Supplementary Information

I_2-mediated oxidative dearomatization for the synthesis of spirooxindole-lactones in water

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1. General information

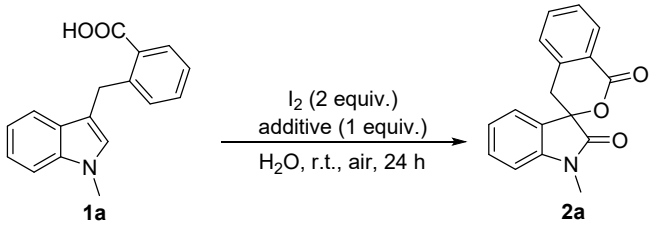
Unless otherwise noted, all reagents were obtained from commercially suppliers and were used without further purification. All products were purified by flash chromatography on silica gel. The chemical yields referred are isolated products. ^{1}H NMR and ^{13}C NMR spectra were recorded on 400 MHz or 600 MHz Bruker spectrometers. If not stated otherwise, the measurements were performed at room temperature. The chemical shifts are given in parts per million (ppm). Calibration was done by referring to the residual solvent signal ($CDCl_3$: ^{1}H NMR 7.26 ppm, ^{13}C NMR 77.16 ppm; DMSO-d_6: ^{1}H NMR 2.50 ppm, ^{13}C NMR 39.52 ppm) in relation to tetramethylsilane. The used abbreviations are as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), br (broad). High resolution mass spectra (HRMS) data were measured on Bruker Solarix FT-ICR-MS qtof esi or Agilent 6540 Q-TOF. Melting points were measured on a X-5A and are not corrected. Reactions were monitored by TLC analysis using silica gel 60 Å F-254 thin layer plates and compounds were visualized with a UV light at 254 nm. Flash column chromatography was performed on silica gel 60 Å, 10 – 40 μm. Compound **5a** was obtained from Zhong's lab.[1]

Note on NMR Solvent Selection：

For certain carboxylic acid starting materials, solubility in $CDCl_3$ was found to be limited, resulting in poor spectral resolution. Therefore, DMSO-d_6 was employed as the NMR solvent for these substrates to ensure complete dissolution and obtain high-quality spectra. All other compounds were sufficiently soluble in $CDCl_3$ and were characterized in this solvent unless otherwise specified. The use of different solvents did not affect the integrity or interpretation of the spectral data, and key signals were consistent with the proposed structures.

2. Reaction condition optimizations

Table S1. The effect of solvent, temperature and additives[a]



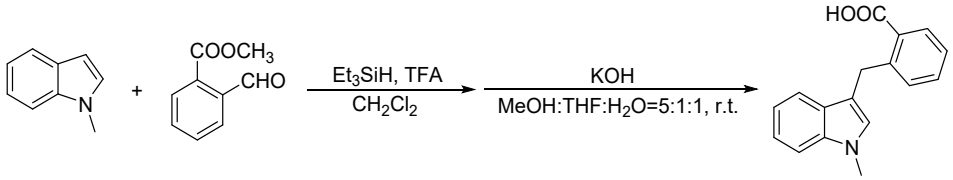
Entry	Solvent	Temperature (°C)	Additive	Yield[b] (%)
1	CH_3CN	r.t.	-	n.d.

2	EtOAc	r.t.	-	n.d.
3	DCM	r.t.	-	trace
4	H_2O	0	-	52
5	H_2O	50	-	85
6	H_2O	r.t.	CF_3COOH	77
7	H_2O	r.t.	KOH	84

[a]Reactions were performed with **1a** (0.2 mmol, 1 equiv.), I_2 (2 equiv.) and additive (1 equiv.) in solvent (2.0 mL) under air in a sealed tube for 24 h. [b]Isolated yield. n.d.: not detected.

3. Preparation of substrates

3.1 Synthesis of oxindole **1a**



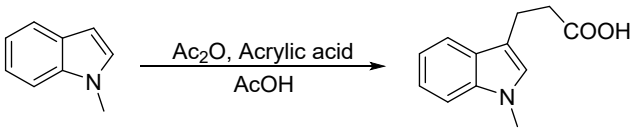
1-Methyl-1*H*-indole (5 mmol, 656 uL), methyl 2-formylbenzoate (5 mmol, 694 uL), and 10 mL of anhydrous CH_2Cl_2 were added to a 50 mL flask equipped with a magnet. Then, the mixture was stirred and cooled to 0°C, Et_3SiH (14.82 mmol, 2.34 mL) and TFA (9.9 mmol, 754 uL) were added sequentially, stirred at 0°C for 15 min, and then gradually raised to room temperature and stirred for several hours, and the reaction process was monitored by thin layer chromatography. After completion of the reaction, the reaction was quenched with water, and extracted with CH_2Cl_2 for 3 times, the organic phase is combined and washed with saturated $NaHCO_3$ and NaCl solution, and the organic phase is dried by anhydrous Na_2SO_4 and then concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (dichloromethane/petroleum ether = 2:1) to afford methyl 2-[(1-methyl-1*H*-indol-3-yl)methyl]benzoate as a light yellow oil.

A 50 mL round-bottom flask equipped with a magnetic stir bar was charged with methyl 2-[(1-methyl-1*H*-indol-3-yl)methyl]benzoate (2 mmol, 558 mg) and KOH (22.53 mmol, 894 mg), the reactants were dissolved in a mixed solvent system (14 mL, MeOH:THF:H_2O = 5:1:1), then stirred at room temperature for several hours, and the reaction was monitored by thin layer chromatography. After completion of the reaction, the organic solvents were removed under reduced pressure. The mixture was diluted with H_2O and carefully acidified to pH 1 with 1 M

aqueous HCl. The solid was filtered off, redissolved in CH_2Cl_2 and purified by column chromatography on silica gel (dichloromethane/methanol = 20:1) to afford compound 2-[(1-methyl-1*H*-indole-3-yl)methyl]benzoic acid (**1a**) as a white solid.

Carboxylic acid derivatives **1b-1l** were synthesized analogously.

3.2 Synthesis of oxindole **3a**

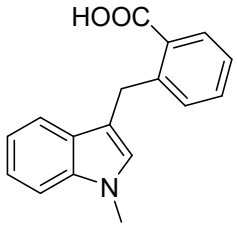


To a solution of 1-methyl-1*H*-indole (394 uL, 3 mmol) in 1.8 mL of acetic acid was added acrylic acid (0.5 mL) and acetic anhydride (0.6 mL), the mixture was heated to 95 °C for 24 hours. The reaction was then cooled to room temperature, which was then extracted with ethyl acetate and 4 mol/L NaOH (aq). The aqueous layer was acidified by 6 mol/L HCl (aq) to pH 2 and then extracted with ethyl acetate. The organic layer was dried over anhydrous Na_2SO_4, filtered, and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (dichloromethane/methanol = 20:1) to afford 3-(1-methyl-1*H*-indol-3-yl)propanoic acid (**3a**) as a white solid.

Carboxylic acid derivatives **3b-3i** were synthesized analogously.

3.3 Characterization data of substrates

2-((1-Methyl-1*H*-indol-3-yl)methyl)benzoic acid(1a)



A white solid, **m.p.**: 184 – 186 °C.

TLC: R_f = 0.36 (dichloromethane/methanol = 20:1) [UV].

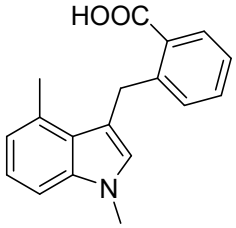
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 7.9 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 1H), 7.35 – 7.26 (m, 3H), 7.21 (t, *J* = 7.5 Hz, 1H), 7.07 (t, *J* = 7.4 Hz, 1H), 6.74 (s, 1H), 4.55 (s, 2H), 3.71 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$+MeOH) δ 170.7 (s), 143.0 (s), 137.0 (s), 131.9 (s), 130.8 (s), 129.9 (s), 128.0 (s), 127.5 (s), 125.8 (s), 121.4 (s), 119.2 (s), 118.6 (s), 113.9 (s), 109.1 (s), 32.5 (s), 29.2 (s).

HRMS (ESI): $C_{17}H_{15}NNaO_2$ [$(M+Na)^+$]: calcd.: 288.0995; found: 288.1001.

The spectra data are matched with those reported.[2]

2-((1,4-Dimethyl-1*H*-indol-3-yl)methyl)benzoic acid(1b)



A white solid, **m.p.**: 247 – 248 °C.

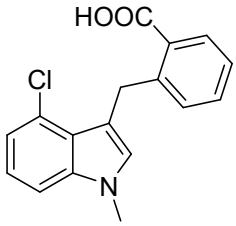
TLC: R_f = 0.31 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.87 (s, 1H), 7.86 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.39 (td, *J* = 7.6, 1.2 Hz, 1H), 7.29 (t, *J* = 7.5 Hz, 1H), 7.20 (d, *J* = 8.2 Hz, 1H), 7.06 (d, *J* = 7.7 Hz, 1H), 7.02 – 6.98 (m, 1H), 6.79 (s, 1H), 6.70 (d, *J* = 7.1 Hz, 1H), 4.58 (s, 2H), 3.67 (s, 3H), 2.37 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 168.9 (s), 142.9 (s), 137.4 (s), 131.6 (s), 130.4 (s), 130.1 (s), 130.0 (s), 129.9 (s), 128.3 (s), 126.1 (s), 125.9 (s), 121.2 (s), 120.0 (s), 113.1 (s), 107.6 (s), 32.3 (s), 30.5 (s), 19.4 (s).

HRMS (ESI): $C_{18}H_{18}NO_2$ [$(M+H)^+$]: calcd.: 280.1332; found: 280.1328.

2-((4-Chloro-1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1c)



A white solid, **m.p.**: 206 – 208 °C.

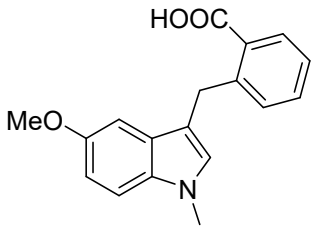
TLC: R_f = 0.21 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.82 (s, 1H), 7.84 (d, *J* = 7.7 Hz, 1H), 7.44 – 7.37 (m, 2H), 7.30 (t, *J* = 7.5 Hz, 1H), 7.14 – 7.07 (m, 2H), 7.00 (d, *J* = 7.5 Hz, 1H), 6.93 (s, 1H), 4.64 (s, 2H), 3.73 (s, 3H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 168.9 (s), 142.5 (s), 138.3 (s), 131.5 (s), 130.5 (s), 130.2 (s), 130.0 (s), 129.8 (s), 125.8 (s), 125.0 (s), 123.8 (s), 121.9 (s), 119.3 (s), 112.7 (s), 109.1 (s), 32.6 (s), 29.7 (s).

HRMS (ESI): $C_{17}H_{15}ClNO_2$ [$(M+H)^+$]: calcd.: 300.0786; found: 300.0789.

2-((5-Methoxy-1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1d)



A white solid, **m.p.**: 219 – 221 °C.

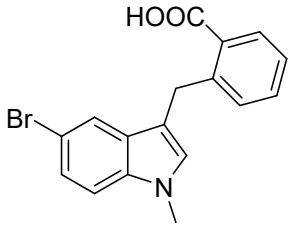
TLC: R_f = 0.28 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.92 (s, 1H), 7.77 (d, J = 7.7 Hz, 1H), 7.41 (t, J = 7.5 Hz, 1H), 7.33 (d, J = 7.6 Hz, 1H), 7.30 – 7.21 (m, 2H), 6.96 (d, J = 2.3 Hz, 1H), 6.91 (s, 1H), 6.76 (dd, J = 8.8, 2.3 Hz, 1H), 4.36 (s, 2H), 3.71 (s, 3H), 3.66 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 169.2 (s), 153.1 (s), 142.1 (s), 132.0 (s), 131.3 (s), 130.8 (s), 130.7 (s), 129.9 (s), 128.1 (s), 127.7 (s), 125.8 (s), 112.8 (s), 110.9 (s), 110.2 (s), 100.7 (s), 55.3 (s), 32.4 (s), 28.4 (s).

HRMS (ESI): $C_{18}H_{18}NO_3$ [$(M+H)^+$]: calcd.: 296.1281; found: 296.1278.

2-((5-Bromo-1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1e)



A white solid, **m.p.**: 220 – 222 °C.

TLC: R_f = 0.25 (dichloromethane/methanol = 10:1) [UV].

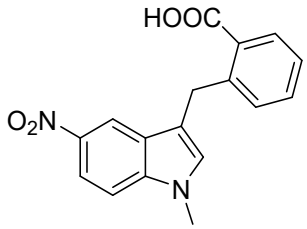
^{1}H NMR (600 MHz, DMSO-d_6) δ 12.92 (s, 1H), 7.79 (d, J = 7.7 Hz, 1H), 7.64 (d, J = 1.6 Hz, 1H), 7.43 (t, J = 7.5 Hz, 1H), 7.35 (d, J = 8.7 Hz, 1H), 7.31 (d, J = 7.5 Hz, 1H), 7.28 (t, J = 7.5 Hz, 1H), 7.22 (dd, J = 8.6, 1.8 Hz, 1H), 7.02 (s, 1H), 4.38 (s, 2H), 3.70 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 169.1 (s), 141.8 (s), 135.3 (s), 131.5 (s), 130.7 (s), 130.1 (s), 129.2 (s), 129.1 (s), 126.0 (s), 123.5 (s), 121.0 (s), 113.1 (s), 111.7 (s), 111.2 (s), 32.4 (s), 28.2 (s).

HRMS (ESI): $C_{17}H_{14}{}^{79}BrNNaO_2$ [$(M+Na)^+$]: calcd.: 366.0100; found: 366.0093.

HRMS (ESI): $C_{17}H_{14}{}^{81}BrNNaO_2$ [$(M+Na)^+$]: calcd.: 368.0080; found: 368.0075.

2-((1-Methyl-5-nitro-1*H*-indol-3-yl)methyl)benzoic acid (1f)



A yellow solid, **m.p.**: 232 – 233 °C.

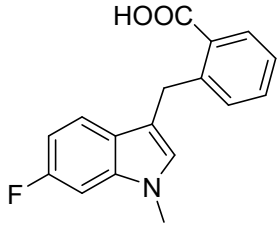
TLC: R_f = 0.30 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.97 (s, 1H), 8.50 (s, 1H), 8.01 (d, J = 9.0 Hz, 1H), 7.82 (d, J = 7.7 Hz, 1H), 7.58 (d, J = 9.1 Hz, 1H), 7.45 (t, J = 7.4 Hz, 1H), 7.36 (d, J = 7.7 Hz, 1H), 7.31 (t, J = 7.5 Hz, 1H), 7.23 (s, 1H), 4.48 (s, 2H), 3.80 (s, 3H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 169.0 (s), 141.4 (s), 140.3 (s), 139.4 (s), 131.6 (s), 131.5 (s), 130.8 (s), 130.2 (s), 126.5 (s), 126.2 (s), 116.6 (s), 116.4 (s), 116.0 (s), 110.3 (s), 32.8 (s), 28.1 (s).

HRMS (ESI): $C_{17}H_{15}N_2O_4$ [$(M+H)^+$]: calcd.: 311.1027; found: 311.1031.

2-((6-Fluoro-1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1g)



A white solid, **m.p.**: 199 – 200 °C.

TLC: R_f = 0.40 (dichloromethane/methanol = 10:1) [UV].

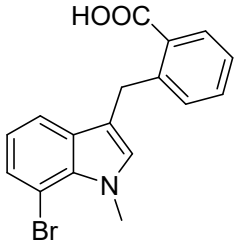
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, J = 7.7 Hz, 1H), 7.47 – 7.38 (m, 2H), 7.33 – 7.20 (m, 3H), 6.95 (s, 1H), 6.82 (t, J = 9.2 Hz, 1H), 4.39 (s, 2H), 3.67 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.2 (s), 159.1 (d, *J* = 234.4 Hz), 141.9 (s), 136.7 (d, *J* = 12.5 Hz), 131.4 (s), 130.9 (s), 130.7 (s), 130.0 (s), 128.2 (d, *J* = 3.5 Hz), 126.0 (s), 124.2 (s), 119.8 (d, *J* = 10.2 Hz), 113.7 (s), 106.8 (d, *J* = 24.4 Hz), 96.0 (d, *J* = 26.1 Hz), 32.4 (s), 28.4 (s).

^{19}F NMR (565 MHz, $CDCl_3$) δ -116.80 – -116.94 (m).

HRMS (ESI): $C_{17}H_{15}FNO_2$ [$(M+H)^+$]: calcd.: 284.1081; found: 284.1075.

2-((7-Bromo-1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1h)



A white solid, **m.p.**: 193 – 194 °C.

TLC: R_f = 0.22 (dichloromethane/methanol = 10:1) [UV].

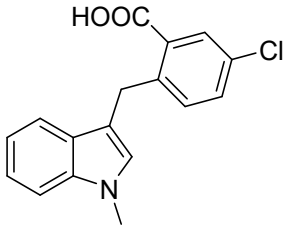
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.79 (dd, *J* = 7.9, 1.0 Hz, 1H), 7.47 (d, *J* = 7.8 Hz, 1H), 7.41 (t, *J* = 7.4 Hz, 1H), 7.34 – 7.20 (m, 3H), 7.00 (s, 1H), 6.86 (t, *J* = 7.7 Hz, 1H), 4.38 (s, 2H), 4.02 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 169.1 (s), 141.5 (s), 132.6 (s), 131.4 (s), 131.1 (s), 130.9 (s), 130.8 (s), 130.6 (s), 130.0 (s), 126.0 (s), 126.0 (s), 120.0 (s), 118.6 (s), 113.5 (s), 103.1 (s), 36.1 (s), 28.2 (s).

HRMS (ESI): $C_{17}H_{14}{}^{79}BrNNaO_2$ [$(M+Na)^+$]: calcd.: 366.0095; found: 366.0091.

HRMS (ESI): $C_{17}H_{14}{}^{81}BrNNaO_2$ [$(M+Na)^+$]: calcd.: 368.0075; found:368.0074.

5-Chloro-2-((1-methyl-1*H*-indol-3-yl)methyl)benzoic acid (1i)



A white solid, **m.p.**: 167 – 169 °C.

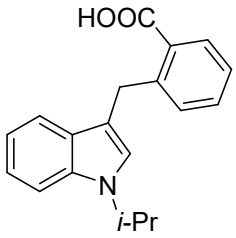
TLC: R_f = 0.19 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.75 (d, *J* = 2.3 Hz, 1H), 7.48 (dd, *J* = 8.3, 2.4 Hz, 1H), 7.43 (d, *J* = 7.9 Hz, 1H), 7.37 (d, *J* = 8.2 Hz, 1H), 7.32 (d, *J* = 8.4 Hz, 1H), 7.12 (t, *J* = 7.2 Hz, 1H), 7.05 – 6.86 (m, 2H), 4.37 (s, 2H), 3.70 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 167.8 (s), 141.1 (s), 136.7 (s), 132.6 (s), 132.6 (s), 131.2 (s), 130.4 (s), 129.4 (s), 127.8 (s), 127.3 (s), 121.2 (s), 118.7 (s), 118.5 (s), 112.6 (s), 109.6 (s), 32.3 (s), 27.9 (s).

HRMS (ESI): $C_{17}H_{15}ClNO_2$ [$(M+H)^+$]: calcd.: 300.0786; found:300.0789.

2-((1-Isopropyl-1*H*-indol-3-yl)methyl)benzoic acid (1j)



A white solid, **m.p.**: 127 – 128 °C.

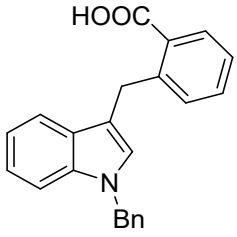
TLC: R_f = 0.29 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.91 (s, 1H), 7.75 (d, J = 7.7 Hz, 1H), 7.43 (d, J = 8.3 Hz, 2H), 7.39 (t, J = 7.5 Hz, 1H), 7.32 (d, J = 7.7 Hz, 1H), 7.26 (t, J = 7.5 Hz, 1H), 7.18 (s, 1H), 7.08 (t, J = 7.7 Hz, 1H), 6.94 (t, J = 7.5 Hz, 1H), 4.71 – 4.64 (m, 1H), 4.41 (s, 2H), 1.40 (d, J = 6.7 Hz, 6H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 169.3 (s), 142.1 (s), 135.5 (s), 131.3 (s), 130.9 (s), 130.5 (s), 129.8 (s), 127.5 (s), 125.8 (s), 122.6 (s), 120.9 (s), 118.8 (s), 118.4 (s), 113.3 (s), 109.7 (s), 46.2 (s), 28.6 (s), 22.5 (s).

HRMS (ESI): $C_{19}H_{20}NO_2$ [$(M+H)^+$]: calcd.: 294.1489; found: 294.1494.

2-((1-Benzyl-1*H*-indol-3-yl)methyl)benzoic acid (1k)



A white solid, **m.p.**: 205 – 206 °C.

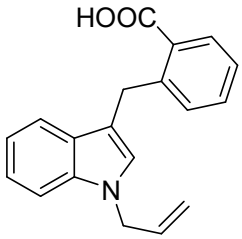
TLC: R_f = 0.34 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.77 (dd, J = 7.7, 1.0 Hz, 1H), 7.47 (d, J = 7.9 Hz, 1H), 7.42 – 7.22 (m, 7H), 7.19 – 7.13 (m, 3H), 7.06 (t, J = 7.6 Hz, 1H), 6.95 (t, J = 7.4 Hz, 1H), 5.34 (s, 2H), 4.44 (s, 2H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 169.5 (s), 141.9 (s), 138.4 (s), 136.1 (s), 131.4 (s), 131.2 (s), 130.5 (s), 129.9 (s), 128.5 (s), 127.8 (s), 127.3 (s), 127.2 (s), 126.9 (s), 125.9 (s), 121.2 (s), 118.9 (s), 118.6 (s), 113.9 (s), 110.0 (s), 48.9 (s), 28.5 (s).

HRMS (ESI): $C_{23}H_{19}NNaO_2$ [$(M+Na)^+$]: calcd.: 364.1308; found: 364.1308.

2-((1-Allyl-1*H*-indol-3-yl)methyl)benzoic acid (1l)



A white solid, **m.p.**: 141 – 143 °C.

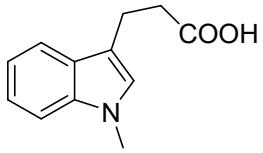
TLC: R_f = 0.31 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (400 MHz, DMSO-d_6) δ 7.75 (d, J = 7.1 Hz, 1H), 7.48 (d, J = 7.9 Hz, 1H), 7.38 – 7.30 (m, 2H), 7.29 – 7.19 (m, 2H), 7.11 – 7.05 (m, 1H), 7.04 (s, 1H), 6.95 (t, J = 7.3 Hz, 1H), 6.00 – 5.88 (m, 1H), 5.10 (dd, J = 10.2, 1.4 Hz, 1H), 4.99 (dd, J = 17.1, 1.4 Hz, 1H), 4.72 (d, J = 5.1 Hz, 2H), 4.43 (s, 2H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 170.4 (s), 141.5 (s), 136.0 (s), 134.5 (s), 132.9 (s), 130.5 (s), 130.2 (s), 129.7 (s), 127.7 (s), 126.8 (s), 125.6 (s), 121.0 (s), 119.0 (s), 118.5 (s), 116.5 (s), 113.8 (s), 109.8 (s), 47.8 (s), 28.4 (s).

HRMS (ESI): $C_{19}H_{17}NNaO_2$ [$(M+Na)^+$]: calcd.: 314.1151; found: 314.1150.

3-(1-Methyl-1*H*-indol-3-yl)propanoic acid (3a)



A white solid, **m.p.**: 146 – 148 °C.

TLC: R_f = 0.31 (dichloromethane/methanol = 10:1) [UV].

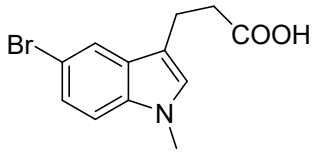
^{1}H NMR (600 MHz, DMSO-d_6) δ 12.08 (s, 1H), 7.53 (d, J = 7.9 Hz, 1H), 7.36 (d, J = 8.2 Hz, 1H), 7.13 (t, J = 7.5 Hz, 1H), 7.09 (s, 1H), 7.01 (t, J = 7.4 Hz, 1H), 3.71 (s, 3H), 2.92 (t, J = 7.6 Hz, 2H), 2.58 (t, J = 7.6 Hz, 2H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 174.1 (s), 136.6 (s), 127.2 (s), 126.7 (s), 121.1 (s), 118.5 (s), 118.3 (s), 112.8 (s), 109.5 (s), 34.6 (s), 32.2 (s), 20.1 (s).

HRMS (ESI): $C_{12}H_{14}NO_2$ [$(M+H)^+$]: calcd.: 204.1019; found: 204.1022.

The spectra data are matched with those reported.[3]

3-(5-Bromo-1-methyl-1*H*-indol-3-yl)propanoic acid (3b)



A white solid, **m.p.**: 161 – 162 °C.

TLC: R_f = 0.41 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 1.6 Hz, 1H), 7.16 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.04 (d, *J* = 8.7 Hz, 1H), 6.80 (s, 1H), 3.61 (s, 3H), 2.91 (t, *J* = 7.6 Hz, 2H), 2.55 (t, *J* = 7.6 Hz, 2H).

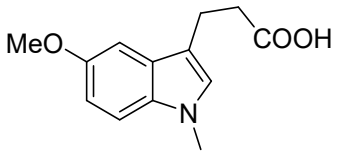
^{13}C NMR (101 MHz, $CDCl_3$+DMSO-d_6) δ 175.2 (s), 135.5 (s), 129.2 (s), 127.5 (s), 124.0 (s), 121.2 (s), 113.2 (s), 111.9 (s), 110.6 (s), 34.8 (s), 32.7 (s), 20.2 (s).

HRMS (ESI): $C_{12}H_{13}{}^{79}BrNO_2$ [$(M+H)^+$]: calcd.: 282.0124; found: 282.0132.

HRMS (ESI): $C_{12}H_{13}{}^{81}BrNO_2$ [$(M+H)^+$]: calcd.: 284.0104; found: 284.0110.

The spectra data are matched with those reported.[4]

3-(5-Methoxy-1-methyl-1*H*-indol-3-yl)propanoic acid (3c)



A white solid, **m.p.**: 155.7 – 156.4 °C.

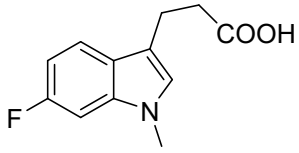
TLC: R_f = 0.47 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.08 (s, 1H), 7.25 (d, *J* = 8.8 Hz, 1H), 7.03 (s, 1H), 7.02 (d, *J* = 2.3 Hz, 1H), 6.77 (dd, *J* = 8.8, 2.3 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.89 (t, *J* = 7.6 Hz, 2H), 2.57 (t, *J* = 7.6 Hz, 2H).

^{13}C NMR (151 MHz, DMSO-*d6*) δ 174.2 (s), 153.1 (s), 132.0 (s), 127.5 (s), 127.2 (s), 112.3 (s), 111.1 (s), 110.3 (s), 100.4 (s), 55.4 (s), 34.6 (s), 32.4 (s), 20.2 (s).

HRMS (ESI): $C_{13}H_{16}NO_3$ [$(M+H)^+$]: calcd.: 234.1125; found: 234.1131.

3-(6-Fluoro-1-methyl-1*H*-indol-3-yl)propanoic acid (3d)



A white solid, **m.p.**: 145 – 146 °C.

TLC: R_f = 0.75 (dichloromethane/methanol = 10:1) [UV].

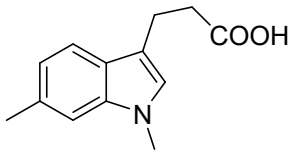
^{1}H NMR (600 MHz, DMSO-d_6) δ 12.09 (s, 1H), 7.51 (dd, J = 8.5, 5.5 Hz, 1H), 7.23 (dd, J = 10.3, 1.7 Hz, 1H), 7.09 (s, 1H), 6.92 – 6.79 (m, 1H), 3.68 (s, 3H), 2.90 (t, J = 7.5 Hz, 2H), 2.56 (t, J = 7.5 Hz, 2H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 174.1 (s), 159.0 (d, J = 234.3 Hz), 136.6 (d, J = 12.5 Hz), 127.3 (d, J = 3.5 Hz), 124.0 (s), 119.6 (d, J = 10.3 Hz), 113.2 (s), 106.7 (d, J = 24.5 Hz), 95.9 (d, J = 26.1 Hz), 34.5 (s), 32.4 (s), 20.0 (s).

^{19}F NMR (565 MHz, $CDCl_3$) δ -121.59 – -121.71 (m).

HRMS (ESI): $C_{12}H_{13}FNO_2$ [$(M+H)^+$]: calcd.: 222.0925; found: 222.0933.

3-(1,6-Dimethyl-1*H*-indol-3-yl)propanoic acid (3e)



A white solid, **m.p.**: 149 – 150 °C.

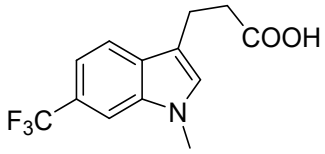
TLC: R_f = 0.38 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, J = 8.0 Hz, 1H), 7.10 (s, 1H), 6.97 (d, J = 8.0 Hz, 1H), 6.81 (s, 1H), 3.71 (s, 3H), 3.09 (t, J = 7.6 Hz, 2H), 2.77 (t, J = 7.7 Hz, 2H), 2.51 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 179.7 (s), 137.5 (s), 131.6 (s), 125.8 (s), 125.5 (s), 120.7 (s), 118.5 (s), 113.0 (s), 109.4 (s), 35.1 (s), 32.6 (s), 22.0 (s), 20.5 (s).

HRMS (ESI): $C_{13}H_{15}NNaO_2$ [$(M+Na)^+$]: calcd.: 240.0995; found: 240.0999.

3-(1-Methyl-6-(trifluoromethyl)-1*H*-indol-3-yl)propanoic acid (3f)



A white solid, **m.p.**: 106.2 – 107.5 °C.

TLC: R_f = 0.50 (dichloromethane/methanol = 10:1) [UV].

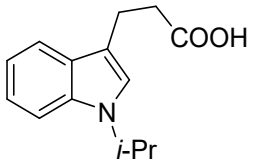
^{1}H NMR (600 MHz, DMSO-d_6) δ 12.12 (s, 1H), 7.80 (s, 1H), 7.73 (d, J = 8.2 Hz, 1H), 7.35 (s, 1H), 7.29 (d, J = 8.1 Hz, 1H), 3.81 (s, 3H), 2.95 (t, J = 7.4 Hz, 2H), 2.59 (t, J = 7.4 Hz, 2H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 174.0 (s), 135.4 (s), 130.2 (s), 129.7 (s), 125.6 (q, J = 271.4 Hz), 121.6 (q, J = 31.1 Hz), 119.4 (s), 114.5 (q, J = 3.4 Hz), 113.4 (s), 107.3 (q, J = 4.2 Hz), 34.6 (s), 32.5 (s), 19.9 (s).

HRMS (ESI): $C_{13}H_{11}F_3NO_2$ [$(M-H)^-$]: calcd.: 270.0747; found: 270.0741.

^{19}F NMR (565 MHz, DMSO-d_6) δ -58.56 (s).

3-(1-Isopropyl-1*H*-indol-3-yl)propanoic acid (3g)



A white solid, **m.p.**: 106 – 108 °C.

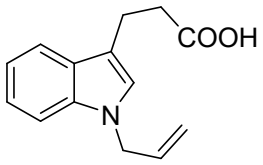
TLC: R_f = 0.52 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.09 (s, 1H), 7.52 (d, J = 7.9 Hz, 1H), 7.43 (d, J = 8.2 Hz, 1H), 7.26 (s, 1H), 7.11 (t, J = 7.6 Hz, 1H), 6.99 (t, J = 7.4 Hz, 1H), 4.72 – 4.64 (m, 1H), 2.93 (t, J = 7.7 Hz, 2H), 2.59 (t, J = 7.7 Hz, 2H), 1.41 (d, J = 6.7 Hz, 6H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 174.2 (s), 135.5 (s), 127.3 (s), 121.6 (s), 120.9 (s), 118.6 (s), 118.3 (s), 113.2 (s), 109.7 (s), 46.2 (s), 34.6 (s), 22.5 (s), 20.4 (s).

HRMS (ESI): $C_{14}H_{18}NO_2$ [$(M+H)^+$]: calcd.: 232.1332; found: 232.1336.

3-(1-Allyl-1*H*-indol-3-yl)propanoic acid (3h)



A white solid, **m.p.**: 88 – 89 °C.

TLC: R_f = 0.68 (dichloromethane/methanol = 10:1) [UV].

^{1}H NMR (600 MHz, DMSO-d_6) δ 12.10 (s, 1H), 7.54 (d, J = 7.9 Hz, 1H), 7.36 (d, J = 8.2 Hz, 1H), 7.14 – 7.09 (m, 2H), 7.02 (t, J = 7.4 Hz, 1H), 5.96 (ddd, J = 22.4, 10.5, 5.4 Hz, 1H), 5.12 (dd, J = 10.2, 1.3 Hz, 1H), 5.01 (dd, J = 17.1, 1.5 Hz, 1H), 4.74 (d, J = 5.4 Hz, 2H), 2.94 (t, J = 7.5 Hz, 2H), 2.59 (t, J = 7.6 Hz, 2H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 174.1 (s), 136.0 (s), 134.5 (s), 127.4 (s), 125.7 (s), 121.1 (s), 118.6 (s), 118.5 (s), 116.6 (s), 113.2 (s), 109.9 (s), 47.9 (s), 34.6 (s), 20.2 (s).

HRMS (ESI): $C_{14}H_{16}NO_2$ [$(M+H)^+$]: calcd.: 230.1176; found: 230.1183.

4. Experimental procedure and characterization data for products

4.1 A typical experimental procedure: To a 10 mL tube was added indole-derived carboxylic acid **1** or **3** (0.2 mmol), I_2 (0.4 mmol) and water (2 mL). The mixture was stirred at room temperature for 24 hours. The reaction mixture was quenched with saturated $Na_2S_2O_3$ solution and then extracted with ethyl acetate (3 mL × 5). Afterword, the combined organic phase was dried by anhydrous Na_2SO_4, and then the solvent was evaporated *in vacuo*. The residue was purified by column chromatography on silica gel to give the spirooxindole products **2** or **4**.

4.2 Scale-up synthesis of 1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2a):

A round bottom flask equipped with a magnetic stir bar was charged with 2-[(1-methyl-1*H*-indole-3-yl)methyl]benzoic acid (**1a**) (2 mmol, 530 mg), I_2 (4 mmol, 1.016 g) and 20 mL water. The reaction mixture was stirred at room temperature for 4d. The reaction mixture was quenched with saturated $Na_2S_2O_3$ solution, then extracted with ethyl acetate and washed with brine. The organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (ethyl acetate/petroleum ether = 1/2) to give 1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (**2a**) as a white solid (453.2 mg, 81% yield).

Scale-up synthesis of 1'-methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4a):

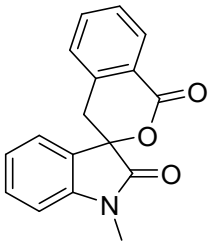
A round bottom flask equipped with a magnetic stir bar was charged with 3-(1-methyl-1*H*-indol-3-yl)propanoic acid (**3a**) (2 mmol, 406 mg), I_2 (4 mmol, 1.016 g) and 20 mL water. The reaction mixture was stirred at room temperature for 3d. The reaction mixture was quenched with saturated $Na_2S_2O_3$ solution, then extracted with ethyl acetate and washed with brine. The organic phase was dried with anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by flash chromatography on silica gel (ethyl acetate/petroleum ether = 1/2) to give 1'-methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (**4a**) as a pale yellow solid (320.7 mg, 74% yield).

4.3 Characterization data for products：

To facilitate reader comprehension and improve the transparency of characterization data, explicit ^{1}H-NMR signal assignments have been provided for representative compounds **2a** and **4a**. These assignments are based on chemical shifts, coupling patterns, and integral values, and

are included in the corresponding experimental sections for these compounds. This information is intended to assist in the verification of structural integrity and to serve as a reference for analogous products reported in this study.

1-Methylspiro[indoline-3,3'-isochromane]-1',2-dione (2a)



A white solid, 47.9 mg, 86% yield.

m.p.: 210 – 212 °C.

TLC: R_f = 0.57 (petroleum ether/ethyl acetate = 2:1) [UV].

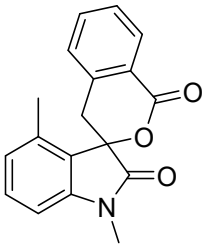
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, *J* = 7.8 Hz, 1H, ArH), 7.60 (t, *J* = 7.5 Hz, 1H, ArH), 7.48 (t, *J* = 7.6 Hz, 1H, ArH), 7.35 (t, *J* = 7.7 Hz, 1H, ArH), 7.25 (d, *J* = 7.6 Hz, 1H, ArH), 6.95 (t, *J* = 7.6 Hz, 1H, ArH), 6.90 (d, *J* = 7.4 Hz, 1H, ArH), 6.86 (d, *J* = 7.8 Hz, 1H, ArH), 3.55 (d, *J* = 16.6 Hz, 1H, CH_2), 3.29 (d, *J* = 16.6 Hz, 1H, CH_2), 3.20 (s, 3H, CH_3).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.4 (s), 163.8 (s), 143.4 (s), 136.0 (s), 134.3 (s), 131.1 (s), 130.2 (s), 128.3 (s), 128.1 (s), 127.4(s), 125.1 (s), 124.1 (s), 123.4 (s), 109.0 (s), 80.5 (s), 34.2 (s), 26.6 (s)

HRMS (ESI): $C_{17}H_{14}NO_3$ [$(M+H)^+$]: calcd.: 280.0968; found: 280.0979.

The spectra data are matched with those reported.[5]

1,4-Dimethylspiro[indoline-3,3'-isochromane]-1',2-dione (2b)



A white solid, 35.6 mg, 61% yield.

m.p.: 157 – 159 °C.

TLC: R_f = 0.77 (petroleum ether/ethyl acetate = 1:1) [UV].

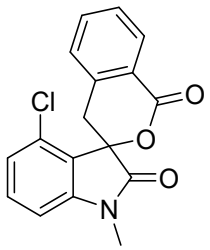
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.19 (d, *J* = 7.3 Hz, 1H), 7.55 (td, *J* = 7.5, 1.2 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.29 (t, *J* = 7.8 Hz, 1H), 7.20 (d, *J* = 7.5 Hz, 1H), 6.93 (d, *J* = 7.9 Hz, 1H),

6.69 (d, J = 7.8 Hz, 1H), 4.01 (d, J = 17.2 Hz, 1H), 3.10 (s, 3H), 3.02 (d, J = 17.3 Hz, 1H), 2.49 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 173.6 (s), 164.5 (s), 143.5 (s), 136.5 (s), 135.5 (s), 134.0 (s), 130.7 (s), 123.0 (s), 128.0 (s), 127.7 (s), 126.1 (s), 125.1 (s), 124.4 (s), 106.5 (s), 81.2 (s), 32.6 (s), 26.4 (s), 18.0 (s).

HRMS (ESI): $C_{18}H_{15}NNaO_3$ [$(M+Na)^+$]: calcd.: 316.0944; found: 316.0936.

4-Chloro-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2c)



A white solid, 48.4 mg, 77% yield.

m.p.: 178 – 179 °C.

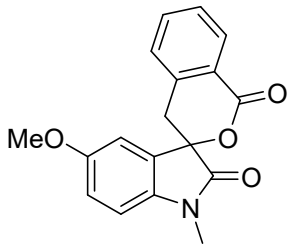
TLC: R_f = 0.47 (petroleum ether/ethyl acetate = 1:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.18 (d, J = 7.7 Hz, 1H), 7.56 (t, J = 7.4 Hz, 1H), 7.44 (t, J = 7.6 Hz, 1H), 7.34 (t, J = 8.0 Hz, 1H), 7.21 (d, J = 7.5 Hz, 1H), 7.09 (d, J = 8.2 Hz, 1H), 6.78 (d, J = 7.8 Hz, 1H), 4.37 (d, J = 17.1 Hz, 1H), 3.12 (s, 3H), 3.00 (d, J = 17.1 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.8 (s), 163.9 (s), 145.2 (s), 135.5 (s), 134.1 (s), 132.5 (s), 132.2 (s), 130.0 (s), 128.0 (s), 127.7 (s), 124.9 (s), 124.8 (s), 123.3 (s), 107.4 (s), 80.6 (s), 31.1 (s), 26.6 (s).

HRMS (ESI): $C_{17}H_{13}ClNO_3$ [$(M+H)^+$]: calcd.: 314.0579; found: 314.0586.

5-Methoxy-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2d)



A white solid, 52.5 mg, 85% yield.

m.p.: 184 – 186 °C.

TLC: R_f = 0.57 (petroleum ether/ethyl acetate = 1:1) [UV].

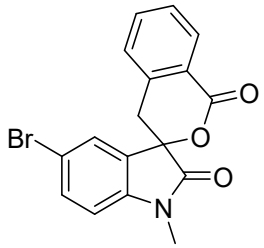
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 7.7 Hz, 1H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 1H), 7.24 (d, *J* = 7.6 Hz, 1H), 6.86 (dd, *J* = 8.5, 2.3 Hz, 1H), 6.77 (d, *J* = 8.5 Hz, 1H), 6.51 (d, *J* = 2.4 Hz, 1H), 3.66 (s, 3H), 3.53 (d, *J* = 16.6 Hz, 1H), 3.27 (d, *J* = 16.6 Hz, 1H), 3.16 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.2 (s), 163.7 (s), 156.3 (s), 136.6 (s), 135.9 (s), 134.33 (s), 130.1 (s), 128.4 (s), 128.3 (s), 128.1 (s), 125.0 (s), 115.1 (s), 111.7 (s), 109.5 (s), 80.8 (s), 55.8 (s), 34.2 (s), 26.6 (s)

HRMS (ESI): $C_{18}H_{15}NNaO_4$ [$(M+Na)^+$]: calcd.: 332.0893; found: 332.0888.

The spectra data are matched with those reported.[5]

5-Bromo-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2e)



A white solid, 53.5 mg, 75% yield.

m.p.: 255 – 257 °C.

TLC: R_f = 0.47 (petroleum ether/ethyl acetate = 1:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.20 (dd, *J* = 7.8, 0.8 Hz, 1H), 7.62 (td, *J* = 7.5, 1.3 Hz, 1H), 7.56 – 7.47 (m, 2H), 7.25 (d, *J* = 6.1 Hz, 1H), 7.06 (d, *J* = 1.9 Hz, 1H), 6.76 (d, *J* = 8.3 Hz, 1H), 3.51 (d, *J* = 16.6 Hz, 1H), 3.32 (d, *J* = 16.7 Hz, 1H), 3.18 (s, 3H).

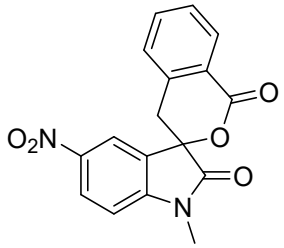
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.0 (s), 163.4 (s), 142.5 (s), 135.5 (s), 134.6 (s), 134.0 (s), 130.4 (s), 129.3 (s), 128.6 (s), 128.1 (s), 127.5 (s), 124.8 (s), 116.0 (s), 110.5 (s), 80.2 (s), 34.1 (s), 26.7 (s).

HRMS (ESI): $C_{17}H_{13}{}^{79}BrNO_3$ [$(M+H)^+$]: calcd.: 358.0074; found: 358.0073.

HRMS (ESI): $C_{17}H_{13}{}^{81}BrNO_3$ [$(M+H)^+$]: calcd.: 360.0054; found: 360.0055.

The spectra data are matched with those reported.[6]

1-Methyl-5-nitrospiro[indoline-3,3'-isochromane]-1',2-dione (2f)



A white solid, 46.0 mg, 71% yield.

m.p.: 258 – 259 °C.

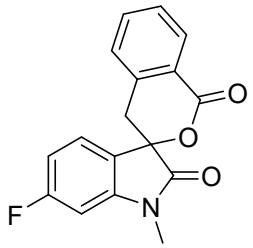
TLC: R_f = 0.39 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.35 (d, *J* = 8.6 Hz, 1H), 8.22 (d, *J* = 7.7 Hz, 1H), 7.88 (s, 1H), 7.64 (t, *J* = 7.5 Hz, 1H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.27 (d, *J* = 8.8 Hz, 1H), 6.98 (d, *J* = 8.6 Hz, 1H), 3.52 (d, *J* = 16.7 Hz, 1H), 3.42 (d, *J* = 16.7 Hz, 1H), 3.27 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.6 (s), 162.9 (s), 148.9 (s), 143.9 (s), 134.9 (s), 134.8 (s), 130.6 (s), 128.9 (s), 128.1 (s), 128.1 (s), 124.6 (s), 120.2 (s), 108.8 (s), 79.5 (s), 34.0 (s), 27.1 (s).

HRMS (ESI): $C_{17}H_{13}N_2O_5$ [$(M+H)^+$]: calcd.: 325.0819; found: 325.0823.

6-Fluoro-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2g)



A white solid, 48.1 mg, 81% yield.

m.p.: 258 – 259 °C.

TLC: R_f = 0.57 (petroleum ether/ethyl acetate = 1:1) [UV].

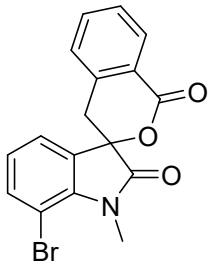
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 7.7 Hz, 1H), 7.61 (t, *J* = 7.1 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J* = 5.7 Hz, 1H), 6.86 (dd, *J* = 8.0, 5.3 Hz, 1H), 6.70 – 6.55 (m, 2H), 3.54 (d, *J* = 16.6 Hz, 1H), 3.28 (d, *J* = 16.6 Hz, 1H), 3.19 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.65 (s), 164.76 (d, *J* = 249.6 Hz), 163.63 (s), 145.34 (d, *J* = 11.8 Hz), 135.78 (s), 134.46 (s), 130.30 (s), 128.46 (s), 128.13 (s), 125.64 (d, *J* = 10.1 Hz), 124.94 (s), 122.92 (d, *J* = 3.3 Hz), 109.52 (d, *J* = 22.6 Hz), 98.03 (d, *J* = 27.7 Hz), 80.06 (s), 34.24 (s), 26.72 (s).

^{19}F NMR (565 MHz, $CDCl_3$) δ -107.14 – -107.27 (m).

HRMS (ESI): $C_{17}H_{12}FNNaO_3$ [$(M+Na)^+$]: calcd.: 320.0693; found: 320.0688.

7-Bromo-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2h)



A white solid, 58.5 mg, 82% yield.

m.p.: 226 – 228 °C.

TLC: R_f = 0.52 (petroleum ether/ethyl acetate = 2:1) [UV].

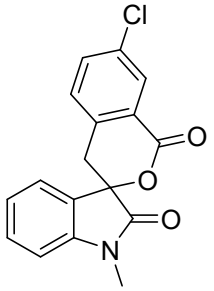
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18 (d, *J* = 7.7 Hz, 1H), 7.59 (td, *J* = 7.5, 1.1 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.23 (d, *J* = 7.5 Hz, 1H), 6.97 (dd, *J* = 7.4, 1.0 Hz, 1H), 6.84 (t, *J* = 7.8 Hz, 1H), 3.56 (s, 3H), 3.45 (d, *J* = 16.7 Hz, 1H), 3.35 (d, *J* = 16.7 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 173.2 (s), 163.5 (s), 140.8 (s), 136.7 (s), 135.5 (s), 134.4 (s), 130.4 (s), 130.2 (s), 128.4 (s), 128.0 (s), 124.9 (s), 124.6 (s), 123.3 (s), 103.2 (s), 79.7 (s), 34.5 (s), 30.2 (s).

HRMS (ESI): $C_{17}H_{12}{}^{79}BrNNaO_3$ [$(M+Na)^+$]: calcd.: 379.9893; found: 379.9887.

The spectra data are matched with those reported.[5]

7'-Chloro-1-methylspiro[indoline-3,3'-isochromane]-1',2-dione (2i)



A white solid, 43.7 mg, 70% yield.

m.p.: 230 – 232 °C.

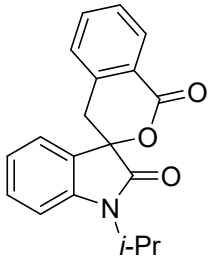
TLC: R_f = 0.34 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.17 (d, *J* = 2.1 Hz, 1H), 7.56 (dd, *J* = 8.1, 2.2 Hz, 1H), 7.41 – 7.37 (m, 1H), 7.20 (d, *J* = 8.1 Hz, 1H), 7.05 – 6.97 (m, 2H), 6.88 (d, *J* = 7.9 Hz, 1H), 3.44 (d, *J* = 16.8 Hz, 1H), 3.34 (d, *J* = 16.8 Hz, 1H), 3.20 (s, 3H).

^{13}C NMR(101 MHz, $CDCl_3$) δ 172.3 (s), 162.8 (s), 143.4 (s), 134.4 (s), 134.3 (s), 134.2 (s), 131.4 (s), 130.0 (s), 129.5 (s), 127.0 (s), 126.5 (s), 124.2 (s), 123.6 (s), 109.1 (s), 80.5 (s), 33.8 (s), 26.6 (s).

HRMS (ESI): $C_{17}H_{12}ClNNaO_3$ [$(M+Na)^+$]: calcd.: 336.0398; found: 336.0394.

1-Isopropylspiro[indoline-3,3'-isochromane]-1',2-dione (2j)



A white solid, 58.8 mg, 96% yield.

m.p.: 173 – 174 °C.

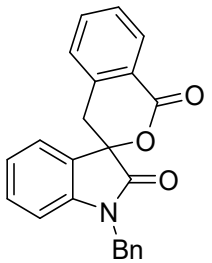
TLC: R_f = 0.47 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.20 (d, *J* = 7.7 Hz, 1H), 7.60 (t, *J* = 7.5 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.36 – 7.30 (m, 1H), 7.26 (d, *J* = 9.8 Hz, 1H), 7.01 (d, *J* = 8.0 Hz, 1H), 6.98 – 6.90 (m, 2H), 4.58 – 4.49 (m, 1H), 3.53 (d, *J* = 16.6 Hz, 1H), 3.29 (d, *J* = 16.6 Hz, 1H), 1.49 (d, *J* = 6.8 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.2 (s), 163.9 (s), 142.2 (s), 136.1 (s), 134.3 (s), 130.9 (s), 130.2 (s), 128.2 (s), 128.1 (s), 127.9 (s), 125.1 (s), 124.4 (s), 122.8 (s), 110.5 (s), 80.3 (s), 44.6 (s), 34.4 (s), 19.5 (s), 19.3 (s).

HRMS (ESI): $C_{19}H_{18}NO_3$ [$(M+H)^+$]: calcd.: 308.1281; found: 308.1286.

1-Benzylspiro[indoline-3,3'-isochromane]-1',2-dione (2k)



A yellow oil, 53.3 mg, 75% yield.

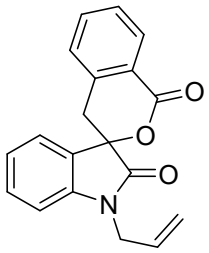
TLC: R_f = 0.66 (petroleum ether/ethyl acetate = 1:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.21 (d, *J* = 7.7 Hz, 1H), 7.61 (t, *J* = 7.5 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.36 – 7.25 (m, 6H), 7.24 – 7.21 (m, 1H), 6.94 – 6.85 (m, 2H), 6.75 (d, *J* = 7.9 Hz, 1H), 4.88 (s, 2H), 3.62 (d, *J* = 16.5 Hz, 1H), 3.33 (d, *J* = 16.5 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.6 (s), 163.8 (s), 142.4 (s), 135.9 (s), 135.0 (s), 134.39 (s), 131.0 (s), 130.2 (s), 129.0 (s), 128.4 (s), 128.2 (s), 128.0 (s), 127.4 (s), 125.0 (s), 124.2 (s), 123.4 (s), 110.1 (s), 80.6 (s), 44.1 (s), 34.4 (s).

HRMS (ESI): $C_{23}H_{18}NO_3$ [$(M+H)^+$]: calcd.: 356.1280; found:356.1280.

1-Allylspiro[indoline-3,3'-isochromane]-1',2-dione (2l)



A white solid, 45.1 mg, 74% yield.

m.p.: 98.7 – 99.5 °C.

TLC: R_f = 0.68 (petroleum ether/ethyl acetate = 1:1) [UV].

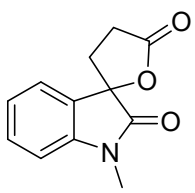
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 7.6 Hz, 1H), 7.60 (td, *J* = 7.5, 1.0 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 1H), 7.31 (td, *J* = 7.7, 1.4 Hz, 1H), 7.26 (d, *J* = 7.5 Hz, 1H), 6.92 (dt, *J* = 7.4, 6.9 Hz, 2H), 6.86 (d, *J* = 7.9 Hz, 1H), 5.90 – 5.74 (m, 1H), 5.29 – 5.23 (m, 2H), 4.37 – 4.24 (m, 2H), 3.57 (d, *J* = 16.6 Hz, 1H), 3.30 (d, *J* = 16.6 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.2 (s), 163.8 (s), 142.5 (s), 135.9 (s), 134.4 (s), 131.0 (s), 130.7 (s), 130.2 (s), 128.3 (s), 128.1 (s), 127.3 (s), 125.0 (s), 124.1 (s), 123.4 (s), 118.4 (s), 109.9 (s), 80.5 (s), 42.7 (s), 34.3 (s).

HRMS (ESI): $C_{19}H_{16}NO_3$ [$(M+H)^+$]: calcd.: 306.1125; found: 306.1129.

The spectra data are matched with those reported.[5]

1'-Methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4a)



A pale yellow solid, 31.1 mg, 72% yield.

m.p.: 121 – 123 °C.

TLC: R_f = 0.28 (petroleum ether/ethyl acetate = 2:1) [UV].

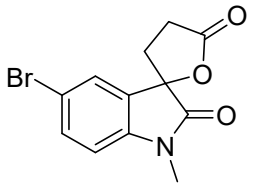
^{1}H NMR(400 MHz, $CDCl_3$) δ 7.40 (td, *J* = 7.8, 1.1 Hz, 1H, ArH), 7.35 (d, *J* = 7.4 Hz, 1H, ArH), 7.13 (td, *J* = 7.6, 0.7 Hz, 1H, ArH), 6.86 (d, *J* = 7.8 Hz, 1H, ArH), 3.25 – 3.15 (m, 4H, CH_3+CH_2), 2.77 (ddd, *J* = 17.6, 9.5, 3.1 Hz, 1H, CH_2), 2.57 (ddd, *J* = 12.9, 9.7, 3.1 Hz, 1H, CH_2), 2.46 (ddd, *J* = 13.3, 10.6, 9.6 Hz, 1H, CH_2).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.2 (s), 174.3 (s), 144.0 (s), 131.3 (s), 126.5 (s), 124.3 (s), 123.7 (s), 109.0 (s), 82.4 (s), 31.4 (s), 28.4 (s), 26.5 (s).

HRMS (ESI): $C_{12}H_{12}NO_3$ [$(M+H)^+$]: calcd.: 218.0812; found: 218.0810.

The spectra data are matched with those reported.[1]

5'-Bromo-1'-methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4b)



A white solid, 43.5 mg, 74% yield.

m.p.: 135 – 136 °C.

TLC: R_f = 0.36 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (dd, *J* = 8.3, 1.9 Hz, 1H), 7.47 (d, *J* = 1.9 Hz, 1H), 6.75 (d, *J* = 8.3 Hz, 1H), 3.30 – 3.06 (m, 4H), 2.76 (ddd, *J* = 17.7, 9.6, 3.1 Hz, 1H), 2.57 (ddd, *J* = 13.0, 9.7, 3.1 Hz, 1H), 2.49 – 2.38 (m, 1H).

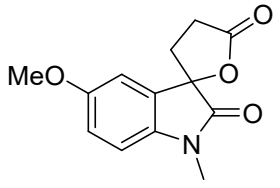
^{13}C NMR (101 MHz, $CDCl_3$) δ 175.7 (s), 173.8 (s), 143.0 (s), 134.1 (s), 128.4 (s), 127.7 (s), 116.2 (s), 110.5 (s), 81.9 (s), 31.3 (s), 28.2 (s), 26.6 (s).

HRMS (ESI): $C_{12}H_{10}{}^{79}BrNNaO_3$ [$(M+Na)^+$]: calcd.: 317.9737; found: 317.9741.

HRMS (ESI): $C_{12}H_{10}{}^{81}BrNNaO_3$ [$(M+Na)^+$]: calcd.: 319.9716; found: 319.9722.

The spectra data are matched with those reported.[7]

5'-methoxy-1'-methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4c)



A white solid, 31 mg, 63% yield.

m.p.: 178 – 179 °C.

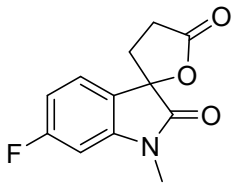
TLC: R_f = 0.35 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 6.96 (d, *J* = 2.5 Hz, 1H), 6.91 (dd, *J* = 8.5, 2.5 Hz, 1H), 6.77 (d, *J* = 8.5 Hz, 1H), 3.80 (s, 3H), 3.24 – 3.16 (m, 4H), 2.76 (ddd, *J* = 17.7, 9.6, 3.0 Hz, 1H), 2.57 (ddd, *J* = 12.8, 9.7, 3.0 Hz, 1H), 2.43 (ddd, *J* = 13.3, 10.6, 9.7 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 176.2 (s), 174.1 (s), 156.8 (s), 137.2 (s), 127.6 (s), 115.8 (s), 111.5 (s), 109.5 (s), 82.7 (s), 56.2 (s), 31.6 (s), 28.4 (s), 26.5 (s).

HRMS (ESI): $C_{13}H_{13}NNaO_4$ [$(M+Na)^+$]: calcd.: 270.0737; found: 270.0750.

6'-Fluoro-1'-methyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4d)



A white solid, 33.4 mg, 71% yield.

m.p.: 127 – 129 °C.

TLC: R_f = 0.31 (petroleum ether/ethyl acetate = 2:1) [UV].

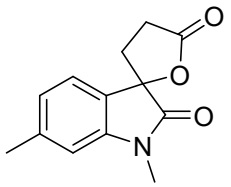
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 – 7.28 (m, 1H), 6.84 – 6.76 (m, 1H), 6.60 (d, *J* = 8.4 Hz, 1H), 3.23 – 3.14 (m, 4H), 2.76 (dd, *J* = 17.7, 9.5 Hz, 1H), 2.60 – 2.52 (m, 1H), 2.47 – 2.40 (m, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 175.9 (s), 174.6 (s), 164.9 (d, *J* = 249.7 Hz), 145.9 (d, *J* = 11.8 Hz), 125.9 (d, *J* = 10.3 Hz), 121.9 (d, *J* = 3.1 Hz), 109.9 (d, *J* = 22.7 Hz), 98.1 (d, *J* = 27.9 Hz), 81.9 (s), 31.4 (s), 28.4 (s), 26.6 (s).

^{19}F NMR (565 MHz, $CDCl_3$) δ -106.93 – -107.01 (m).

HRMS (ESI): $C_{12}H_{10}FNNaO_3$ [$(M+Na)^+$]: calcd.: 258.0537; found: 258.0540.

1',6'-Dimethyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4e)



A white solid, 32.3 mg, 70% yield.

m.p.: 139 – 140 °C.

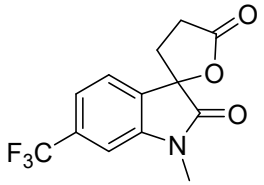
TLC: R_f = 0.51 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 7.6 Hz, 1H), 6.68 (s, 1H), 3.24 – 3.13 (m, 4H), 2.75 (ddd, *J* = 17.6, 9.5, 3.1 Hz, 1H), 2.54 (ddd, *J* = 12.9, 9.7, 3.1 Hz, 1H), 2.47 – 2.41 (m, 1H), 2.39 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.3 (s), 174.6 (s), 144.1 (s), 142.0 (s), 124.1 (s), 124.1 (s), 123.5 (s), 109.9 (s), 82.5 (s), 31.4 (s), 28.5 (s), 26.4 (s), 22.1 (s).

HRMS (ESI): $C_{13}H_{13}NNaO_3$[(M+Na)$^+$]: calcd.: 254.0788; found: 254.0793.

1'-methyl-6'-(trifluoromethyl)-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4f)



A white solid, 47.8 mg, 84% yield.

m.p.: 164 – 166 °C.

TLC: R_f = 0.63 (petroleum ether/ethyl acetate = 1:1) [UV].

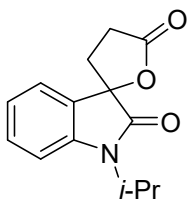
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.7 Hz, 1H), 7.41 (d, *J* = 7.7 Hz, 1H), 7.07 (s, 1H), 3.24 (s, 3H), 3.18 (dt, *J* = 17.8, 10.2 Hz, 1H), 2.78 (ddd, *J* = 17.7, 9.6, 2.9 Hz, 1H), 2.58 (ddd, *J* = 12.9, 9.7, 2.9 Hz, 1H), 2.47 (dt, *J* = 13.4, 10.2 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 175.7 (s), 174.0 (s), 144.7 (s), 133.6 (q, *J* = 32.8 Hz), 130.2 (s), 124.7 (s), 123.59 (q, *J* = 272.7 Hz), 120.8 (q, *J* = 4.0 Hz), 105.8 (q, *J* = 3.7 Hz), 81.6 (s), 31.3 (s), 28.1 (s), 26.6 (s).

^{19}F NMR (565 MHz, $CDCl_3$) δ -62.89 (s).

HRMS (ESI): $C_{13}H_{10}F_3NaO_3$ [(M+Na)$^+$]: calcd.: 308.0505; found: 308.0503.

1'-Isopropyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4g)



A yellow oil, 40.3 mg, 82% yield.

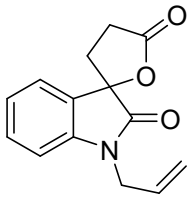
TLC: R_f = 0.56 (petroleum ether/ethyl acetate = 2:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 – 7.31 (m, 2H), 7.10 (t, *J* = 7.5 Hz, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 4.55 – 4.47 (m, 1H), 3.19 (dt, *J* = 17.7, 10.2 Hz, 1H), 2.75 (ddd, *J* = 17.7, 9.6, 2.9 Hz, 1H), 2.55 (ddd, *J* = 12.9, 9.8, 2.9 Hz, 1H), 2.43 (dt, *J* = 13.3, 10.2 Hz, 1H), 1.48 (d, *J* = 7.0 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.2 (s), 174.1(s), 142.8 (s), 131.0 (s), 127.0 (s), 124.6 (s), 123.2 (s), 110.5 (s), 82.3 (s), 44.5 (s), 31.5 (s), 28.5 (s), 19.5 (s), 19.3 (s).

HRMS (ESI): $C_{14}H_{16}NO_3$ [$(M+H)^+$]: calcd.:246.1125; found: 246.1128.

1'-allyl-3,4-dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4h)



A white solid, 29.4 mg, 60% yield.

TLC: R_f = 0.59 (petroleum ether/ethyl acetate = 1:1) [UV].

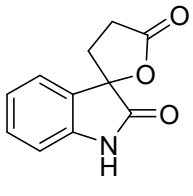
^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 – 7.33 (m, 2H), 7.13 (t, *J* = 7.6 Hz, 1H), 6.86 (d, *J* = 7.9 Hz, 1H), 5.88 – 5.76 (m, 1H), 5.26 (d, *J* = 0.8 Hz, 1H), 5.26 – 5.22 (m, 1H), 4.35 – 4.27 (m, 2H), 3.21 (ddd, *J* = 17.7, 10.5, 9.9 Hz, 1H), 2.77 (ddd, *J* = 17.7, 9.5, 3.0 Hz, 1H), 2.59 (ddd, *J* = 12.9, 9.7, 3.0 Hz, 1H), 2.48 (ddd, *J* = 13.4, 10.6, 9.7 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 176.2 (s), 174.1 (s), 143.2 (s), 131.2 (s), 130.7 (s), 126.5 (s), 124.4 (s), 123.7 (s), 118.3 (s), 109.9 (s), 82.4 (s), 42.6 (s), 31.5 (s), 28.4 (s).

HRMS (ESI): $C_{14}H_{14}NO_3$ [$(M+H)^+$]: calcd.: 244.0968; found: 244.0974.

The spectra data are matched with those reported.[7]

3,4-Dihydro-5*H*-spiro[furan-2,3'-indoline]-2',5-dione (4i)



A white solid, 21.3 mg, 52% yield.

m.p.: 108 – 110 °C.

TLC: R_f = 0.56 (petroleum ether/ethyl acetate = 1:1) [UV].

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.65 (s, 1H), 7.35 – 7.31 (m, 2H), 7.11 (t, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 7.7 Hz, 1H), 3.17 (dt, *J* = 17.7, 10.1 Hz, 1H), 2.79 (ddd, *J* = 17.7, 9.6, 3.0 Hz, 1H), 2.62 (ddd, *J* = 13.0, 9.7, 3.0 Hz, 1H), 2.47 (ddd, *J* = 13.5, 10.4, 9.8Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 176.6 (s), 176.4 (s), 141.1 (s), 131.4 (s), 126.8 (s), 124.7 (s), 123.8 (s), 111.0 (s), 82.8 (s), 31.5 (s), 28.3 (s).

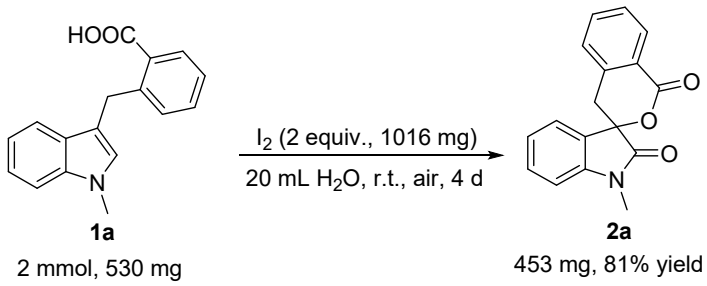
HRMS (ESI): $C_{11}H_{10}NO_3$ [$(M+H)^+$]: calcd.: 204.0654; found: 204.0650.

The spectra data are matched with those reported.[1]

5. Green metrics calculation

E-factor[8] was calculated based on the scale-up synthesis of compound **2a** and **4a**. The calculation of *E*-factor is based on the equation and excluding water: **E-factor = m(waste)/m(product)**. All chemicals used, including solvents and quenching reagent for work-up procedures, are considered.

*E-factor of compound **2a**：*



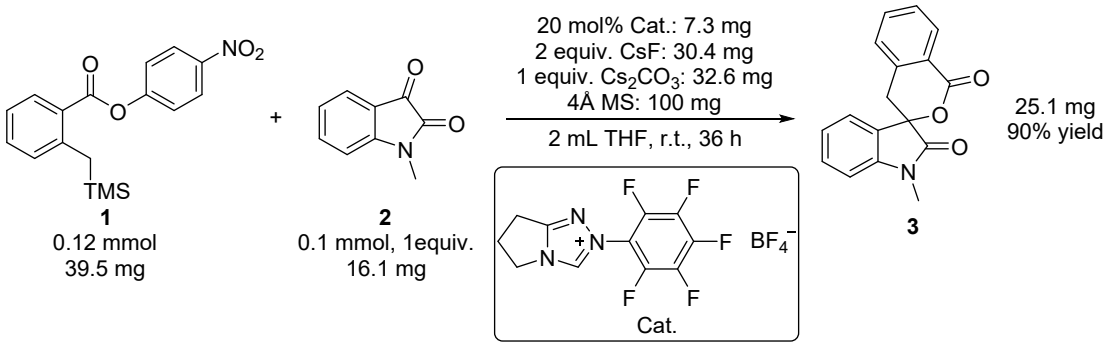
1a
2 mmol, 530 mg

2a
453 mg, 81% yield

$$\text{E-factor} = \frac{\text{m (total waste)}}{\text{m (product)}} \times 100\% = \frac{\begin{array}{c}530\ (\mathbf{1a}) + 1016\ (I_2) + 632\ (Na_2S_2O_3) \\ + 54120\ (\text{EtOAc}) - 453\ (\mathbf{2a}) - 53218\ (\text{EtOAc})\end{array}}{453\ (\mathbf{2a})} \times 100\% = 5.80$$

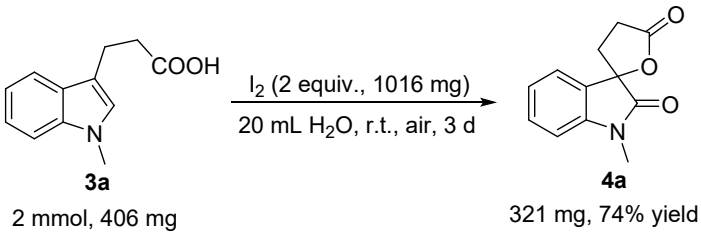
Reactant:	**1a**	530 mg	2 mmol	FW 265.11
Oxidant:	I_2	1016 mg	4 mmol	FW 253.81
Iodine quenching reagent:	$Na_2S_2O_3$	632 mg	4 mmol	FW 158.11
Solvent used for the extraction of product:	EtOAc	54120 mg (60 mL)	614 mmol	FW 88.11
Recovered solvent after extraction:	EtOAc	53218 mg (59 mL)	604 mmol	FW 88.11
Product:	**2a**	453 mg	1.62 mmol	FW 279.09

The *E*-factor of the present protocol was compared with that of established intermolecular synthesis routes for the same target compound. As a representative case, the N-heterocyclic carbene (NHC)-catalyzed intermolecular coupling reaction reported by Chi et al. (H. Wang, X. Chen, Y. Li, J. Wang, S. Wu, W. Xue, S. Yang, Y. R. Chi, *Org. Lett.*, 2018, **20**, 333-336) was selected. Based on the synthetic procedure detailed in the supporting information of that work, the reaction equation and corresponding stoichiometry are provided below.



$$\text{E-factor} = \frac{\text{m (total waste)}}{\text{m (product)}} \times 100\% = \frac{\begin{array}{c}39.5\ (\mathbf{1})+16.1\ (\mathbf{2})+7.3\ (\text{Cat.})+30.4\ (\text{CsF}) \\ +32.6\ (Cs_2CO_3)+100\ (4\ \text{Å MS})+1774\ (\text{THF})-25.1\ (\mathbf{3})\end{array}}{25.1\ (\mathbf{3})} \times 100\% = 78.68$$

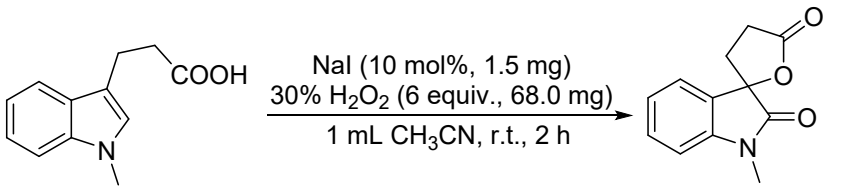
*E-factor of compound **4a**：*



$$\text{E-factor} = \frac{\text{m (total waste)}}{\text{m (product)}} \times 100\% = \frac{\begin{array}{c}406\ (\mathbf{3a})+1016\ (I_2)+632\ (Na_2S_2O_3) \\ +54120\ (\text{EtOAc})-321\ (\mathbf{4a})-53218\ (\text{EtOAc})\end{array}}{321\ (\mathbf{4a})} \times 100\% = 8.21$$

Reactant:	**3a**	406 mg	2 mmol	FW 203.09
Oxidant:	I_2	1016 mg	4 mmol	FW 253.81
Iodine quenching reagent:	$Na_2S_2O_3$	632 mg	4 mmol	FW 158.11
Solvent used for the extraction of product:	EtOAc	54120 mg (60 mL)	614 mmol	FW 88.11
Recovered solvent after extraction:	EtOAc	53218 mg (59 mL)	604 mmol	FW 88.11
Product:	**4a**	321 mg	1.48 mmol	FW 217.07

The *E*-factor of the present protocol was compared with that of established synthesis routes for the same target compound. As a representative case, the NaI/H_2O_2-mediated oxidation/lactonization in CH_3CN reported by Wang et al. (G. Li, L. Huang, J. Xu, W. Sun, J. Xie, L. Hong, R. Wang, *Adv. Synth. Catal.*, 2016, **358**, 2873–2877) was selected. Based on the synthetic procedure detailed in the supporting information of that work, the reaction equation and corresponding stoichiometry are provided below.

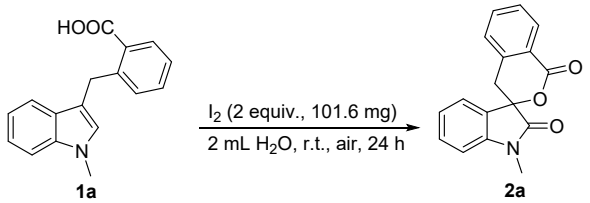


3a
0.1 mmol, 20.3 mg

4a
20.6 mg, 95% yield

$$\text{E-factor} = \frac{\text{m (total waste)}}{\text{m (product)}} \times 100\% = \frac{\begin{array}{c}20.3\ (\mathbf{3a}) + 1.5\ (\text{NaI}) + 68.0\ (H_2O_2) \\ + 786.0\ (CH_3CN) - 20.6\ (\mathbf{4a})\end{array}}{20.6\ (\mathbf{4a})} \times 100\% = 41.51$$

Table S2. EcoScale[9] calculation for the synthesis of **2a**



1a
0.2 mmol, 53.0 mg

2a
48.0 mg, 86% yield

Parameters		Penalty points
1 Yield	(100-%yield)/2=(100-86)/2=7	7
2 Price of reaction components (per 10 mmol of end products)	a. **1a** = 3.074 g = $ 3.40 b. I_2 = 5.893 g = $ 1.17 Total price (USD) = $ 4.57 Thus, inexpensive (Total < $10)	0
3 Safety	N (dangerous for environment) [I_2]	5
4 Technical setup	Common setup (0)	0
5 Temperature and time	Room temperature, < 24 h (1)	1
6 Workup and purification	Adding solvent (0); Liquid-liquid extraction (3); Removal of solvent with bp < 150°C (0); Classical chromatography (10)	13
Total Penalty points		26
EcoScale		74

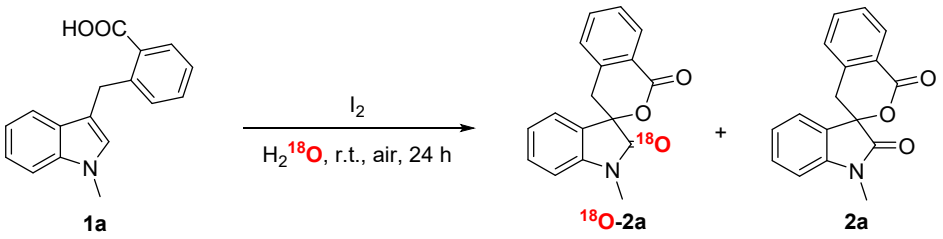
EcoScale = 100 - Sum of individual penalties

Scores on EcoScale: >75, Excellent; >50, Acceptable; <50, inadequate

The Ecoscale value of the present synthesis is 74, which is closed to an excellent point.

The cost analysis was performed using commercial reagent prices from Adamas (specifications: 100g or 100ml), while the price of substrate was determined based on its total synthetic production cost.

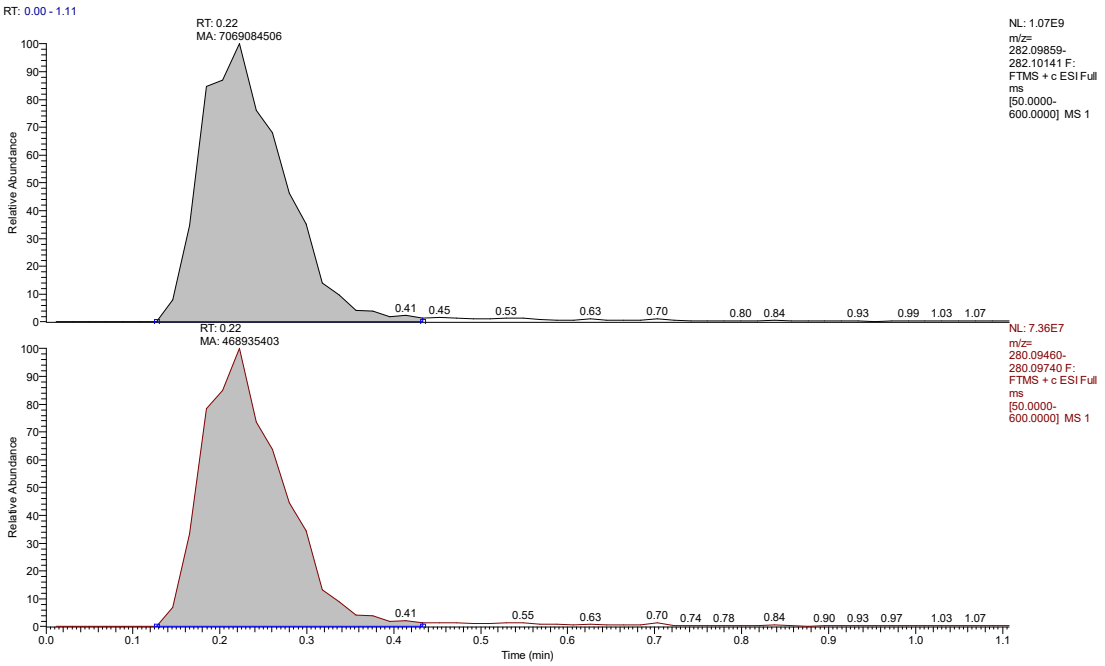
6. Isotope labelling experiments



^{18}O-2a : 2a = 0.94 : 0.06

83% total yield

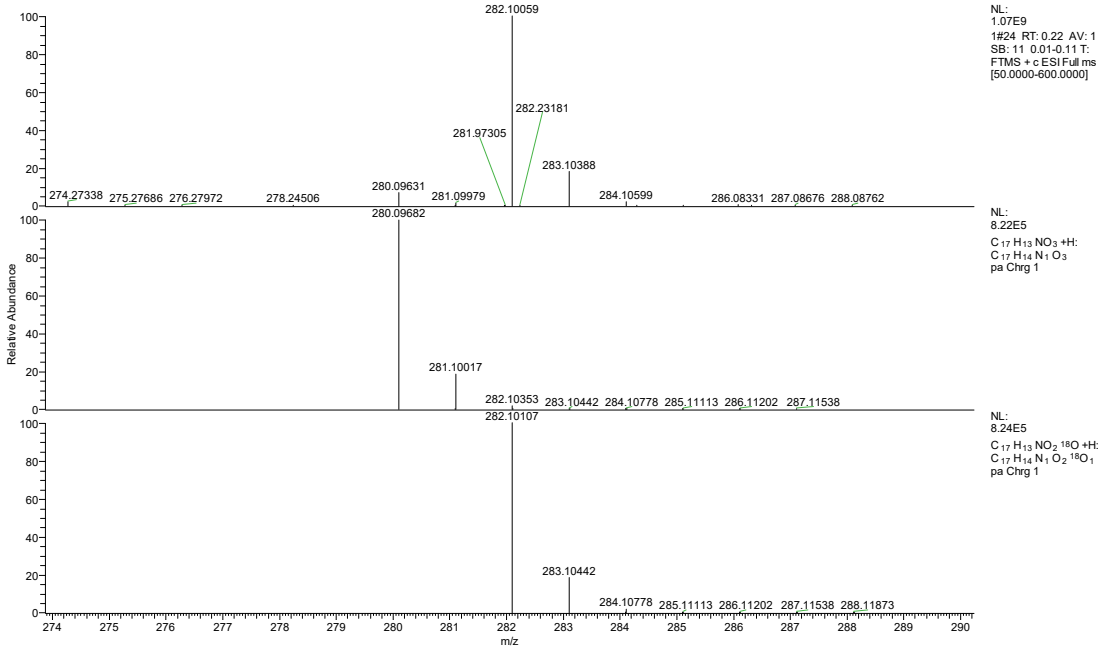
Isotope labelling of the oxygen atom in water was used to determine if the inserted oxygen atom of oxindole in the lactone products were derived from water. For these experiments, 97% $H_2{}^{18}O$ (Purchase from Aladdin) was used instead of $H_2{}^{16}O$. Liquid chromatography-mass spectroscopy (LC-MS) (1100 LC/MSD Trap XCT, Agilent) was used to quantify the products, and determine any shifts in the mass to charge ratio of these products. Two products were detected on the base of LC-MS analysis: **^{18}O-2a** and **2a** with the ratio 0.94:0.06. (**^{18}O-2a/2a**=7069084506/468935403=0.94/0.06)



The molecular weight information in LC-MS:

2a: HRMS (ESI): $C_{17}H_{14}NO_3$ [$(M+H)^+$]: calcd.: 280.0968; found: 280.0968.

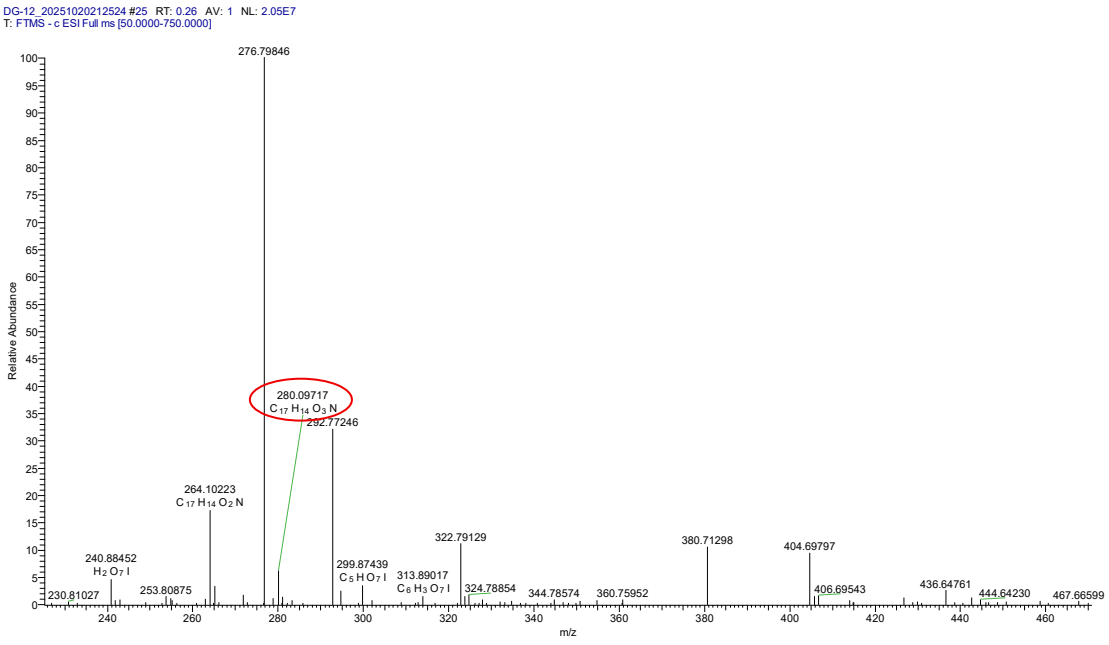
^{18}O-2a: HRMS (ESI): $C_{17}H_{14}NO_2{}^{18}O$ [$(M+H)^+$]: calcd.: 282.1011; found: 282.1011.

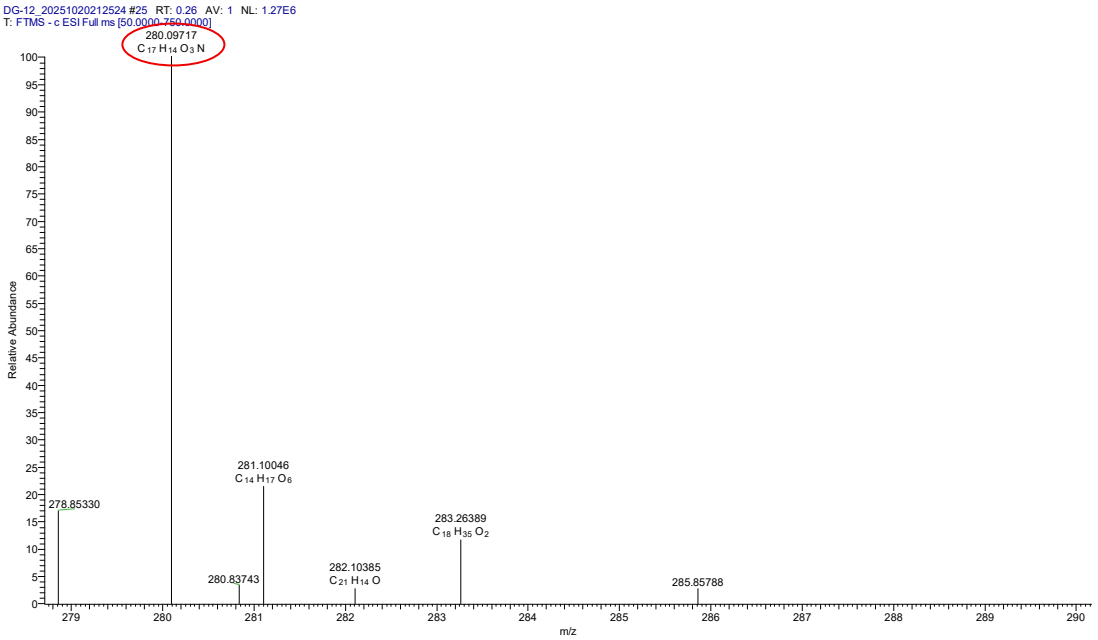


7. Reaction intermediate detection

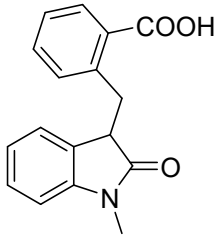
Mechanistic insight was sought through in-situ LC-MS analysis (1100 LC/MSD Trap XCT, Agilent) to detect potential reaction intermediates. For this purpose, the model reaction of **1a** was stirred for 2 h, then extracted with ethyl acetate for direct analysis.

ESI mass spectrum in negative ion mode:



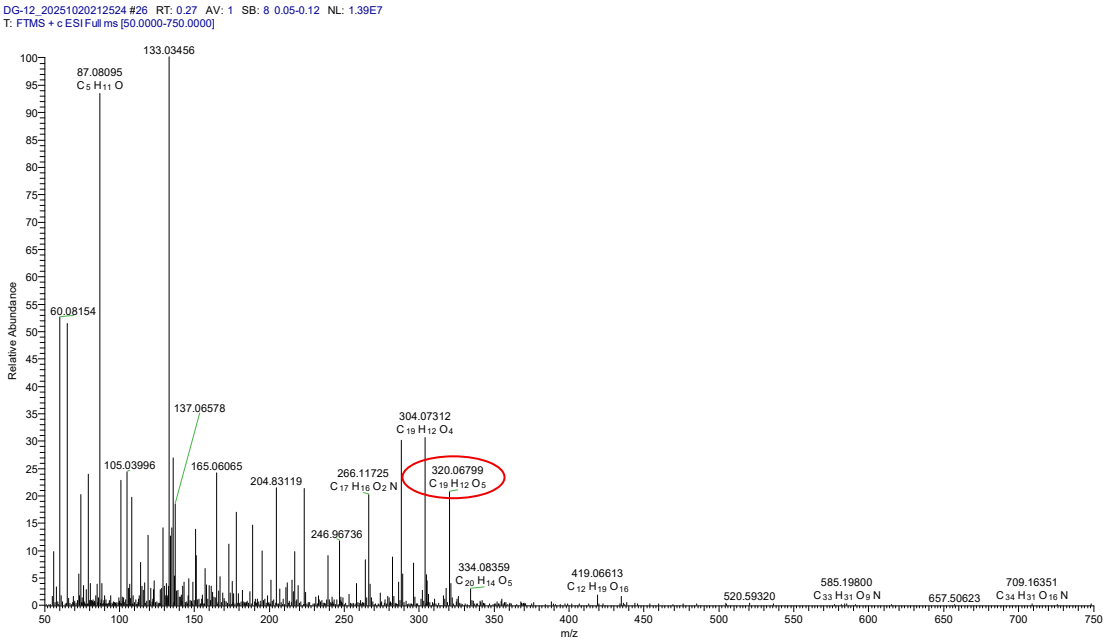


The following possible intermediate have been detected in negative ion mode:

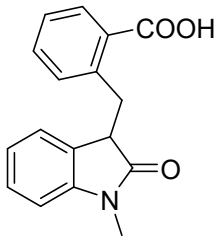


5a: HRMS (ESI): $C_{17}H_{14}NO_3$ [$(M-H)^-$]: calcd.: 280.0979; found: 280.0972.

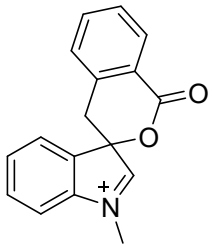
ESI mass spectrum in positive ion mode:



The following possible intermediates have been detected in positive ion mode:



5a: HRMS (ESI): $C_{17}H_{15}KNO_3$ [$(M+K)^+$]: calcd.: 320.0684; found: 320.0680.



6a: HRMS (ESI): $C_{17}H_{14}NO_2$ [M^+]: calcd.: 264.1019; found: 264.1017.

8. References

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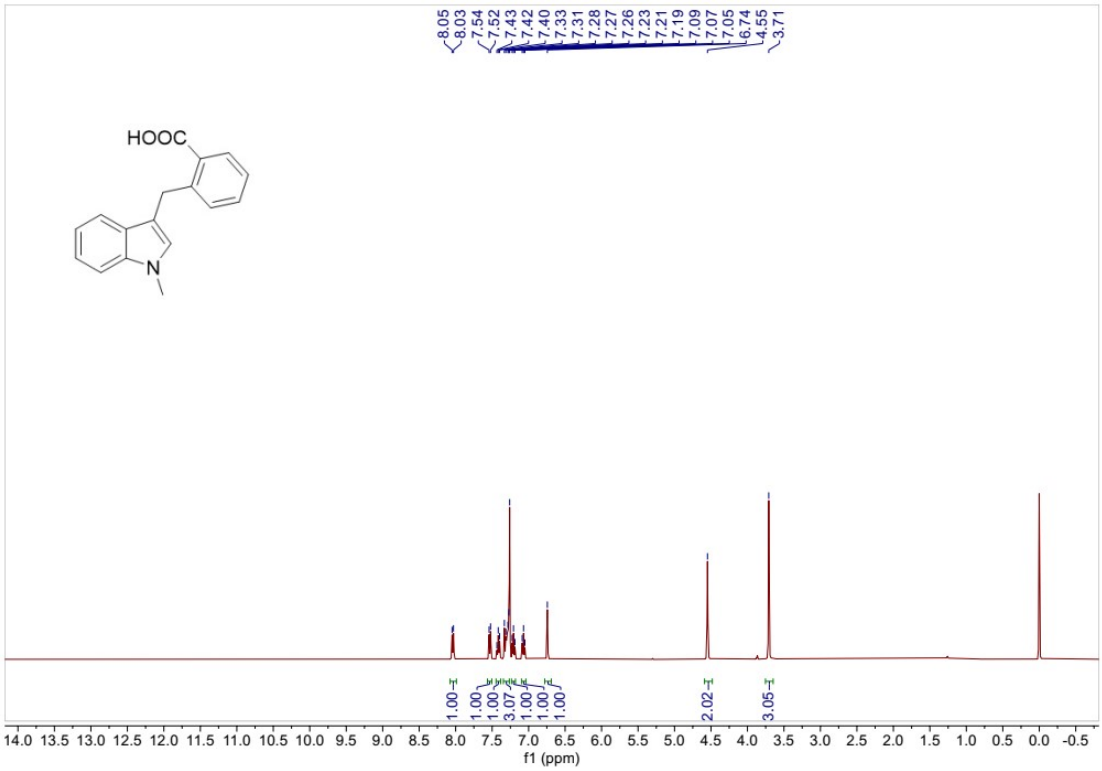
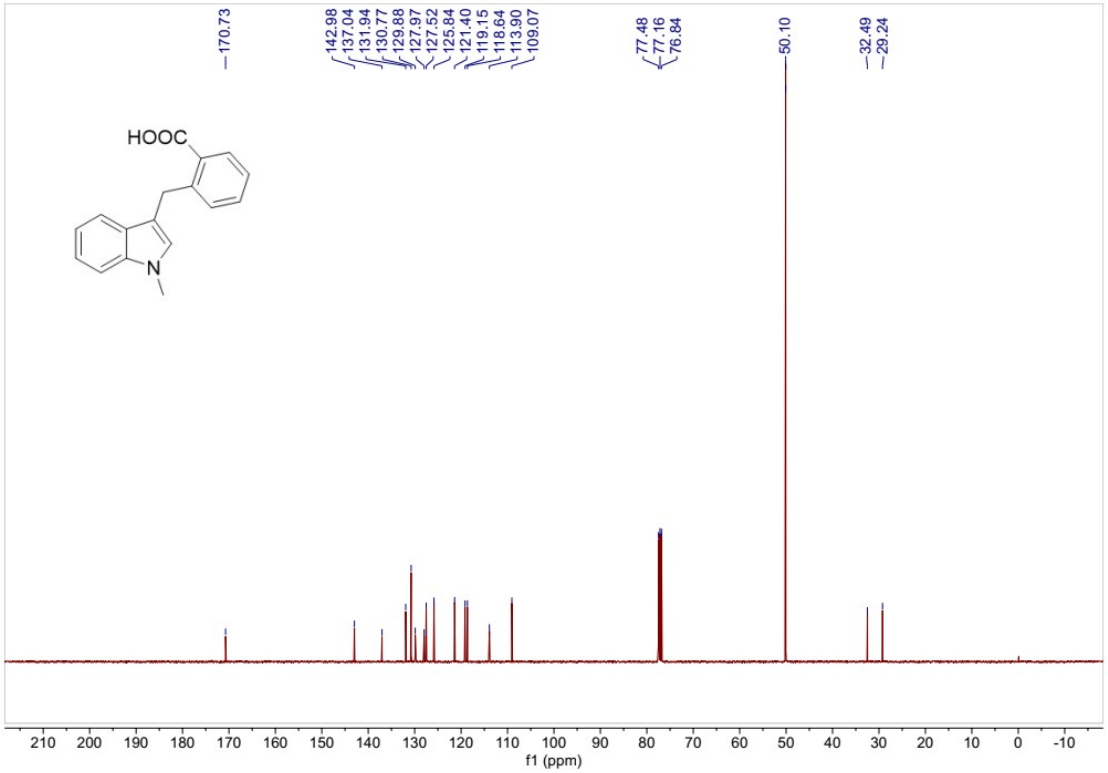
9. Copies of ^{1}H and ^{13}C NMR spectra

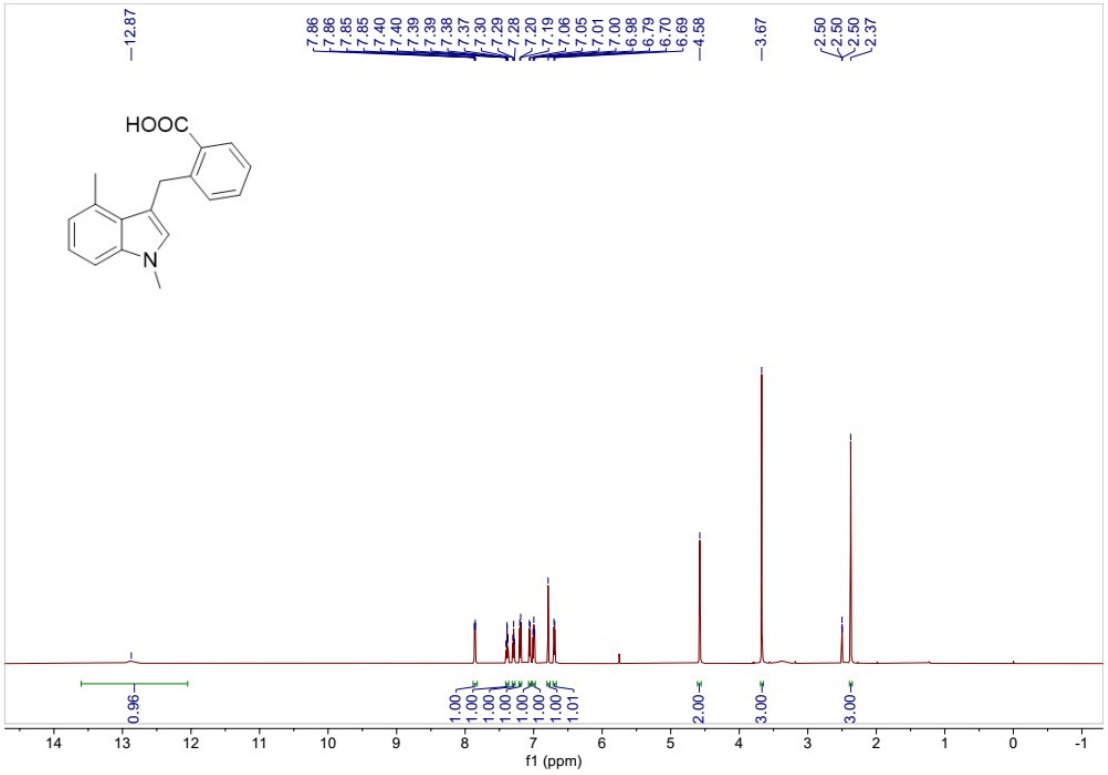
^{1}H NMR spectrum for compound **1a** (In $CDCl_3$, 400MHz)



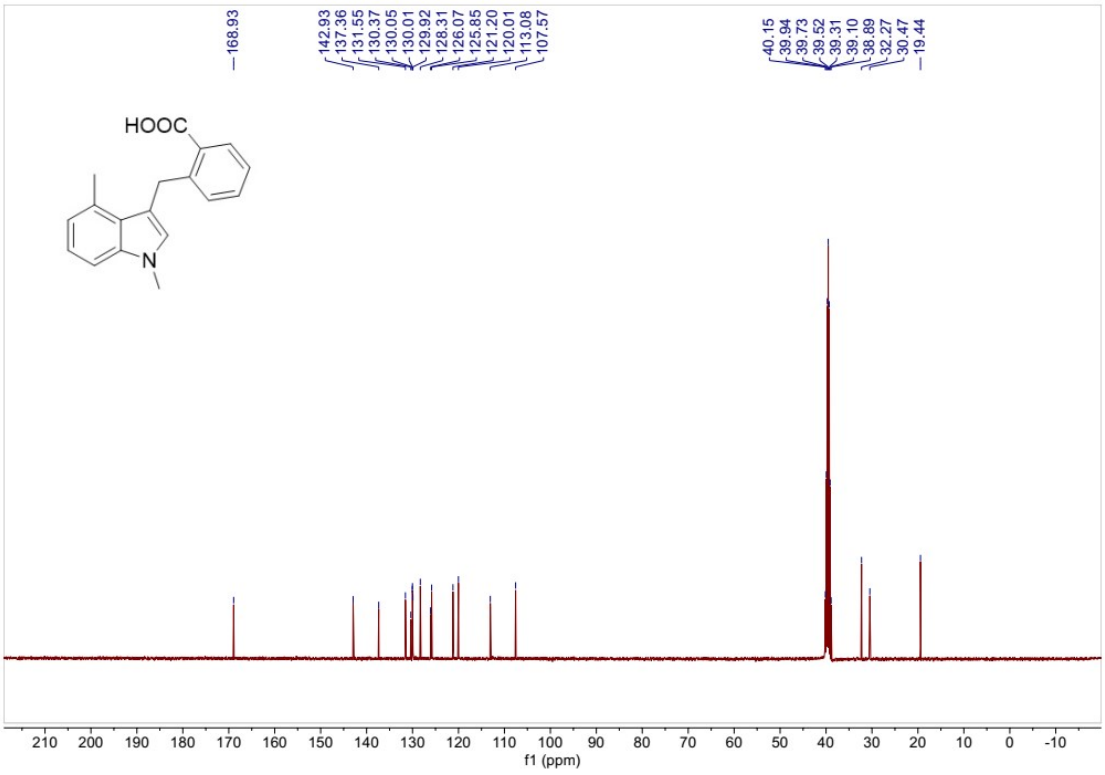
^{13}C NMR spectrum for compound **1a** (In $CDCl_3$+MeOH, 101MHz)



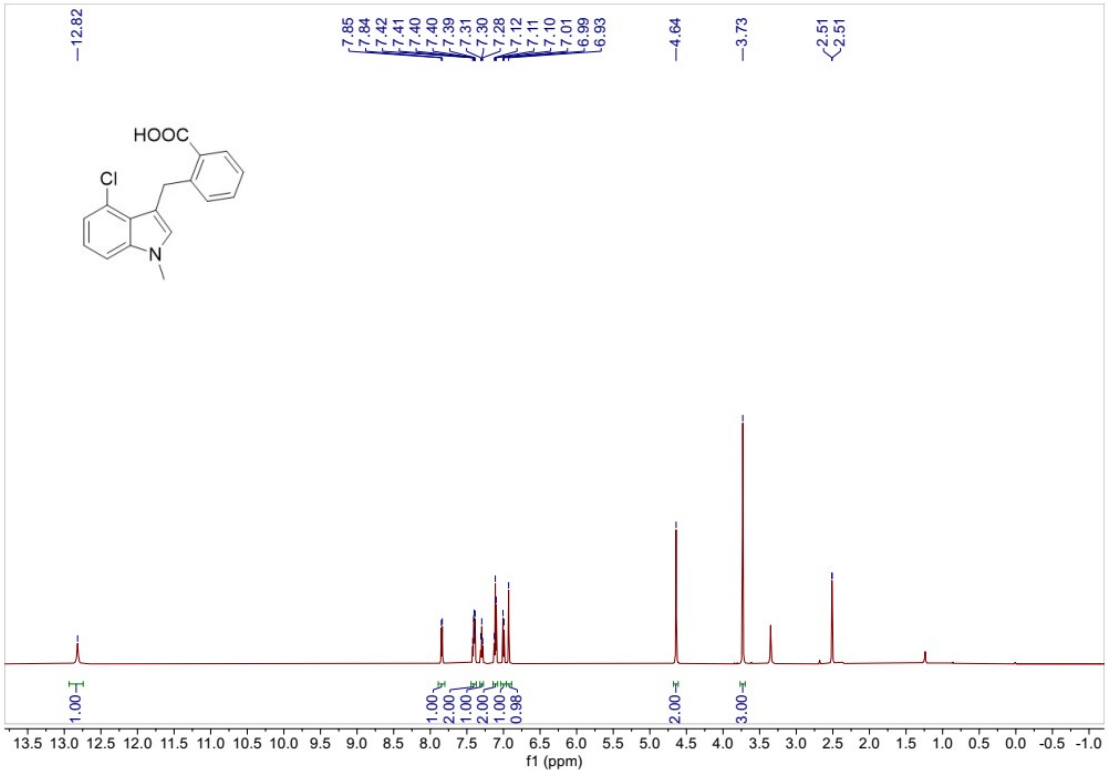
^{1}H NMR spectrum for compound **1b** (In DMSO-d_6, 600MHz)



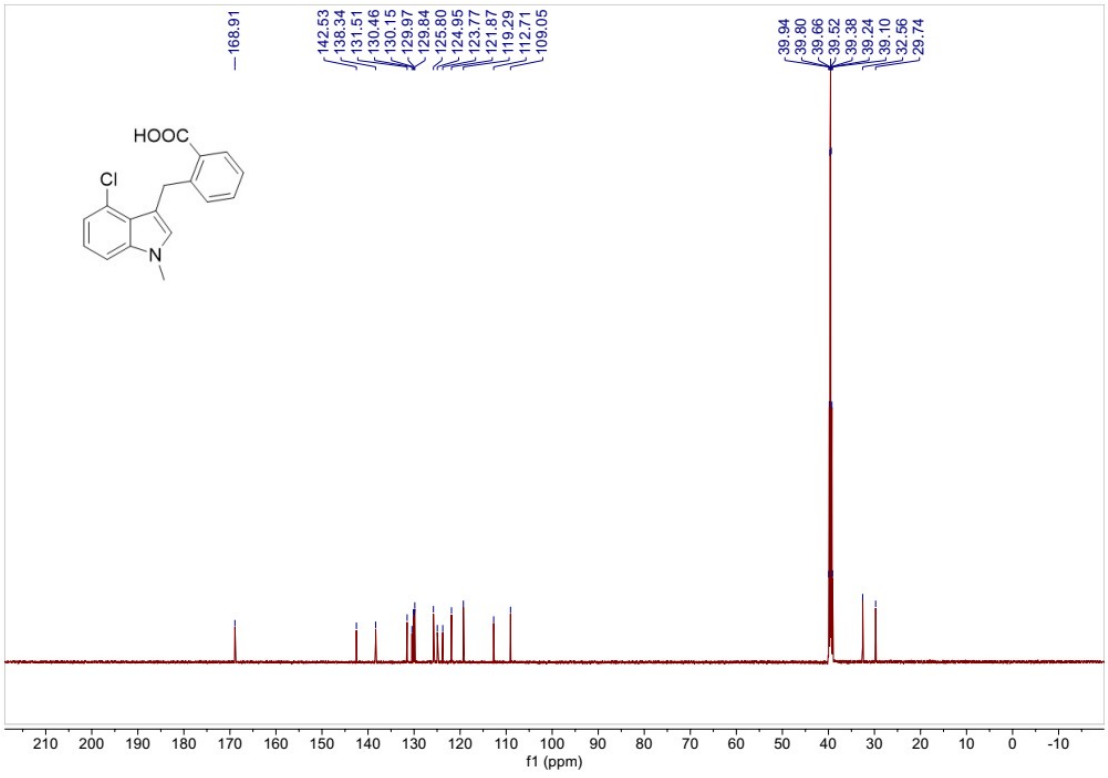
^{13}C NMR spectrum for compound **1b** (In DMSO-d_6, 101MHz)



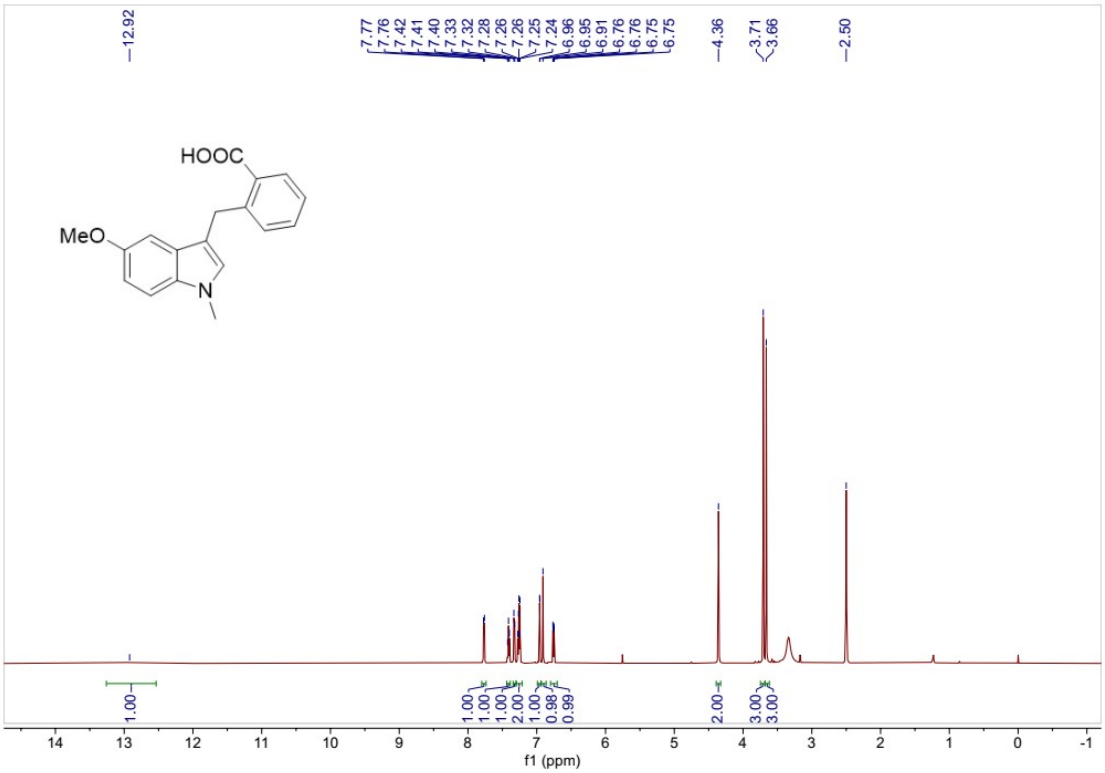
^{1}H NMR spectrum for compound **1c** (In DMSO-d_6, 600MHz)



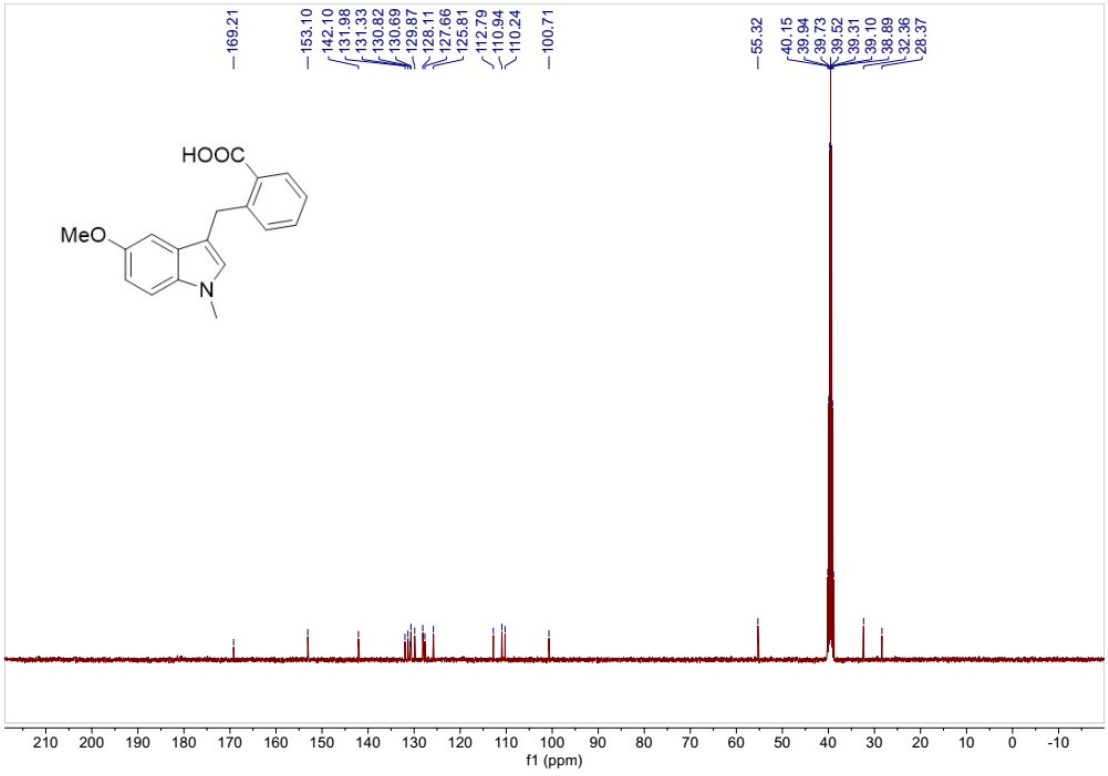
^{13}C NMR spectrum for compound **1c** (In DMSO-d_6, 151MHz)



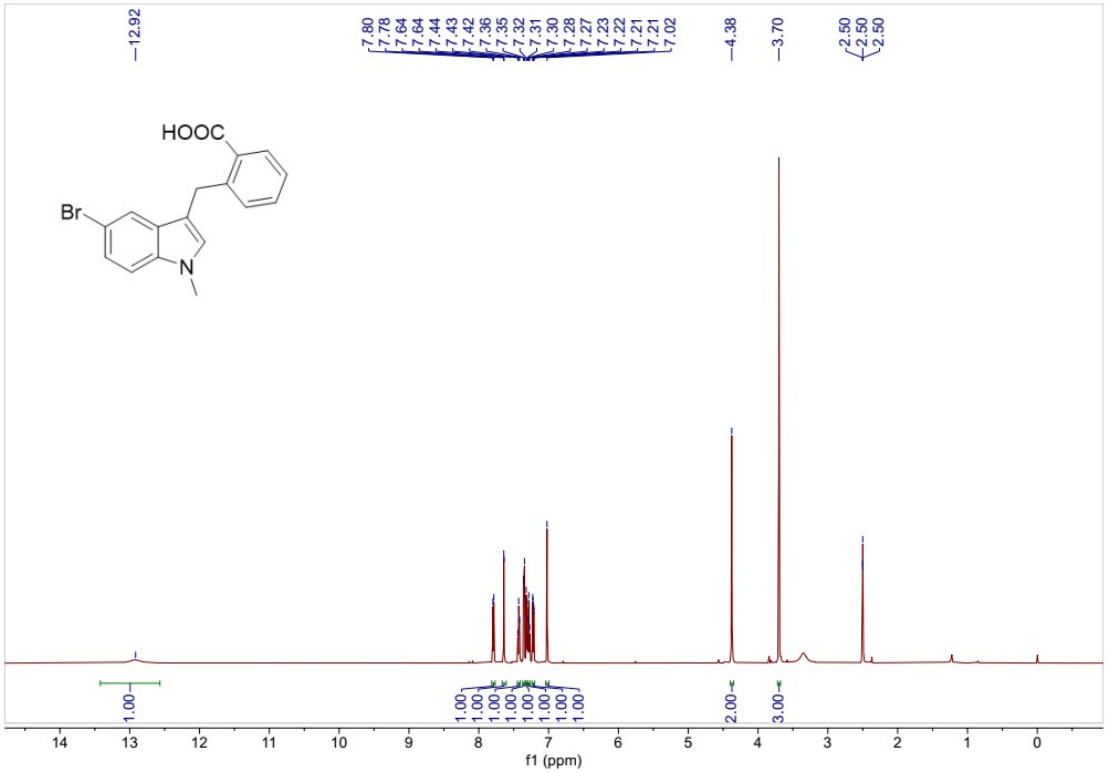
^{1}H NMR spectrum for compound **1d** (In DMSO-d_6, 600MHz)



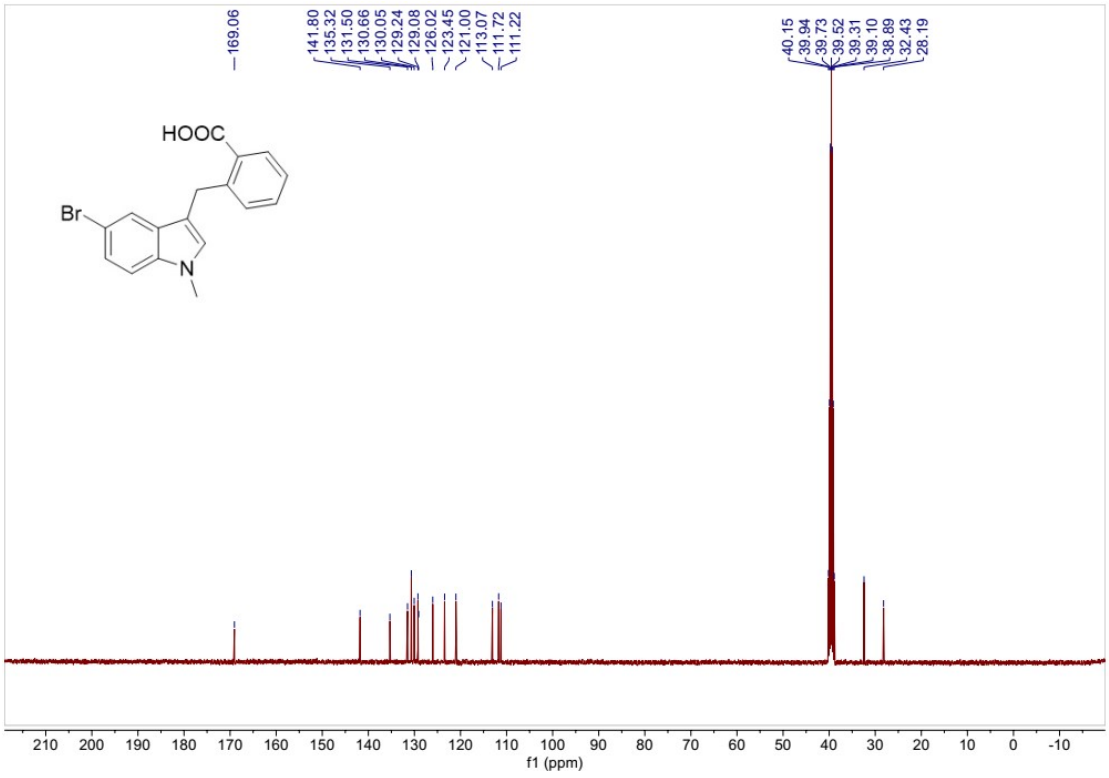
^{13}C NMR spectrum for compound **1d** (In DMSO-d_6, 101MHz)



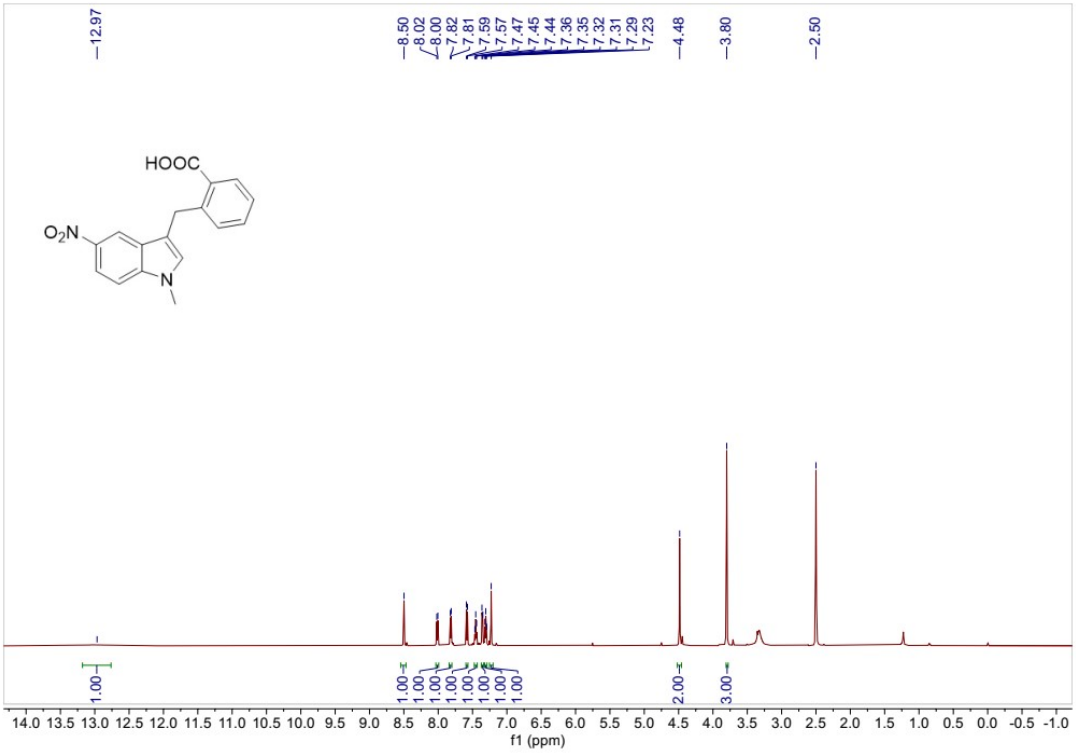
^{1}H NMR spectrum for compound **1e** (In DMSO-d_6, 600MHz)



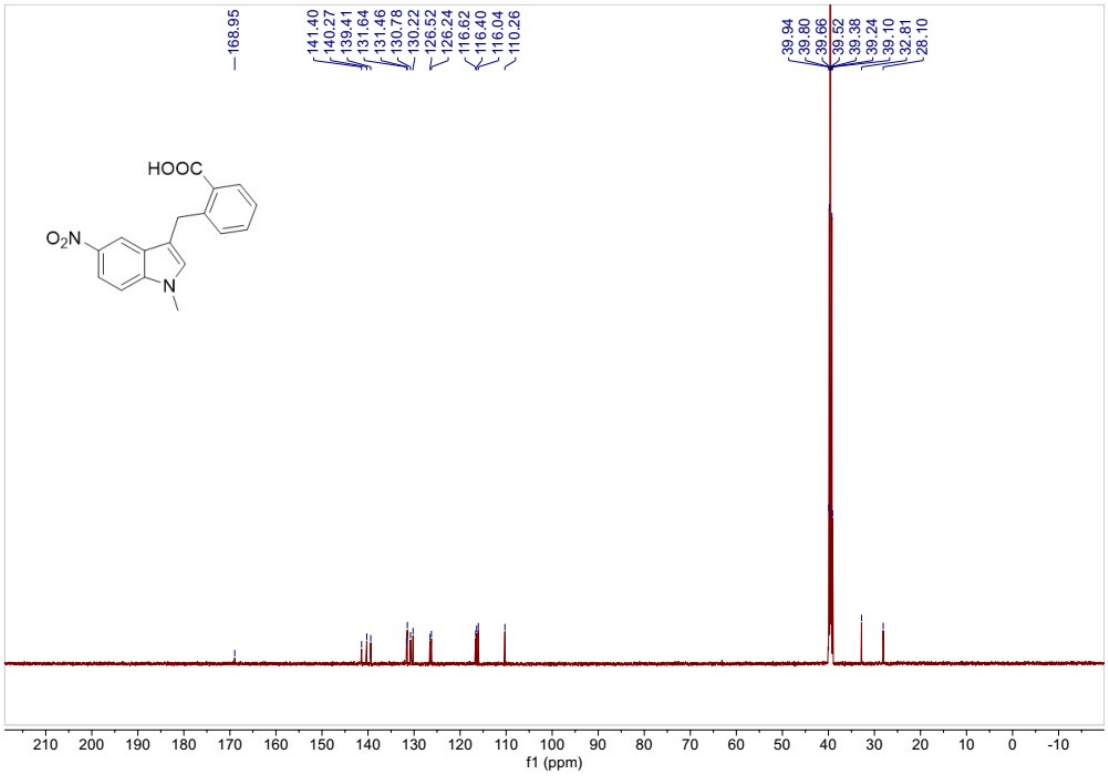
^{13}C NMR spectrum for compound **1e** (In DMSO-d_6, 101MHz)



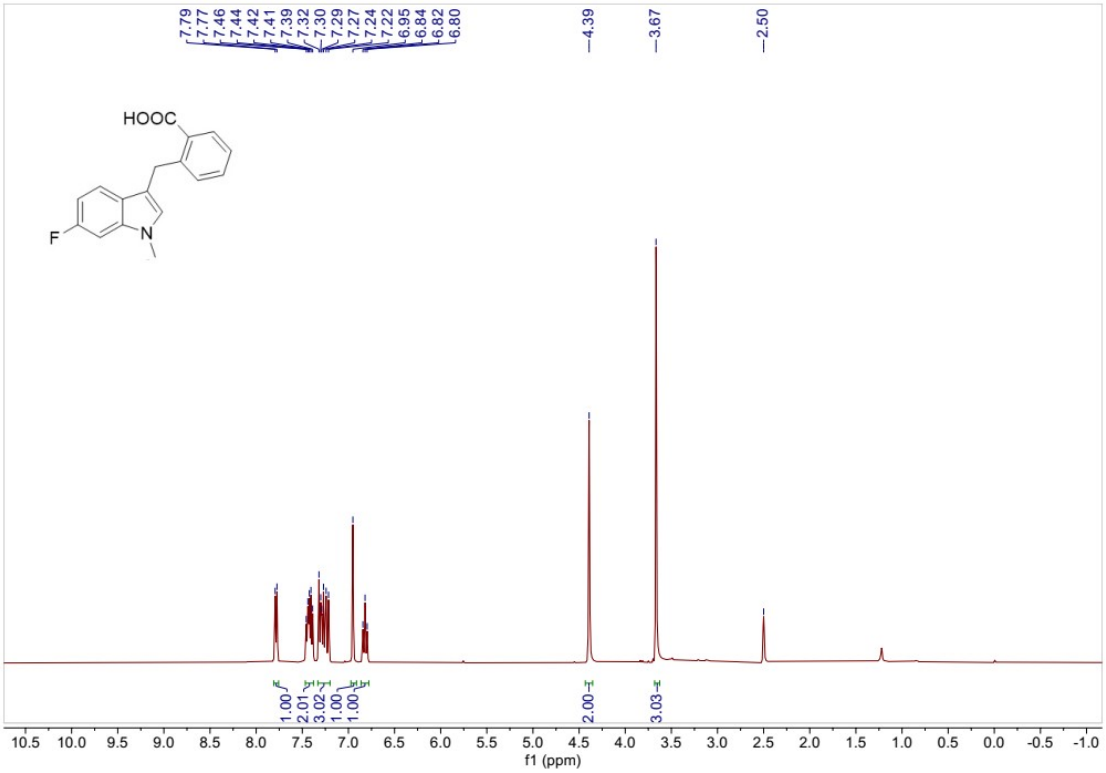
^{1}H NMR spectrum for compound **1f** (In DMSO-d_6, 600MHz)



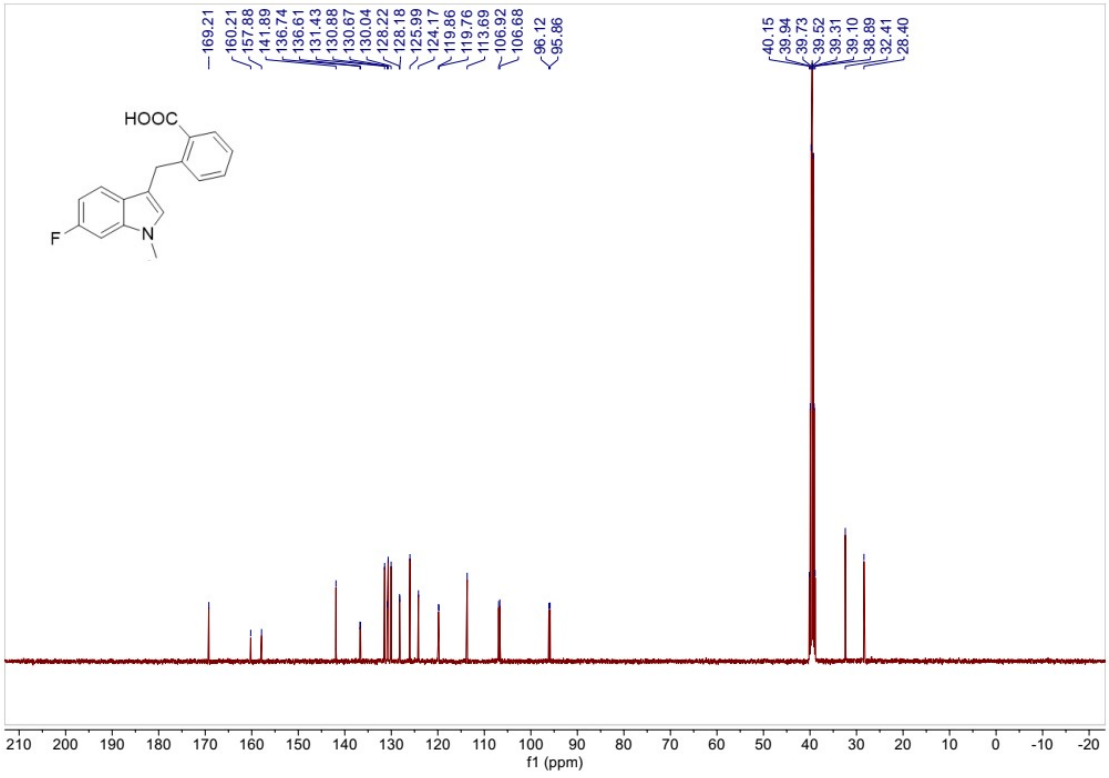
^{13}C NMR spectrum for compound **1f** (In DMSO-d_6, 151MHz)



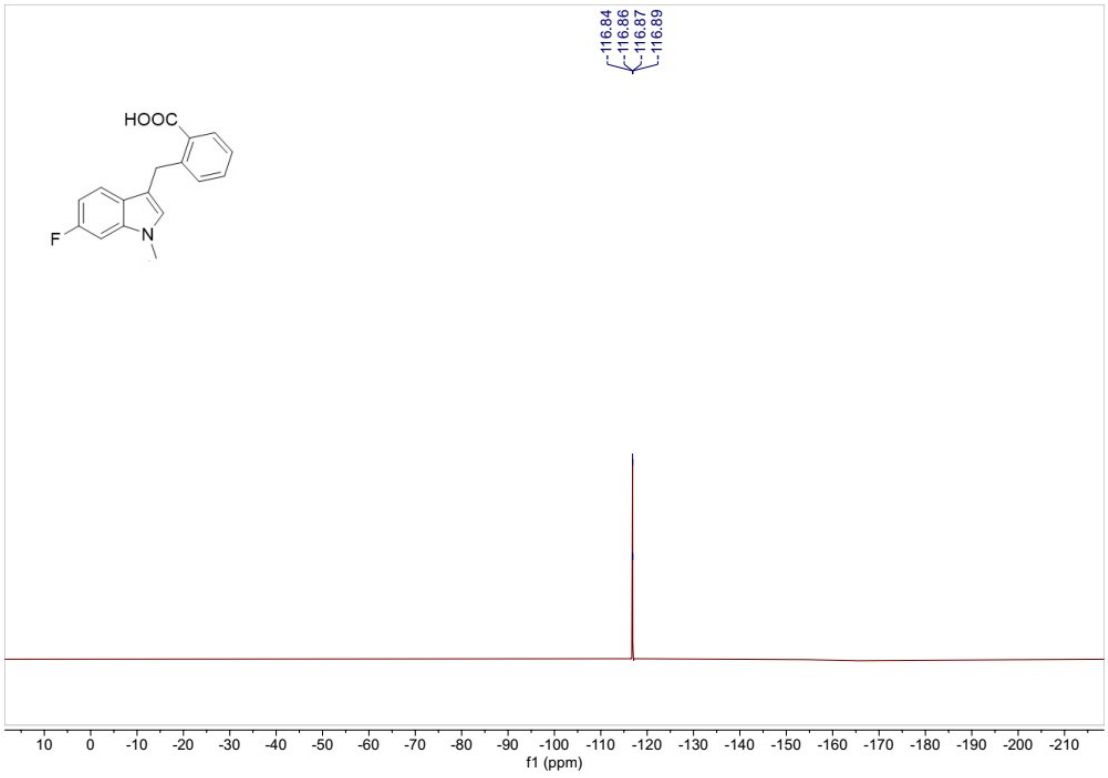
^{1}H NMR spectrum for compound **1g** (In $CDCl_3$, 400MHz)



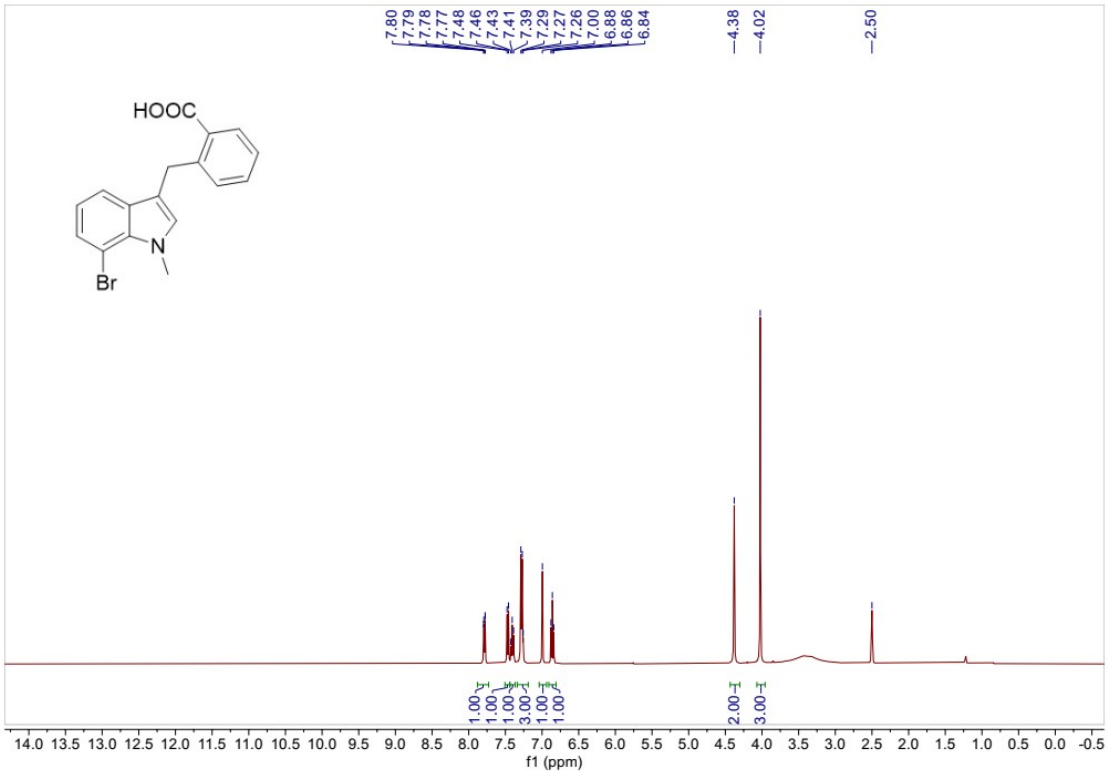
^{13}C NMR spectrum for compound **1g** (In $CDCl_3$, 101MHz)



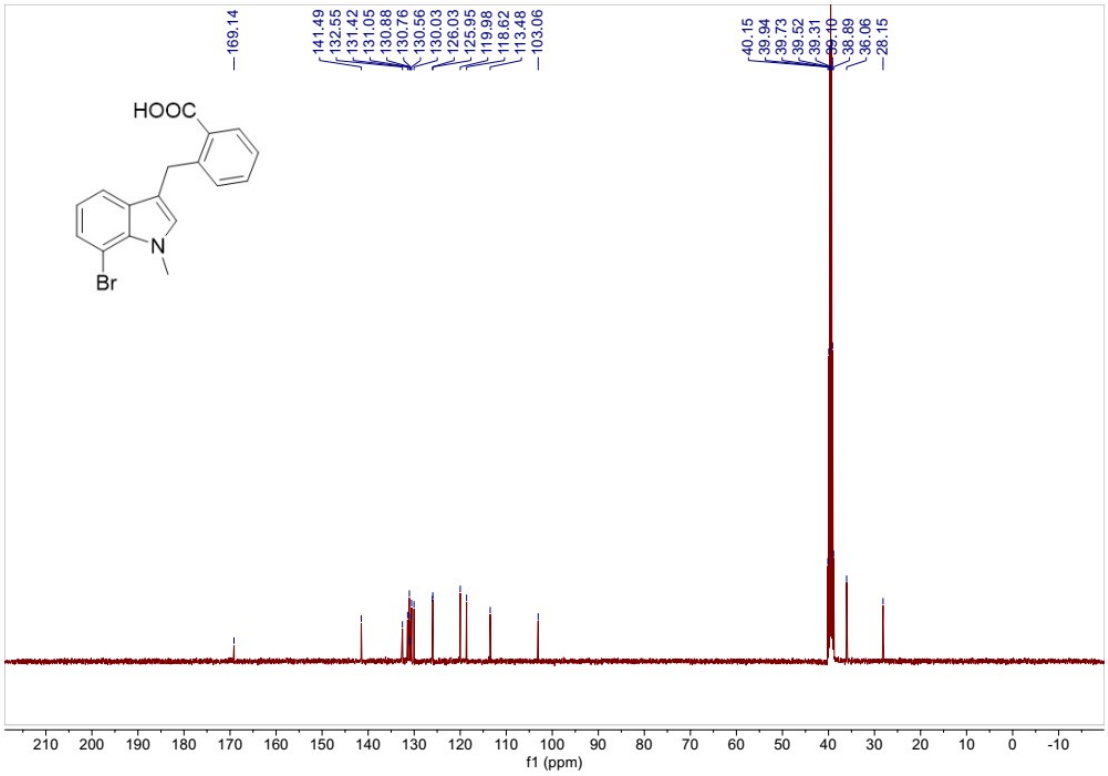
^{19}F NMR spectrum for compound **1g** (In $CDCl_3$, 565MHz)



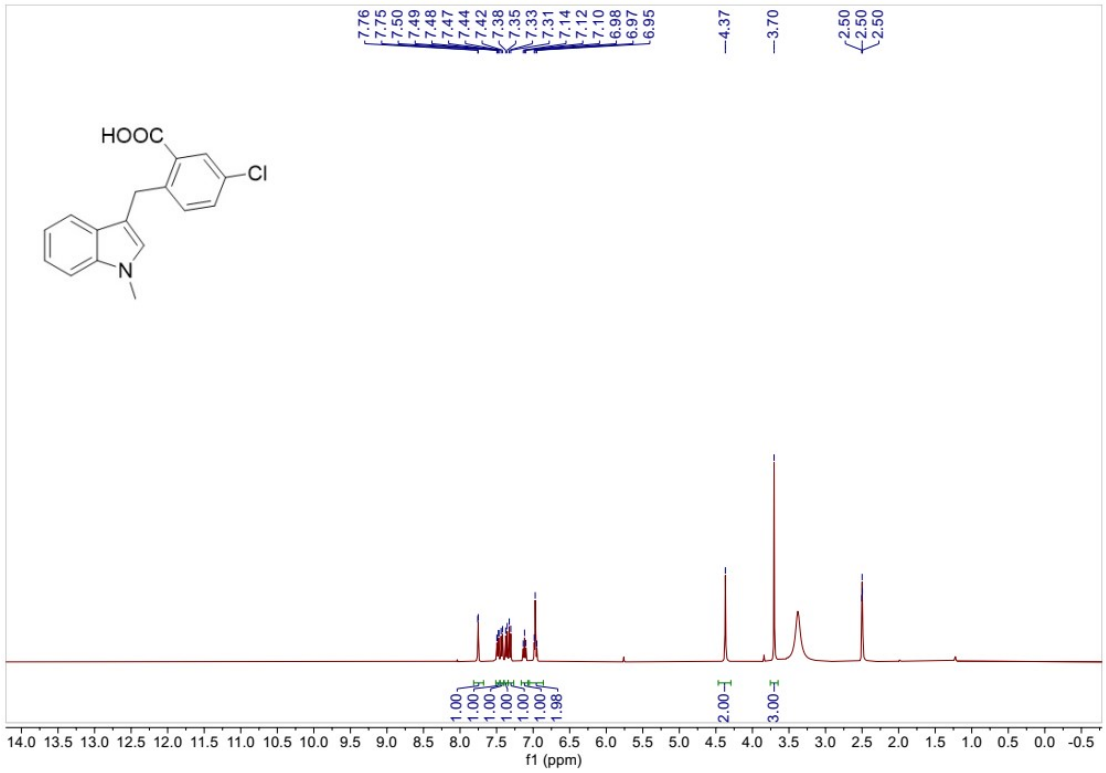
^{1}H NMR spectrum for compound **1h** (In DMSO-d_6, 400MHz)



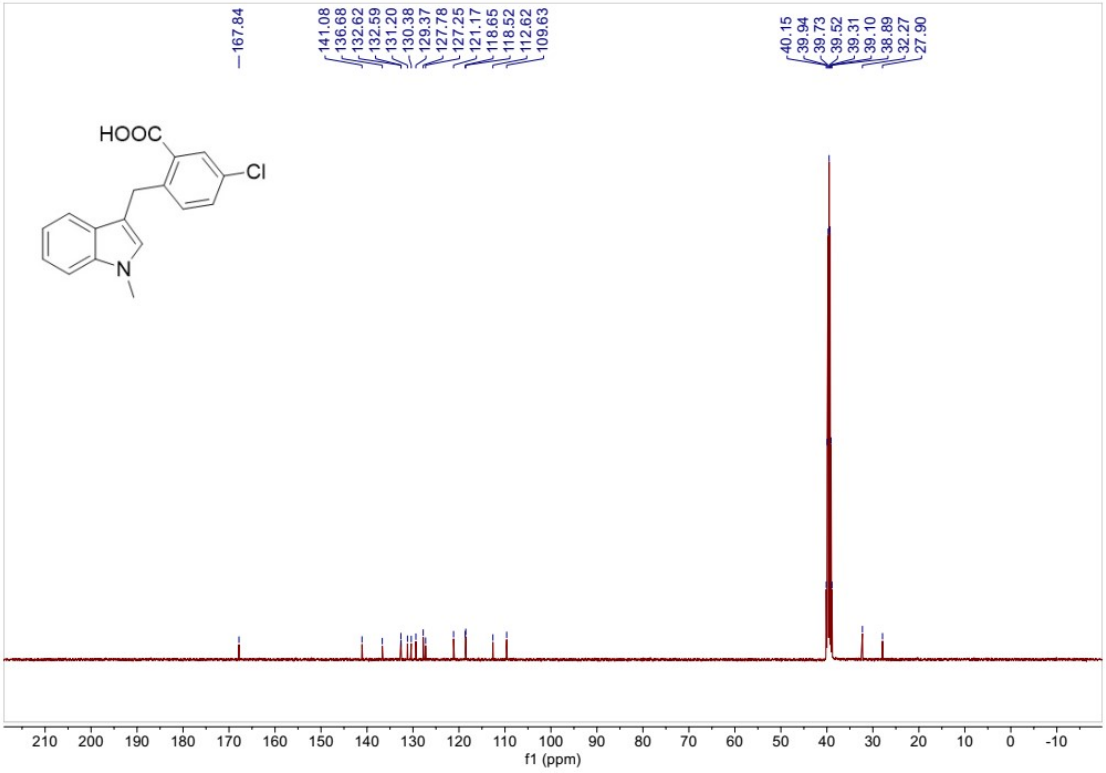
^{13}C NMR spectrum for compound **1h** (In DMSO-d_6, 101MHz)



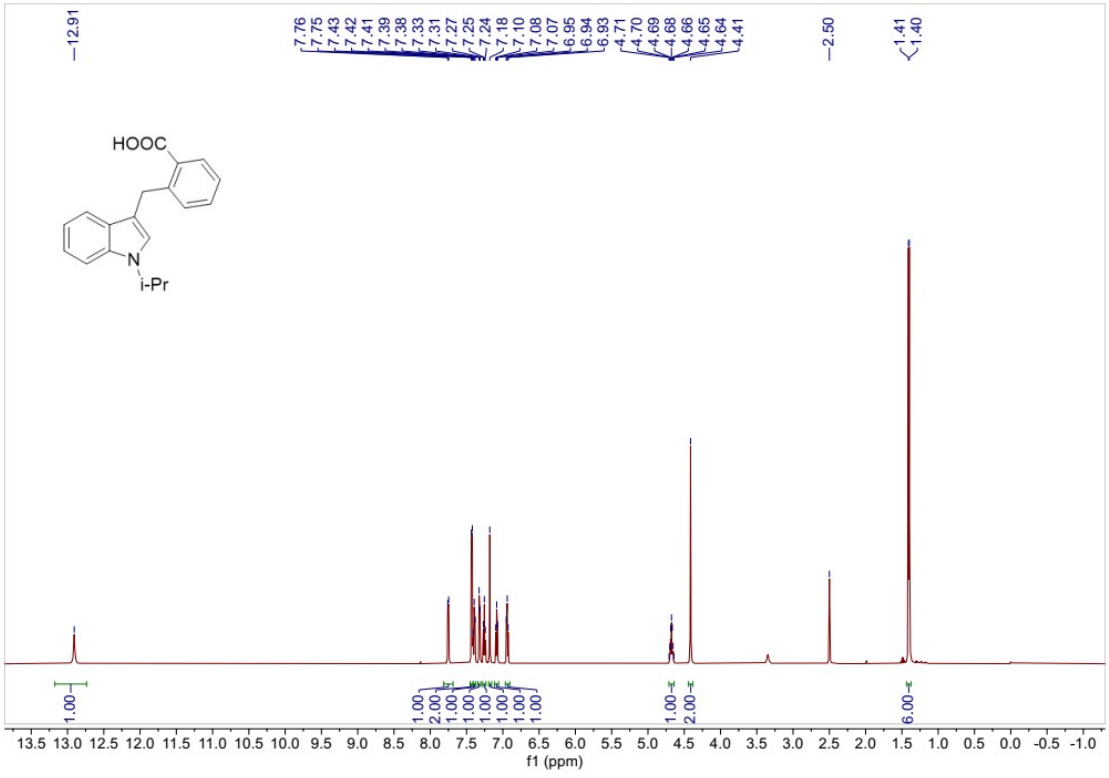
^{1}H NMR spectrum for compound **1i** (In DMSO-d_6, 400MHz)



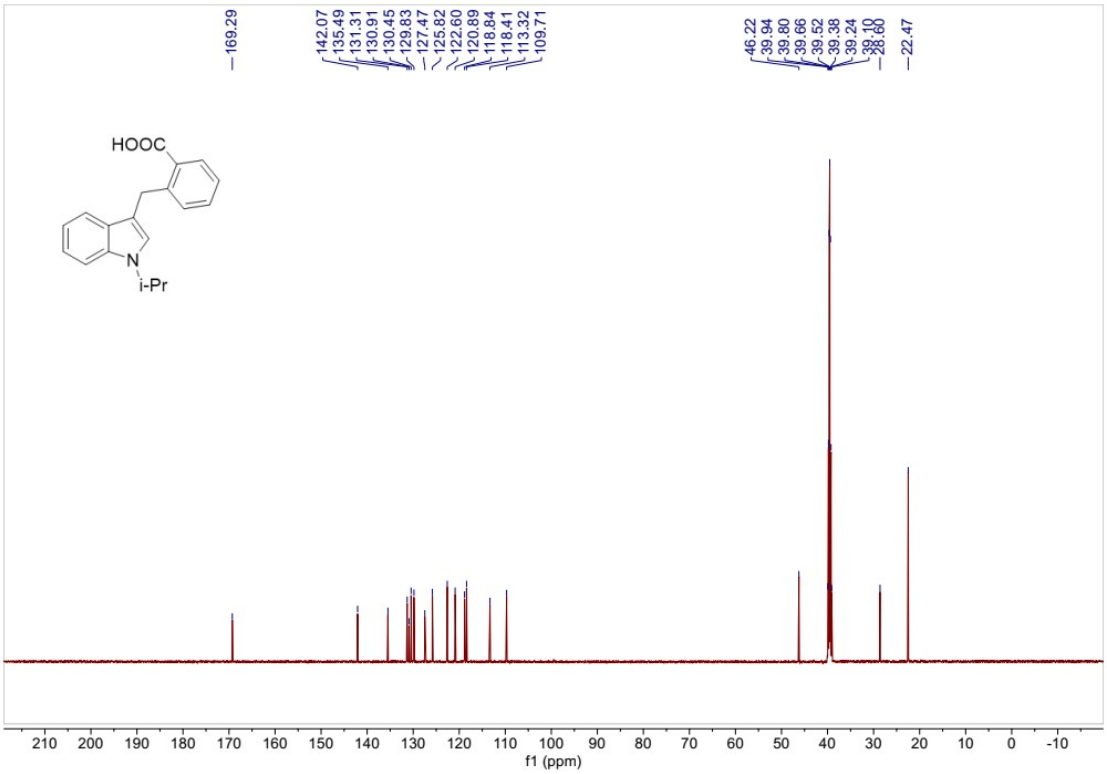
^{13}C NMR spectrum for compound **1i** (In DMSO-d_6, 101MHz)



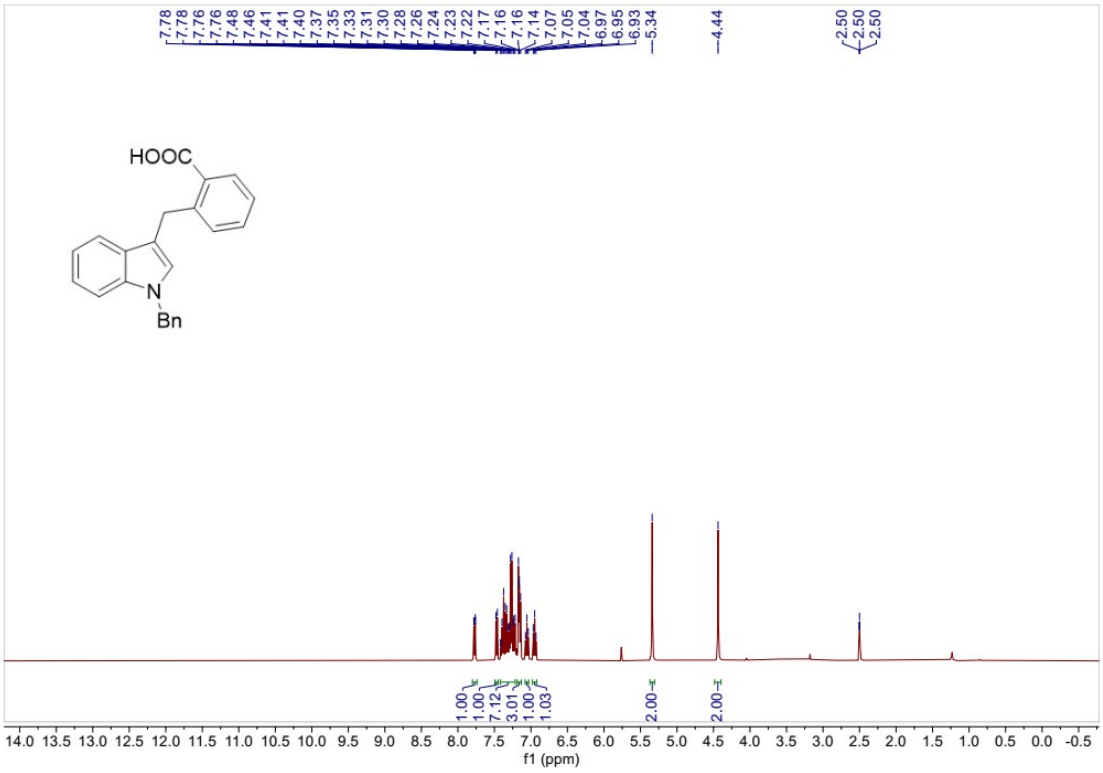
^{1}H NMR spectrum for compound **1j** (In DMSO-d_6, 600MHz)



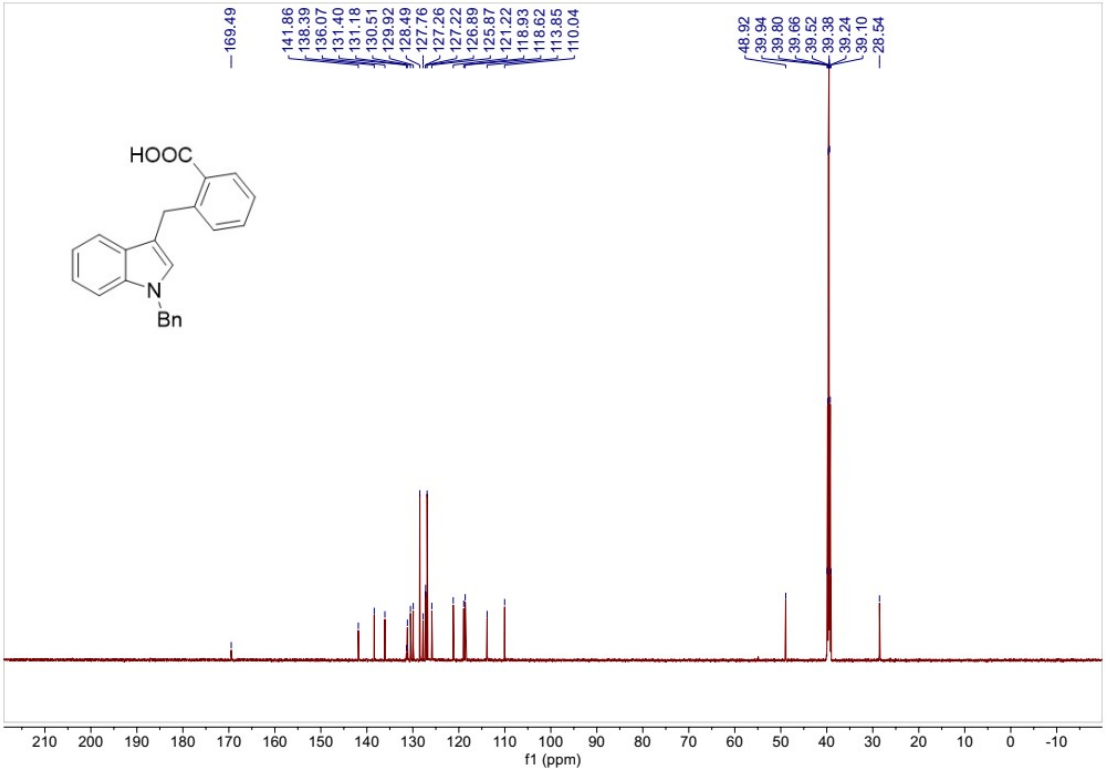
^{13}C NMR spectrum for compound **1j** (In DMSO-d_6, 151MHz)



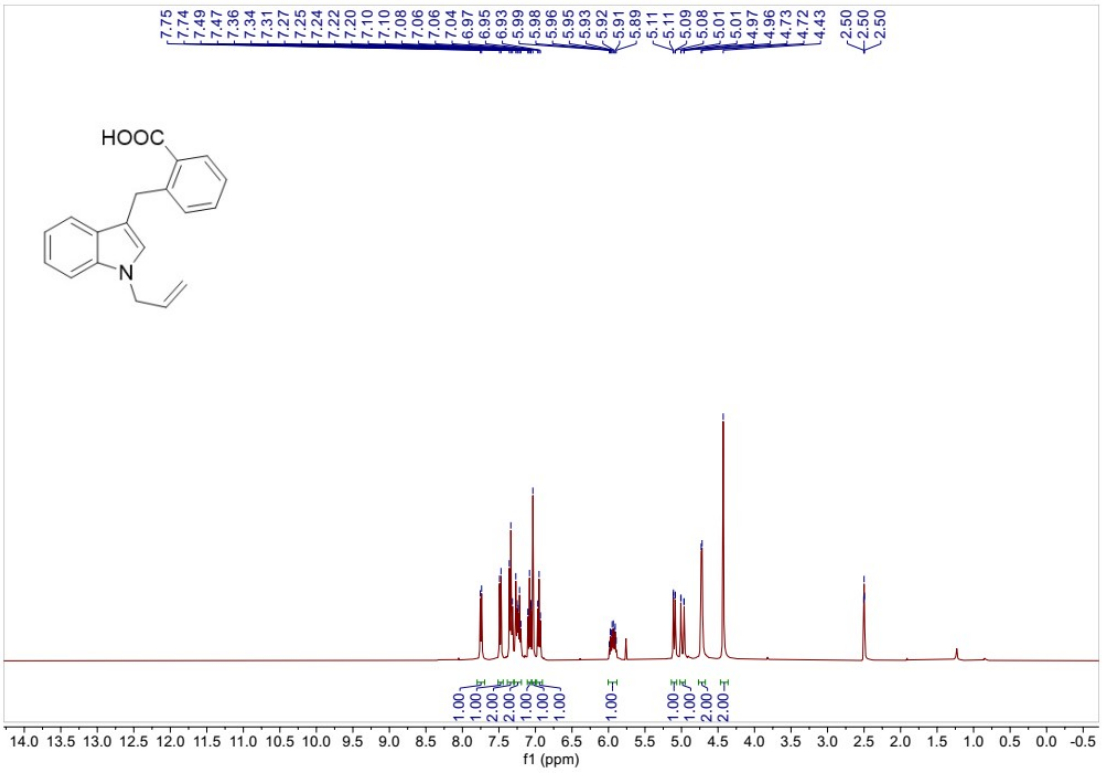
^{1}H NMR spectrum for compound **1k** (In DMSO-d_6, 400MHz)



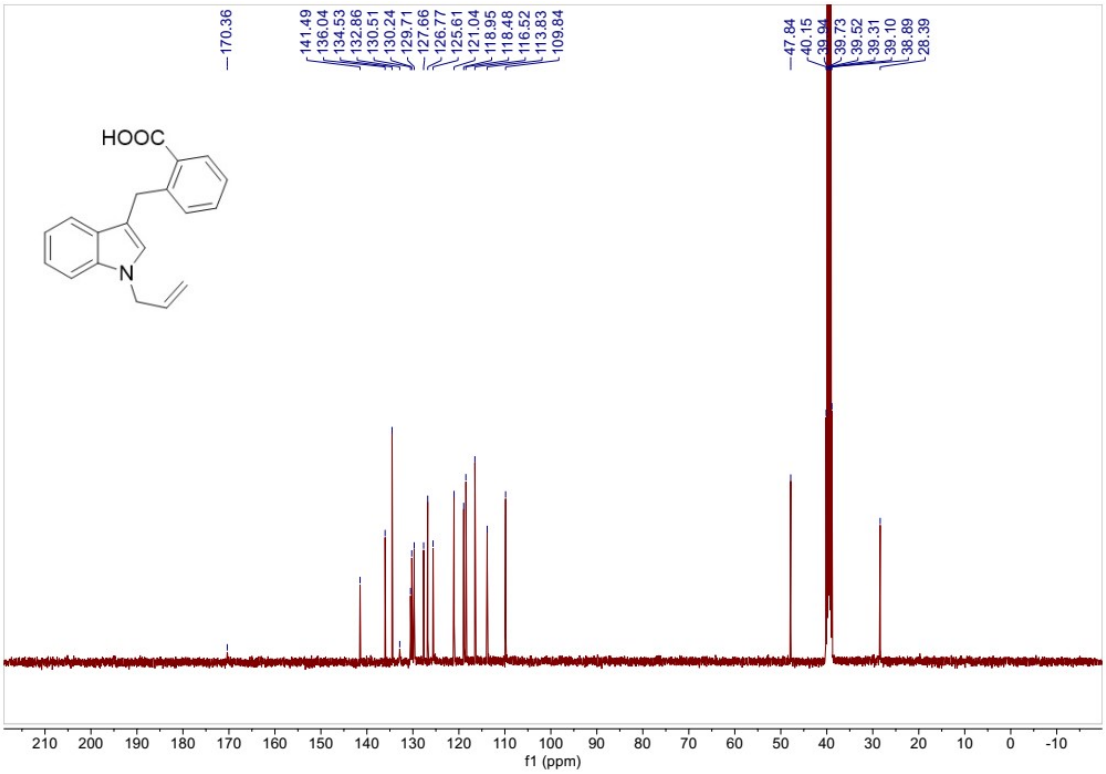
^{13}C NMR spectrum for compound **1k** (In DMSO-d_6, 151MHz)



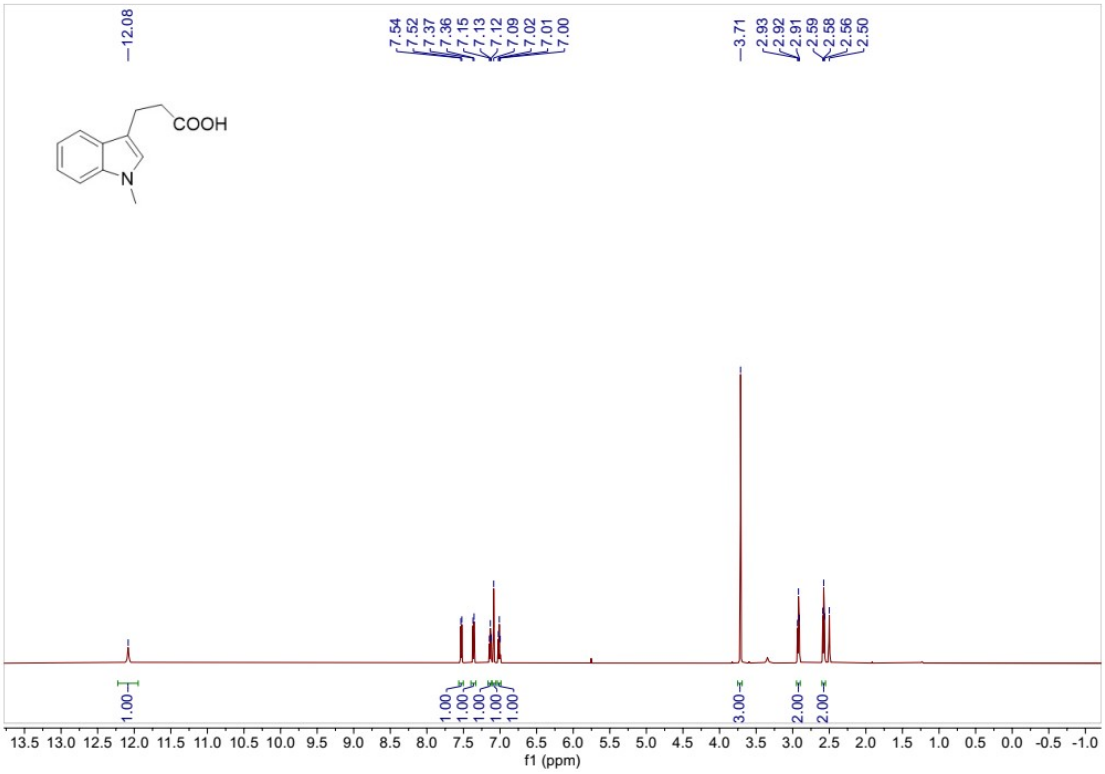
^{1}H NMR spectrum for compound **1l** (In DMSO-d_6, 400MHz)



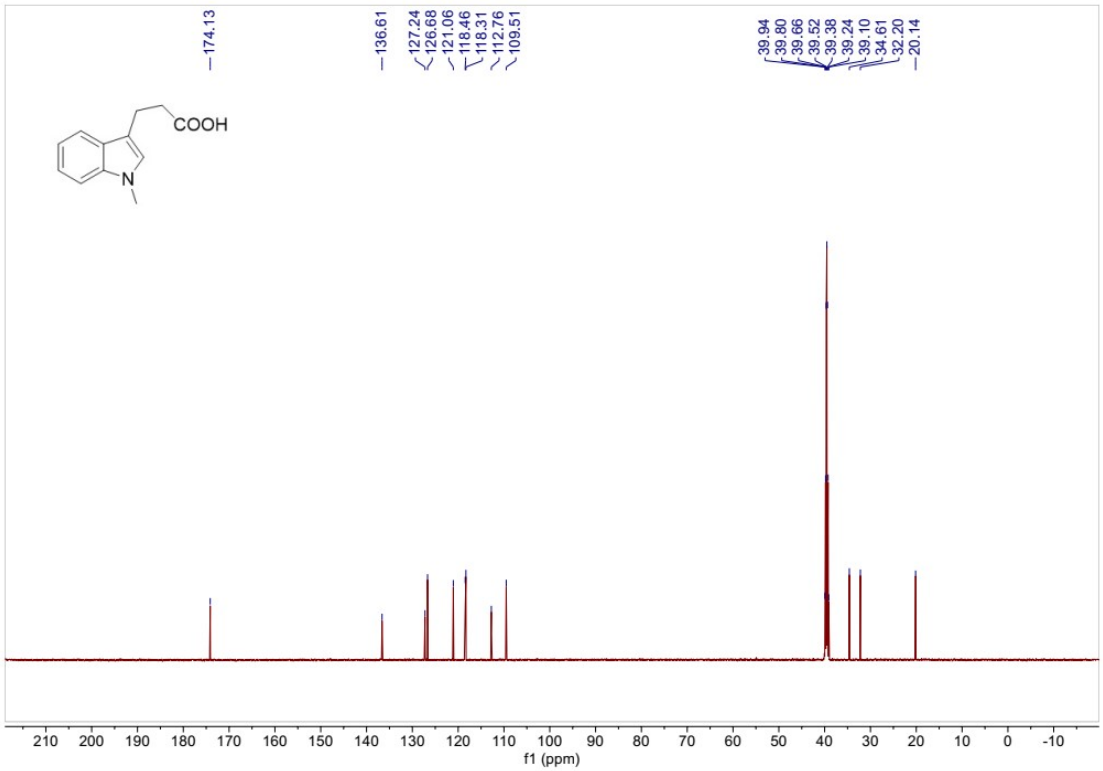
^{13}C NMR spectrum for compound **1l** (In DMSO-d_6, 101MHz)



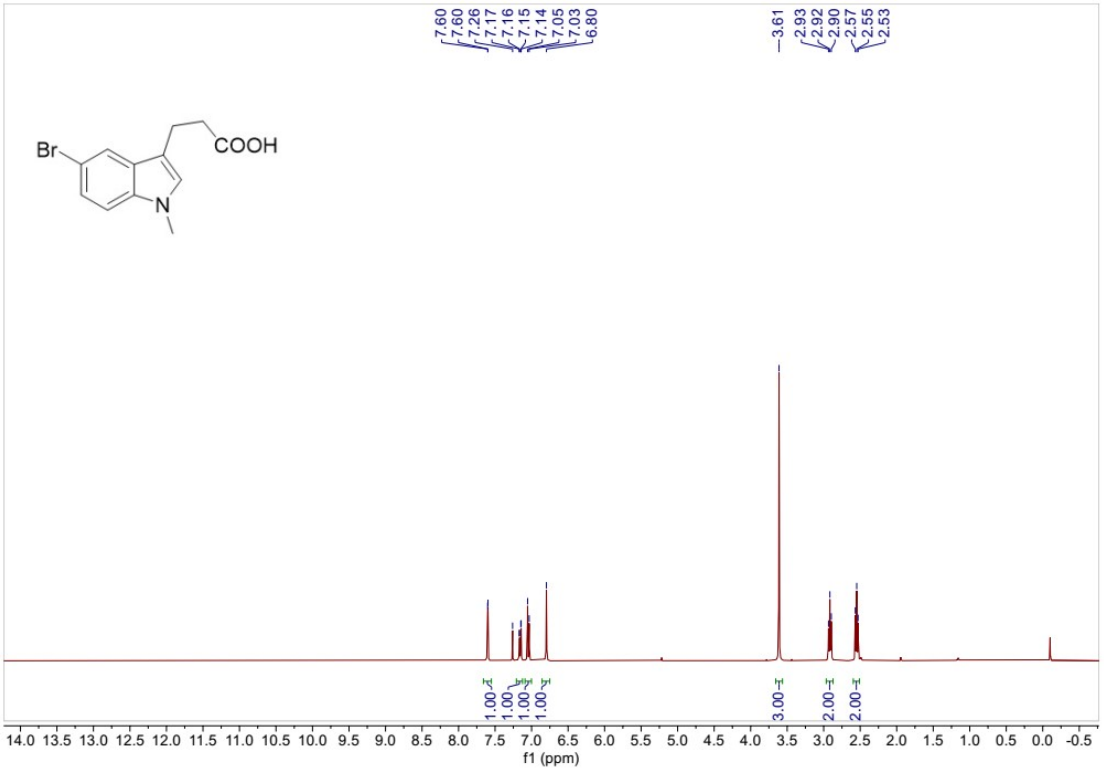
H NMR spectrum for compound **3a** (In DMSO-d_6, 600MHz)



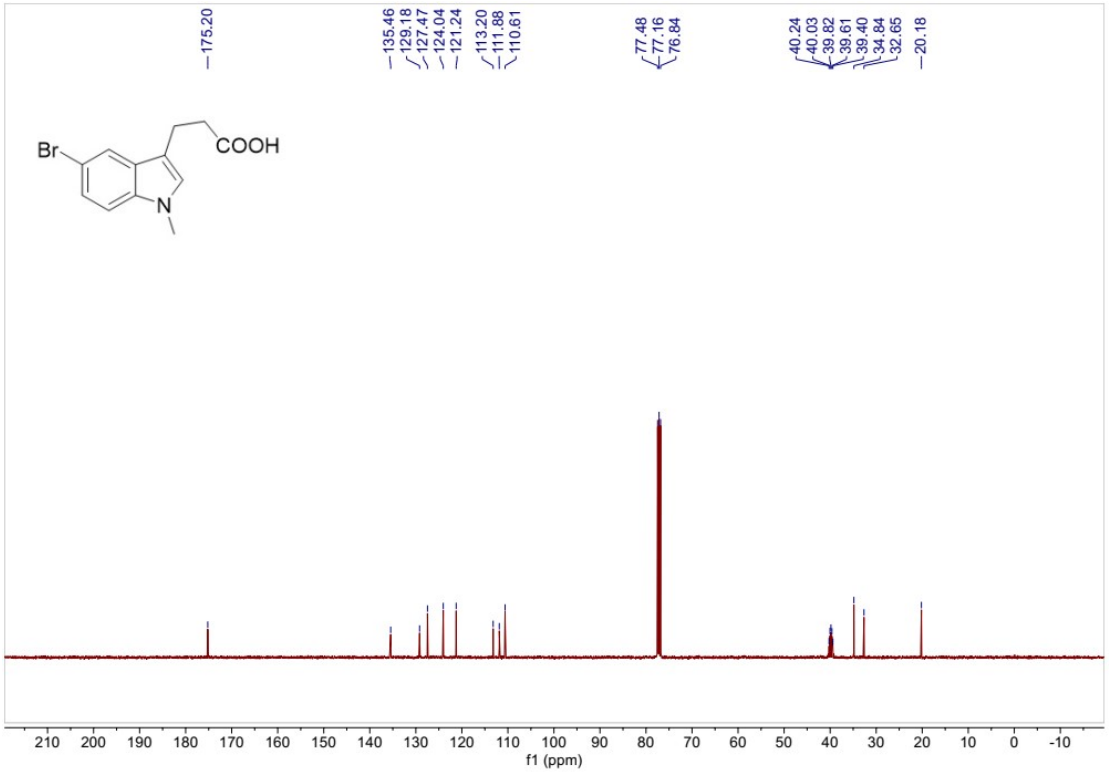
^{13}C NMR spectrum for compound **Cat-4** (In DMSO-d_6, 151MHz)



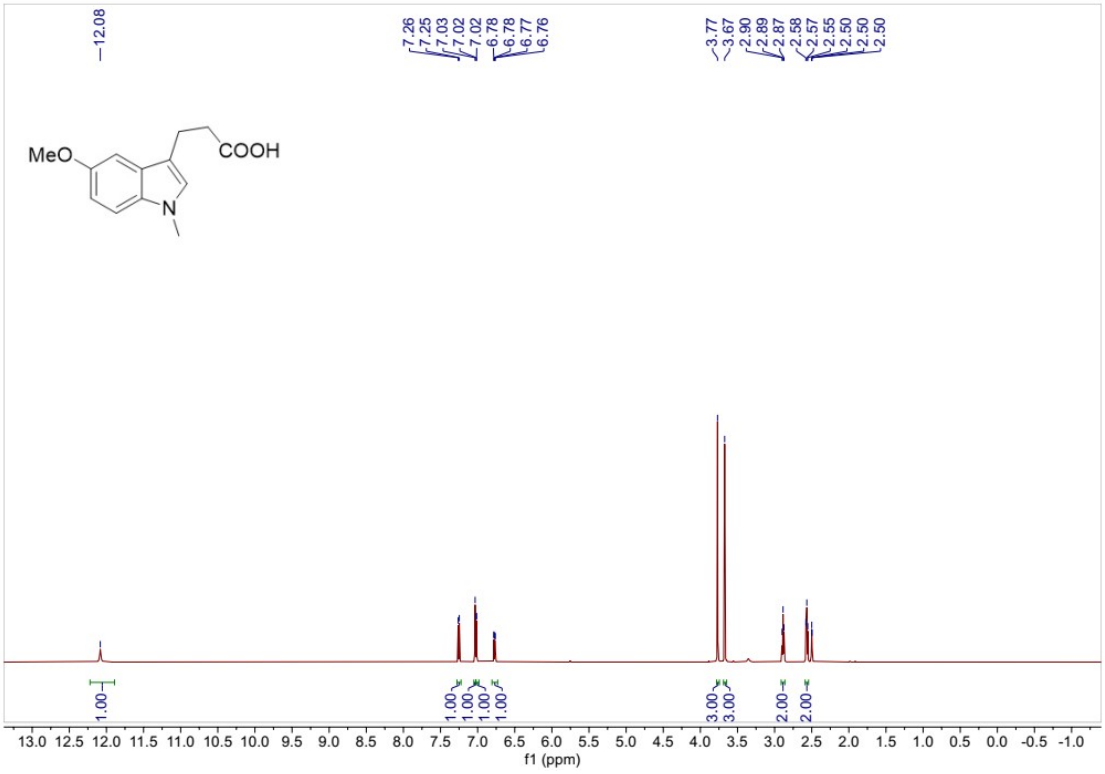
^{1}H NMR spectrum for compound **3b** (In $CDCl_3$, 400MHz)



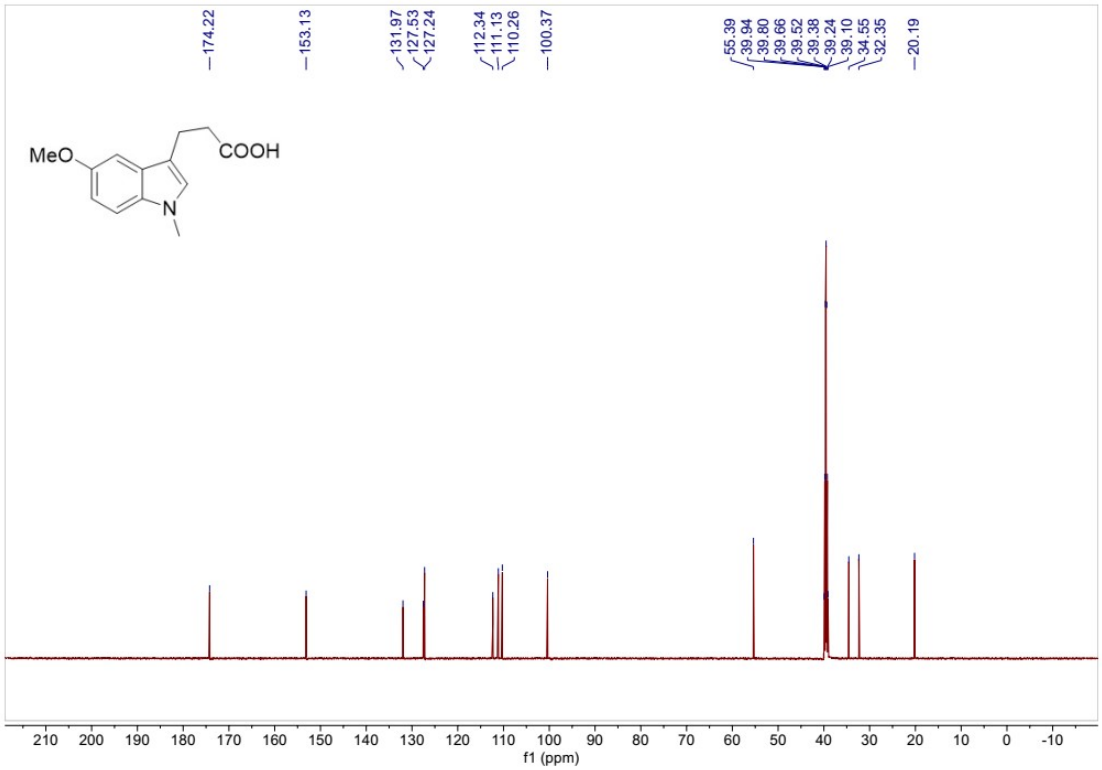
^{13}C NMR spectrum for compound **Cat-4** (In $CDCl_3$+DMSO-d_6, 101MHz)



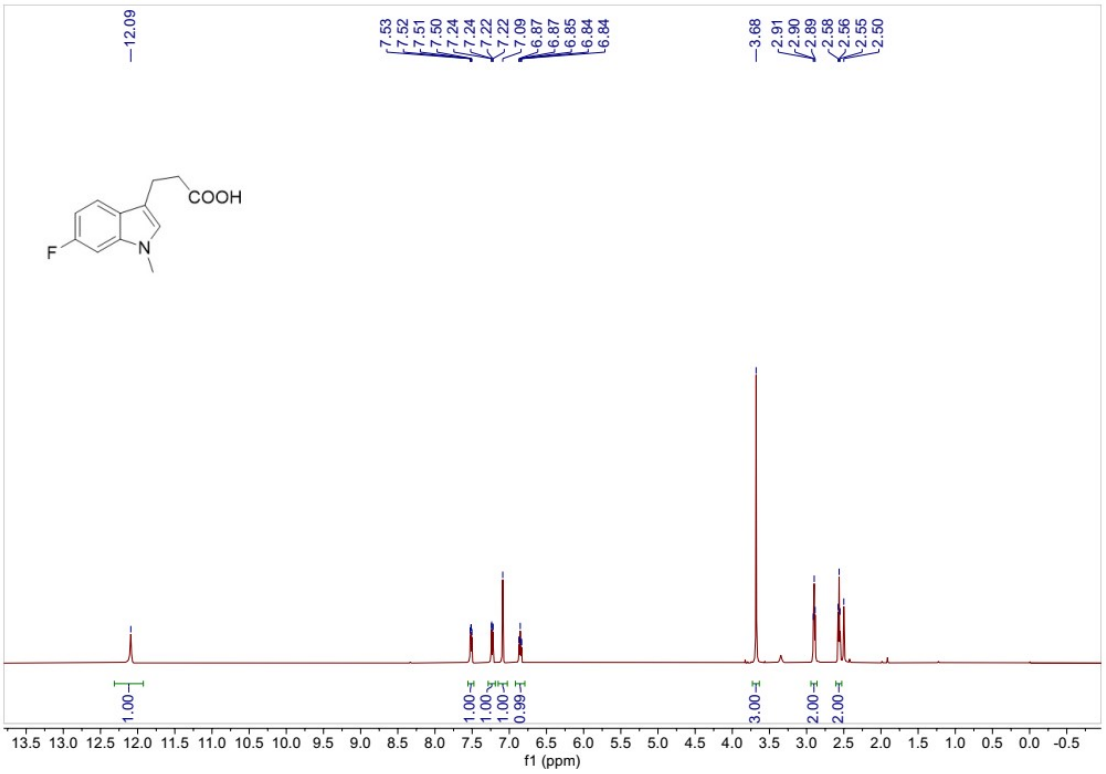
^{1}H NMR spectrum for compound **3c** (In DMSO-d_6, 600MHz)



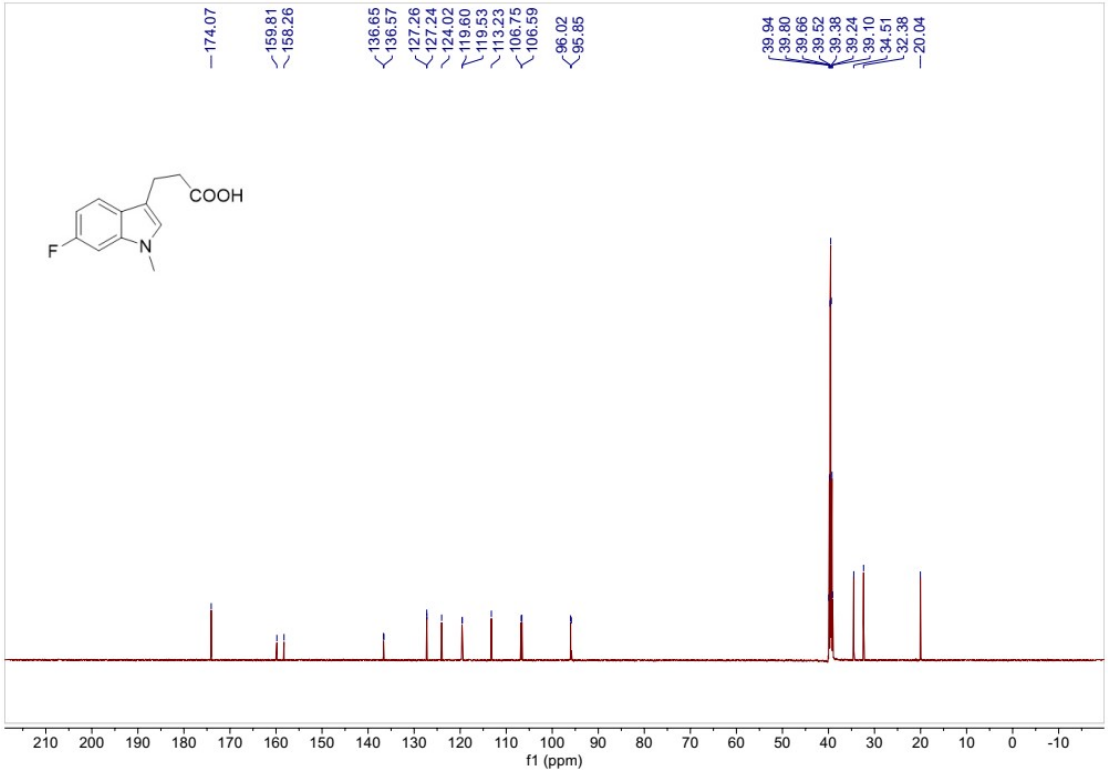
^{13}C NMR spectrum for compound **3c** (In DMSO-d_6, 151MHz)



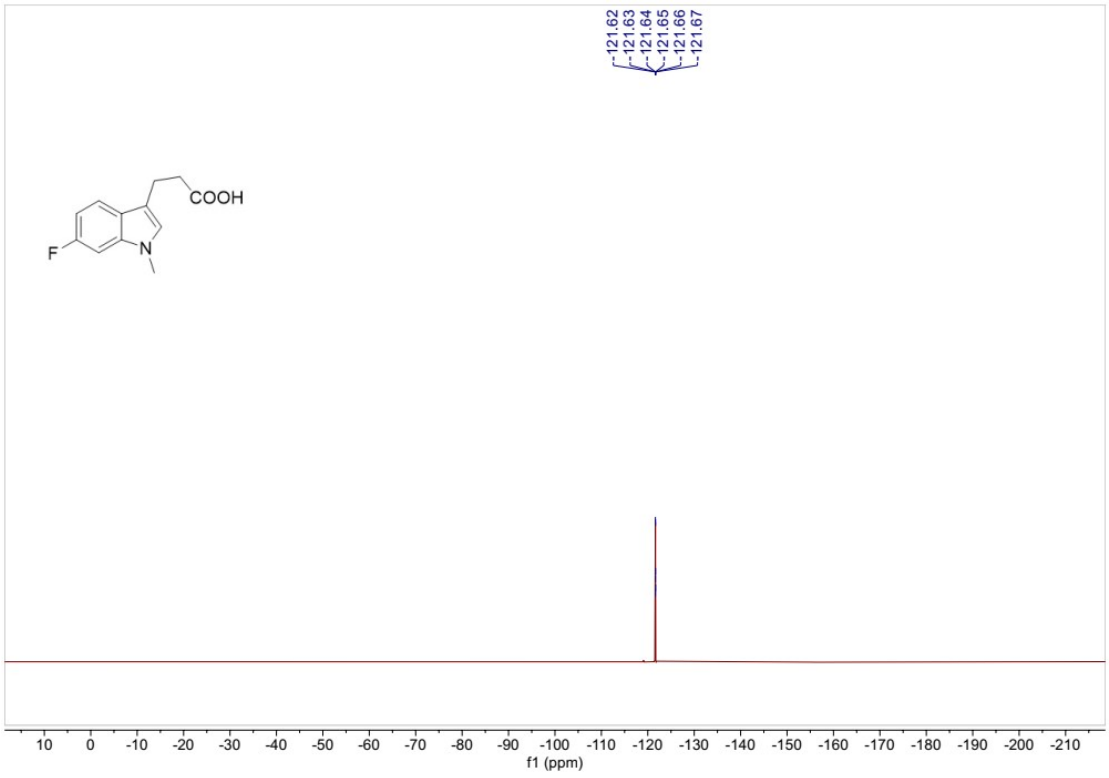
^{1}H NMR spectrum for compound **3d** (In DMSO-d_6, 600MHz)



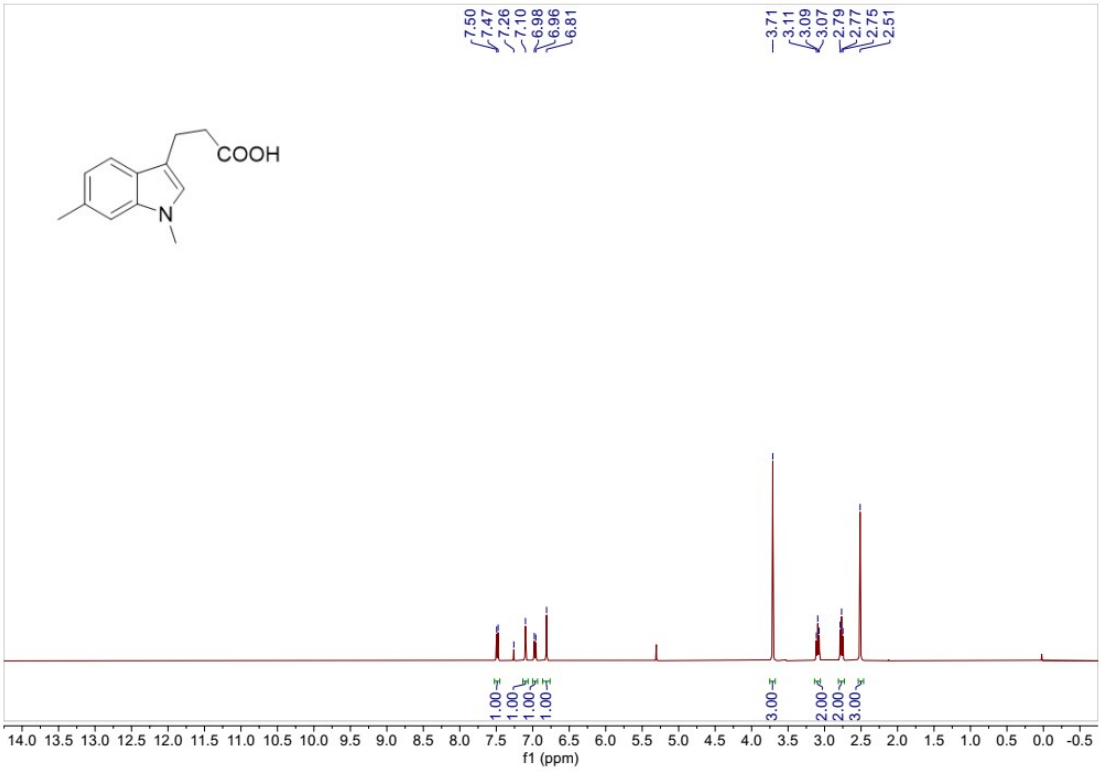
^{13}C NMR spectrum for compound **3d** (In DMSO-d_6, 151MHz)



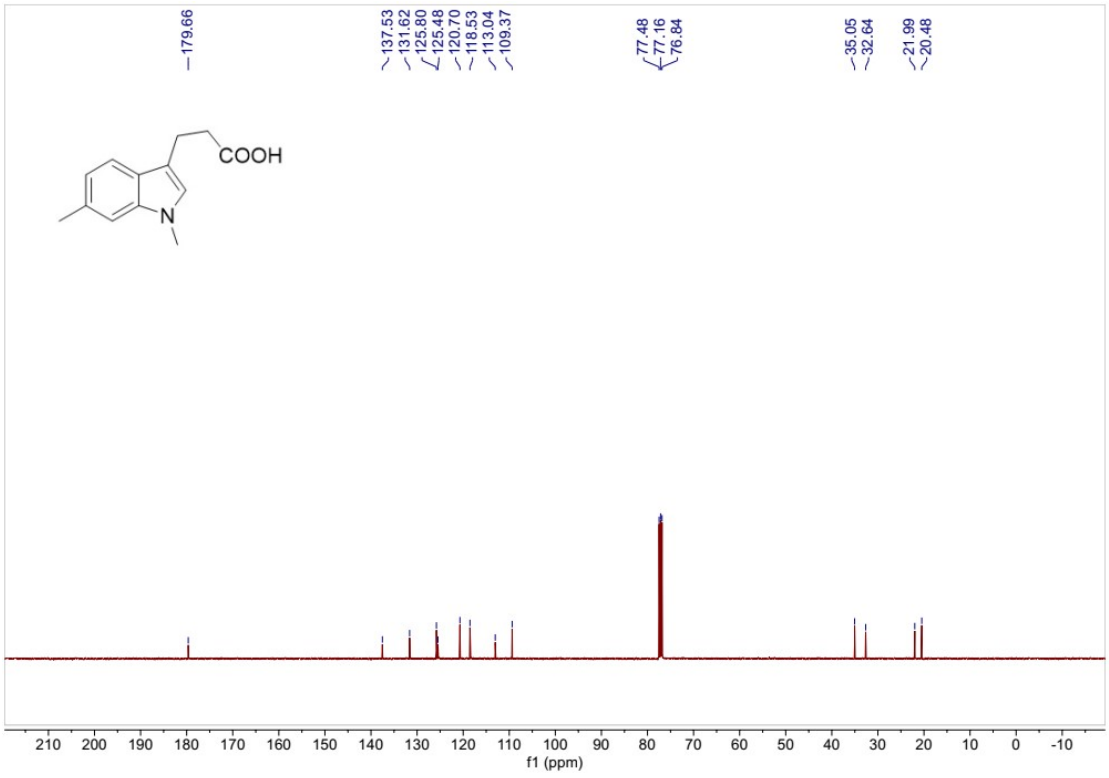
^{19}F NMR spectrum for compound **3d** (In $CDCl_3$, 565MHz)



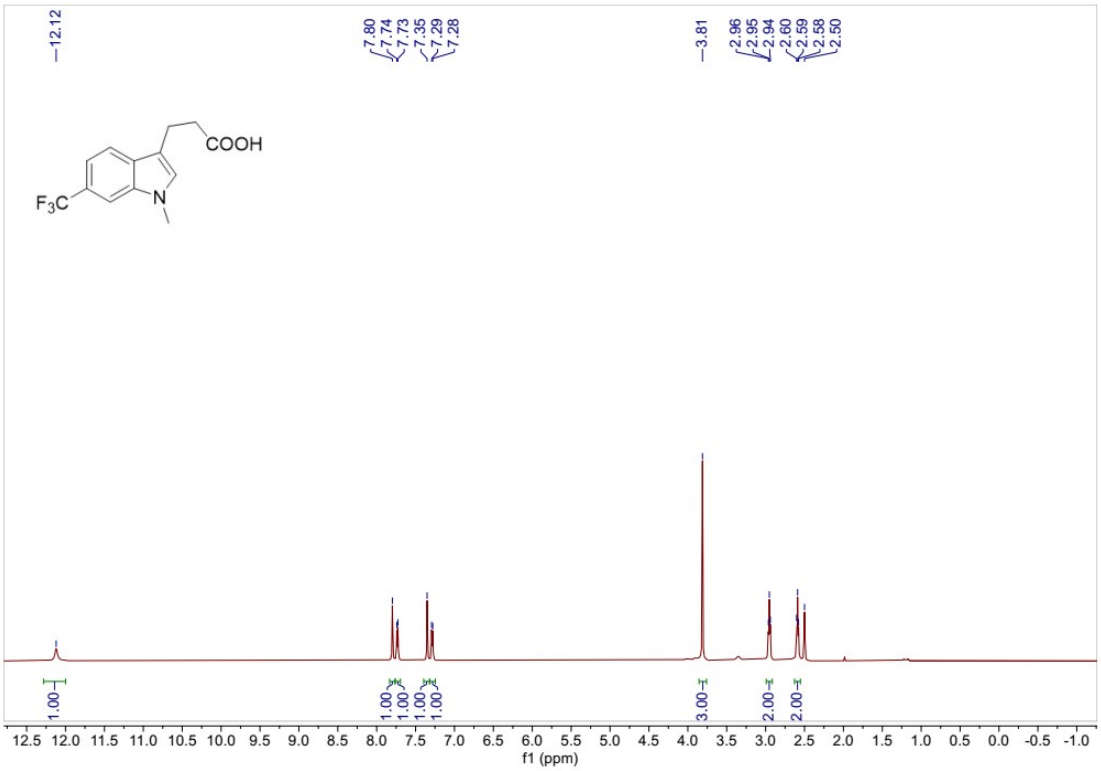
^{1}H NMR spectrum for compound **3e** (In $CDCl_3$, 400MHz)



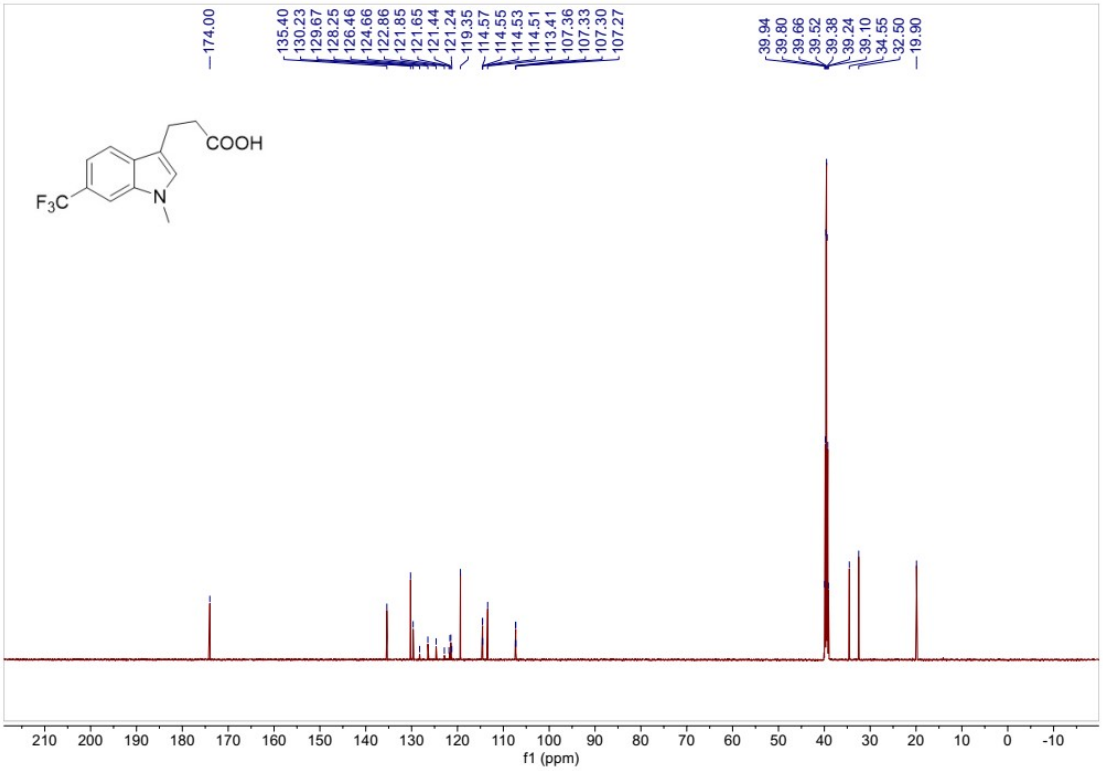
^{13}C NMR spectrum for compound **3e** (In $CDCl_3$, 101MHz)



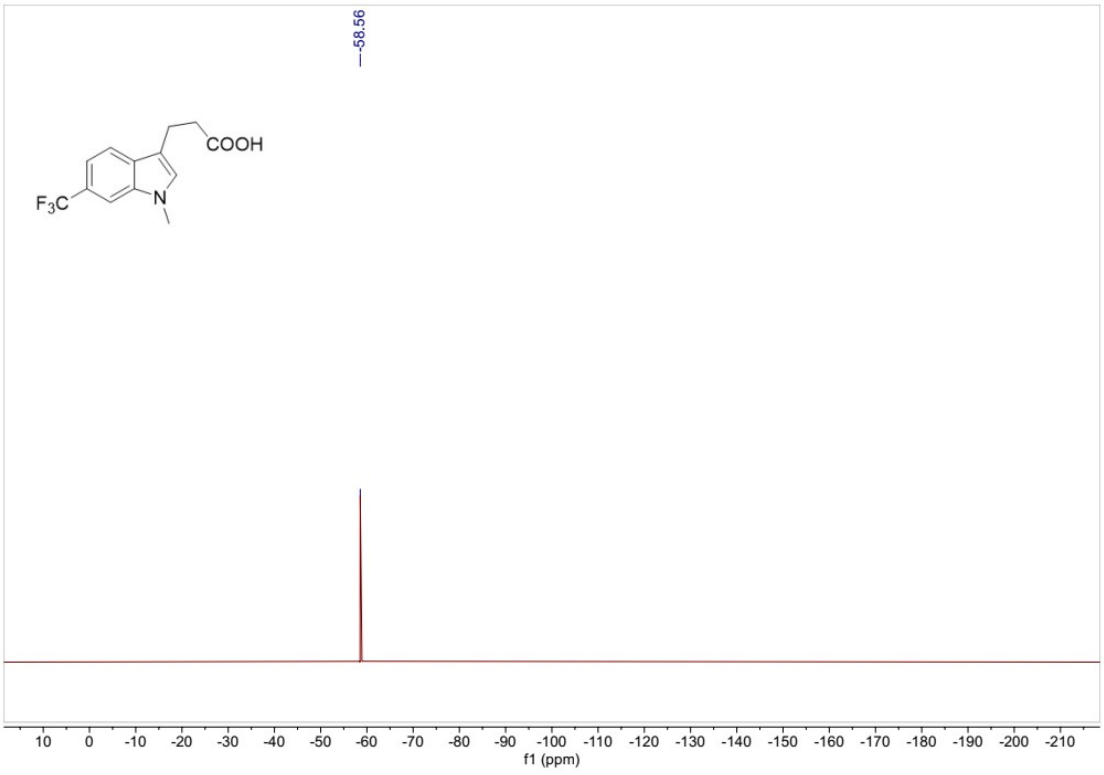
^{1}H NMR spectrum for compound **3f** (In DMSO-d_6, 600MHz)



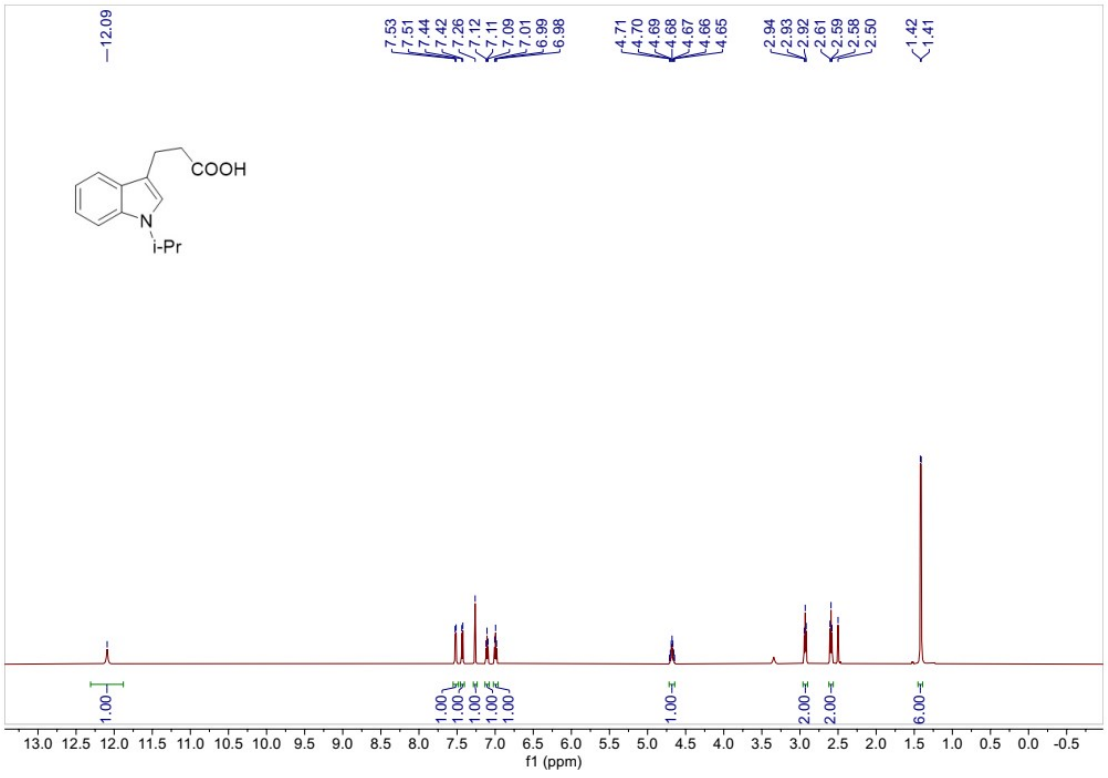
^{13}C NMR spectrum for compound **3f** (In DMSO-d_6, 151MHz)



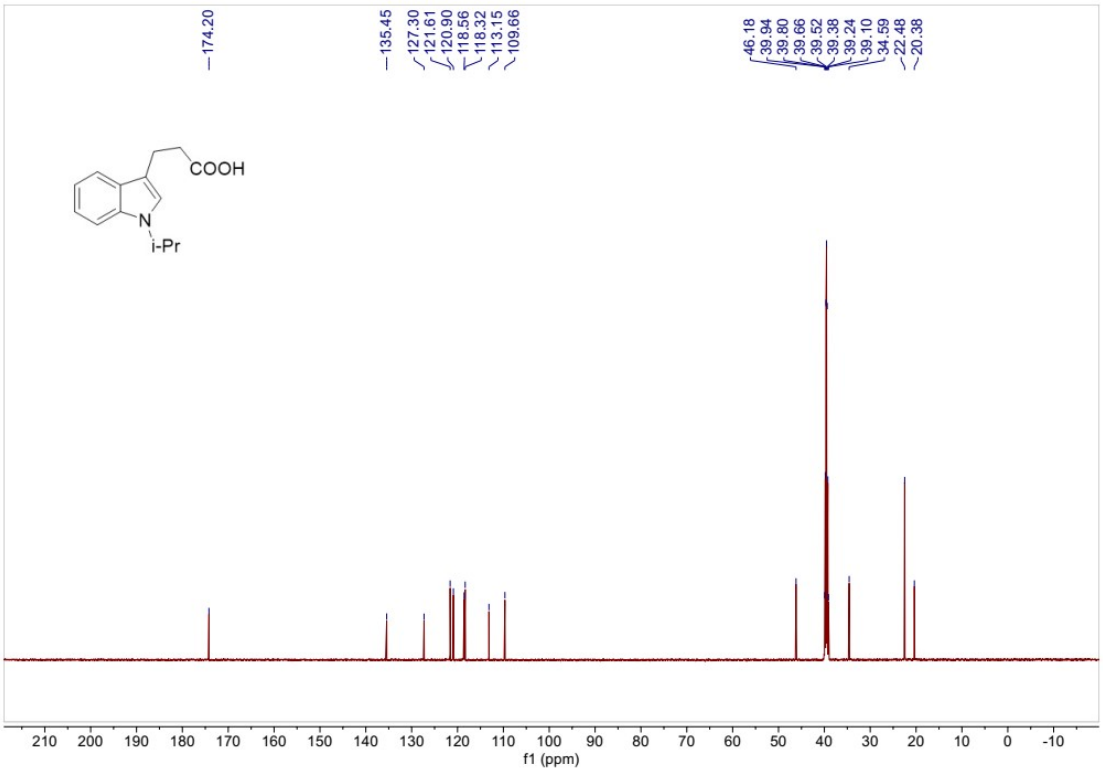
^{19}F NMR spectrum for compound **3f** (In DMSO-d_6, 565MHz)



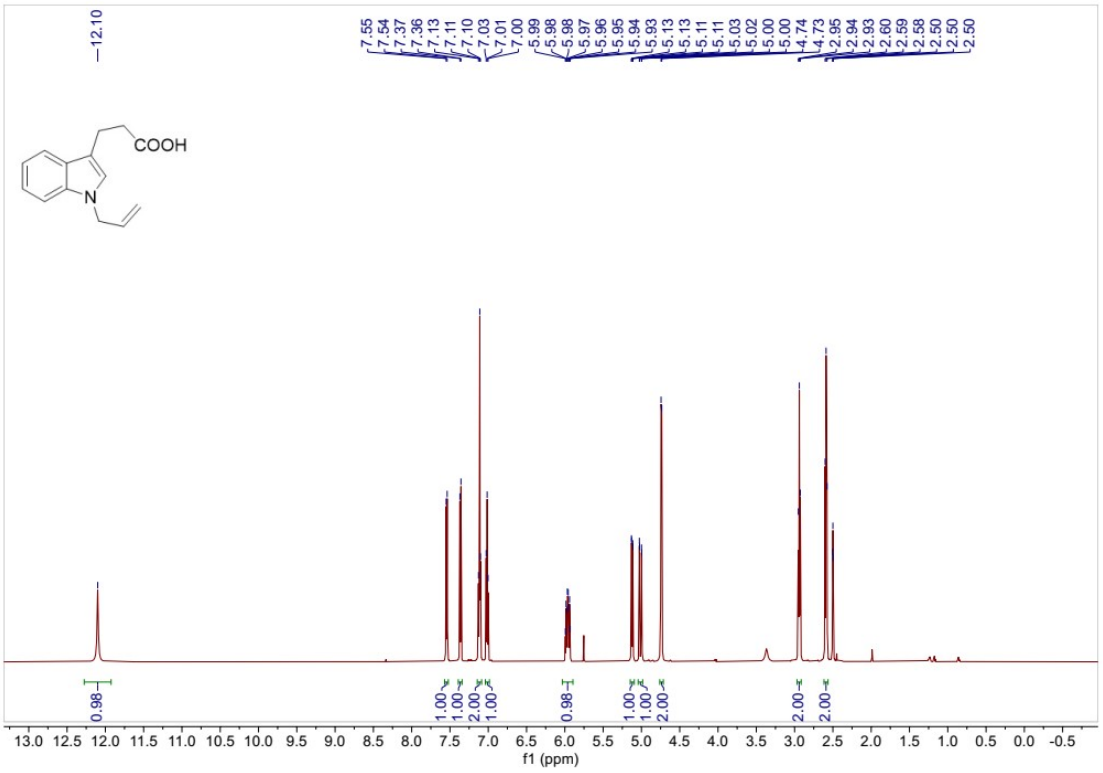
^{1}H NMR spectrum for compound **3g** (In DMSO-d_6, 600MHz)



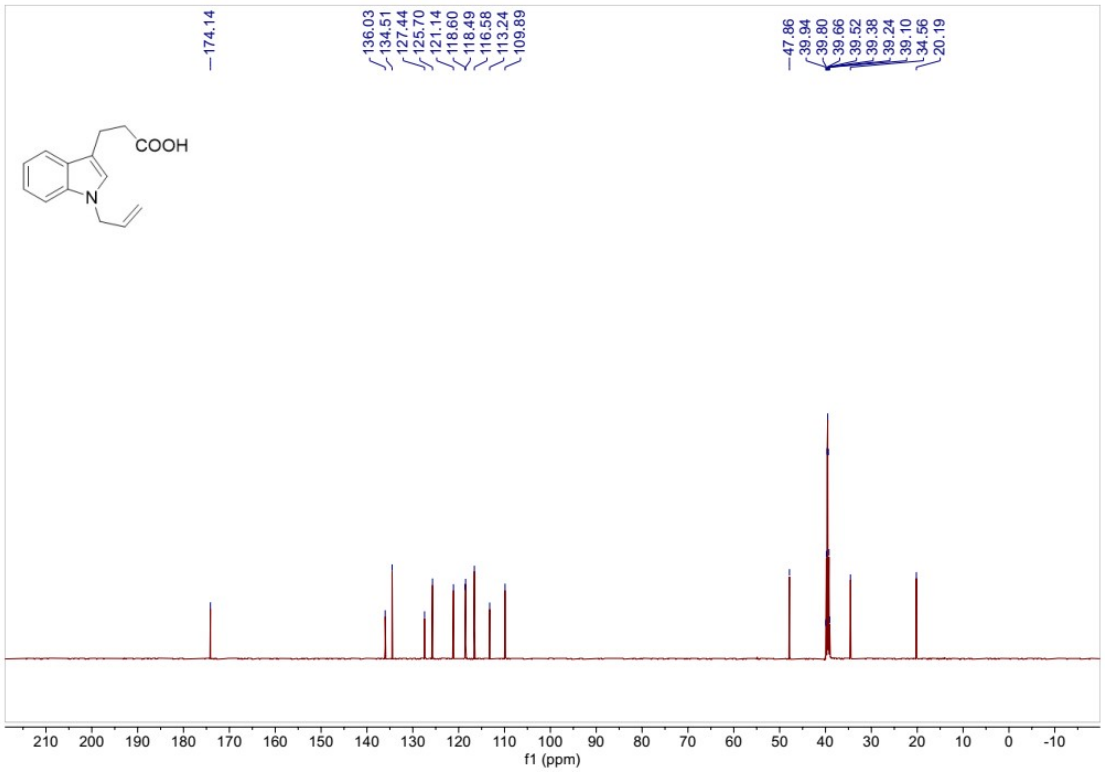
^{13}C NMR spectrum for compound **3g** (In DMSO-d_6, 151MHz)



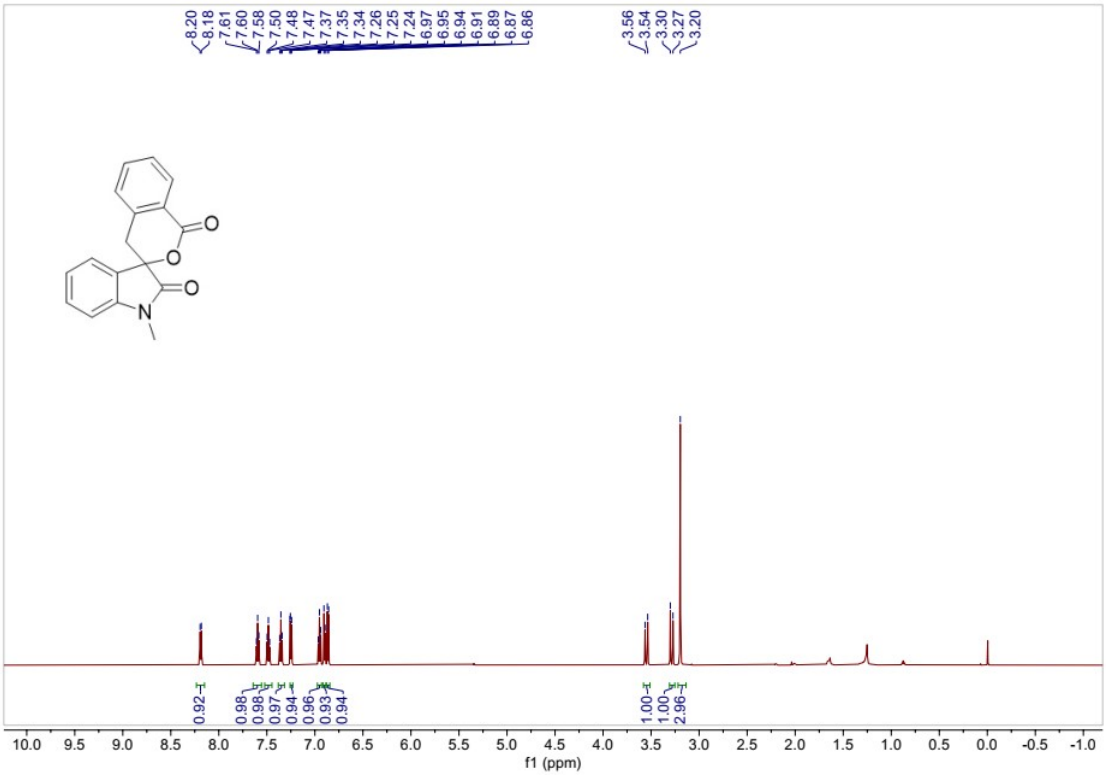
^{1}H NMR spectrum for compound **3h** (In DMSO-d_6, 600MHz)



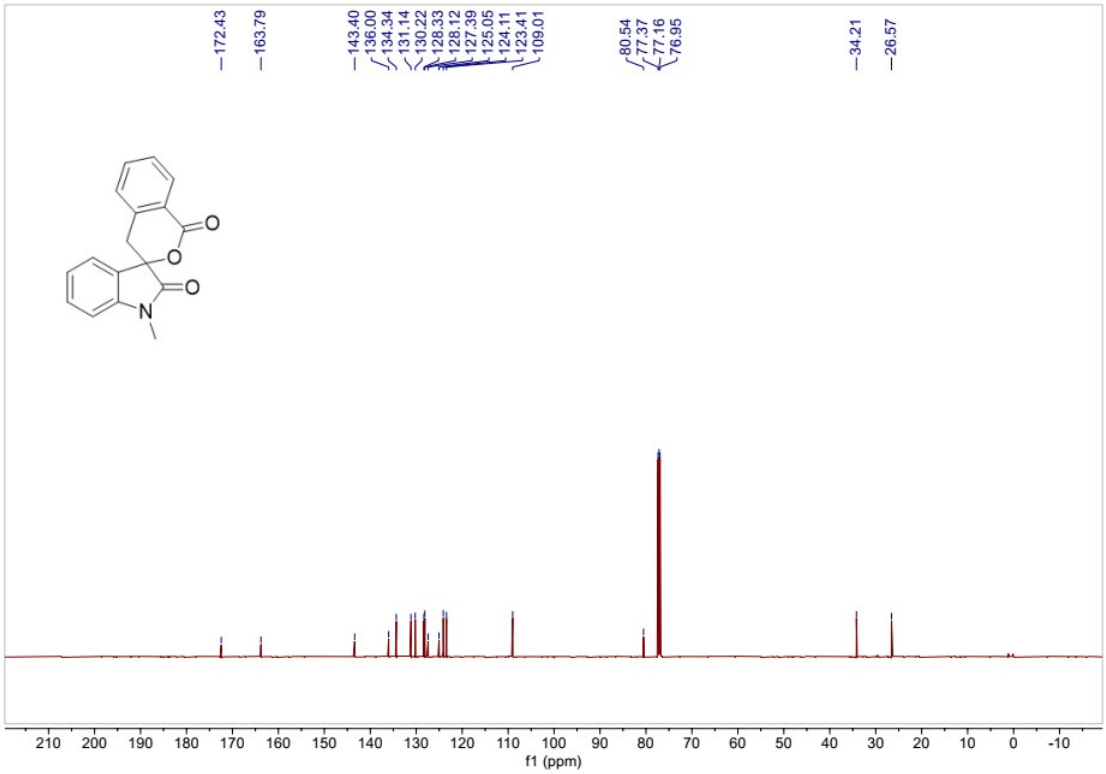
^{13}C NMR spectrum for compound **3h** (In DMSO-d_6, 151MHz)



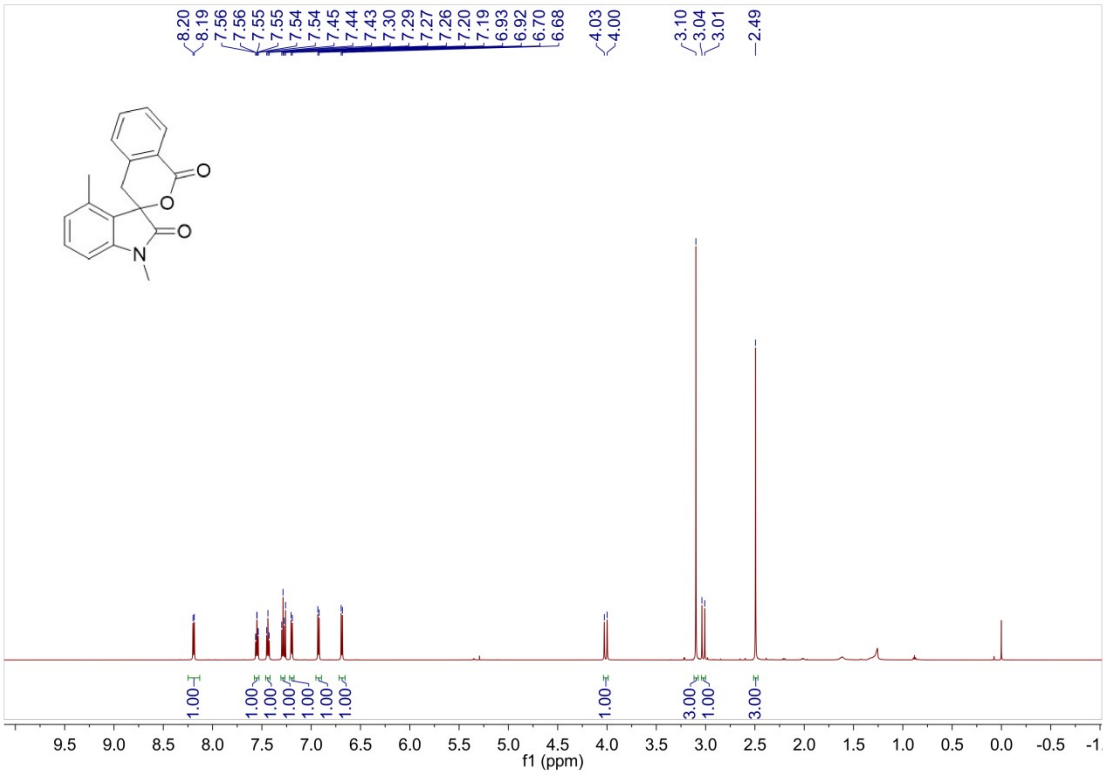
^{1}H NMR spectrum for compound **2a** (In $CDCl_3$, 600MHz)



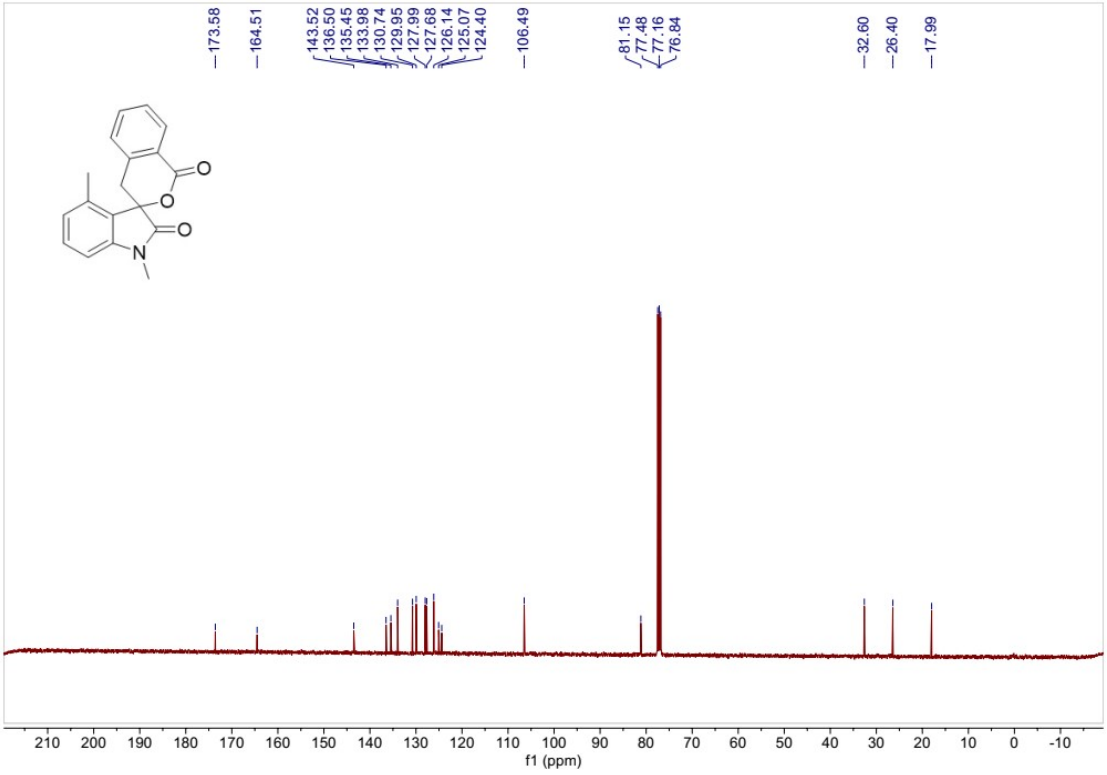
^{13}C NMR spectrum for compound **2a** (In $CDCl_3$, 151MHz)



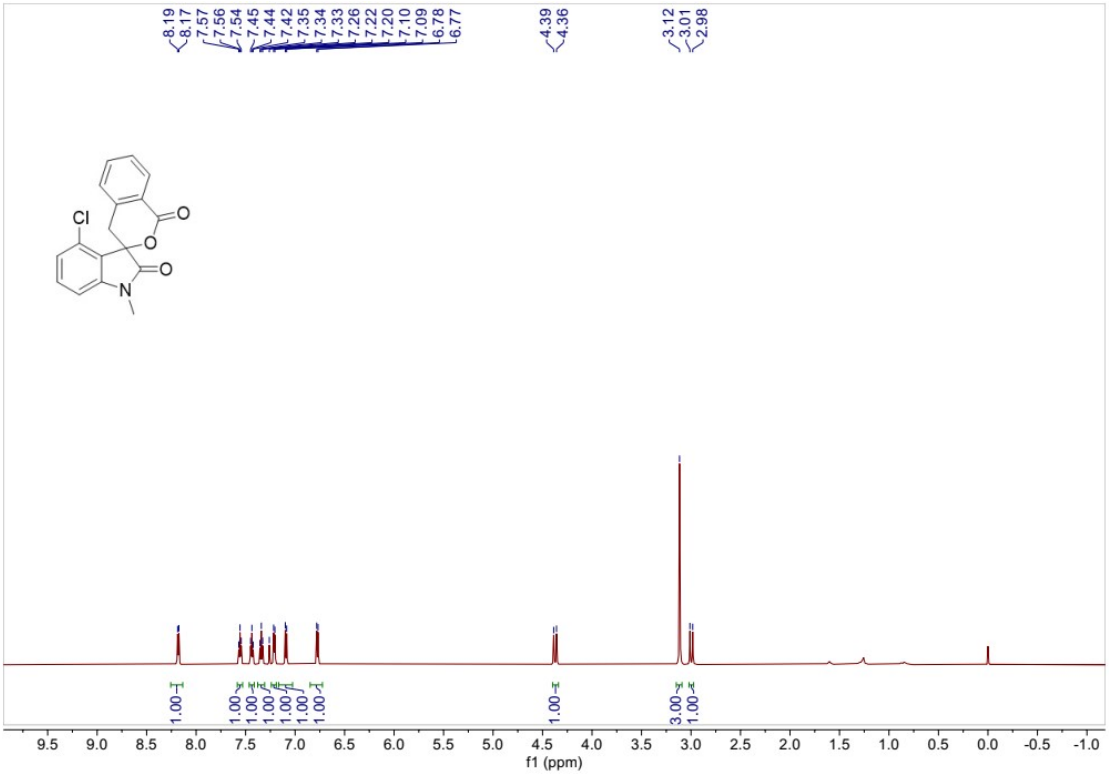
^{1}H NMR spectrum for compound **2b** (In $CDCl_3$, 600MHz)



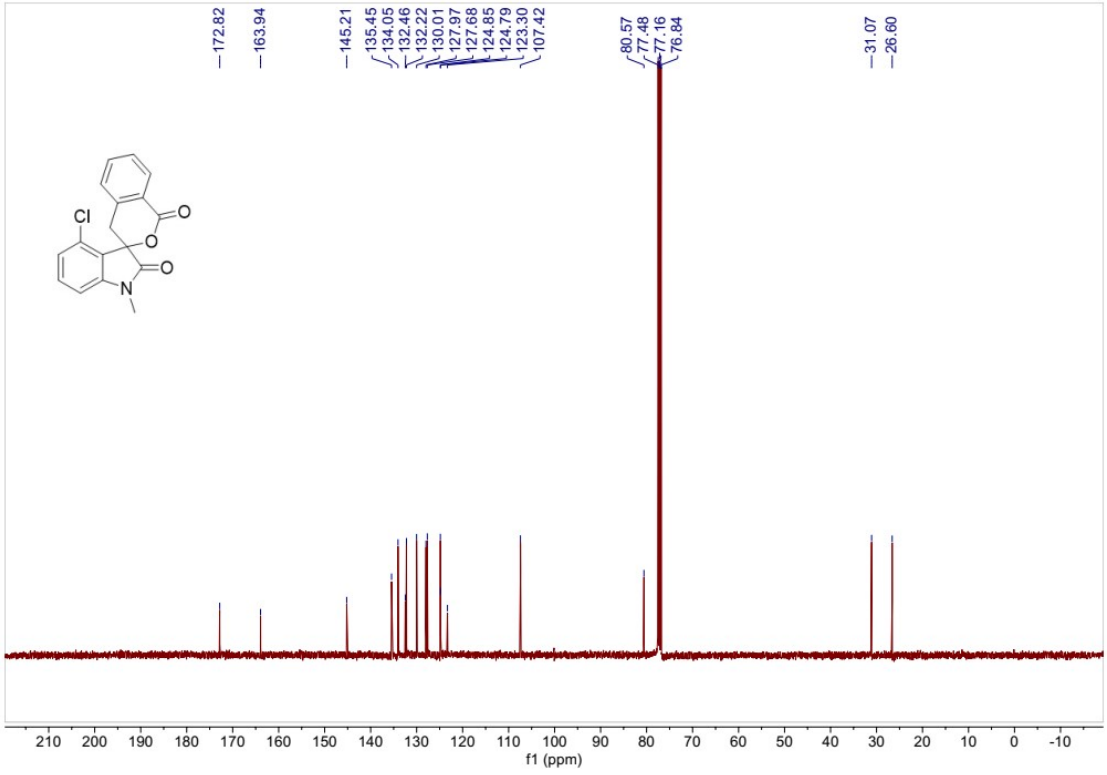
^{13}C NMR spectrum for compound **Cat-4** (In $CDCl_3$, 101MHz)



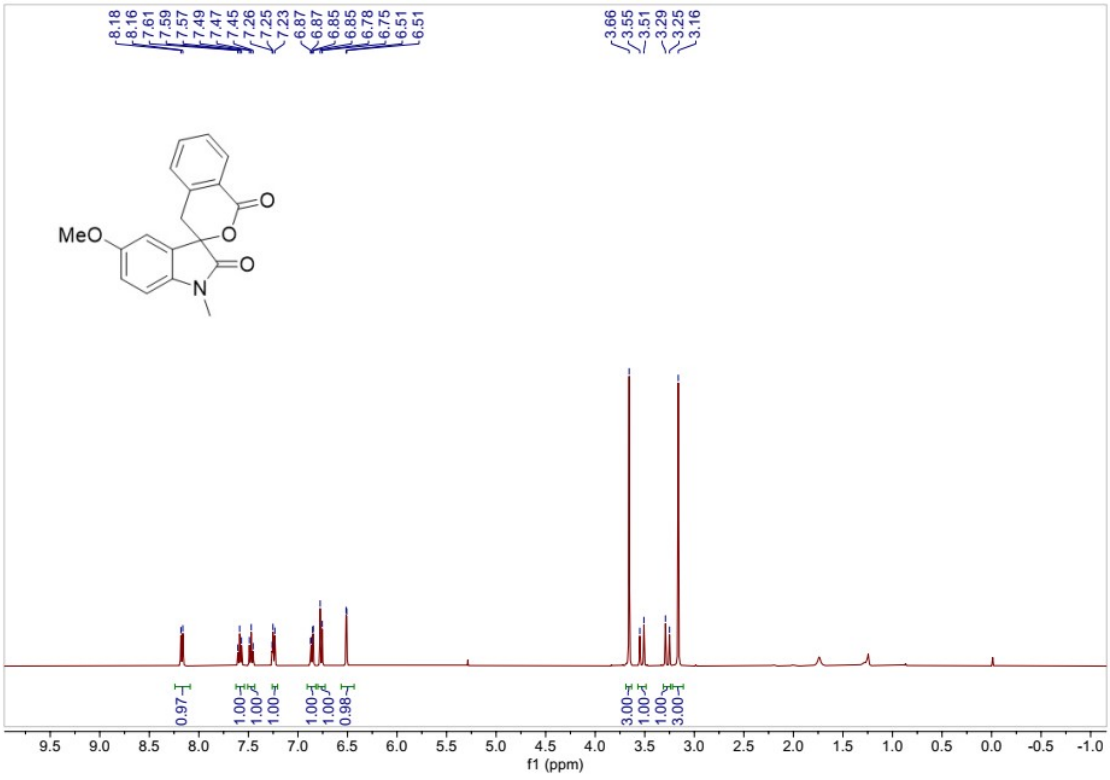
^{1}H NMR spectrum for compound **2c** (In $CDCl_3$, 600MHz)



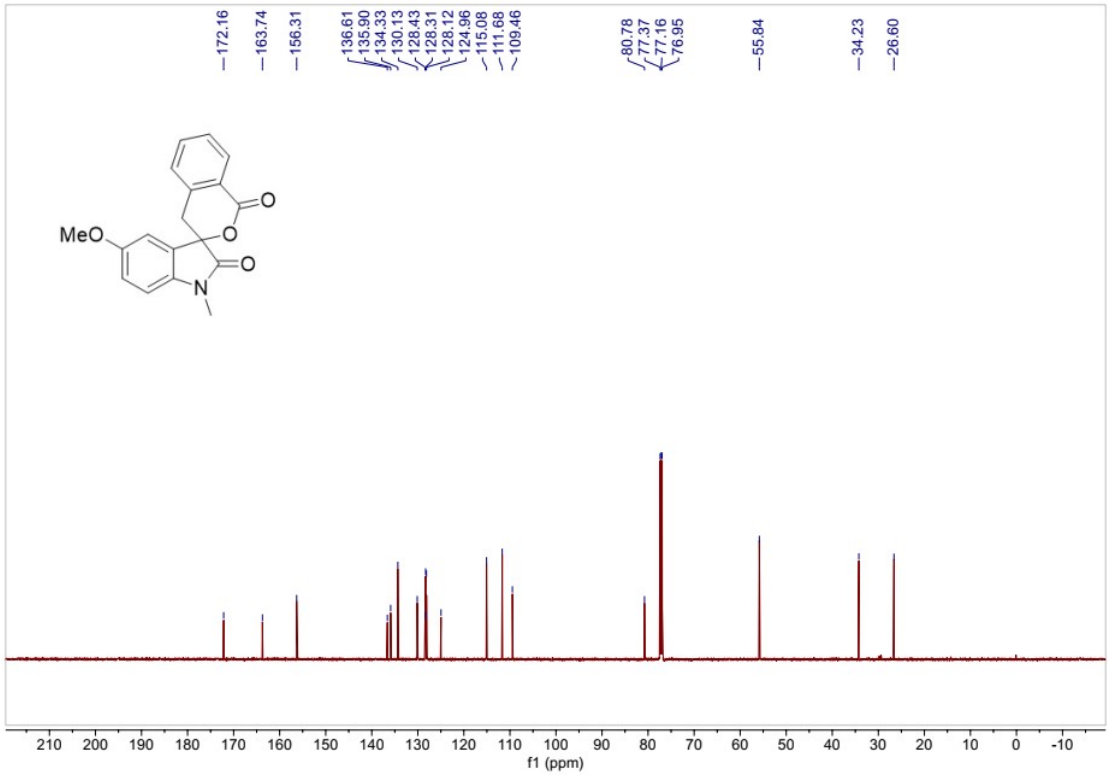
^{13}C NMR spectrum for compound **2c** (In $CDCl_3$, 101MHz)



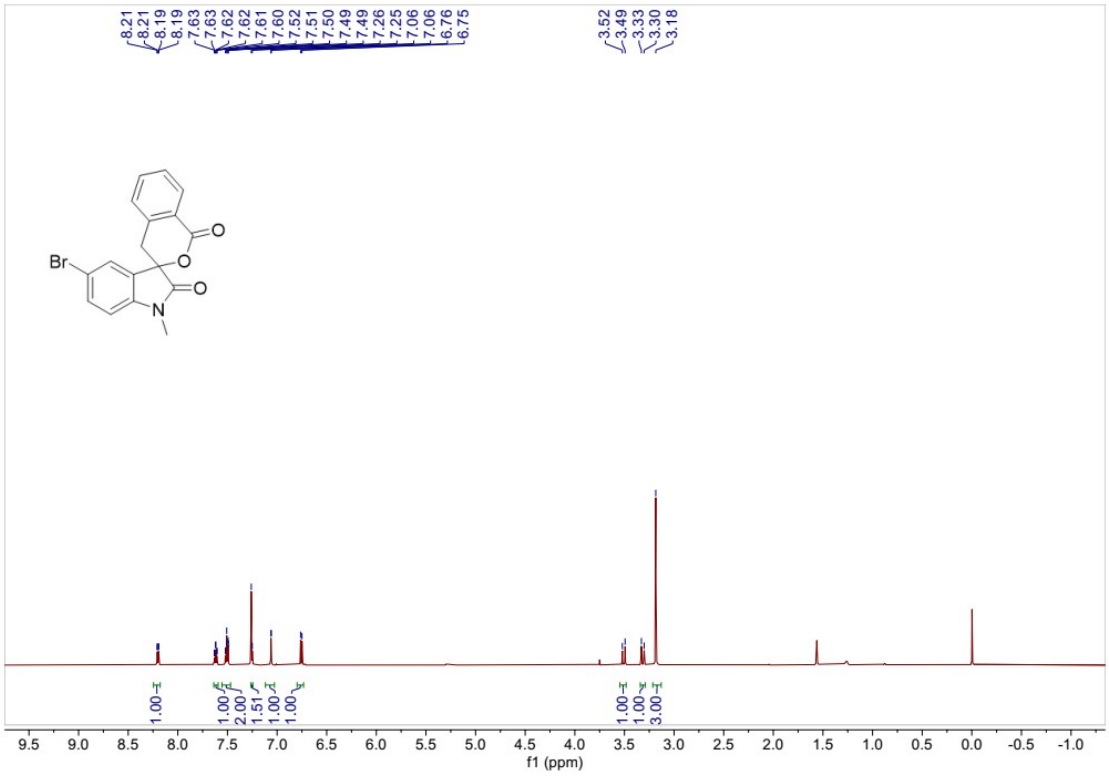
^{1}H NMR spectrum for compound **2d** (In $CDCl_3$, 400MHz)



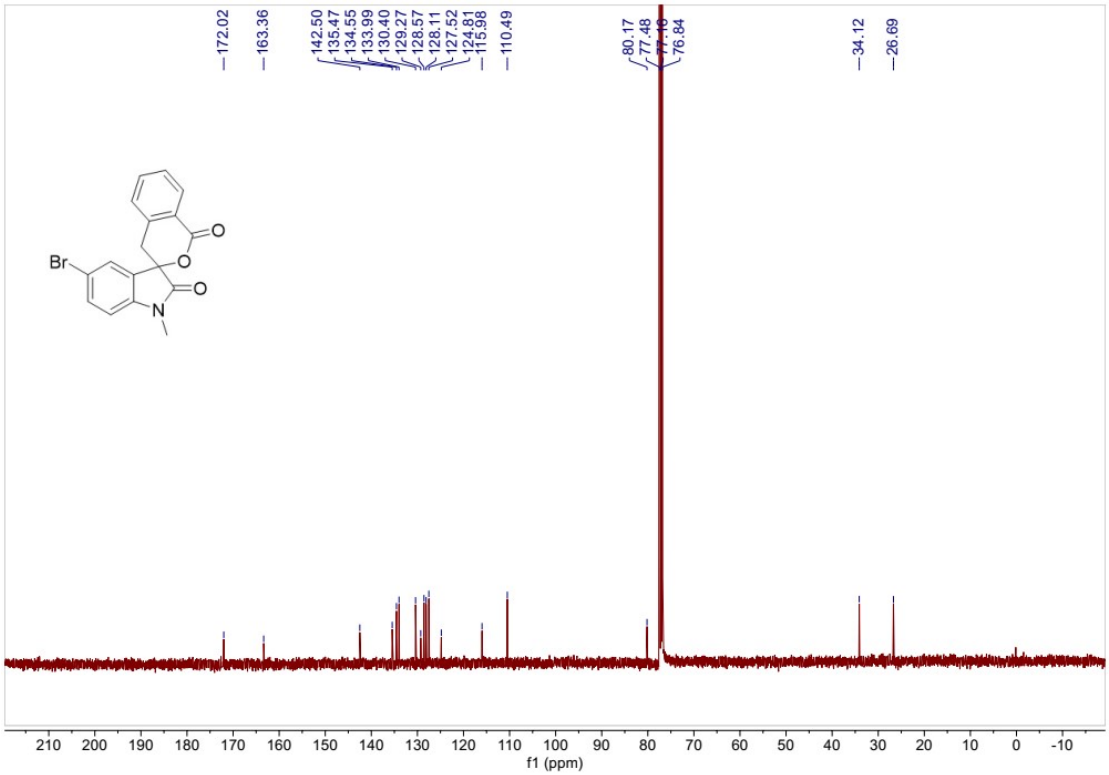
^{13}C NMR spectrum for compound **2d** (In $CDCl_3$, 151MHz)



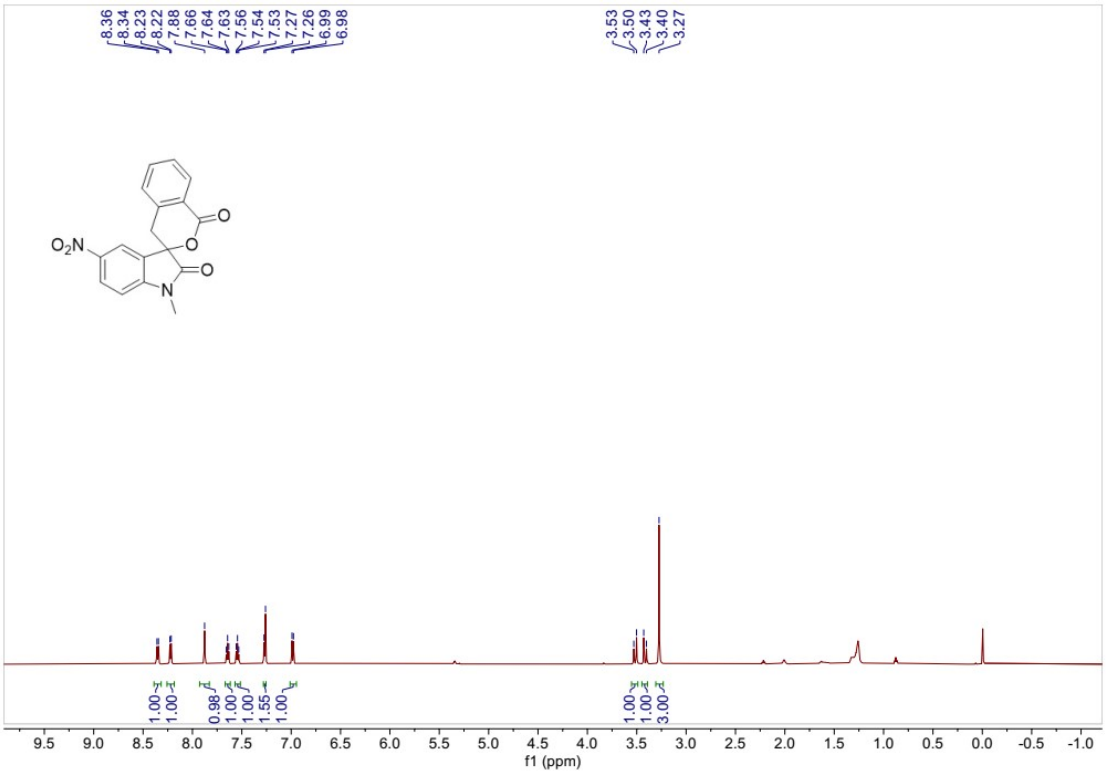
^{1}H NMR spectrum for compound **2e** (In $CDCl_3$, 600MHz)



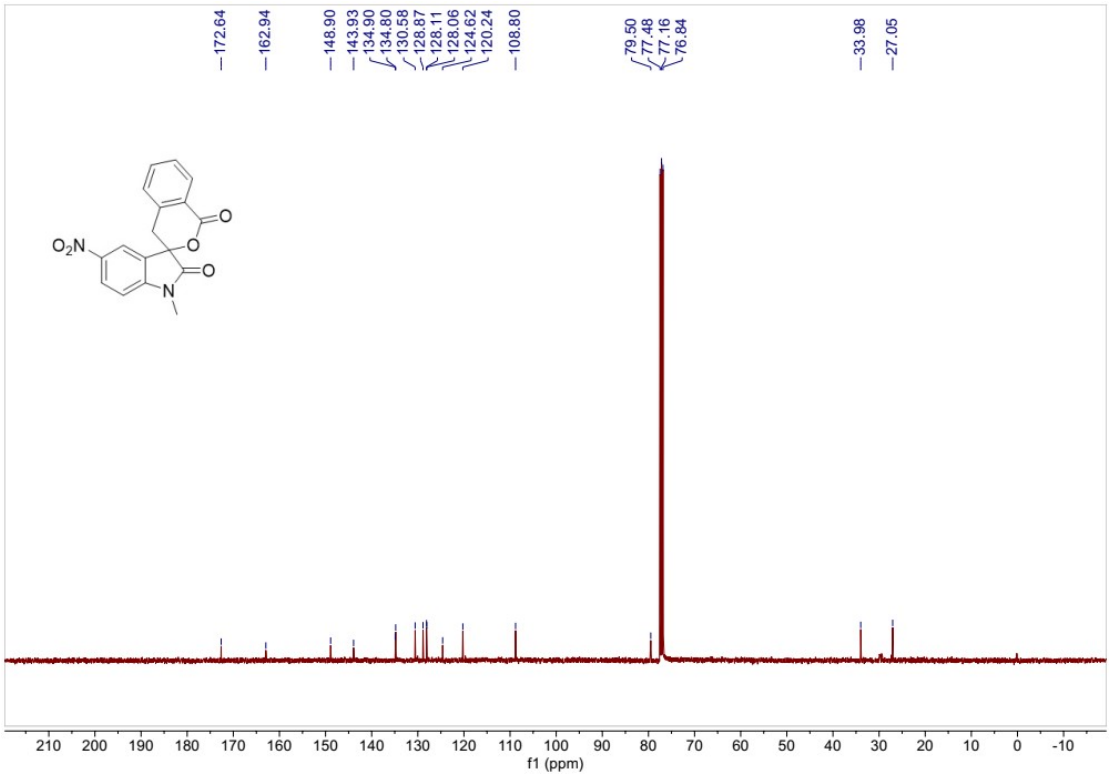
^{13}C NMR spectrum for compound **2e** (In $CDCl_3$, 101MHz)



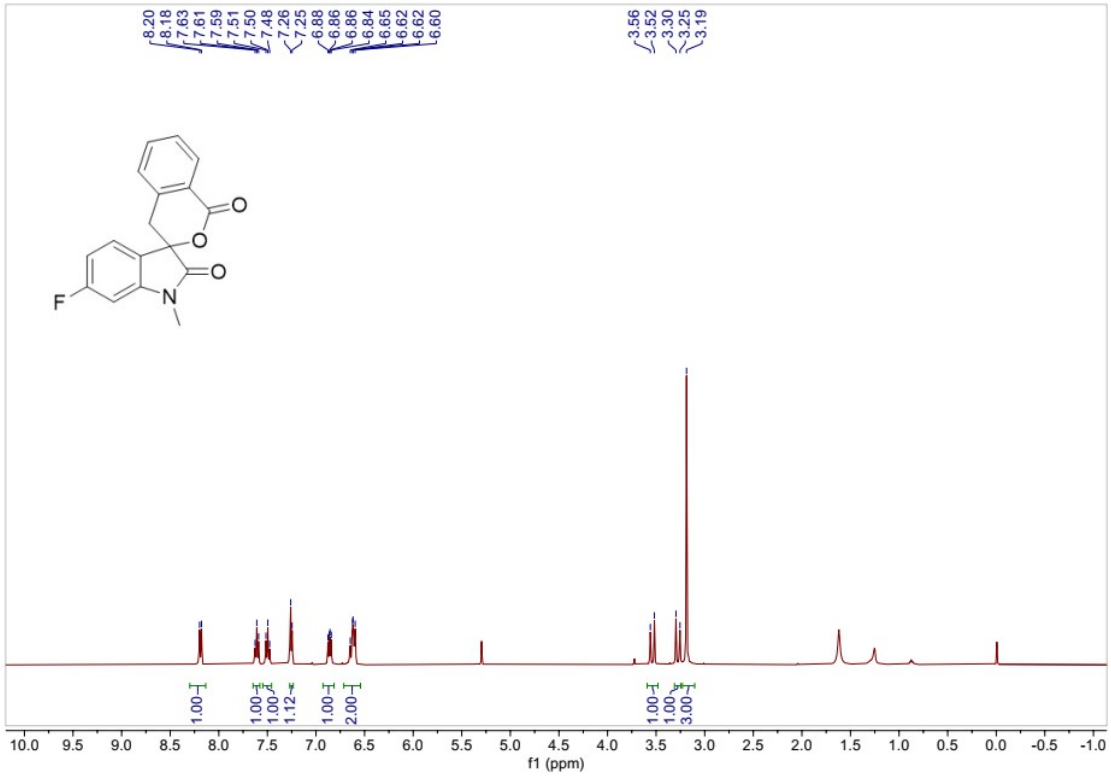
^{1}H NMR spectrum for compound **2f** (In $CDCl_3$, 600MHz)



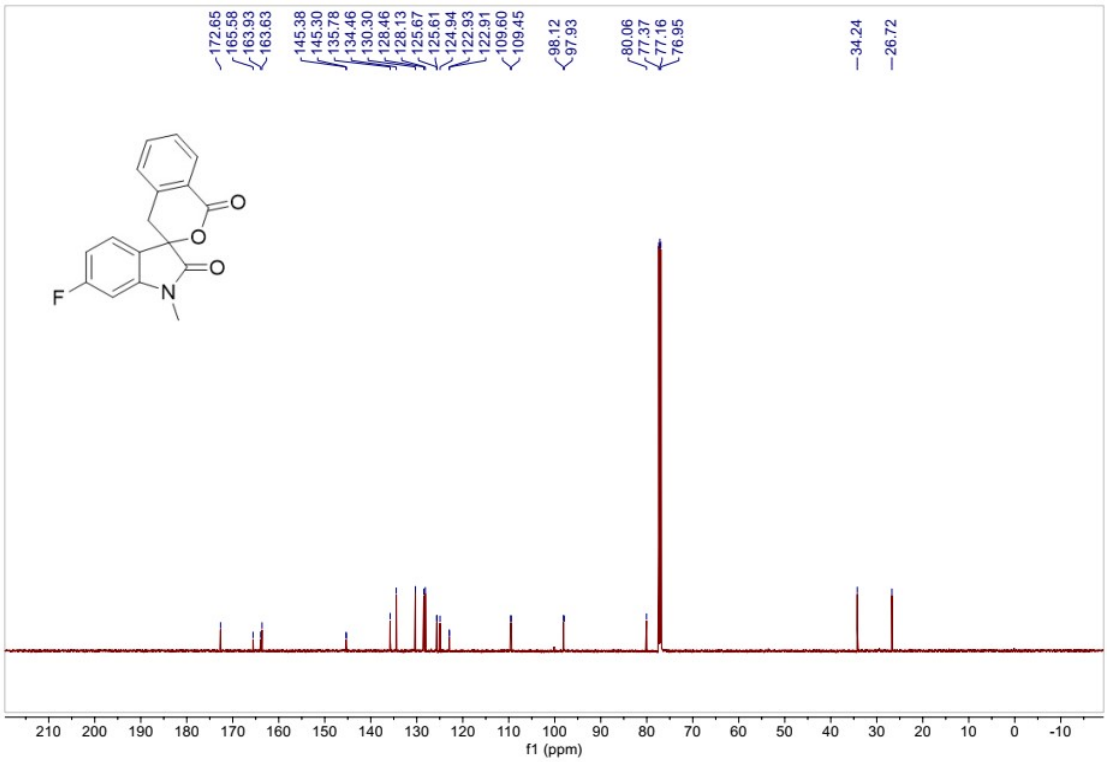
^{13}C NMR spectrum for compound **2f** (In $CDCl_3$, 101MHz)



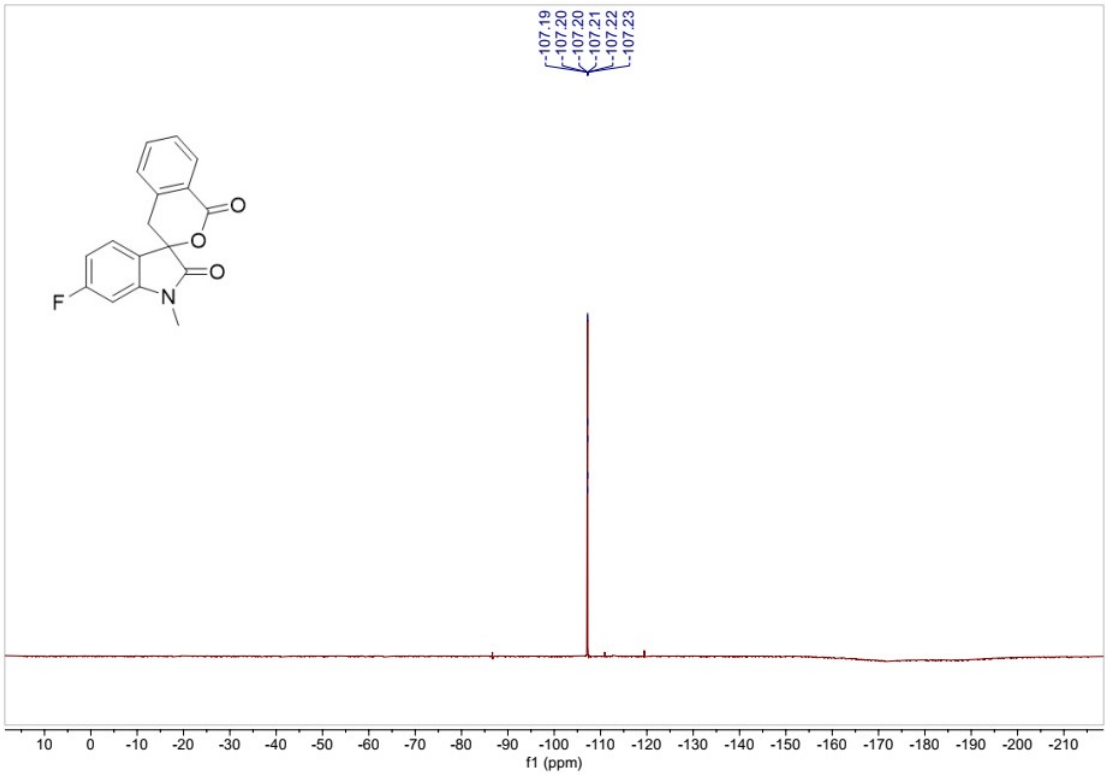
^{1}H NMR spectrum for compound **2g** (In $CDCl_3$, 400MHz)



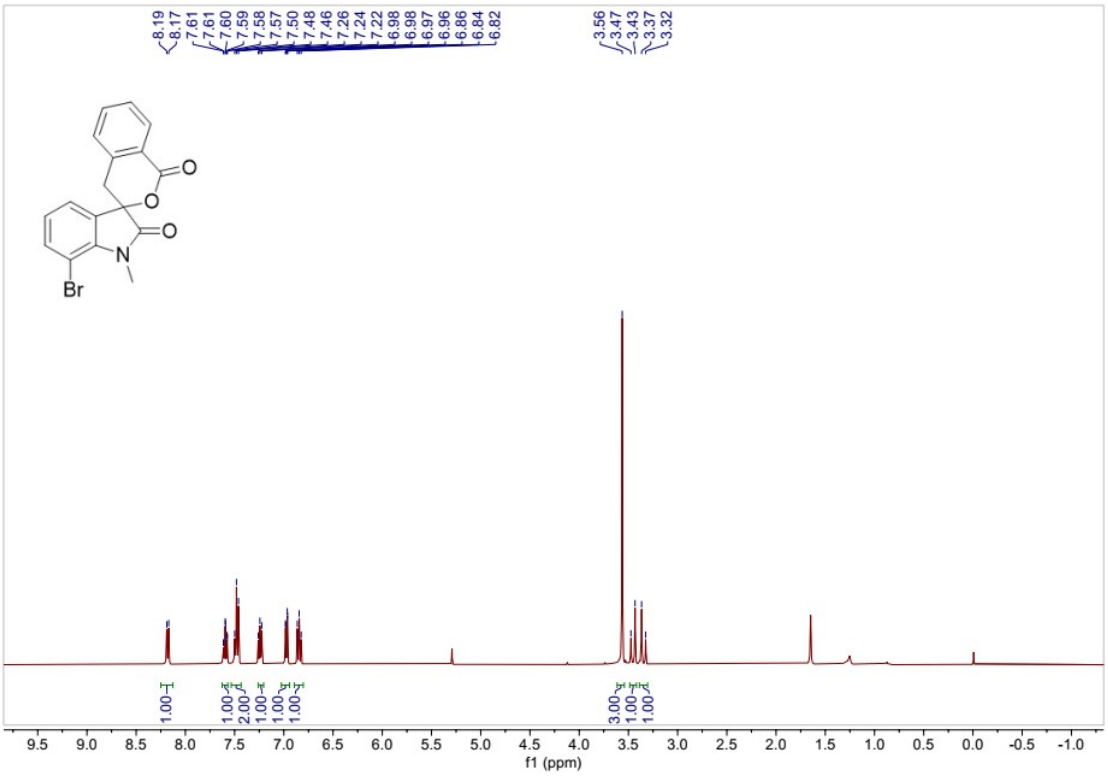
^{13}C NMR spectrum for compound **2g** (In $CDCl_3$, 151MHz)



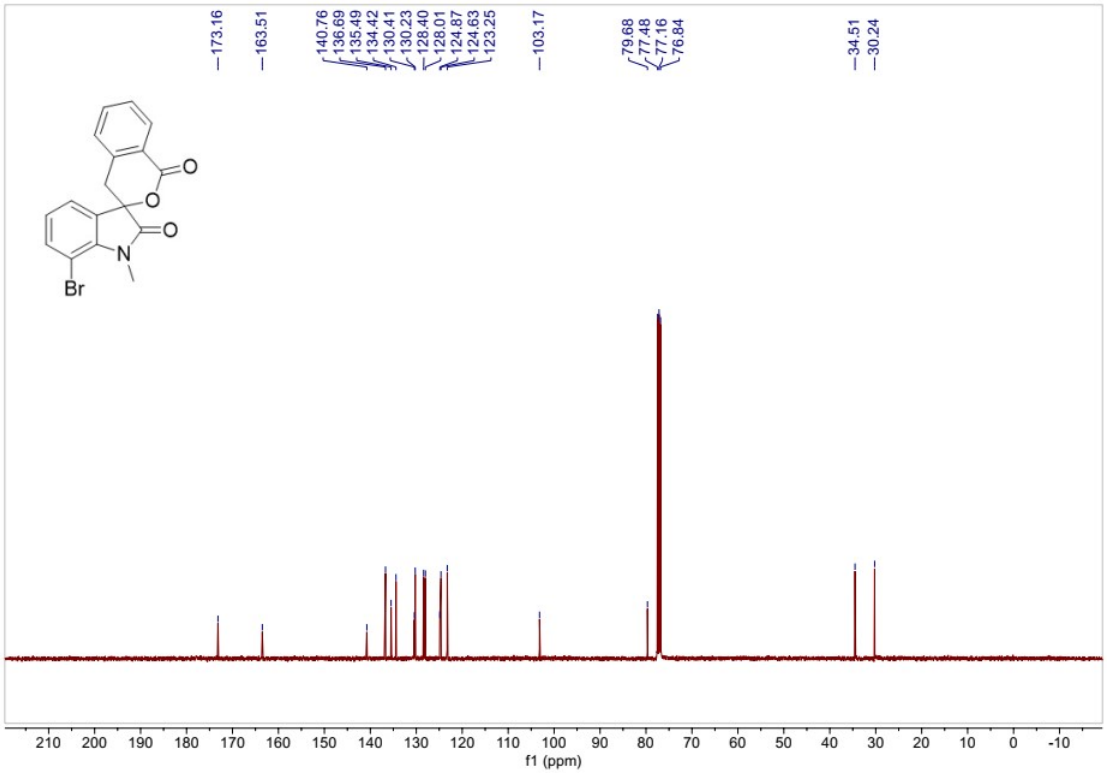
^{19}F NMR spectrum for compound **3gc** (In **2g**, 565MHz)



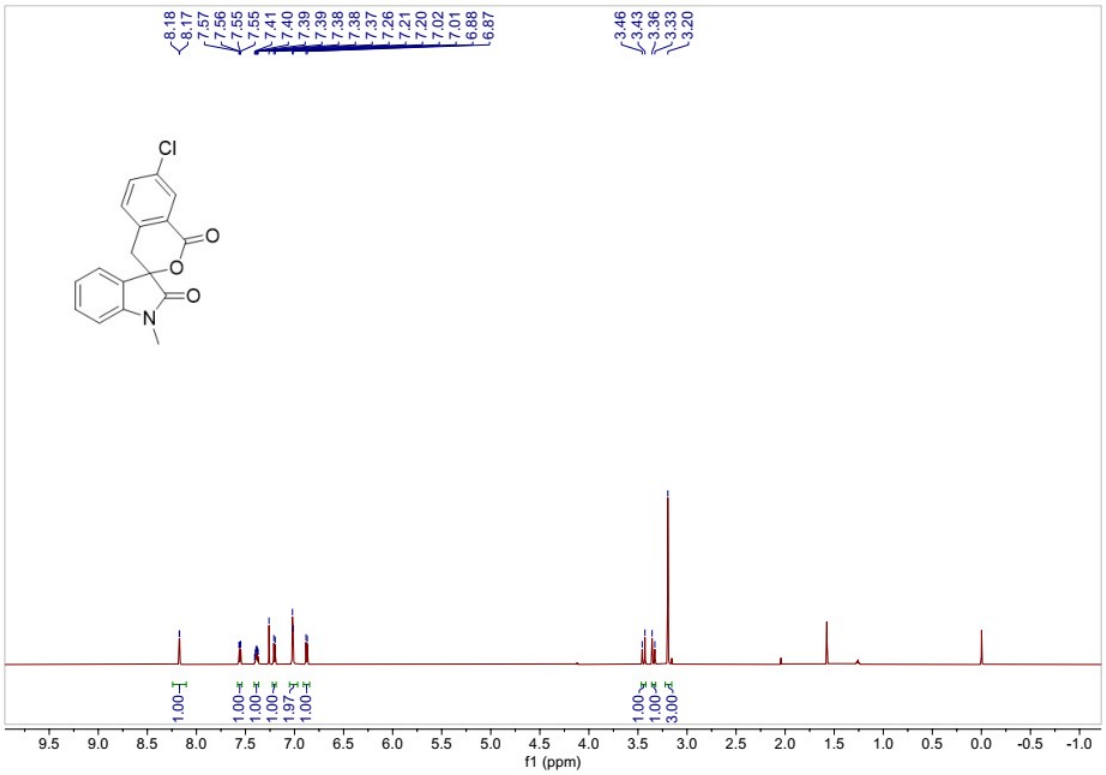
^{1}H NMR spectrum for compound **2h** (In $CDCl_3$, 400MHz)



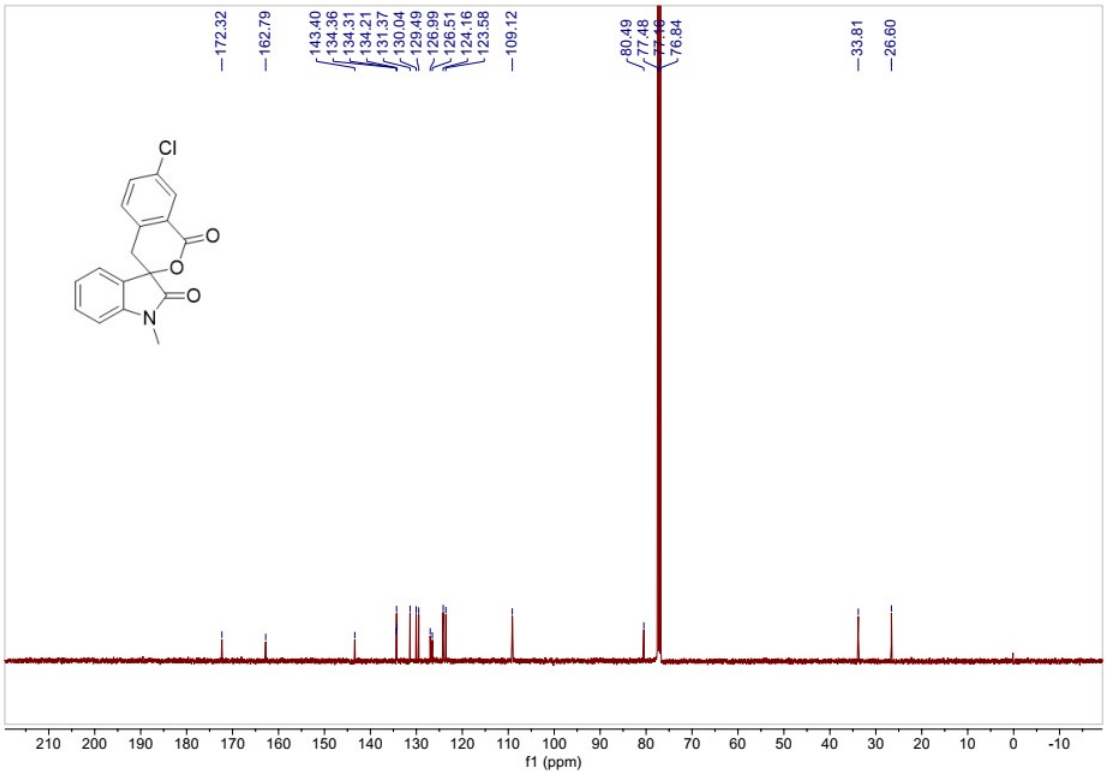
^{13}C NMR spectrum for compound **2h** (In $CDCl_3$, 101MHz)



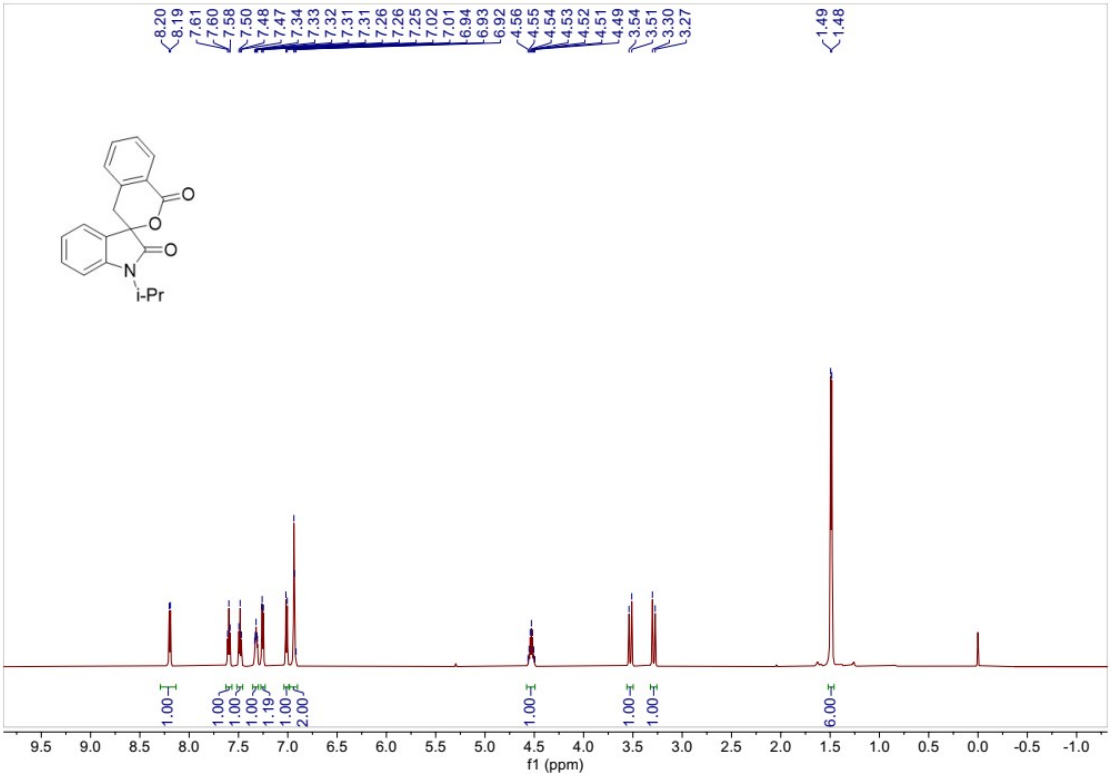
^{1}H NMR spectrum for compound **2i** (In $CDCl_3$, 600MHz)



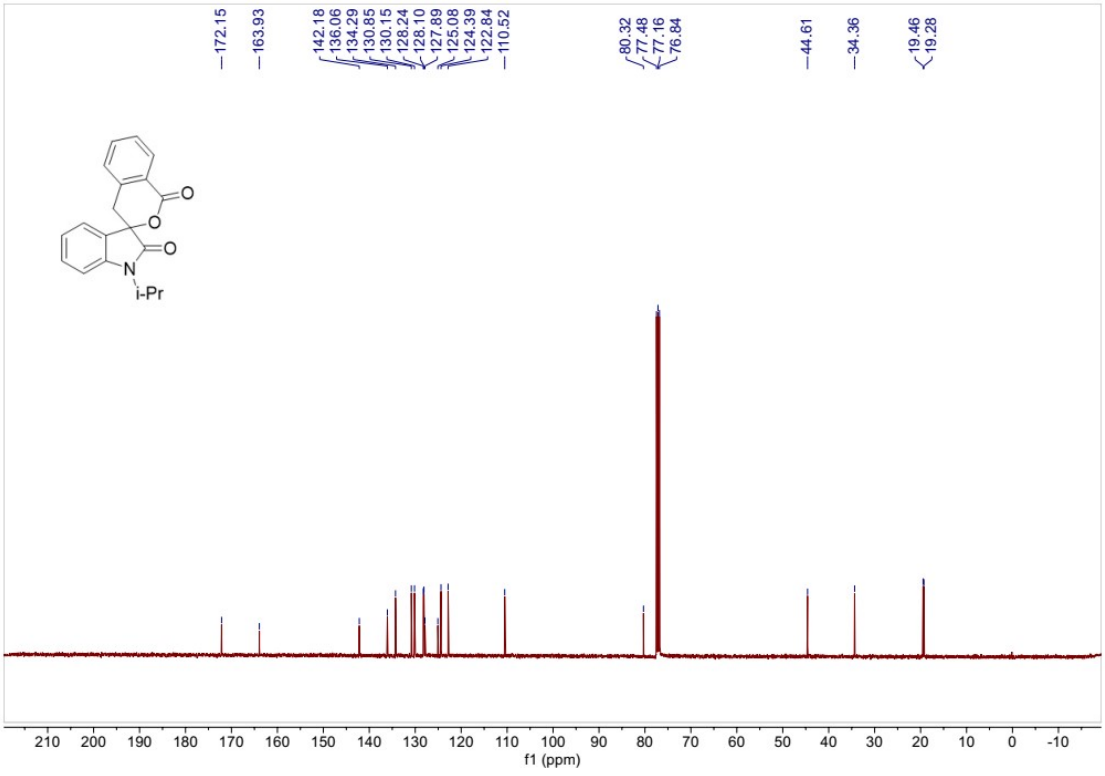
^{13}C NMR spectrum for compound **2i** (In $CDCl_3$, 101MHz)



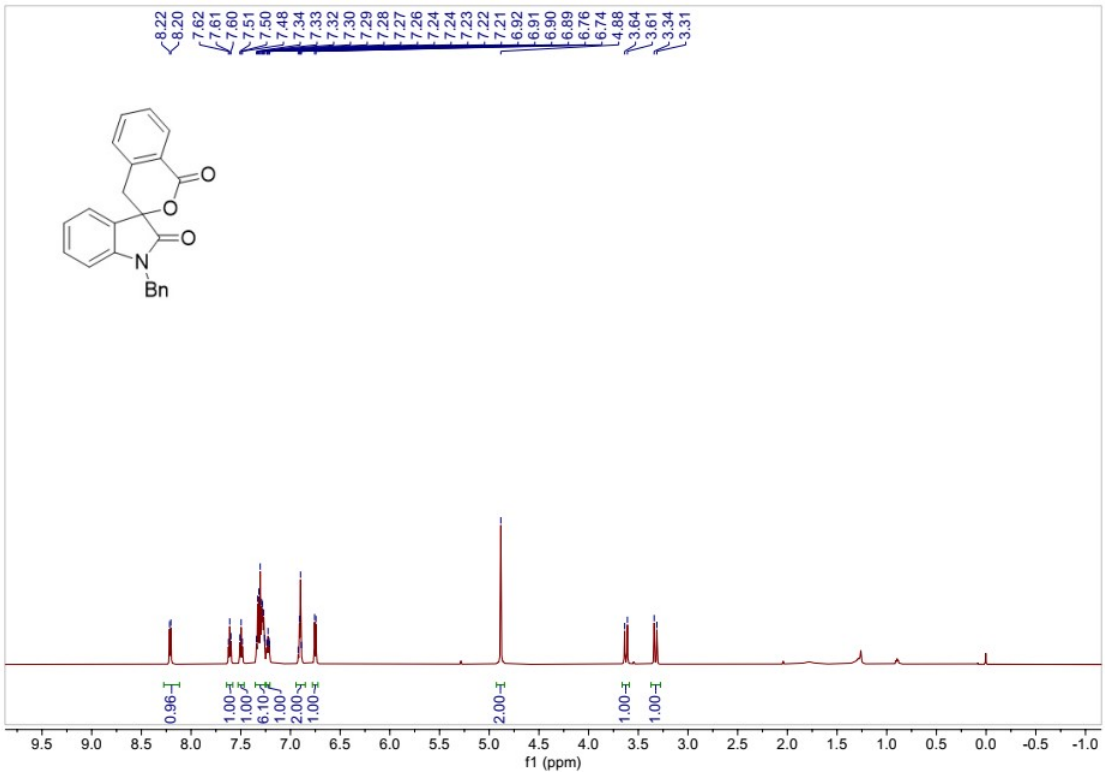
^{1}H NMR spectrum for compound **2j** (In $CDCl_3$, 600MHz)



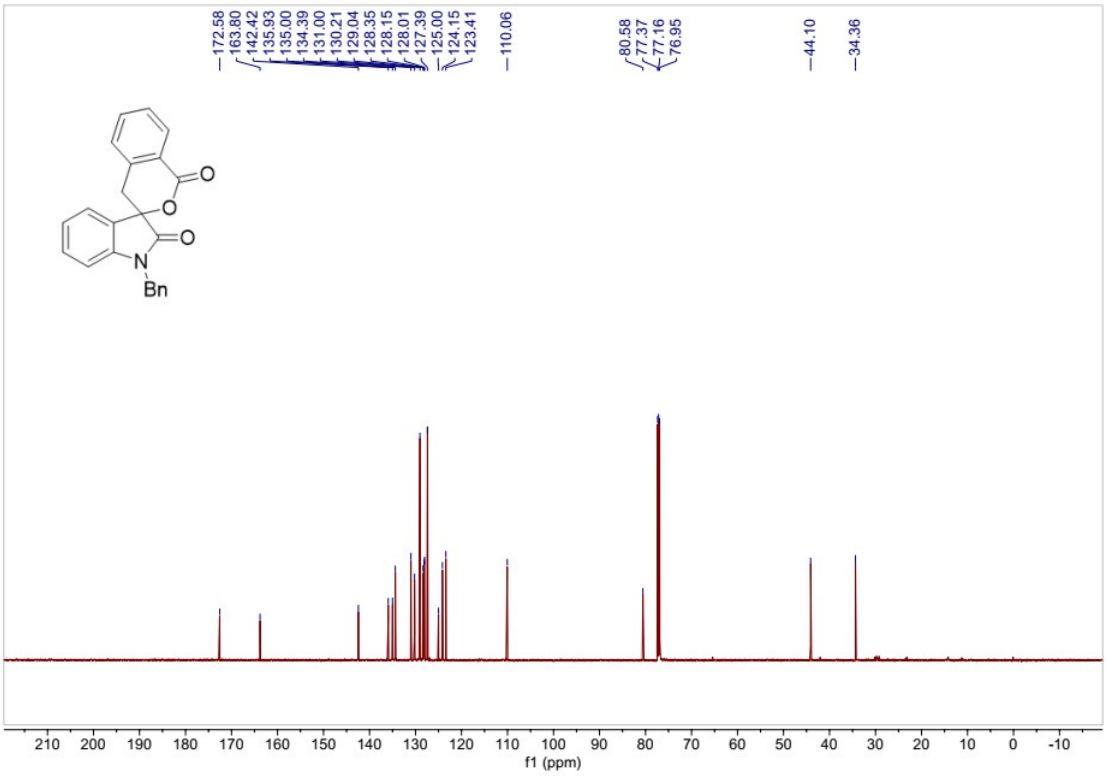
^{13}C NMR spectrum for compound **2j** (In $CDCl_3$, 101MHz)



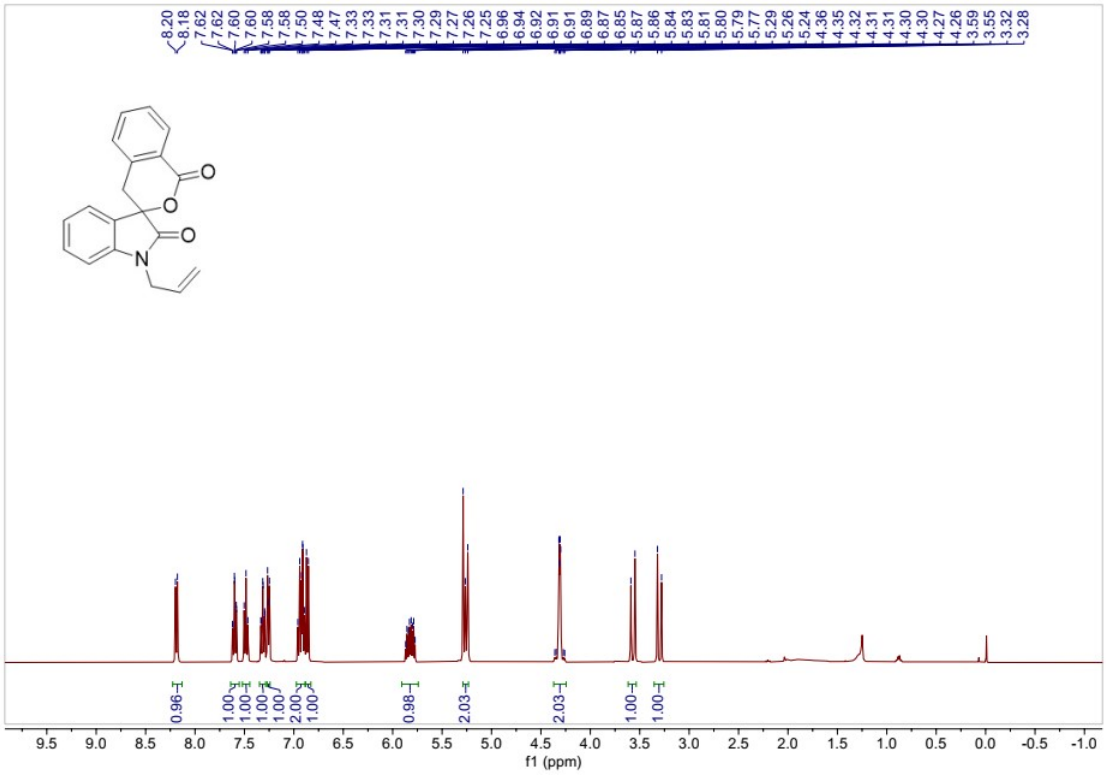
^{1}H NMR spectrum for compound **2k** (In $CDCl_3$, 600MHz)



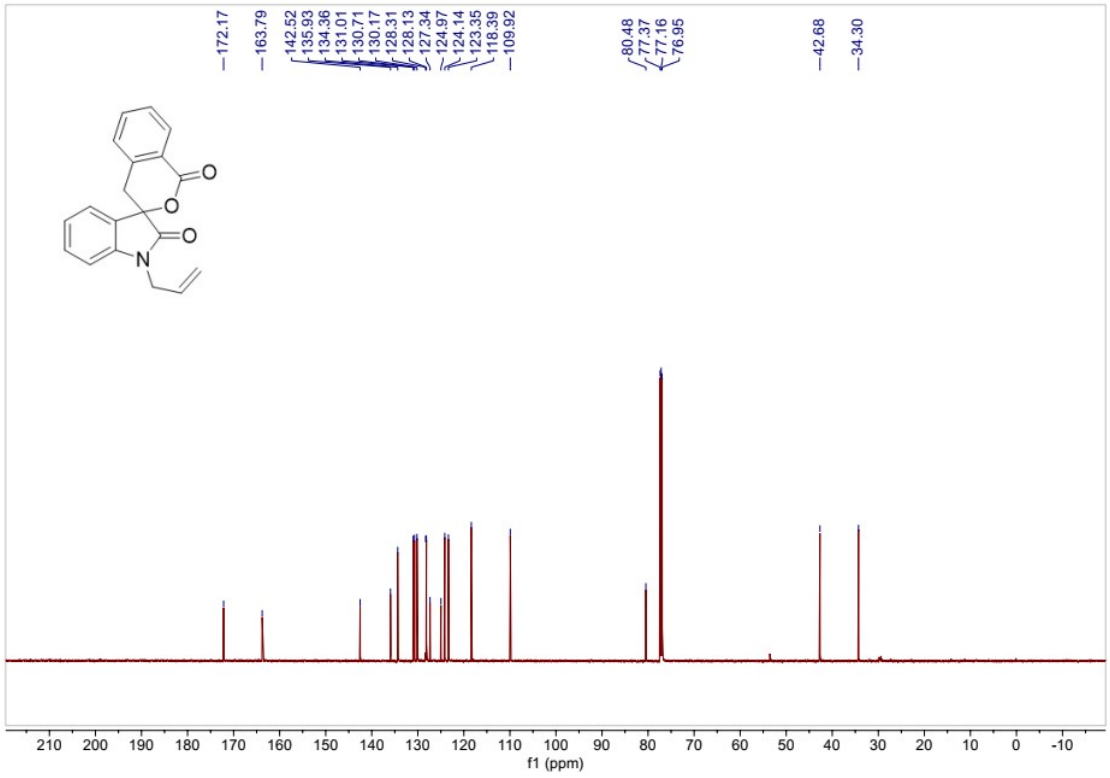
^{13}C NMR spectrum for compound **2k** (In $CDCl_3$, 151MHz)



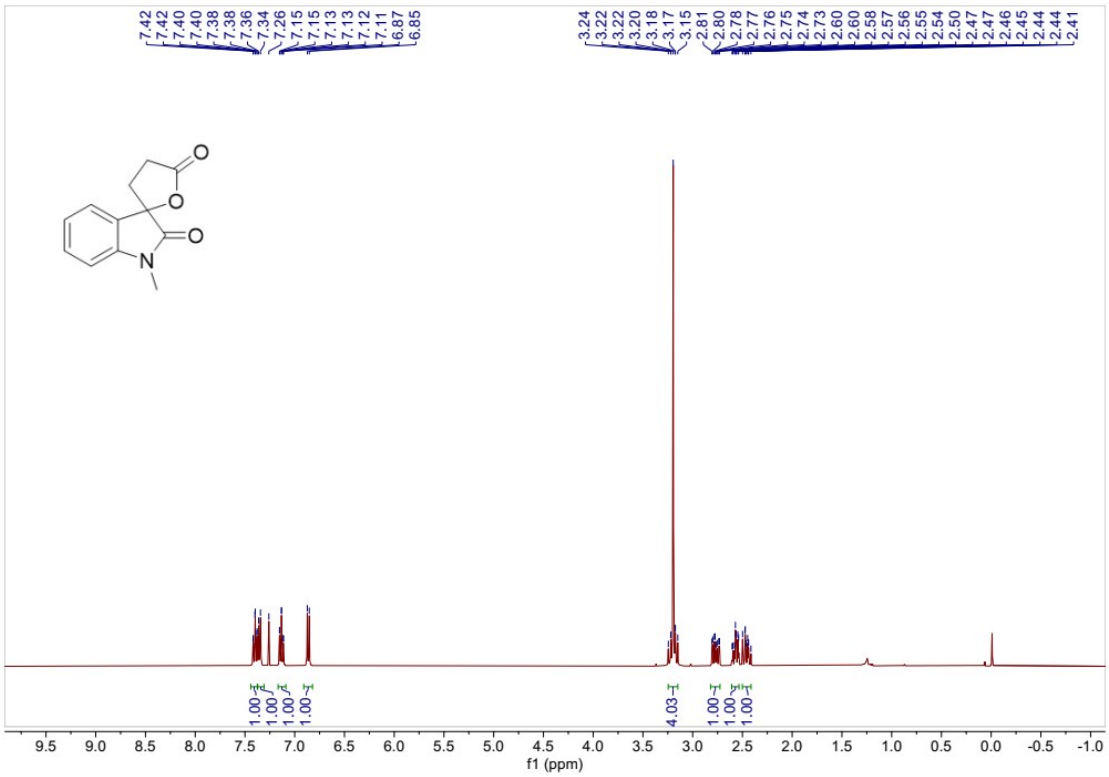
^{1}H NMR spectrum for compound **2l** (In $CDCl_3$, 400MHz)



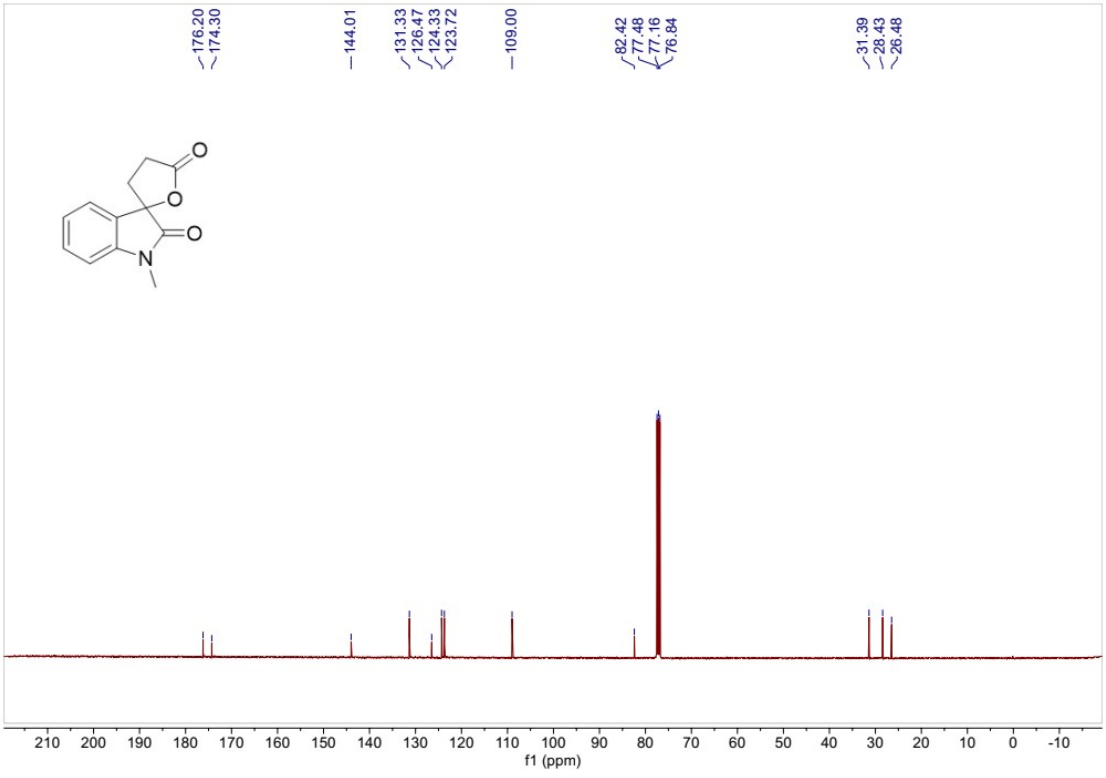
^{13}C NMR spectrum for compound **2l** (In $CDCl_3$, 151MHz)



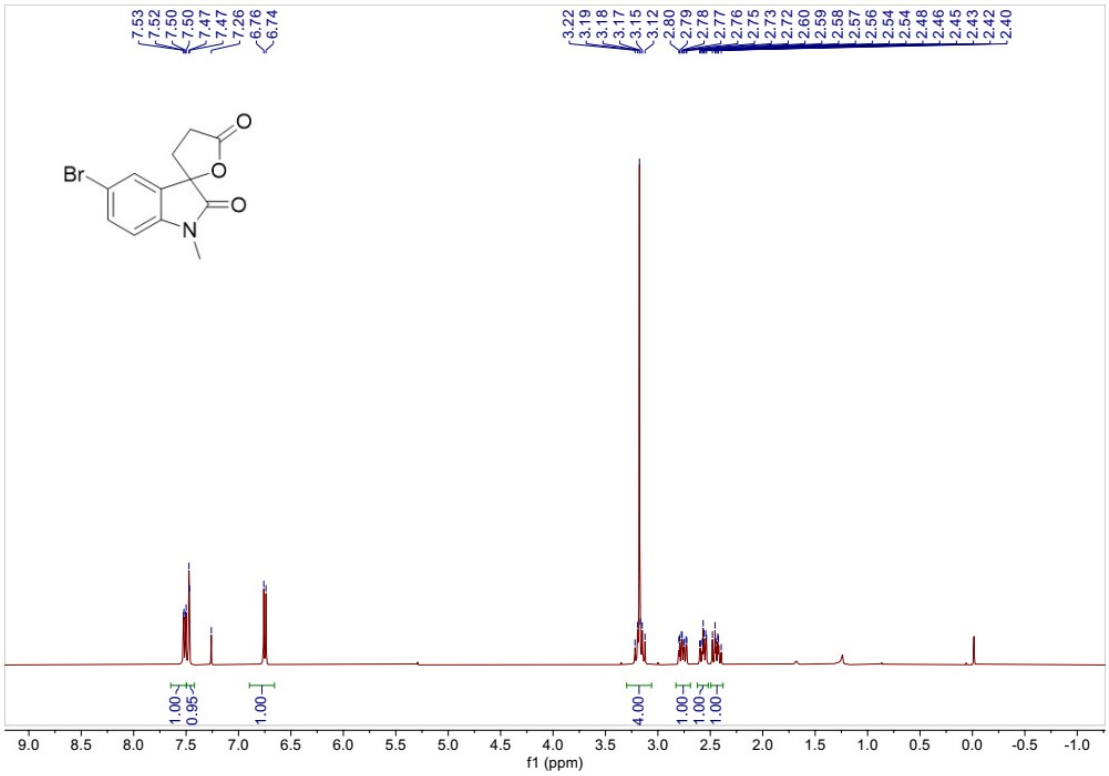
^{1}H NMR spectrum for compound **4a** (In $CDCl_3$, 400MHz)



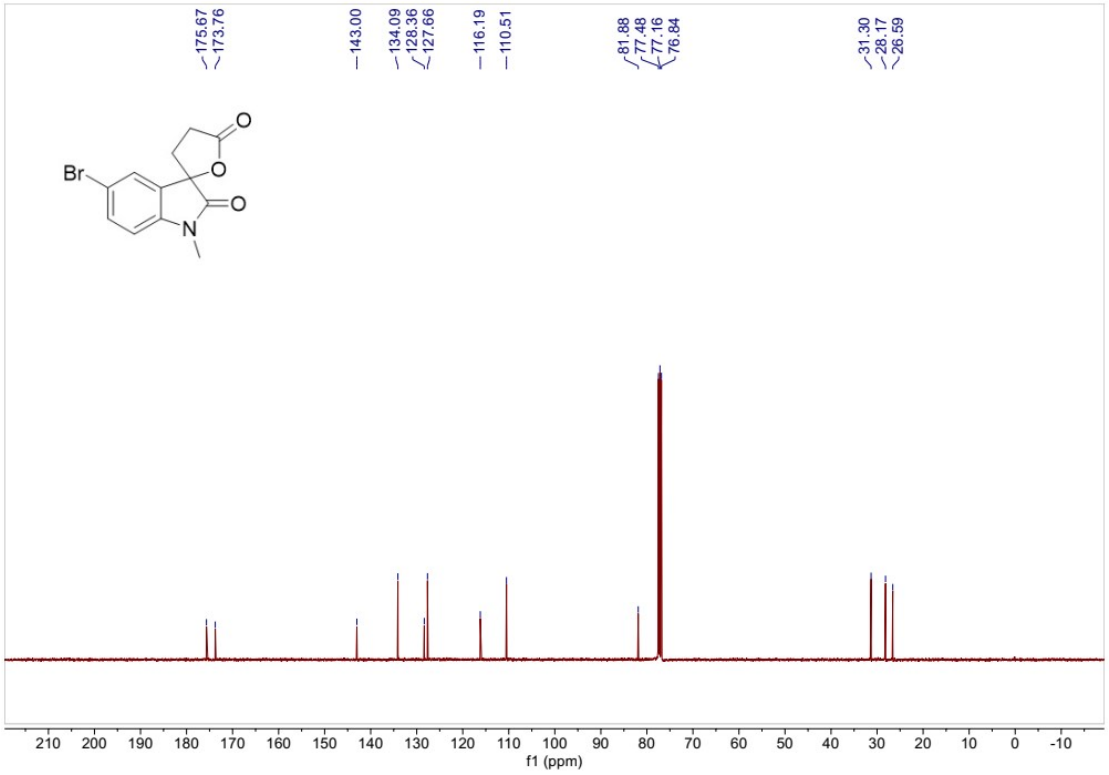
^{13}C NMR spectrum for compound **4a** (In $CDCl_3$, 101MHz)



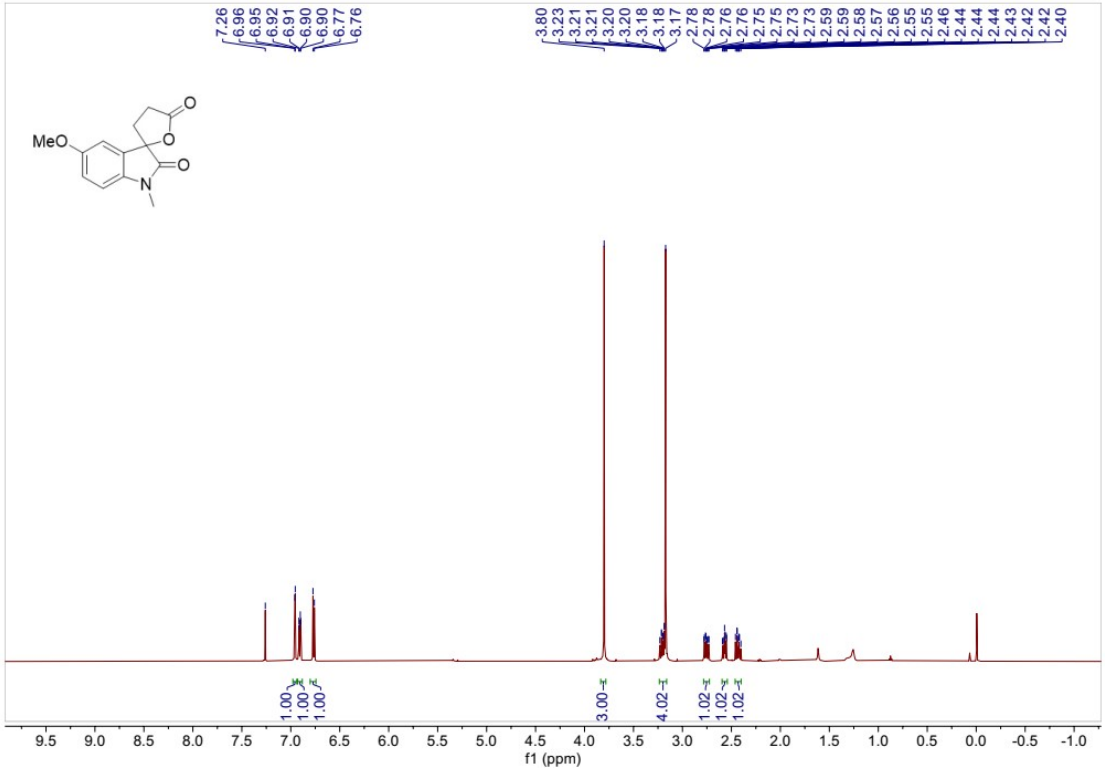
^{1}H NMR spectrum for compound **4b** (In $CDCl_3$, 400MHz)



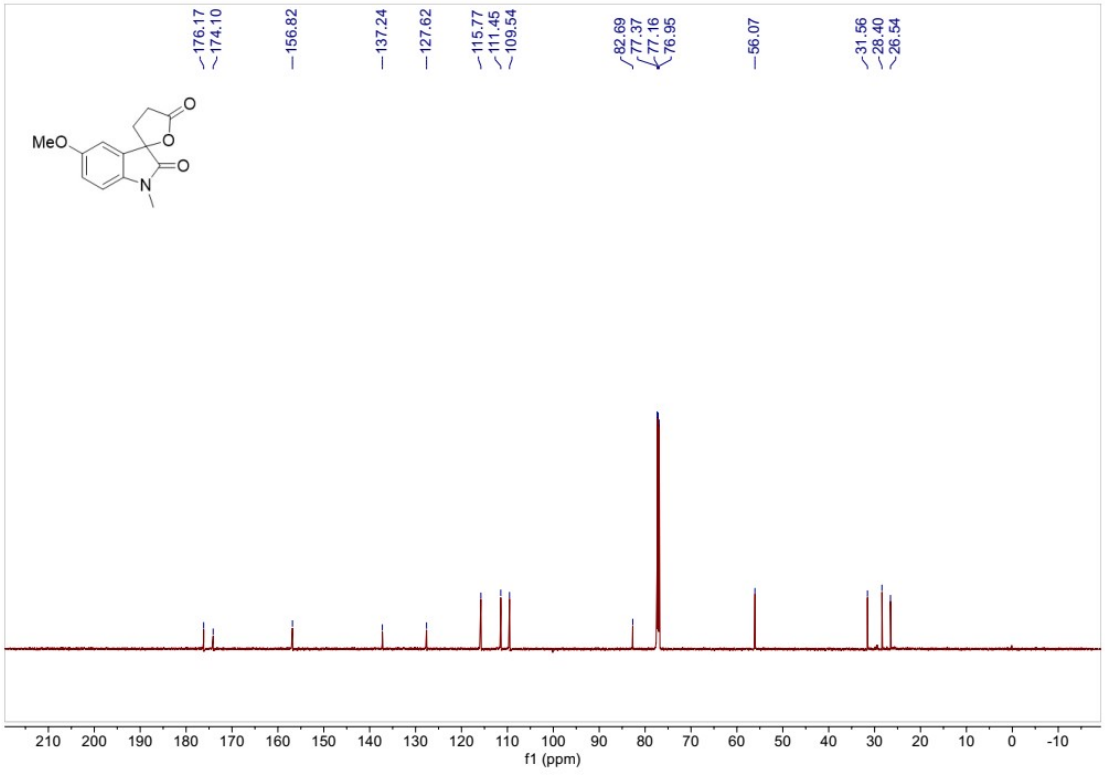
^{13}C NMR spectrum for compound **4b** (In $CDCl_3$, 101MHz)



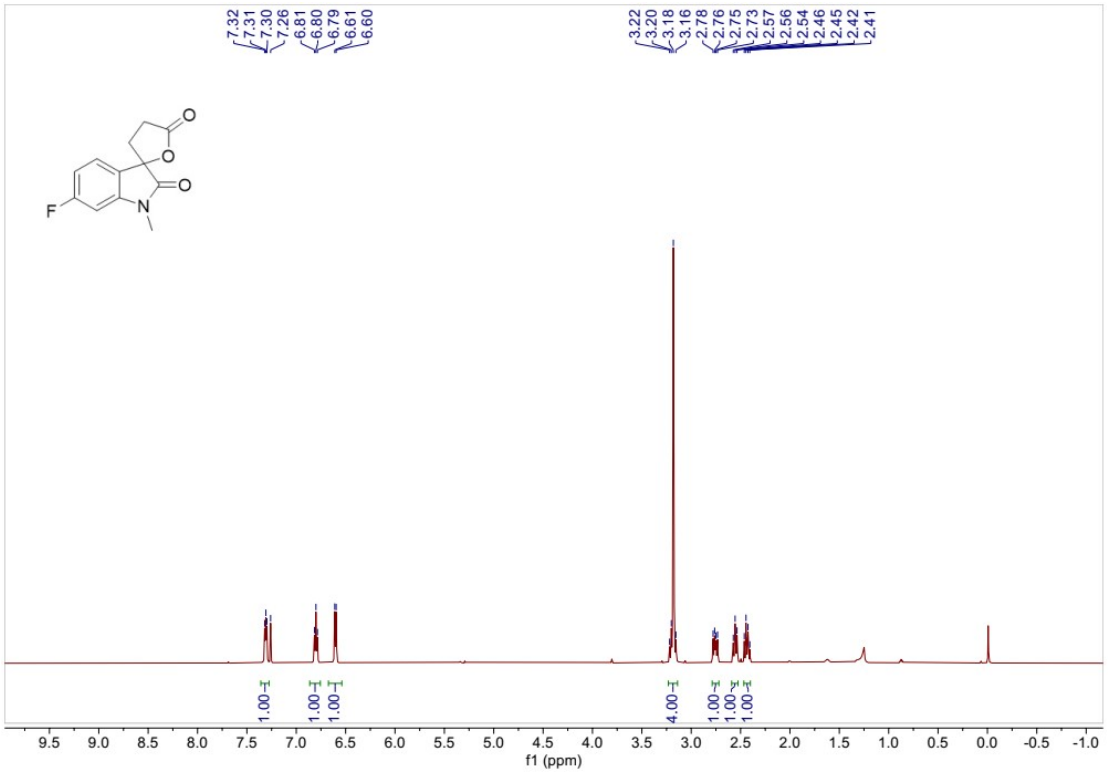
^{1}H NMR spectrum for compound **4c** (In $CDCl_3$, 600MHz)



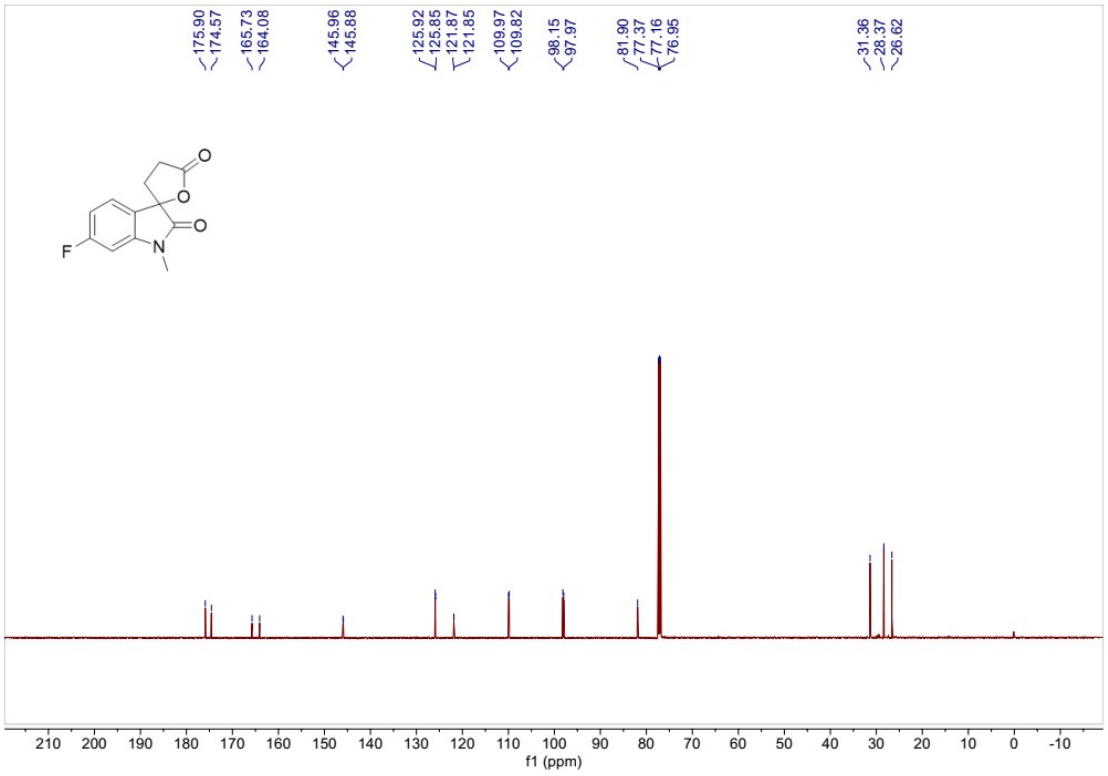
^{13}C NMR spectrum for compound **4c** (In $CDCl_3$, 151MHz)



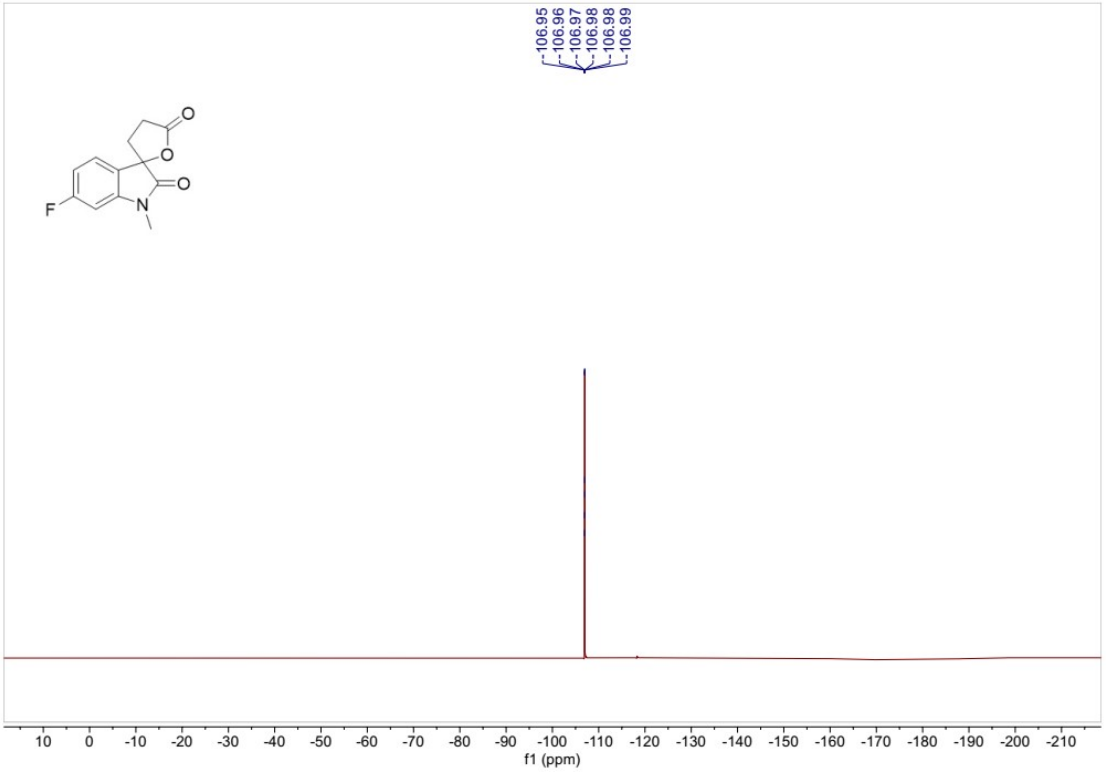
^{1}H NMR spectrum for compound **4d** (In $CDCl_3$, 600MHz)



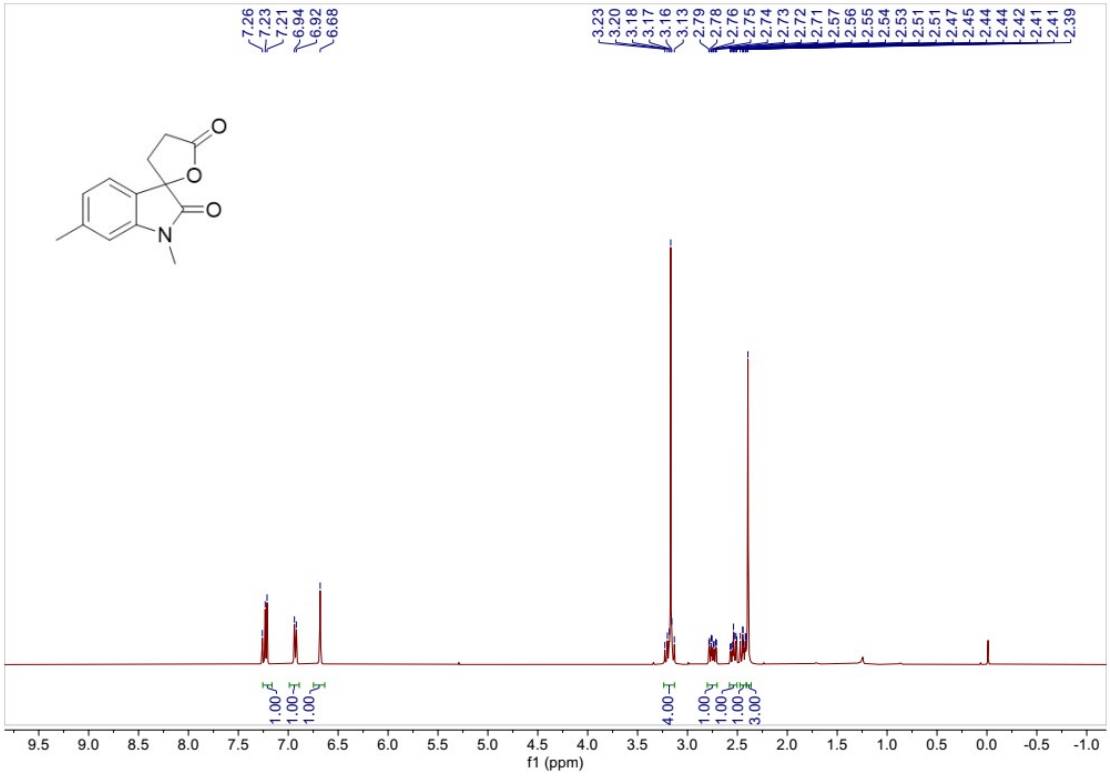
^{13}C NMR spectrum for compound **4d** (In $CDCl_3$, 151MHz)



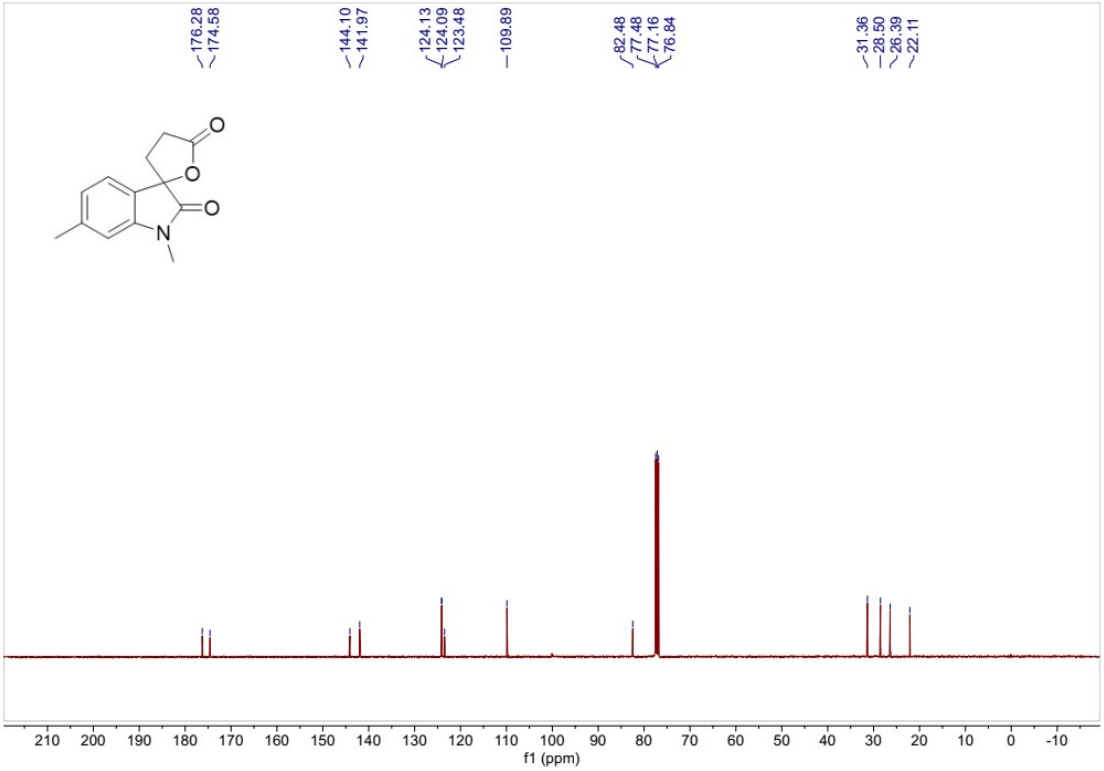
^{19}F NMR spectrum for compound **4d** (In $CDCl_3$, 565MHz)



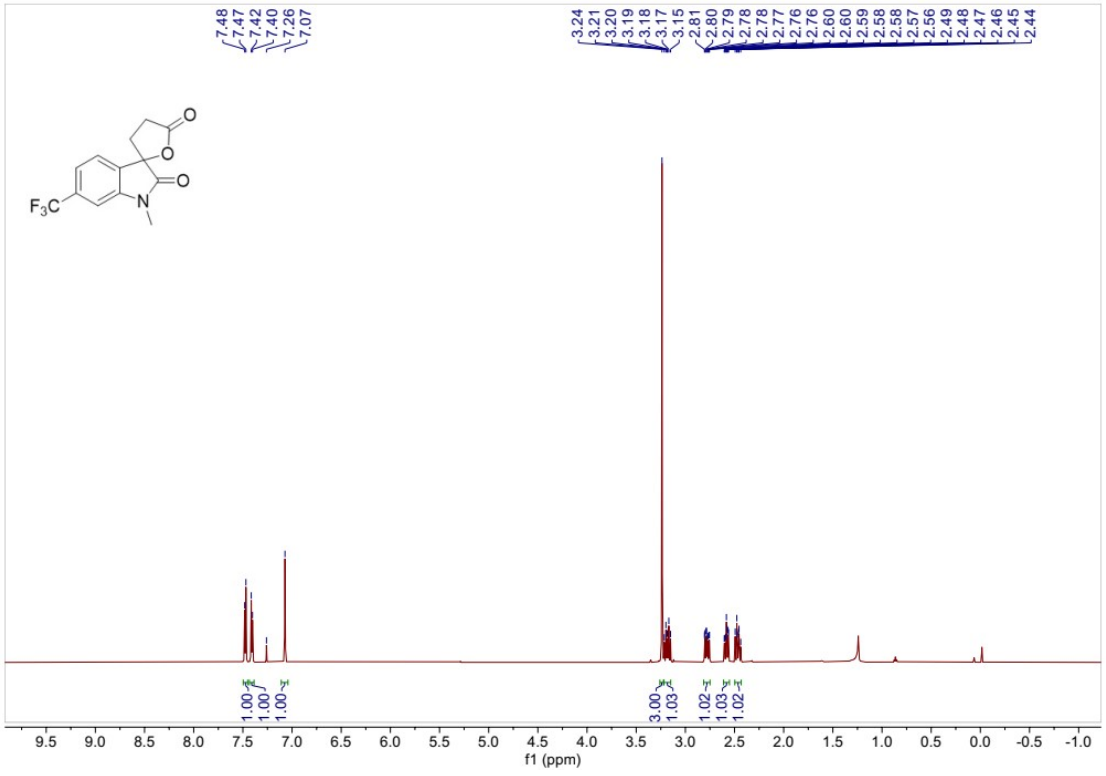
^{1}H NMR spectrum for compound **4e** (In $CDCl_3$, 400MHz)



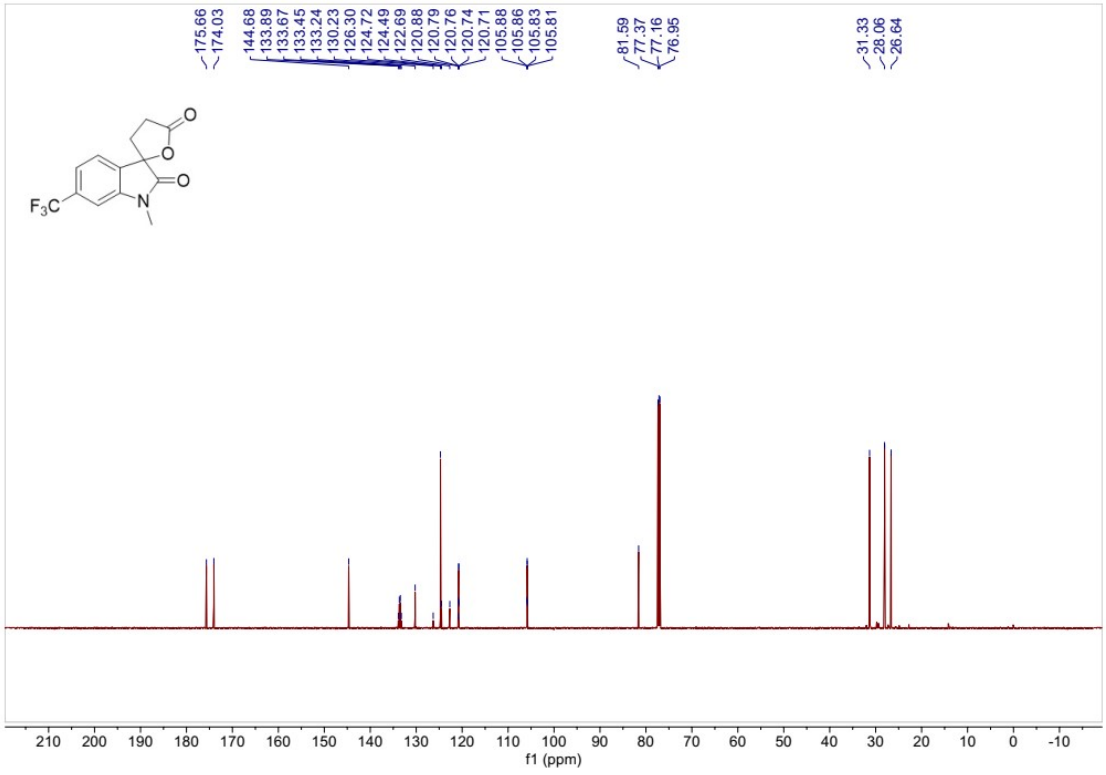
^{13}C NMR spectrum for compound **4e** (In $CDCl_3$, 101MHz)



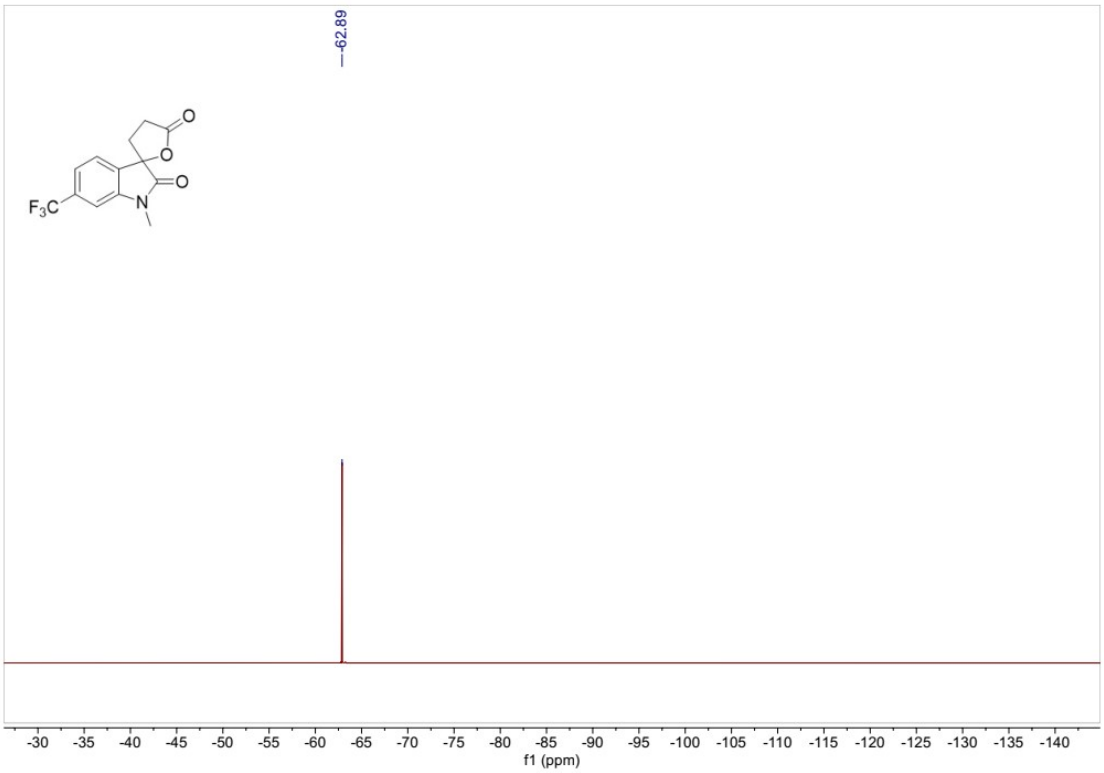
^{1}H NMR spectrum for compound **4f** (In $CDCl_3$, 600MHz)



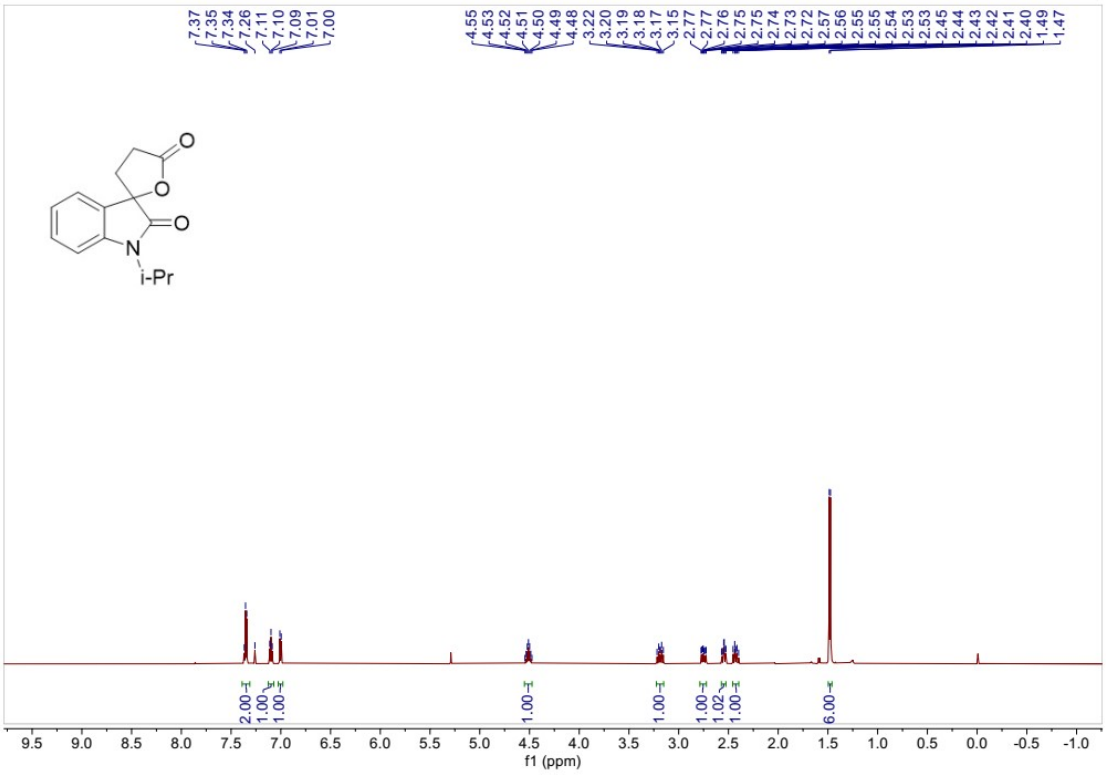
^{13}C NMR spectrum for compound **4f** (In $CDCl_3$, 151MHz)



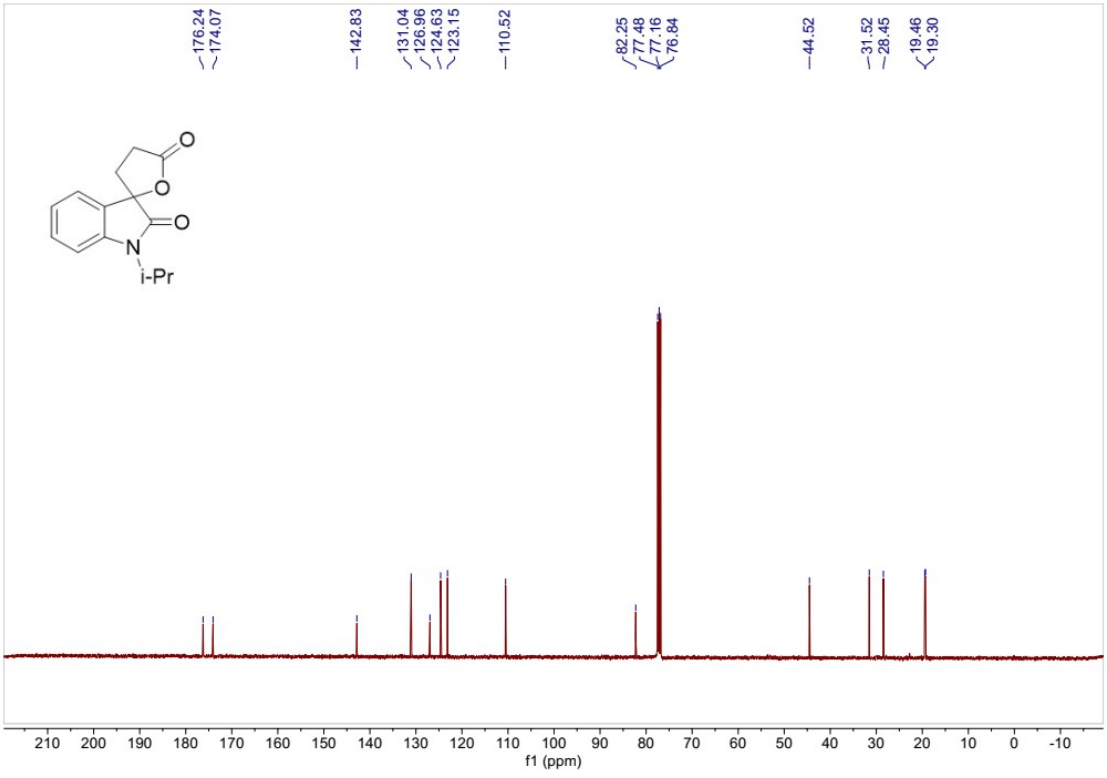
^{19}F NMR spectrum for compound **4f** (In $CDCl_3$, 565MHz)



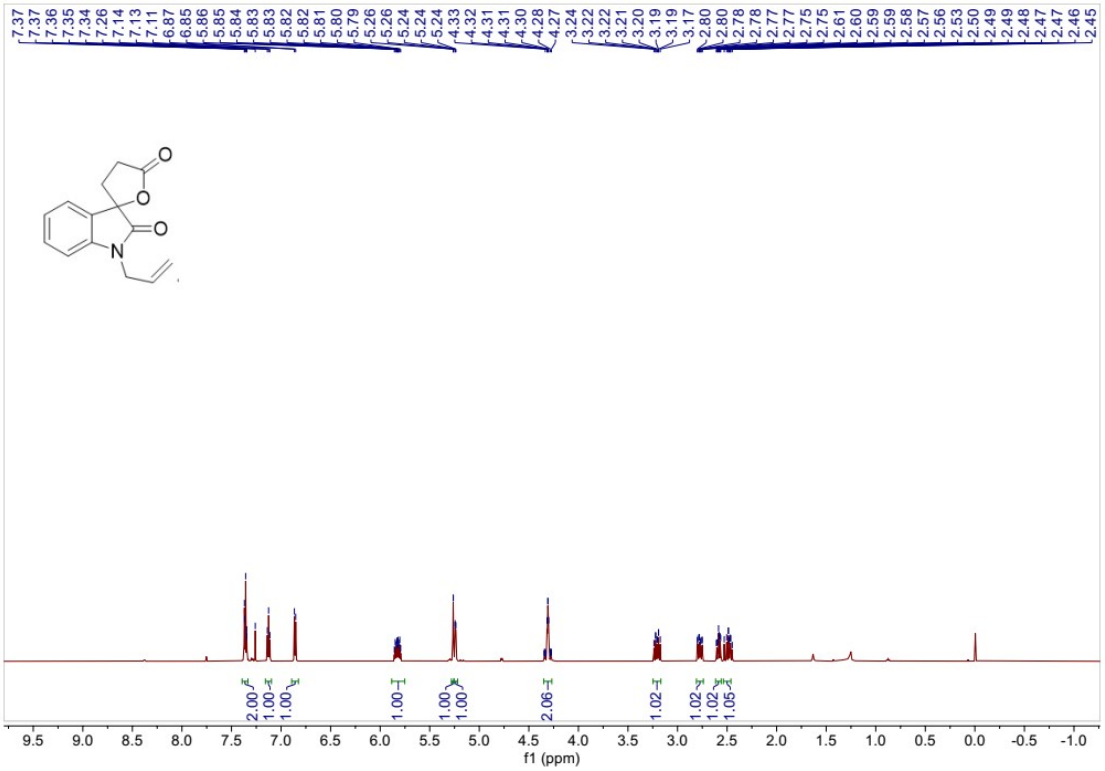
^{1}H NMR spectrum for compound **4g** (In $CDCl_3$, 600MHz)



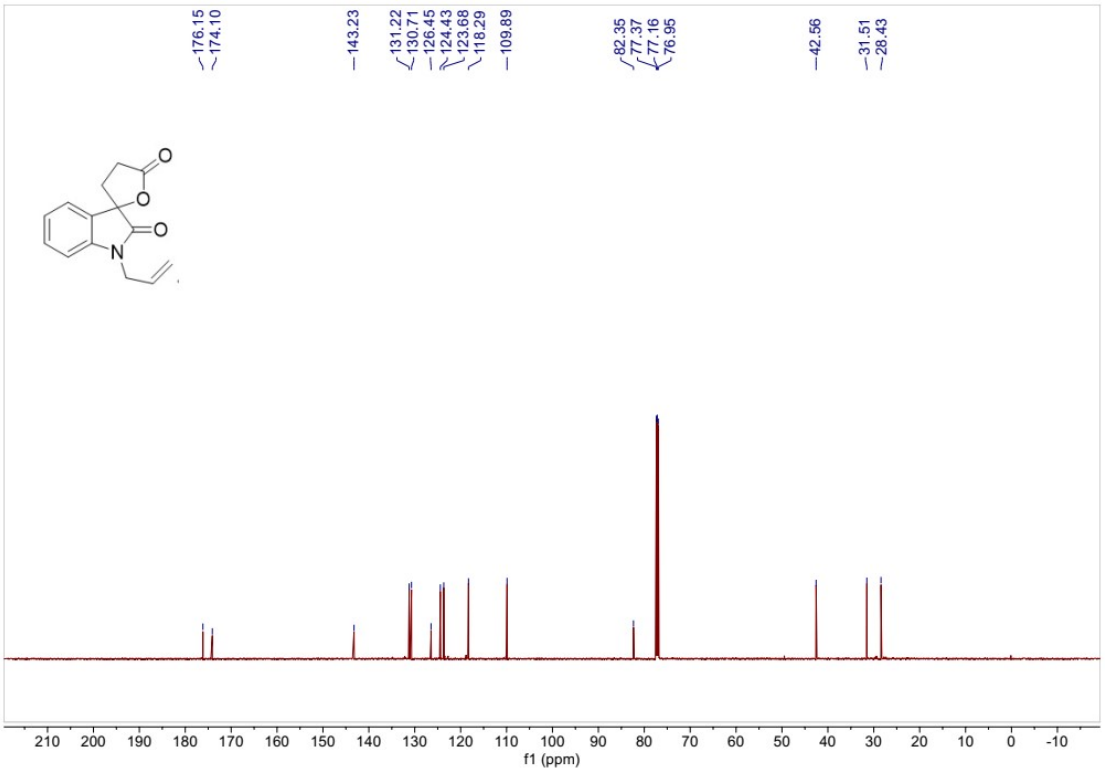
^{13}C NMR spectrum for compound **4g** (In $CDCl_3$, 101MHz)



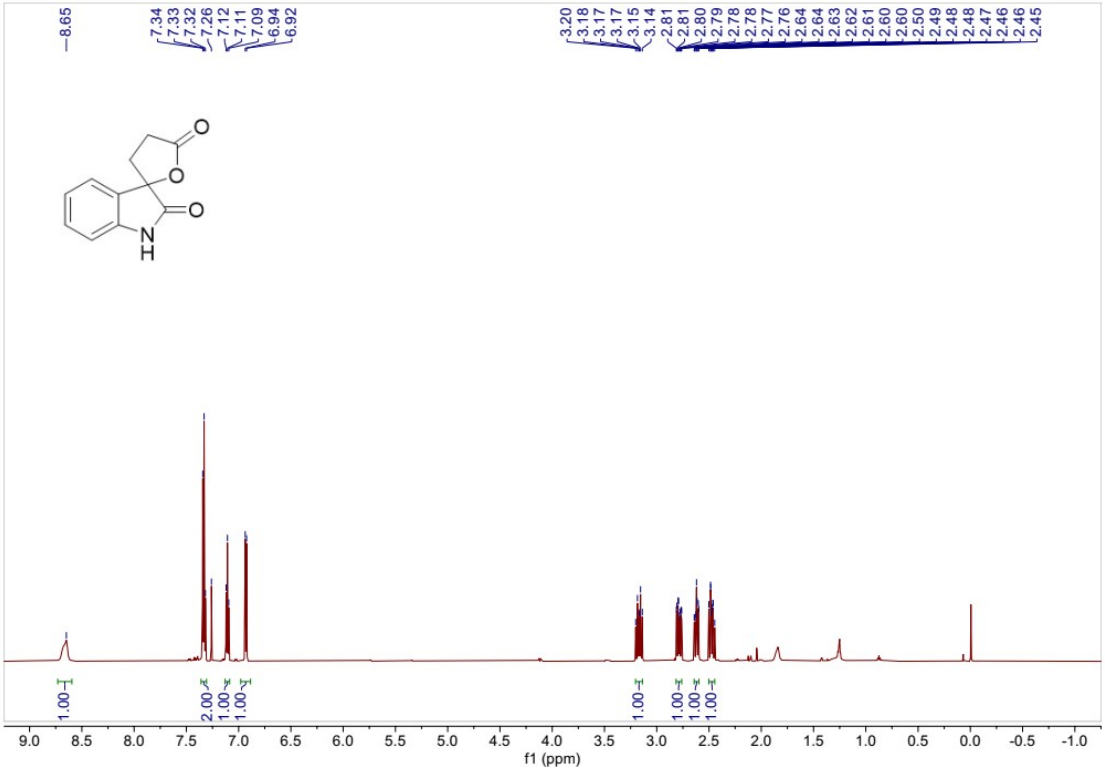
^{1}H NMR spectrum for compound **4h** (In $CDCl_3$, 600MHz)



^{13}C NMR spectrum for compound **4h** (In $CDCl_3$, 151MHz)



^{1}H NMR spectrum for compound **4i** (In $CDCl_3$, 600MHz)



^{13}C NMR spectrum for compound **4i** (In $CDCl_3$, 101MHz)