Supporting Information

Access to 2-thio/selenoquinolines via domino reaction of isocyanides with sulfur and selenium in water

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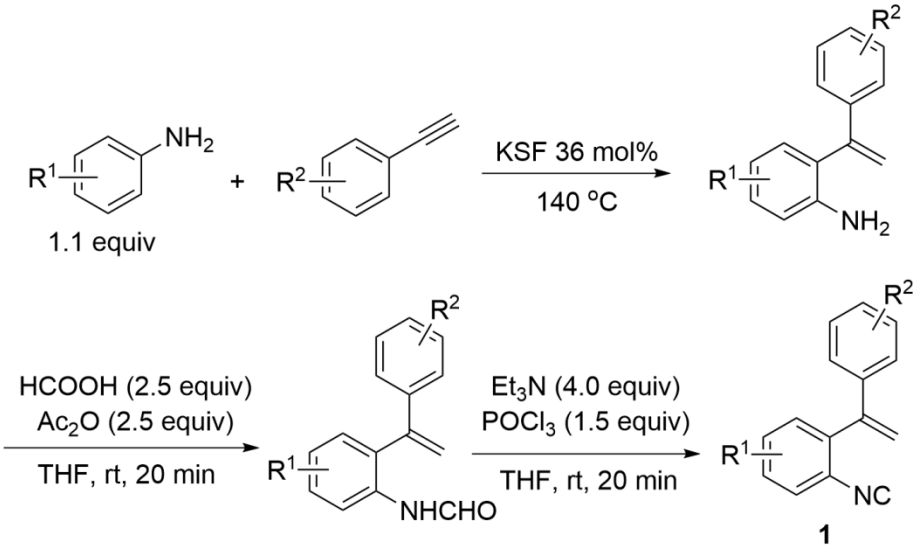
I. General information

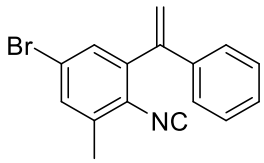
All reagents were commercially available and used without further purification, unless otherwise indicated. Chromatography was carried out on flash silica gel (300−400 mesh). All reactions were monitored by TLC, performed on glass plates with precoated silica gel 60 (F254). ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra were measured on a 400 MHz Bruker instrument, with TMS as the internal standard. All chemical shifts are reported in ppm scale. High-resolution mass spectra (HRMS) were acquired using a Bruker microTOF II focusing spectrometer (ESI).

II. Preparation and analytical data of isocyanide 1

o-Vinylphenyl isocyanides **1** was prepared according to previous literature report[1-2].

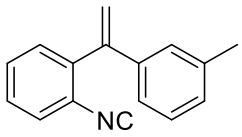


Analytical data of 1 (1j, 1k, 1n, 1o, 1t)

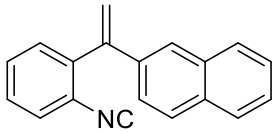


5-bromo-2-isocyano-1-methyl-3-(1-phenylvinyl)benzene (1j). Eluent: PE/EA (30:1), yellow oil, 504 mg, 85% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 2.0 Hz, 1H), 7.36 - 7.31 (m, 4H), 7.27 - 7.24 (m, 2H), 5.87 (s, 1H), 5.38 (s, 1H), 2.42 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 144.9, 141.0, 138.8, 137.5, 132.5, 131.1, 128.5,

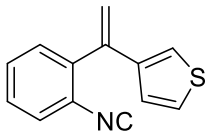
128.3, 126.7, 122.7, 118.0, 18.9. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{13}BrN^+$ 298.0226; found 298.0229.



1-isocyano-2-(1-(m-tolyl)vinyl)benzene (1k). Eluent: PE/EA (30:1)，colorless oil，329 mg，76% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 - 7.37 (m, 2H), 7.36 - 7.32 (m, 2H), 7.20 (t, J = 7.6 Hz, 1H), 7.11 (d, J = 7.6 Hz, 1H), 7.08 (s, 1H), 7.04 (d, J = 8.0 Hz, 1H), 5.85 (d, J = 1.2 Hz, 1H), 5.37 (d, J = 0.8 Hz, 1H), 2.32 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.6, 145.5, 139.3, 139.3, 137.9, 130.8, 129.1, 128.9, 128.3, 128.2, 127.4, 127.3, 125.3, 124.0, 117.4, 21.4. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}N^+$ 220.1121; found 220.1126.

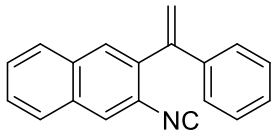


2-(1-(2-isocyanophenyl)vinyl)naphthalene (1n). Eluent: PE/EA (30:1)，yellow oil，382 mg，75% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.84 - 7.82 (m, 2H), 7.75 - 7.72 (m, 1H), 7.56 - 753 (m, 2H), 7.48 - 7.39 (m, 6H), 6.03 (s, 1H), 5.51 (s, 1H). **^{13} C NMR** (100 MHz, $CDCl_3$) δ 145.4, 139.3, 136.7, 133.2, 133.1, 130.9, 129.3, 128.5, 128.3, 128.2, 127.6, 127.4, 126.3, 126.2, 126.1, 124.5, 118.1. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{19}H_{14}N^+$ 256.1121; found 256.1127.



3-(1-(2-isocyanophenyl)vinyl)thiophene (3o). Eluent: PE/EA (30:1)，yellow oil，253 mg, 60% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.35 - 7.25 (m, 4H), 7.21 (q, J_1 = 4.8 Hz, J_2 = 2.8 Hz, 1H), 7.12 (q, J_1 = 4.8 Hz, J_2 = 1.2 Hz, 1H), 6.78 (q, J_1 = 2.8 Hz, J_2 = 1.2 Hz, 1H), 5.77 (s, 1H), 5.20 (s, 1H). **^{13} C NMR** (100 MHz, $CDCl_3$) δ 166.5, 141.0, 140.0, 139.1, 130.3, 129.2, 128.4, 127.2, 126.0, 125.7, 122.8 116.0. **HRMS (ESI)** m/z:

[M+H] $^{+}$ calcd for $C_{13}H_{10}NS^{+}$ 212.0528; found 212.0523.



2-isocyano-3-(1-phenylvinyl)naphthalene (3t). Eluent: PE/EA (30:1)，yellow oil，398 mg, 78% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.92 - 7.85 (m, 3H), 7.57 - 7.45 (m, 3H), 7.30 - 7.24 (m, 5H), 6.28 (d, *J* = 2.4 Hz, 1H), 5.42 (d, *J* = 2.4 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.4, 142.7, 138.7, 137.4, 133.0, 132.0, 129.0, 128.6, 128.2, 128.1, 127.6, 127.5, 126.9, 126.2, 123.5, 118.4. **HRMS (ESI)** m/z: [M+H] $^{+}$ calcd for $C_{19}H_{14}N^{+}$ 256.1121; found 256.1112.

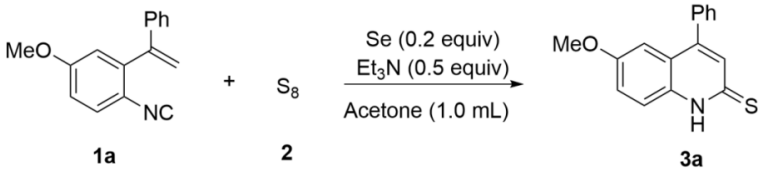
References

1、Y. Liu, S.-J. Li, X.-L. Chen, L.-L. Fan, X.-Y. Li, S.-S. Zhu, L.-B. Qu and B. Yu, *Adv. Synth. Catal.*, 2020, **362**, 688 - 694.

2、Jyotshna Phukona, Sanjib Gogoi, *Chem. Commun.*, 2020, **56**, 1133 - 1136.

III. Optimization of reaction conditions

Table 1. Optimization of reaction temperature [a].

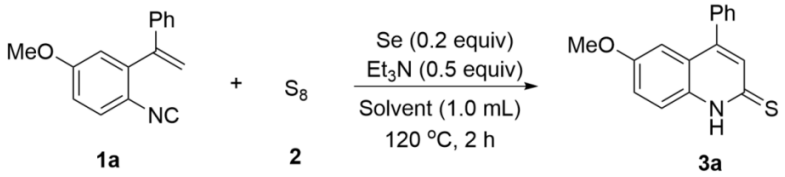


1a **2** **3a**

Entry	**1a** : **2**	Temp. (°C)	Time (h)	Yield (%)[b]
1	1 : 2	rt	24	Trace
2	1 : 2	40	24	Trace
3	1 : 2	60	14	40
4	1 : 2	80	9	57
5	1 : 2	100	6	76
6	1 : 2	120	2	85

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), Se (0.2 equiv), Et_3N (2.0 equiv) in acetone (1.0 mL), and the reaction was monitored by TLC. b) Determined by ^1H NMR using CH_2Br_2 as internal standard.

Table 2. Optimization of reaction solvent [a].

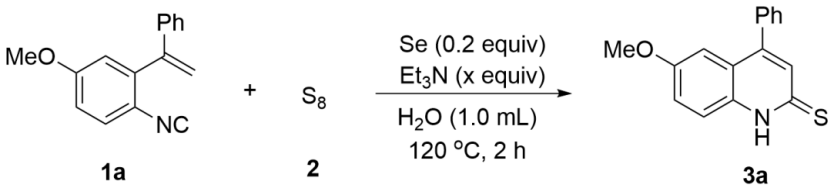


1a **2** **3a**

Entry	**1a** : **2**	Solvent (1.0 mL)	Yield (%)[b]
1	1 : 2	Acetone	85
2	1 : 2	MeCN	80
3	1 : 2	DMSO-d_6	53
4	1 : 2	DMF	84
5	1 : 2	EtOH	94
6	1 : 2	THF	87
7	1 : 2	Toluene	21
8	1 : 2	DCM	73
9	1 : 2	EA	82
10	1 : 2	H_2O	87

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), Se (0.2 equiv), Et_3N (2.0 equiv) in solvent (1.0 mL) at 120 °C for 2 hours. b) Determined by ^1H NMR using CH_2Br_2 as internal standard.

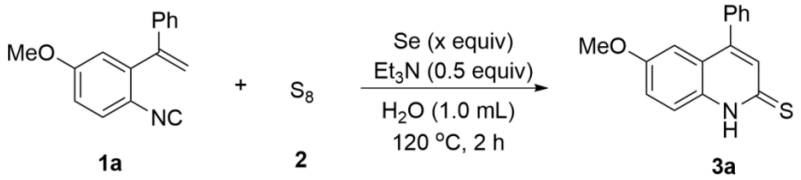
Table 3. Optimization of base usage [a].



Entry	**1a** : **2**	Base (x equiv)	Yield (%)[b]
1	1 : 2	Et_3N (2.0 equiv)	87
2	1 : 2	Et_3N (1.0 equiv)	92
3	1 : 2	Et_3N (0.5 equiv)	94
4	1 : 2	Et_3N (0.2 equiv)	79
5	1 : 2	Et_3N (0 equiv)	75

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), Se (0.2 equiv), Et_3N (x equiv) in water (1.0 mL) at 120 °C for 2 hours. b) Determined by ^1H NMR using CH_2Br_2 as internal standard.

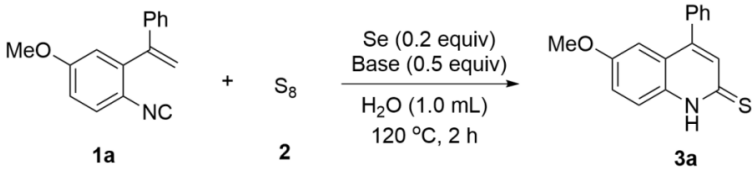
Table 4. Optimization of catalyst Se powder [a].



Entry	**1a** : **2**	Se (x equiv)	Yield (%)[b]
1	1 : 2	0.2	94
2	1 : 2	0.1	92
3	1 : 2	0.05	77
4	1 : 2	0	76
5[c]	1 : 2	0	24

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), Se (x equiv), Et_3N (0.5 equiv) in water (1.0 mL) at 120 °C for 2 hours. b) Determined by ^1H NMR using CH_2Br_2 as internal standard. c) Without Et_3N.

Table 5. Optimization of Base [a].

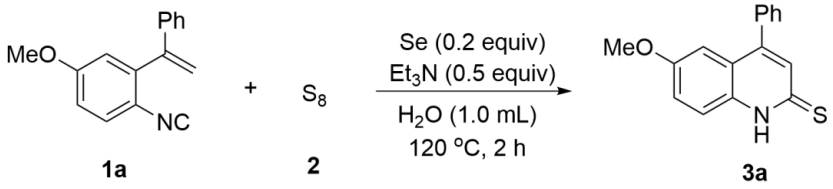


Entry	**1a** : **2**	Base (0.5 equiv)	Yield (%)[b]
1	1 : 2	Et_3N	94
2	1 : 2	DIPEA	94

3	1 : 2	K_2CO_3	87
4	1 : 2	DBU	92
5	1 : 2	Cs_2CO_3	79
6	1 : 2	NaOH	86

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), Se (0.2 equiv), base (0.5 equiv) in water (1.0 mL) at 120 °C for 2 hours. b) Determined by ^{1}H NMR using CH_2Br_2 as internal standard.

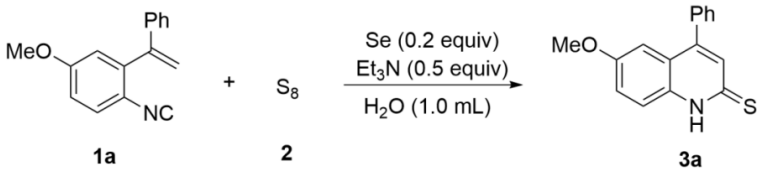
Table 6. Optimization of feeding ratio [a].



Entry	**1a** : **2**	Yield[b]
1	1 : 2	94
2	1 : 1.5	94
3	1 : 1.2	86

a)Reaction conditions: **1a** (0.2 mmol), **2** (x mmol), Se (0.2 equiv), Et_3N (0.5 equiv) in water (1.0 mL) at 120 °C for 2 hours. b) Determined by ^{1}H NMR using CH_2Br_2 as internal standard.

Table 7. Optimization of reaction temperature [a].

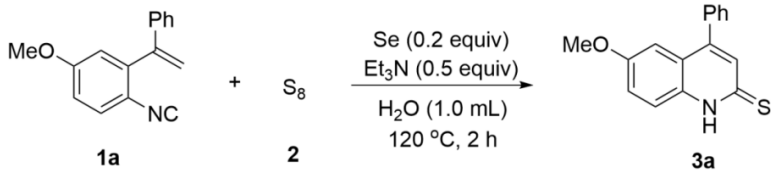


Entry	**1a** : **2**	Temp. (°C)	Yield (%)[b]
1	1 : 1.5	100	81
2	1 : 1.5	120	94(95)[c]
3	1 : 1.5	140	90

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.3 mmol), Se (0.2 equiv), Et_3N (0.5 equiv) in water (1.0 mL). b) Determined by ^{1}H NMR using CH_2Br_2 as internal standard. c) Isolated yield.

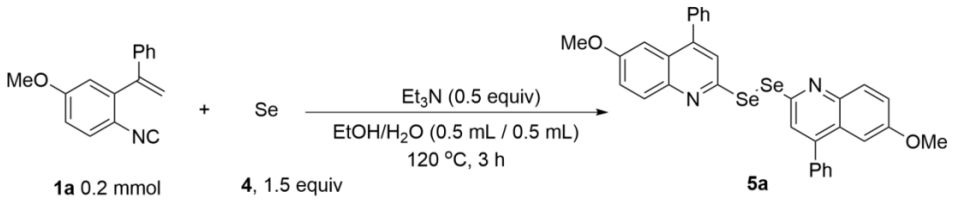
IV. Preparation and analytical data of quinoline 3, 5, 6, 7.

Typical procedure for the synthesis of quinoline-2 (1H) - thione 3 (with **3a** as an example)



A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (0.2 mmol, 47 mg), **2** (1.5 equiv, 0.3 mmol, 9.6 mg), Se (0.2 equiv, 3.1 mg), Et_3N (0.5 equiv, 10.2 mg) and pure water (1 mL) in a sealed was heated at 120 °C. The reaction was monitored by TCL, and after 2 hours substrate **1a** was consumed. Then, the reaction mixture was cooled to room temperature and extracted with ethyl acetate (3 × 10 mL). The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 5 : 1) to give 6-methoxy-4-phenylquinoline-2(1H)-thione **3a** (50.7 mg, 95 %).

Typical procedure for the synthesis of 1,2-di(quinolin-2-yl)diselane 5 (with **5a** as an example)

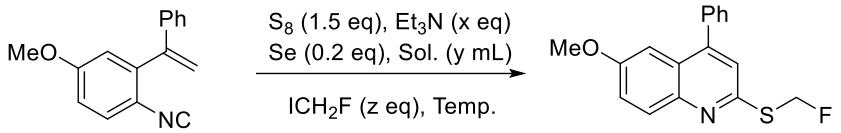


A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (0.2 mmol, 47 mg), **4** (1.5 equiv, 0.3 mmol, 24.0 mg), Et_3N (0.5 equiv, 10.2 mg) , pure water (0.5 mL) and ethanol (0.5 mL) in a sealed tube was heated at 120 °C. The reaction was monitored by TCL, and the substrate was consumed after 3 hours. Then, the reaction mixture was cooled to room temperature and extracted by ethyl acetate (3 × 10 mL). The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 20 : 1) to give

1,2-bis(6-methoxy-4-phenylquinolin-2-yl)diselane **5a** (56.4 mg, 90 %).

Typical procedure for the synthesis of 2-((fluoromethyl)thio)quinolone 6.

Table 8. Optimization of reaction conditions

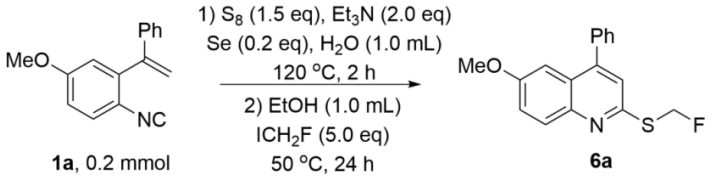


1a, 0.2 mmol **6a**

Entry	Et_3N	ICH_2F	Sol.	Temp. (°C)	Yield (%)[d]
1[a]	0.5 eq	2.0 eq	H_2O (1.0 mL)	120 °C	9
2[b]	0.5 eq	2.0 eq	H_2O (1.0 mL)	120 °C to 50 °C	Trace
3[b][c]	2.0 eq	5.0 eq	H_2O/EtOH (1.0 mL+1.0 mL)	120 °C to 50 °C	83%

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.3 mmol), Se (0.2 equiv), Et_3N (0.5 equiv), ICH_2F (2.0 equiv) in water (1.0 mL) at 120 °C for 2 hours. b) Two steps in one pot: **1a** (0.2 mmol), **2** (0.3 mmol), Se (0.2 equiv), Et_3N (x equiv) in water at 120 °C for 2 hours, cooled to room temperature, then added ICH_2F(y eq) and continued to react. c) Step 2 1.0 mL EtOH was added. d) Isolated yield.

with **6a** as an example



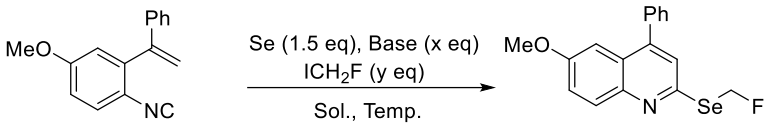
1a, 0.2 mmol **6a**

A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (0.2 mmol, 47 mg), **S8** (1.5 equiv, 0.3 mmol, 9.6 mg), Se (0.2 equiv, 3.1 mg), Et_3N (2.0 equiv, 41 mg) and water (1.0 mL) in a sealed tube was heated at 120 °C. The reaction was monitored by TCL, and the substrate was consumed after 2 hours. Then, the reaction mixture was cooled to room temperature, ICH_2F (5.0 equiv) and ethanol (1.0 mL) were added, the reaction mixture was heated at 50 °C. After the reaction is completed (24 h), the mixture was cooled to room temperature and extracted with ethyl acetate (3 × 10 mL).

The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 20 : 1) to give 2-((fluoromethyl)thio)-6-methoxy-4-phenylquinoline **6a** (49.3 mg, 83 %).

Typical procedure for the synthesis of 2-((fluoromethyl)selanyl)quinoline 7.

Table 9. Optimization of reaction conditions[a]

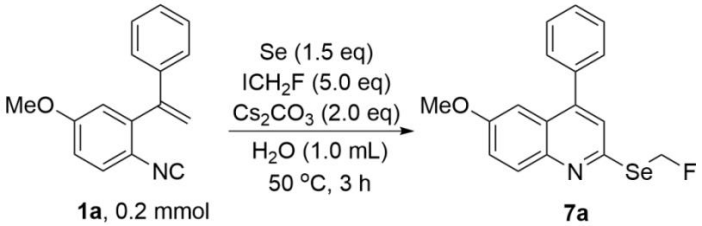


1a, 0.2 mmol **7a**

Entry	Base	ICH_2F	Sol.	Temp.(°C)	Yield[b]
1	Et_3N (1.5 eq)	1.5 eq	H_2O (1.0 mL)	50	26%
2	KOH (0.5 eq)	5.0 eq	H_2O (1.0 mL)	50	52%
3	KOH (1.0 eq)	5.0 eq	H_2O (1.0 mL)	50	56%
4	KOH (2.0 eq)	5.0 eq	H_2O (1.0 mL)	50	58%
5	KOH (2.0 eq)	5.0 eq	H_2O (1.0 mL)	80	32%
6	KOH (2.0 eq)	2.0 eq	H_2O (1.0 mL)	50	50%
7	Cs_2CO_3 (2.0 eq)	5.0 eq	H_2O (1.0 mL)	50	58%

a)Reaction conditions: **1a** (0.2 mmol), **2** (0.3 mmol), Se (1.5 equiv), Base (x equiv), ICH_2F (y equiv) reacted in solvent. b) Isolated yield.

with **7a** as an example

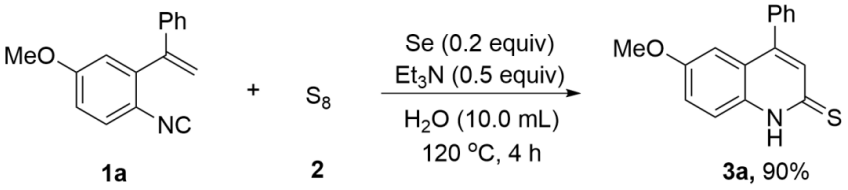


1a, 0.2 mmol **7a**

A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (0.2 mmol, 47 mg), **Se** (1.5 equiv, 0.3 mmol, 23.7 mg), Cs_2CO_3 (2.0 equiv, 131 mg), ICH_2F (5.0 equiv, 160 mg) and pure water (1.0 mL) was heated at 120 °C. The reaction was

monitored by TCL, and the substrate was consumed after 3 hours. Then, the mixture was cooled to room temperature and extracted with ethyl acetate (3 × 10 mL). The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 30 : 1) to give 2-((fluoromethyl)selanyl)-6-methoxy-4-phenylquinoline **7a** (40.0 mg, 58 %).

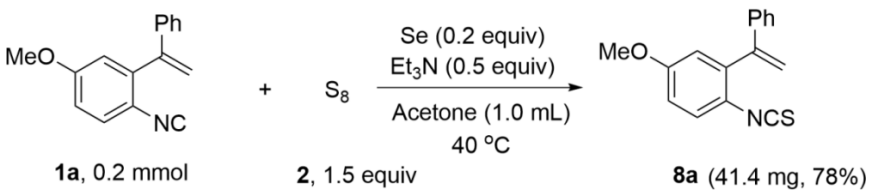
V. Scale-up experiment



A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (7 mmol, 1.646 g), **2** (1.5 equiv, 10.5 mmol, 336 mg), Se (0.2 equiv, 110.6 mg), Et_3N (0.5 equiv, 357 mg) and water (10.0 mL) was heated at 120 °C. The reaction was monitored by TCL, the substrate was consumed after 4 hours. Then, the mixture was cooled to room temperature and extracted with DCM (3 × 100 mL). The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 5 : 1) to give 6-methoxy-4-phenylquinoline-2(1H)-thione **3a** (1.6757 mg, 90 %).

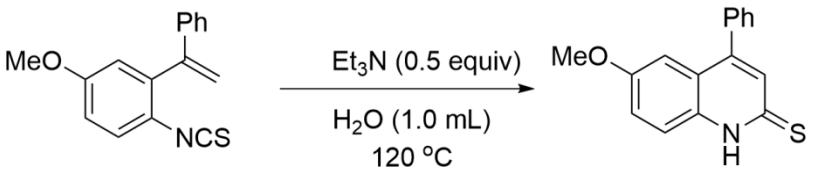
VI. Mechanistic investigation

Controlled experiment **I**



A mixture of 1-isocyano-4-methoxy-2-(1-phenylvinyl)benzene **1a** (0.2 mmol, 47 mg), **2** (1.5 equiv, 0.3 mmol, 9.6 mg), Se (0.2 equiv, 3.1 mg), Et_3N (0.5 equiv, 10.2 mg) and acetone (1 mL) was heated at 40 °C. The reaction was completed for about 10 minutes (monitored by TLC). Then, the reaction mixture was concentrated by vacuum distillation, and the crude product was purified by column chromatography (petroleum ether/ethyl acetate=30/1) to obtain 1-isothiocyanato-4-methoxy-2-(1-phenylvinyl)benzene **8a** (41.4 mg, 78%).

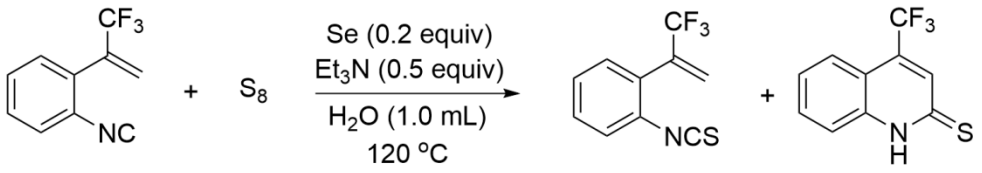
Controlled experiment **II**



8a, 0.2 mmol　　**3a**, (53 mg, 98%)

A mixture of 1-isothiocyanato-4-methoxy-2-(1-phenylvinyl)benzene **8a** (0.2 mmol, 54 mg), Et_3N (0.5 equiv) and pure water (1 mL) was heated at 120 °C. The reaction was monitored by TLC, and the substrate was consumed after 2 hours. Then, the reaction mixture was cooled to room temperature and extracted with ethyl acetate (3 × 10 mL). The organic phase was combined, dried over anhydrous Mg_2SO_4, and concentrate under reduced pressure. Purify the crude product through column chromatography (petroleum ether/ethyl acetate=5/1) to obtain 6-methoxy-4-phenylquinoline-2(1H)-thione **3a** (53 mg, 98%)

Controlled experiment **III**



1s　　**2**　　**8s**　　**3s**, ND

A mixture of 1-isocyano-2-(3,3,3-trifluoroprop-1-en-2-yl)benzene **1s** (0.2 mmol, 40 mg), **2** (1.5 equiv, 0.3 mmol, 9.6 mg), Se (0.2 equiv, 3.1 mg), Et_3N (0.5 equiv, 10.2

mg) and water (1.0 mL) was heated at 120 °C. The reaction was monitored by TCL, and the substrate was consumed after 4 h. Afterwards, the mixture was cooled to room temperature and extracted by ethyl acetate (3 × 10 mL). The organic layers were combined, dried over anhydrous Mg_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography (petroleum ether / ethyl acetate = 30 : 1) to give 1-isothiocyanato-2-(3,3,3-trifluoroprop-1-en-2-yl)benzene **8s** (28.5 mg, 63 %).

VII. Analytical data of compounds

The characterization data of these compounds match the data previously reported in the literature.

6-methoxy-4-phenylquinoline-2(1H)-thione (**3a**)[1],

6-methyl-4-phenylquinoline-2(1H)-thione (**3b**)[1],

4-phenylquinoline-2(1H)-thione (**3e**)[1],

6-chloro-4-phenyl-quinoline-2(1H)-thione (**3f**)[1],

4-methylquinoline-2(1H)-thione (**3o**)[1],

8-methyl-4-phenylquinoline-2(1H)-thione (**3h**)[1],

4-(4-methoxyphenyl)quinoline-2(1H)-thione (**3m**)[2],

1-isothiocyanato-4-methoxy-2-(1-phenylvinyl)benzene (**8a**)[3].

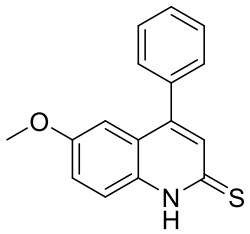
References:

1. X. Zhang, T. Wang, et al. Base-controlled chemoselectivity reaction of vinylanilines with isothiocyanates for synthesis of quinolino-2-thione and 2-aminoquinoline derivatives. *Chem. Commun.* **2018,** *54***,** 3114 - 3117.

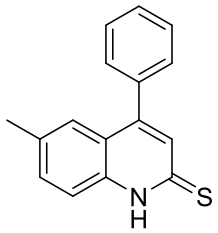
2. T. Otani, S. Kunimatsu, et al. Synthesis of Quinoline-2-thiones via Tandem Indium(III)-Promoted Friedel-Crafts Alkenylation-Cyclization of 2-Alkynylphenyl Isothiocyanates. *Org. Lett.* **2007**, *9*, 5513 - 5516.

3. K. Kobayashi., S. Fujita, et al. One-Pot Synthesis of Quinoline-2(1H)-thiones from 2-Isocyanostyrenes via Electrocyclic Reaction of the Corresponding

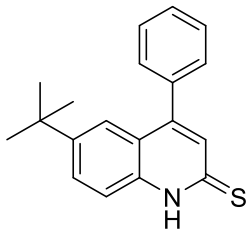
2-Isothiocyanatestyrenes. *Synthesis*, **2009**, *20*, 3378 - 3382.



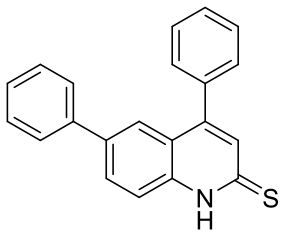
6-methoxy-4-phenylquinoline-2(1H)-thione (3a). Eluent: PE/EA (5:1), Yellow solid, 50.7 mg，95% yield, m.p.: 229 - 230 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.72 (s, 1H), 7.68 (d, J = 9.2 Hz, 1 H), 7.59 - 7.55 (m, 5 H), 7.35 (dd, J_1 = 9.2 Hz, J_2 = 2.8 Hz, 1 H), 7.13 (s, 1H), 6.91 (d, J = 2.4 Hz, 1 H), 3.68 (s, 3 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 178.4, 156.1, 145.9, 136.5, 135.3, 131.7, 129.6, 129.4, 129.2, 122.6, 121.2, 118.8, 107.4, 55.8. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NOS^+$ 268.0791**;** found 268.0784.



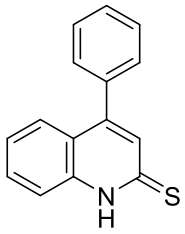
6-methyl-4-phenylquinoline-2(1H)-thione (3b). Eluent: PE/EA (5:1), Yellow solid, 46.7 mg，93% yield, m.p.: 249 - 250 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.71 (s, 1H), 7.61 (d, J = 8.4 Hz, 1 H), 7.57 - 7.52 (m, 3 H), 7.48 - 7.46(m, 3 H), 7.26 (s, 1 H), 7.09 (d, J = 1.6 Hz, 1 H), 2.27 (s, 3 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 179.8, 146.2, 138.5, 136.5, 134.2, 133.2, 131.4, 129.5, 129.3, 129.3, 125.7, 121.7, 117.1, 21.3. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NS^+$ 252.0841; found 252.0838.



6-(tert-butyl)-4-phenylquinoline-2(1H)-thione (3c). Eluent: PE/EA (5:1), Yellow solid, 49.8 mg, 85% yield, m.p.: 236 - 238 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.71 (s, 1H), 7.78 (dd, J_1 = 8.8 Hz, J_2 = 2.0 Hz, 1H), 7.67 (d, J = 8.8 Hz, 1 H), 7.59 - 7.52 (m , 5 H), 7.48 (d, J = 2.0 Hz, 1 H), 7.13 (s, 1 H), 1.21 (s, 9 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.0, 147.0, 146.6, 138.4, 136.4, 131.4, 130.1, 129.6, 129.3, 129.3, 121.6, 121.2, 117.1, 34.9, 31.2. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{19}H_{20}NS^+$ 294.1311; found 294.1317.

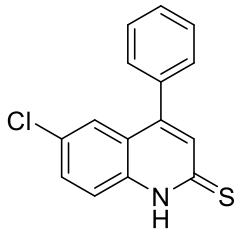


4,6-diphenylquinoline-2(1H)-thione (3d). Eluent: PE/EA (5:1), Yellow solid, 56.7 mg, 91% yield, m.p.: 289 - 291 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.85 (s, 1H), 7.97 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 1H), 7.80 (d, J = 8.4 Hz, 1 H), 7.67 (d, J = 1.6 Hz, 1 H), 7.57 - 7.52 (m, 7 H), 7.42 (t, J = 8.0 Hz, 2 H), 7.33 (t, J = 7.2 Hz, 1 H), 7.17 (d, J = 1.2 Hz, 1 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.6, 146.4, 139.6, 139.6, 136.6, 136.3, 131.9, 130.7, 129.7, 129.6, 129.4, 128.2, 127.1, 124.0, 122.0, 117.9. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{21}H_{16}NS^+$ 314.0998; found 314.0995.

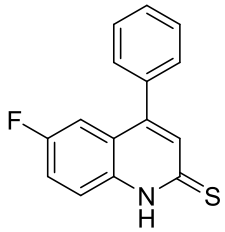


4-phenylquinoline-2(1H)-thione (3e). Eluent: PE/EA (5:1), Yellow solid, 39.2 mg，83% yield, m.p.: 210 - 211 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.77 (s, 1H), 7.71 (d, J = 8.0 Hz, 1 H), 7.66 (t, J = 7.6 Hz, 1 H), 7.55 - 7.50 (m, 6 H), 7.32 (t, J = 7.6 Hz, 1 H), 7.14 (s, 1 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.7, 146.4, 140.2, 136.4,

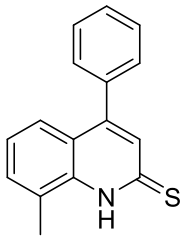
131.8, 131.4, 129.6, 129.4, 129.3, 126.5, 124.8, 121.7, 117.2. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{15}H_{12}NS^+$ 238.0685; found 238.0690.



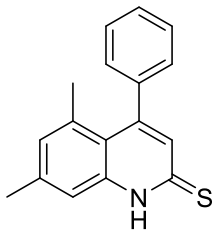
6-chloro-4-phenylquinoline-2(1H)-thione (3f). Eluent: PE/EA (5:1), Yellow solid, 51.6 mg，95% yield, m.p.: 251 - 252 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.88 (s, 1H), 7.71 (s, 2 H), 7.60 - 7.55 (m, 3 H), 7.53 - 7.51(m, 2 H), 7.39 (s, 1 H), 7.17 (d, J = 1.2 Hz, 1 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 181.1, 145.2, 138. 9, 135.7, 132.4, 131.8, 129.8, 129.5, 129.3, 128.8, 125.3, 123.0, 119.2. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{15}H_{11}ClNS^+$ 272.0295; found 272.0294.



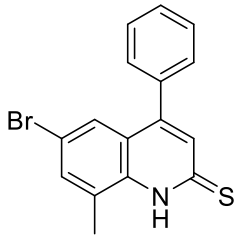
6-fluoro-4-phenylquinoline-2(1H)-thione (3g). Eluent: PE/EA (5:1), Yellow solid, 47 mg，92% yield, m.p.:246 - 248 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.86 (s, 1H), 7.75 (dd, J_1= 9.2 Hz, , J_2= 5.2 Hz, 1 H), 7.61 - 7.50 (m, 6 H), 7.18 - 7.14 (m, 2 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.4, 158.7 (J = 240.5 Hz), 145.6 (J = 3.6 Hz), 137.2, 135.9, 132.3, 129.8, 129.5, 129.3, 122.7 (J = 8.7 Hz), 120.3 (J = 24.7 Hz), 119.5 (J = 8.6 Hz), 111.1 (J = 23.9 Hz). **^{19}F NMR** (376 MHz, DMSO-d_6) δ -116.5 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{15}H_{11}FNS^+$256.0591; found 256.0598.



8-methyl-4-phenylquinoline-2(1H)-thione (3h). Eluent: PE/EA (5:1), Yellow solid, 39.2 mg, 79% yield, m.p.:170 - 172 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.29 (s, 1H), 7.57 - 7.54 (m, 3 H), 7.50 - 7.47 (m, 3 H), 7.33 (d, J = 8.0 Hz, 1 H), 7.33 (t, J = 7.6 Hz, 1 H), 7.16 (s, 1H), 2.63 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 181.5, 146.7, 138.7, 136.7, 133.1, 131.6, 129.5, 129.3, 129.2, 125.4, 124.7, 124.5, 122.1, 18.1. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NS^+$ 252.0841; found 252.0852.

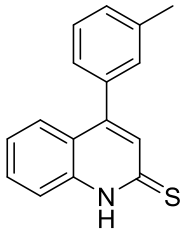


5,7-dimethyl-4-phenylquinoline-2(1H)-thione (3i). Eluent: PE/EA (5:1), Yellow solid, 50.9 mg, 96% yield, m.p.: 249 - 251 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.62 (s, 1H), 7.47 - 7.44 (m, 3H), 7.40 (s, 1H), 7.34 - 7.29 (m, 2H), 6.92 (s, 1 H), 6.88 (s, 1H), 2.34 (s, 3H), 1.73 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 178.9,147.4, 141.6, 141.5, 140.9, 136.3, 132.6, 130.3, 128.8, 128.7, 128.4, 118.9, 115.4, 23.7, 24.6. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{16}NS^+$ 266.0998; found 266.0995.

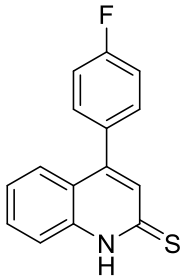


6-bromo-8-methyl-4-phenylquinoline-2(1H)-thione (3j). Eluent: PE/EA (5:1), Yellow solid, 61.0 mg, 93% yield, m.p.:233 - 235 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6)

δ 12.46 (s, 1H), 7.70 (d, *J* = 1.2 Hz, 1H), 7.58 - 7.54 (m, 3H), 7.50 - 7.48(m, 2H), 7.35 (d, *J* = 1.6 Hz, 1H), 7.18 (s, 1H), 2.62 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 181.9, 145.3, 137.9, 136.0, 135.2, 132.7, 129.8, 129.4, 129.3, 128.3, 126.3, 123.7, 116.5, 17.9. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{13}BrNS^+$ 329.9947; found 329.9969.

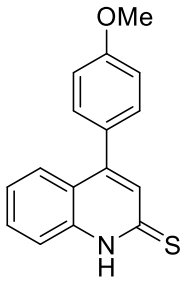


4-(m-tolyl)quinoline-2(1H)-thione (3k). Eluent: PE/EA (5:1), Yellow solid, 41.6 mg, 83% yield, m.p.:195 - 197 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.75 (s, 1H), 7.71 (d, *J* = 8.4 Hz, 1 H), 7.65 (t, *J* = 7.2 Hz, 1H), 7.53(d, *J* = 8.0 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.36 - 7.28 (m, 4H), 7.12 (s, 1H), 2.40 (s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.7, 146.6, 140.2, 138.7, 136.3, 131.8, 131.3, 130.2, 129.8, 129.2, 126.6, 126.5, 124.8, 121.7, 117.1, 21.5. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NS^+$252.0841; found 252.0855.

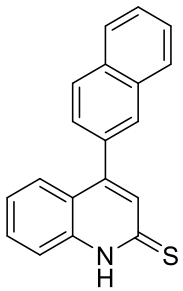


4-(4-fluorophenyl)quinoline-2(1H)-thione (3l). Eluent: PE/EA (5:1), Yellow solid, 45.7 mg, 90% yield, m.p.:252 - 254 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.77 (s, 1H), 7.72 - 7.64 (m, 2H), 7.60 - 7.56 (m, 2H), 7.49 (d, *J* = 8.0 Hz, 1H), 7.39 (t, *J* = 8.4 Hz, 2H), 7.32(t, *J* = 7.2 Hz, 1H), 7.14 (s, 1H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.7, 163.0 (*J* = 244.8 Hz), 145.4, 140.2, 132.7(*J* = 3.2 Hz), 131.8, 131.7(*J* = 8.2 Hz),

131.6, 126.4, 124.8, 121.7, 117.2, 116.3 (J = 31.5 Hz). **^{19}F NMR** (376 MHz, DMSO-d_6) δ -112.5 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{15}H_{11}FNS^+$ 256.0591; found 256.0602.

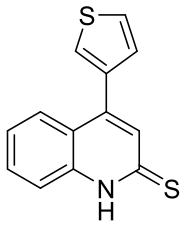


4-(4-methoxyphenyl)quinoline-2(1H)-thione (3m). Eluent: PE/EA (5:1), Yellow solid, 48.2 mg, 91% yield, m.p.:236 - 278 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.69 (s, 1H), 7.69 (t, J = 8.0 Hz, 1H), 7.64 (d, J = 8.0 Hz, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.47 (d, J = 8.8 Hz, 2H), 7.32(t, J = 7.2 Hz, 1H), 7.13 - 7.11(m, 3H), 3.84(s, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.6, 160.4, 146.2, 140.2, 131.7, 131.1, 130.9, 128.4, 126.6, 124.7, 121.8, 117.2, 114.8, 55.8. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NOS^+$ 268.0791; found 268.0804.

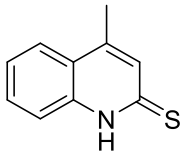


4-(naphthalen-2-yl)quinoline-2(1*H*)-thione (3n). Eluent: PE/EA (5:1)，Yellow solid, 35.0 mg，61% yield, m.p.: 259 - 261 ℃. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.80 (s, 1H), 8.12 (s, 1H), 8.09 (d, J = 8.8 Hz, 1H), 8.05 - 8.02 (m, 2H), 7.74 (d, J = 8.4 Hz, 1H), 7.68 (d, J = 7.2 Hz, 1H), 7.64 - 7.60 (m, 3H), 7.58 (d, J = 8.4 Hz, 1H), 7.32 (t, J = 7.2 Hz, 1H), 7.27 (s, 1H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.7, 146.4, 140.2, 133.9, 133.3, 133.3, 131.8, 131.7, 128.8, 128.7, 128.2, 127.5, 127.3, 127.0, 126.7,

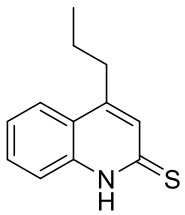
124.9, 121.8, 117.2. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{19}H_{14}NS^+$ 288.0841; found 288.0858.



4-(thiophen-3-yl)quinoline-2(1H)-thione (3o). Eluent: PE/EA (5:1), Yellow solid, 37.0 mg, 77% yield, m.p.:224 - 226 ℃, **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.69 (s, 1 H), 7.97 (s, 1 H), 7.80 - (m, 2 H), 7.71 - 7.64(m, 2 H), 7.42 (d, J = 3.2 Hz, 1 H), 7.36 (t, J = 7.2 Hz, 1 H), 7.23 (s, 1 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.6, 141.3, 140.2, 136.7, 131.8, 131.0, 128.9, 128.0, 127.3, 126.5, 124.8, 121.5, 117.1. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{13}H_{18}NS_2^+$ 244.0249; found 244.0240.

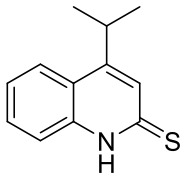


4-methylquinoline-2(1H)-thione (3p). Eluent: PE/EA (5:1), Yellow solid, 26.3 mg, 76% yield, m.p.:265 - 267 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.48 (s, 1H), 7.82 (d, J = 8.0 Hz, 1 H), 7.62 (d, J = 4.4 Hz, 2 H), 7.39 - 7.33(m, 1 H), 7.21 (s, 1 H), 2.45 (s, 3 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.8, 143.8, 139.3, 131.5, 131.4, 125.2, 124.5, 123.0, 116.9, 18.4. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{10}H_{10}NS^+$176.0528; found 176.0526.

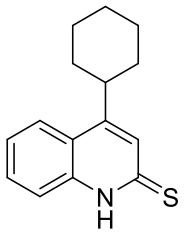


4-propylquinoline-2(1H)-thione (3q). Eluent: PE/EA (5:1)， Yellow solid, 31 mg, 77%

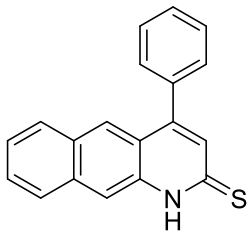
yield, m.p.: 194 - 196 ℃. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.51 (s, 1H), 7.88 (d, J = 8.0 Hz, 1H), 7.65 - 7.58 (m, 2H), 7.37 - 7.33 (m, 1H), 7.16 (s, 1H), 2.81 (t, J = 7.6 Hz, 2H), 1.69 - 1.59 (m, 2H), 0.96 (t, J = 7.2 Hz, 3H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.7, 147.3, 139.7, 131.4, 130.6, 125.0, 124.5, 122.2, 117.2, 33.3, 22.6, 14.3. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{12}H_{14}NS^+$ 204.0841; found 204.0853.



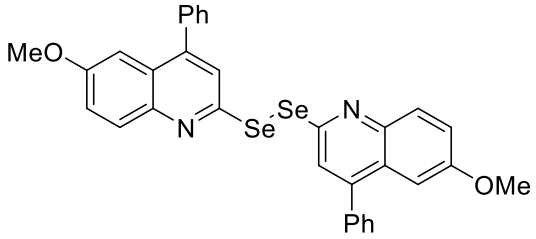
4-isopropylquinoline-2(1H)-thione (3r). Eluent: PE/EA (5:1), Yellow solid, 26.5 mg, 64% yield, m.p.:177 - 179 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.54 (s, 1H), 7.96 (d, J = 8.0 Hz, 1 H), 7.66 - 7.60 (m, 2 H), 7.40 - 7.35(m, 1 H), 7.15 (s, 1 H), 3.50 (m, 1 H), 1.27 (d, J = 6.8 Hz, 6 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 181.0, 152.9, 139.8, 131.3, 127.3, 124.6, 124.5, 121.7, 117.3, 28.0, 22.5. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{12}H_{14}NS^+$ 204.0841; found 204.0854.



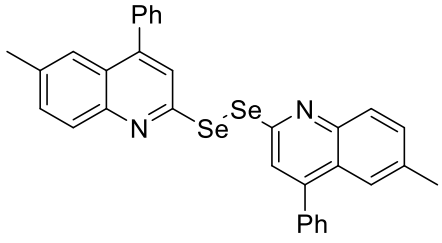
4-cyclohexylquinoline-2(1H)-thione (3s). Eluent: PE/EA (5:1)，Yellow solid, 38.4 mg, 79 % yield, m.p.: 260 - 261 ℃. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.53 (s, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.65 - 7.59 (m, 2H), 7.38 - 7.34 (m, 1H), 7.11 (s, 1H), 3.11 (t, J = 11.6 Hz, 1H), 1.82 (t, J = 12.4 Hz, 4H), 1.73 (d, J = 12.8 Hz, 1H), 1.55 - 1.36 (m, 4H), 1.31 - 1.15 (m, 2H) . **^{13}C NMR** (100 MHz, DMSO-d_6) δ 180.9, 151.8, 139.8, 131.3, 127.8, 124.6, 124.4, 121.6, 117.4, 38.1, 32.9, 26.6, 26.1. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{15}H_{18}NS^+$ 244.1154; found 244.1162.



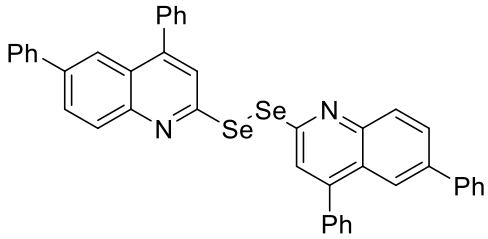
4-phenylbenzo[g]quinoline-2(1H)-thione (3v). Eluent: PE/EA (5:1), Yellow solid, 53.0 mg, 93% yield, m.p.:266 - 268 ℃**, ^{1}H NMR** (400 MHz, DMSO-d_6) δ 14.04 (s, 1H), 8.15 (d, J = 9.2 Hz, 1 H), 7.95 (d, J = 8.0 Hz, 1 H), 7.84(d, J = 9.2 Hz, 1 H), 7.56 - 7.52 (m, 3 H), 7.45 - 7.39 (m, 3 H), 7.24 (d, J = 8.4 Hz, 1 H), 7.16 (d, J = 7.2 Hz, 1 H), (s, 1 H). **^{13}C NMR** (100 MHz, DMSO-d_6) δ 178.2, 147.4, 141.1, 134.2, 134.1, 131.3, 129.8, 129.1, 128.0, 127.1, 126.2, 125.9, 117.4, 116.7. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{19}H_{14}NS^+$288.0841; found 288.0830.



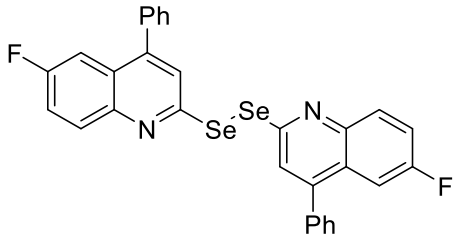
1,2-bis(6-methoxy-4-phenylquinolin-2-yl)diselane (5a). Eluent: PE/EA (20:1), yellow solid, 56.4 mg, 90% yield, m.p.:169 - 171 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 (d, J = 9.2 Hz, 2H), 7.89 (s, 2H), 7.49 - 7.45 (m, 6H), 7.43 - 7.40 (m, 4H),7.36 (dd, J_1 = 9.2 Hz, J_2 = 2.8 Hz, 2H), 7.13 (d, J = 2.8 Hz, 2H), 3.76 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.8, 151.6, 148.3, 144.6, 137.6, 130.3, 129.3, 128.6, 128.5, 126.1, 122.1, 121.7, 104.1, 55.4. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{32}H_{25}N_2O_2Se_2^+$ 629.0241; found 629.0223.



1,2-bis(6-methyl-4-phenylquinolin-2-yl)diselane (5b). Eluent: PE/EA (20:1), yellow solid, 48.7 mg, 82% yield, m.p.:195 - 197 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.4 Hz, 2H), 7.89 (s, 2H), 7.58 (s, 2H), 7.52 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 2H), 7.48 -7.45 (m, 6H), 7.42 - 7.38 (m, 4H), 2.43 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.6, 148.9, 147.2, 137.5, 136.4, 132.2, 129.4, 128.5, 128.5, 128.4, 125.0, 124.7, 121.0, 21.7. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{32}H_{25}N_2Se_2^+$ 597.0343; found 597.0328.

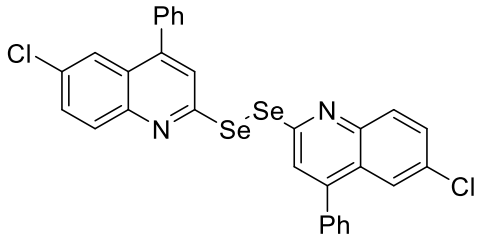


1,2-bis(4,6-diphenylquinolin-2-yl)diselane (5c). Eluent: PE/EA (20:1), yellow solid, 65.5 mg, 91% yield, m.p.:238 - 240 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.8 Hz, 2H), 8.03 (d, *J* = 1.6 Hz, 2H), 7.98 -7.95 (m, 4H), 7.57 (d, *J* = 7.2 Hz, 4H), 7.47 - 7.47 (m, 10H), 7.43 (t, *J* = 7.6 Hz, 4H), 7.35 (t, *J* = 7.2 Hz, 2H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.7, 149.7, 148.0, 140.3, 139.2, 137.3, 129.7, 129.5, 129.2, 128.9, 128.7, 127.7, 127.4, 125.3, 123.7, 121.3. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{42}H_{29}N_2Se_2^+$ 721.0656; found 721.0678.

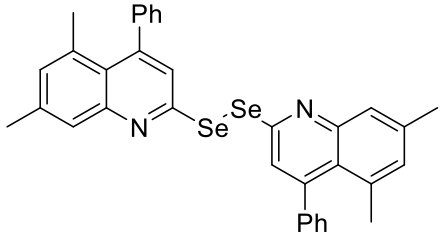


1,2-bis(6-fluoro-4-phenylquinolin-2-yl)diselane (5d). Eluent: PE/EA (20:1), yellow solid, 49.3 mg, 82% yield, m.p.:205 - 207 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 - 8.01 (m, 2H), 7.93 (s, 2H), 7.49 - 7.44 (m, 10H), 7.40 - 7.38 (m, 4H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.5 (*J* = 246.2 Hz), 153.9 (*J* = 2.9 Hz), 149.1 (*J* = 5.4 Hz), 145.7,

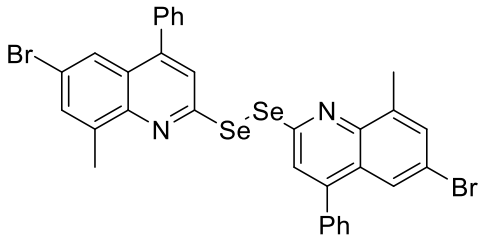
136.9, 131.2 (*J* = 9.0 Hz), 129.3, 128.9, 128.8, 126.0 (*J* = 9.5 Hz), 121.6, 120.1 (*J* = 25.5 Hz), 109.5 (*J* = 23.1 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -112.4 (s, 2F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{30}H_{19}F_2N_2Se_2^+$ 604.9841; found 604.9828.



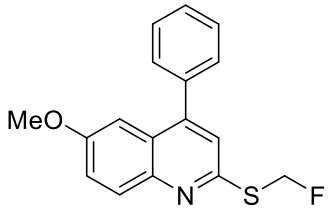
1,2-bis(6-chloro-4-phenylquinolin-2-yl)diselane (5e). Eluent: PE/EA (20:1), yellow solid, 49.8 mg, 79% yield, m.p.:206 - 207 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.8 Hz, 2H), 7.91 (s, 2H), 7.80 (d, *J* = 2.4 Hz, 2H), 7.63 (dd, *J* = 8.8 Hz, *J* = 2.0 Hz, 2H), 7.52 - 7.48 (m, 6H), 7.41 - 7.37 (m, 4H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.0, 148.8, 146.9, 136.4, 132.6, 130.9, 130.4, 129.3, 128.9, 128.8, 125.9, 124.8, 121.6. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{30}H_{19}Cl_2N_2Se_2^+$ 636.9250; found 636.9244.



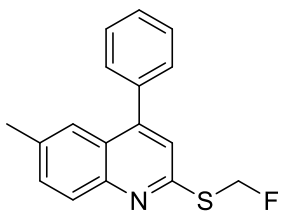
1,2-bis(5,7-dimethyl-4-phenylquinolin-2-yl)diselane (5f). Eluent: PE/EA (20:1), yellow solid, 46.1 mg, 74% yield, m.p.:212 - 214 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.69 (s, 2H), 7.68 (s, 2H), 7.41 - 7.34 (m, 6H), 7.21 - 7.19 (m, 4H), 7.06 (s, 2H), 2.46 (s, 6H), 1.90 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.2, 149.9, 149.8, 141.7, 139.7, 135.3, 132.0, 128.6, 127.9, 127.8, 126.8, 122.6, 122.3, 24.2, 21.4. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{34}H_{29}N_2Se_2^+$ 625.0656; found 625.0688.



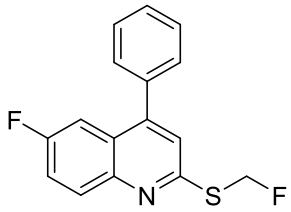
1,2-bis(6-bromo-8-methyl-4-phenylquinolin-2-yl)diselane (5g). PE/EA (20:1), yellow solid, 68.6 mg, 92% yield, m.p.:226 - 228 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.85 (s, 2H), 7.78 (d, *J* = 1.6 Hz, 2H), 7.61 (s, 2H), 7.51 - 7.47 (m, 6H), 7.38 - 7.6 (m, 4H), 2.67 (s, 6H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.8, 148.5, 146.4, 139.2, 137.2, 133.2, 129.4, 128.7, 128.7, 126.3, 125.8, 121.5, 120.1, 17.9. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{32}H_{23}Br_2N_2Se_2^+$ 752.8553; found 752.8549.



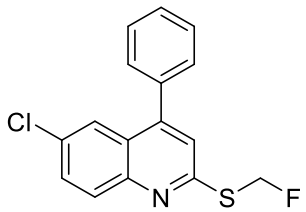
2-((fluoromethyl)thio)-6-methoxy-4-phenylquinoline (6a). Eluent: PE/EA (20:1), white solid, 49.3 mg, 83% yield, m.p.:156 - 157 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 9.2 Hz, 1H), 7.53 -7.49 (m, 5H), 7.36 (dd, J_1 = 9.2 Hz, J_2 = 2.8 Hz, 1H), 7.23 (s, 1H), 7.13 (d, *J* = 2.8 Hz, 1H), 6.40 (s, 1H), 6.27 (s, 1H), 3.77 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.5, 151.7 (*J* = 3.5 Hz), 148.0, 144.7, 137.7, 130.4, 129.2, 128.7, 128.6, 126.2, 121.8, 121.2, 104.2, 84.2 (*J* = 214.3 Hz), 55.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -187.8 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNOS^+$ 300.0853; found 300.0849.



2-((fluoromethyl)thio)-6-methyl-4-phenylquinoline (6b). Eluent: PE/EA (20:1), white solid, 42.0 mg, 75% yield, m.p.:147 - 148 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.4 Hz, 1H), 7.58 (s, 1H), 7.55 -7.47 (m, 6H), 7.22 (s, 1H), 6.42 (s, 1H), 6.29 (s, 1H), 2.45 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.4 (*J* = 3.5 Hz), 148.6, 147.2, 137.6, 136.0, 132.0, 129.4, 128.6, 128.6, 128.5, 125.3, 124.7, 120.8, 83.0 (*J* = 214.1Hz), 21.7. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -188.2 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNS^+$ 284.0904; found 284.0900.

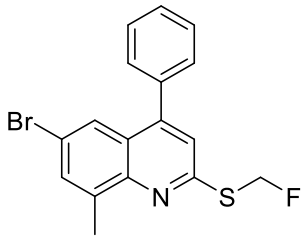


6-fluoro-2-((fluoromethyl)thio)-4-phenylquinoline (6c). Eluent: PE/EA (20:1), white solid, 42.0 mg, 74% yield, m.p.:147 - 148 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.10 - 8.06 (m, 1H), 7.56 - 7.51 (m, 3H), 7.49 - 7.44 (m, 4H), 7.27 (s, 1H), 6.41 (s, 1H), 6.28 (s, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.3 (*J* = 245.4 Hz), 153.9, 148.7 (*J* = 5.4 Hz), 145.7, 136.9, 131.2 (*J* = 8.9 Hz), 129.2, 128.9, 128.8, 126.1 (*J* = 9.5 Hz), 121.3, 119.8 (*J* = 25.5 Hz), 109.5 (*J* = 23.1 Hz), 82.7 (*J* = 214.6 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -113.3 (s, 1F), -188.8 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{12}F_2NS^+$ 288.0653; found 288.0643.

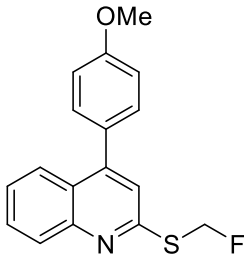


6-chloro-2-((fluoromethyl)thio)-4-phenylquinoline (6d). Eluent: PE/EA (20:1), white solid, 35.0 mg, 58% yield, m.p.:150 - 152 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.8 Hz, 1H), 7.79 (d, *J* = 2.4 Hz, 1H), 7.64 (dd, J_1 = 8.8 Hz, J_2 = 2.0 Hz,

1H), 7.57 -7.50 (m, 3H), 7.49 - 7.44 (m, 2H), 7.26 (s, 1H), 6.41 (s, 1H), 6.28 (s, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.1 (*J* = 2.0 Hz), 148.4, 147.0, 136.7, 131.9, 130.8, 130.5, 129.3, 128.9, 128.8, 126.1, 124.8, 121.5, 82.5 (*J* = 214.7 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -189.1 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{12}ClFNS^+$ 304.0358; found 304.0339.

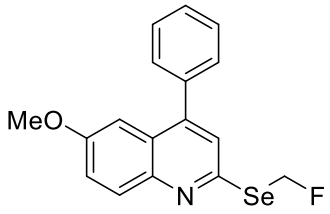


6-bromo-2-((fluoromethyl)thio)-8-methyl-4-phenylquinoline (6e). Eluent: PE/EA (20:1), white solid, 54.7 mg, 76% yield, m.p.:144 - 145 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.79 (d, *J* = 2.0 Hz, 1H), 7.66 - 7.65 (m, 1H), 7.56 -7.50 (m, 3H), 7.47 - 7.42 (m, 2H), 7.23 (s, 1H), 6.44 (s, 1H), 6.32 (s, 1H), 2.82 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.6 (*J* = 3.3 Hz), 148.6, 146.2, 139.0, 137.1, 133.3, 129.3, 128.8, 128.7, 126.5, 125.9, 121.2, 119.6, 82.5 (*J* = 214.9Hz), 17.9. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -190.3 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{14}BrFNS^+$ 362.0009; found 362.0002.

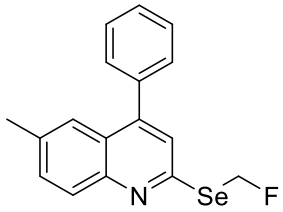


2-((fluoromethyl)thio)-4-(4-methoxyphenyl)quinoline (6f). Eluent: PE/EA (20:1), white solid, 49.5 mg, 83% yield, m.p.:112 - 113 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.4 Hz, 1H), 7.88 (dd, J_1 = 8.4 Hz, J_2 = 0.8 Hz, 1H), 7.71 - 7.67 (m, 1H), 7.46 - 7.38 (m, 3H), 7.23 (s, 1H), 7.07 - 7.04 (m, 2H), 6.43 (s, 1H), 6.30 (s, 1H), 3.90

(s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.0, 154.5(*J* = 3.4 Hz), 148.9, 148.7, 130.7, 129.8, 129.7, 128.9, 126.0, 125.9, 125.6, 120.6, 114.1, 82.8(*J* = 214.2 Hz), 55.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -188.5 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNOS^+$ 300.0853; found 300.0848.

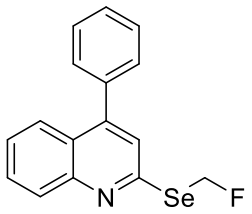


2-((fluoromethyl)selanyl)-6-methoxy-4-phenylquinoline (7a). Eluent: PE/EA (30:1), white solid, 40.0 mg, 58% yield, m.p.:133 - 135 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 9.2 Hz, 1H), 7.53 - 7.49 (m, 5H), 7.36 (dd, J_1 = 9.2 Hz, J_2 = 2.8 Hz, 1H), 7.33 (s, 1H), 7.13 (d, *J* = 2.8 Hz, 1H), 6.66 (t, *J* = 8.8 Hz, 1H), 6.54 (t, *J* = 8.8 Hz, 1H), 3.78 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.6, 149.2 (*J* = 2.8 Hz), 147.6, 145.3, 137.6, 130.4, 129.2, 128.7, 128.6, 126.4, 123.6, 121.8, 104.2, 81.2 (*J* = 224.7 Hz), 55.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -194.4 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNOSe^+$ 348.0297; found 348.0290.

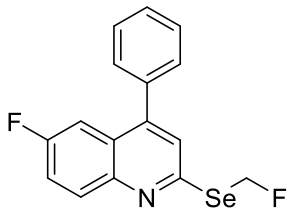


2-((fluoromethyl)selanyl)-6-methyl-4-phenylquinoline (7b). Eluent: PE/EA (30:1), white solid, 34.0 mg, 52% yield, m.p.:136 - 138 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.4 Hz, 1H), 7.58 - 7.48 (m, 7H), 7.32 (s, 1H), 6.69 (t, *J* = 8.0 Hz, 1H), 6.56 (t, *J* = 8.0 Hz, 1H), 2.45 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 151.2 (*J* = 2.8), 148.2, 147.7, 137.6, 136.1, 132.0, 129.4, 128.7, 128.6, 128.5, 125.5, 124.8, 123.2,

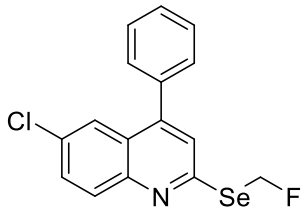
81.1 (J = 224.6 Hz), 21.7. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -194.8 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNSe^+$ 332.0348; found 332.0335.



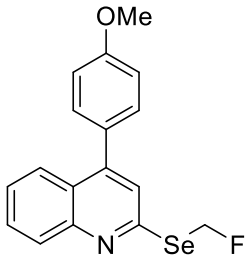
2-((fluoromethyl)selanyl)-4-phenylquinoline (7c). Eluent: PE/EA (30:1), white solid, 35.0 mg, 56% yield, m.p.:115 - 117 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.09 (d, J = 8.4 Hz, 1H), 7.84 (d, J = 8.0 Hz, 1H), 7.73 - 7.68 (m, 1H), 7.57 - 7.44 (m, 6H), 7.36 (s, 1H), 6.71 (t, J = 8.8 Hz, 1H), 6.58 (t, J = 8.8 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 152.5 (J = 2.7 Hz), 149.1, 148.8, 137.4, 129.8, 129.4, 129.0, 128.6, 128.6, 126.2, 126.0, 125.6, 123.1, 81.0 (J = 224.7 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -195.1 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{13}FNSe^+$ 318.0192; found 318.0179.



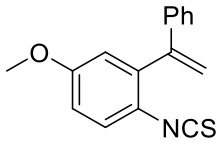
6-fluoro-2-((fluoromethyl)selanyl)-4-phenylquinoline (7d). Eluent: PE/EA (30:1), white solid, 32.0 mg, 48% yield, m.p.:121 - 123 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.11 - 8.07 (m, 1H), 7.56 - 7.51 (m, 3H), 7.49 - 7.44 (m, 4H), 7.37 (s, 1H), 6.68 (t, J = 8.8 Hz, 1H), 6.55 (t, J = 8.8 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.4 (J = 245.6 Hz), 151.8, 148.3 (J = 5.2 Hz), 146.3, 136.9, 131.3 (J = 9.1 Hz), 129.2, 128.9, 128.8, 126.4 (J = 9.5 Hz), 123.7, 119.8 (J = 25.4 Hz), 109.6 (J = 23.2 Hz), 80.9 (J = 225.2 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -113.0 (s, 1F), -195.2 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{12}F_2NSe^+$ 336.0098; found 336.0088.



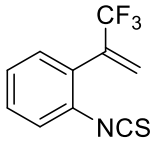
6-chloro-2-((fluoromethyl)selanyl)-4-phenylquinoline (7e). Eluent: PE/EA (30:1), white solid, 32.0 mg, 46% yield, m.p.:148 - 150 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 9.2 Hz, 1H), 7.80 (d, *J* = 2.4 Hz, 1H), 7.65 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 7.57 - 7.50 (m, 3H), 7.48 - 7.45 (m, 2H), 7.36 (s, 1H), 6.68 (t, *J* = 8.8 Hz, 1H), 6.56 (t, *J* = 8.8 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.1 (*J* = 2.8 Hz), 148.0, 147.5, 136.7, 132.1, 130.7, 130.5, 129.3, 128.9, 128.8, 126.3, 124.9, 123.9, 80.8 (*J* = 225.2 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -195.4 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{12}ClFNSe^+$ 351.9802; found 351.9814.



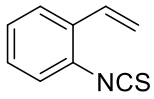
2-((fluoromethyl)selanyl)-4-(4-methoxyphenyl)quinoline (4f). Eluent: PE/EA (30:1), white solid, 36.5 mg, 53% yield, m.p.:111 - 112 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.4 Hz, 1H), 7.89 (d, *J* = 8.4 Hz, 1H), 7.69 (t, *J* = 8.0 Hz, 1H), 7.47 - 7.39 (m, 3H), 7.34 (s, 1H), 7.05 (d, *J* = 8.4 Hz, 2H), 6.70 (t, *J* = 8.8 Hz, 1H), 6.57 (t, *J* = 8.8 Hz, 1H), 3.90 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.0, 152.5 (*J* = 2.8 Hz), 149.2, 148.5, 130.7, 129.7, 129.6, 129.0, 128.0, 126.1, 125.8, 123.0, 114.1, 81.0 (*J* = 224.6 Hz), 55.4. **^{19}F NMR** (376 MHz, $CDCl_3$) δ -195.0 (s, 1F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{17}H_{15}FNOSe^+$ 348.0297; found 348.0289.



1-isothiocyanato-4-methoxy-2-(1-phenylvinyl)benzene (8a). Eluent: PE/EA (30:1), yellow solid, 41.4 mg, 78% yield, m.p.:124 - 126 ℃, **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 - 7.29 (m, 5H), 7.19 - 7.17 (m, 1H), 6.87 (m, 2H), 5.84 (s, 1H), 5.37 (s, 1H), 3.82 (s, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 158.4, 146.0, 140.5, 139.2, 128.5, 128.2, 127.5, 126.7, 122.0, 117.2, 116.1, 114.1, 55.6. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{16}H_{14}NOS^+$ 268.0796; found 268.0799.



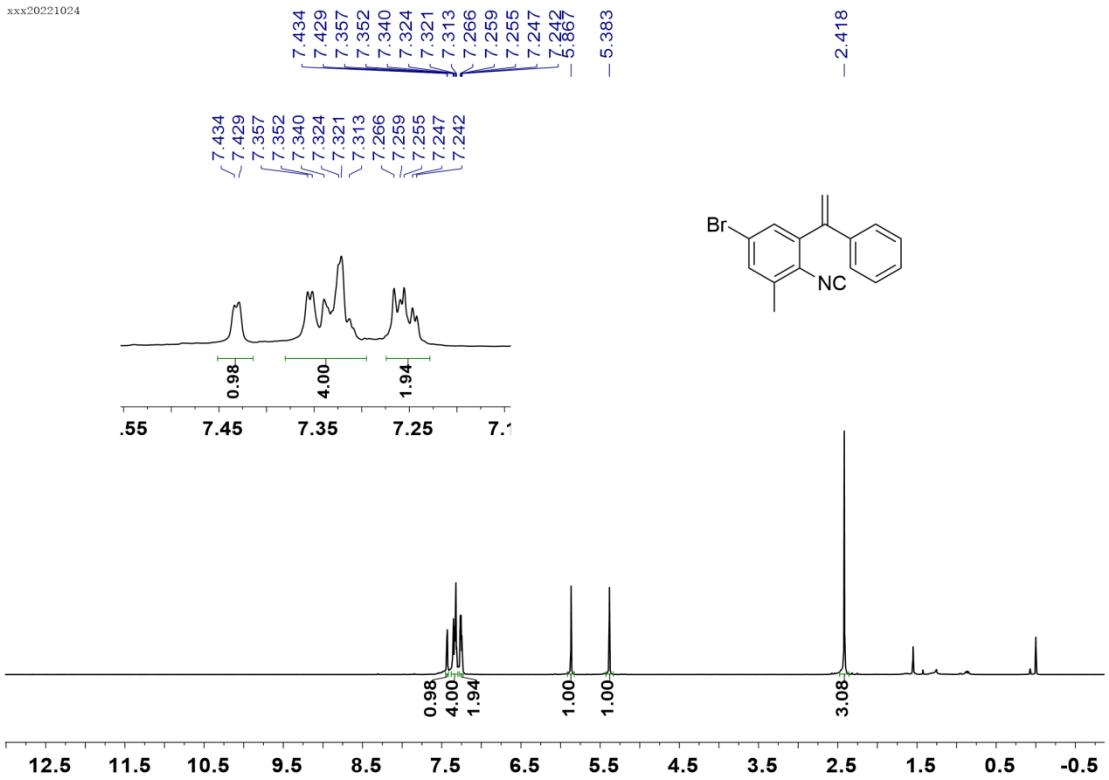
1-isothiocyanato-2-(3,3,3-trifluoroprop-1-en-2-yl)benzene (8t). Eluent: PE/EA (30:1), yellow oil, 28.5 mg, 63% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41 -7.28 (m, 4H), 6.27 (d, J = 1.2 Hz, 1H), 5.73 (d, J = 1.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.8, 134.5, 130.4, 130.4, 130.1, 127.0, 126.9, 125.0 (q, J_1 = 10.3 Hz, J_2 = 5.2 Hz), 122.5 (q, J_1 = 544.1 Hz, J_2 = 272.0 Hz). **^{19}F NMR** (376 MHz, $CDCl_3$) δ -66.7 (s, 3F). **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_{10}H_7F_3NS^+$ 230.0246; found 230.0252.



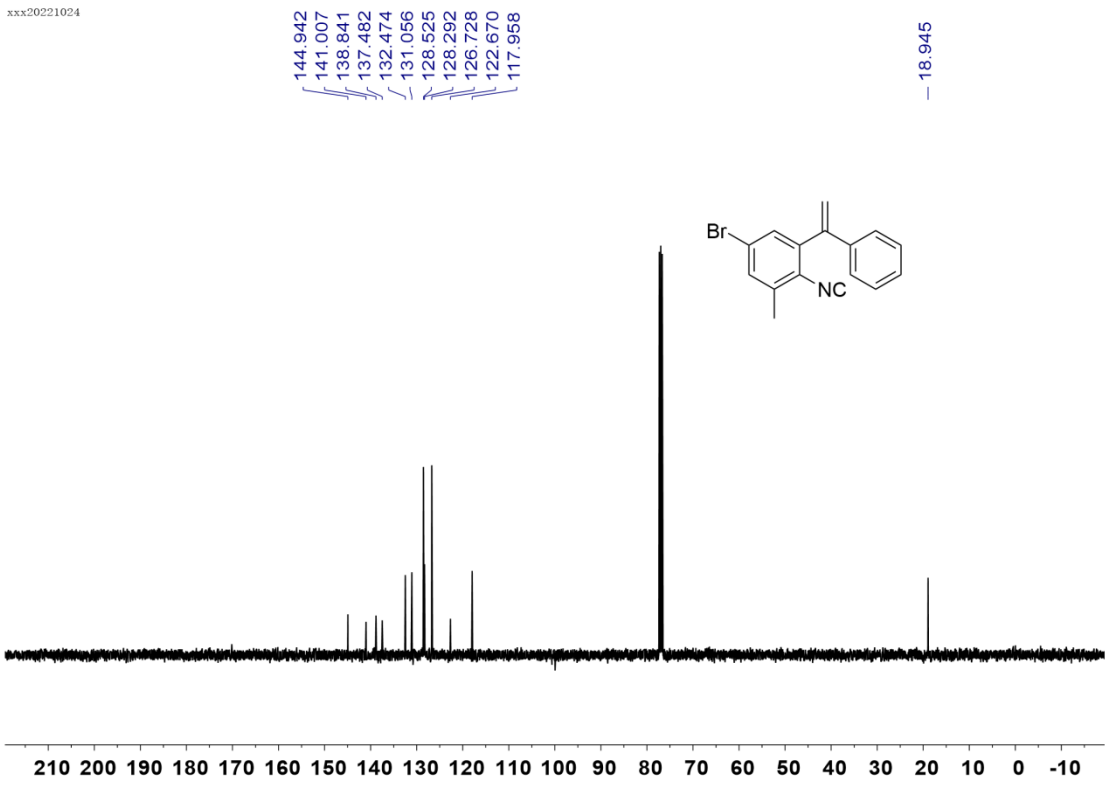
1-isothiocyanato-2-vinylbenzene (8u). Eluent: PE/EA (30:1), yellow oil, 18.0 mg, 56% yield. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 -7.54 (m, 1H), 7.28 - 7.24 (m, 3H), 6.98 (q, J_1 = 17.6 Hz, J_2 = 11.2 Hz, 1H), 5.82 (d, J = 17.6 Hz, 1H), 5.45 (d, J = 11.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$) δ 133.8, 131.3, 128.7, 127.4, 127.0, 126.0, 117.4. **HRMS (ESI)** m/z: $[M+H]^+$ calcd for $C_9H_8NS^+$ 162.0372; found 162.0381.

IX. NMR spectra of compounds 1, 3，5, 6, 7, 8a and 8s.

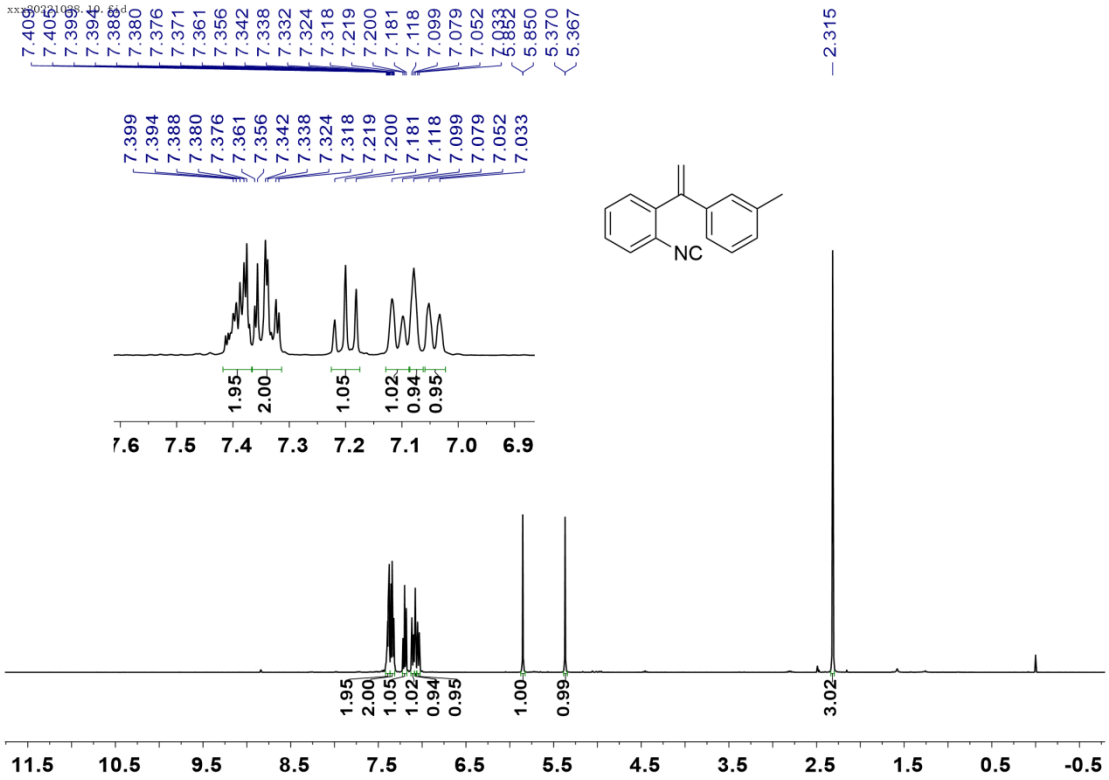
^{1}H NMR (400 MHz, $CDCl_3$) for **1j**



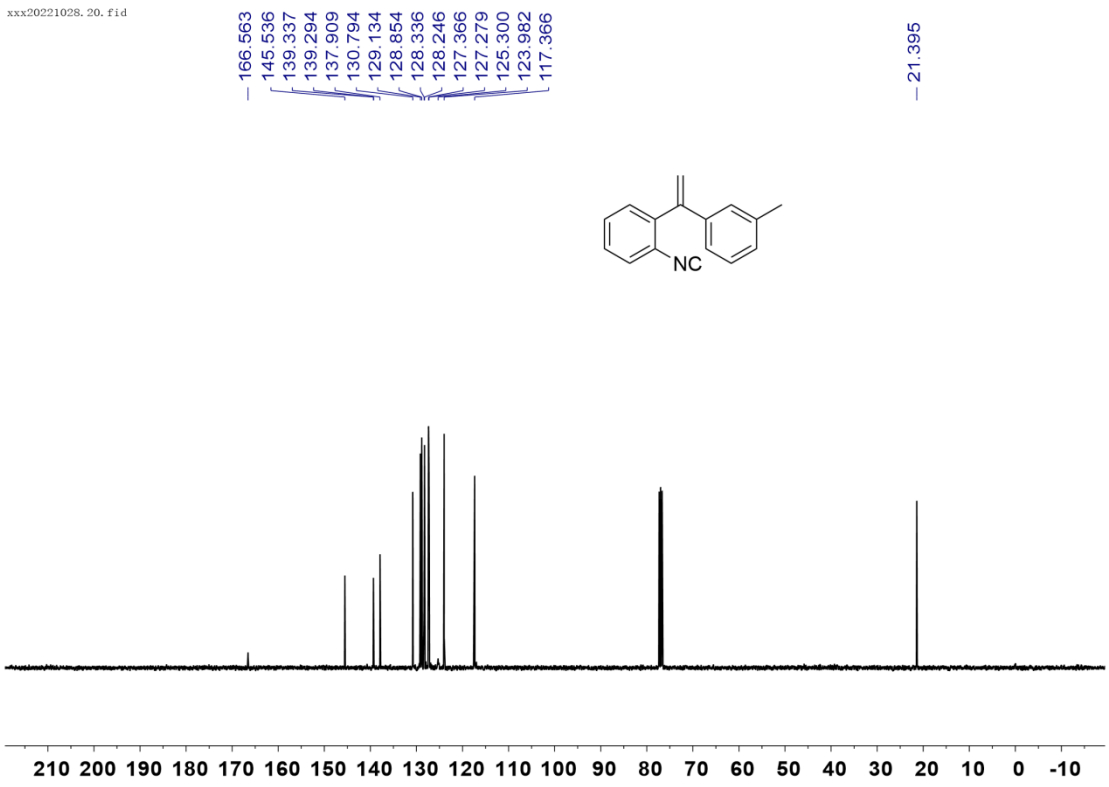
^{13}C NMR (100 MHz, $CDCl_3$) for **1j**



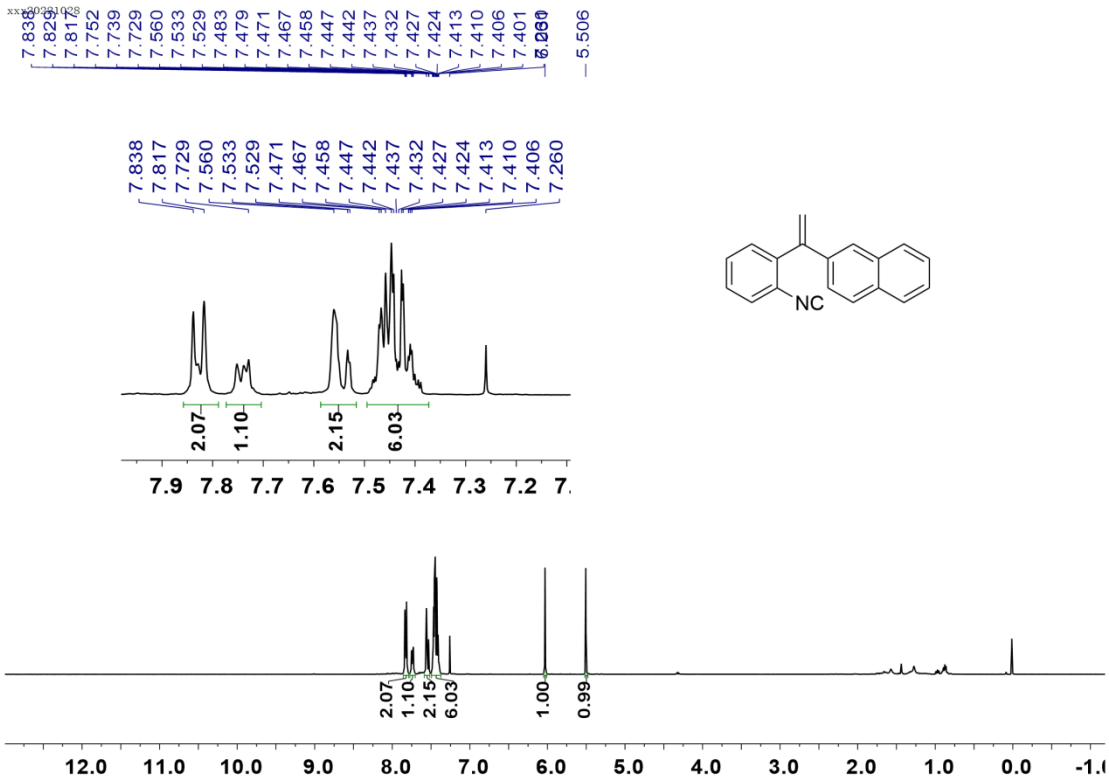
^{1}H NMR (400 MHz, $CDCl_3$) for **1k**



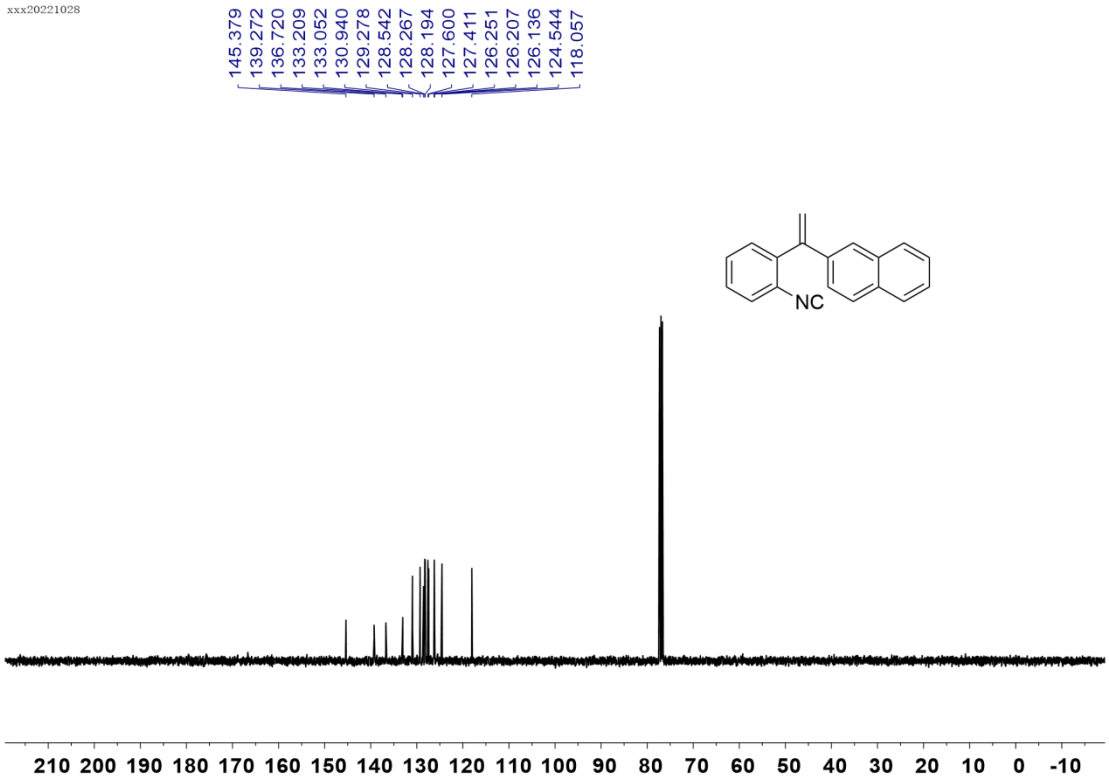
^{13}C NMR (100 MHz, $CDCl_3$) for **1k**



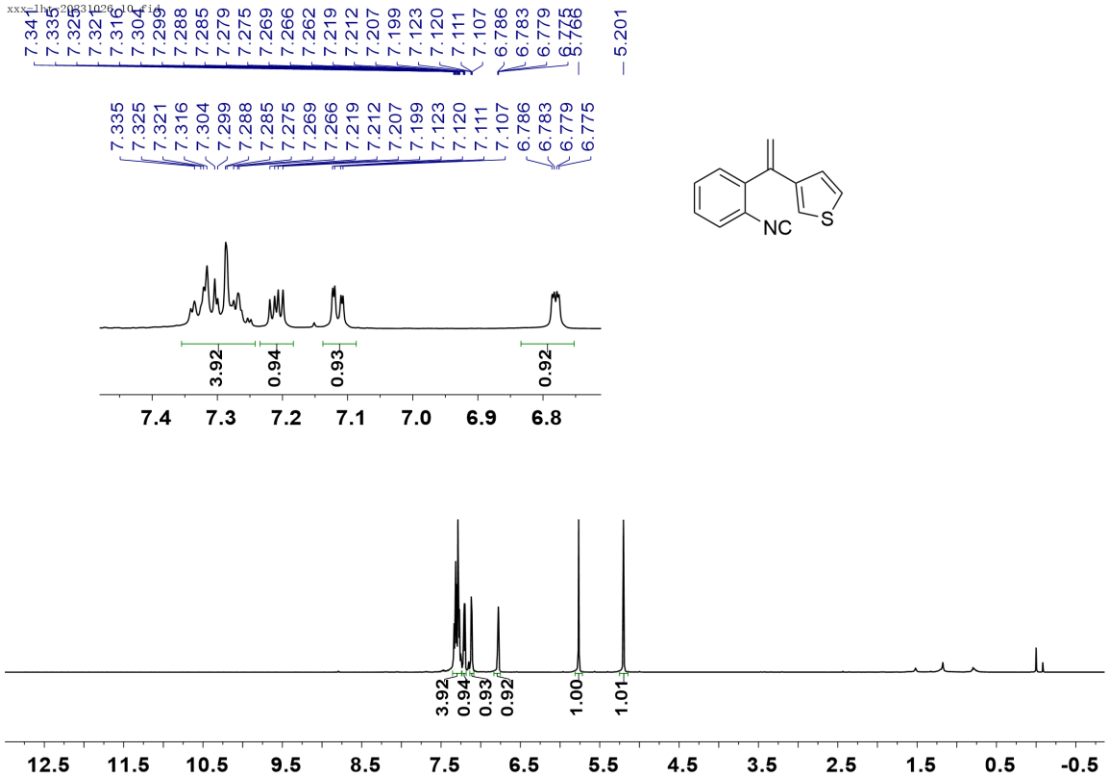
^{1}H NMR (400 MHz, $CDCl_3$) for **1n**



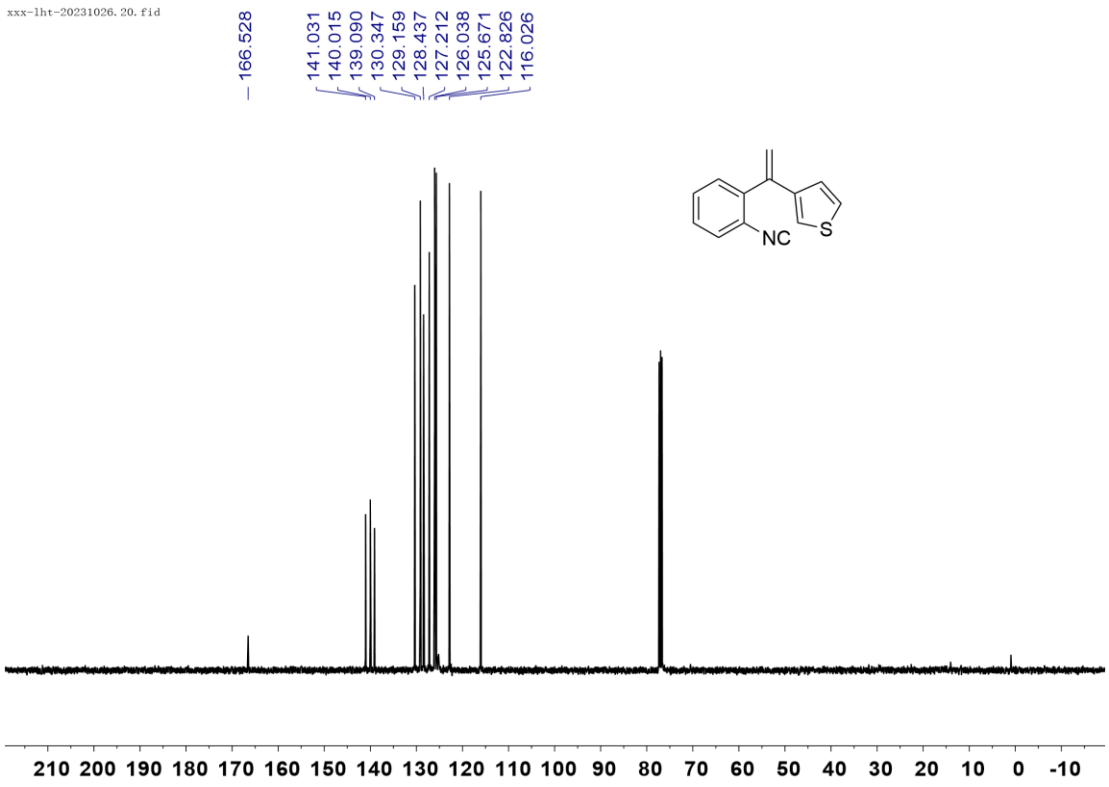
^{13}C NMR (100 MHz, $CDCl_3$) for **1n**



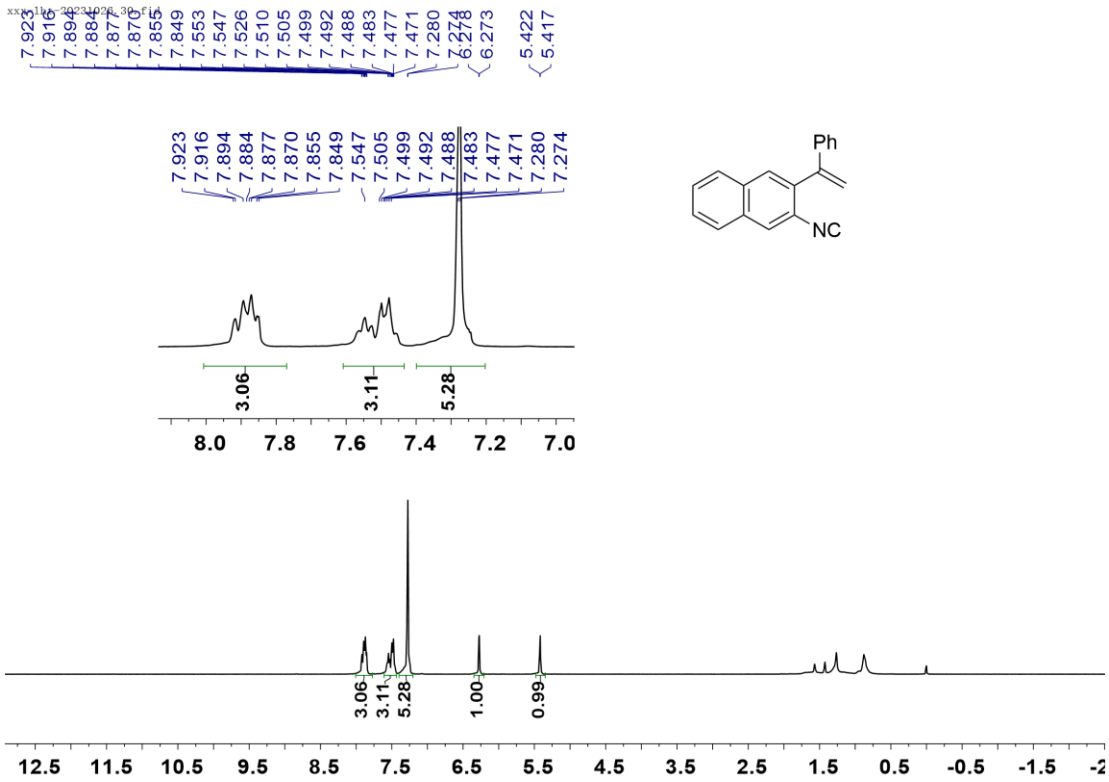
^{1}H NMR (400 MHz, $CDCl_3$) for **1o**



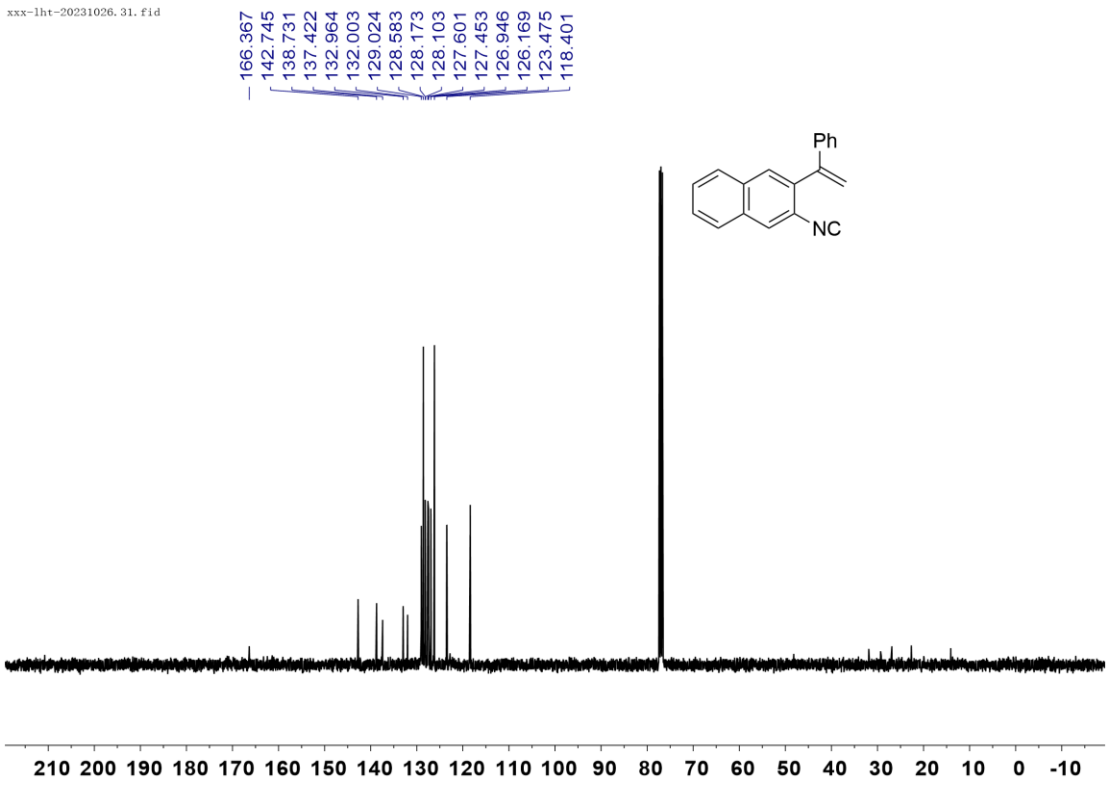
^{13}C NMR (100 MHz, $CDCl_3$) for **1o**



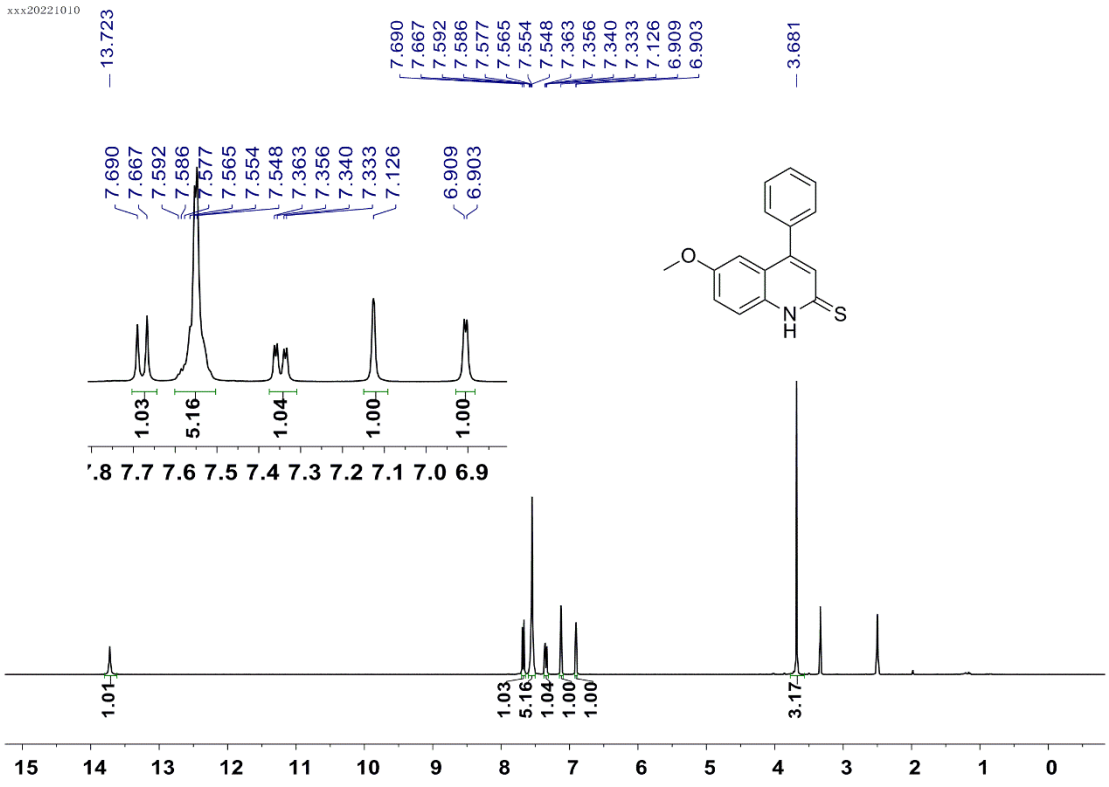
^{1}H NMR (400 MHz, $CDCl_3$) for **1t**



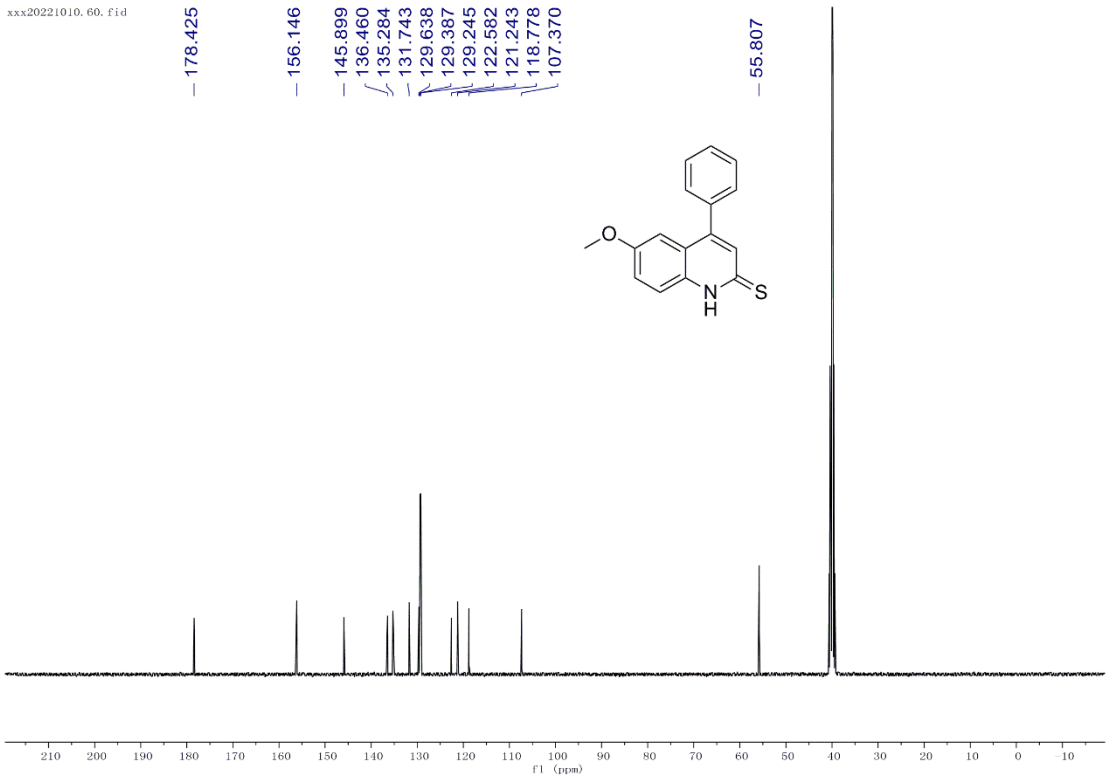
^{13}C NMR (100 MHz, $CDCl_3$) for **1t**



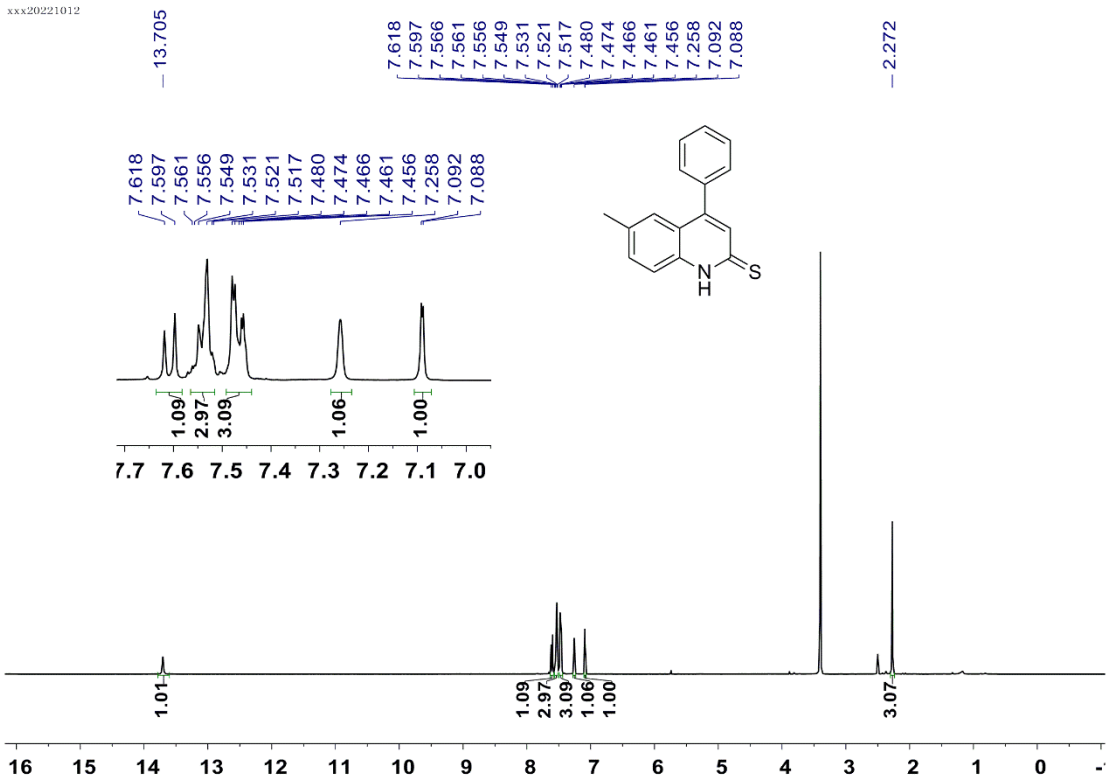
^{1}H NMR (400 MHz, DMSO-d_6) for **3a**



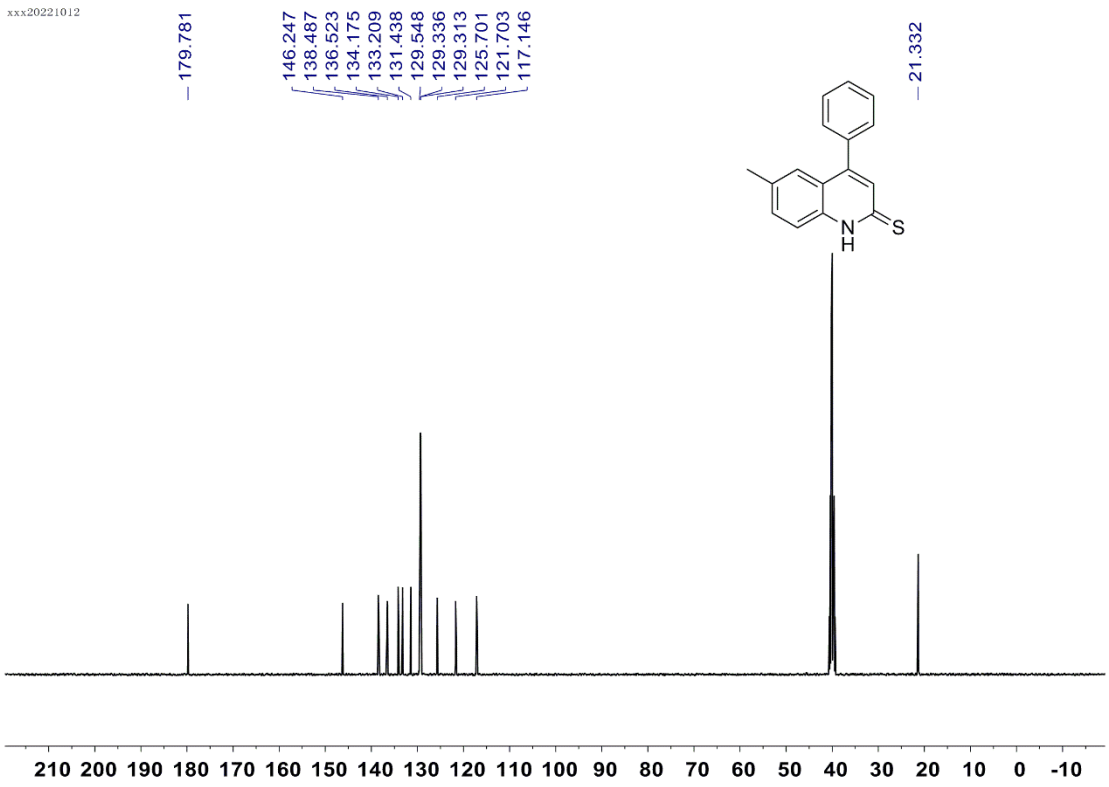
^{13}C NMR (100 MHz, DMSO-d_6) for **3a**



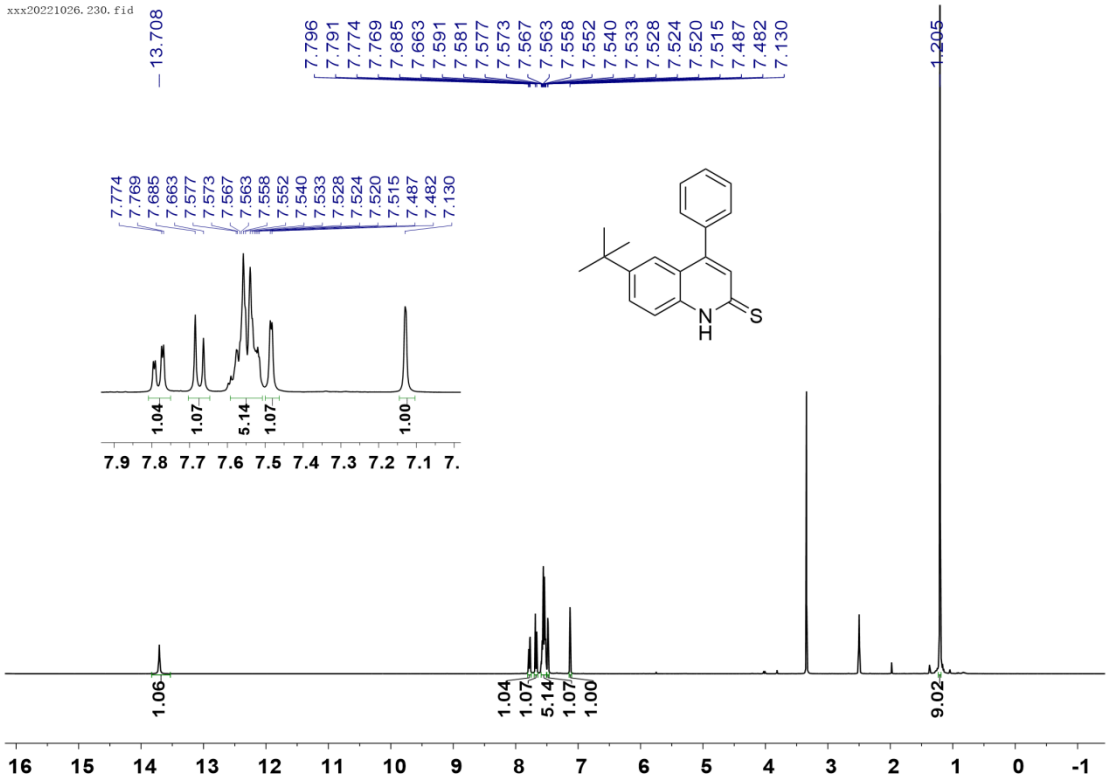
[1]H NMR (400 MHz, DMSO-d_6) for **3b**



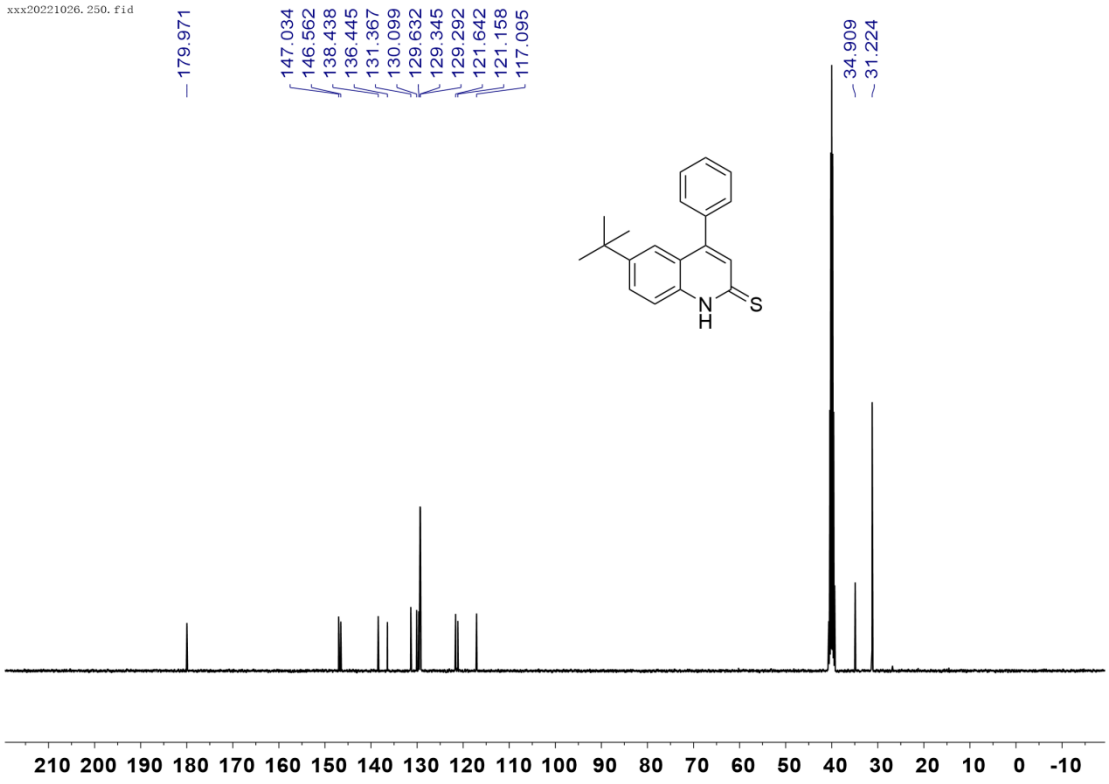
[13]C NMR (100 MHz, DMSO-d_6) for **3b**



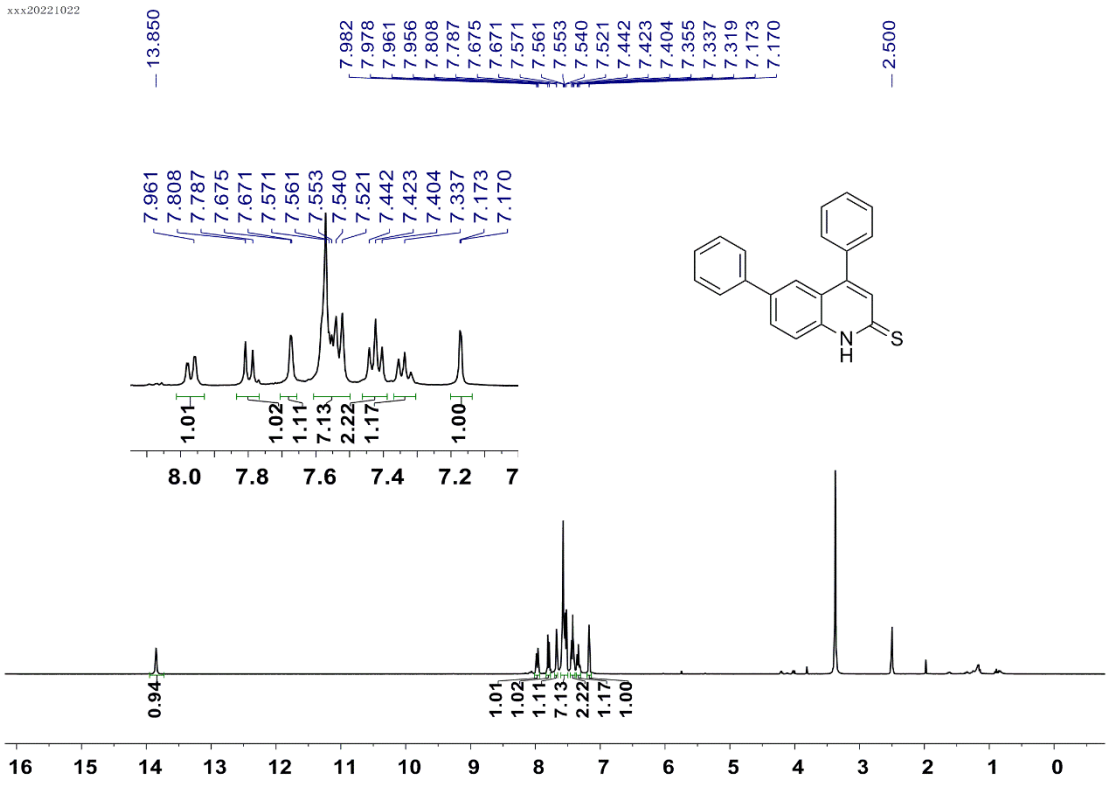
^{1}H NMR (400 MHz, DMSO-d_6) for **3c**



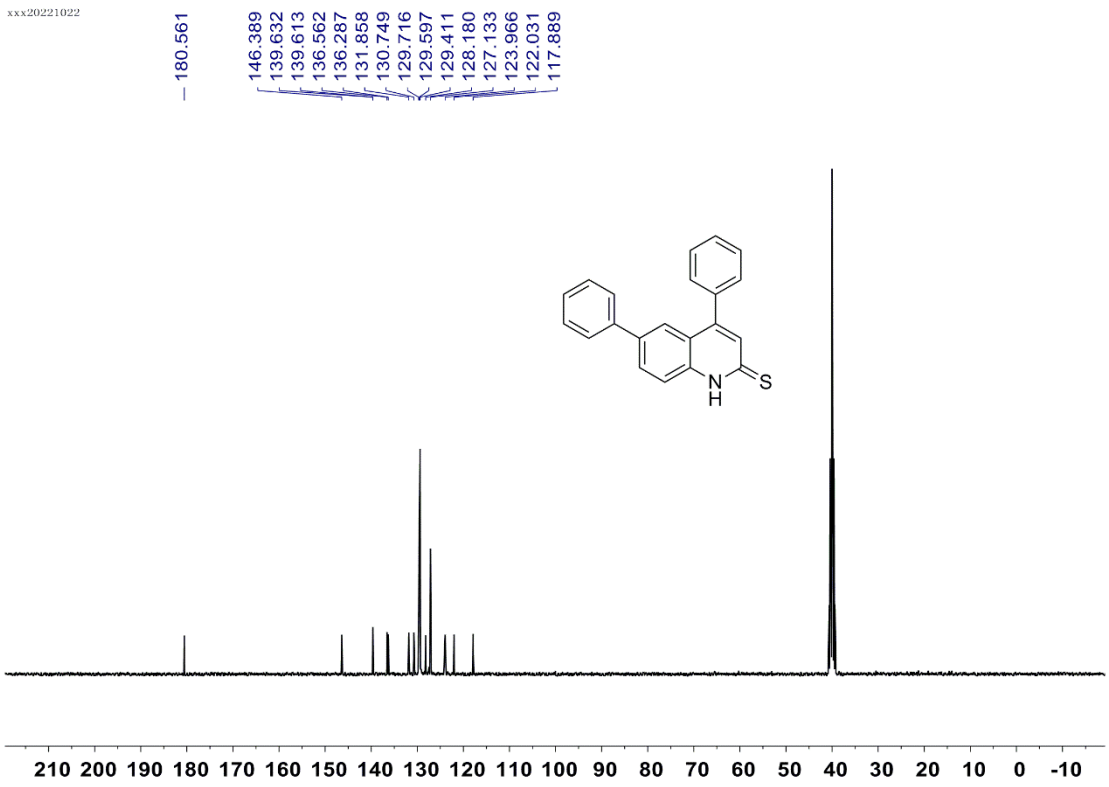
^{13}C NMR (100 MHz, DMSO-d_6) for **3c**



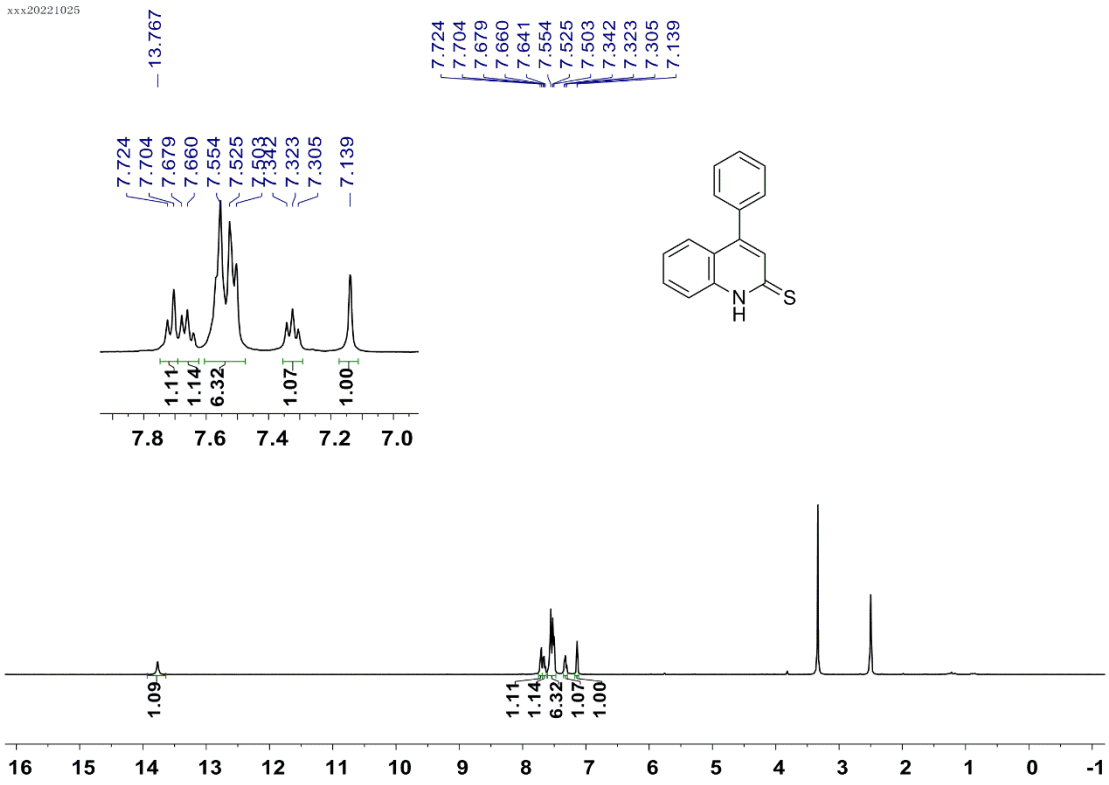
^{1}H NMR (400 MHz, DMSO-d_6) for **3d**



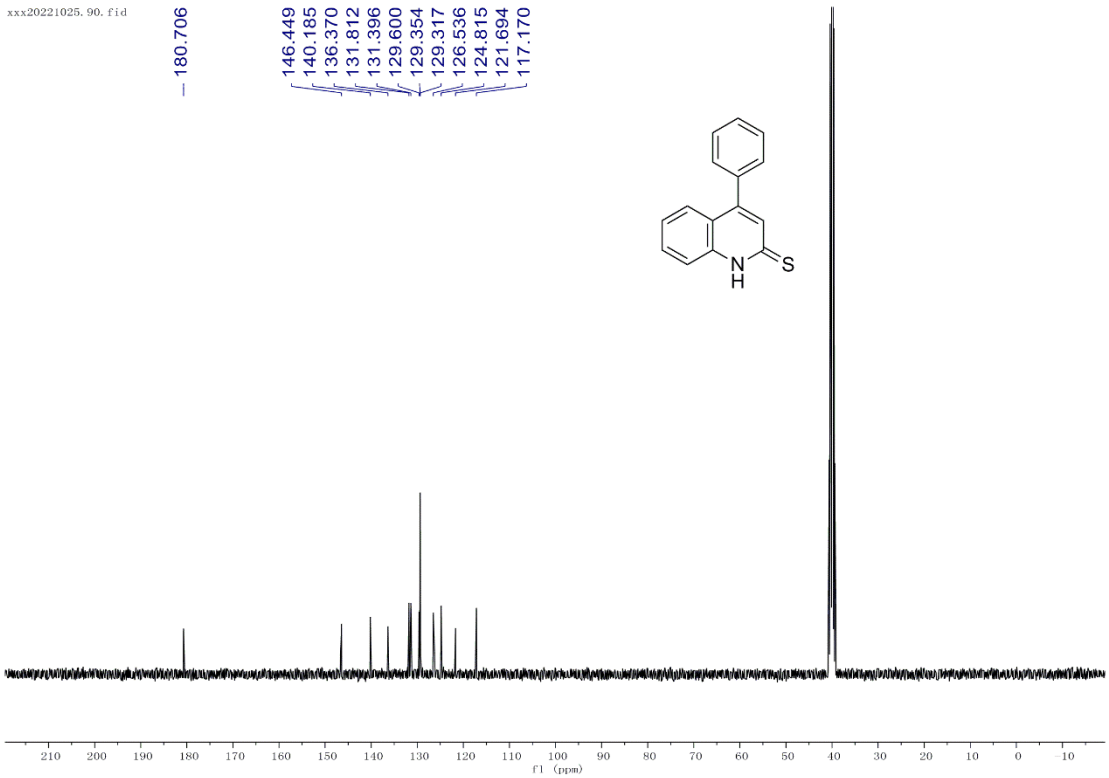
^{13}C NMR (100 MHz, DMSO-d_6) for **3d**



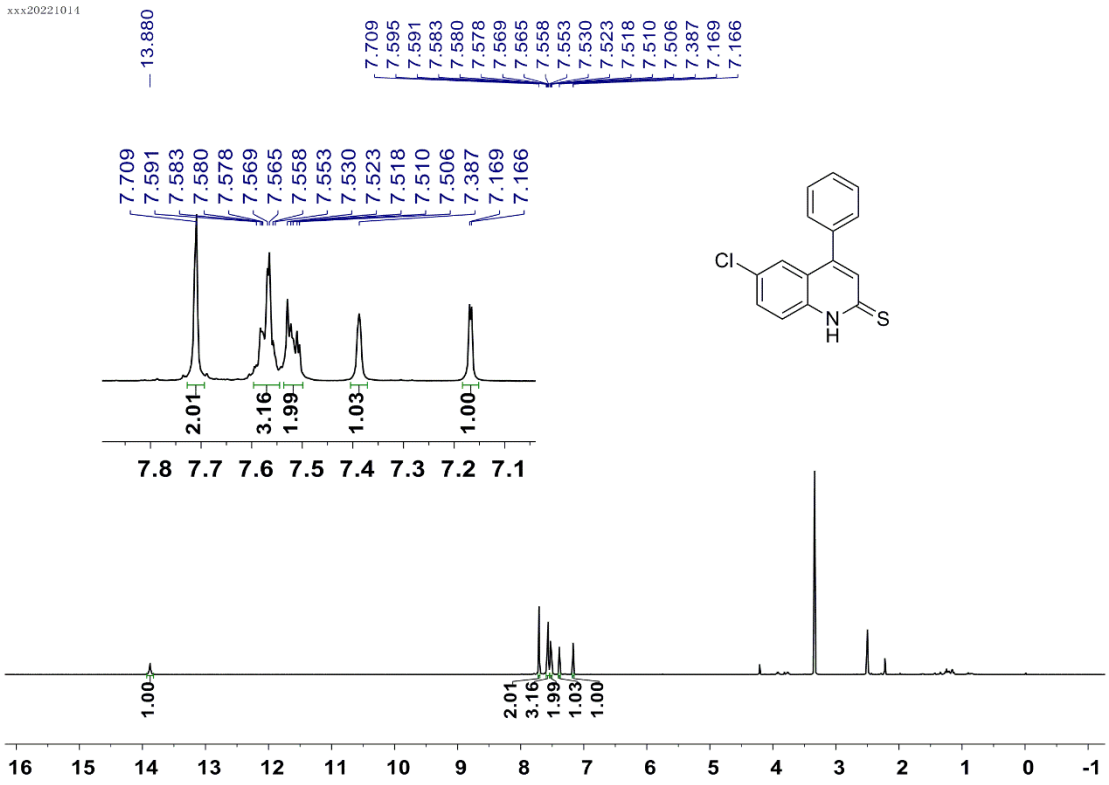
^{1}H NMR (400 MHz, DMSO-d_6) for **3e**



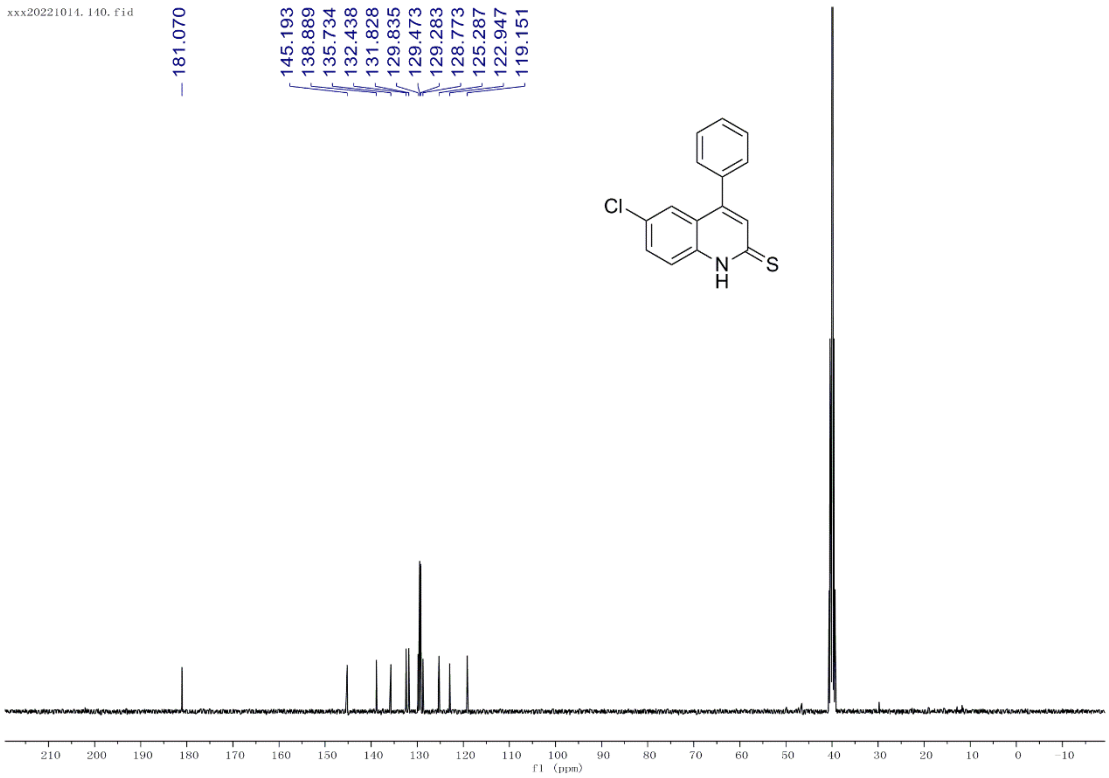
^{13}C NMR (100 MHz, DMSO-d_6) for **3e**



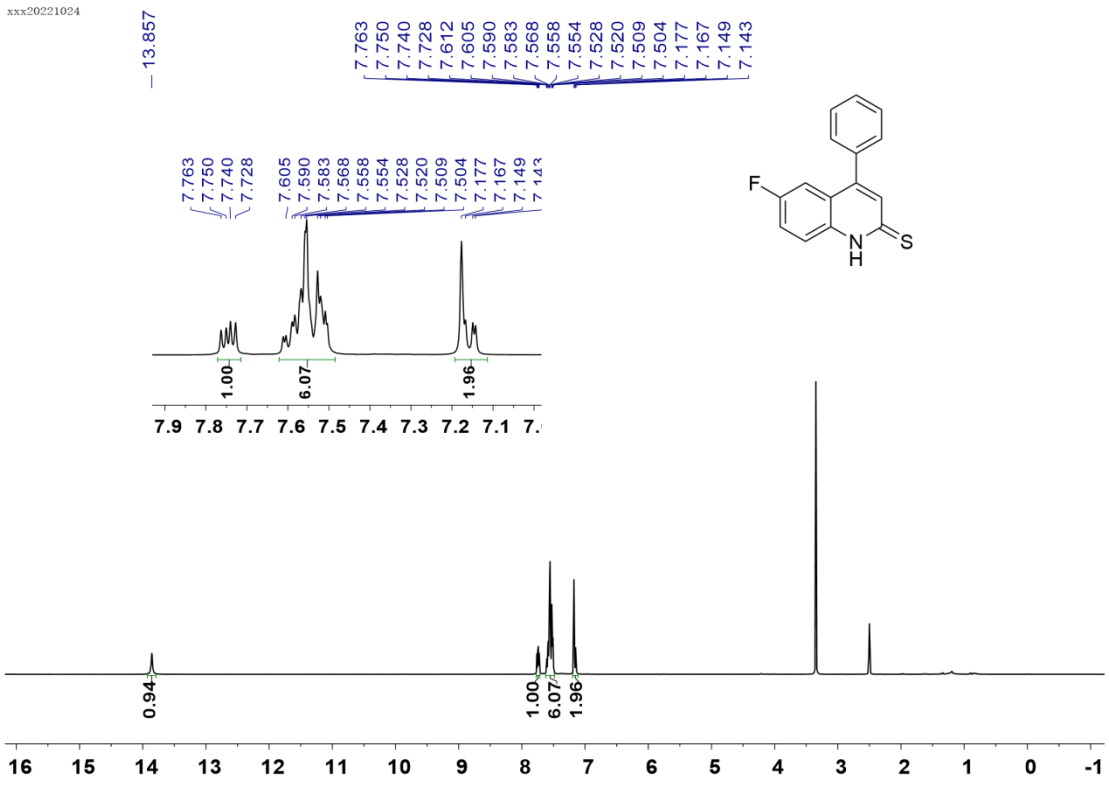
[1]H NMR (400 MHz, DMSO-d_6) for **3f**



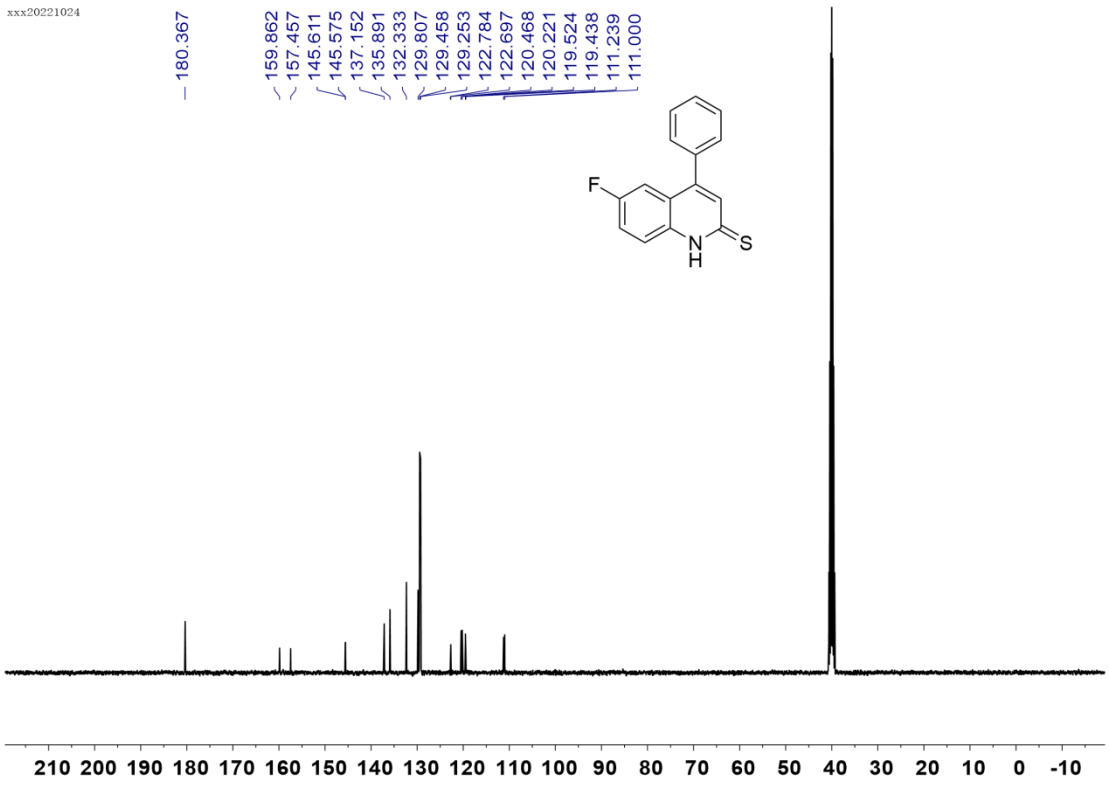
[13]C NMR (100 MHz, DMSO-d_6) for **3f**



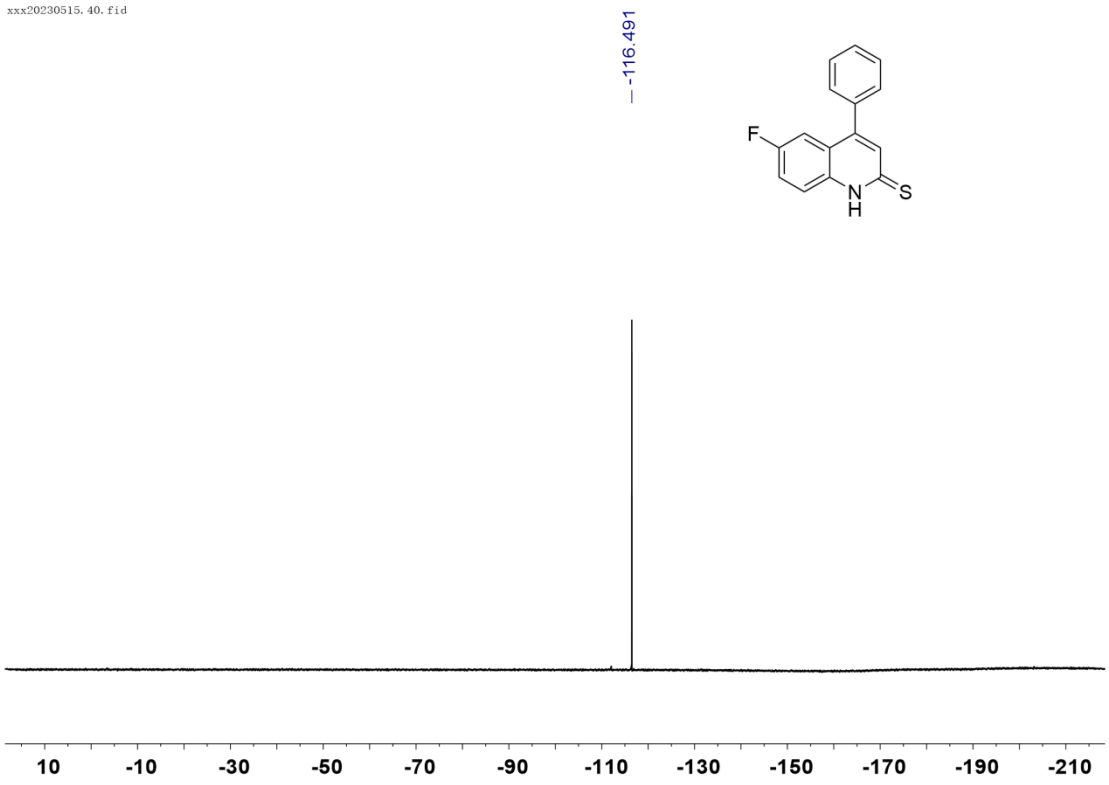
[1]H NMR (400 MHz, DMSO-d_6) for **3g**



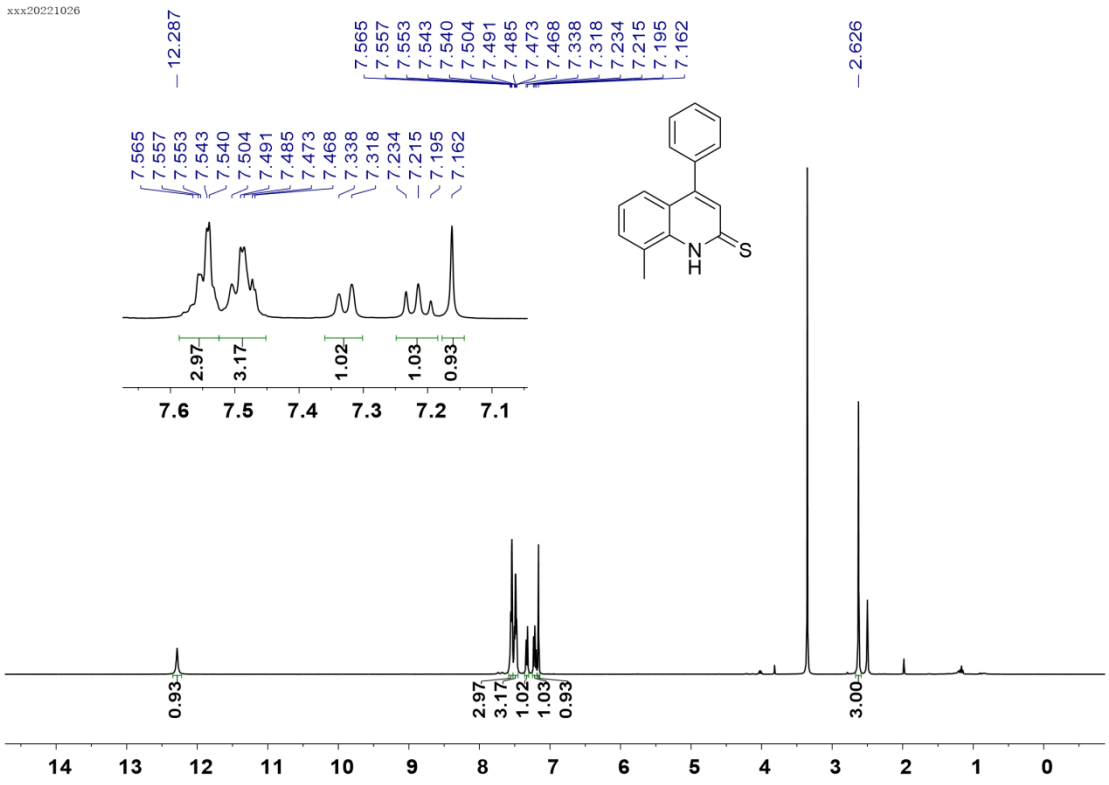
[13]C NMR (100 MHz, DMSO-d_6) for **3g**



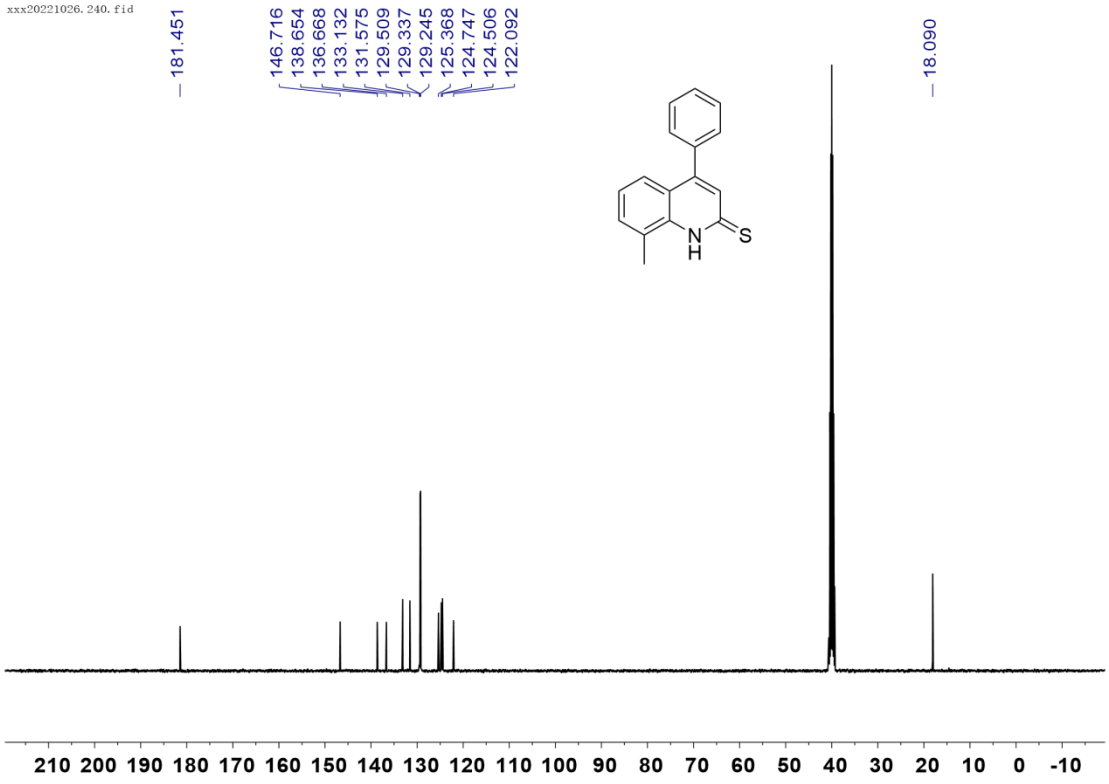
^{19}F NMR (376 MHz, DMSO-d_6) for **3g**



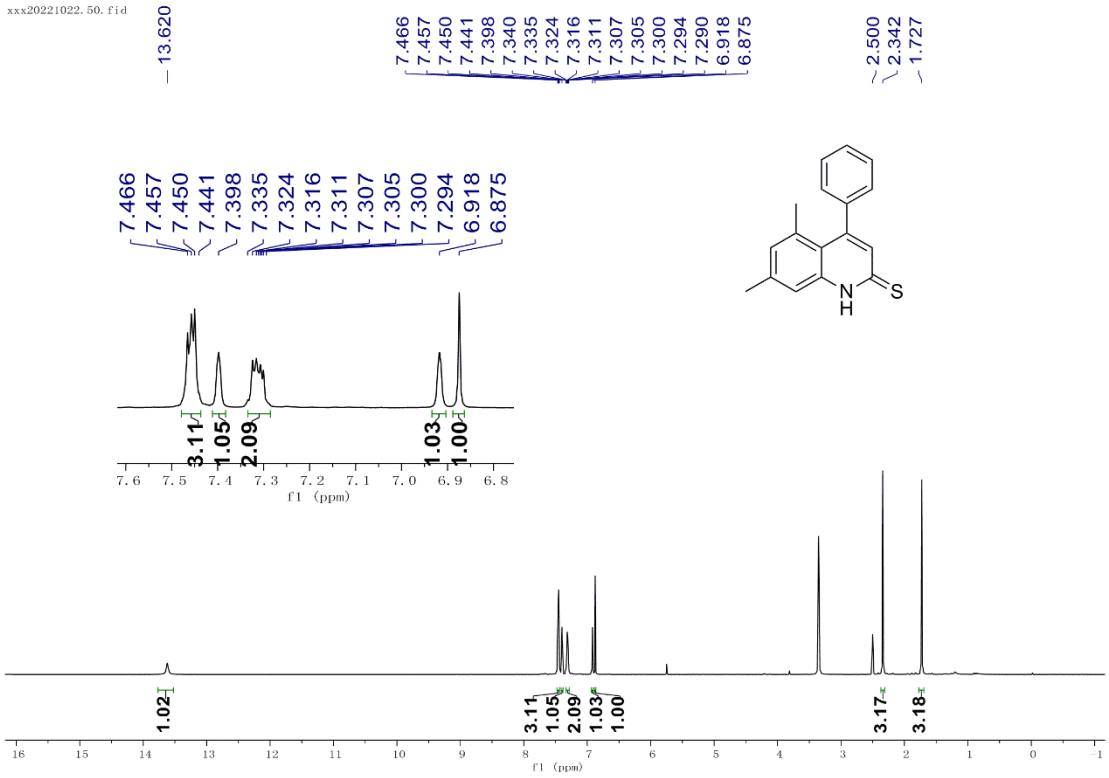
^{1}H NMR (400 MHz, DMSO-d_6) for **3h**



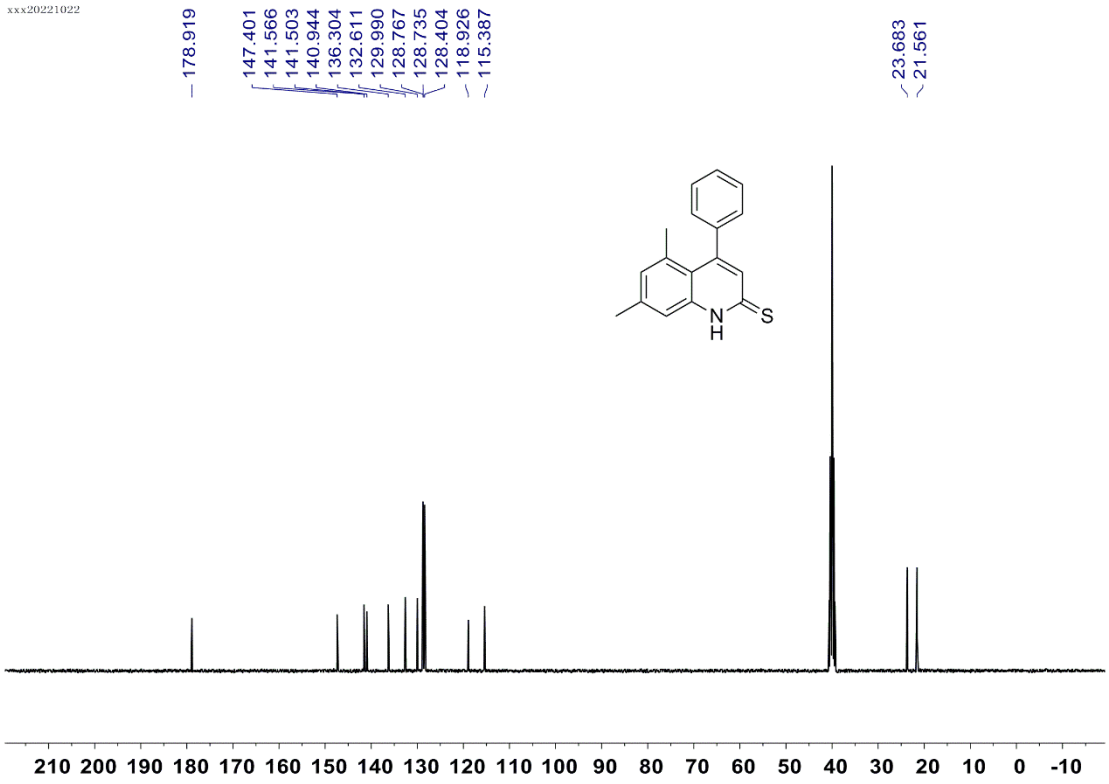
^{13}C NMR (100 MHz, DMSO-d_6) for **3h**



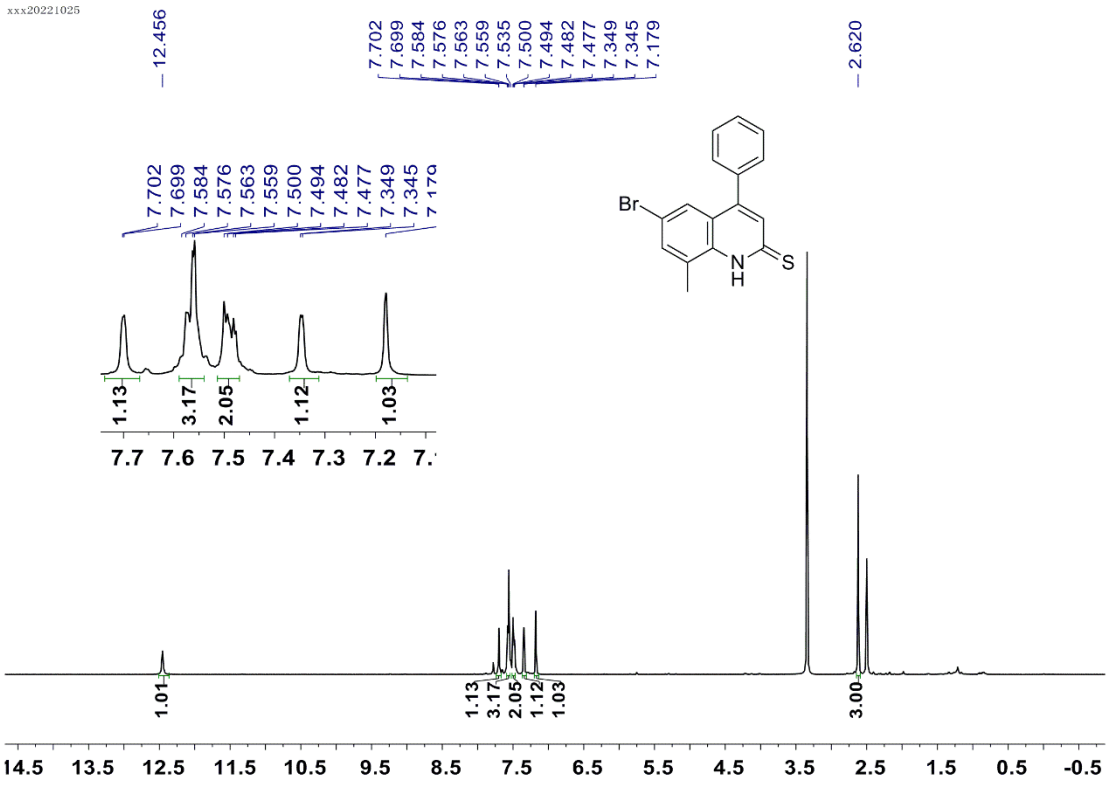
[1]H NMR (400 MHz, DMSO-d_6) for **3i**



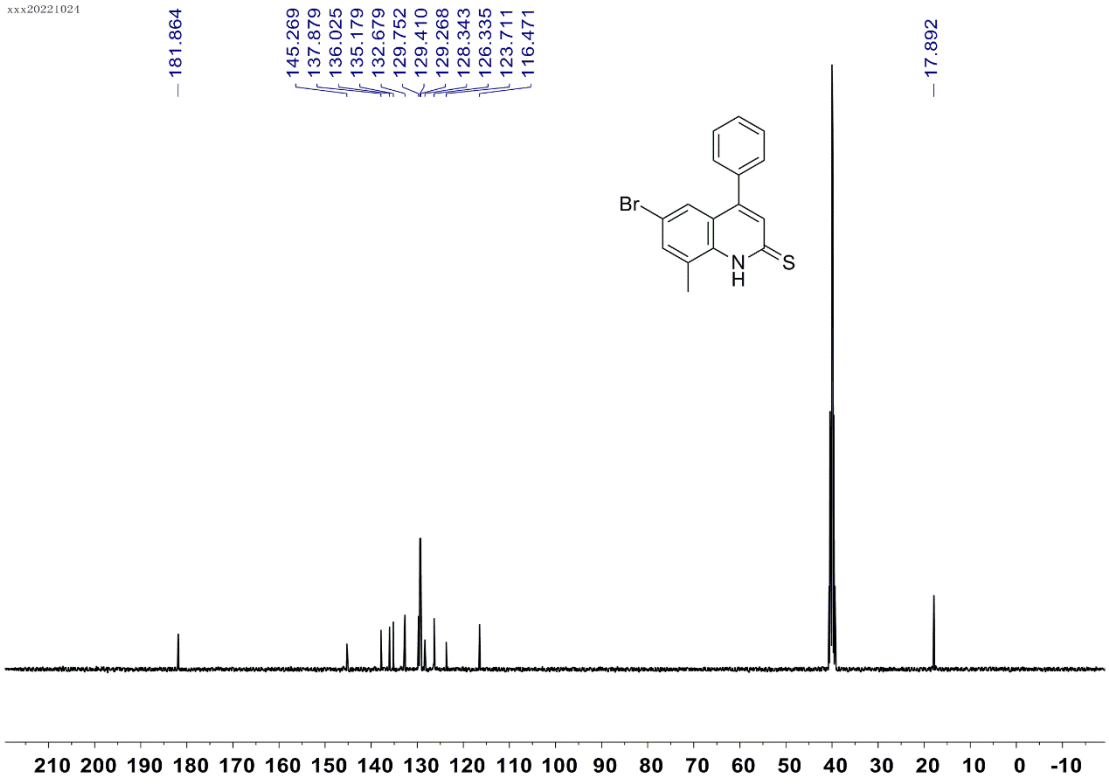
[13]C NMR (100 MHz, DMSO-d_6) for **3i**



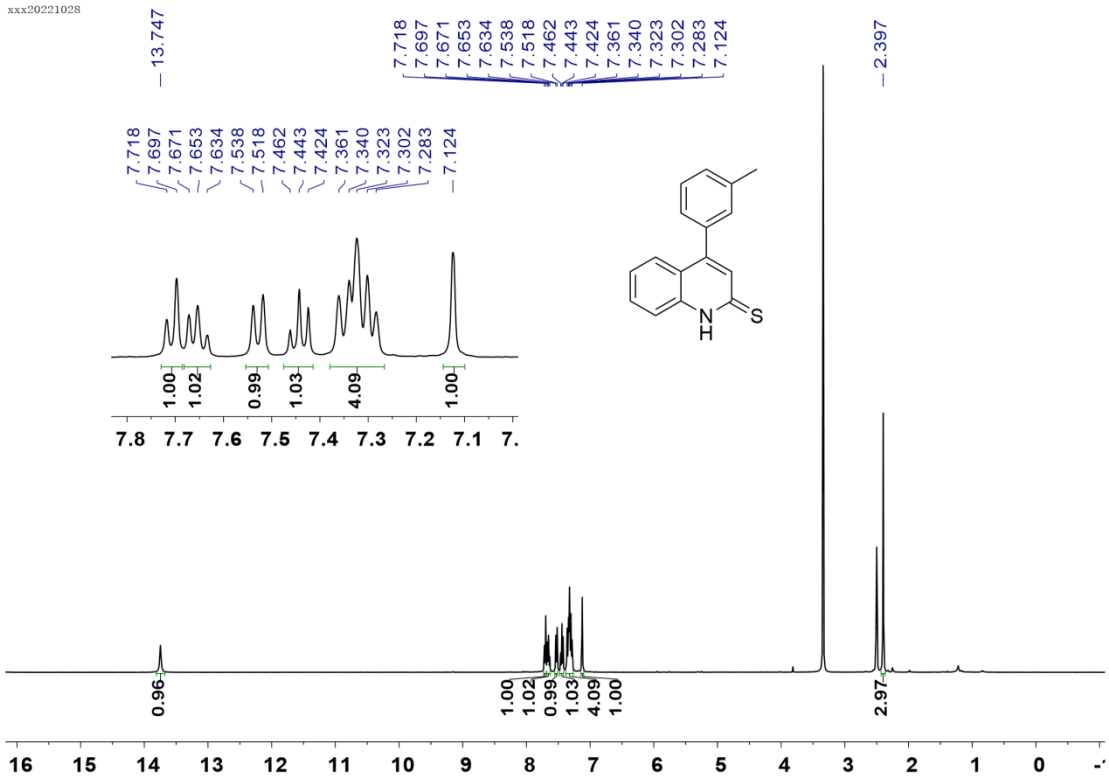
[1]H NMR (400 MHz, DMSO-d_6) for **3j**



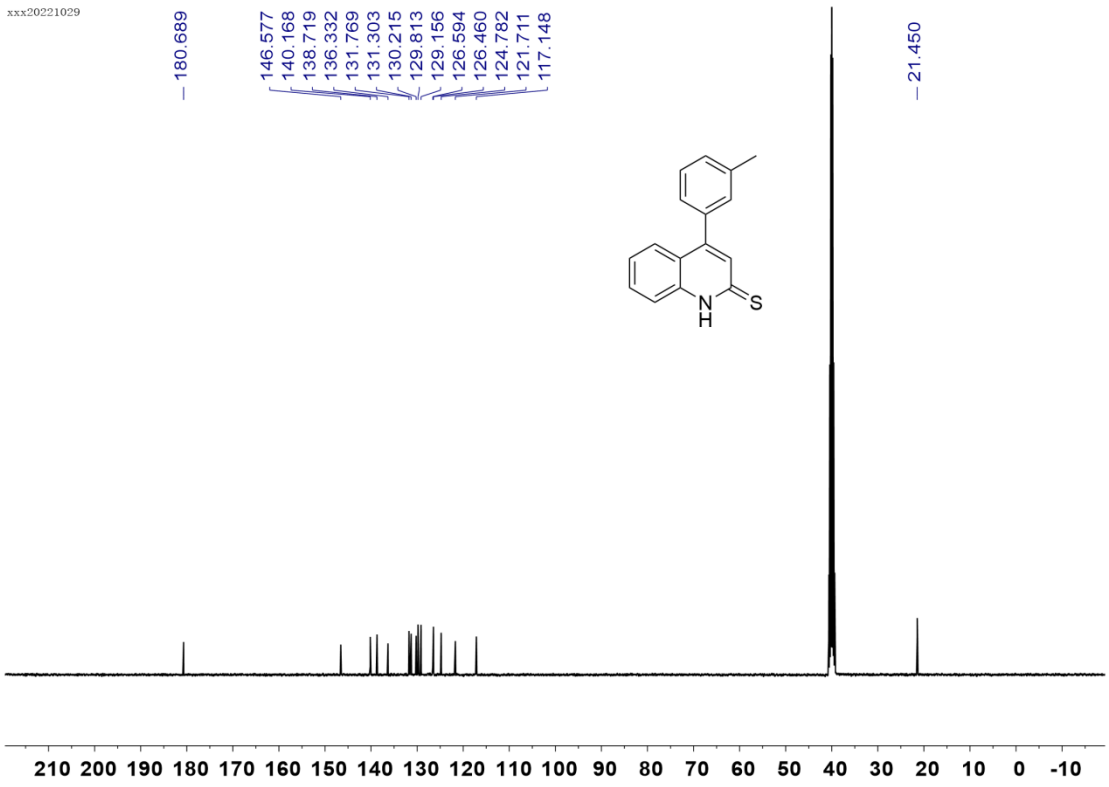
[13]C NMR (100 MHz, DMSO-d_6) for **3j**



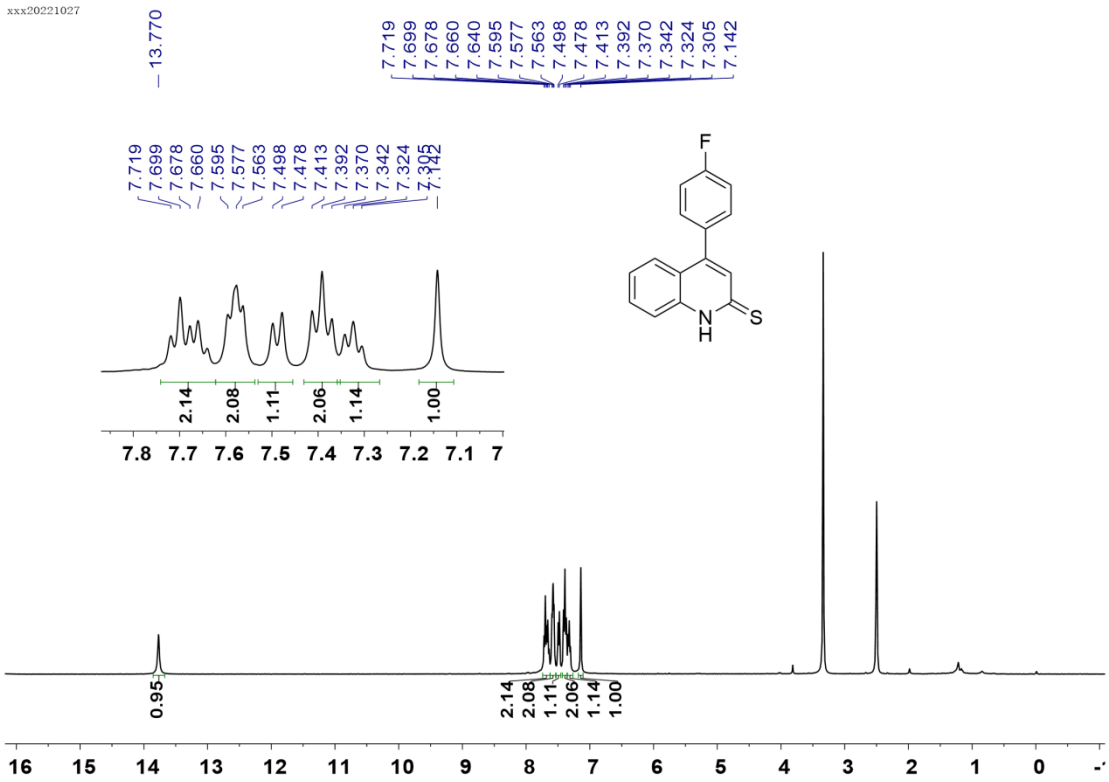
[1]H NMR (400 MHz, DMSO-d_6) for **3k**



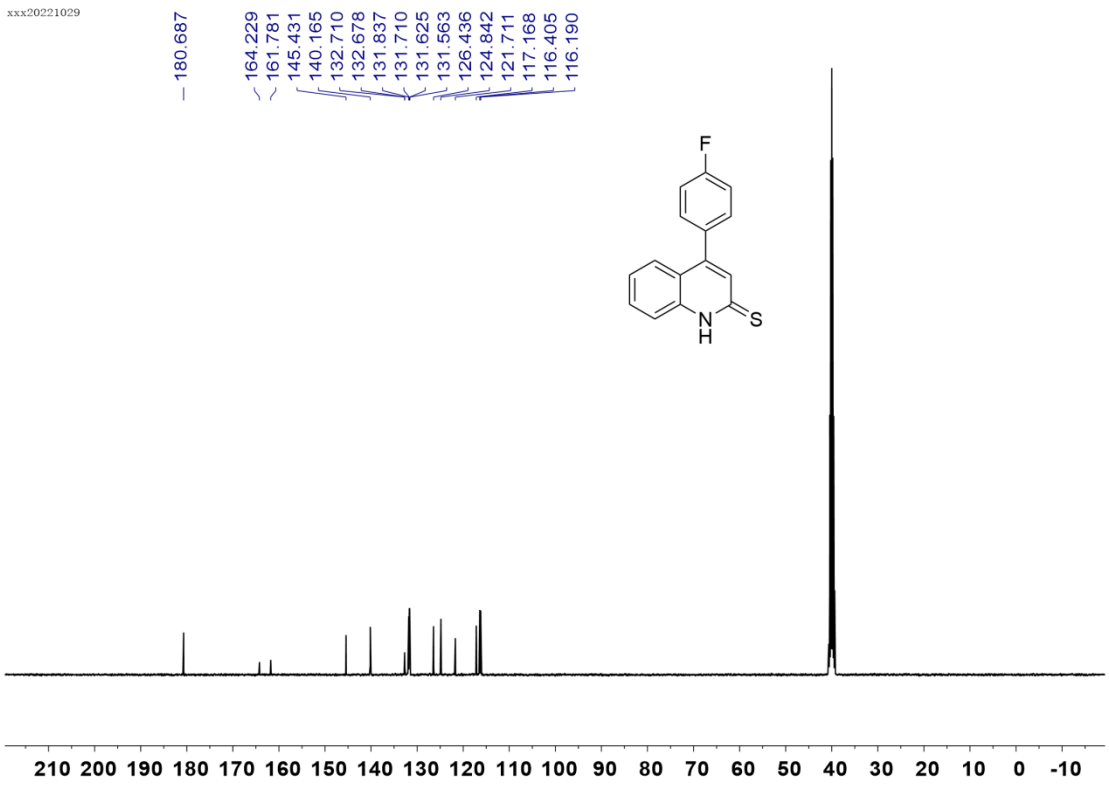
[13]C NMR (100 MHz, DMSO-d_6) for **3k**



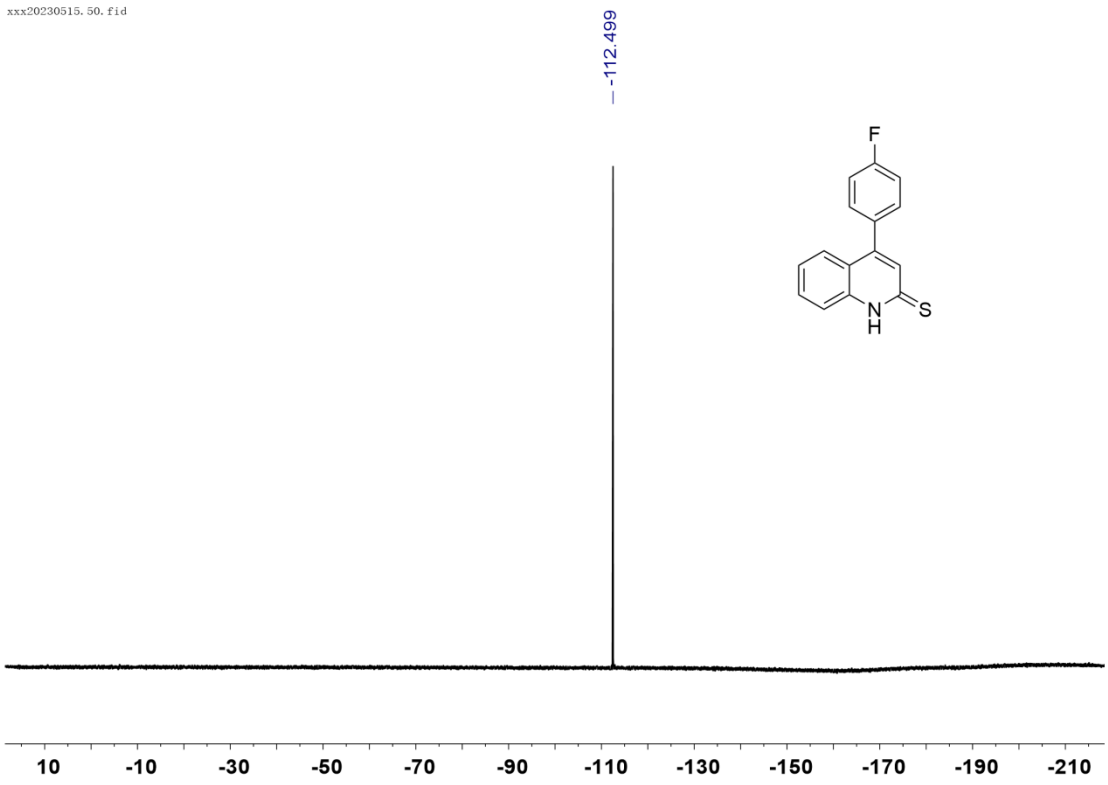
[1]H NMR (400 MHz, DMSO-d_6) for **3l**



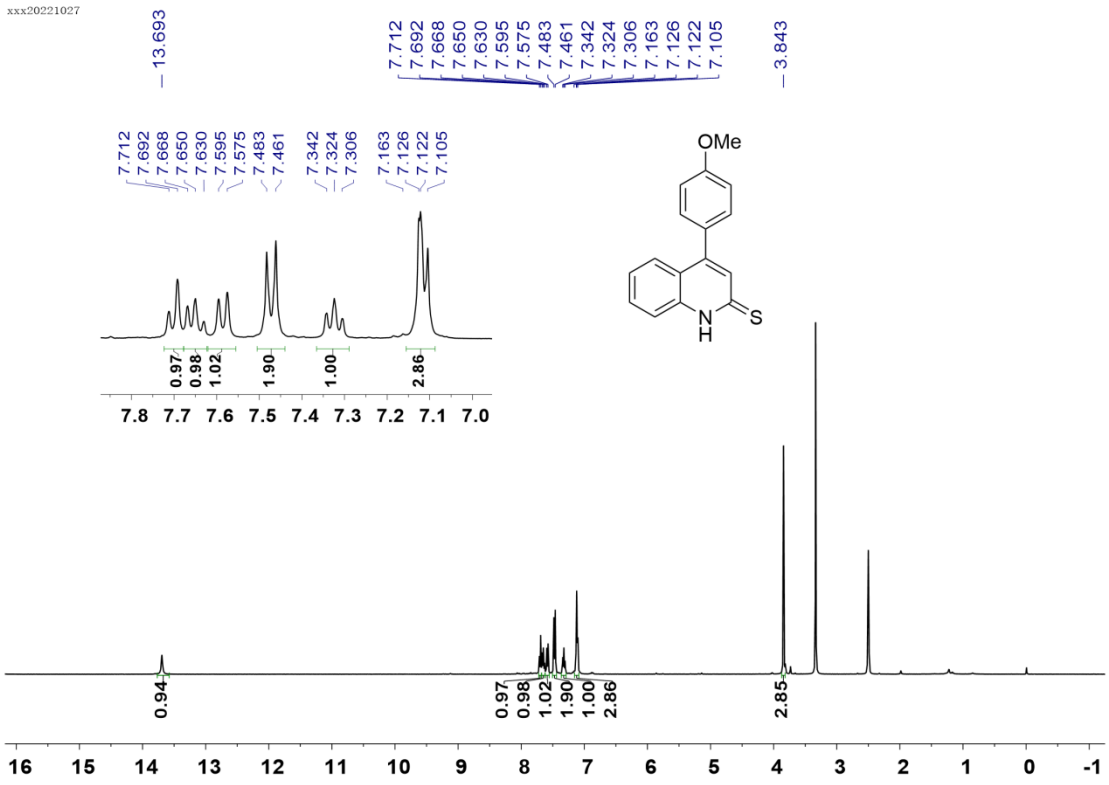
[13]C NMR (100 MHz, DMSO-d_6) for **3l**



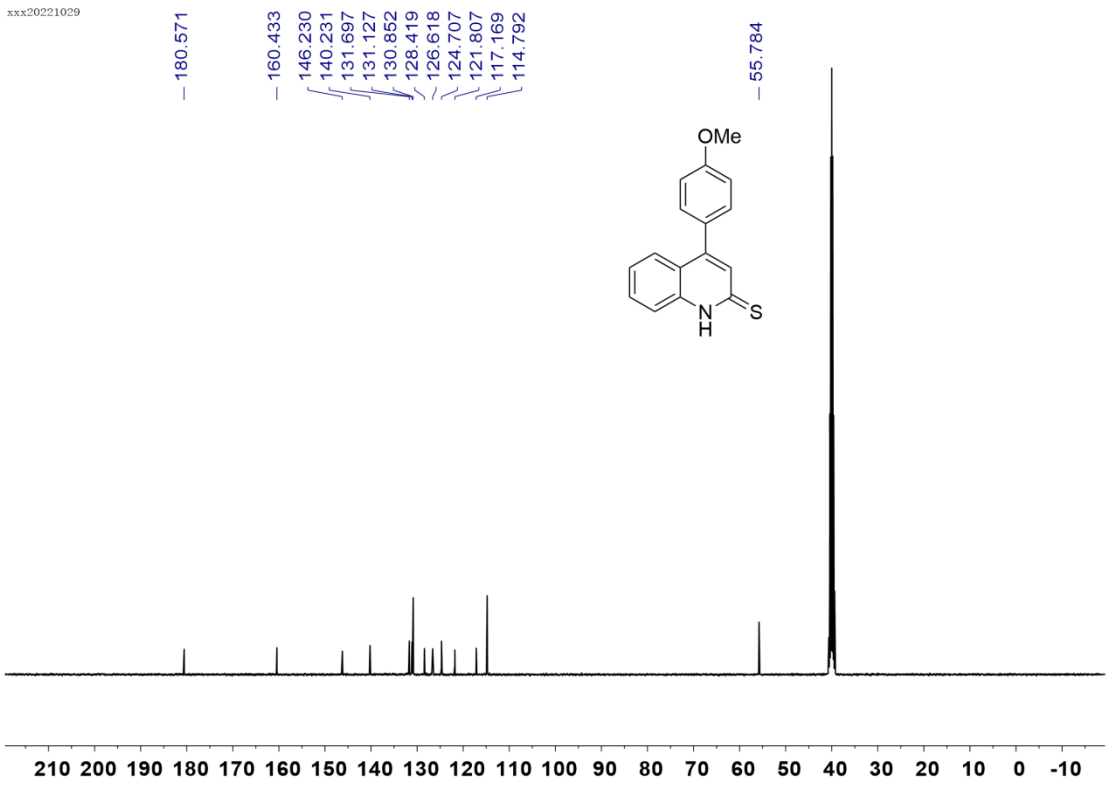
^{19}F NMR (376 MHz, DMSO-d_6) for **3l**



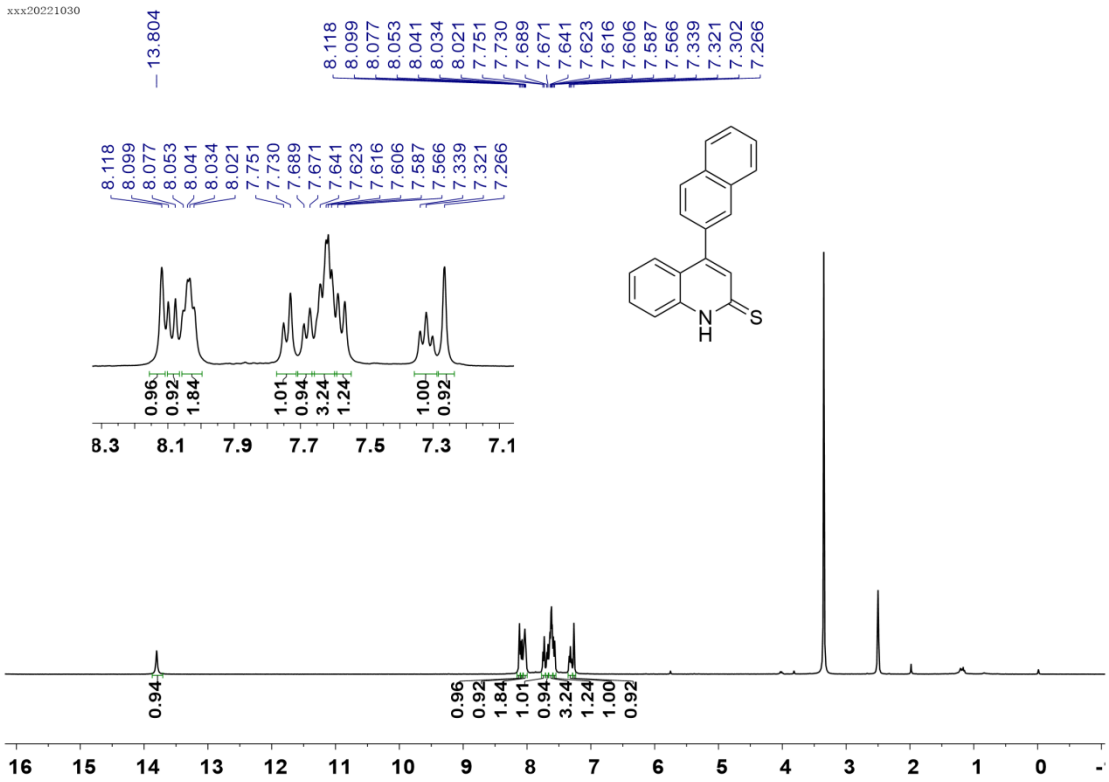
^{1}H NMR (400 MHz, DMSO-d_6) for **3m**



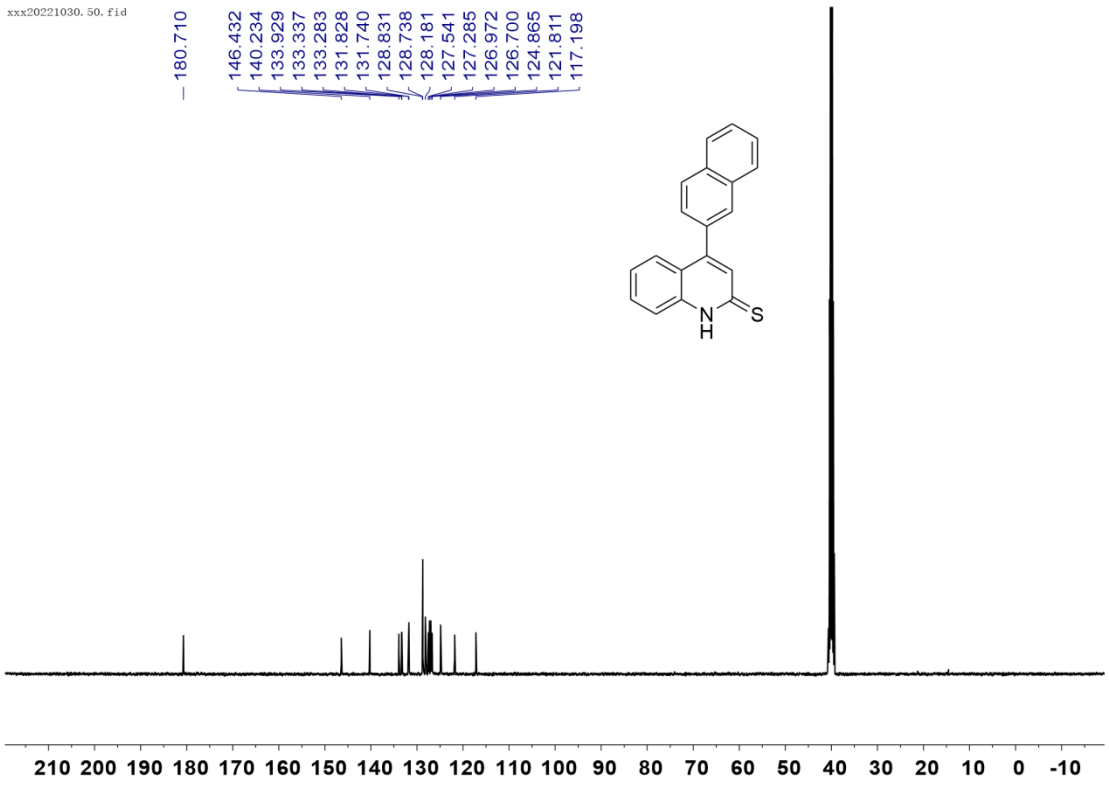
^{13}C NMR (100 MHz, DMSO-d_6) for **3m**



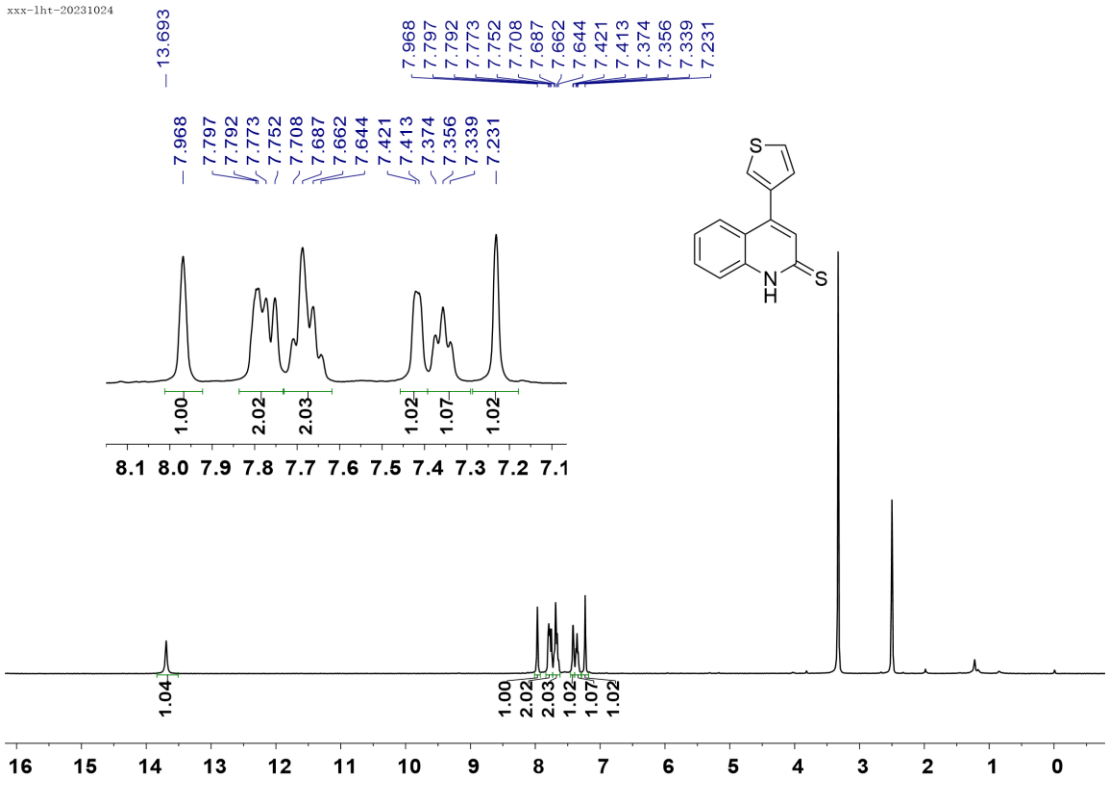
[1]H NMR (400 MHz, DMSO-d_6) for **3n**



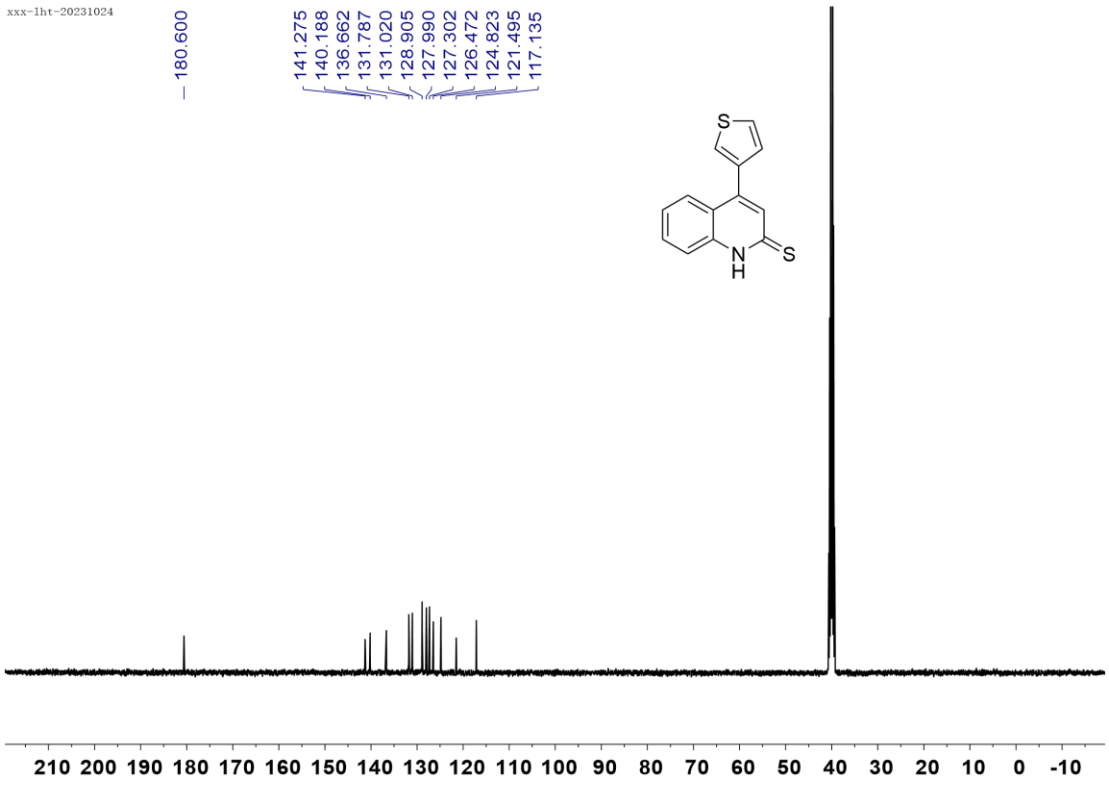
[13]C NMR (100 MHz, DMSO-d_6) for **3n**



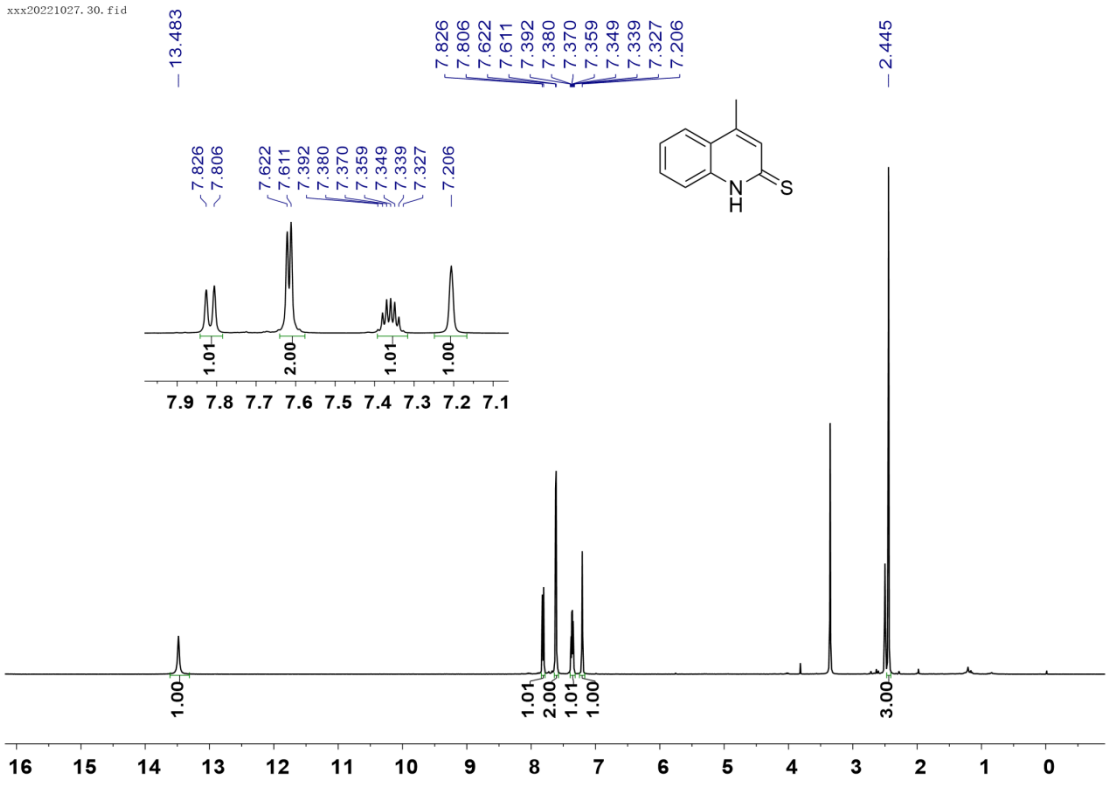
^{1}H NMR (400 MHz, DMSO-d_6) for **3o**



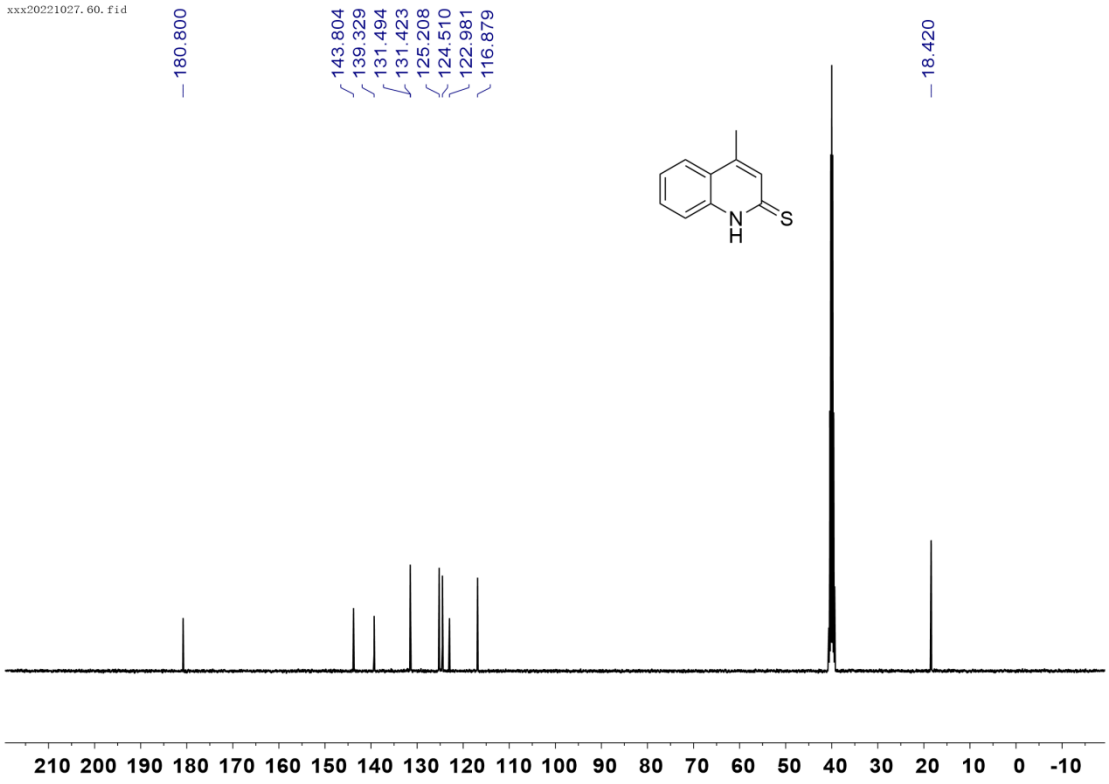
^{13}C NMR (100 MHz, DMSO-d_6) for **3o**



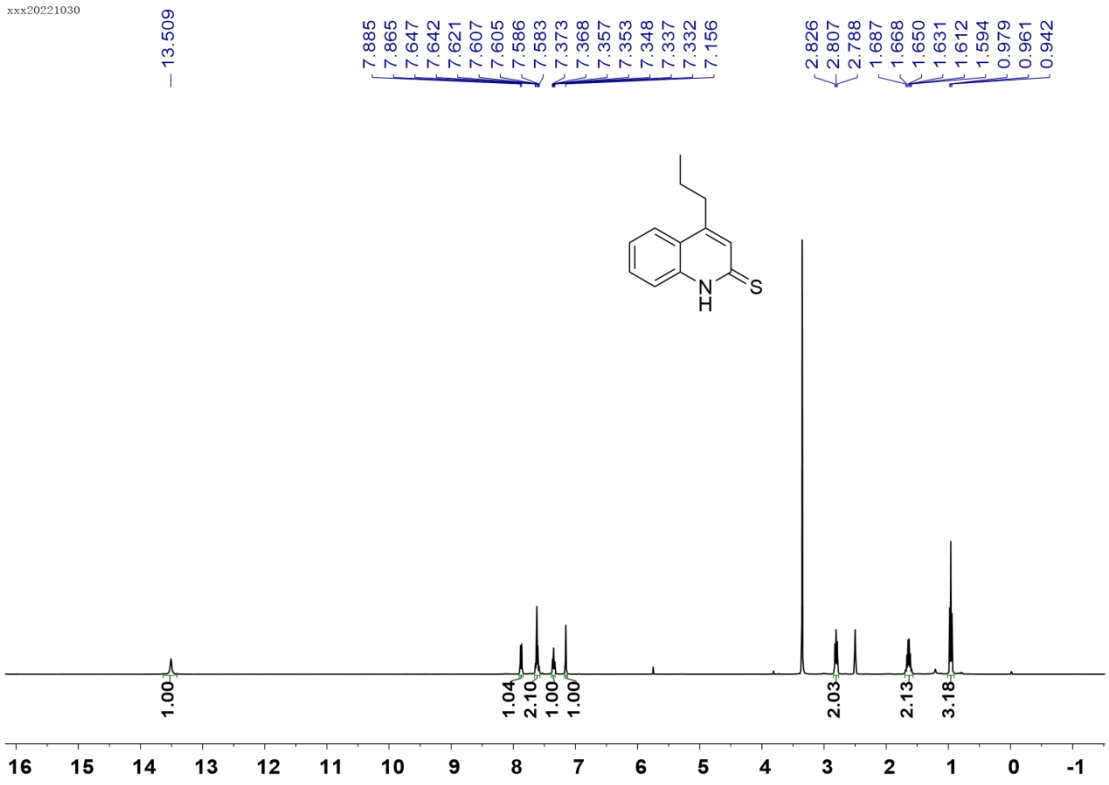
^{1}H NMR (400 MHz, DMSO-d_6) for **3p**



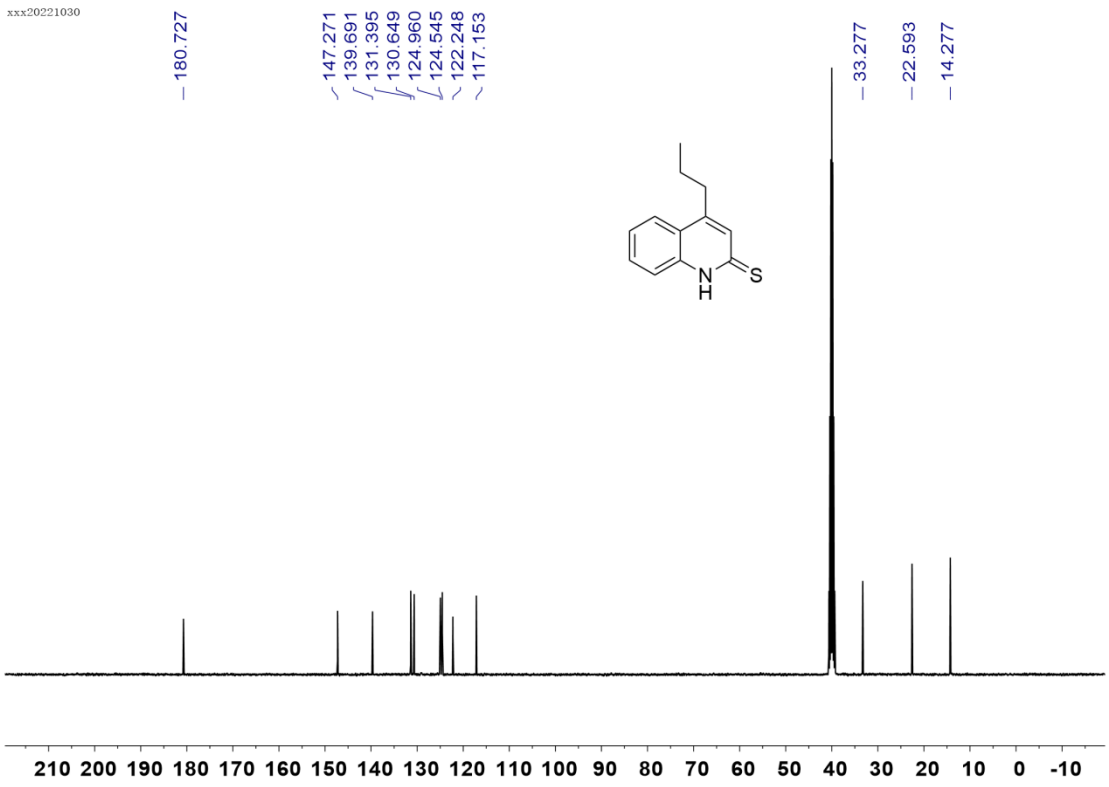
^{13}C NMR (100 MHz, DMSO-d_6) for **3p**



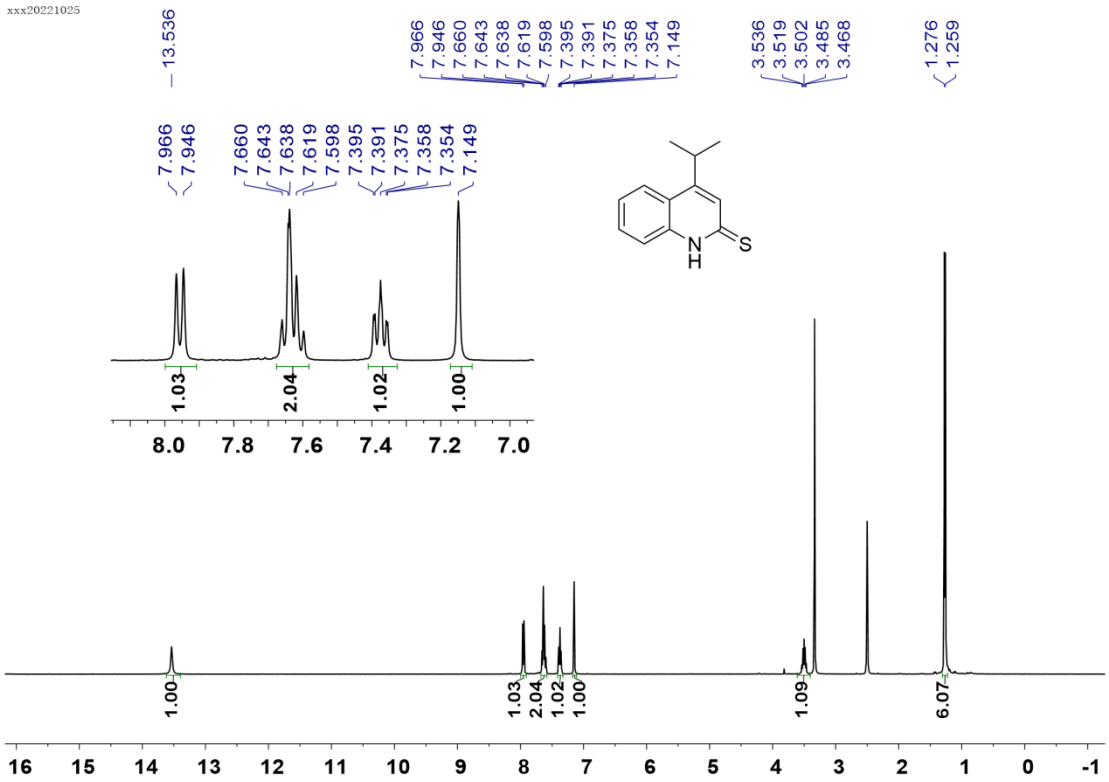
^{1}H NMR (400 MHz, DMSO-d_6) for **3q**



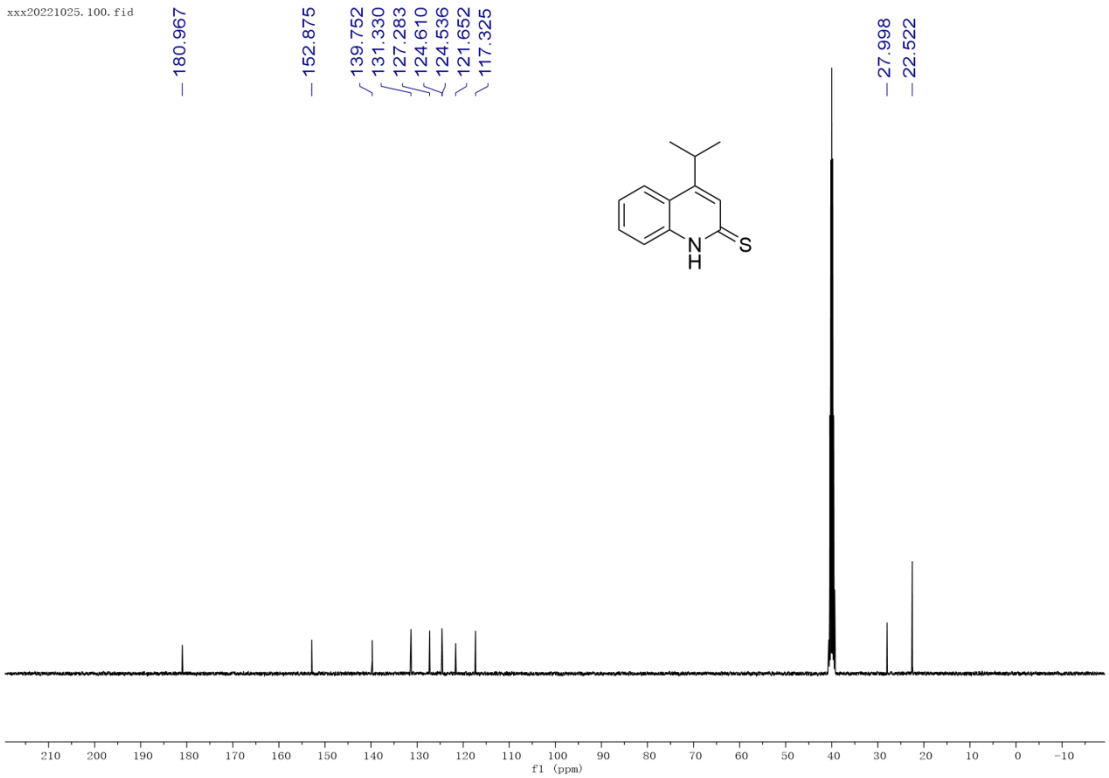
^{13}C NMR (100 MHz, DMSO-d_6) for **3q**



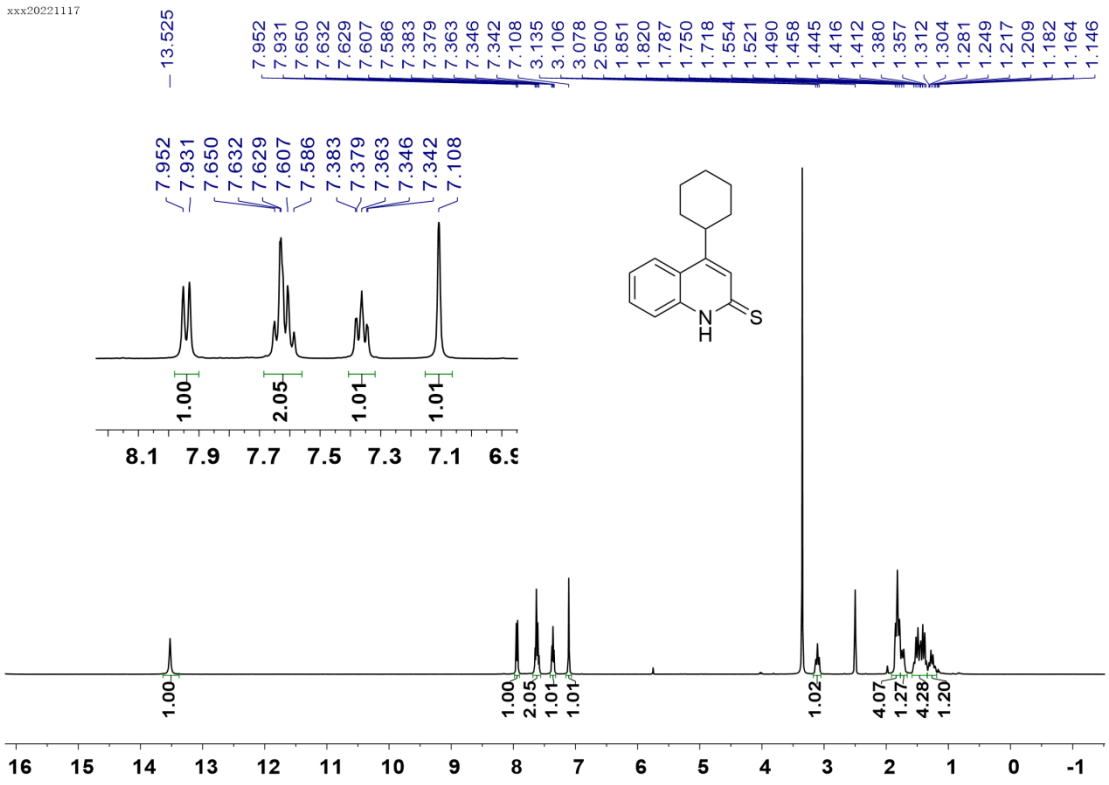
^{1}H NMR (400 MHz, DMSO-d_6) for **3r**



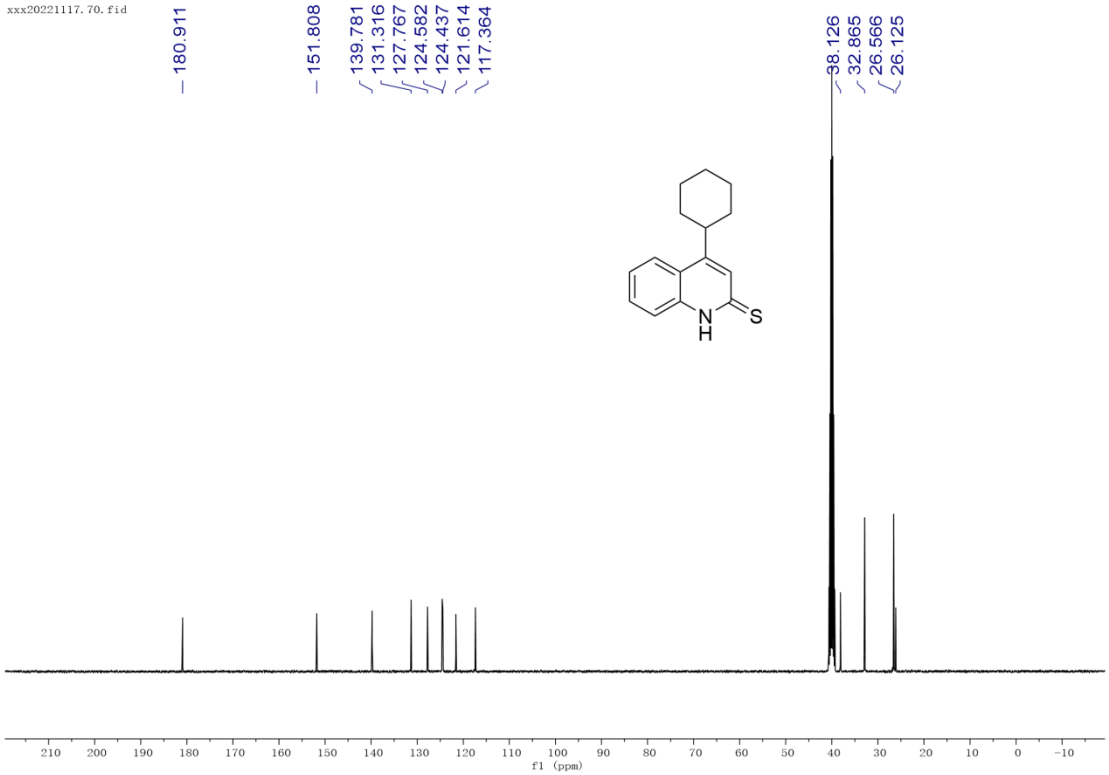
^{13}C NMR (100 MHz, DMSO-d_6) for **3r**



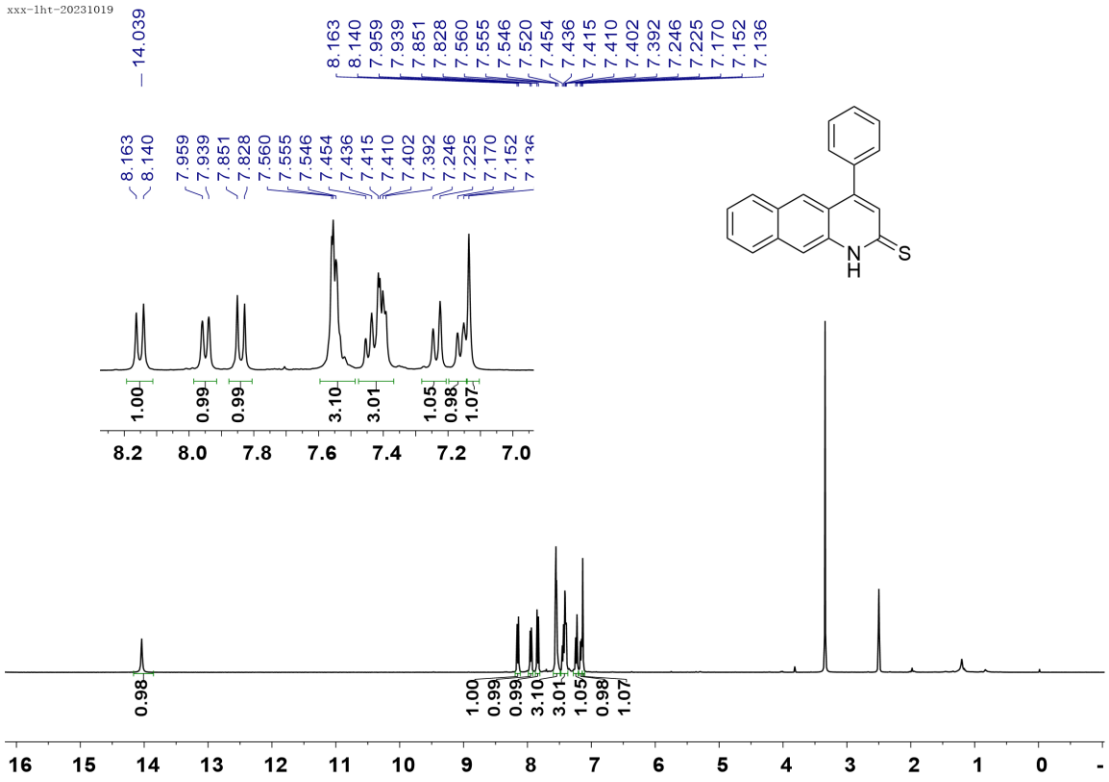
^{1}H NMR (400 MHz, DMSO-d_6) for **3s**



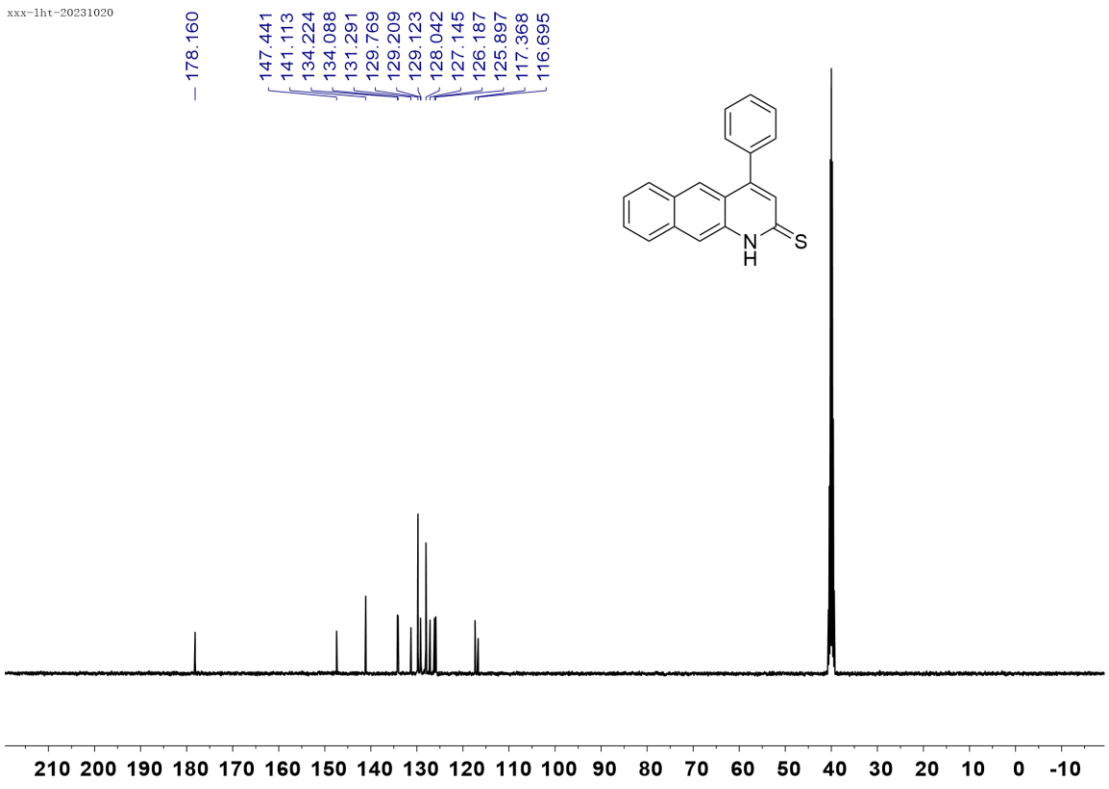
^{13}C NMR (100 MHz, DMSO-d_6) for **3s**



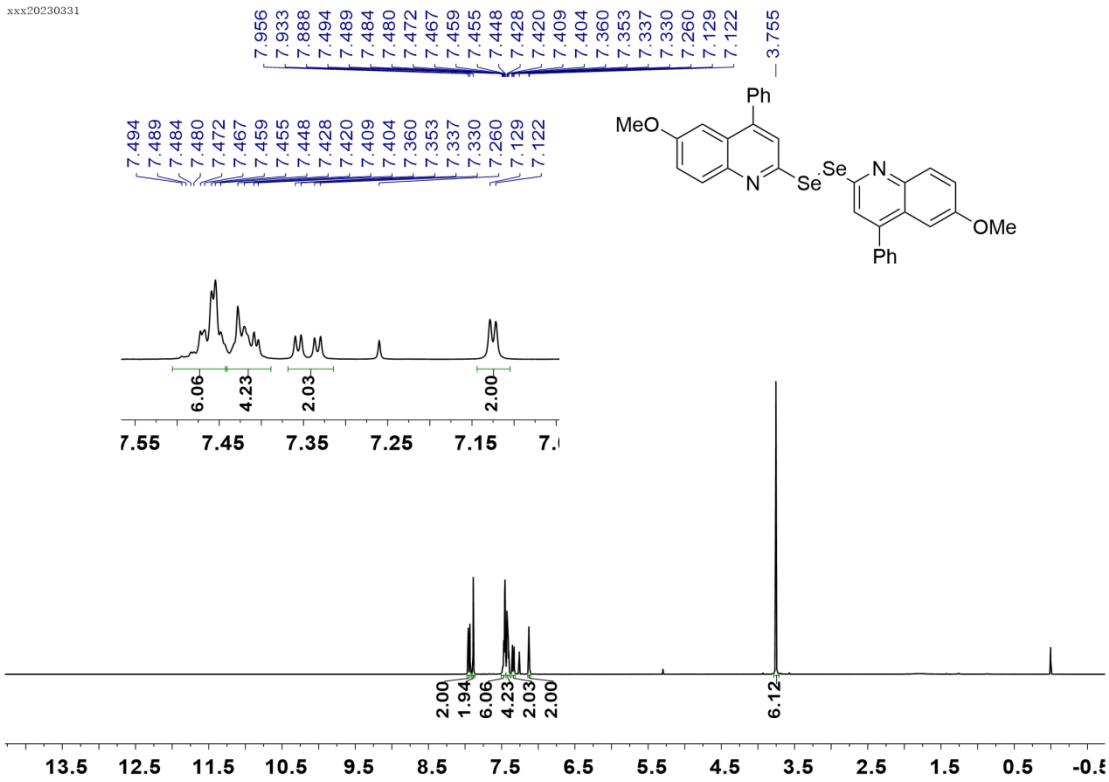
^{1}H NMR (400 MHz, DMSO-d_6) for **3v**



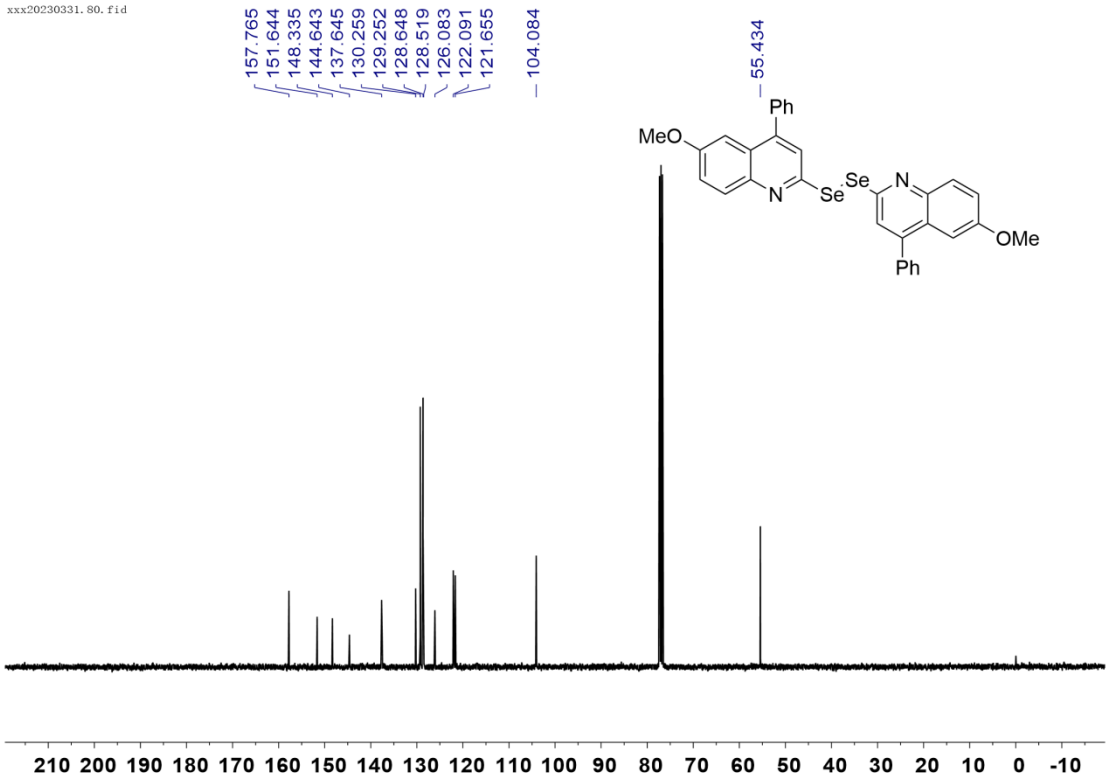
^{13}C NMR (100 MHz, DMSO-d_6) for **3v**



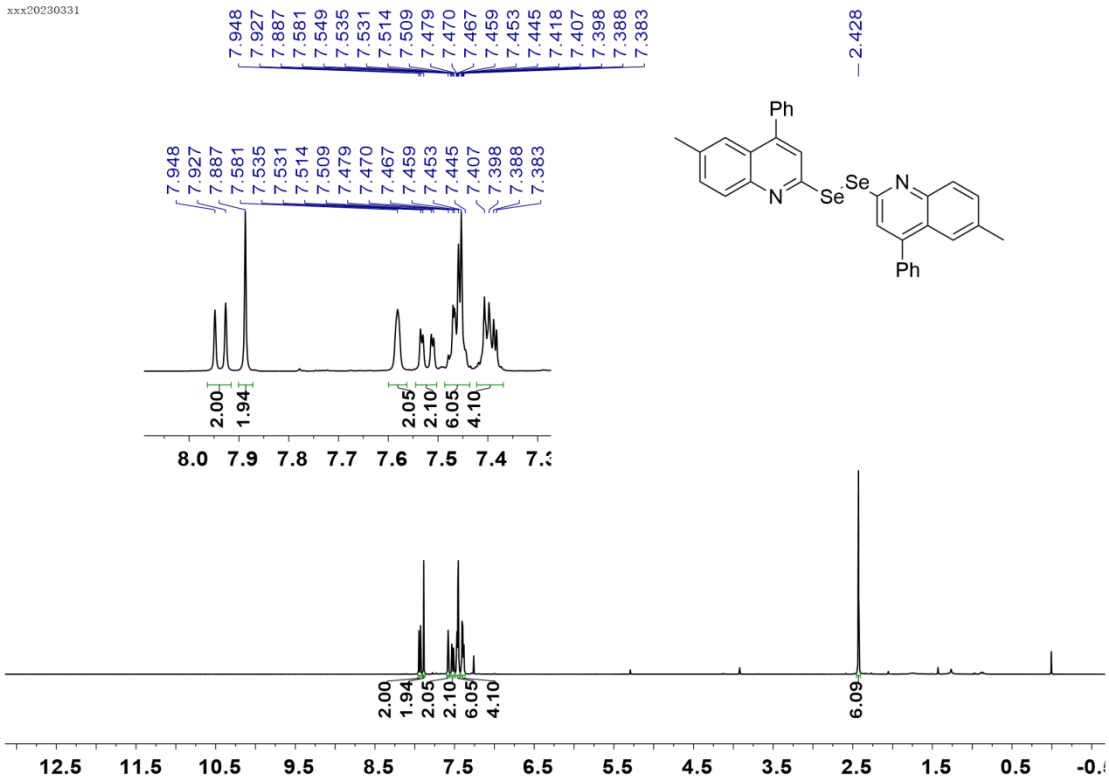
^{1}H NMR (400 MHz, $CDCl_3$) for **5a**



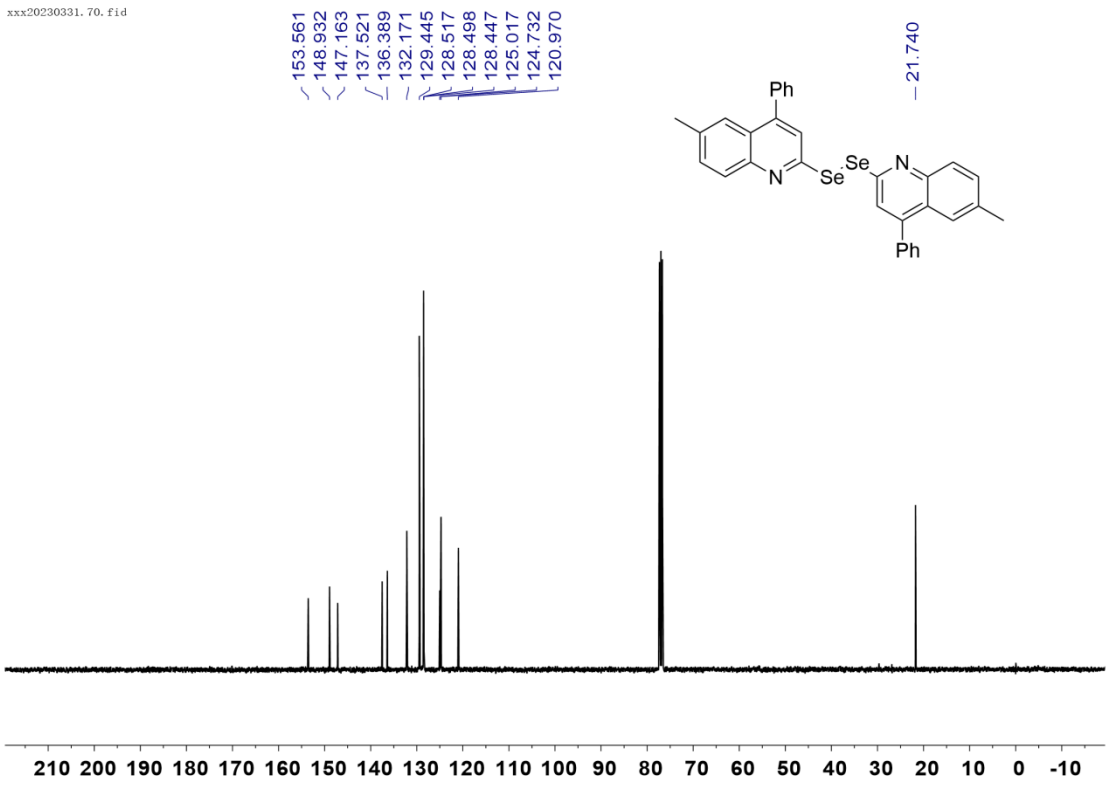
^{13}C NMR (100 MHz, $CDCl_3$) for **5a**



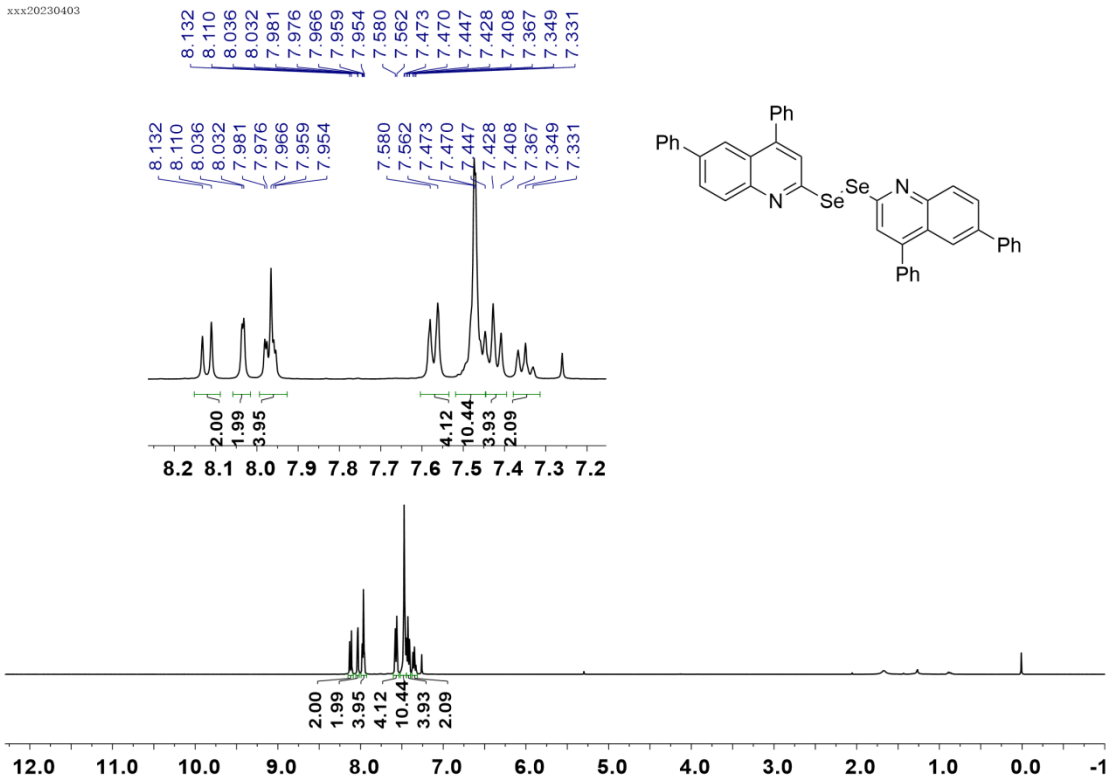
^{1}H NMR (400 MHz, $CDCl_3$) for **5b**



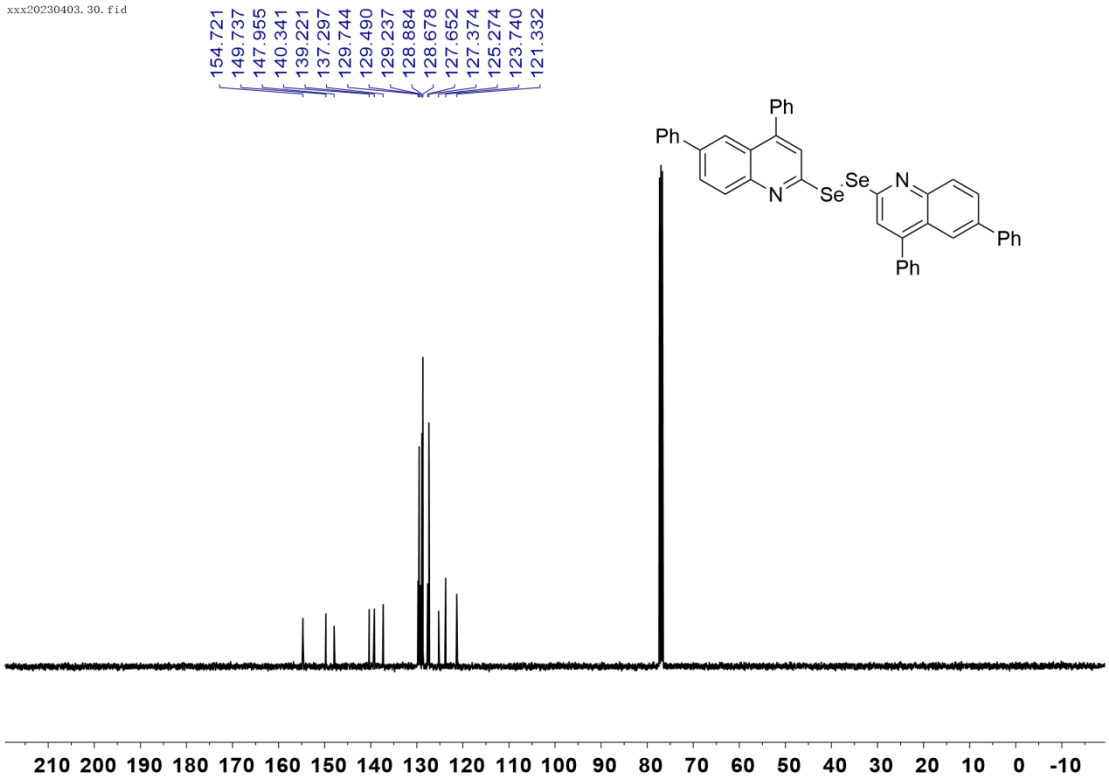
^{13}C NMR (100 MHz, $CDCl_3$) for **5b**



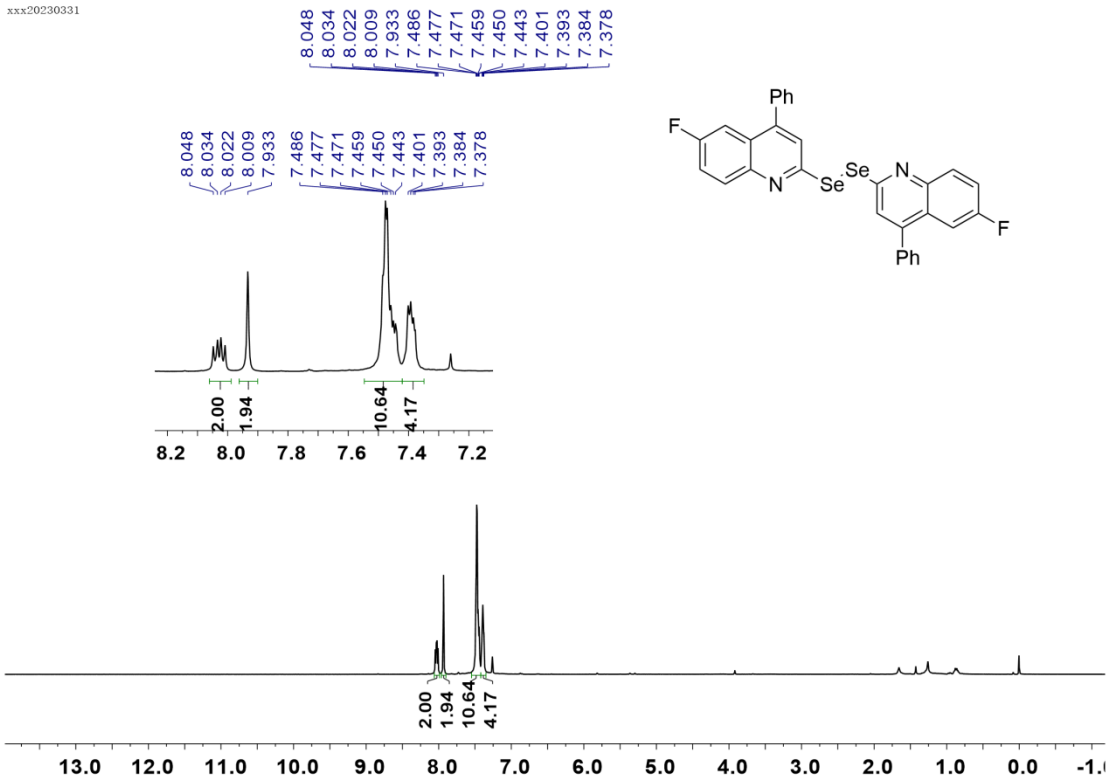
^{1}H NMR (400 MHz, $CDCl_3$) for **5c**



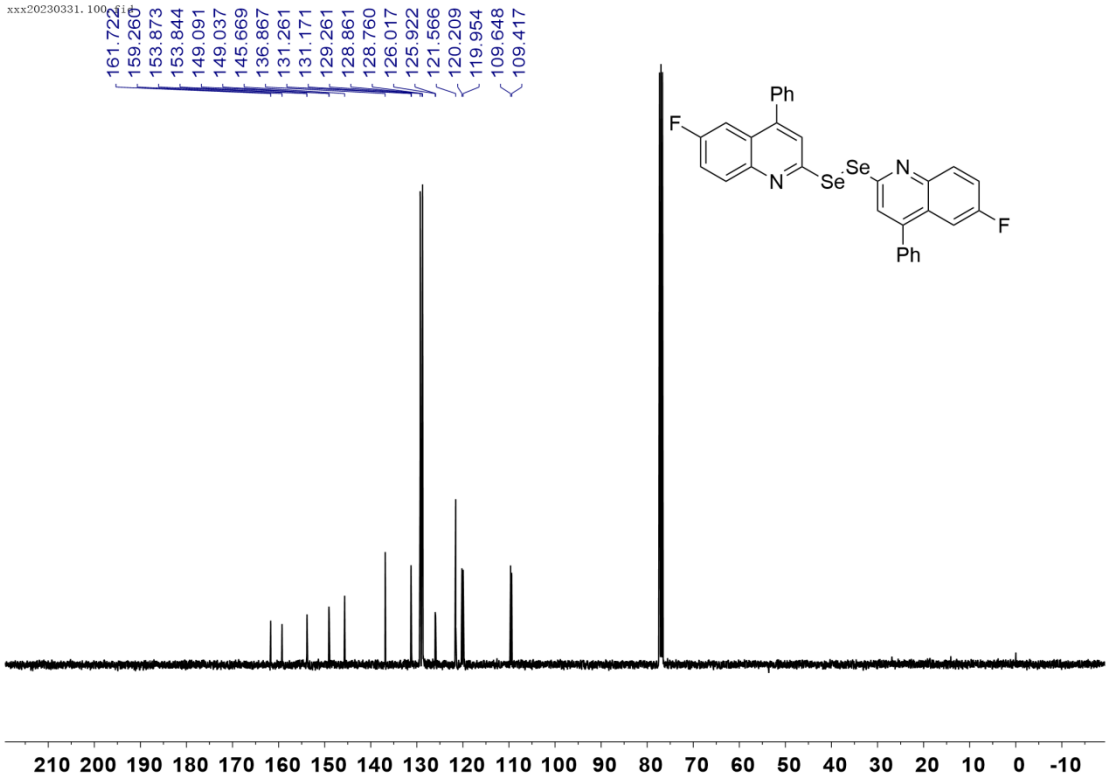
^{13}C NMR (100 MHz, $CDCl_3$) for **5c**



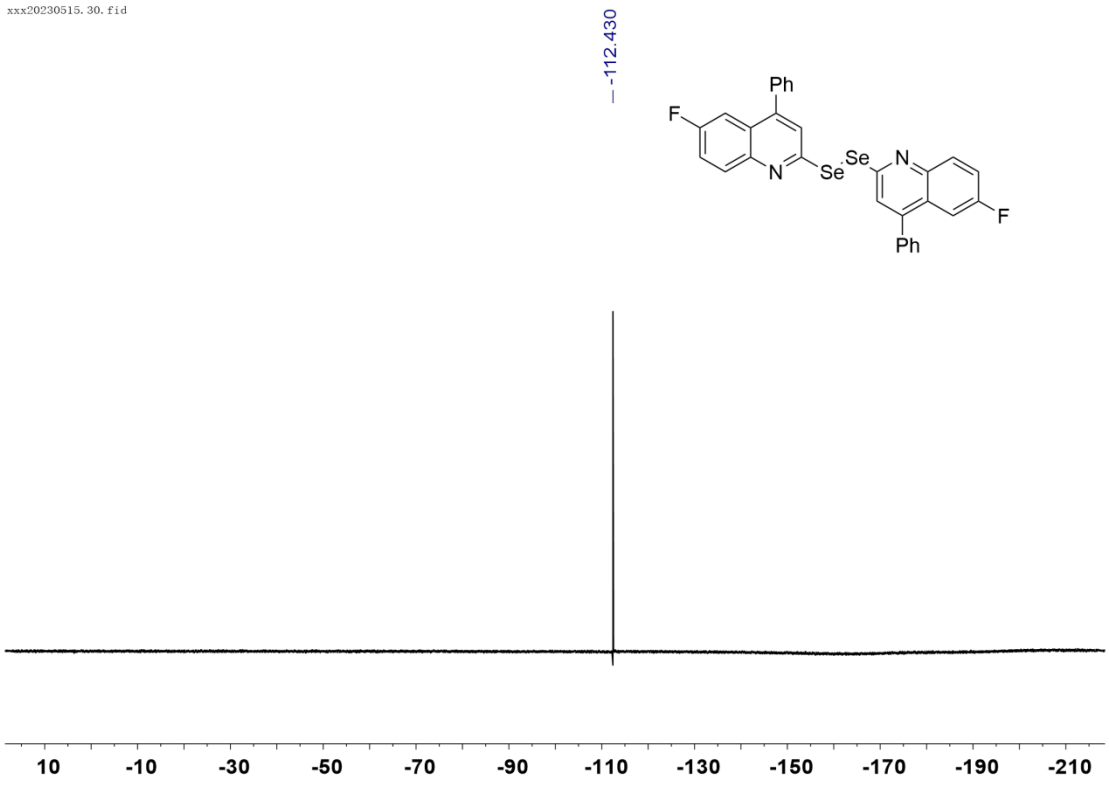
^{1}H NMR (400 MHz, $CDCl_3$) for **5d**



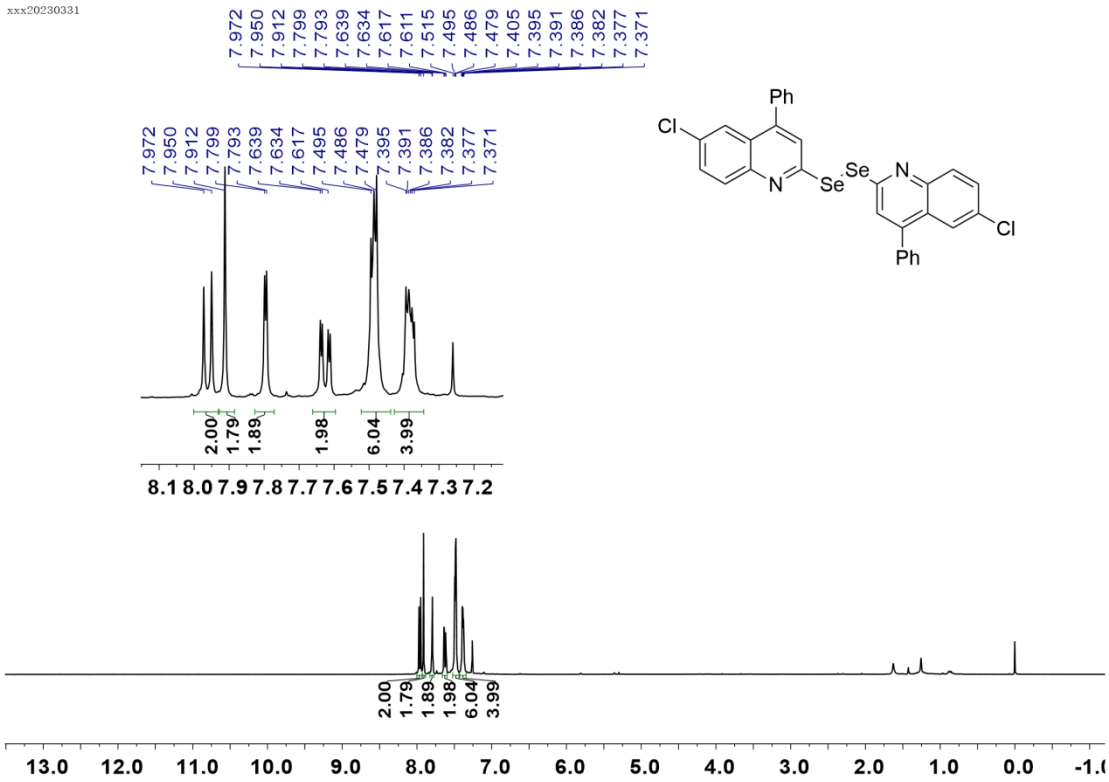
^{13}C NMR (100 MHz, $CDCl_3$) for **5d**



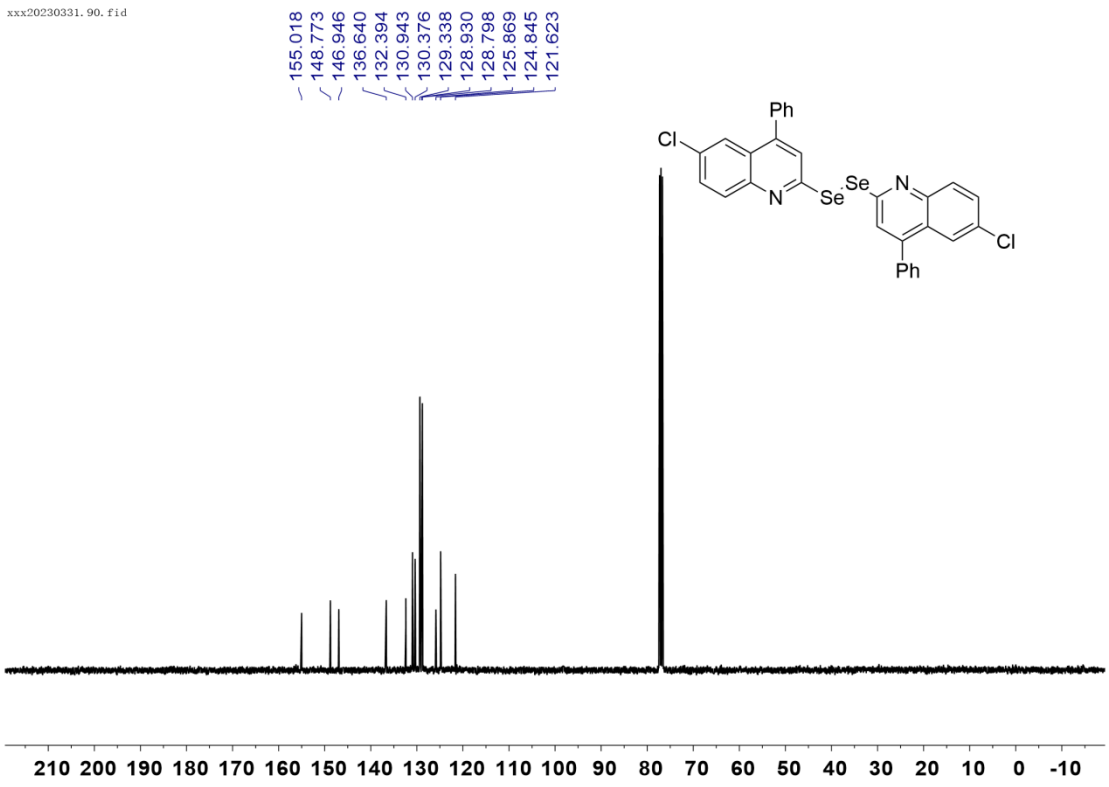
^{19}F NMR (376 MHz, $CDCl_3$) for **5d**



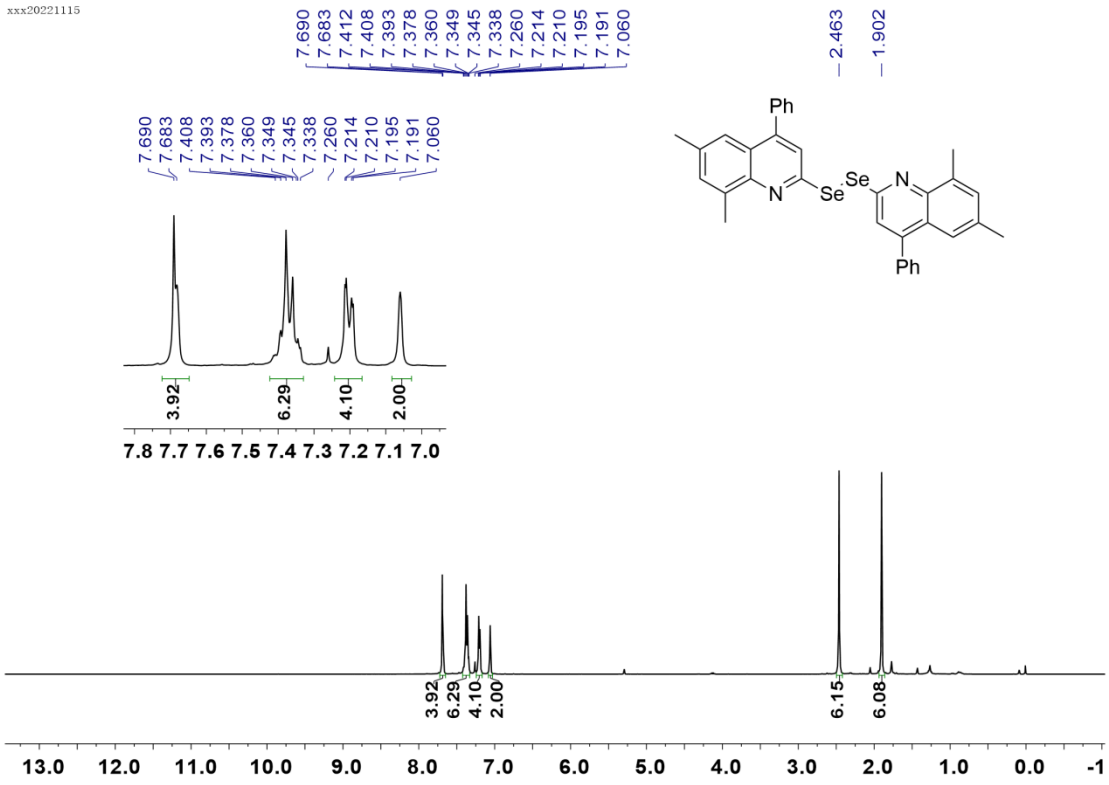
[1]H NMR (400 MHz, $CDCl_3$) for **5e**



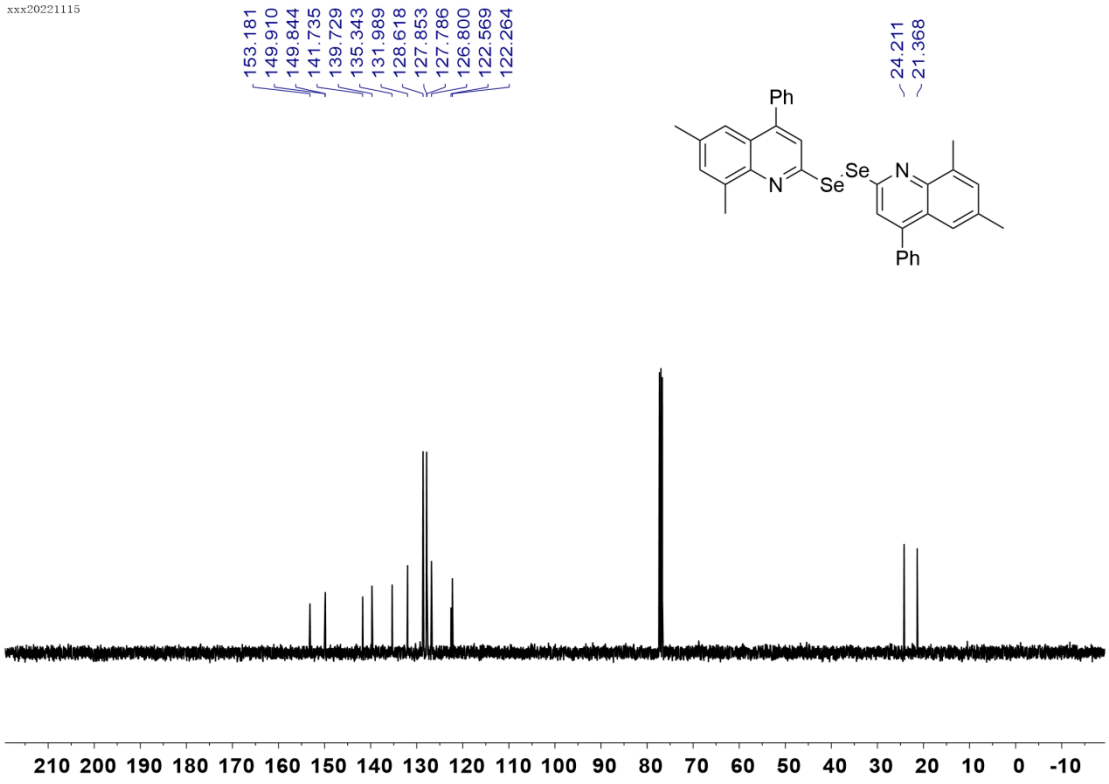
[13]C NMR (100 MHz, $CDCl_3$) for **5e**



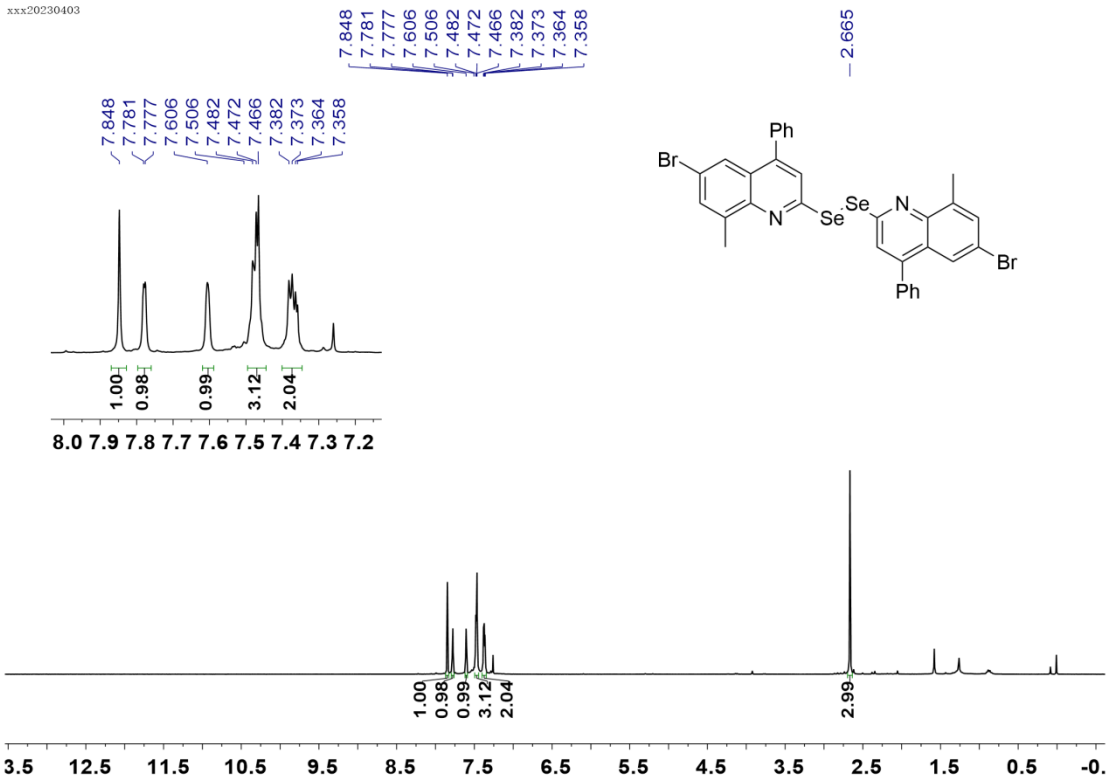
^{1}H NMR (400 MHz, $CDCl_3$) for **5f**



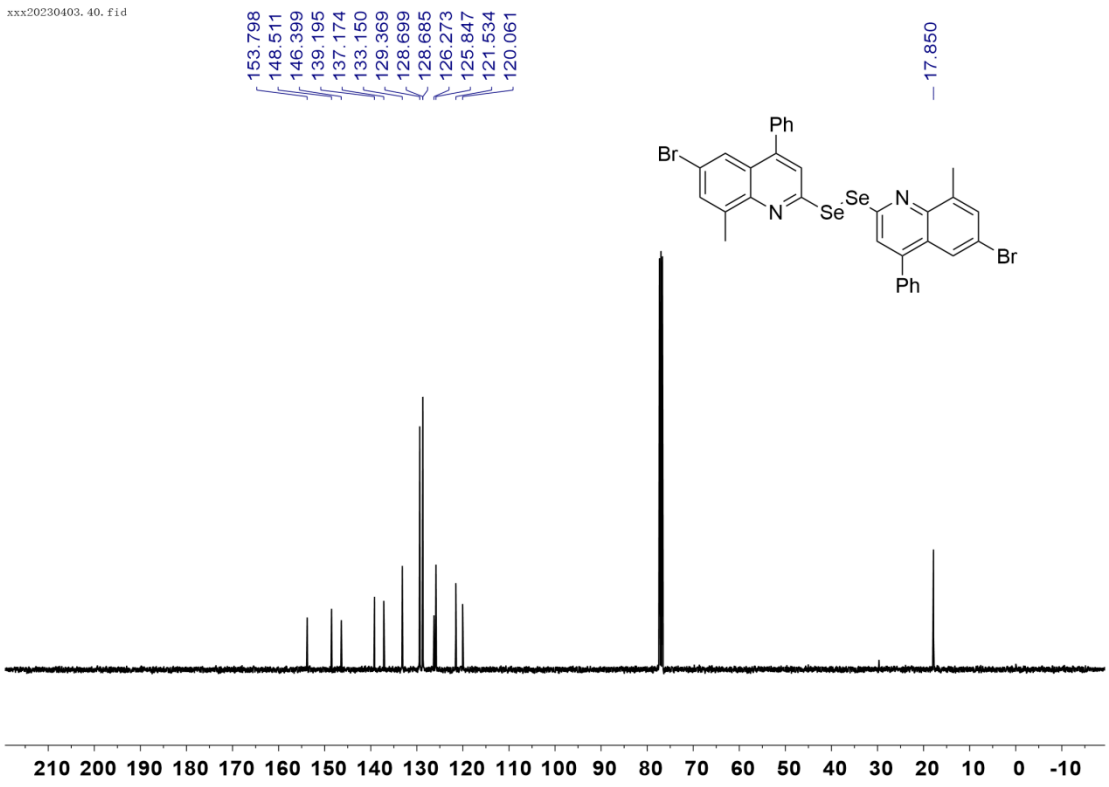
^{13}C NMR (100 MHz, $CDCl_3$) for **5f**



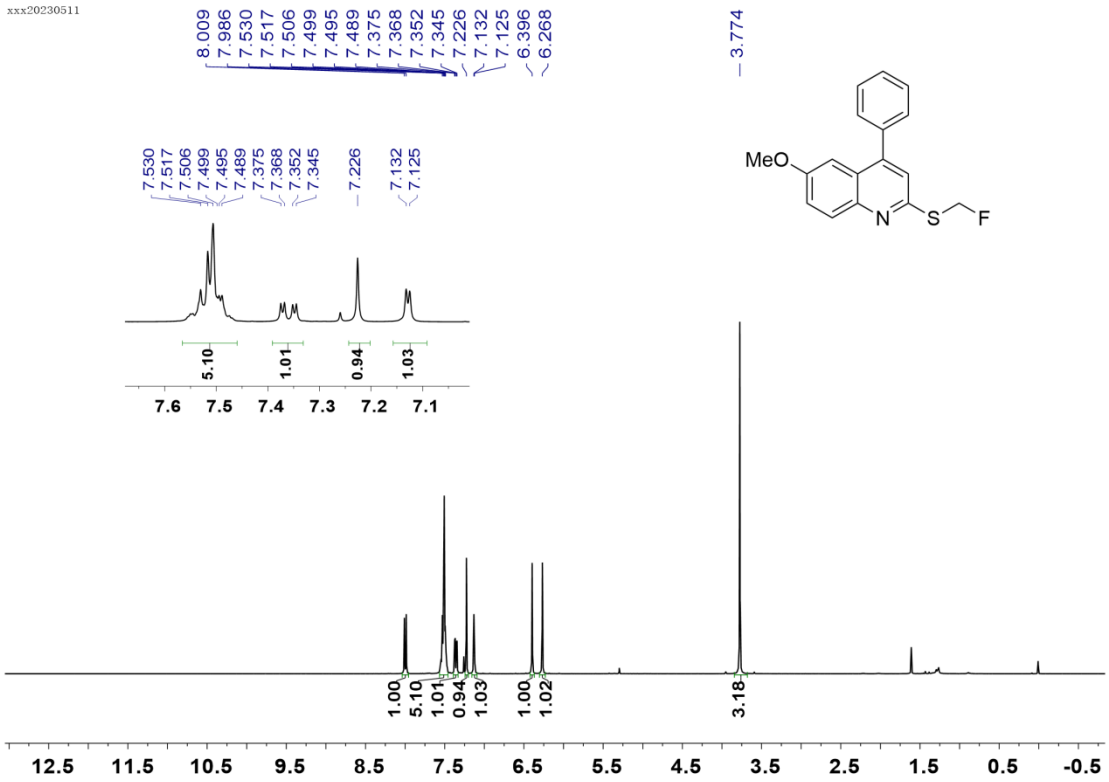
^{1}H NMR (400 MHz, $CDCl_3$) for **5g**



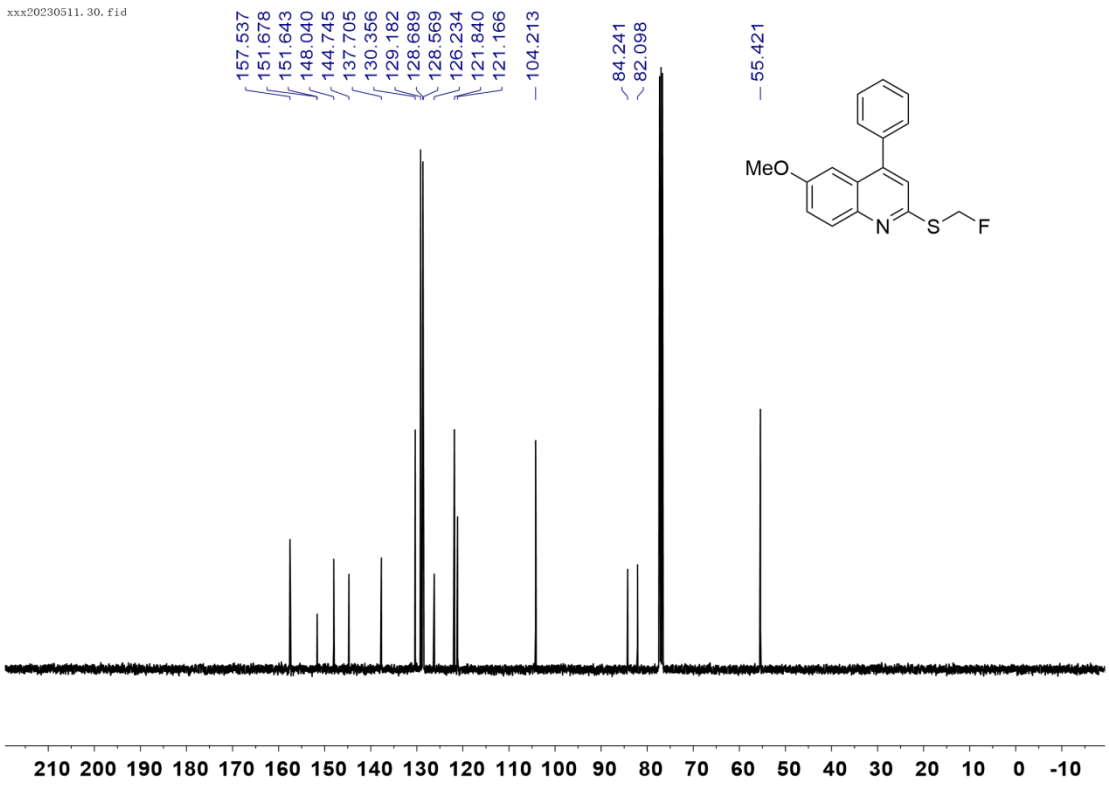
^{13}C NMR (100 MHz, $CDCl_3$) for **5g**



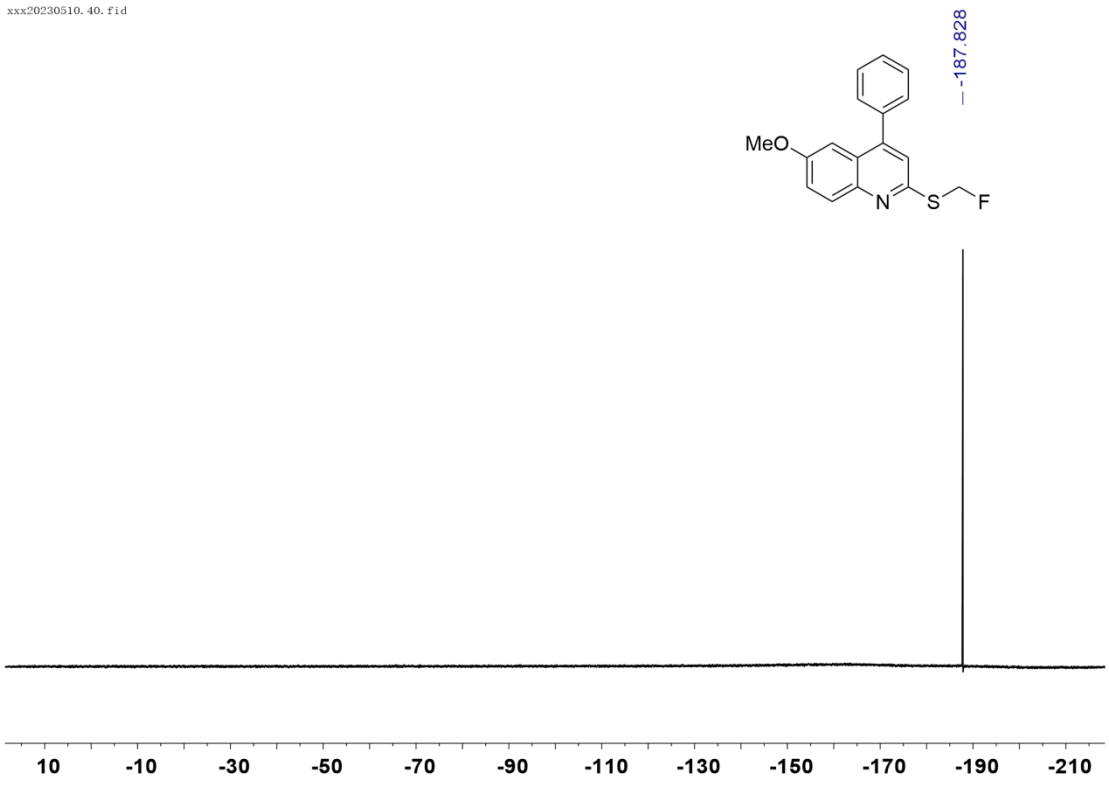
^{1}H NMR (400 MHz, $CDCl_3$) for **6a**



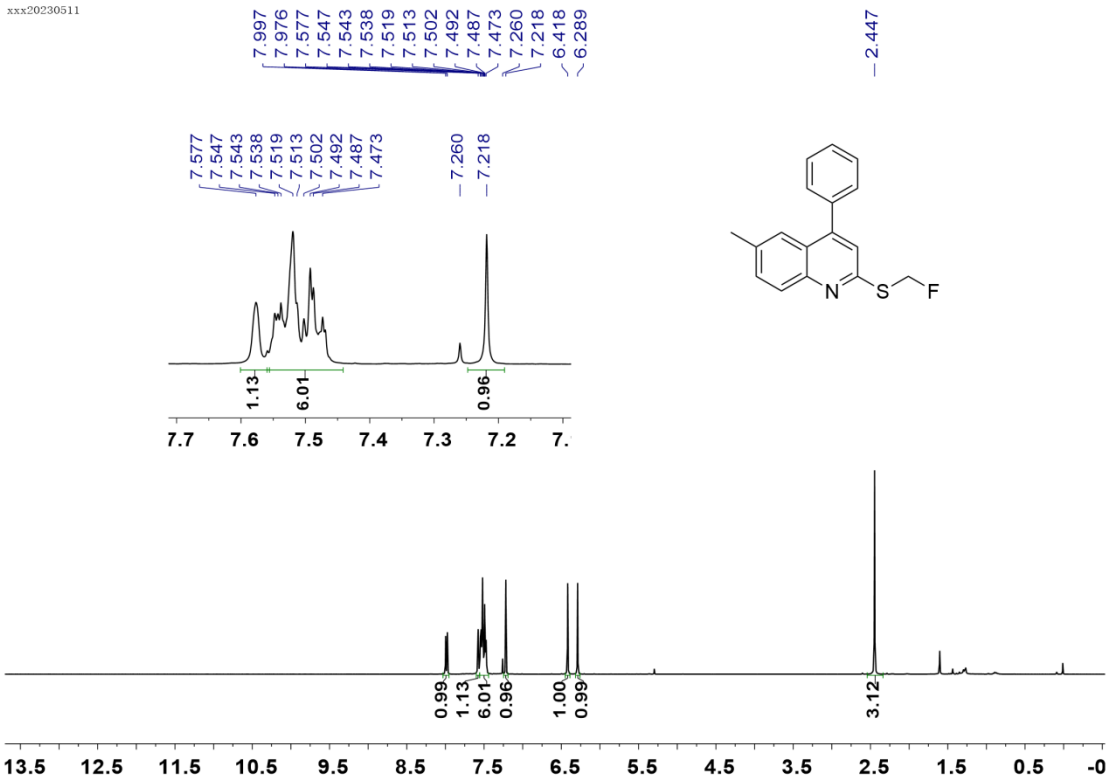
^{13}C NMR (100 MHz, $CDCl_3$) for **6a**



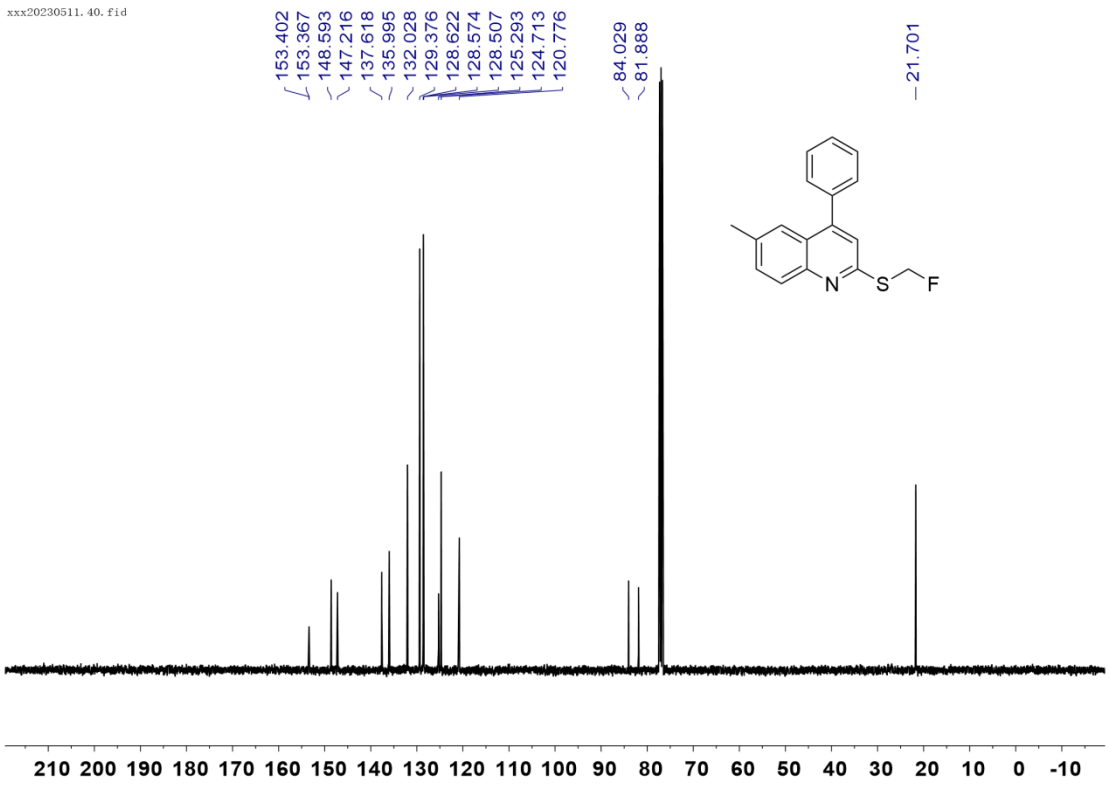
^{19}F NMR (376 MHz, $CDCl_3$) for **6a**



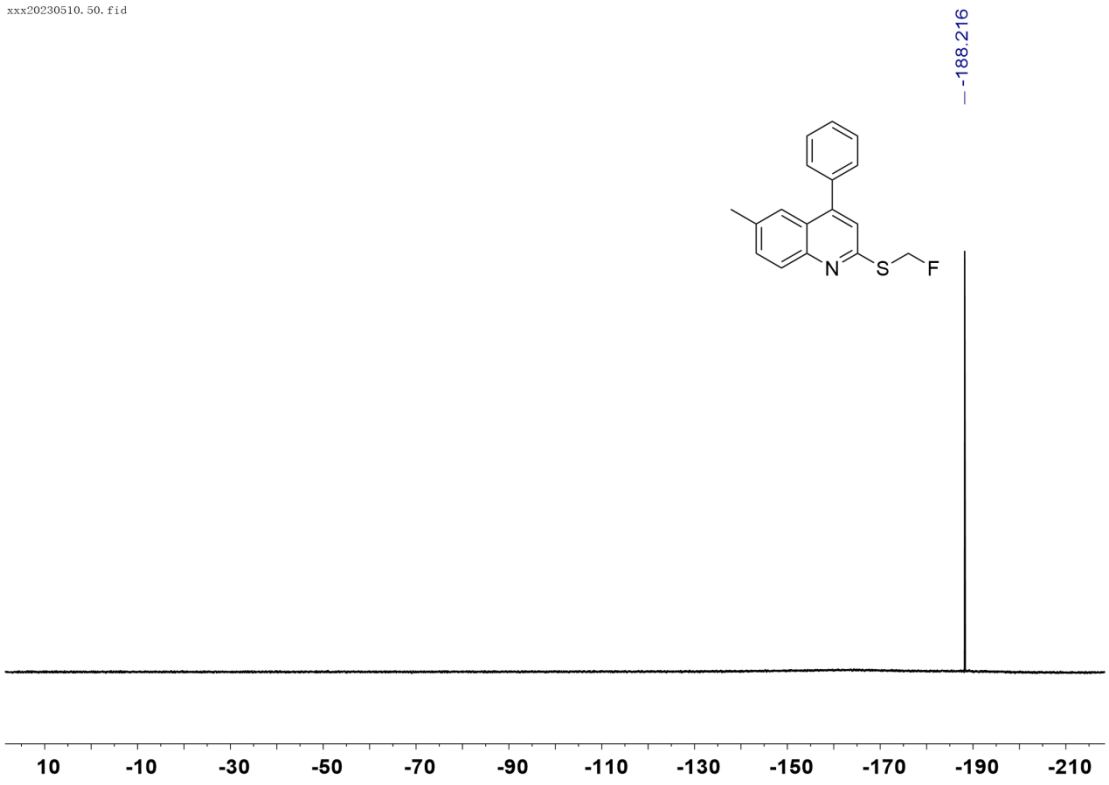
^{1}H NMR (400 MHz, $CDCl_3$) for **6b**



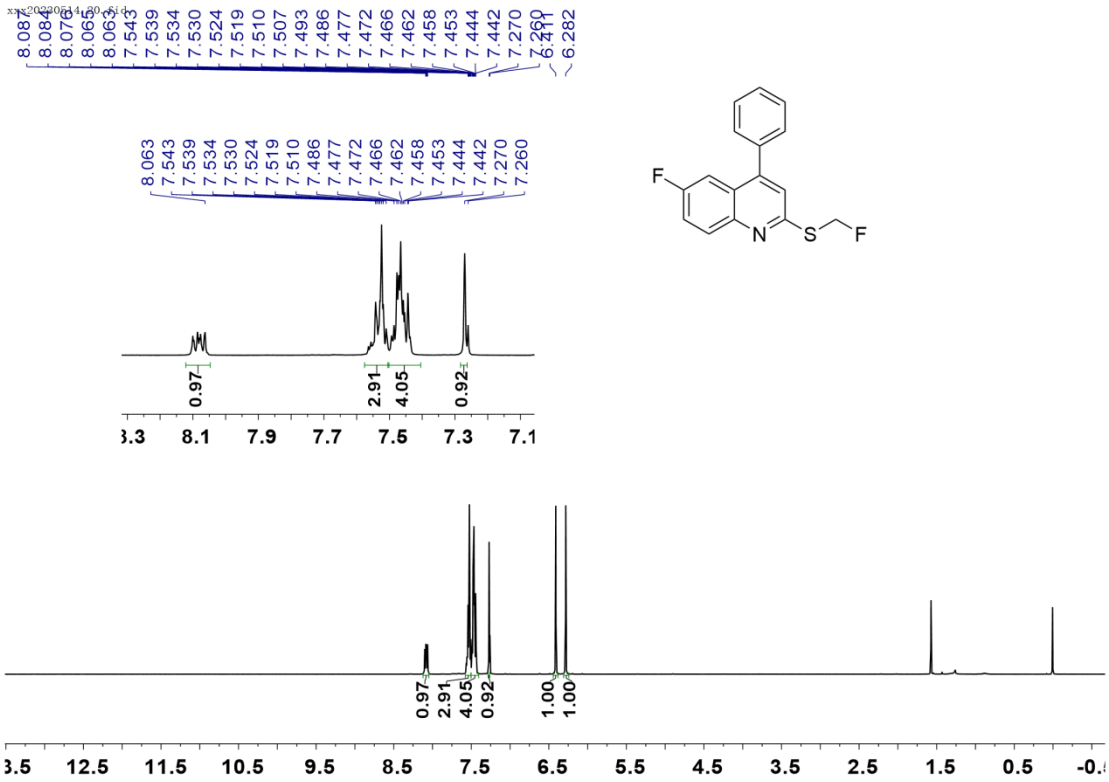
^{13}C NMR (100 MHz, $CDCl_3$) for **6b**



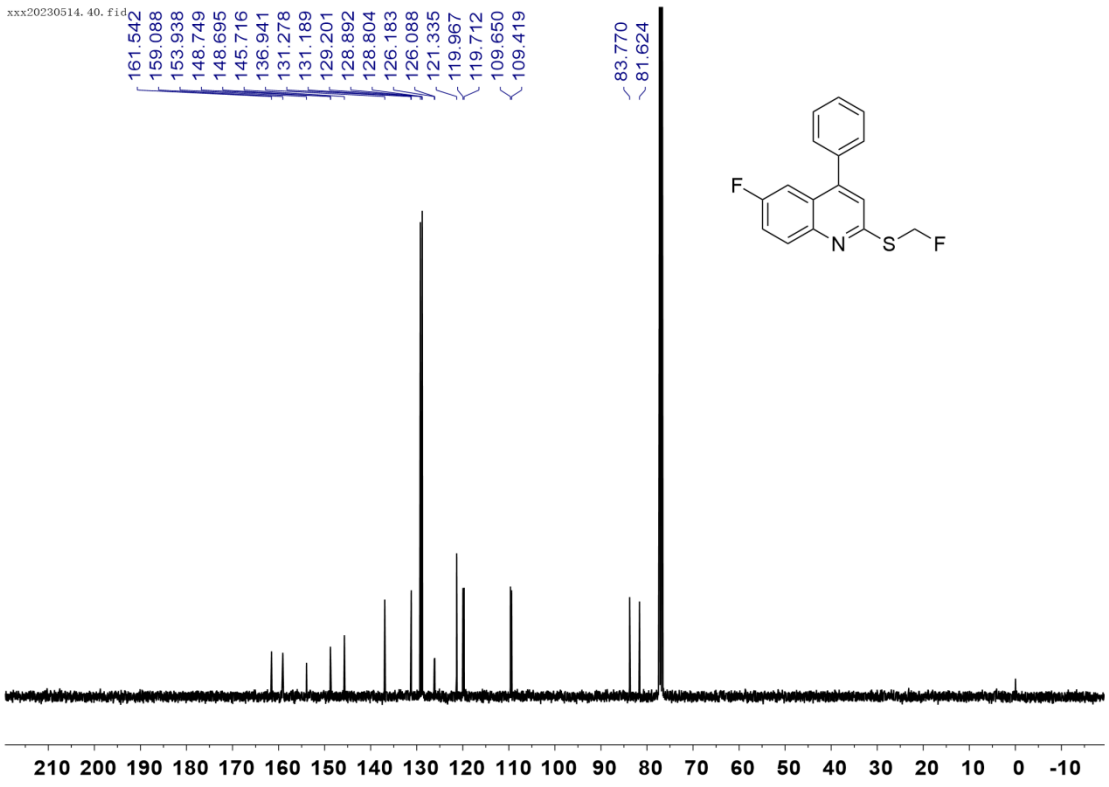
^{19}F NMR (376 MHz, $CDCl_3$) for **6b**



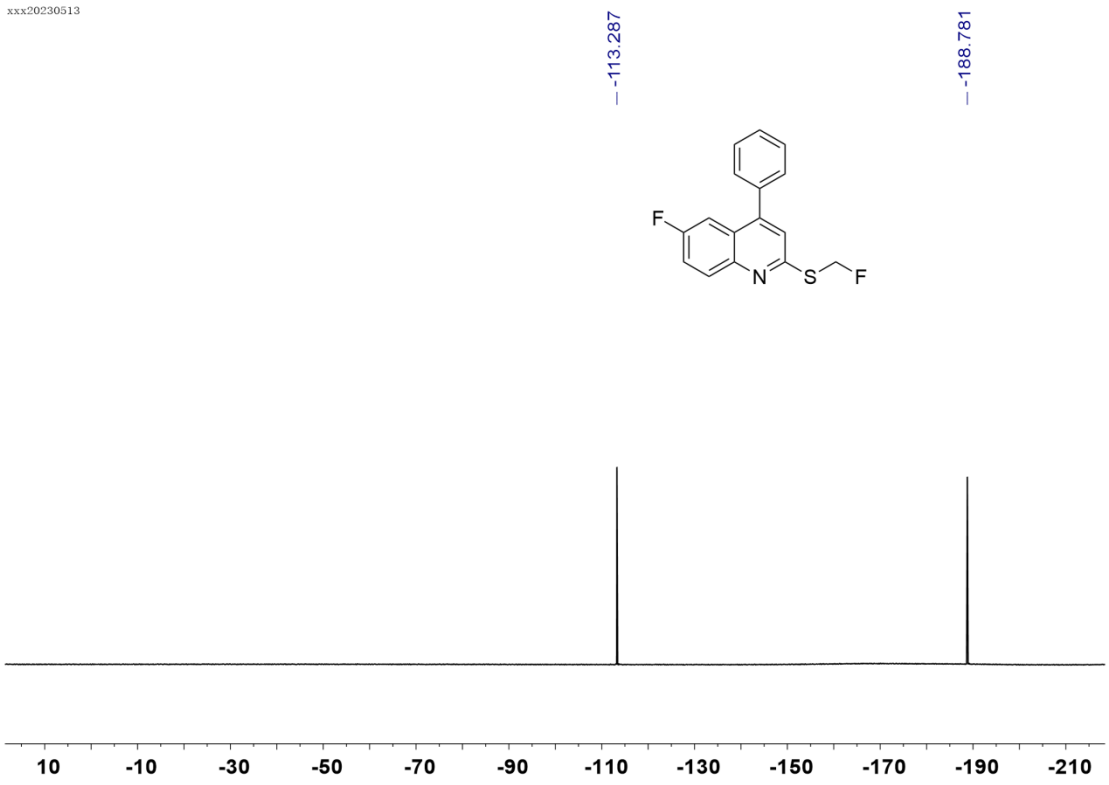
^{1}H NMR (400 MHz, $CDCl_3$) for **6c**



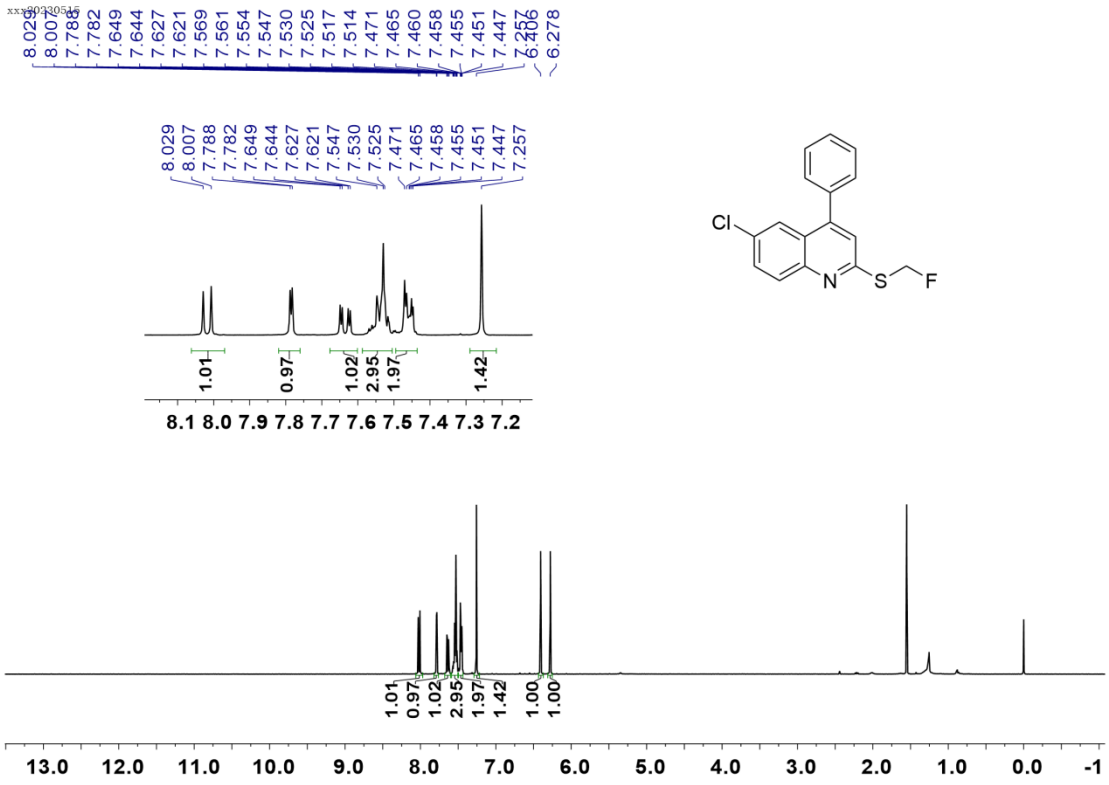
^{13}C NMR (100 MHz, $CDCl_3$) for **6c**



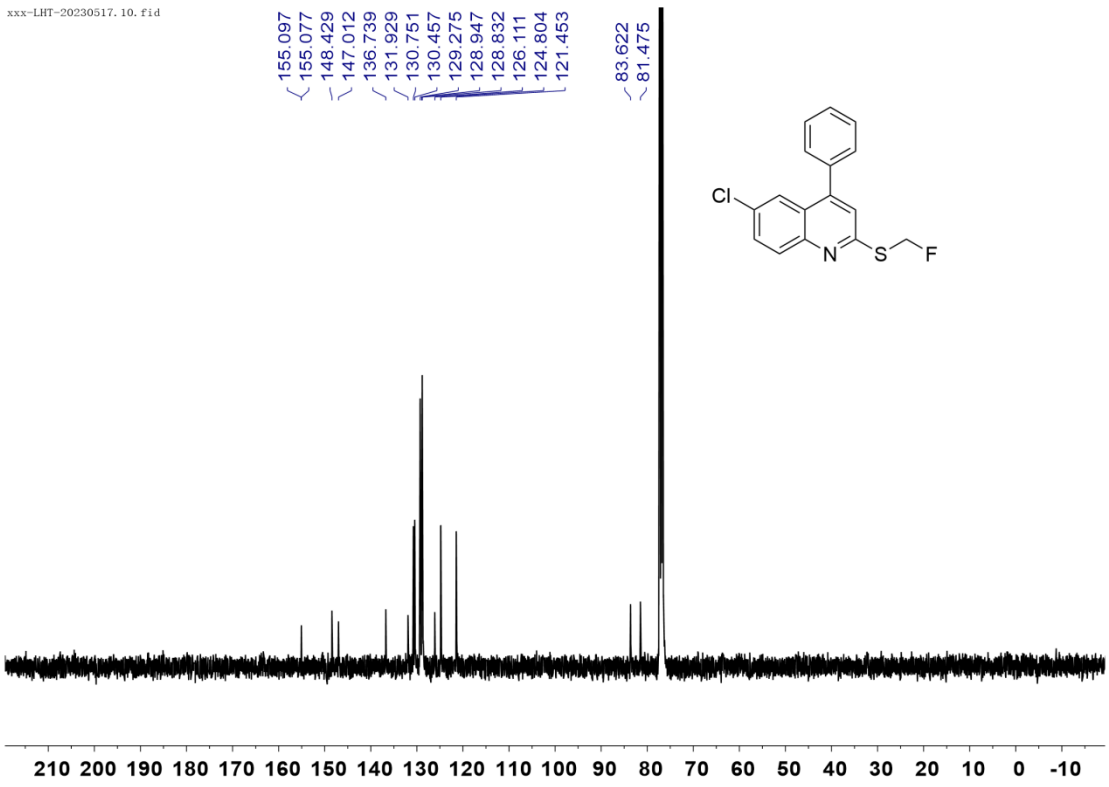
^{19}F NMR (376 MHz, $CDCl_3$) for **6c**



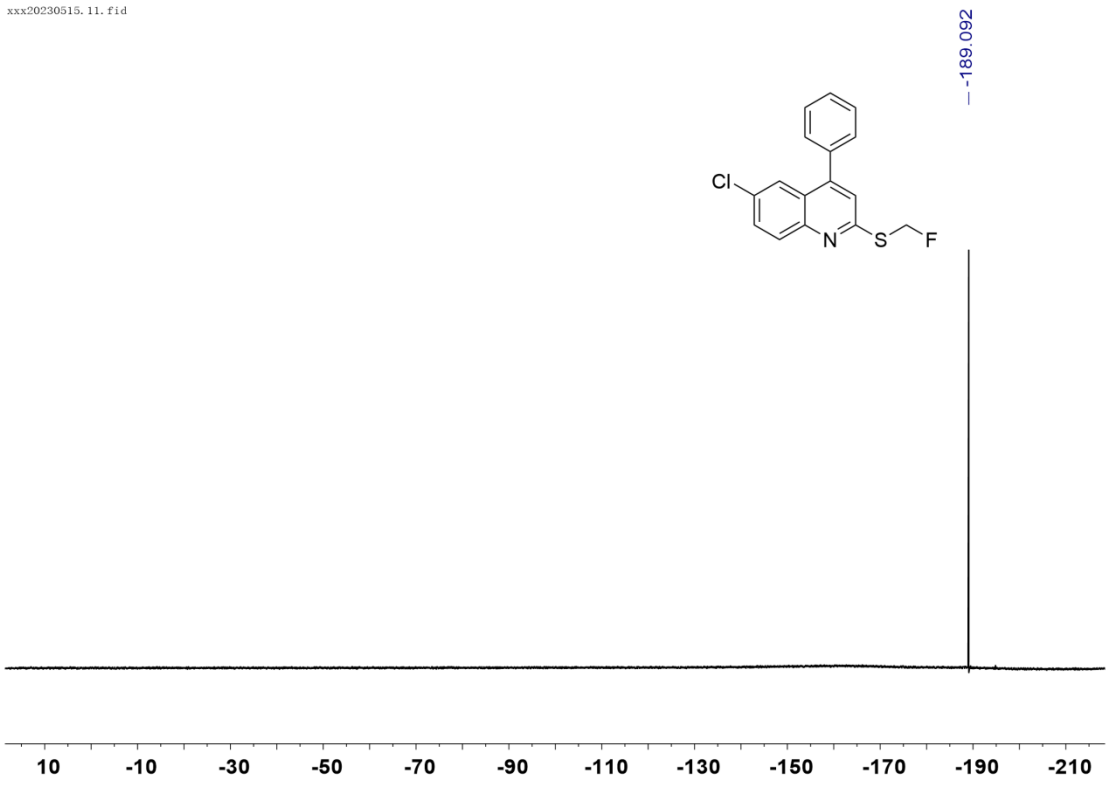
^{1}H NMR (400 MHz, $CDCl_3$) for **6d**



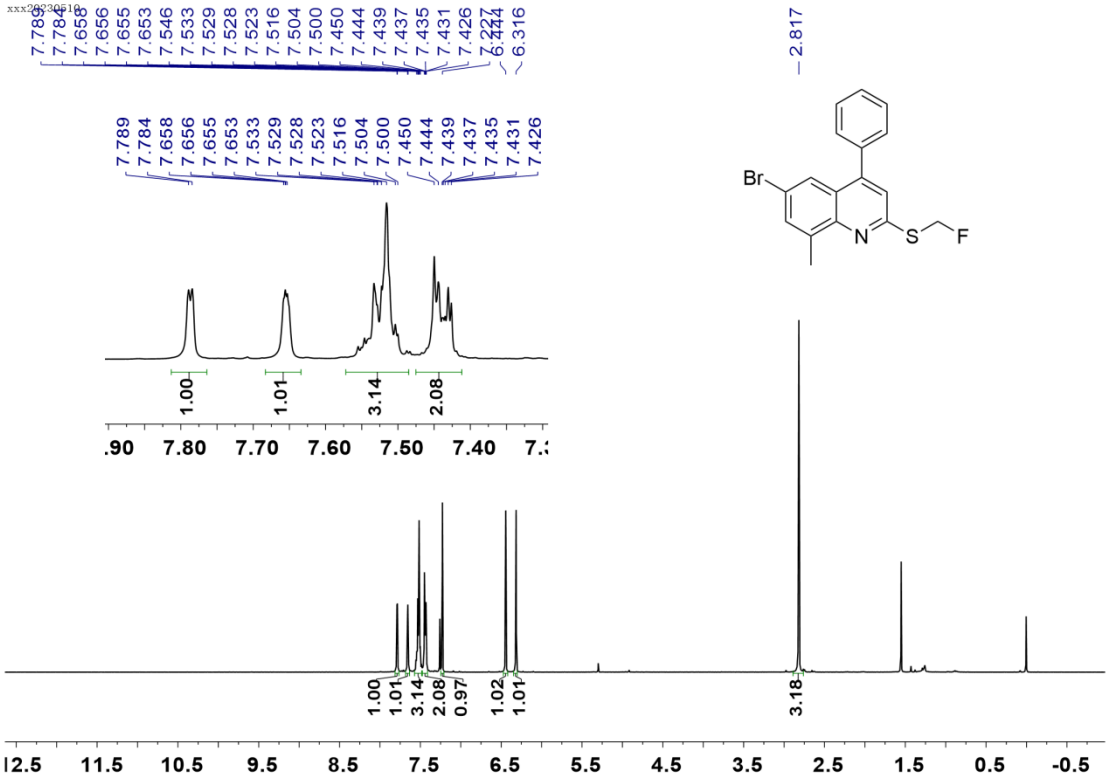
^{13}C NMR (100 MHz, $CDCl_3$) for **6d**



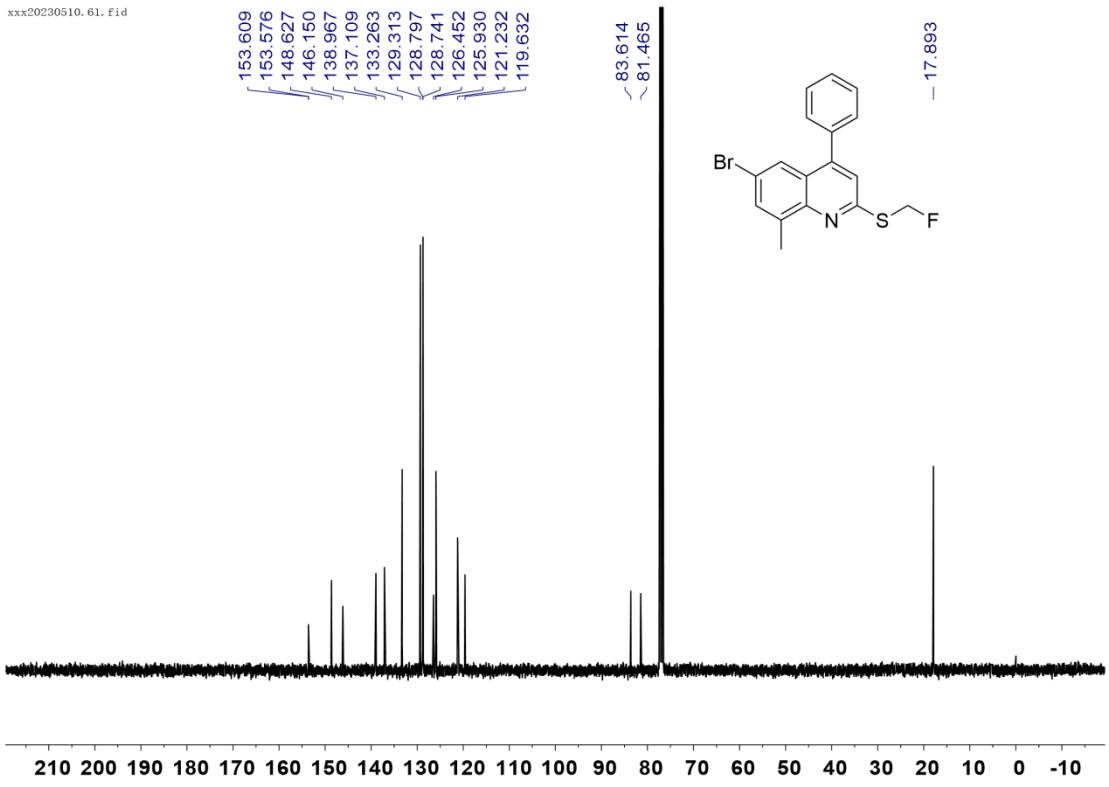
^{19}F NMR (376 MHz, $CDCl_3$) for **6d**



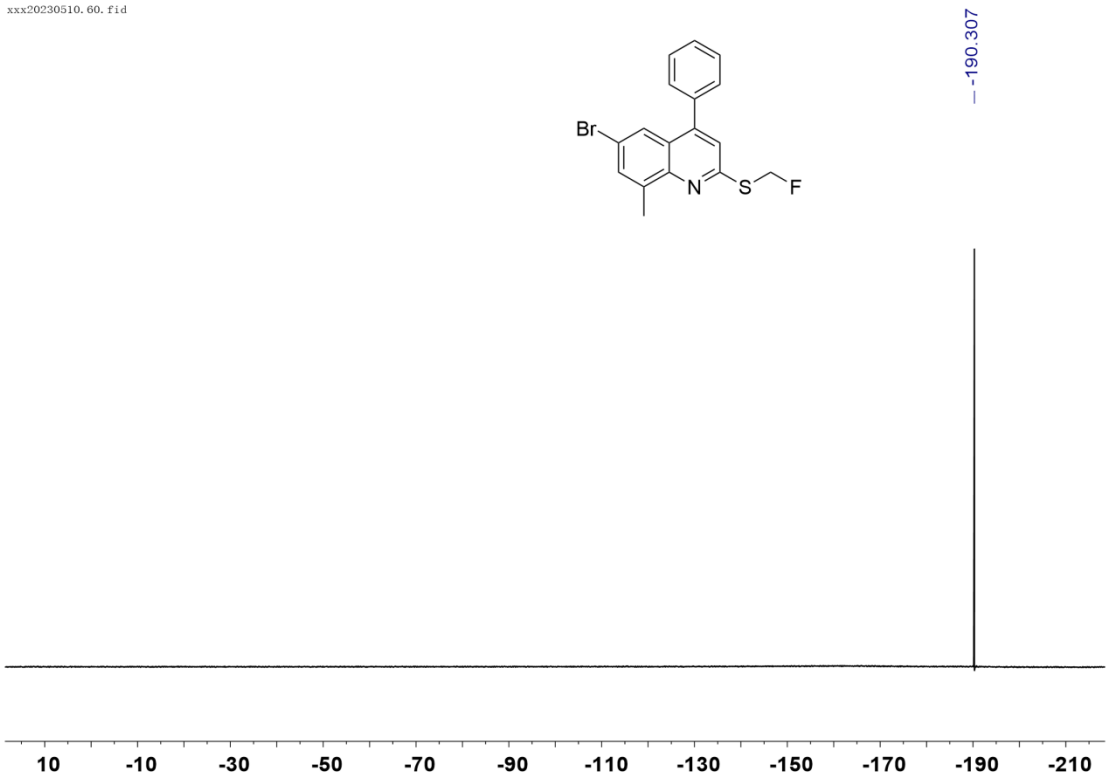
^{1}H NMR (400 MHz, $CDCl_3$) for **6e**



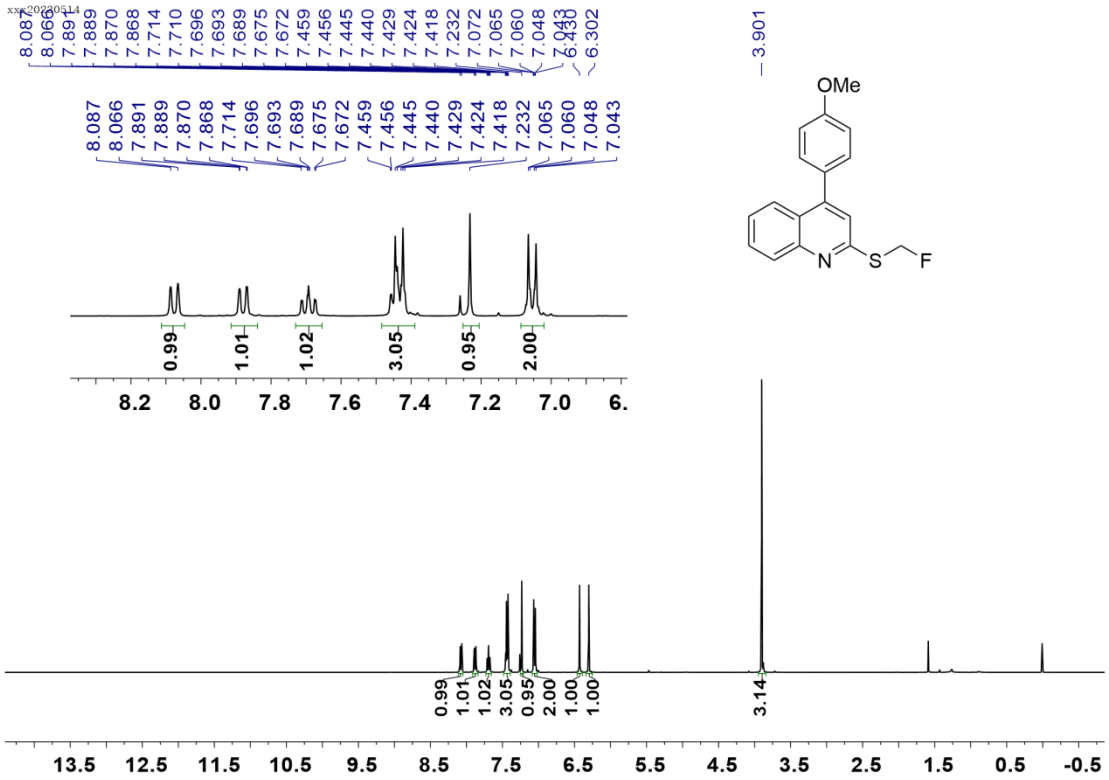
^{13}C NMR (100 MHz, $CDCl_3$) for **6e**



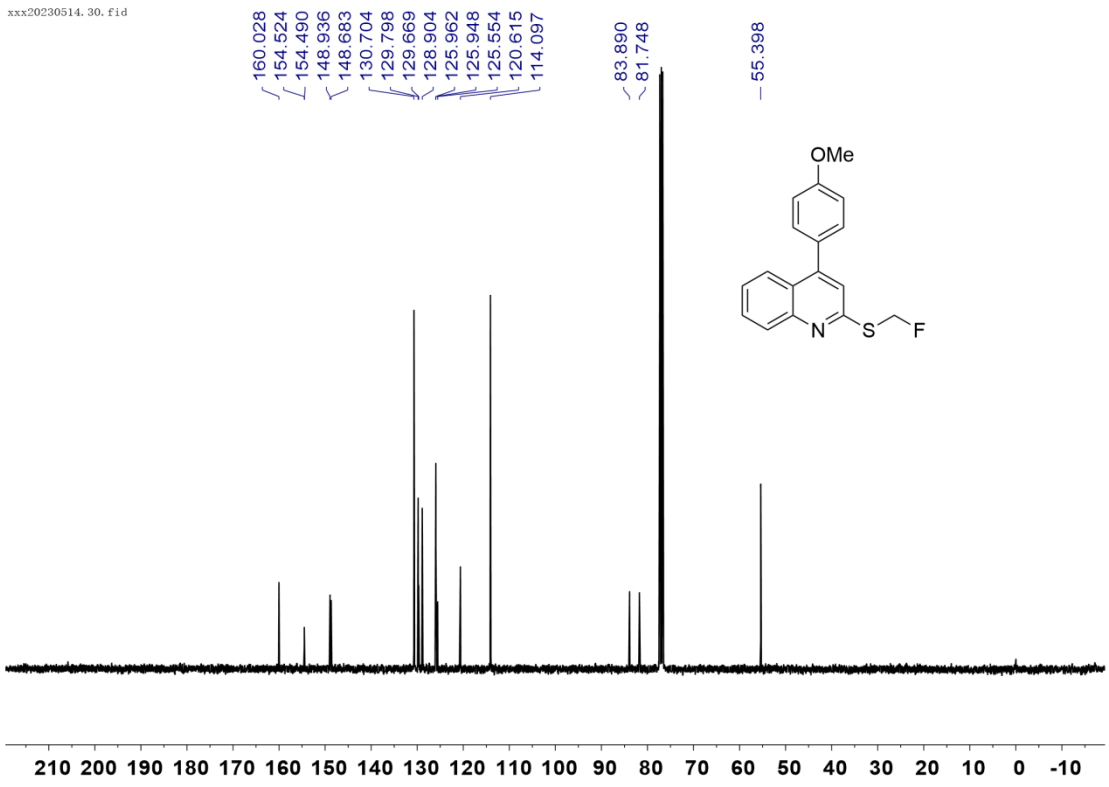
^{19}F NMR (376 MHz, $CDCl_3$) for **6e**



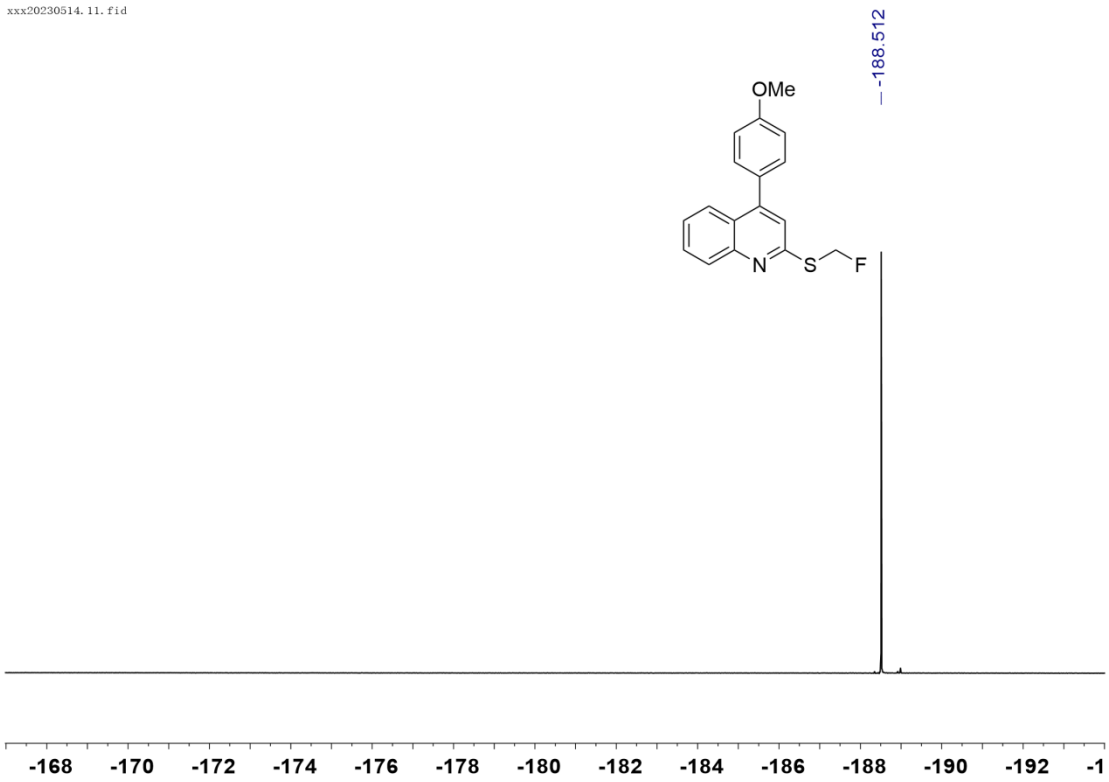
^{1}H NMR (400 MHz, $CDCl_3$) for **6f**



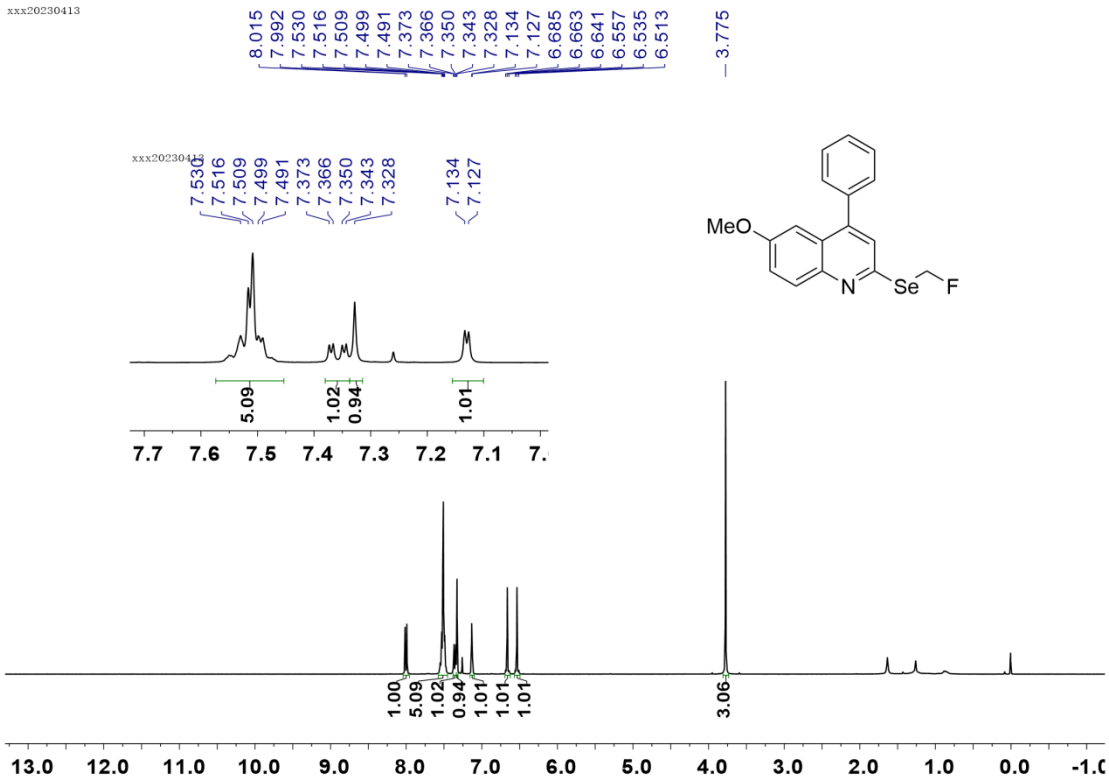
^{13}C NMR (100 MHz, $CDCl_3$) for **6f**



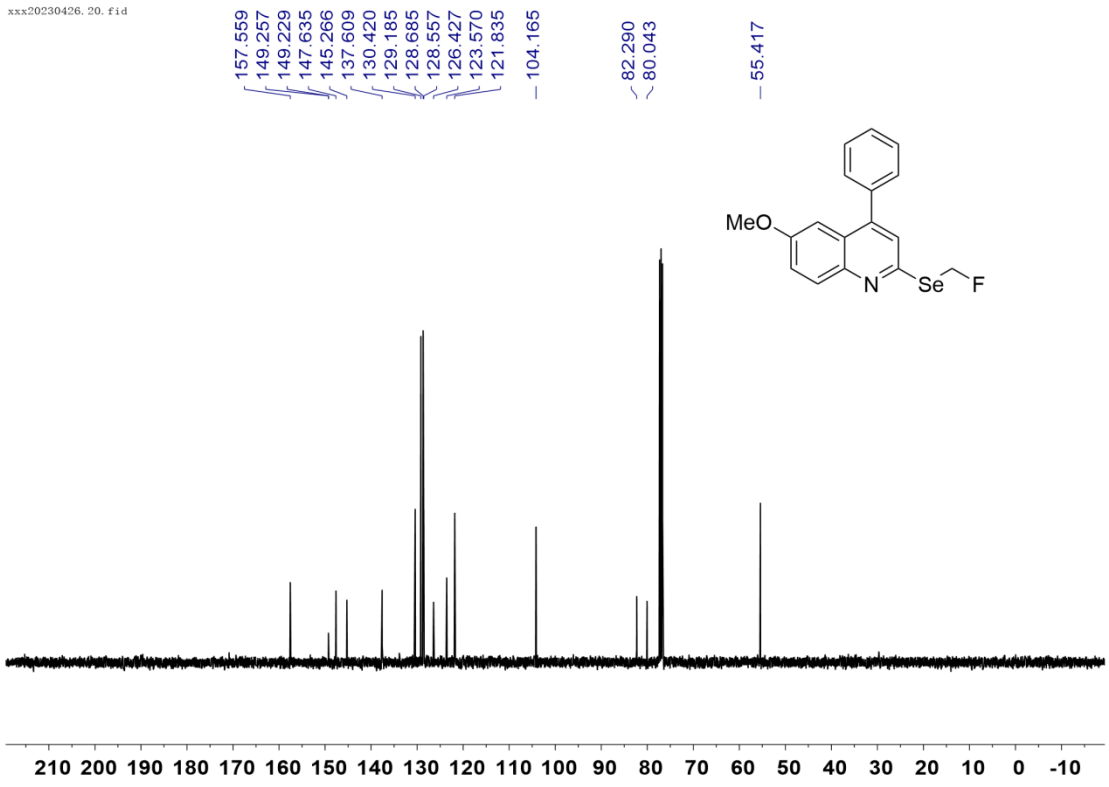
^{19}F NMR (376 MHz, $CDCl_3$) for **6f**



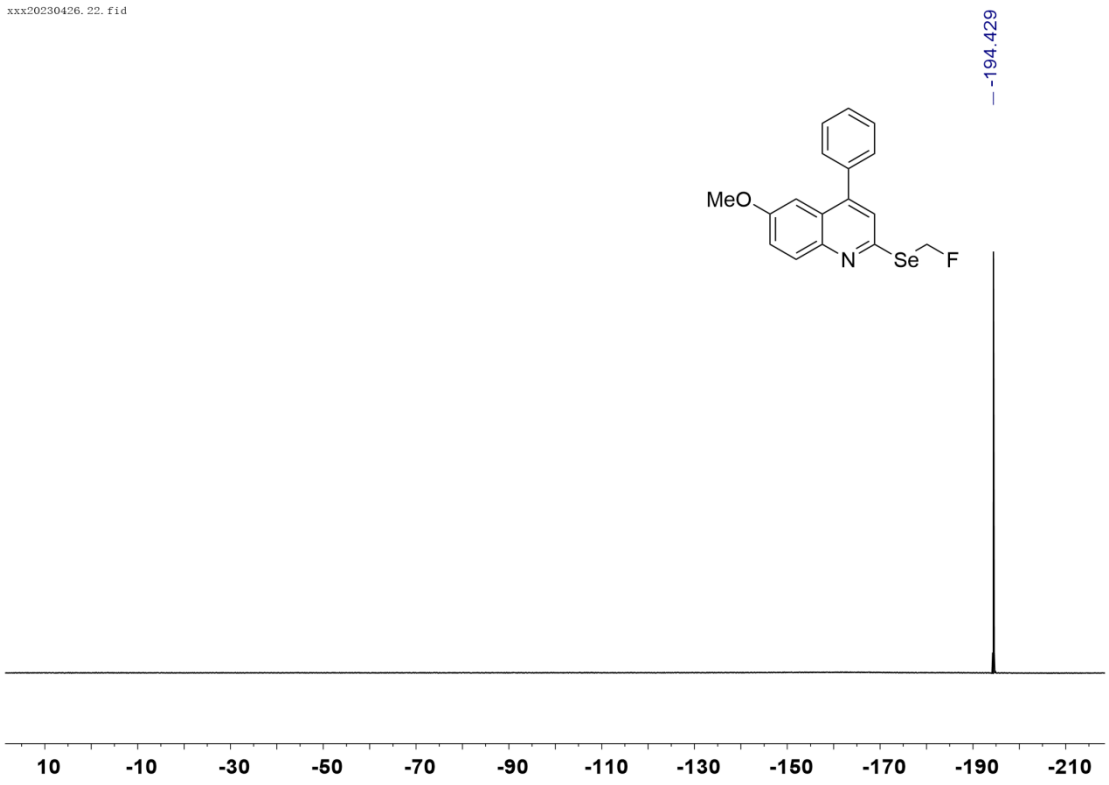
^{1}H NMR (400 MHz, $CDCl_3$) for **7a**



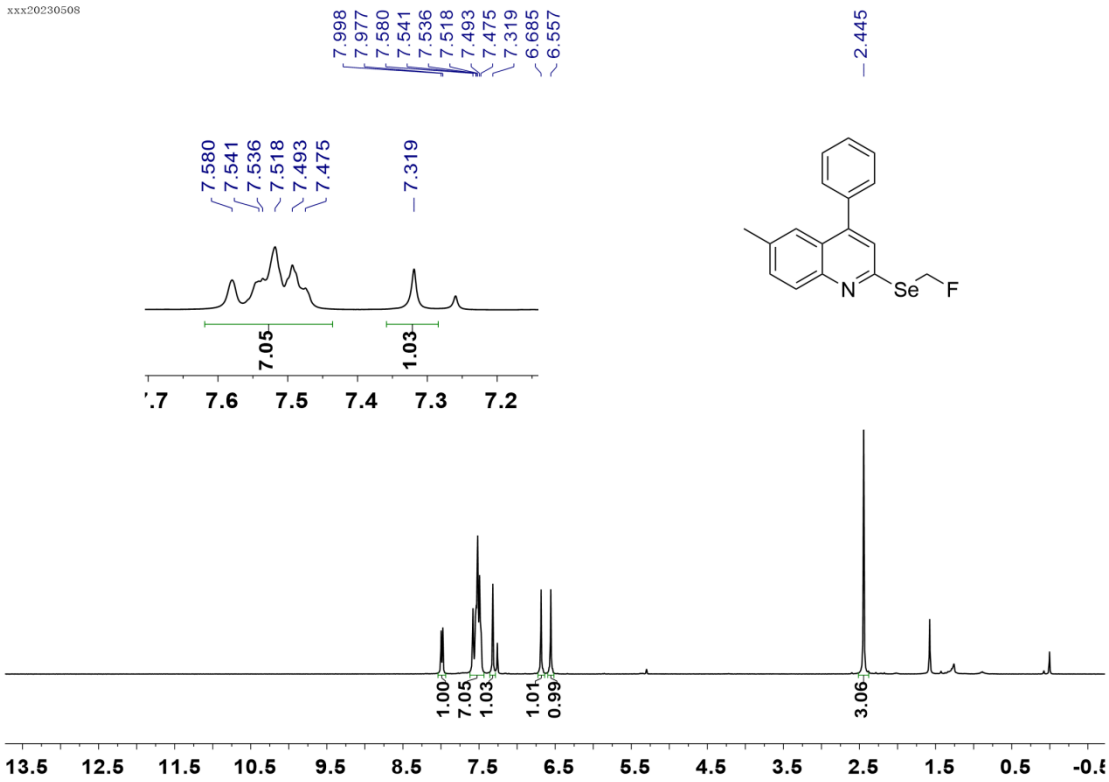
^{13}C NMR (100 MHz, $CDCl_3$) for **7a**



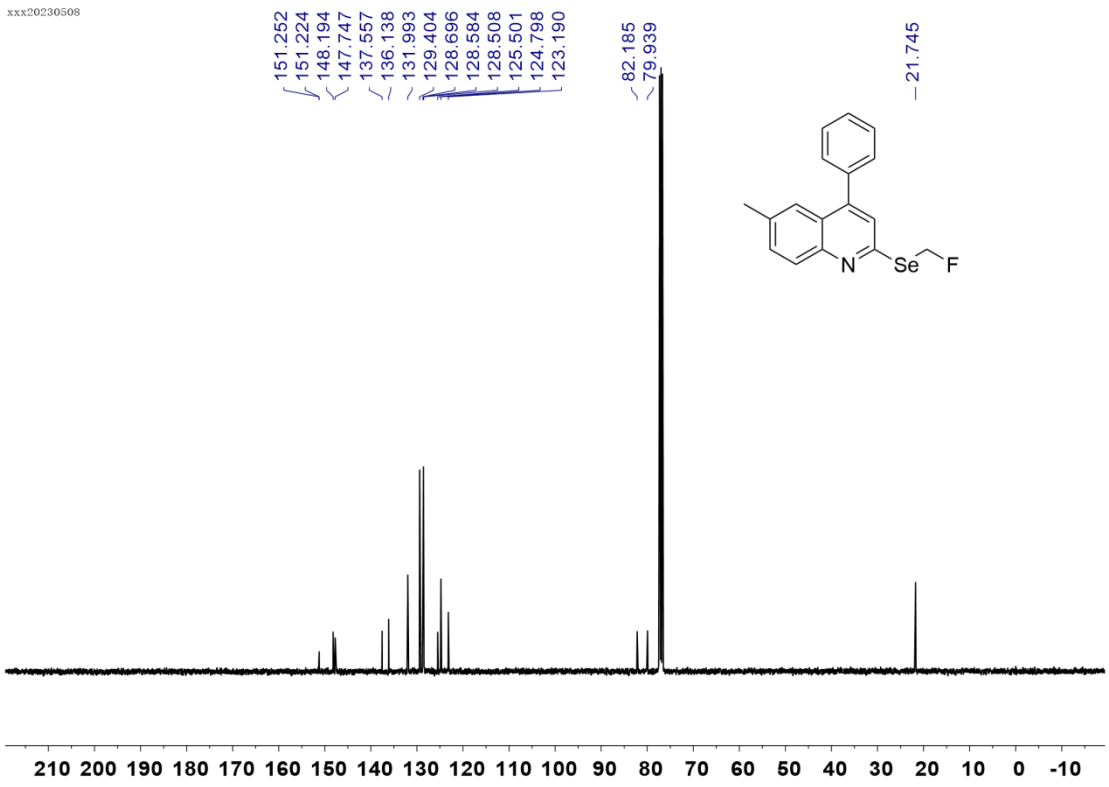
^{19}F NMR (376 MHz, $CDCl_3$) for **7a**



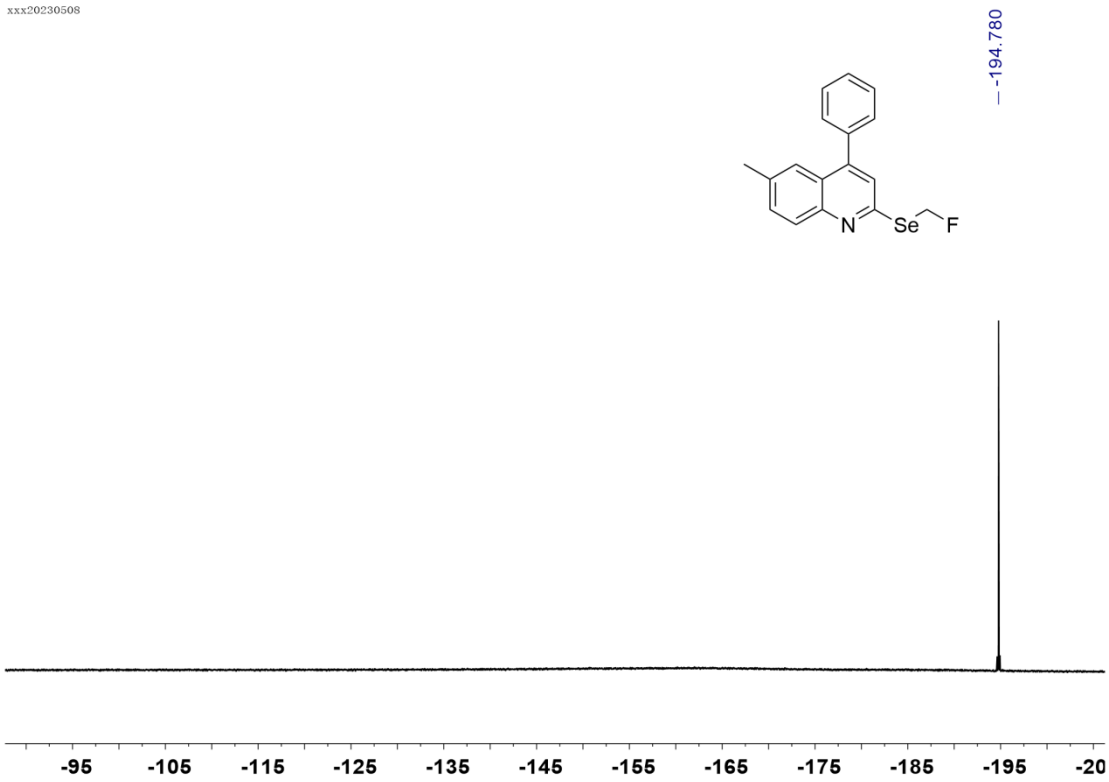
^{1}H NMR (400 MHz, $CDCl_3$) for **7b**



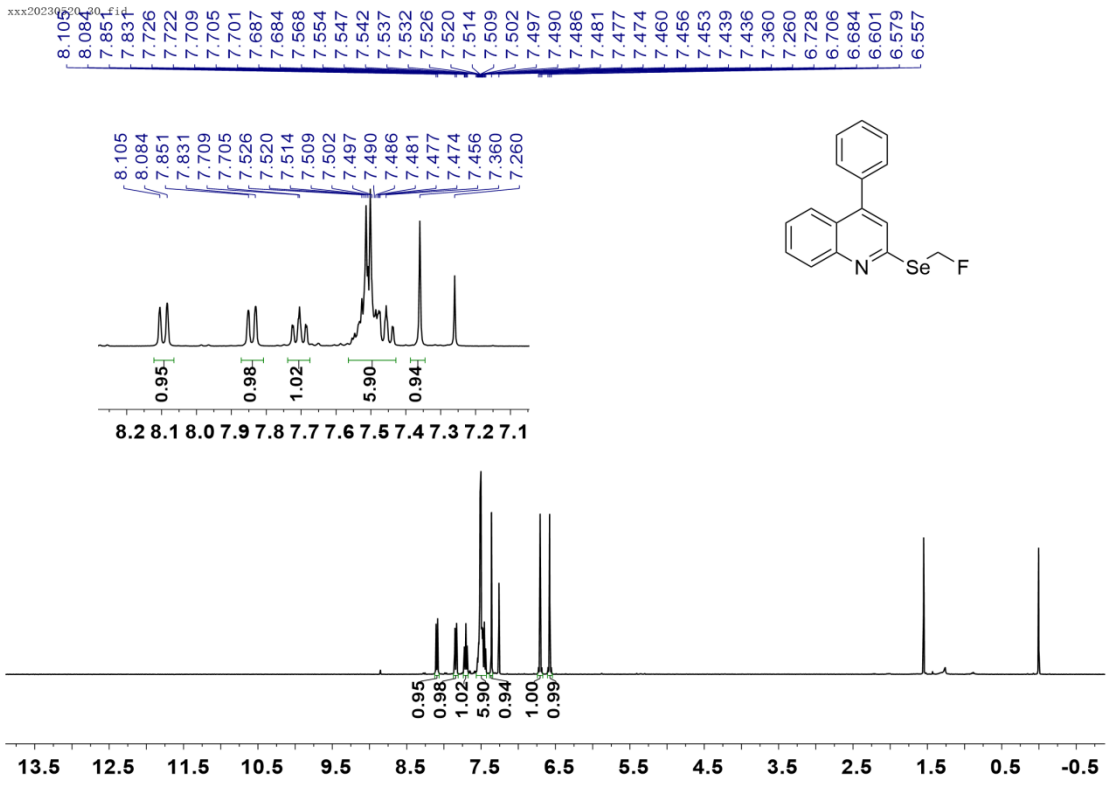
^{13}C NMR (100 MHz, $CDCl_3$) for **7b**



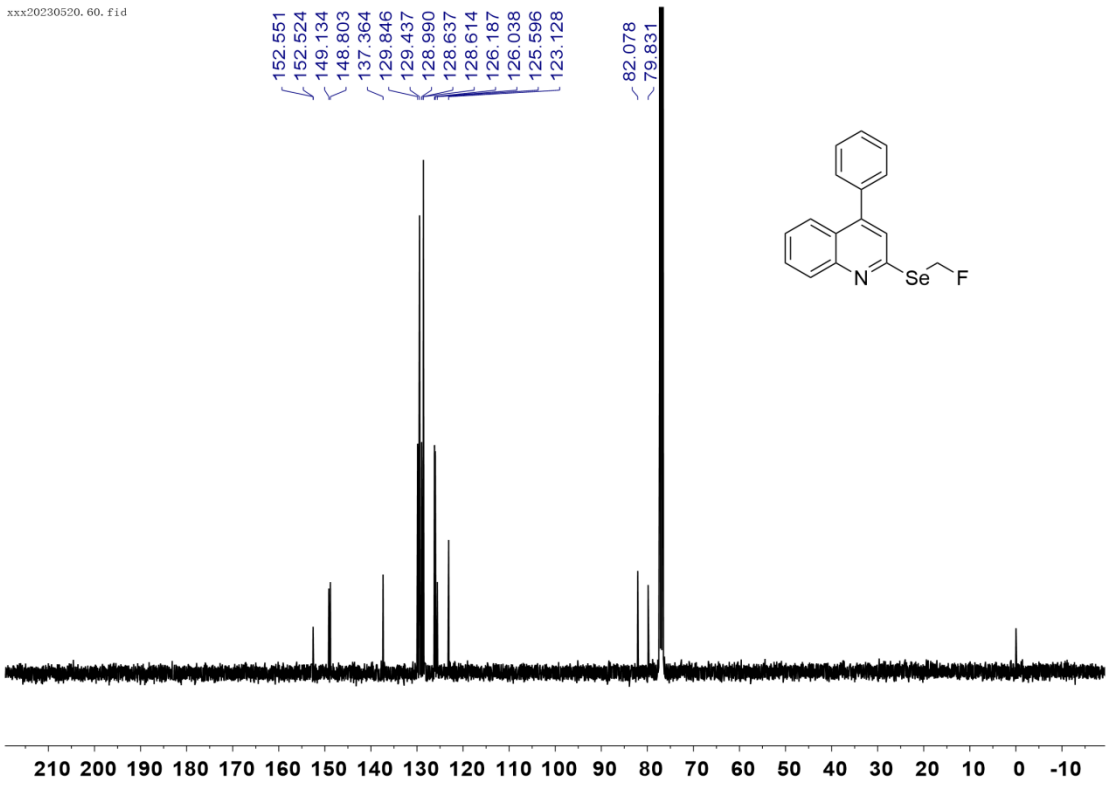
^{19}F NMR (376 MHz, $CDCl_3$) for **7b**



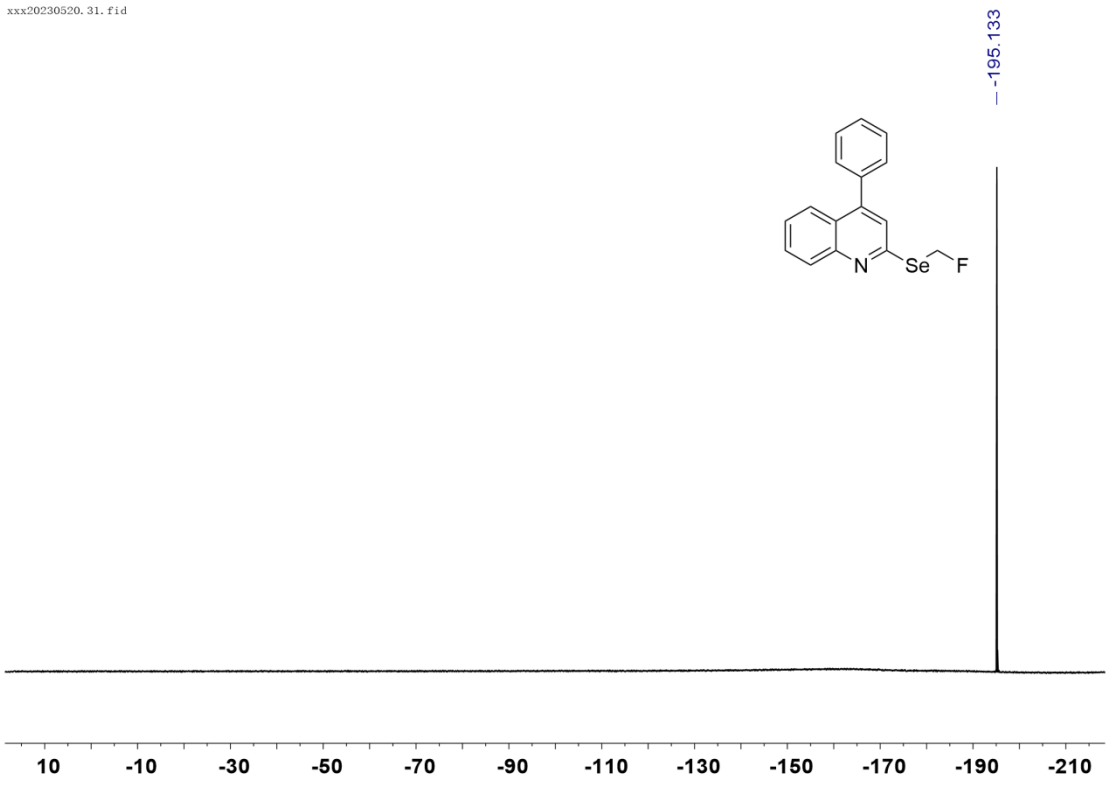
^{1}H NMR (400 MHz, $CDCl_3$) for **7c**



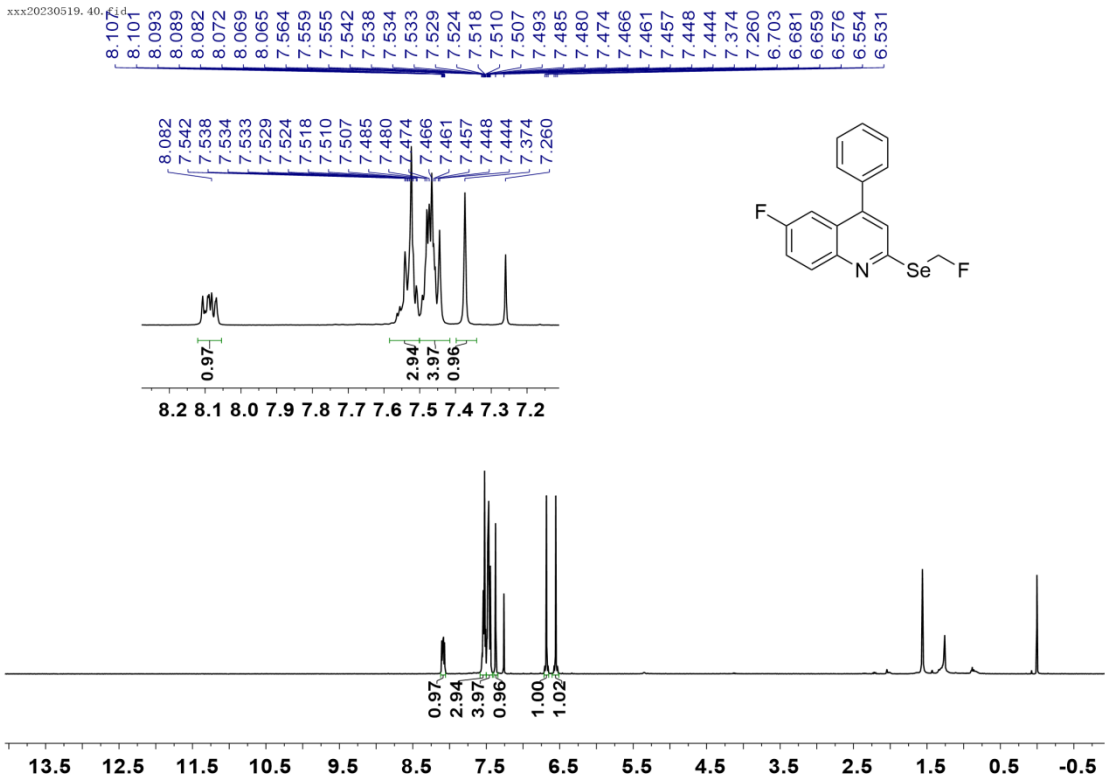
^{13}C NMR (100 MHz, $CDCl_3$) for **7c**



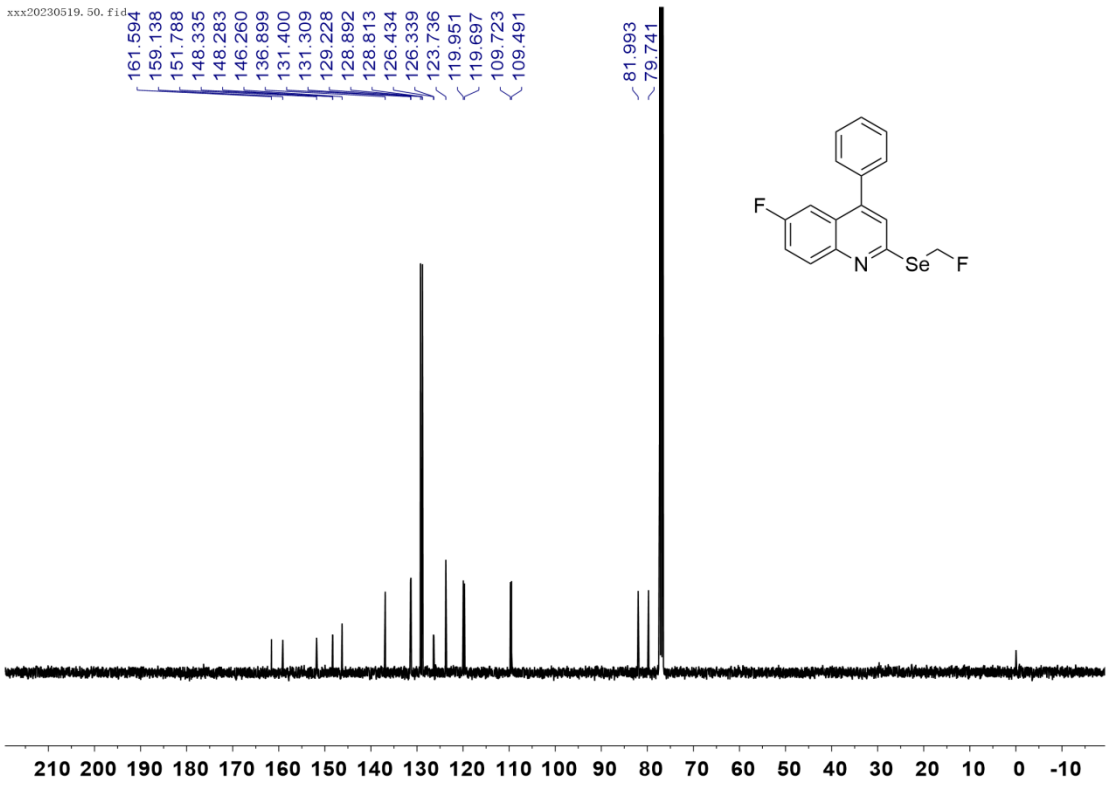
^{19}F NMR (376 MHz, $CDCl_3$) for **7c**



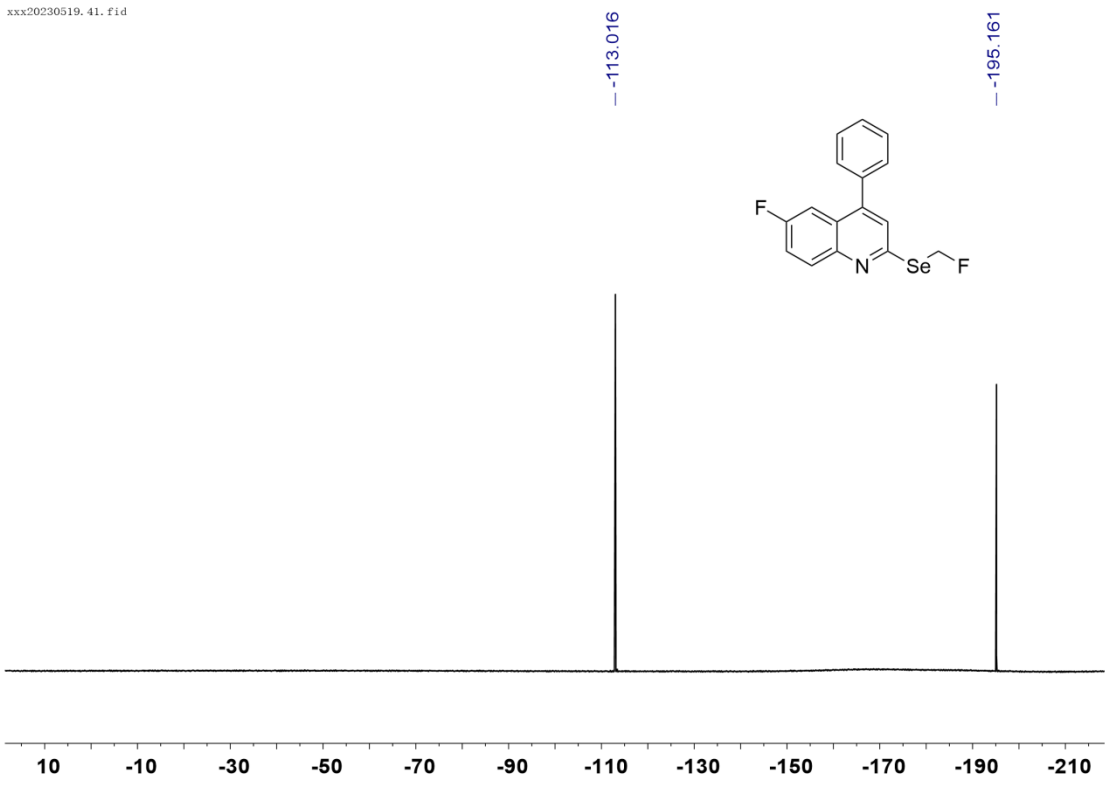
^{1}H NMR (400 MHz, $CDCl_3$) for **7d**



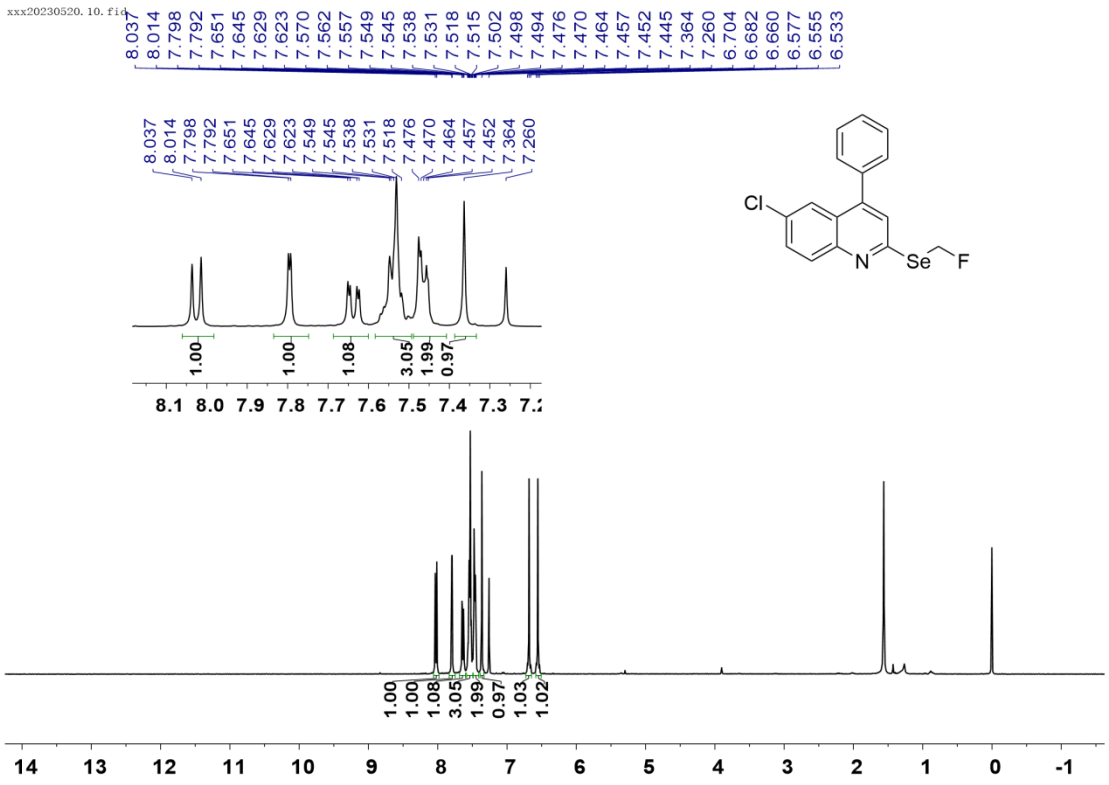
^{13}C NMR (100 MHz, $CDCl_3$) for **7d**



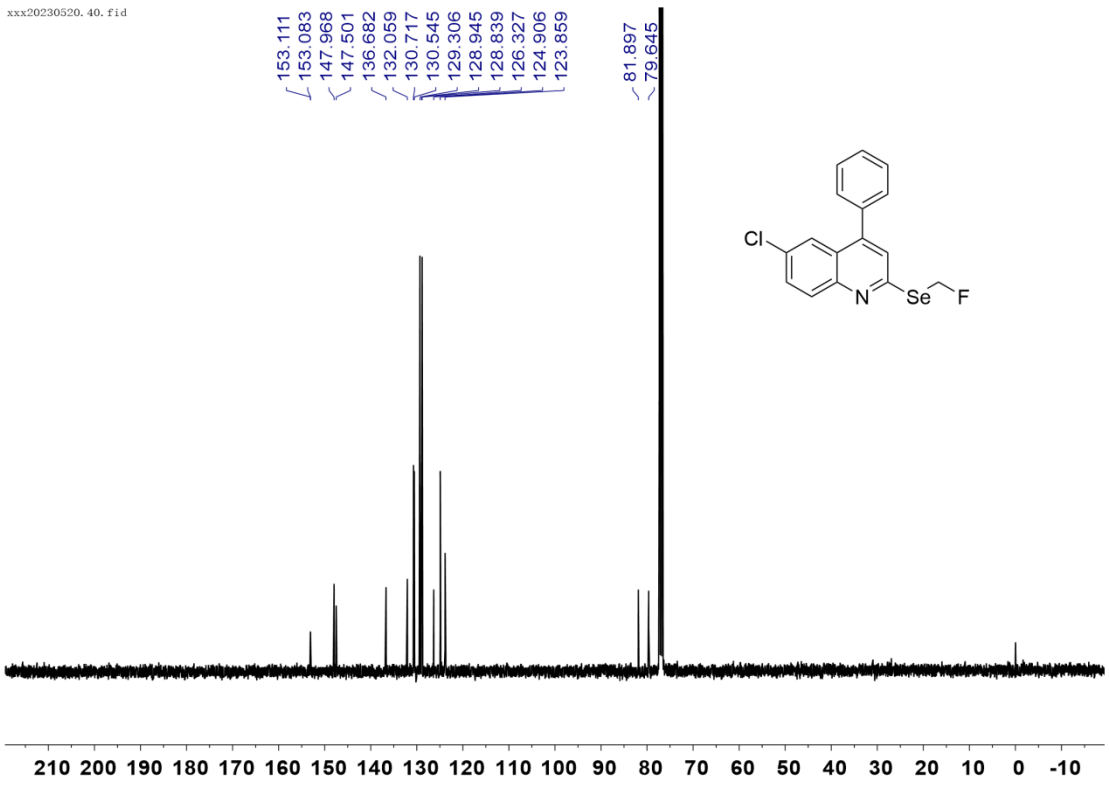
^{19}F NMR (376 MHz, $CDCl_3$) for **7d**



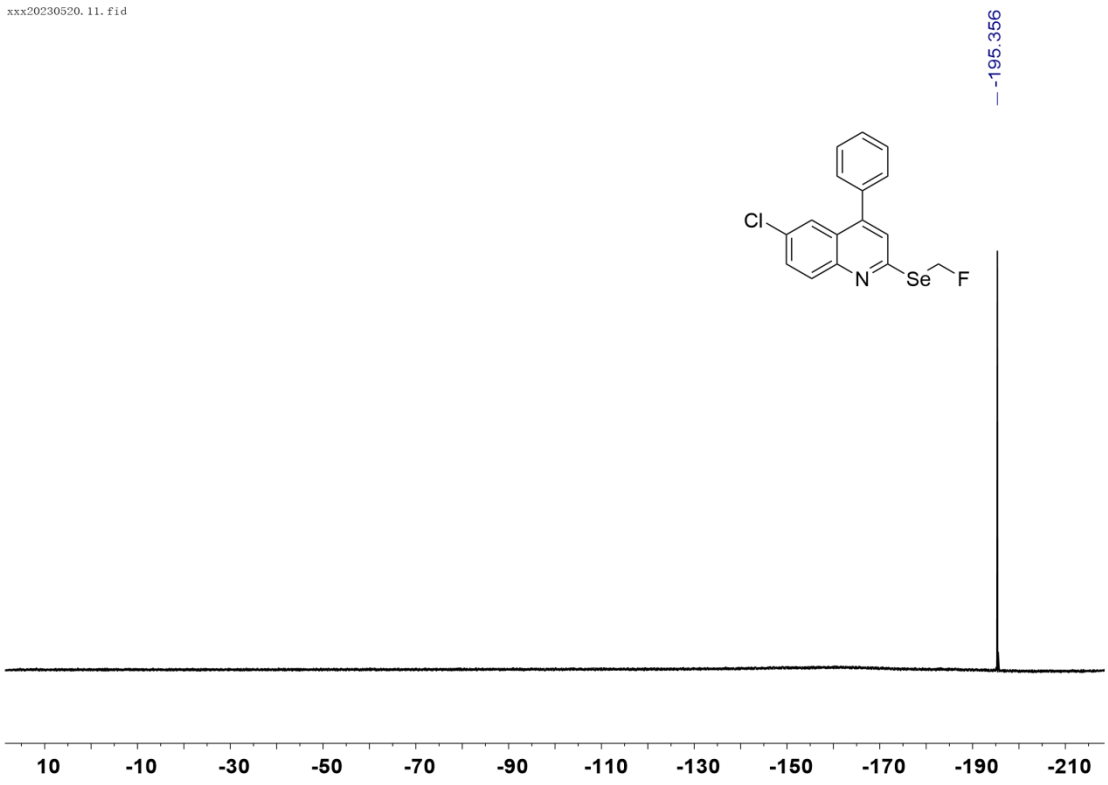
^{1}H NMR (400 MHz, $CDCl_3$) for **7e**



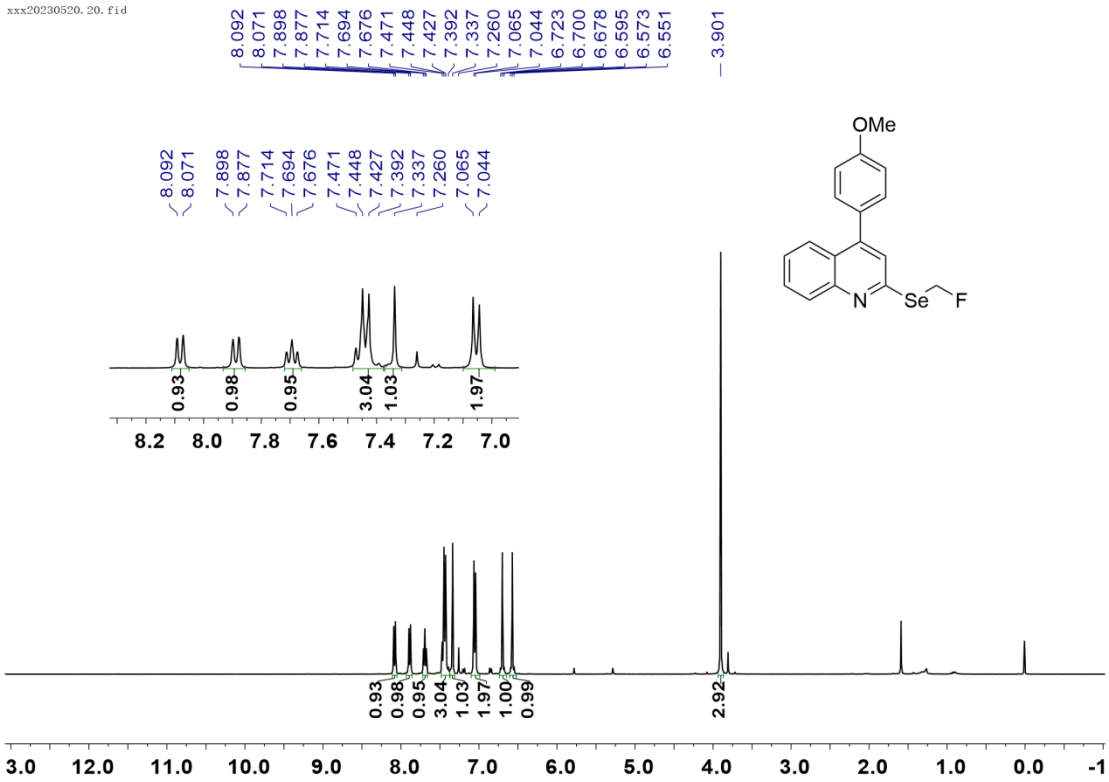
^{13}C NMR (100 MHz, $CDCl_3$) for **7e**



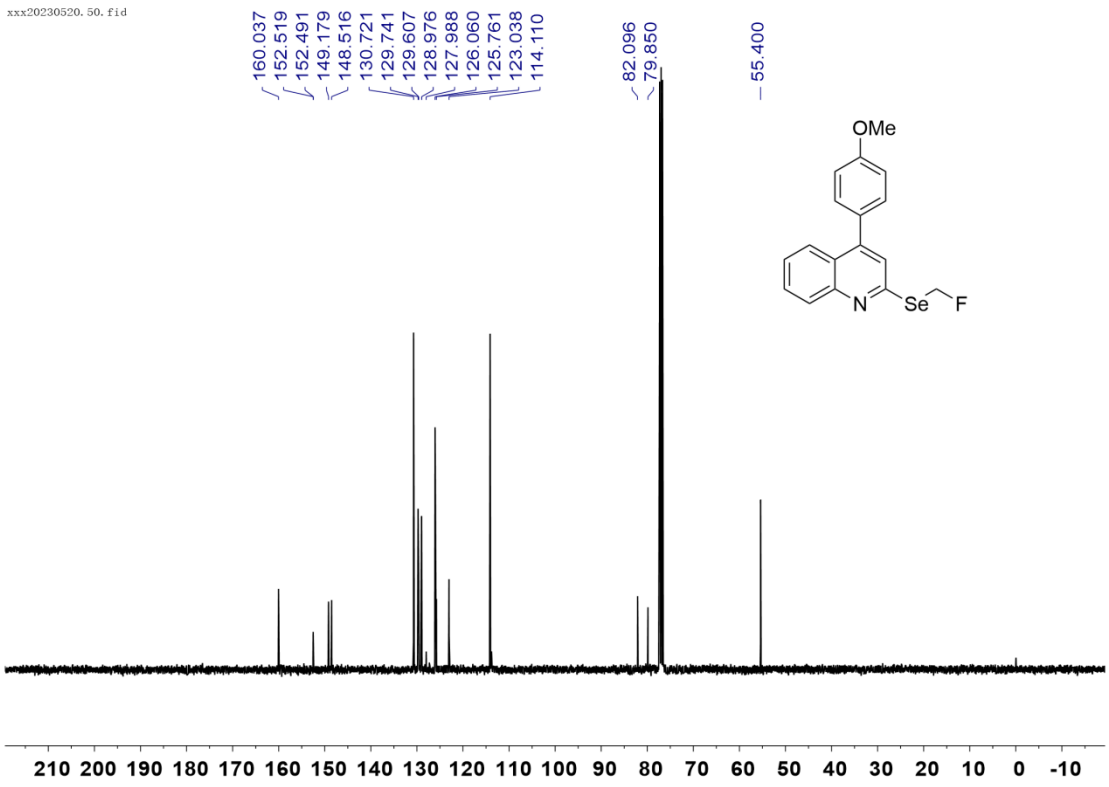
^{19}F NMR (376 MHz, $CDCl_3$) for **7e**



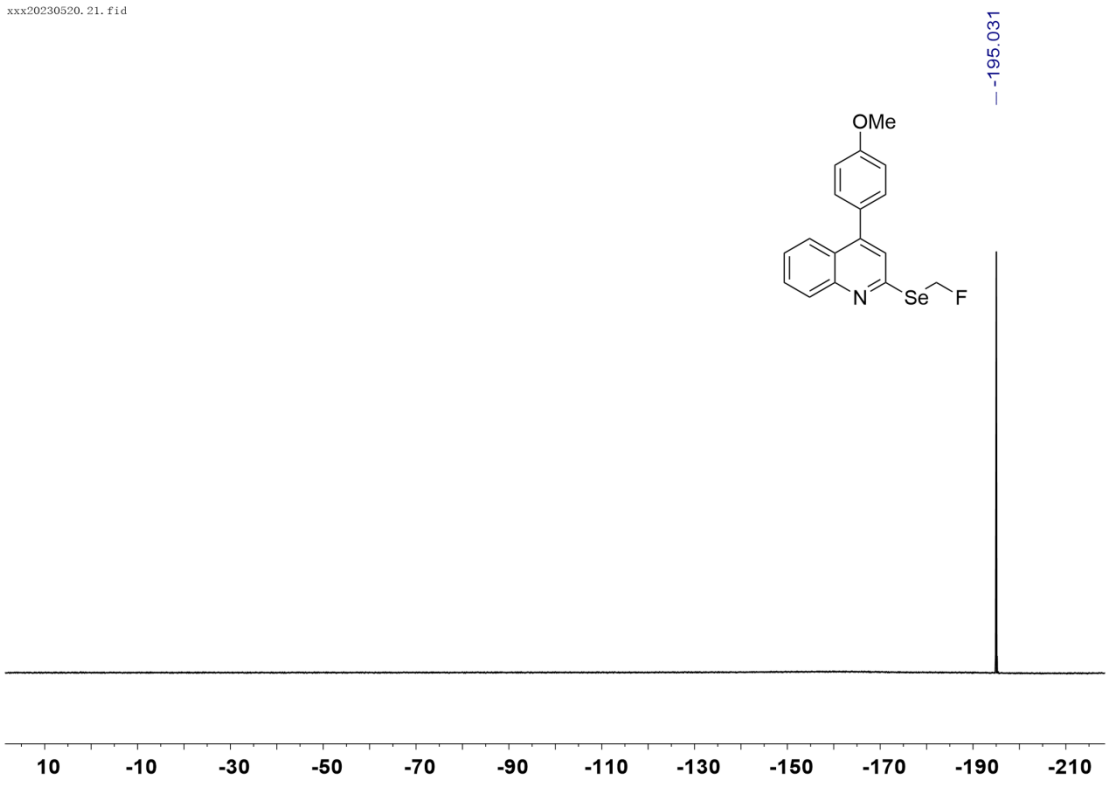
^{1}H NMR (400 MHz, $CDCl_3$) for **7f**



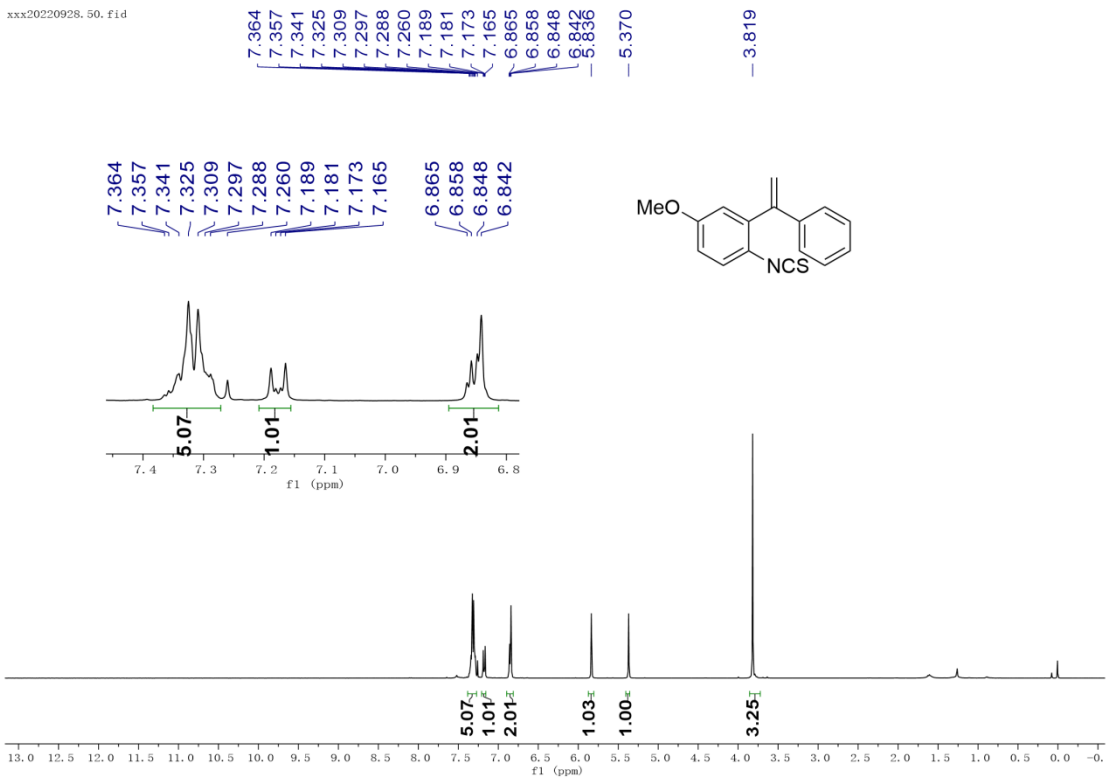
^{13}C NMR (100 MHz, $CDCl_3$) for **7f**



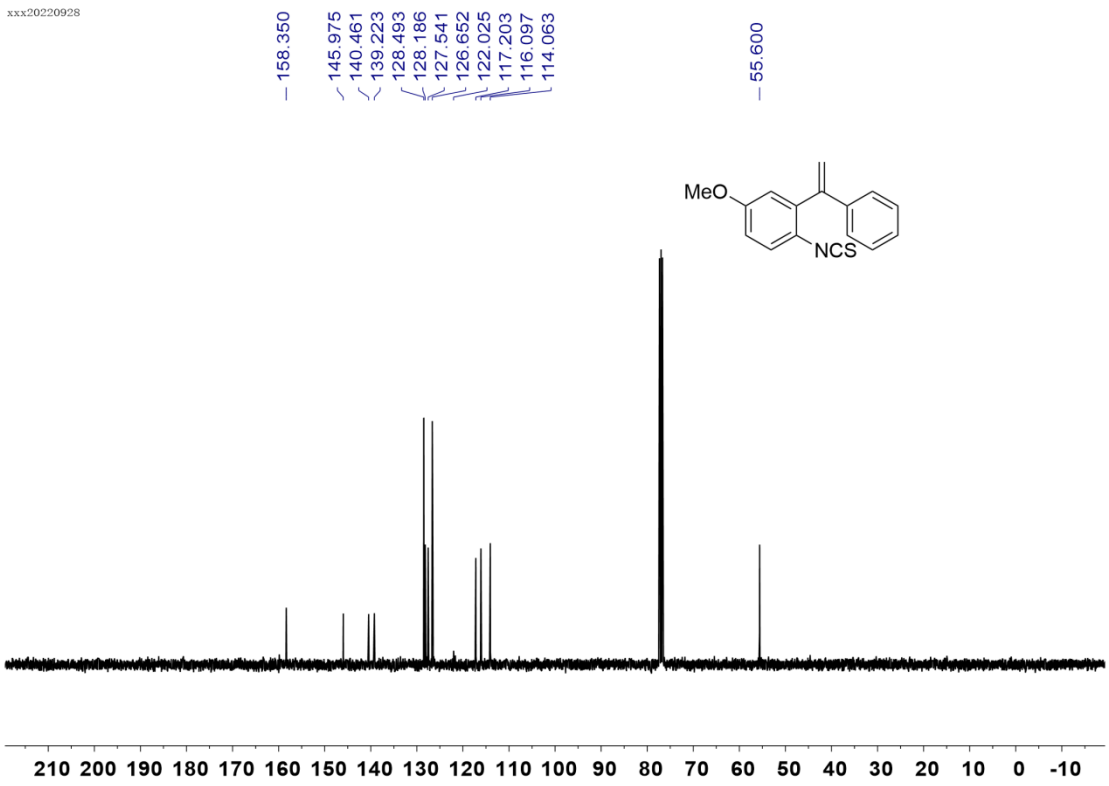
^{19}F NMR (376 MHz, $CDCl_3$) for **7f**



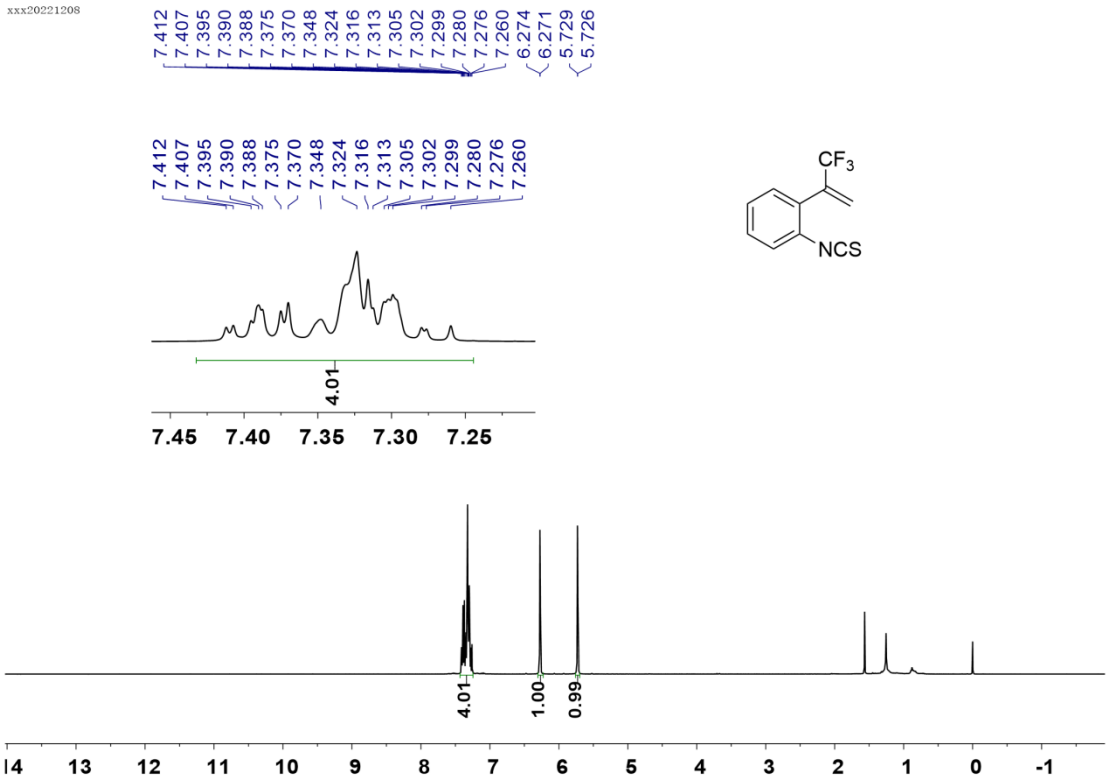
^{1}H NMR (400 MHz, $CDCl_3$) for **8a**



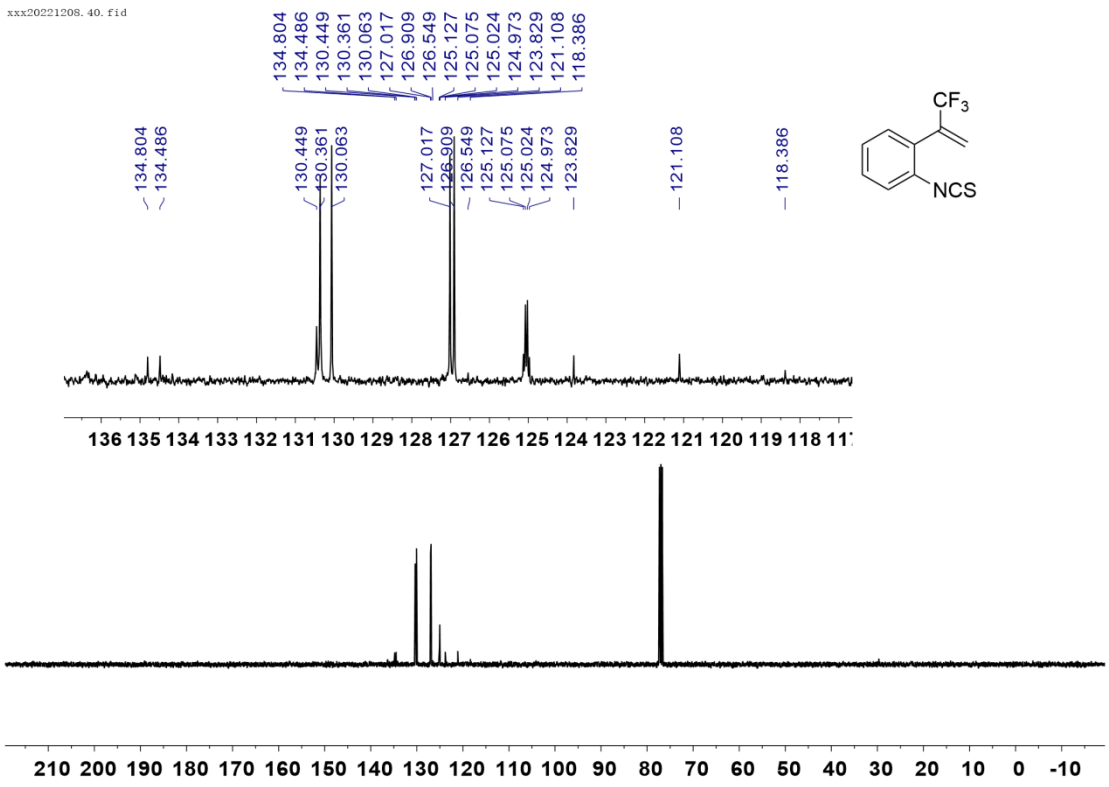
^{13}C NMR (100 MHz, $CDCl_3$) for **8a**



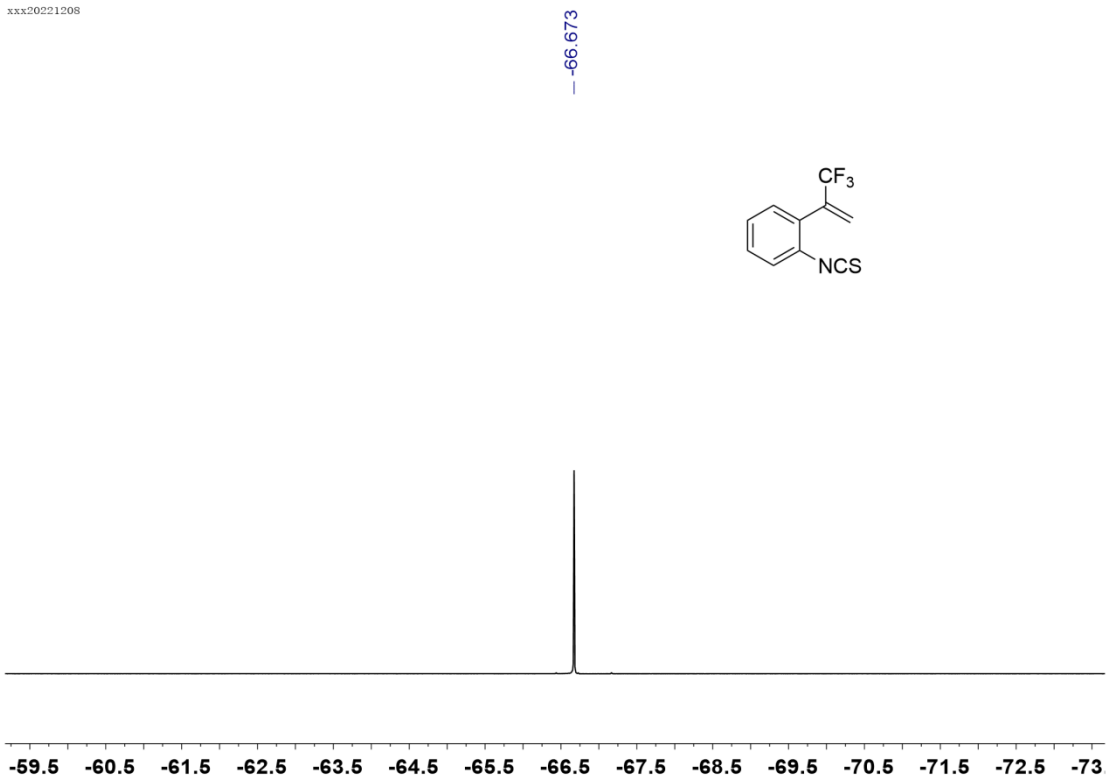
^{1}H NMR (400 MHz, $CDCl_3$) for **8t**



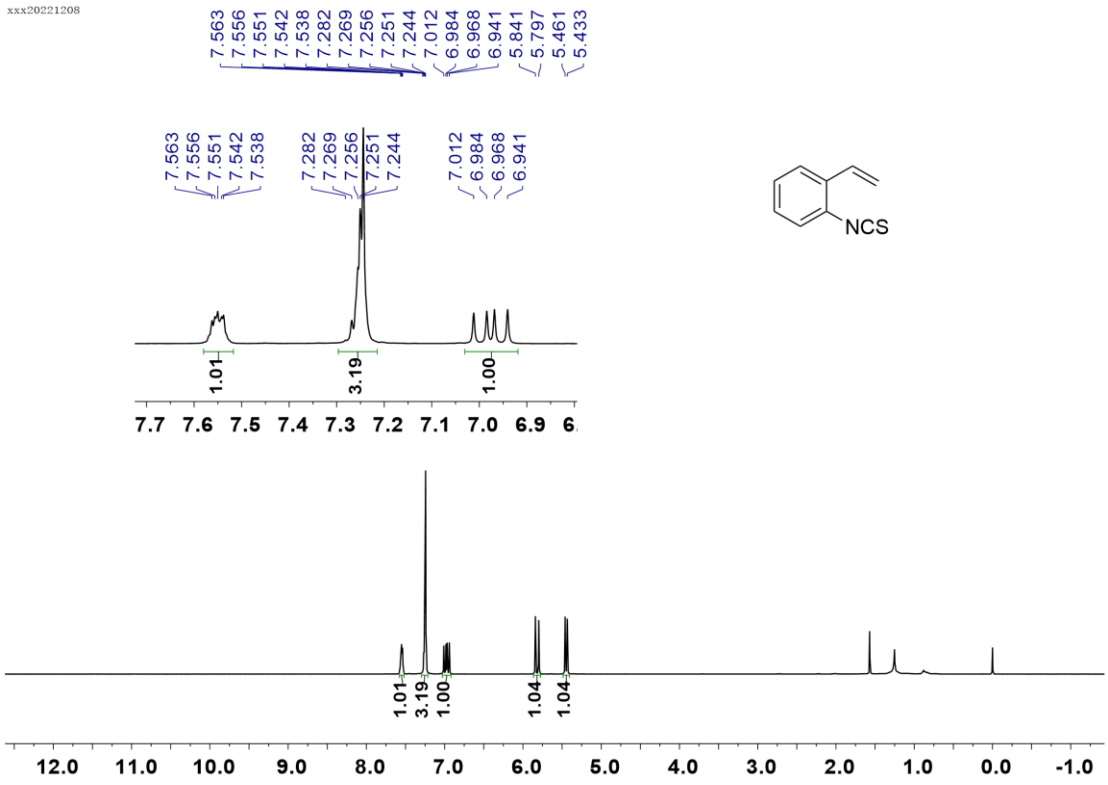
^{13}C NMR (100 MHz, $CDCl_3$) for **8t**



^{19}F NMR (376 MHz, $CDCl_3$) for **8t**



^{1}H NMR (400 MHz, $CDCl_3$) for **8u**



^{13}C NMR (100 MHz, $CDCl_3$) for **8u**