Synthesis of Deuteriodifluoromethylthiolated Isocoumarins-1-imines and Isocoumarins Enabled by Multi-Component Reagents System (MCRS)

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I. General Information

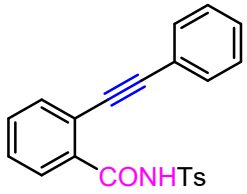
^{1}H, ^{13}C and ^{19}F NMR spectra were recorded on a 400 MHz spectrometer at 25 ^{o}C. Chemical shifts values are given in ppm relative to residual solvent peak in the NMR solvent ($CHCl_3$ (7.26 ppm) for ^{1}H and $CDCl_3$ (77.2 ppm) for ^{13}C). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, dt = doublet of triplets, br = broad, m = multiplet). The coupling constants *J* are reported in Hertz (Hz). High resolution mass data were collected by the Thermo scientific Q Exactive HF (Orbitrap). Melting points were determined with a Micromelting point apparatus. TLC plates were visualized by exposure to ultraviolet light.

Reagents and solvents were purchased as reagent grade and were used without further purification. All reactions were performed in standard glassware, heated at 70 ^{o}C for 3 h before used. Substrates **1a-o**, **3a-m** were prepared according to the literature procedures[1] and they are known compounds except **1e**, **1i**, **1k**, **1l**, **1n**, **1o**. The compound $BnSCF_2D$ was prepared according to the previously reported procedure and it is a known compound.[2] Flash column chromatography was performed over silica gel (200-300 m) using a mixture of ethyl acetate (EtOAc) and petroleum ether (PE).

II. Experimental Procedures and Spectroscopic Data

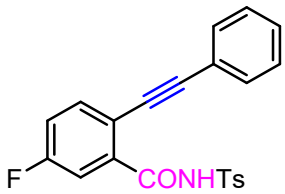
1. Spectroscopic Data of Substrates 1a-o and 3a-m

2-(Phenylethynyl)-*N*-tosylbenzamide (1a)[1b]



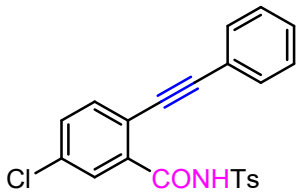
Following the general procedure,[1] **1a** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (1.02 mg, 91%), mp. 121 – 123 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.53 (s, 1H), 8.08 (dd, *J* = 8.0, 1.2 Hz, 1H), 8.03 (d, *J* = 8.4 Hz, 2H), 7.77 – 7.70 (m, 2H), 7.63 (dd, *J* = 7.7, 1.3 Hz, 1H), 7.52 (td, *J* = 7.6, 1.4 Hz, 1H), 7.48 – 7.39 (m, 4H), 7.31 (d, *J* = 8.1 Hz, 2H), 2.41 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 145.2, 135.7, 134.1, 132.7, 132.0, 131.5, 131.1, 130.0, 129.7, 129.2, 128.90, 128.87, 121.2, 120.5, 98.9, 86.8, 21.8.

5-Fluoro-2-(phenylethynyl)-*N*-tosylbenzamide (1b)[1a]



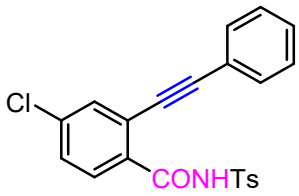
Following the general procedure,[1] **1b** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (990 mg, 84%), mp. 156 – 158 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.57 (s, 1H), 8.05 – 7.98 (m, 2H), 7.79 (dd, *J* = 9.4, 2.8 Hz, 1H), 7.73 (dd, *J* = 6.7, 3.0 Hz, 2H), 7.64 (dd, *J* = 8.6, 5.3 Hz, 1H), 7.46 (dd, *J* = 5.0, 1.9 Hz, 3H), 7.32 (d, *J* = 8.1 Hz, 2H), 7.26 – 7.20 (m, 1H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.8 (d, $J_{C\text{-}F}$ = 254.0 Hz), 161.7 (d, $J_{C\text{-}F}$ = 2.3 Hz), 145.5, 136.3 (d, $J_{C\text{-}F}$ = 7.8 Hz), 135.6, 133.9 (d, $J_{C\text{-}F}$ = 7.7 Hz), 131.9, 130.1, 129.8, 128.97, 128.96, 121.1, 120.4 (d, $J_{C\text{-}F}$ = 22.3 Hz), 118.1 (d, $J_{C\text{-}F}$ = 24.7 Hz), 116.7 (d, $J_{C\text{-}F}$ = 3.7 Hz), 98.8, 85.8, 21.9.

5-Chloro-2-(phenylethynyl)-*N*-tosylbenzamide (1c)[1a]



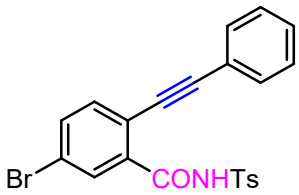
Following the general procedure,[1] **1c** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (920 mg, 75%), mp. 160 – 162 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.49 (s, 1H), 8.11 – 7.97 (m, 3H), 7.79 – 7.69 (m, 2H), 7.57 (d, J = 8.3 Hz, 1H), 7.46 (tt, J = 6.3, 3.3 Hz, 4H), 7.33 (d, J = 8.2 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.8, 145.5, 135.7, 135.5, 135.3, 132.9, 132.8, 132.0, 131.1, 130.2, 129.8, 128.98, 128.96, 120.9, 118.9, 100.0, 85.9, 21.9.

4-Chloro-2-(phenylethynyl)-*N*-tosylbenzamide (1d)[1a]



Following the general procedure,[1] **1d** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (1.0 g, 82%), mp. 109 – 111 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.45 (s, 1H), 8.02 (dd, J = 8.5, 2.2 Hz, 3H), 7.77 – 7.71 (m, 2H), 7.62 (d, J = 2.1 Hz, 1H), 7.49 – 7.44 (m, 3H), 7.38 (dd, J = 8.6, 2.2 Hz, 1H), 7.32 (d, J = 8.1 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1, 145.4, 139.1, 135.6, 133.6, 132.6, 132.1, 130.4, 129.8, 129.7, 129.6, 129.0, 128.9, 122.1, 120.7, 100.0, 85.7, 21.9.

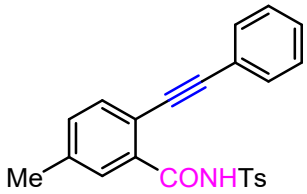
5-Bromo-2-(phenylethynyl)-*N*-tosylbenzamide (1e)



Following the general procedure,[1] **1e** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (965 mg, 71%), mp. 162 – 164 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.45 (s, 1H), 8.19 (d, J = 2.2 Hz, 1H), 8.02 (d, J = 8.1 Hz, 2H), 7.72 (dd, J = 7.4, 2.4 Hz, 2H), 7.63 (dd, J = 8.3, 2.2 Hz, 1H), 7.51 – 7.43 (m, 4H), 7.32 (d, J = 8.0 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.7, 145.5, 135.7, 135.5, 135.3, 134.0, 132.9, 132.0, 130.2, 129.7, 129.0, 123.6, 121.0, 119.4, 100.0, 86.0, 21.9.

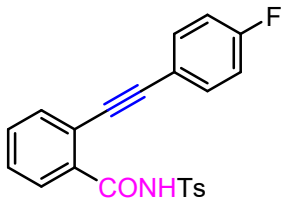
HRMS (ESI) calcd for $C_{22}H_{16}{}^{79}BrNNaO_3S^+$ [M + Na^+] 475.9926, found 475.9924.

5-Methyl-2-(phenylethynyl)-*N*-tosylbenzamide (1f)[1a]



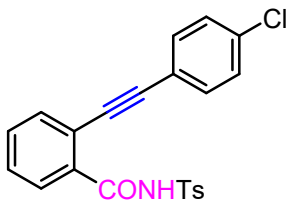
Following the general procedure,[1] **1f** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (980 mg, 84%), mp. 150 – 152 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.56 (s, 1H), 8.03 (d, *J* = 8.4 Hz, 2H), 7.90 (d, *J* = 1.8 Hz, 1H), 7.76 – 7.69 (m, 2H), 7.53 (d, *J* = 7.9 Hz, 1H), 7.45 (dp, *J* = 4.8, 1.8 Hz, 3H), 7.35 – 7.28 (m, 3H), 2.41 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.2, 145.2, 139.9, 135.8, 134.1, 133.6, 131.9, 131.6, 131.2, 129.8, 129.7, 128.92, 128.90, 121.5, 117.5, 98.2, 87.0, 21.9, 21.5.

2-((4-Fluorophenyl)ethynyl)-*N*-tosylbenzamide (1g)[1a]



Following the general procedure,[1] **1g** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (896 mg, 76%), mp. 153 – 155 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.43 (s, 1H), 8.07 (d, *J* = 7.9 Hz, 1H), 8.02 (d, *J* = 8.3 Hz, 2H), 7.73 (dd, *J* = 8.7, 5.3 Hz, 2H), 7.62 (dd, *J* = 7.7, 1.3 Hz, 1H), 7.57 – 7.49 (m, 1H), 7.47 – 7.40 (m, 1H), 7.32 (d, *J* = 8.2 Hz, 2H), 7.15 (t, *J* = 8.6 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.6 (d, $J_{C\text{-}F}$ = 253.2 Hz), 162.9, 145.3, 135.8, 134.1 (d, $J_{C\text{-}F}$ = 8.6 Hz), 134.0, 132.8, 131.6, 131.2, 129.7, 129.3, 128.9, 120.4, 117.4 (d, $J_{C\text{-}F}$ = 3.4 Hz), 116.4 (d, $J_{C\text{-}F}$ = 22.2 Hz), 97.8, 86.7, 21.9.

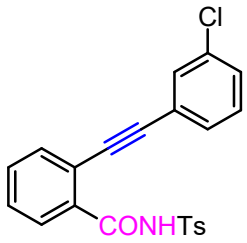
2-((4-Chlorophenyl)ethynyl)-*N*-tosylbenzamide (1h)[1a]



Following the general procedure,[1] **1h** was purified by silica gel chromatography (15%

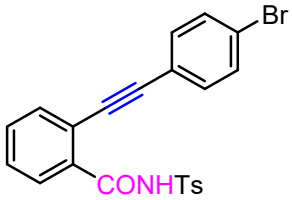
EtOAc/PE). A white solid (910 mg, 74%), mp. 156 – 158 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.36 (s, 1H), 8.06 (dd, *J* = 8.0, 1.4 Hz, 1H), 8.04 – 7.99 (m, 2H), 7.68 – 7.64 (m, 2H), 7.62 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.53 (td, *J* = 7.6, 1.4 Hz, 1H), 7.44 (td, *J* = 8.5, 7.9, 1.7 Hz, 3H), 7.32 (d, *J* = 8.1 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.9, 145.3, 136.2, 135.7, 134.1, 133.2, 132.7, 131.7, 131.1, 129.7, 129.5, 129.4, 128.9, 120.2, 119.8, 97.6, 87.7, 21.9.

2-((3-Chlorophenyl)ethynyl)-*N*-tosylbenzamide (1i)



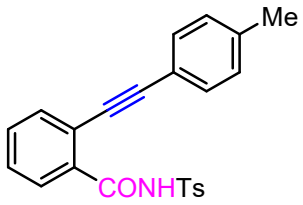
Following the general procedure,[1] **1i** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (810 mg, 66%), mp. 124 – 126 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.14 (s, 1H), 7.98 – 7.90 (m, 3H), 7.57 (t, *J* = 1.8 Hz, 1H), 7.52 (ddd, *J* = 7.7, 2.9, 1.5 Hz, 2H), 7.43 (td, *J* = 7.5, 1.5 Hz, 1H), 7.37 – 7.31 (m, 2H), 7.29 (d, *J* = 7.5 Hz, 1H), 7.22 (d, *J* = 8.1 Hz, 2H), 2.32 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 145.4, 135.7, 134.7, 134.1, 132.7, 132.0, 131.8, 131.0, 130.21, 130.16, 130.1, 129.7, 129.6, 128.9, 123.0, 120.0, 96.9, 87.7, 21.9. HRMS (ESI) calcd for $C_{22}H_{16}{}^{35}ClNNaO_3S^+$ [M + Na^+] 432.0432, found 432.0427.

2-((4-Bromophenyl)ethynyl)-*N*-tosylbenzamide (1j)[1a]



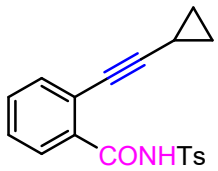
Following the general procedure,[1] **1j** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (965 mg, 71%), mp. 169 – 171 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.34 (s, 1H), 8.06 (dd, *J* = 7.9, 1.4 Hz, 1H), 8.04 – 7.99 (m, 2H), 7.59 (s, 5H), 7.53 (td, *J* = 7.6, 1.4 Hz, 1H), 7.44 (td, *J* = 7.7, 1.4 Hz, 1H), 7.35 – 7.30 (m, 2H), 2.42 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.9, 145.4, 135.7, 134.1, 133.4, 132.7, 132.3, 131.7, 131.1, 129.7, 129.5, 128.9, 124.5, 120.24, 120.21, 97.6, 87.9, 21.9.

2-(*p*-Tolylethynyl)-*N*-tosylbenzamide (1k)



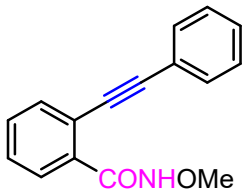
Following the general procedure,[1] **1k** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (957 mg, 82%), mp. 154 – 156 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.57 (s, 1H), 8.07 (d, *J* = 8.0 Hz, 1H), 8.02 (d, *J* = 8.1 Hz, 2H), 7.62 (t, *J* = 7.0 Hz, 3H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.40 (t, *J* = 7.7 Hz, 1H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.27 – 7.21 (m, 2H), 2.41 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 145.2, 140.4, 135.9, 134.0, 132.7, 131.9, 131.3, 131.1, 129.69, 129.68, 129.0, 128.9, 120.8, 118.2, 99.3, 86.4, 21.84, 21.83. HRMS (ESI) calcd for $C_{23}H_{19}NNaO_3S^+$ [M + Na^+] 412.0978, found 412.0974.

2-(Cyclopropylethynyl)-*N*-tosylbenzamide (1l)



Following the general procedure,[1] **1l** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (753 mg, 74%), mp. 117 – 119 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.61 (s, 1H), 8.04 (d, *J* = 8.2 Hz, 3H), 7.49 – 7.41 (m, 2H), 7.35 (d, *J* = 8.2 Hz, 3H), 2.43 (s, 3H), 1.69 – 1.60 (m, 1H), 1.06 (tt, *J* = 8.0, 2.6 Hz, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 145.1, 136.0, 134.2, 132.6, 131.4, 131.0, 129.7, 128.9, 128.5, 121.2, 104.3, 74.3, 21.8, 9.2. HRMS (ESI) calcd for $C_{19}H_{17}NNaO_3S^+$ [M + Na^+] 362.0821, found 362.0824.

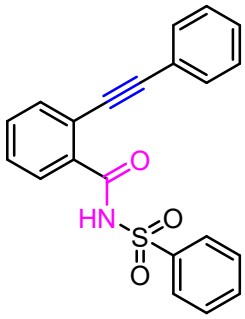
***N*-Methoxy-2-(phenylethynyl)benzamide (1m)[1b]**



Following the general procedure,[1] **1m** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (444 mg, 59%), mp. 94 – 96 °C. ^{1}H NMR (400 MHz,

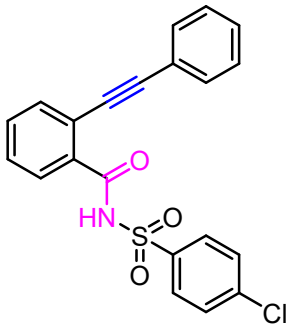
$CDCl_3$) δ 9.77 (s, 1H), 8.02 – 7.91 (m, 1H), 7.63 – 7.51 (m, 3H), 7.51 – 7.36 (m, 5H), 3.92 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.2, 133.7, 133.2, 131.7, 131.1, 129.8, 129.3, 129.0, 128.7, 122.1, 120.0, 95.4, 87.3, 64.8.

2-(Phenylethynyl)-*N*-(phenylsulfonyl)benzamide (1n)



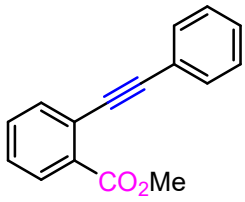
Following the general procedure,[1] **1n** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (931 mg, 86%), mp. 138 – 140 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 10.54 (s, 1H), 8.18 – 8.12 (m, 2H), 8.08 (dd, J = 7.9, 1.4 Hz, 1H), 7.77 – 7.70 (m, 2H), 7.63 (td, J = 7.6, 1.3 Hz, 2H), 7.56 – 7.49 (m, 3H), 7.48 – 7.40 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.0, 138.8, 134.14, 134.12, 132.8, 132.0, 131.5, 131.1, 130.0, 129.3, 129.1, 128.9, 128.8, 121.2, 120.5, 98.9, 86.8. HRMS (ESI) calcd for $C_{21}H_{15}NNaO_3S^+$ [M + Na^+] 384.0665, found 384.0663.

***N*-((4-Chlorophenyl)sulfonyl)-2-(phenylethynyl)benzamide (1o)**



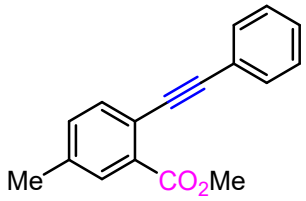
Following the general procedure,[1] **1o** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (1.02 g, 86%), mp. 120 – 122 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 10.53 (s, 1H), 8.07 (t, J = 7.7 Hz, 3H), 7.64 (d, J = 7.7 Hz, 1H), 7.53 (t, J = 7.5 Hz, 1H), 7.45 (dt, J = 14.2, 8.5 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.1, 140.8, 137.2, 134.1, 132.9, 131.9, 131.3, 131.0, 130.4, 130.0, 129.4, 129.3, 128.9, 121.2, 120.6, 98.9, 86.8. HRMS (ESI) calcd for $C_{21}H_{14}{}^{35}ClNNaO_3S^+$ [M + Na^+] 418.0275, found 418.0270.

Methyl 2-(phenylethynyl)benzoate (3a)[1c]



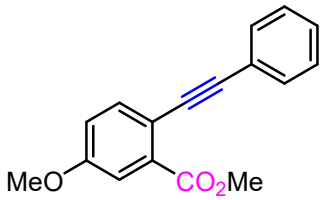
Following the general procedure,[1] **3a** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.12 g, 95%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.68 – 7.63 (m, 1H), 7.62 – 7.57 (m, 2H), 7.49 (td, *J* = 7.6, 1.4 Hz, 1H), 7.42 – 7.33 (m, 4H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.9, 134.1, 132.0, 131.9, 131.8, 130.6, 128.7, 128.5, 128.0, 123.8, 123.4, 94.5, 88.4, 52.4.

Methyl 5-methyl-2-(phenylethynyl)benzoate (3b)[1c]



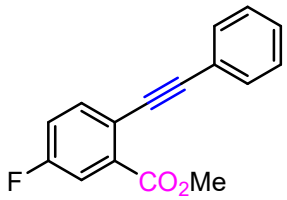
Following the general procedure,[1] **3b** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.18 g, 94%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 1.9 Hz, 1H), 7.56 – 7.49 (m, 2H), 7.46 (d, *J* = 7.9 Hz, 1H), 7.33 – 7.22 (m, 3H), 7.22 – 7.16 (m, 1H), 3.88 (s, 3H), 2.29 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.8, 138.2, 133.9, 132.6, 131.64, 131.61, 131.0, 128.3, 123.5, 120.7, 93.5, 88.4, 52.1, 21.2.

Methyl 5-methoxy-2-(phenylethynyl)benzoate (3c)[1c]



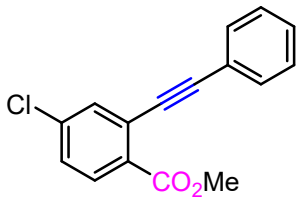
Following the general procedure,[1] **3c** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.16 g, 87%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.42 (m, 3H), 7.38 (d, *J* = 2.8 Hz, 1H), 7.27 – 7.18 (m, 3H), 6.91 (dd, *J* = 8.6, 2.8 Hz, 1H), 3.86 (s, 3H), 3.71 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.5, 159.1, 135.3, 133.2, 131.6, 128.4, 128.2, 123.7, 118.3, 115.8, 115.1, 92.6, 88.3, 55.5, 52.3.

Methyl 5-fluoro-2-(phenylethynyl)benzoate (3d)[1c]



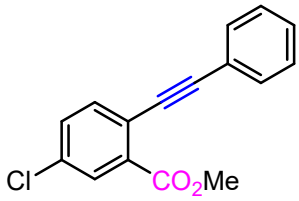
Following the general procedure,[1] **3d** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.05 g, 83%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (dd, J = 9.2, 2.8 Hz, 1H), 7.63 (dd, J = 8.6, 5.4 Hz, 1H), 7.59 – 7.55 (m, 2H), 7.36 (dd, J = 5.0, 1.9 Hz, 3H), 7.21 (ddd, J = 8.5, 7.9, 2.8 Hz, 1H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.7 (d, $J_{C\text{-}F}$ = 2.6 Hz), 161.7 (d, $J_{C\text{-}F}$ = 250.7 Hz), 136.0 (d, $J_{C\text{-}F}$ = 7.9 Hz), 133.9 (d, $J_{C\text{-}F}$ = 7.5 Hz), 131.8, 128.8, 128.6, 123.3, 120.1 (d, $J_{C\text{-}F}$ = 3.7 Hz), 119.4 (d, $J_{C\text{-}F}$ = 21.8 Hz), 117.7 (d, $J_{C\text{-}F}$ = 24.1 Hz), 94.2 (d, $J_{C\text{-}F}$ = 1.8 Hz), 87.3, 52.6.

Methyl 4-chloro-2-(phenylethynyl)benzoate (3e)[1c]



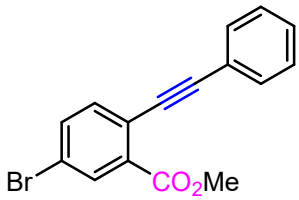
Following the general procedure,[1] **3e** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.23 g, 91%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, J = 8.5 Hz, 1H), 7.63 (d, J = 2.2 Hz, 1H), 7.61 – 7.55 (m, 2H), 7.40 – 7.31 (m, 4H), 3.96 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.9, 138.2, 133.8, 132.1, 132.0, 130.1, 129.1, 128.6, 128.3, 125.7, 123.0, 95.8, 87.2, 52.5.

Methyl 5-chloro-2-(phenylethynyl)benzoate (3f)[3]



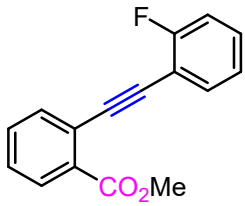
Following the general procedure,[1] **3f** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.19 g, 88%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, J = 2.2 Hz, 1H), 7.60 – 7.54 (m, 3H), 7.46 (dd, J = 8.4, 2.2 Hz, 1H), 7.36 (dd, J = 4.8, 1.9 Hz, 3H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.6, 135.2, 134.0, 133.2, 132.0, 131.9, 130.7, 128.9, 128.6, 123.1, 122.4, 95.5, 87.4, 52.6.

Methyl 5-bromo-2-(phenylethynyl)benzoate (3g)[1c]



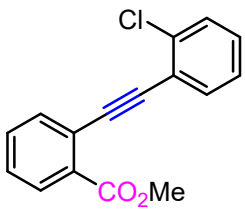
Following the general procedure,[1] **3g** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.18 g, 75%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, J = 2.2 Hz, 1H), 7.65 – 7.54 (m, 3H), 7.50 (d, J = 8.3 Hz, 1H), 7.41 – 7.33 (m, 3H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.5, 135.4, 135.0, 133.6, 133.4, 131.9, 129.0, 128.6, 123.1, 122.9, 122.0, 95.7, 87.5, 52.7.

Methyl 2-((2-fluorophenyl)ethynyl)benzoate (3h)[4]



Following the general procedure,[1] **3h** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.0 g, 79%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (ddd, J = 7.8, 1.5, 0.5 Hz, 1H), 7.67 (ddd, J = 7.7, 1.4, 0.6 Hz, 1H), 7.57 (td, J = 7.5, 1.9 Hz, 1H), 7.50 (td, J = 7.6, 1.5 Hz, 1H), 7.40 (td, J = 7.7, 1.3 Hz, 1H), 7.32 (dddd, J = 8.3, 7.2, 5.2, 1.8 Hz, 1H), 7.17 – 7.07 (m, 2H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.9, 162.8 (d, $J_{C\text{-}F}$ = 252.0 Hz), 134.3, 133.8 (d, $J_{C\text{-}F}$ = 1.3 Hz), 132.1, 131.9, 130.7, 130.4 (d, $J_{C\text{-}F}$ = 8.0 Hz), 128.4, 124.2 (d, $J_{C\text{-}F}$ = 3.7 Hz), 123.4, 115.7 (d, $J_{C\text{-}F}$ = 20.8 Hz), 112.1 (d, $J_{C\text{-}F}$ = 15.6 Hz), 93.2 (d, $J_{C\text{-}F}$ = 3.2 Hz), 87.7, 52.4.

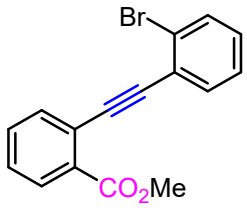
Methyl 2-((2-chlorophenyl)ethynyl)benzoate (3i)[1c]



Following the general procedure,[1] **3i** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (932 mg, 69%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 – 7.96 (m, 1H), 7.74 – 7.67 (m, 1H), 7.66 – 7.59 (m, 1H), 7.51 (td, J = 7.6, 1.4 Hz, 1H), 7.46

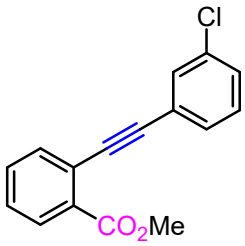
– 7.37 (m, 2H), 7.32 – 7.21 (m, 2H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.9, 136.0, 134.5, 133.8, 132.0, 131.9, 130.7, 129.7, 129.5, 128.5, 126.7, 123.44, 123.42, 93.4, 91.1, 52.5.

Methyl 2-((2-bromophenyl)ethynyl)benzoate (3j)[1a]



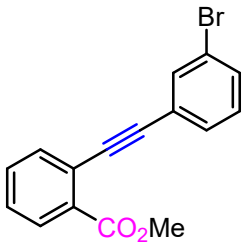
Following the general procedure,[1] **3j** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.21 g, 77%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (dd, J = 7.9, 1.4 Hz, 1H), 7.72 (dd, J = 7.7, 1.3 Hz, 1H), 7.62 (dt, J = 8.0, 1.4 Hz, 2H), 7.51 (td, J = 7.6, 1.4 Hz, 1H), 7.41 (td, J = 7.7, 1.4 Hz, 1H), 7.30 (td, J = 7.6, 1.2 Hz, 1H), 7.19 (td, J = 7.7, 1.7 Hz, 1H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.8, 134.5, 133.8, 132.6, 131.91, 131.88, 130.6, 129.8, 128.4, 127.2, 125.6, 123.4, 92.9, 92.7, 52.5.

Methyl 2-((3-chlorophenyl)ethynyl)benzoate (3k)[1c]



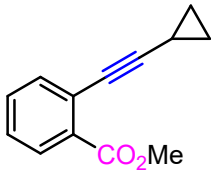
Following the general procedure,[1] **3k** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (1.11 g, 82%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (ddd, J = 7.8, 1.4, 0.5 Hz, 1H), 7.63 (ddd, J = 7.7, 1.4, 0.5 Hz, 1H), 7.58 – 7.55 (m, 1H), 7.49 (td, J = 7.6, 1.4 Hz, 1H), 7.45 (dt, J = 7.2, 1.5 Hz, 1H), 7.39 (td, J = 7.7, 1.4 Hz, 1H), 7.34 – 7.24 (m, 2H), 3.96 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 134.3, 134.2, 132.0, 131.9, 131.6, 130.7, 130.0, 129.7, 128.9, 128.4, 125.2, 123.4, 92.9, 89.5, 52.4.

Methyl 2-((3-bromophenyl)ethynyl)benzoate (3l)[1a]



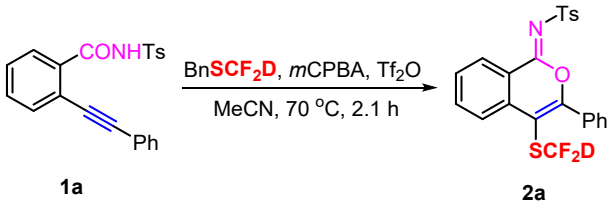
Following the general procedure,[1] **3l** was purified by silica gel chromatography (3% EtOAc/PE). Yellow oil (1.26 g, 80%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 – 7.95 (m, 1H), 7.72 (t, *J* = 1.8 Hz, 1H), 7.66 – 7.60 (m, 1H), 7.53 – 7.45 (m, 3H), 7.40 (td, *J* = 7.6, 1.4 Hz, 1H), 7.22 (t, *J* = 7.9 Hz, 1H), 3.96 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.6, 134.5, 134.2, 132.1, 131.9, 131.8, 130.7, 130.5, 130.0, 128.4, 125.5, 123.4, 122.3, 92.8, 89.6, 52.4.

Methyl 2-(cyclopropylethynyl)benzoate (3m)[1c]



Following the general procedure,[1] **3m** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (950 mg, 95%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.47 (dd, *J* = 7.8, 1.3 Hz, 1H), 7.39 (td, *J* = 7.5, 1.4 Hz, 1H), 7.32 – 7.24 (m, 1H), 3.90 (s, 3H), 1.51 (tt, *J* = 8.2, 5.1 Hz, 1H), 0.94 – 0.79 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0, 134.2, 132.0, 131.7, 130.4, 127.2, 124.6, 99.4, 74.6, 52.2, 9.1.

2. Typical Synthetic Procedure A and Spectroscopic Data of Products 2a-o and 4a-m



1a **2a**

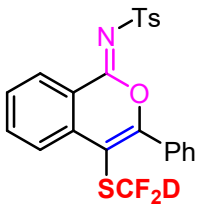
To a solution of $BnSCF_2D$ (263 mg, 1.5 mmol, 3.0 equiv) in MeCN (3.0 mL) was slowly added *m*CPBA (85% w/w, 306 mg, 1.5 mmol, 3.0 equiv), and the mixture was

stirred at 70 °C (oil bath) for 2.0 h. Then substrate **1a** (188 mg, 0.5 mmol, 1.0 equiv) and triflic anhydride (424 mg, 1.5 mmol, 3.0 equiv) were added and the reaction mixture was stirred at 70 °C (oil bath) until TLC indicated the total consumption of substrates **1a**. H_2O (25 mL) was added and the reaction mixture was extracted with DCM (30 mL × 3). The combined organic layer was washed with aq. NaOH solution, then washed with brine, dried with anhydrous Na_2SO_4 and evaporated under vacuum. The crude residue was purified by flash column chromatography, using a mixture of EtOAc and PE as eluent, to give the desired products **2a** as a white solid (185 mg, yield: 81%).

Gram-scale synthesis of 2a.

To a solution of $BnSCF_2D$ (1.578 g, 9.0 mmol, 3.0 equiv) in MeCN (20.0 mL) was slowly added *m*CPBA (85% w/w, 1.836 g, 9.0 mmol, 3.0 equiv), and the mixture was stirred at 70 °C (oil bath) for 2.0 h. Then substrate **1a** (1.128 g, 3.0 mmol, 1.0 equiv) and triflic anhydride (2.544 g, 9.0 mmol, 3.0 equiv) were added and the reaction mixture was stirred at 70 °C (oil bath) until TLC indicated the total consumption of substrates **1a**. H_2O (100 mL) was added and the reaction mixture was extracted with DCM (100 mL × 3). The combined organic layer was washed with aq. NaOH solution, then washed with brine, dried with anhydrous Na_2SO_4 and evaporated under vacuum. The crude residue was purified by flash column chromatography, using a mixture of EtOAc and PE as eluent, to give the desired products **2a** as a white solid (1.05 g, yield: 77%)."

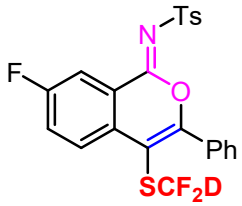
(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2a)



Following the general procedure A, **2a** was purified by silica gel chromatography (15% EtOAc/PE). A white solid (185 mg, 81%), mp. 165 – 167 °C. ^{1}H NMR (400 MHz,

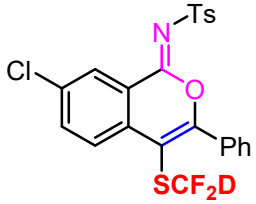
$CDCl_3$) δ 8.43 (d, J = 8.0 Hz, 1H), 8.17 (d, J = 8.1 Hz, 1H), 7.85 (t, J = 7.7 Hz, 1H), 7.79 (d, J = 8.0 Hz, 2H), 7.76 (d, J = 7.7 Hz, 2H), 7.59 – 7.50 (m, 4H), 7.09 (d, J = 8.0 Hz, 2H), 2.34 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.3, 157.8, 143.5, 138.3, 136.7, 136.0, 131.1, 131.0, 130.6, 129.8, 129.2, 128.3, 127.6, 125.9, 120.8, 104.1 (t, $J_{C\text{-}F}$ = 3.2 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.5 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{16}DF_2NNaO_3S_2^+$ [M + Na^+] 481.0573, found 481.0572.

(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-7-fluoro-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2b)



Following the general procedure A, **2b** was purified by silica gel chromatography (15% EtOAc/PE). White solid (186 mg, 78%), mp. 194 – 196 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20 (dd, J = 8.9, 4.9 Hz, 1H), 8.07 (dd, J = 8.5, 2.7 Hz, 1H), 7.84 – 7.75 (m, 4H), 7.60 – 7.49 (m, 4H), 7.13 (d, J = 8.1 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.8 (d, $J_{C\text{-}F}$ = 253.2 Hz), 160.0, 156.8 (d, $J_{C\text{-}F}$ = 3.8 Hz), 143.7, 138.2, 133.5, 131.2, 131.0, 130.7, 129.3, 128.9 (d, $J_{C\text{-}F}$ = 8.1 Hz), 128.4, 127.7, 124.2 (d, $J_{C\text{-}F}$ = 23.0 Hz), 122.8 (d, $J_{C\text{-}F}$ = 9.1 Hz), 114.7 (d, $J_{C\text{-}F}$ = 24.4 Hz), 103.3 (t, $J_{C\text{-}F}$ = 3.6 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.3 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F), -108.29 (s). HRMS (ESI) m/z: [M + Na]$^+$ Calcd for $C_{23}H_{15}DF_3NNaO_3S_2^+$ 499.0479; Found 499.0474.

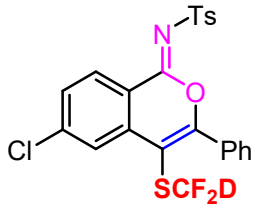
(*Z*)-*N*-(7-Chloro-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2c)



Following the general procedure A, **2c** was purified by silica gel chromatography (15% EtOAc/PE). White solid (207 mg, 84%), mp. 197 – 199 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.38 (d, J = 2.2 Hz, 1H), 8.13 (d, J = 8.7 Hz, 1H), 7.85 – 7.74 (m, 5H), 7.60

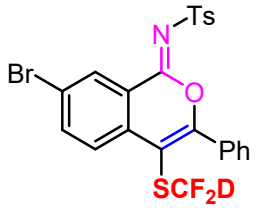
– 7.50 (m, 3H), 7.13 (d, J = 8.1 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.6, 156.5, 143.7, 138.1, 136.1, 136.0, 135.4, 131.2, 130.9, 130.6, 129.3, 128.4, 128.3, 127.8, 127.7, 122.1, 103.3 (t, $J_{C\text{-}F}$ = 3.1 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{35}ClF_2NNaO_3S_2^+$ [M + Na^+] 515.0183, found 515.0188.

(*Z*)-*N*-(6-Chloro-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2d)



Following the general procedure A, **2d** was purified by silica gel chromatography (15% EtOAc/PE). White solid (180 mg, 73%), mp. 214 – 216 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.35 (d, J = 8.6 Hz, 1H), 8.16 (d, J = 1.9 Hz, 1H), 7.83 – 7.75 (m, 4H), 7.61 – 7.51 (m, 4H), 7.12 (d, J = 8.0 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6, 157.0, 143.7, 143.2, 138.5, 138.3, 131.4, 131.0, 130.8, 130.7, 130.3, 129.3, 128.4, 127.7, 125.8, 119.2, 101.9 (t, $J_{C\text{-}F}$ = 3.3 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.5 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{35}ClF_2NNaO_3S_2^+$ [M + Na^+] 515.0183, found 515.0187.

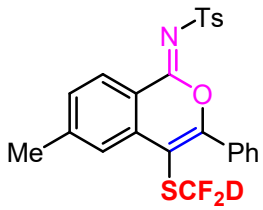
(*Z*)-*N*-(7-Bromo-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2e)



Following the general procedure A, **2e** was purified by silica gel chromatography (15% EtOAc/PE). White solid (222 mg, 83%), mp. 176 – 178 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.54 (d, J = 2.0 Hz, 1H), 8.05 (d, J = 8.7 Hz, 1H), 7.92 (dd, J = 8.7, 2.2 Hz, 1H), 7.80 (td, J = 8.3, 7.5, 1.8 Hz, 4H), 7.54 (tt, J = 8.8, 5.9 Hz, 3H), 7.13 (d, J = 8.0 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.7, 156.4, 143.7, 138.9,

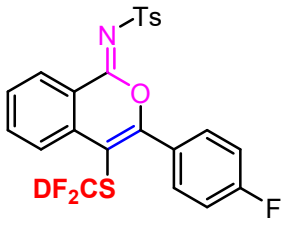
138.2, 135.8, 131.4, 131.3, 131.0, 130.7, 129.4, 128.4, 127.8, 127.7, 123.9, 122.3, 103.5 (t, $J_{C\text{-}F}$ = 3.2 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.3 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{79}BrF_2NNaO_3S_2^+$ [M + Na^+] 558.9678, found 558.9682.

(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-6-methyl-3-phenyl-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2f)



Following the general procedure A, **2f** was purified by silica gel chromatography (10% EtOAc/PE). White solid (194 mg, 82%), mp. 198 – 200 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.06 (d, *J* = 8.3 Hz, 1H), 7.79 (d, *J* = 8.2 Hz, 2H), 7.77 – 7.71 (m, 2H), 7.70 – 7.64 (m, 1H), 7.59 – 7.48 (m, 3H), 7.07 (d, *J* = 8.1 Hz, 2H), 2.48 (s, 3H), 2.34 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.5, 158.1, 143.4, 140.6, 138.3, 137.4, 134.4, 131.2, 130.9, 130.6, 129.2, 128.9, 128.3, 127.7, 125.9, 120.7, 104.2 (t, $J_{C\text{-}F}$ = 3.2 Hz), 21.7, 21.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.5 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{24}H_{18}DF_2NNaO_3S_2^+$ [M + Na^+] 495.0729, found 495.0726.

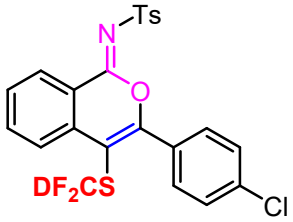
(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-3-(4-fluorophenyl)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2g)



Following the general procedure A, **2g** was purified by silica gel chromatography (10% EtOAc/PE). White solid (188 mg, 79%), mp. 130 – 132 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (dd, *J* = 8.0, 1.3 Hz, 1H), 8.17 (d, *J* = 8.1 Hz, 1H), 7.92 – 7.78 (m, 5H), 7.57 (ddd, *J* = 8.2, 7.4, 1.1 Hz, 1H), 7.25 – 7.18 (m, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.2 (d, $J_{C\text{-}F}$ = 252.9 Hz), 159.2, 157.7, 143.6, 138.6, 136.6, 136.0, 133.0 (d, $J_{C\text{-}F}$ = 8.8 Hz), 129.9, 129.3, 129.2, 127.5, 127.3

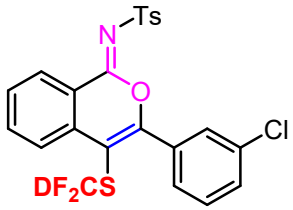
(d, $J_{C\text{-}F}$ = 3.5 Hz), 125.9, 120.8, 115.6 (d, $J_{C\text{-}F}$ = 22.1 Hz), 104.0 (t, $J_{C\text{-}F}$ = 3.1 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F), -107.9 (s). HRMS (ESI) calcd for $C_{23}H_{15}DF_3NNaO_3S_2^+$ [M + Na^+] 499.0479; Found 499.0481.

(*Z*)-*N*-(3-(4-Chlorophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2h)



Following the general procedure A, **2h** was purified by silica gel chromatography (15% EtOAc/PE). White solid (170 mg, 69%), mp. 122 – 124 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (dd, *J* = 8.0, 1.3 Hz, 1H), 8.17 (d, *J* = 8.1 Hz, 1H), 7.89 – 7.76 (m, 5H), 7.58 (ddd, *J* = 8.2, 7.3, 1.1 Hz, 1H), 7.53 – 7.47 (m, 2H), 7.20 – 7.14 (m, 2H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.1, 157.6, 143.6, 138.6, 137.4, 136.6, 136.0, 132.1, 130.0, 129.7, 129.4, 129.2, 128.7, 127.5, 126.0, 120.9, 104.3 (t, $J_{C\text{-}F}$ = 3.2 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{35}ClF_2NNaO_3S_2^+$ [M + Na^+] 515.0183, found 515.0188.

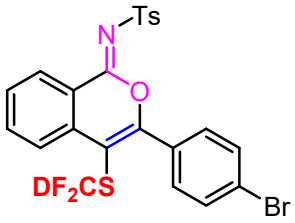
(*Z*)-*N*-(3-(3-Chlorophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2i)



Following the general procedure A, **2i** was purified by silica gel chromatography (10% EtOAc/PE). White solid (128 mg, 52%), mp. 183 – 185 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.45 (dd, *J* = 8.1, 1.3 Hz, 1H), 8.18 (d, *J* = 8.1 Hz, 1H), 7.92 – 7.85 (m, 1H), 7.81 (d, *J* = 8.2 Hz, 2H), 7.72 – 7.66 (m, 2H), 7.65 – 7.58 (m, 1H), 7.54 (dt, *J* = 8.0, 1.6 Hz, 1H), 7.48 (dd, *J* = 9.0, 7.3 Hz, 1H), 7.16 (d, *J* = 8.0 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.8, 157.4, 143.6, 138.5, 136.4, 136.1, 134.3, 132.9, 131.1, 130.6, 130.2, 129.8, 129.4, 128.9, 127.6, 126.1, 121.1, 104.8 (t, $J_{C\text{-}F}$ = 3.0 Hz),

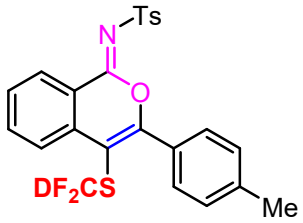
21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.3 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{35}ClF_2NNaO_3S_2^+$ [M + Na^+] 515.0183, found 515.0187.

(*Z*)-*N*-(3-(4-Bromophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2j)



Following the general procedure A, **2j** was purified by silica gel chromatography (15% EtOAc/PE). White solid (190 mg, 71%), mp. 137 – 139 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (dd, *J* = 8.1, 1.3 Hz, 1H), 8.17 (d, *J* = 8.1 Hz, 1H), 7.89 – 7.81 (m, 3H), 7.74 – 7.69 (m, 2H), 7.69 – 7.64 (m, 2H), 7.59 (ddd, *J* = 8.2, 7.3, 1.1 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.2, 157.6, 143.6, 138.6, 136.6, 136.0, 132.2, 131.7, 130.1, 130.0, 129.4, 129.3, 127.5, 126.0, 125.8, 120.9, 104.3 (t, $J_{C\text{-}F}$ = 3.1 Hz), 21.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{23}H_{15}D^{79}BrF_2NNaO_3S_2^+$ [M + Na^+] 558.9678, found 558.9674.

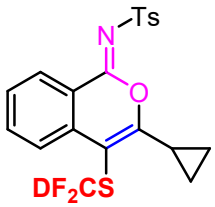
(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-3-(*p*-tolyl)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2k)



Following the general procedure A, **2k** was purified by silica gel chromatography (10% EtOAc/PE). White solid (172 mg, 73%), mp. 150 – 152 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.41 (dd, *J* = 8.0, 1.3 Hz, 1H), 8.16 (d, *J* = 8.1 Hz, 1H), 7.88 – 7.80 (m, 3H), 7.70 (d, *J* = 8.3 Hz, 2H), 7.55 (ddd, *J* = 8.2, 7.3, 1.1 Hz, 1H), 7.33 (d, *J* = 7.9 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 2.47 (s, 3H), 2.35 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.5, 158.0, 143.4, 141.5, 138.6, 136.9, 135.9, 130.6, 129.6, 129.24, 129.17, 129.0, 128.3, 127.6, 125.8, 120.8, 103.6 (t, $J_{C\text{-}F}$ = 3.4 Hz), 21.8, 21.7. ^{19}F NMR (376 MHz,

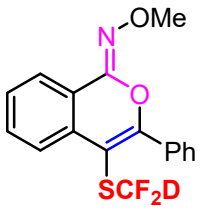
$CDCl_3$) δ -92.5 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{24}H_{18}DF_2NNaO_3S_2^+$ [M + Na^+] 495.0729, found 495.0733.

(*Z*)-*N*-(3-Cyclopropyl-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-ylidene)-4-methylbenzenesulfonamide (2l)



Following the general procedure A, **2l** was purified by silica gel chromatography (5% EtOAc/PE). White solid (120 mg, 57%), mp. 194 – 196 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (dd, *J* = 8.0, 1.3 Hz, 1H), 8.03 (d, *J* = 8.1 Hz, 1H), 7.97 – 7.90 (m, 2H), 7.78 (ddd, *J* = 8.4, 7.2, 1.4 Hz, 1H), 7.47 – 7.39 (m, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 2.81 (tt, *J* = 8.2, 4.9 Hz, 1H), 2.45 (s, 3H), 1.53 (dd, *J* = 4.9, 2.6 Hz, 2H), 1.16 (dt, *J* = 8.2, 3.6 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.3, 158.2, 143.4, 139.5, 137.3, 135.9, 129.6, 128.9, 128.4, 126.9, 124.6, 120.1, 101.0 (t, $J_{C\text{-}F}$ = 3.5 Hz), 21.8, 13.5, 10.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.3 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{20}H_{16}DF_2NNaO_3S_2^+$ [M + Na^+] 445.0573, found 445.0578.

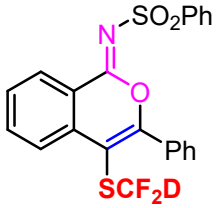
(*Z*)-4-((Difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-one *O*-methyl oxime (2m)



Following the general procedure A, **2m** was purified by silica gel chromatography (10% EtOAc/PE). White solid (152 mg, 91%), mp. 118 – 120 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.95 (d, *J* = 8.0 Hz, 1H), 7.74 – 7.66 (m, 2H), 7.55 (td, *J* = 7.7, 1.3 Hz, 1H), 7.46 (dd, *J* = 5.1, 1.9 Hz, 3H), 7.38 (td, *J* = 7.6, 1.2 Hz, 1H), 3.97 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.7, 147.2, 133.0, 132.1, 131.6, 130.4, 130.1, 129.0, 128.2, 125.3, 124.1, 121.4, 100.9 (t, $J_{C\text{-}F}$ = 3.0 Hz), 63.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -93.2 (t, $J_{D\text{-}F}$ = 8.7 Hz, 2F). HRMS (ESI) calcd for

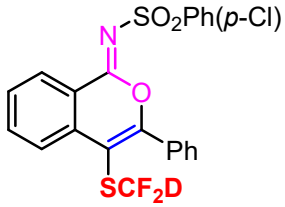
$C_{17}H_{12}DF_2NNaO_2S^+$ [M + Na^+] 357.0590, found 357.0596.

(*Z*)-*N*-(4-((Difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)benzenesulfonamide (2n)



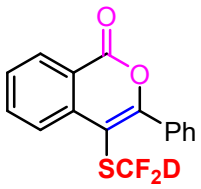
Following the general procedure A, **2n** was purified by silica gel chromatography (10% EtOAc/PE). White solid (180 mg, 81%), mp. 157 – 159 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.45 (dd, *J* = 8.1, 1.3 Hz, 1H), 8.19 (d, *J* = 8.1 Hz, 1H), 7.96 – 7.90 (m, 2H), 7.87 (ddd, *J* = 8.3, 7.3, 1.4 Hz, 1H), 7.79 – 7.73 (m, 2H), 7.60 (ddd, *J* = 8.3, 7.4, 1.2 Hz, 1H), 7.57 – 7.50 (m, 3H), 7.50 – 7.45 (m, 1H), 7.35 – 7.28 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.4, 158.1, 141.4, 136.8, 136.1, 132.7, 131.2, 131.1, 130.7, 129.9, 129.3, 128.7, 128.4, 127.6, 126.0, 120.8, 104.3 (t, $J_{C\text{-}F}$ = 3.4 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{22}H_{14}DF_2NNaO_3S_2^+$ [M + Na^+] 467.0416, found 467.0411.

(*Z*)-4-Chloro-*N*-(4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-ylidene)benzenesulfonamide (2o)



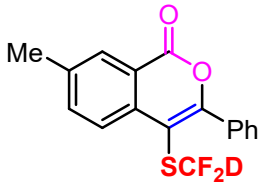
Following the general procedure A, **2o** was purified by silica gel chromatography (10% EtOAc/PE). White solid (198 mg, 83%), mp. 168 – 170 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.43 (d, *J* = 7.9 Hz, 1H), 8.19 (d, *J* = 8.1 Hz, 1H), 7.91 – 7.85 (m, 1H), 7.85 – 7.81 (m, 2H), 7.78 – 7.71 (m, 2H), 7.63 – 7.51 (m, 4H), 7.29 – 7.21 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.3, 158.3, 139.9, 139.1, 136.9, 136.3, 131.2, 131.1, 130.6, 130.0, 129.3, 129.1, 128.9, 128.5, 126.1, 120.6, 104.5 (t, $J_{C\text{-}F}$ = 3.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.4 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{22}H_{13}D^{35}ClF_2NNaO_3S_2^+$ [M + Na^+] 501.0027, found 501.0025.

4-((Difluoromethyl-d)thio)-3-phenyl-1*H*-isochromen-1-one (4a)



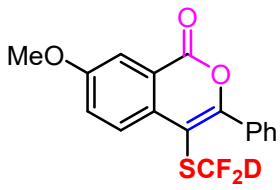
Following the general procedure A, **4a** was purified by silica gel chromatography (2% EtOAc/PE). White solid (137 mg, 90%), mp. 123 – 125 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.35 (d, J = 7.8 Hz, 1H), 8.20 (d, J = 8.1 Hz, 1H), 7.86 (t, J = 7.7 Hz, 1H), 7.77 – 7.68 (m, 2H), 7.60 (t, J = 7.5 Hz, 1H), 7.48 (d, J = 6.8 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.1, 161.0, 138.5, 135.5, 132.7, 130.5, 130.1, 129.9, 129.2, 128.2, 125.9, 120.6, 102.1 (t, $J_{C\text{-}F}$ = 3.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.8 (t, $J_{D\text{-}F}$ = 8.6 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_9DF_2NaO_2S^+$ [M + Na^+] 328.0325, found 328.0321.

4-((Difluoromethyl-*d*)thio)-7-methyl-3-phenyl-1*H*-isochromen-1-one (4b)



Following the general procedure A, **4b** was purified by silica gel chromatography (3% EtOAc/PE). White solid (128 mg, 80%), mp. 130 – 132 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (t, J = 1.2 Hz, 1H), 8.08 (d, J = 8.2 Hz, 1H), 7.73 – 7.65 (m, 3H), 7.47 (qd, J = 4.8, 1.7 Hz, 3H), 2.51 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.22, 161.19, 139.7, 136.8, 136.1, 132.7, 130.4, 130.2, 129.7, 128.2, 125.9, 120.5, 102.1 (t, $J_{C\text{-}F}$ = 3.3 Hz), 21.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.8 (t, $J_{D\text{-}F}$ = 8.7 Hz, 2F). HRMS (ESI) calcd for $C_{17}H_{11}DF_2NaO_2S^+$ [M + Na^+] 342.0481, found 342.0486.

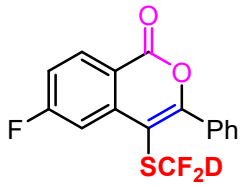
4-((Difluoromethyl-*d*)thio)-7-methoxy-3-phenyl-1*H*-isochromen-1-one (4c)



Following the general procedure A, **4c** was purified by silica gel chromatography (2% EtOAc/PE). White solid (142 mg, 85%), mp. 118 – 120 °C. ^{1}H NMR (400 MHz,

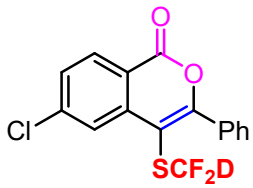
$CDCl_3$) δ 8.11 (d, J = 8.9 Hz, 1H), 7.75 (d, J = 2.8 Hz, 1H), 7.73 – 7.66 (m, 2H), 7.51 – 7.40 (m, 4H), 3.94 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.2, 160.3, 159.9, 132.7, 132.0, 130.3, 130.2, 128.2, 127.8, 124.8, 121.9, 110.5, 102.0 (t, $J_{C\text{-}F}$ = 3.2 Hz), 56.1. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.8 (t, $J_{D\text{-}F}$ = 8.3 Hz, 2F). HRMS (ESI) calcd for $C_{17}H_{11}DF_2NaO_3S^+$ [M + Na^+] 358.0430, found 358.0434.

4-((Difluoromethyl-*d*)thio)-6-fluoro-3-phenyl-1*H*-isochromen-1-one (4d)



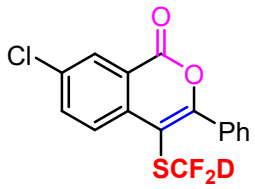
Following the general procedure A, **4d** was purified by silica gel chromatography (1% EtOAc/PE). White solid (124 mg, 77%), mp. 114 – 116 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 8.22 (dd, J = 9.0, 4.9 Hz, 1H), 7.99 (dd, J = 8.2, 2.8 Hz, 1H), 7.74 – 7.66 (m, 2H), 7.58 (ddd, J = 9.0, 7.9, 2.8 Hz, 1H), 7.53 – 7.44 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.5 (d, $J_{C\text{-}F}$ = 253.5 Hz), 161.5 (d, $J_{C\text{-}F}$ = 2.4 Hz), 160.2 (d, $J_{C\text{-}F}$ = 3.3 Hz), 135.1 (d, $J_{C\text{-}F}$ = 2.6 Hz), 132.4, 130.6, 130.1, 128.9 (d, $J_{C\text{-}F}$ = 8.0 Hz), 128.3, 123.7 (d, $J_{C\text{-}F}$ = 22.8 Hz), 122.3 (d, $J_{C\text{-}F}$ = 8.3 Hz), 115.4 (d, $J_{C\text{-}F}$ = 23.5 Hz), 101.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.7 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F), -109.6 (s). HRMS (ESI) m/z: [M + $Na]^+$ Calcd for $C_{16}H_8DF_3NaO_2S^+$ 346.0230; Found 346.0226.

6-Chloro-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-one (4e)



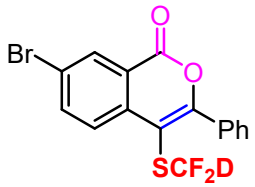
Following the general procedure A, **4e** was purified by silica gel chromatography (1% EtOAc/PE). White solid (141 mg, 83%), mp. 150 – 152 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, J = 8.4 Hz, 1H), 8.18 (d, J = 1.9 Hz, 1H), 7.73 – 7.68 (m, 2H), 7.56 (dd, J = 8.4, 2.0 Hz, 1H), 7.52 – 7.45 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.5, 160.3, 142.7, 140.3, 132.4, 131.6, 130.8, 130.1, 129.7, 128.3, 125.9, 118.9, 101.1 (t, $J_{C\text{-}F}$ = 3.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.9 (t, $J_{D\text{-}F}$ = 8.5 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{35}ClF_2NaO_2S^+$ [M + Na^+] 361.9935, found 361.9937.

7-Chloro-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-one (4f)



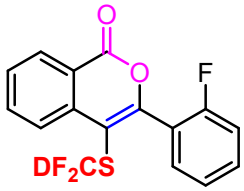
Following the general procedure A, **4f** was purified by silica gel chromatography (1% EtOAc/PE). White solid (137 mg, 81%), mp. 140 – 142 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (d, J = 2.3 Hz, 1H), 8.16 (d, J = 8.7 Hz, 1H), 7.81 (dd, J = 8.7, 2.3 Hz, 1H), 7.73 – 7.68 (m, 2H), 7.54 – 7.45 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.4, 160.0, 137.2, 135.8, 135.3, 132.4, 130.8, 130.2, 129.3, 128.3, 127.9, 121.8, 101.5 (t, $J_{C\text{-}F}$ = 3.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.7 (t, $J_{D\text{-}F}$ = 8.6 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{35}ClF_2NaO_2S^+$ [M + Na^+] 361.9935, found 361.9940.

7-Bromo-4-((difluoromethyl-*d*)thio)-3-phenyl-1*H*-isochromen-1-one (4g)



Following the general procedure A, **4g** was purified by silica gel chromatography (1% EtOAc/PE). White solid (160 mg, 84%), mp. 134 – 136 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.45 (d, J = 2.1 Hz, 1H), 8.07 (d, J = 8.6 Hz, 1H), 7.94 (dd, J = 8.7, 2.1 Hz, 1H), 7.75 – 7.67 (m, 2H), 7.54 – 7.44 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.5, 159.7, 138.6, 137.5, 132.33, 132.31, 130.7, 130.1, 128.3, 127.9, 123.0, 121.9, 101.5 (t, $J_{C\text{-}F}$ = 3.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.7 (t, $J_{D\text{-}F}$ = 8.6 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{79}BrF_2NaO_2S^+$ [M + Na^+] 405.9430, found 405.9436.

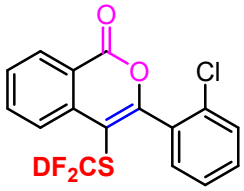
4-((Difluoromethyl-*d*)thio)-3-(2-fluorophenyl)-1*H*-isochromen-1-one (4h)



Following the general procedure A, **4h** was purified by silica gel chromatography (1% EtOAc/PE). White solid (115 mg, 71%), mp. 98 – 100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (dd, J = 7.9, 1.3 Hz, 1H), 8.17 (d, J = 8.1 Hz, 1H), 7.88 (ddd, J = 8.3,

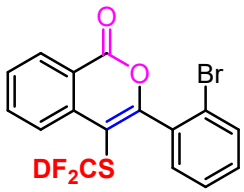
7.4, 1.4 Hz, 1H), 7.64 (td, J = 7.7, 1.2 Hz, 1H), 7.56 – 7.46 (m, 2H), 7.31 – 7.24 (m, 1H), 7.23 – 7.13 (m, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.7 (d, $J_{C\text{-}F}$ = 250.5 Hz), 157.1, 137.9, 135.6, 132.6 (d, $J_{C\text{-}F}$ = 8.5 Hz), 131.4 (d, $J_{C\text{-}F}$ = 1.8 Hz), 130.1, 129.6, 126.0, 124.2 (d, $J_{C\text{-}F}$ = 3.6 Hz), 121.4, 121.3, 120.9, 116.1 (d, $J_{C\text{-}F}$ = 21.6 Hz), 105.3 (t, $J_{C\text{-}F}$ = 3.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.3 (t, $J_{D\text{-}F}$ = 8.1 Hz, 2F), -111.7 (s). HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{16}H_8DF_3NaO_2S^+$ 346.0230; Found 346.0234.

3-(2-Chlorophenyl)-4-((difluoromethyl-d)thio)-1*H*-isochromen-1-one (4i)



Following the general procedure A, **4i** was purified by silica gel chromatography (1% EtOAc/PE). White solid (114 mg, 67%), mp. 120 – 122 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.38 (dd, J = 7.9, 1.3 Hz, 1H), 8.17 (d, J = 8.1 Hz, 1H), 7.89 (td, J = 7.8, 1.4 Hz, 1H), 7.65 (td, J = 7.6, 1.1 Hz, 1H), 7.53 – 7.36 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.9, 159.8, 137.8, 135.6, 133.8, 132.3, 131.63, 131.60, 130.2, 129.8, 129.6, 126.8, 126.0, 121.0, 105.0 (t, $J_{C\text{-}F}$ = 3.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.1 (dd, J = 244.8, 1020.9 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{35}ClF_2NaO_2S^+$ [M + Na^+] 361.9935, found 361.9939.

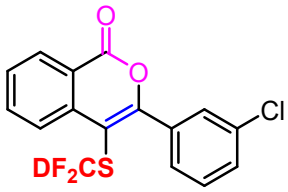
3-(2-Bromophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-one (4j)



Following the general procedure A, **4j** was purified by silica gel chromatography (1% EtOAc/PE). White solid (120 mg, 63%), mp. 98 – 100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.42 – 8.36 (m, 1H), 8.17 (d, J = 8.1 Hz, 1H), 7.94 – 7.86 (m, 1H), 7.72 – 7.63 (m, 2H), 7.45 (qd, J = 7.6, 1.6 Hz, 2H), 7.37 (td, J = 7.5, 7.1, 2.3 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.0, 160.9, 137.8, 135.7, 134.3, 133.0, 131.73, 131.70, 130.2, 129.6, 127.4, 126.1, 123.4, 121.0, 104.8 (t, $J_{C\text{-}F}$ = 3.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -91.9 (dd, J = 240.3, 1107.09 Hz, 2F). HRMS (ESI) calcd for

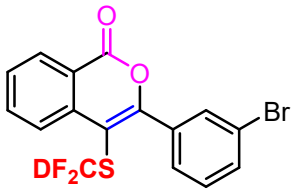
$C_{16}H_8D^{79}BrF_2NaO_2S^+$ [M + Na^+] 405.9430, found 405.9426.

3-(3-Chlorophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-one (4k)



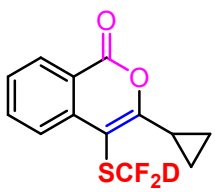
Following the general procedure A, **4k** was purified by silica gel chromatography (3% EtOAc/PE). Colorless oil (95 mg, 56%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (dd, J = 7.9, 1.4 Hz, 1H), 8.20 (d, J = 8.1 Hz, 1H), 7.89 (ddd, J = 8.4, 7.4, 1.5 Hz, 1H), 7.71 (t, J = 1.9 Hz, 1H), 7.67 – 7.58 (m, 2H), 7.47 (dt, J = 8.2, 1.5 Hz, 1H), 7.42 (d, J = 7.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.7, 160.5, 138.2, 135.7, 134.3, 134.2, 130.6, 130.2, 130.1, 129.5, 128.4, 126.1, 120.73, 102.7 (t, J_{C-F} = 3.0 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.7 (t, J = 8.4 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{35}ClF_2NaO_2S^+$ [M + Na^+] 361.9935, found 361.9931.

3-(3-Bromophenyl)-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-one (4l)



Following the general procedure A, **4l** was purified by silica gel chromatography (2% EtOAc/PE). Colorless oil (115 mg, 60%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 – 8.32 (m, 1H), 8.19 (d, J = 8.1 Hz, 1H), 7.91 – 7.84 (m, 2H), 7.67 – 7.59 (m, 3H), 7.35 (t, J = 7.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 160.6, 160.4, 138.2, 135.7, 134.5, 133.5, 133.0, 130.0, 129.7, 129.5, 128.9, 126.1, 122.1, 120.7, 102.8 (t, J_{C-F} = 3.2 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.8 (t, J_{D-F} = 8.6 Hz, 2F). HRMS (ESI) calcd for $C_{16}H_8D^{79}BrF_2NaO_2S^+$ [M + Na^+] 405.9430, found 405.9436.

3-Cyclopropyl-4-((difluoromethyl-*d*)thio)-1*H*-isochromen-1-one (4m)



Following the general procedure A, **4m** was purified by silica gel chromatography (3%

EtOAc/PE). White solid (69 mg, 51%), mp. 107 – 109 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29 – 8.19 (m, 1H), 8.02 (d, *J* = 8.1 Hz, 1H), 7.78 (td, *J* = 8.3, 7.8, 1.4 Hz, 1H), 7.53 – 7.43 (m, 1H), 2.84 (tt, *J* = 8.3, 5.0 Hz, 1H), 1.31 – 1.24 (m, 2H), 1.07 (dt, *J* = 8.3, 3.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.0, 160.9, 138.9, 135.5, 129.9, 127.9, 124.6, 119.9, 99.4 (t, J_{C-F} = 3.3 Hz), 13.36, 9.27. ^{19}F NMR (376 MHz, $CDCl_3$) δ -92.6 (t, J_{D-F} = 8.3 Hz, 2F). HRMS (ESI) calcd for $C_{13}H_9DF_2NaO_2S^+$ [M + Na^+] 292.0325, found 292.0332.

III. X-ray Crystal Structure and Data of Product 2a.

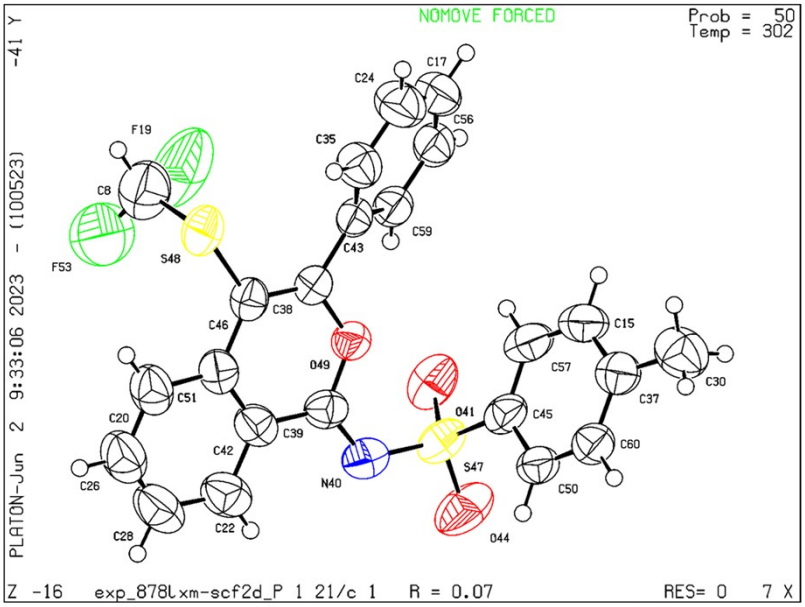


Figure S1 X-ray crystal structure of **2a** with 50% ellipsoid probability

X-ray structure determination of 2a. Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from a Diethyl ether/*n*-hexane solution of **2a**. Crystal data collection and refinement parameters of **2a** are summarized in Table S1. Intensity data were collected at 160 K on a ROD, Synergy Custom system, HyPix diffractometer using mirror-monochromated Cu Kα radiation, λ = 1.54184 Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. The structure was solved by the ShelXT [2] structure solution program using Intrinsic Phasing and refined with the ShelXL [3] refinement package using Least Squares minimisation.

Table S1 Crystal data and structure refinement for 2a.

Identification code	**2a**
Empirical formula	$C_{23}H_{17}F_2NO_3S_2$
Formula weight	457.49
Temperature/K	301.54(10)
Crystal system	monoclinic

Space group	$P2_1/c$
a/Å	13.09300(10)
b/Å	19.0071(2)
c/Å	8.60340(10)
α/°	90
β/°	104.2530(10)
γ/°	90
Volume/Å^3	2075.14(4)
Z	4
ρ_{calc}g/cm^3	1.464
μ/mm^{-1}	2.718
F(000)	944.0
Crystal size/mm^3	0.2 × 0.15 × 0.1
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	8.378 to 150.548
Index ranges	-16 ≤ h ≤ 16, -23 ≤ k ≤ 23, -10 ≤ l ≤ 10
Reflections collected	38596
Independent reflections	4194 [R_{int} = 0.0277, R_{sigma} = 0.0134]
Data/restraints/parameters	4194/186/281
Goodness-of-fit on F^2	1.090
Final R indexes [I>=2σ (I)]	R_1 = 0.0722, wR_2 = 0.2244
Final R indexes [all data]	R_1 = 0.0770, wR_2 = 0.2296
Largest diff. peak/hole / e Å^{-3}	1.49/-0.48

IV. References

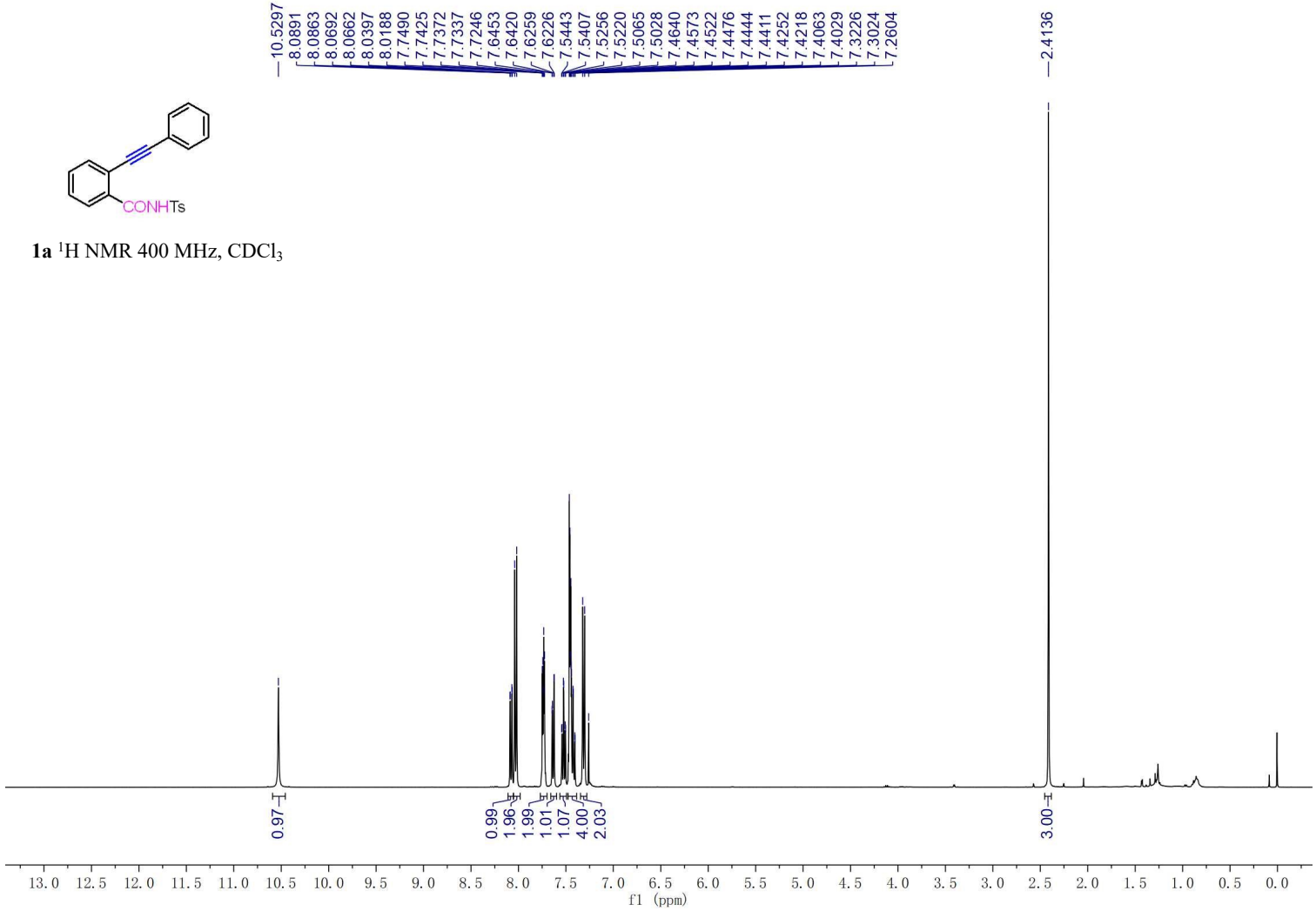
1. (a) Z. Shi, N. Li, W.-Z. Wang, H.-K. Lu, Y. Yuan, Z. Li and K.-Y. Ye, *Org. Biomol. Chem.*, 2022, **20**, 4320; (b) C. Yang, X. Zhang, D. Zhang-Negrerie, Y. Du and K. Zhao, *J. Org. Chem.*, 2015, **80**, 5320; (c) K. Norseeda, N. Chaisan, C. Thongsornkleeb, J. Tummatorn and S. Ruchirawat, *J. Org. Chem.*, 2019, **84**, 16222.

2. C. Hu, F. Chen, G.-P. Lu and W.-B. Yi, *Chin. Chem. Lett.*, 2022, **33**, 4293.

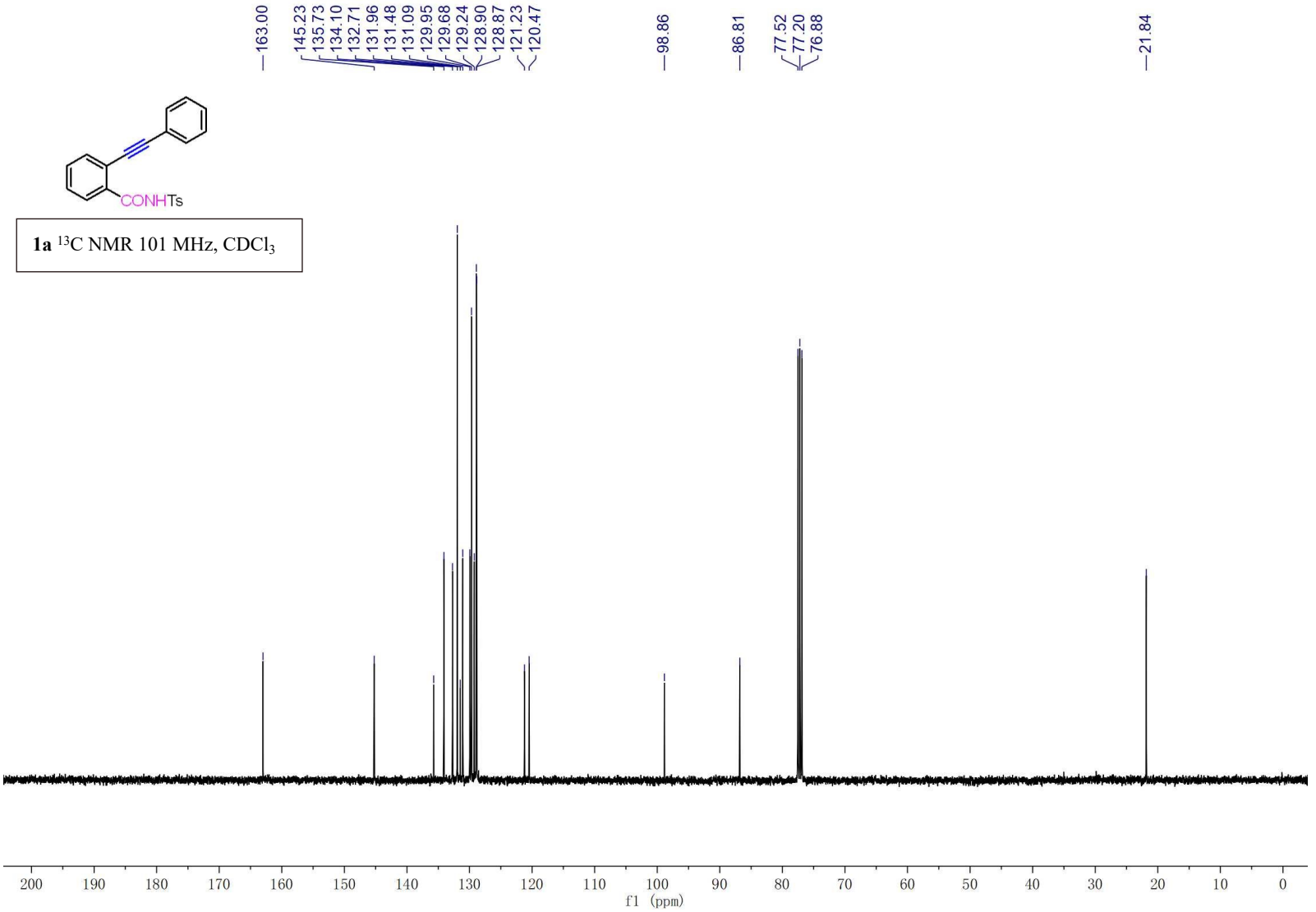
3. H. Shi, X. Wang, X. Li, B. Zhang, X. Li, J. Zhang, J. Yang and Y. Du, *Org. Lett.*, 2022, **24**, 2214.

4. V. Pirovano, E. Brambilla, G. Fanciullacci and G. Abbiati, *Org. Biomol. Chem.*, 2022, **20**, 8065.

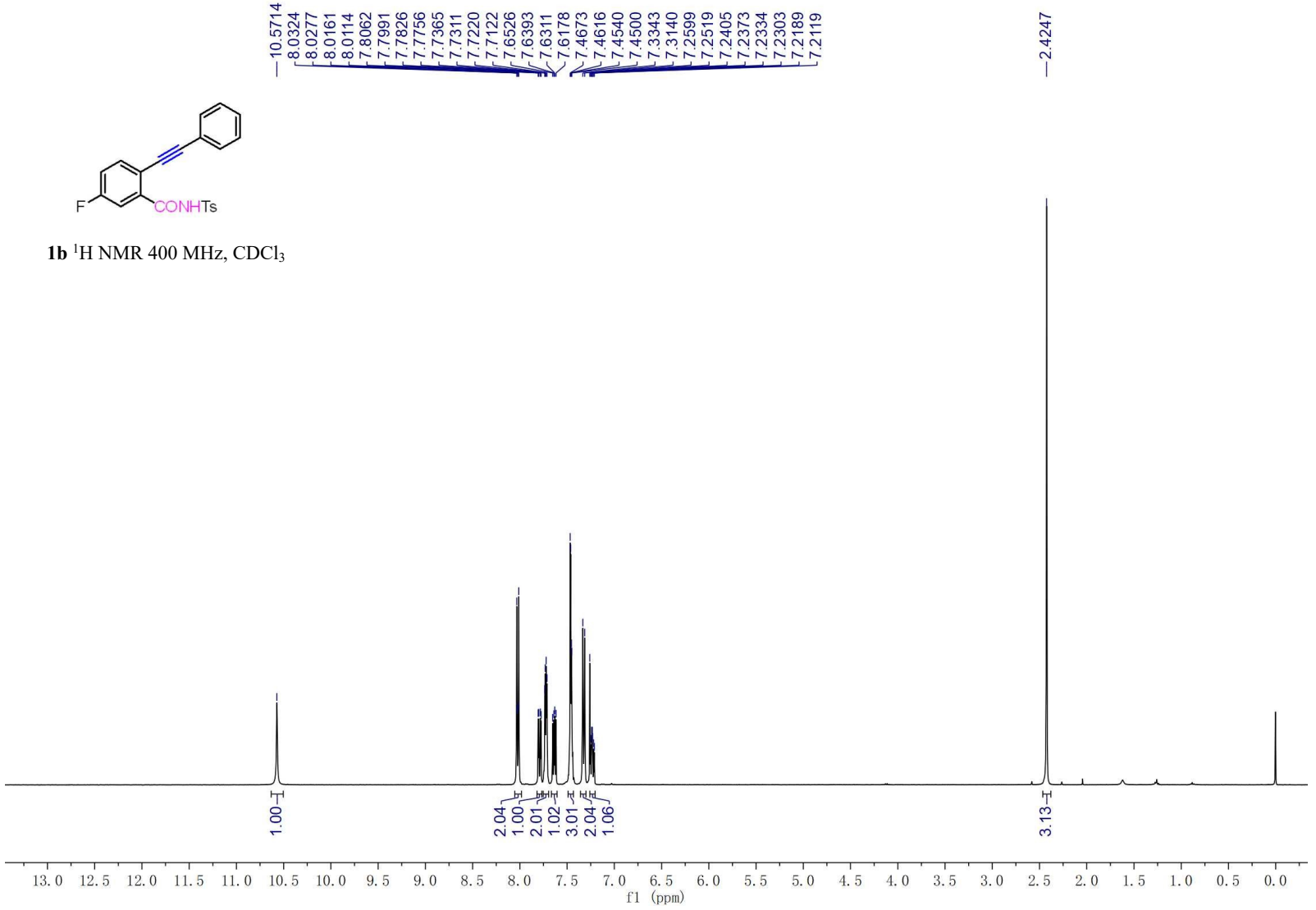
V. ^{1}H, ^{13}C and ^{19}F NMR Spectra of Compounds 1a-o, 3a-m, 2a-o, 4a-m:



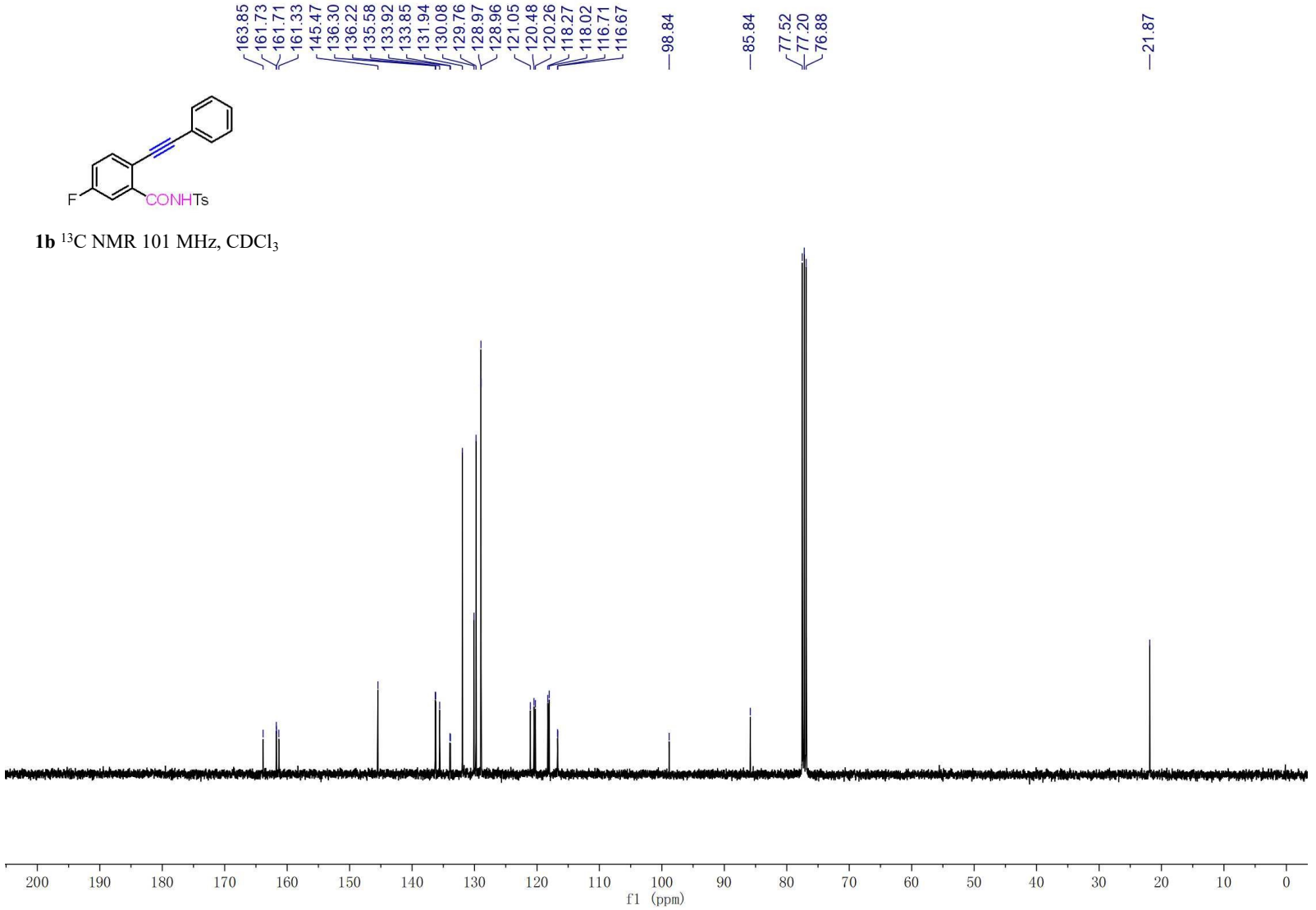
1a ^{1}H NMR 400 MHz, $CDCl_3$



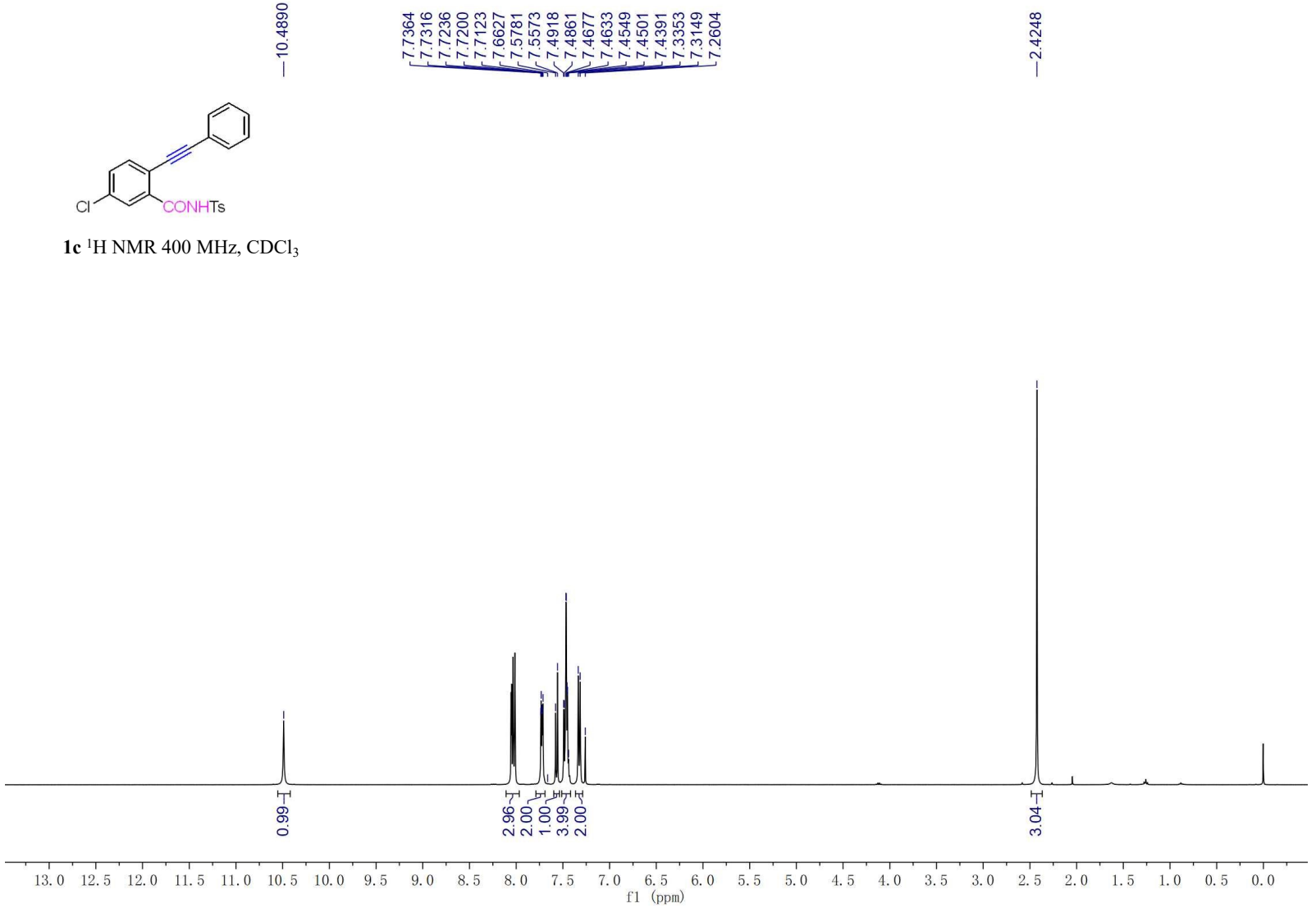
1a ^{13}C NMR 101 MHz, $CDCl_3$



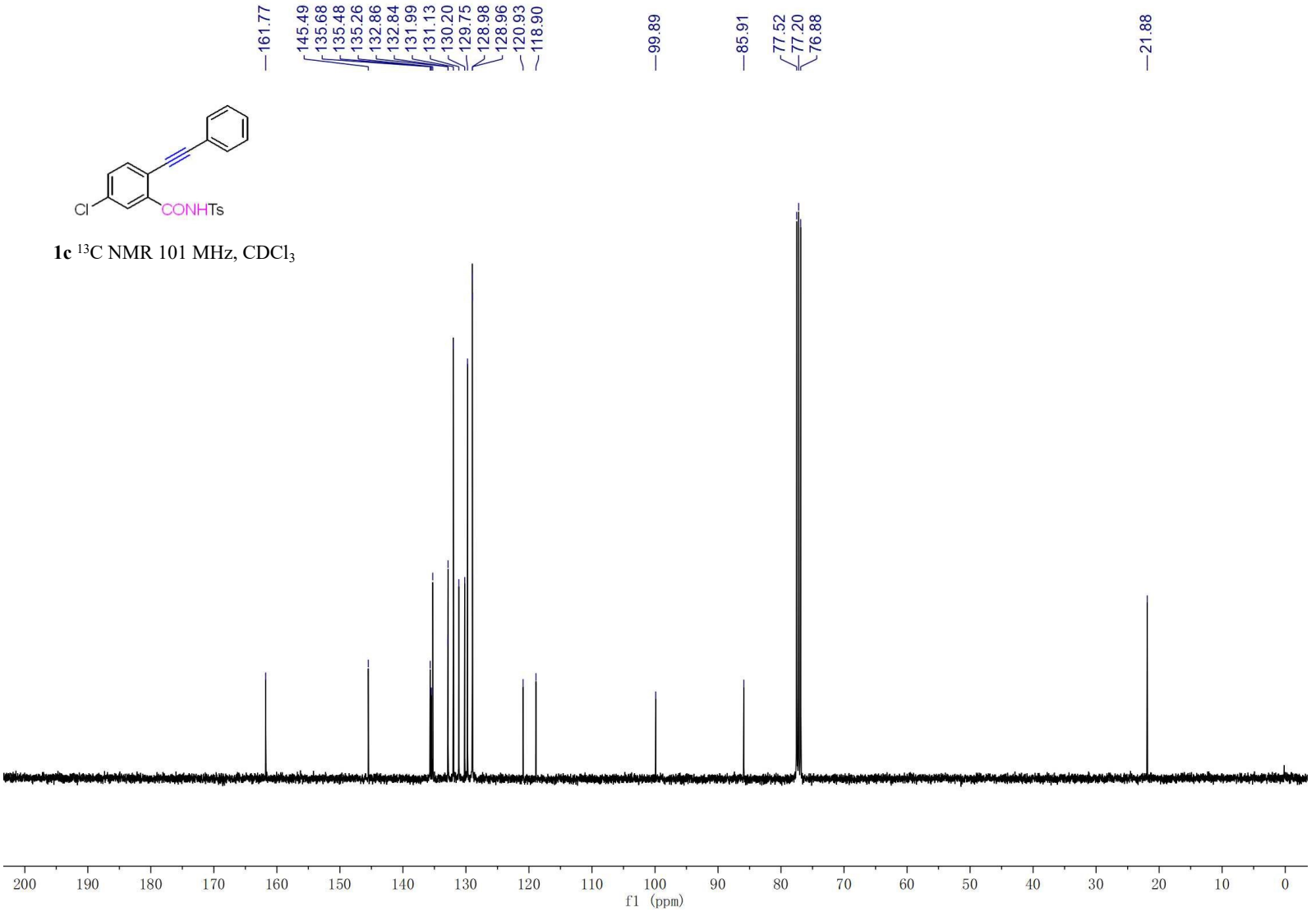
1b ^{1}H NMR 400 MHz, $CDCl_3$



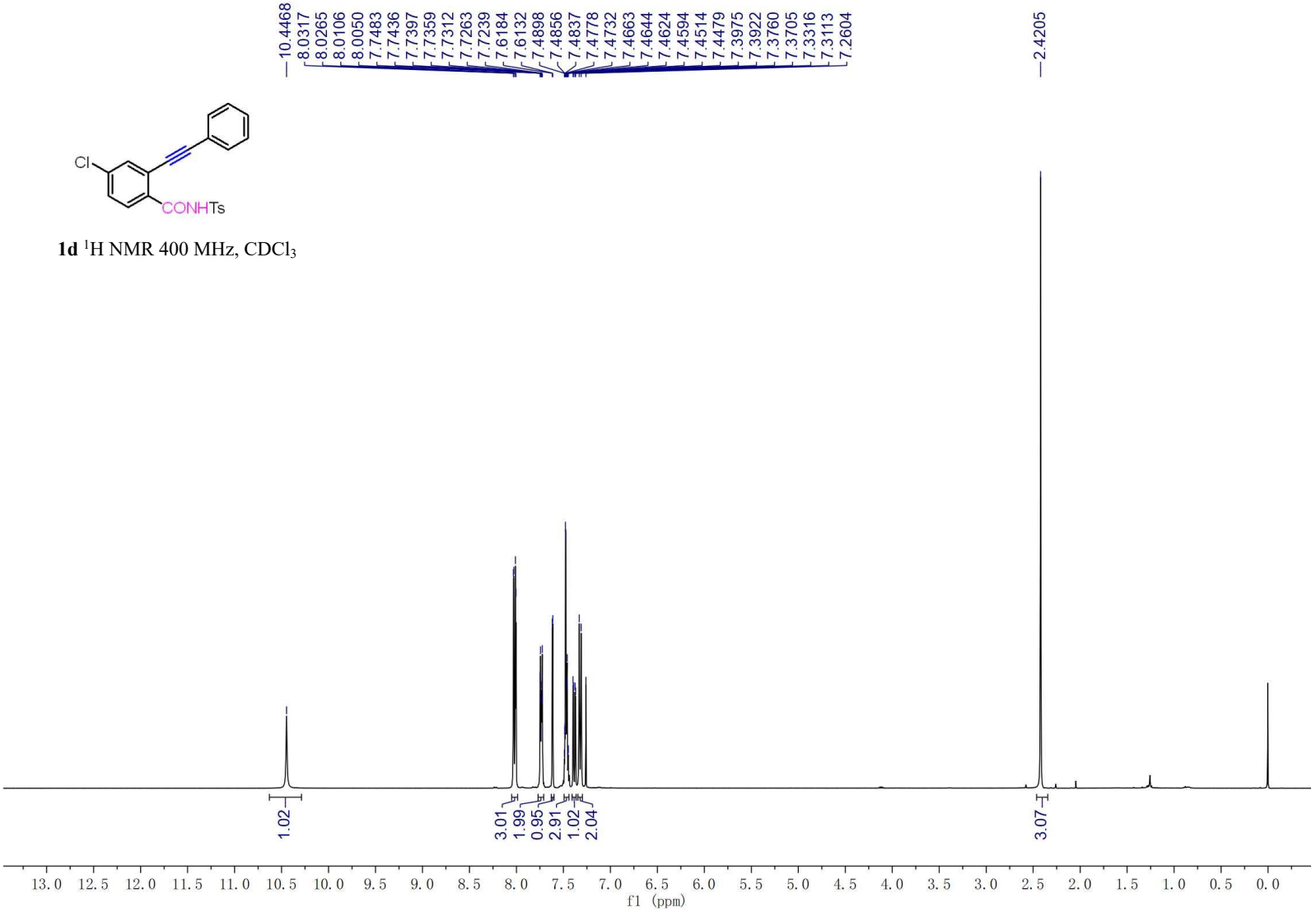
1b ^{13}C NMR 101 MHz, $CDCl_3$



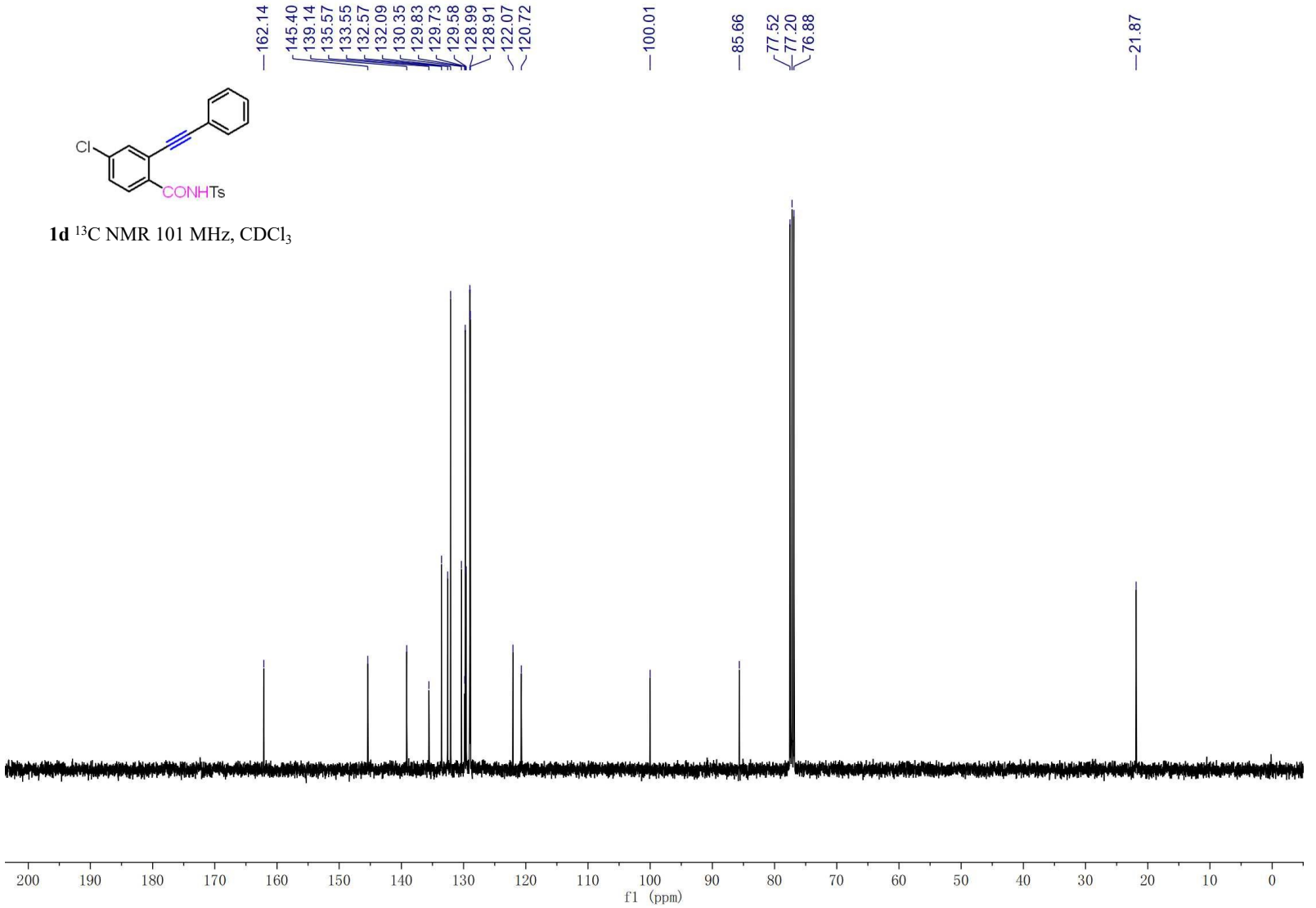
1c ^{1}H NMR 400 MHz, $CDCl_3$



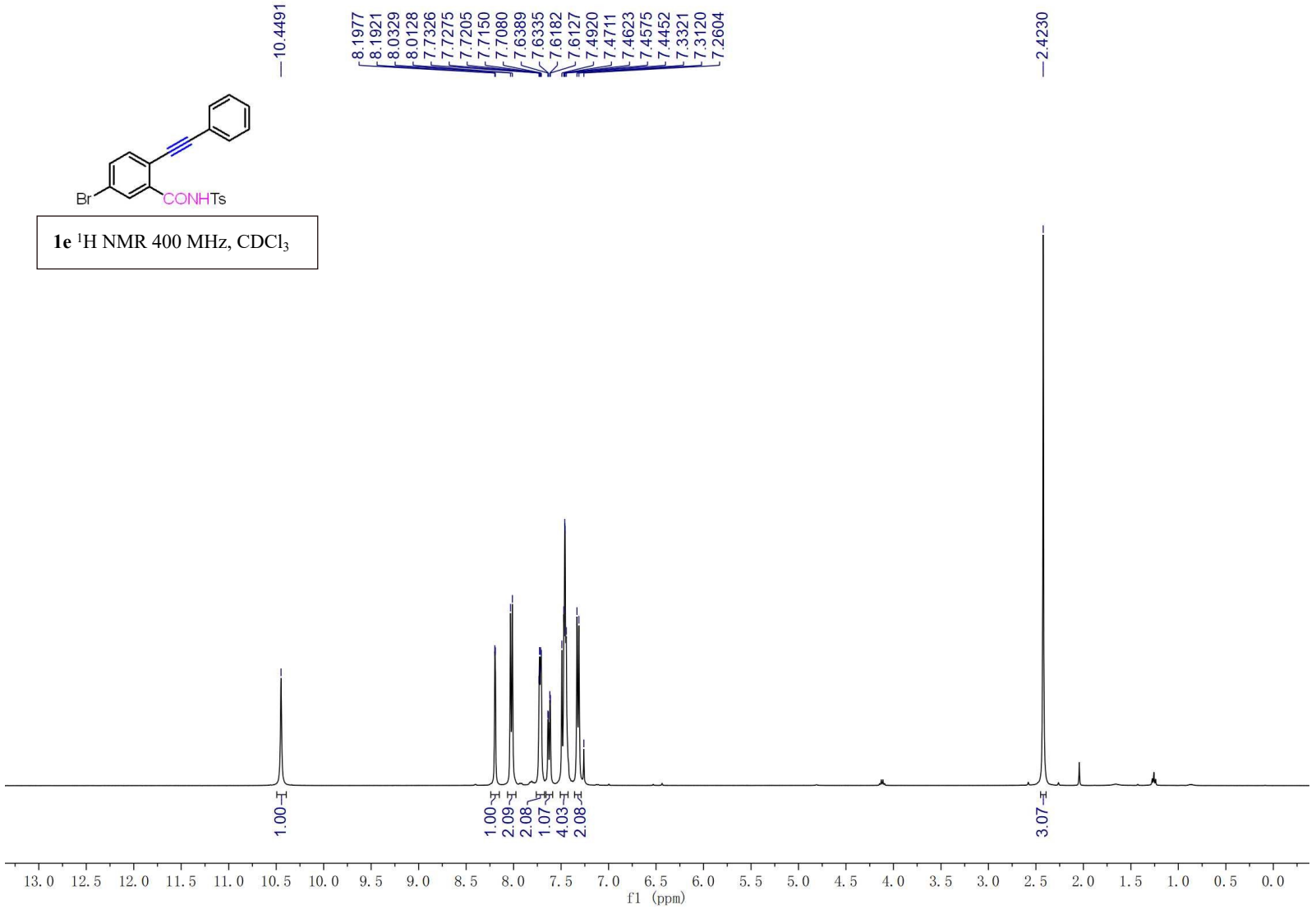
1c ^{13}C NMR 101 MHz, $CDCl_3$



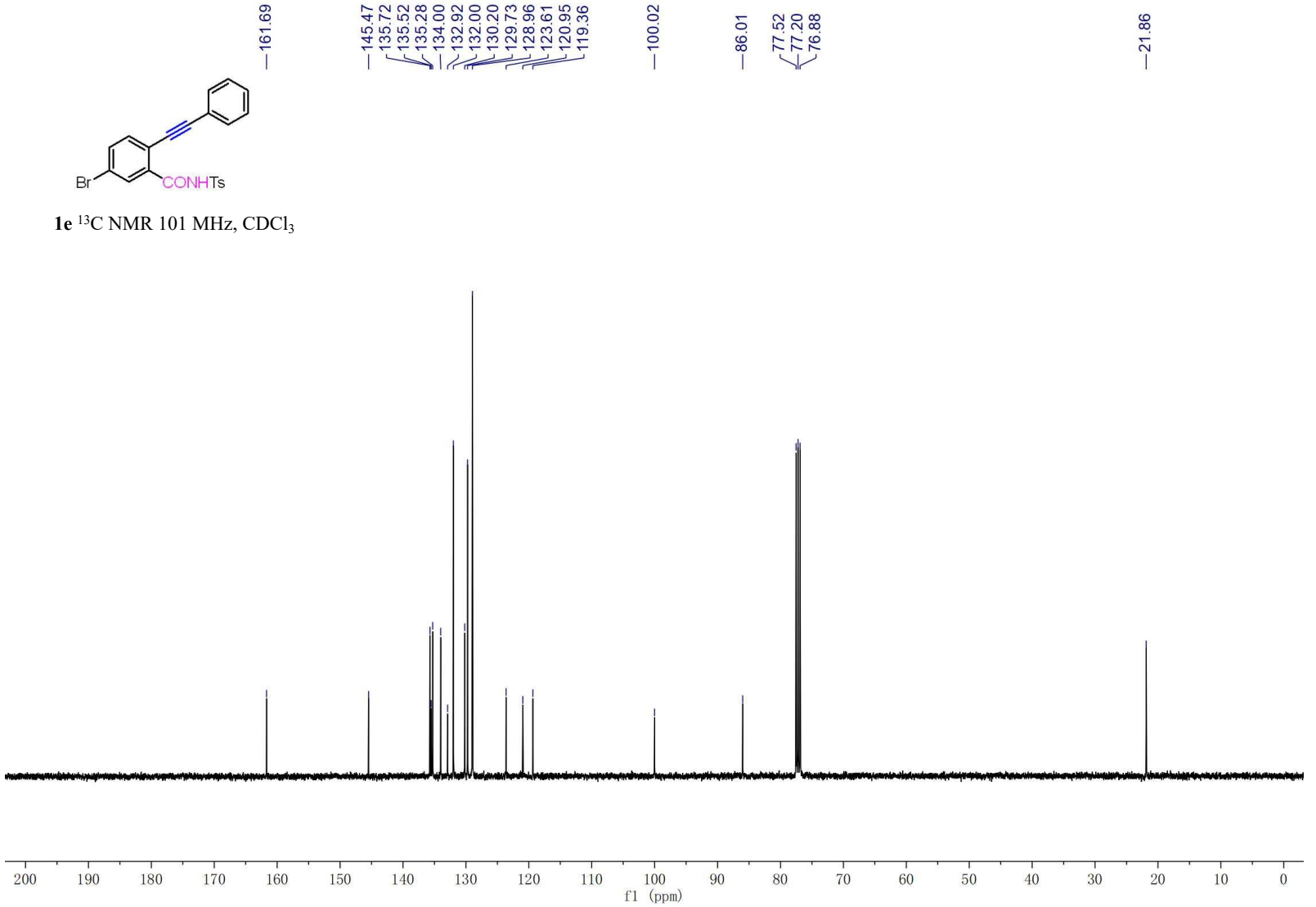
1d ^{1}H NMR 400 MHz, $CDCl_3$



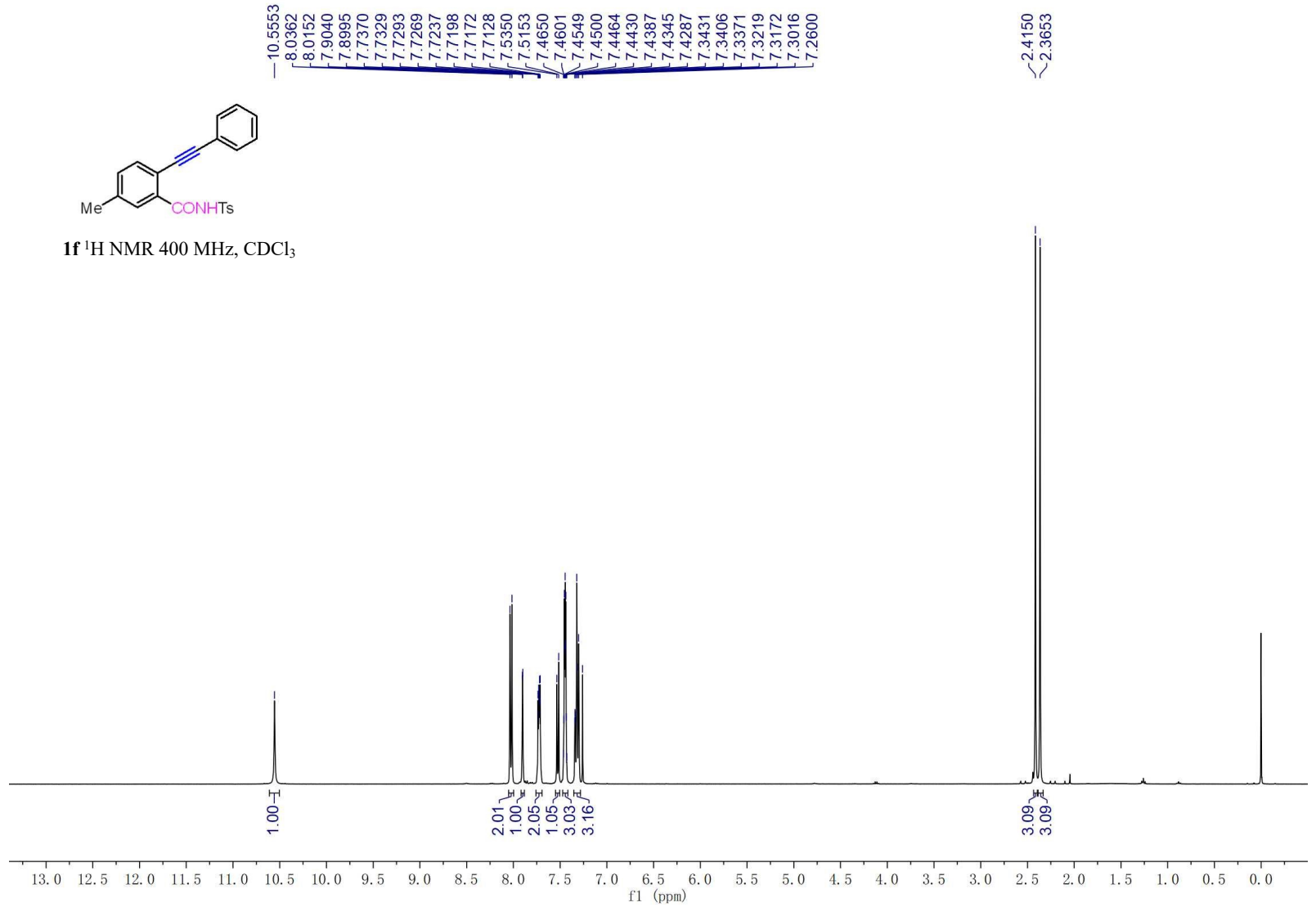
1d ^{13}C NMR 101 MHz, $CDCl_3$



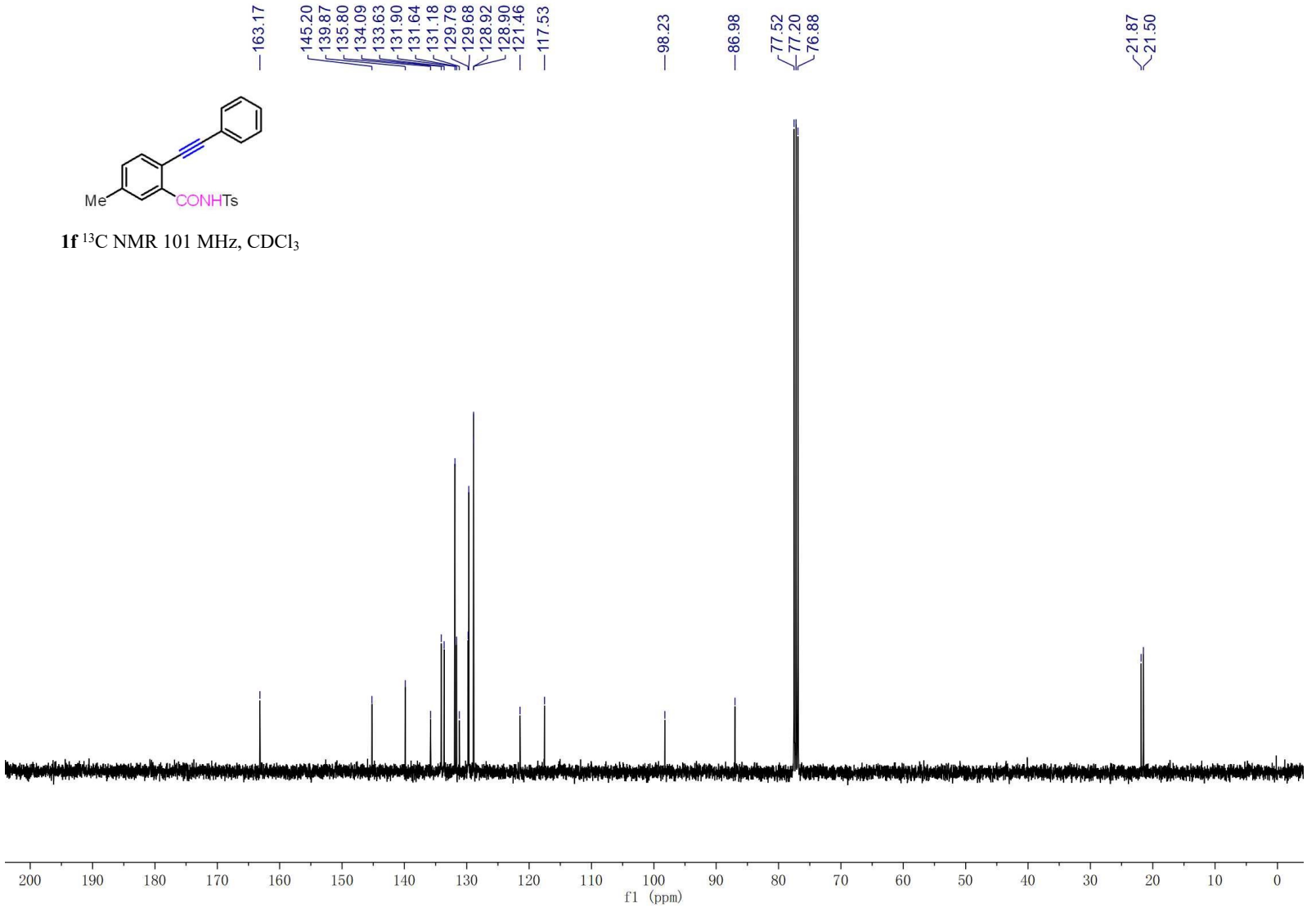
1e ^{1}H NMR 400 MHz, $CDCl_3$



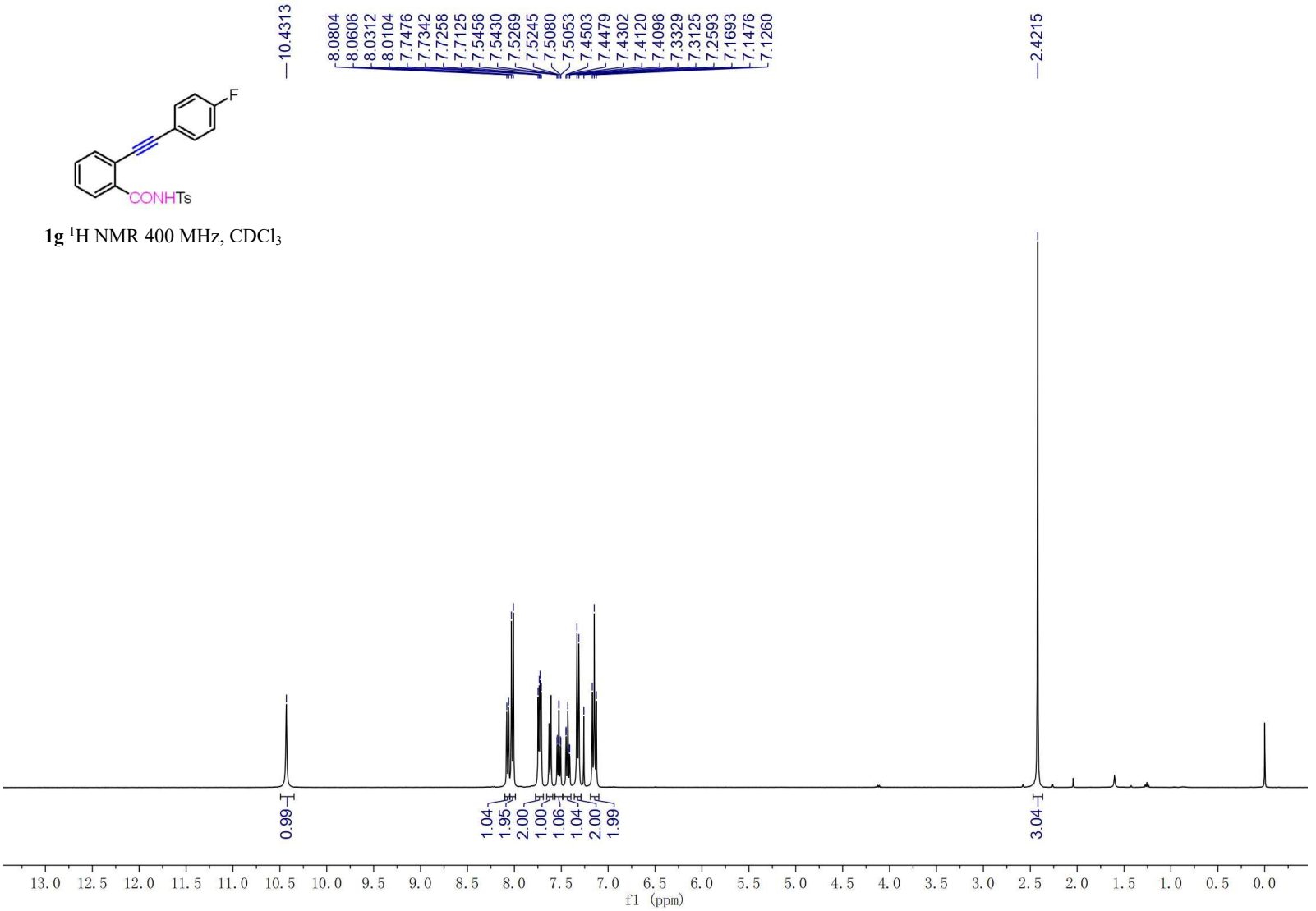
1e ^{13}C NMR 101 MHz, $CDCl_3$



1f ^{1}H NMR 400 MHz, $CDCl_3$



1f ^{13}C NMR 101 MHz, $CDCl_3$



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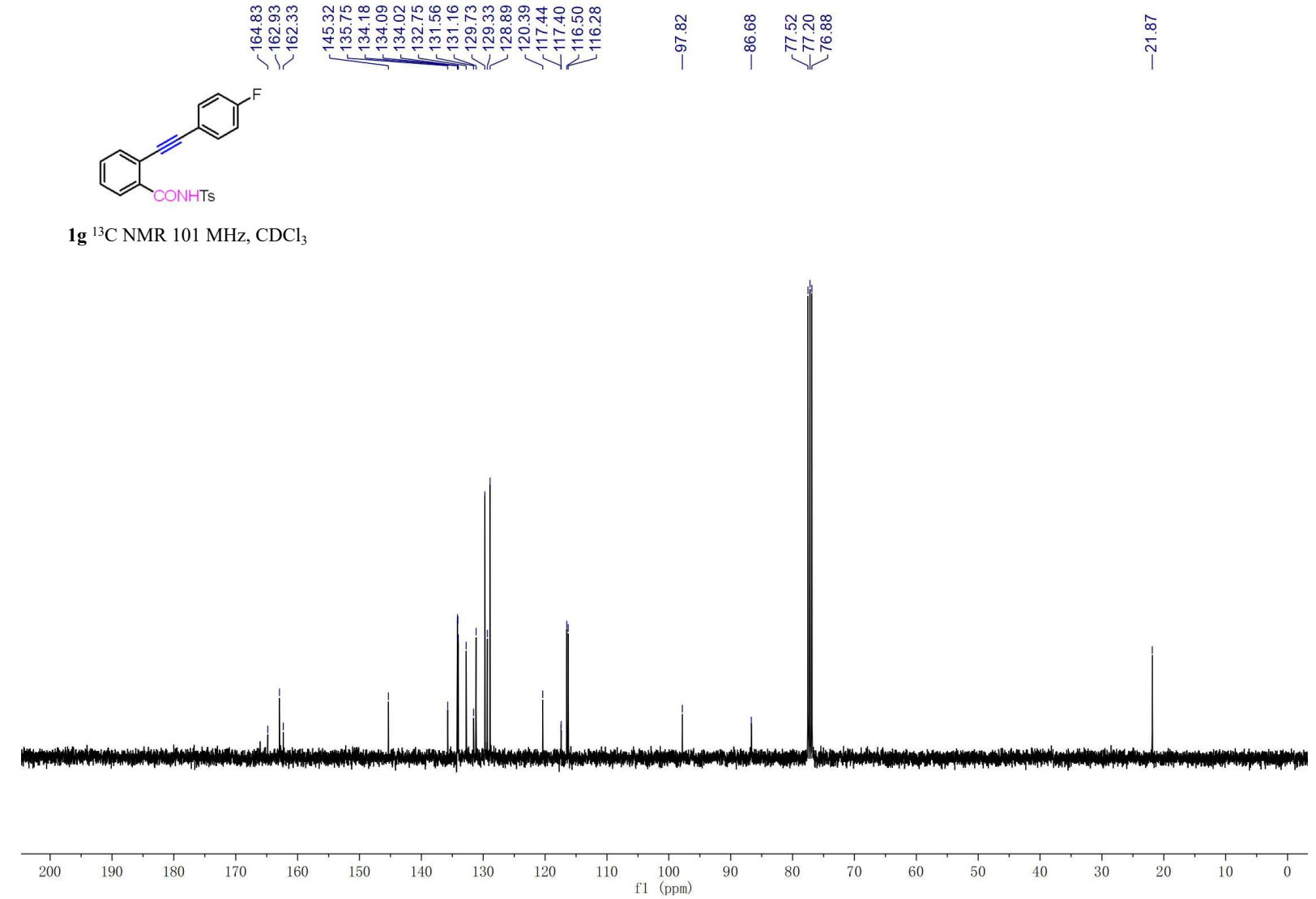
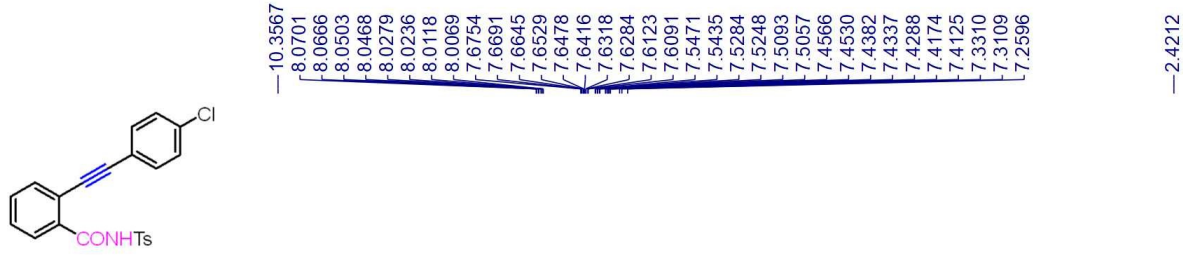


1g ^{13}C NMR 101 MHz, $CDCl_3$



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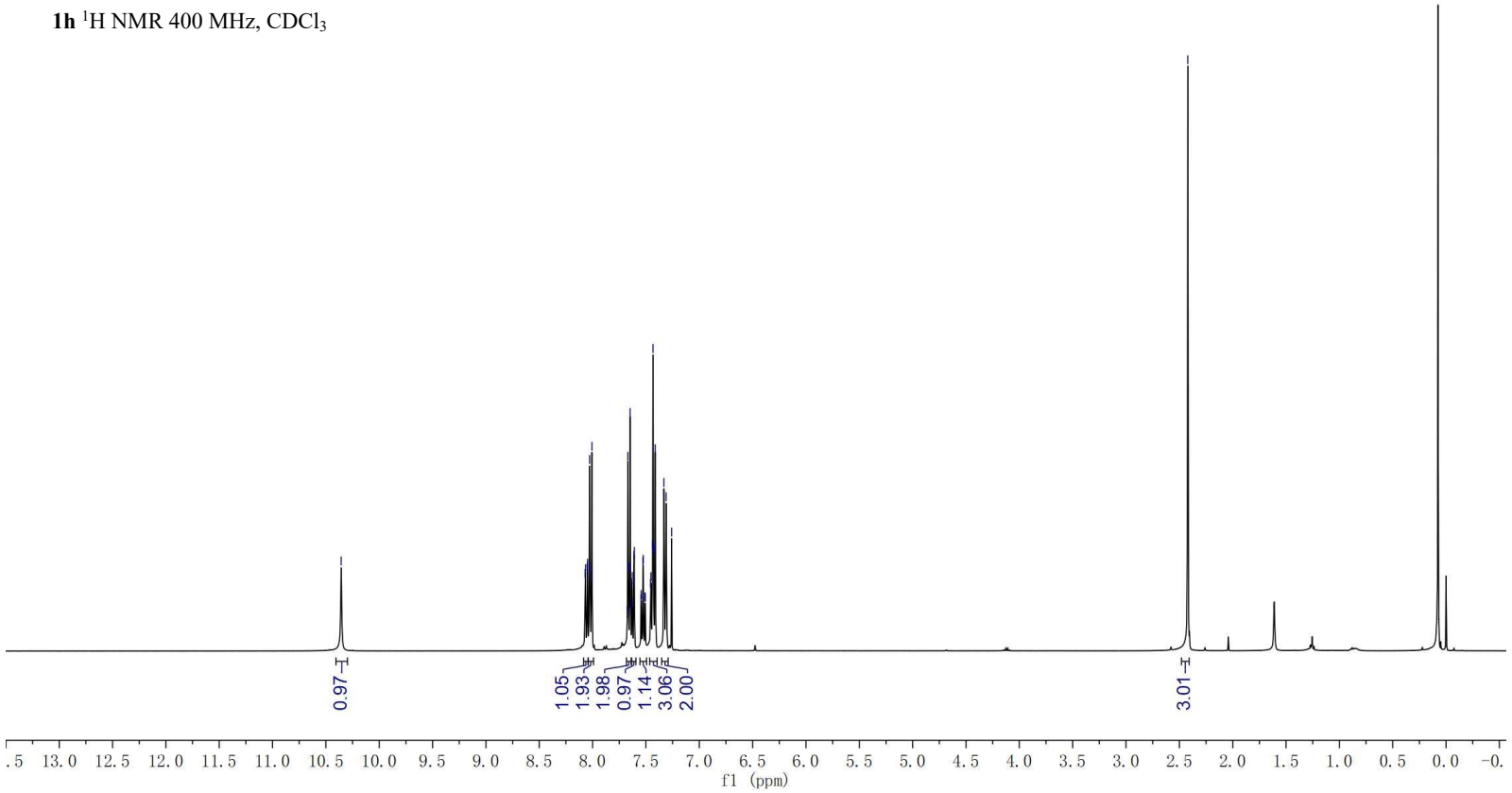
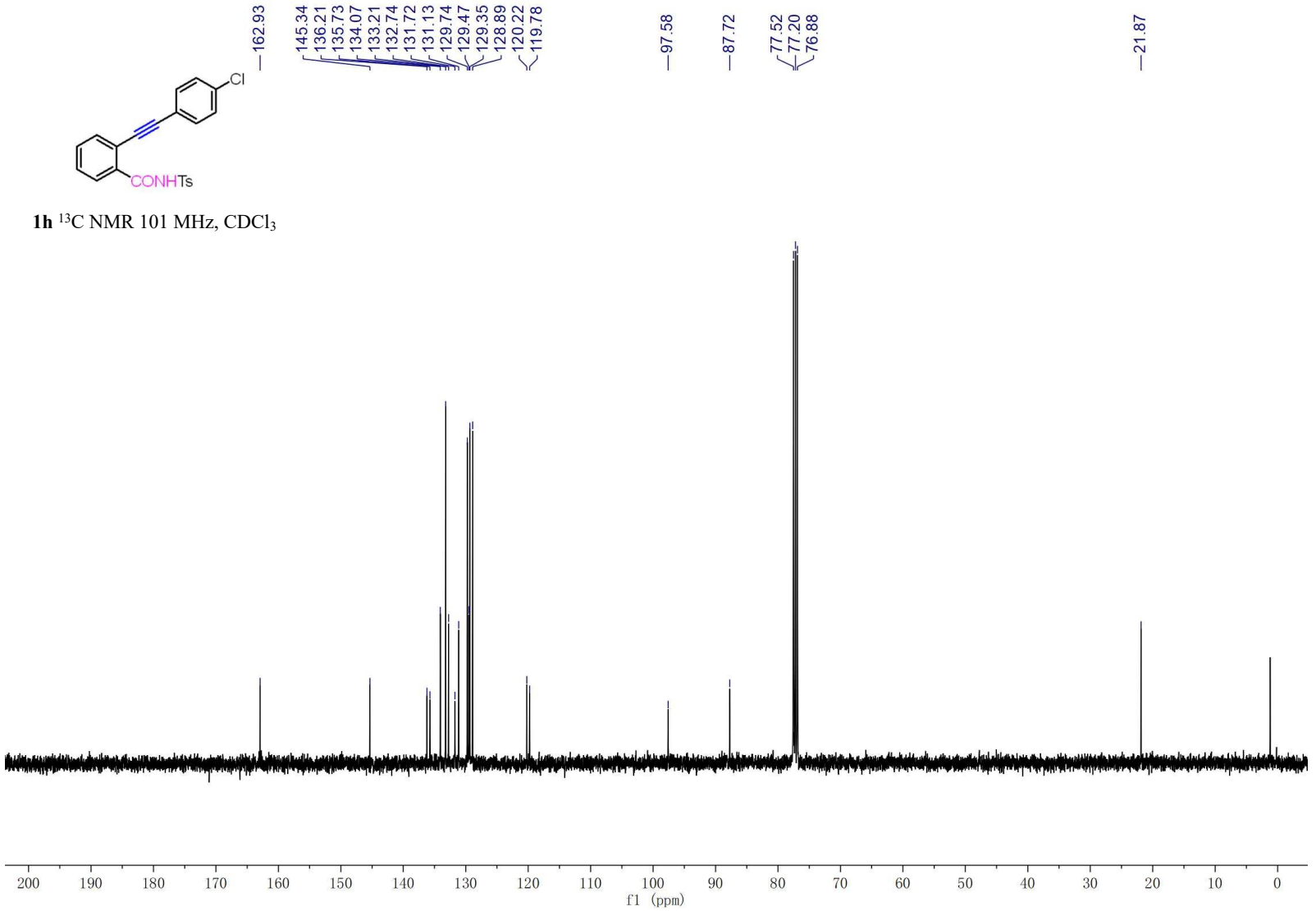
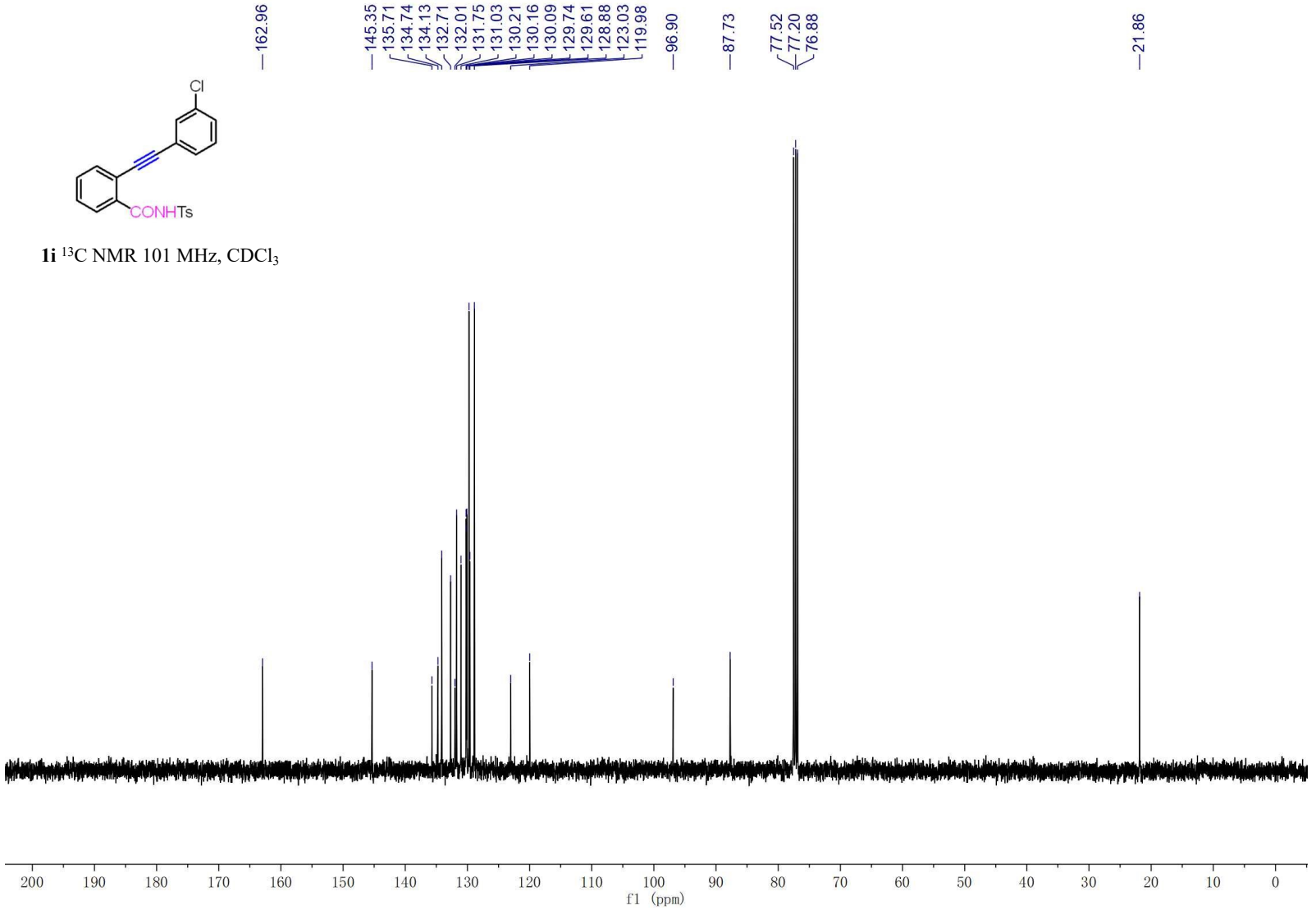




1h ^{13}C NMR 101 MHz, $CDCl_3$

1i ^{1}H NMR 400 MHz, $CDCl_3$



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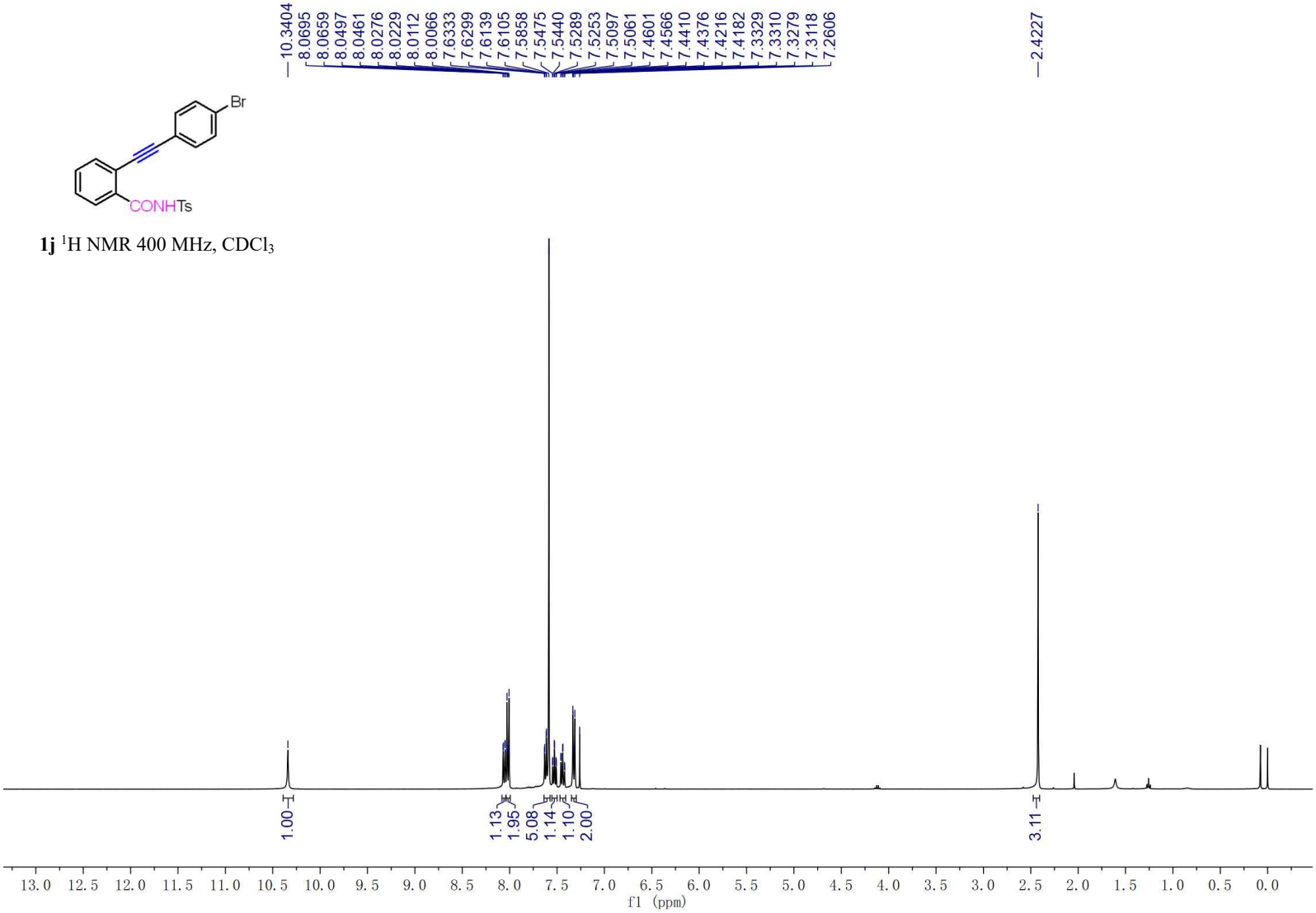

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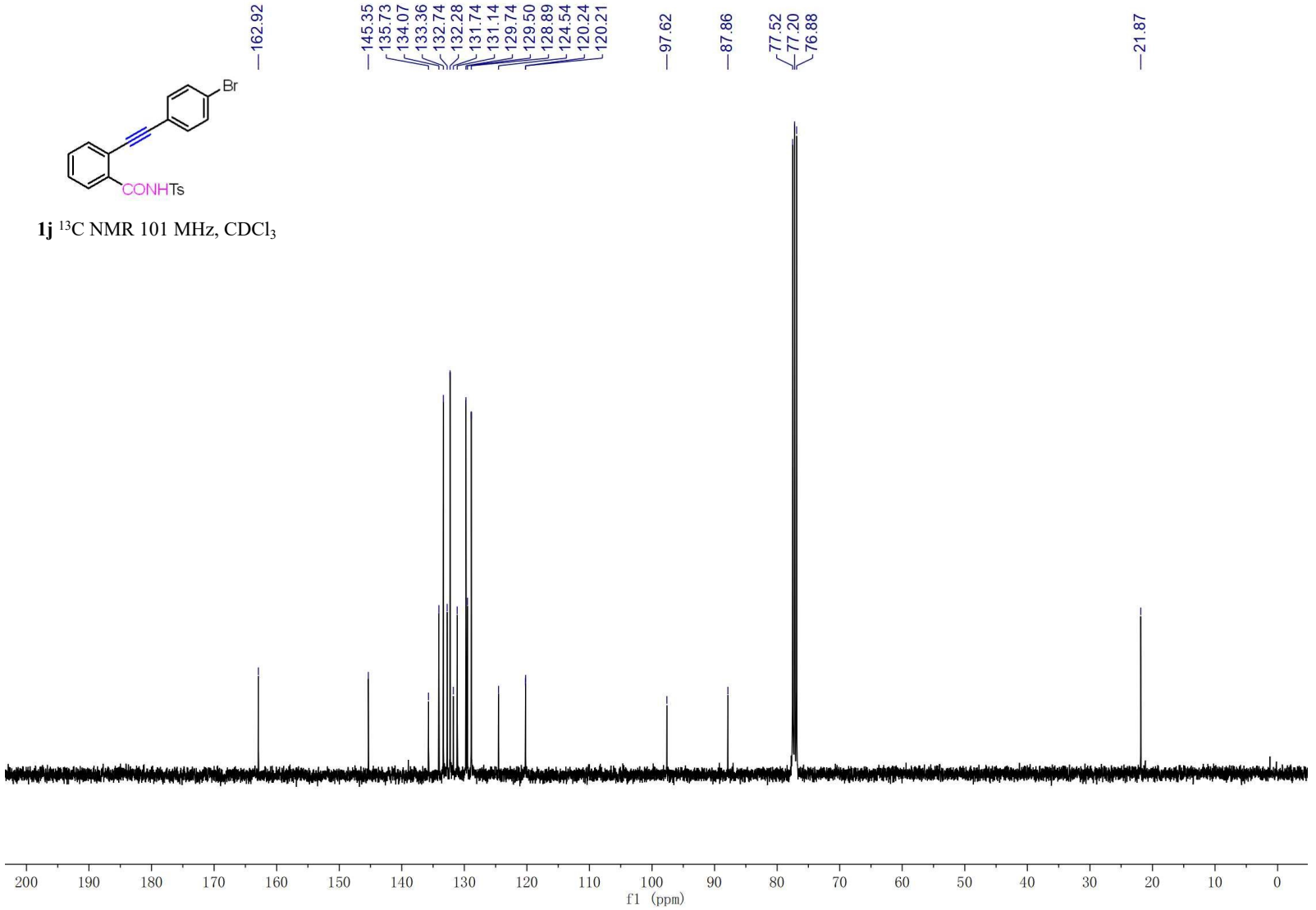

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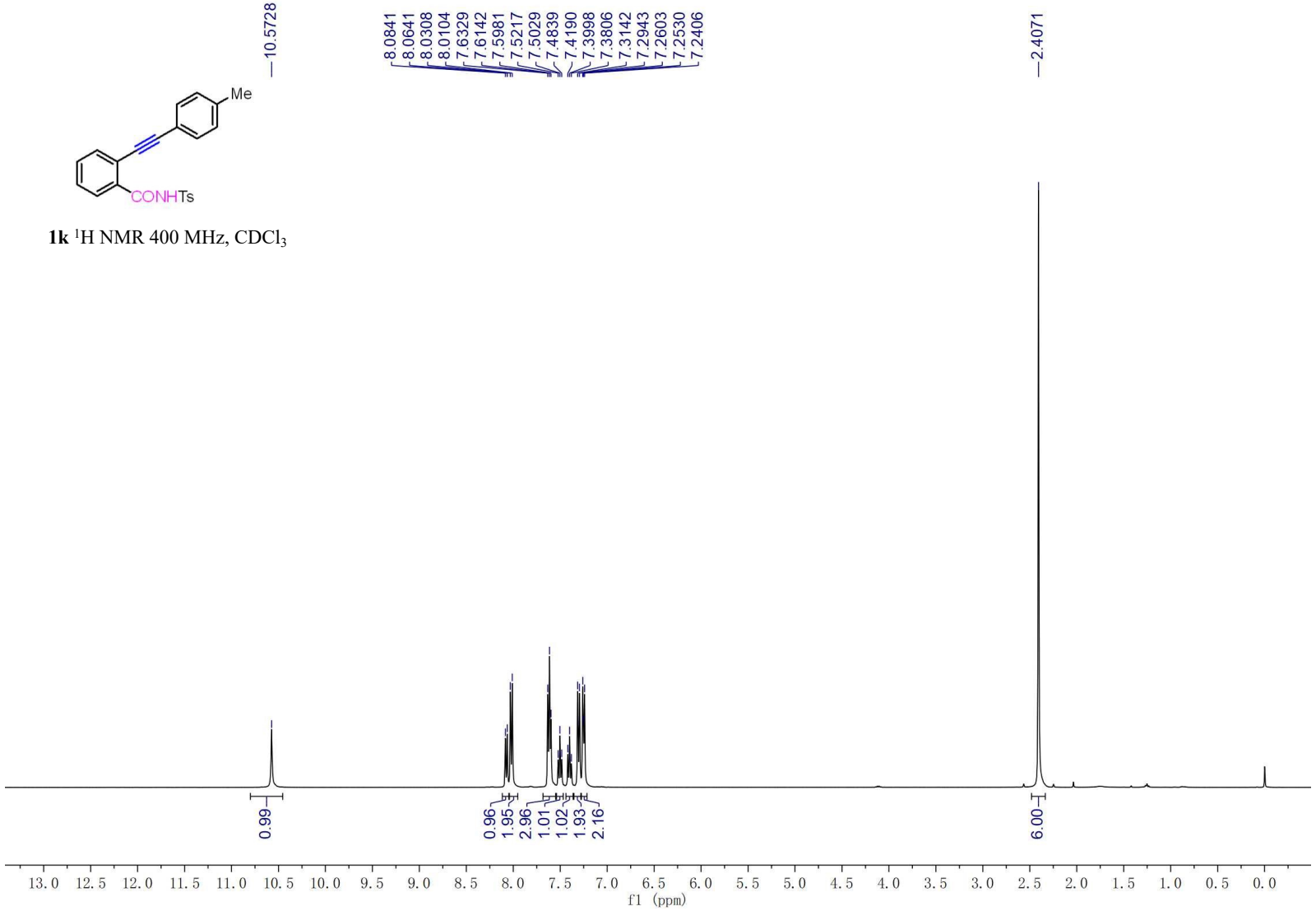

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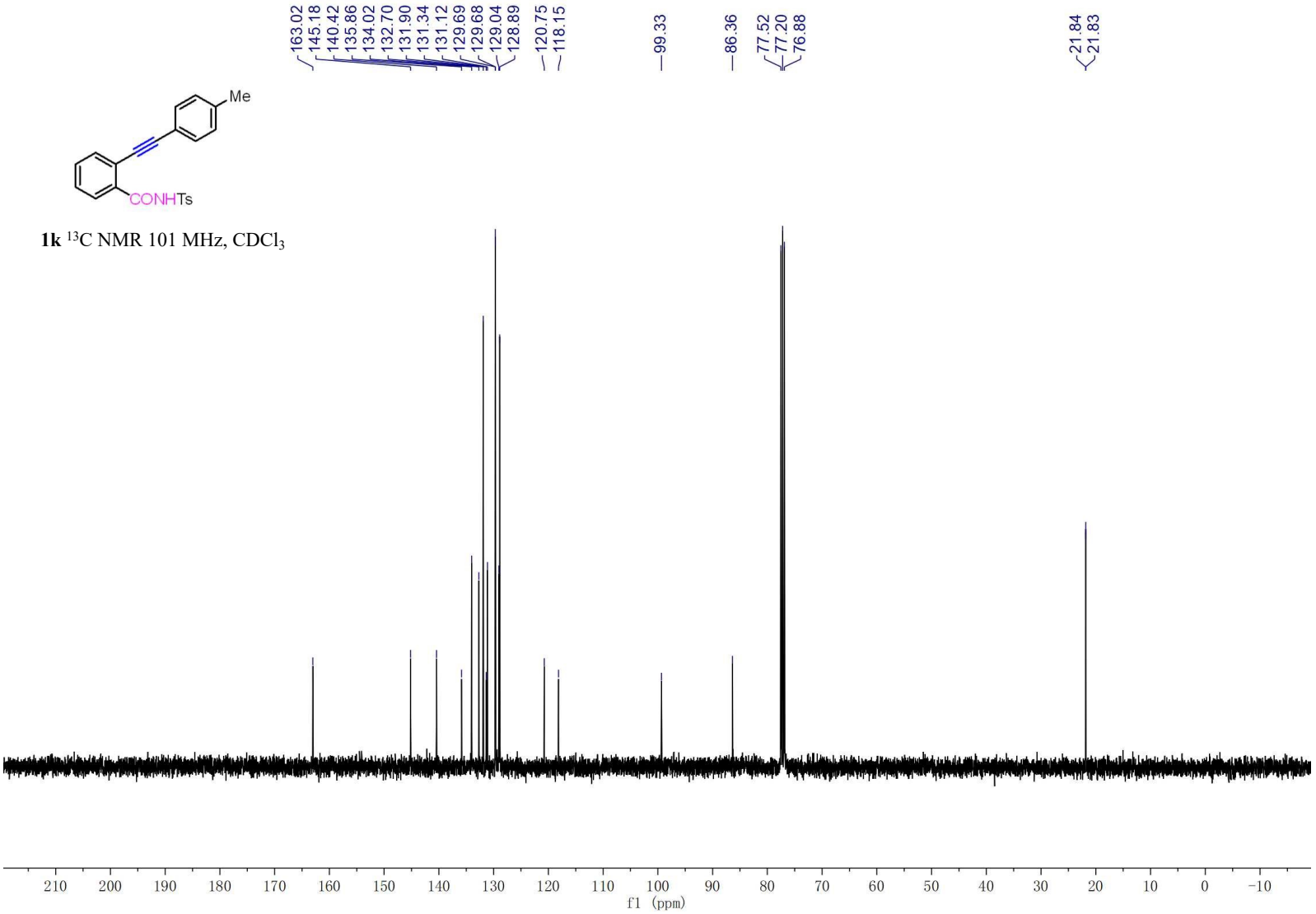
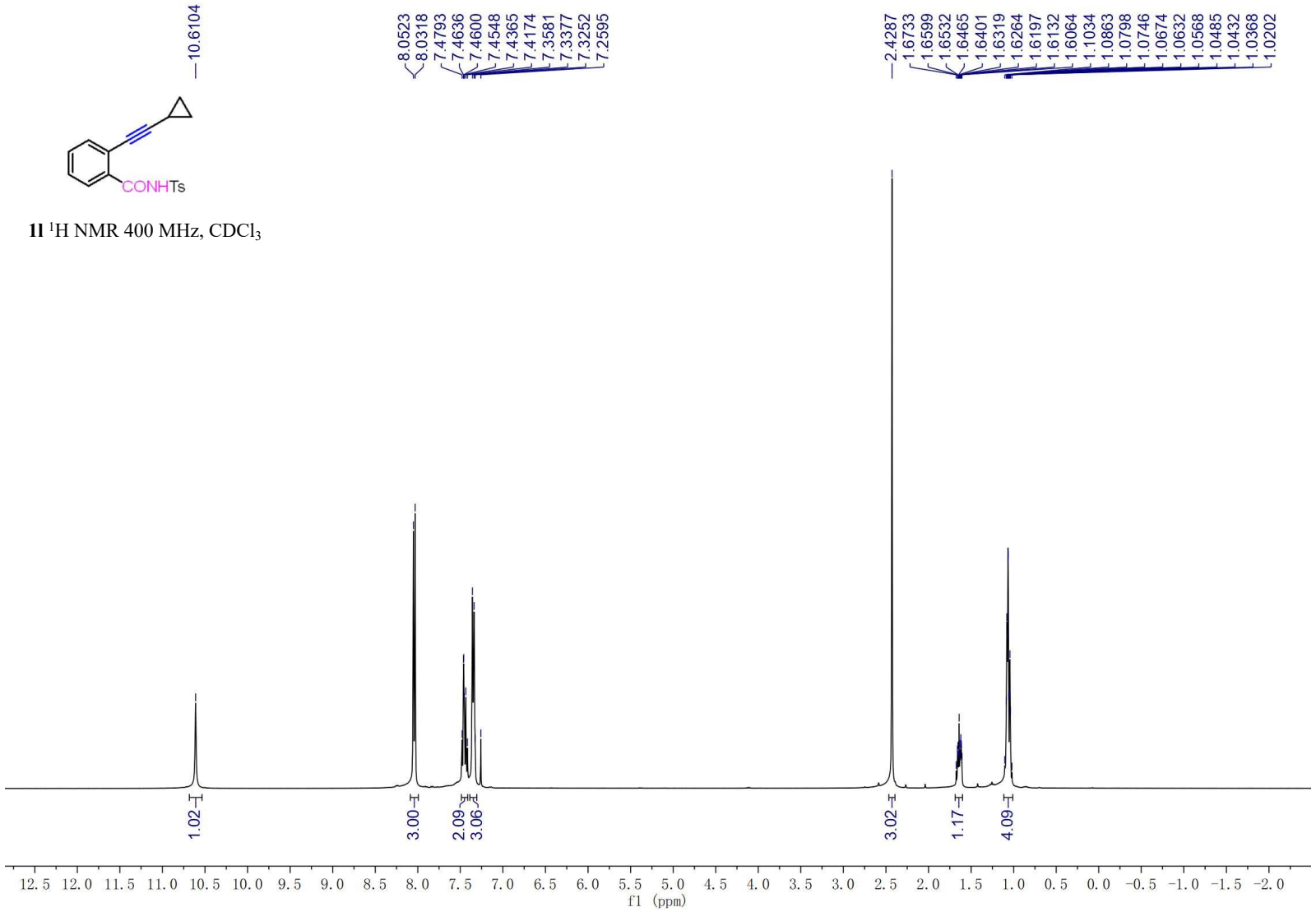
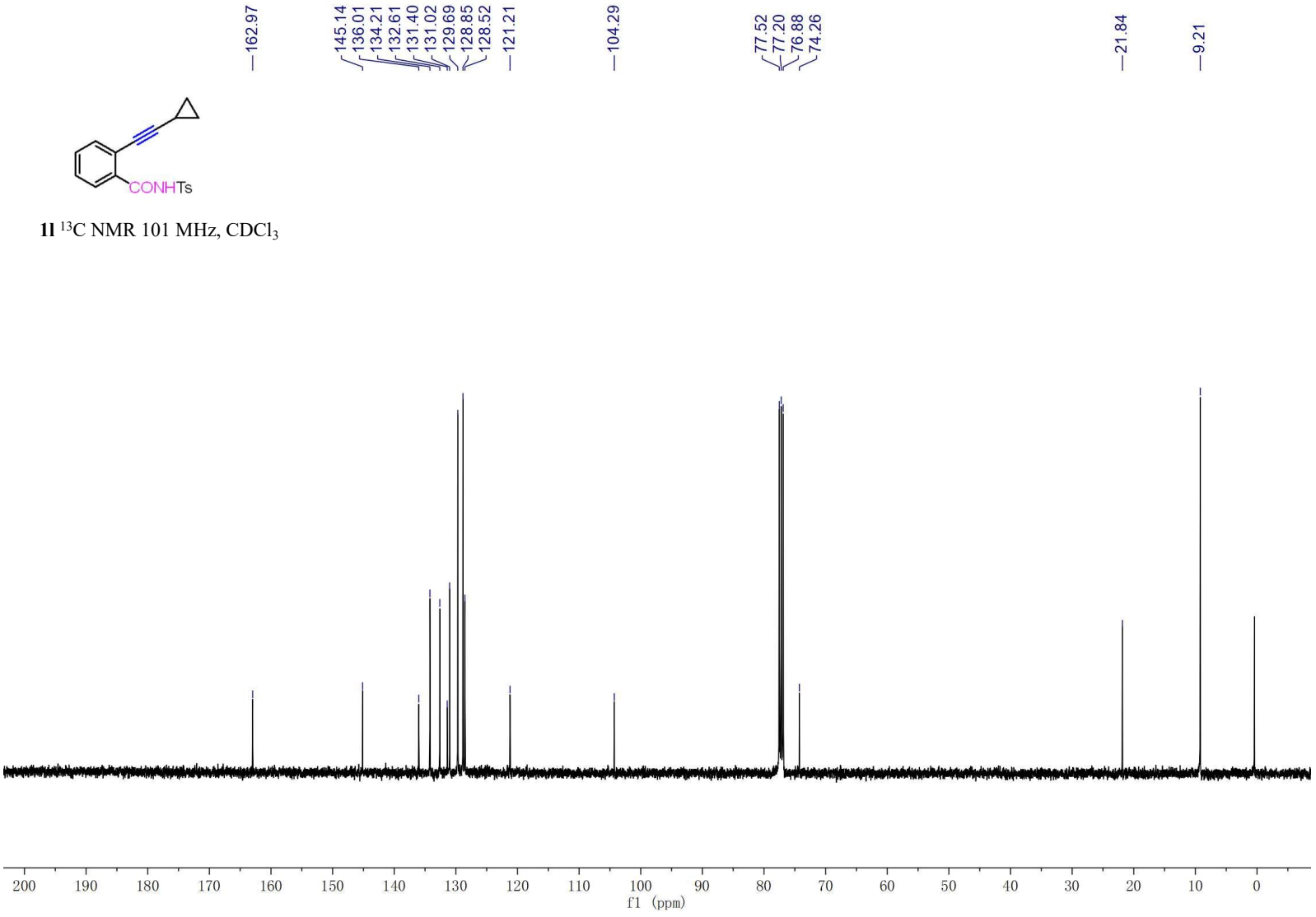


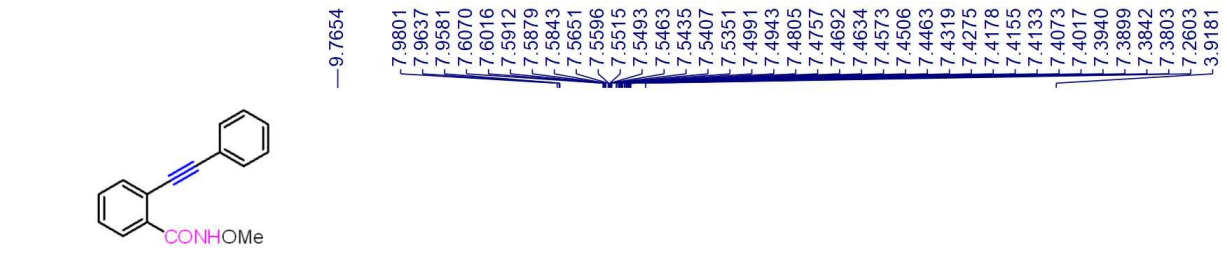
1k ^{13}C NMR 101 MHz, $CDCl_3$



1l ^{1}H NMR 400 MHz, $CDCl_3$



1l ^{13}C NMR 101 MHz, $CDCl_3$



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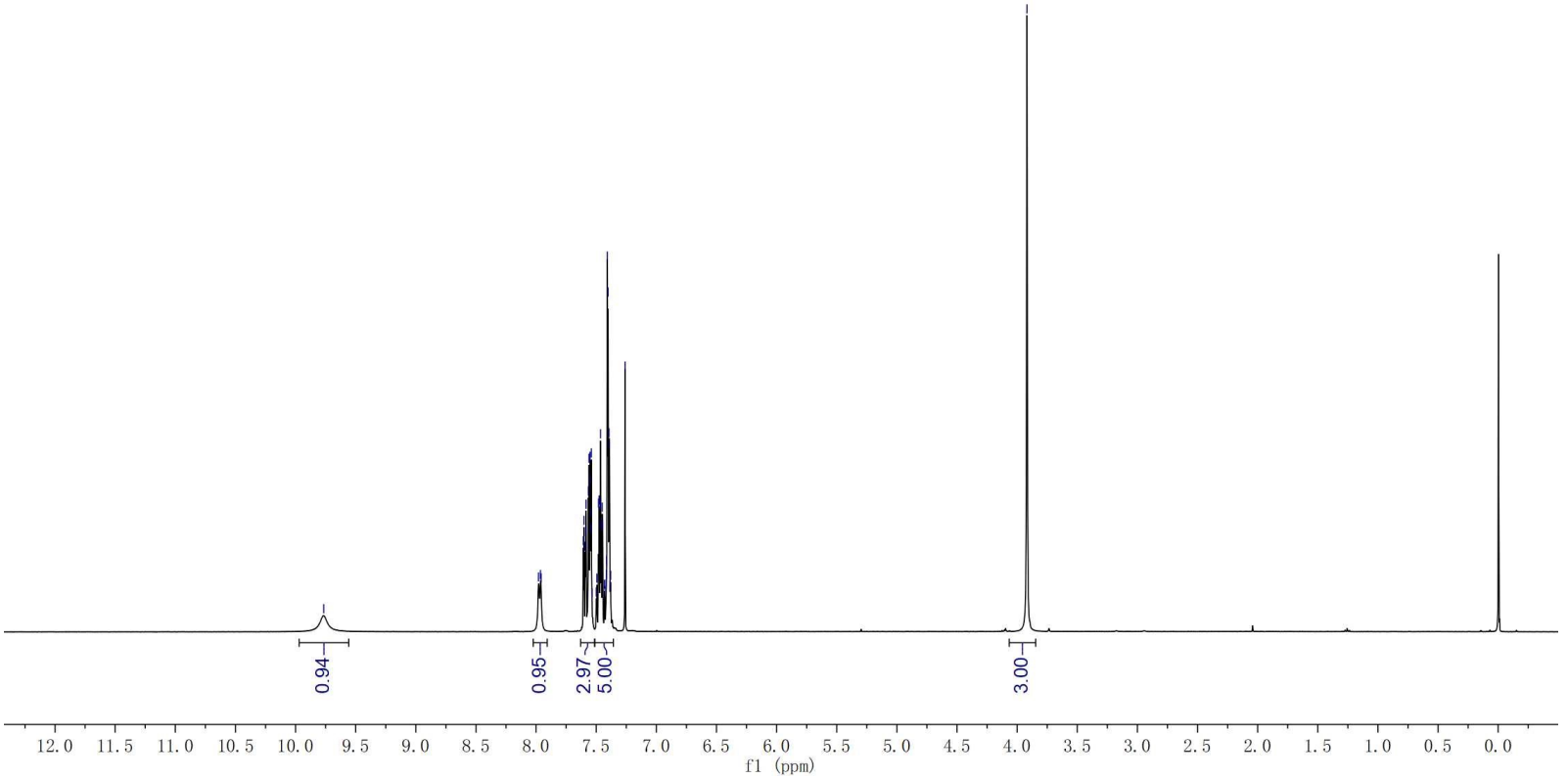

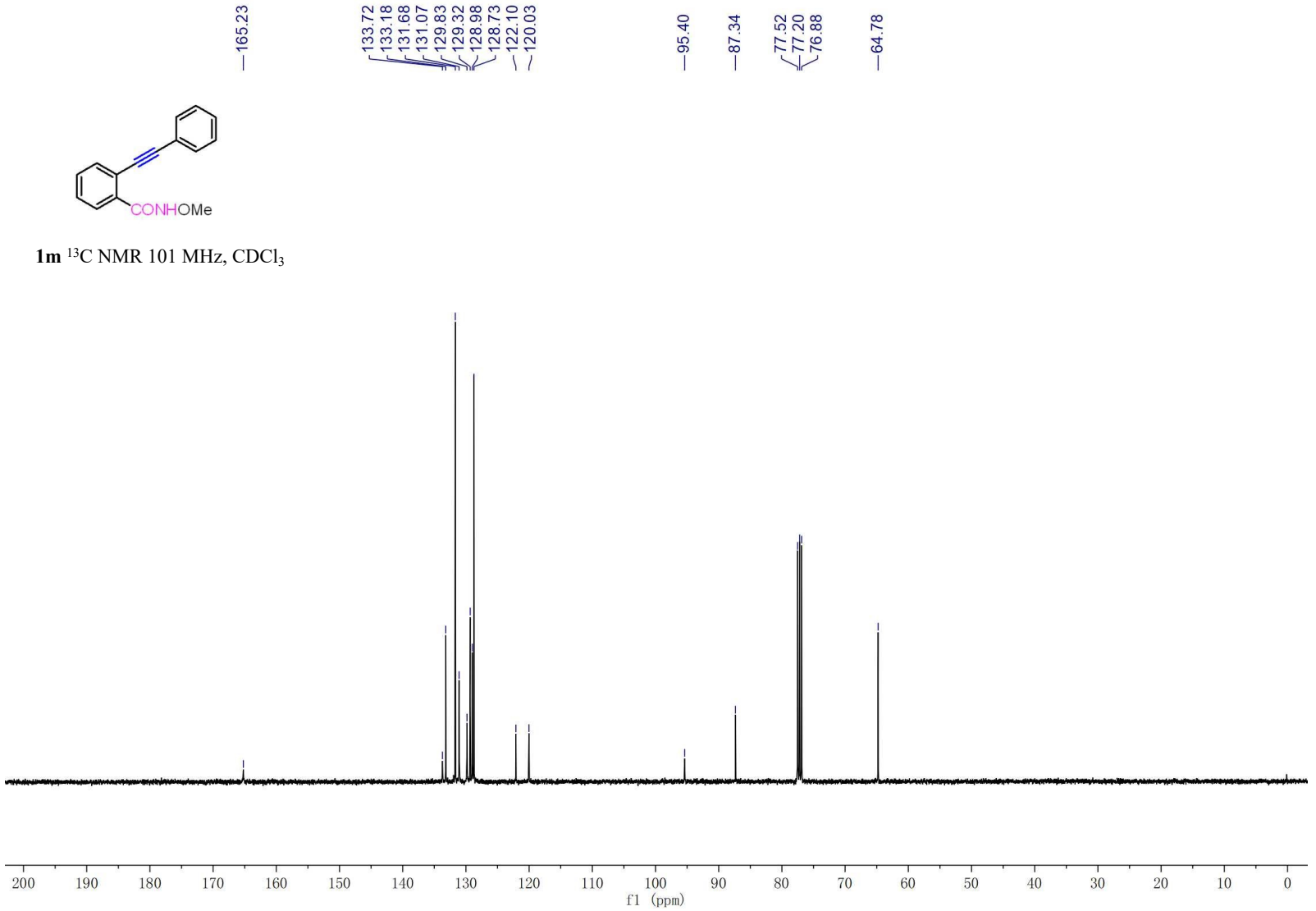

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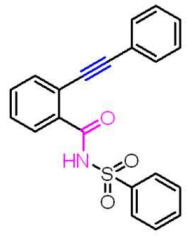

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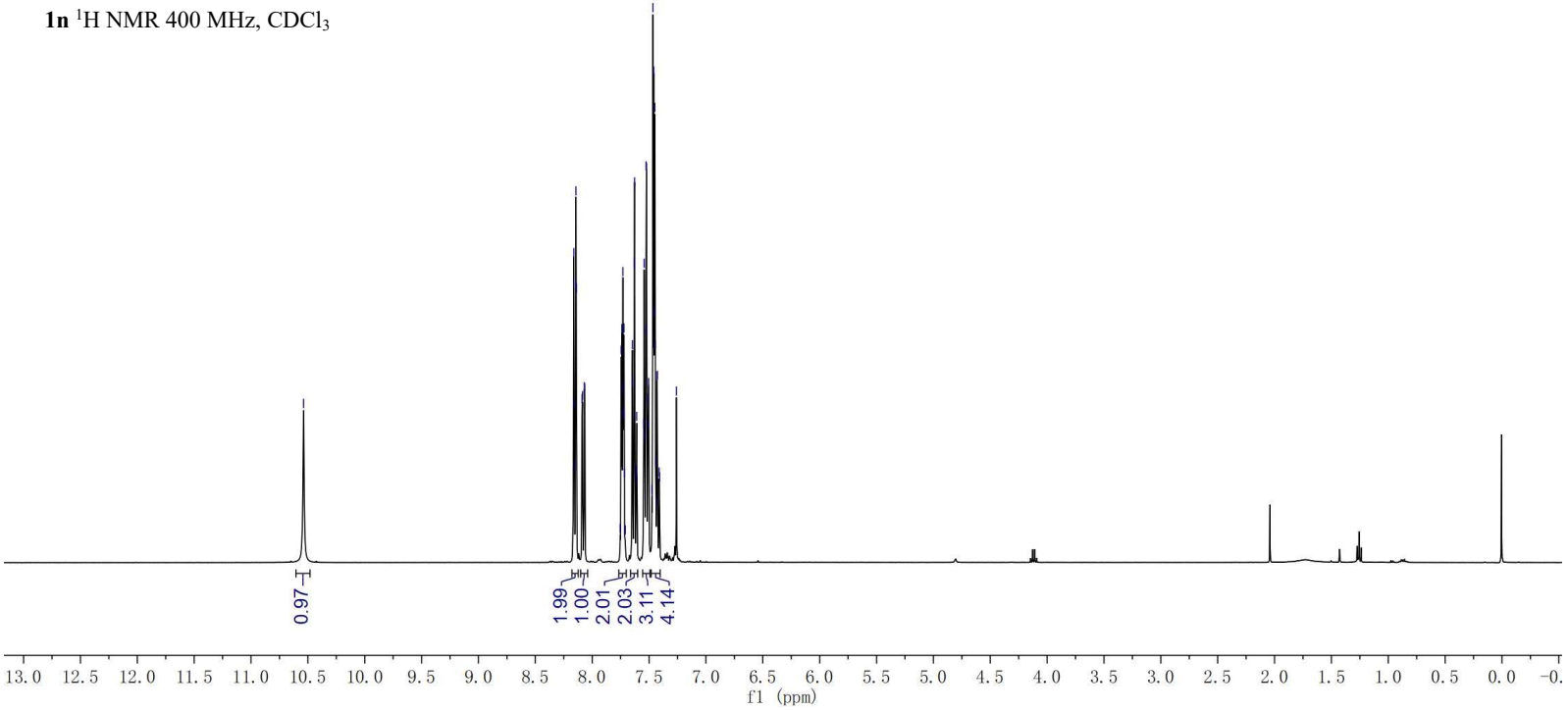
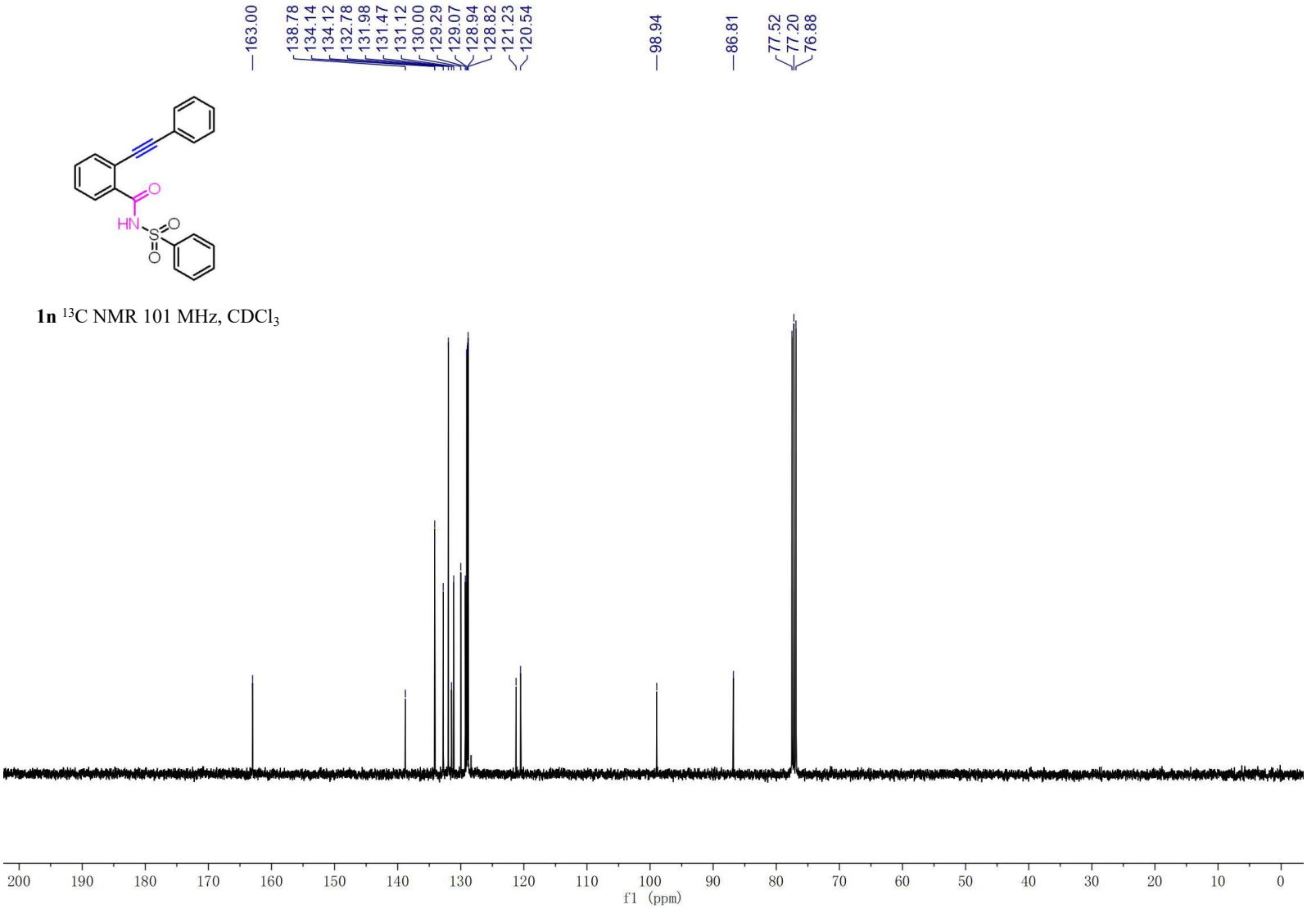
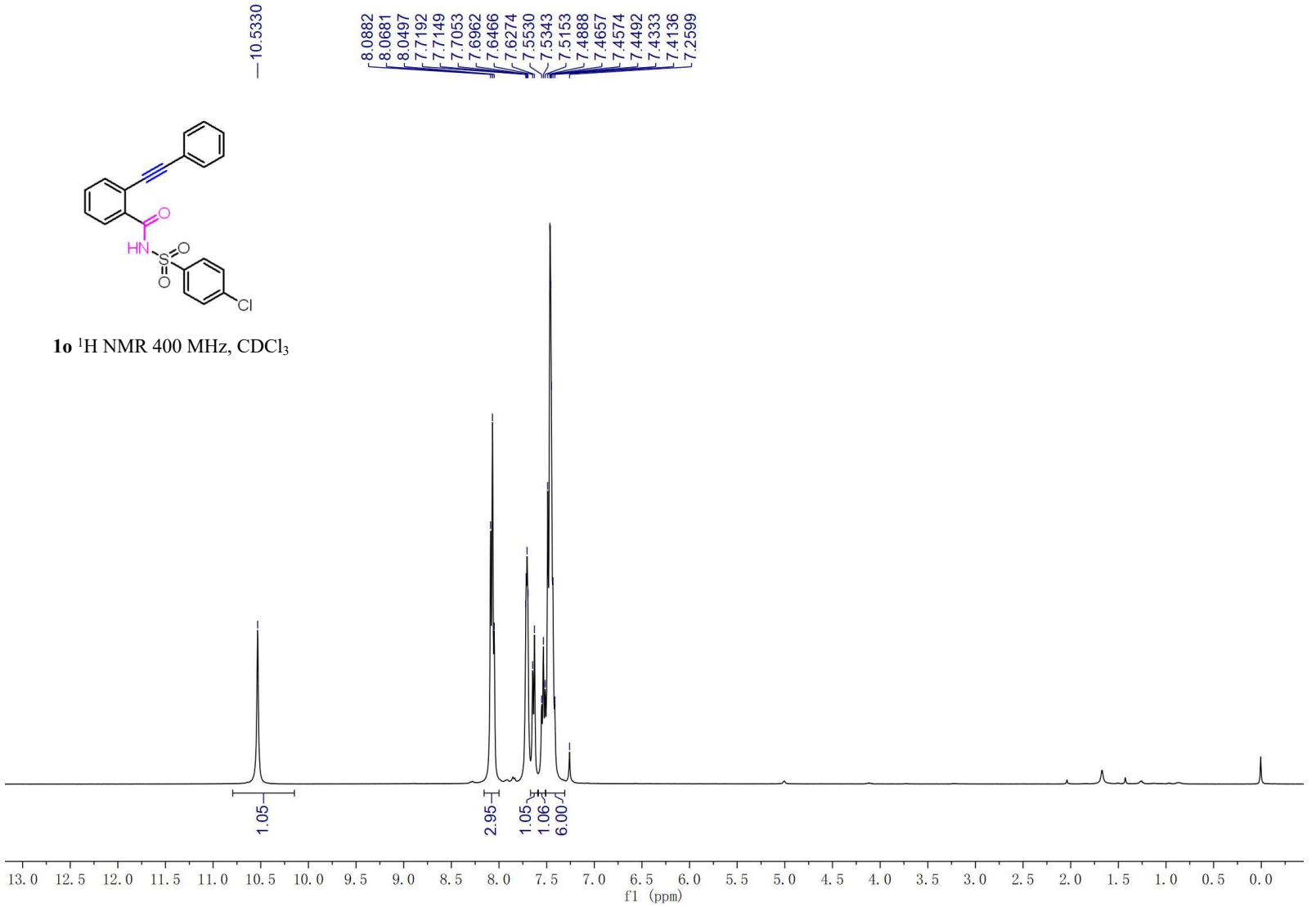




1n ^{13}C NMR 101 MHz, $CDCl_3$



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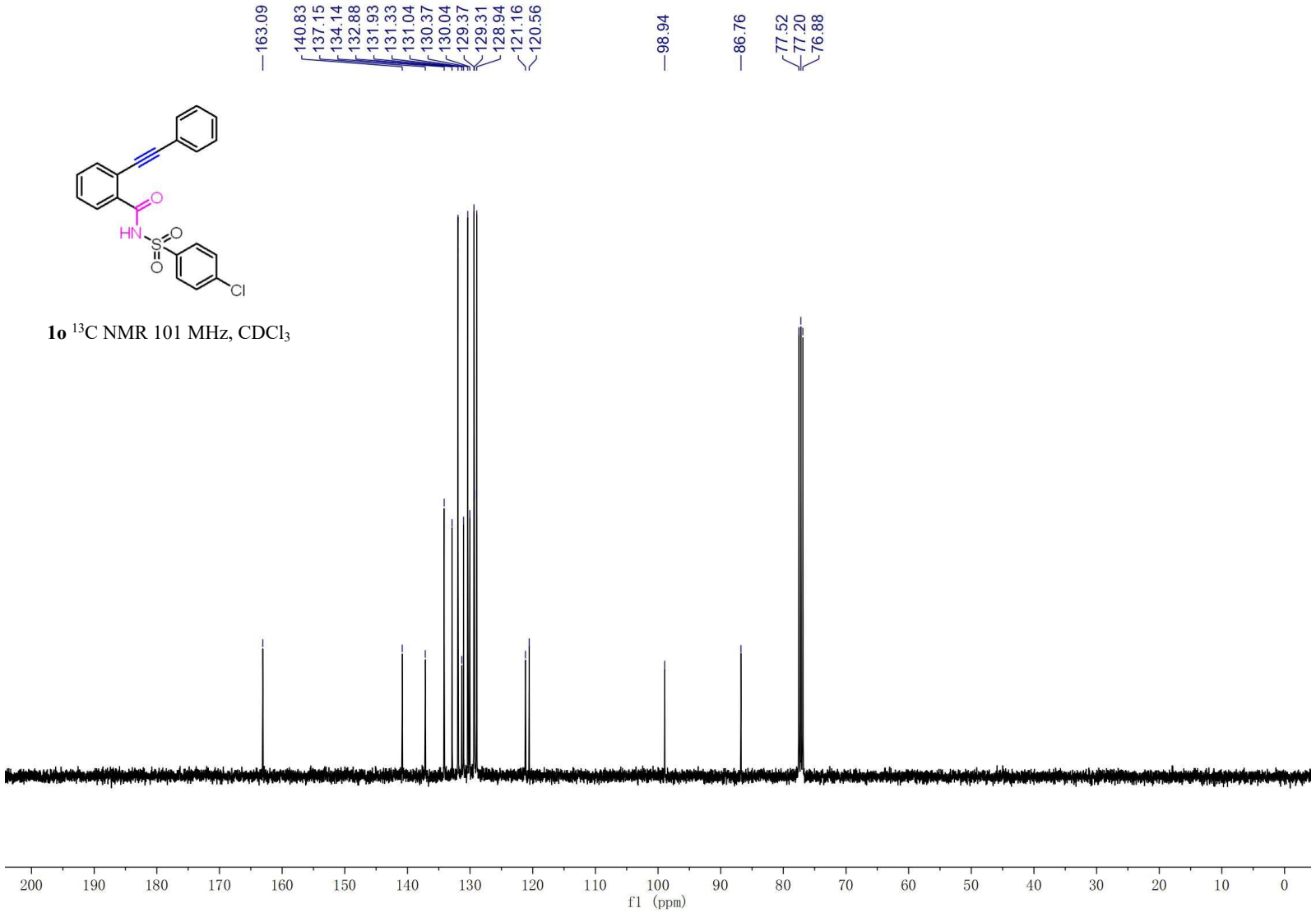

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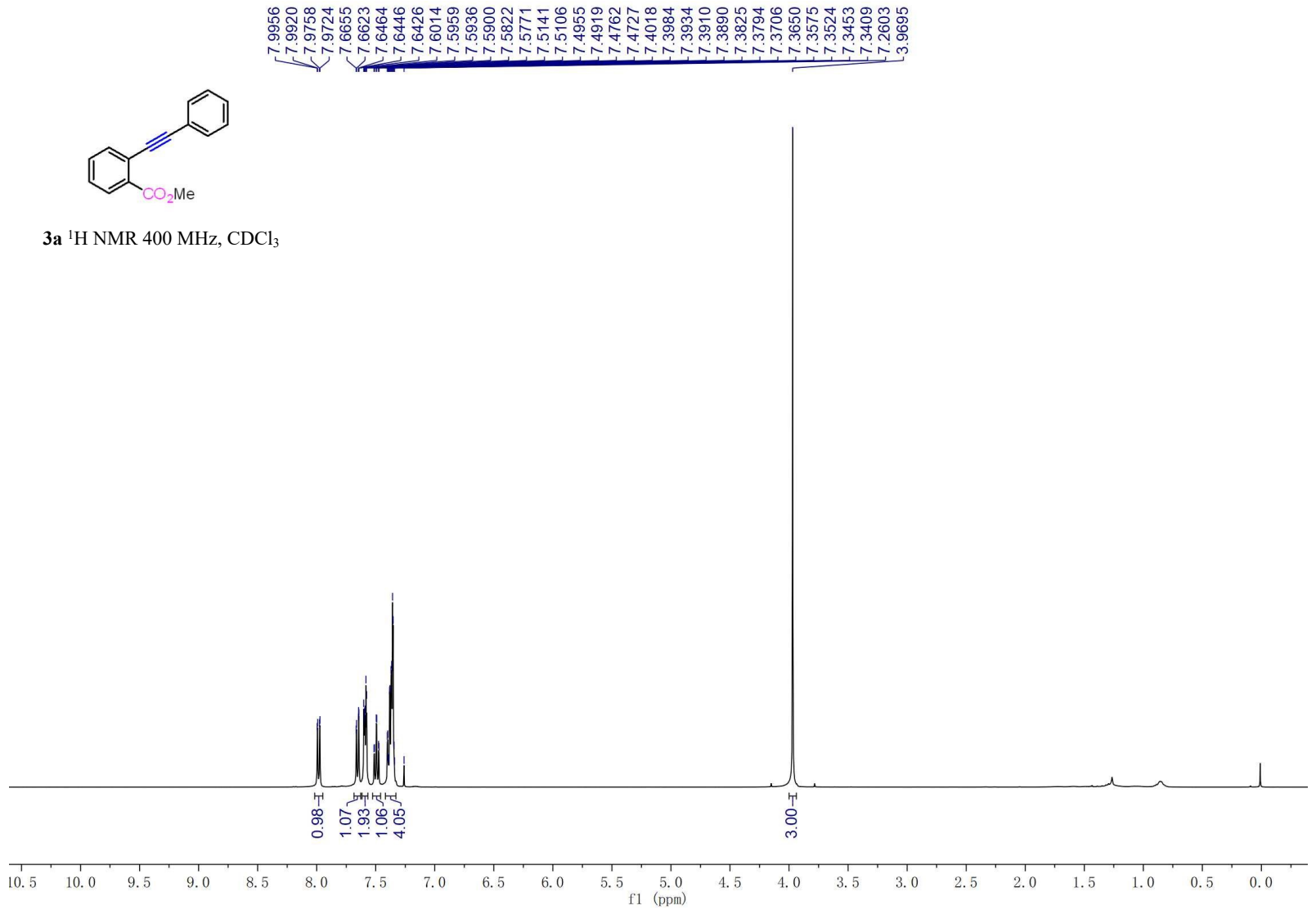
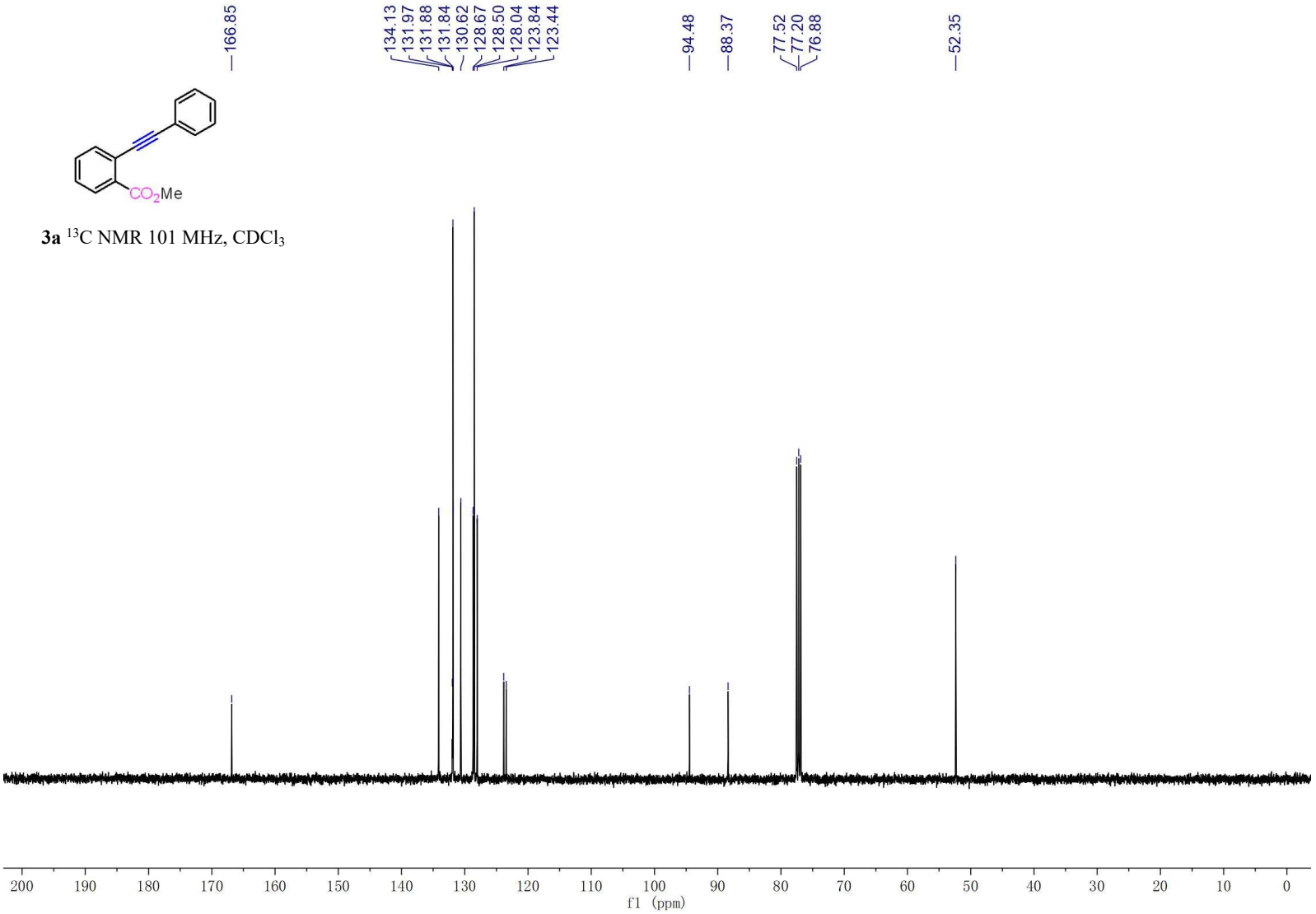
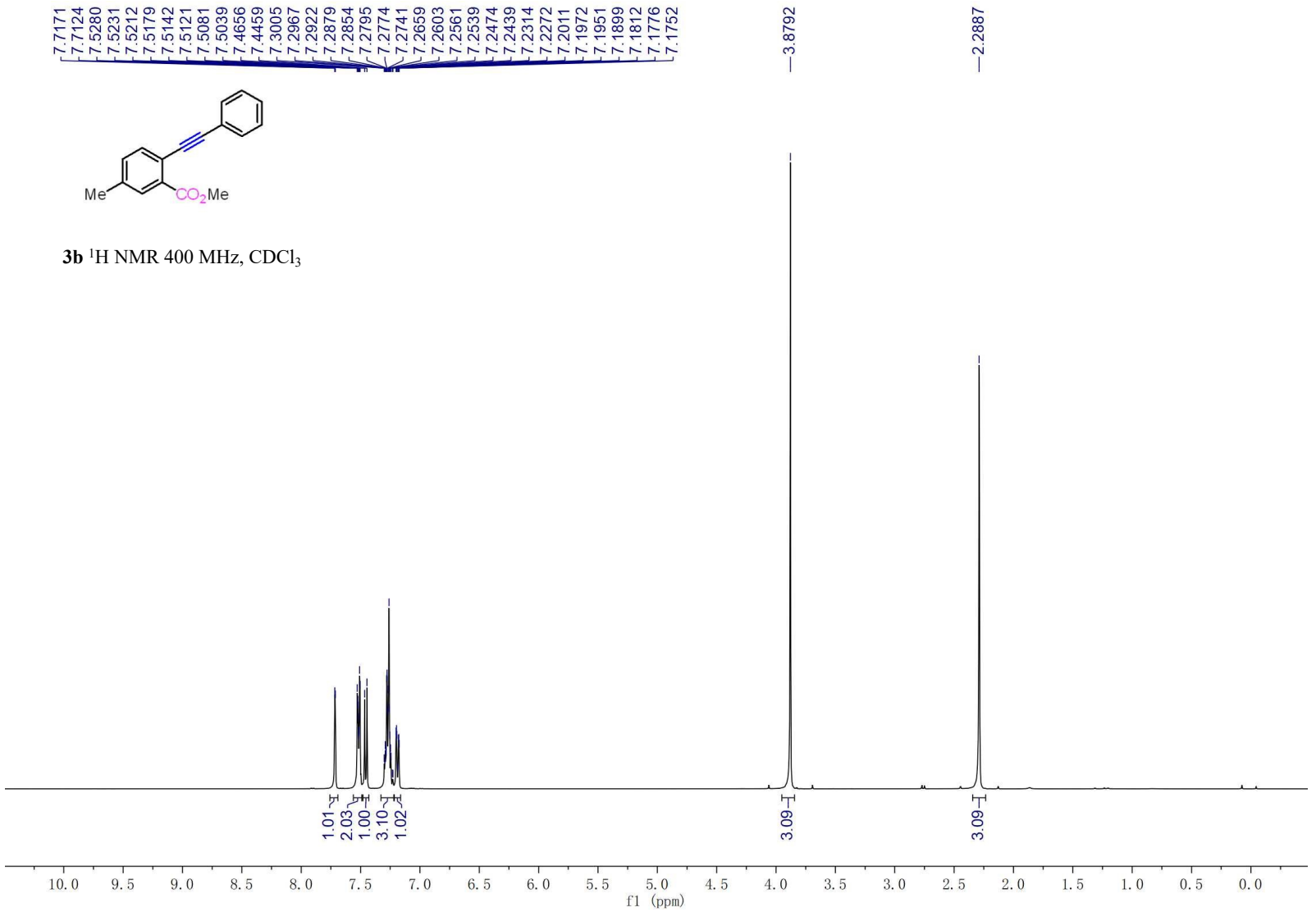


3a ^{1}H NMR 400 MHz, $CDCl_3$



3a ^{13}C NMR 101 MHz, $CDCl_3$



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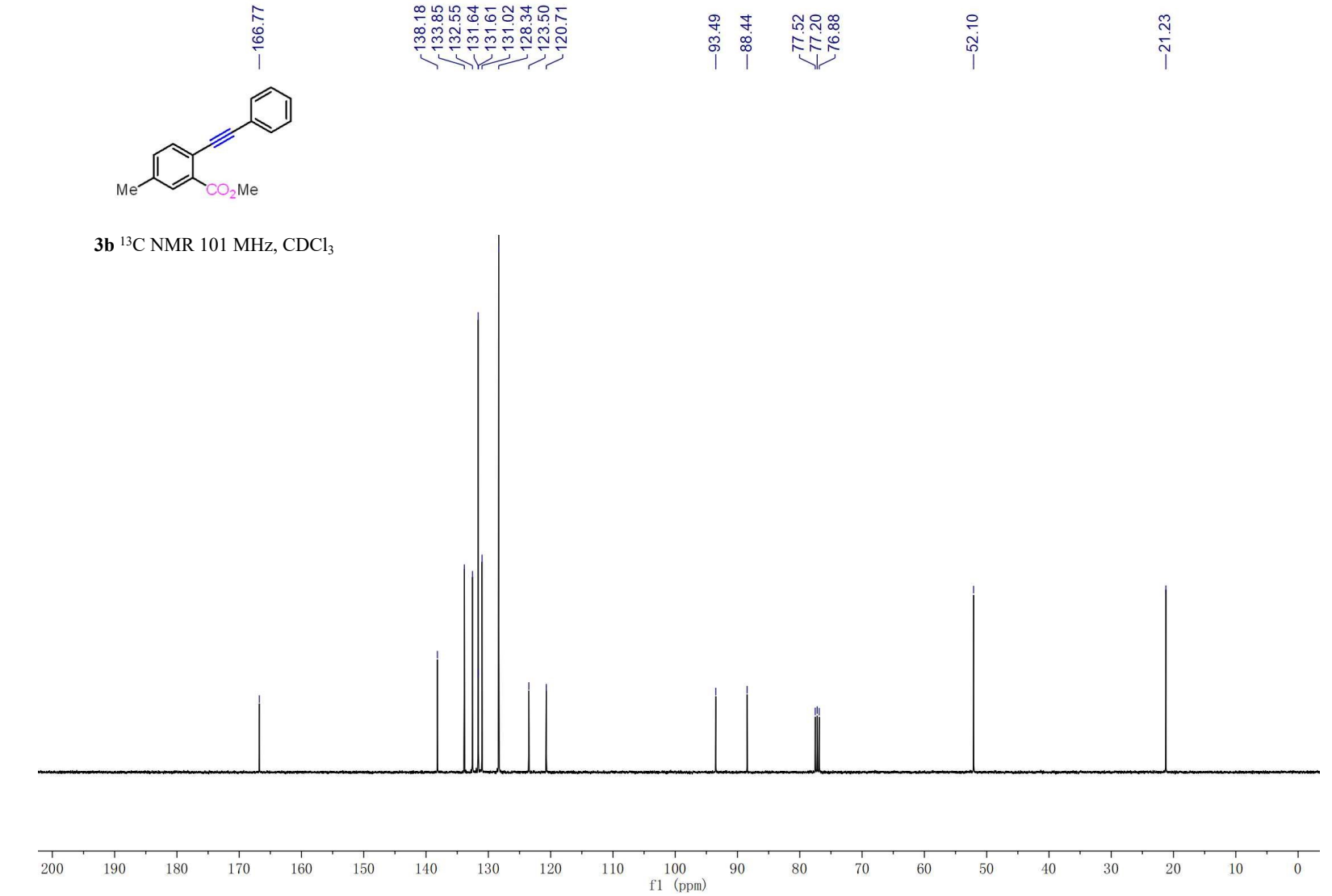

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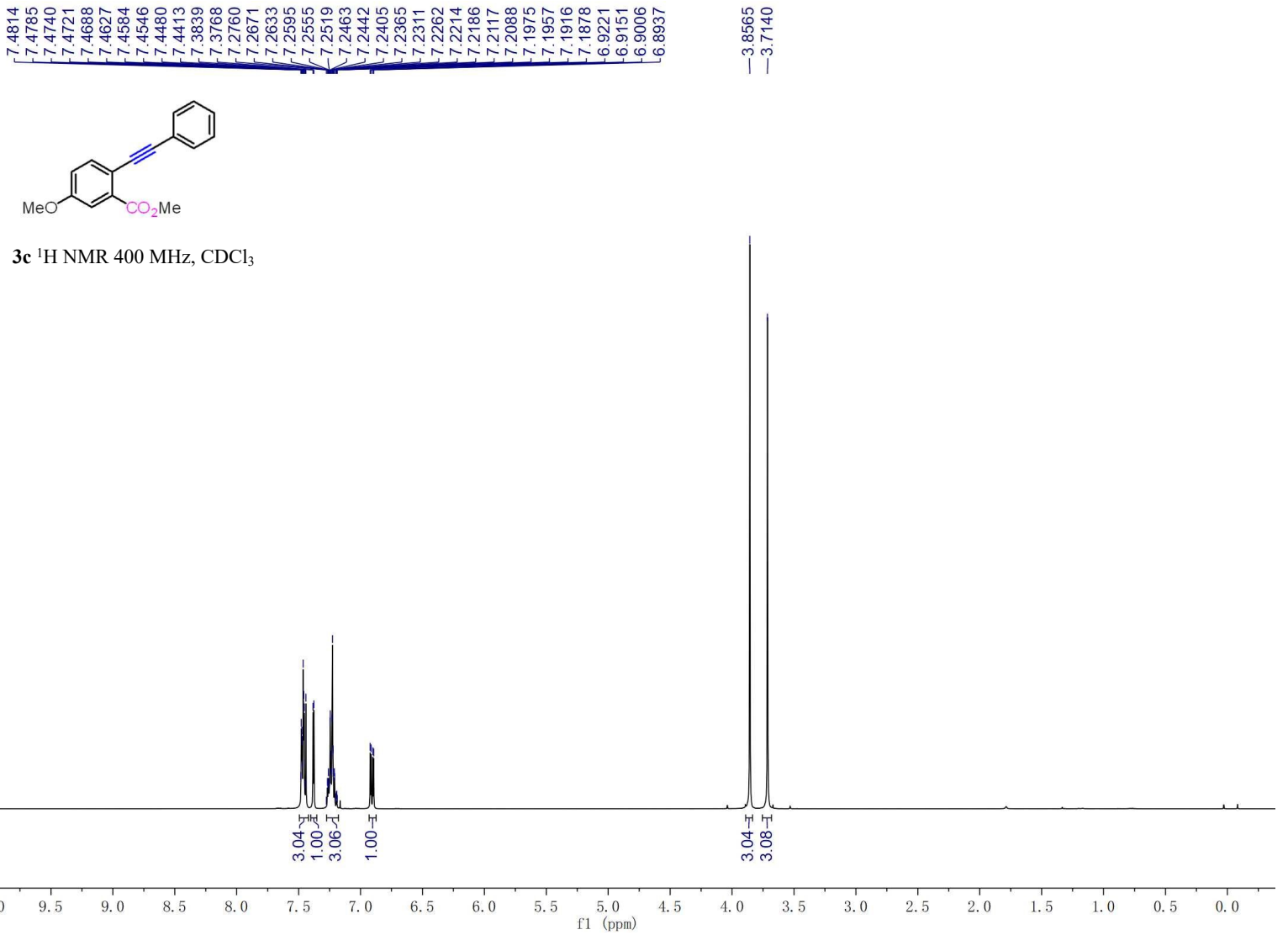

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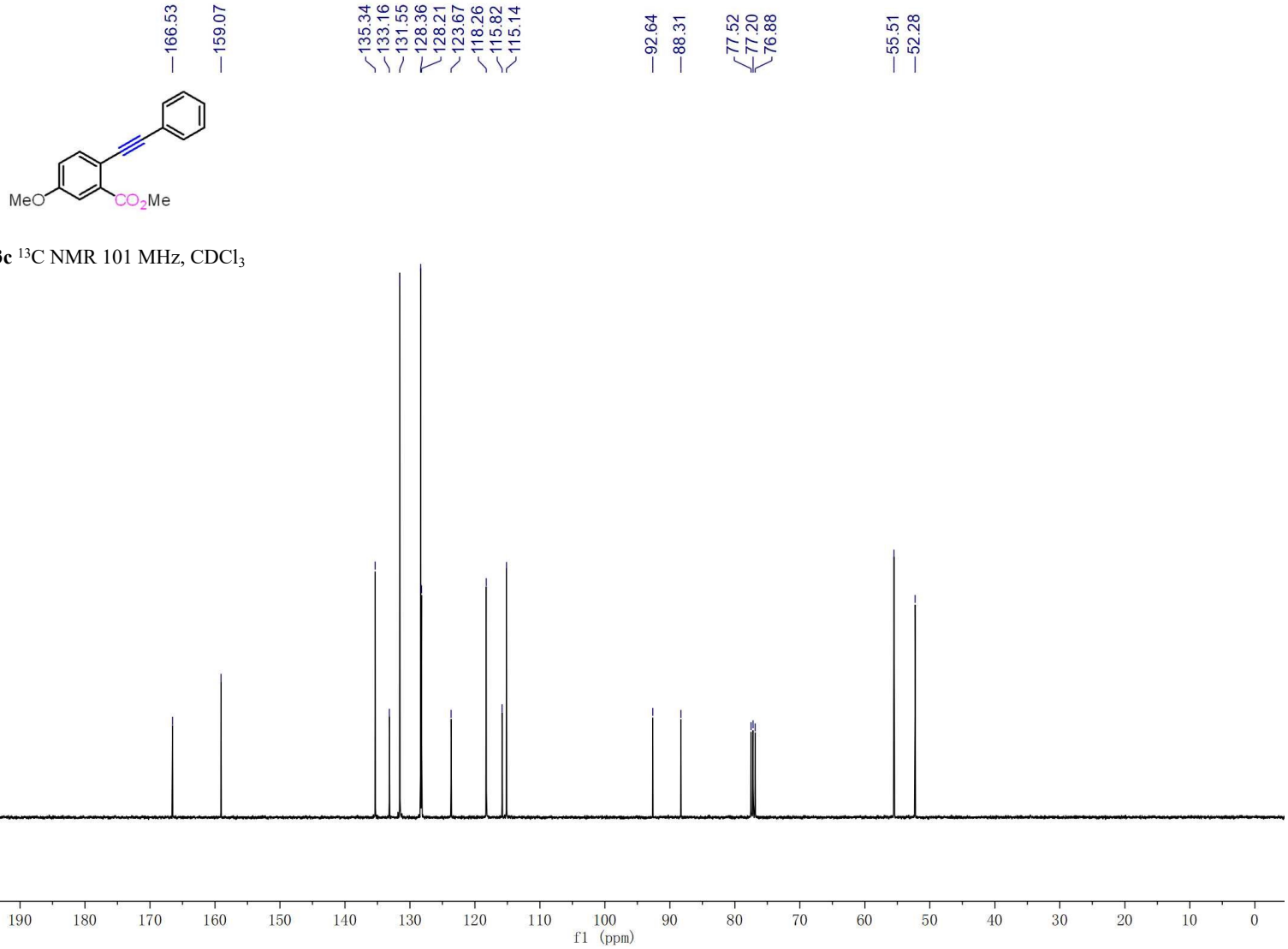

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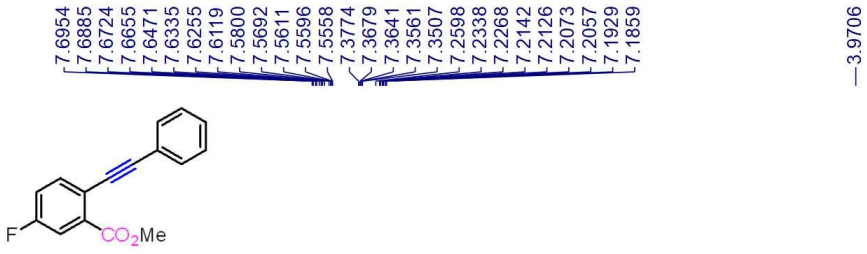

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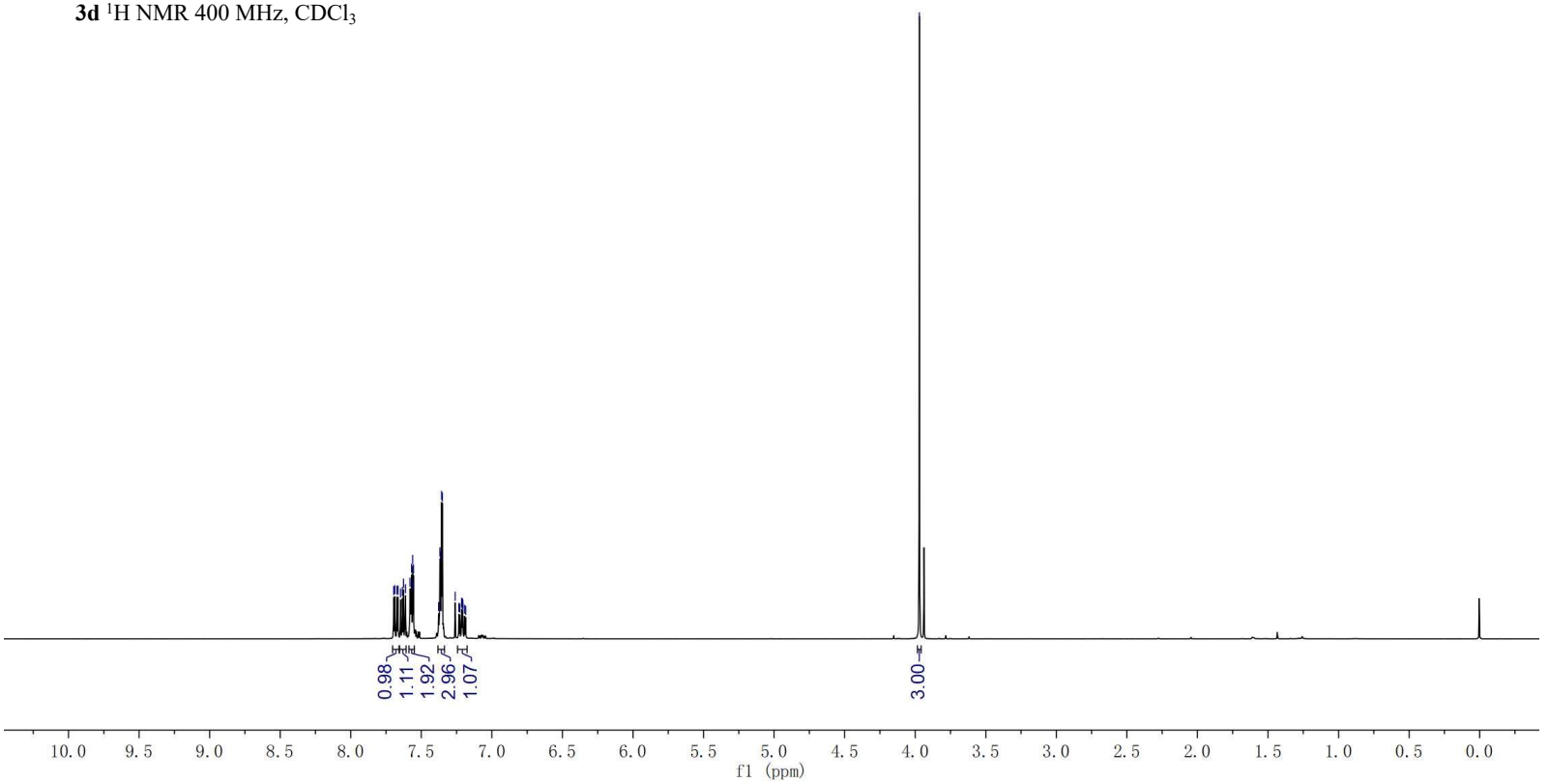

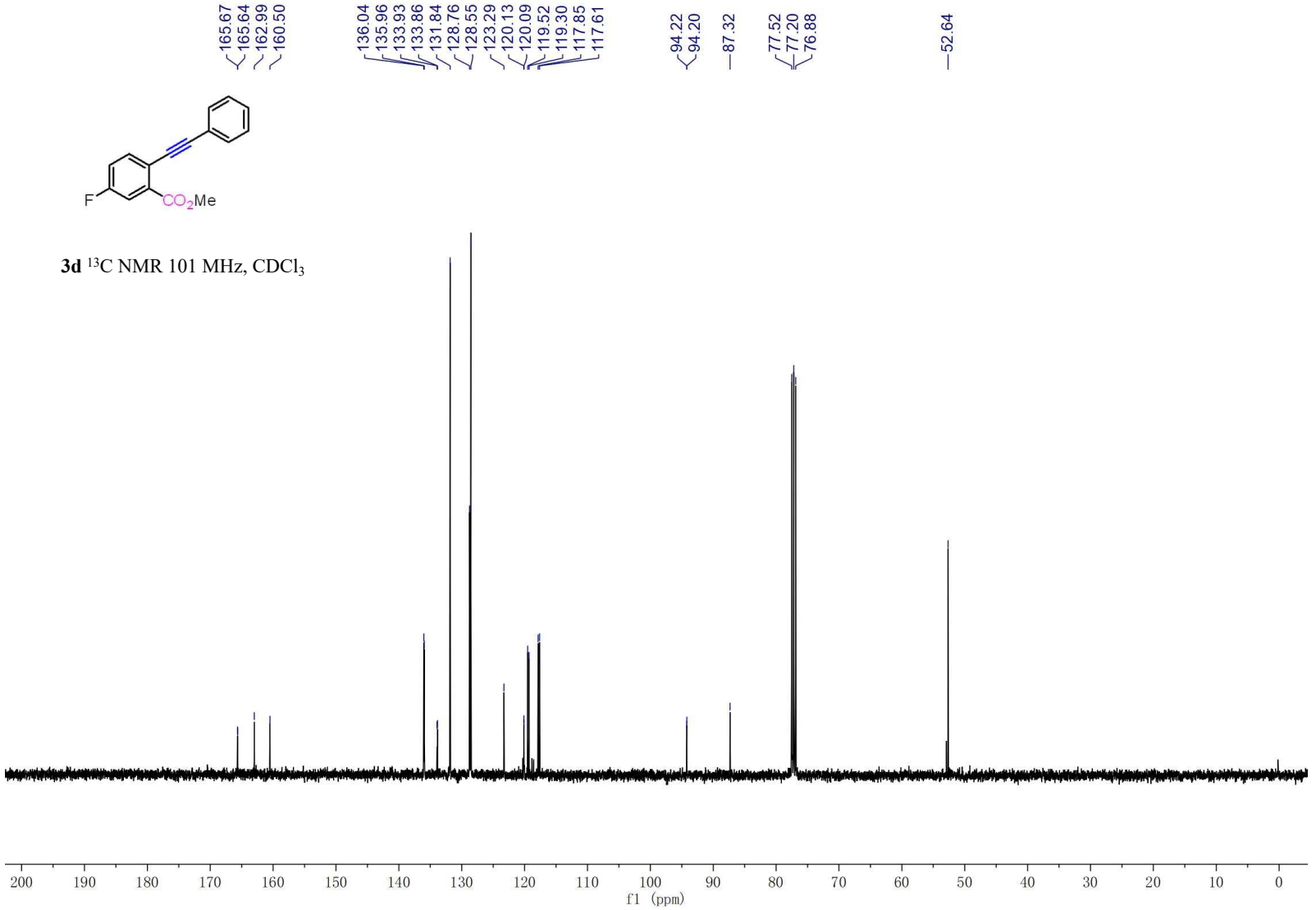

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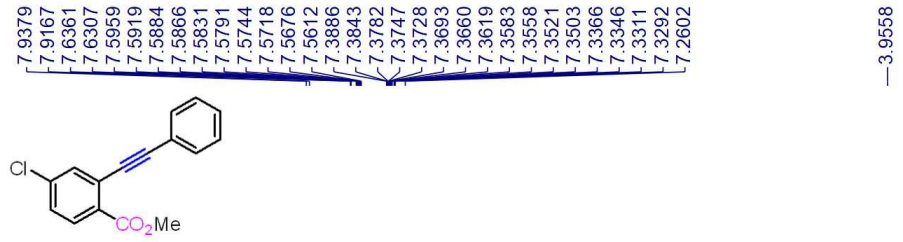

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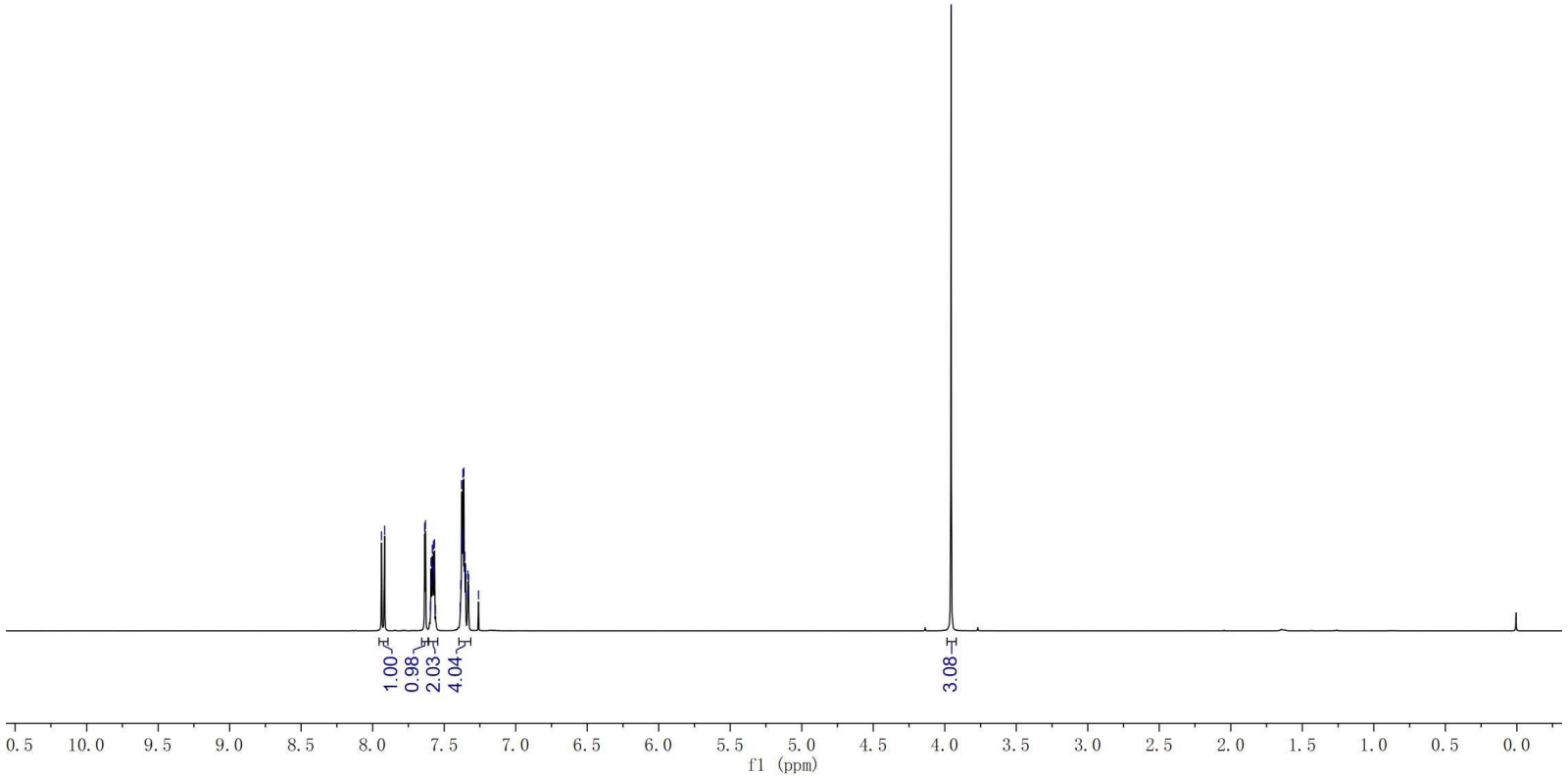

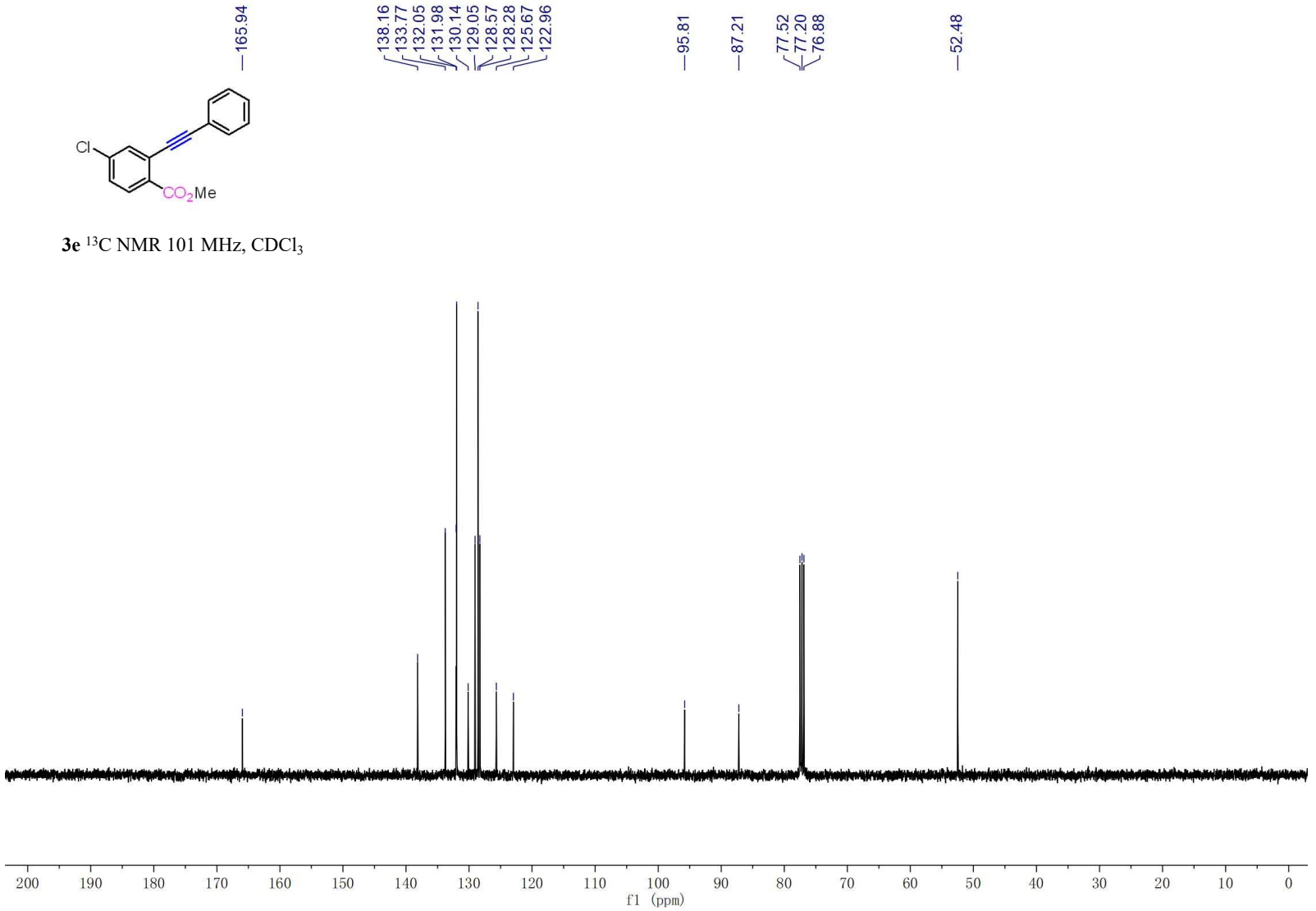

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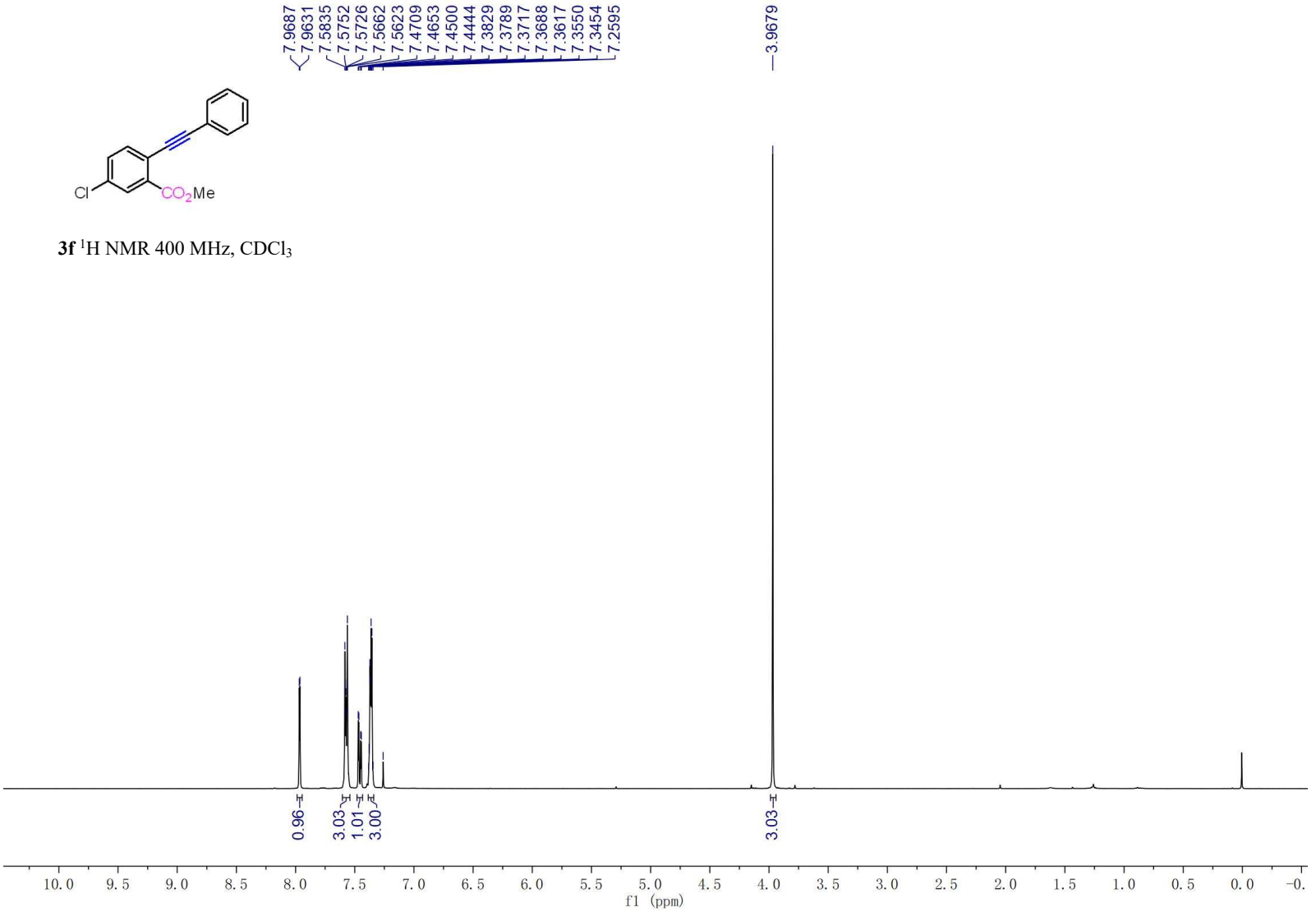

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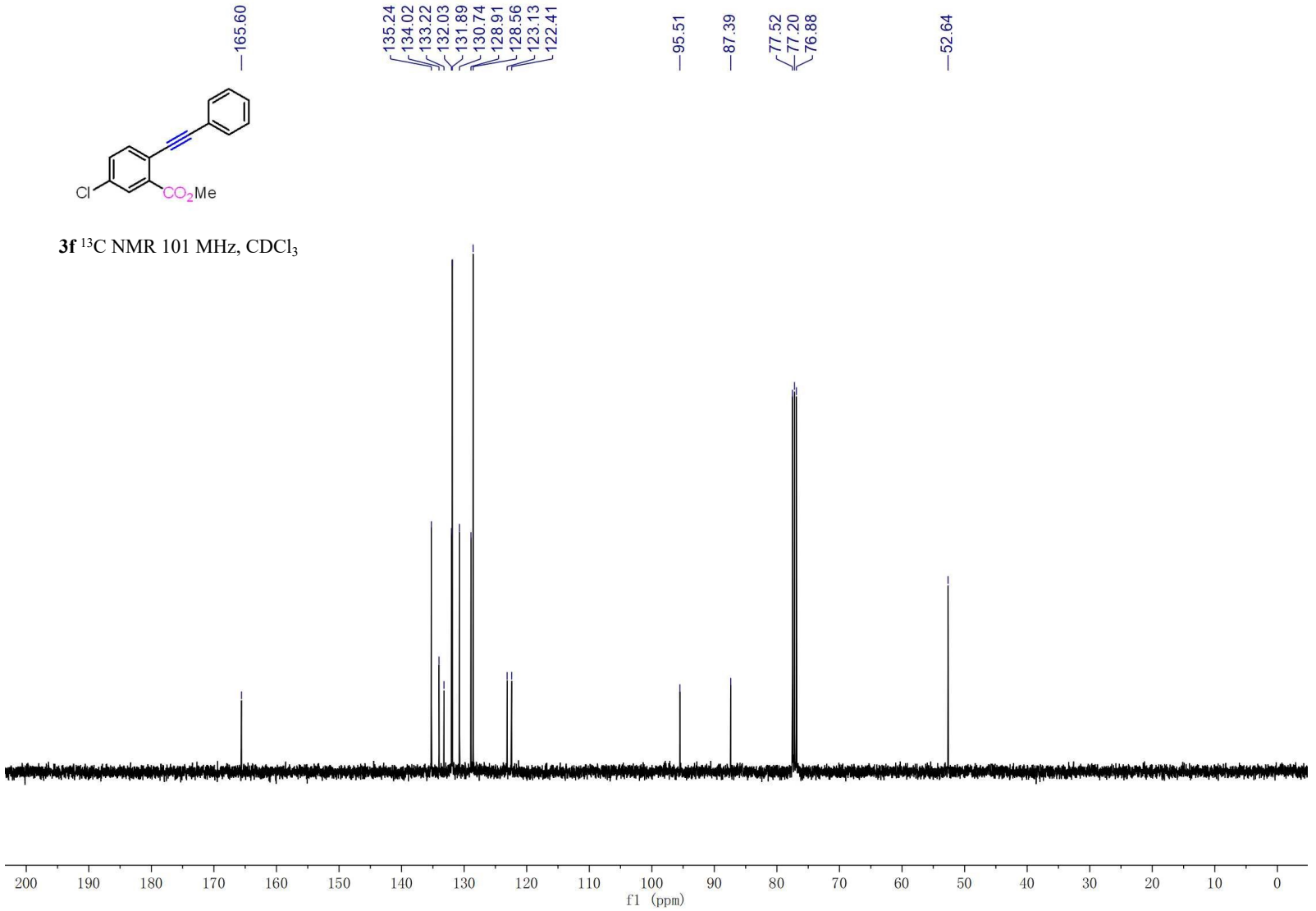

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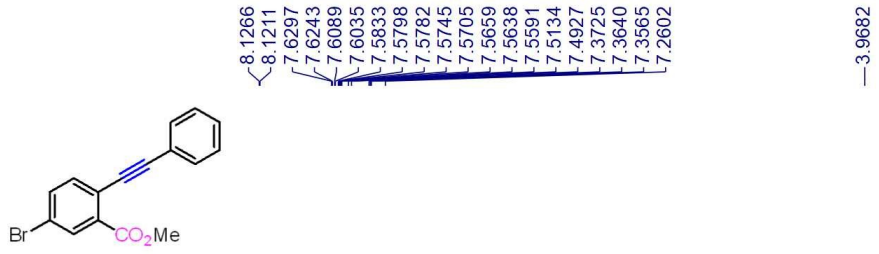

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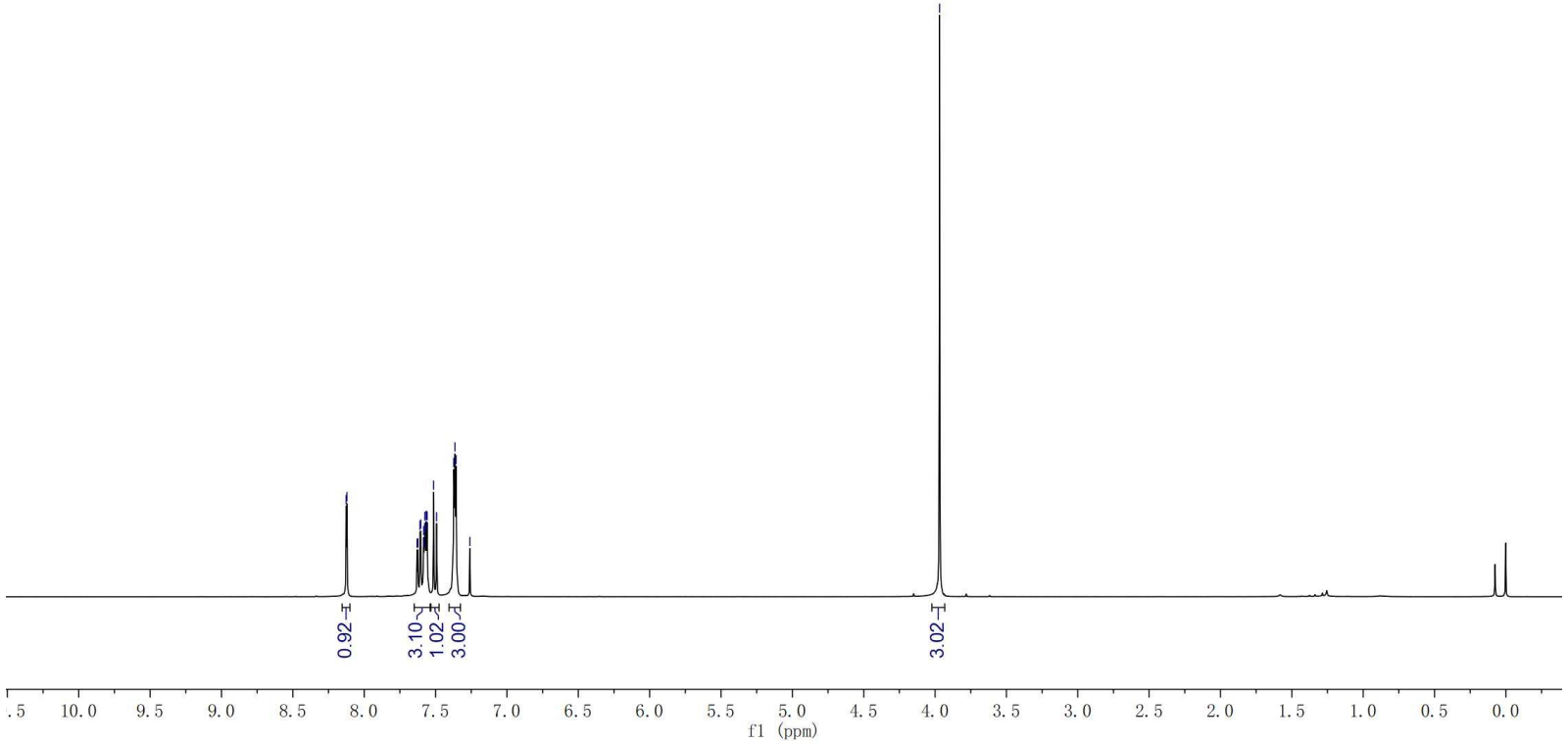
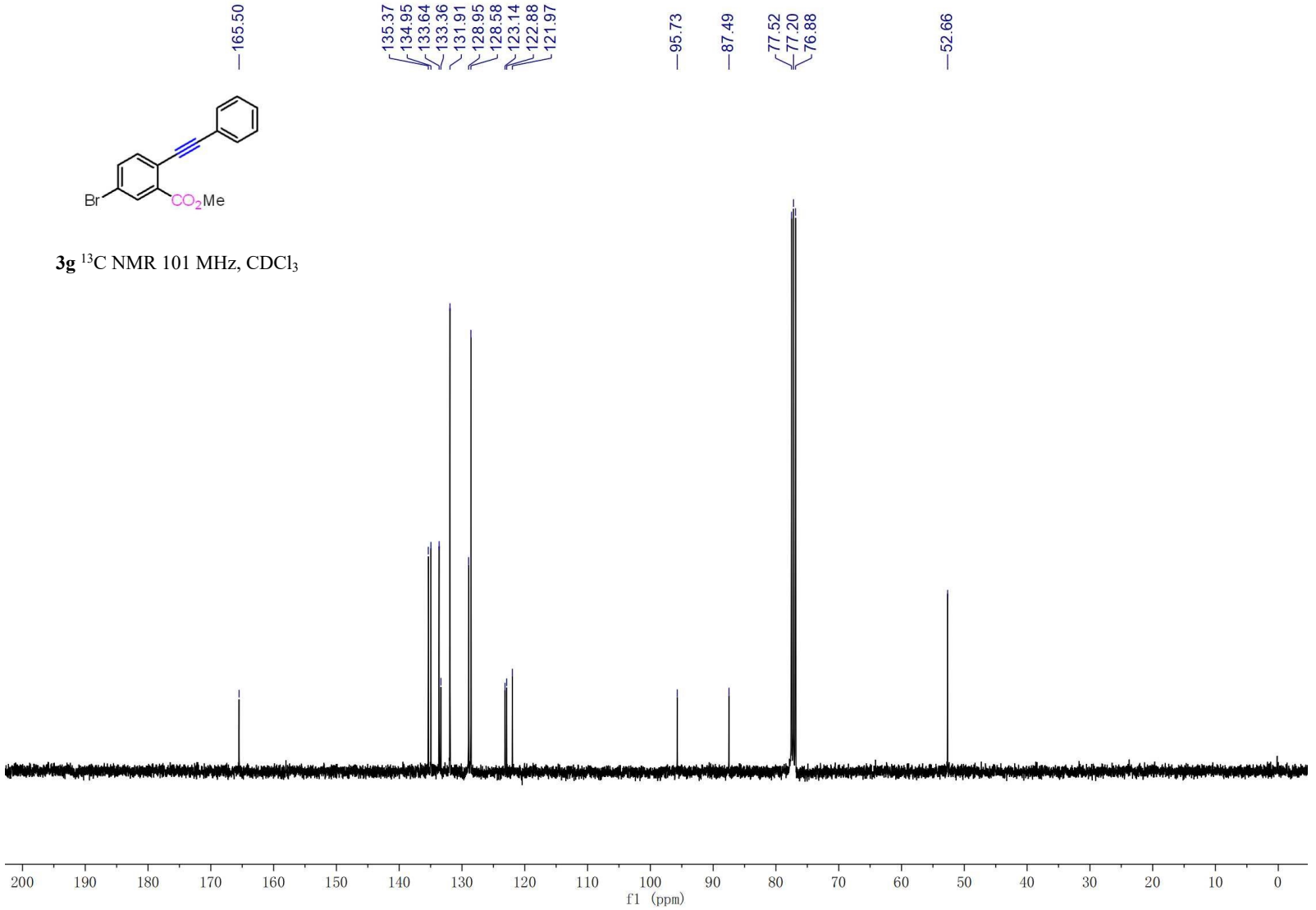
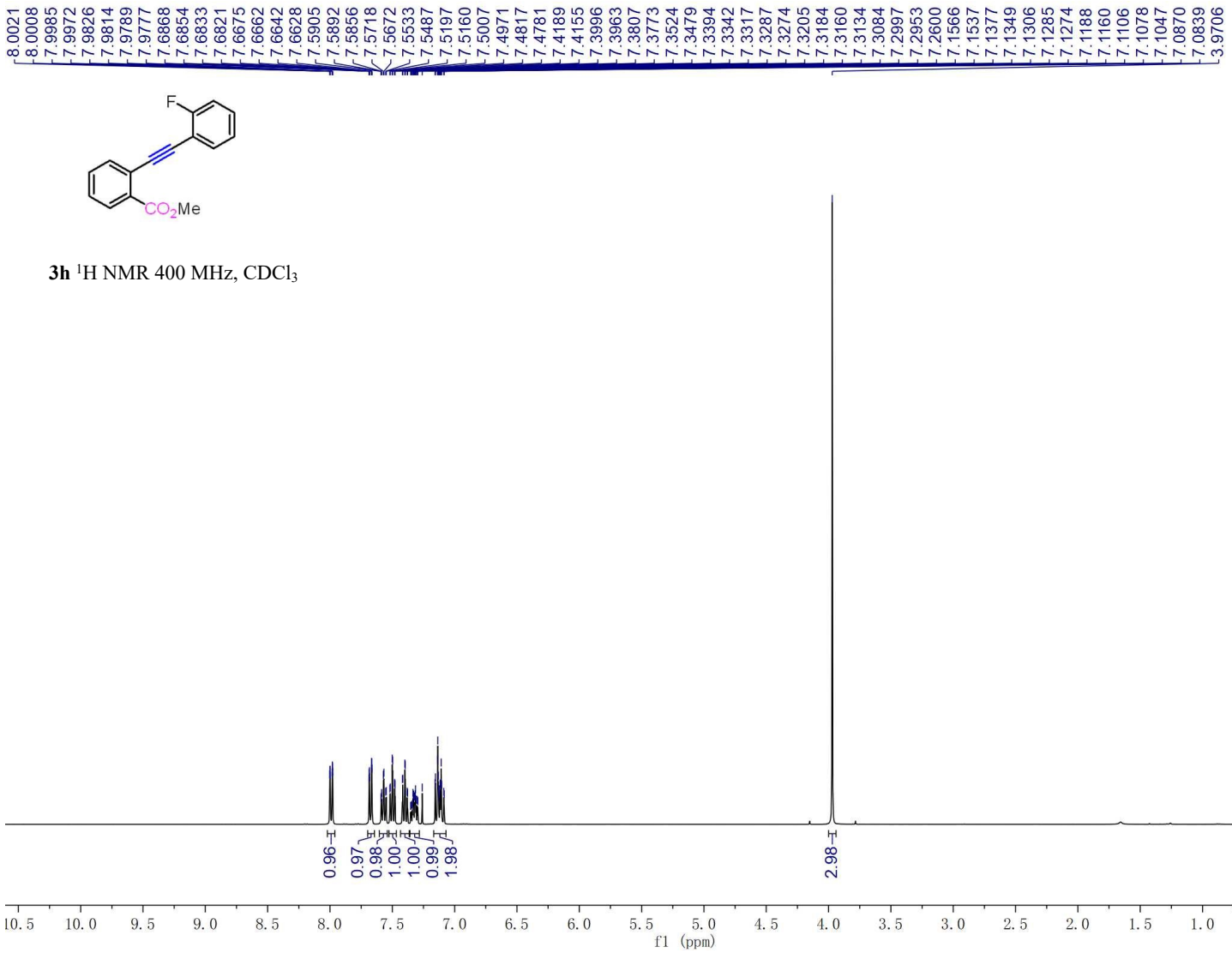
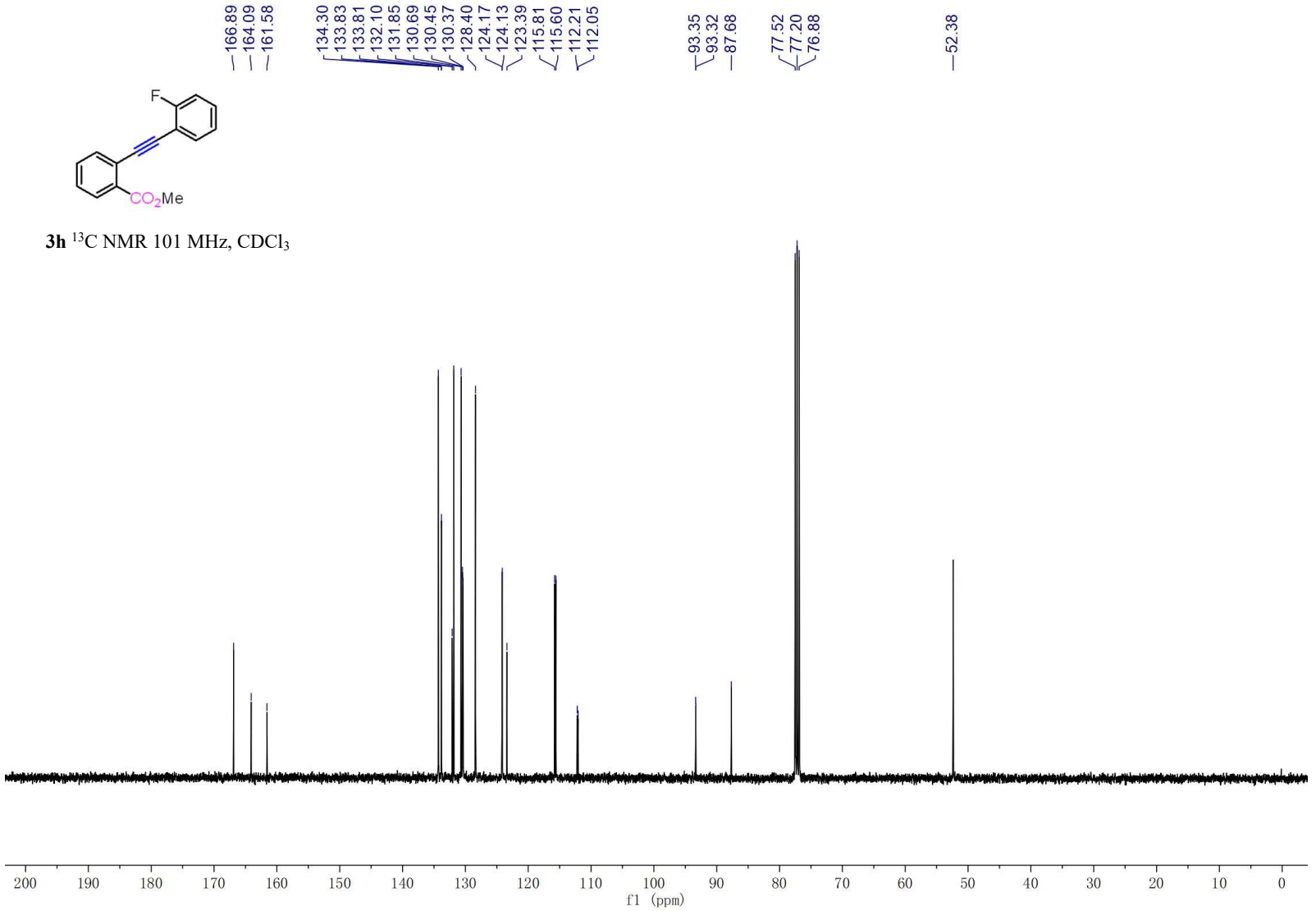




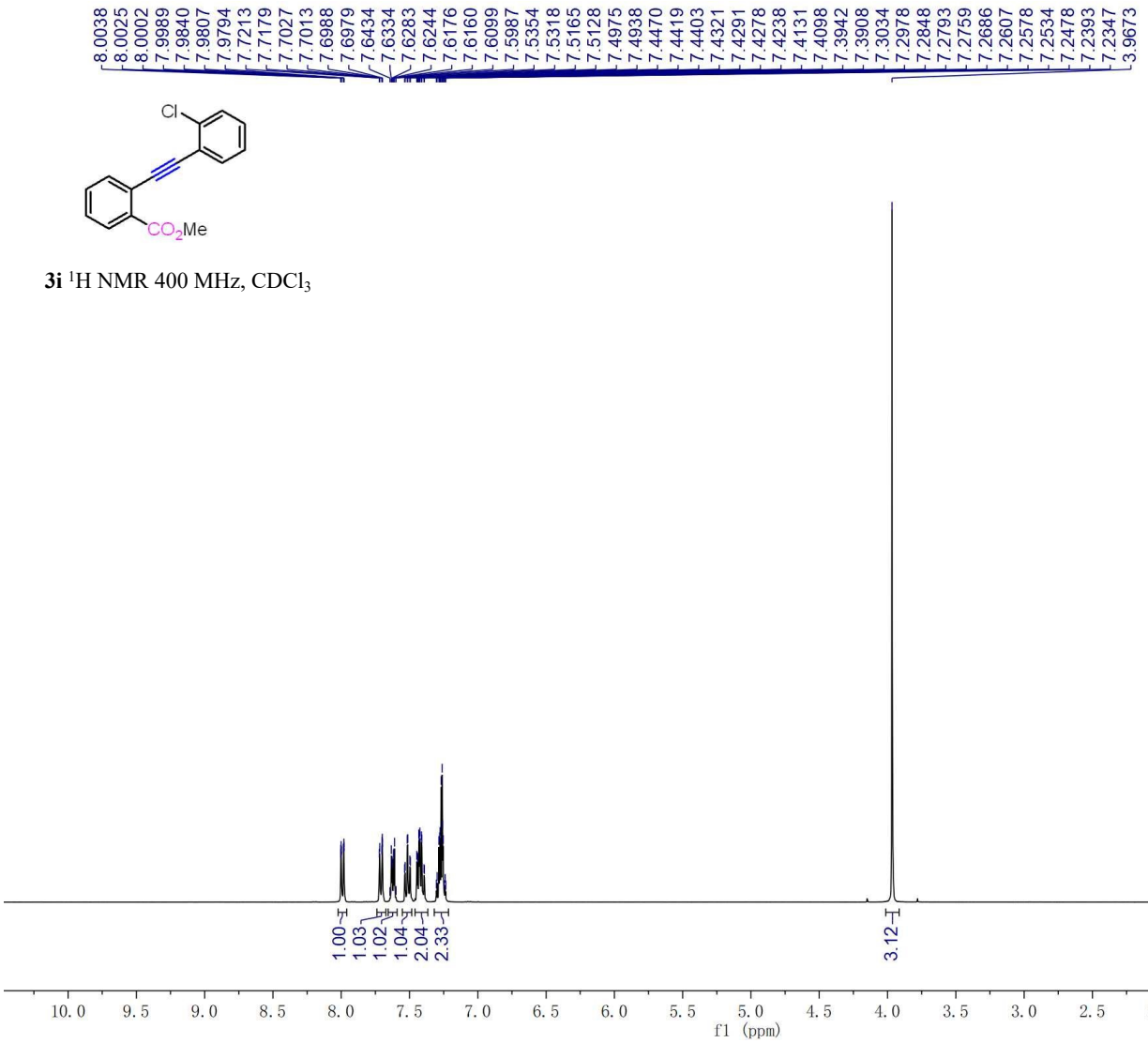
3g ^{13}C NMR 101 MHz, $CDCl_3$



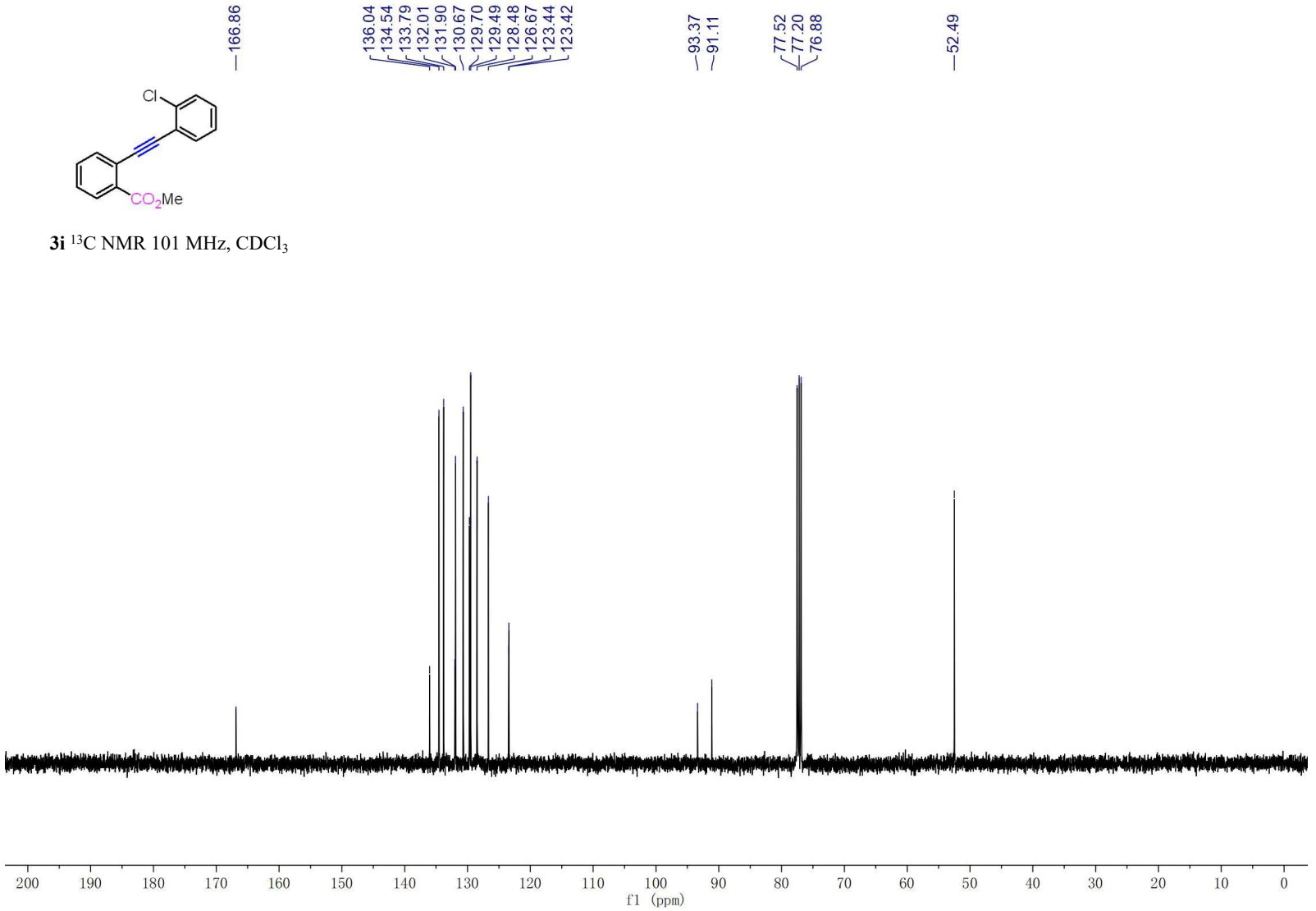
3h ^{1}H NMR 400 MHz, $CDCl_3$



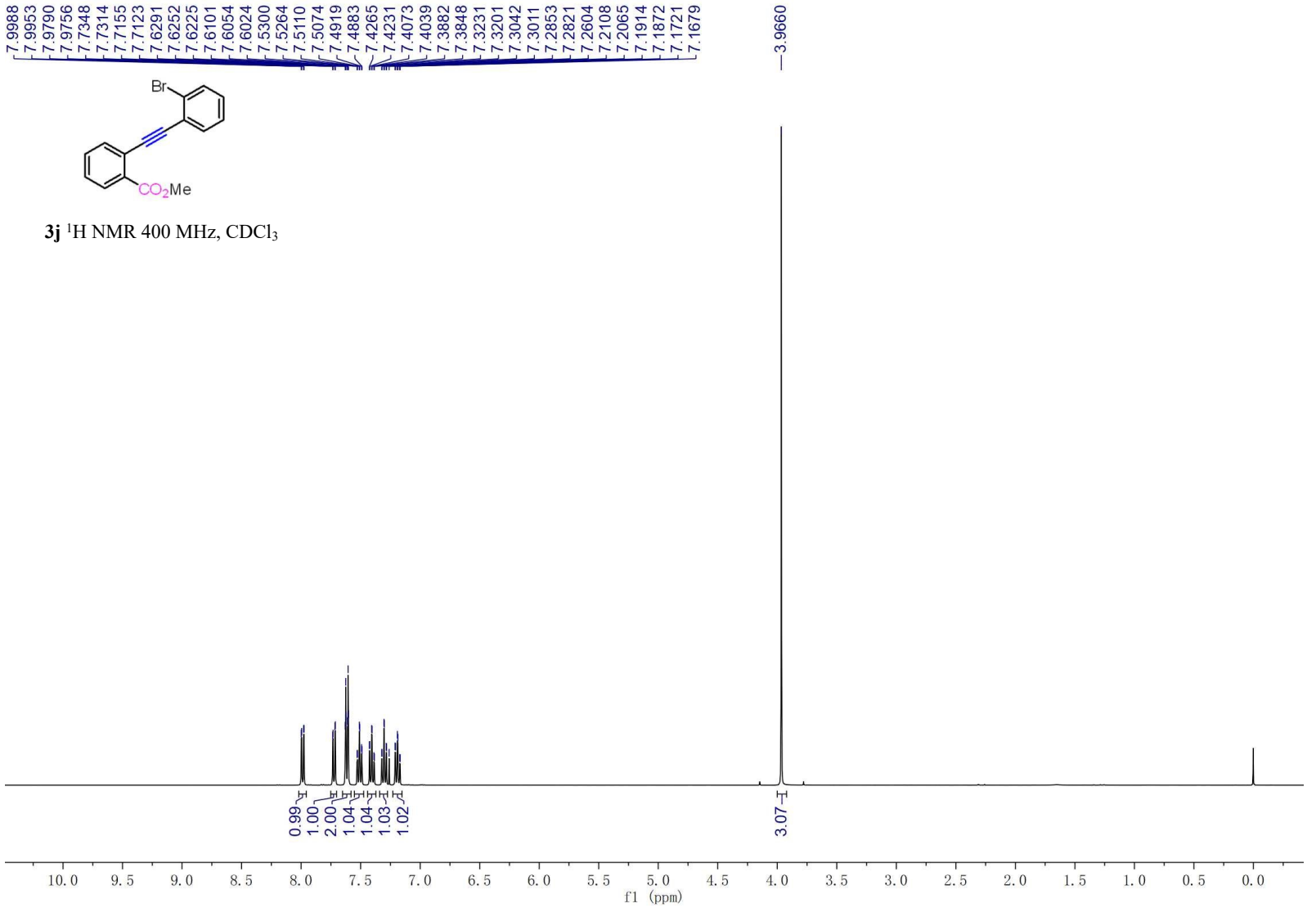
3h ^{13}C NMR 101 MHz, $CDCl_3$



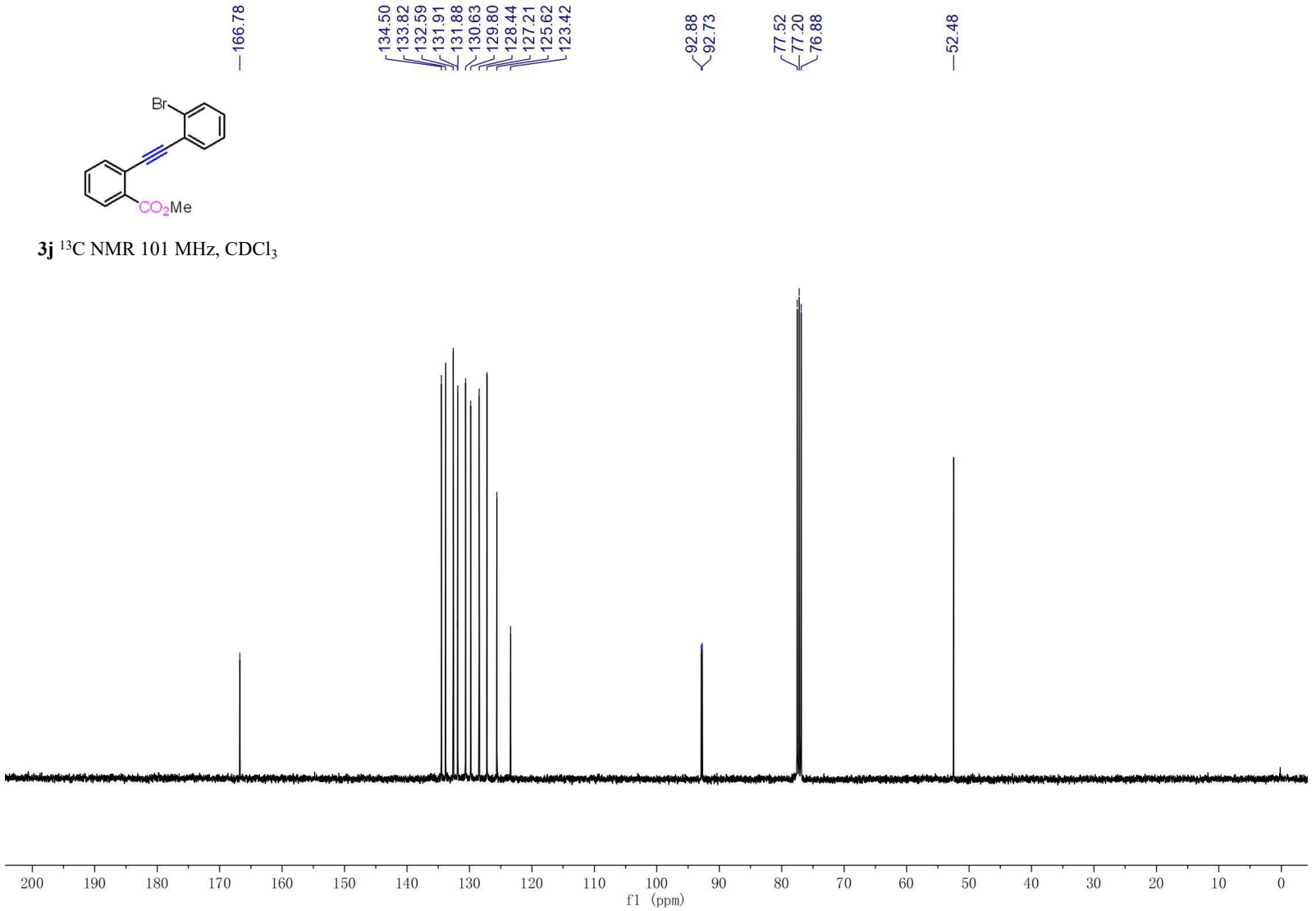
3i ^{1}H NMR 400 MHz, $CDCl_3$



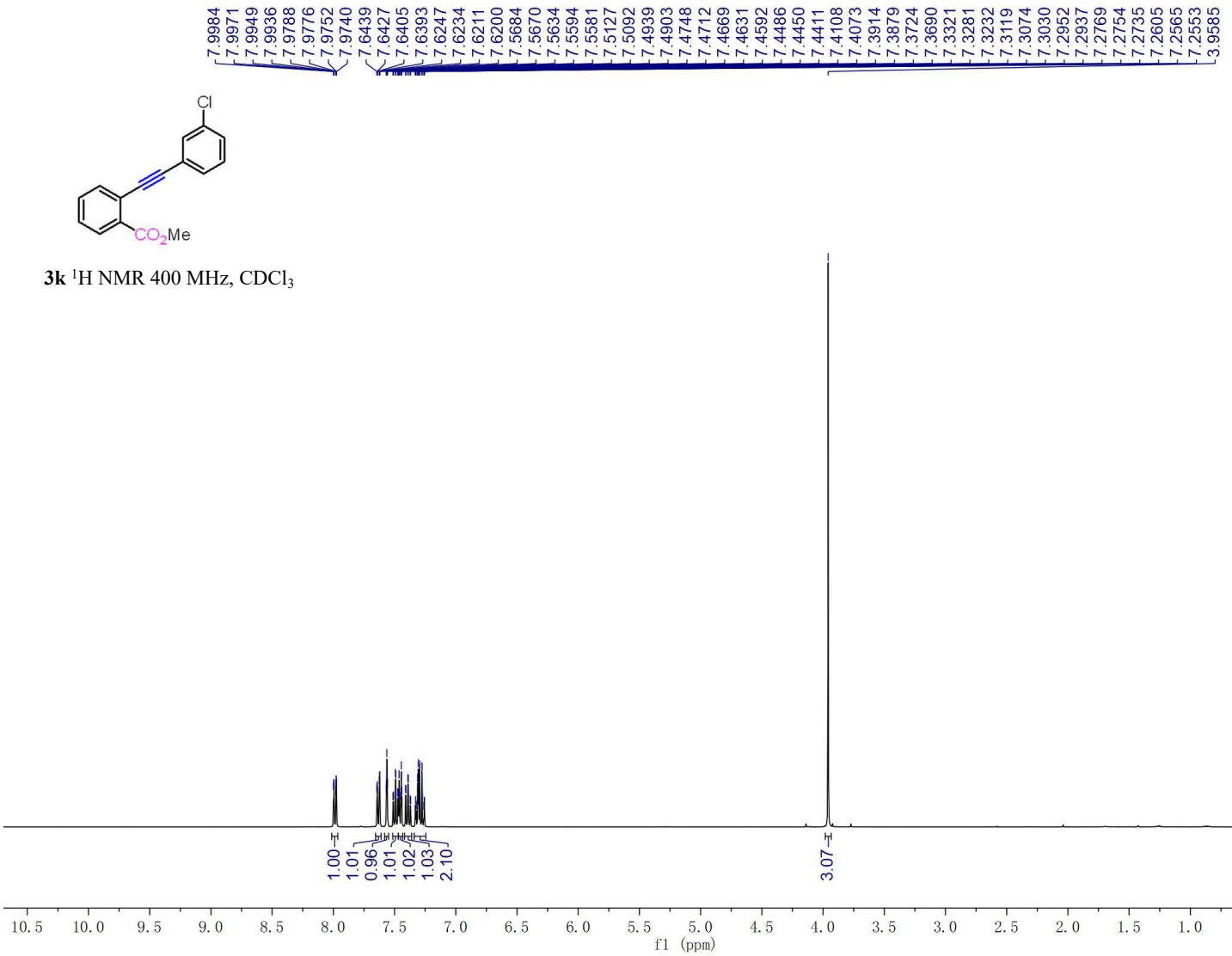
3i ^{13}C NMR 101 MHz, $CDCl_3$



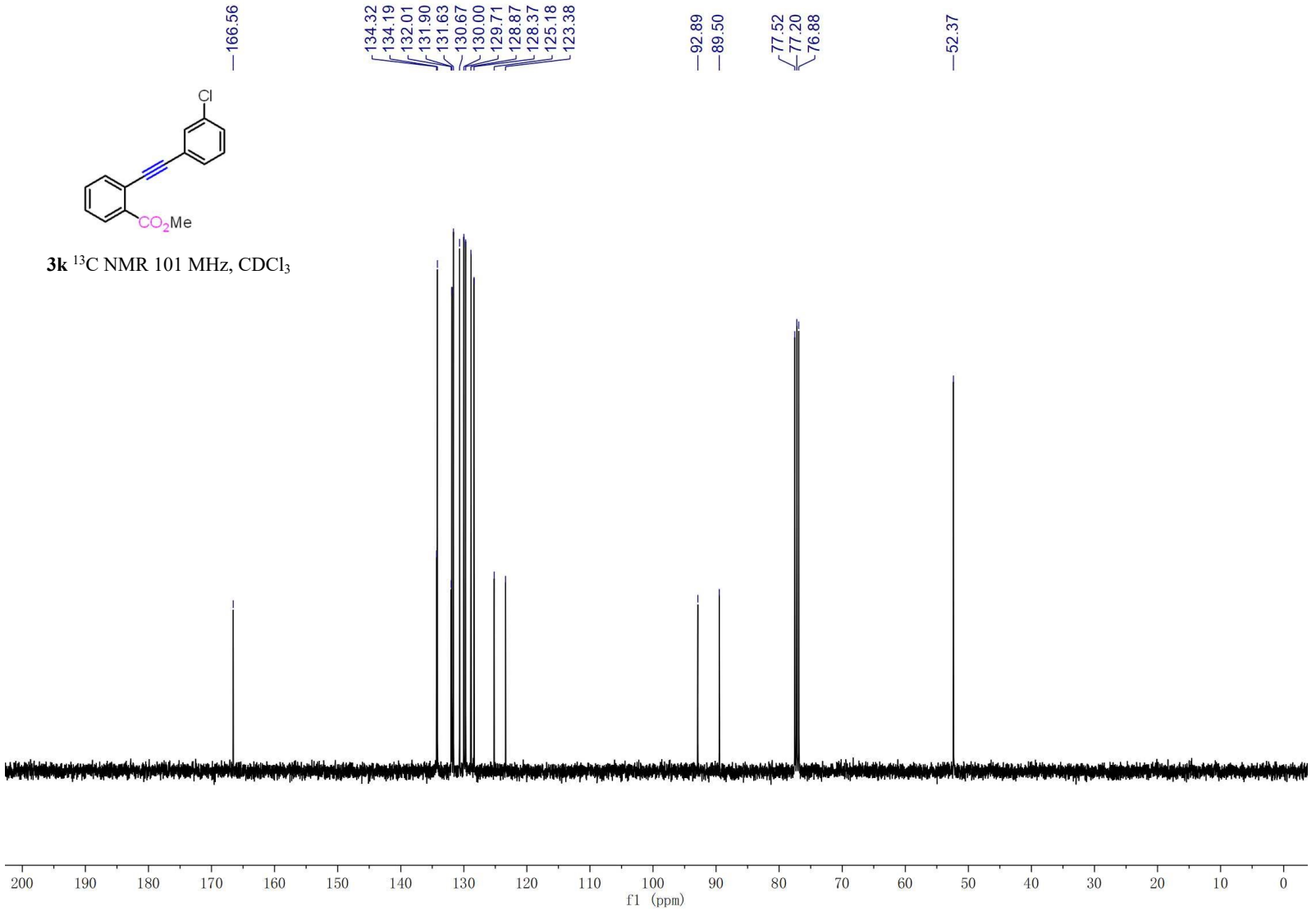
3j ^{1}H NMR 400 MHz, $CDCl_3$



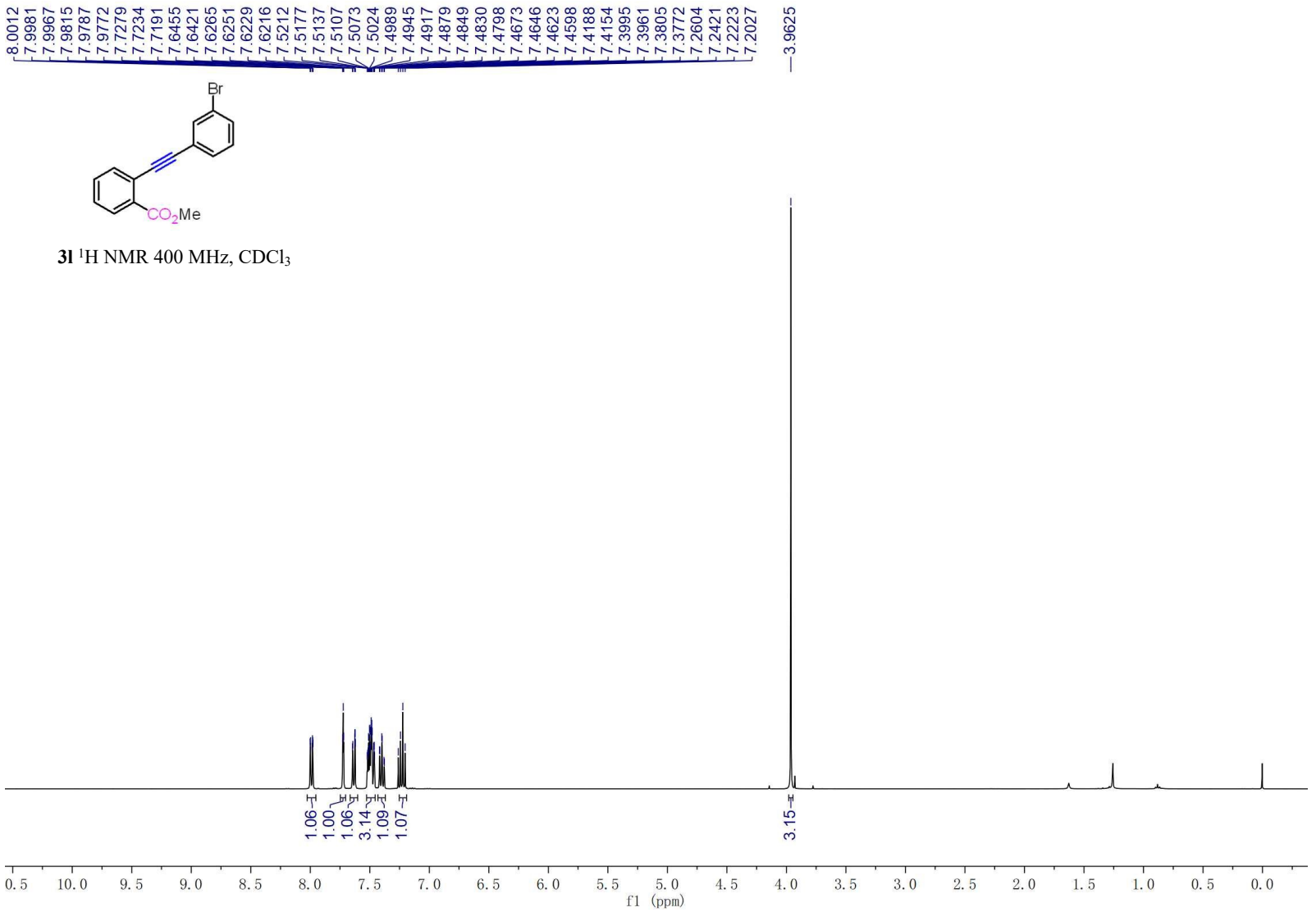
3j ^{13}C NMR 101 MHz, $CDCl_3$



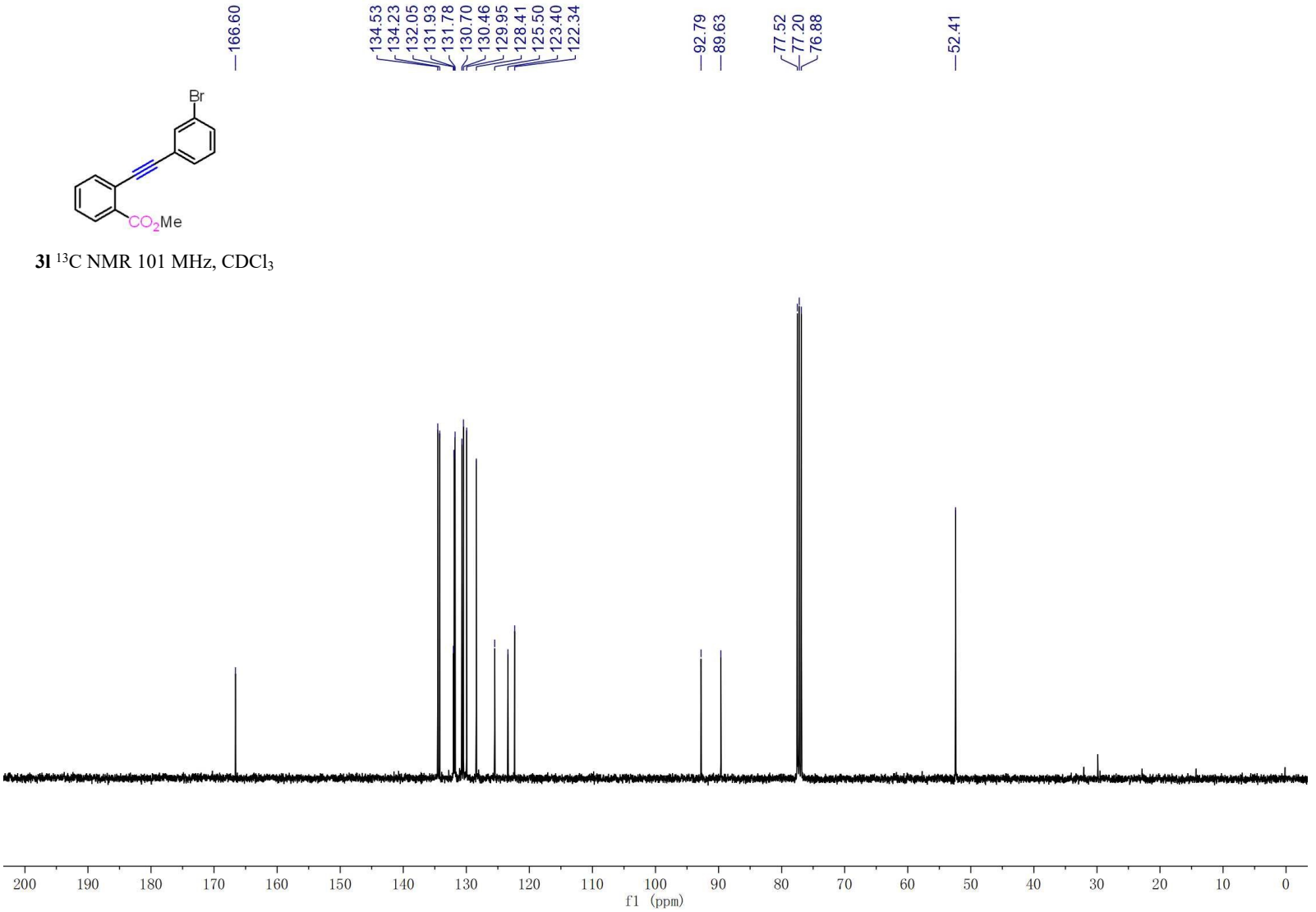
3k ^{1}H NMR 400 MHz, $CDCl_3$



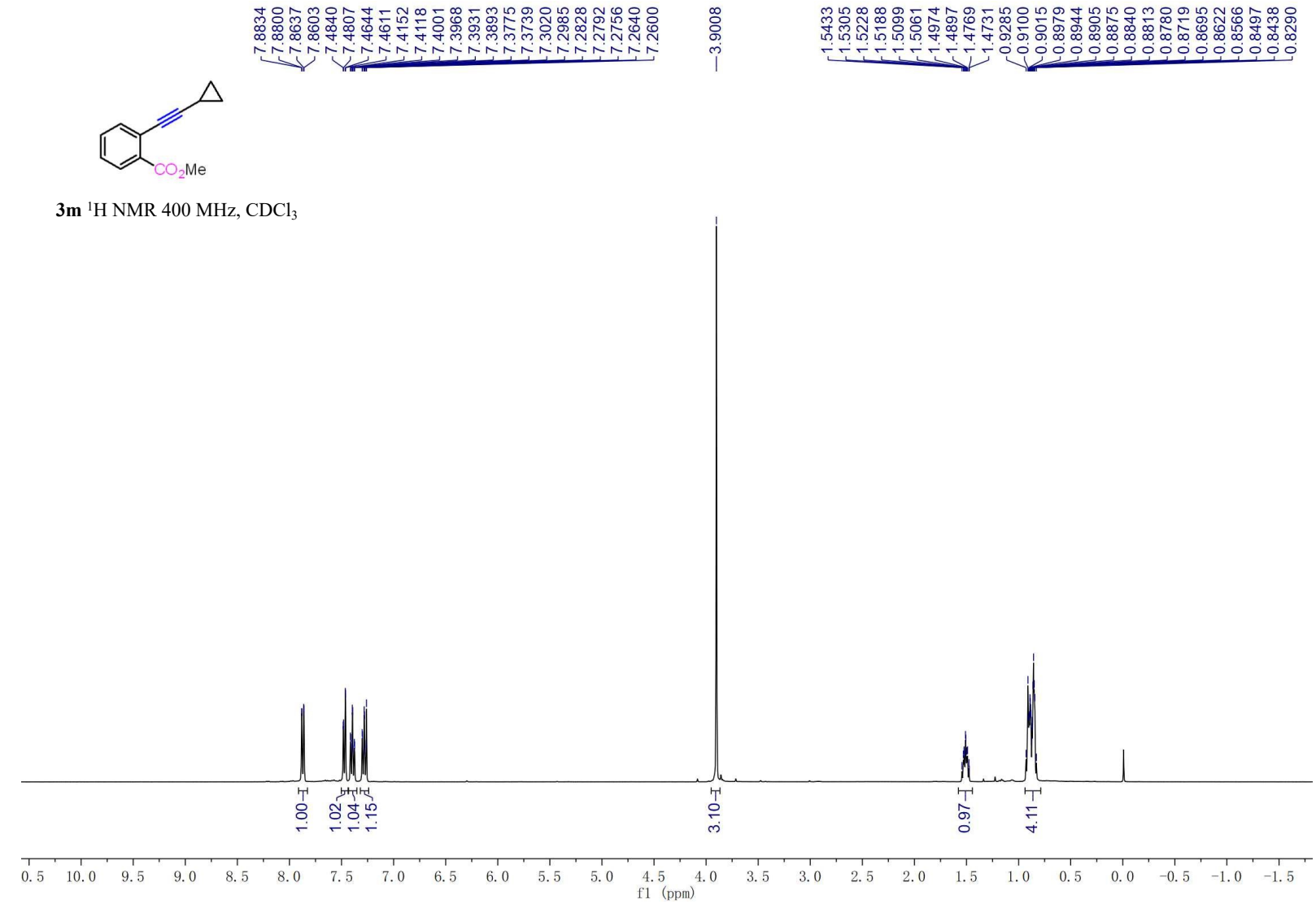
3k ^{13}C NMR 101 MHz, $CDCl_3$



3l ^{1}H NMR 400 MHz, $CDCl_3$



3l ^{13}C NMR 101 MHz, $CDCl_3$



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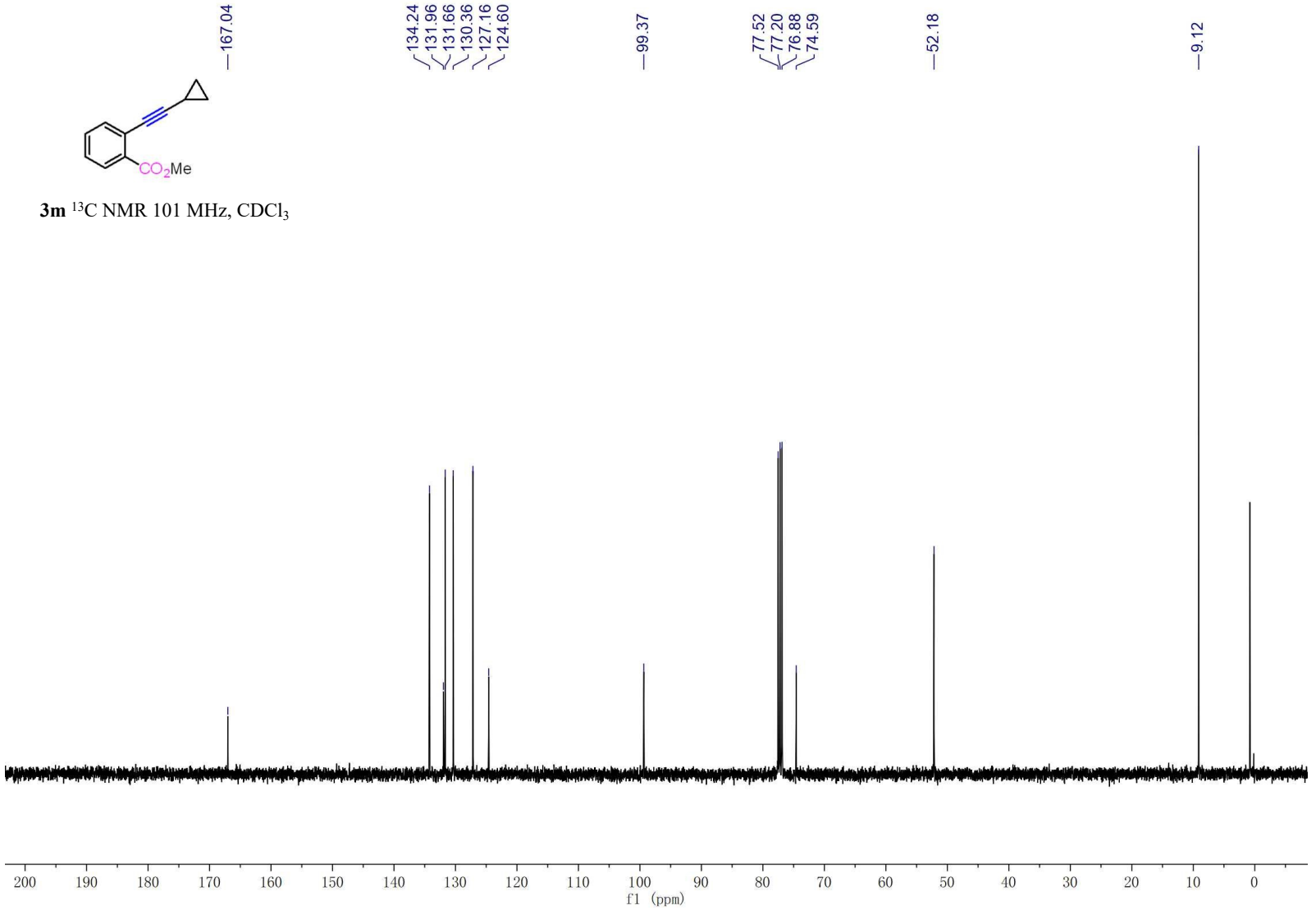
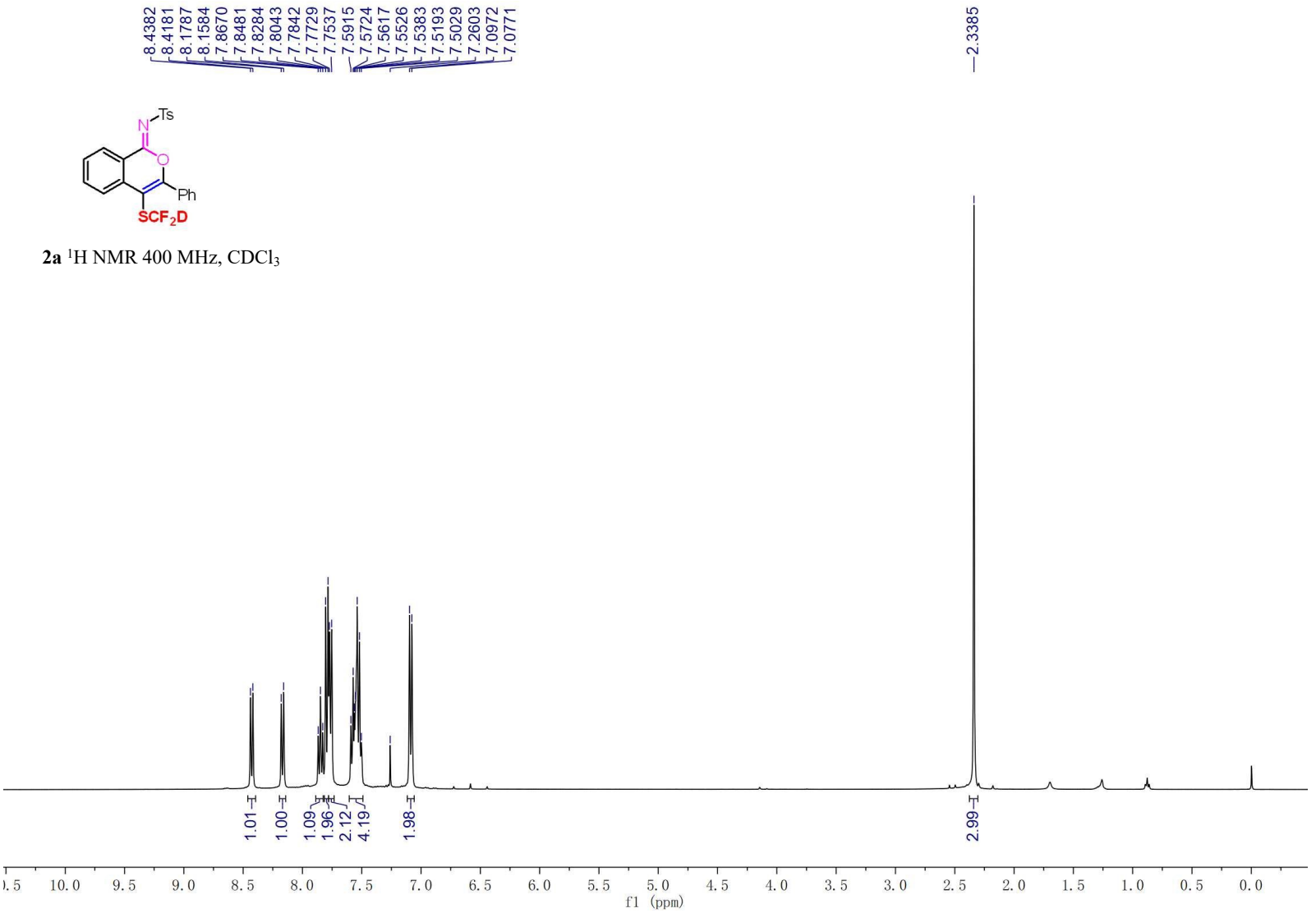
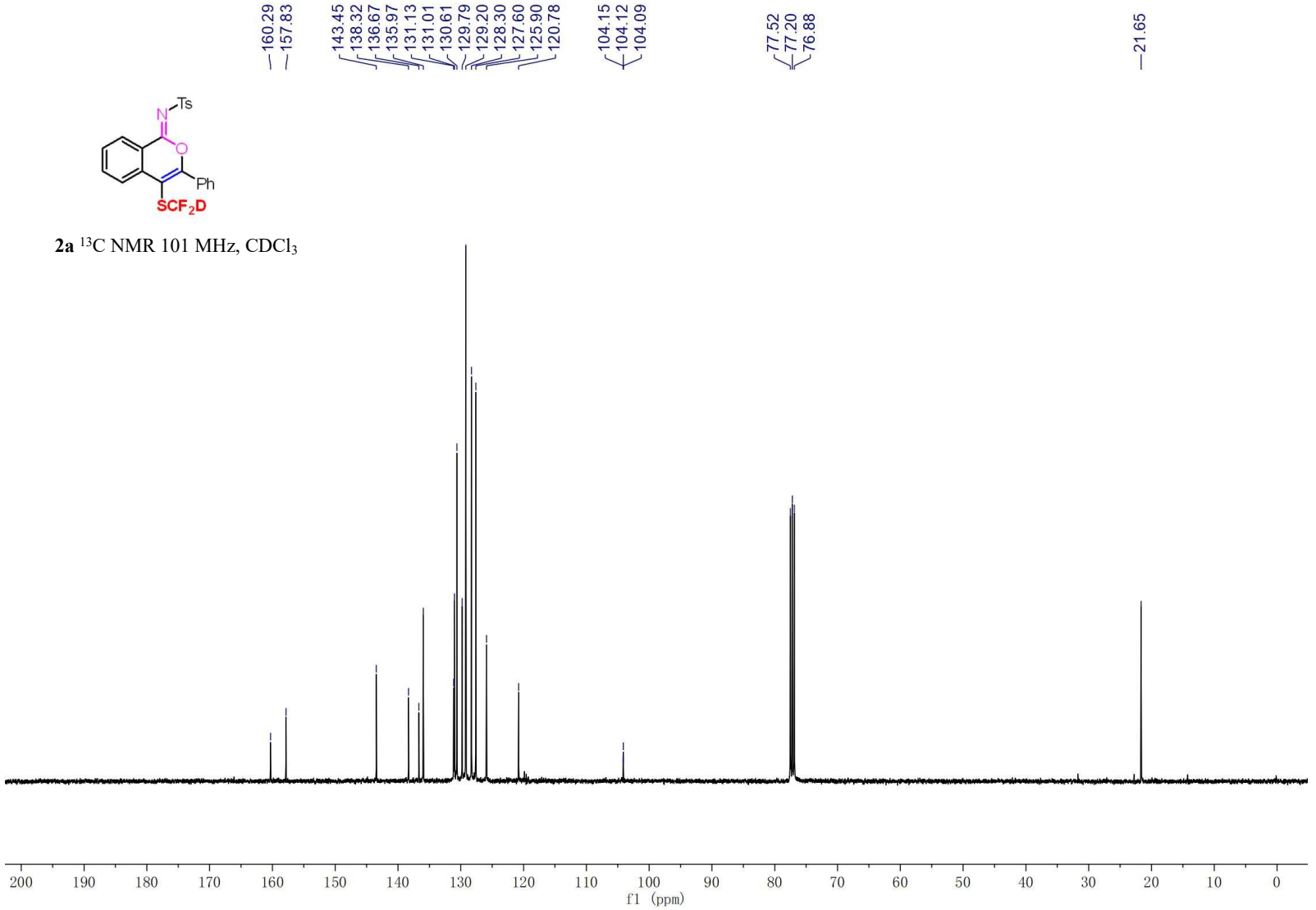


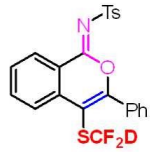
3m ^{13}C NMR 101 MHz, $CDCl_3$



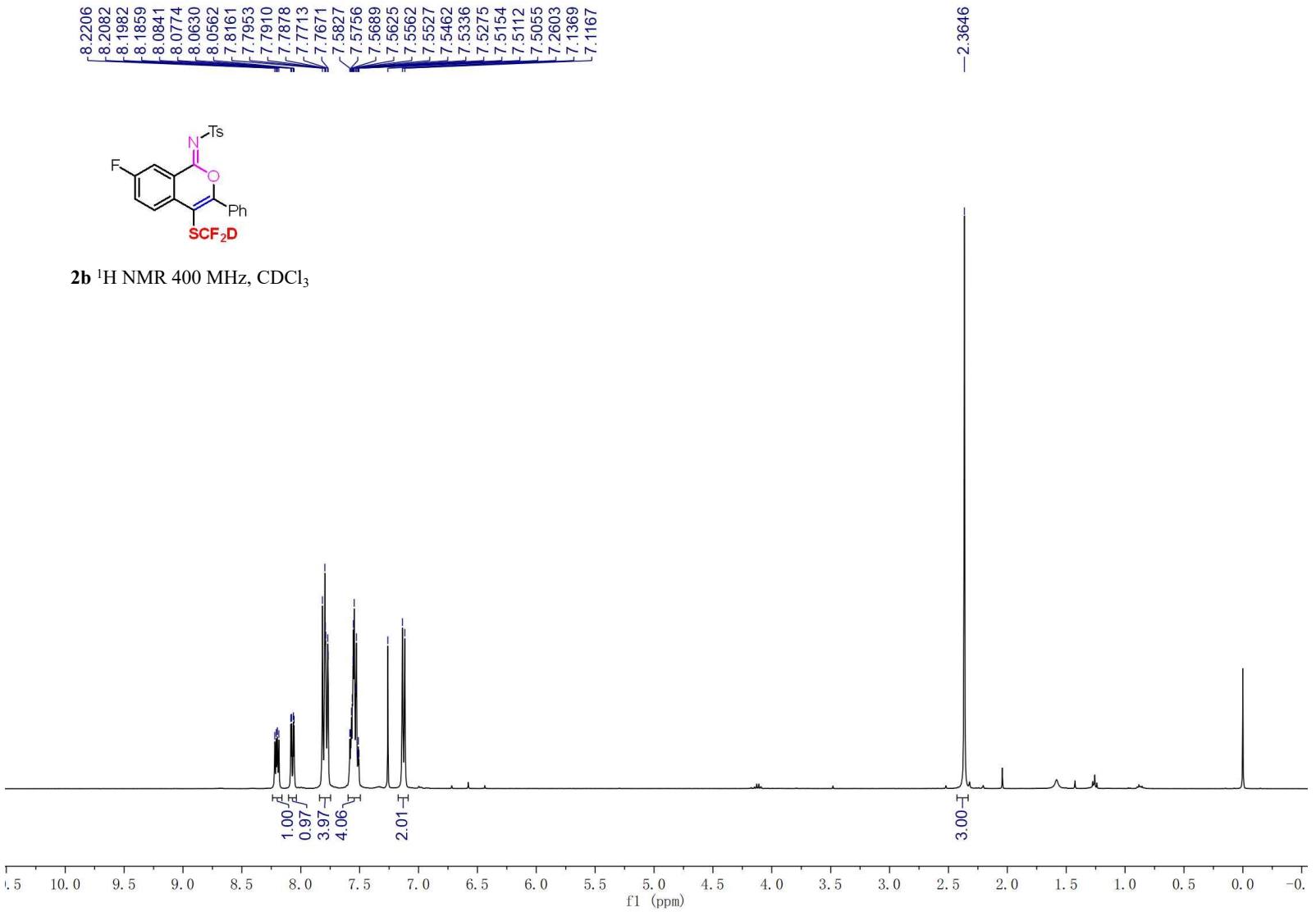
2a ^{1}H NMR 400 MHz, $CDCl_3$



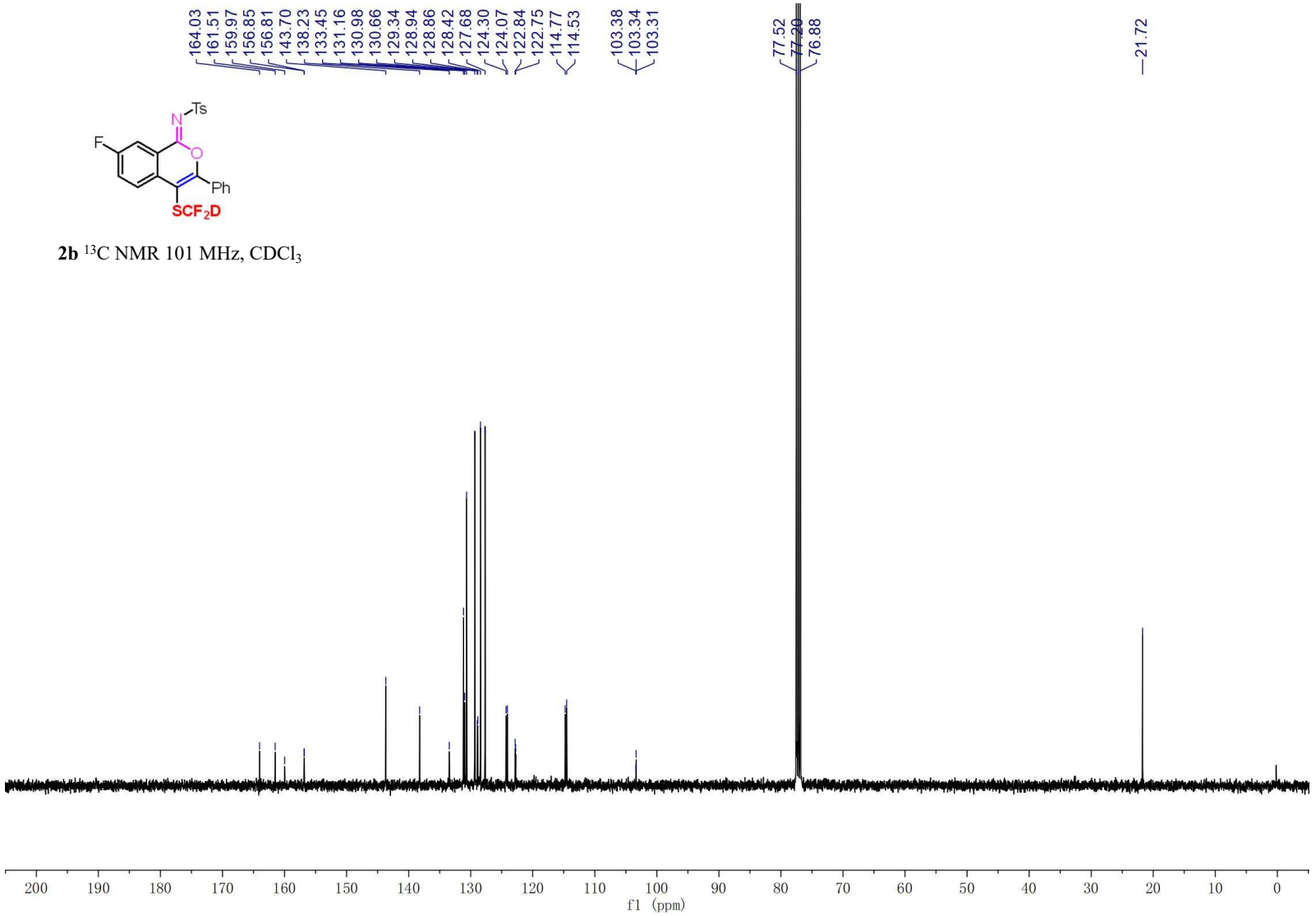
2a ^{13}C NMR 101 MHz, $CDCl_3$



2a ^{19}F NMR 376 MHz, $CDCl_3$



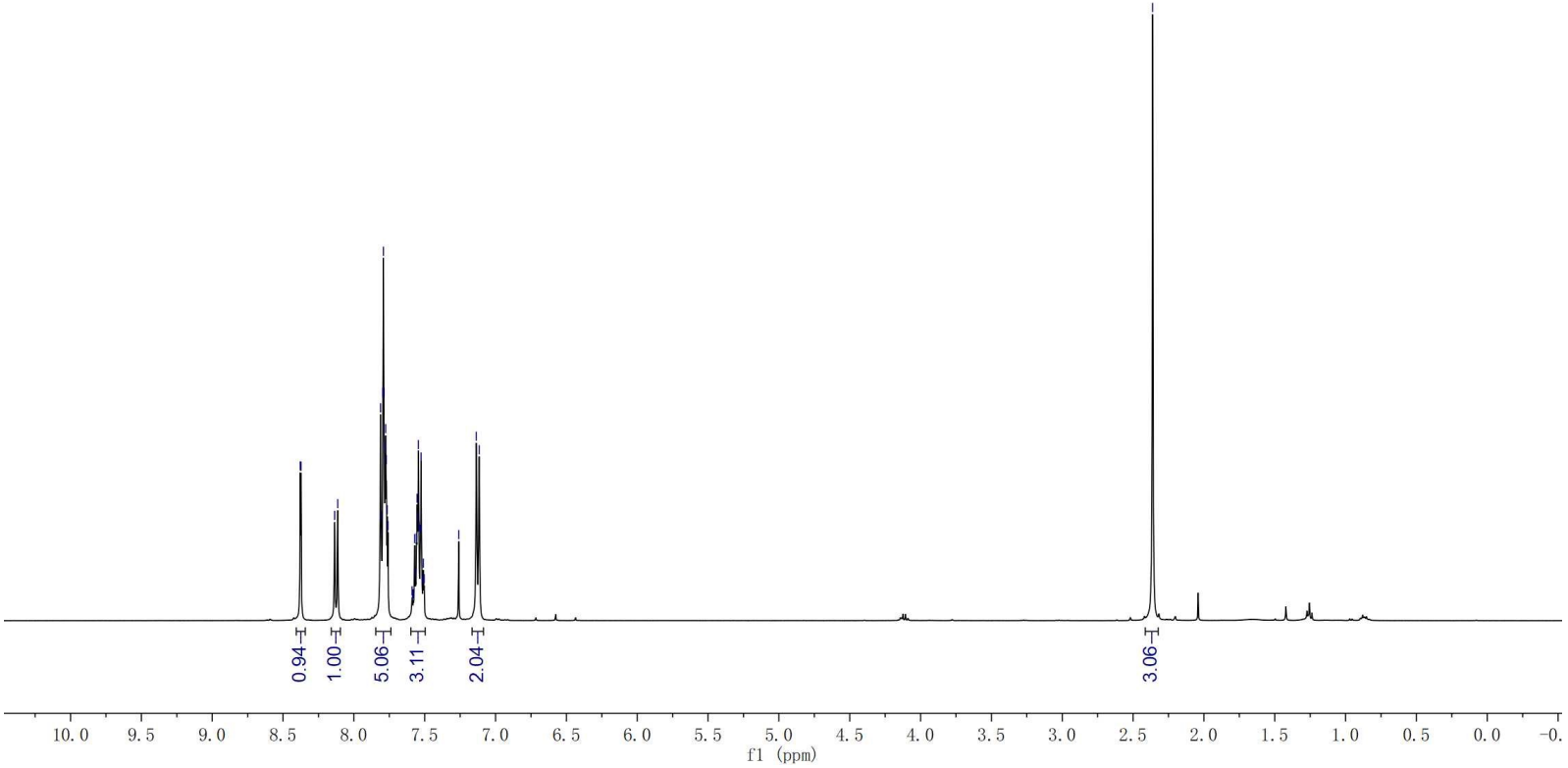
2b ^{1}H NMR 400 MHz, $CDCl_3$

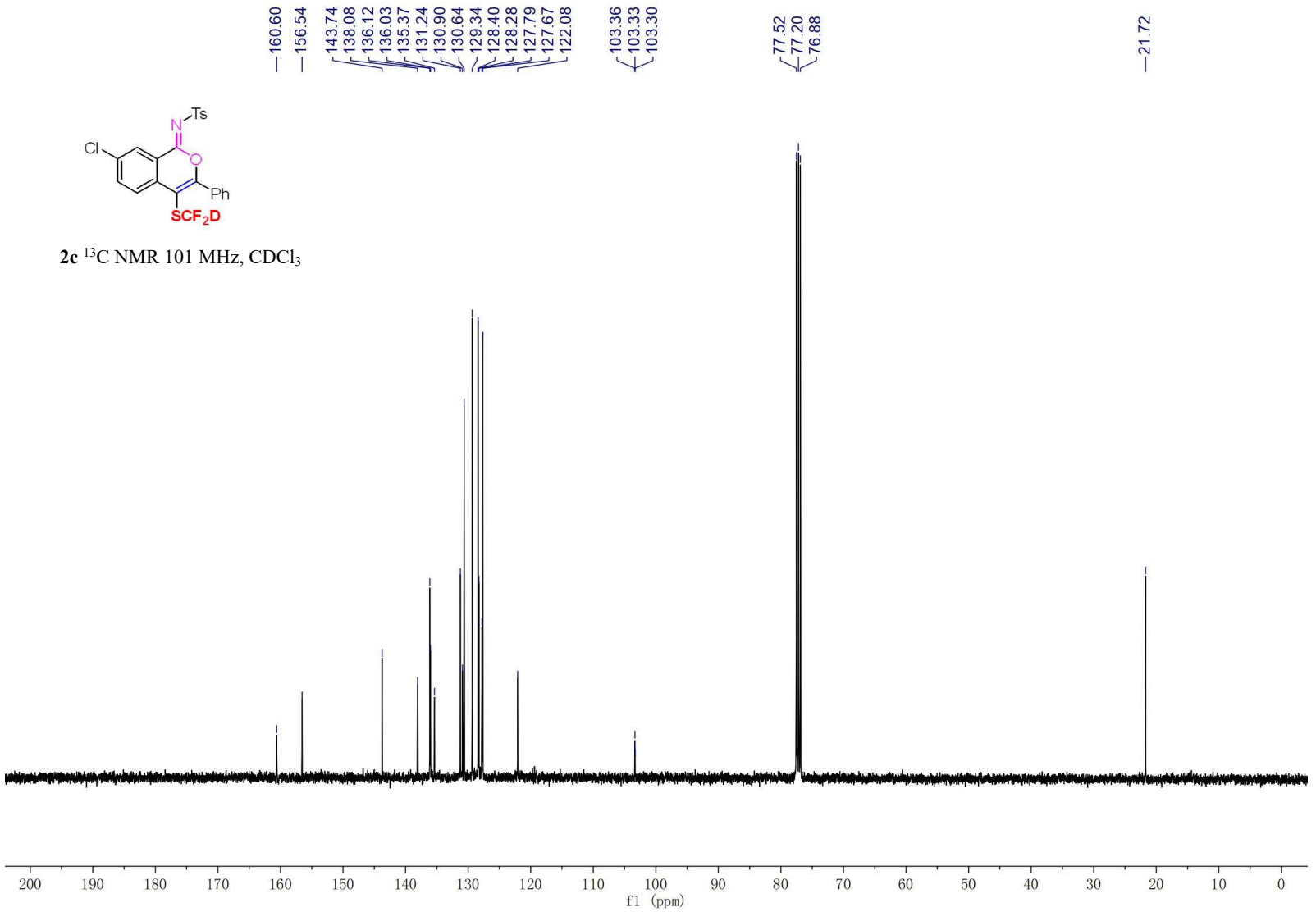


2b ^{13}C NMR 101 MHz, $CDCl_3$

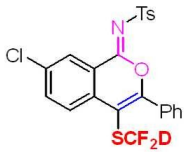
2b ^{19}F NMR 376 MHz, $CDCl_3$

2c ^{1}H NMR 400 MHz, $CDCl_3$

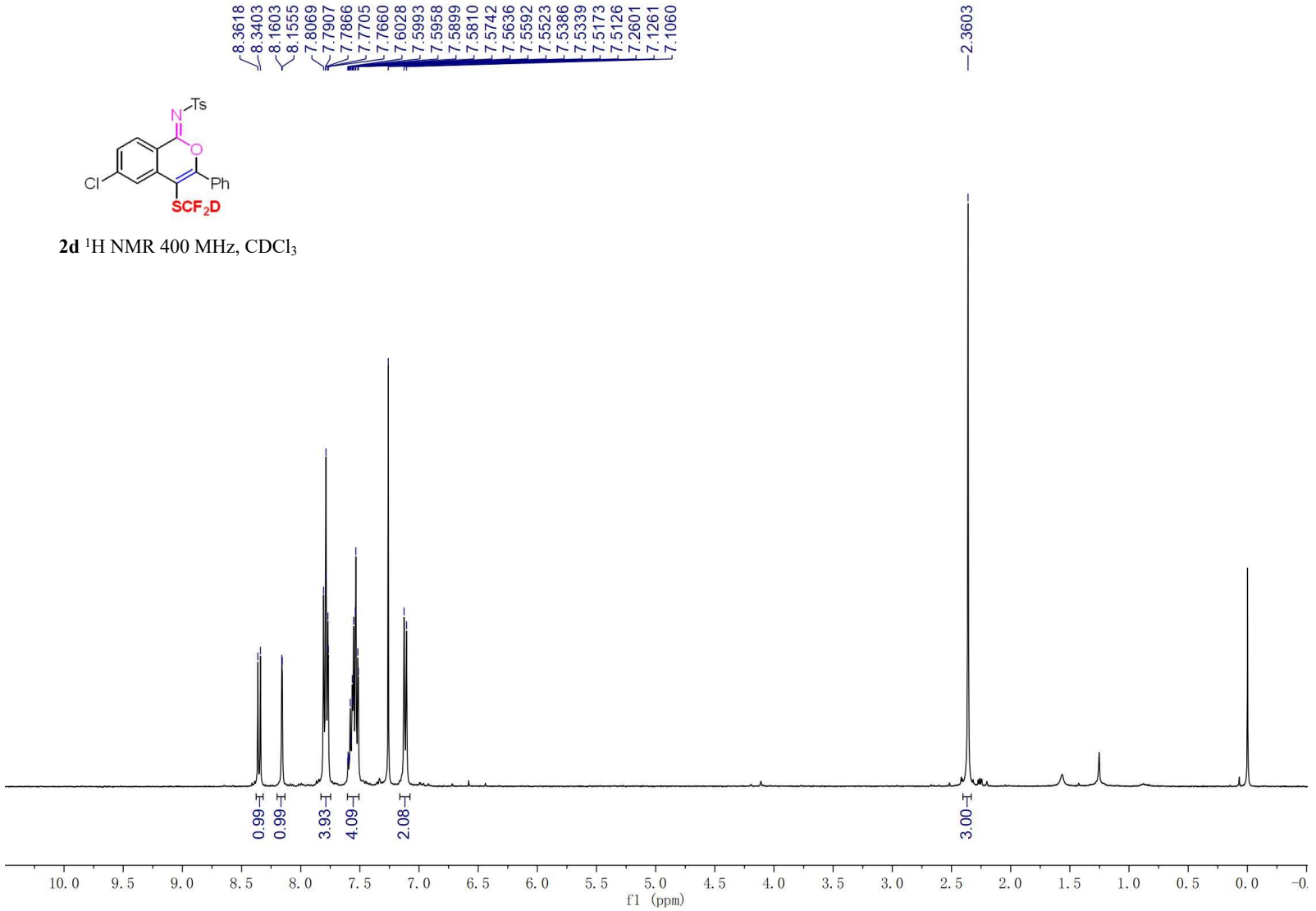




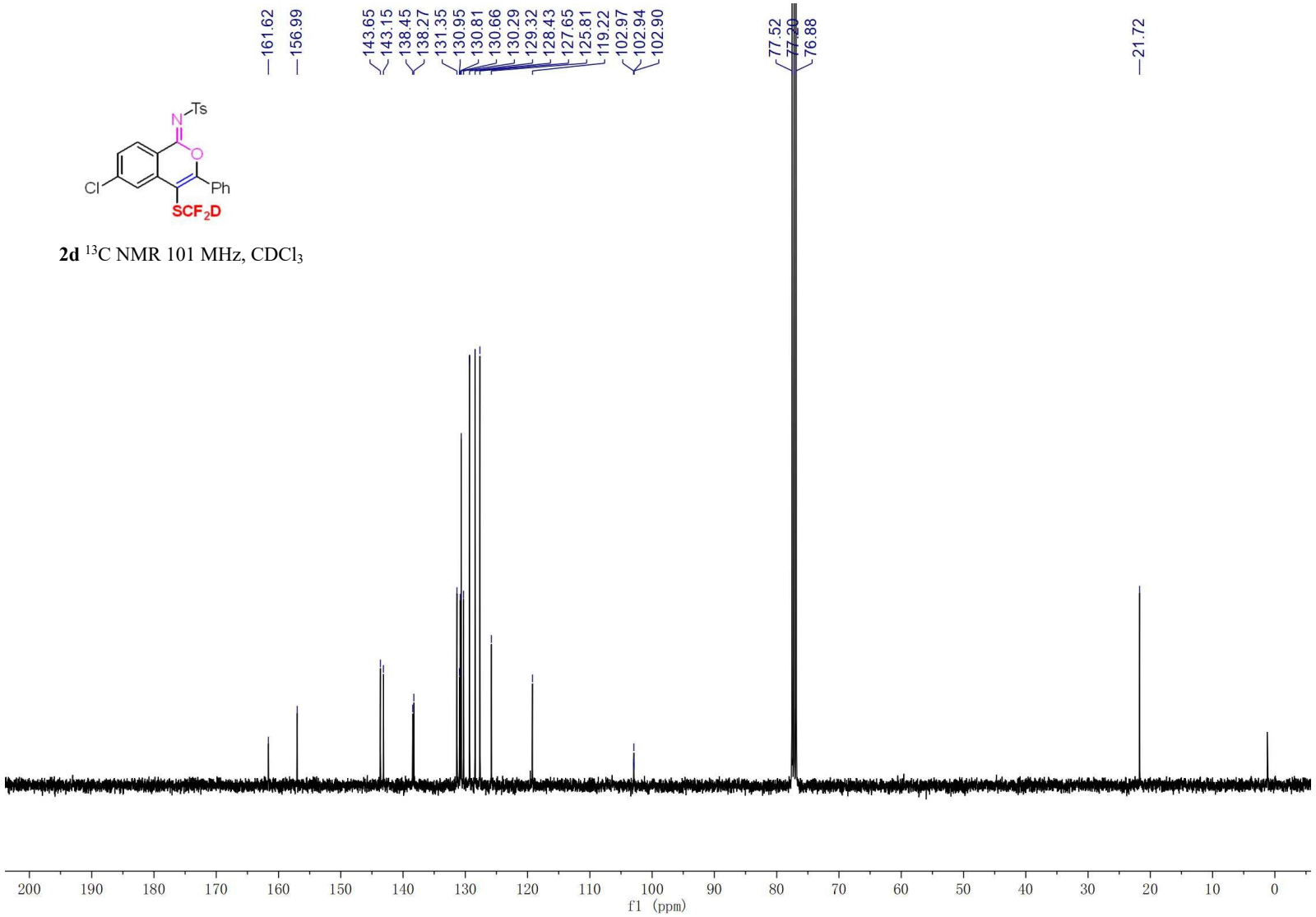
2c ^{13}C NMR 101 MHz, $CDCl_3$



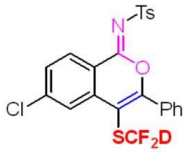
2c ^{19}F NMR 376 MHz, $CDCl_3$



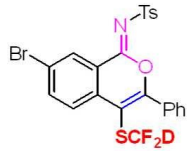
2d ^{1}H NMR 400 MHz, $CDCl_3$



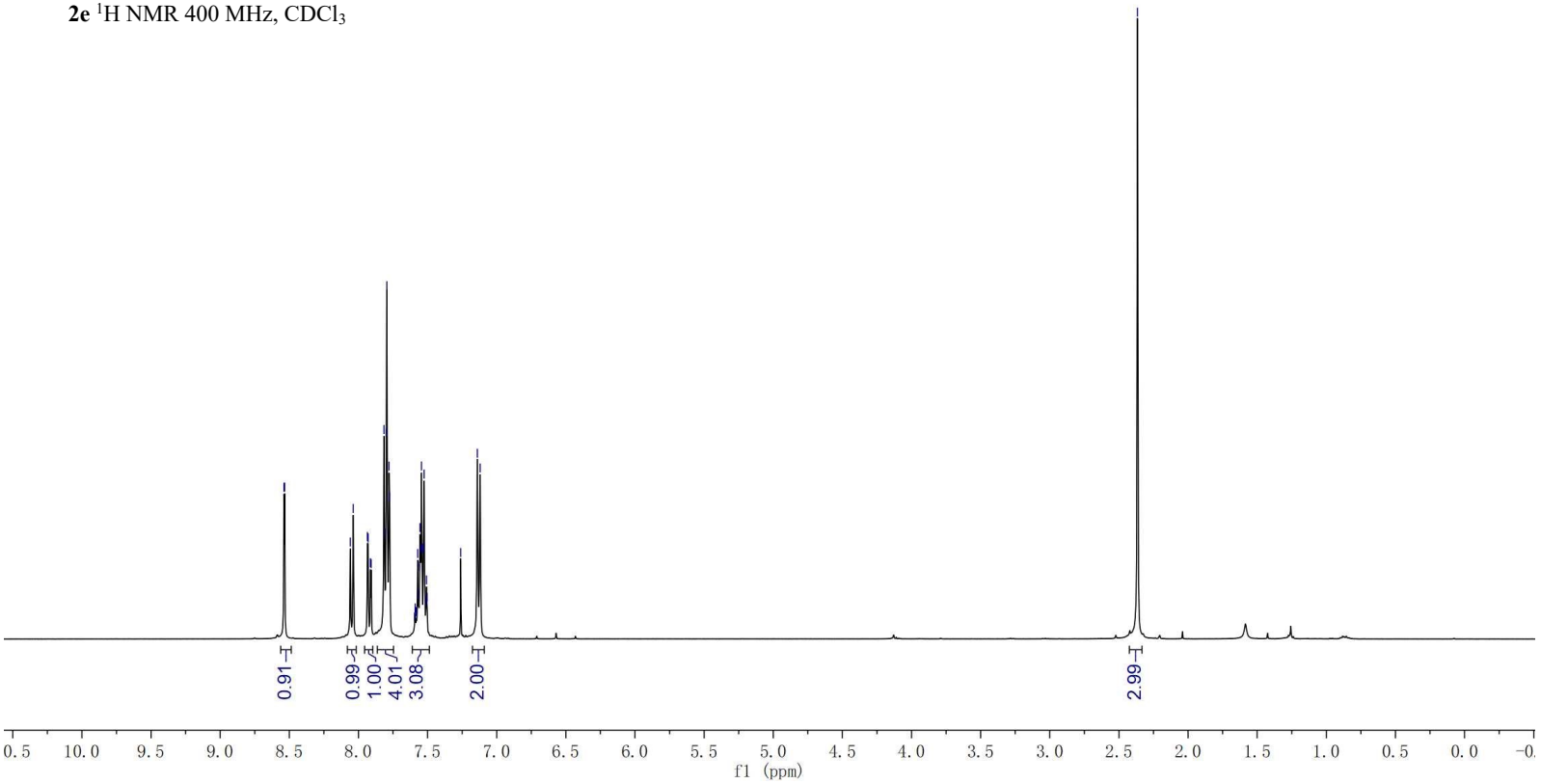
2d ^{13}C NMR 101 MHz, $CDCl_3$

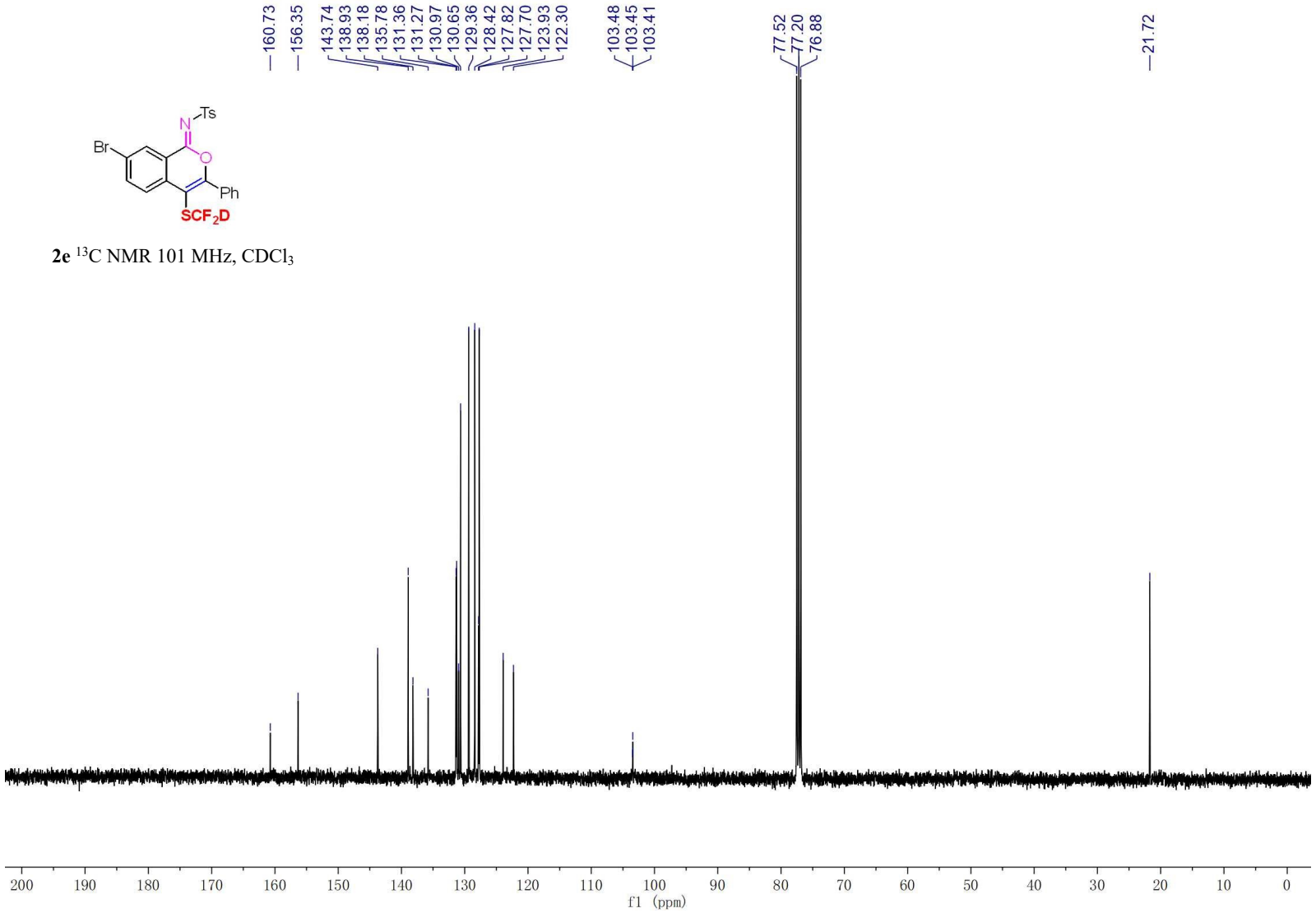


2d ^{19}F NMR 376 MHz, $CDCl_3$

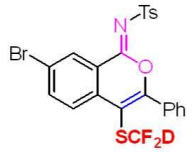


2e ^{1}H NMR 400 MHz, $CDCl_3$

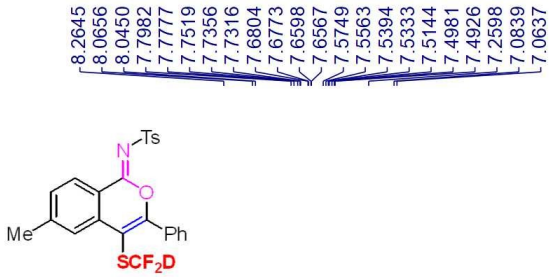




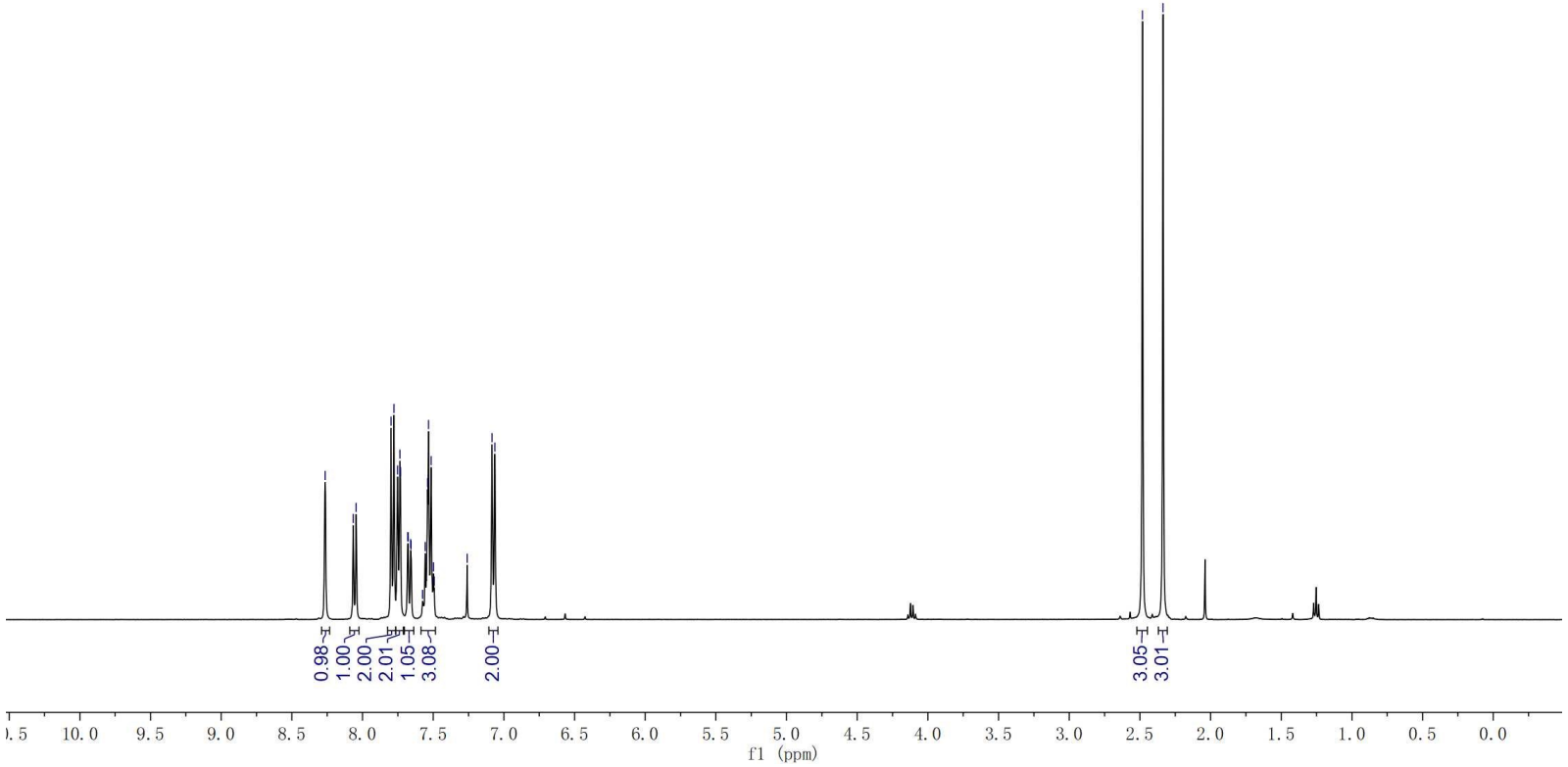
2e ^{13}C NMR 101 MHz, $CDCl_3$

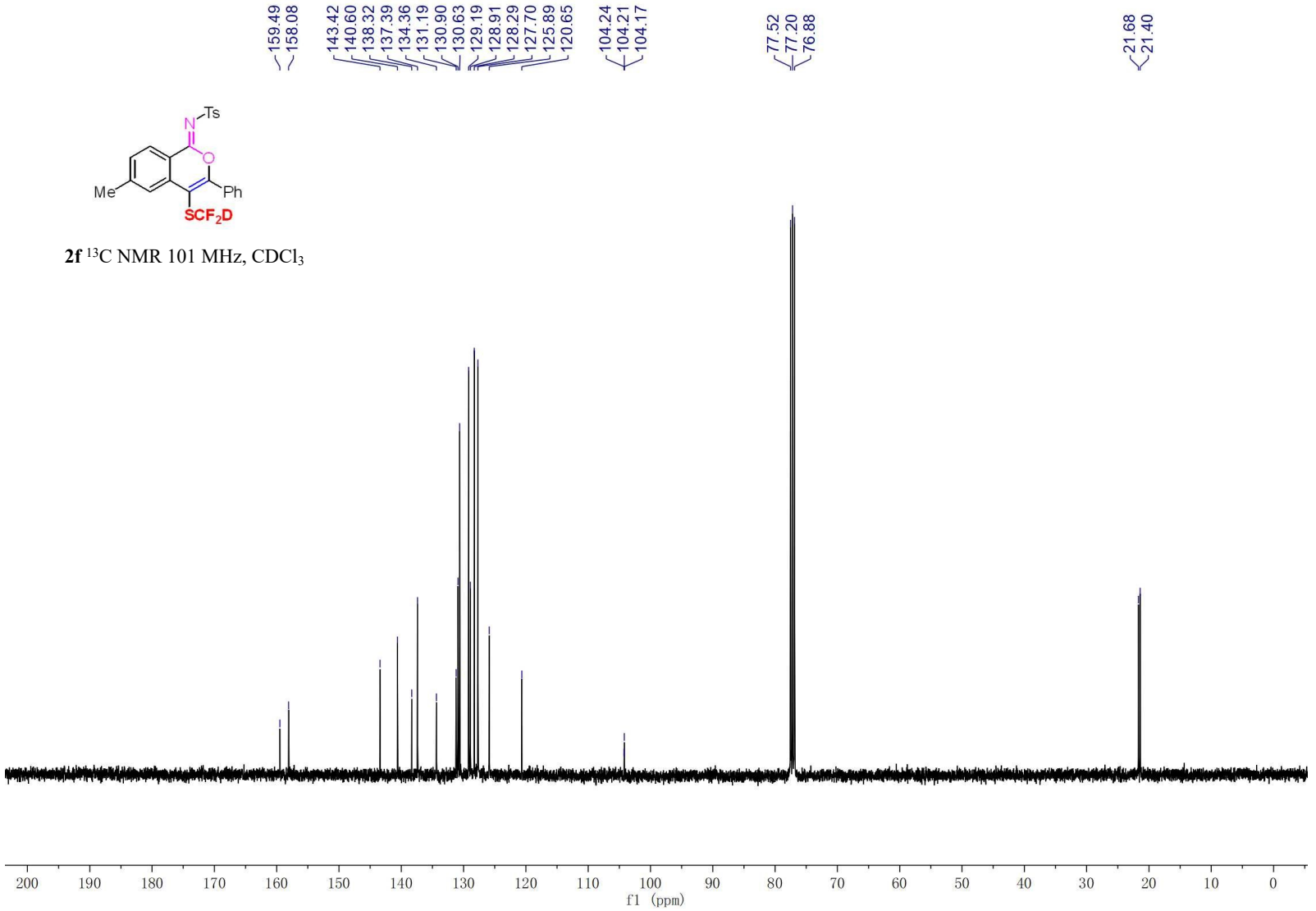


2e ^{19}F NMR 376 MHz, $CDCl_3$



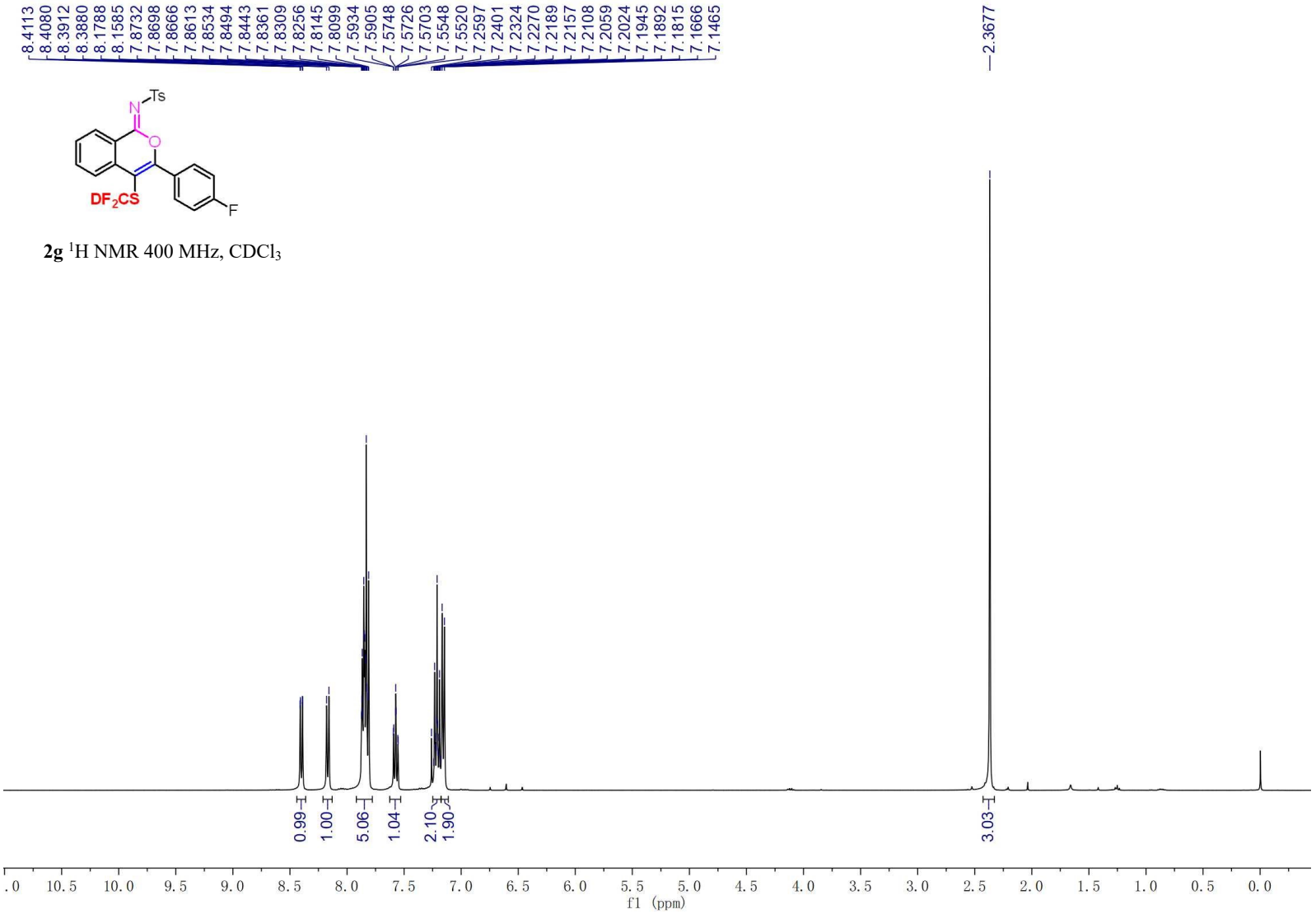
2f ^{1}H NMR 400 MHz, $CDCl_3$



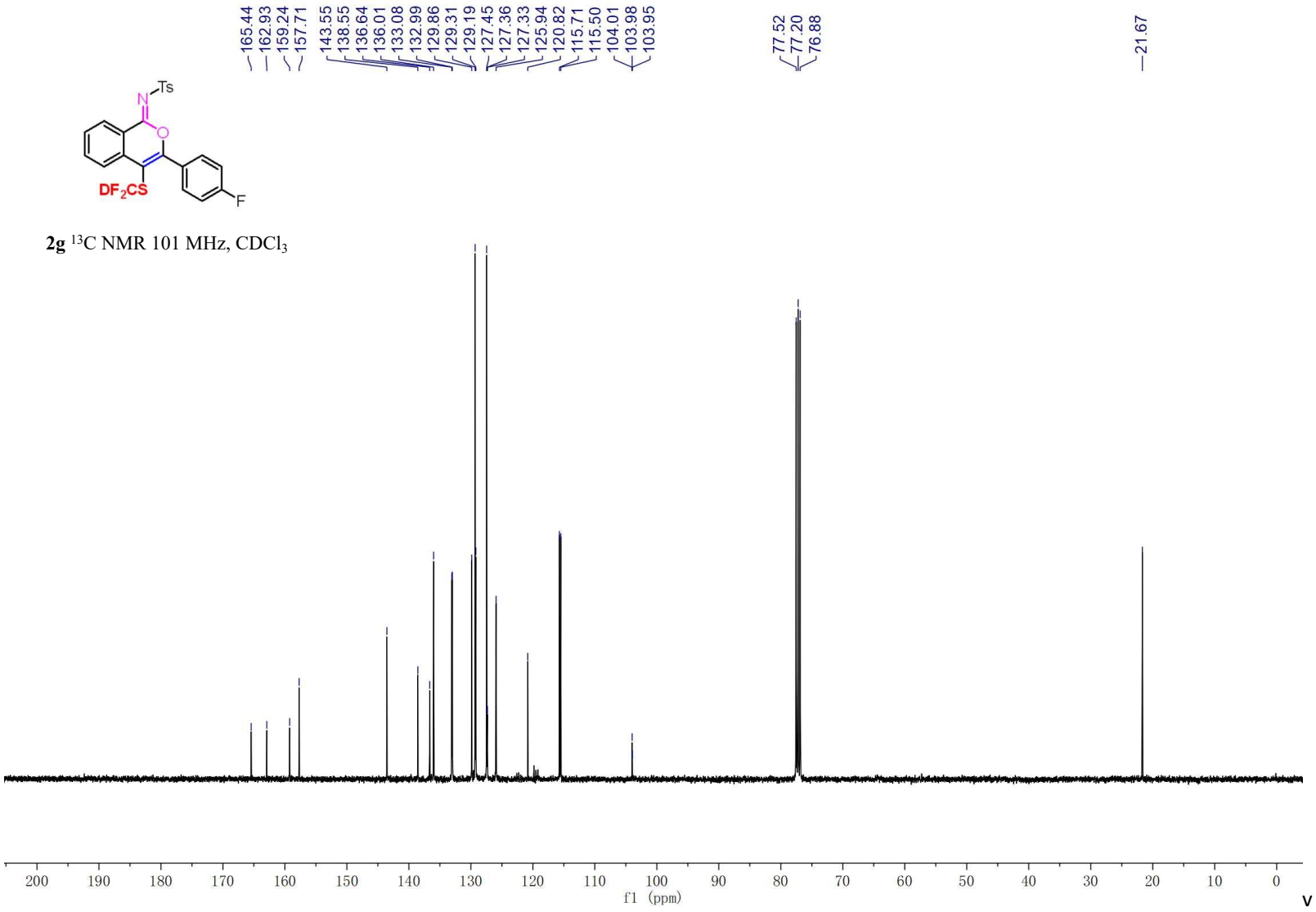


2f ^{13}C NMR 101 MHz, $CDCl_3$

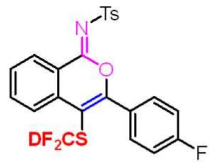
2f ^{19}F NMR 376 MHz, $CDCl_3$



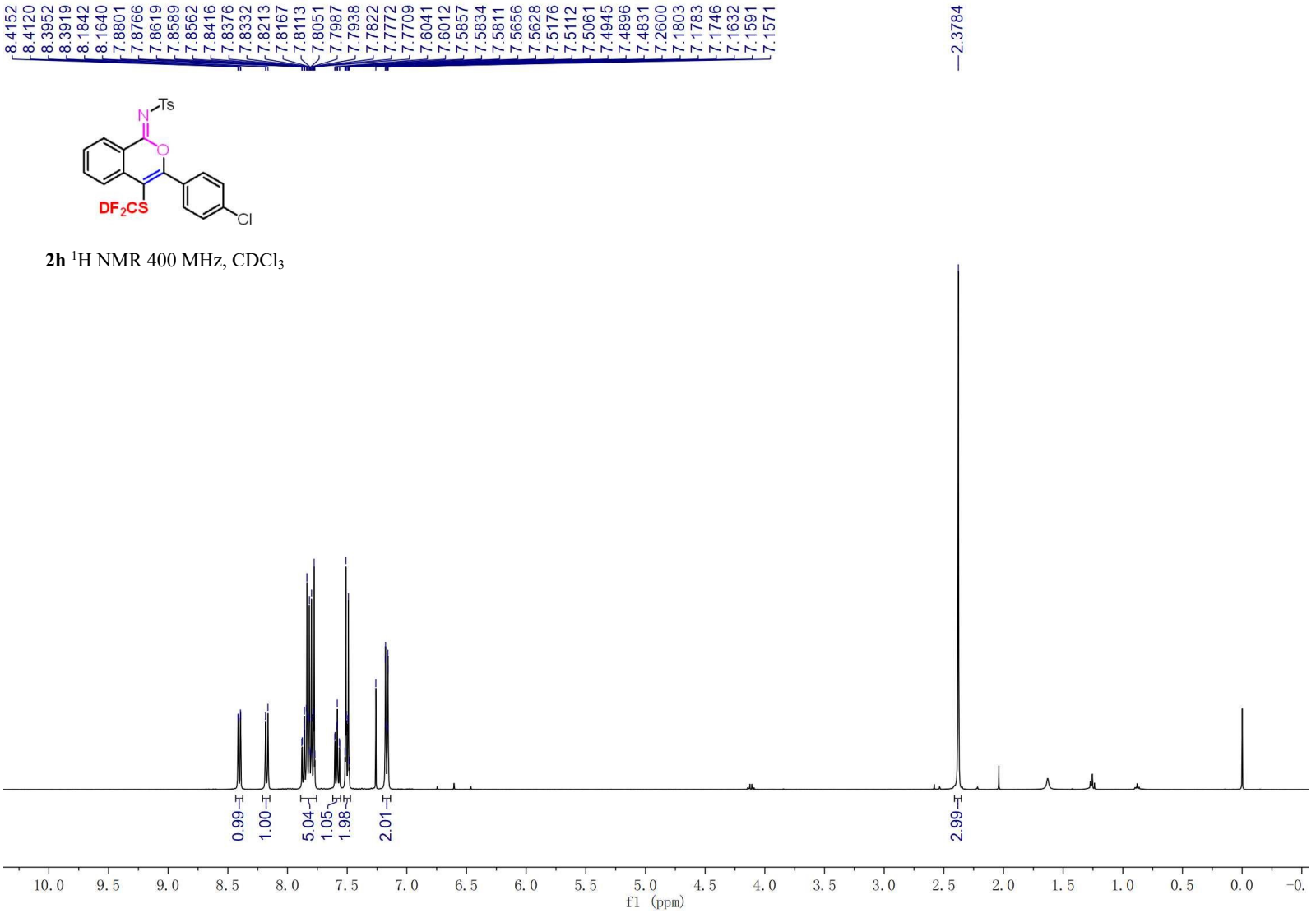
2g ^{1}H NMR 400 MHz, $CDCl_3$



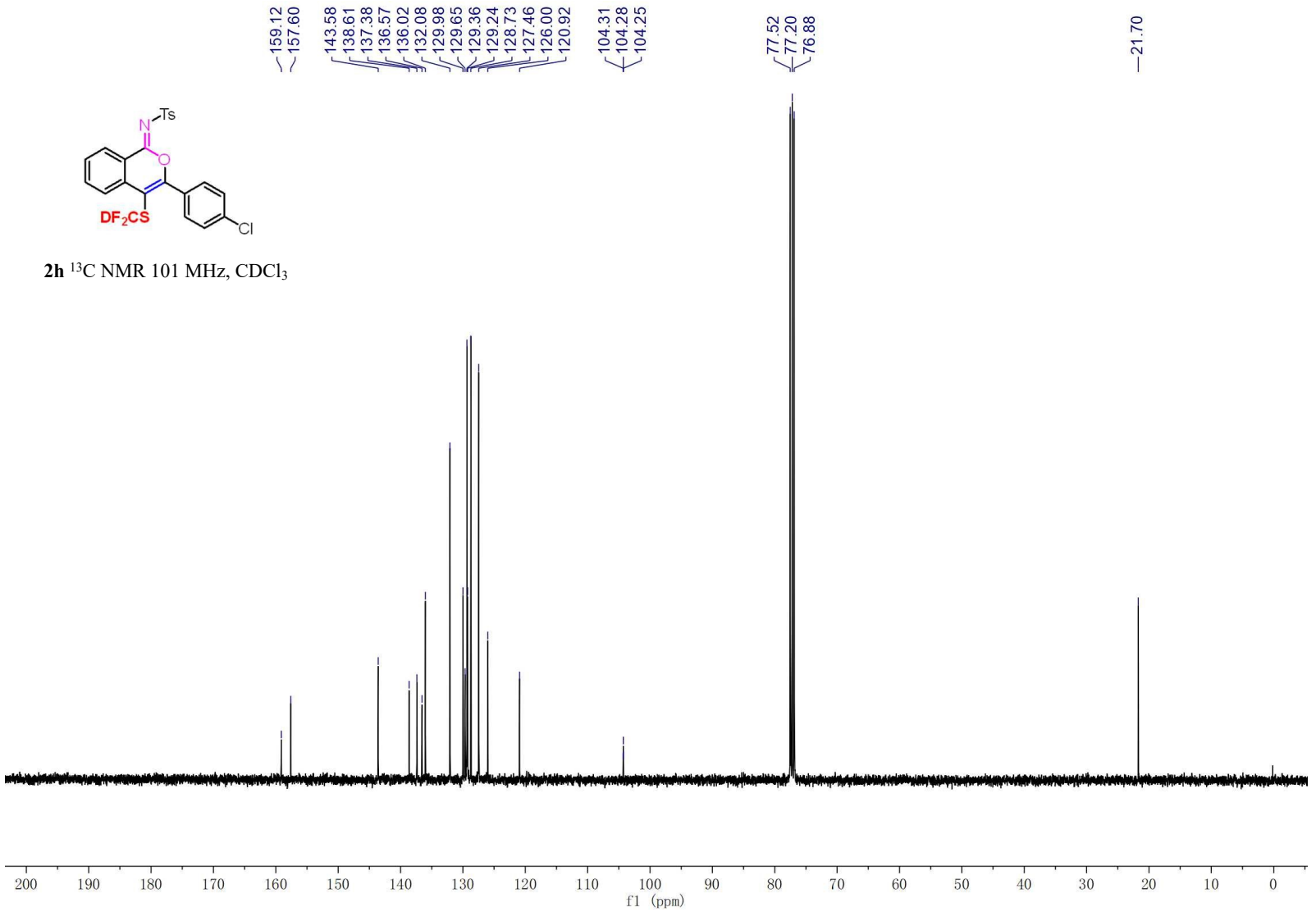
2g ^{13}C NMR 101 MHz, $CDCl_3$



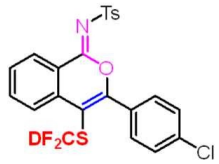
2g ^{19}F NMR 376 MHz, $CDCl_3$



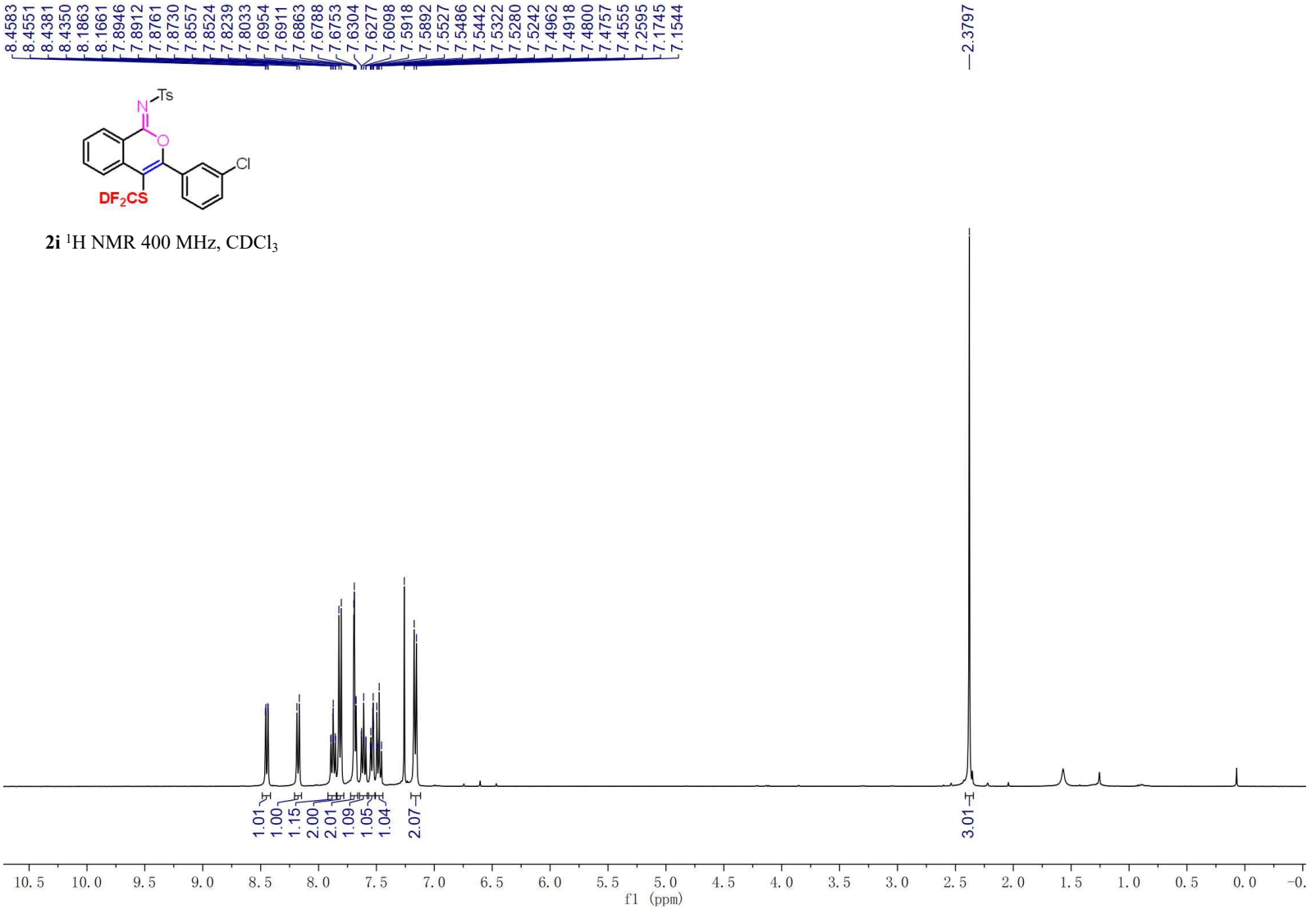
2h ^{1}H NMR 400 MHz, $CDCl_3$



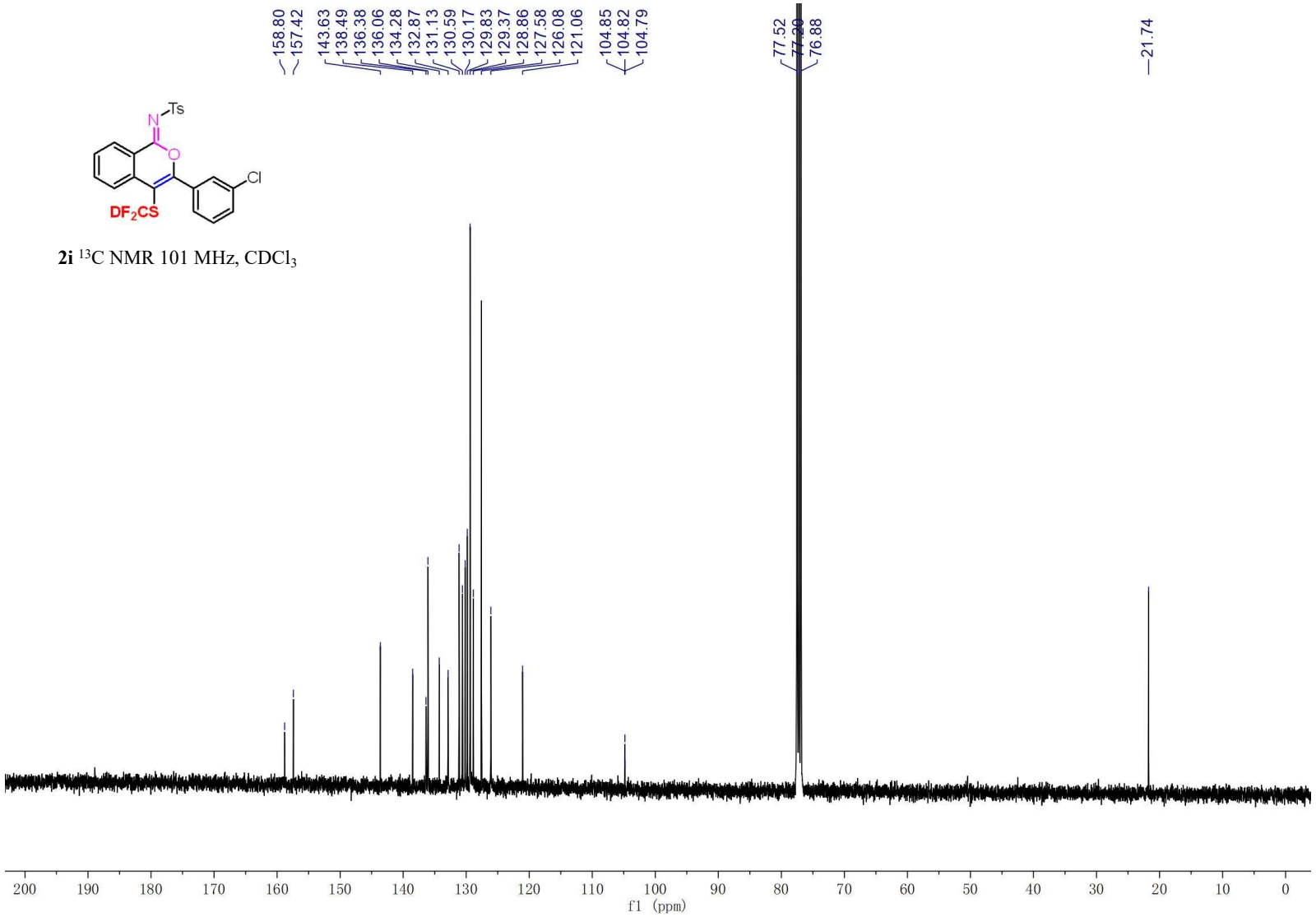
2h ^{13}C NMR 101 MHz, $CDCl_3$



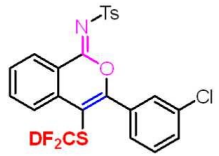
2h ^{19}F NMR 376 MHz, $CDCl_3$



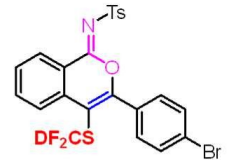
2i ^{1}H NMR 400 MHz, $CDCl_3$



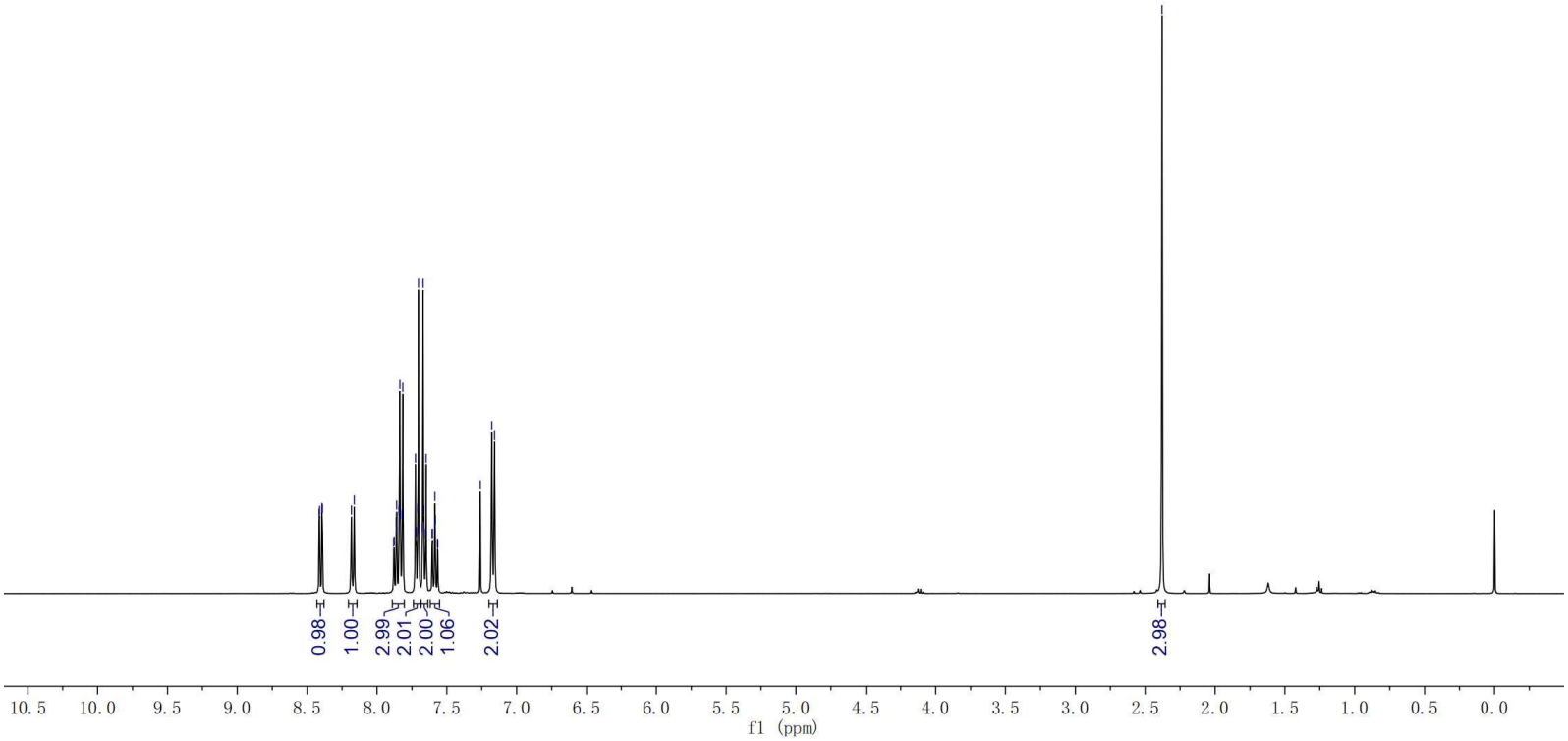
2i ^{13}C NMR 101 MHz, $CDCl_3$

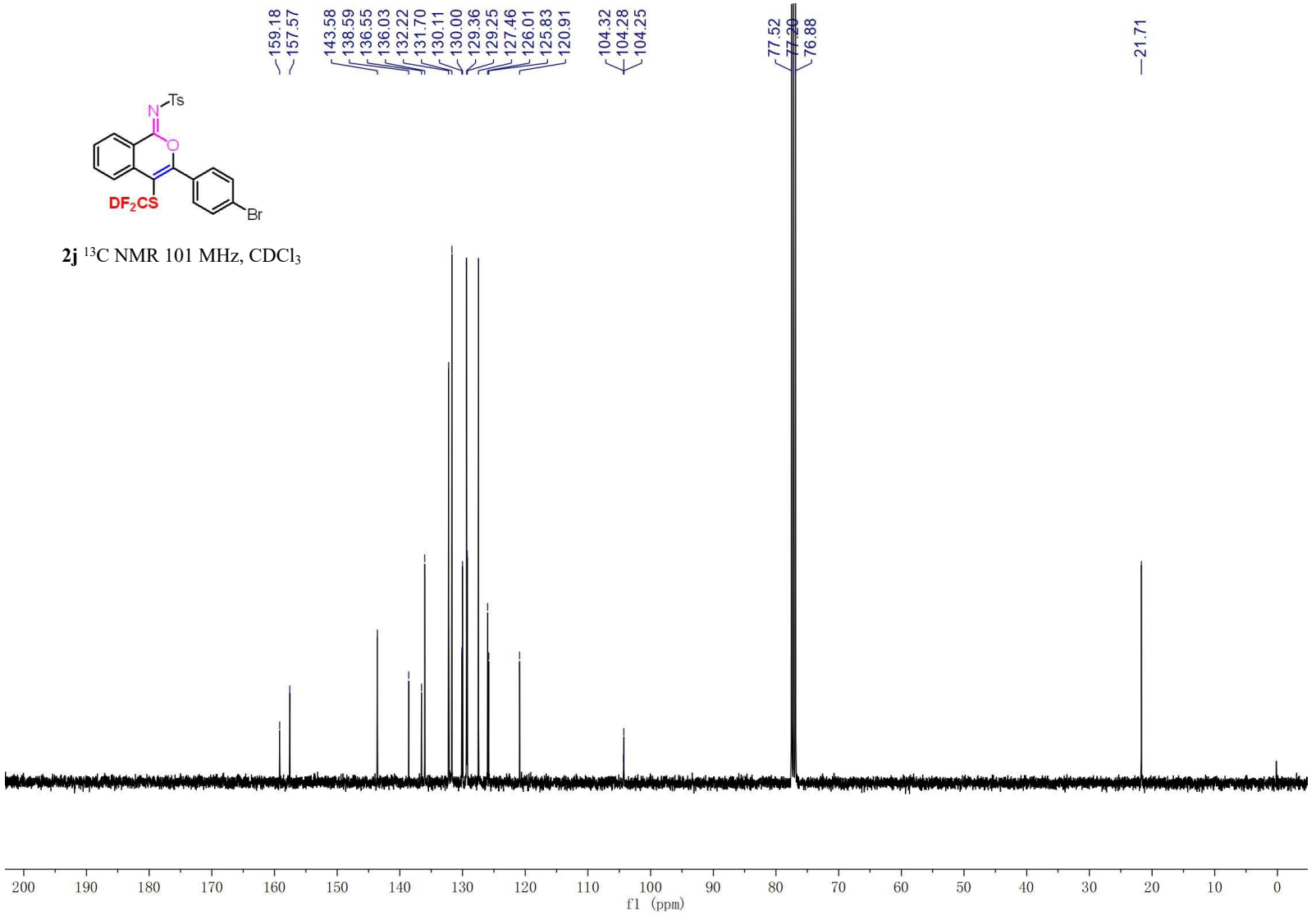


2i ^{19}F NMR 376 MHz, $CDCl_3$

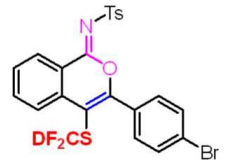


2j ^{1}H NMR 400 MHz, $CDCl_3$

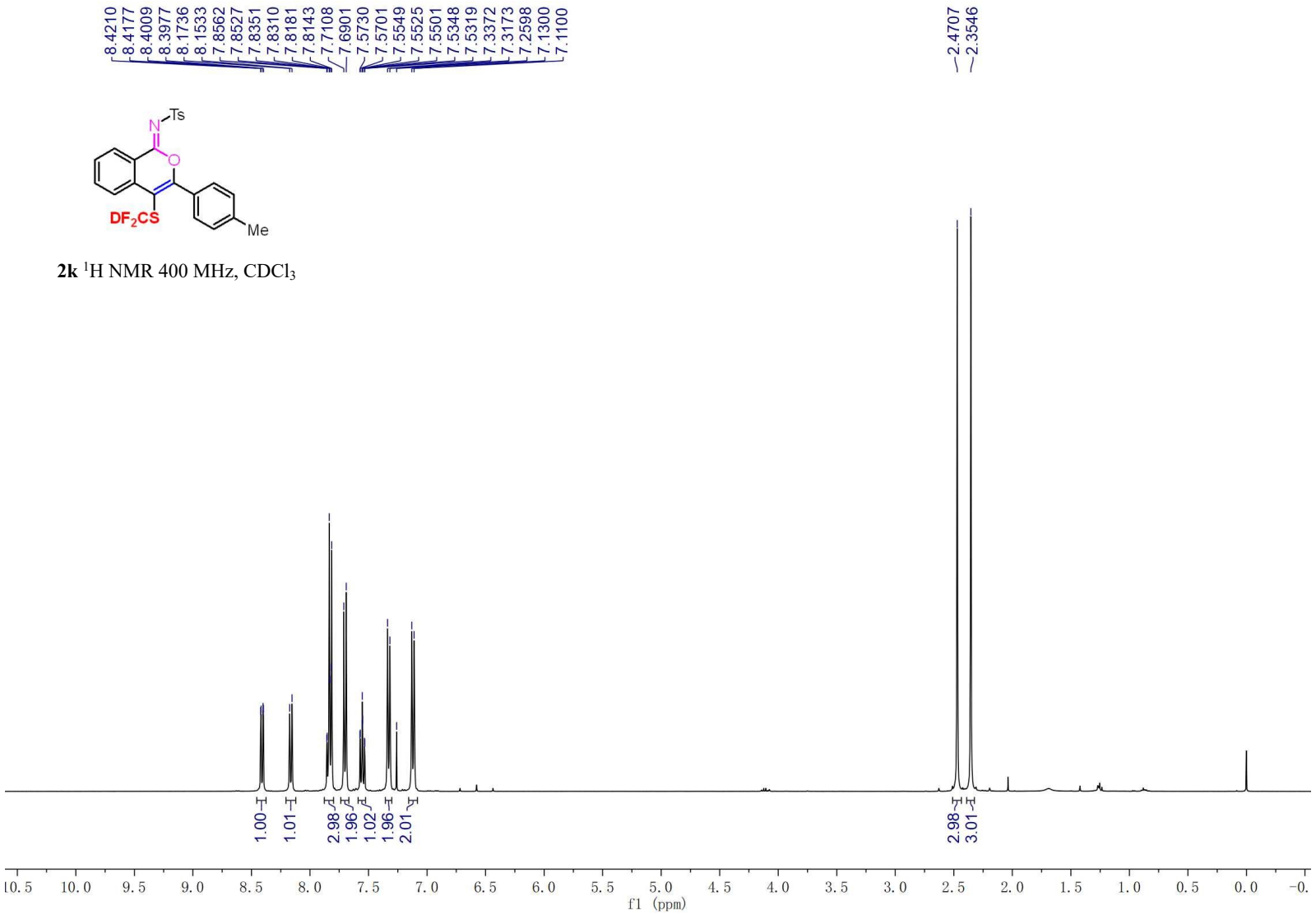




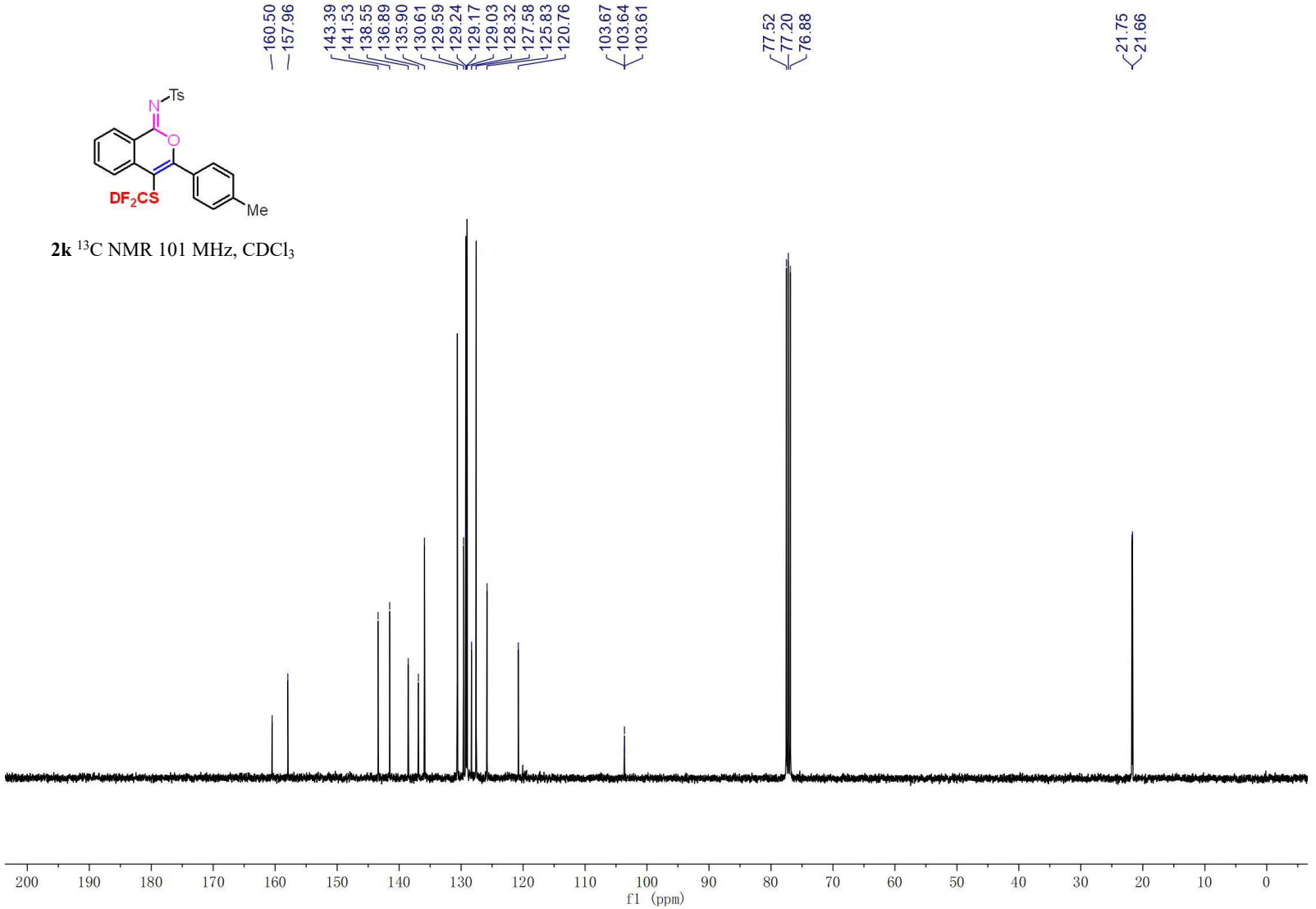
2j ^{13}C NMR 101 MHz, $CDCl_3$



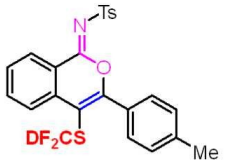
2j ^{19}F NMR 376 MHz, $CDCl_3$



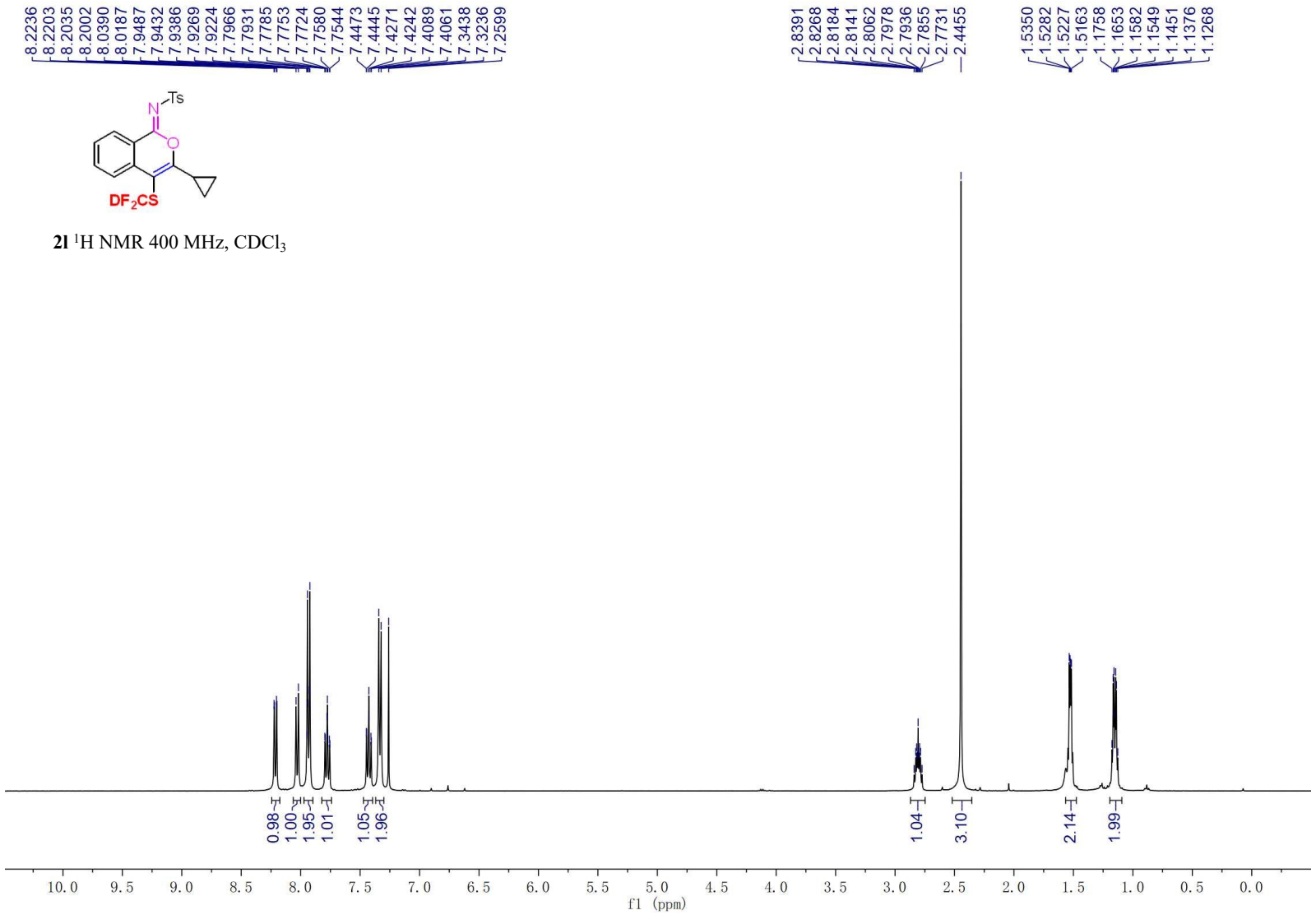
2k ^{1}H NMR 400 MHz, $CDCl_3$



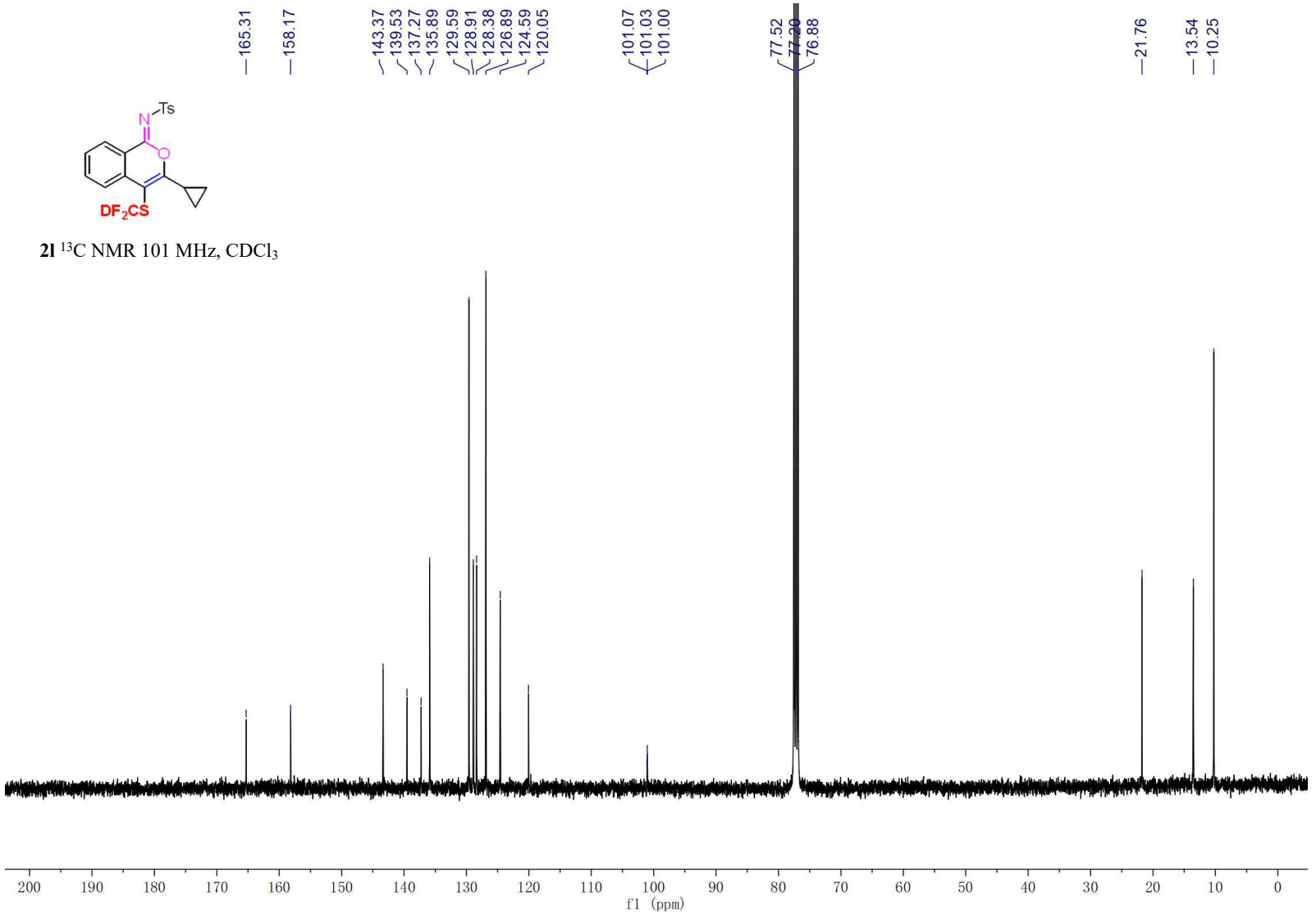
2k ^{13}C NMR 101 MHz, $CDCl_3$



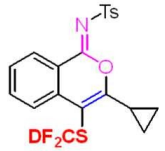
2k ^{19}F NMR 376 MHz, $CDCl_3$



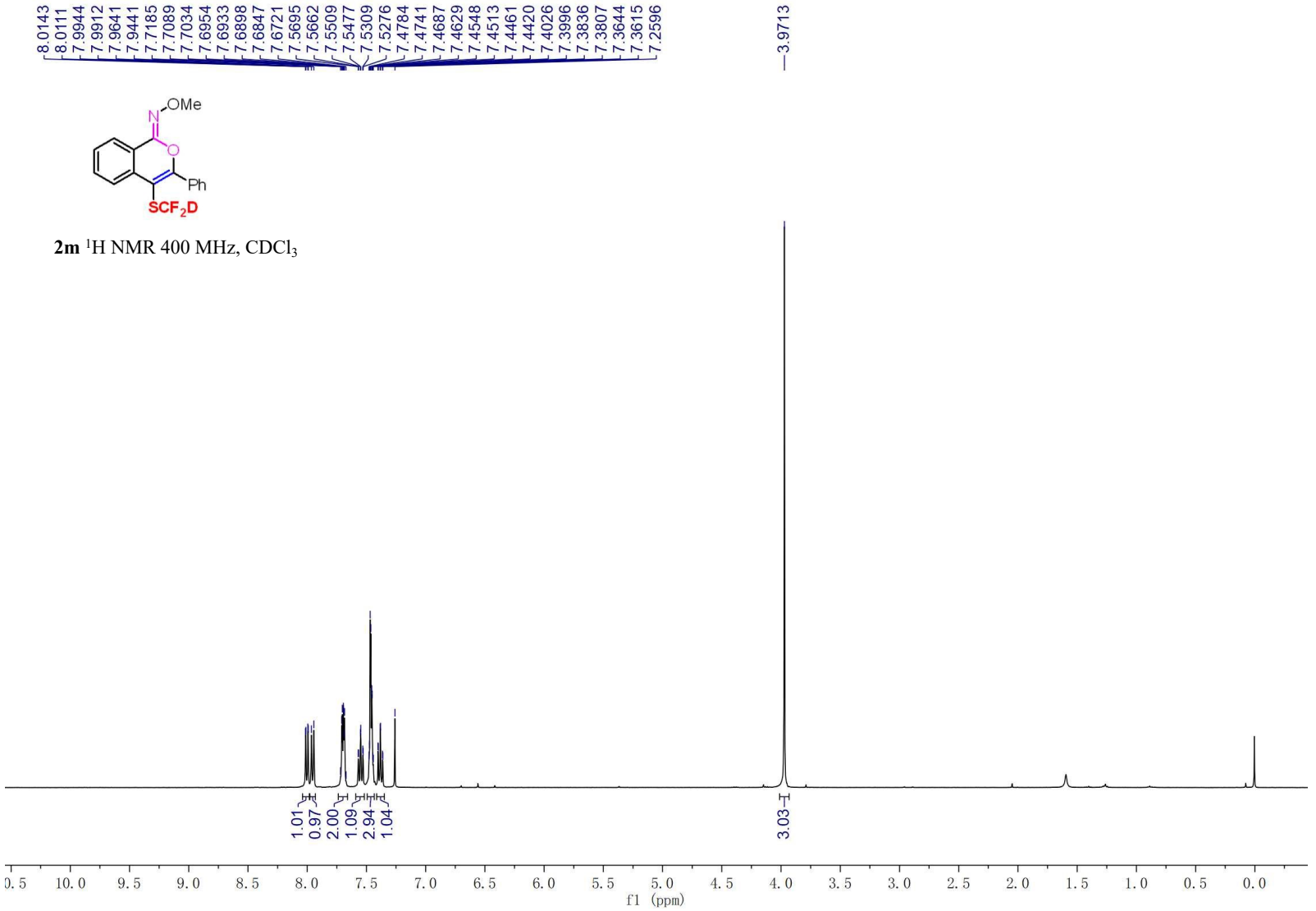
2l ^{1}H NMR 400 MHz, $CDCl_3$



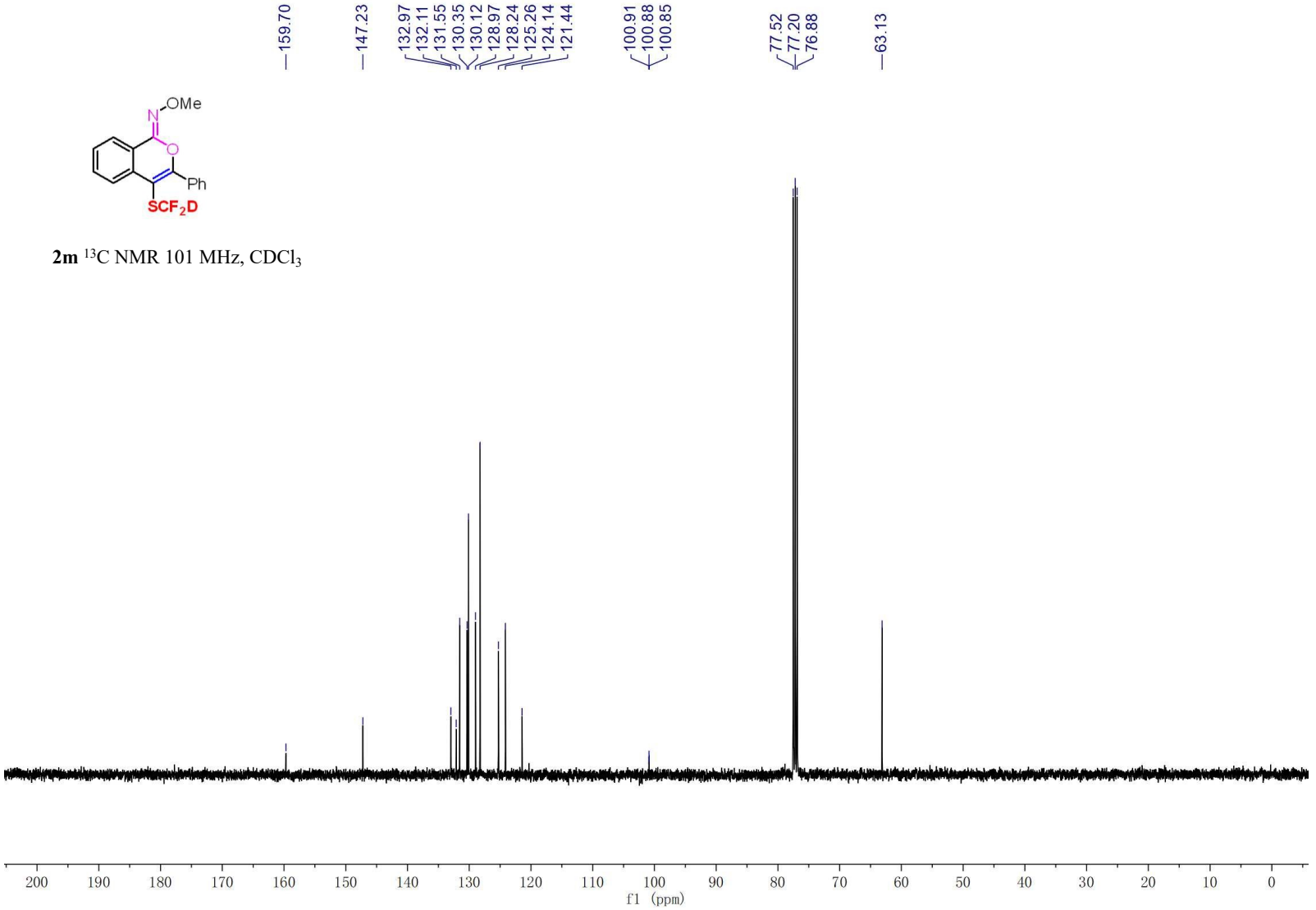
2l ^{13}C NMR 101 MHz, $CDCl_3$



2l ^{19}F NMR 376 MHz, $CDCl_3$

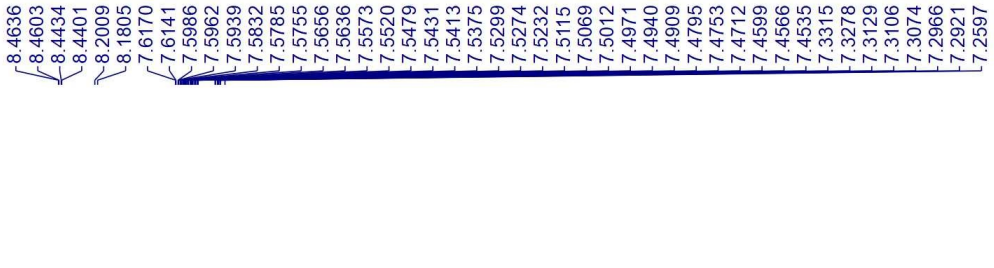


2m ^{1}H NMR 400 MHz, $CDCl_3$

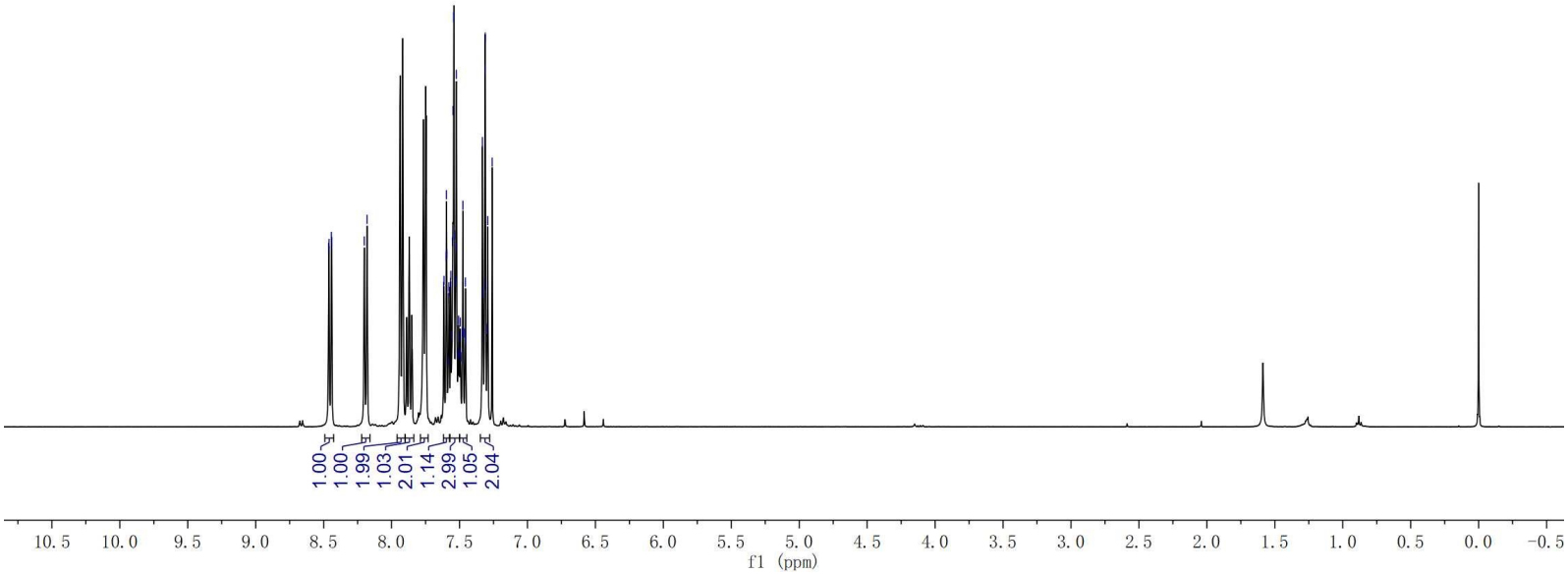


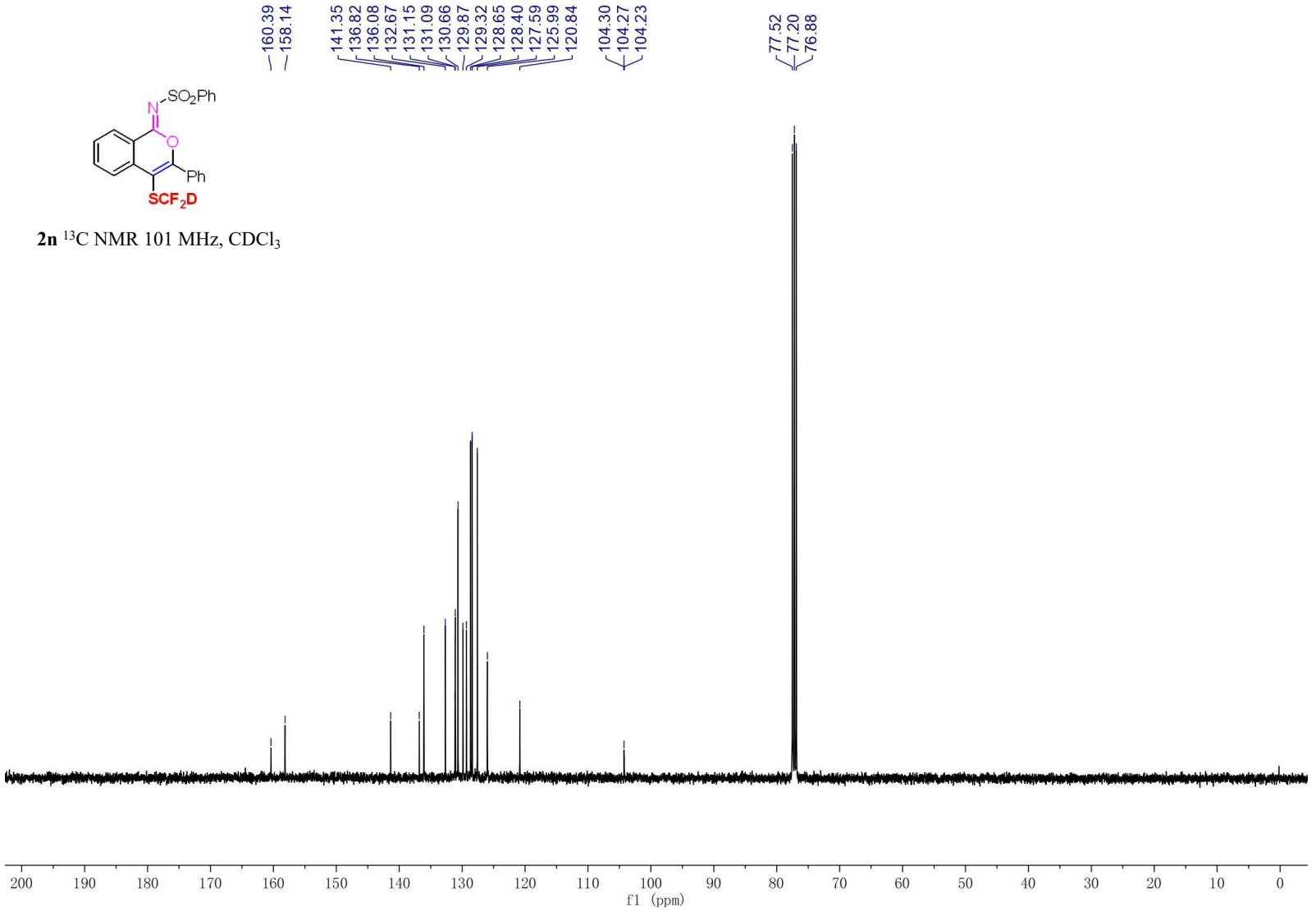
2m ^{13}C NMR 101 MHz, $CDCl_3$

2m ^{19}F NMR 376 MHz, $CDCl_3$



2n ^{1}H NMR 400 MHz, $CDCl_3$

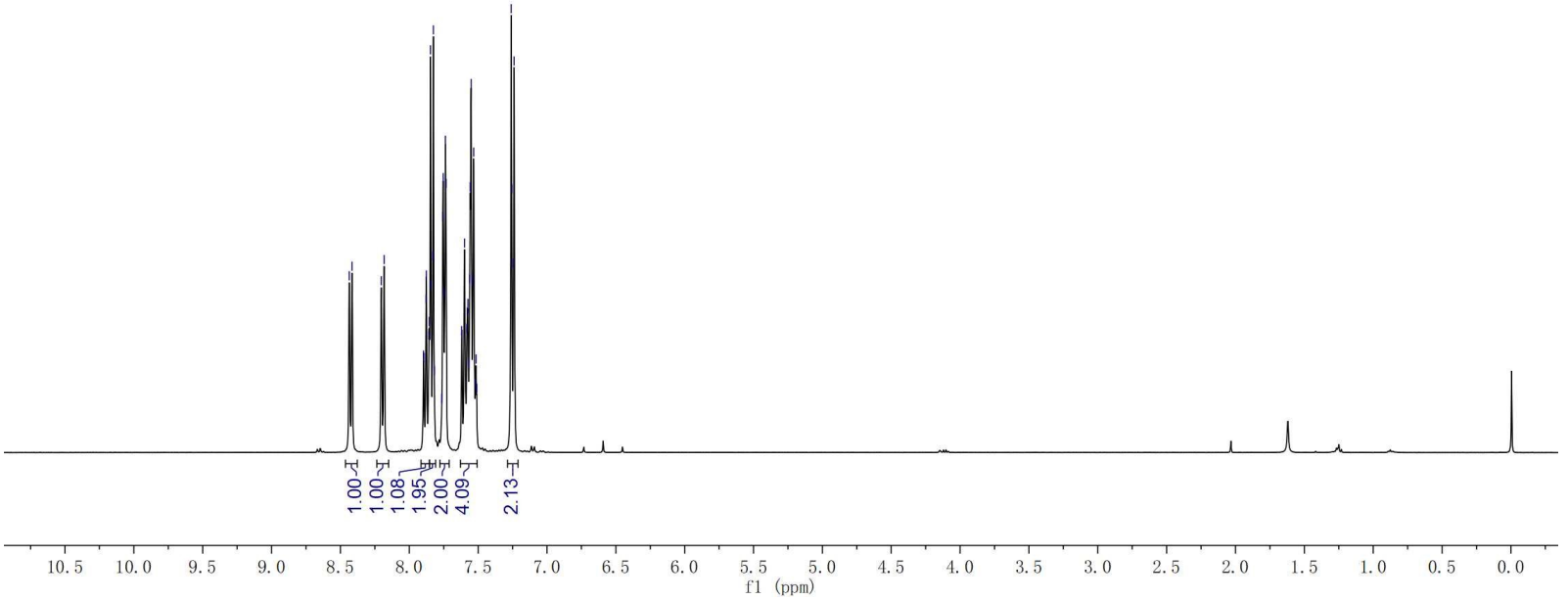


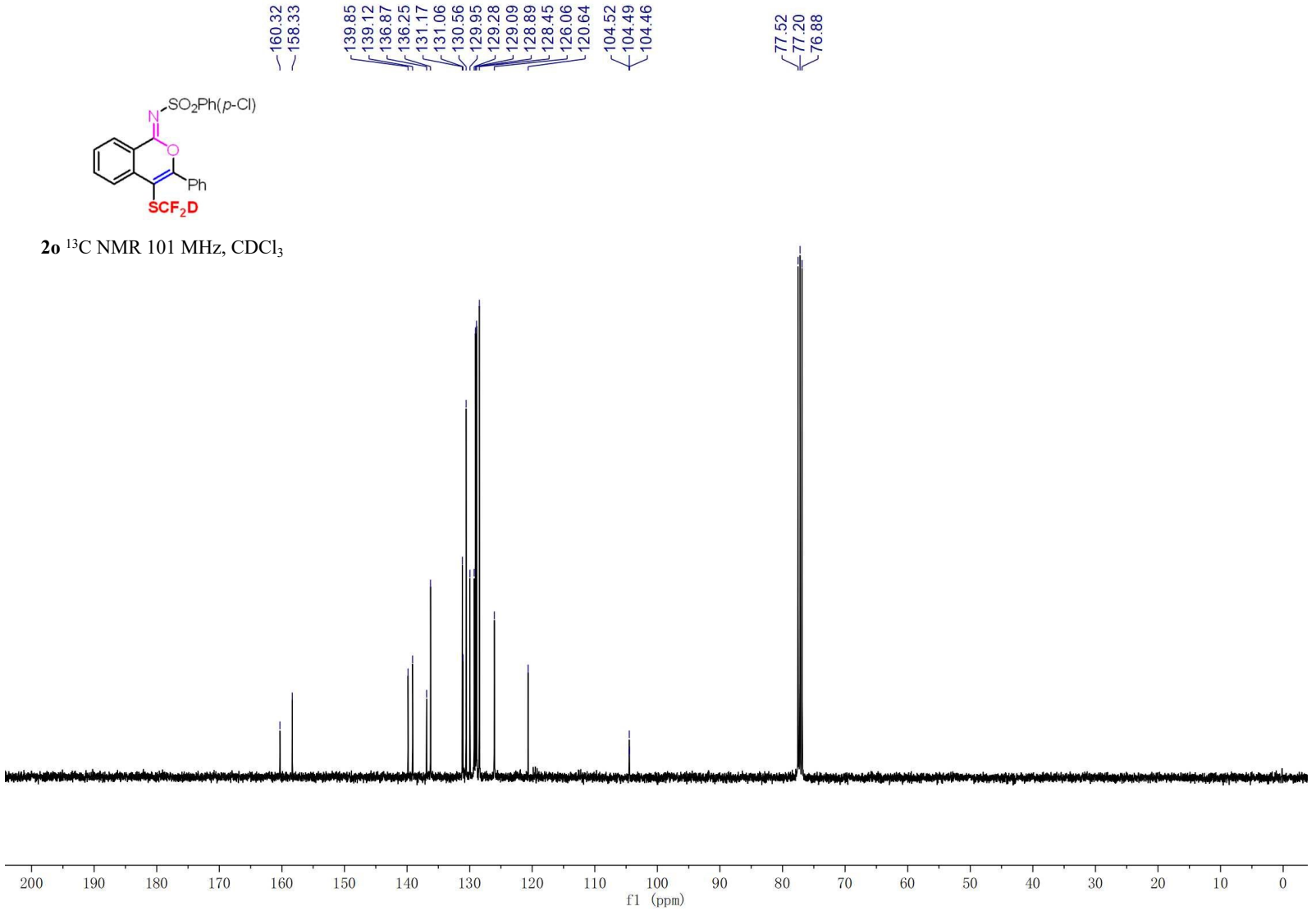


2n ^{13}C NMR 101 MHz, $CDCl_3$

2n ^{19}F NMR 376 MHz, $CDCl_3$

2o ^{1}H NMR 400 MHz, $CDCl_3$

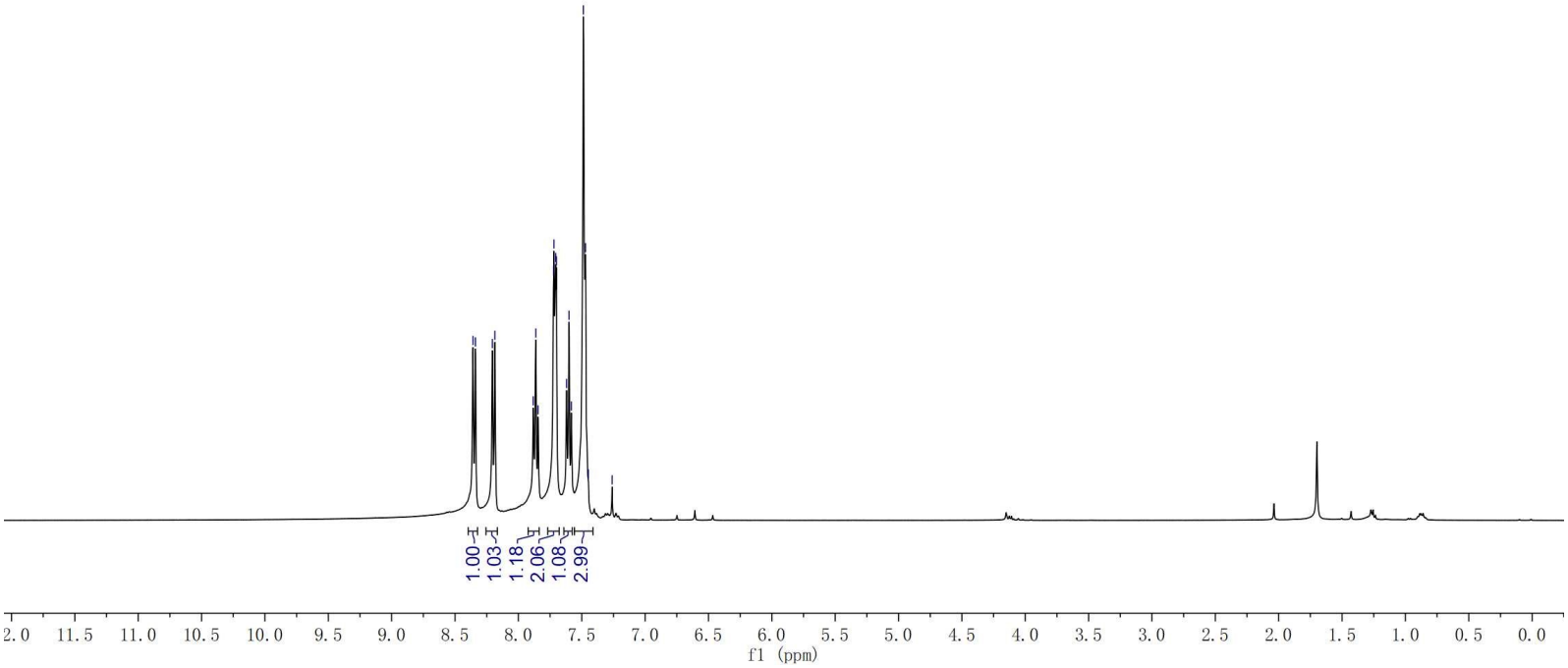


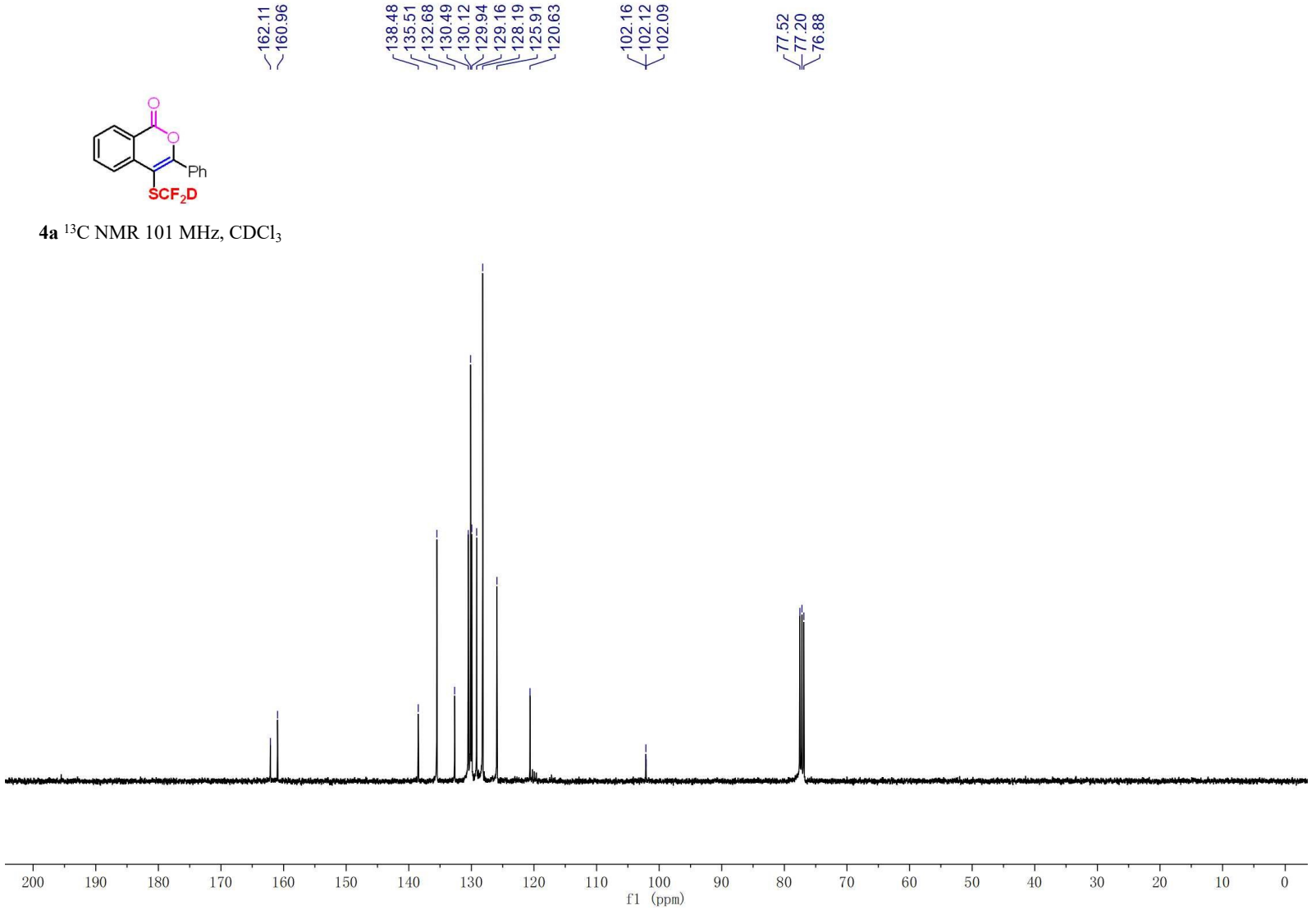


2o ^{13}C NMR 101 MHz, $CDCl_3$

2o ^{19}F NMR 376 MHz, $CDCl_3$

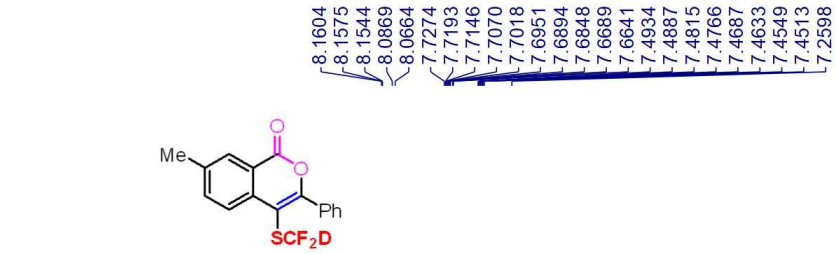
4a ^{1}H NMR 400 MHz, $CDCl_3$



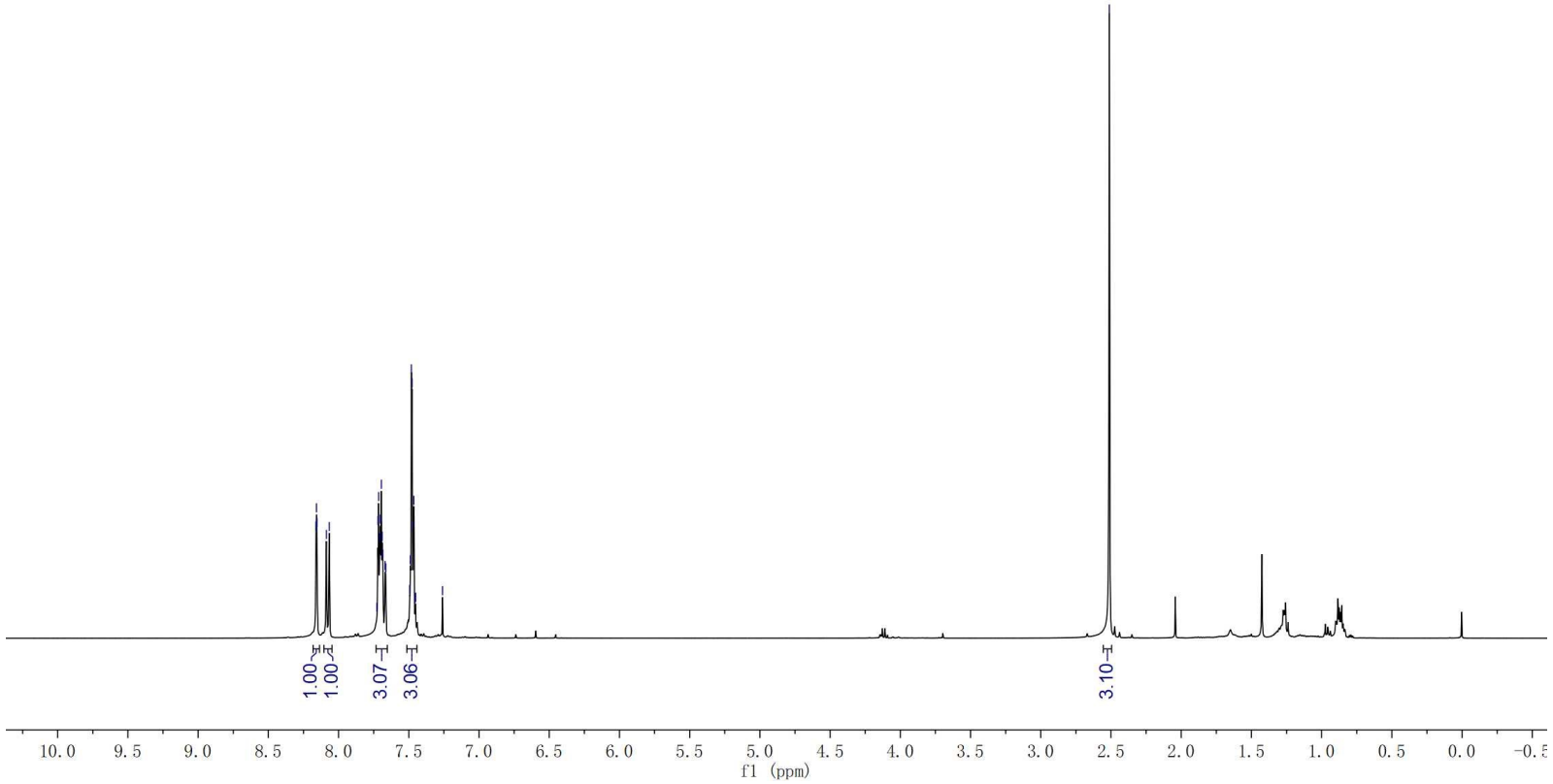


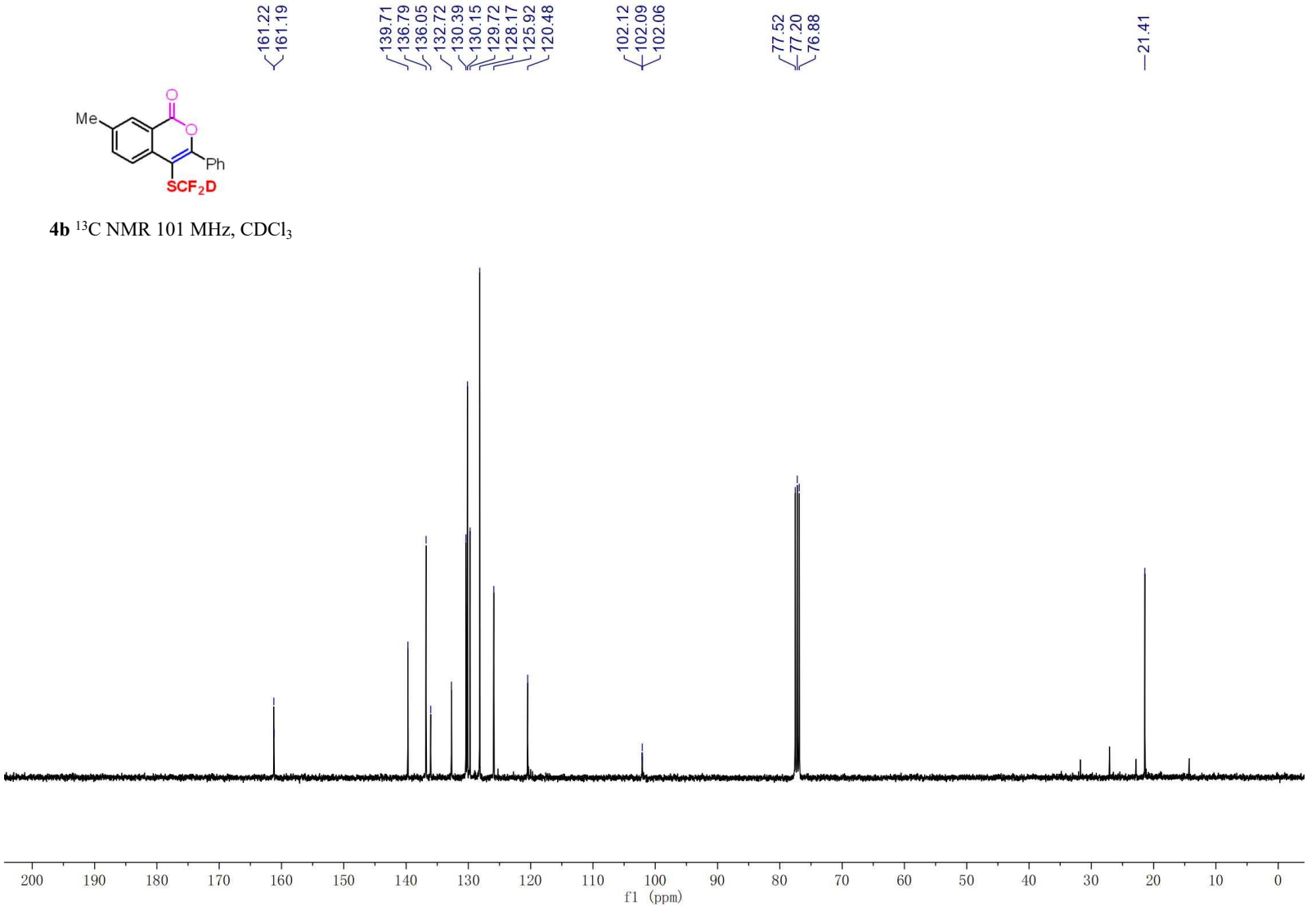
4a ^{13}C NMR 101 MHz, $CDCl_3$

4a ^{19}F NMR 376 MHz, $CDCl_3$



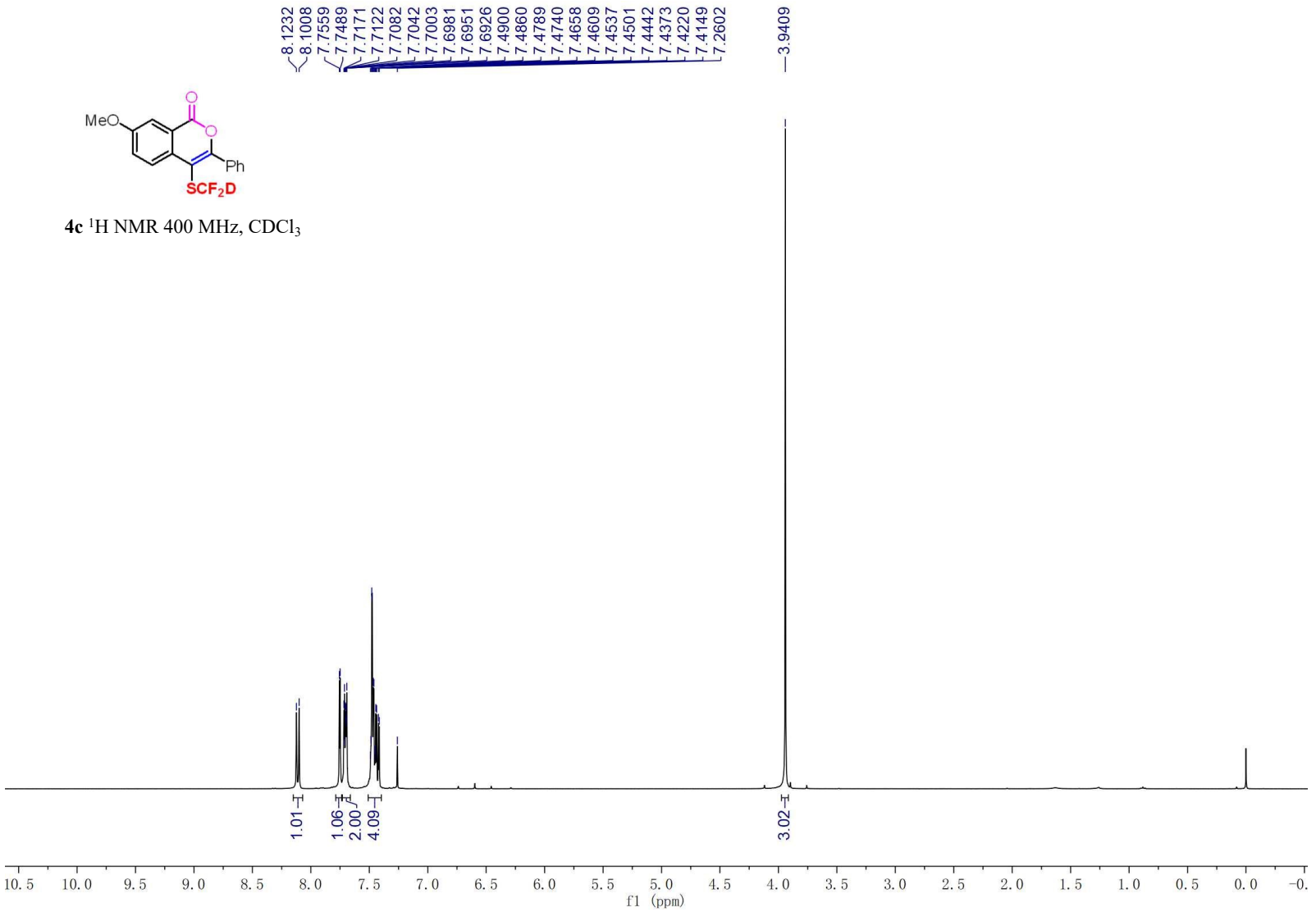
4b ^{1}H NMR 400 MHz, $CDCl_3$



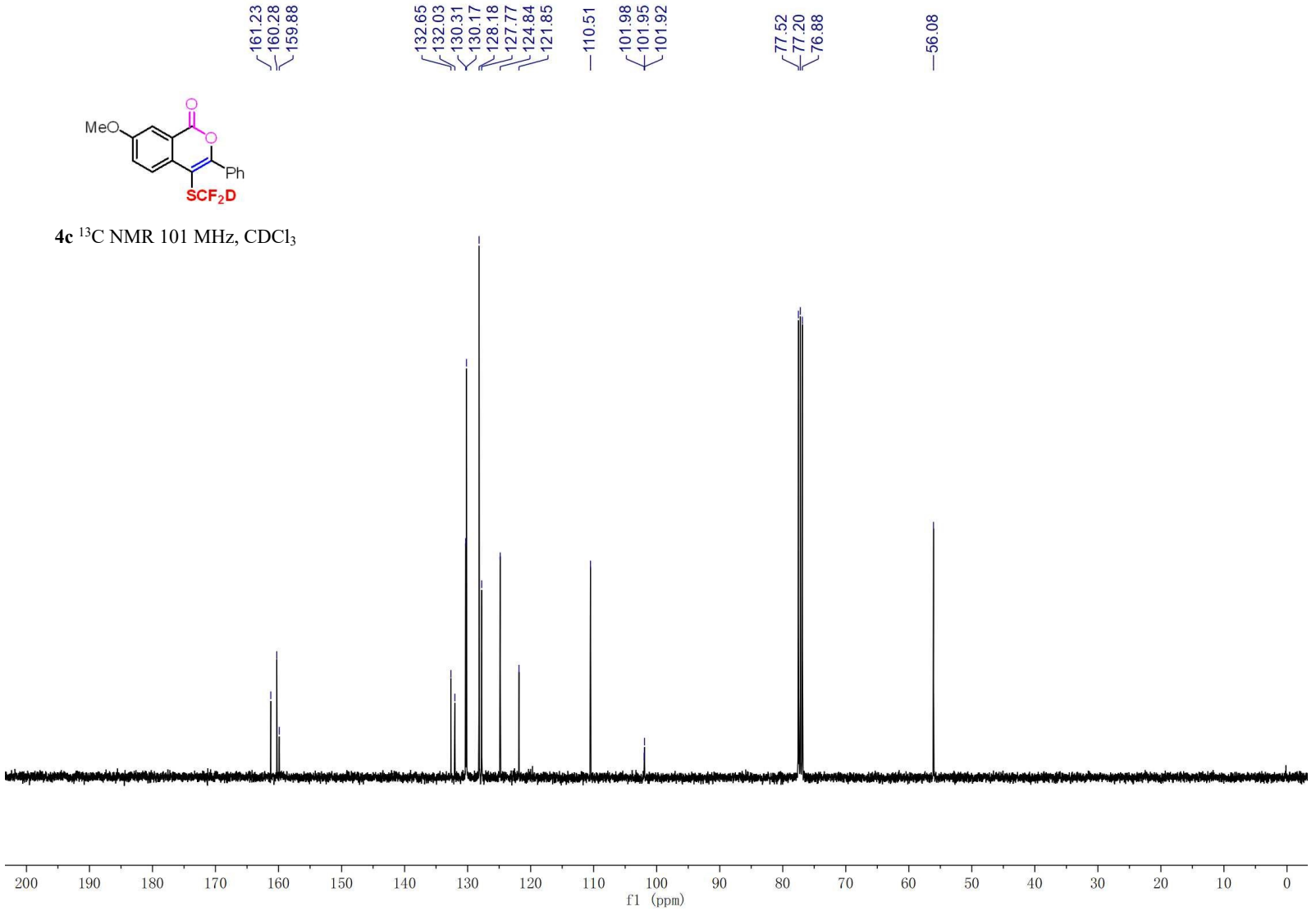


4b ^{13}C NMR 101 MHz, $CDCl_3$

4b ^{19}F NMR 376 MHz, $CDCl_3$

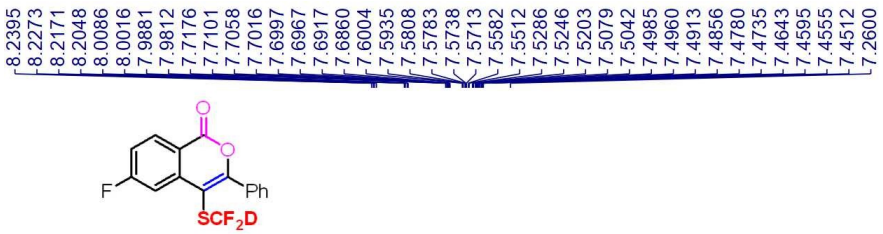


4c ^{1}H NMR 400 MHz, $CDCl_3$

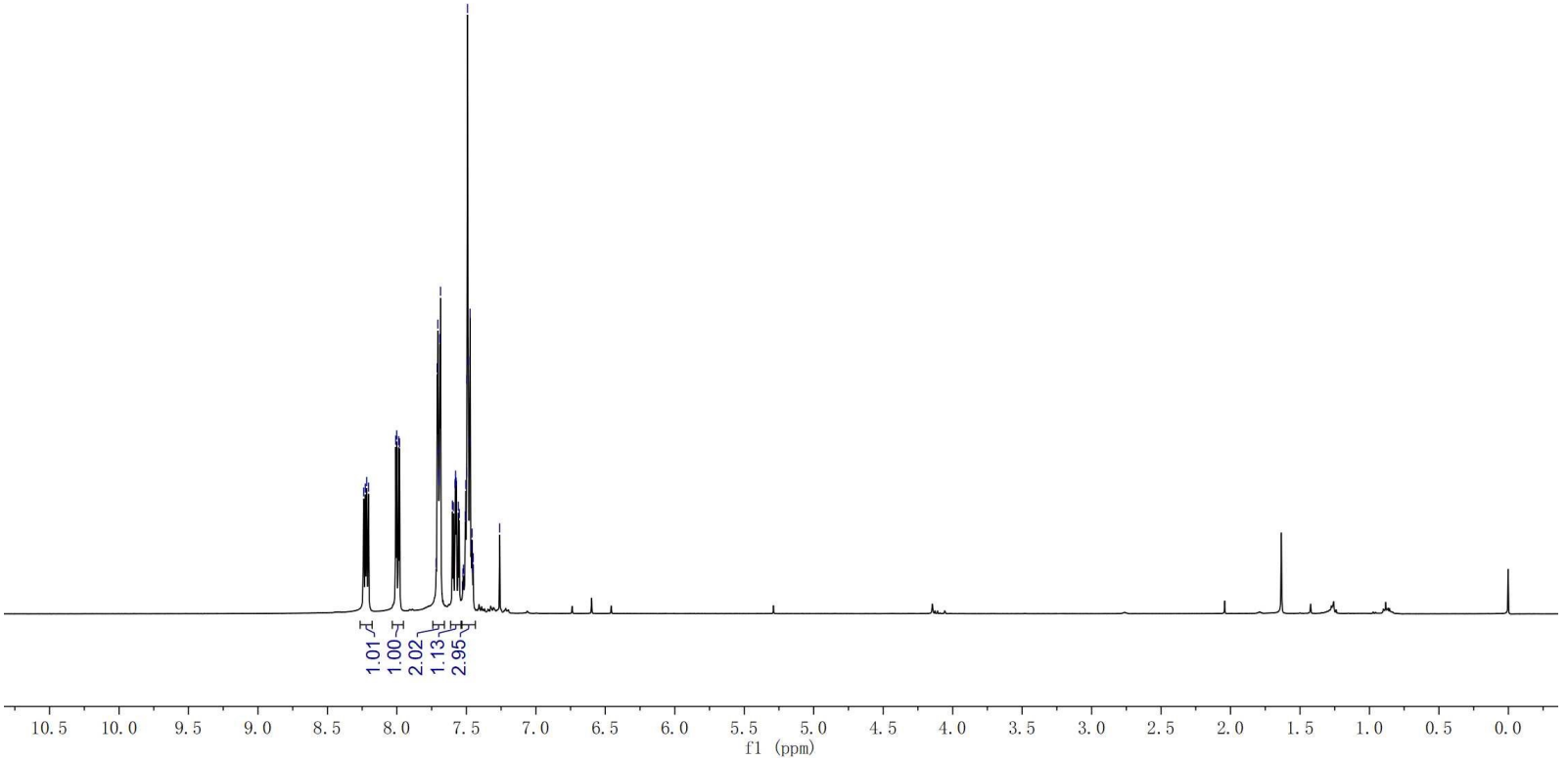


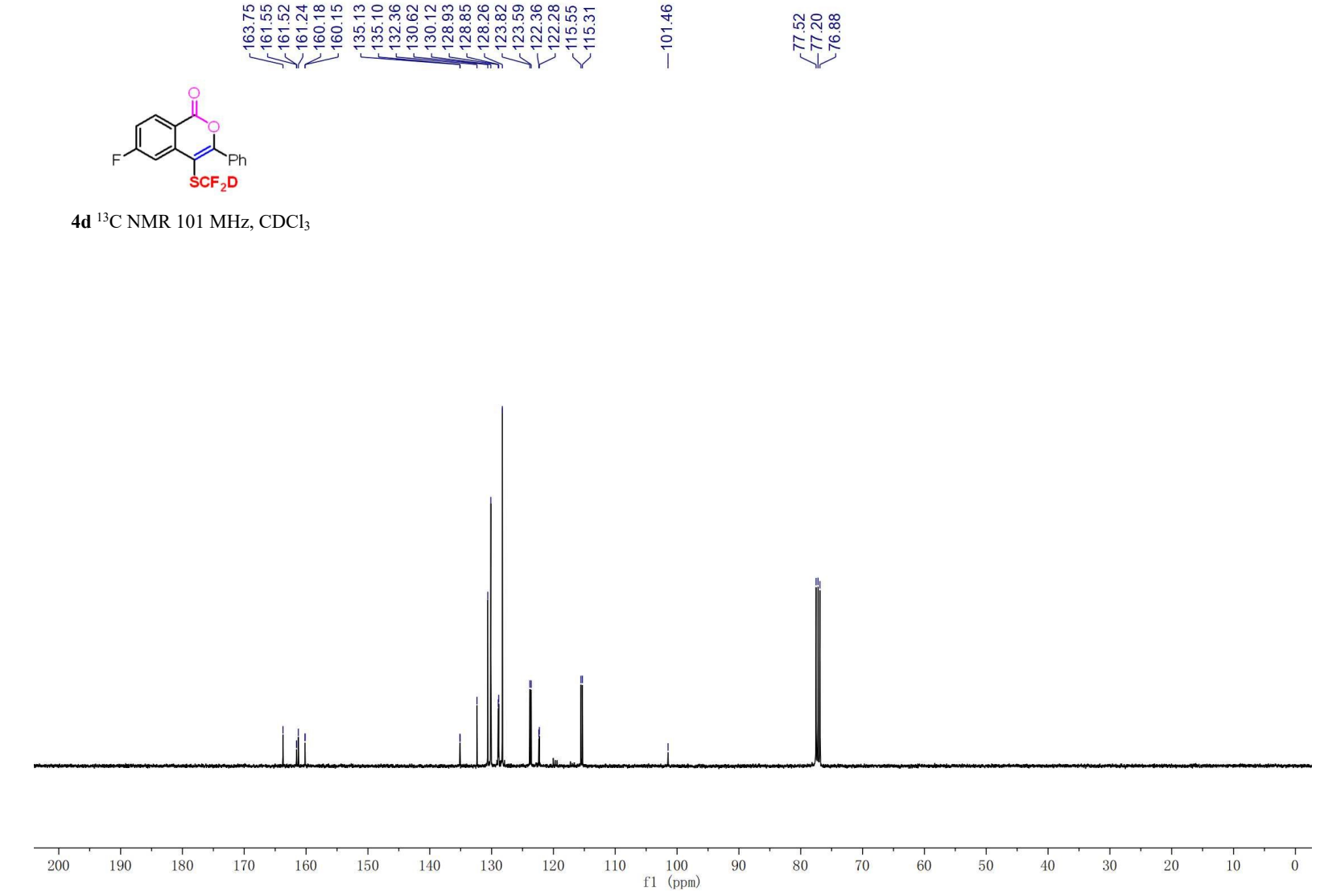
4c ^{13}C NMR 101 MHz, $CDCl_3$

4c ^{19}F NMR 376 MHz, $CDCl_3$



4d ^{1}H NMR 400 MHz, $CDCl_3$

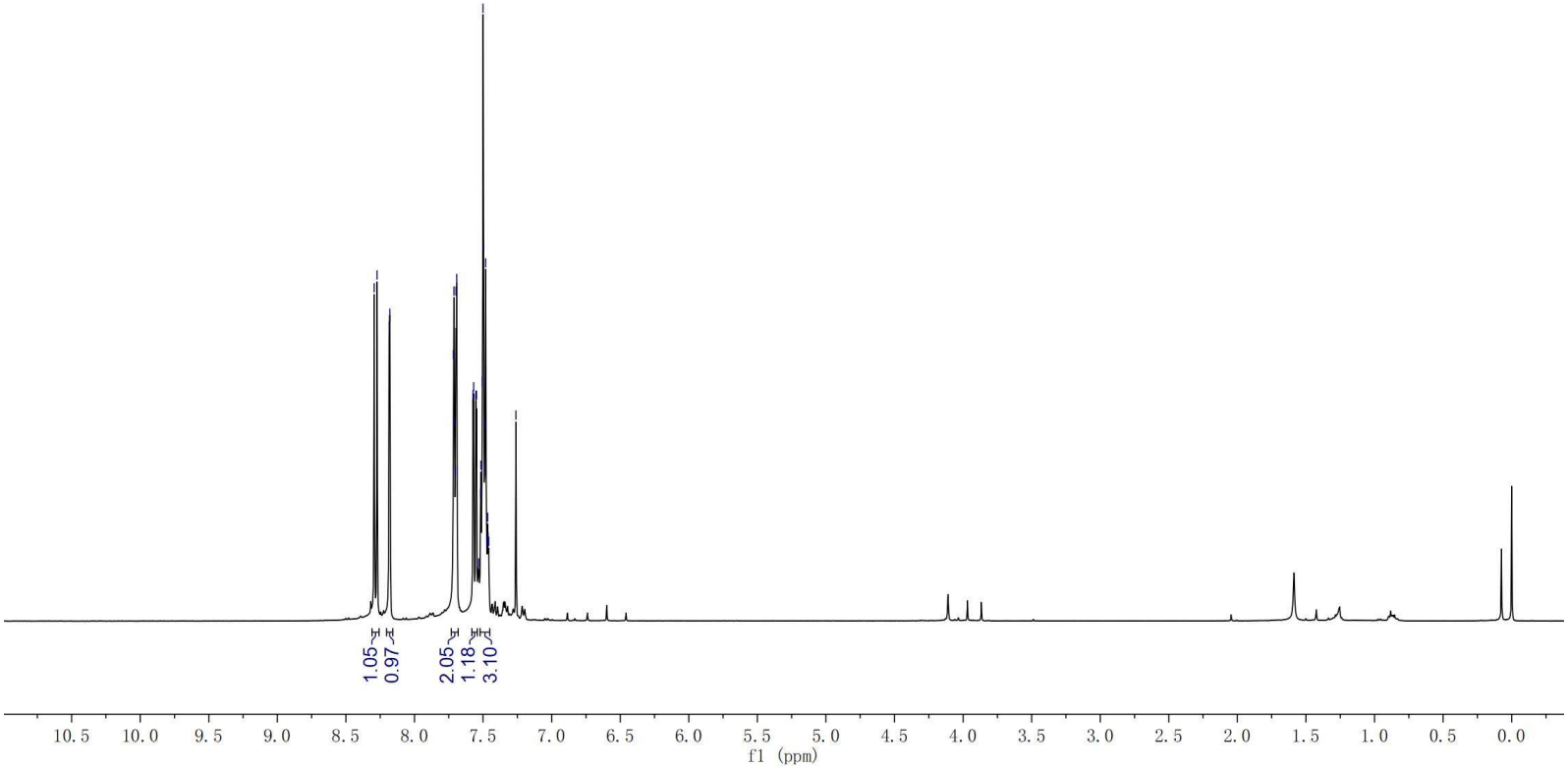


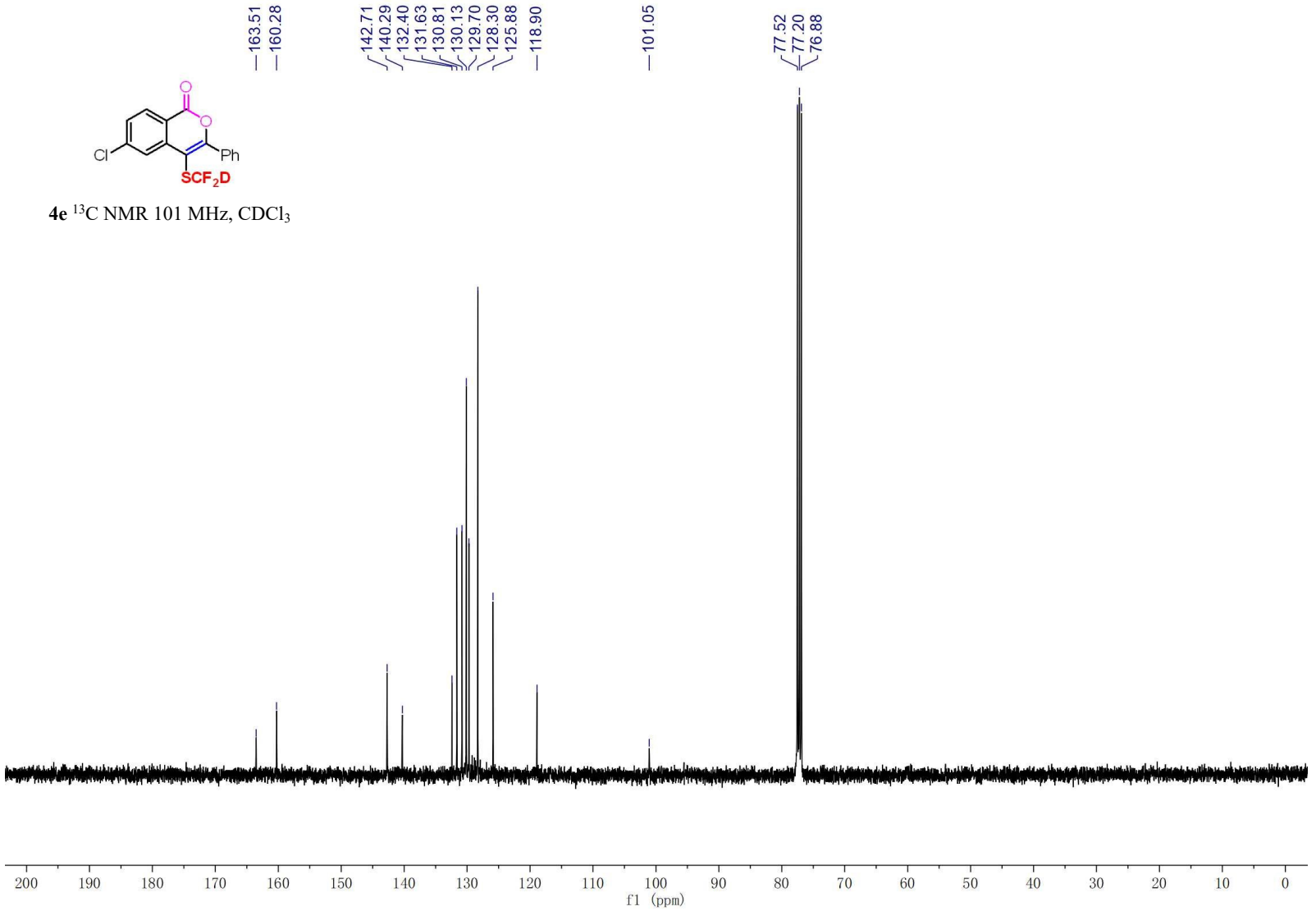


4d ^{13}C NMR 101 MHz, $CDCl_3$

4d ^{19}F NMR 376 MHz, $CDCl_3$

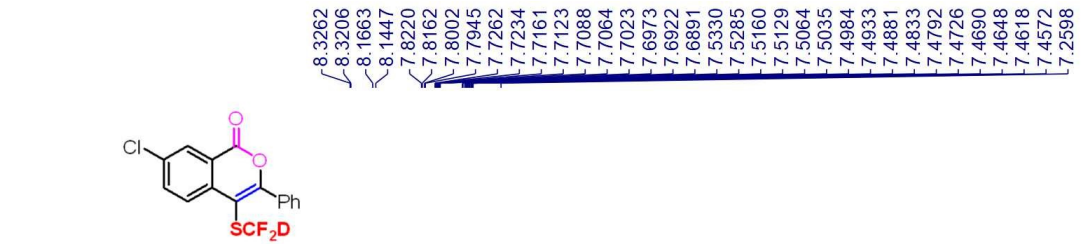
4e ^{1}H NMR 400 MHz, $CDCl_3$



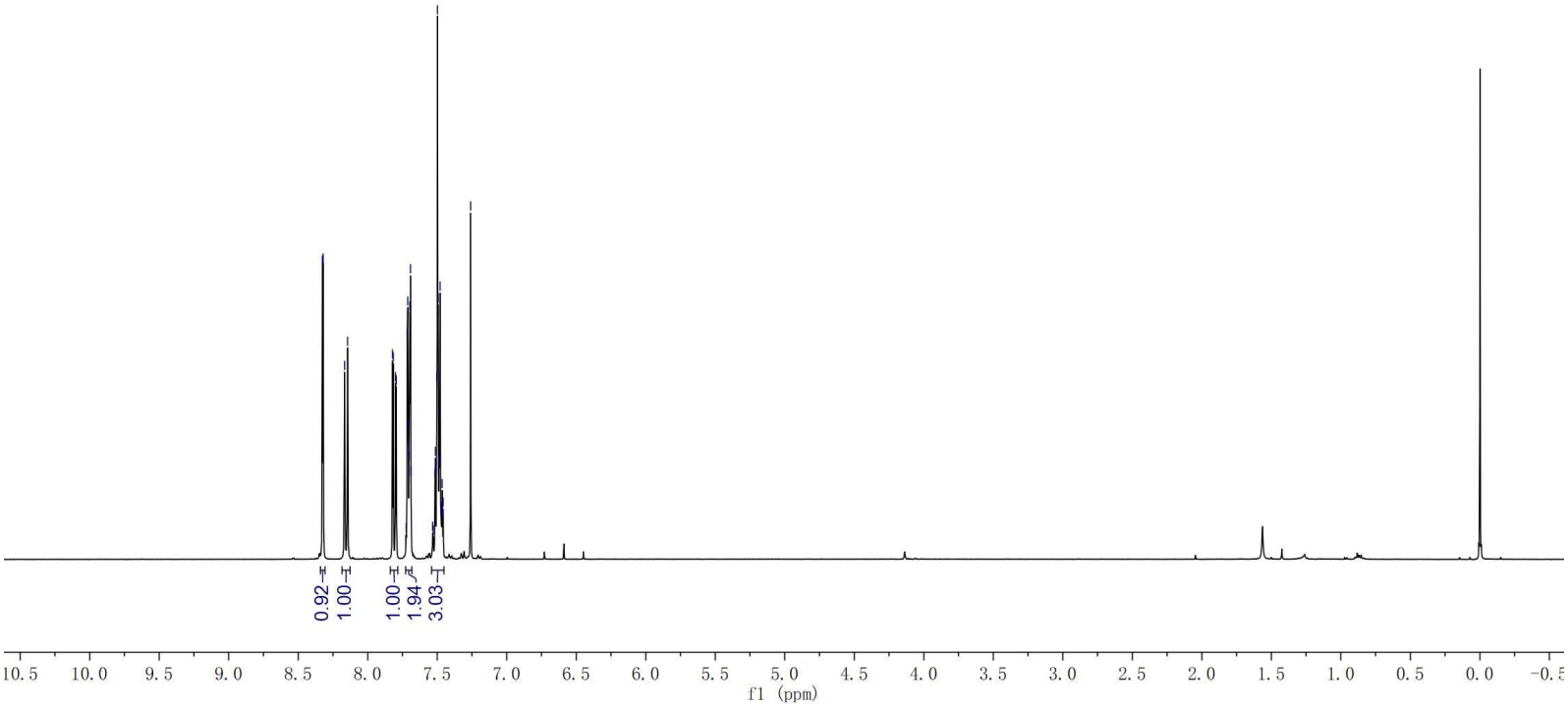


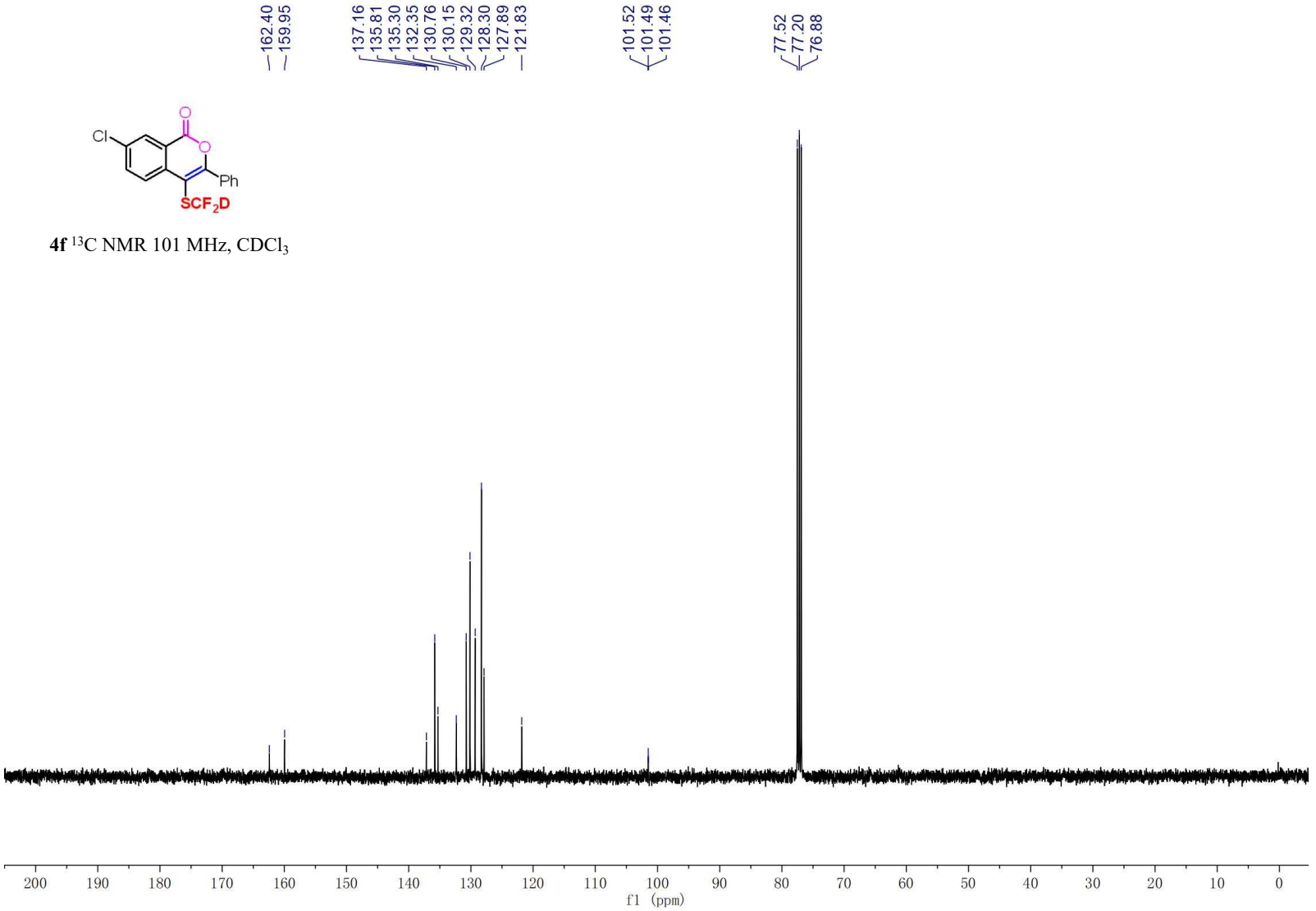
4e ^{13}C NMR 101 MHz, $CDCl_3$

4e ^{19}F NMR 376 MHz, $CDCl_3$



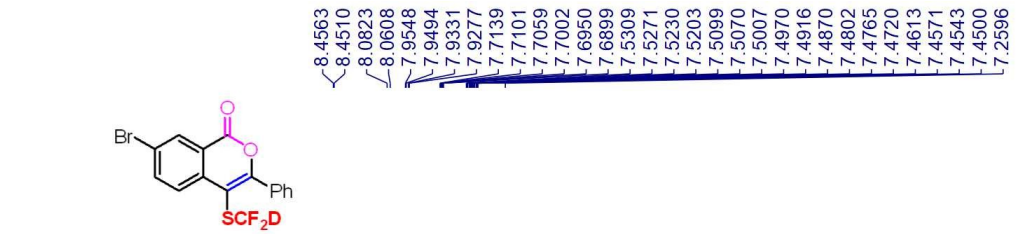
4f ^{1}H NMR 400 MHz, $CDCl_3$



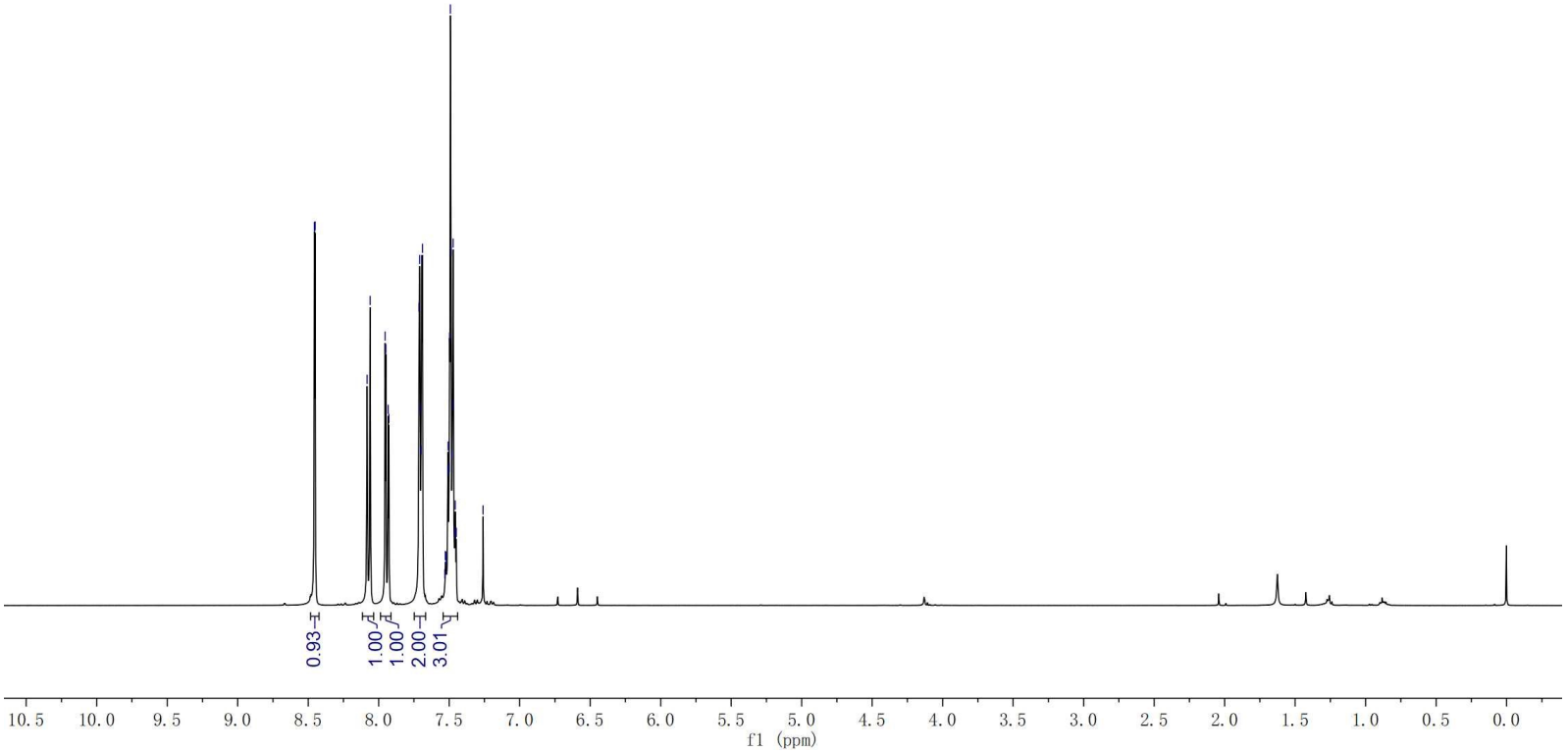


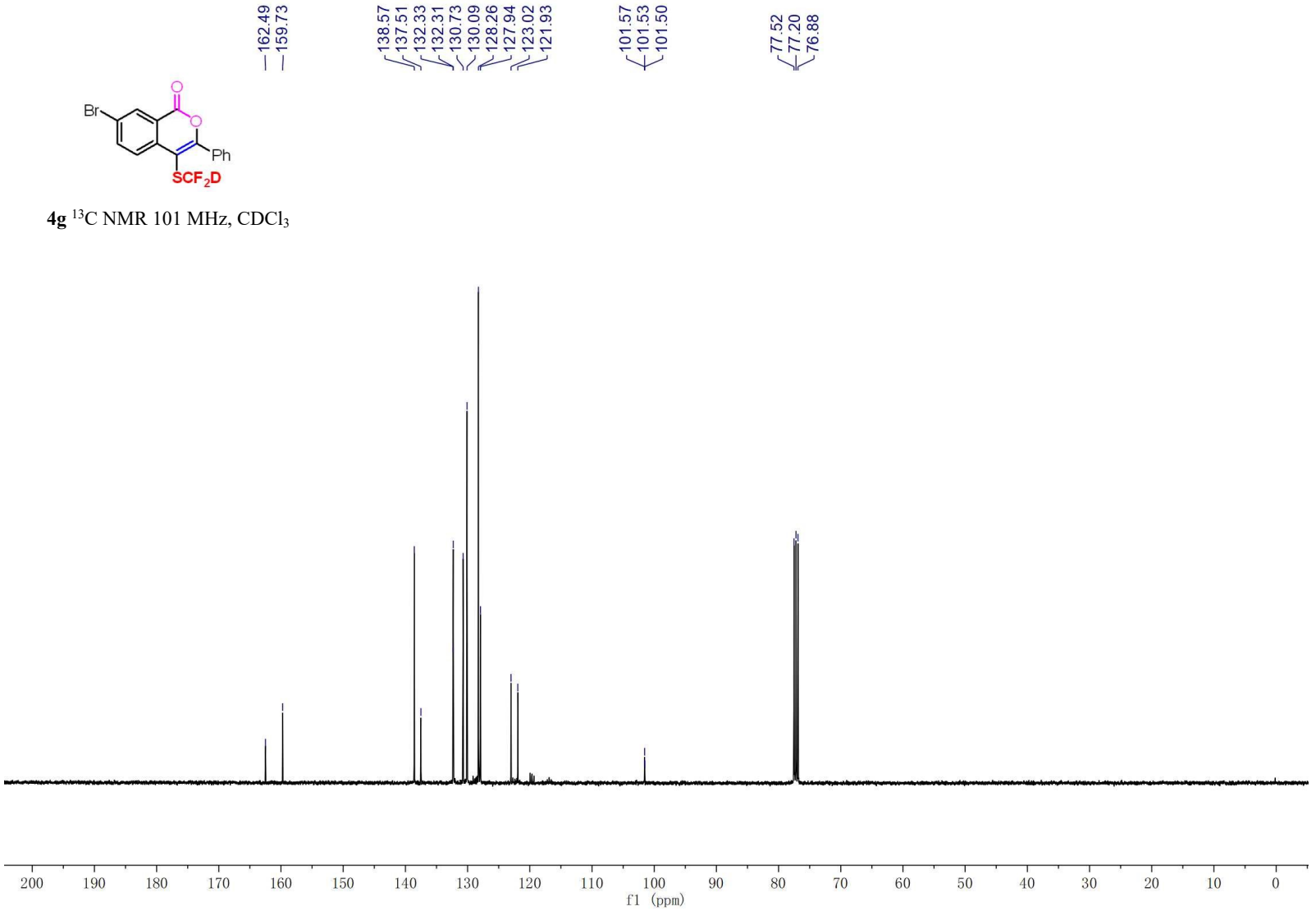
4f ^{13}C NMR 101 MHz, $CDCl_3$

4f ^{19}F NMR 376 MHz, $CDCl_3$



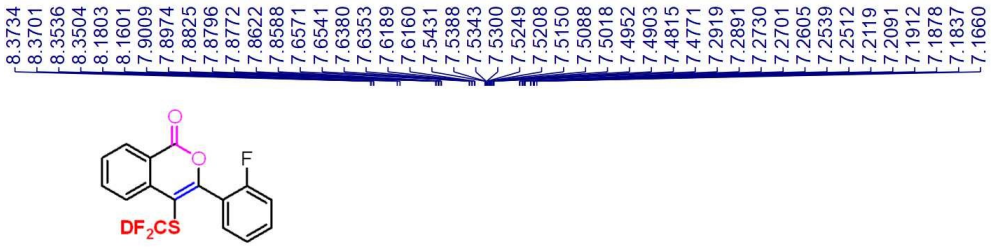
4g ^{1}H NMR 400 MHz, $CDCl_3$



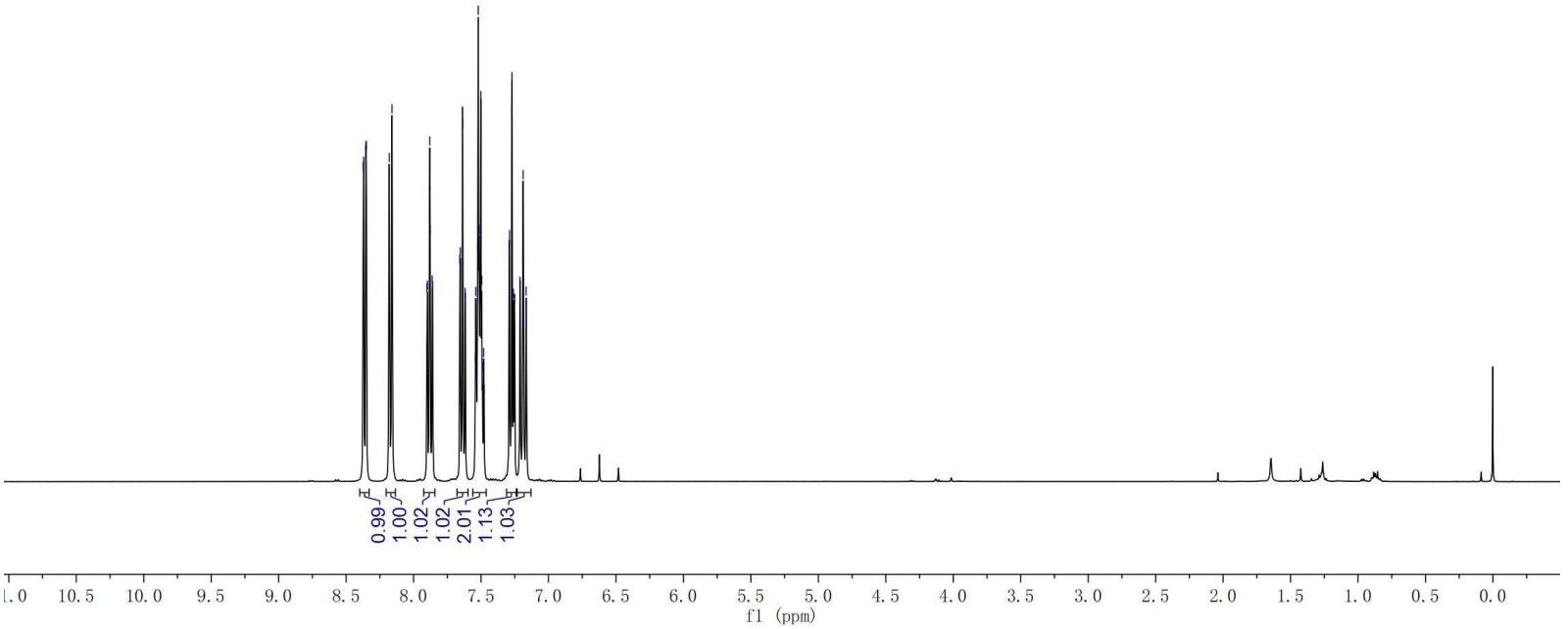


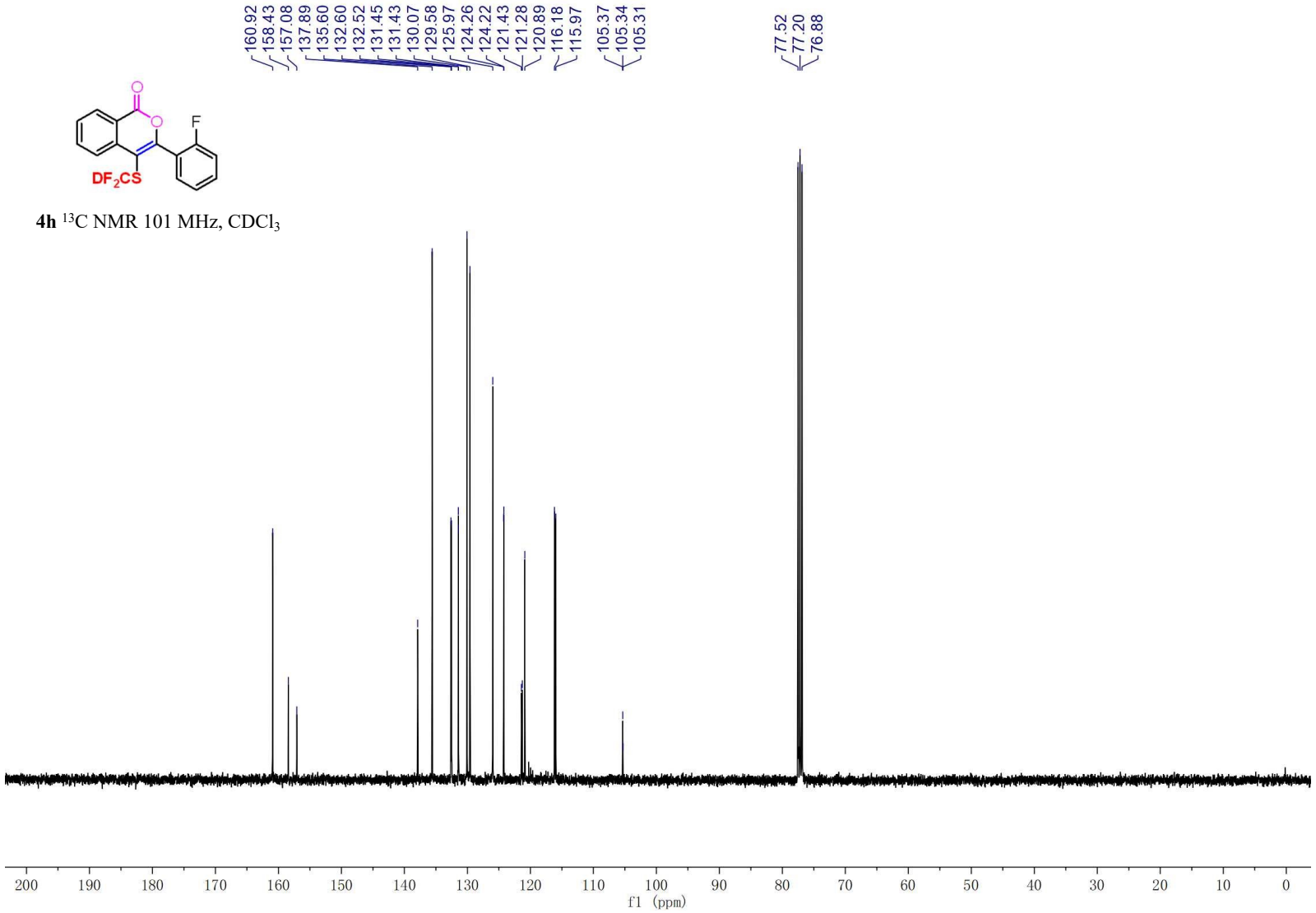
4g ^{13}C NMR 101 MHz, $CDCl_3$

4g ^{19}F NMR 376 MHz, $CDCl_3$

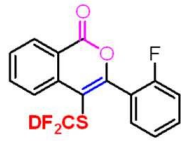


4h ^{1}H NMR 400 MHz, $CDCl_3$

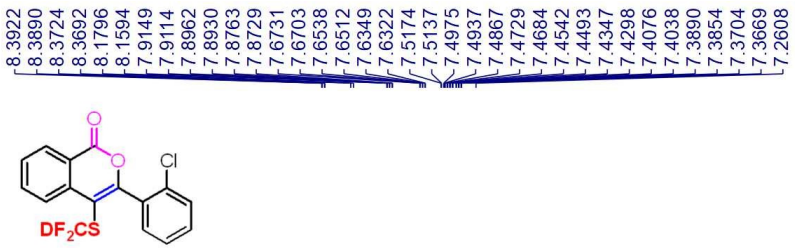




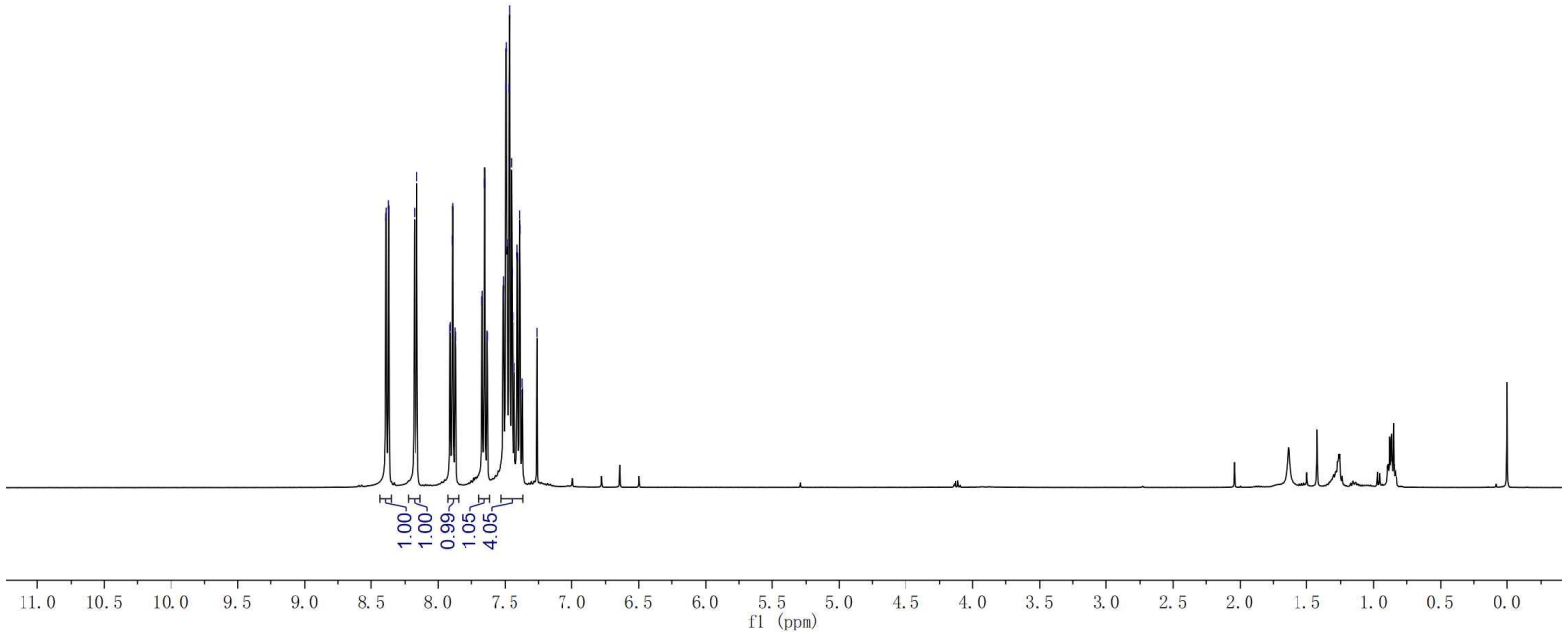
4h ^{13}C NMR 101 MHz, $CDCl_3$

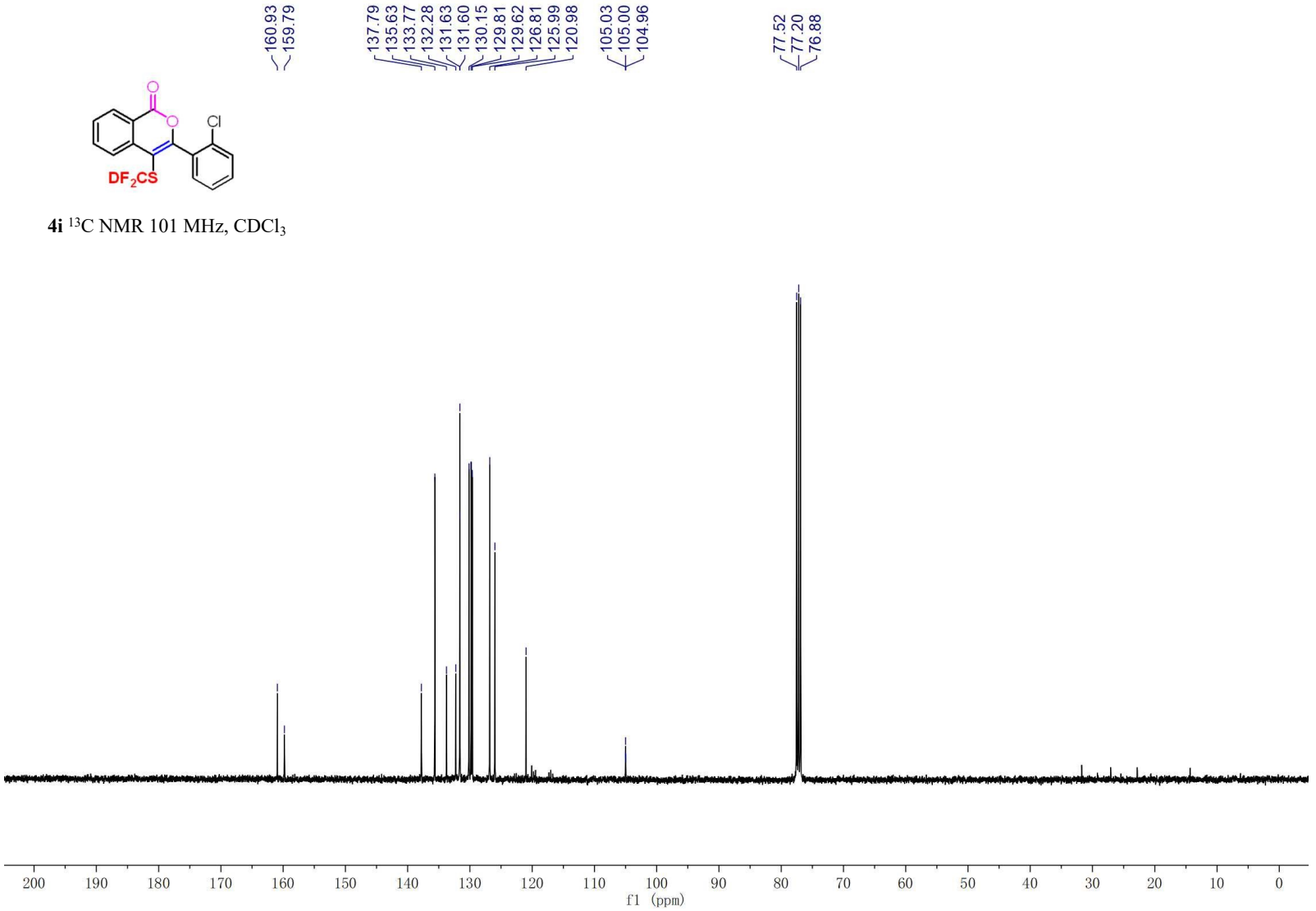


4h ^{19}F NMR 376 MHz, $CDCl_3$

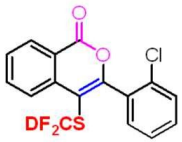


4i ^{1}H NMR 400 MHz, $CDCl_3$



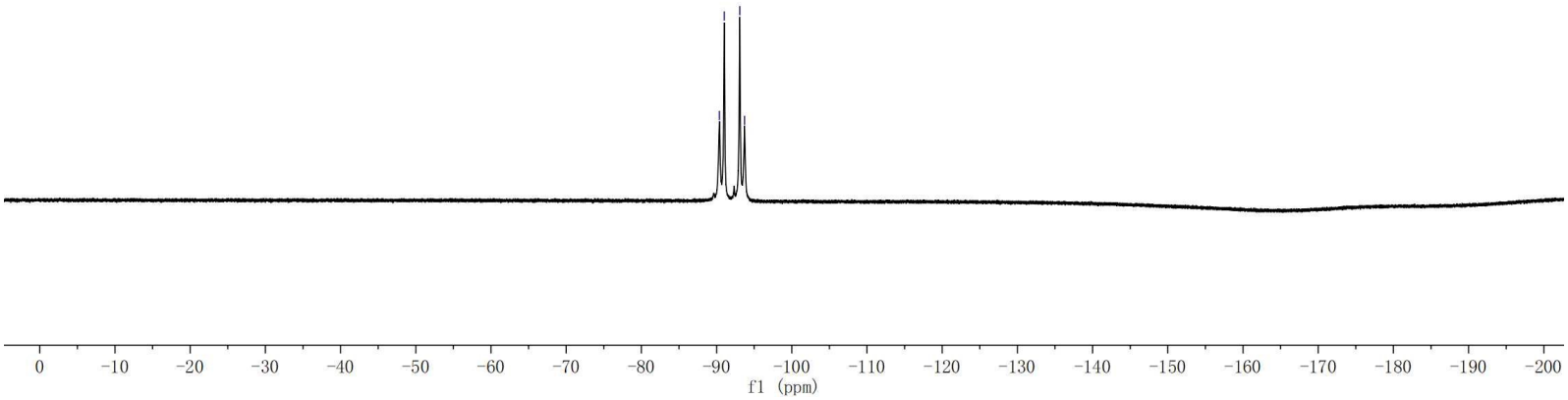


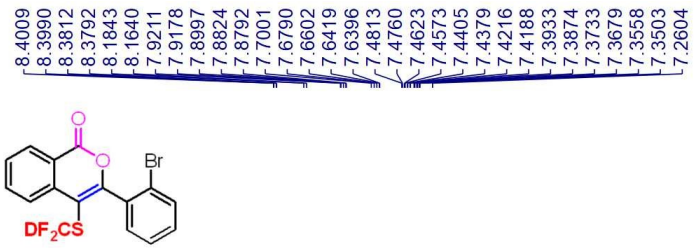
4i ^{13}C NMR 101 MHz, $CDCl_3$



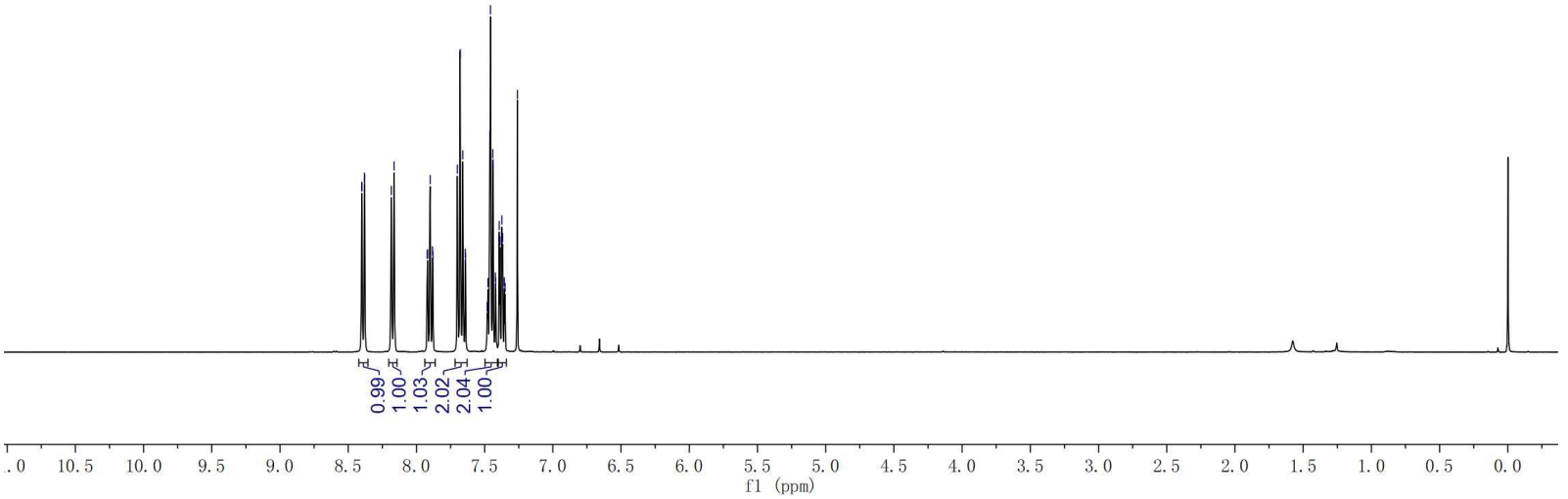
-90.3678
-91.0188
-93.0830
-93.7184

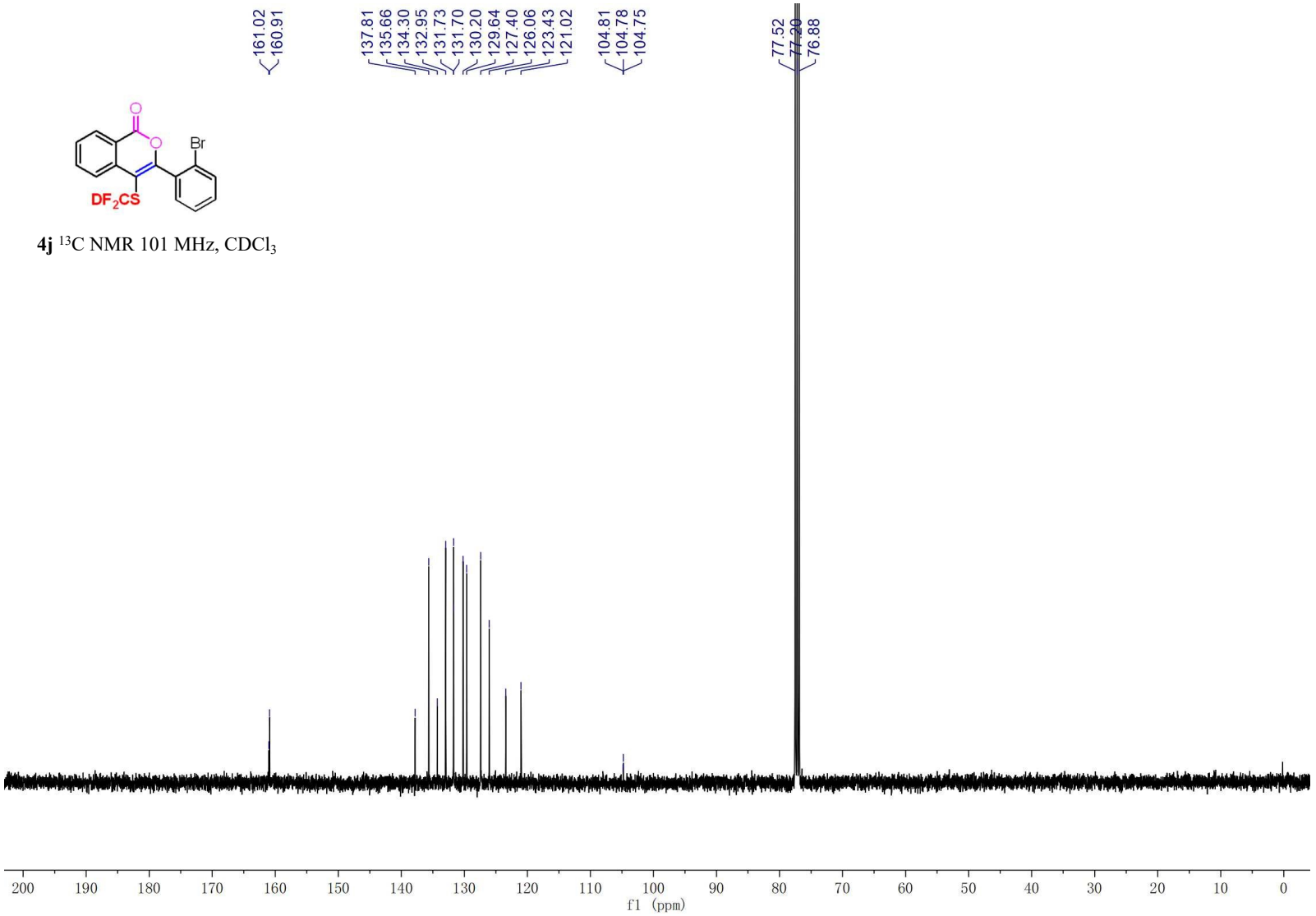
4i ^{19}F NMR 376 MHz, $CDCl_3$



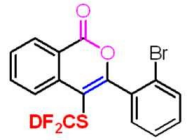


4j ^{1}H NMR 400 MHz, $CDCl_3$



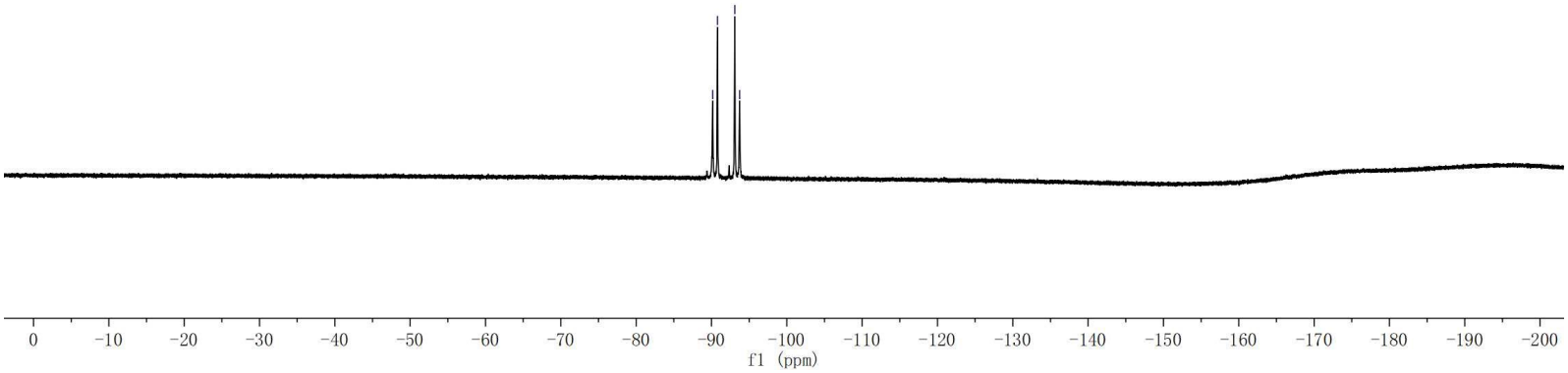


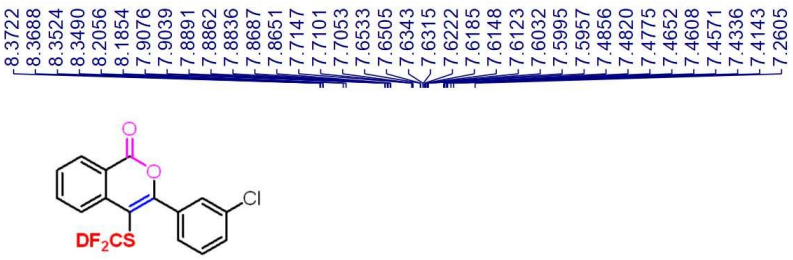
4j ^{13}C NMR 101 MHz, $CDCl_3$



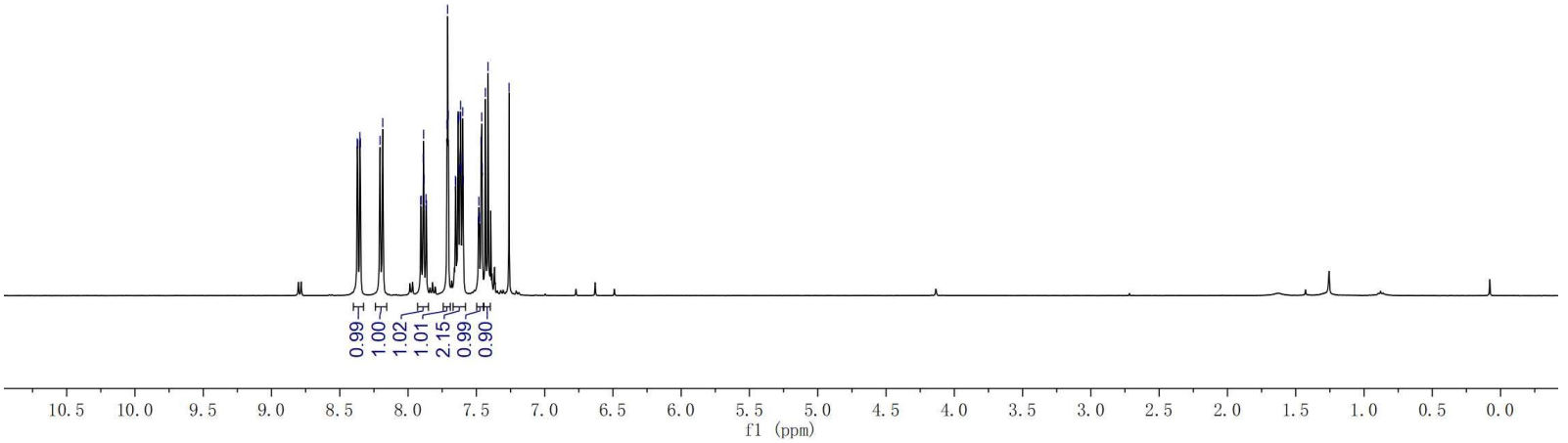
-90.1516
-90.7908
-93.0960
-93.7343

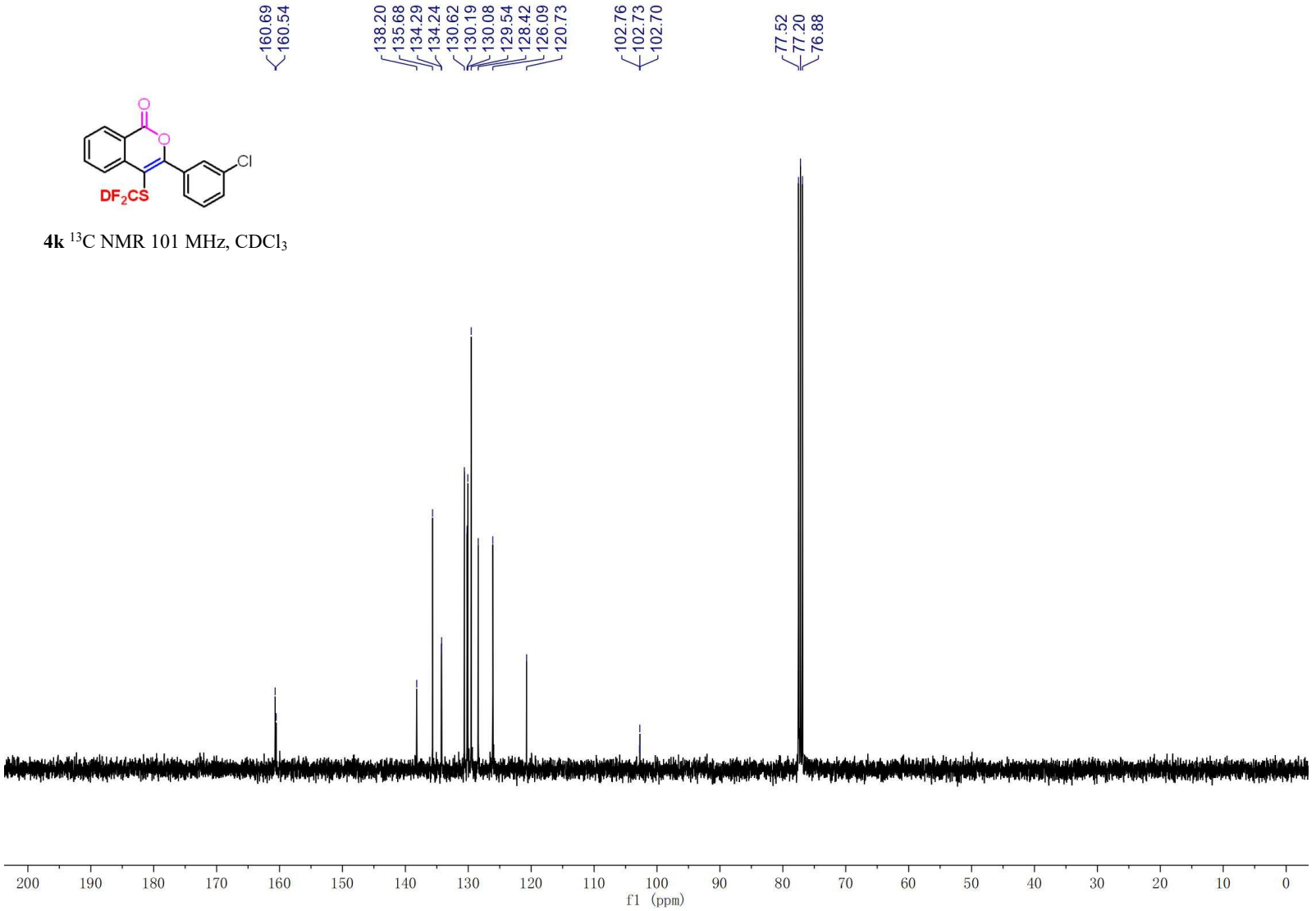
4j ^{19}F NMR 376 MHz, $CDCl_3$



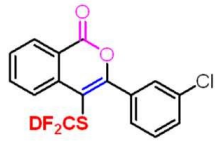


4k ^{1}H NMR 400 MHz, $CDCl_3$

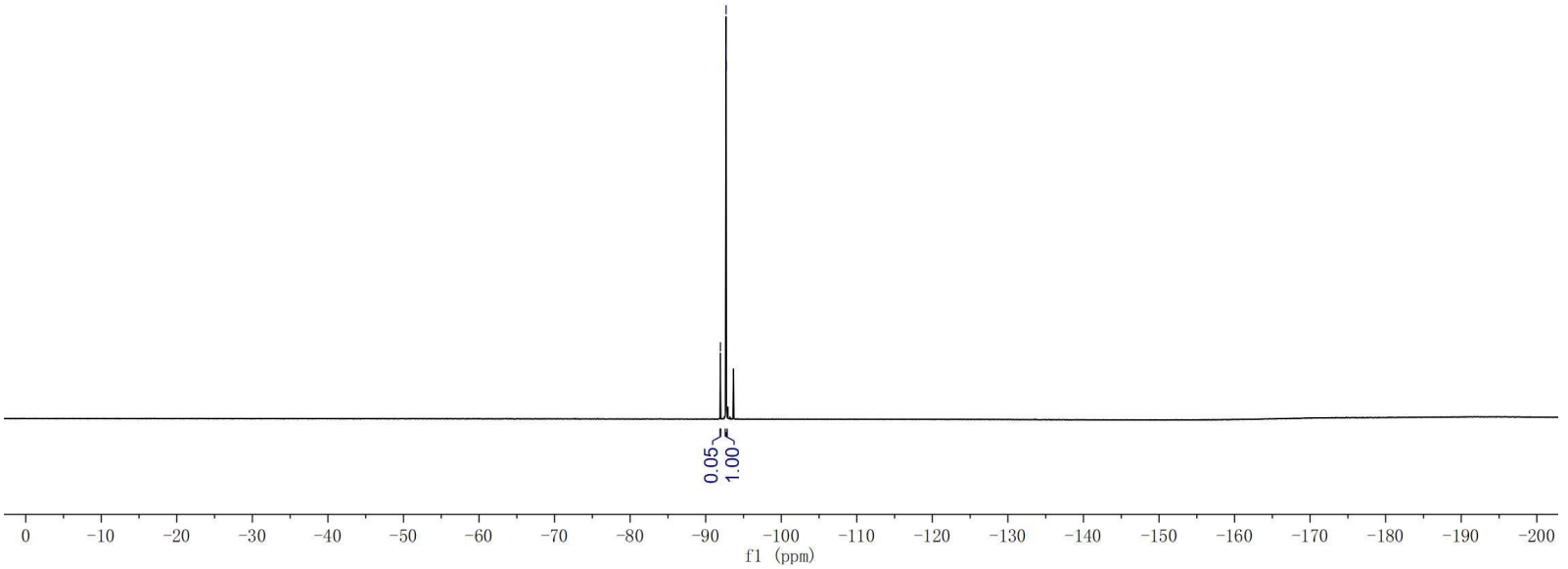


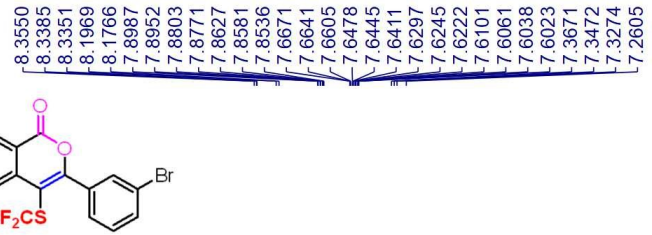


4k ^{13}C NMR 101 MHz, $CDCl_3$

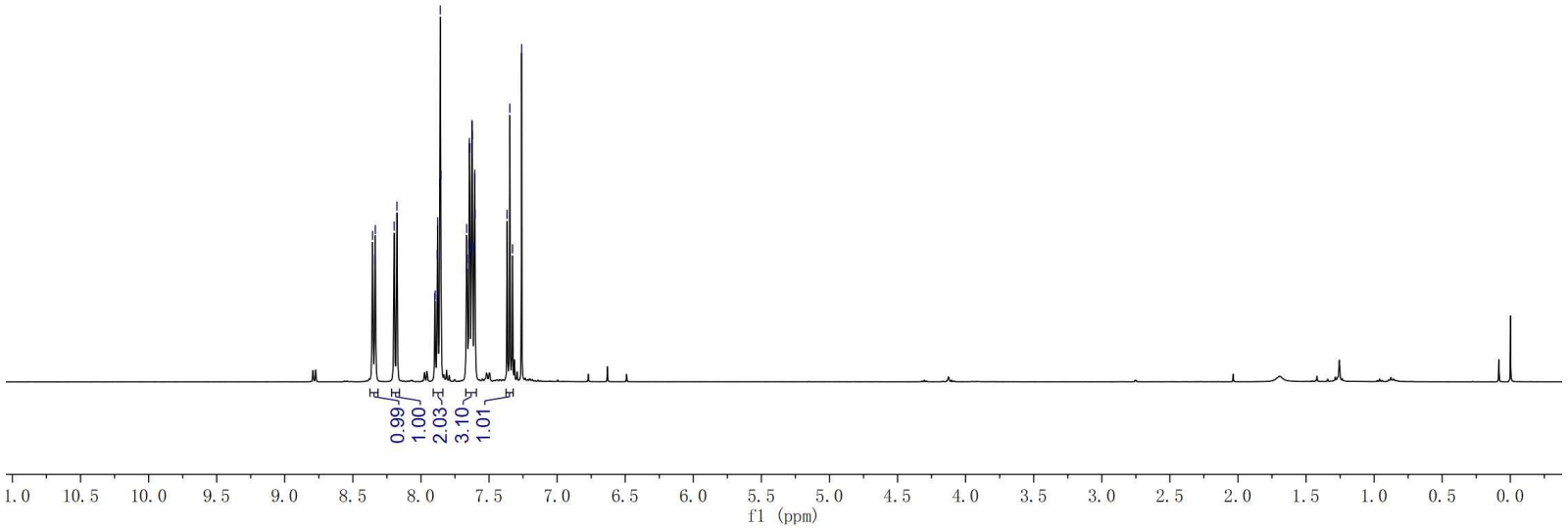


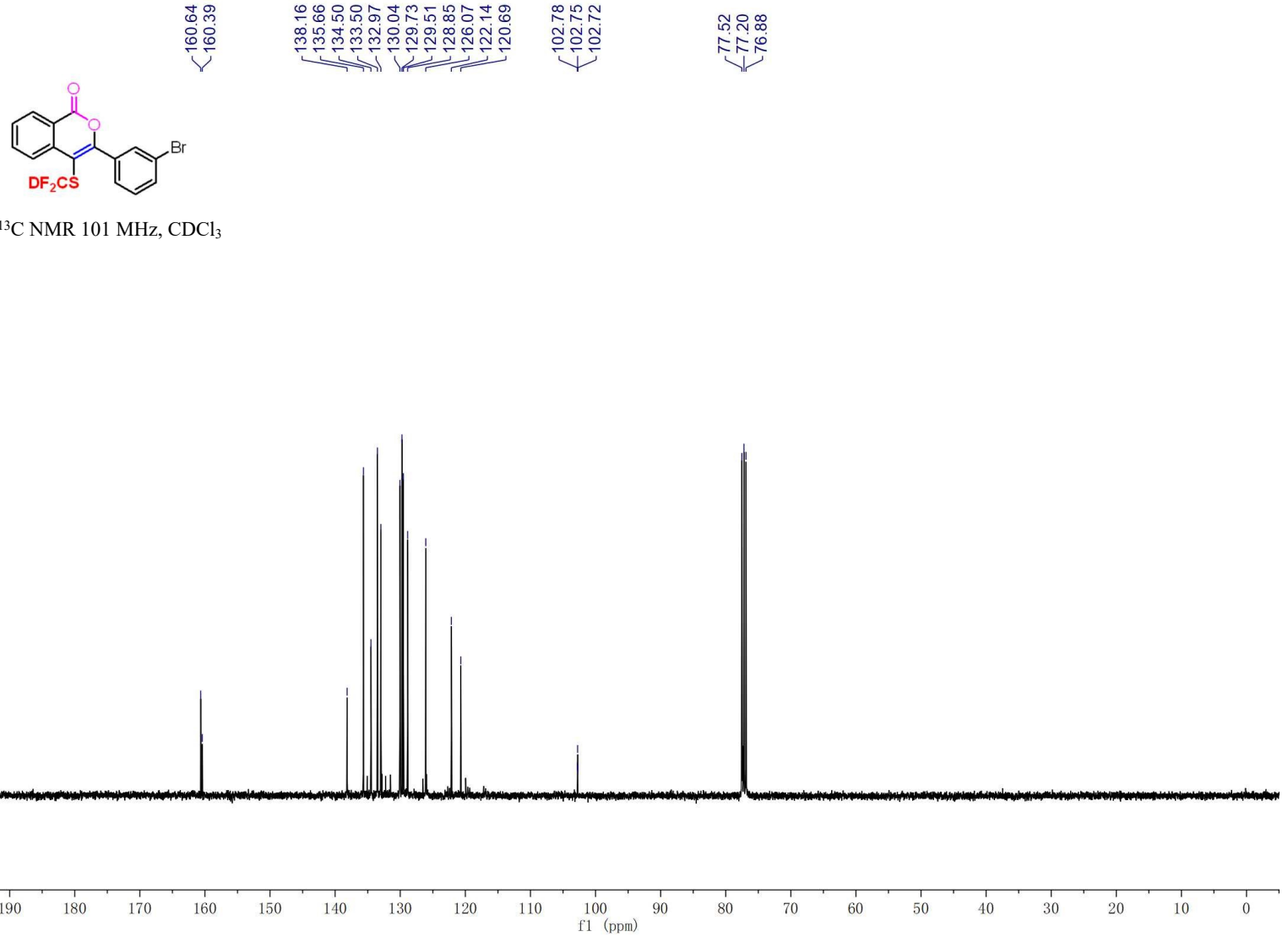
4k ^{19}F NMR 376 MHz, $CDCl_3$



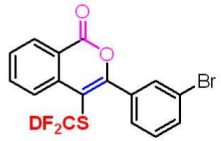


4l ^{1}H NMR 400 MHz, $CDCl_3$



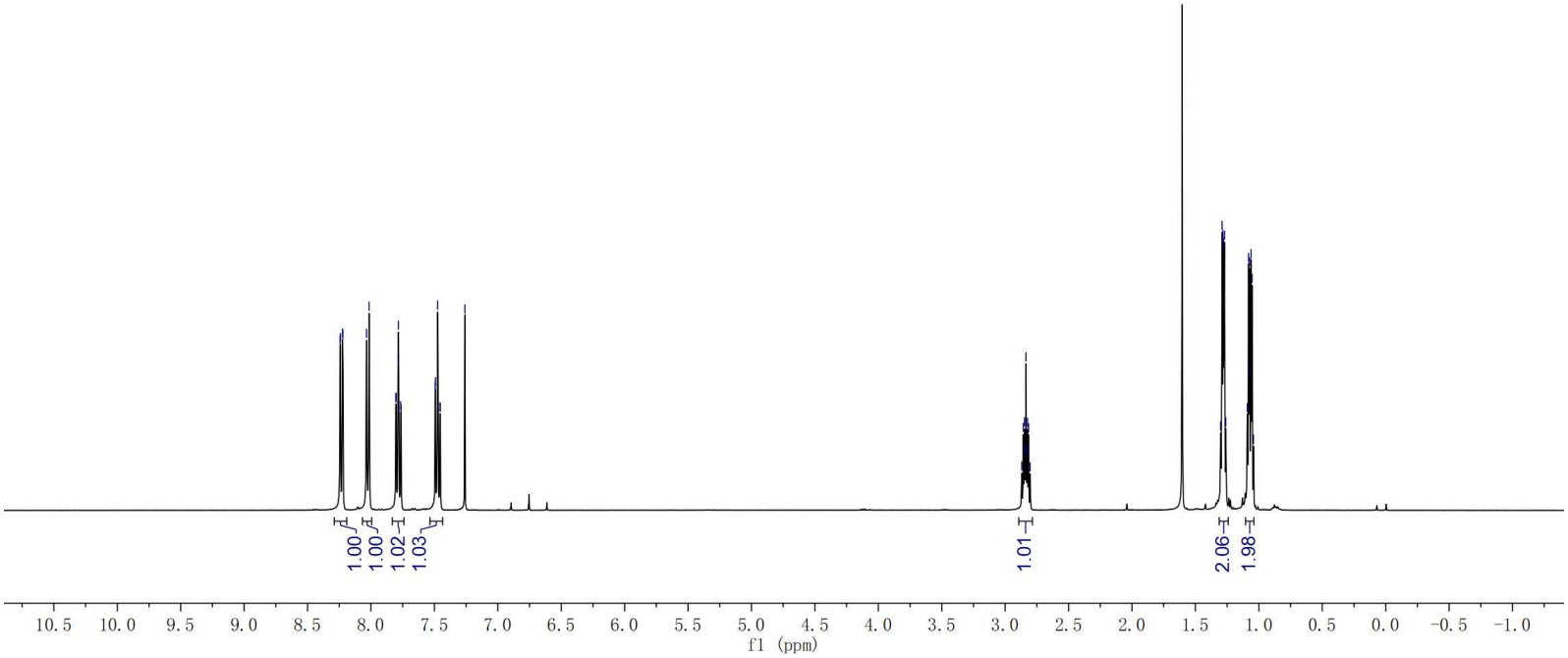


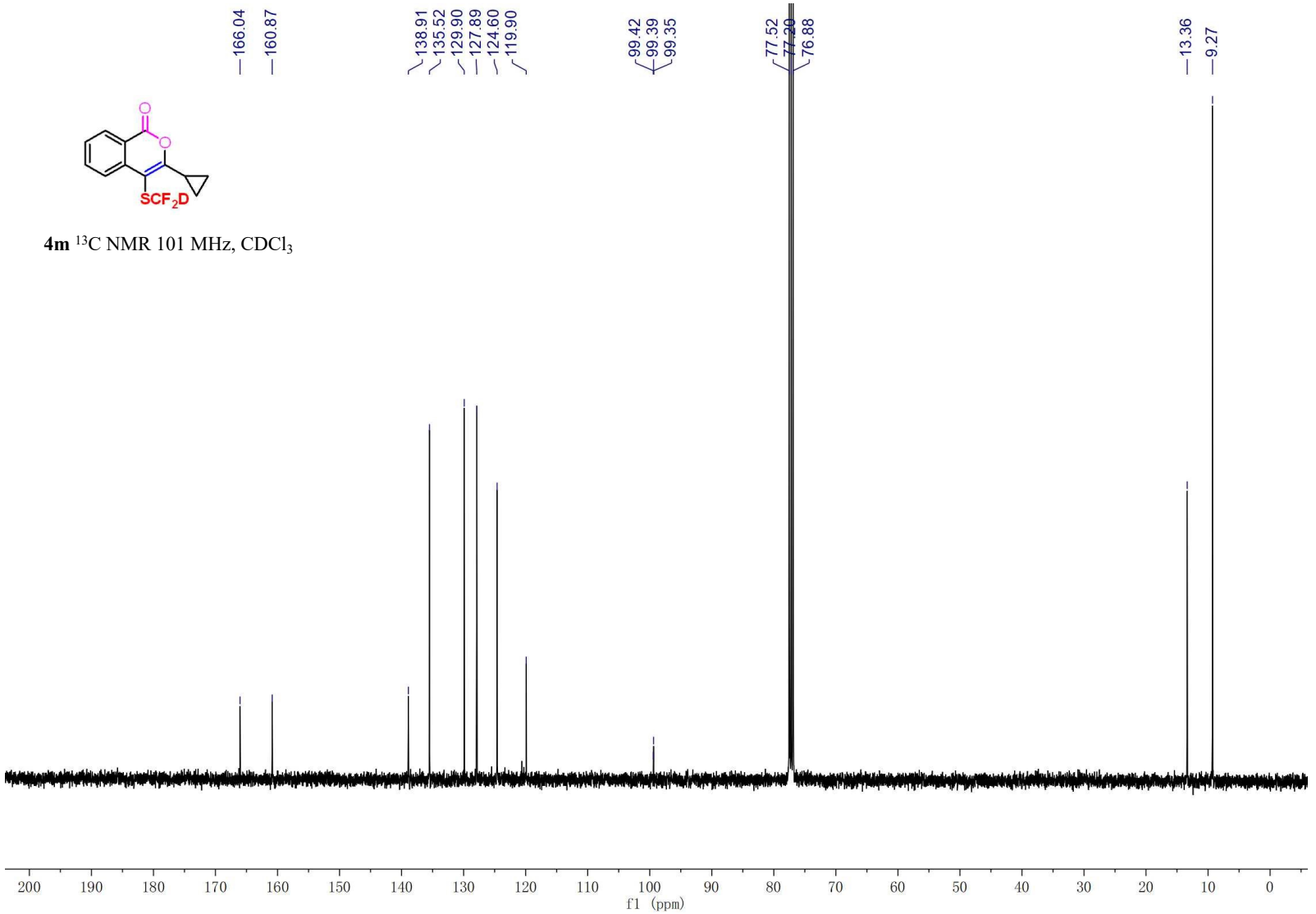
4l ^{13}C NMR 101 MHz, $CDCl_3$



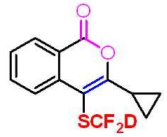
4l ^{19}F NMR 376 MHz, $CDCl_3$

4m ^{1}H NMR 400 MHz, $CDCl_3$





4m ^{13}C NMR 101 MHz, $CDCl_3$



4m ^{19}F NMR 376 MHz, $CDCl_3$