, 2H), 7.20–7.12 (m, 3H), 7.05 (d, J = 8.4 Hz, 2H), 6.87–6.80 (m, 2H), 3.85 (s, 3H), 2.71 (d, J = 0.8 Hz, 3H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 159.0, 143.4, 142.8, 141.1, 140.2, 133.5, 132.5, 132.0, 131.3, 130.4, 130.3, 129.0, 127.6, 126.5, 126.5, 126.4, 124.5, 112.9, 55.3, 21.5, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{25}H_{23}O_3S$ 403.1368 $[M+H]^+$, found 403.1388.

*2-(4-Methoxyphenyl)-4-methyl-1-(phenylsulfonyl)naphthalene (**4n**)*



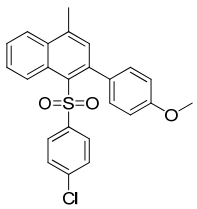
White solid, mp 184-185 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.13 (m, 1H), 8.05 (m, 1H), 7.63–7.49 (m, 4H), 7.37 (t, J = 7.4 Hz, 1H), 7.25 (t, J = 8.8 Hz, 2H), 7.21–7.09 (m, 3H), 6.88–6.77 (m, 2H), 3.84 (s, 3H), 2.72 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.5, 143.3, 141.5, 140.2, 135.5, 132.6, 132.3, 131.0, 130.0, 129.0, 128.8, 127.7, 127.4, 127.2, 126.5, 126.5, 124.6, 113.7, 55.5, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{21}O_3S$ 389.1211 $[M+H]^+$, found 389.1205.

*1-((4-Fluorophenyl)sulfonyl)-2-(4-methoxyphenyl)-4-methylnaphthalene (**4o**)*



Yellow solid, mp 121-122 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.16 (m,1H), 8.07 (m, 1H), 7.66–7.58 (m, 2H), 7.52–7.44 (m, 2H), 7.18–7.09 (m, 3H), 6.94–6.81 (m, 4H), 3.85 (s, 3H), 2.72 (s , 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 164.6($^1J_{CF}$ = 252.0), 159.2, 143.2, 143.2, 140.6, 140.0, 133.1, 132.5, 131.9, 131.2, 130.7, 130.3, 129.2($^3J_{CF}$ = 9.3), 127.8, 126.5, 126.3, 124.6($^4J_{CF}$ = 2.1), 115.5($^2J_{CF}$ = 23.0), 113.0, 77.4, 77.0, 76.7, 55.4, 19.9; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{20}FO_3S$ 407.1117 $[M+H]^+$, found 407.1137.

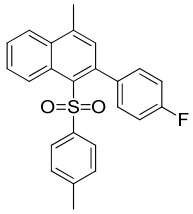
*1-((4-Chlorophenyl)sulfonyl)-2-(4-methoxyphenyl)-4-methylnaphthalene (**4p**)*



Yellow solid, mp 141-142 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.14 (m, 1H), 8.07 (m, 1H), 7.66–7.58 (m,

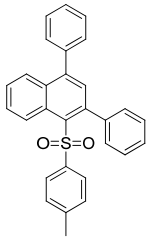
2H), 7.41–7.37 (m, 2H), 7.21–7.15 (m, 3H), 7.12–7.07 (m, 2H), 6.84–6.80 (m, 2H), 3.85 (s, 3H), 2.72 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 159.3, 143.2, 142.4, 140.7, 138.5, 133.0, 132.5, 131.7, 131.1, 130.7, 130.3, 128.6, 128.0, 127.9, 126.6, 126.3, 124.7, 113.0, 55.4, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{20}ClO_3S$ 423.0822 $[M+H]^+$, found 423.0823.

*2-(4-Fluorophenyl)-4-methyl-1-tosylnaphthalene (**4q**)*



White solid, mp 165-166 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.11 (m, 1H), 8.06 (m, 1H), 7.64–7.57 (m, 2H), 7.45 (d, J = 8.0 Hz, 2H), 7.22–7.18 (m, 2H), 7.16 (s, 1H), 7.09 (d, J = 8.4 Hz, 2H), 7.03–6.98 (m, 2H), 2.72 (s, 3H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.2($^1J_{CF}$ = 245.1), 143.1, 142.5, 140.9, 140.6, 137.2, 137.2, 132.6, 132.0, 130.9, 130.7($^3J_{CF}$ = 8.1), 130.1, 129.2, 127.9, 126.6, 126.5($^4J_{CF}$ = 4.9), 124.6, 114.3($^2J_{CF}$ = 22.4), 21.5, 20.0; HRMS (APCI-TOF) m/z Calcd. For $C_{24}H_{20}FO_2S$ 391.1168 $[M+H]^+$, found 391.1170.

*2,4-Diphenyl-1-tosylnaphthalene (**4r**)*



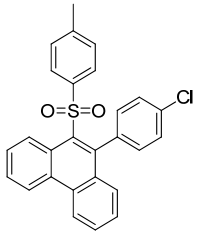
Yellow solid, mp 188-189 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.17 (d, J = 8.9 Hz, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.65–7.60 (m, 1H), 7.54–7.39 (m, 8H), 7.33–7.24 (m, 6H), 7.10 (d, J = 8.3 Hz, 2H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 145.3, 143.2, 143.1, 141.2, 140.7, 139.1, 132.9, 131.84, 130.9, 130.6, 129.9, 129.2, 129.2, 128.4, 128.2, 127.9, 127.4, 127.4, 127.0, 126.8, 126.6, 126.2, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{29}H_{23}O_2S$ 435.1419 $[M+H]^+$, found 435.1423.

General Procedure for the Synthesis of Products 6

Example for the synthesis of **6a**:

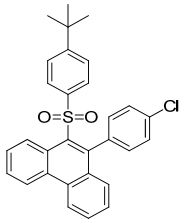
2-((4-Chlorophenyl)ethynyl)-1,1'-biphenyl (**5a**, 58 mg, 0.2 mmol, 1.0 equiv), *p*-toluenesulfonyl hydrazine (**2a**, 149 mg, 0.8 mmol, 4.0 equiv), $Cu(OTf)_2$ (7.0 mg, 10 mol%), and DCE (1.0 mL) were introduced in a 10-mL reaction tube, 4Å MS (100 mg) and DTBP (175.2 mg, 6.0 equiv) were then successively added and sealed. The mixture stirred at 120 ºC until complete consumption of the starting material **5a**. After completion of the reaction, the reaction mixture was concentrated in vacuum. The crude product was purified by flash column chromatography (petroleum ether/ethyl acetate) to afford the desired product **5a**.

*9-(4-Chlorophenyl)-10-tosylphenanthrene (**6a**)*



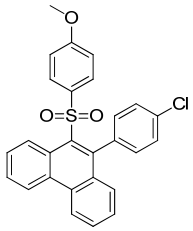
Yellow solid, mp 214-216 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.03 (d, J = 8.8 Hz, 1H), 8.74 (m, 2H), 7.78–7.67 (m, 2H), 7.63–7.54 (m, 3H), 7.52–7.47 (m, 1H), 7.38 (m, 3H), 7.24–7.19 (m, 2H), 7.15 (d, J = 8.0 Hz, 2H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.5, 142.2, 140.6, 136.2, 133.7, 133.06, 132.2, 131.4, 131.3, 130.9, 129.6, 129.4, 129.3, 127.9, 127.5, 127.4, 127.3, 127.1, 126.7, 126.4, 122.9, 122.5, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{20}ClO_2S$ 429.0716 $[M+H]^+$, found 429.0728.

*9-((4-(tert-Butyl)phenyl)sulfonyl)-10-(4-chlorophenyl)phenanthrene (**6b**)*



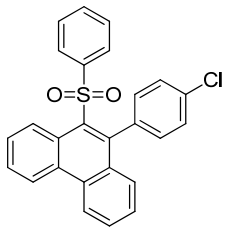
Yellow solid, mp 197-198 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.13 (d, J = 8.8 Hz, 1H), 8.75 (t, J = 8.8 Hz, 2H), 7.70 (m, 3H), 7.57–7.45 (m, 3H), 7.40–7.28 (m, 5H), 7.19–7.14 (m, 2H), 1.28 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 156.4, 141.7, 140.5, 136.0, 133.7, 133.6, 132.2, 131.6, 131.3, 130.9, 129.6, 129.2, 127.9, 127.6, 127.5, 127.3, 127.2, 126.9, 126.3, 125.9, 122.9, 122.6, 35.1, 31.1; HRMS (APCI-TOF) m/z Calcd. For $C_{30}H_{26}ClO_2S$ 485.1342 $[M+H]^+$, found 485.1353.

*9-(4-Chlorophenyl)-10-((4-methoxyphenyl)sulfonyl)phenanthrene (**6c**)*



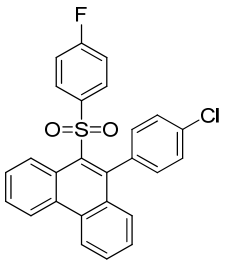
Yellow solid, mp 203-205 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.10 (dd, J = 8.4, 0.8 Hz, 1H), 8.73 (t, J = 8.0 Hz, 2H), 7.77–7.58 (m, 5H), 7.51–7.46 (m, 1H), 7.42–7.38 (m, 2H), 7.33 (d, J = 8.4 Hz, 1H), 7.22–7.18 (m, 2H), 6.83–6.78 (m, 2H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.8, 141.7, 136.3, 135.2, 133.8, 133.7, 132.2, 131.5, 131.4, 131.0, 129.6, 129.3, 128.8, 127.9, 127.6 127.5, 127.3, 127.1, 126.8, 122.9, 122.5, 114.0, 55.6; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{20}ClO_3S$ 459.0822 $[M+H]^+$, found 459.0829.

*9-(4-Chlorophenyl)-10-(phenylsulfonyl)phenanthrene (**6d**)*



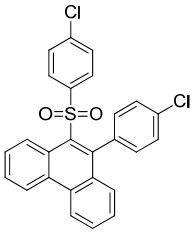
Yellow solid, mp 207-208 ºC; ^{1}H NMR (400 MHz, DMSO; δ, ppm) 9.00 (d, J = 8.4 Hz, 2H), 8.71 (d, J = 8.4 Hz, 1H), 7.91–7.86 (m, 1H), 7.85–7.80 (m, 2H), 7.78–7.73 (m, 1H), 7.69–7.45 (m, 9H), 7.31–7.26 (m, 1H); ^{13}C NMR (100 MHz, DMSO; δ, ppm) 143.3, 142.9, 137.0, 133.6, 132.8, 132.2, 131.9, 131.7, 131.2, 131.0, 130.7, 129.9, 129.4, 128.4, 128.4, 128.1, 126.8, 126.5, 126.1, 124.2, 123.7; HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{18}ClO_2S$ 429.0716 $[M+H]^+$, found 429.0719.

*9-(4-Chlorophenyl)-10-((4-fluorophenyl)sulfonyl)phenanthrene (**6e**)*



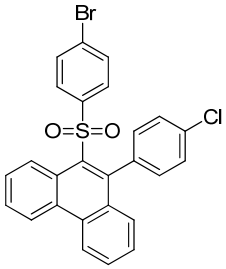
Yellow solid, mp 175-177 ºC; 1H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.03 (d, J = 8.4 Hz, 1H), 8.75 (t, J = 8.4 Hz, 2H), 7.80–7.60 (m, 5H), 7.53–7.34 (m, 4H), 7.23–7.16 (m, 2H), 7.03 (t, J = 8.6 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 164.6($^{1}J_{CF}$ = 253.9), 142.4, 139.7, 135.9, 134.0, 132.9, 132.3, 131.5, 131.2, 131.0, 129.9, 129.3, 129.2($^{3}J_{CF}$ = 9.4), 128.0, 127.7, 127.6, 127.5, 126.9, 126.6, 123.0, 122.6, 116.1($^{2}J_{CF}$ = 22.5); HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{17}ClFO_2S$ 447.0622 [M+H]+, found 447.0625.

*9-(4-Chlorophenyl)-10-((4-chlorophenyl)sulfonyl)phenanthrene (**6f**)*



Yellow solid, mp 212-214 ºC; ^{1}H NMR (400 MHz, DMSO; δ, ppm) 9.01 (d, J = 8.4 Hz, 2H), 8.68 (d, J = 8.0 Hz, 1H), 7.89 (m, 1H), 7.85–7.75 (m, 3H), 7.67 (t, J = 7.6 Hz, 2H), 7.60–7.40 (m, 6H), 7.29 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, DMSO; δ, ppm) 143.1, 142.1, 138.5, 136.8, 132.9, 132.3, 131.9, 131.4, 131.2, 131.0, 130.8, 130.0, 129.4, 128.6, 128.5, 128.2, 128.1, 126.6, 125.9, 124.3, 123.7; HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{17}Cl_2O_2S$ 463.0326 $[M+H]^+$, found 463.0329.

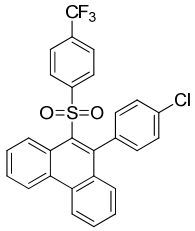
*9-((4-Bromophenyl)sulfonyl)-10-(4-chlorophenyl)phenanthrene (**6g**)*



Yellow solid, mp 226-227 ºC; ^{1}H NMR (400 MHz, DMSO; δ, ppm) 9.01 (d, J = 8.4 Hz, 2H), 8.68 (d, J = 8.4 Hz, 1H), 7.90 (s, 1H), 7.81–7.63 (m, 7H), 7.56–7.42 (m, 4H), 7.29 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, DMSO; δ, ppm) 143.1, 142.6, 136.8, 132.9, 132.3, 131.9, 131.4, 131.2, 131.0, 130.9, 129.4, 128.6, 128.5, 128.2, 128.1, 127.6,

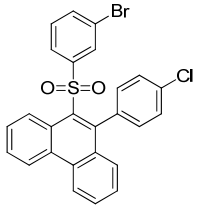
126.6, 125.9, 124.3, 123.7; HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{17}BrClO_2S$ 506.9821 $[M+H]^+$, found 506.9872.

*9-(4-Chlorophenyl)-10-((4-(trifluoromethyl)phenyl)sulfonyl)phenanthrene (**6h**)*



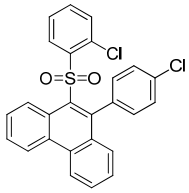
Yellow solid, mp 198-199 °C; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.00 (d, J = 8.8 Hz, 1H), 8.76 (t, J = 9.4 Hz, 2H), 7.75 (m, 4H), 7.63 (m, 3H), 7.51 (t, J = 7.8 Hz, 1H), 7.37 (d, J = 7.2 Hz, 3H), 7.17 (d, J = 7.6 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 147.0, 142.7, 135.5, 134.2, 134.1($^2J_{CF}$ = 32.8), 132.4, 132.3, 131.7, 131.0, 130.9, 130.1, 129.3, 128.0, 127.9, 127.8, 127.6, 126.8, 126.8, 126.5, 126.0, 126.0($^3J_{CF}$ = 3.7), 125.90, 123.2, 123.1($^1J_{CF}$ = 271.3), 122.7, 30.96; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{17}ClF_3O_2S$ 497.0590 $[M+H]^+$, found 497.0629.

*9-((3-Bromophenyl)sulfonyl)-10-(4-chlorophenyl)phenanthrene (**6i**)*



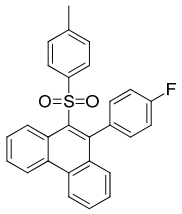
Yellow solid, mp 162-163 °C; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.07 (d, J = 8.4 Hz, 1H), 8.77 (t, J = 9.0 Hz, 2H), 7.81–7.66 (m, 4H), 7.59–7.48 (m, 3H), 7.37 (m, 3H), 7.22 (t, J = 8.0 Hz, 1H), 7.18–7.13 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 145.3, 142.5, 135.6, 135.4, 134.2, 132.69, 132.4, 131.7, 131.1, 130.9, 130.3, 129.9, 129.4, 129.2, 128.0, 127.8, 127.7, 127.5, 126.8, 126.6, 124.9, 123.1, 122.9, 122.6; HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{17}BrClO_2S$ 506.9821 $[M+H]^+$, found 506.9855.

*9-(4-Chlorophenyl)-10-((2-chlorophenyl)sulfonyl)phenanthrene (**6j**)*



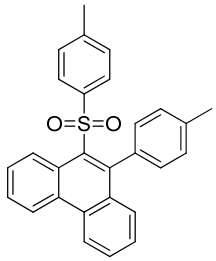
Yellow solid, mp 267-269 °C; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.22 (d, J = 8.8 Hz, 1H), 8.77 (t, J = 9.2 Hz, 2H), 7.78–7.61 (m, 4H), 7.50–7.45 (m, 1H), 7.38–7.32 (m, 2H), 7.25–7.18 (m, 4H), 7.11 (d, J = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 141.6, 140.7, 134.6, 134.4, 134.2, 133.3, 132.4, 132.3, 131.7, 131.1, 131.0, 130.9, 129.5, 128.9, 128.8, 127.7, 127.6, 127.4, 127.2, 126.8, 126.8, 123.0, 122.7; HRMS (APCI-TOF) m/z Calcd. For $C_{26}H_{17}Cl_2O_2S$ 463.0326 $[M+H]^+$, found 463.0341.

*9-(4-Fluorophenyl)-10-tosylphenanthrene (**6l**)*



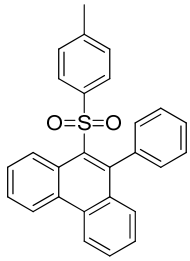
Yellow solid, mp 196-198 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.04 (d, J = 8.4 Hz, 1H), 8.77–8.72 (m, 2H), 7.78–7.67 (m, 2H), 7.61 (m, 1H), 7.56–7.47 (m, 3H), 7.36 (d, J = 8.4 Hz, 1H), 7.23 (m, 2H), 7.16–7.10 (m, 4H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.4($^1J_{CF}$ = 245.5), 143.4, 142.5, 140.8, 133.4, 133.4, 133.3, 132.3, 131.7($^3J_{CF}$ = 8.0), 130.9, 129.6, 129.4, 129.3, 127.5($^4J_{CF}$ = 4.5), 127.3, 127.1, 126.9 126.4 122.9, 122.5, 114.7($^2J_{CF}$ = 21.5), 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{20}FO_2S$ 427.1168 $[M+H]^+$, found 427.1175.

*9-(p-Tolyl)-10-tosylphenanthrene (**6m**)*



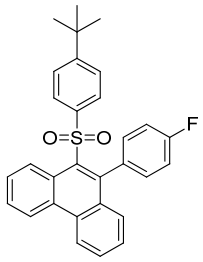
Yellow solid, mp 207-209 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.01 (dd, J = 8.4, 0.8 Hz, 1H), 8.73 (t, J = 7.6 Hz, 2H), 7.75–7.65 (m, 2H), 7.61–7.42 (m, 5H), 7.25–7.10 (m, 6H), 2.47 (s, 3H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 142.7, 142.1, 139.9, 136.2, 133.6, 131.8, 131.1, 130.8, 129.8, 128.9, 128.7, 128.4, 128.2, 127.3, 126.3, 126.2, 126.1, 125.9, 125.5, 125.4, 121.8, 121.3, 29.9, 20.4; HRMS (APCI-TOF) m/z Calcd. For $C_{28}H_{23}O_2S$ 423.1419 $[M+H]^+$, found 423.1451.

*9-Phenyl-10-tosylphenanthrene **(6n)***



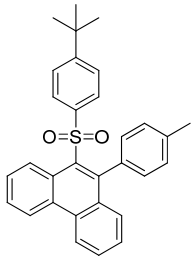
Yellow solid, mp 164-166 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.08 (d, J = 8.4 Hz, 1H), 8.76 (t, J = 8.2 Hz, 2H), 7.79–7.60 (m, 5H), 7.49 (m, 4H), 7.41 (d, J = 8.4 Hz, 1H), 7.33 (m, 2H), 7.15 (d, J = 7.2 Hz, 2H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.6, 143.2 140.8, 137.7, 132.7, 132.2, 131.7, 130.9, 130.1, 129.6, 129.5, 129.4, 127.5, 127.4, 127.3, 127.2, 127.1, 126.9, 126.4, 122.9, 122.4, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{21}O_2S$ 409.1262 $[M+H]^+$, found 409.1273.

*9-((4-(tert-Butyl)phenyl)sulfonyl)-10-(4-fluorophenyl)phenanthrene (**6o**)*



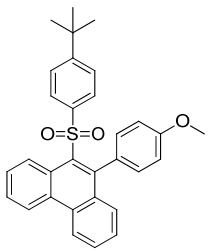
Yellow solid, mp 200-202 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.17 (d, J = 8.4 Hz, 1H), 8.78 (t, J = 8.8 Hz, 2H), 7.76 (m, 2H), 7.68 (t, J = 7.8 Hz, 1H), 7.58 (d, J = 8.4 Hz, 2H), 7.53–7.49 (m, 1H), 7.37 (d, J = 8.4 Hz, 3H), 7.25–7.19 (m, 2H), 7.10 (t, J = 8.6 Hz, 2H), 1.30 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 162.3($^1J_{CF}$ = 245.7), 156.3, 142.1, 140.7, 133.7, 133.3, 133.2, 132.2, 132.0($^3J_{CF}$ = 8.0), 131.6, 130.9, 129.5, 129.3, 127.5($^4J_{CF}$ = 4.1), 127.3, 127.0, 126.2, 125.8, 122.9, 122.5, 114.7($^2J_{CF}$ = 21.5), 35.1, 31.0; HRMS (APCI-TOF) m/z Calcd. For $C_{30}H_{26}FO_2S$ 469.1638 $[M+H]^+$, found 469.1631.

*9-((4-(tert-Butyl)phenyl)sulfonyl)-10-(p-tolyl)phenanthrene (**6p**)*



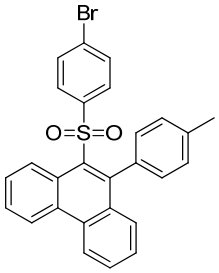
Yellow solid, mp 213-215 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.12 (d, J = 8.4 Hz, 1H), 8.74 (m, 2H), 7.69 (m, 3H), 7.56–7.51 (m, 2H), 7.44 (m, 2H), 7.32–7.28 (m, 2H), 7.15 (m, 4H), 2.45 (s, 3H), 1.27 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 156.0, 143.3, 140.8, 137.2, 134.4, 133.3, 132.2, 131.8, 130.8, 130.2, 129.6, 129.4, 128.3, 127.3, 127.3, 127.2, 127.1, 127.1, 126.4, 126.3, 125.6, 122.9, 122.4, 35.0, 31.1, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{31}H_{29}O_2S$ 465.1888 $[M+H]^+$, found 4 465.1887.

*9-((4-(tert-Butyl)phenyl)sulfonyl)-10-(4-methoxyphenyl)phenanthrene (**6q**)*



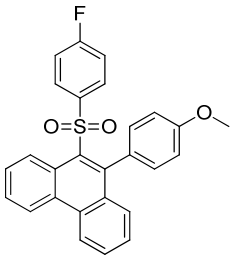
Yellow solid, mp 213-215 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.16 (d, J = 9.2Hz, 1H), 8.77–8.70 (m, 2H), 7.74–7.62 (m, 3H), 7.52–7.40 (m, 4H), 7.32–7.28 (m, 2H), 7.13–7.09 (m, 2H), 6.90–6.86 (m, 2H), 3.89 (s, 3H), 1.27 (s, 9H)**;** ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 159.1, 155.9, 143.0, 140.9, 133.8, 132.2, 132.0, 131.7, 130.8, 129.4, 129.4, 129.3, 127.3, 127.3, 127.2, 127.1, 126.3, 125.7, 122.9, 122.4, 113.1, 55.3, 35.1, 31.1; HRMS (APCI-TOF) m/z Calcd. For $C_{31}H_{29}O_3S$ 481.1837 $[M+H]^+$, found 481.1883.

*9-((4-Bromophenyl)sulfonyl)-10-(p-tolyl)phenanthrene (**6r**)*



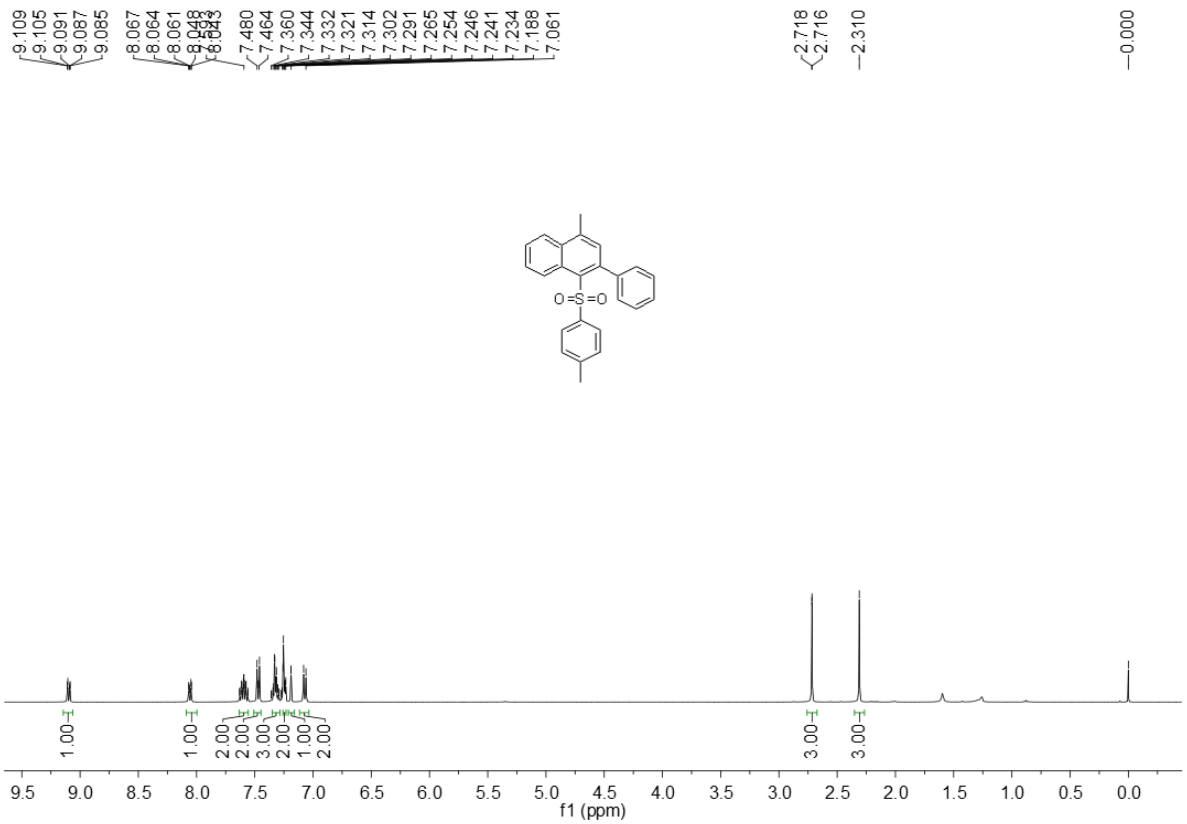
Yellow solid, mp 204-206 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.05 (d, J = 8.8 Hz, 1H), 8.77 (m, 2H), 7.80–7.71 (m, 2H), 7.67 (m, 1H), 7.51–7.43 (m, 6H), 7.19 (m, 2H), 2.50 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 143.7, 142.8, 137.7, 134.1, 132.7, 132.3, 131.8, 131.6, 130.8, 130.3, 129.7, 129.6, 128.4, 128.1, 128.0, 127.5, 127.3, 126.9, 126.8, 123.0, 122.4, 21.5; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{20}BrO_2S$ 487.0367 $[M+H]^+$, found 487.0404.

*9-((4-Fluorophenyl)sulfonyl)-10-(4-methoxyphenyl)phenanthrene (**6s**)*

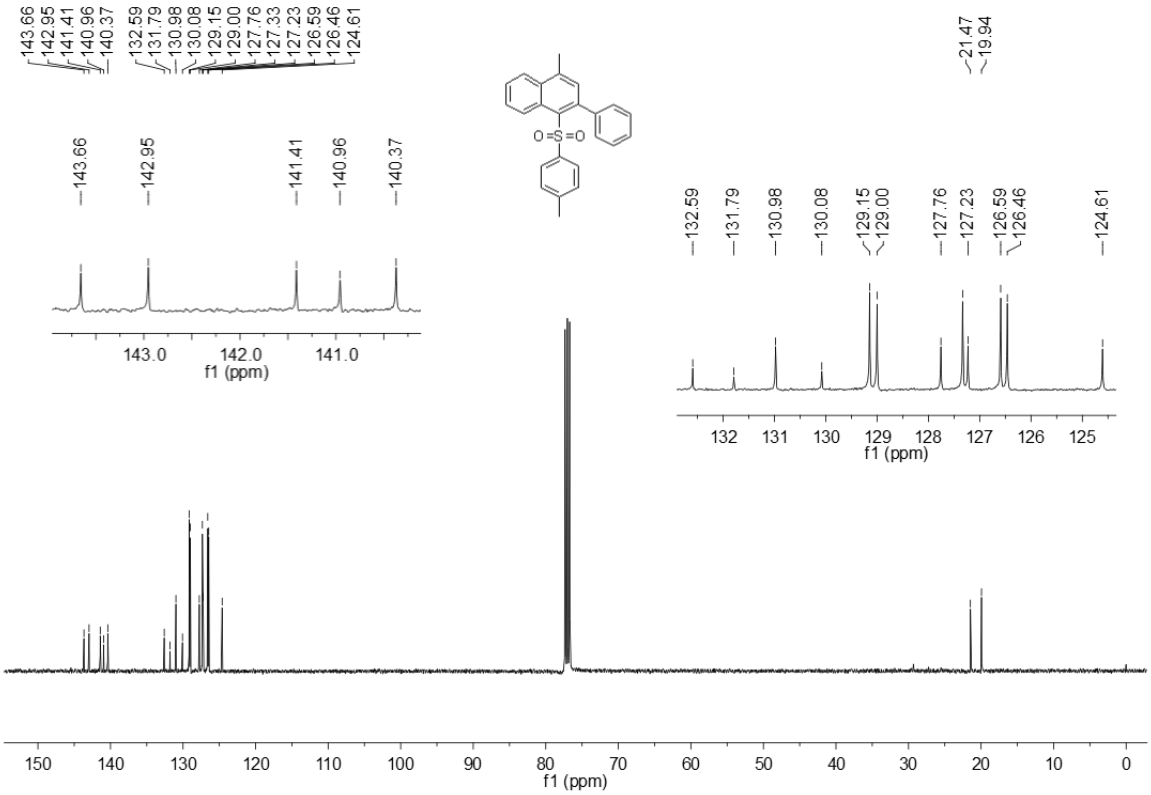


Yellow solid, mp 173-175 ºC; ^{1}H NMR (400 MHz, $CDCl_3$; δ, ppm) 9.14 (d, J = 8.8 Hz, 1H), 8.77 (m, 2H), 7.79–7.66 (m, 3H), 7.62–7.58 (m, 2H), 7.51–7.43 (m, 2H), 7.14–7.10 (m, 2H), 7.01–6.93 (m, 4H), 3.93 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$; δ, ppm) 164.6($^{1}J_{CF}$ = 253.1), 159.3, 143.2, 140.0, 139.9, 133.4, 132.2, 131.8, 131.7, 130.8, 129.6, 129.4, 129.1($^{3}J_{CF}$ = 9.4), 129.0, 127.4, 127.4, 127.2, 126.9, 123.0, 122.5, 115.8($^{2}J_{CF}$ = 22.5), 113.2, 55.3; HRMS (APCI-TOF) m/z Calcd. For $C_{27}H_{20}FO_3S$ 443.1117 $[M+H]^+$, found 443.1168.

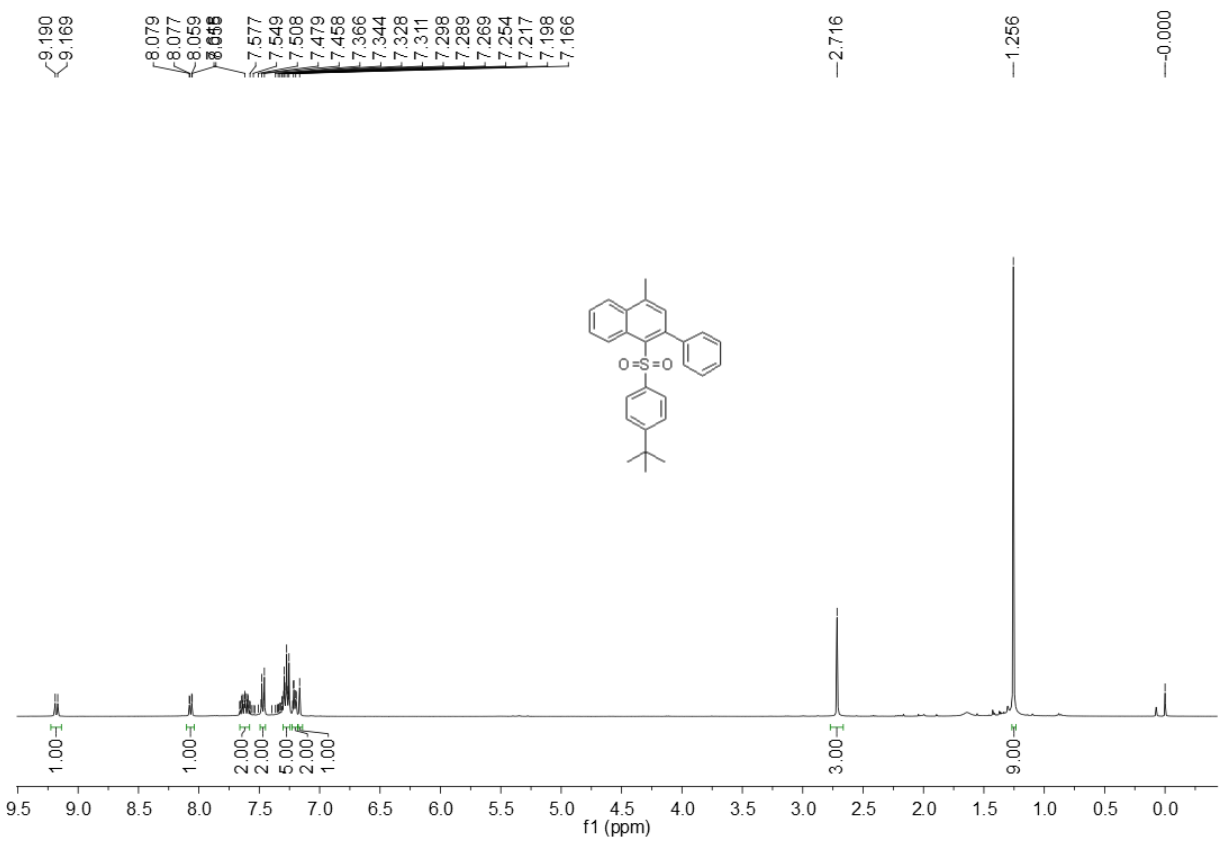
Copies of ^{1}H NMR and ^{13}C NMR of compounds 4 and 6



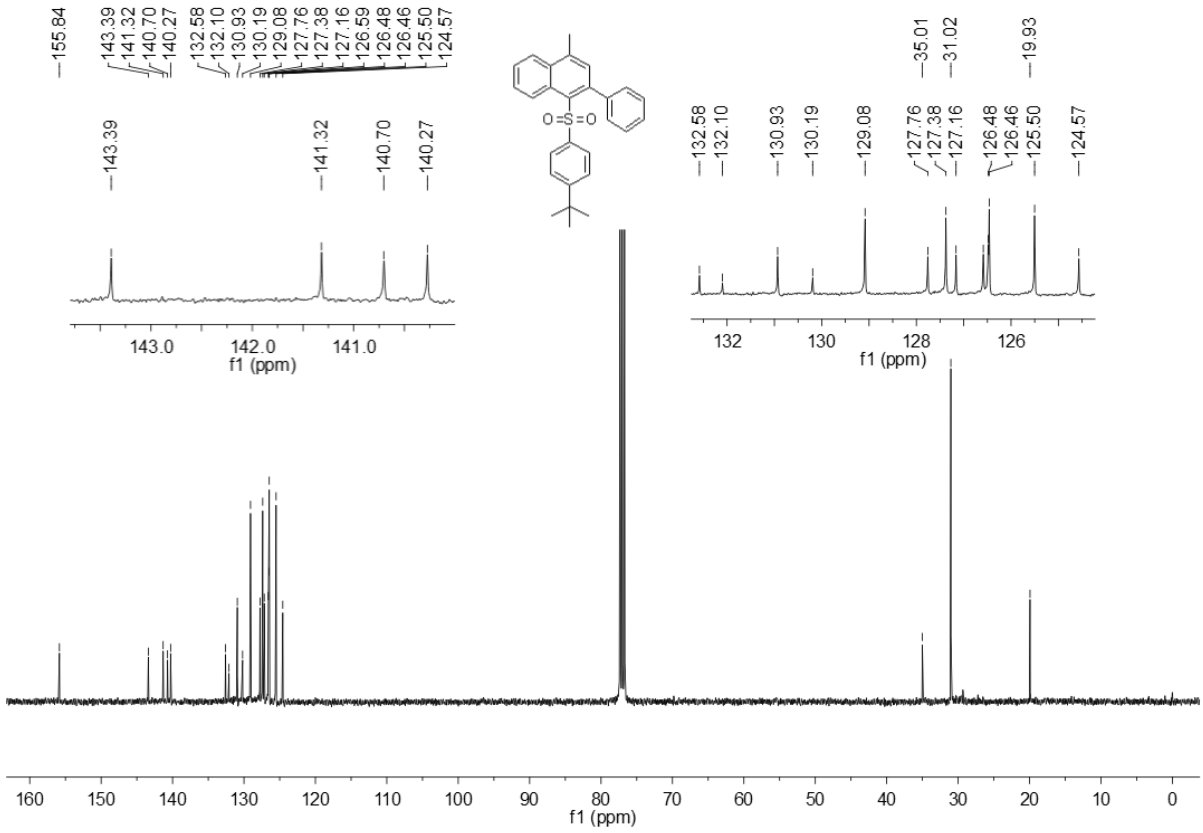
^{1}H NMR Spectrum of Compound 4a



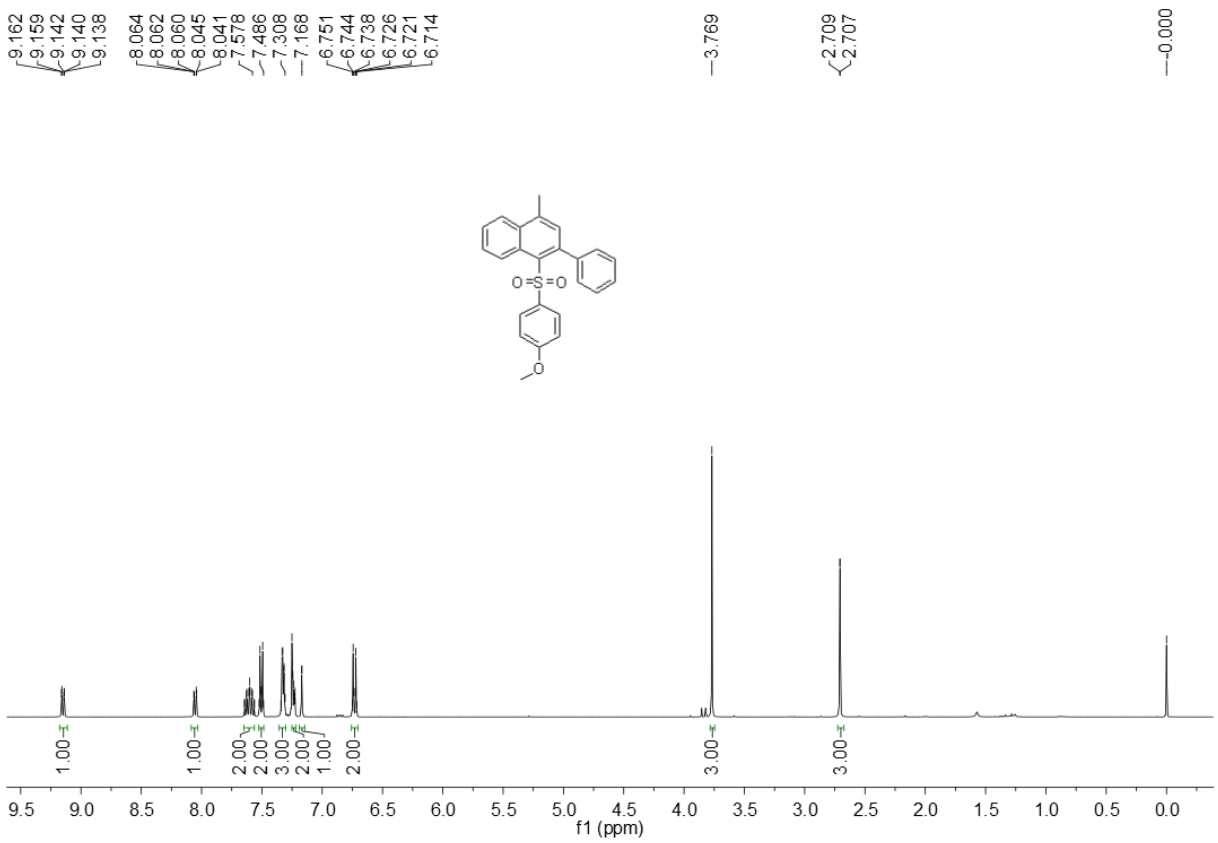
^{13}C NMR Spectrum of Compound 4a



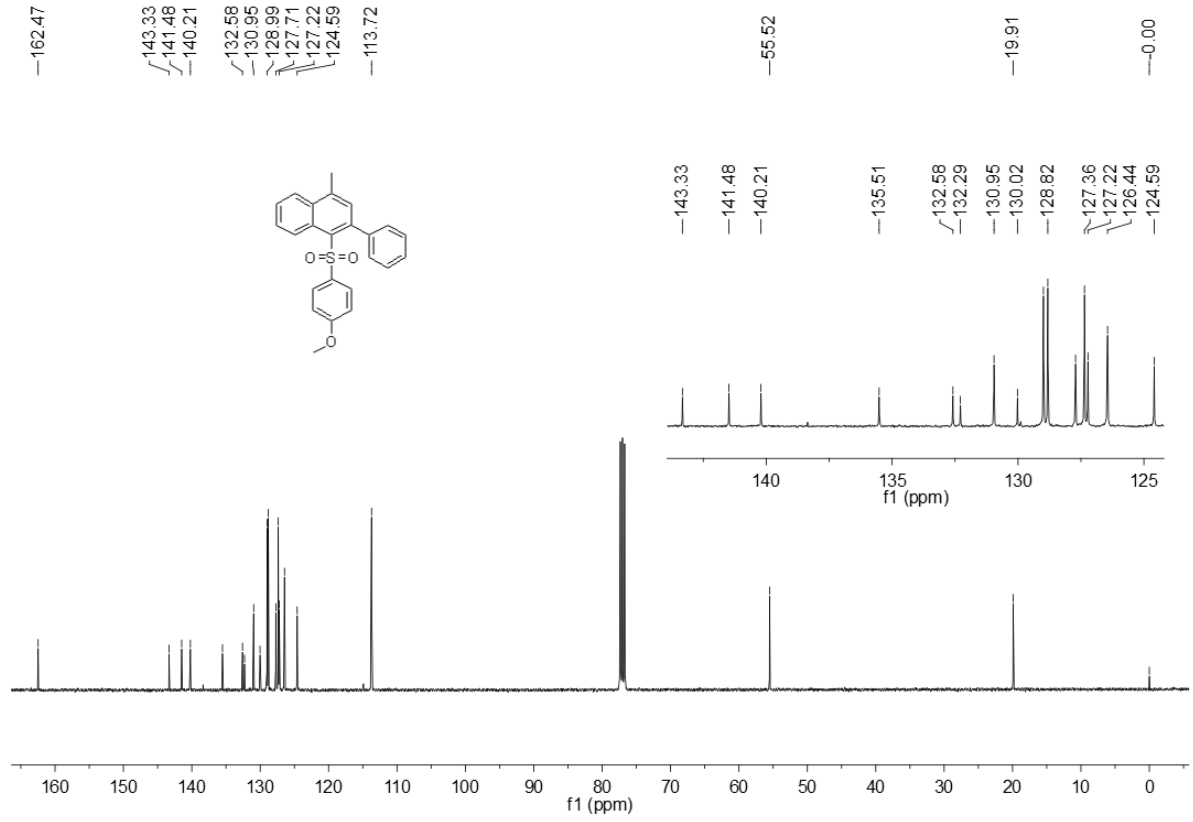
^{1}H NMR Spectrum of Compound 4b



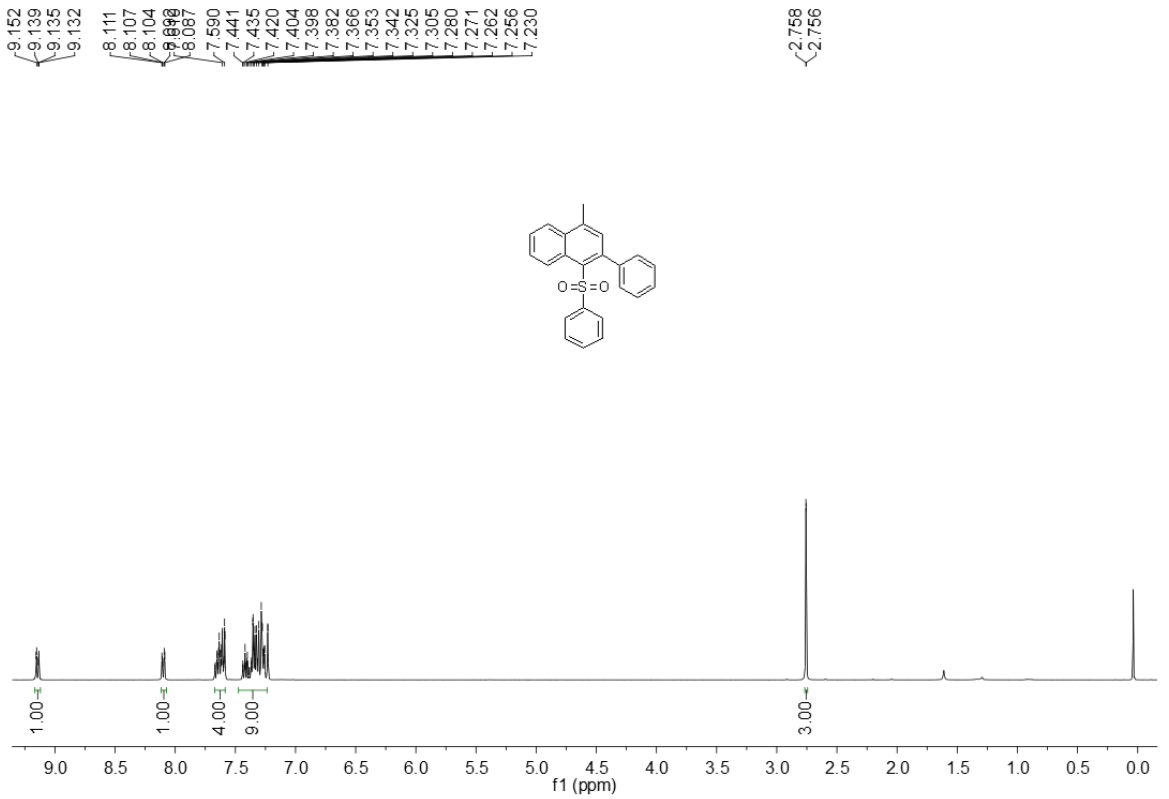
^{13}C NMR Spectrum of Compound 4b



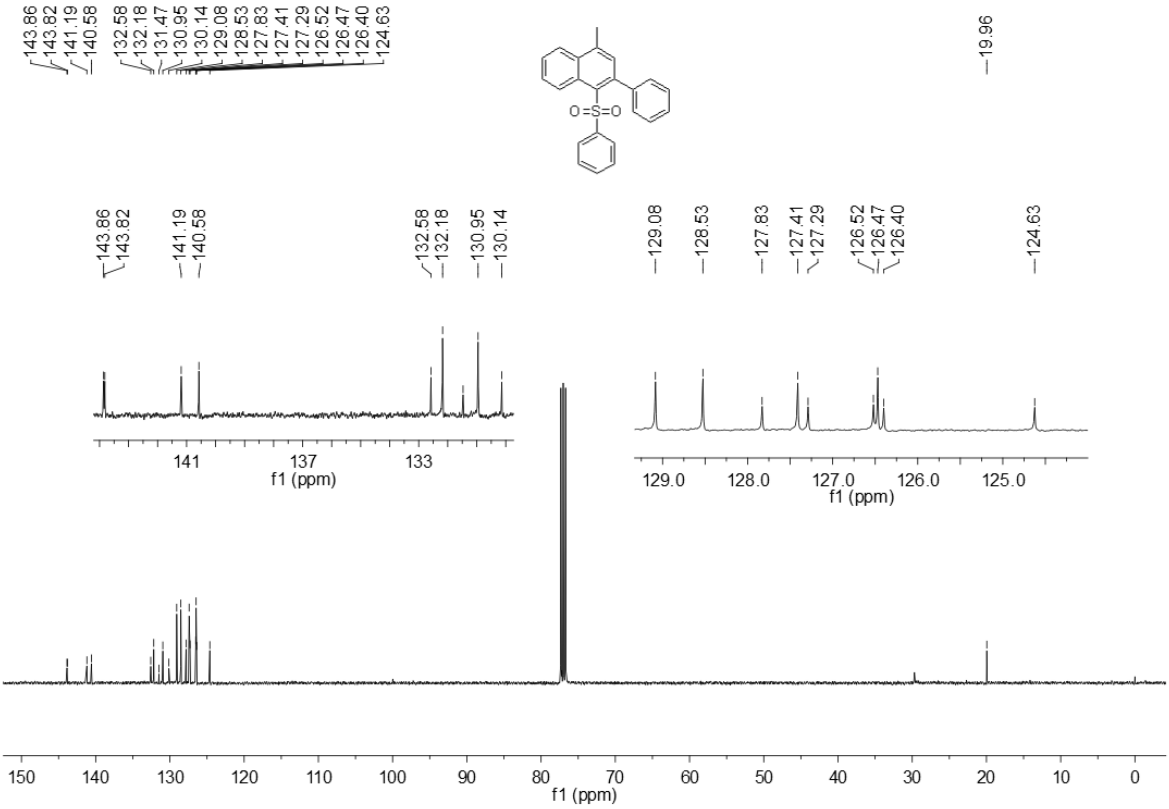
^{1}H NMR Spectrum of Compound 4c



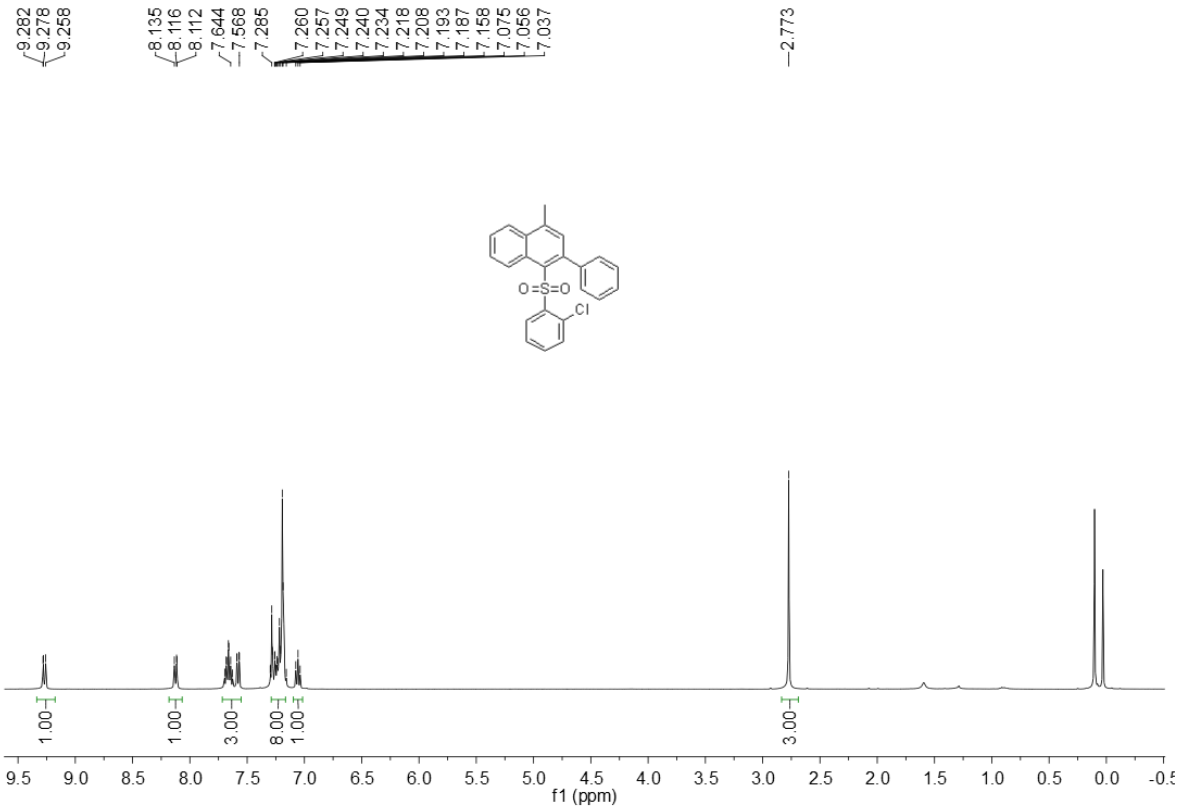
^{13}C NMR Spectrum of Compound 4c



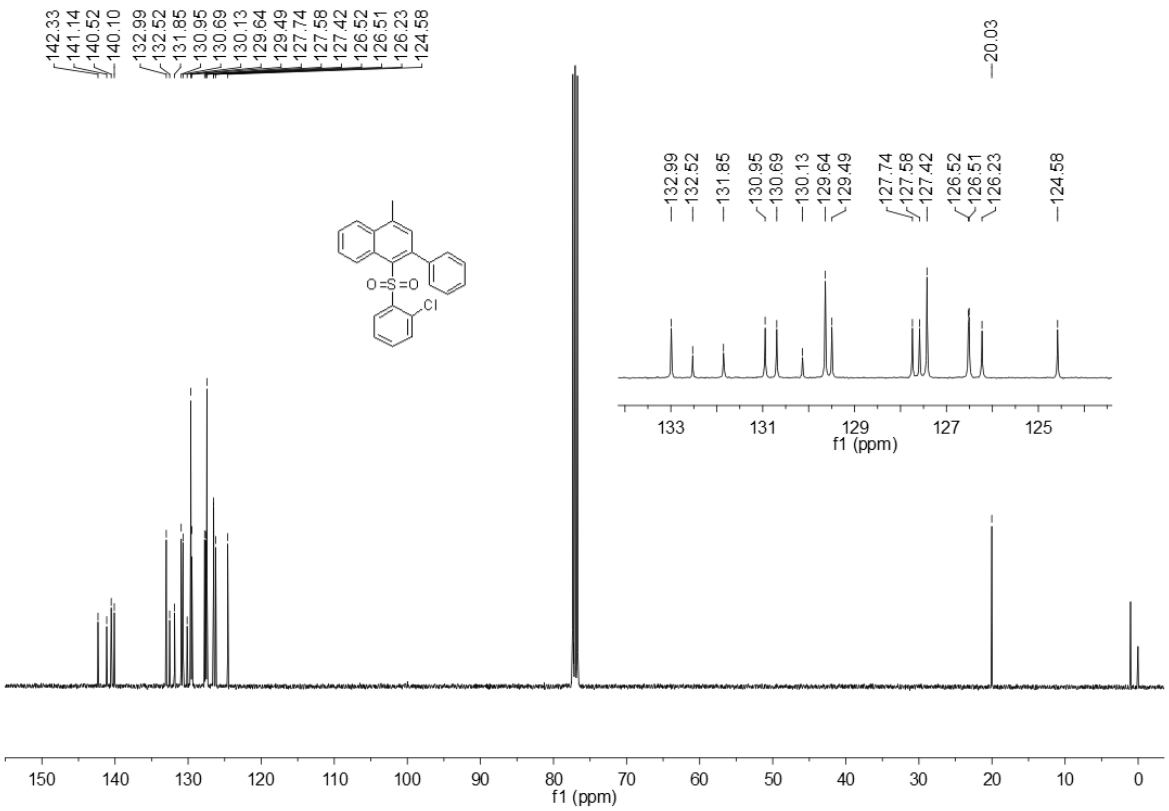
^{1}H NMR Spectrum of Compound 4d



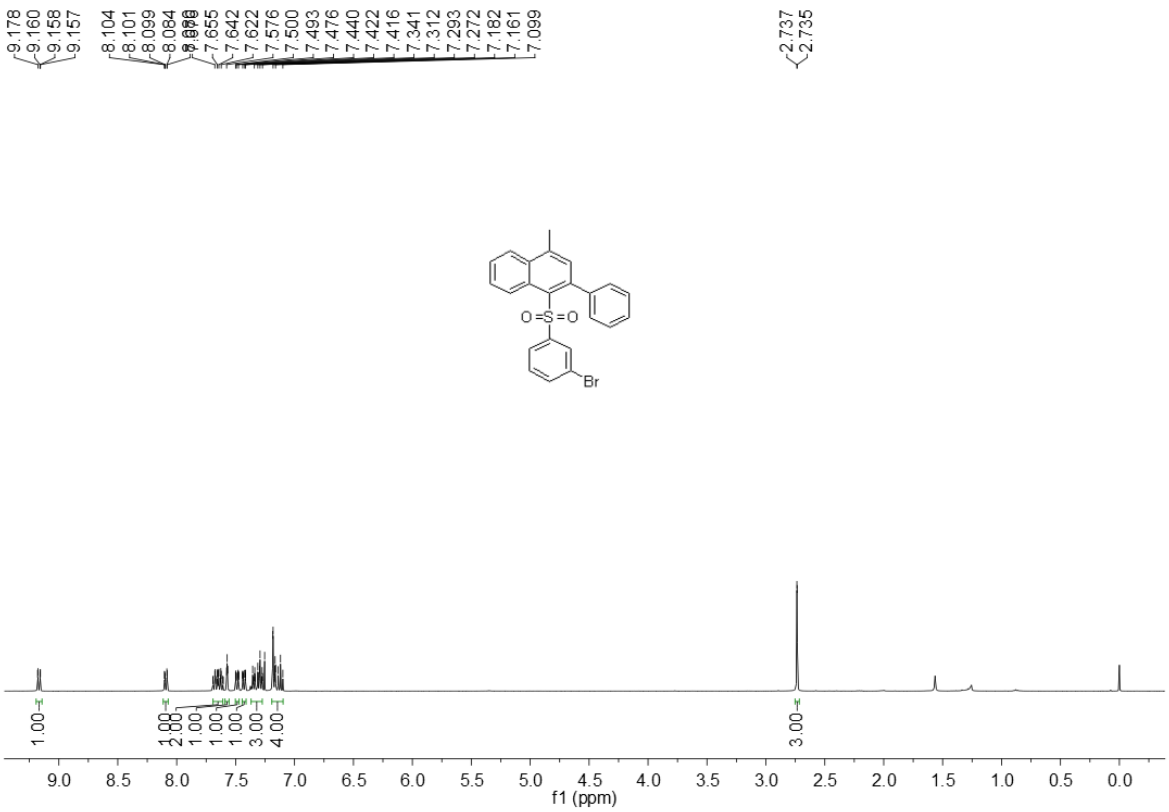
^{13}C NMR Spectrum of Compound 4d



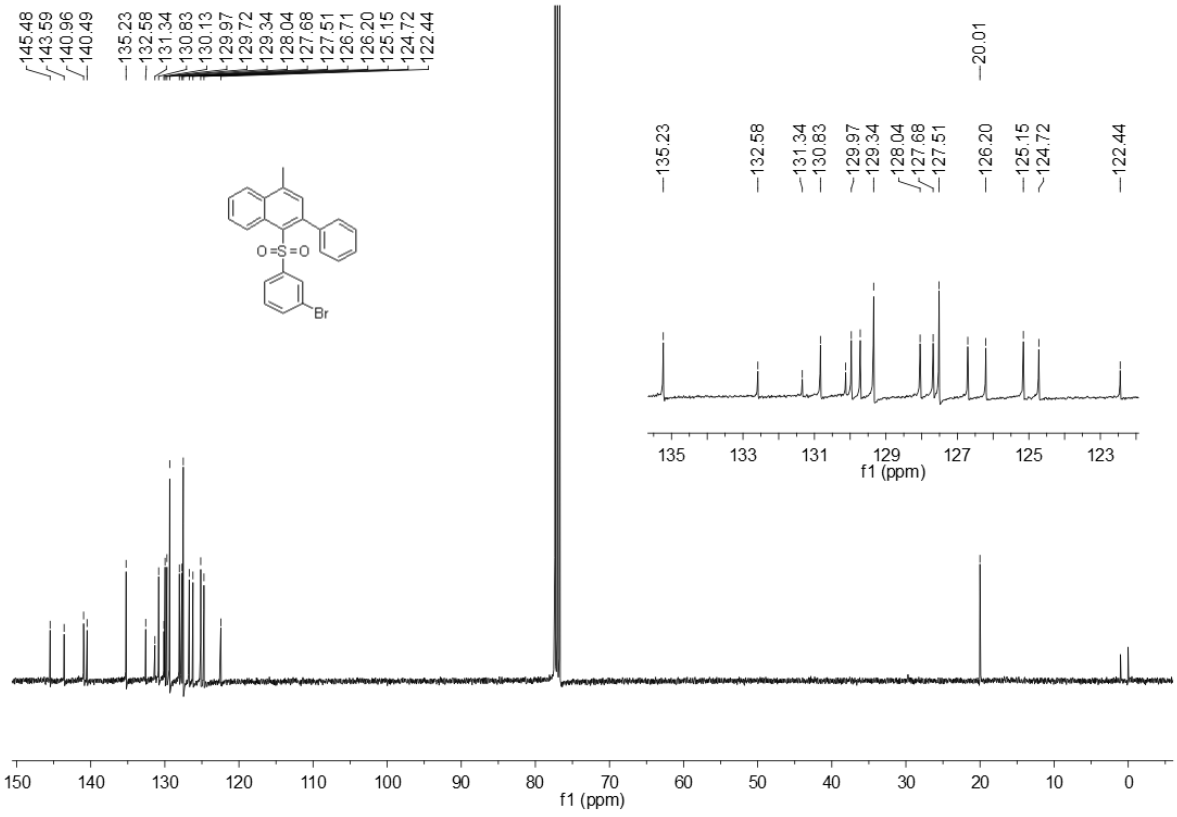
^{1}H NMR Spectrum of Compound 4e



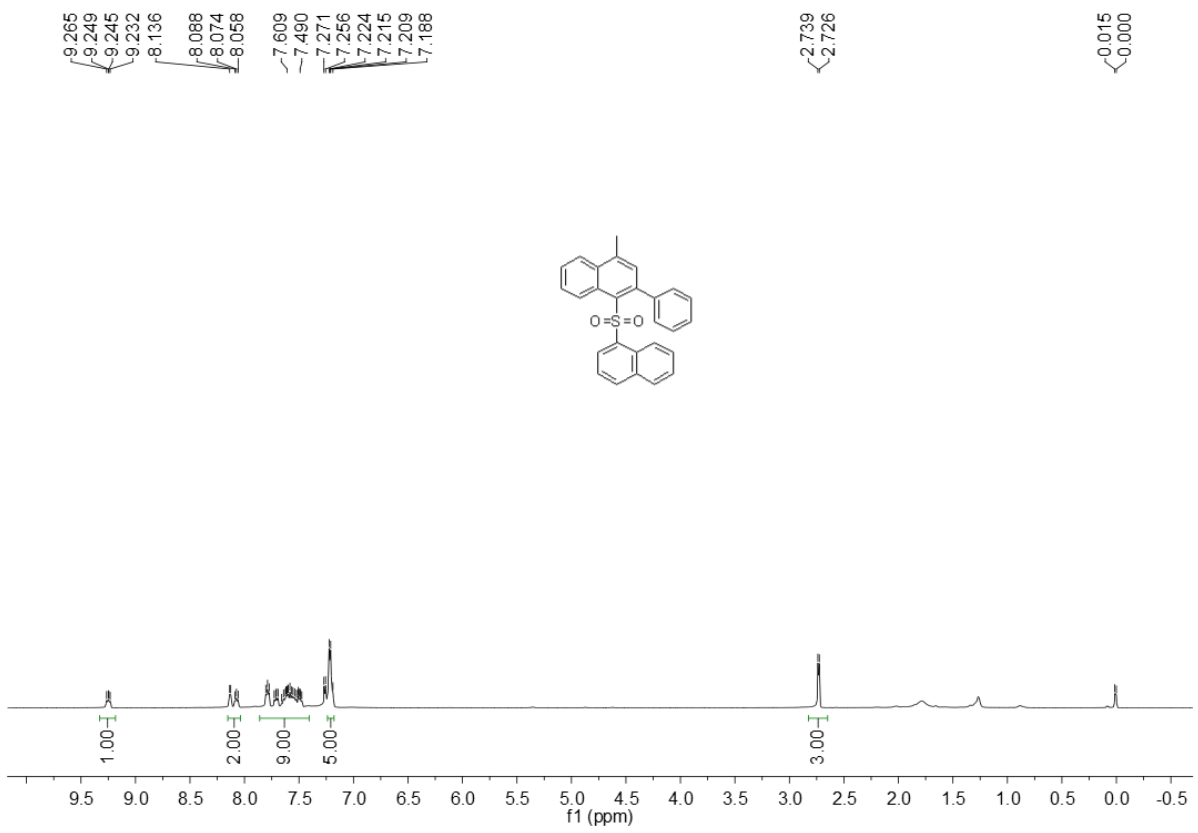
^{13}C NMR Spectrum of Compound 4e



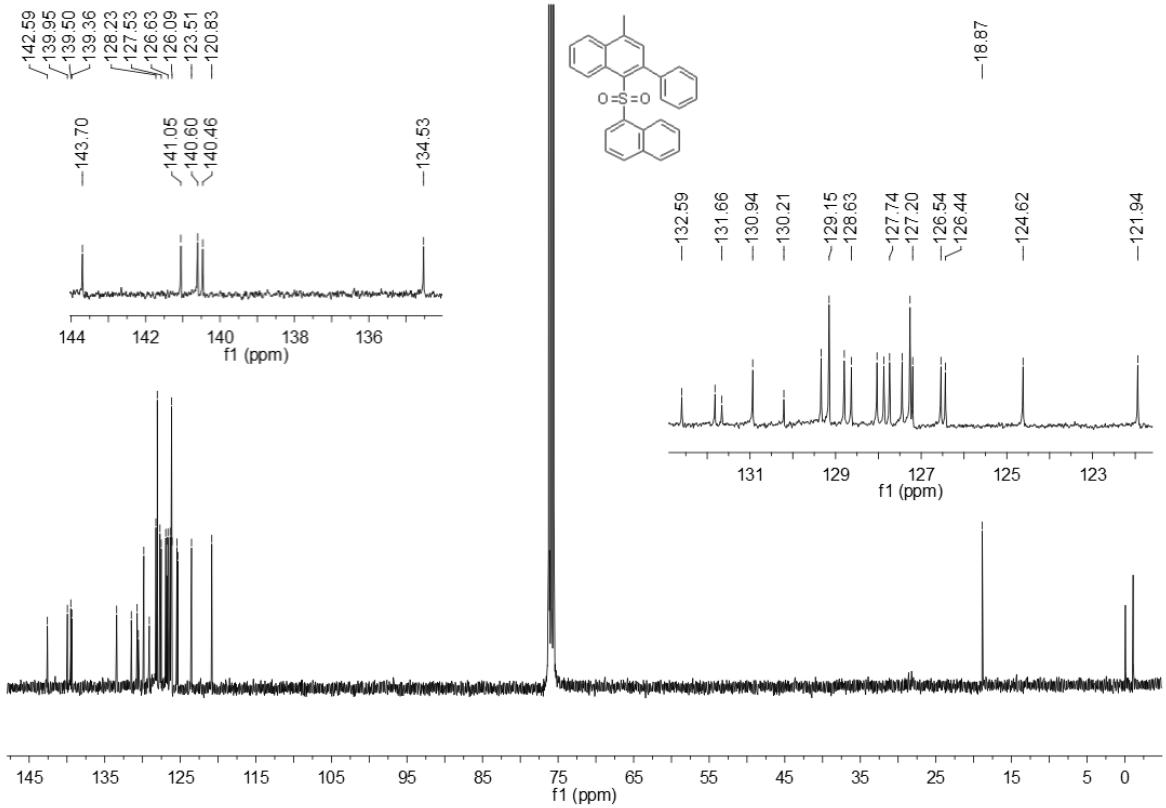
^{1}H NMR Spectrum of Compound 4f



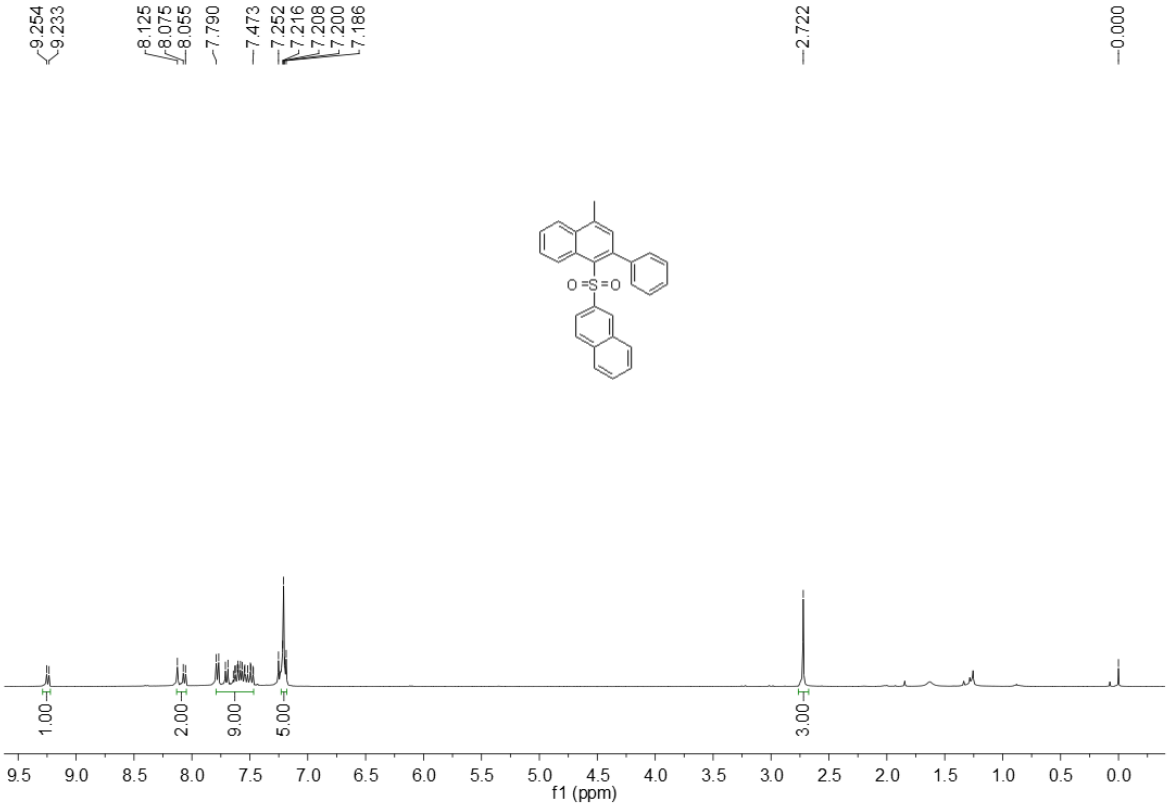
^{13}C NMR Spectrum of Compound 4f



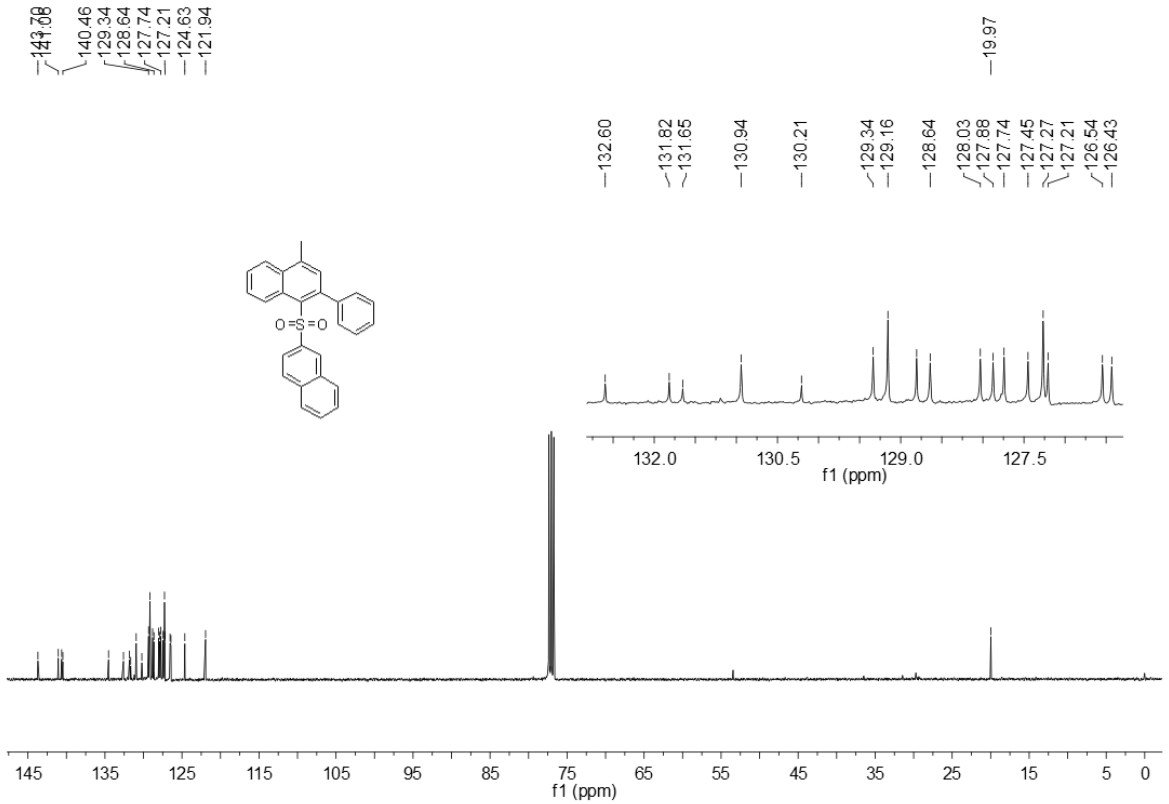
^{1}H NMR Spectrum of Compound 4g



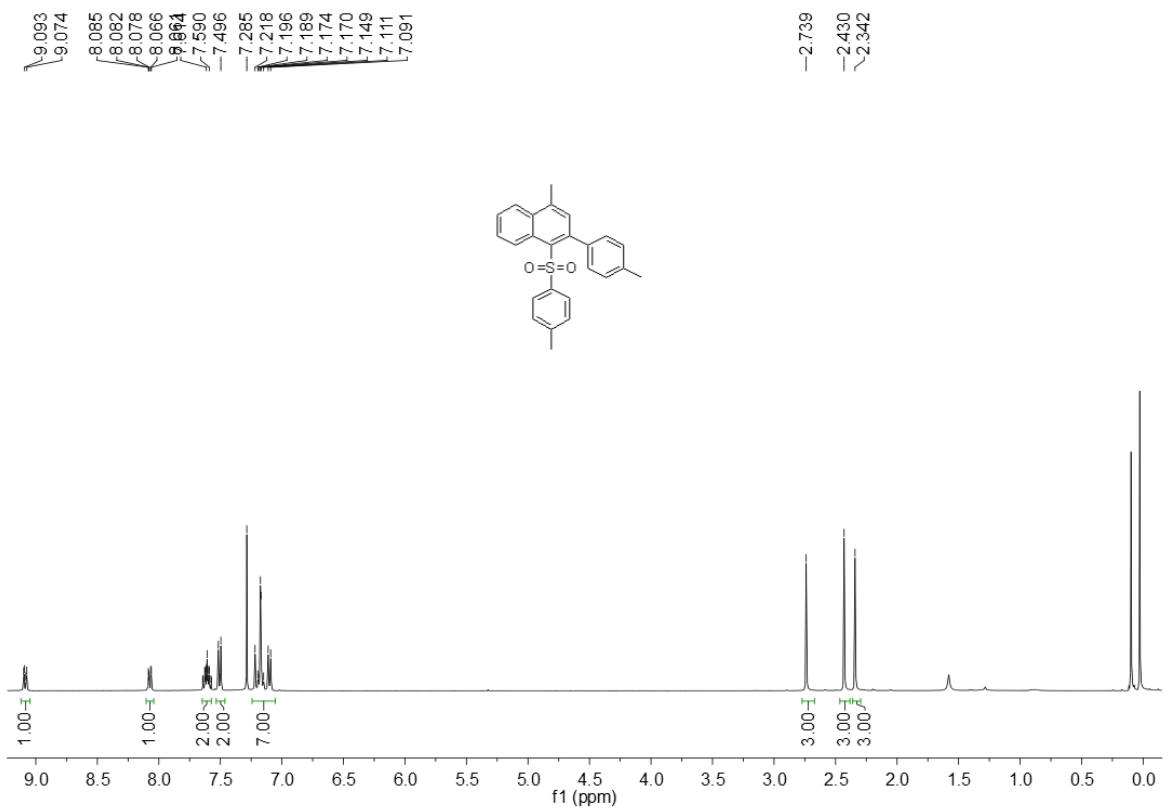
^{13}C NMR Spectrum of Compound 4g



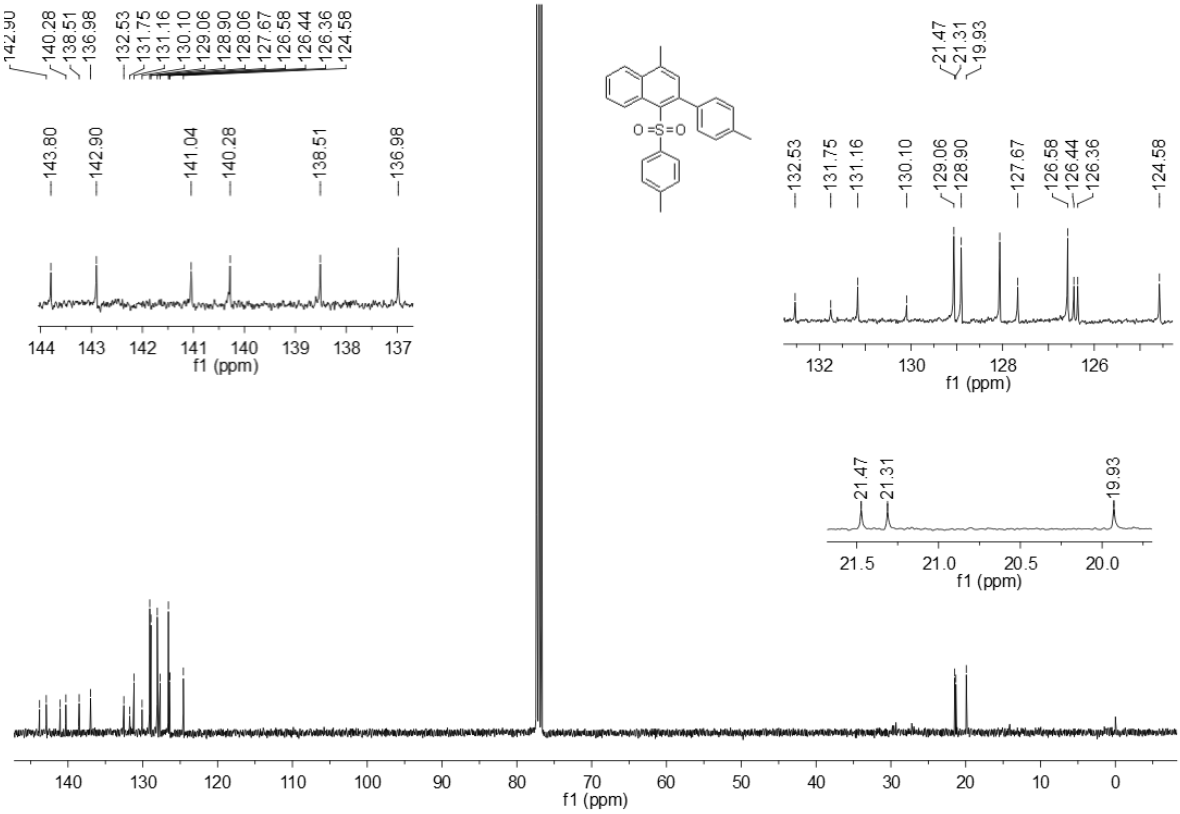
^{1}H NMR Spectrum of Compound 4h



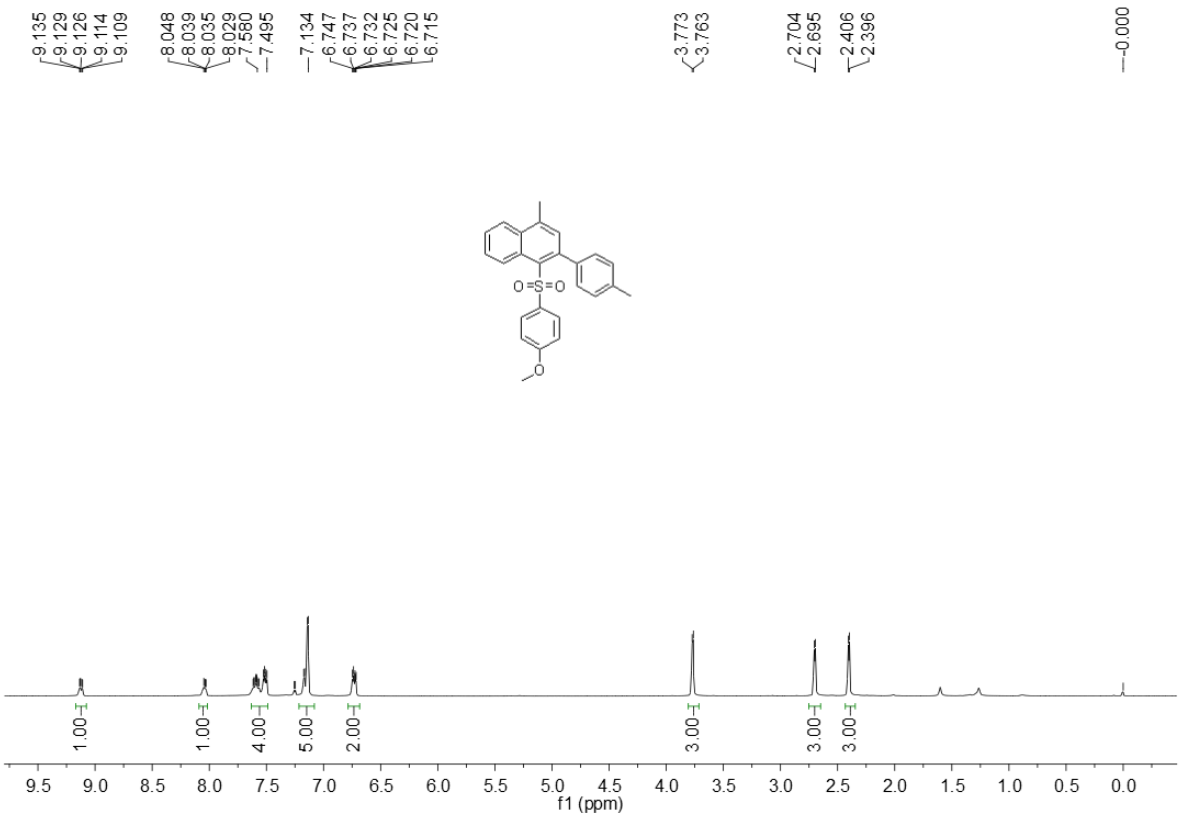
^{13}C NMR Spectrum of Compound 4h



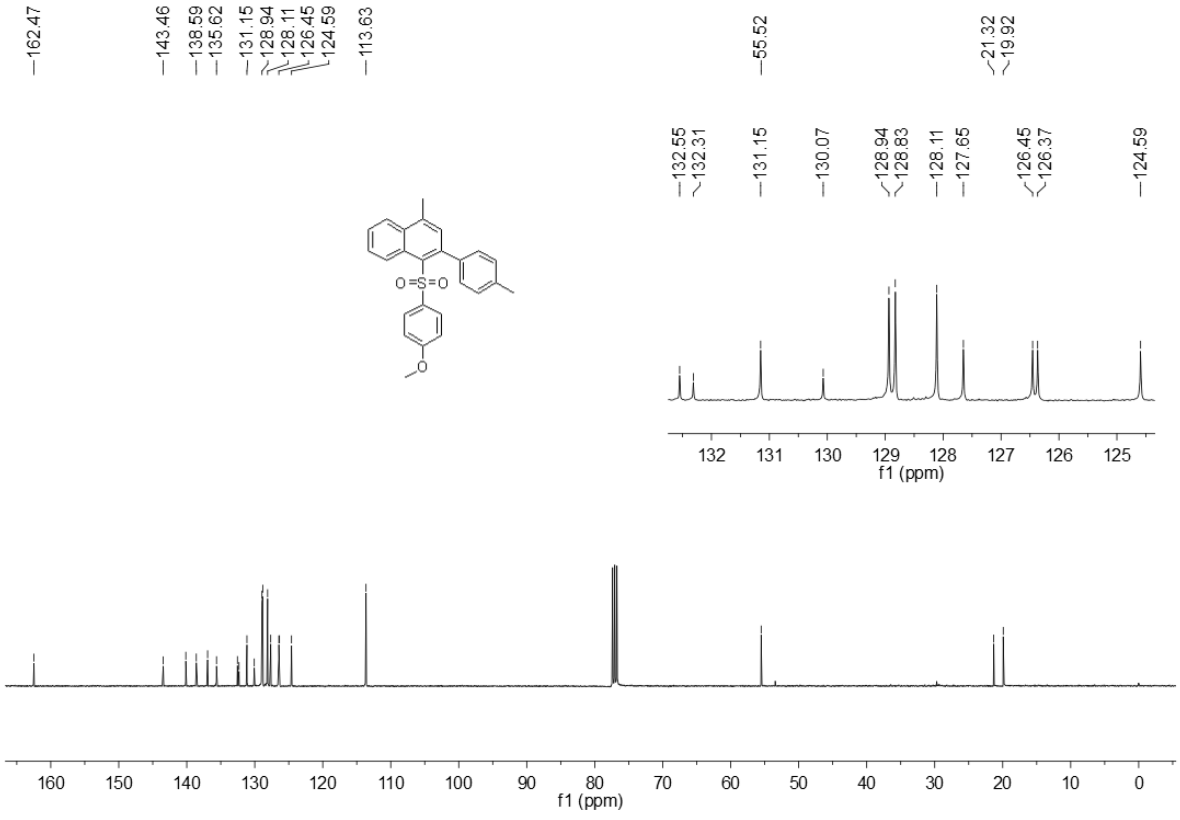
[1]H NMR Spectrum of Compound 4j



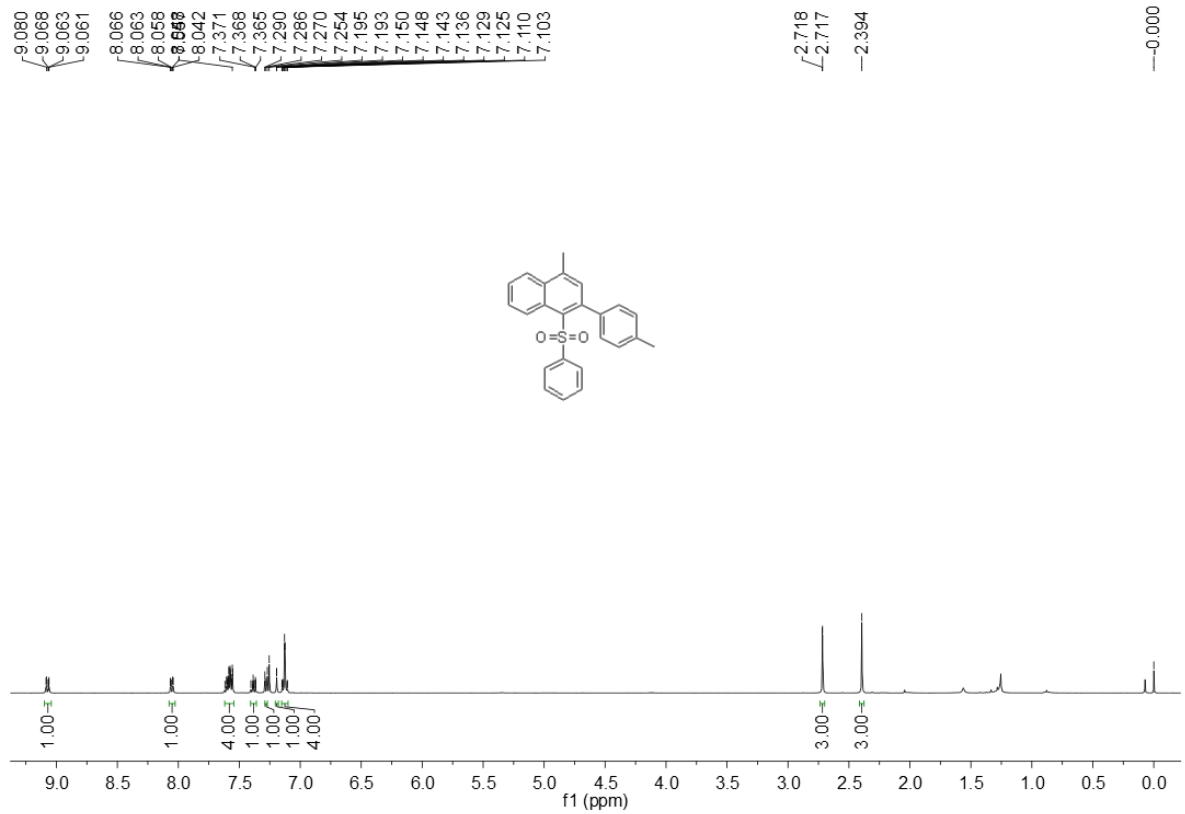
[13]C NMR Spectrum of Compound 4j



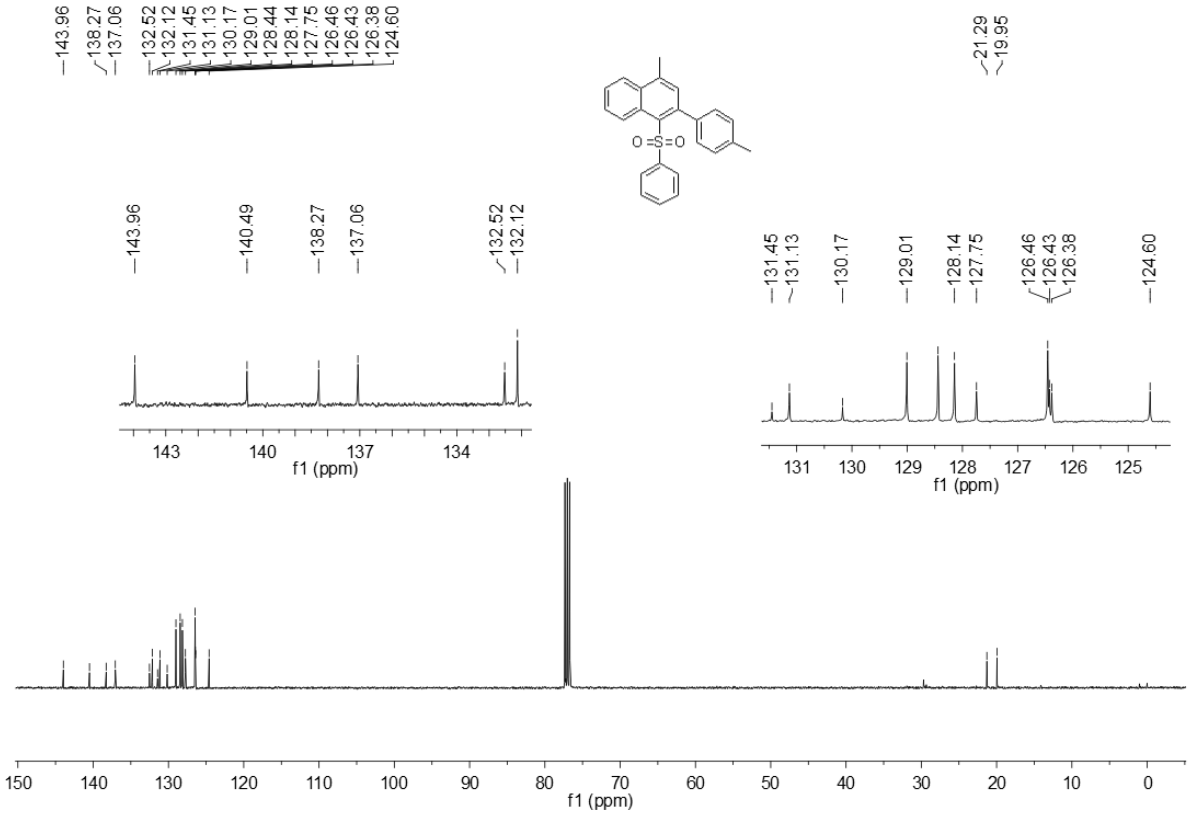
^{1}H NMR Spectrum of Compound 4k



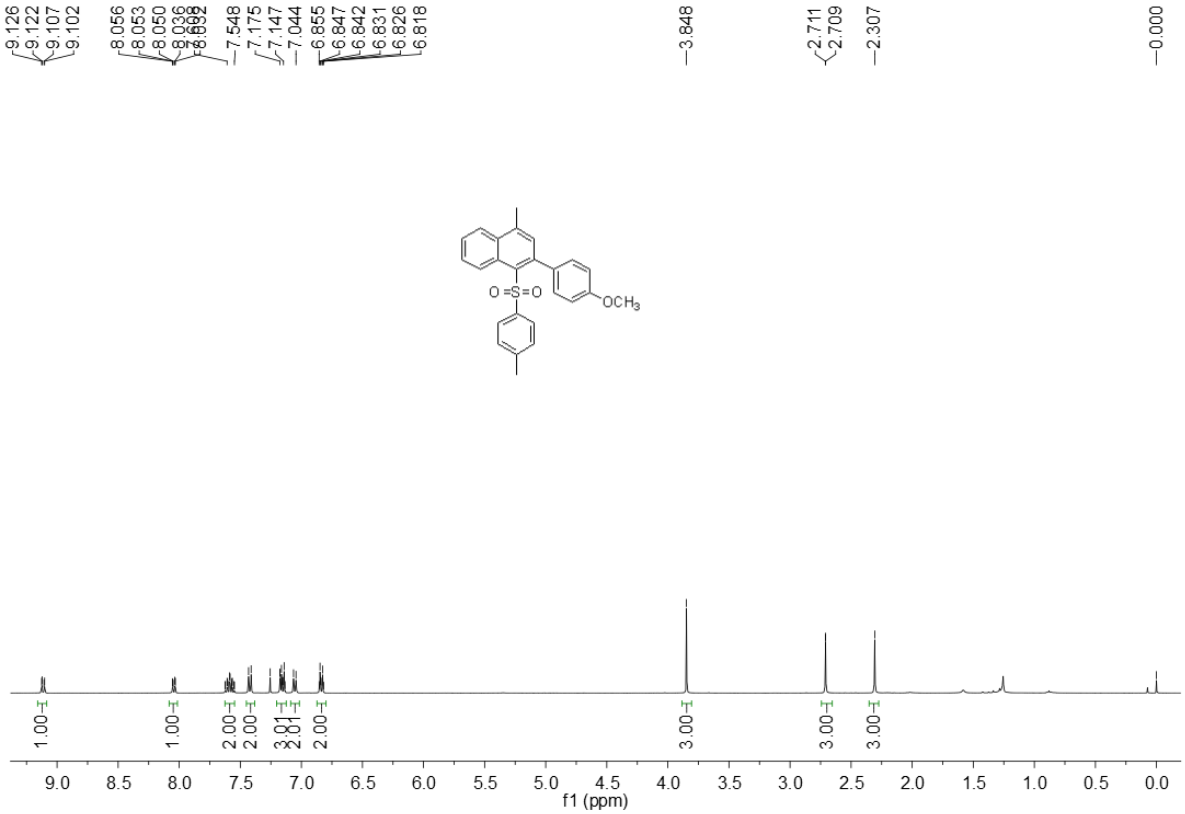
^{13}C NMR Spectrum of Compound 4k



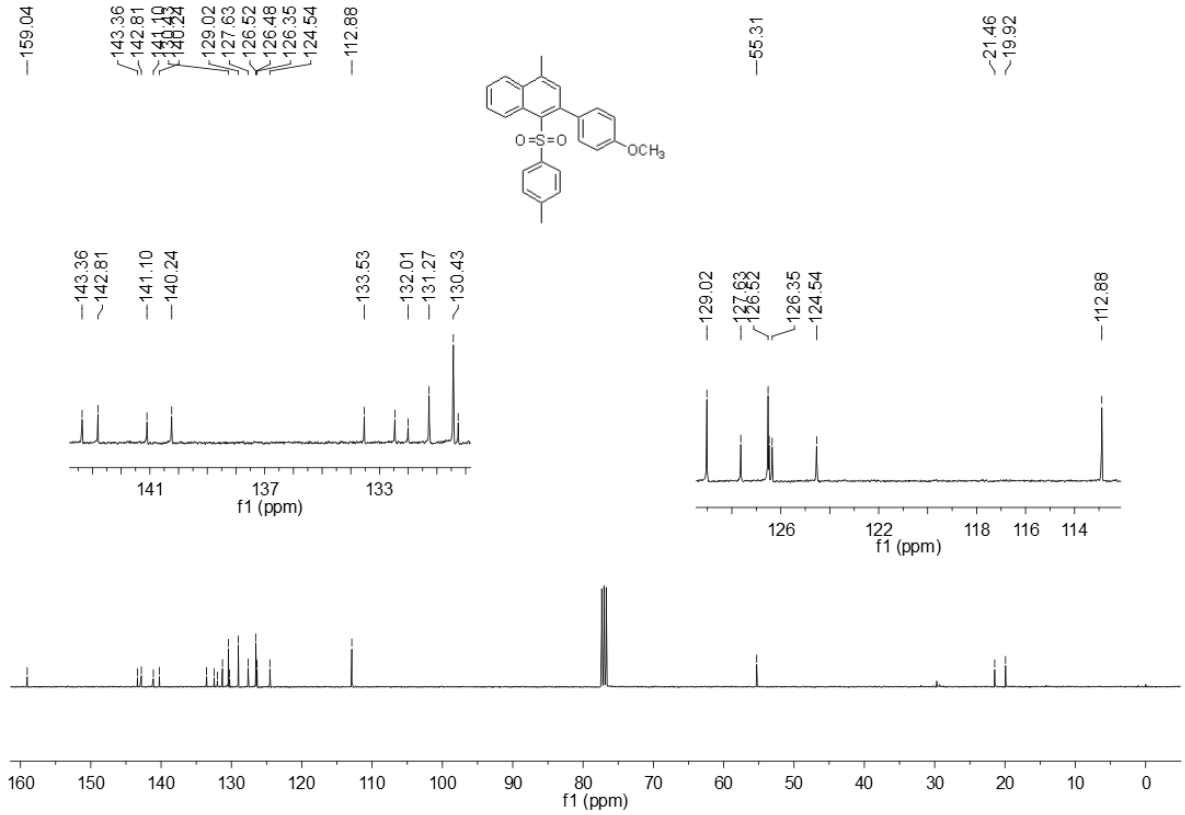
^{1}H NMR Spectrum of Compound 4l



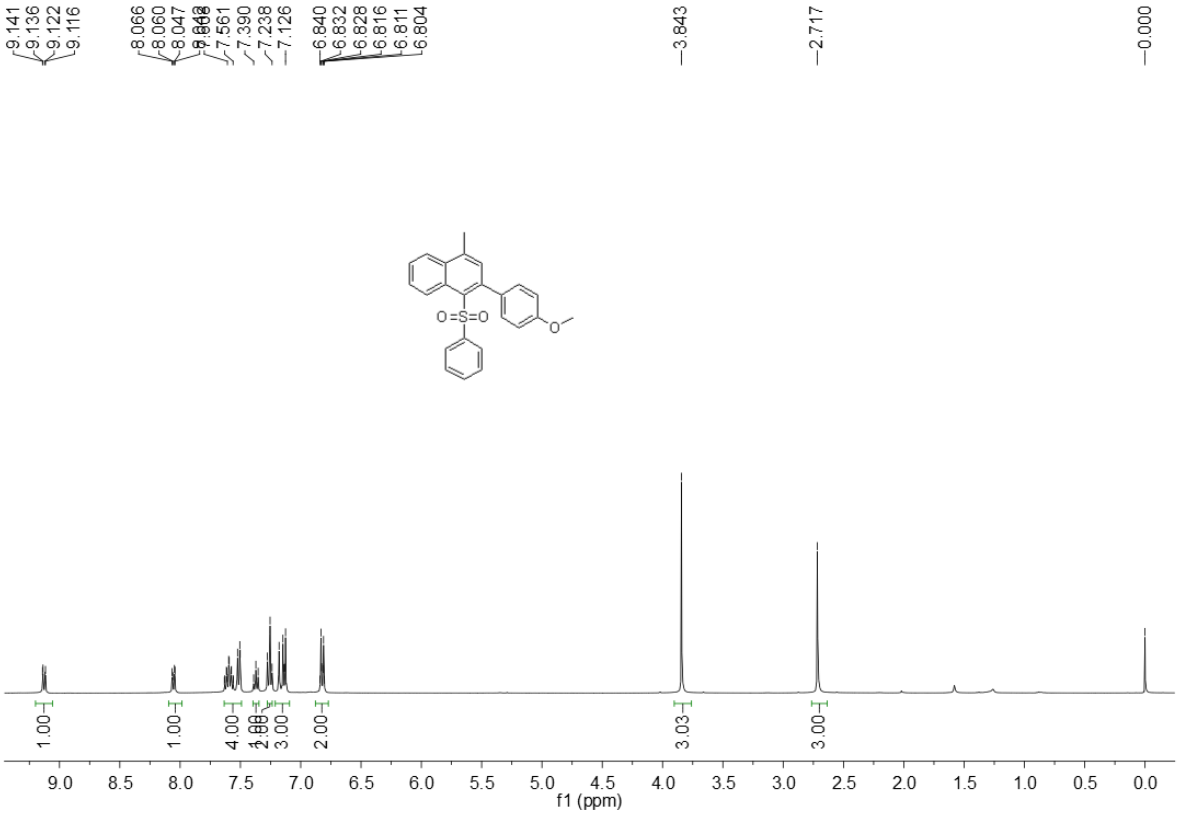
^{13}C NMR Spectrum of Compound 4l



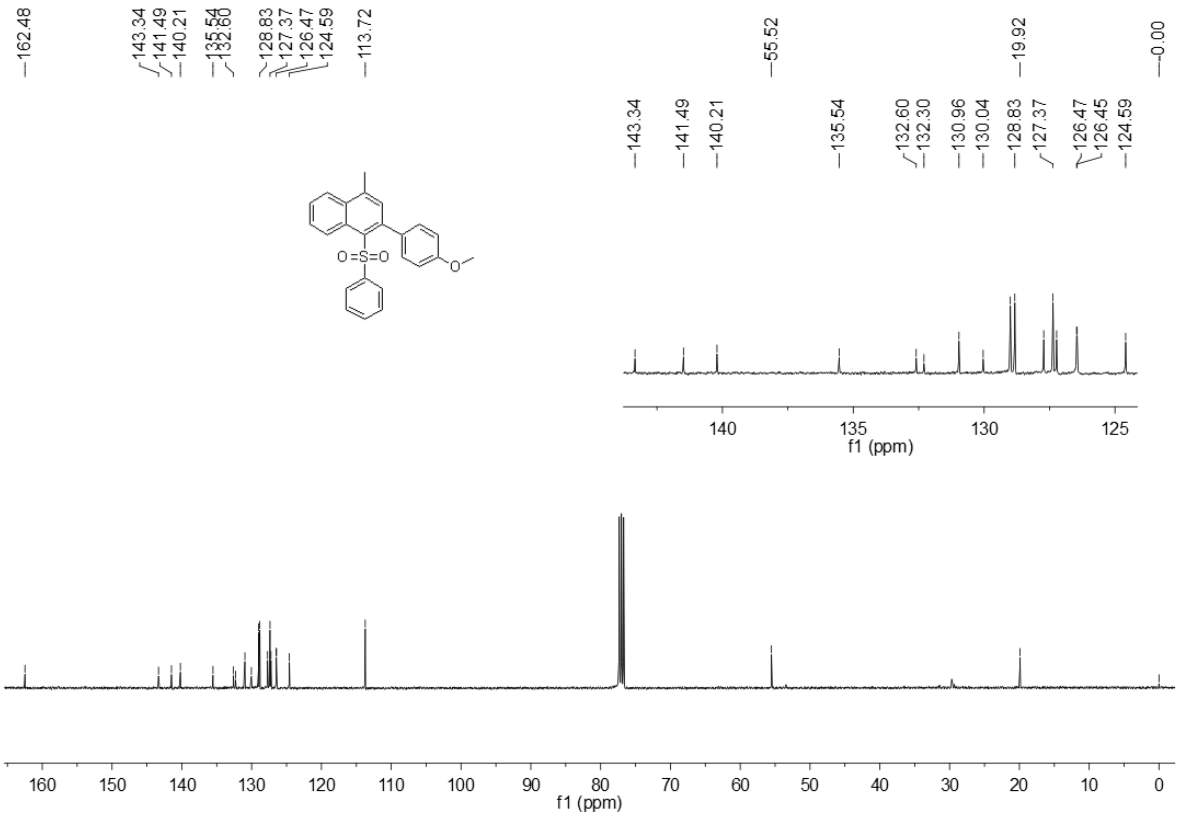
^{1}H NMR Spectrum of Compound 4m



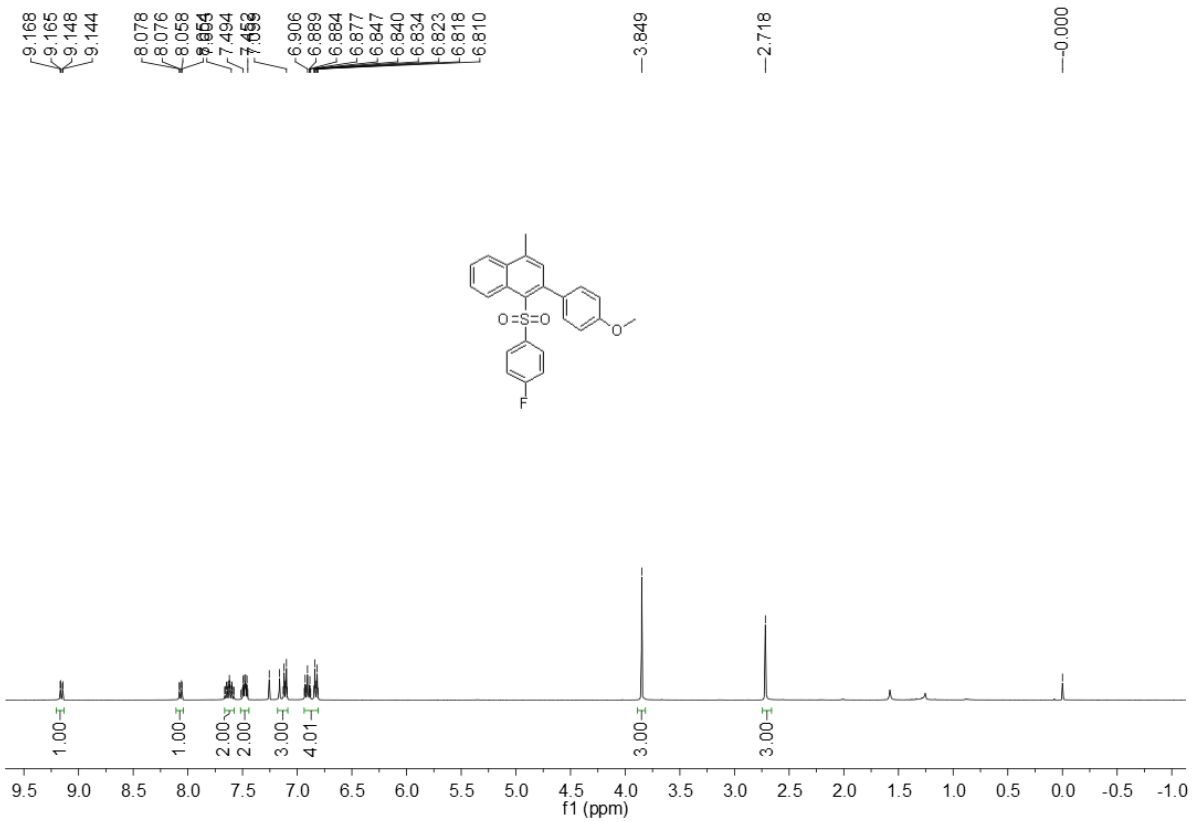
^{13}C NMR Spectrum of Compound 4m



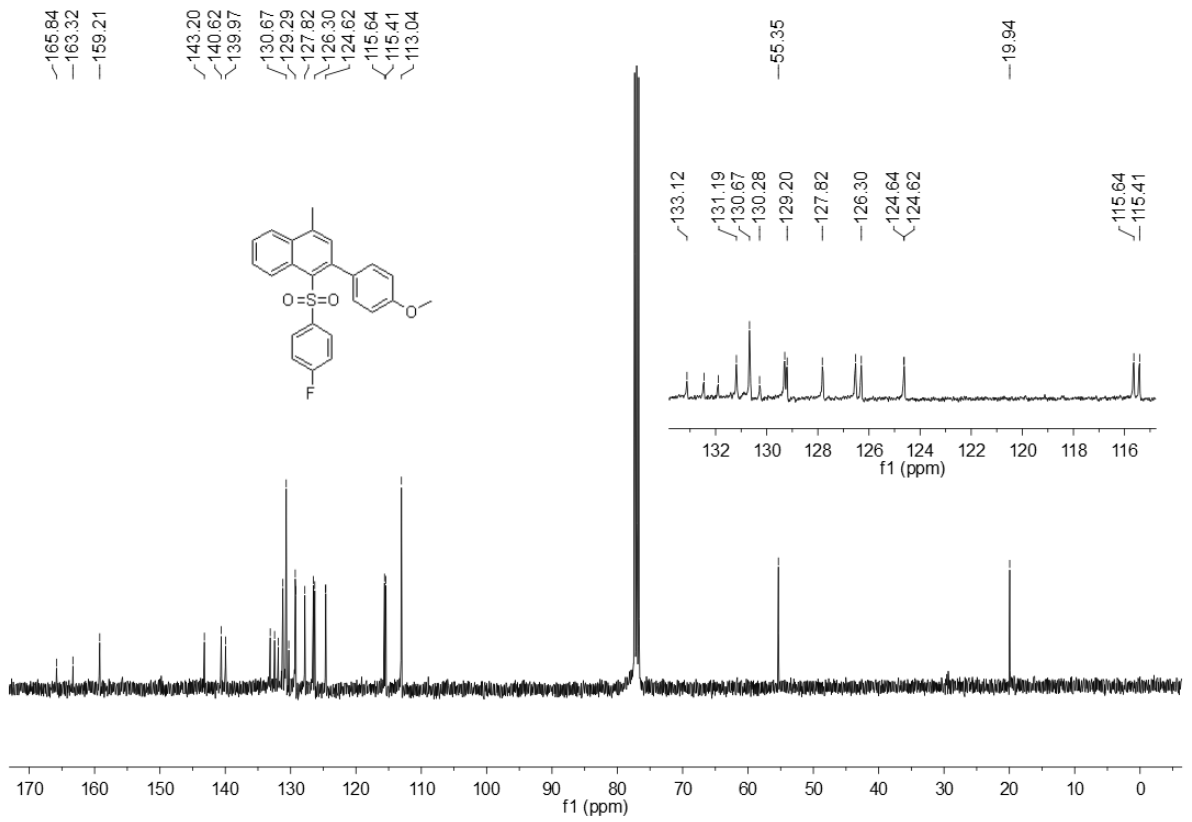
^{1}H NMR Spectrum of Compound 4n



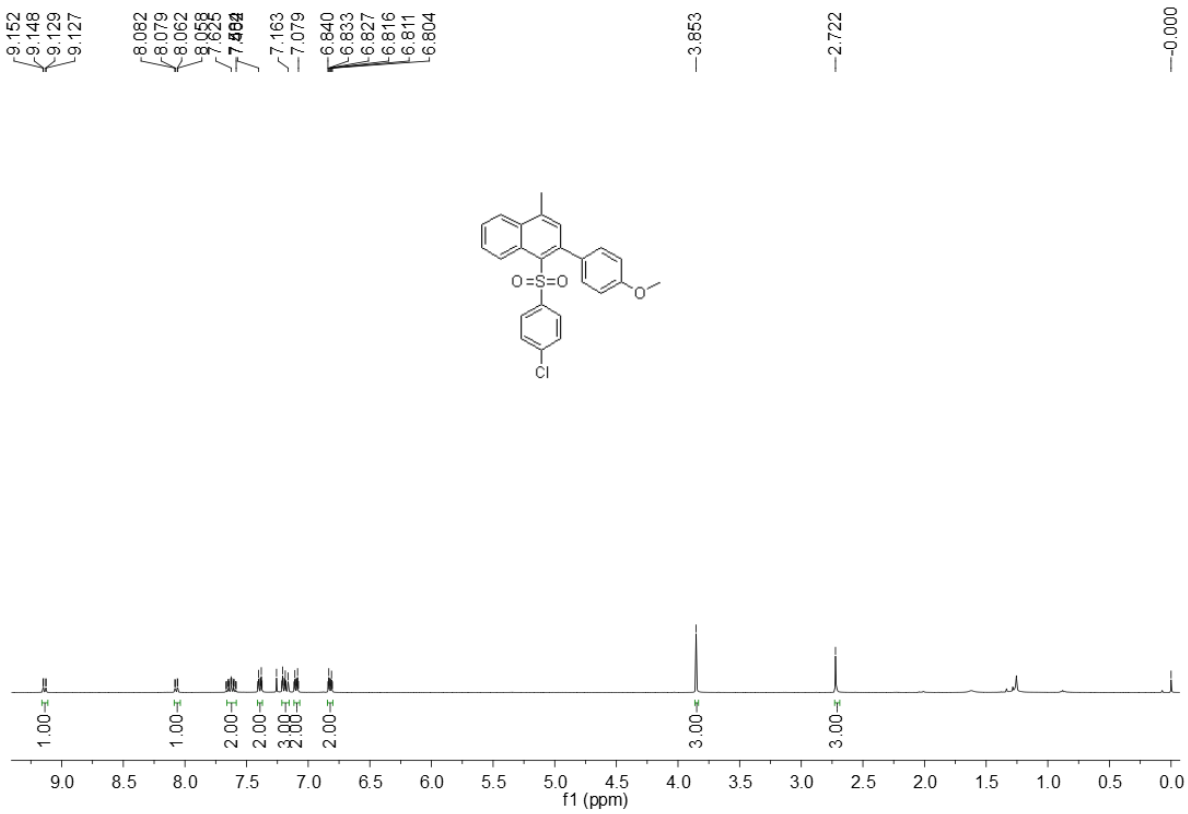
^{13}C NMR Spectrum of Compound 4n



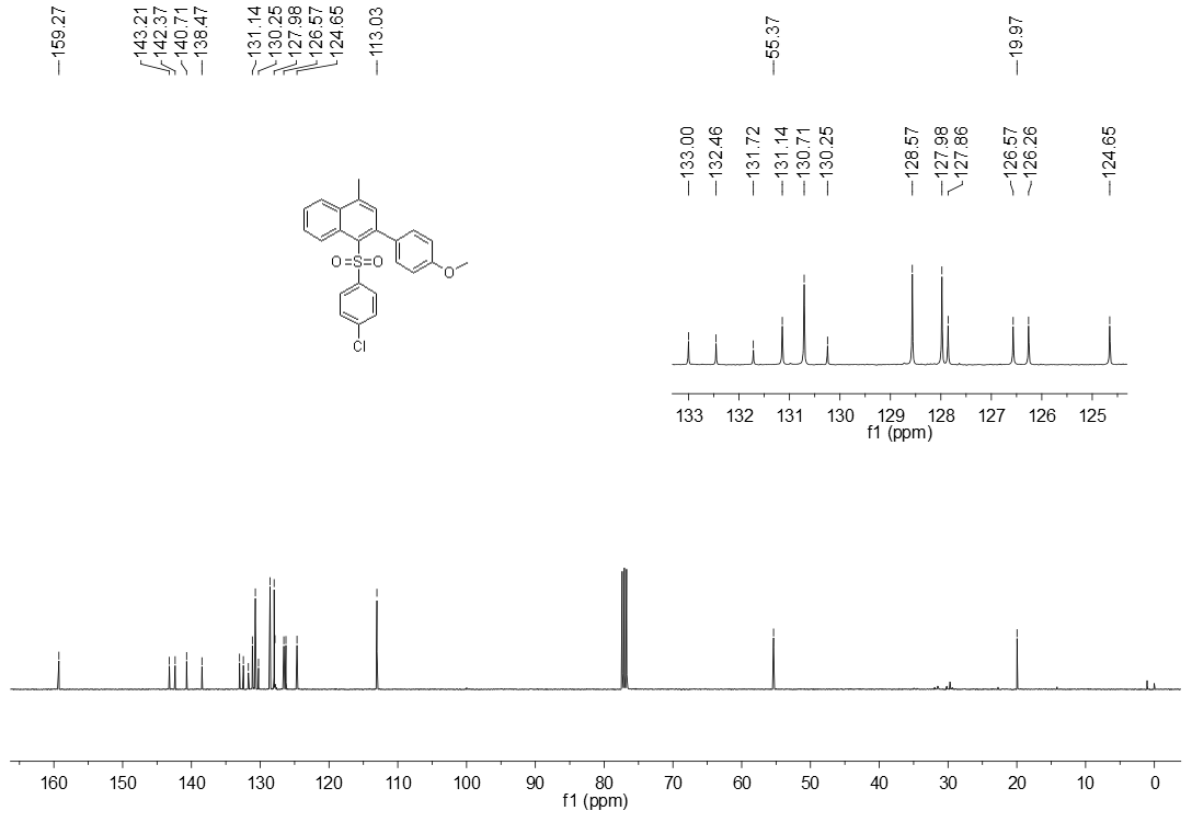
^{1}H NMR Spectrum of Compound 4o



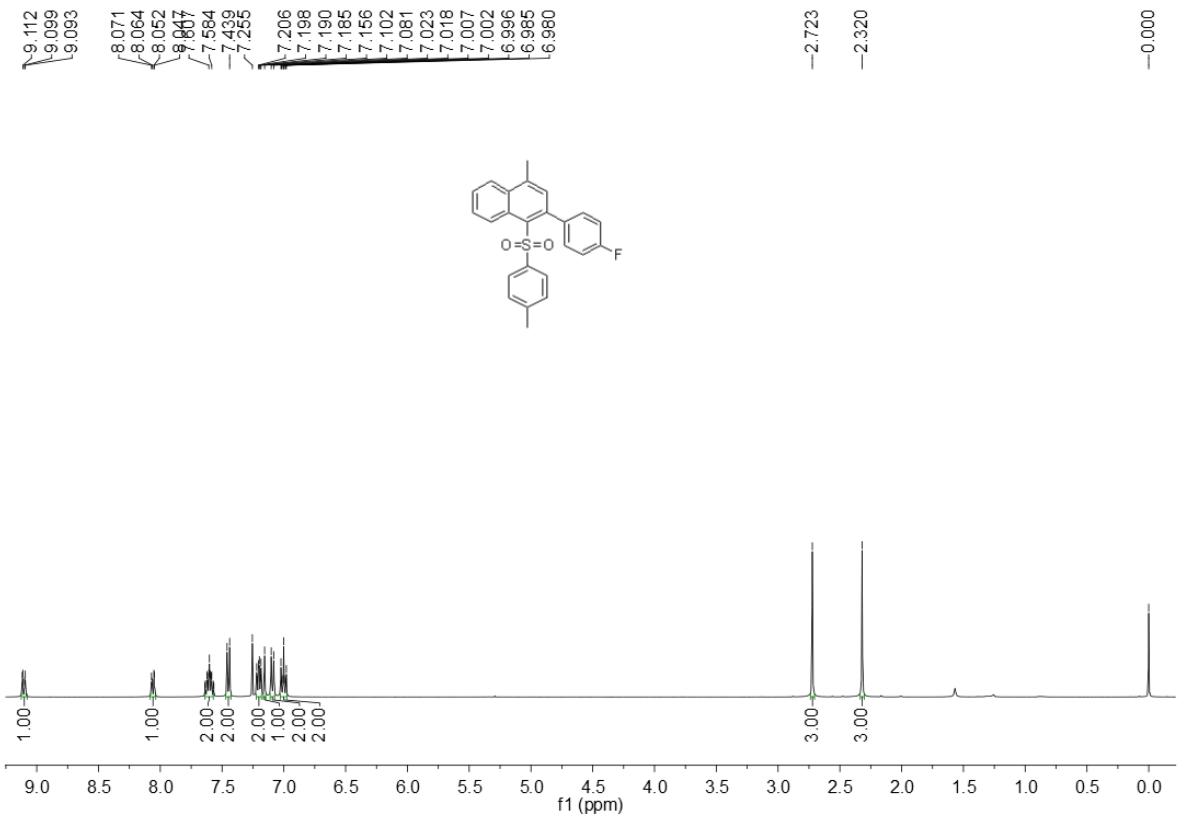
^{13}C NMR Spectrum of Compound 4o



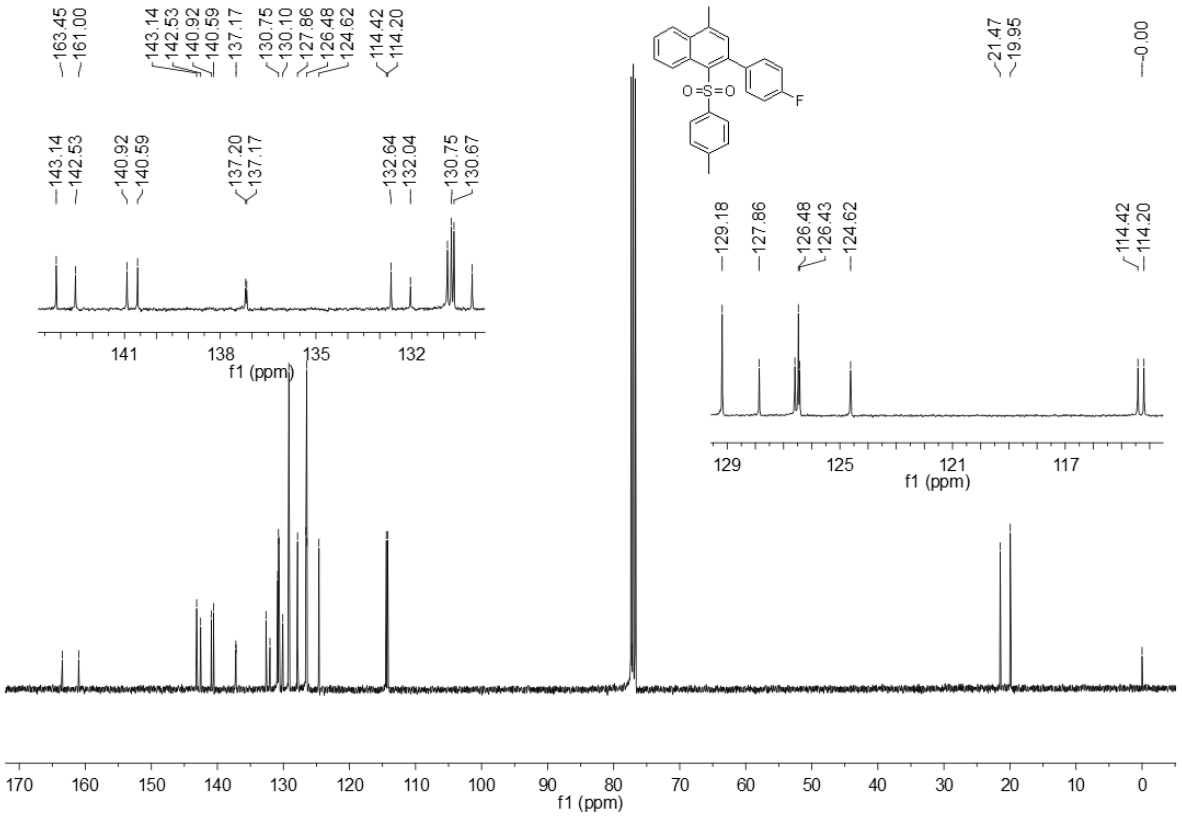
^{1}H NMR Spectrum of Compound 4p



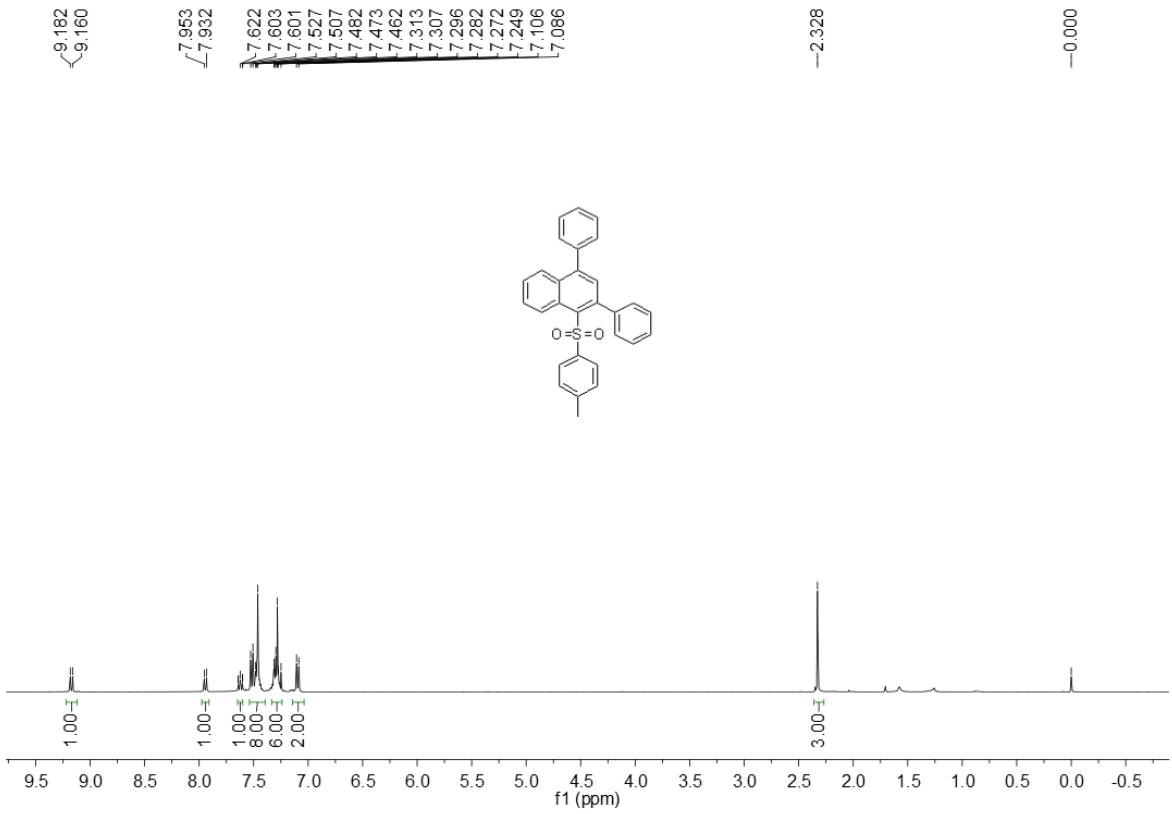
^{13}C NMR Spectrum of Compound 4p



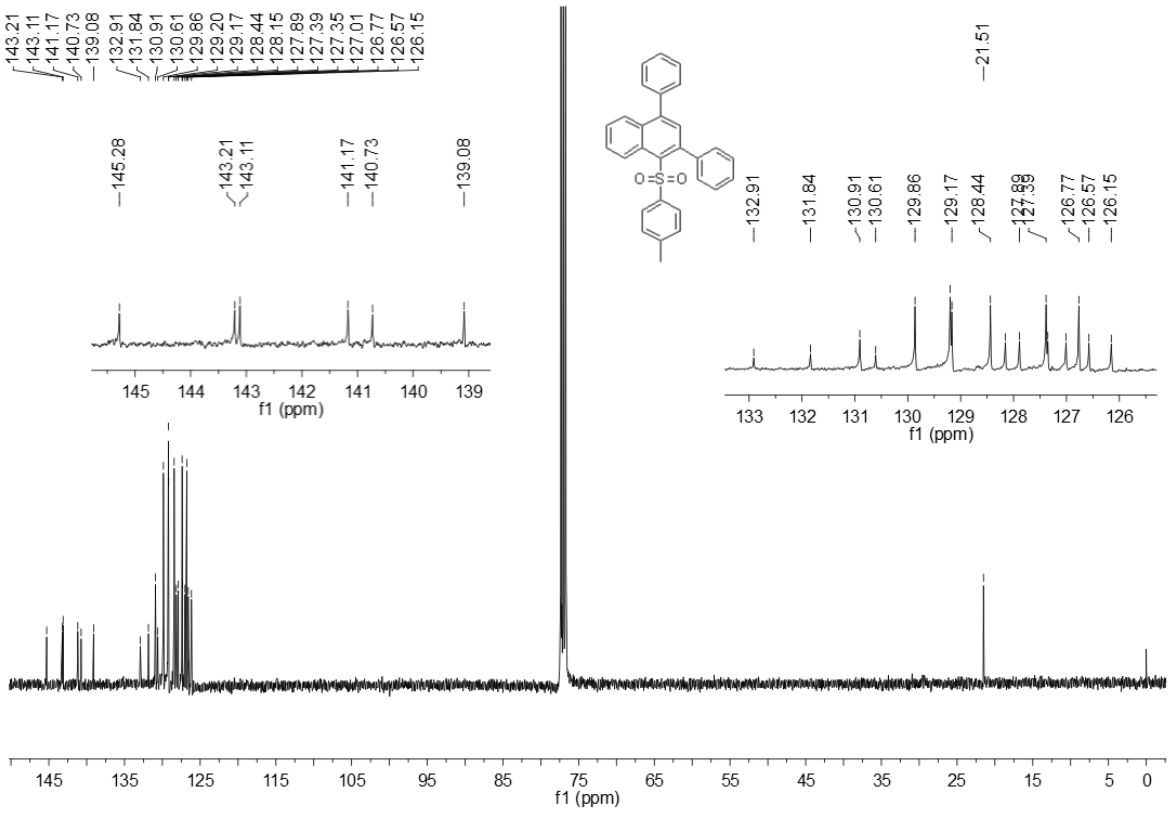
^{1}H NMR Spectrum of Compound 4q



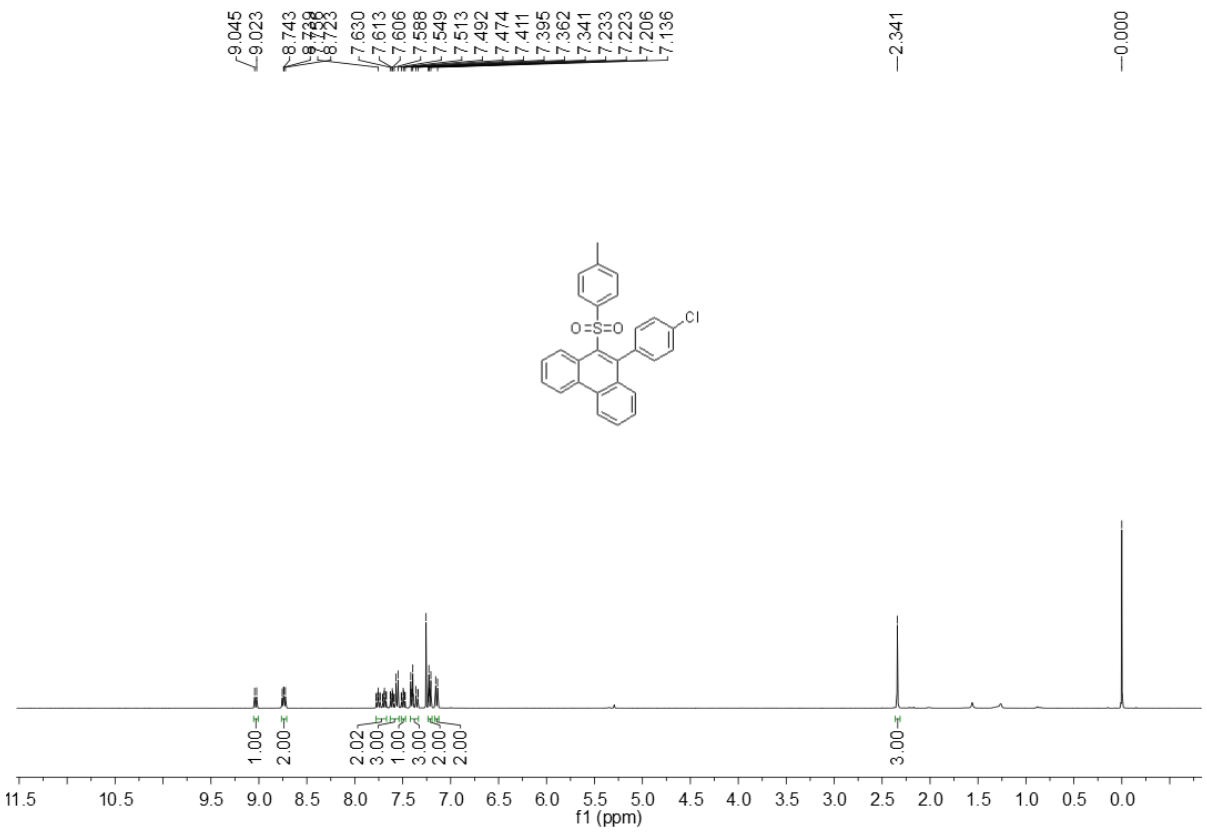
^{13}C NMR Spectrum of Compound 4q



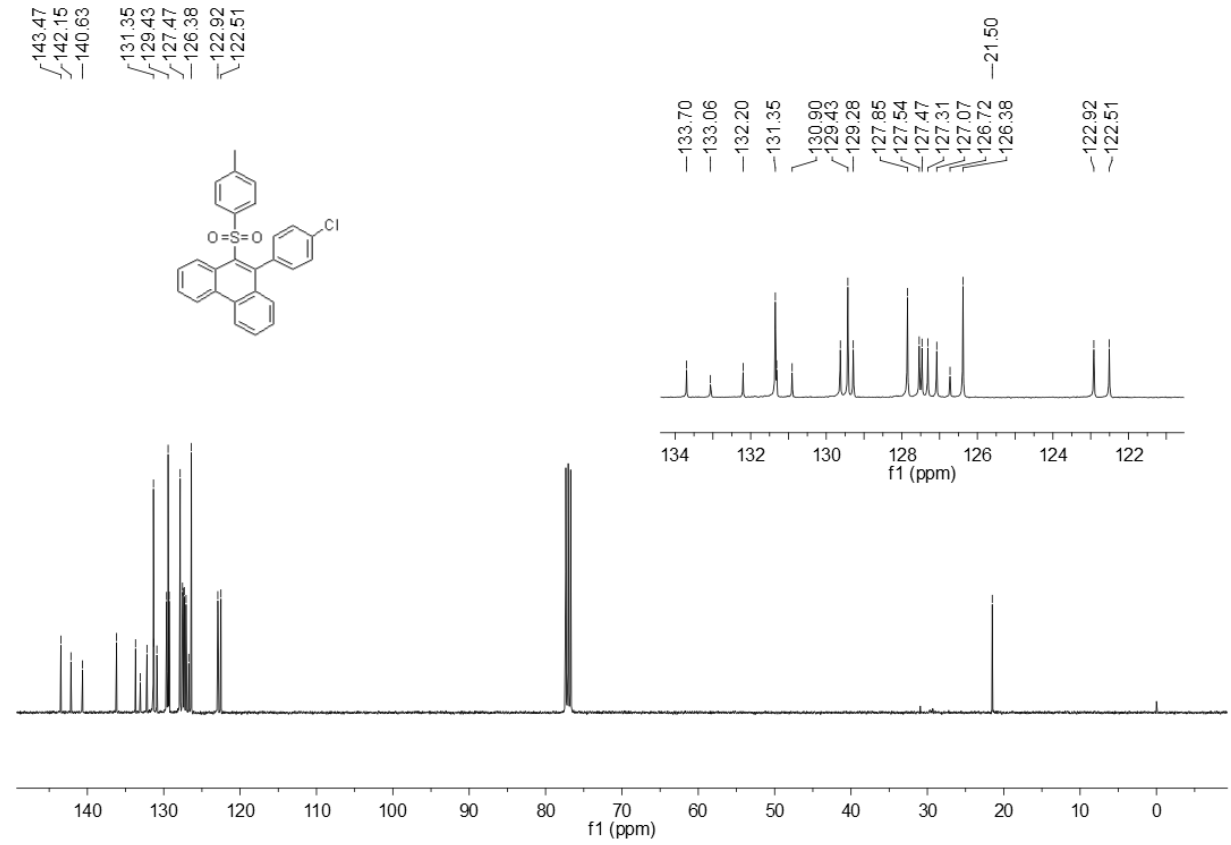
^{1}H NMR Spectrum of Compound 4r



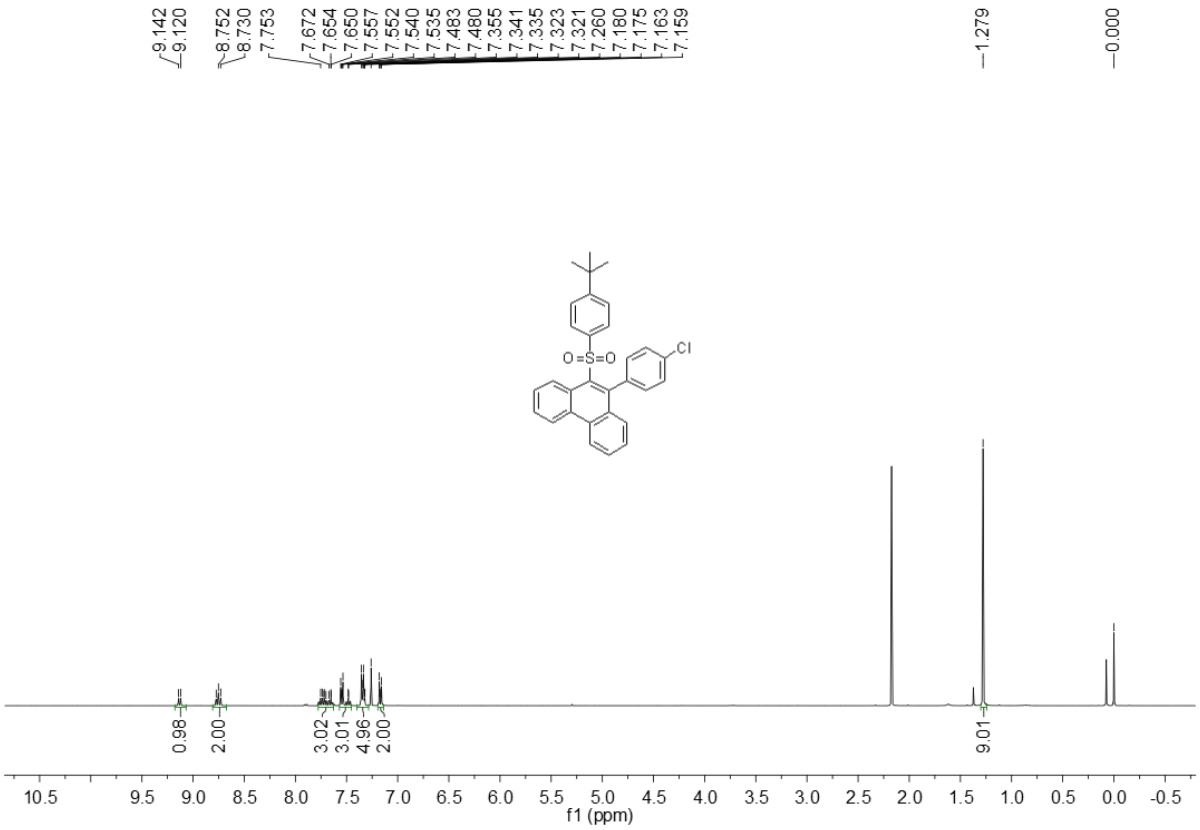
^{13}C NMR Spectrum of Compound 4r



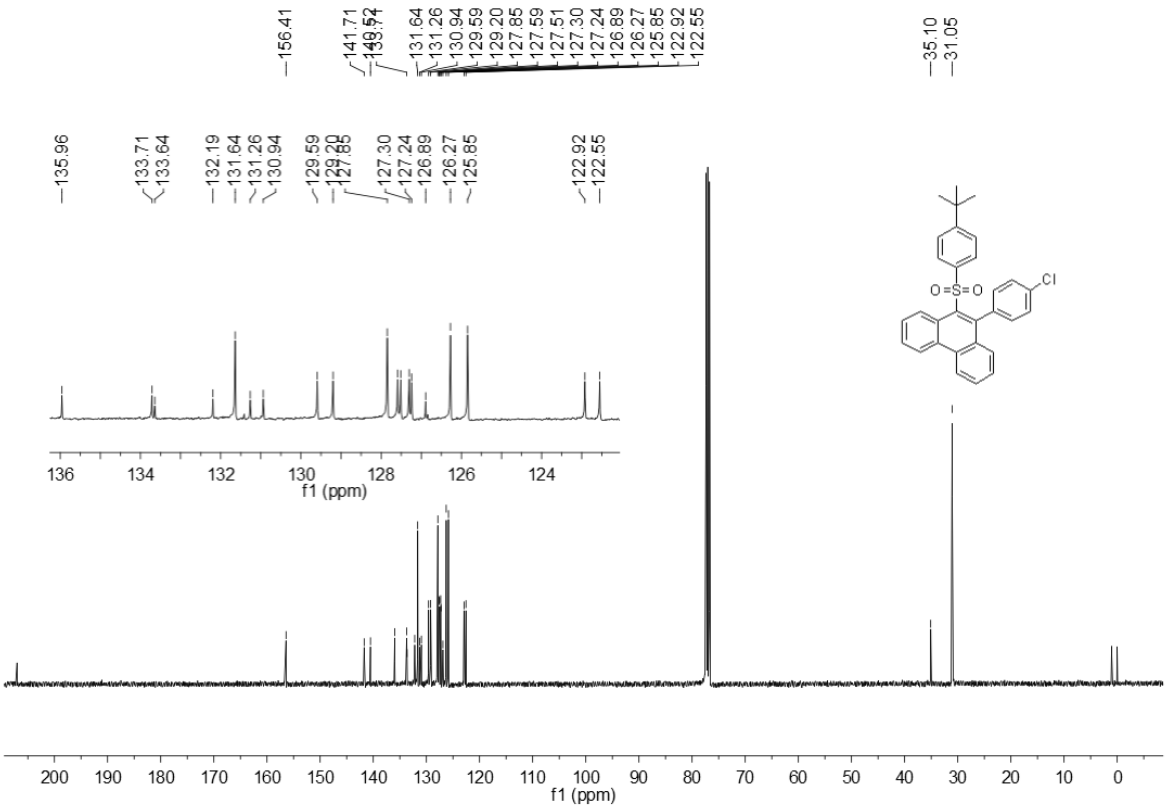
^{1}H NMR Spectrum of Compound 6a



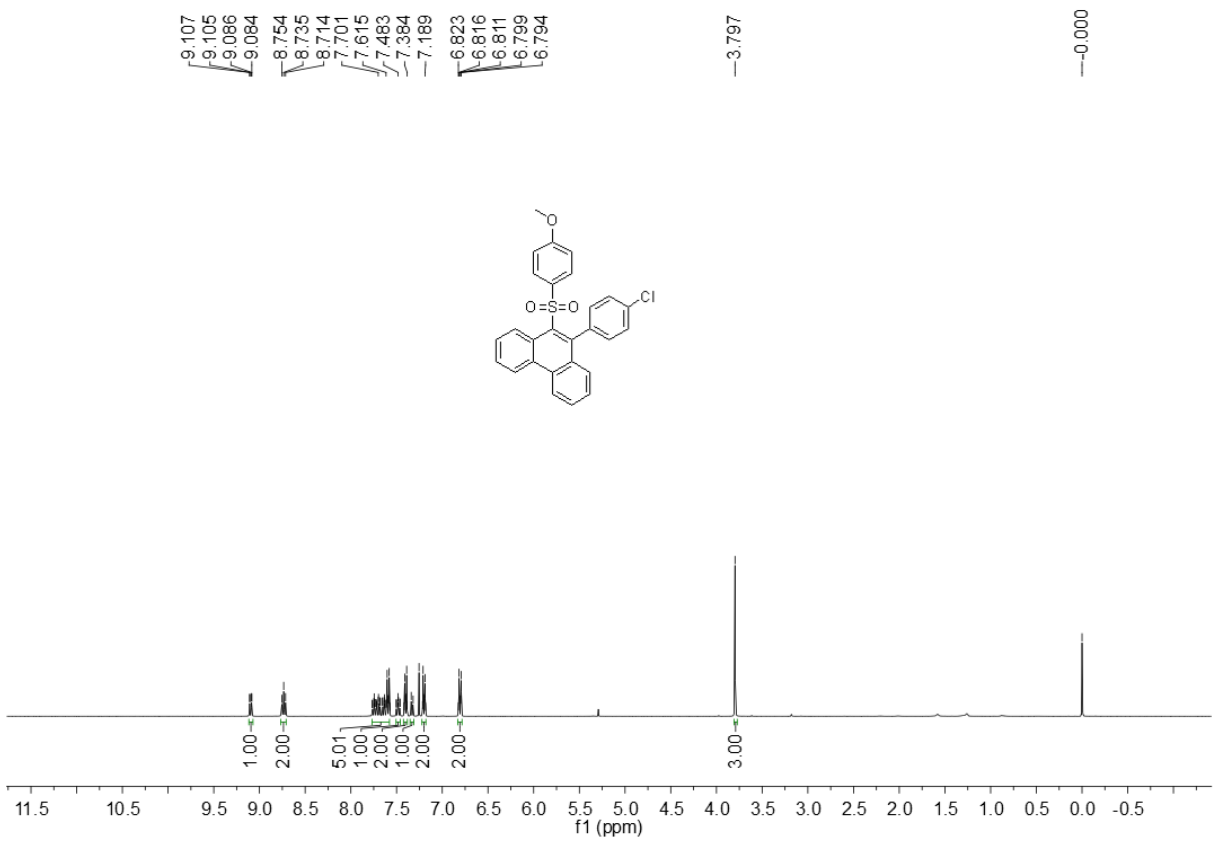
^{13}C NMR Spectrum of Compound 6a



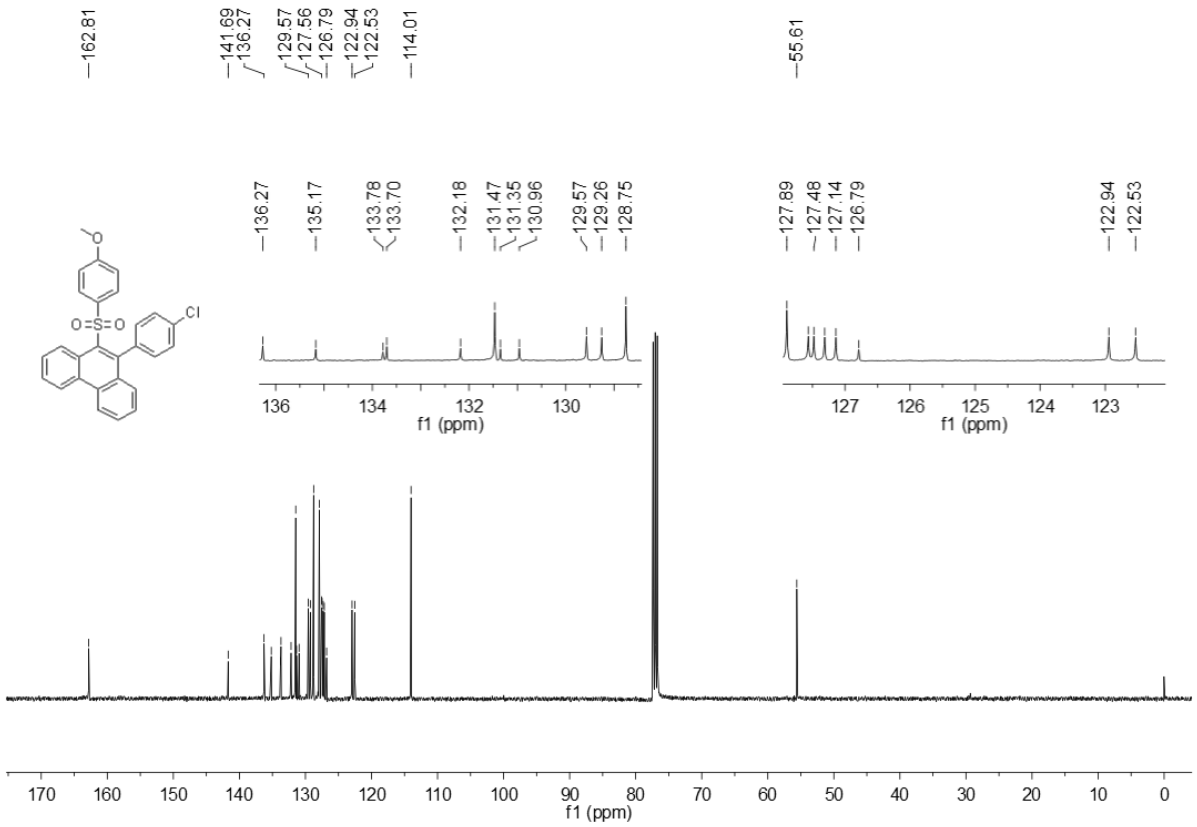
^{1}H NMR Spectrum of Compound 6b



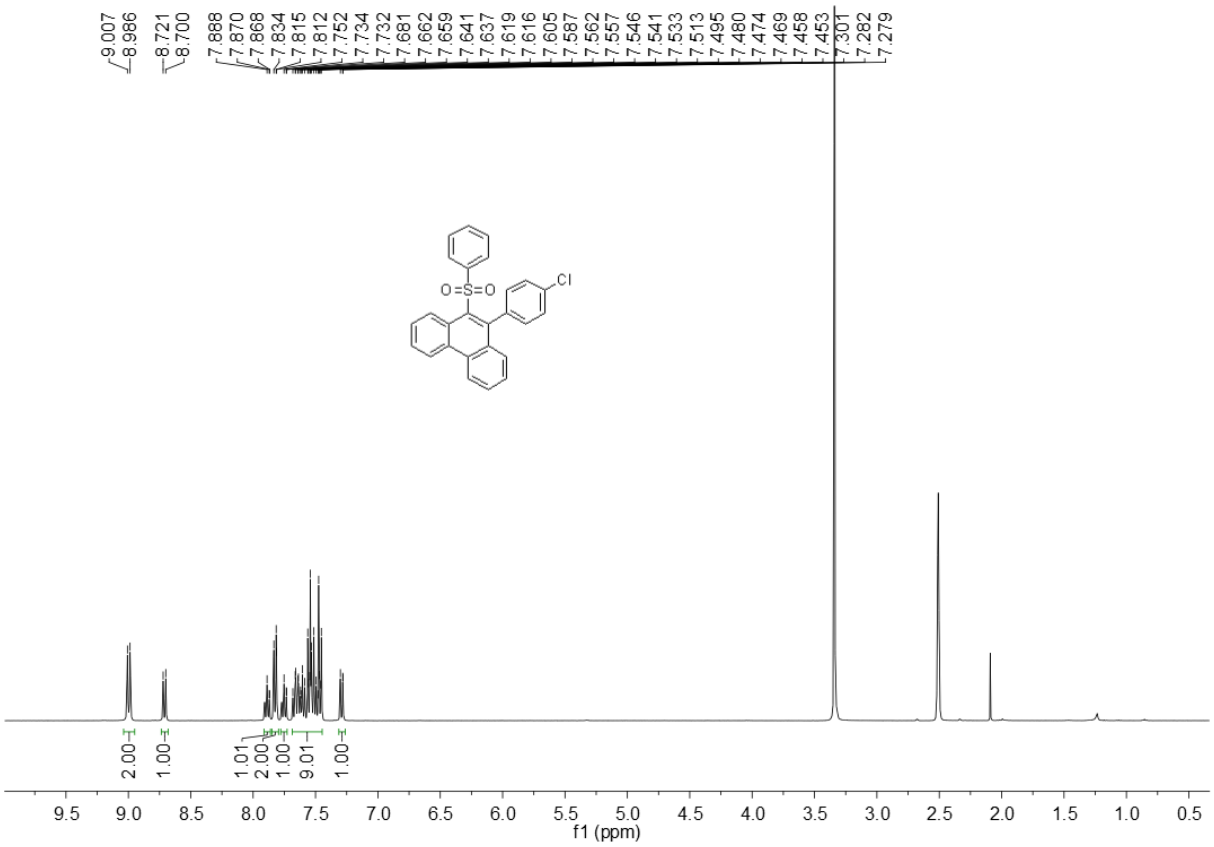
^{13}C NMR Spectrum of Compound 6b



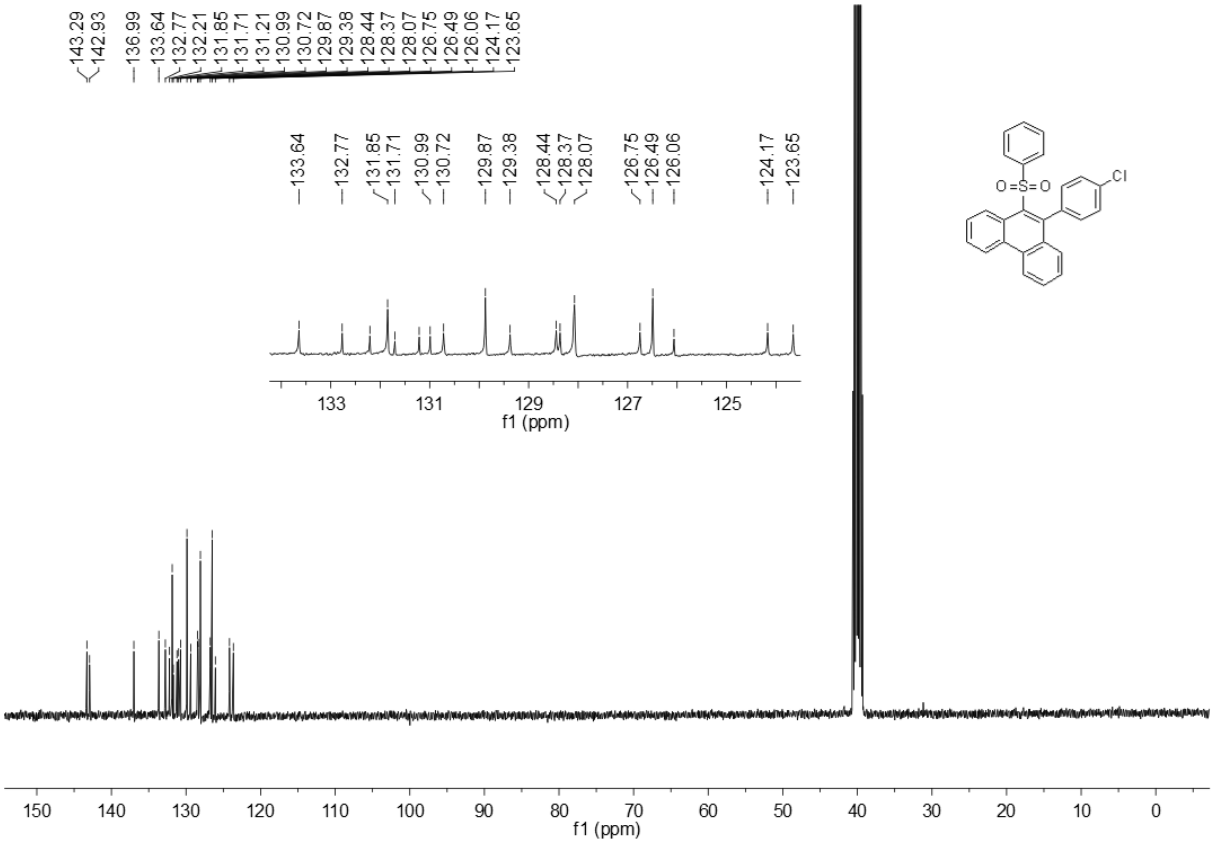
^{1}H NMR Spectrum of Compound 6c



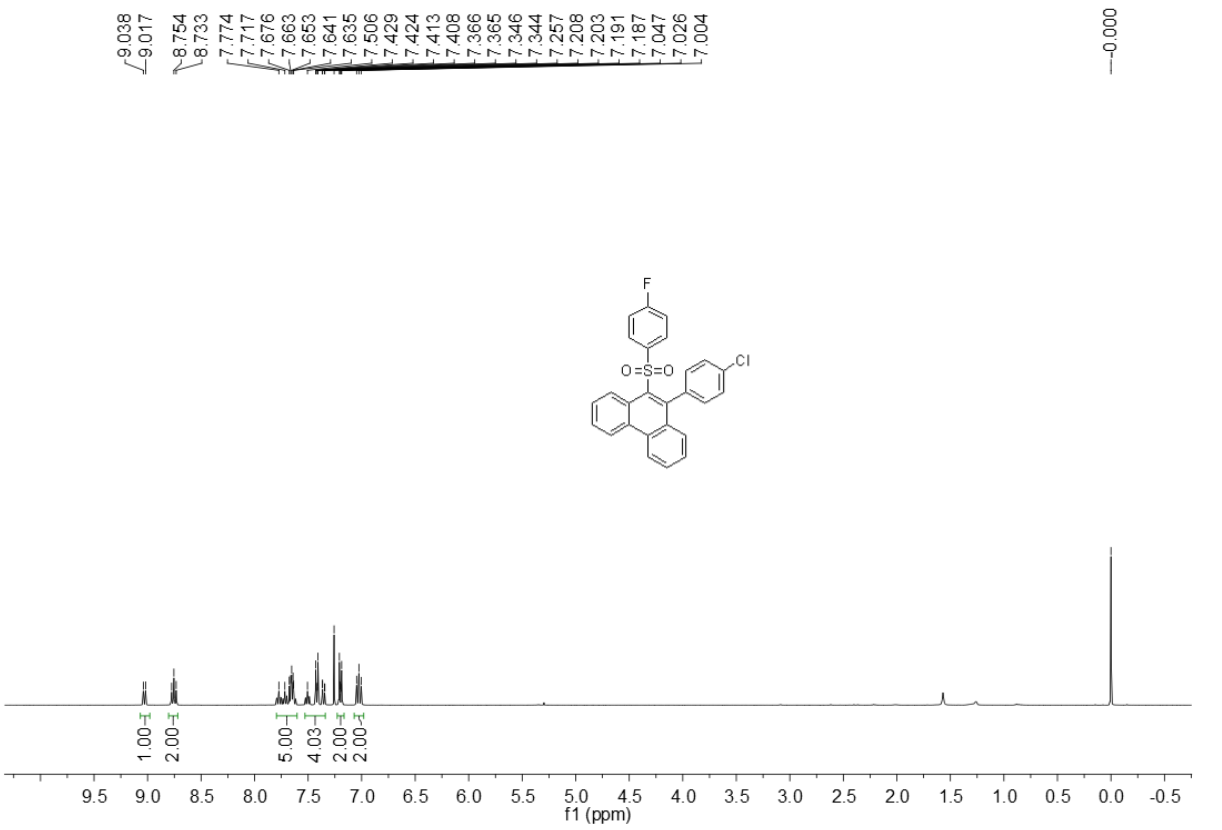
^{13}C NMR Spectrum of Compound 6c



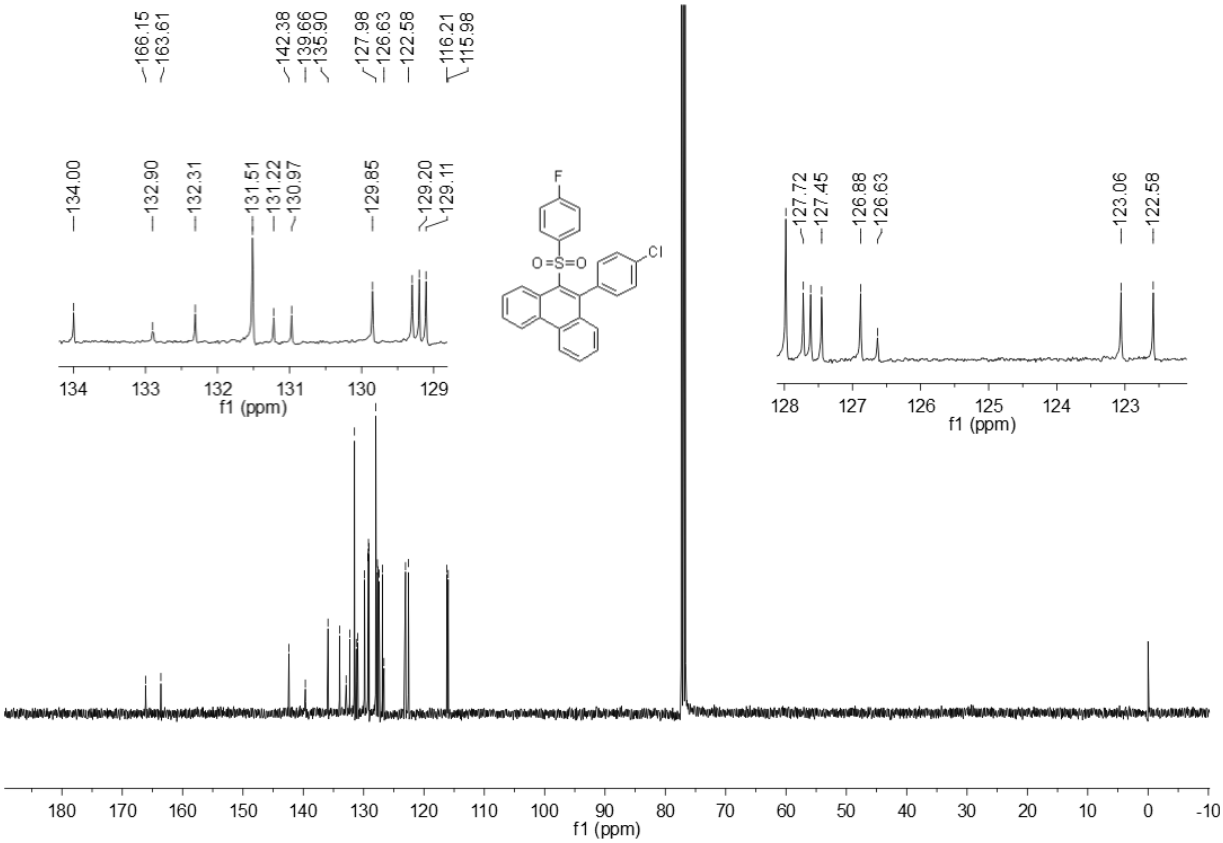
^{1}H NMR Spectrum of Compound 6d



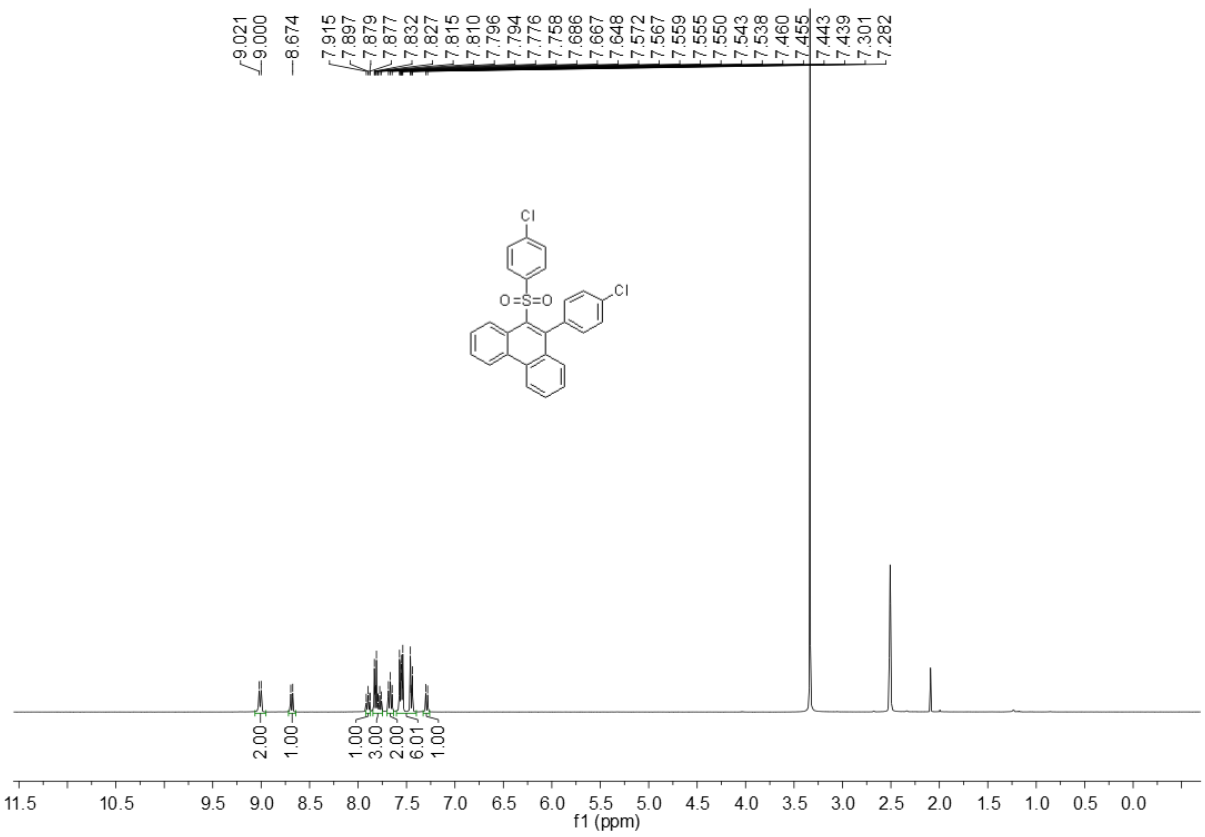
^{13}C NMR Spectrum of Compound 6d



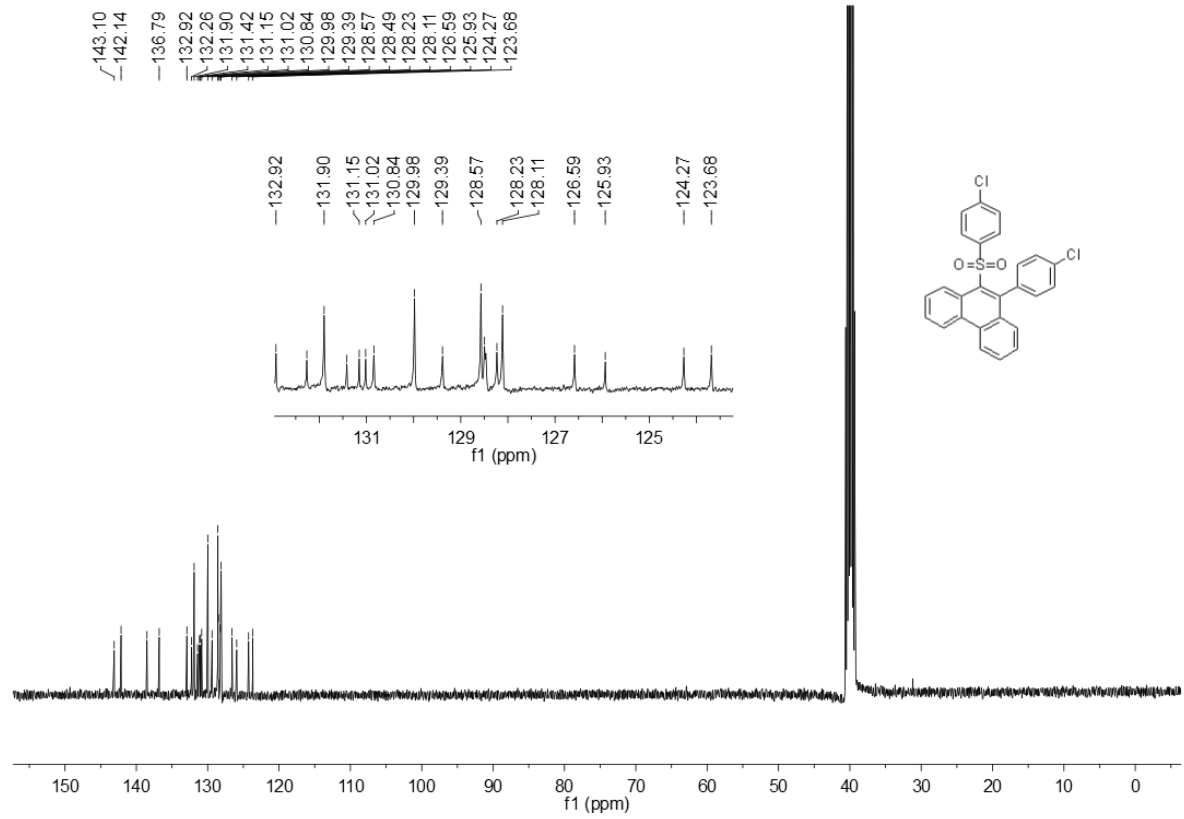
^{1}H NMR Spectrum of Compound 6e



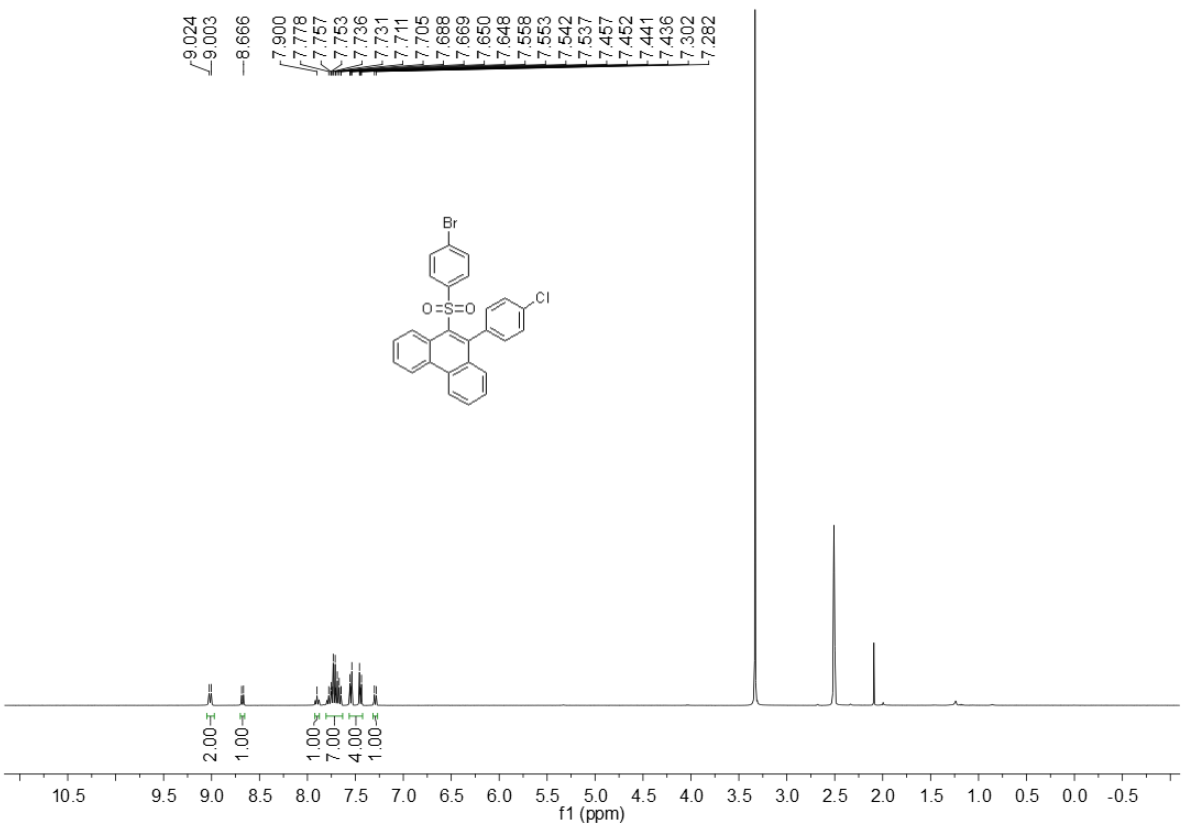
^{13}C NMR Spectrum of Compound 6e



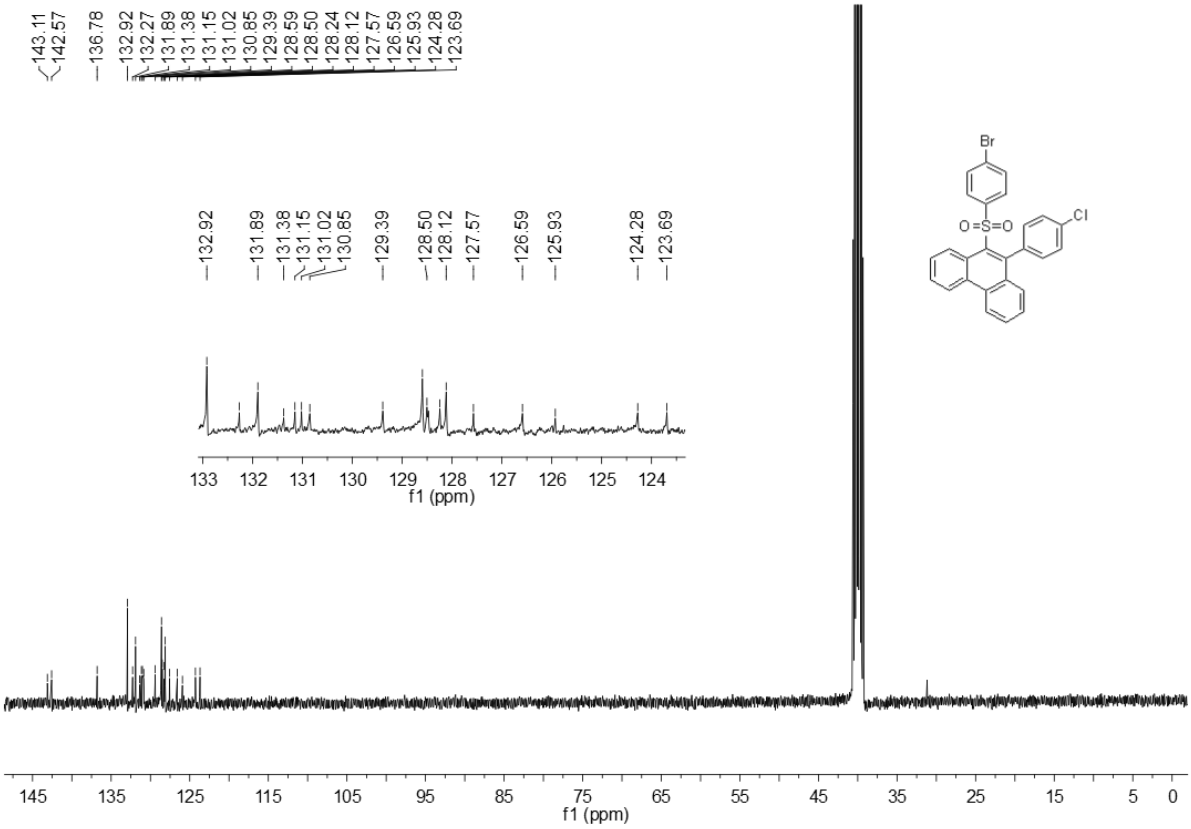
^{1}H NMR Spectrum of Compound 6f



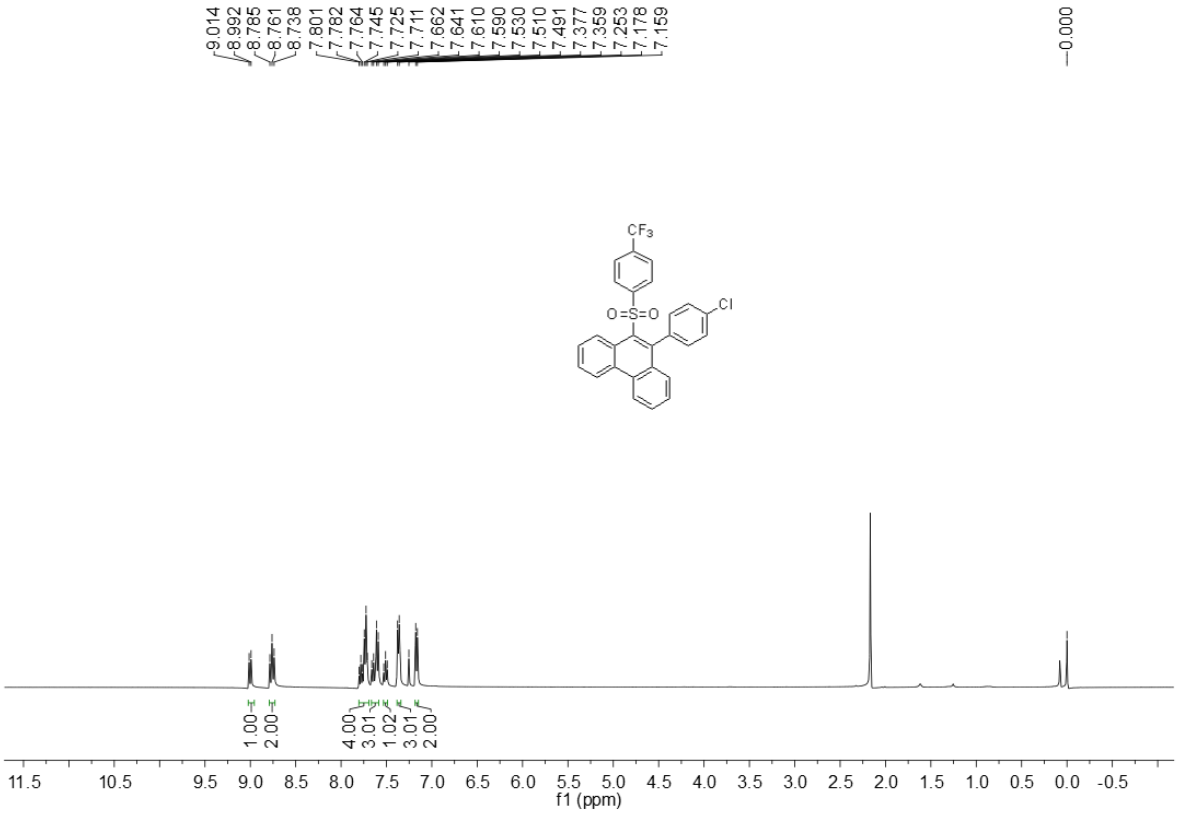
^{13}C NMR Spectrum of Compound 6f



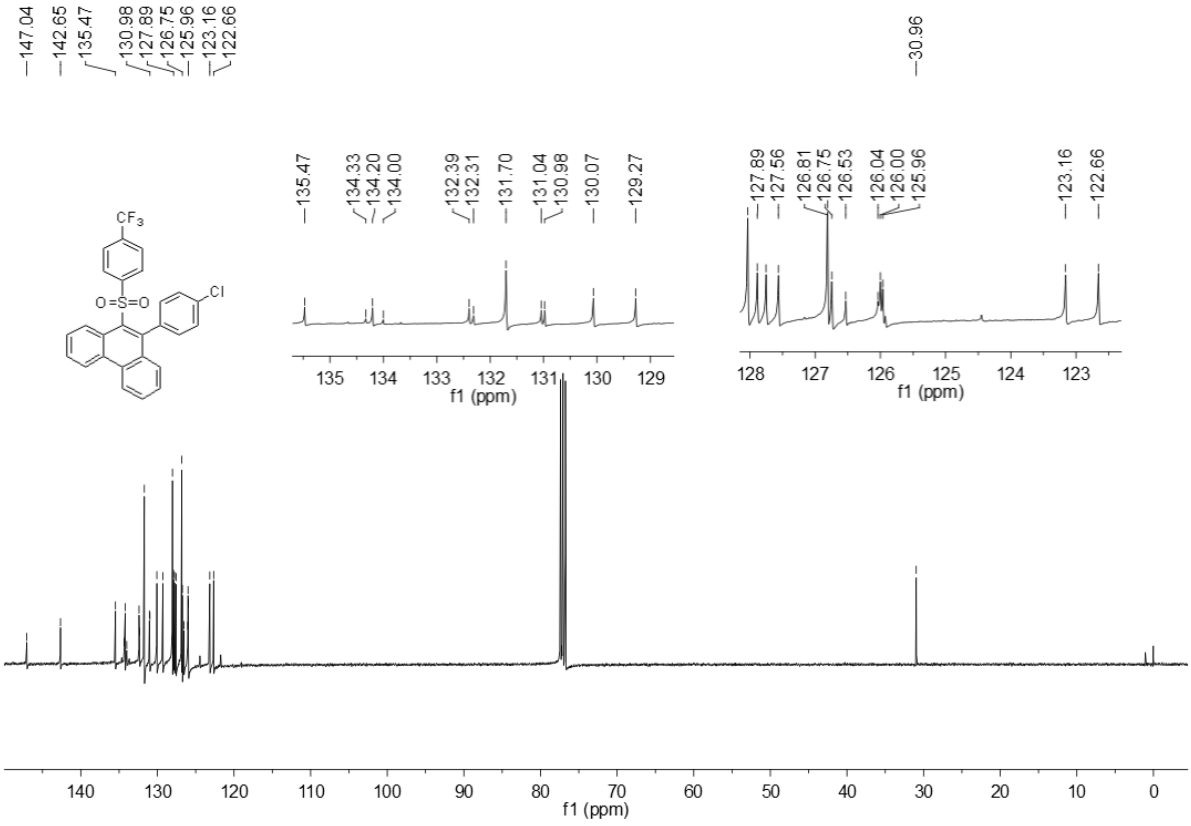
^{1}H NMR Spectrum of Compound 6g



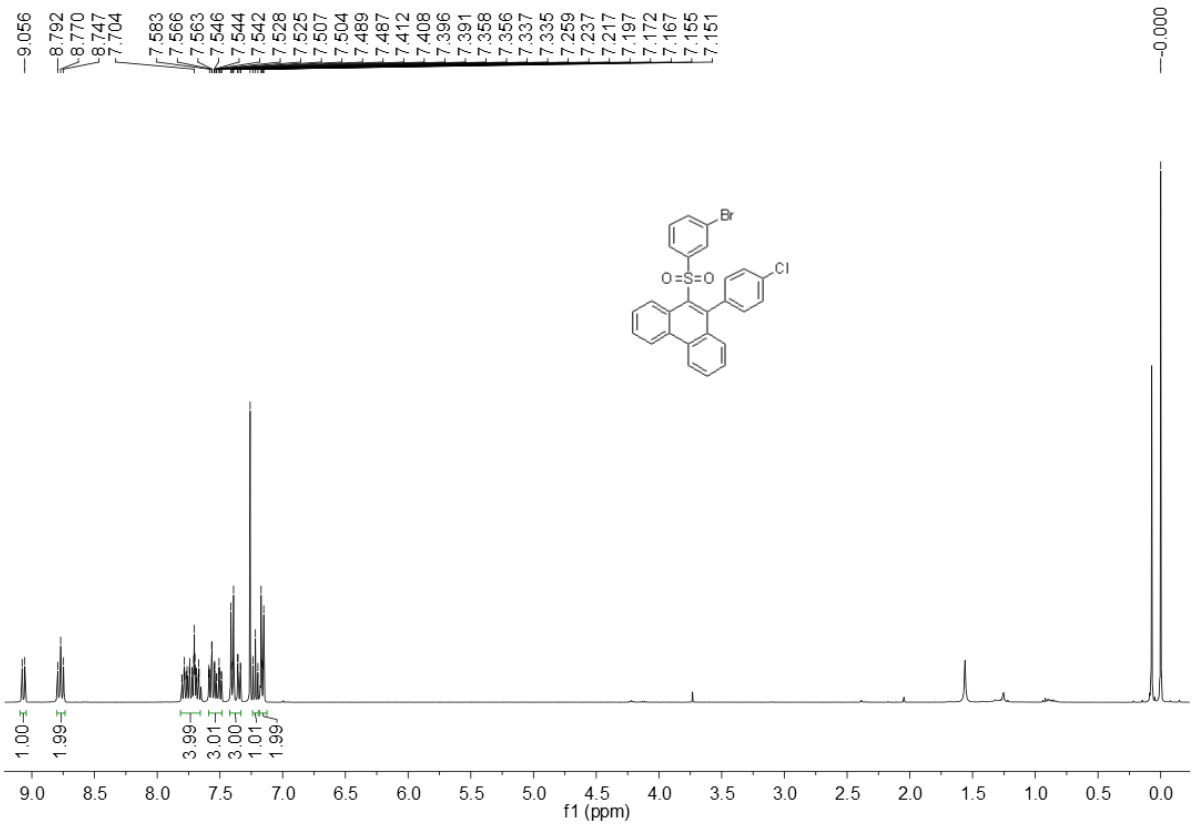
^{13}C NMR Spectrum of Compound 6g



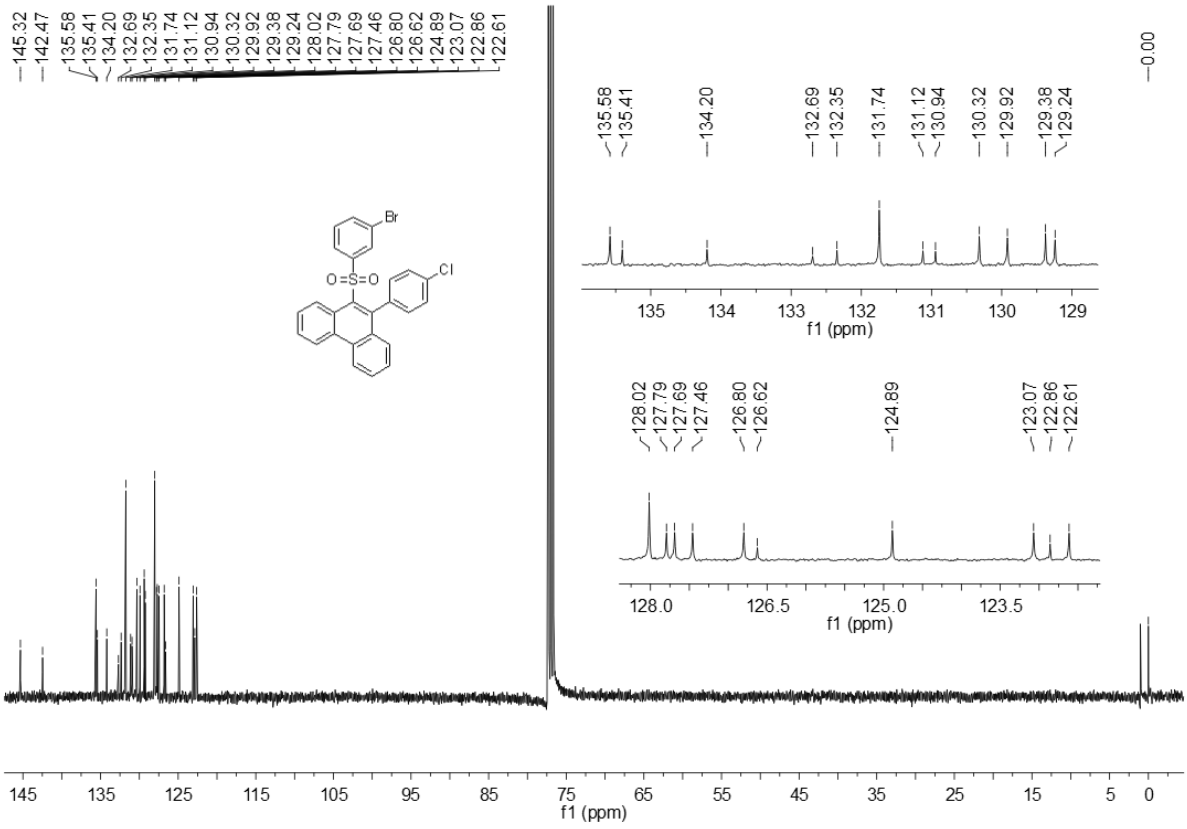
^{1}H NMR Spectrum of Compound 6h



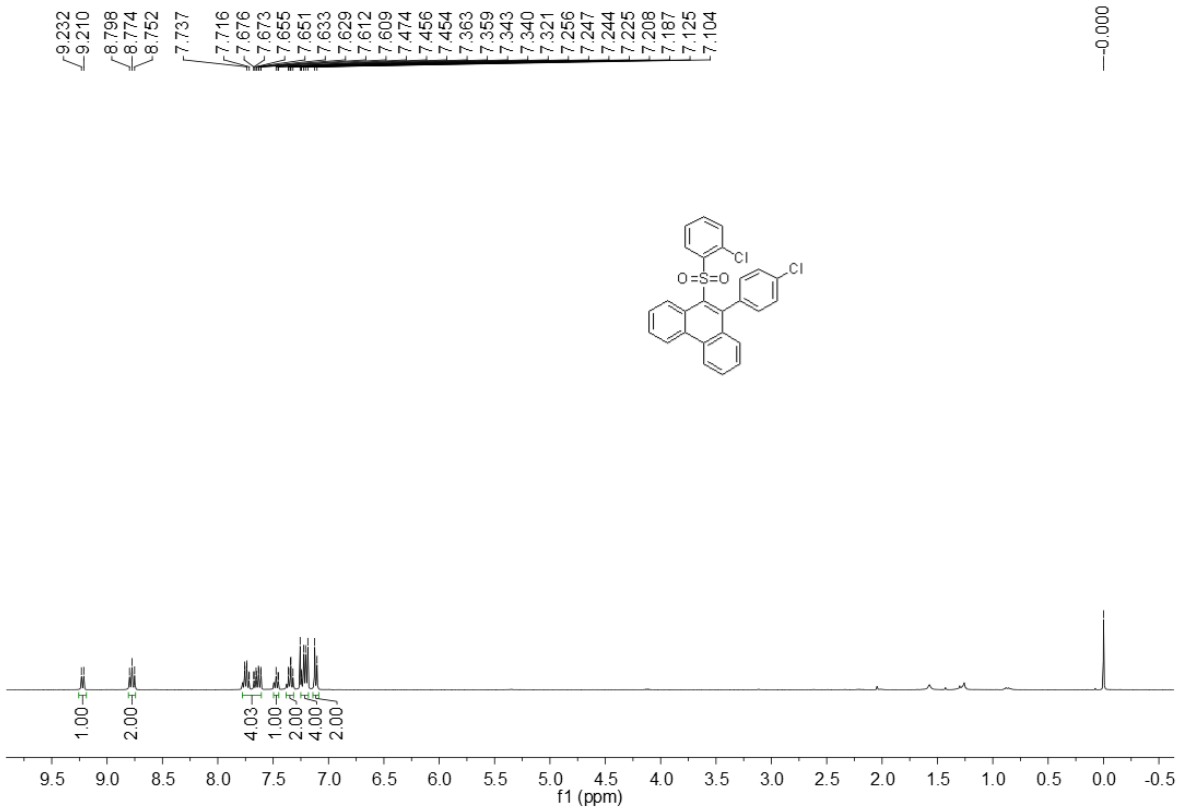
^{13}C NMR Spectrum of Compound 6h



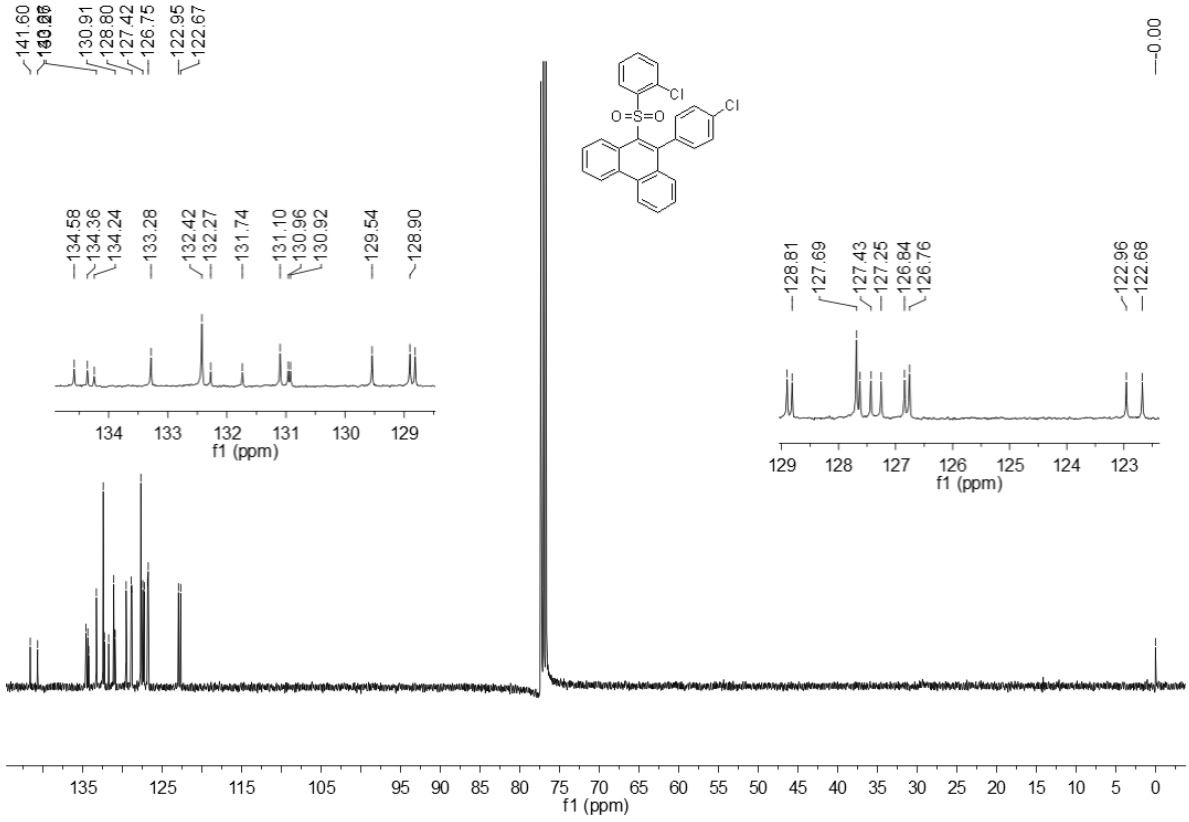
^{1}H NMR Spectrum of Compound 6i



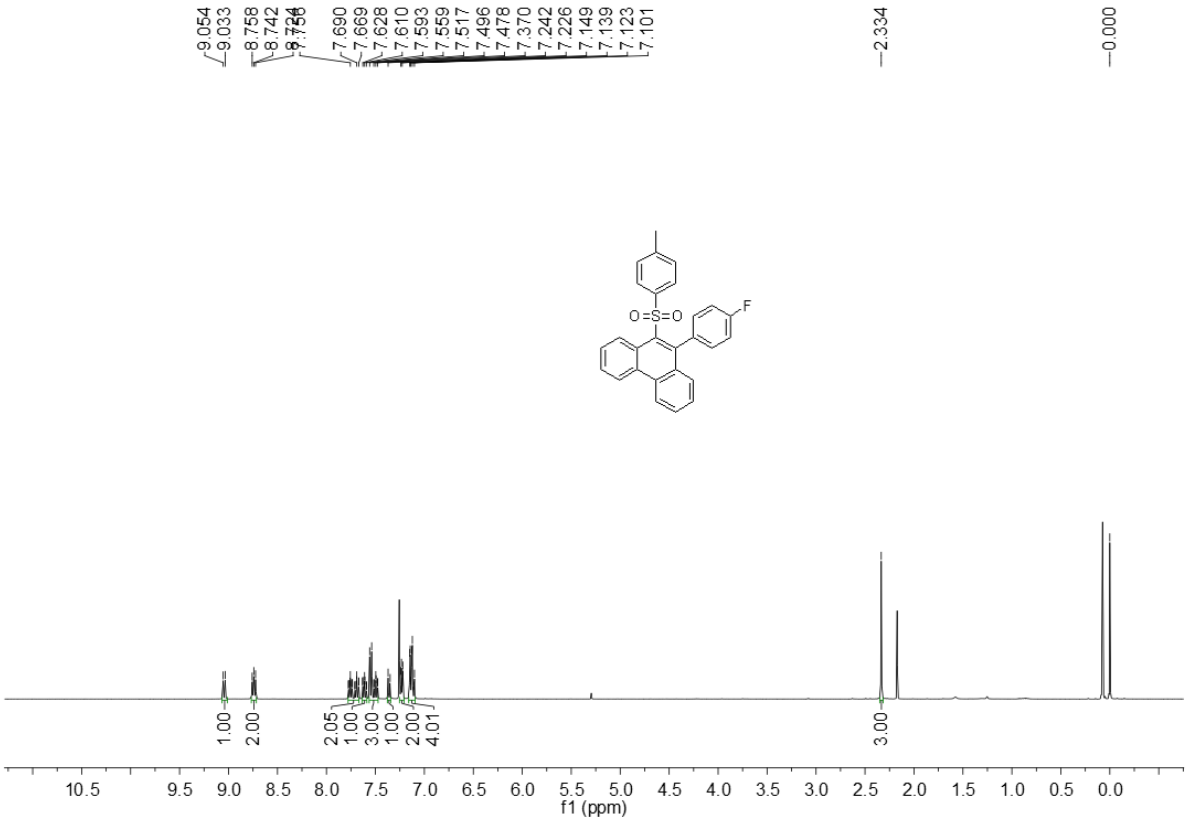
^{13}C NMR Spectrum of Compound 6i



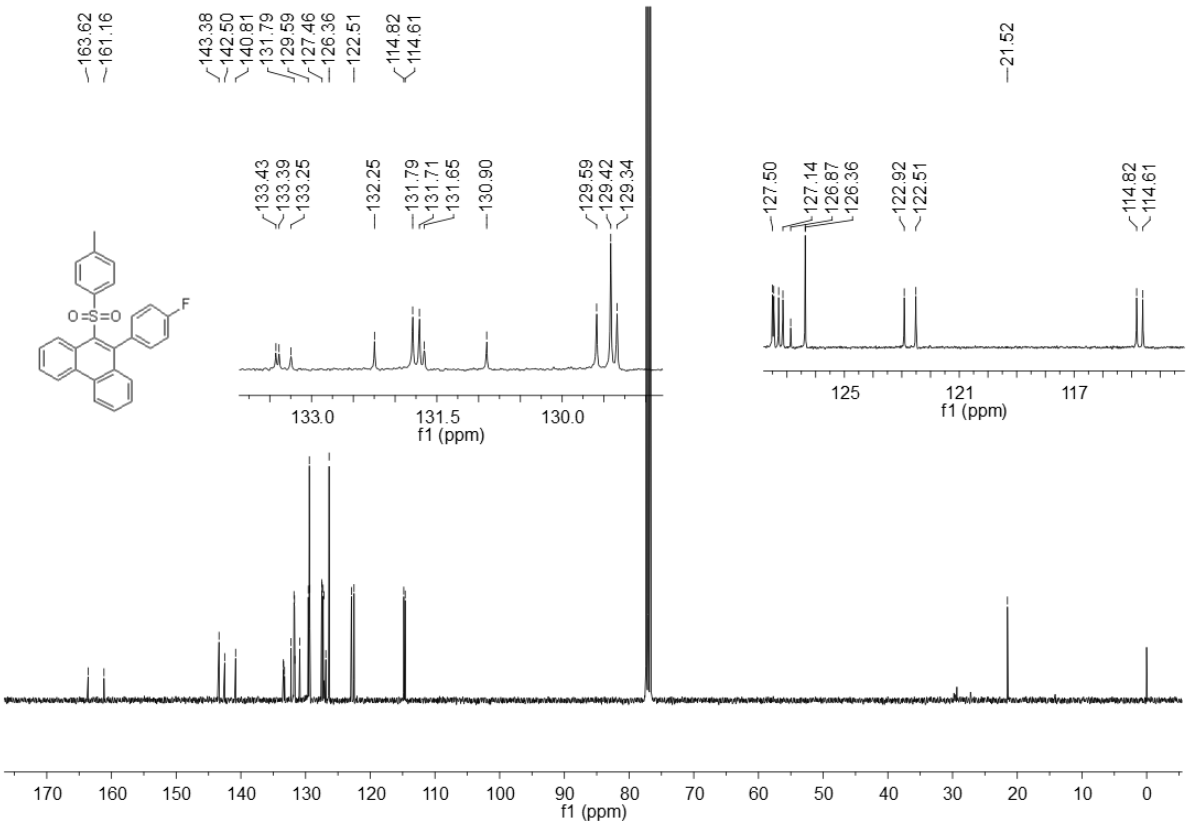
^{1}H NMR Spectrum of Compound 6j



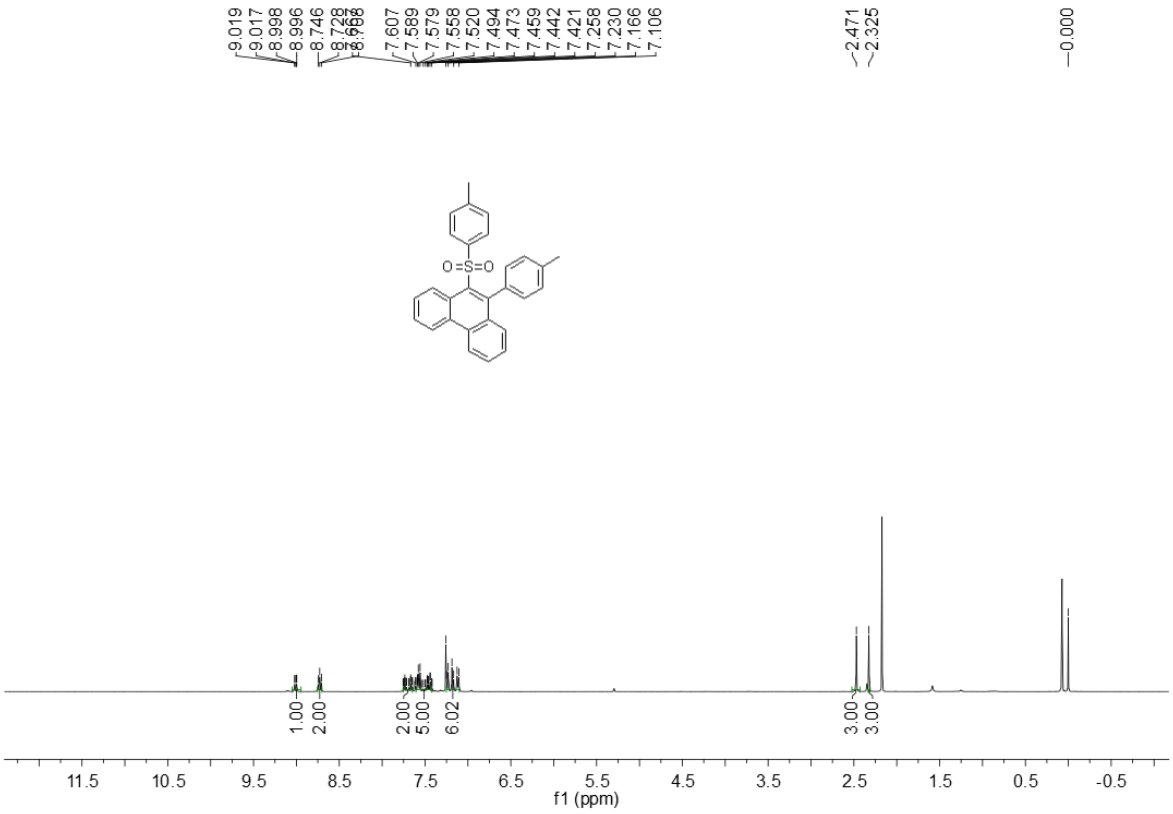
^{13}C NMR Spectrum of Compound 6j



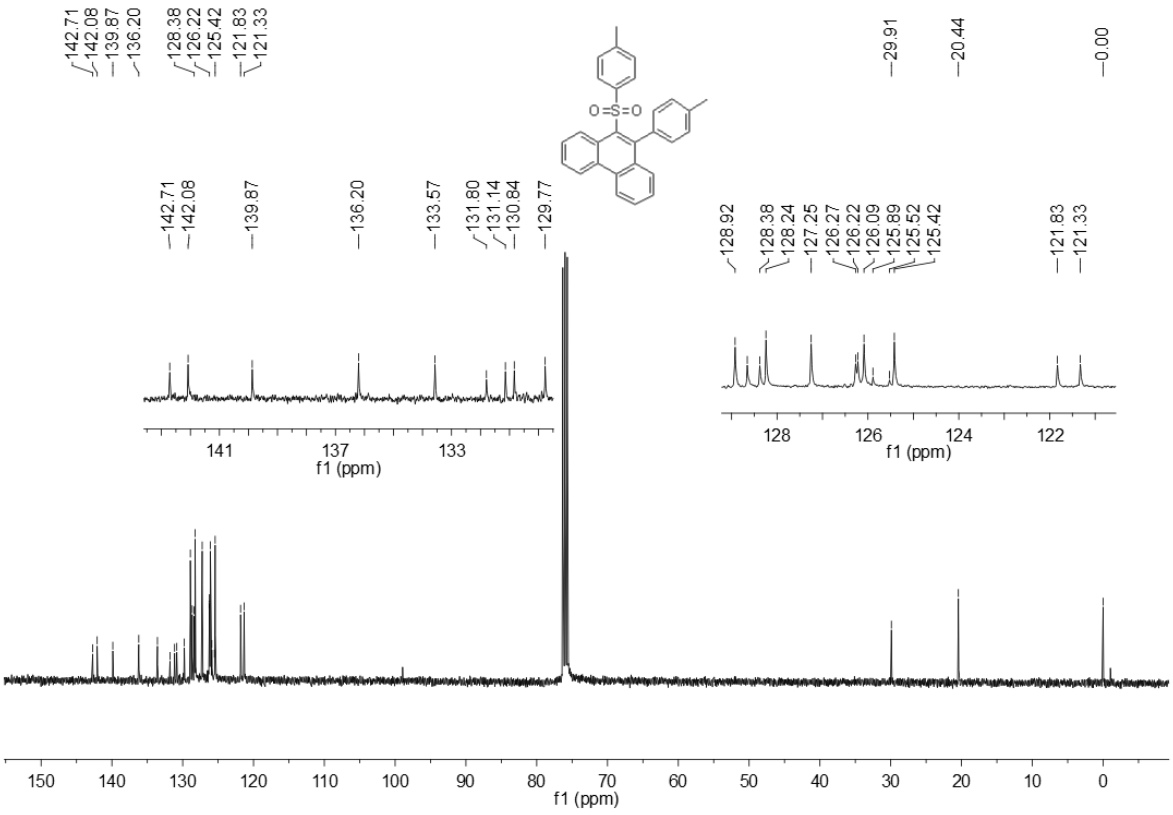
^{1}H NMR Spectrum of Compound 6l



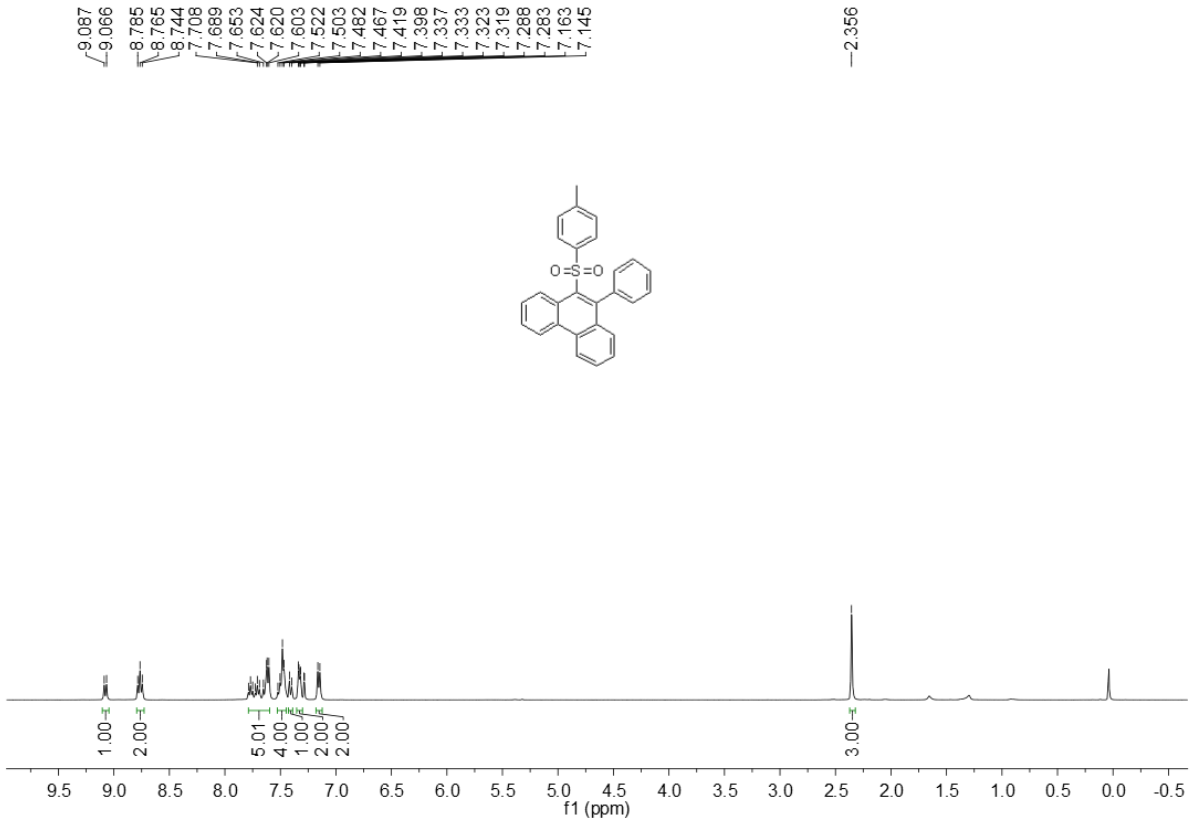
^{13}C NMR Spectrum of Compound 6l



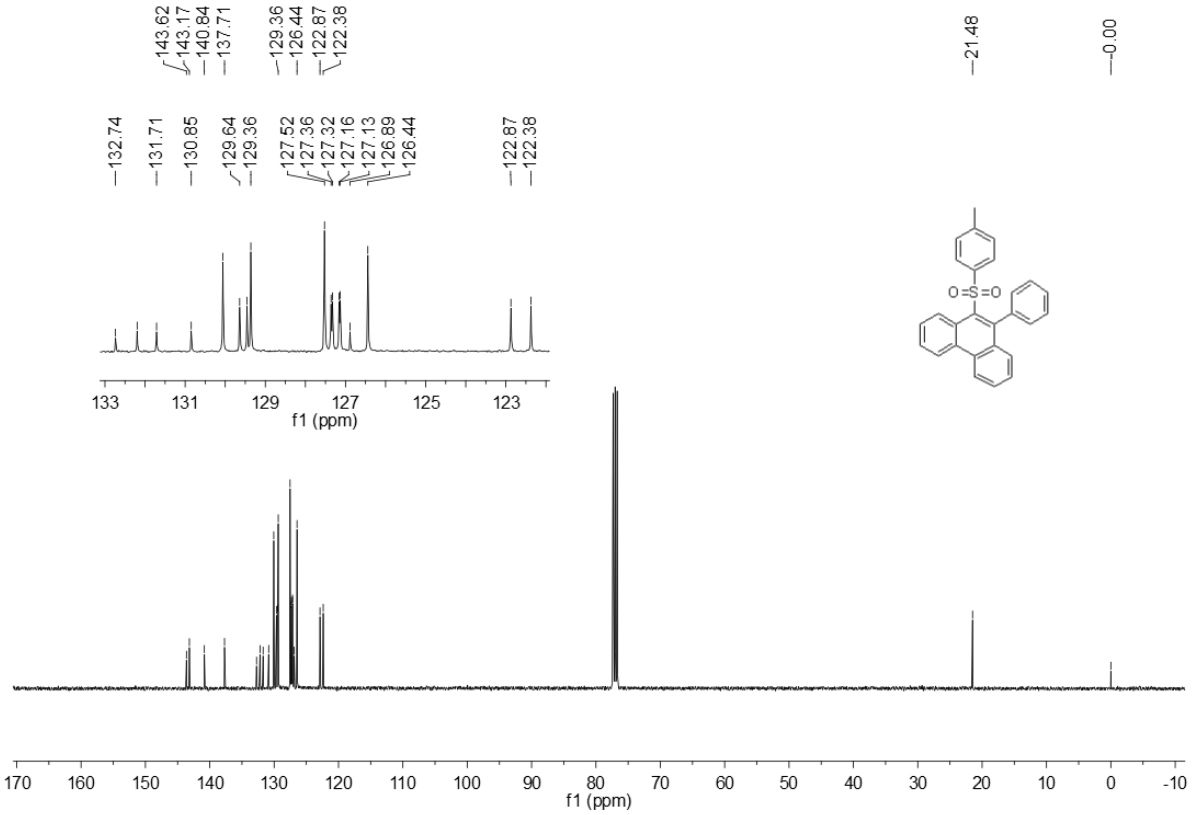
^{1}H NMR Spectrum of Compound 6m



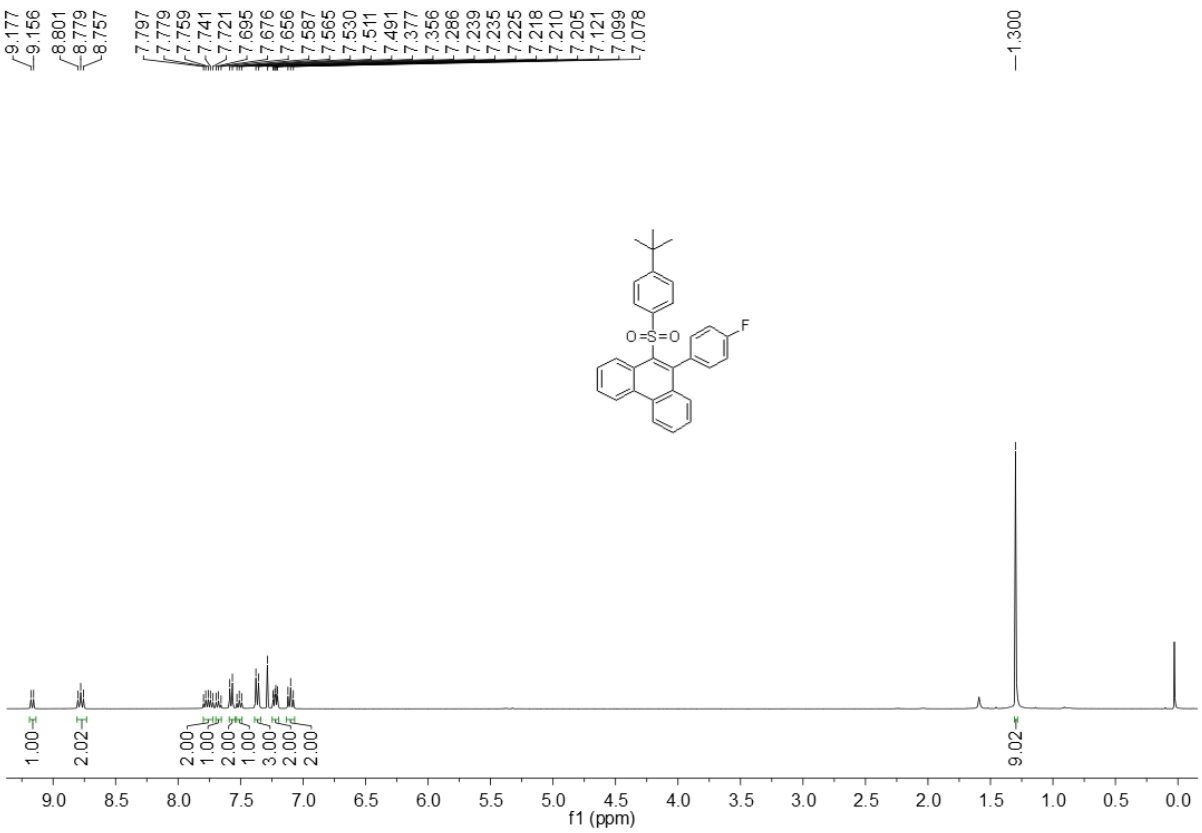
^{13}C NMR Spectrum of Compound 6m



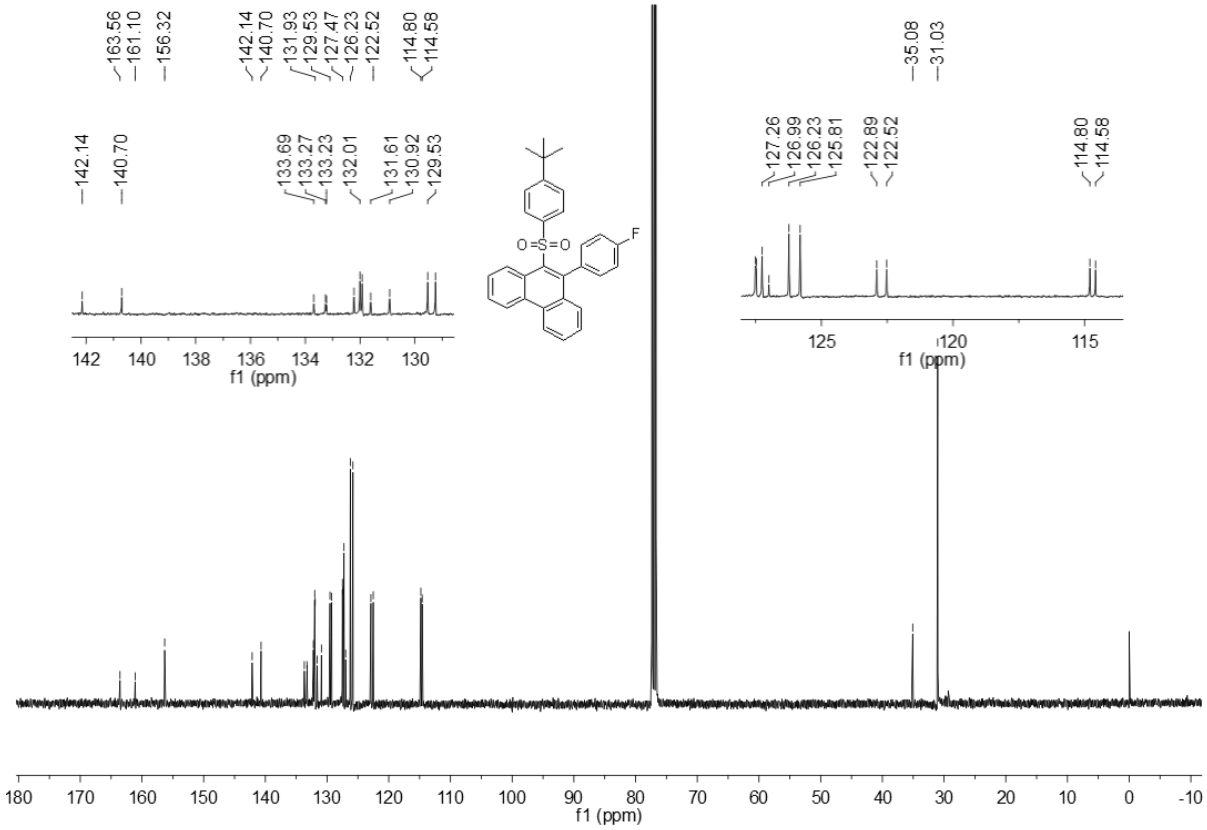
^{1}H NMR Spectrum of Compound 6n



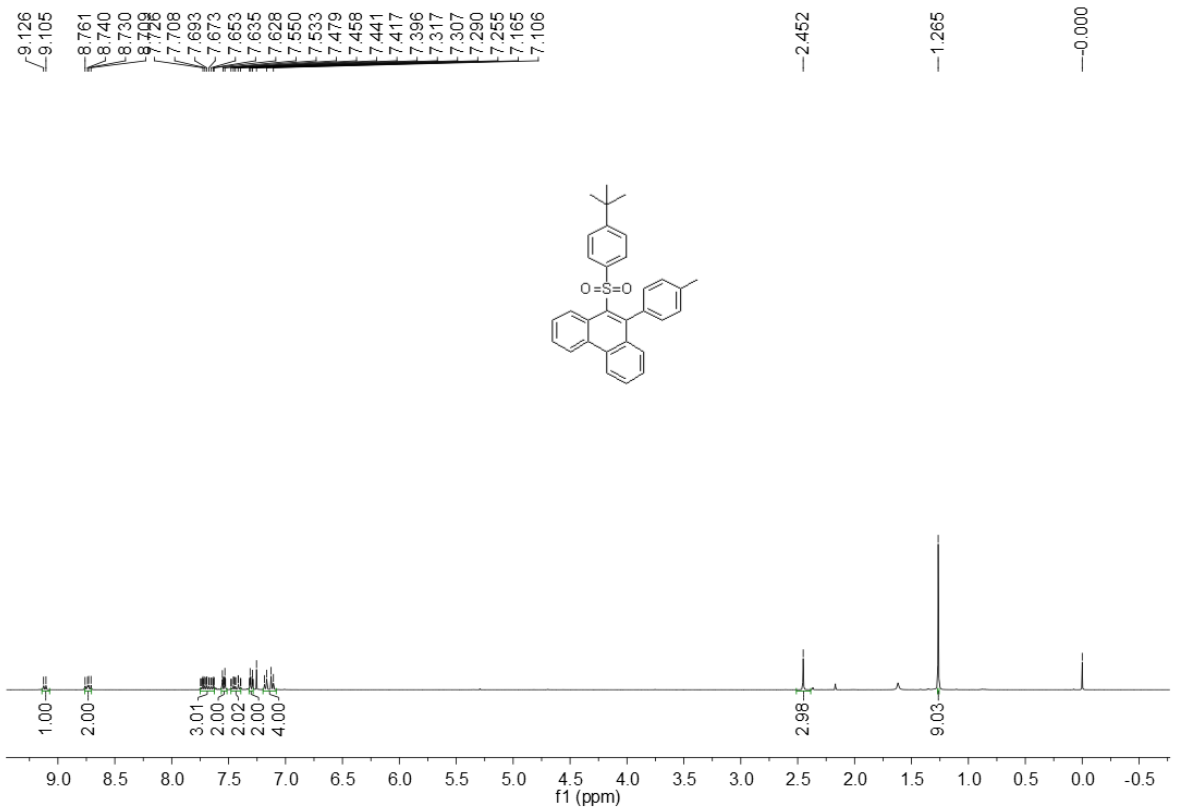
^{13}C NMR Spectrum of Compound 6n



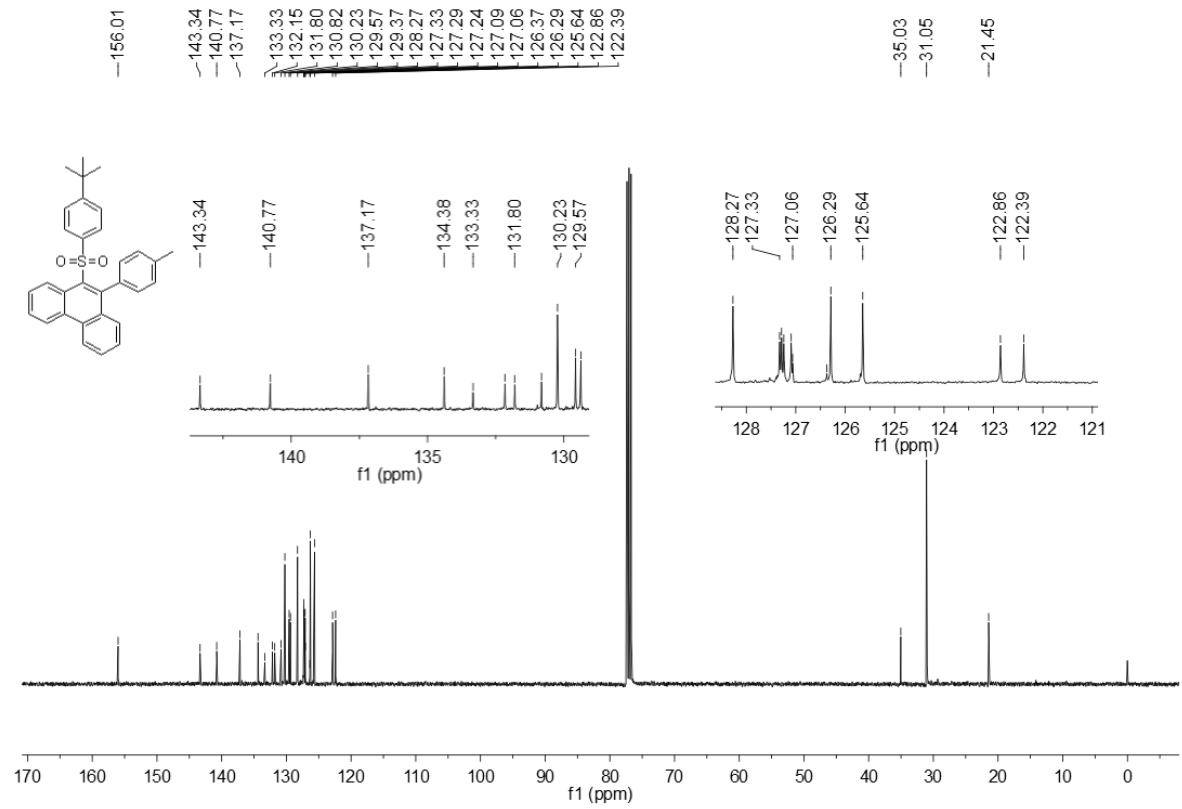
^{1}H NMR Spectrum of Compound 6o



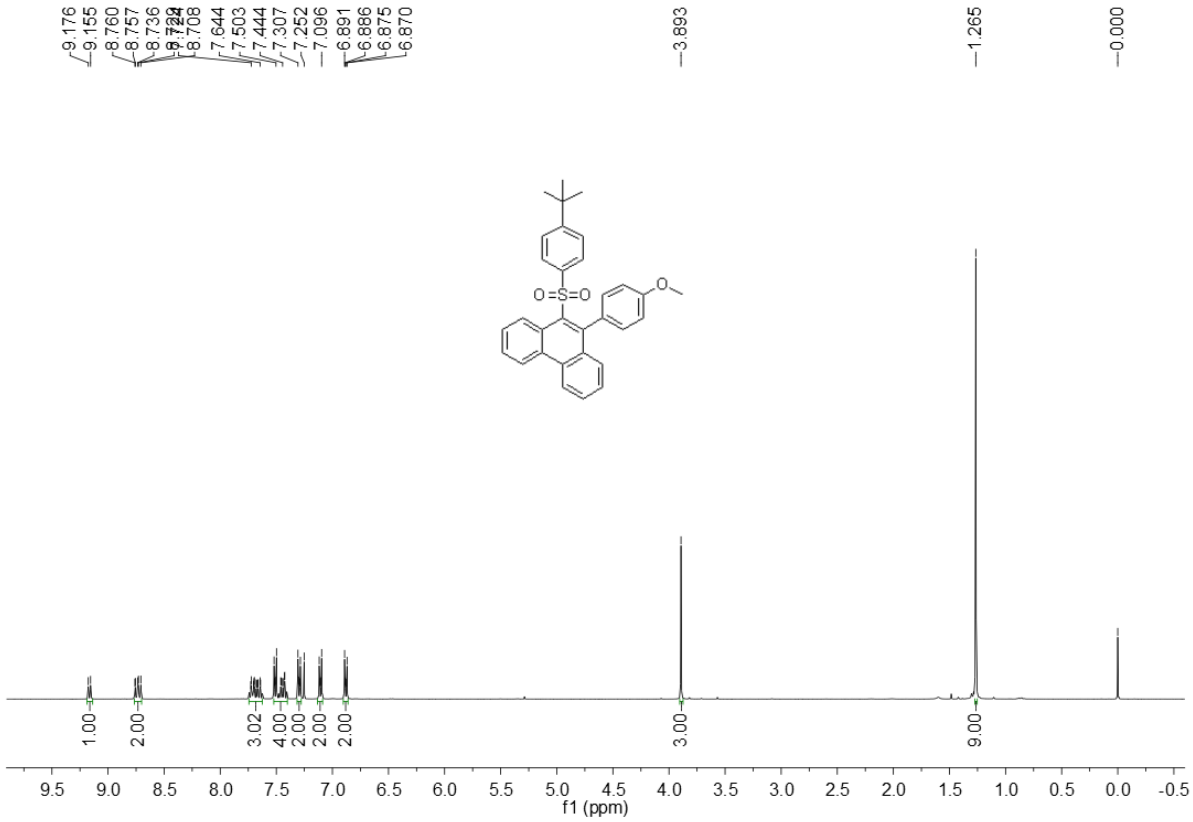
^{13}C NMR Spectrum of Compound 6o



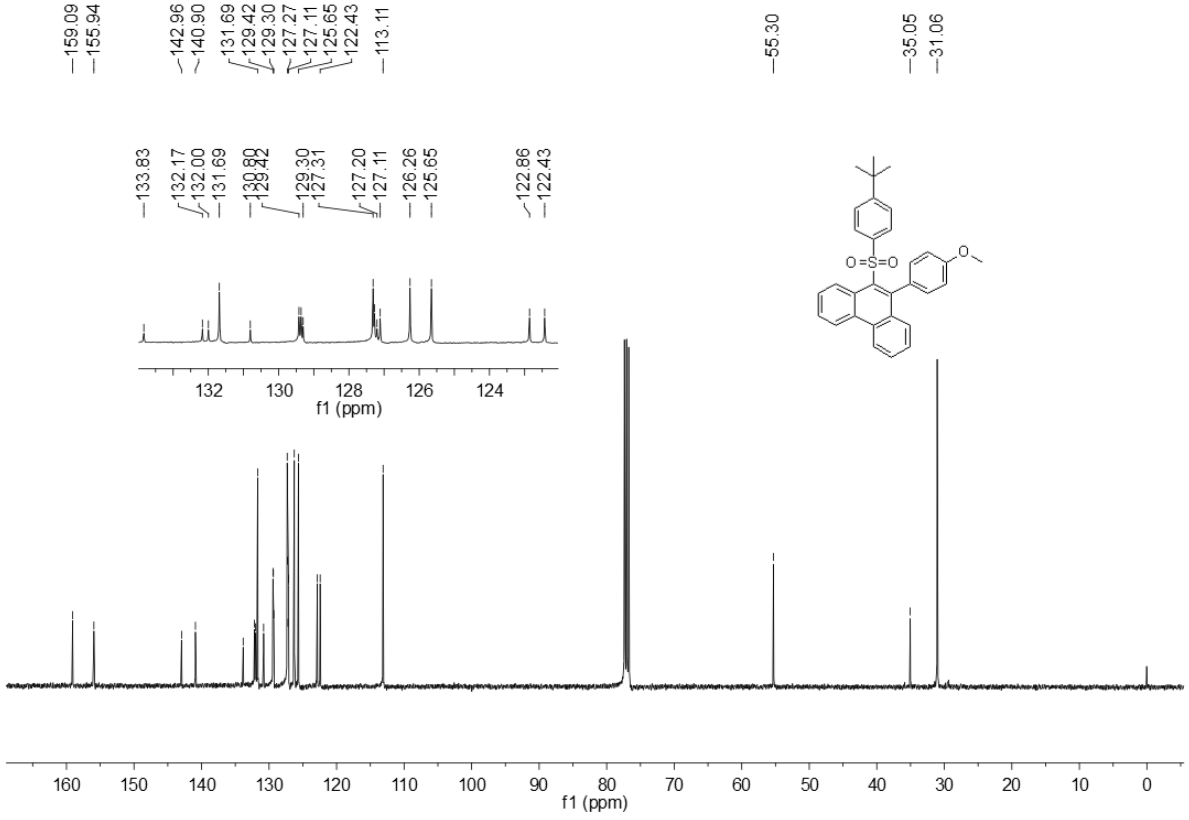
^{1}H NMR Spectrum of Compound 6p



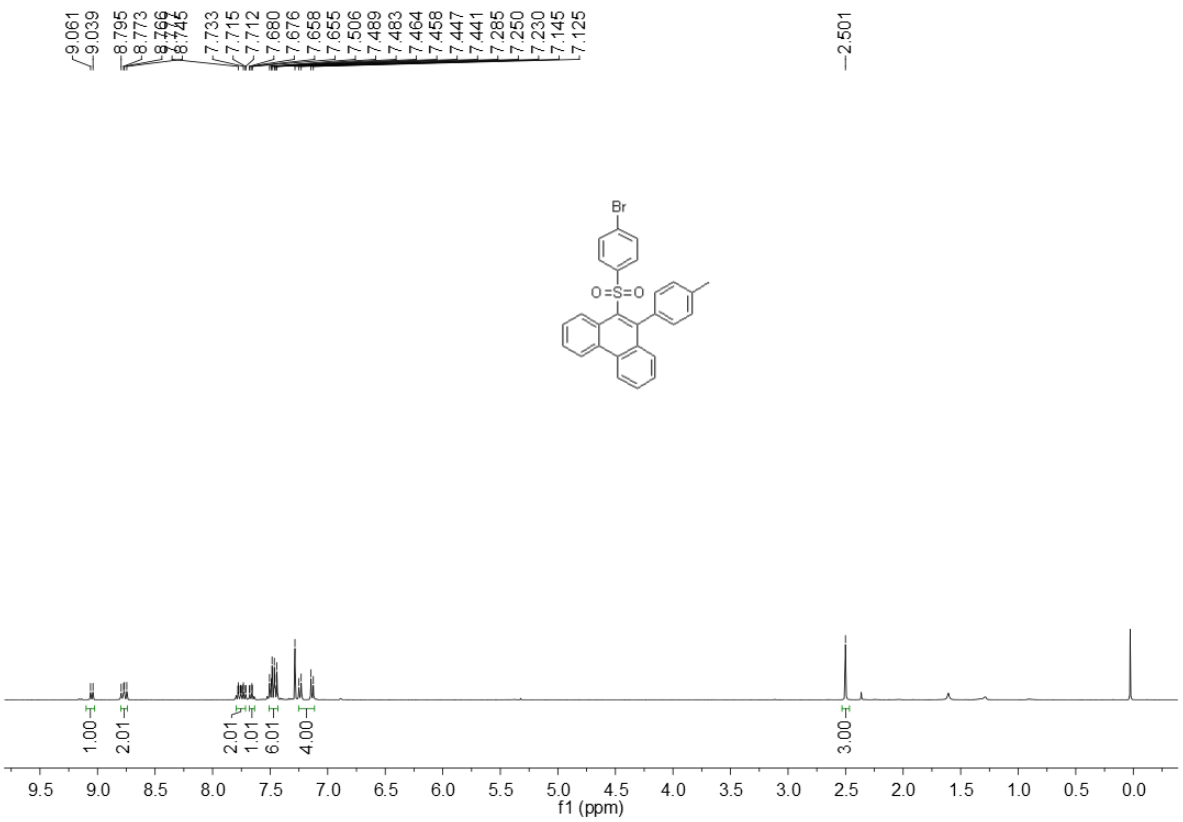
^{13}C NMR Spectrum of Compound 6p



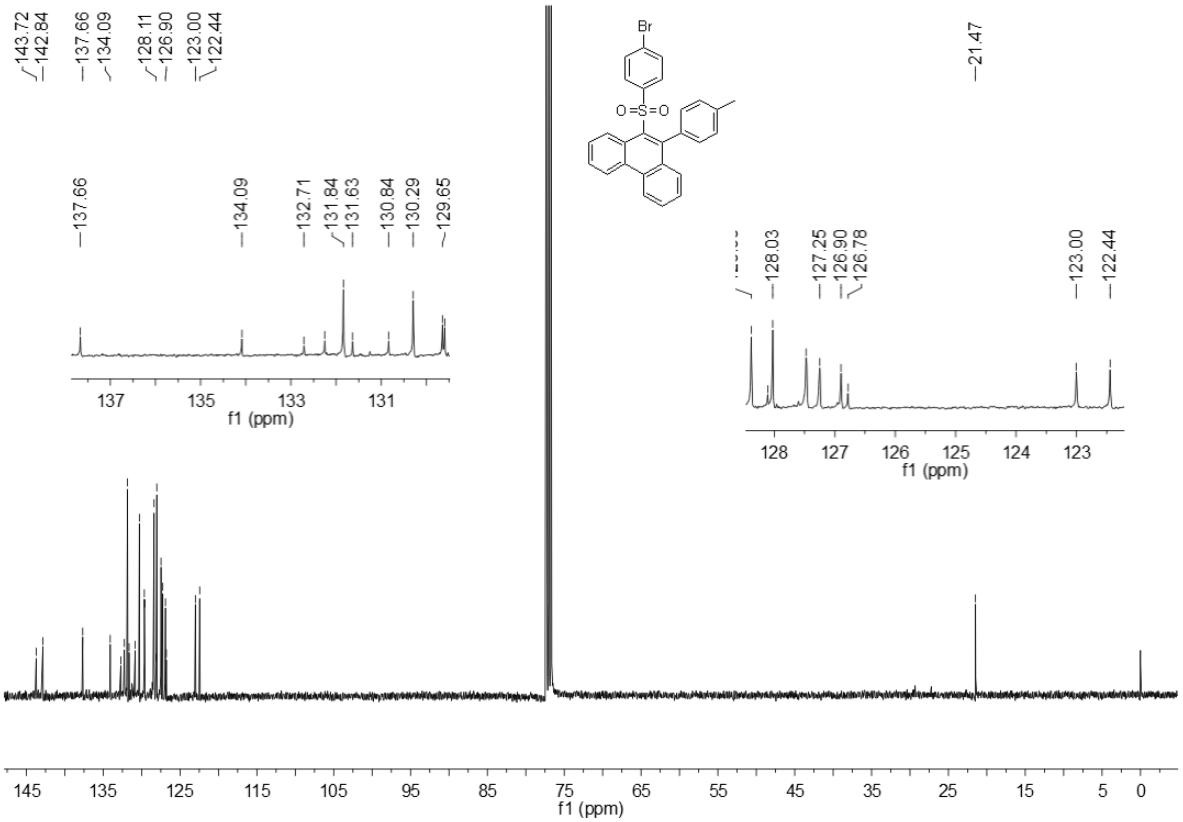
^{1}H NMR Spectrum of Compound 6q



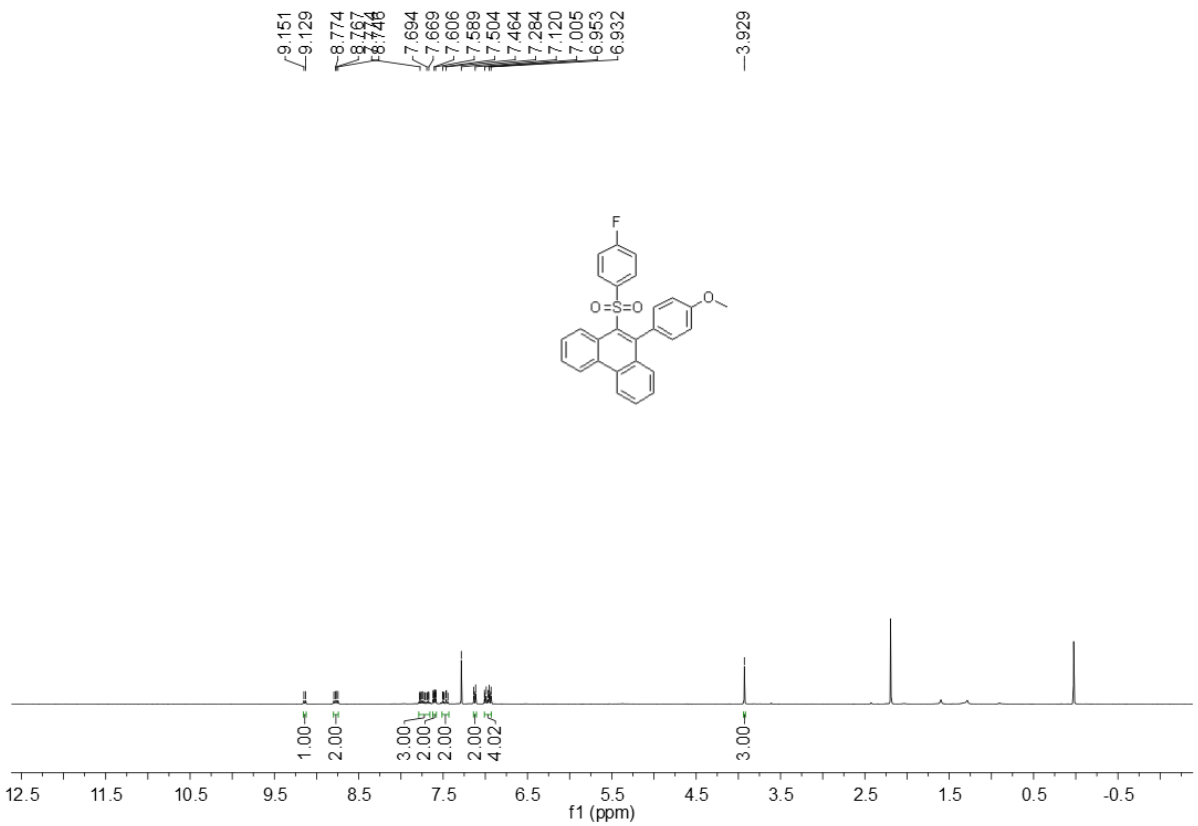
^{13}C NMR Spectrum of Compound 6q



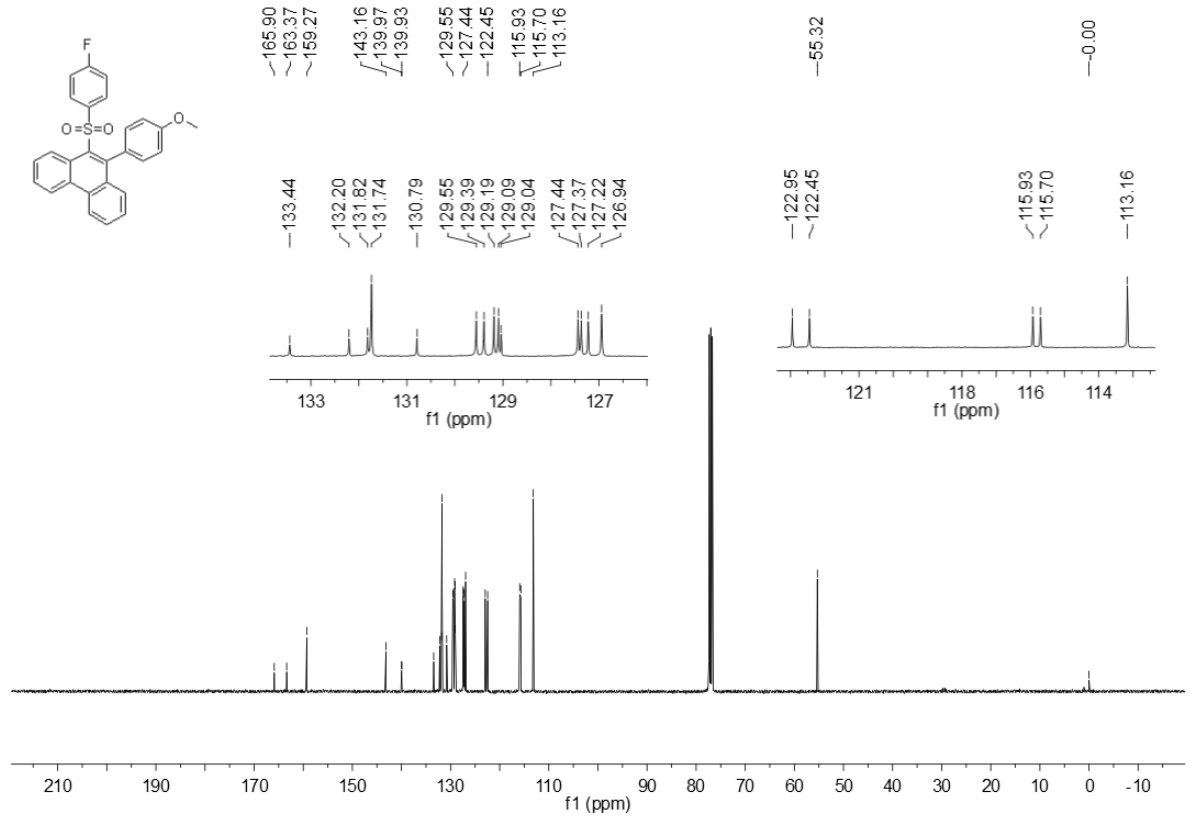
^{1}H NMR Spectrum of Compound 6r



^{13}C NMR Spectrum of Compound 6r



^{1}H NMR Spectrum of Compound 6s



^{13}C NMR Spectrum of Compound 6s