Supporting Information

The Silane-Promoted Cycloaddition of Thiobenzhydrazide with Carbon Dioxide toward 1,3,4-Thiadiazol-2(3*H*)-one

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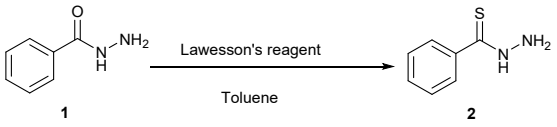
1. General Information

All reagents and solvents were purchased from TCI, Sigma-Aldrich, Alfa Aesar, Acros and Meryer. All reactions were conducted using standard Schlenk techniques. Column chromatography was performed using EM silica gel 60 (300 − 400 mesh). ^{1}H NMR and ^{13}C NMR spectra were measured on a 400 MHz Bruker AVANCE spectrometer, using DMSO-d_6 or $CDCl_3$ as the solvent with tetramethylsilane (TMS) as the internal standard at room temperature. Chemical shifts were reported in ppm. ^{1}H NMR spectra were referenced to DMSO-d_6 (2.50 ppm), where peak of water in DMSO-d_6 is 3.40-3.31 ppm, and 13C NMR spectra were referenced to DMSO-d_6 (39.5 ppm). Peak multiplicities were designated by the following abbreviations: s, singlet; d, doublet; t, triplet; m, multiplet; q, quartet. Chemical shifts are given in δ relative to TMS, the coupling constants J are given in Hz. Analysis of crude reaction mixture was done on the Varian 4000 GC/MS and Agilent 7890A/5975C. High-resolution mass spectra were recorded on a microTOF-Q II 10410 mass spectrometer. Unless otherwise noted, all reagents and solvents were obtained commercially and used without further purification. The thiobenzhydrazide[1] were prepared according to corresponding literature procedures.

2. General Experimental Procedures

General procedure (2a-2q, 3a-3q, 4, 5, 6, 7)

2.1 Synthesis of thiobenzhydrazide (2a-2q)[1].



Scheme S1

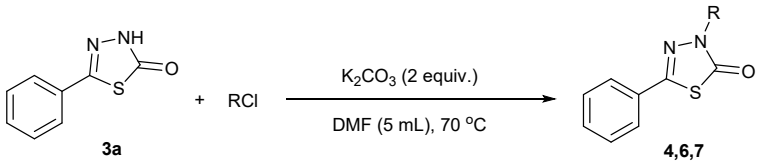
A solution in which benzohydrazide (1.36 g, 10 mmol) and Lawesson's reagent (4.04 g, 10 mmol) were dissolved in toluene (20 mL) at 100 °C was stirred overnight at the same temperature, and then the reaction was terminated by lowering the temperature to room temperature. Water was poured into the reaction mixture, and the mixture was extracted with ethyl acetate. The organic layer was washed with a saturated aqueous sodium chloride solution, dried over anhydrous magnesium sulfate, filtered, and concentrated under reduced pressure and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (V_1/V_2, 4:1) as the eluent to give the desired products (yield: 36% - 55%).

2.2 Synthesis of 5-phenyl-1,3,4-thiadiazol-2(3*H*)-one (3a-3q)

Scheme S2

A 20 mL Schlenk tube equipped with a stir bar was charged with thiobenzhydrazide (0.2 mmol, 1.0 equiv.), $HSi(OMe)_3$ (1.0 mmol, 5 equiv.), Na^tOBu (0.4 mmol, 2.0 equiv.) and DMF (2 mL). Then the Schlenk tube was charged with CO_2 (1 atm) three times. The tube was sealed with a PTFE cap. The reaction mixture was stirred at 140 °C for 24 h in oil bath. After the completion of the reaction, the mixture was directly evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (V_1/V_2, 15:1) as the eluent to give the desired products (yield: 53% - 98%).

2.3 Synthesis of compounds 4, 6 and 7.

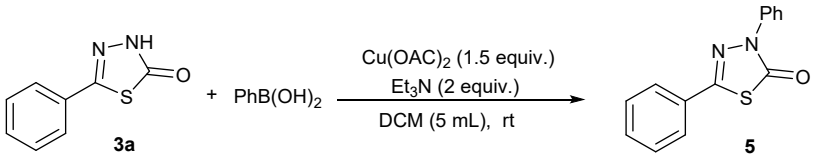


RCl = chloroethane, ethyl 2-chloropropionate, propargyl chloride

Scheme S3

To a solution of compound **3a** (1.0 equiv.) in DMF (5 mL) at room temperature under nitrogen was added K_2CO_3 (2.0 equiv.), followed by substituted halide (1.2 equiv.). The reaction mixture was stirred at 70 °C for 10 min. After the reaction mixture was cooled to room temperature, water (10 mL) and EtOAc (20 mL) were added. The layers were separated. The organic layer was dried with $MgSO_4$. The crude product was directly evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (V_1/V_2, 30:1) as the eluent to give the desired products (yield: 60% - 96%).[2]

2.4 Synthesis of compound 5.

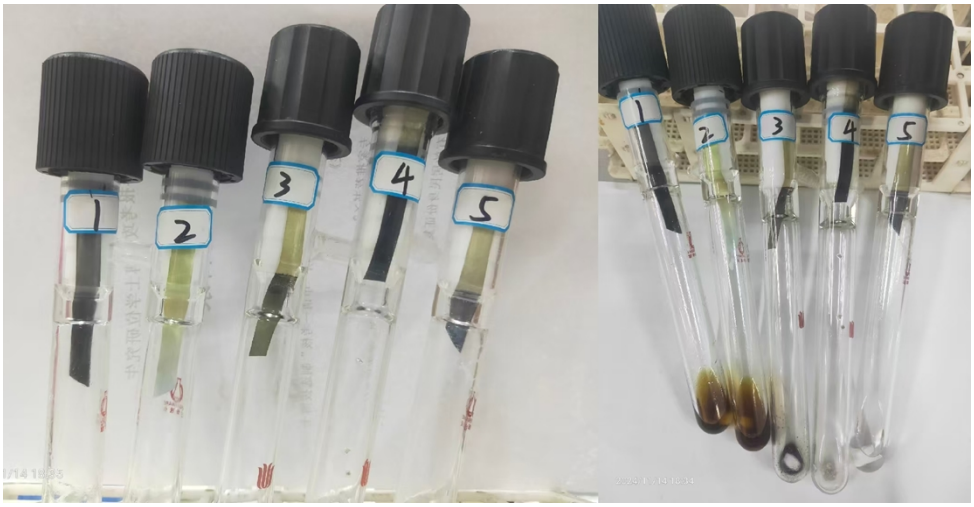


Scheme S4

5-Phenyl-1,3,4-thiadiazol-2(3*H*)-one (0.26 mmol, 1.0 equiv.), the aryl boronic compound (0.52mmol, 2.0 equiv.), copper (II) acetate (0.52 mmol, 2.0 equiv.) and triethylamine (0.52 mmol, 1.0 equiv.) were dissolved in dichloromethane (5mL) along with 20 mg of activated 4Å molecular sieves and allowed to stir at room temperature for up to 20 hours. The reaction mixture was then subjected to an appropriate aqueous workup (usually partitioning between 1M HCl and ethyl acetate), and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (V_1/V_2, 25:1) as the eluent to give the desired products (yield: 61%).

3. Mechanism study

A small piece of paper soaked with the solution of molybdophosphoric acid/$PdCl_2$ is sensitive to reducing gas, such as H_2. [2]



Scheme S5

Table **S1** Detection of H_2 by indicator paper [a]

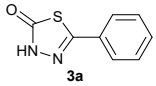
Entry	thiobenzhydrazide (0.2 mmol)	silane (1.0 mmol)	DMF(2 mL)	Rose-red
1	√	√	√	++++
2	√	×	√	-
3	√	√	×	+
4	H_2			+++++
5	×	√	√	+

[a] Reaction conditions: thiobenzhydrazide **1a** (0.2 mmol), NaO^{t}Bu (0.4 mmol), DMF (2.0 mL), $HSi(OMe)_3$ (1 mmol). The number of "+" represents the intensity of positive reactions.

Under standard conditions, gas is released during the addition of reactants, which causes the test paper to turn black (Entry 1). Under the same conditions, no gas is produced without silane, and the test paper has no obvious change (Entry 2). When DMF comes into contact with silane, the test paper will also slowly turn gray and then black (Entry 5). When the thiobenzhydrazide and silane are in direct contact, the test paper will turn black (Entry 3). The test paper appeared black, which proved the existence of H_2 (Entry 4).

4. Characterization of Products in Details

5-Phenyl-1,3,4-thiadiazol-2(3*H*)-one (3a)

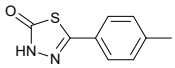


3a

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (32.8 mg, 92%), Melting Point: 141.6 – 142.8 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.10 (s, 1H), 7.70 – 7.67 (m, 2H), 7.51 – 7.50 (m, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 151.4, 130.8, 130.6, 129.2, 125.7. HRMS: (ESI) calculated for

$C_8H_6N_2OSNa$ $[M+Na]^+$ 201.0093, found 201.0095.

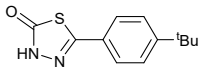
5-(4-Methylphenyl)-1,3,4-thiadiazol-2(3*H*)-one (3b)



3b

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (31.9 mg, 83%), Melting Point: 177.2 – 177.9 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.03 (s, 1H), 7.58 (d, *J* = 8.0 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 2.35 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 151.4, 140.8, 129.8, 127.9, 125.6, 20.9. HRMS: (ESI) calculated for $C_9H_9N_2OS$ $[M+H]^+$ 193.0430, found 193.0423.

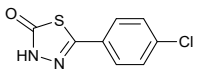
5-[4-(1,1-Dimethylethyl)phenyl]-1,3,4-thiadiazol-2(3*H*)-one (3c)



3c

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (43.4 mg, 93%), Melting Point: 69.7 – 72.8 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.02 (s, 1H), 7.61 (d, *J* = 8.4 Hz, 2H), 7.52 (d, *J* = 8.4 Hz, 2H), 1.29 (s, 9H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 153.7, 151.4, 127.9, 126.0, 125.5, 34.6, 30.8. HRMS: (ESI) calculated for $C_{12}H_{15}N_2OS$ $[M+H]^+$ 235.0900, found 235.0898.

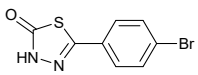
5-(4-Chlorophenyl)-1,3,4-thiadiazol-2(3*H*)-one (3d)



3d

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (40.2 mg, 95%), Melting Point: 194.3 – 194.8 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.17 (s, 1H), 7.71 (d, *J* = 8.8 Hz, 2H), 7.57 (d, *J* = 8.8 Hz, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.1, 150.2, 135.3, 129.4, 129.3, 127.4. HRMS: (ESI) calculated for $C_8H_6ClN_2OS$ $[M+H]^+$ 212.9884, found 212.9881.

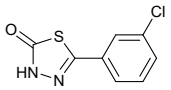
5-(4-Bromophenyl)-1,3,4-thiadiazol-2(3*H*)-one (3e)



3e

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow oil (27.3 mg, 53%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.20 (s, 1H), 7.71 (d, *J* = 8.8 Hz, 2H), 7.64 (d, *J* = 8.8 Hz, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.1, 150.4, 132.2, 129.8, 127.6, 124.1. HRMS: (ESI) calculated for $C_8H_5BrN_2OSNa$ $[M+Na]^+$ 278.9198, found 278.9190.

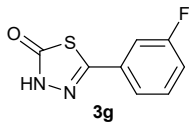
5-(3-Chlorophenyl)-1,3,4-thiadiazol-2(3*H*)-one (3f)



3f

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a white solid (39.9 mg, 94%), Melting Point: 179.1 – 180.0 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.25 (s, 1H), 7.71 (s, 1H), 7.64 (d, *J* = 7.6 Hz, 1H), 7.59 – 7.57 (m, 1H), 7.55 – 7.51 (m, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.1, 149.9, 134.0, 132.5, 131.2, 130.5, 125.0, 124.5. HRMS: (ESI) calculated for $C_8H_6ClN_2OS$ $[M+H]^+$ 212.9884, found 212.9884.

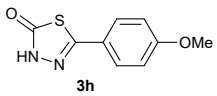
5-(3-Fluorophenyl)-1,3,4-thiadiazol-2(3*H*)-one (3g)



3g

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (34.8 mg, 89%), Melting Point: 159.9 – 161.3 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.23 (s, 1H), 7.58 – 7.51 (m, 3H), 7.39 – 7.35 (m, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.1, 162.3 (d, $J_{C\text{-}F}$ = 245.7 Hz), 150.1, 132.7 (d, $J_{C\text{-}F}$ = 8.3 Hz), 131.5 (d, $J_{C\text{-}F}$ = 8.7 Hz), 122.1 (d, $J_{C\text{-}F}$ = 3.8 Hz), 117.6 (d, $J_{C\text{-}F}$ = 21.4 Hz), 112.2 (d, $J_{C\text{-}F}$ = 23.9 Hz). **^{19}F NMR** (471 MHz, DMSO-d_6) δ -111.8. HRMS: (ESI) calculated for $C_8H_5FN_2OSNa$ $[M+Na]^+$ 218.9999, found 218.9989.

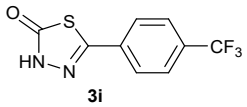
5-(4-Methoxyphenyl)-1,3,4-thiadiazol-2(3*H*)-one (3h)



3h

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (39.1 mg, 94%), Melting Point: 159.9 – 162.1 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.94 (s, 1H), 7.62 (d, *J* = 8.8 Hz, 2H), 7.04 (d, *J* = 8.8 Hz, 2H), 3.81 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 161.2, 151.2, 127.3, 123.2, 114.6, 55.4. HRMS: (ESI) calculated for $C_9H_9N_2O_2S$ $[M+H]^+$ 209.0379, found 209.0385.

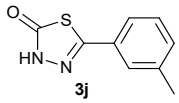
5-[4-(Trifluoromethyl)phenyl]-1,3,4-thiadiazol-2(3*H*)-one (3i)



3i

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (45.9 mg, 93%), Melting Point: 189.5 – 190.9 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.34 (s, 1H), 7.90 (d, *J* = 8.4 Hz, 2H), 7.86 (d, *J* = 8.4 Hz, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.1, 149.9, 134.2, 130.3 (q, $J_{C\text{-}F}$ = 31.5 Hz), 126.5, 126.2 (q, $J_{C\text{-}F}$ = 3.8 Hz), 123.8 (q, $J_{C\text{-}F}$ = 272.2 Hz). **^{19}F NMR** (471 MHz, DMSO-d_6) δ -61.4. HRMS: (ESI) calculated for $C_9H_6F_3N_2OS$ $[M+H]^+$ 247.0148, found 247.0146.

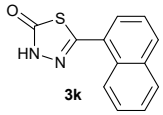
5-(3-Methylphenyl)-1,3,4-thiadiazol-2(3*H*)-one (3j)



3j

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (23.6 mg, 61%), Melting Point: 130.2 – 131.0 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.08 (s, 1H), 7.49 (d, *J* = 8.8 Hz, 2H), 7.40 – 7.38 (m, 1H), 7.32 (d, *J* = 7.2 Hz, 1H), 2.36 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 151.5, 138.7, 131.5, 130.5, 129.1, 126.1, 122.9, 20.8. HRMS: (ESI) calculated for $C_9H_9N_2OS$ $[M+H]^+$ 193.0430, found 193.0427.

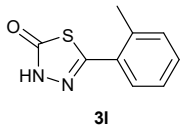
5-(1-Naphthalenyl)-1,3,4-thiadiazol-2(3*H*)-one (3k)



3k

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a brown solid (39.2 mg, 86%), Melting Point: 149.1 – 152.4˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.27 (s, 1H), 8.61 (d, *J* = 8.0 Hz, 1H), 8.10 (d, *J* = 8.0 Hz, 1H), 8.05 (d, *J* = 7.2 Hz, 1H), 7.73 (d, *J* = 7.2 Hz, 1H), 7.66 – 7.59 (m, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.3, 151.0, 133.5, 131.1, 129.3, 128.7, 128.7, 127.8, 127.2, 126.7, 125.4, 124.7. HRMS: (ESI) calculated for $C_{12}H_8N_2OSNa$ $[M+Na]^+$ 251.0249, found 251.0247.

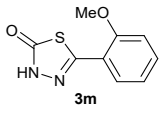
5-(2-Methylphenyl)-1,3,4-thiadiazol-2(3*H*)-one (3l)



3l

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (27.4 mg, 71%), Melting Point: 97.5 – 99.1 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.10 (s, 1H), 7.46 (d, *J* = 7.6 Hz, 1H), 7.42 – 7.30 (m, 3H), 2.47 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.5, 151.4, 136.1, 131.6, 130.1, 129.6, 129.3, 126.5, 20.9. HRMS: (ESI) calculated for $C_9H_9N_2OS$ $[M+H]^+$ 193.0430, found 193.0420.

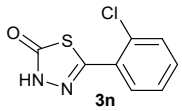
5-(2-Methoxyphenyl)-1,3,4-thiadiazol-2(3*H*)-one (3m)



3m

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (33.2 mg, 80%), Melting Point: 121.9 – 123.6 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.96 (s, 1H), 7.87 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.50 – 7.46 (m, 1H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.10 – 7.06 (m, 1H), 3.90 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 172.5, 155.9, 146.7, 131.9, 126.5, 121.1, 119.0, 112.6, 56.0. HRMS: (ESI) calculated for $C_9H_9N_2O_2S$ $[M+H]^+$ 209.0379, found 209.0381.

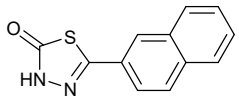
5-(2-Chlorophenyl)-1,3,4-thiadiazol-2(3*H*)-one (3n)



3n

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (41.4 mg, 98%), Melting Point: 132.9 – 135.3 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.30 (s, 1H), 7.80 (d, *J* = 7.6 Hz, 1H), 7.61 (d, *J* = 7.6 Hz, 1H), 7.56 – 7.47 (m, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.6, 147.9, 132.0, 131.0, 130.6, 130.4, 129.1, 127.8. HRMS: (ESI) calculated for $C_8H_6ClN_2OS$ $[M+H]^+$ 212.9884, found 212.9887.

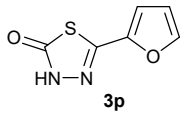
5-(2-Naphthalenyl)-1,3,4-thiadiazol-2(3*H*)-one (3o)



3o

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a yellow solid (29.8 mg, 65%), Melting Point: 249.6 – 252.7 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.18 (s, 1H), 8.20 (s, 1H), 8.08 – 8.02 (m, 2H), 7.97 (d, *J* = 5.2 Hz, 1H), 7.89 (d, *J* = 8.8 Hz, 1H), 7.61 – 7.59 (m, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 171.2, 151.5, 133.7, 132.6, 128.9, 128.5, 128.0, 127.8, 127.6, 127.1, 126.2, 121.9. HRMS: (ESI) calculated for $C_{12}H_8N_2OSNa$ $[M+Na]^+$ 251.0249, found 251.0248.

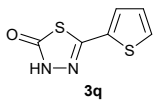
5-(2-Furanyl)-1,3,4-thiadiazol-2(3*H*)-one (3p)



3p

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a brown solid (28.9 mg, 86%), Melting Point: 149.7 – 150.1 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.10 (s, 1H), 7.89 (d, *J* = 0.8 Hz, 1H), 7.03 (d, *J* = 2.8 Hz, 1H), 6.69 (dd, *J* = 3.6, 1.6 Hz, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 170.6, 145.3, 144.6, 142.3, 112.4, 110.6. HRMS: (ESI) calculated for $C_6H_4N_2O_2SNa$ $[M+Na]^+$ 190.9886, found 190.9893.

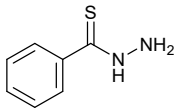
5-(2-Thienyl)-1,3,4-thiadiazol-2(3*H*)-one (3q)



3q

Following the general procedure, using 15/1 petroleum ether/EtOAc as the eluant afford a brown solid (29.1 mg, 79%), Melting Point: 106.1 – 108.4 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 13.01 (s, 1H), 7.75 (dd, *J* = 5.2, 1.2 Hz, 1H), 7.47 (dd, *J* = 4.0, 1.2 Hz, 1H), 7.16 (dd, *J* = 4.8, 3.6 Hz, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 170.7, 146.1, 133.1, 131.9, 129.1, 128.5, 128.0. HRMS: (ESI) calculated for $C_6H_4N_2OS_2Na$ $[M+Na]^+$ 206.9657, found 206.9666.

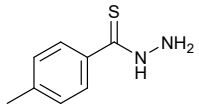
Benzenecarbothiohydrazide (2a)



2a

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green solid (0.65 g, 43%), Melting Point: 88.8 – 91.4 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.70 (d, *J* = 6.4 Hz, 2H), 7.44 – 7.38 (m, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 182.7, 138.8, 130.1, 128.1, 127.2. known compound.[3]

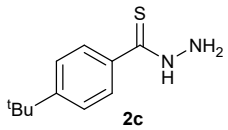
4-Methylbenzenecarbothioic acid hydrazide (2b)



2b

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a gray solid (0.60 g, 36%), Melting Point: 131.8 – 132.2 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.00 (br, 1H), 7.63 (d, *J* = 7.2 Hz, 2H), 7.21 (d, *J* = 7.6 Hz, 2H), 6.21 (br, 2H), 2.32 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 139.9, 135.9, 128.5, 127.1, 20.8. The signal of C=S did not appear because the signal intensity was low.

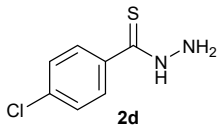
4-(1,1-Dimethylethyl)benzenecarbothioic acid hydrazide (2c)



2c

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a gray oil (0.96 g, 46%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.00 (br, 1H), 7.65 (d, *J* = 8.0 Hz, 2H), 7.42 (d, *J* = 8.4 Hz, 2H), 6.19 (br, 2H), 1.29 (s, 9H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 182.7, 152.9, 136.0, 127.0, 124.8, 34.5, 30.9.

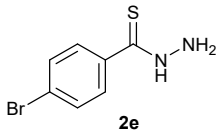
4-Chlorobenzenecarbothioic acid hydrazide (2d)



2d

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (1.02 g, 55%), Melting Point: 113.2 – 116.5 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.80 – 7.79 (m, 2H), 7.47 (d, *J* = 8.8 Hz, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 137.5, 134.7, 128.9, 127.9. The signal of C=S did not appear because the signal intensity was low.

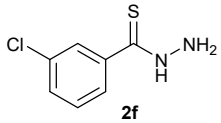
4-Bromobenzenecarbothioic acid hydrazide (2e)



2e

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (0.94 g, 41%), Melting Point: 87.3 – 91.3 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.22 (br, 1H), 7.66 (s, 2H), 7.61 (d, *J* = 8.0 Hz, 2H), 6.30 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 132.5, 130.9, 129.2, 123.4. The signal of C=S did not appear because the signal intensity was low.

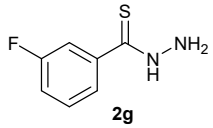
3-Chlorobenzenecarbothioic acid hydrazide (2f)



2f

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a laurel-green solid (0.96 g, 52%), Melting Point: 120.3 – 120.6 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.29 (br, 1H), 7.75 (s, 1H), 7.68 (s, 1H), 7.50 (d, *J* = 7.6 Hz, 1H), 7.45 – 7.41 (m, 1H), 6.29 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 179.4, 140.9, 132.7, 129.8, 129.5, 127.0, 125.8.

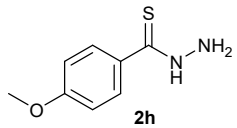
3-Fluorobenzenecarbothioic acid hydrazide (2g)



2g

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green oil (0.93 g, 55%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.25 (br, 1H), 7.57 (s, 1H), 7.53 (d, *J* = 9.6 Hz, 1H), 7.45 (dd, *J* = 14.0, 7.6 Hz, 1H), 7.30 – 7.26 (m, 1H), 6.32 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 161.5 (d, $J_{C\text{-}F}$ = 244.1 Hz), 141.0, 130.0 (d, $J_{C\text{-}F}$ = 8.4 Hz), 123.20 (d, $J_{C\text{-}F}$ = 2.5 Hz), 116.7 (d, $J_{C\text{-}F}$ = 21.3 Hz), 114.0 (d, $J_{C\text{-}F}$ = 23.3 Hz). The signal of C=S did not appear because the signal intensity was low. **^{19}F NMR** (471 MHz, DMSO-d_6) δ -113.3.

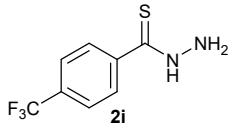
4-Methoxybenzenecarbothioic acid hydrazide (2h)



2h

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (1.01 g, 55%), Melting Point: 122.3 – 125.1 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.91 (br, 1H), 7.75 (d, *J* = 6.8 Hz, 2H), 6.96 (d, *J* = 6.8 Hz, 2H), 6.15 (br, 2H), 3.79 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 182.4, 160.9, 130.9, 128.8, 113.2, 55.3.

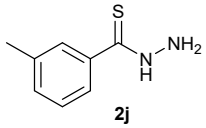
4-Trifluoromethylbenzenecarbothioic acid hydrazide (2i)



2i

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green solid (0.84 g, 39%), Melting Point: 101.7 – 102.3 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.96 (s, 2H), 7.77 (d, *J* = 8.4 Hz, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 142.8, 129.8 (q, $J_{C\text{-}F}$ = 31.9 Hz), 128.0, 124.9 (q, $J_{C\text{-}F}$ = 3.7 Hz), 124.0 (q, $J_{C\text{-}F}$ = 272.8 Hz). The signal of C=S did not appear because the signal intensity was low. **^{19}F NMR** (471 MHz, DMSO-d_6) δ -61.2.

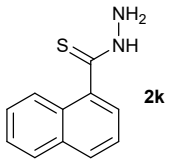
3-Methylbenzenecarbothioic acid hydrazide (2j)



2j

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green solid (0.89 g, 54%), Melting Point: 91.5 – 92.3 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.04 (br, 1H), 7.53 (s, 1H), 7.49 (s, 1H), 7.30 – 7.26 (m, 2H), 6.23 (br, 2H), 2.34 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 182.6, 138.9, 137.2, 130.6, 127.9, 127.8, 124.3, 20.9.

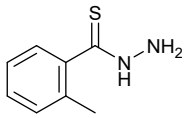
1-Naphthalenecarbothioic acid hydrazide (2k)



2k

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (0.78 g, 39%), Melting Point: 85.4 – 88.6 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.31 (br, 1H), 7.97 – 7.94 (m, 3H), 7.56 – 7.50 (m, 3H), 7.39 (d, *J* = 6.4 Hz, 1H), 6.38 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 182.2, 138.8, 133.0, 129.5, 128.6, 128.0, 126.4, 126.1, 125.1, 124.6.

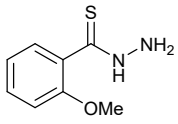
2-Methylbenzenecarbothioic acid hydrazide (2l)



2l

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green oil (0.72 g, 43%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.96 (br, 1H), 7.28 – 7.24 (m, 1H), 7.21 – 7.17 (m, 2H), 7.13 (d, *J* = 7.6 Hz, 1H), 6.17 (br, 2H), 2.23 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 141.1, 133.5, 130.0, 128.3, 127.3, 125.4, 18.8. The signal of C=S did not appear because the signal intensity was low.

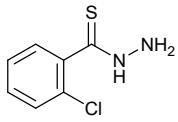
2-Methoxybenzenecarbothioic acid hydrazide (2m)



2m

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a gray solid (1.01 g, 55%), Melting Point: 103.3 – 106.7 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 11.83 (br, 1H), 7.51 (d, *J* = 7.2 Hz, 1H), 7.36 (t, *J* = 7.2 Hz, 1H), 7.05 (d, *J* = 8.4 Hz, 1H), 6.99 – 6.95 (m, 1H), 6.21 (br, 2H), 3.78 (s, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 179.0, 154.6, 130.7, 130.4, 128.7, 120.1, 111.6, 55.6.

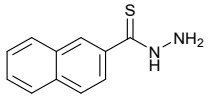
2-Chlorobenzenecarbothioic acid hydrazide (2n)



2n

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a gray oil (0.86 g, 46%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.24 (br, 1H), 7.48 – 7.46 (m, 1H), 7.40 – 7.34 (m, 3H), 6.26 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 179.5, 139.9, 129.9, 129.5, 129.3, 129.3, 126.9.

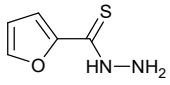
2-Naphthalenecarbothioic acid hydrazide (2o)



2o

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a green solid (0.95 g, 47%), Melting Point: 145.0 – 145.9 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.27 (br, 1H), 8.25 (s, 1H), 8.01 (d, *J* = 4.8 Hz, 1H), 7.93 (d, *J* = 6.4 Hz, 3H), 7.58 – 7.56 (m, 2H), 6.46 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 133.5, 132.0, 128.7, 127.5, 127.4, 127.2, 126.7, 125.0. The signal of C=S did not appear because the signal intensity was low.

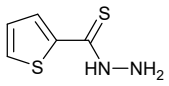
2-Furancarbothioic acid hydrazide (2p)



2p

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (0.67 g, 47%), Melting Point: 119.5 – 121.6 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 12.10 (br, 1H), 7.81 (s, 1H), 7.04 (d, *J* = 3.2 Hz, 1H), 6.59 (s, 1H), 6.16 (br, 2H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 144.5, 114.2, 112.2, 111.9. The signal of C=S did not appear because the signal intensity was low.

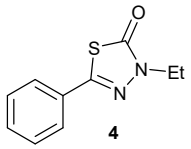
2-Thiophenecarbothioic acid hydrazide (2q)



2q

Following the general procedure, using 4/1 petroleum ether/EtOAc as the eluant afford a brown solid (0.69 mg, 44%), Melting Point: 107.8 – 110.5 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.64 – 7.61 (m, 2H), 7.11 – 7.09 (m, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 175.4, 144.5, 131.2, 127.6, 124.0.

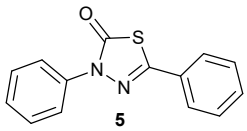
3-ethyl-5-phenyl-1,3,4-thiadiazol-2(3*H*)-one (4)



4

Following the general procedure, using 30/1 petroleum ether/EtOAc as the eluant afford a colorless oil (33.2 mg, 0.27mmol, 60%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.72 – 7.69 (m, 2H), 7.52 – 7.49 (m, 3H), 3.96 (q, *J* = 7.2 Hz, 2H), 1.31 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 168.0, 149.0, 130.9, 130.1, 129.3, 125.6, 42.1, 13.7. HRMS: (ESI) calculated for $C_{10}H_{11}N_2OS$ $[M+H]^+$ 207.0587, found 207.0588.

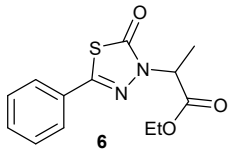
3,5-diphenyl-1,3,4-thiadiazol-2(3*H*)-one (5)[4]



5

Following the general procedure, using 25/1 petroleum ether/EtOAc as the eluant afford a white solid (40.3 mg, 0.26mmol, 61%), Melting Point: 79.5 – 83.1 ˚C. **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.84 – 7.80 (m, 4H), 7.60 – 7.52 (m, 5H), 7.42 – 7.38 (m, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 167.6, 150.0, 137.4, 131.4, 129.8, 129.3, 129.1, 127.3, 126.0, 122.0. HRMS: (ESI) calculated for $C_{14}H_{11}N_2OS$ $[M+H]^+$ 255.0587, found 255.0586.

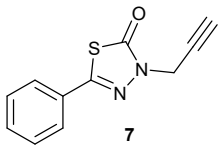
Ethyl α-methyl-2-oxo-5-phenyl-1,3,4-thiadiazole-3-acetate (6)[5]



6

Following the general procedure, using 30/1 petroleum ether/EtOAc as the eluant afford a yellow oil (65.3 mg, 0.29mmol, 81%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.73 – 7.71 (m, 2H), 7.53 (d, *J* = 6.4 Hz, 3H), 5.21 (d, *J* = 7.2 Hz, 1H), 4.17 – 4.13 (m, 2H), 1.65 (d, *J* = 7.2 Hz, 3H), 1.19 – 1.15 (m, 3H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 169.2, 168.6, 149.3, 131.2, 129.9, 129.3, 125.8, 61.4, 54.5, 15.5, 13.9. HRMS: (ESI) calculated for $C_{13}H_{15}N_2O_3S$ $[M+H]^+$ 279.0798, found 279.0796.

3-propargyl-5-Phenyl-1,3,4- thiadiazol-2(3*H*)-one (7)



7

Following the general procedure, using 30/1 petroleum ether/EtOAc as the eluant afford a white oil (53.9 mg, 0.26mmol, 96%). **^{1}H NMR** (400 MHz, DMSO-d_6) δ 7.73 – 7.71 (m, 2H), 7.54 (d, *J* = 6.8 Hz, 3H), 4.81 (d, *J* = 2.4 Hz, 2H), 3.46 – 3.45 (m, 1H). **^{13}C NMR** (126 MHz, DMSO-d_6) δ 167.9, 149.8, 131.2, 129.7, 129.3, 125.7, 77.5, 75.8, 36.5. HRMS: (ESI) calculated for $C_{11}H_9N_2OS$ $[M+H]^+$ 217.0430, found 217.0431.

Reference

(1) N. B. Almandil, M. Taha, F. Rahim, A. Wadood, S. Imran, M. A. Alqahtani, Y. A. Bamarouf, M. Ibrahim, A. Mosaddik and M. Gollapalli, *Bioorg. Chem.*, 2019, **85**, 109-116.

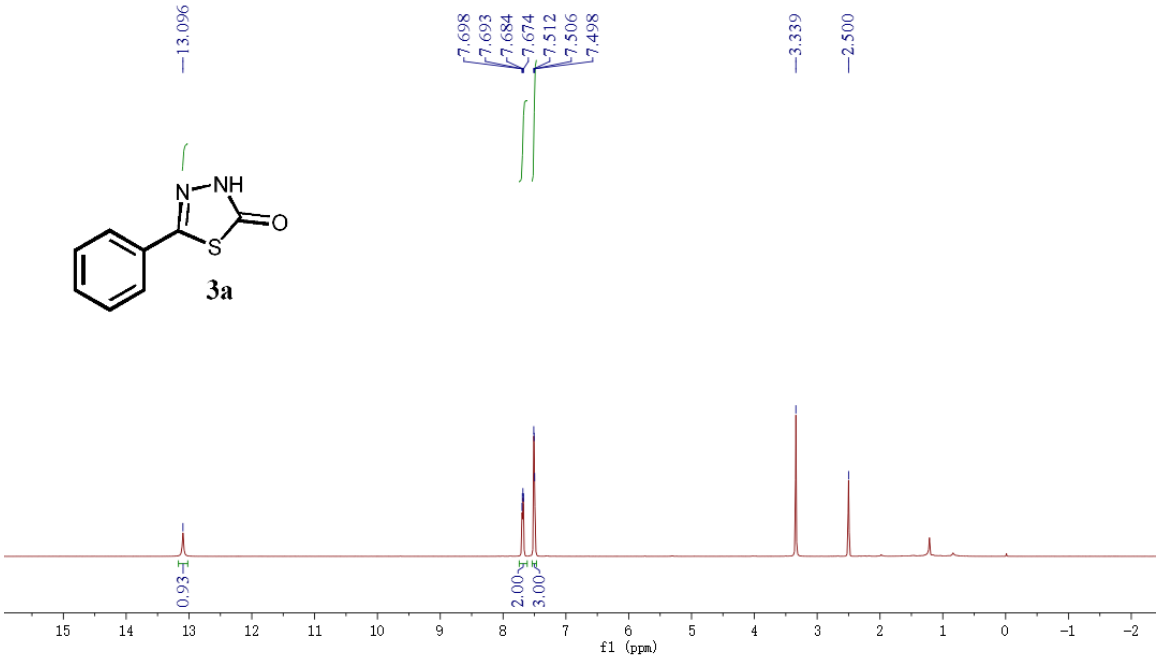
(2) X. Wu, S. Sun, B. Wang and J.Cheng, *Adv. Synth. Catal.,* 2017, **359**, 3855-3859.

(3) J. Laborde, C. Deraeve, L. Lecoq, A. Sournia-Saquet, J.-L. Stigliani, B. S. Orena, G. Mori, G. Pratviel and V. Bernardes-Génisson, *ChemistrySelect*, 2016, **1**, 172-179.

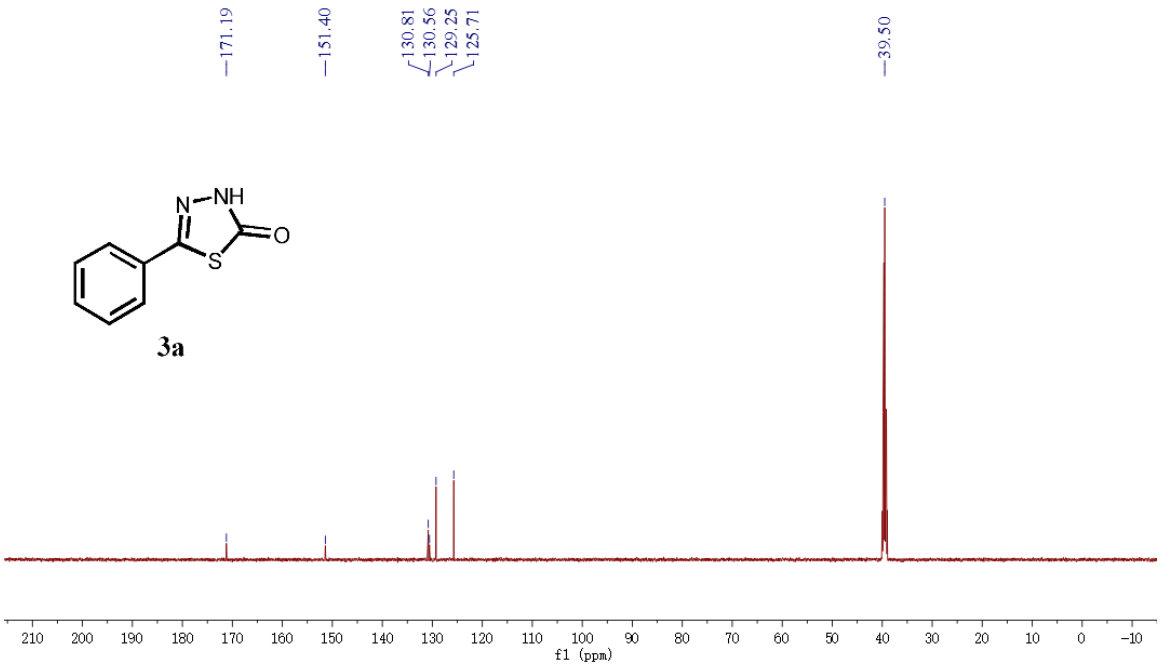
(4) C.-X. Guo, W.-Z. Zhang, N. Zhang and X.-B. Lu, *J. Org. Chem.*, 2017, **82**, 7637-7642.

(5) J. R. Beck, G. E. Babbitt and M. P. Lynch, *J. Heterocycl. Chem.*, 1988**, 25**, 1467-1470.

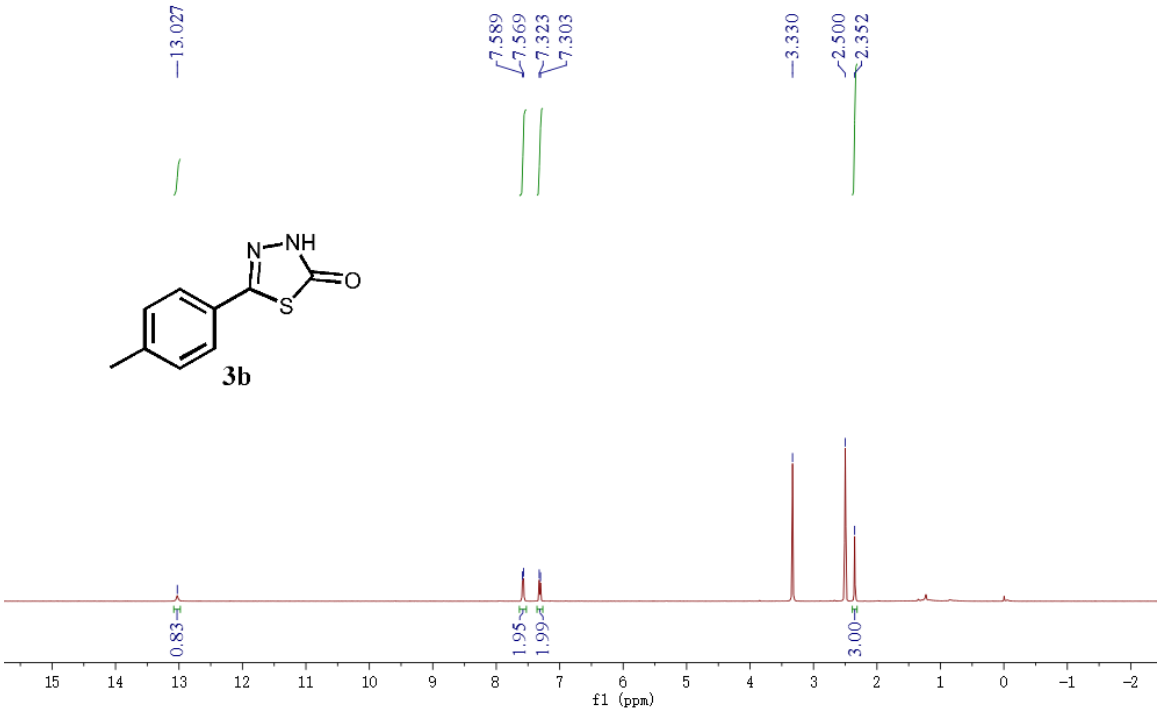
5. NMR Spectra



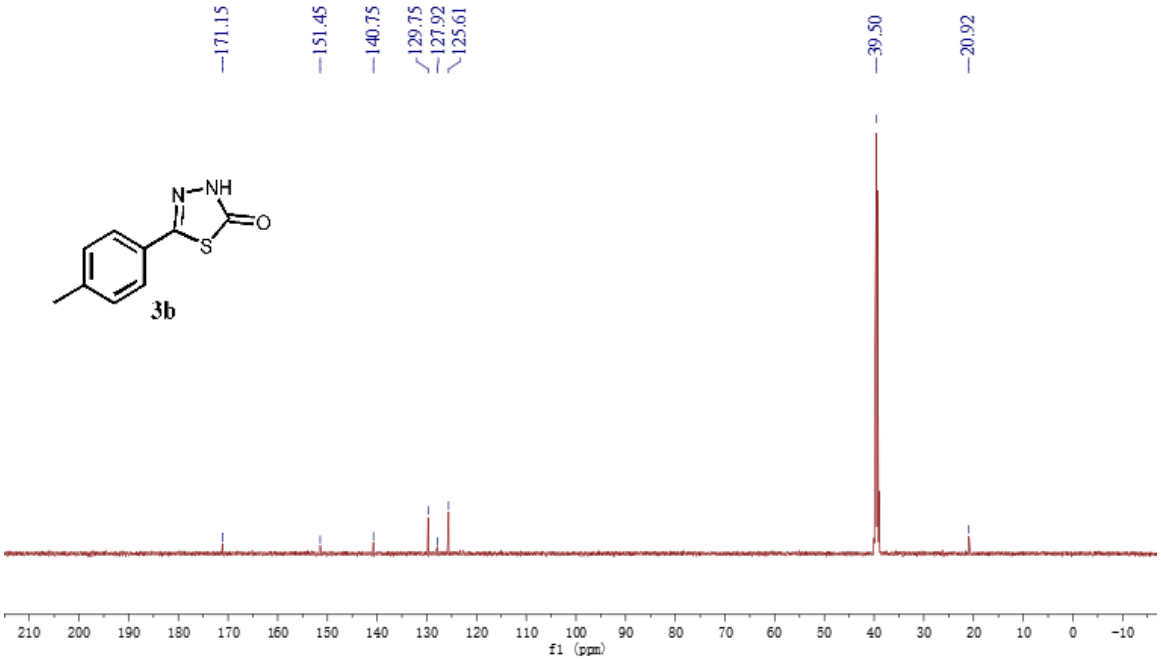
(400 MHz for ^{1}H NMR with DMSO as solvent)



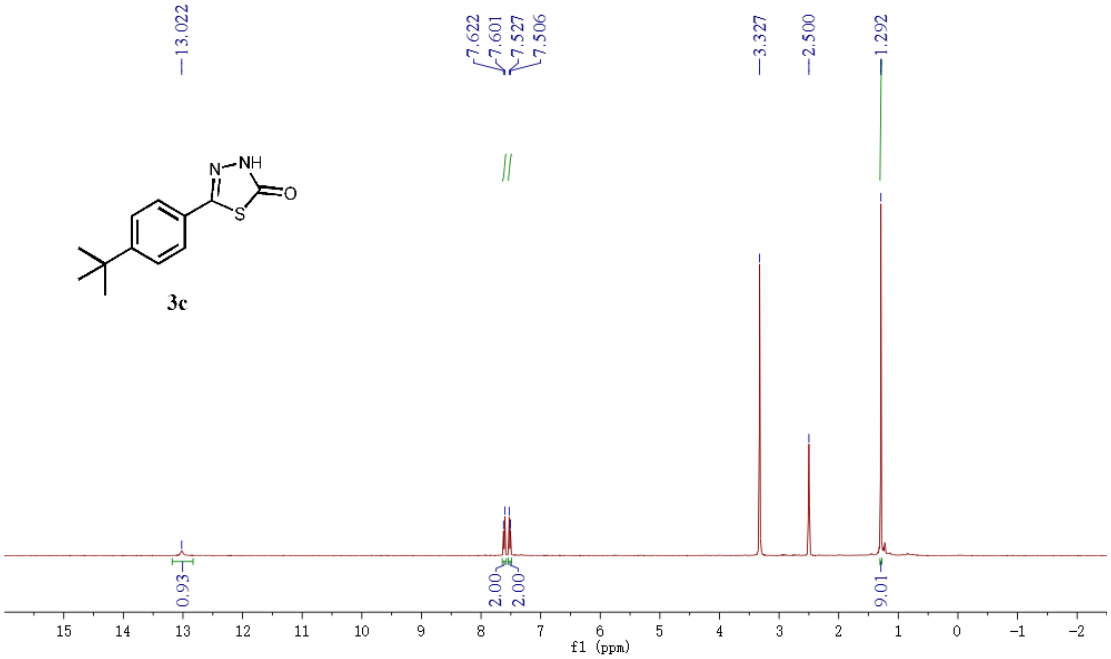
(126 MHz for ^{13}C NMR with DMSO as solvent)



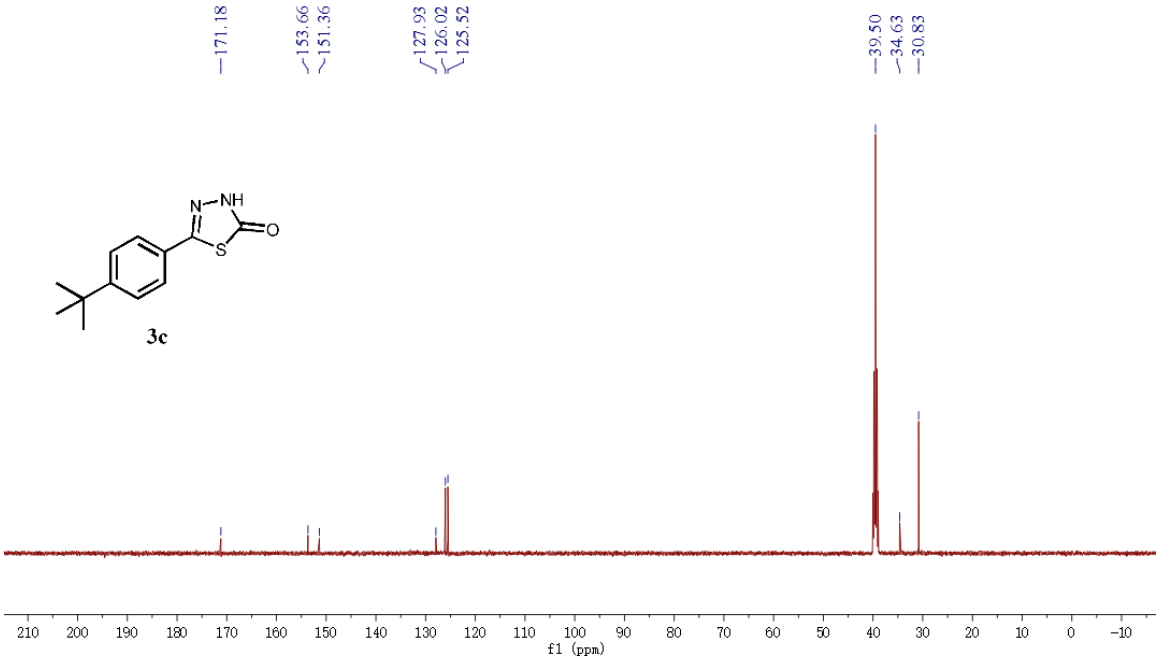
(400 MHz for ^{1}H NMR with DMSO as solvent)



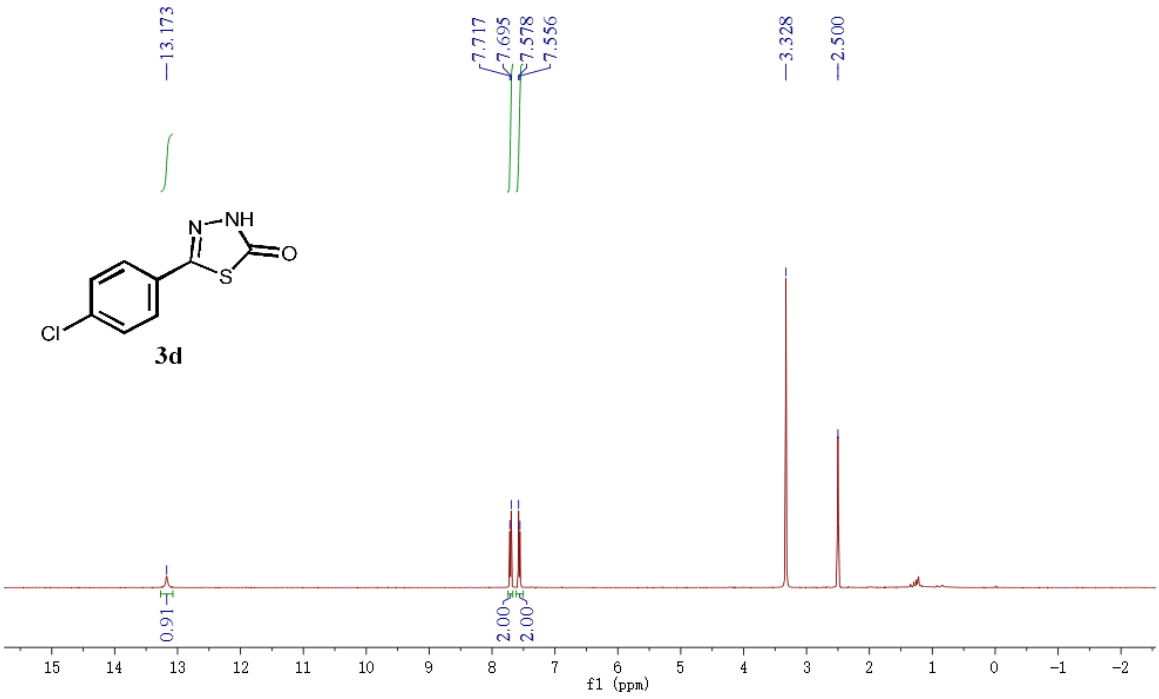
(126 MHz for ^{13}C NMR with DMSO as solvent)



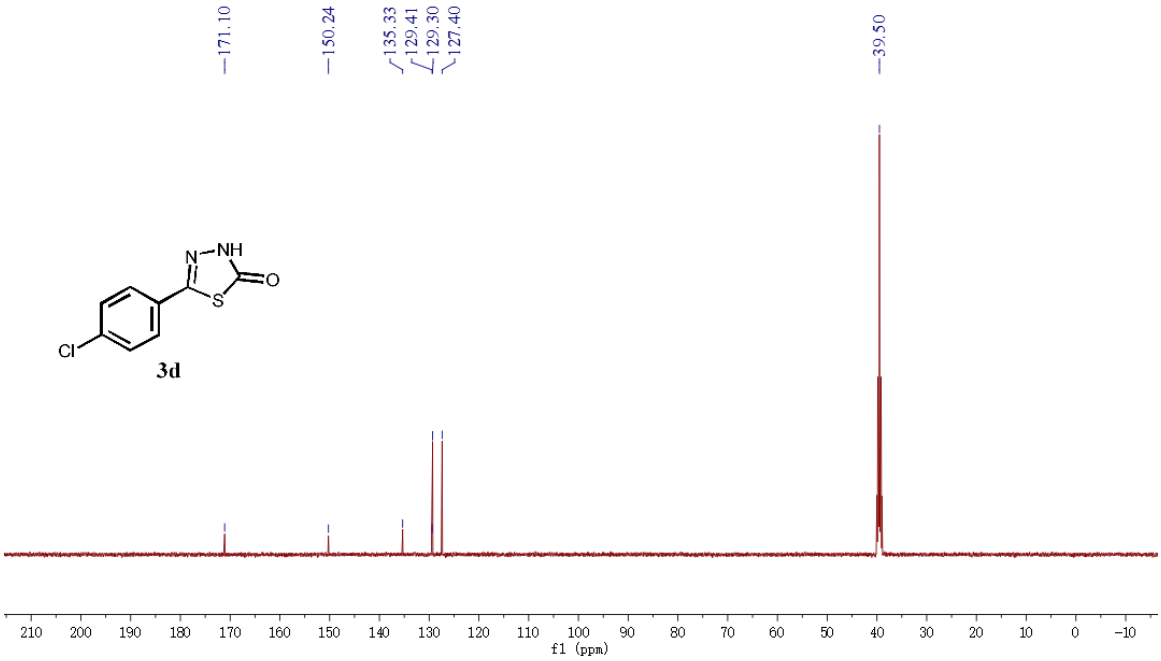
(400 MHz for ^{1}H NMR with DMSO as solvent)



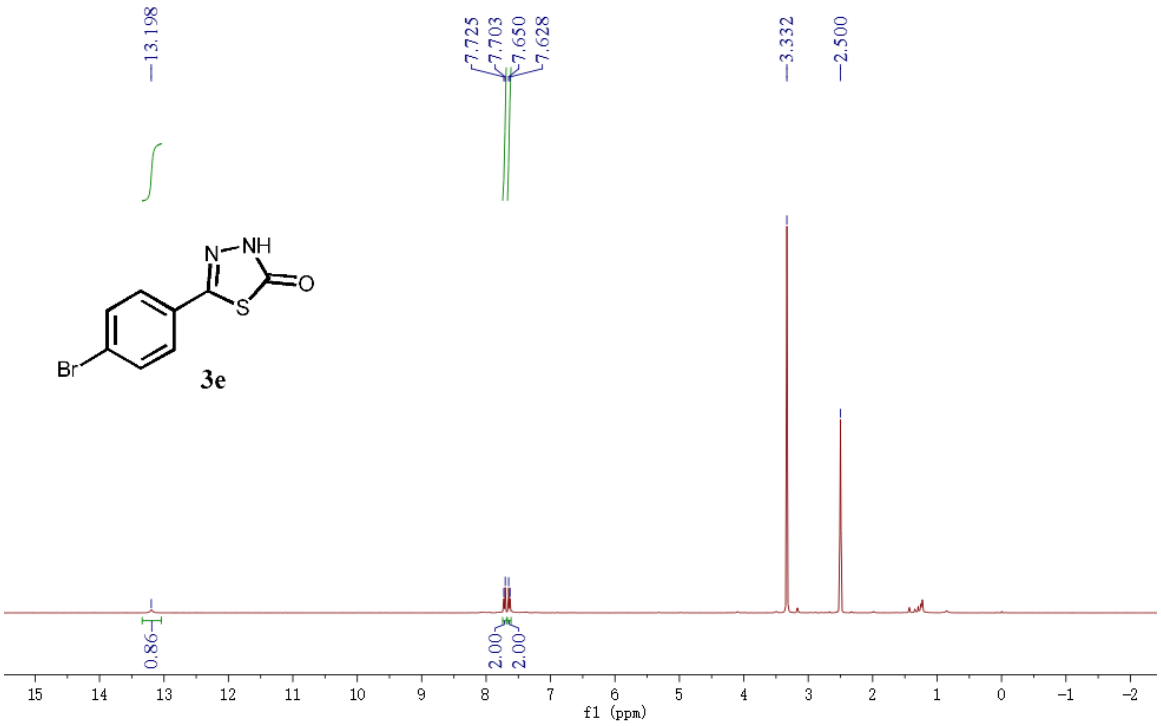
(126 MHz for ^{13}C NMR with DMSO as solvent)



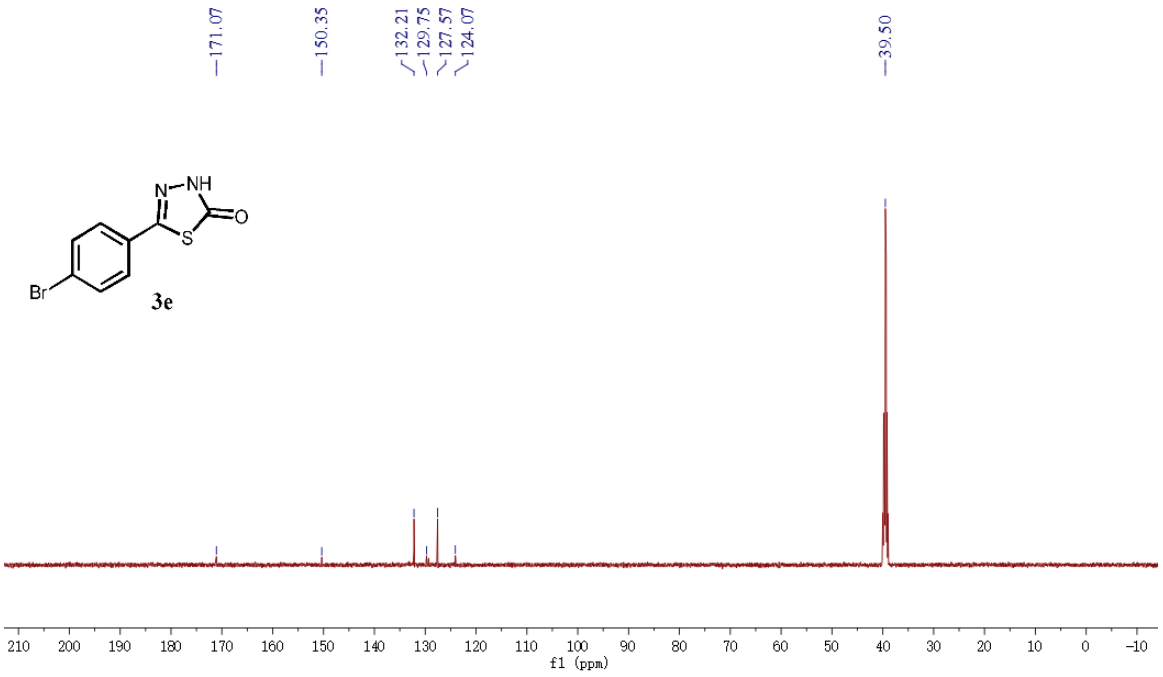
(400 MHz for ^{1}H NMR with DMSO as solvent)



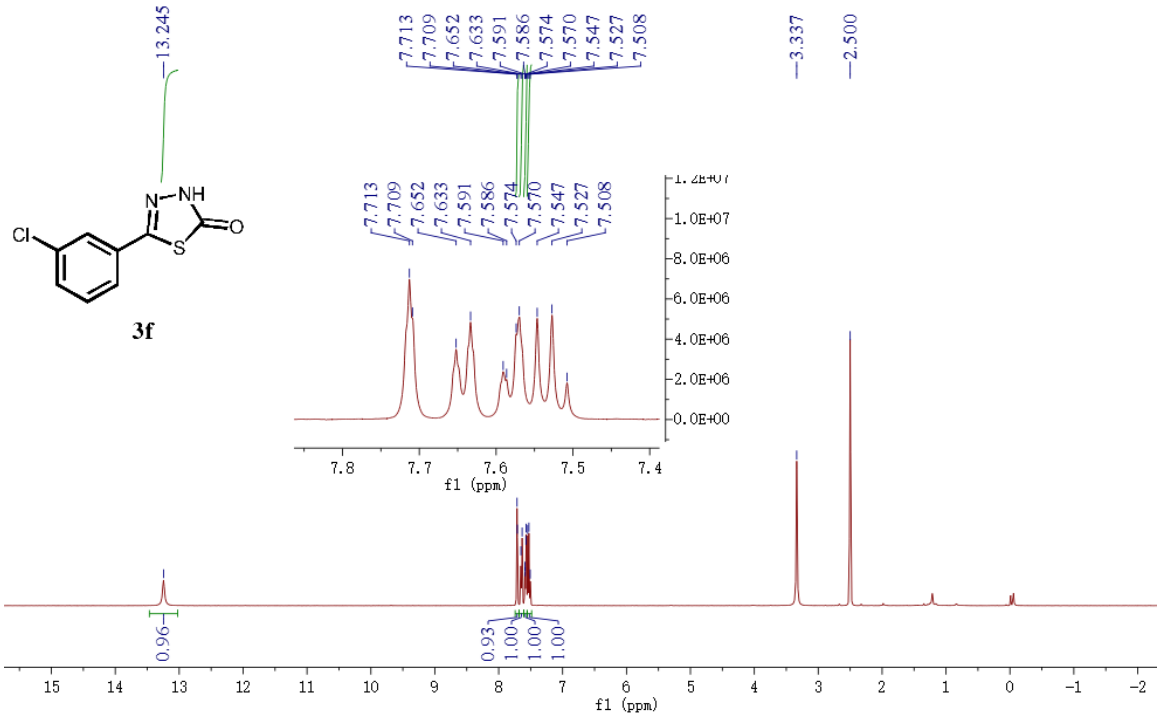
(126 MHz for ^{13}C NMR with DMSO as solvent)



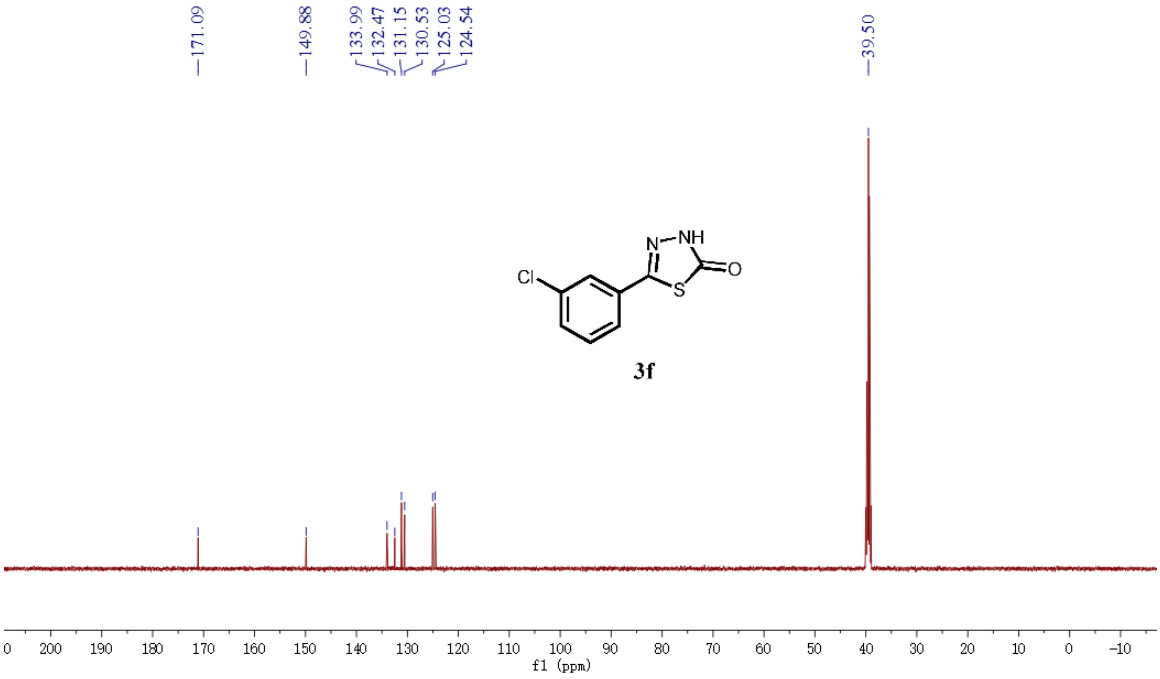
(400 MHz for ^{1}H NMR with DMSO as solvent)



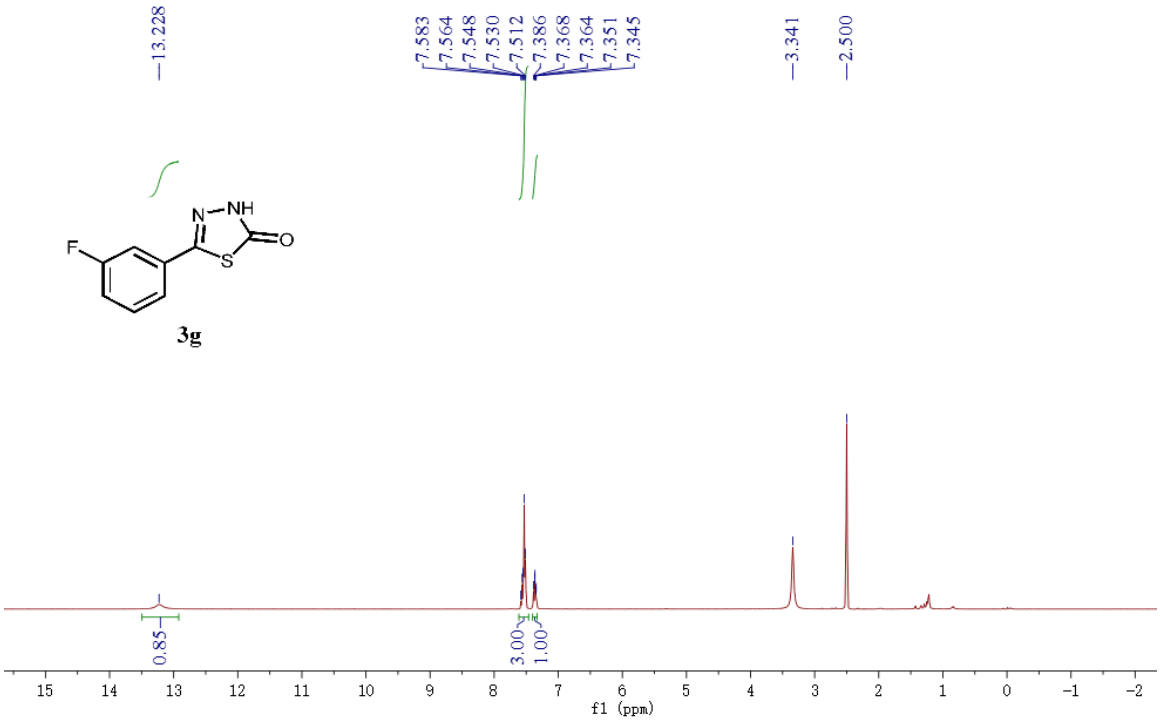
(126 MHz for ^{13}C NMR with DMSO as solvent)



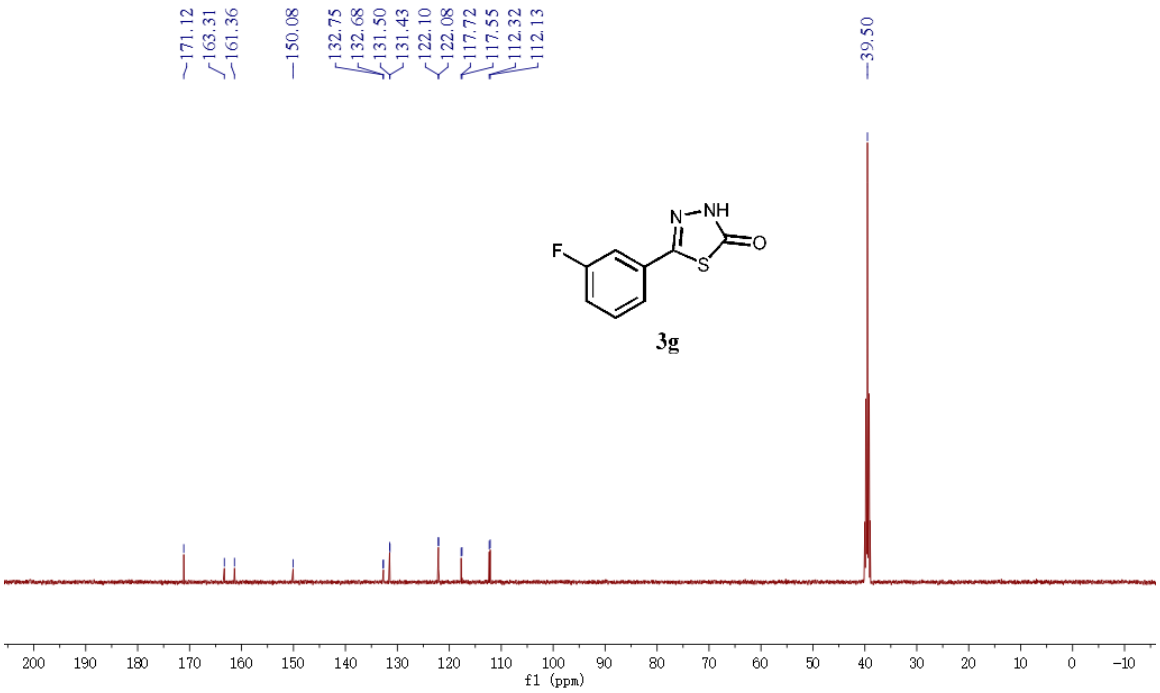
(400 MHz for ^{1}H NMR with DMSO as solvent)



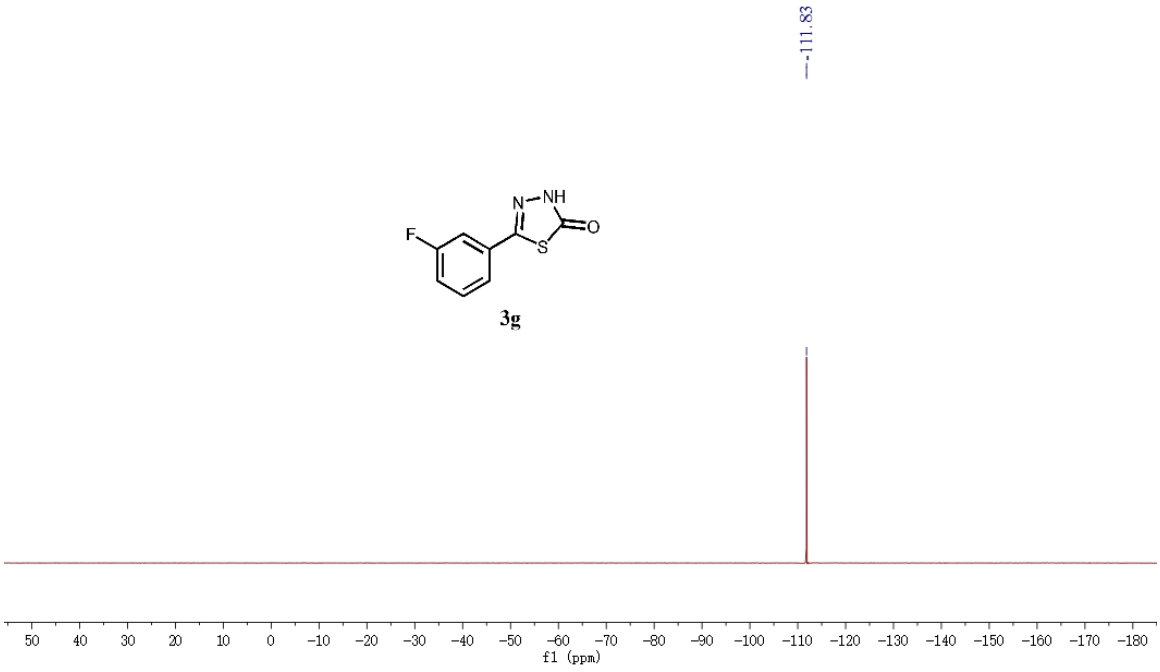
(126 MHz for ^{13}C NMR with DMSO as solvent)



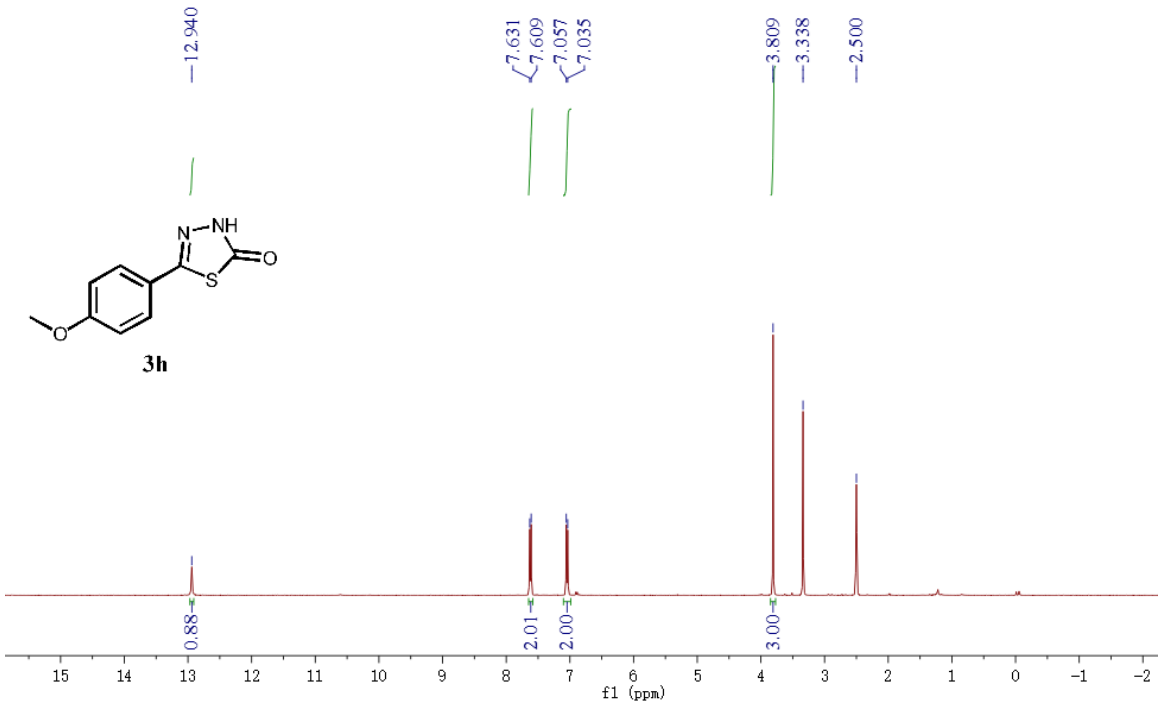
(400 MHz for ^{1}H NMR with DMSO as solvent)



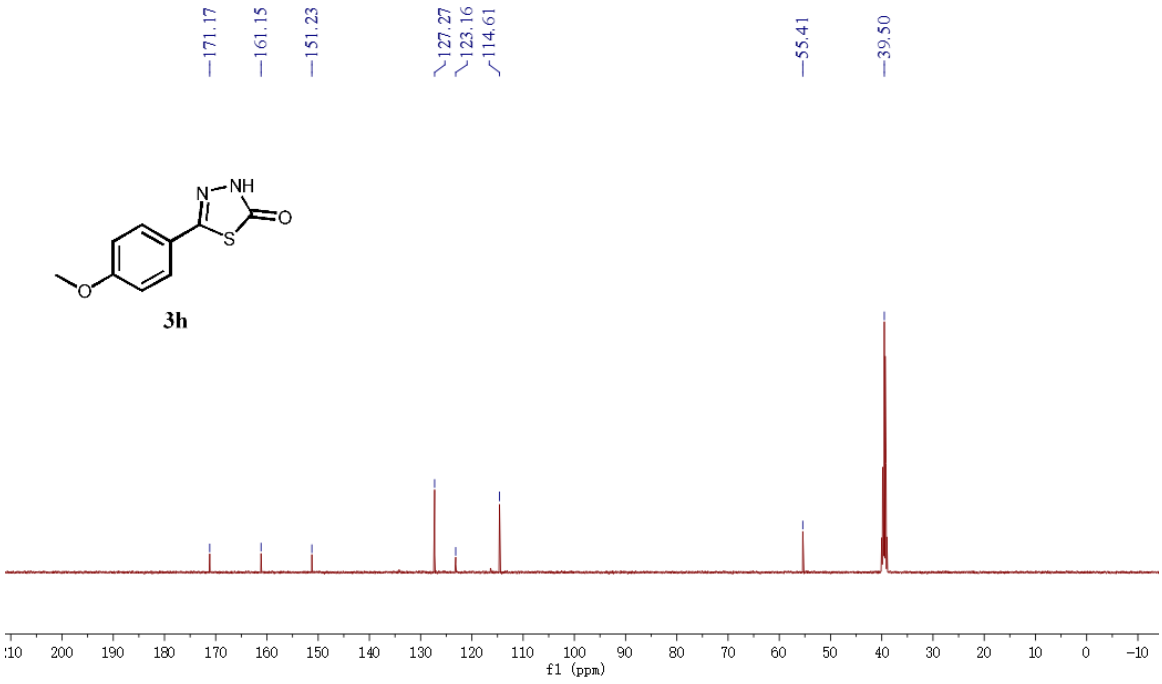
(126 MHz for ^{13}C NMR with DMSO as solvent)



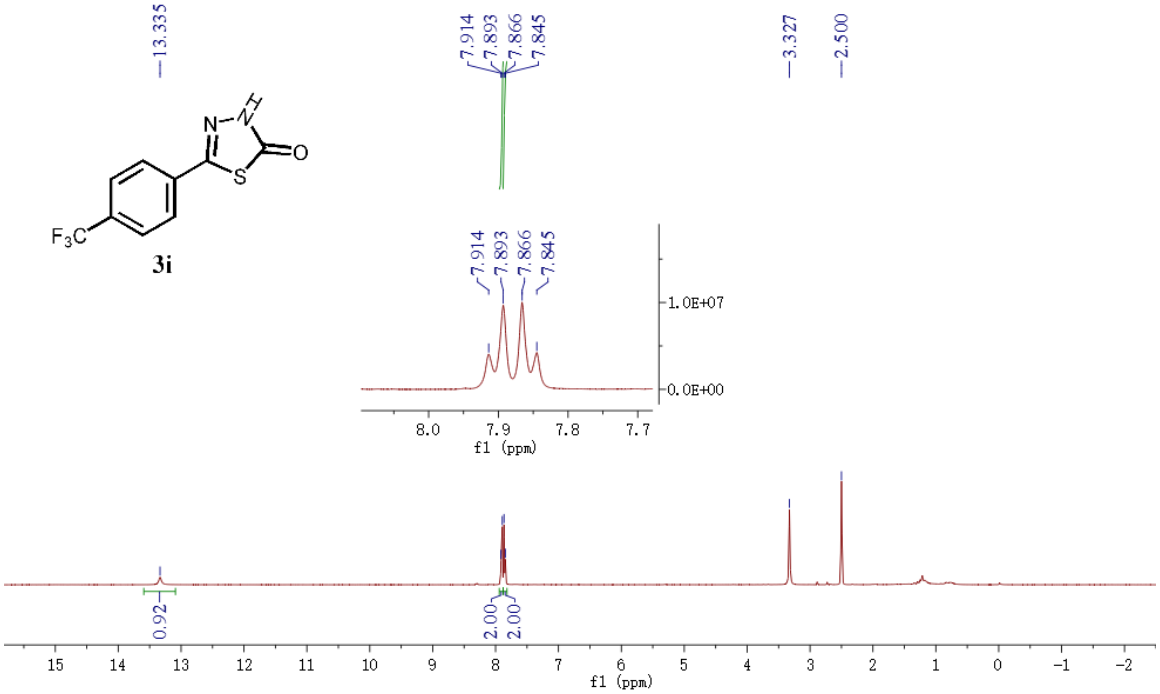
(471 MHz for ^{19}F NMR with DMSO as solvent)



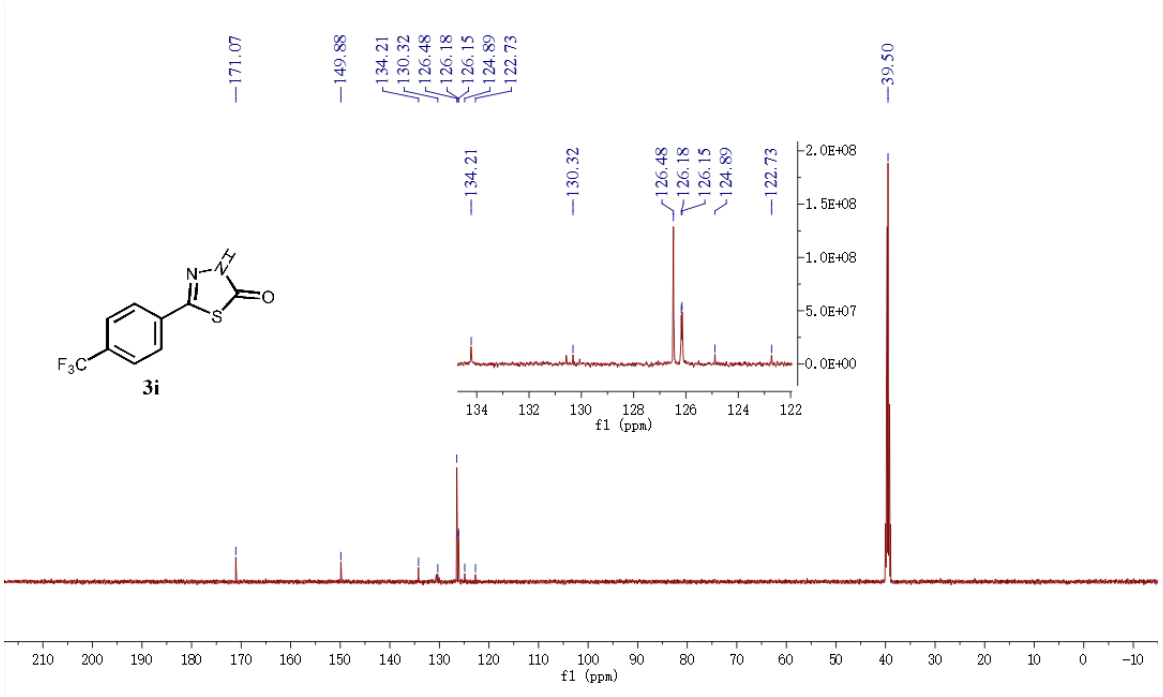
(400 MHz for ^{1}H NMR with DMSO as solvent)



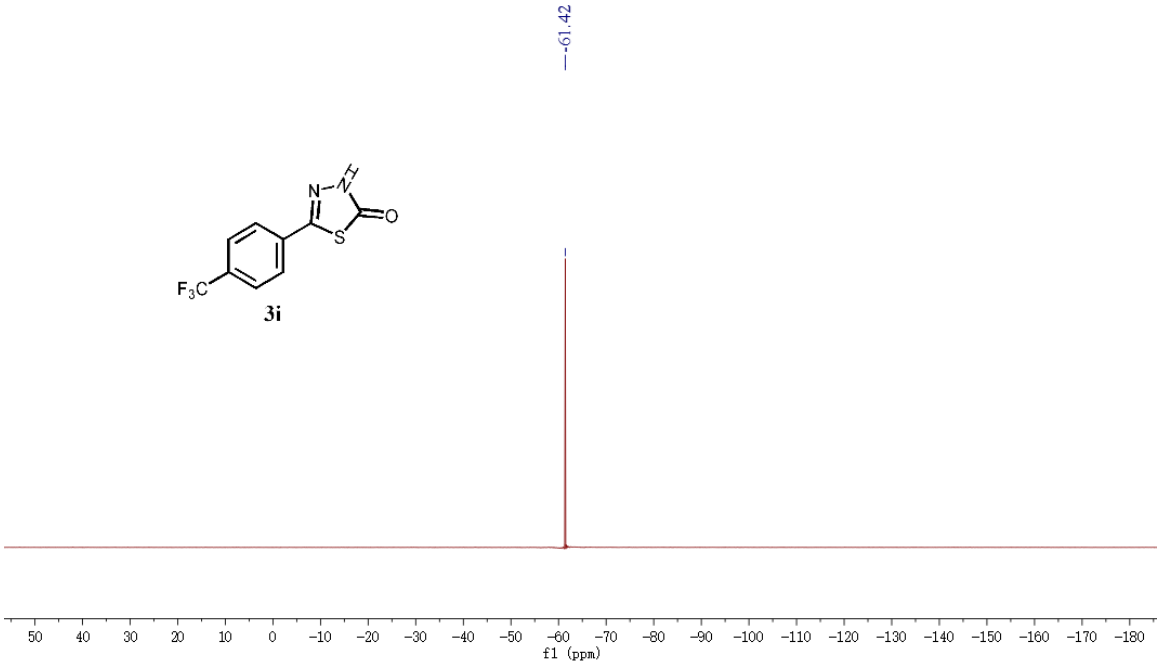
(126 MHz for ^{13}C NMR with DMSO as solvent)



(400 MHz for ^{1}H NMR with DMSO as solvent)



(126 MHz for ^{13}C NMR with DMSO as solvent)



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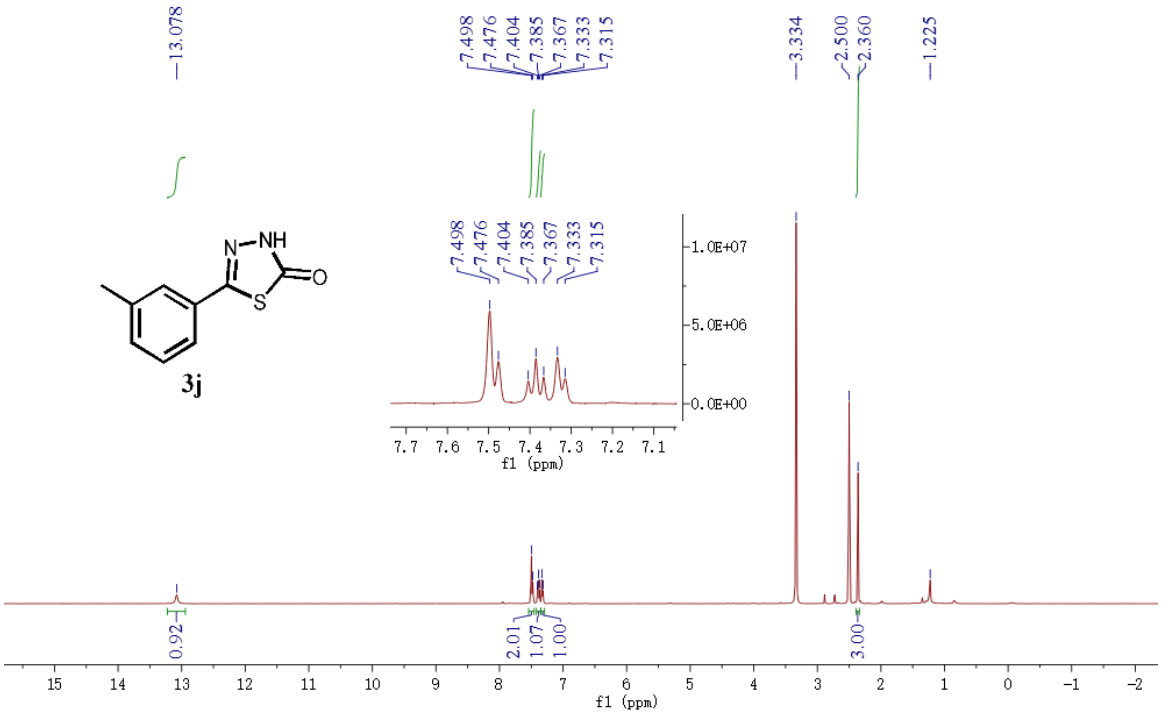

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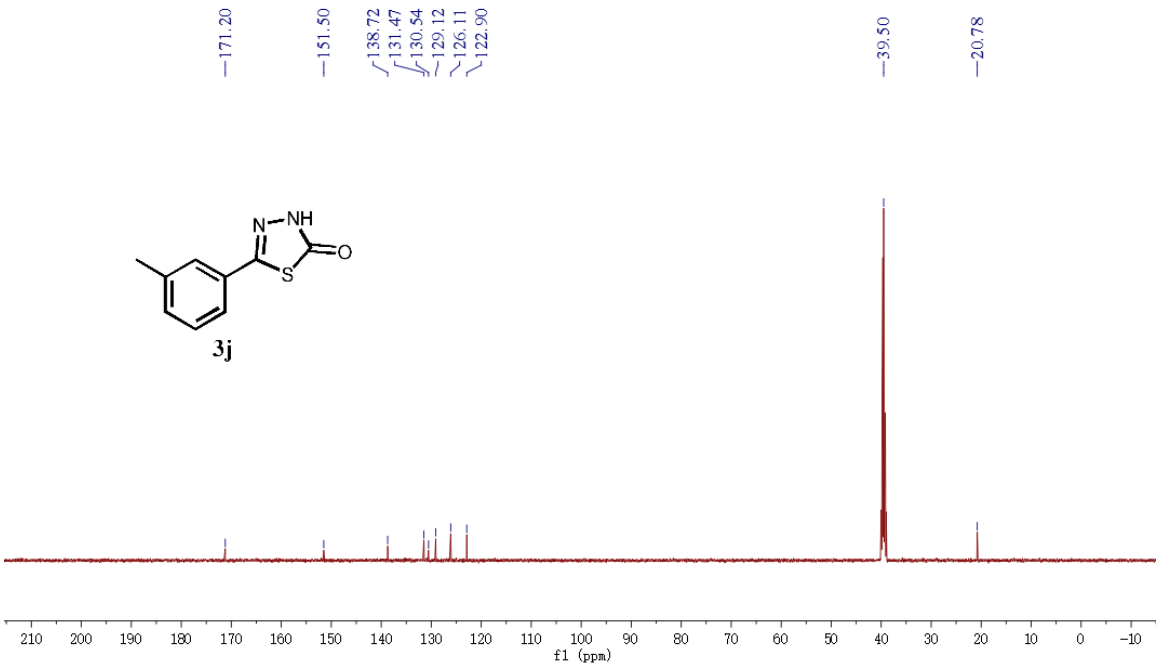

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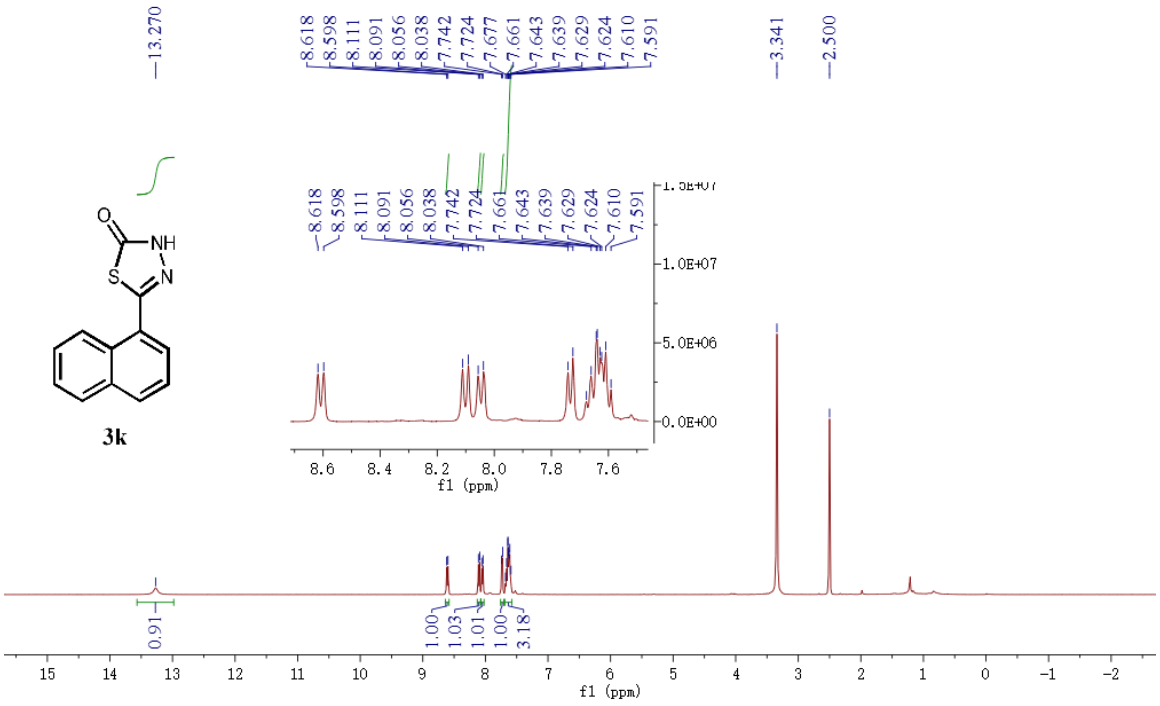

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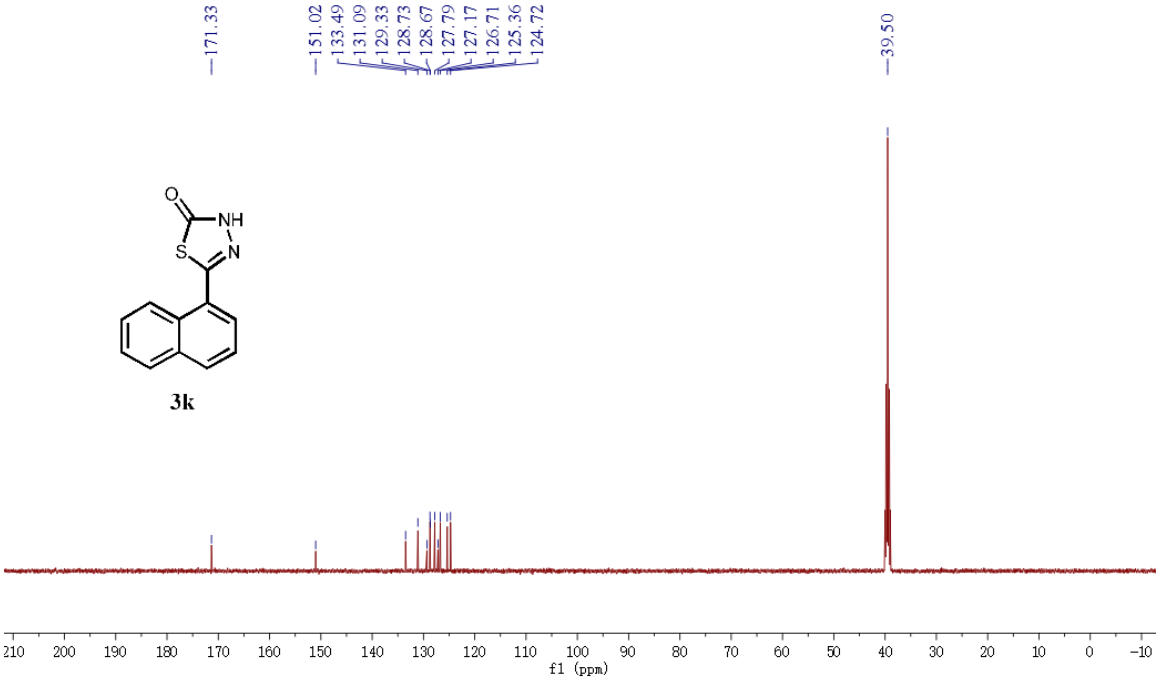

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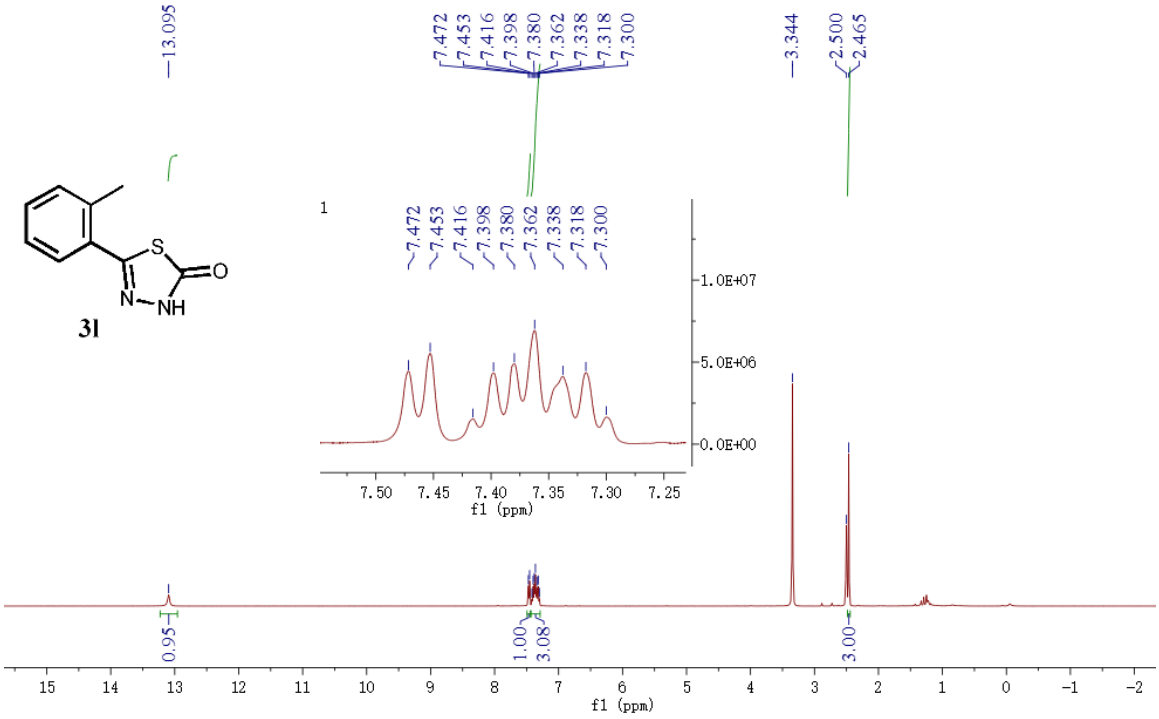

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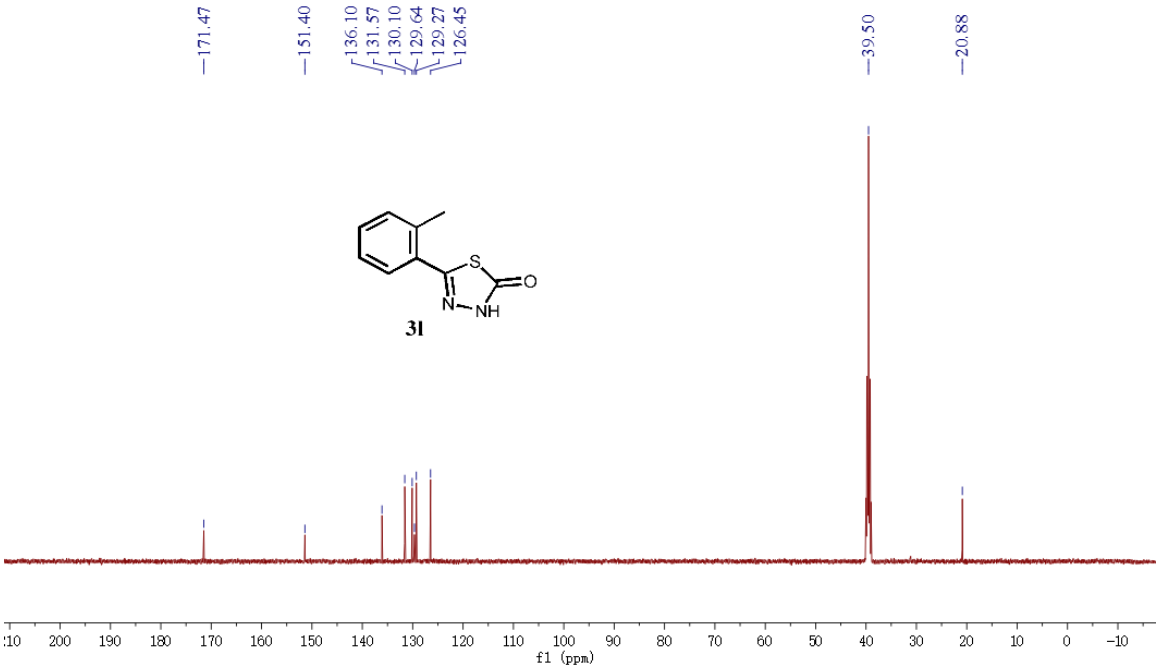
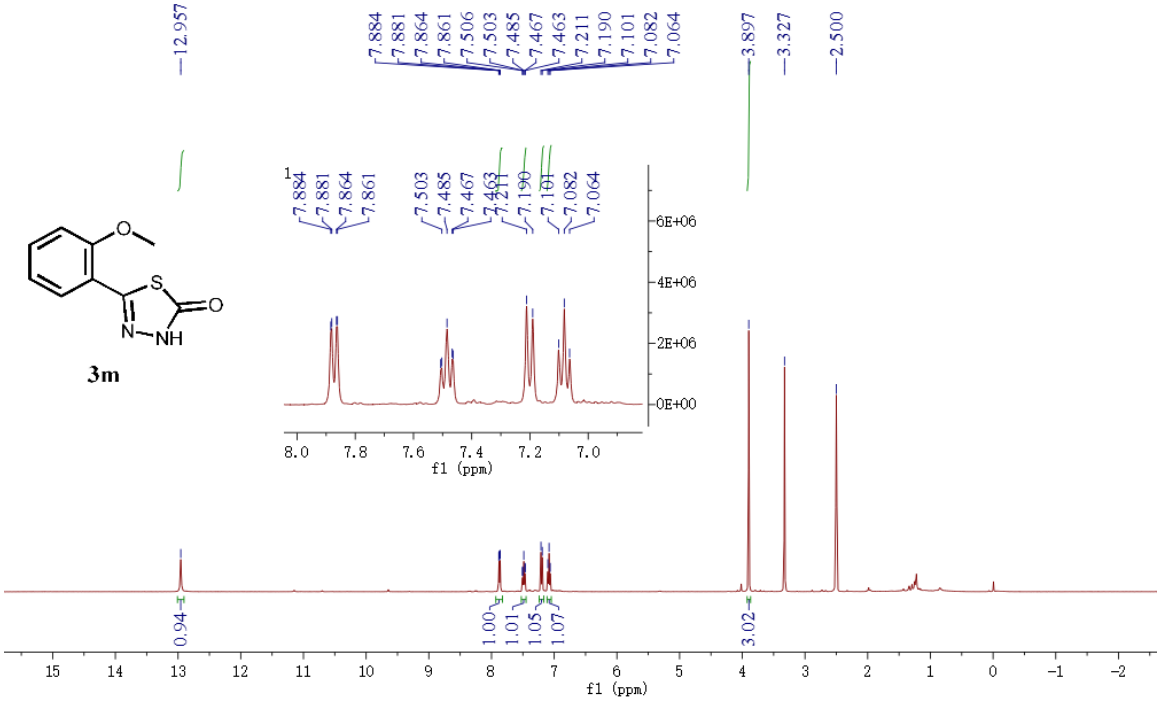


(126 MHz for ^{13}C NMR with DMSO as solvent)



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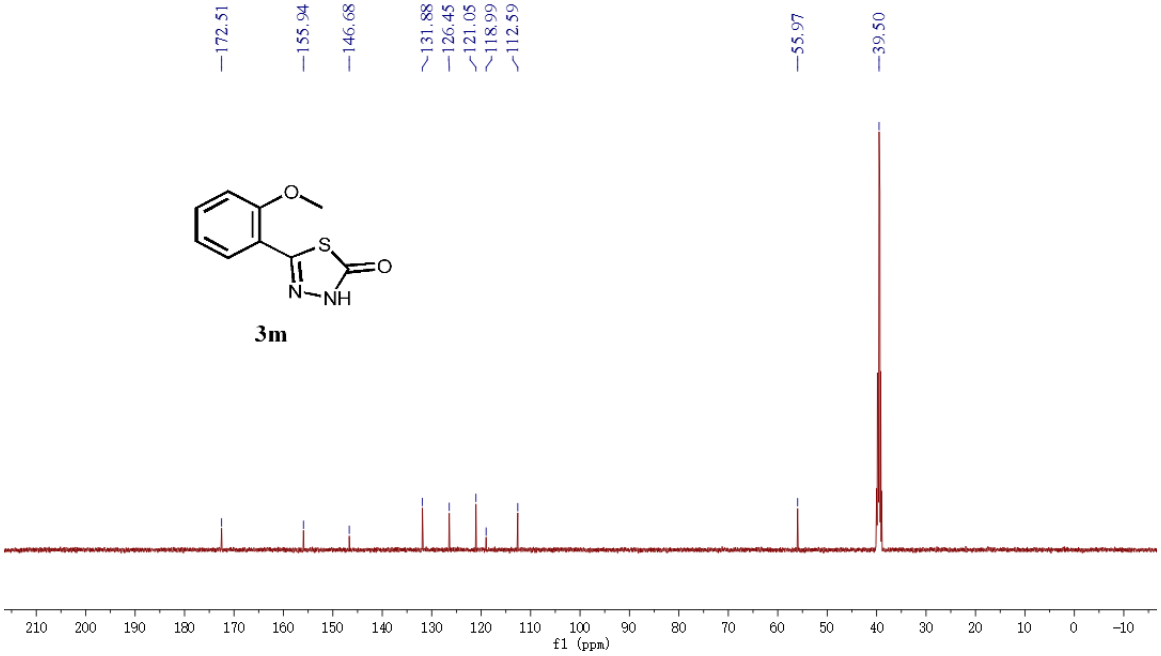
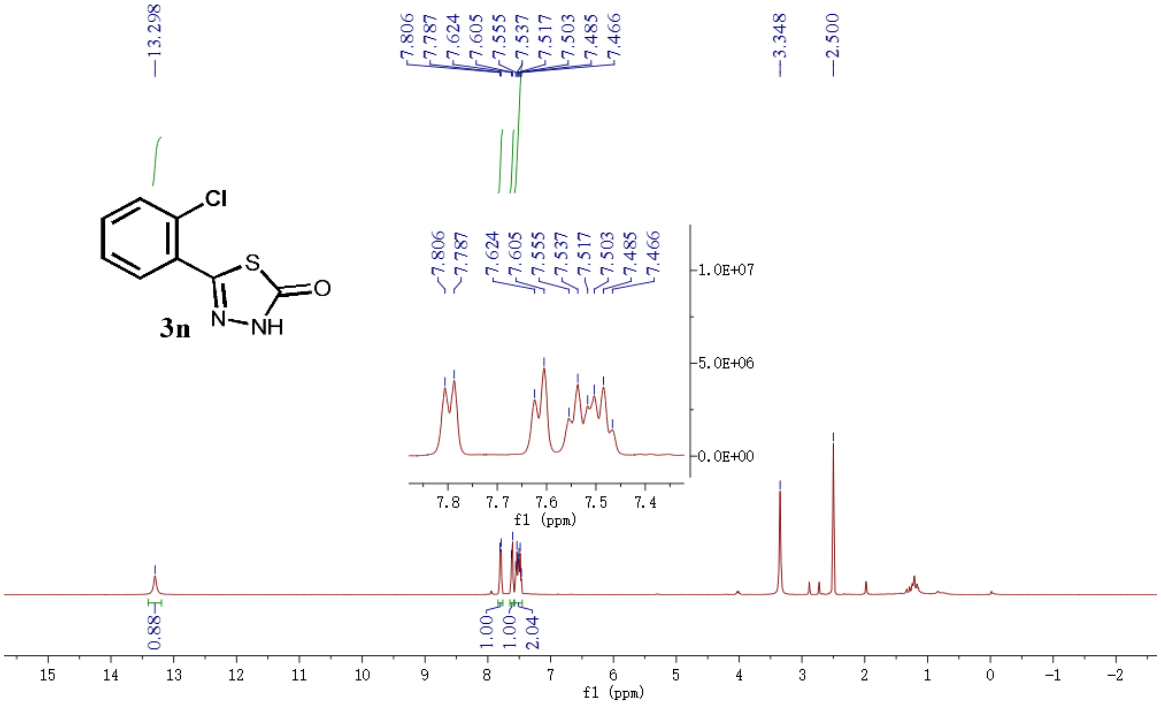


(126 MHz for ^{13}C NMR with DMSO as solvent)



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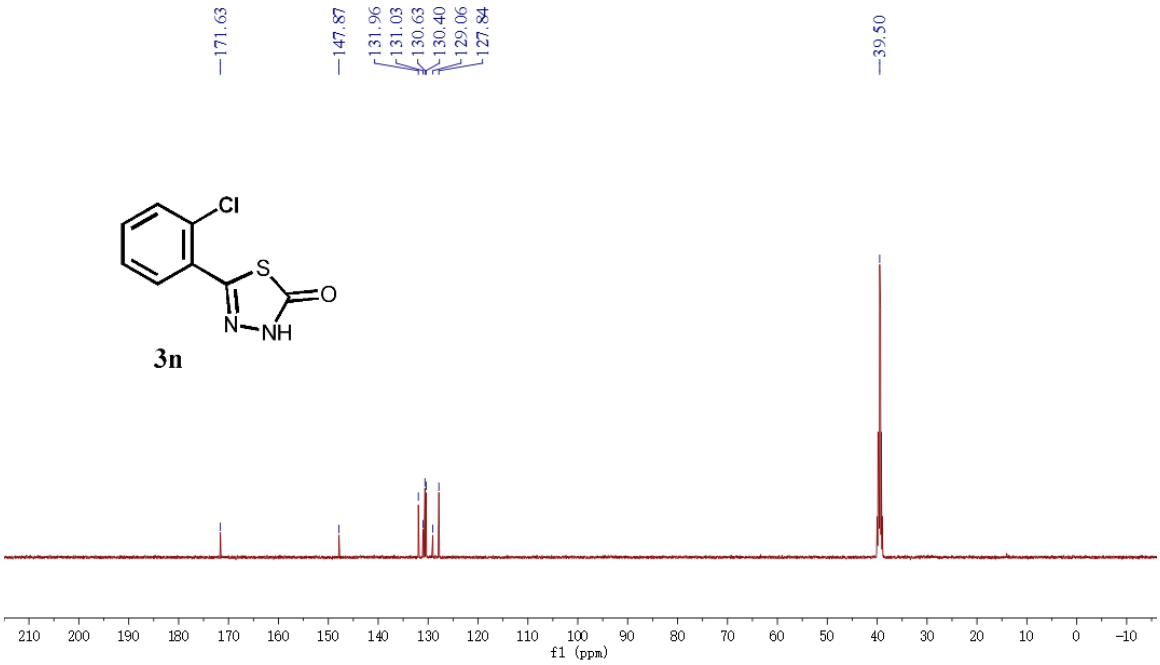

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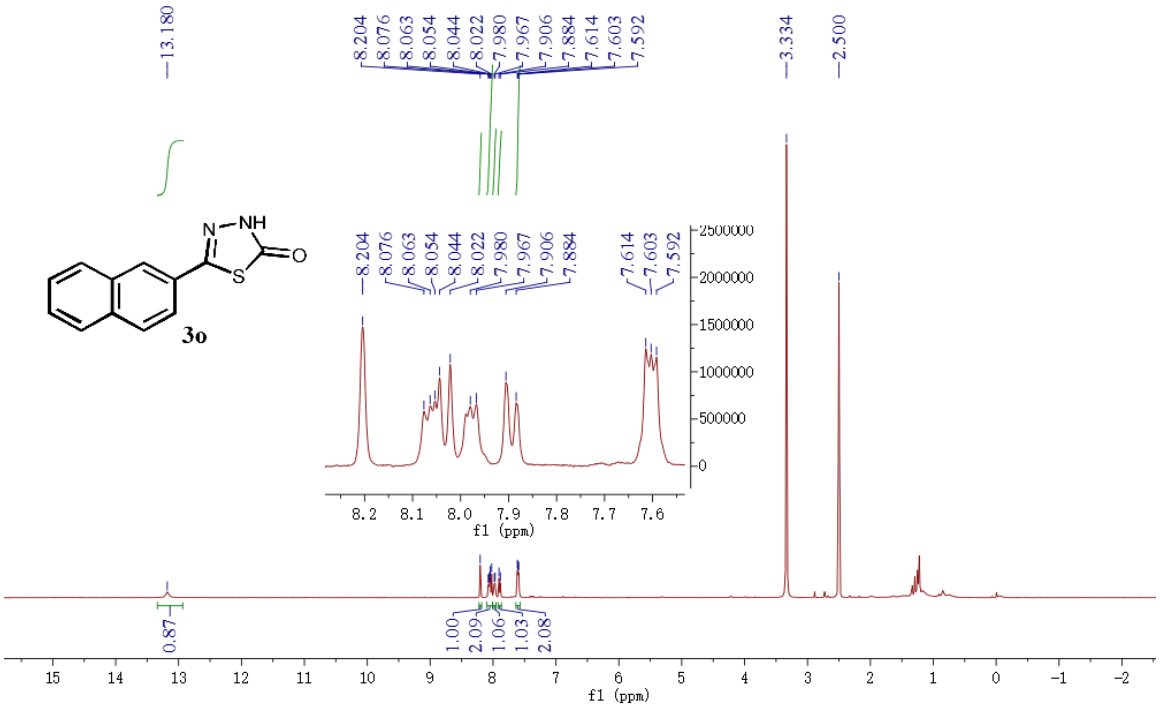

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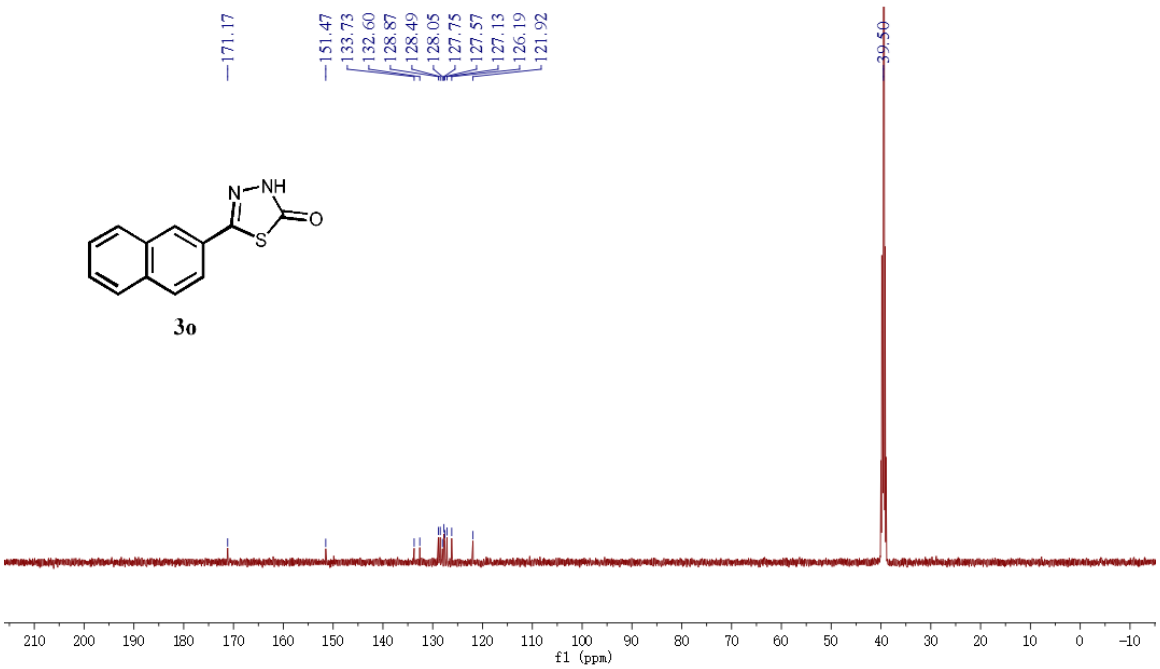
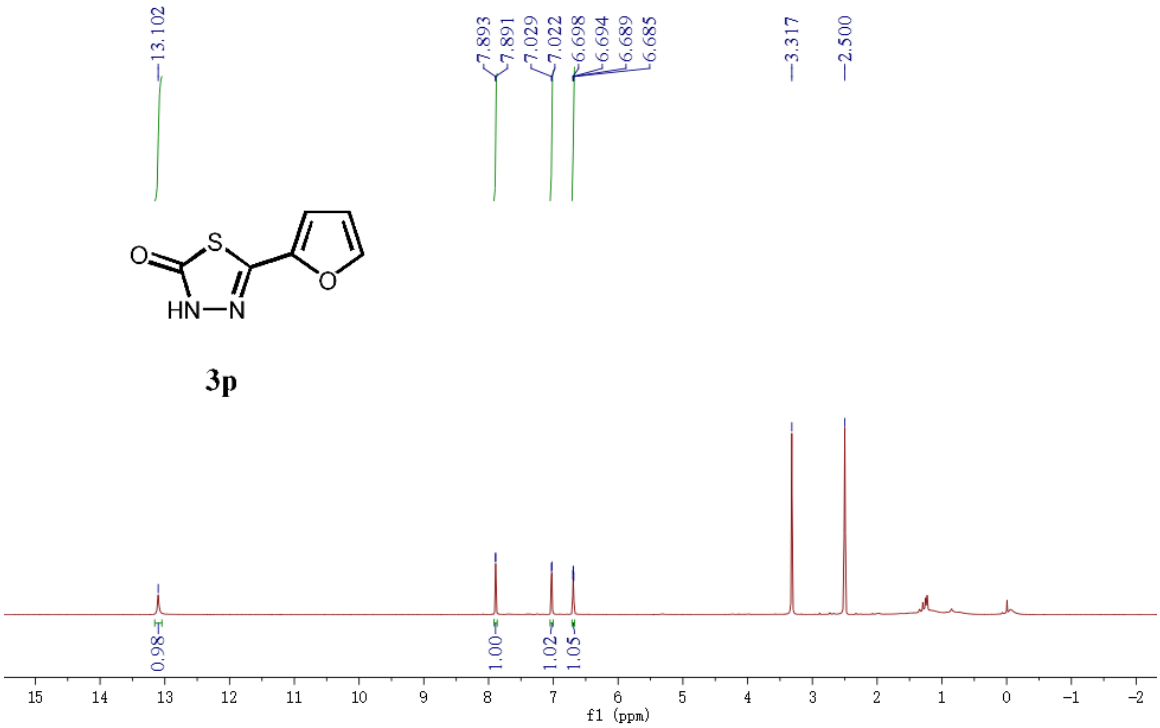


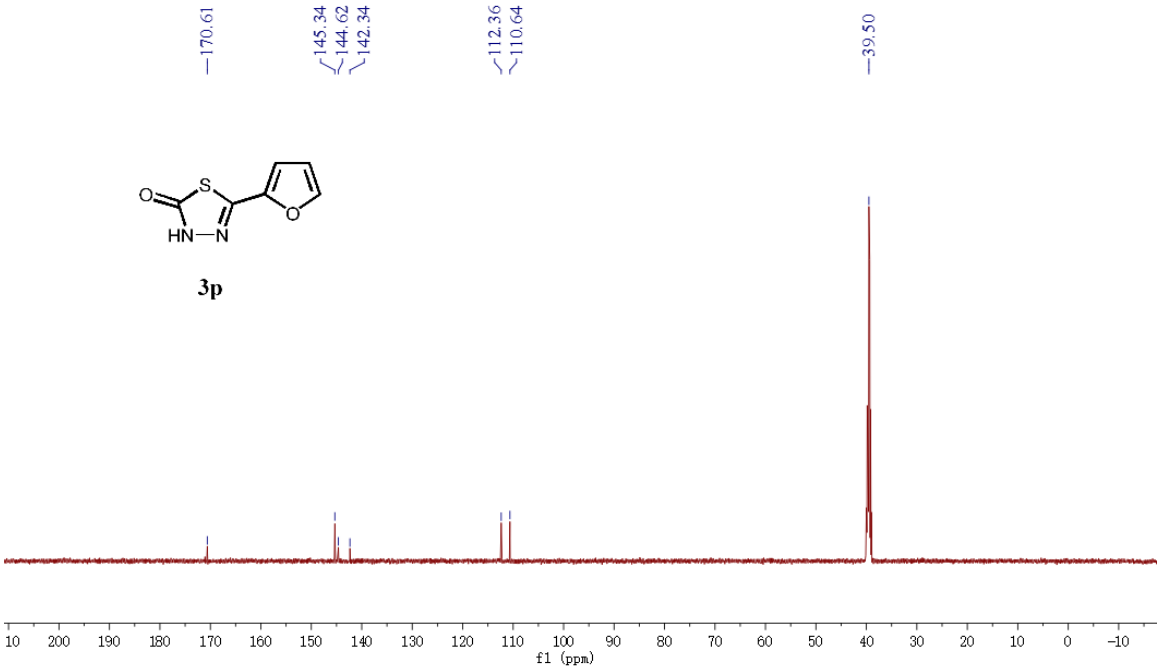
3o

(126 MHz for ^{13}C NMR with DMSO as solvent)



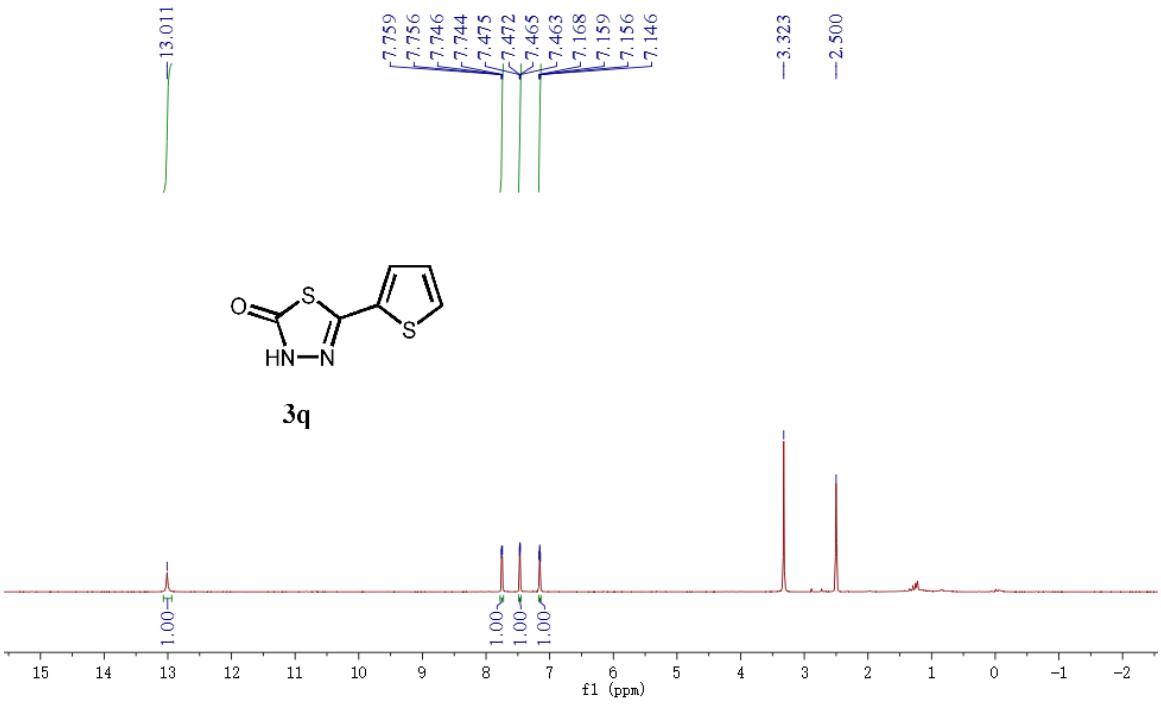
3p

(400 MHz for ^{1}H NMR with DMSO as solvent)



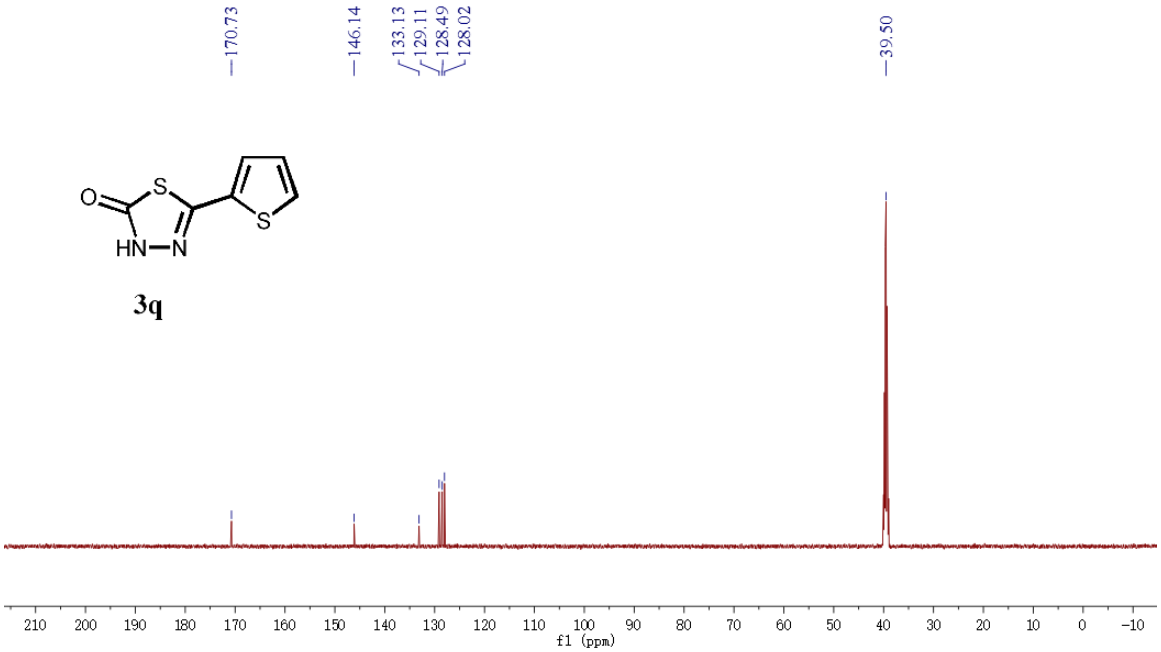
3p

(126 MHz for ^{13}C NMR with DMSO as solvent)

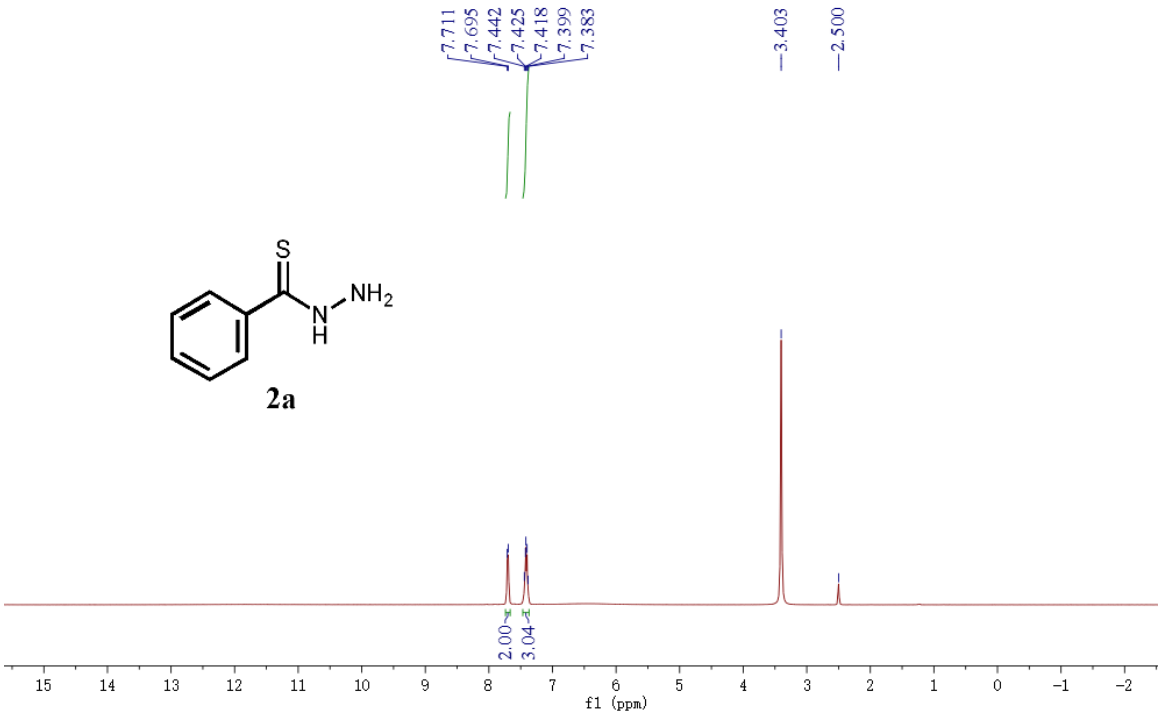


3q

(400 MHz for ^{1}H NMR with DMSO as solvent)



(126 MHz for ^{13}C NMR with DMSO as solvent)



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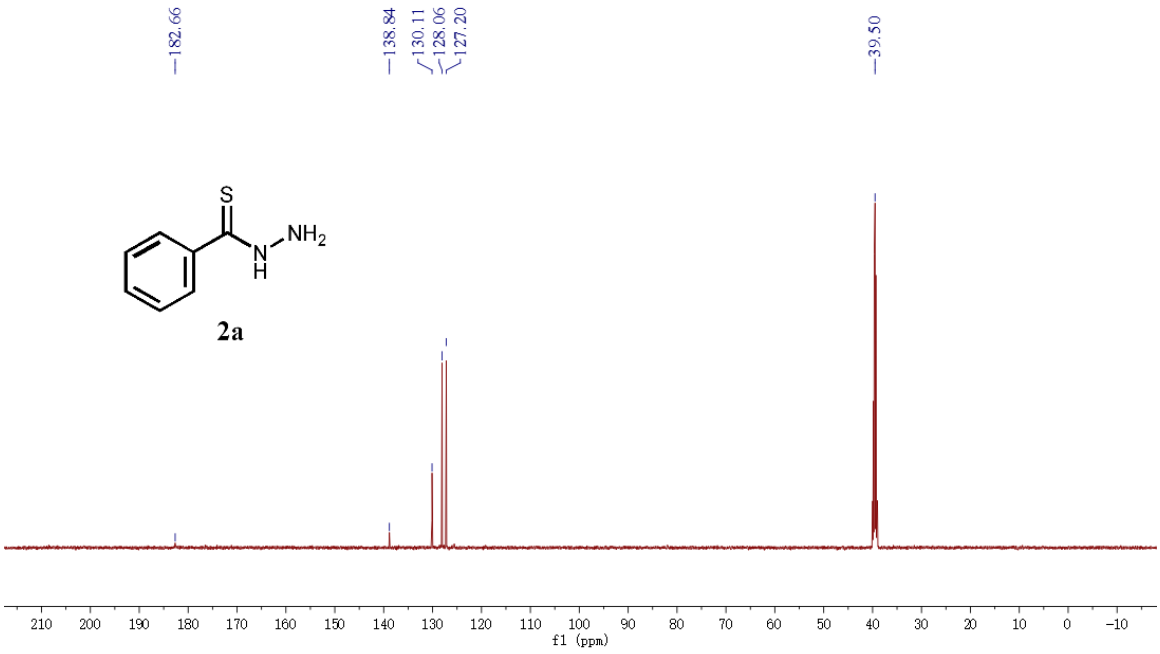
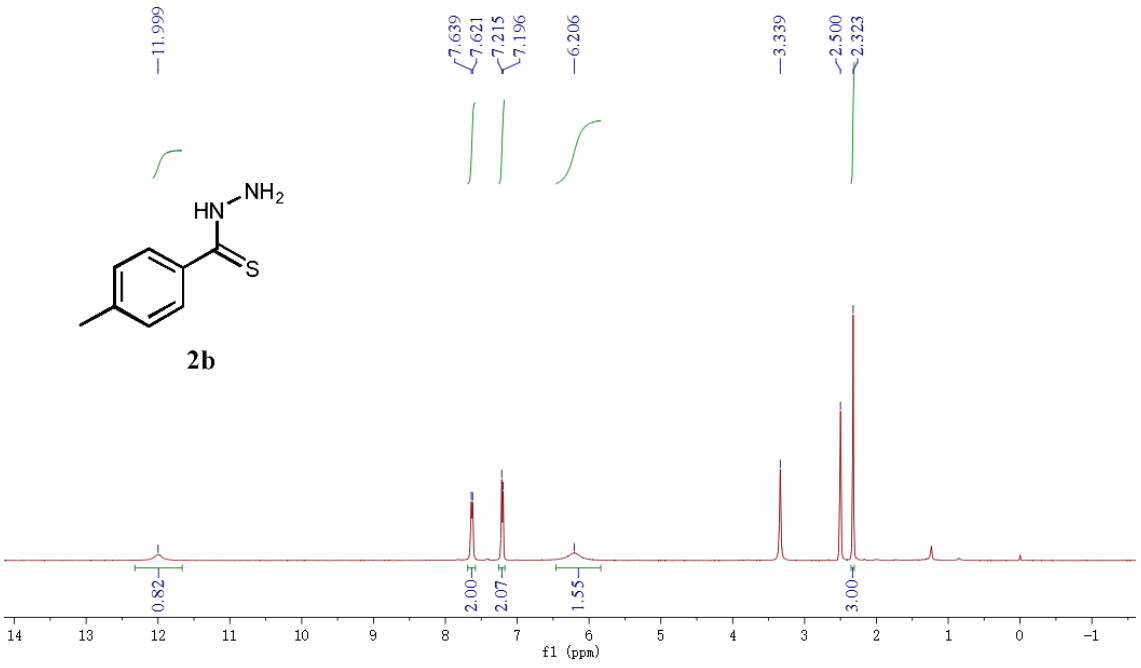


(126 MHz for ^{13}C NMR with DMSO as solvent)



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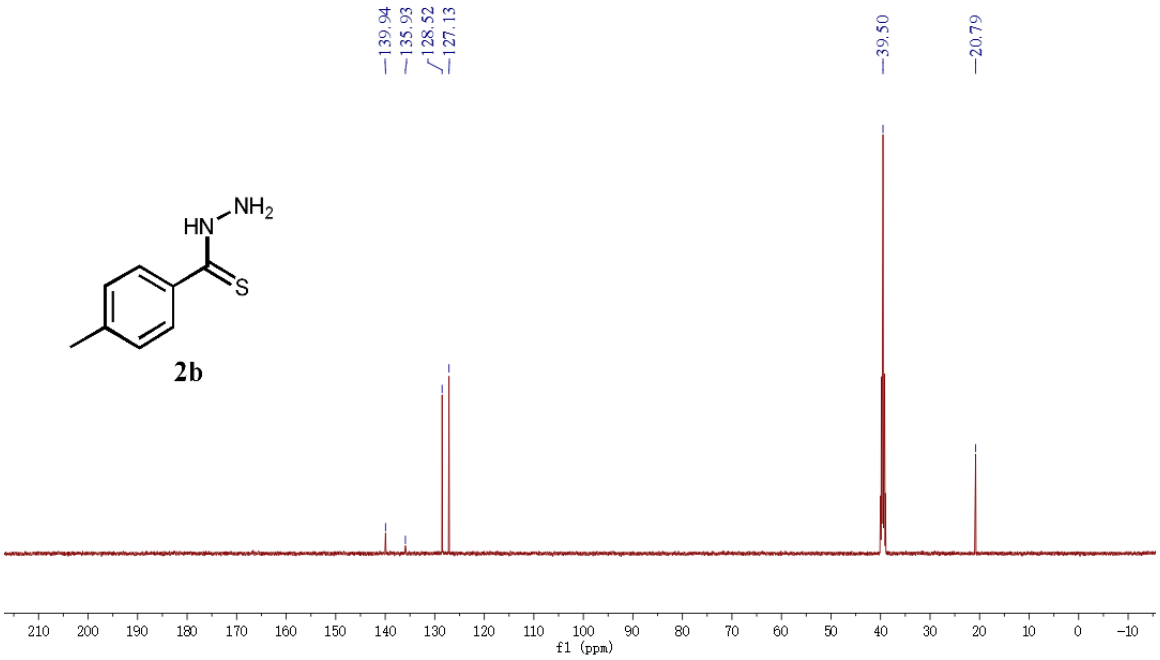
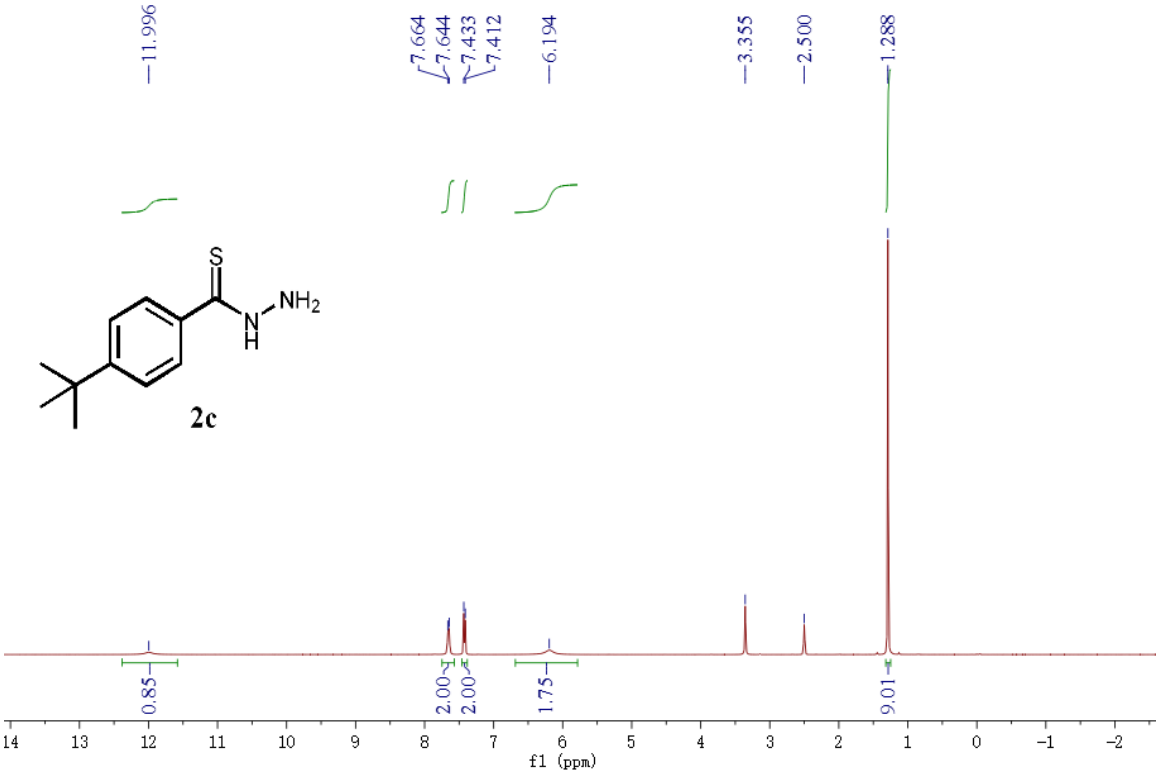
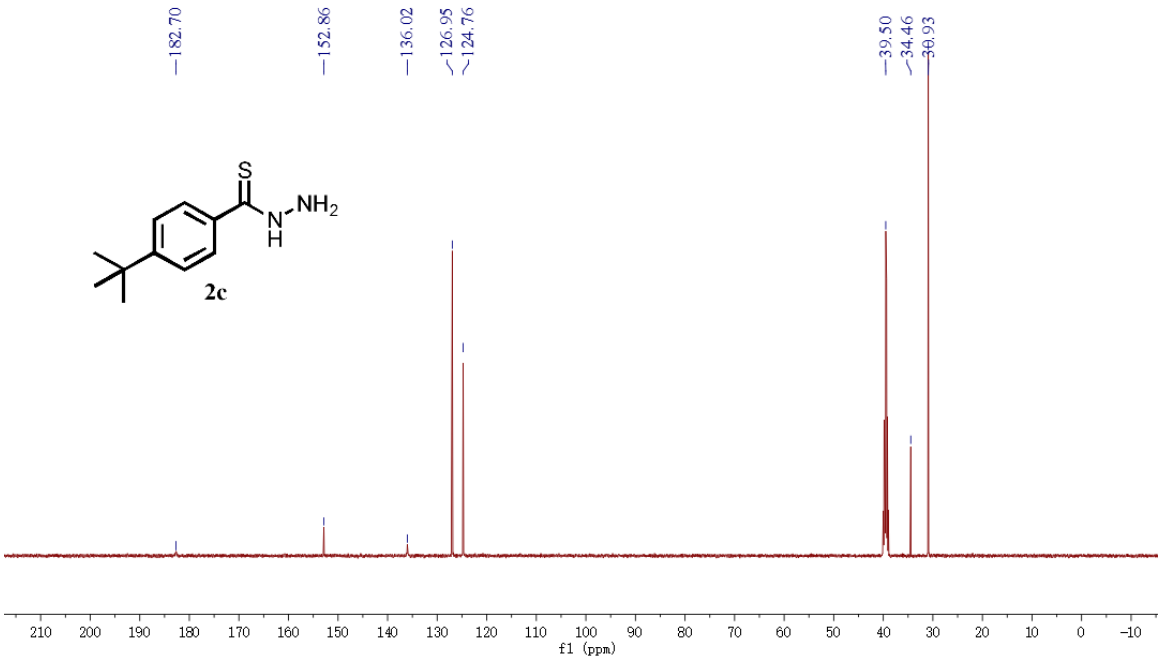


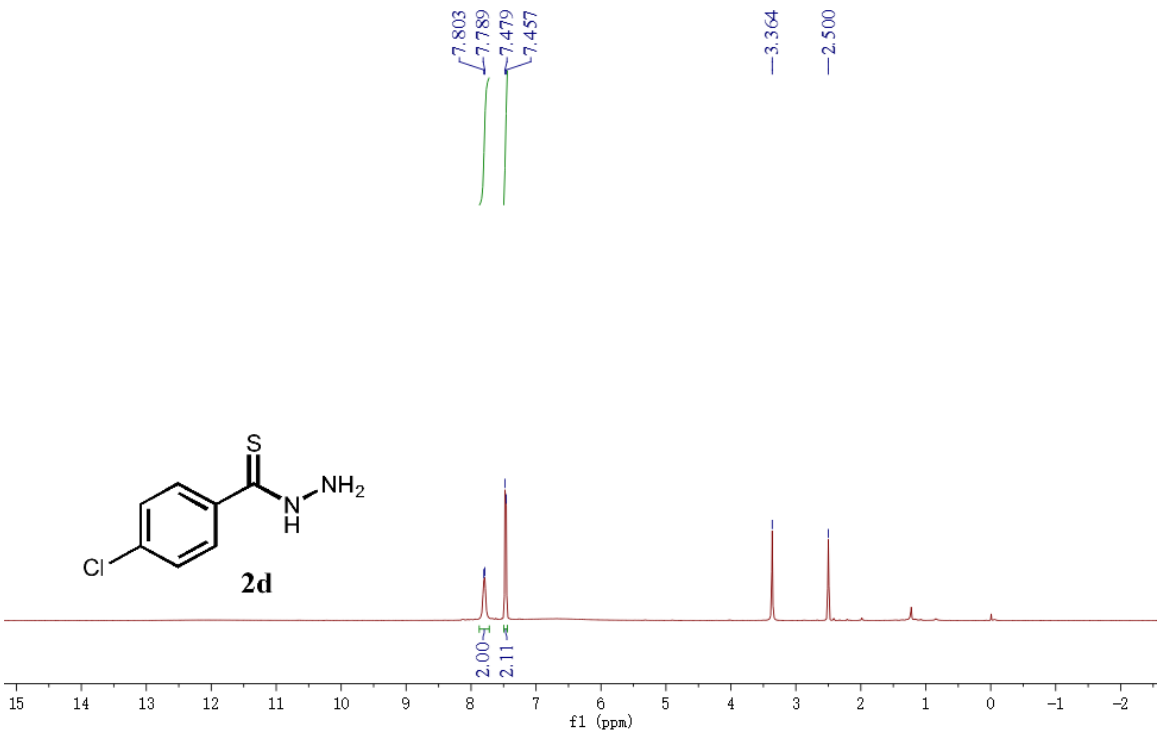
(126 MHz for ^{13}C NMR with DMSO as solvent)



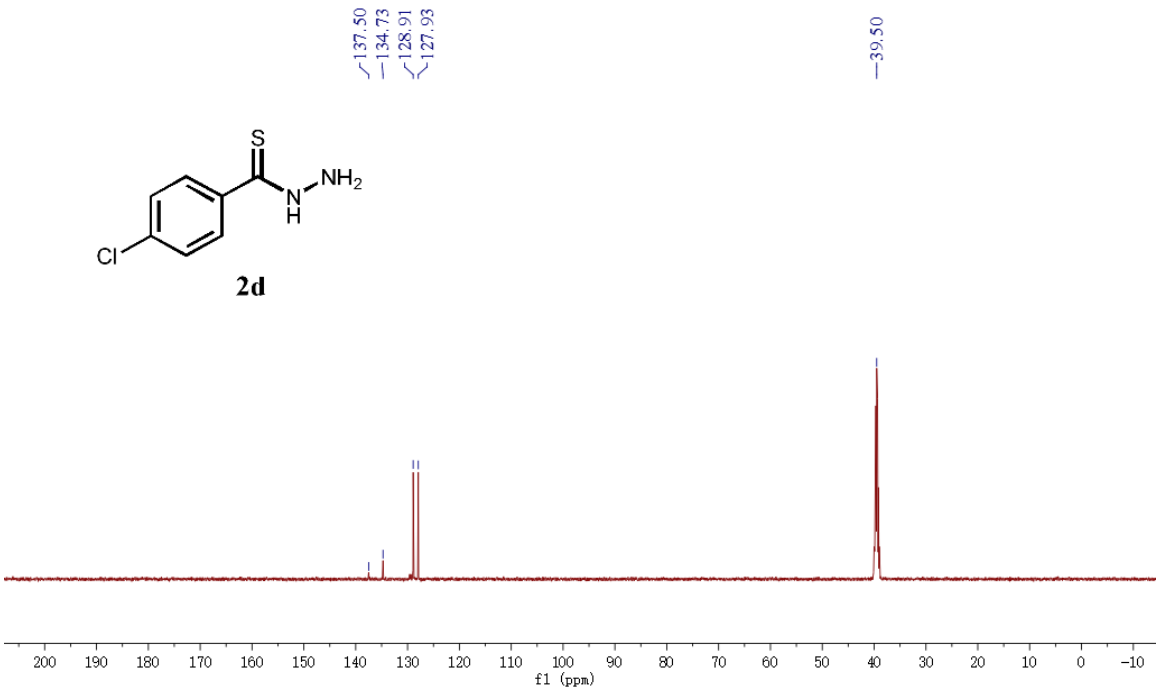
(400 MHz for ^{1}H NMR with DMSO as solvent)



(126 MHz for ^{13}C NMR with DMSO as solvent)



(400 MHz for ^{1}H NMR with DMSO as solvent)



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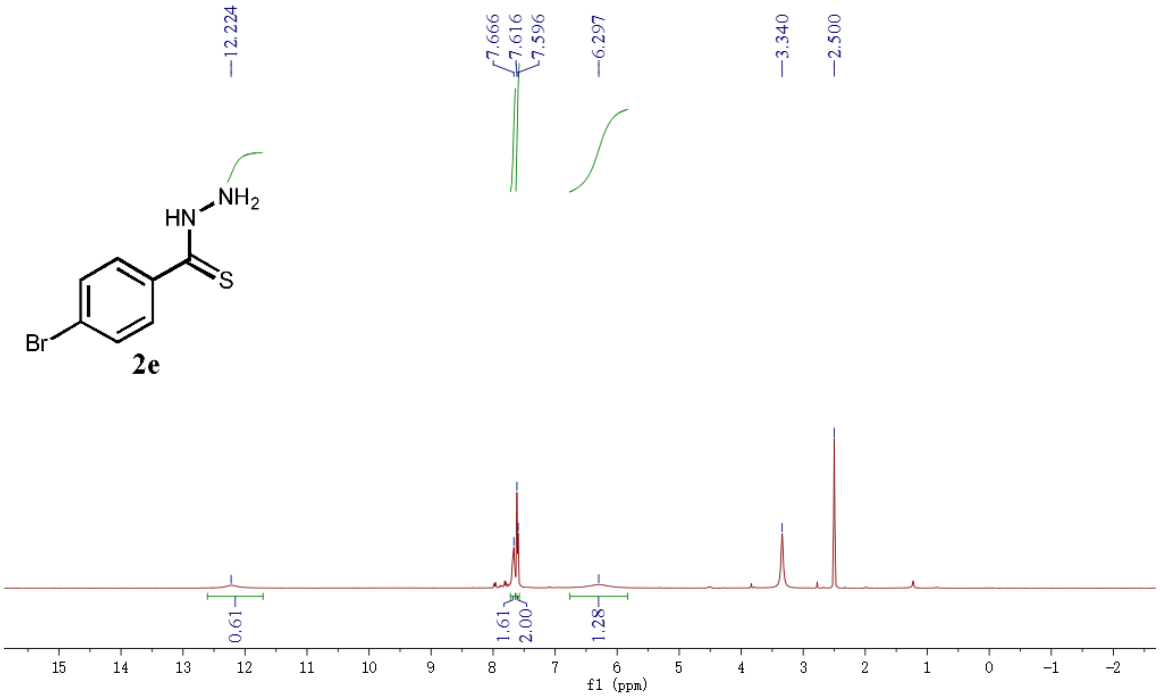
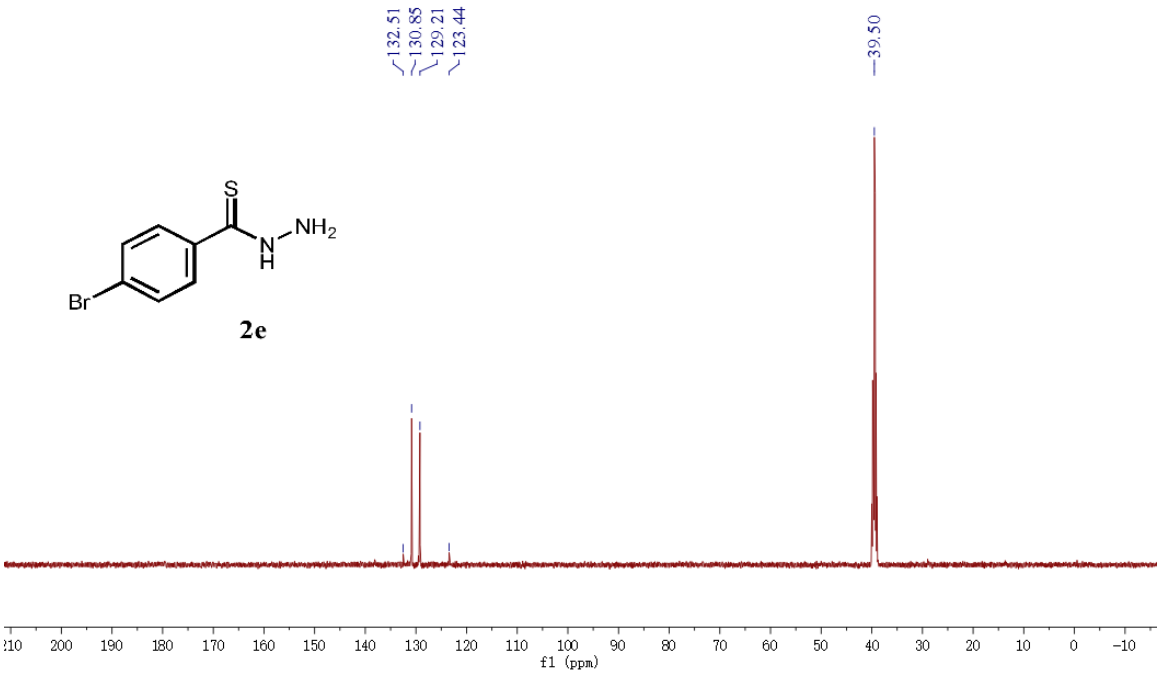


(400 MHz for ^{1}H NMR with DMSO as solvent)



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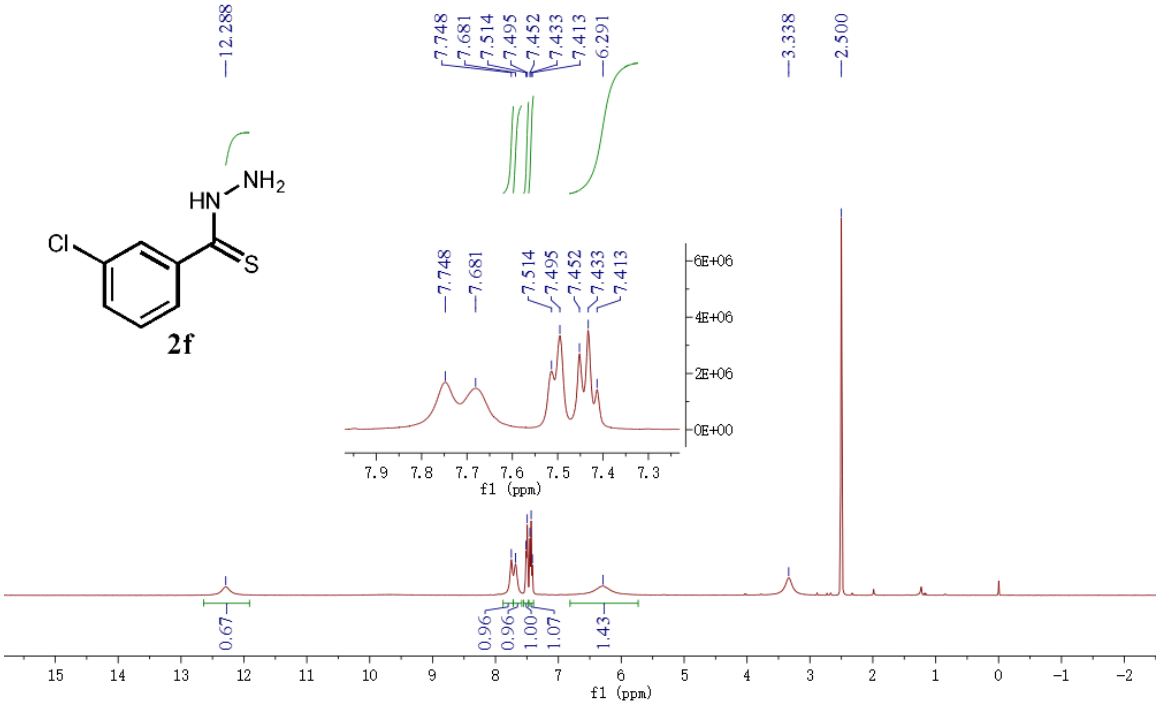
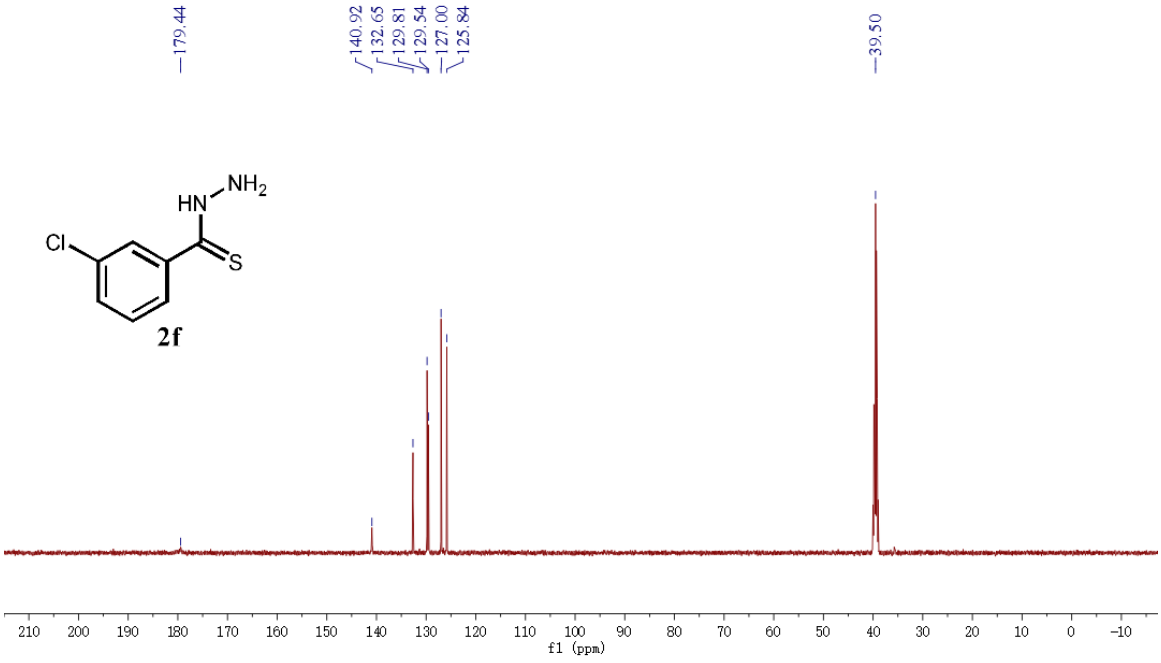
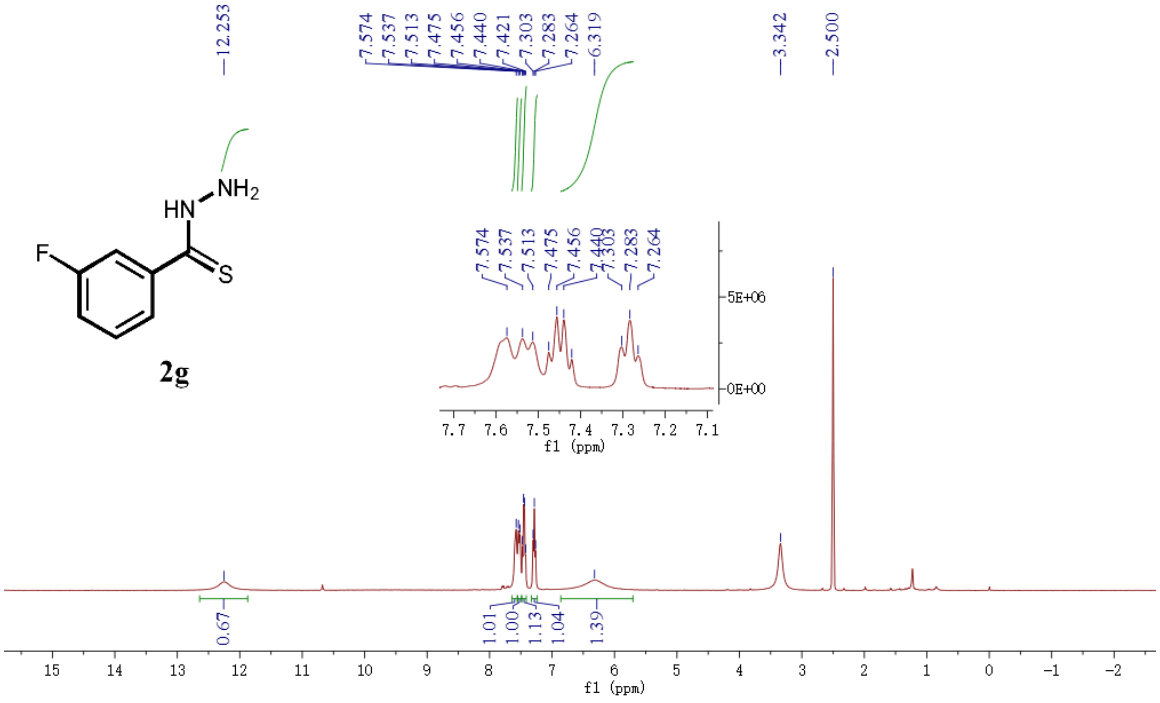


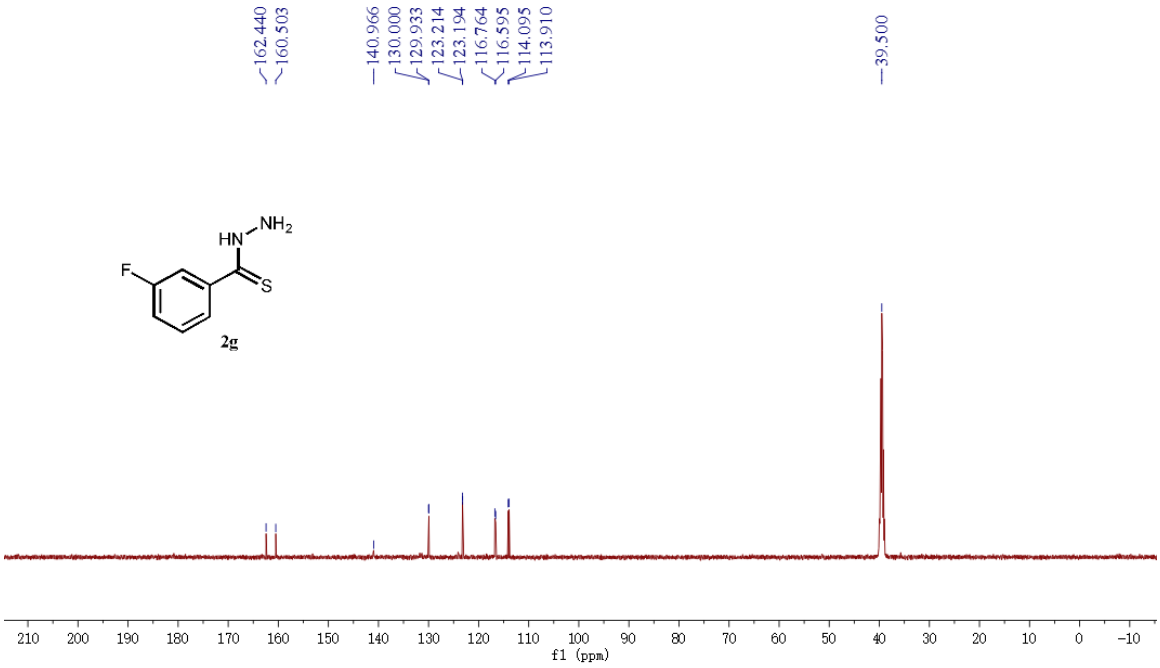
(400 MHz for ^{1}H NMR with DMSO as solvent)



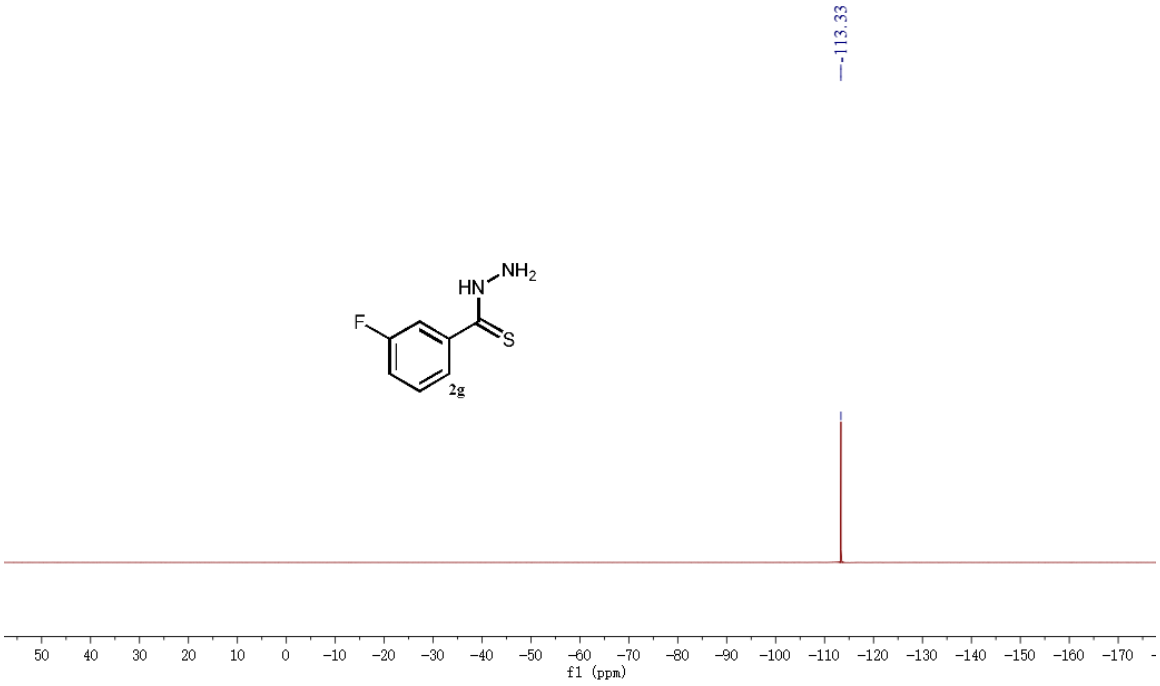
(126 MHz for ^{13}C NMR with DMSO as solvent)



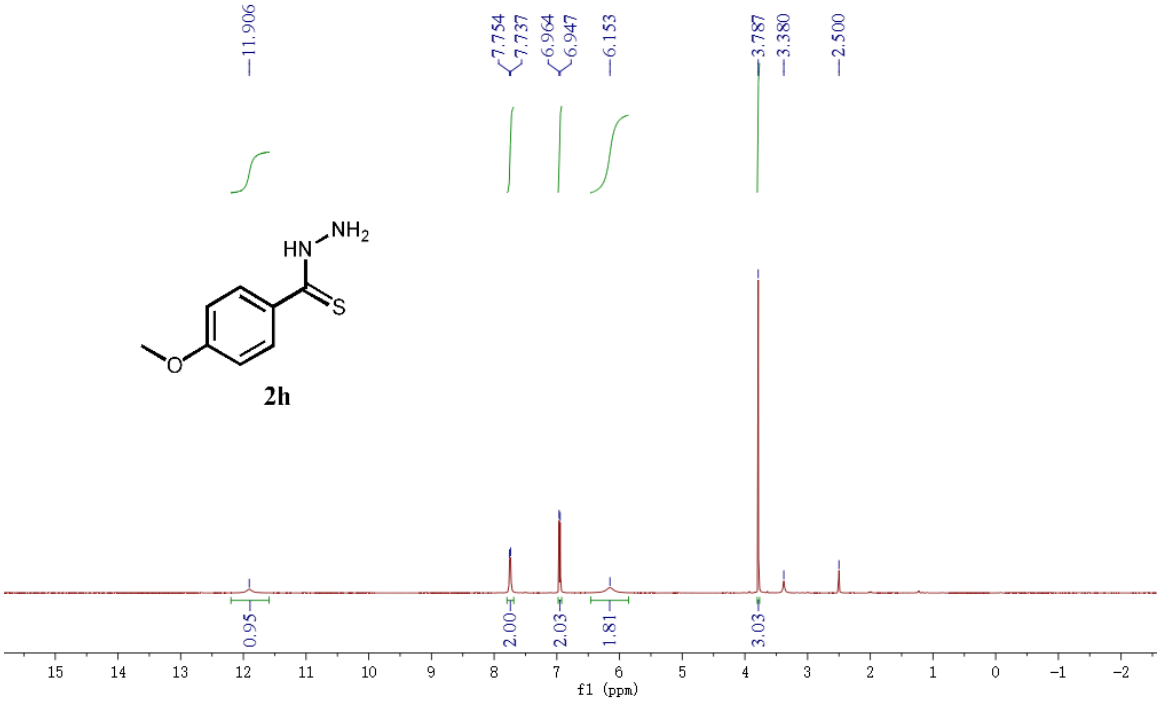
(400 MHz for ^{1}H NMR with DMSO as solvent)



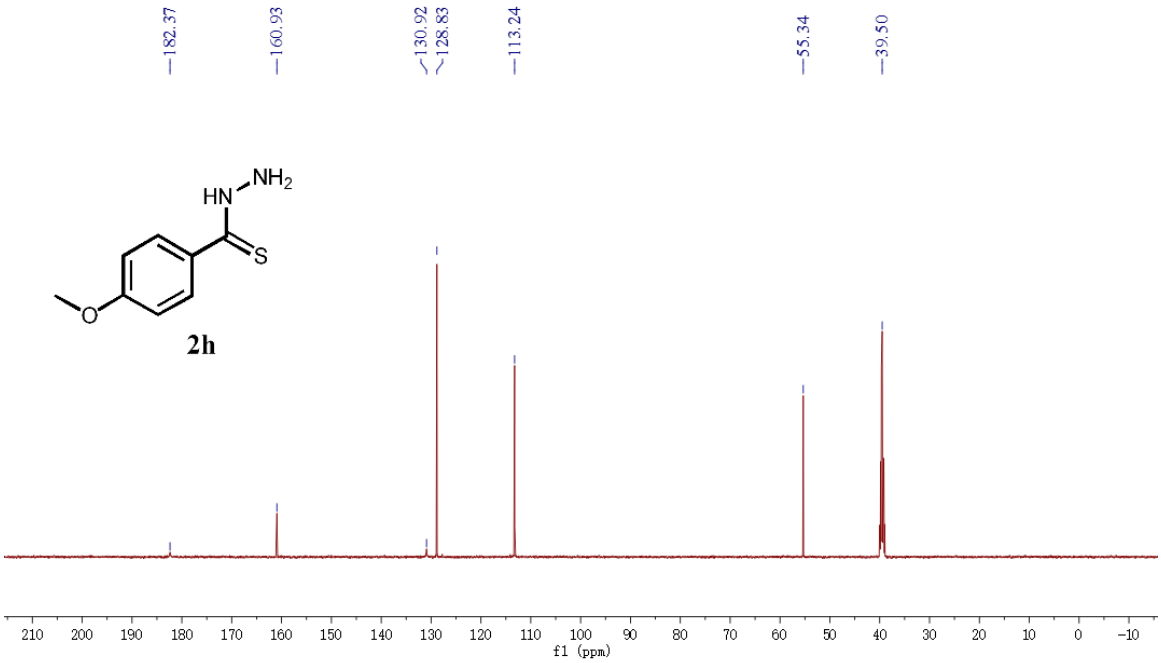
(126 MHz for ^{13}C NMR with DMSO as solvent)



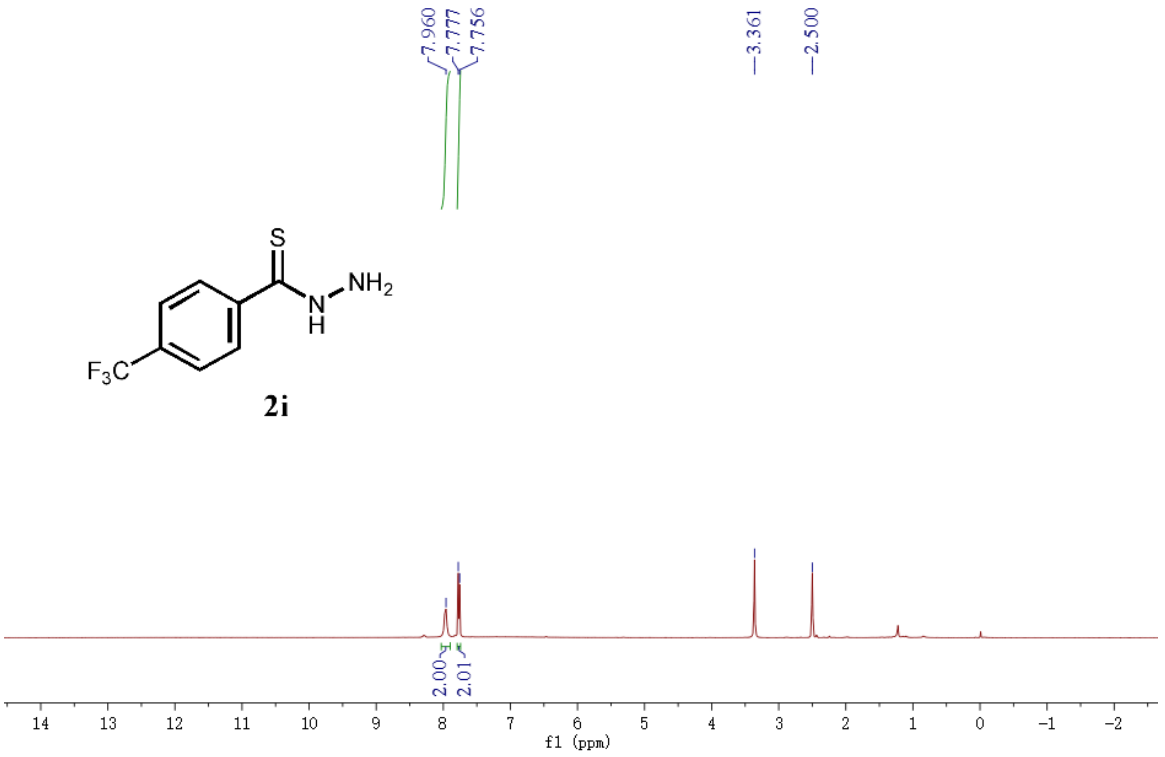
(471 MHz for ^{19}F NMR with DMSO as solvent)



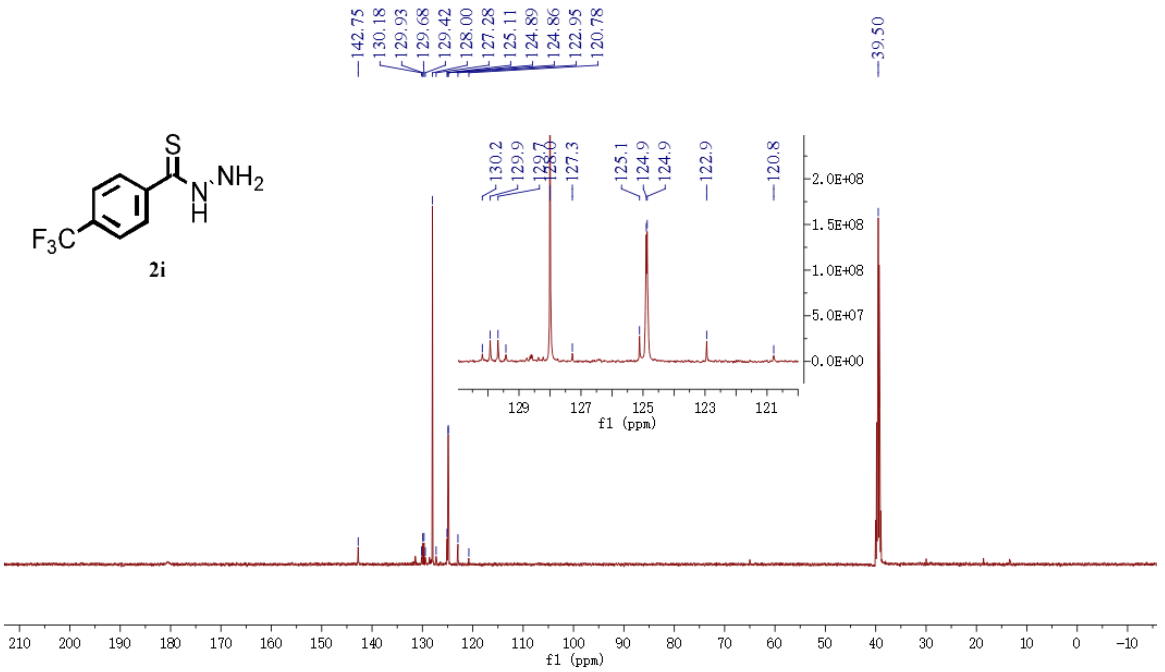
(400 MHz for ^{1}H NMR with DMSO as solvent)



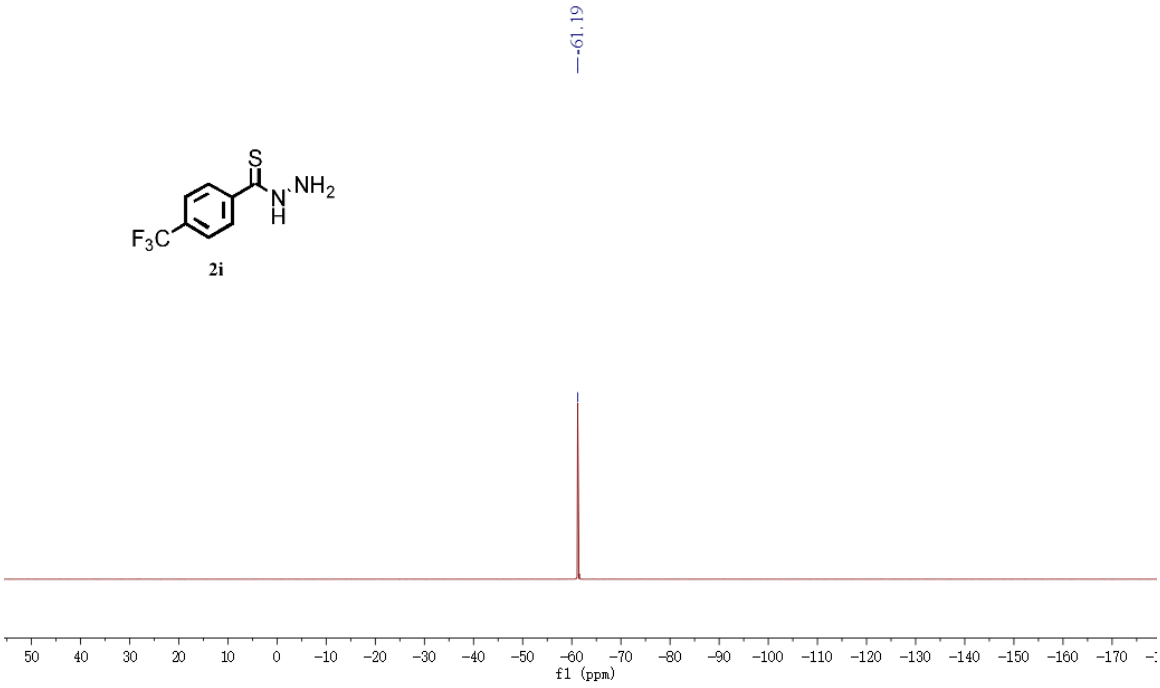
(126 MHz for ^{13}C NMR with DMSO as solvent)



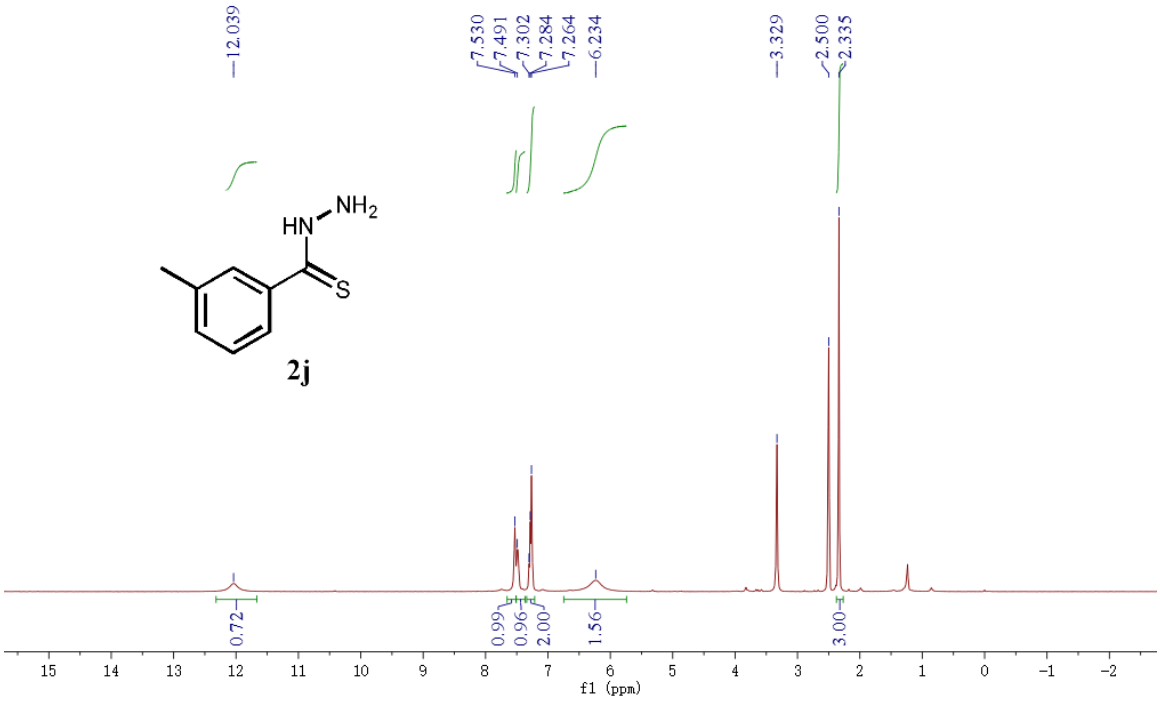
(400 MHz for ^{1}H NMR with DMSO as solvent)



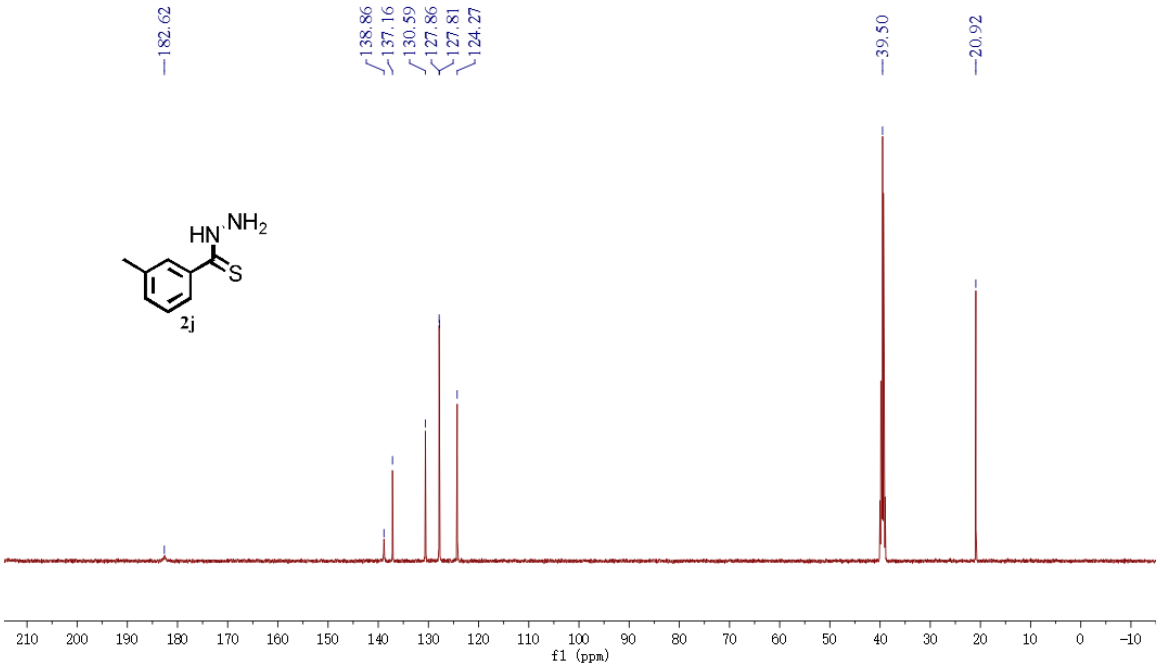
(126 MHz for ^{13}C NMR with DMSO as solvent)



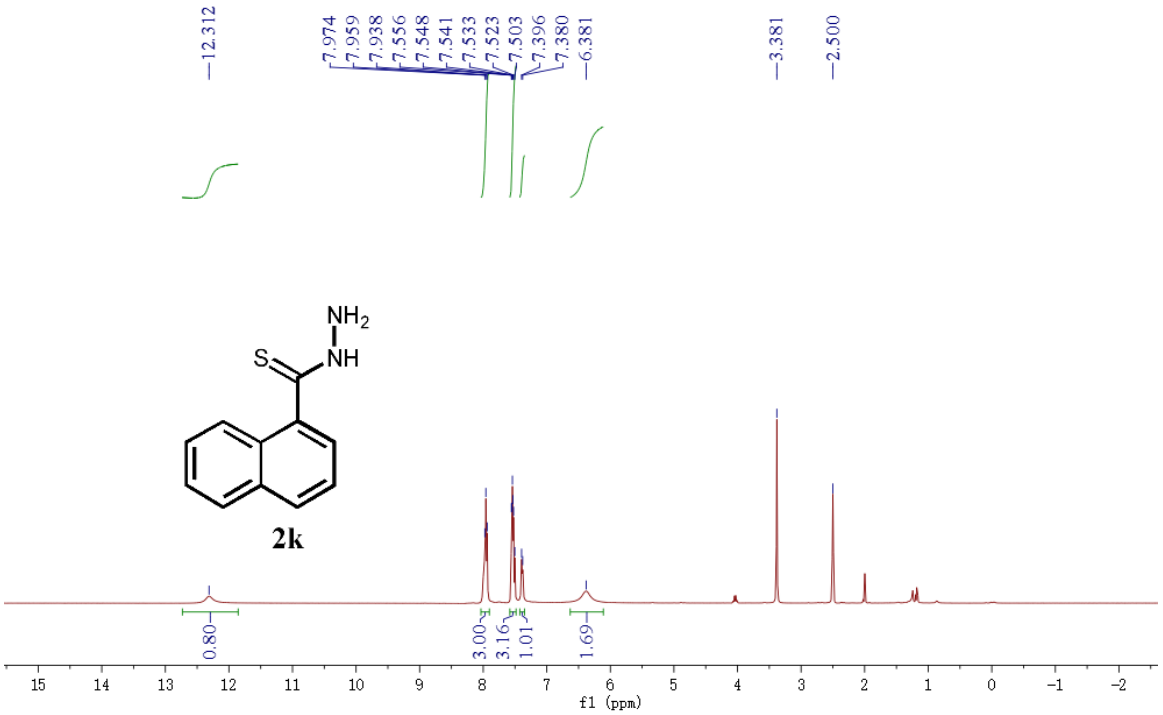
(471 MHz for ^{19}F NMR with DMSO as solvent)



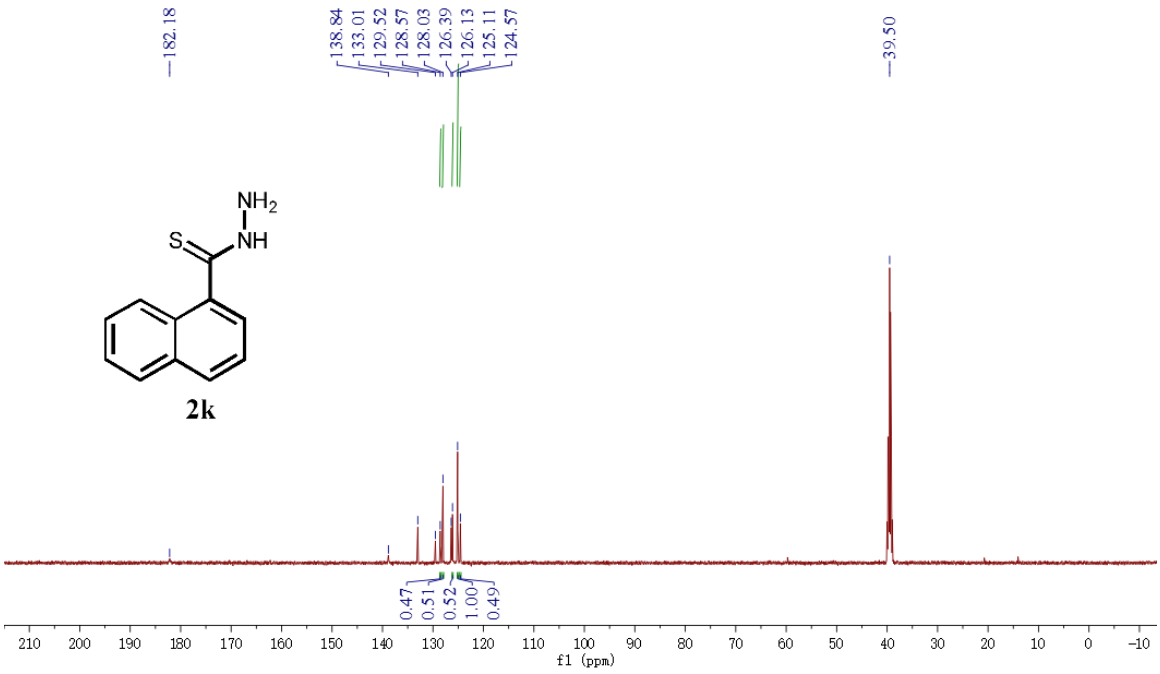
(400 MHz for ^{1}H NMR with DMSO as solvent)



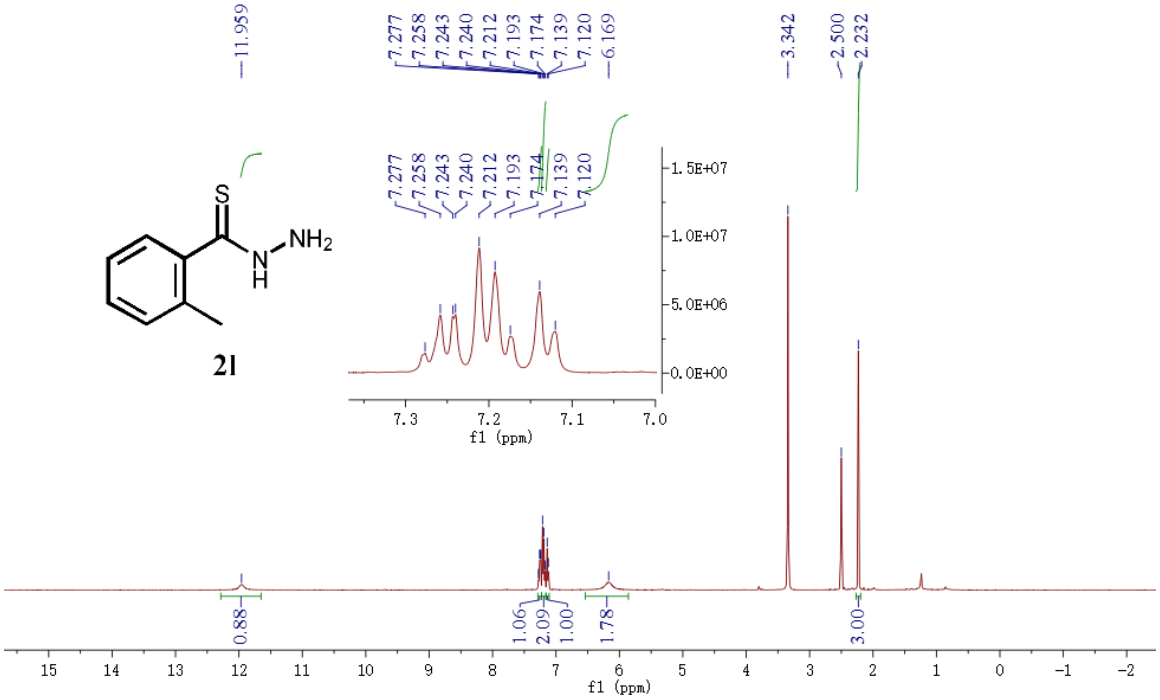
(126 MHz for ^{13}C NMR with DMSO as solvent)



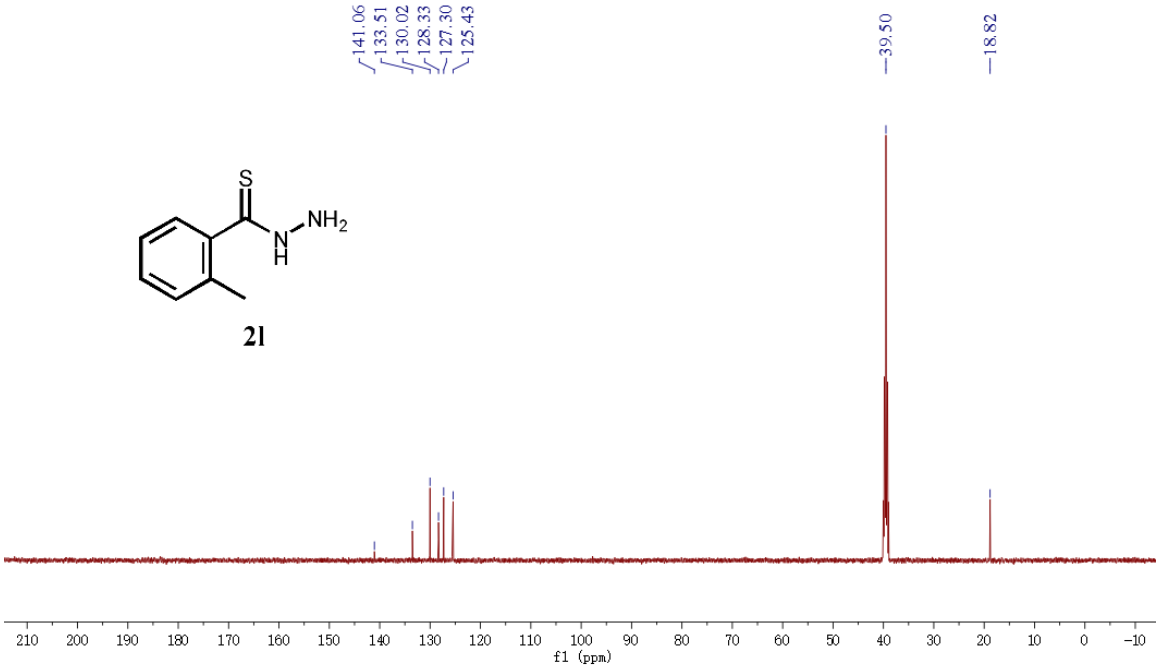
(400 MHz for ^{1}H NMR with DMSO as solvent)



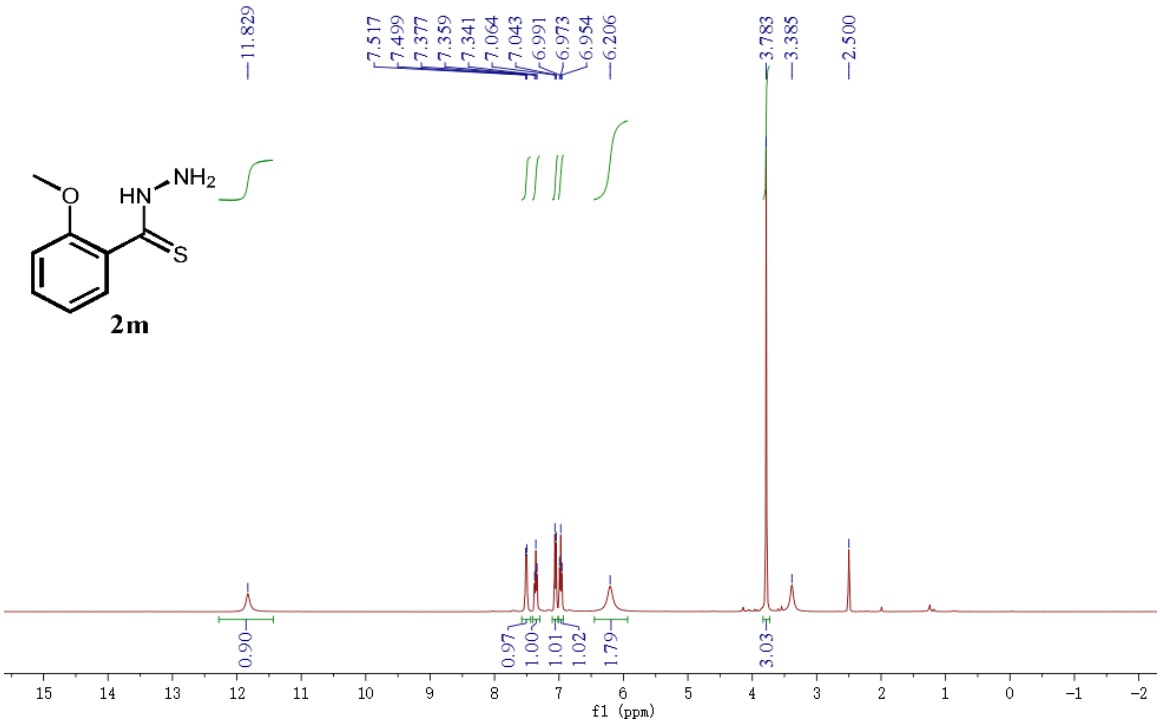
(126 MHz for ^{13}C NMR with DMSO as solvent)



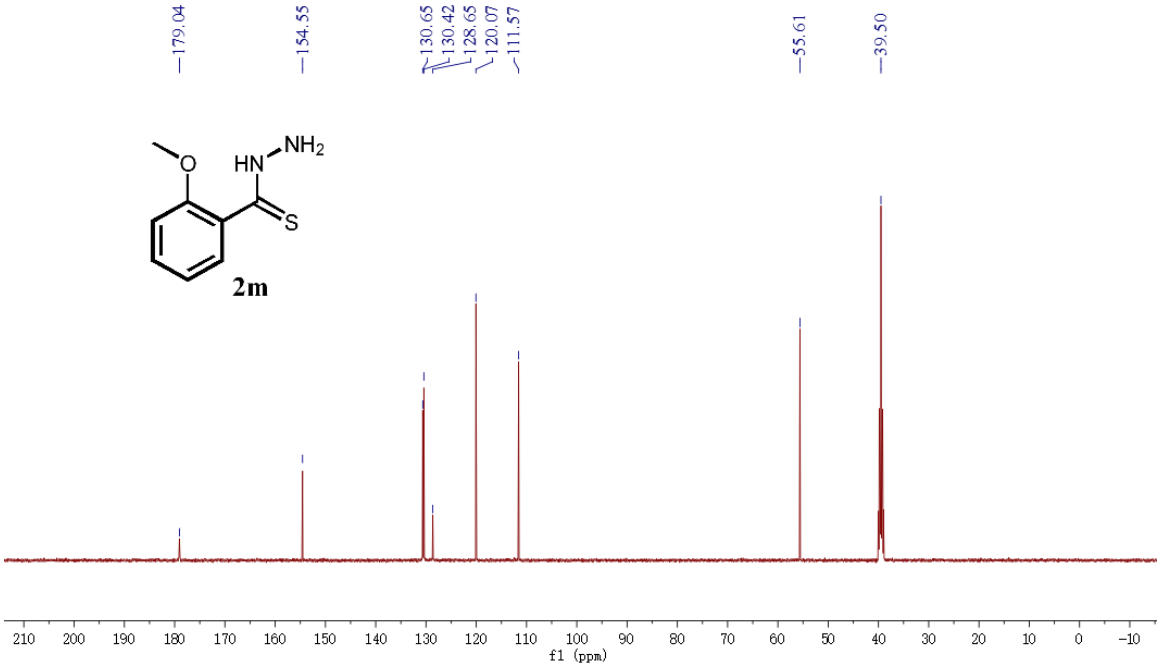
(400 MHz for ^{1}H NMR with DMSO as solvent)



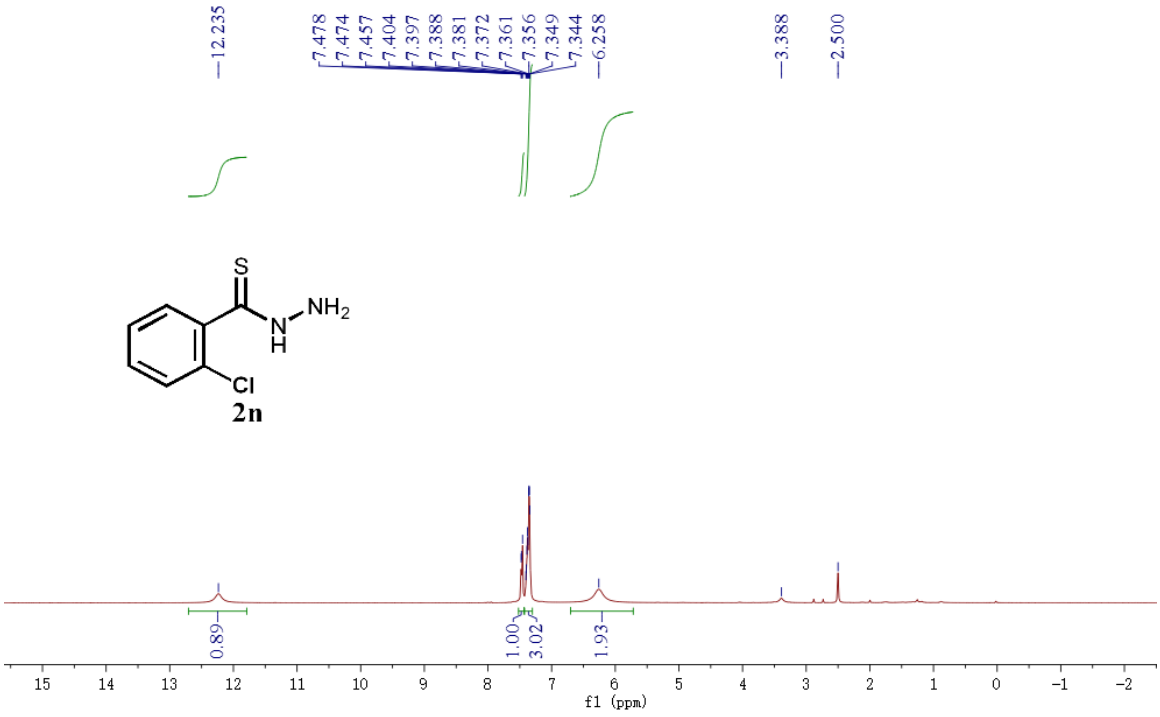
(126 MHz for ^{13}C NMR with DMSO as solvent)



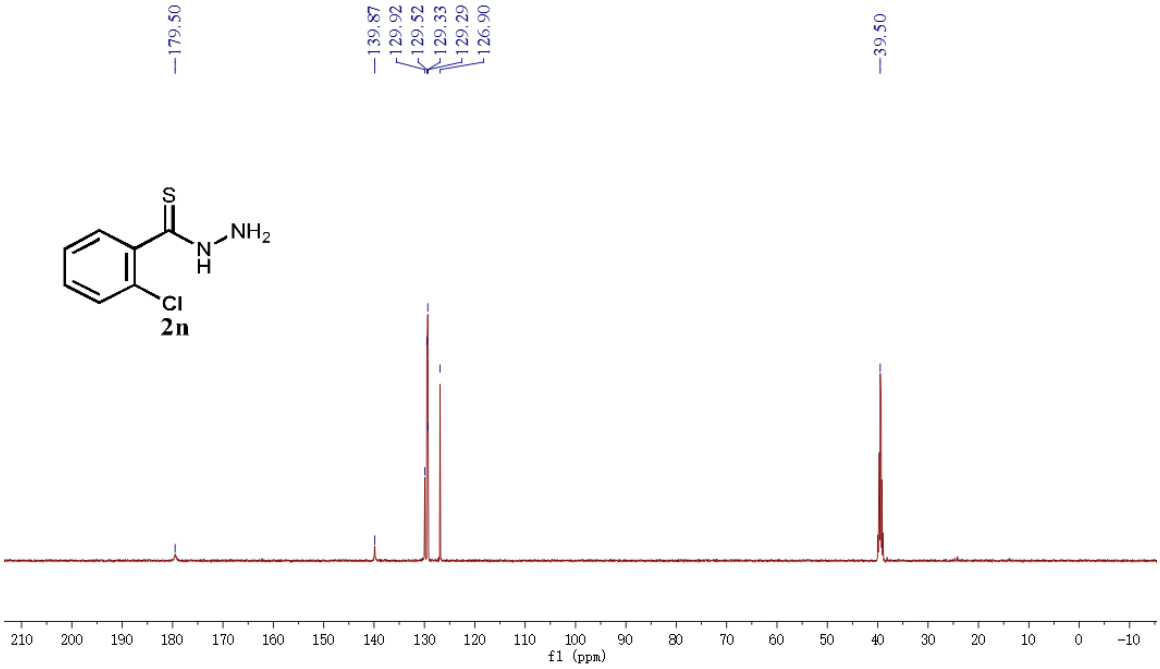
(400 MHz for ^{1}H NMR with DMSO as solvent)



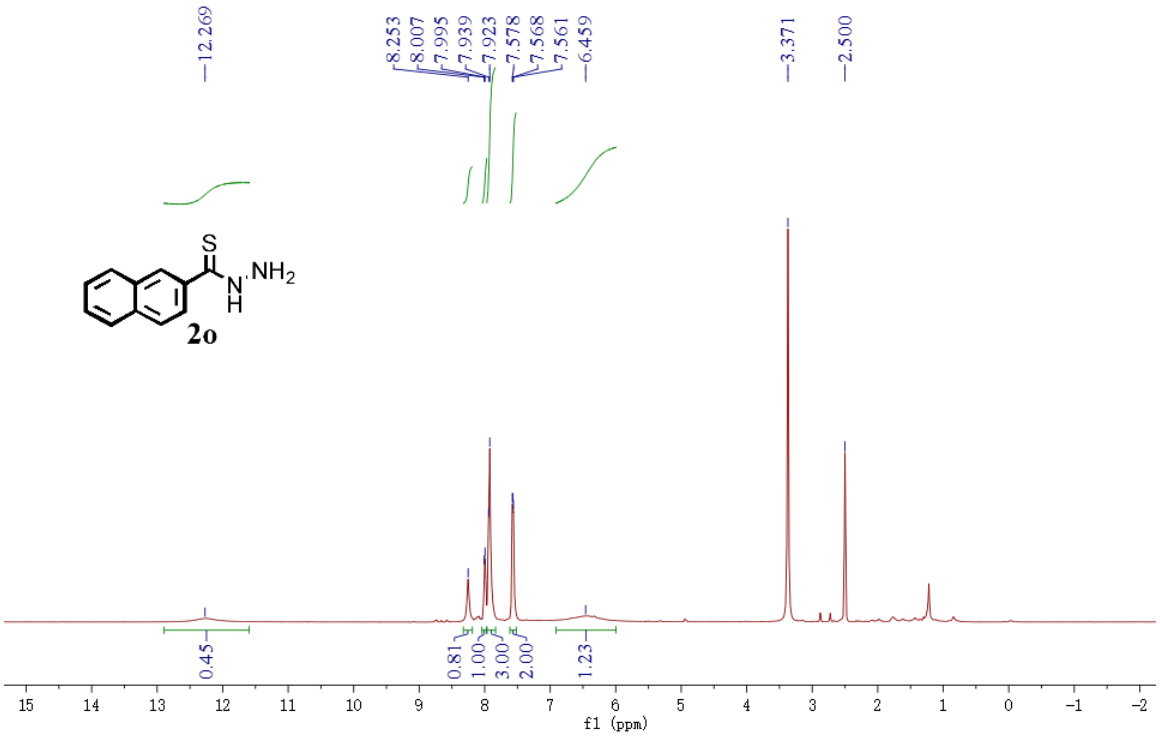
(126 MHz for ^{13}C NMR with DMSO as solvent)



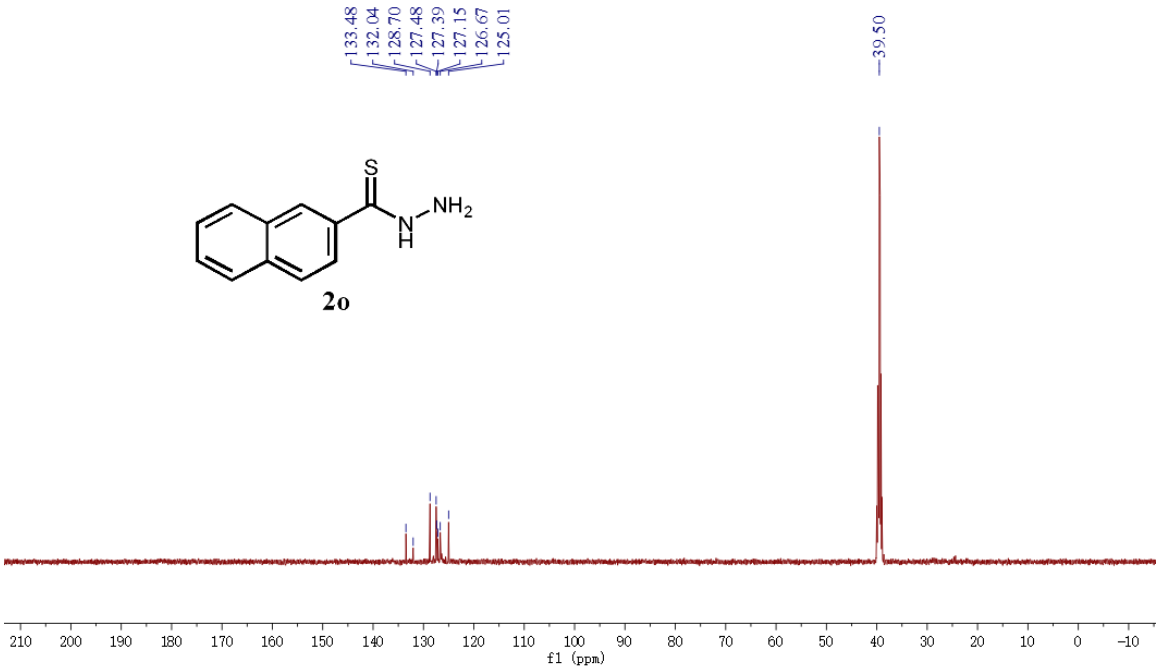
(400 MHz for ^{1}H NMR with DMSO as solvent)



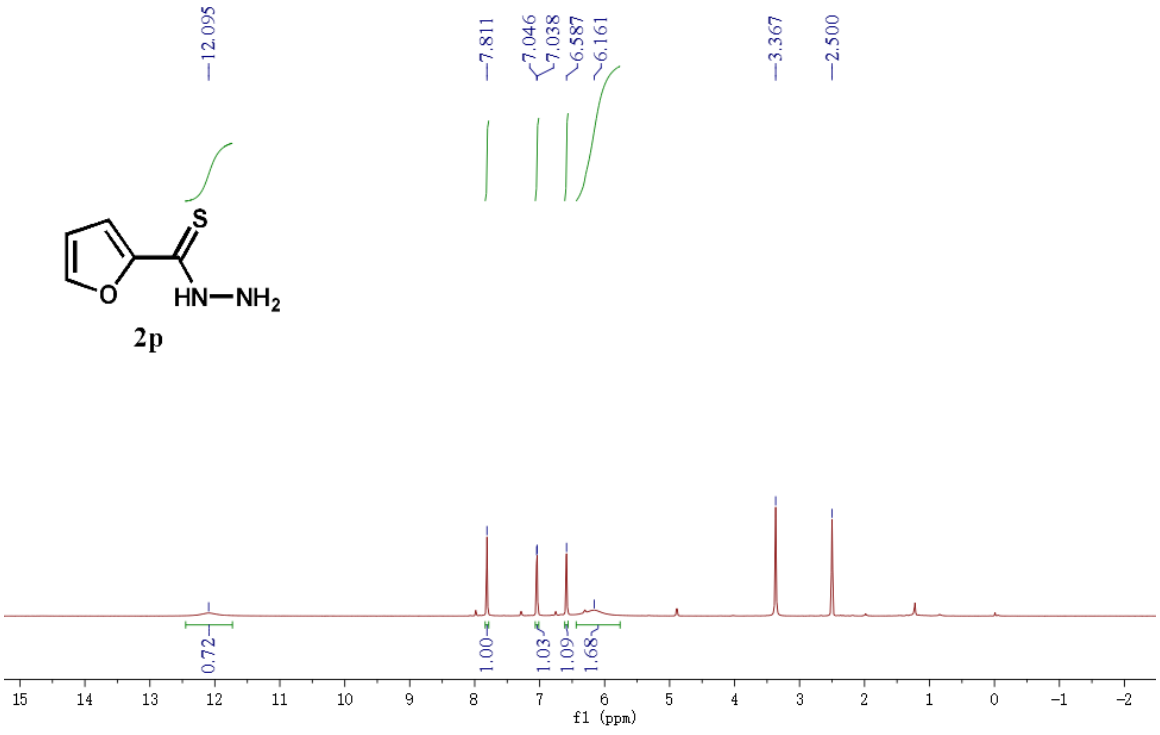
(126 MHz for ^{13}C NMR with DMSO as solvent)



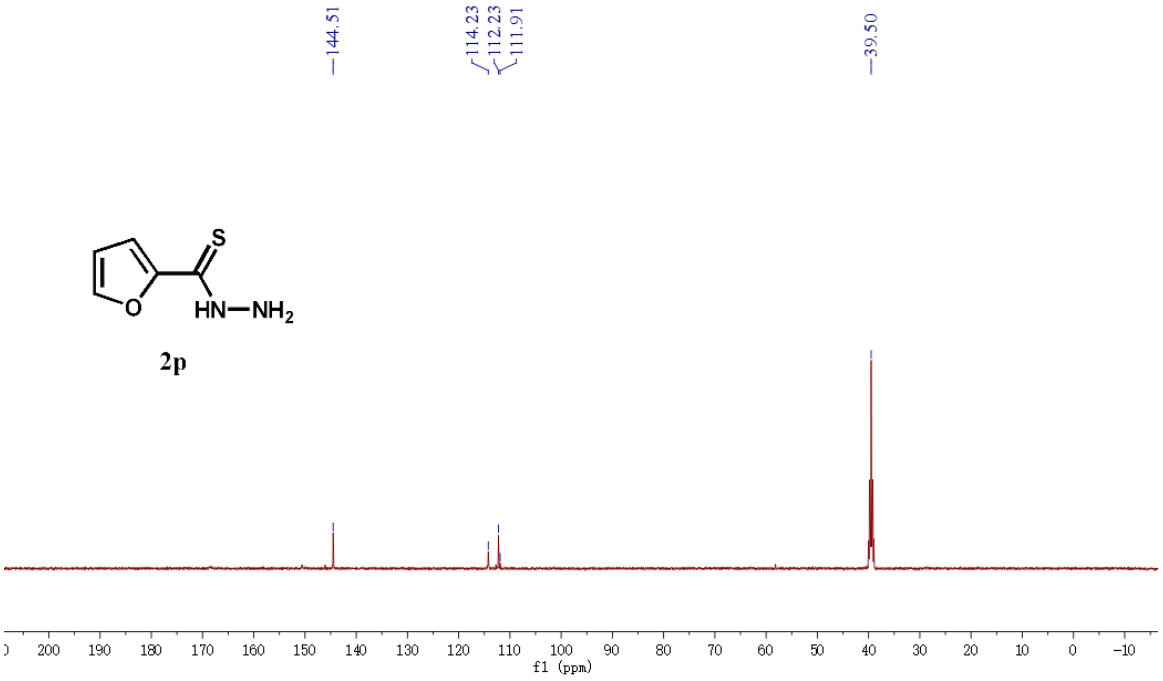
(400 MHz for ^{1}H NMR with DMSO as solvent)



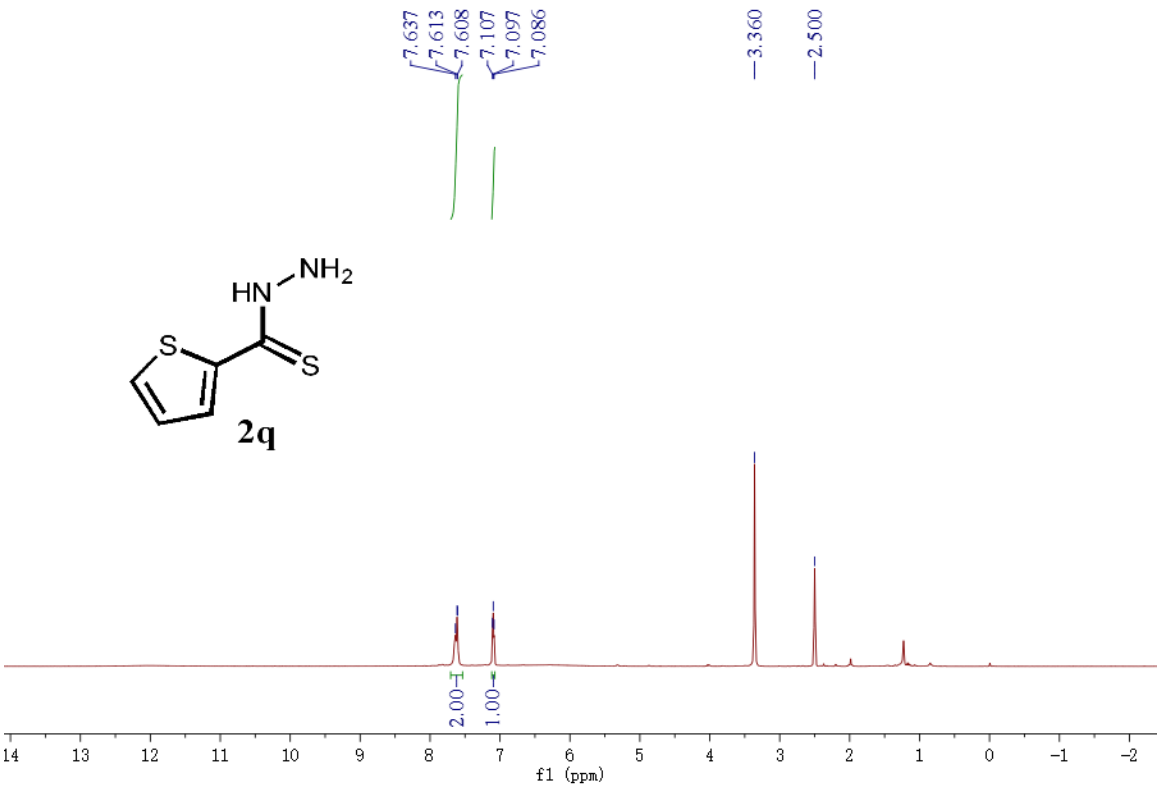
(126 MHz for ^{13}C NMR with DMSO as solvent)



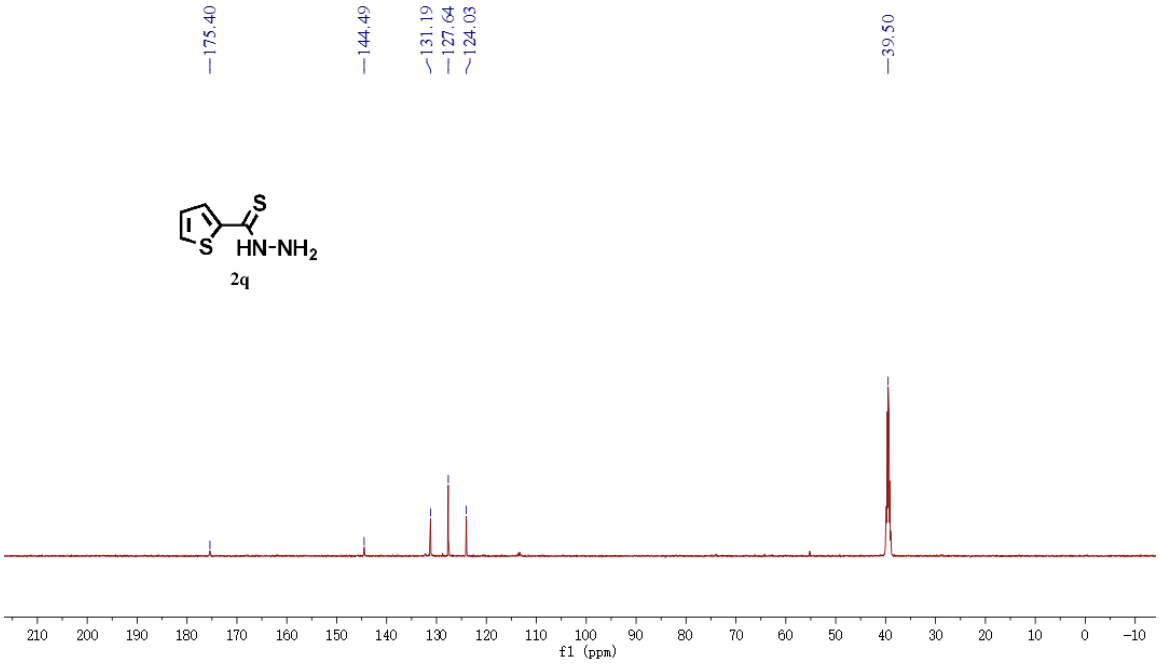
(400 MHz for ^{1}H NMR with DMSO as solvent)



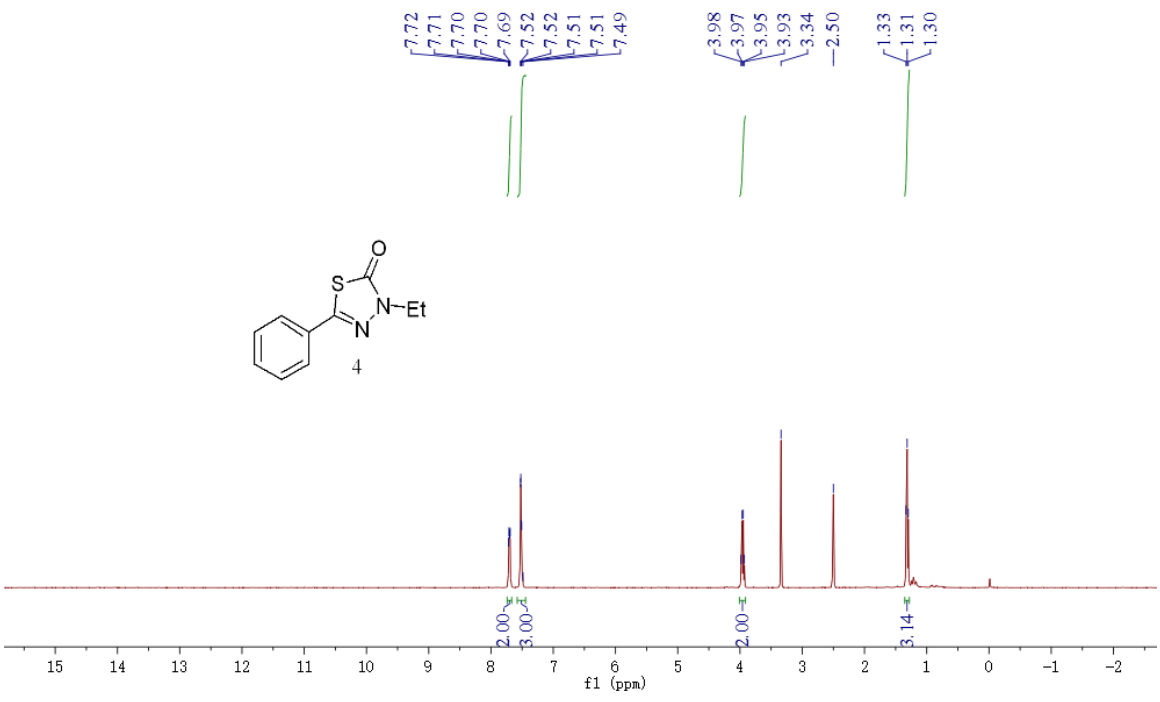
(126 MHz for ^{13}C NMR with DMSO as solvent)



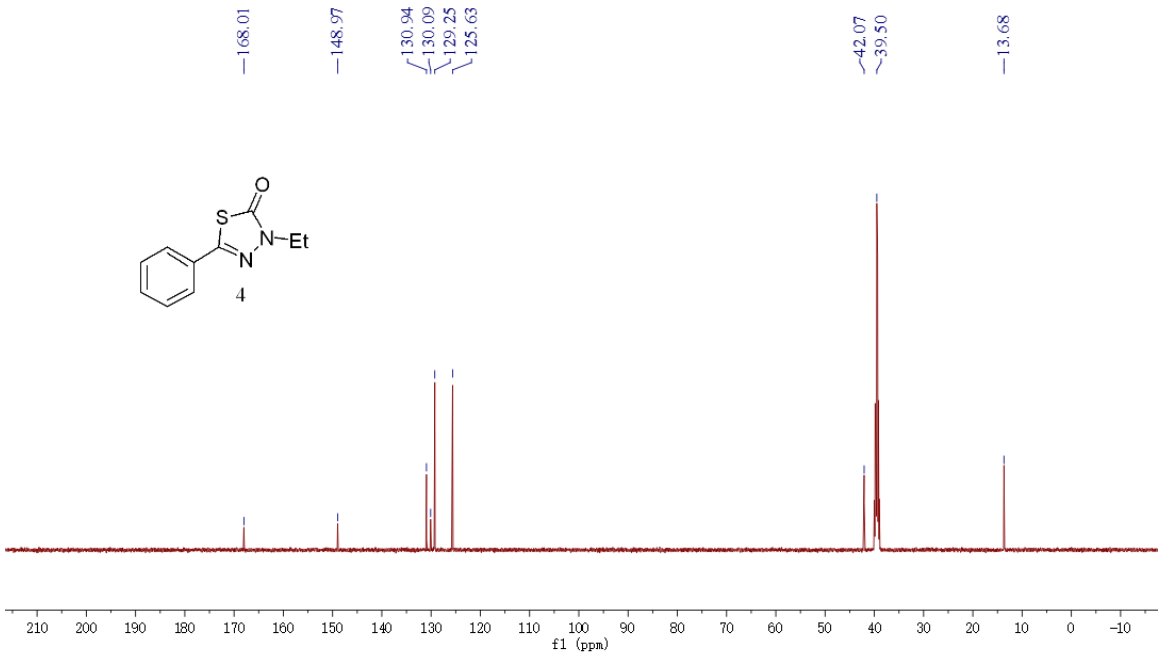
(400 MHz for ^{1}H NMR with DMSO as solvent)



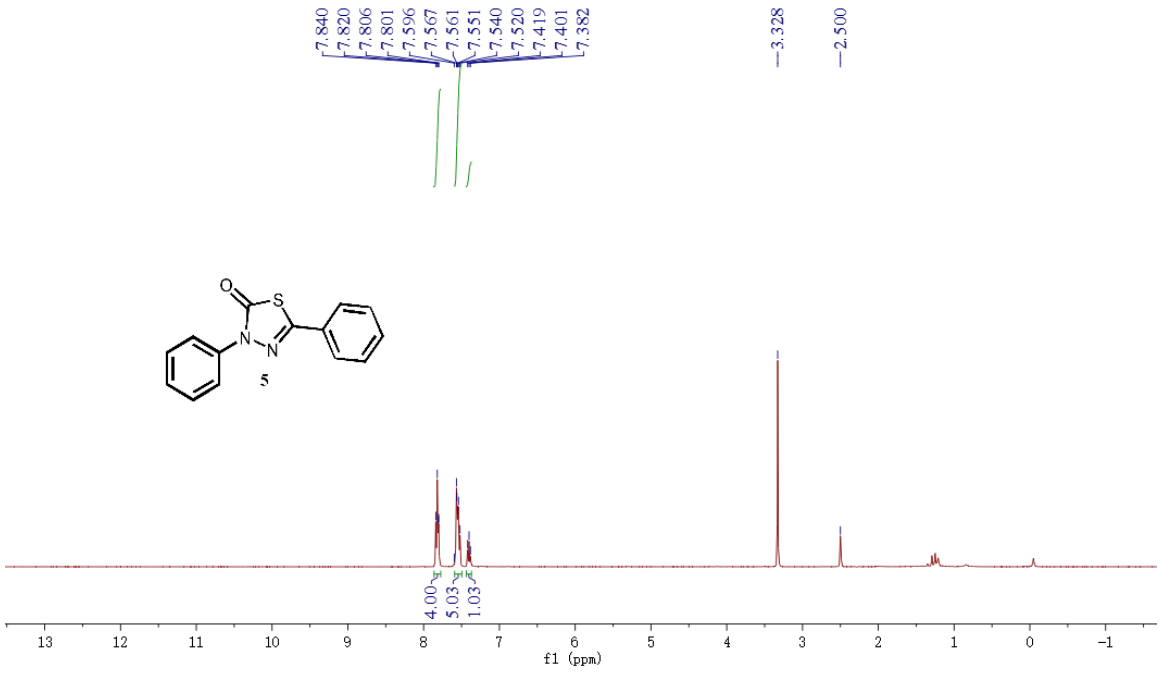
(126 MHz for ^{13}C NMR with DMSO as solvent)



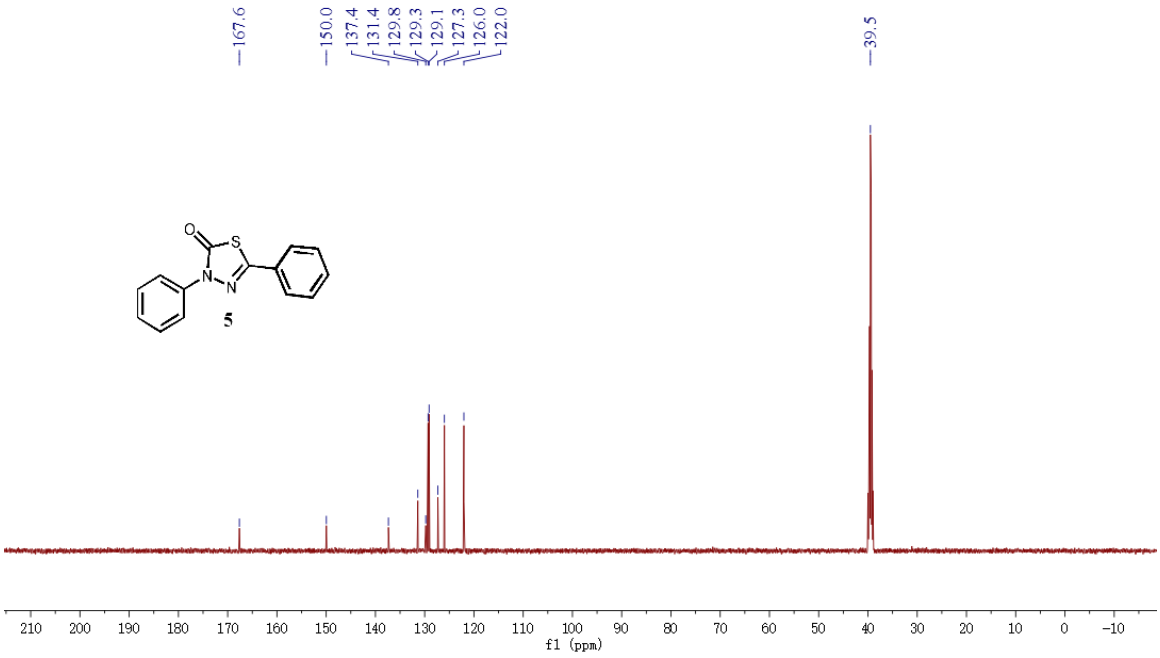
(400 MHz for ^{1}H NMR with DMSO as solvent)



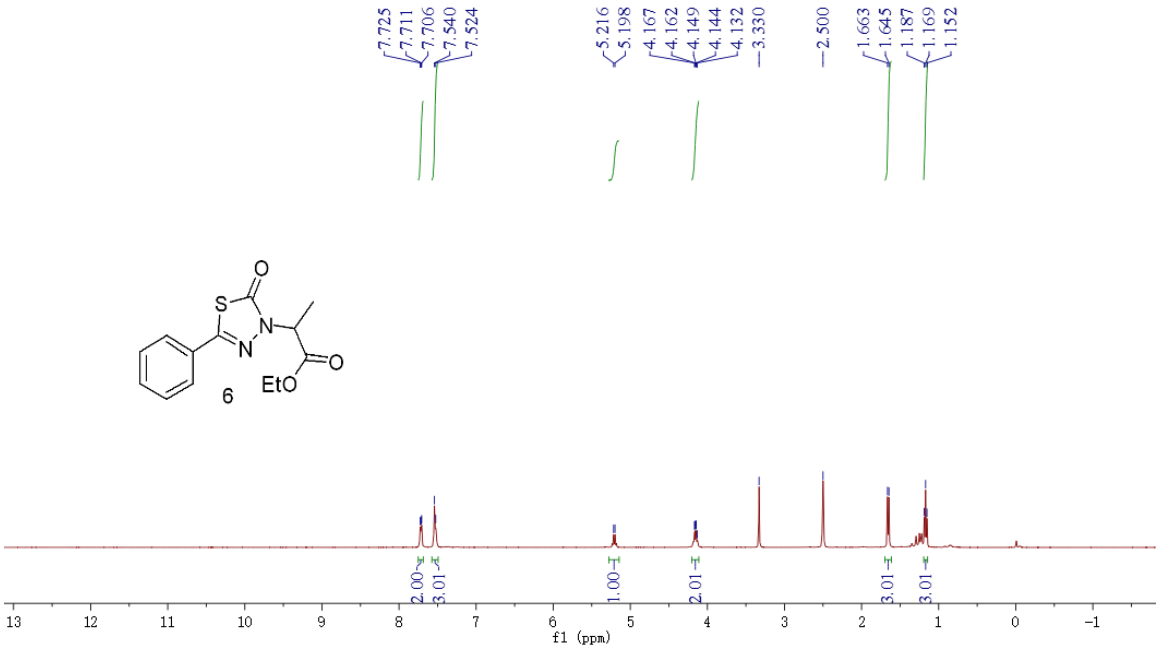
(126 MHz for ^{13}C NMR with DMSO as solvent)



(400 MHz for ^{1}H NMR with DMSO as solvent)



(126 MHz for ^{13}C NMR with DMSO as solvent)



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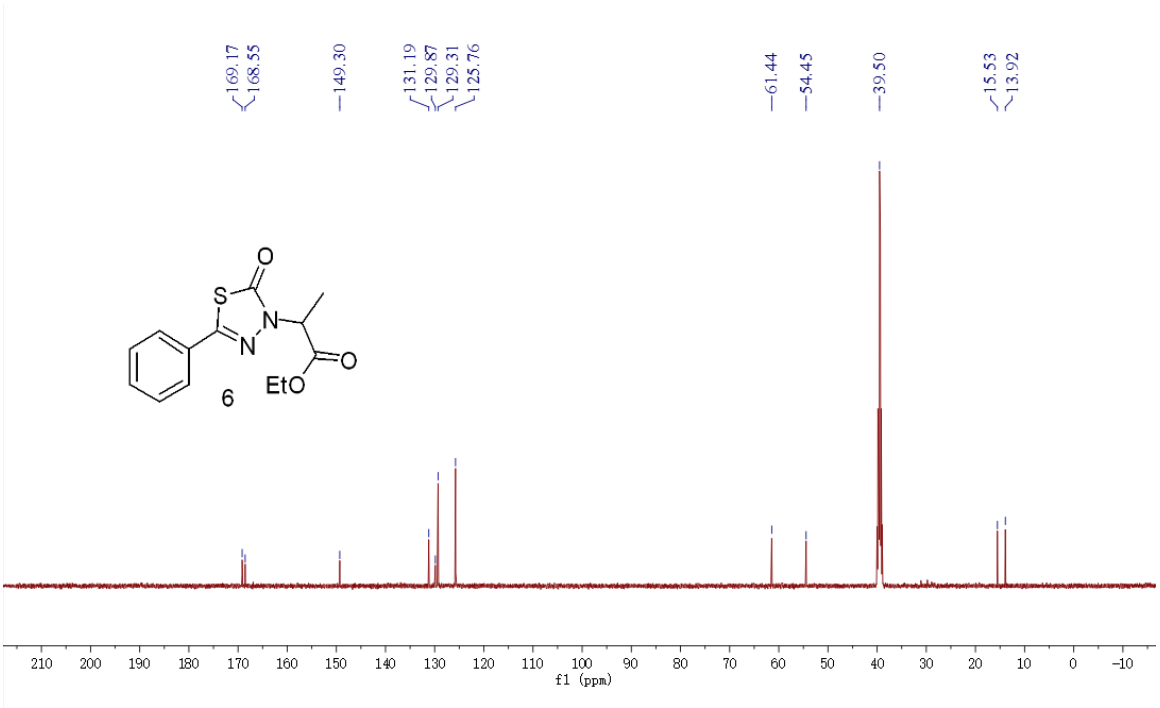
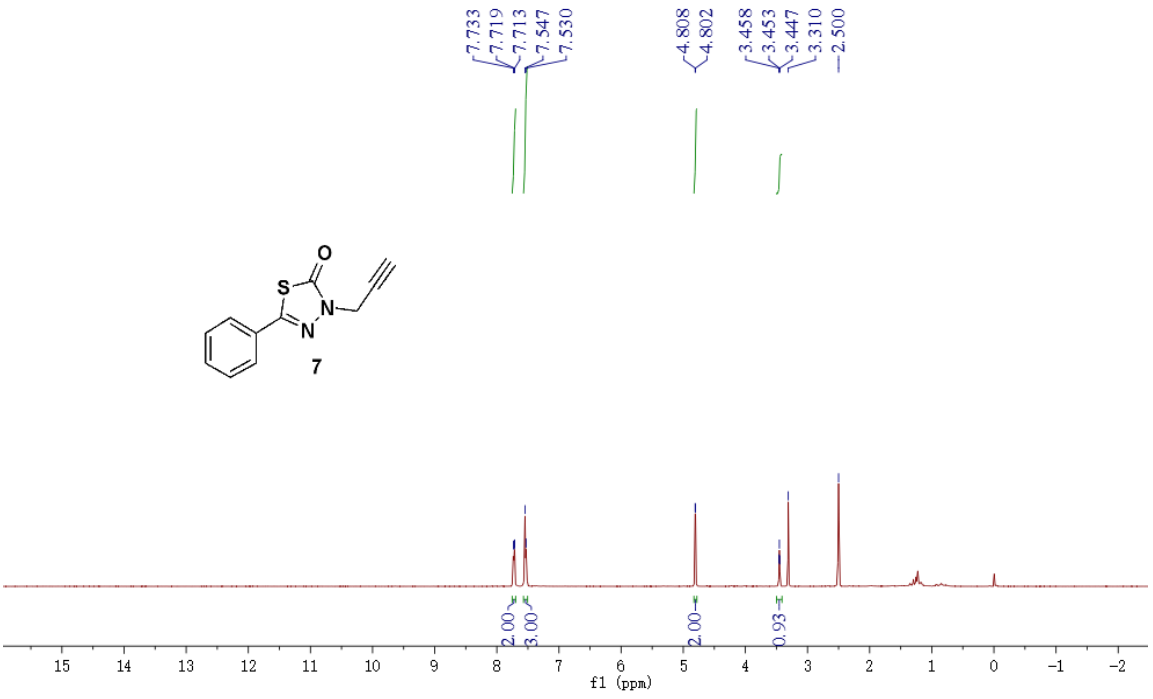
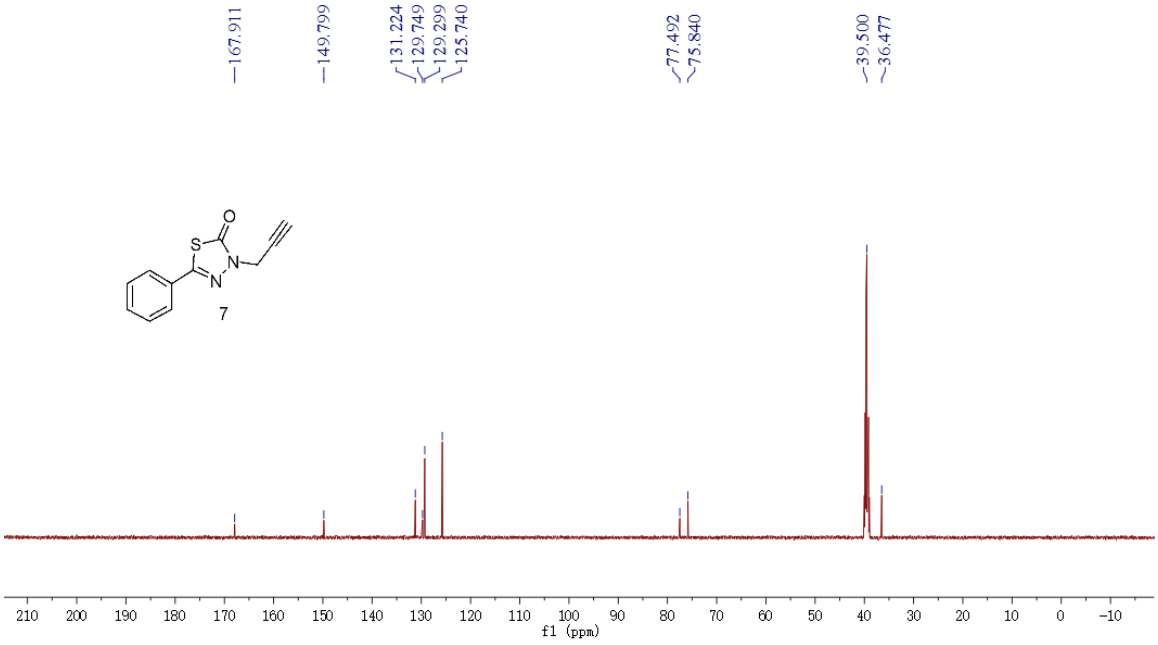


(126 MHz for ^{13}C NMR with DMSO as solvent)



(400 MHz for ^{1}H NMR with DMSO as solvent)



(126 MHz for ^{13}C NMR with DMSO as solvent)