Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Diastereoselective trifunctionalization of pyridinium salts to access structurally crowded azaheteropolycycles

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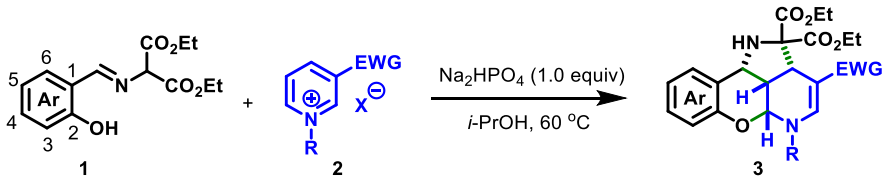
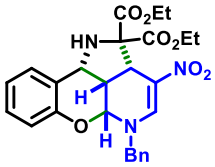
1. General methods

NMR spectra were recorded with tetramethylsilane as the internal standard. For compounds **3o**, **7** and **10**, ^{1}H NMR spectra were recorded at 400 MHz, and ^{13}C NMR spectra were recorded at 100 MHz (JNM-ECZ 400S/L1). For compounds **3u-z**, **3ab** and **3ab'**, ^{1}H NMR spectra were recorded at 300 MHz, and ^{13}C NMR spectra were recorded at 75 MHz (Bruker Avance). For other compounds, ^{1}H NMR spectra were recorded at 400 MHz, and ^{13}C NMR spectra were recorded at 100 MHz (Bruker Avance). ^{1}H NMR chemical shifts (δ) are reported in ppm relative to tetramethylsilane (TMS) with the solvent signal as the internal standard ($CDCl_3$ at 7.26 ppm, $(CD_3)_2SO$ at 2.50 ppm). ^{13}C NMR chemical shifts are reported in ppm from tetramethylsilane (TMS) with the solvent resonance as the internal standard ($CDCl_3$ at 77.00 ppm, $(CD_3)_2SO$ at 39.52 ppm). Data are given as: s (singlet), d (doublet), t (triplet), q (quartet), dd (double of doublet), br (broad) or m (multiplets), coupling constants (Hz) and integration. Flash column chromatography was carried out using silica gel eluting with ethyl acetate and petroleum ether. High resolution mass spectra were obtained with the Q-TOF-Premier mass spectrometer. Reactions were monitored by TLC and visualized with ultraviolet light. IR spectra were recorded on a Thermo Fisher Nicolet Avatar 360 FTIR spectrometer on a KBr beam splitter. All the solvents were used directly without any purification.

2. Experimental data for the formation of 3

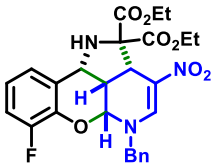


General procedure： To a 5.0 mL vial were successively added azomethine ylides **1** (0.36 mmol, 1.8 equiv), pyridinium salts **2** (0.20 mmol), Na_2HPO_4 (28.4 mg, 0.2 mmol) and 1.0 mL of *i*-PrOH. The resulting mixture was stirred at 60 ^{o}C for 42-48 h, and then the reaction mixture was directly subjected to flash column chromatography on silica gel (petroleum ether/ ethyl acetate) to afford the corresponding products **3**. Notably, when methanol was employed as the solvent, **3a** was afforded in 51% yield together with a 9% yield of **4**. For the preparation of **3aa**, slightly modified conditions were used and the detailed conditions were: 0.15 mmol of **1a**, 2.5 equivalents of *N*-benzyl quinolinium salt, 2.0 equivalents of Na_2HPO_4 and 1.0 mL of ethanol at 60 ^{o}C for 2 h.



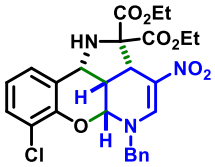
Diethyl 5-benzyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3a**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 80.0 mg, 81% yield; dr > 20:1; reaction time = 48 h; mp 126.3-126.8 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.38-7.33 (m, 3H), 7.28-7.20 (m, 4H), 7.05 (t, *J* = 8.0 Hz, 1H), 6.87 (d, *J* = 8.0 Hz, 1H), 4.89 (d, *J* = 8.0 Hz, 1H), 4.74 (d, *J* = 16.0 Hz, 1H), 4.60 (dd, J_1 = 4.0 Hz, J_2 = 12.0 Hz, 2H), 4.45 (d, *J* = 12.0 Hz, 1H), 4.29-4.21 (m, 2H), 4.09-4.01 (m, 1H), 3.89-3.81 (m, 1H), 3.08-3.02 (m, 1H), 2.83 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.03 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 168.5, 155.0, 142.3, 134.8, 129.0, 129.0, 128.6, 128.5, 128.1, 128.0, 123.9, 123.8, 117.5, 82.8, 74.5, 62.5, 61.5, 57.7, 57.7, 42.3, 41.3, 13.8, 13.3. IR (KBr) ν 3432, 2923, 1735, 1637, 1195, 762 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{28}N_3O_7$ $[M+H]^+$: 494.1922, found: 494.1921.



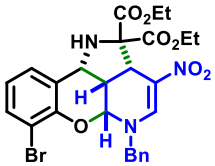
Diethyl 5-benzyl-7-fluoro-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3b**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 72.1 mg, 71% yield; dr > 20:1; reaction time = 42 h; mp 150.1-150.5 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (s, 1H), 7.38-7.28 (m, 5H), 7.05-6.96 (m, 3H), 4.92 (d, *J* = 8.0 Hz, 1H), 4.77 (d, *J* = 12.0 Hz, 1H), 4.63 (d, *J* = 8.0 Hz, 1H), 4.61 (s, 1H), 4.43 (d, *J* = 12.0 Hz, 1H), 4.30-4.21 (m, 2H), 4.10-4.02 (m, 1H), 3.95-3.87 (m, 1H), 3.11-3.05 (m, 1H), 2.87 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.05 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.5, 151.5 (d, *J* = 247.0 Hz, 1C), 142.7 (d, *J* = 12.0 Hz, 1C), 142.1, 134.5, 130.7, 129.1, 128.6, 128.3, 124.1, 123.6 (d, *J* = 6.0 Hz, 1C), 123.5 (d, *J* = 3.0 Hz, 1C), 115.8 (d, *J* = 18.0 Hz, 1C), 83.2, 74.6, 62.5, 61.7, 57.7, 57.3, 42.2, 41.1, 13.7, 13.3; ^{19}F NMR (375 MHz, $CDCl_3$) δ -135.2. IR (KBr) ν 3357, 2929, 1735, 1640, 1246, 1210, 745 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}FN_3O_7$ $[M+H]^+$: 512.1828, found: 512.1828.



Diethyl 5-benzyl-7-chloro-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3c**)

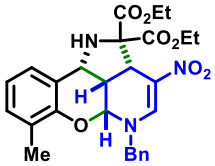
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 84.6 mg, 80% yield; dr > 20:1; reaction time = 48 h; mp 152.3-152.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.38-7.28 (m, 6H), 7.16 (d, *J* = 8.0 Hz, 1H), 6.99 (t, *J* = 8.0 Hz, 1H), 4.92 (d, *J* = 8.0 Hz, 1H), 4.81 (d, *J* = 16.0 Hz, 1H), 4.64 (d, *J* = 16.0 Hz, 1H), 4.56 (d, *J* = 4.0 Hz, 1H), 4.42 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 4.31-4.19 (m, 2H), 4.15-4.07 (m, 1H), 3.95-3.86 (m, 1H), 3.11-3.05 (m, 1H), 2.84 (br, 1H), 1.28-1.24 (m, 3H), 1.09-1.04 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.4, 150.8, 142.3, 134.4, 129.9, 129.4, 129.1, 128.6, 128.3, 127.0, 124.1, 122.8, 83.2, 74.5, 62.6, 61.8, 57.7, 57.5, 42.3, 41.1, 13.8, 13.3, one carbon missing in the aromatic region. IR (KBr) ν 3472, 3416, 1987, 1744, 1634, 1297, 1205, 742 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}ClN_3O_7$ $[M+H]^+$: 528.1532, found: 528.1531.



Diethyl 5-benzyl-7-bromo-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3d**)

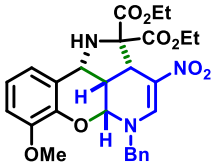
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 73.5 mg, 64% yield; dr > 20:1; reaction time = 48 h; mp 158.2-158.8 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (s, 1H), 7.44 (d, *J* = 8.0 Hz, 1H), 7.37-7.30 (m, 5H), 7.19 (d, *J* = 8.0 Hz, 1H), 6.93 (t, *J* = 8.0 Hz, 1H), 4.91 (d, *J* = 12.0 Hz, 1H), 4.83 (d, *J* = 12.0 Hz, 1H), 4.63 (d, *J* = 16.0 Hz, 1H), 4.53 (d, *J* = 4.0 Hz, 1H), 4.41 (d, *J* = 8.0 Hz, 1H), 4.30-4.18 (m, 2H), 4.15-4.07 (m, 1H), 3.94-3.86 (m, 1H), 3.08-3.02 (m, 1H), 2.84 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.06 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 168.3, 151.8, 142.3, 134.4, 132.4, 130.0, 129.1, 128.7, 128.3, 127.7, 124.8, 124.1, 111.8, 83.2, 74.5, 62.6, 61.8, 57.9, 57.4, 42.3, 41.2, 13.8, 13.4. IR (KBr) ν 3470, 3416, 1931, 1744, 1635, 1296, 1204, 740 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}BrN_3O_7$

$[M+H]^+$: 572.1027, found: 572.1028.



Diethyl 5-benzyl-7-methyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3e**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 71.8 mg, 71% yield; dr > 20:1; reaction time = 48 h; mp 78.6-79.3 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.39-7.33 (m, 3H), 7.26-7.24 (m, 2H), 7.08 (d, *J* = 8.0 Hz, 2H), 6.94 (t, *J* = 8.0 Hz, 1H), 4.89 (d, *J* = 8.0 Hz, 1H), 4.76 (d, *J* = 12.0 Hz, 1H), 4.62 (d, *J* = 16.0 Hz, 1H), 4.57 (d, *J* = 4.0 Hz, 1H), 4.47 (d, *J* = 12.0 Hz, 1H), 4.31-4.23 (m, 2H), 4.09-4.03 (m, 1H), 3.90-3.82 (m, 1H), 3.07-3.01 (m, 1H), 2.83 (s, 1H), 2.15 (s, 3H), 1.27 (t, *J* = 8.0 Hz, 3H), 1.05 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.0, 168.5, 153.3, 142.4, 134.9, 130.4, 129.2, 128.7, 127.8, 126.8, 126.2, 124.1, 123.3, 83.2, 74.6, 62.6, 61.5, 58.0, 57.9, 42.3, 41.5, 15.1, 13.8, 13.4, one carbon missing in the aromatic region. IR (KBr) ν 3417, 2982, 1735, 1631, 1300, 1198, 747 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_7$ $[M+H]^+$: 508.2078, found: 503.2078.

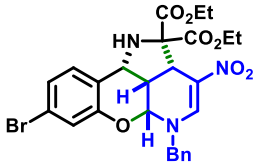


Diethyl

5-benzyl-7-methoxy-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3f**)

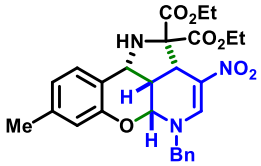
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 99.6 mg, 95% yield; dr > 20:1; reaction time = 48 h; mp 85.2-85.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.36-7.29 (m, 5H), 6.98 (t, *J* = 8.0 Hz, 1H), 6.85 (t, *J* = 8.0 Hz, 2H), 4.84 (d, *J* = 8.0 Hz, 1H), 4.76 (d, *J* = 16.0 Hz, 1H), 4.59 (d, *J* = 16.0 Hz, 1H), 4.56 (d, *J* = 8.0 Hz, 1H), 4.46 (d, *J* = 12.0 Hz, 1H), 4.27-4.22 (m, 2H), 4.04-4.00 (m, 1H), 3.92-3.87 (m, 1H), 3.84 (s, 3H), 3.05-2.99 (m, 1H), 2.81 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.01 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 168.4, 149.1, 144.1, 142.5, 134.8, 129.1, 129.0, 128.5, 128.3, 123.8, 123.6, 120.1, 111.9, 83.1, 74.6, 62.5, 61.7, 57.7, 57.6, 56.0, 42.3, 41.5, 13.8, 13.3. IR (KBr) ν 3422, 2933, 1726, 1642,

1318, 1201, 728 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_8$ $[M+H]^+$: 524.2027, found: 524.2029.



Diethyl 5-benzyl-8-bromo-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3g**)

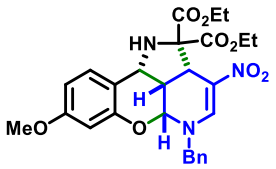
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 80.3 mg, 70% yield; dr > 20:1; reaction time = 48 h; mp 176.2-176.7 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.40-7.33 (m, 3H), 7.26 (d, *J* = 8.0 Hz, 2H), 7.18 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 7.12 (d, *J* = 8.0 Hz, 1H), 7.02 (d, *J* = 4.0 Hz, 1H), 4.87 (d, *J* = 8.0 Hz, 1H), 4.71 (d, *J* = 16.0 Hz, 1H), 4.60 (d, *J* = 16.0 Hz, 1H), 4.58 (s, 1H), 4.41 (d, *J* = 12.0 Hz, 1H), 4.27-4.22 (m, 2H), 4.09-4.01 (m, 1H), 3.91-3.83 (m, 1H), 3.08-3.02 (m, 1H), 2.82 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.05 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 168.6, 155.9, 142.1, 134.7, 130.0, 129.2, 128.8, 128.2, 127.3, 127.1, 124.3, 122.2, 121.0, 83.3, 74.7, 62.7, 61.8, 57.9, 57.4, 42.4, 41.2, 13.9, 13.5. IR (KBr) ν 3473, 3416, 2927, 1732, 1636, 1301, 1195, 754 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}BrN_3O_7$ $[M+H]^+$: 572.1027, found: 572.1030.



Diethyl 5-benzyl-8-methyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3h**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 93.7 mg, 92% yield; dr > 20:1; reaction time = 48 h; mp 182.3-182.6 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 7.39-7.31 (m, 3H), 7.25 (d, *J* = 8.0 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 1H), 6.85 (d, *J* = 8.0 Hz, 1H), 6.69 (s, 1H), 4.86 (d, *J* = 8.0 Hz, 1H), 4.73 (d, *J* = 16.0 Hz, 1H), 4.59 (d, *J* = 16.0 Hz, 1H), 4.57 (s, 1H), 4.45 (d, *J* = 8.0 Hz, 1H), 4.31-4.19 (m, 2H), 4.09-4.01 (m, 1H), 3.91-3.83 (m, 1H), 3.05-2.99 (m, 1H), 2.81 (br, 1H), 2.31 (s, 3H), 1.26 (t, *J* = 8.0 Hz, 3H), 1.04 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 168.6, 155.0, 142.3, 139.3, 134.8, 129.0, 128.6, 128.3, 128.0, 125.1, 124.6, 123.9, 118.0, 82.9, 74.6, 62.4, 61.6, 57.7, 57.5, 42.2, 41.3, 21.2,

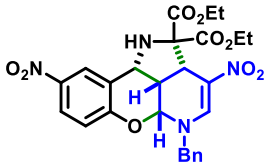
13.8, 13.3. IR (KBr) ν 3431, 3324, 1735, 1635, 1305, 1263, 757 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_7$ $[M+H]^+$: 508.2078, found: 508.2078.



Diethyl

5-benzyl-8-methoxy-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3i**)

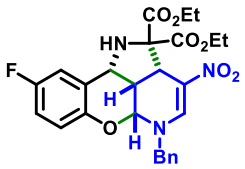
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 80.3 mg, 77% yield; dr > 20:1; reaction time = 48 h; mp 97.2-97.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 7.34 (d, *J* = 4.0 Hz, 3H), 7.27 (d, *J* = 4.0 Hz, 2H), 7.15-7.12 (m, 1H), 6.59 (s, 1H), 6.40 (d, *J* = 4.0 Hz, 1H), 4.85 (t, *J* = 4.0 Hz, 1H), 4.72 (dd, J_1 = 4.0 Hz, J_2 = 16.0 Hz, 1H), 4.61 (d, *J* = 12.0 Hz, 2H), 4.42 (t, *J* = 8.0 Hz, 1H), 4.25-4.21 (m, 2H), 4.06-4.02 (m, 1H), 3.90-3.84 (m, 1H), 3.76 (d, *J* = 8.0 Hz, 3H), 3.01 (t, *J* = 8.0 Hz, 1H), 2.81 (s, 1H), 1.27-1.22 (m, 3H), 1.07-1.02 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 168.6, 160.2, 156.0, 142.2, 134.8, 129.1, 128.9, 128.4, 128.0, 123.9, 120.2, 109.4, 103.1, 82.9, 74.4, 62.3, 61.5, 57.7, 57.2, 55.2, 42.1, 41.1, 13.7, 13.3. IR (KBr) ν 3417, 2933, 1732, 1633, 1302, 1265, 754 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_8$ $[M+H]^+$: 524.2027, found: 524.2028.



Diethyl 5-benzyl-3,9-dinitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3j**)

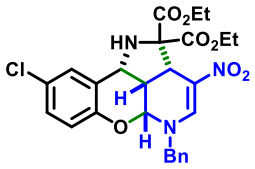
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 65.2 mg, 61% yield; dr > 20:1; reaction time = 48 h; mp 172.1-172.6 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 8.16 (d, *J* = 4.0 Hz, 1H), 8.11 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 7.41-7.36 (m, 3H), 7.28 (d, *J* = 4.0 Hz, 2H), 6.92 (d, *J* = 8.0 Hz, 1H), 5.01 (d, *J* = 8.0 Hz, 1H), 4.76-4.61 (m, 3H), 4.39 (d, *J* = 12.0 Hz, 1H), 4.28-4.20 (m, 2H), 4.07-4.03 (m, 1H), 3.89-3.81 (m, 1H), 3.20-3.14 (m, 1H), 2.90 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.06 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 168.6, 160.4, 143.5, 141.9, 134.5, 129.3, 129.0, 128.9, 128.3, 125.0, 124.9, 124.7, 118.4, 83.6, 74.8, 62.9, 61.9, 58.1, 57.3, 42.6, 40.9, 13.9, 13.5. IR (KBr) ν 3445, 3357,

2984, 1733, 1637, 1206, 749 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}N_4O_9$ $[M+H]^+$: 539.1773, found: 539.1776.



Diethyl 5-benzyl-9-fluoro-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3k**)

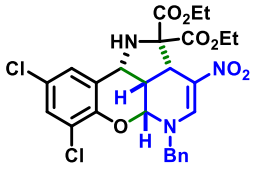
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 75.2 mg, 74% yield; dr > 20:1; reaction time = 43 h; mp 147.1-147.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25 (s, 1H), 7.39-7.34 (m, 3H), 7.28-7.25 (m, 2H), 6.97 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 6.93-6.88 (m, 1H), 6.81 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 4.85 (d, J = 8.0 Hz, 1H), 4.73 (d, J = 16.0 Hz, 1H), 4.61 (d, J = 8.0 Hz, 1H), 4.58 (s, 1H), 4.42 (d, J = 8.0 Hz, 1H), 4.29-4.19 (m, 2H), 4.09-4.01 (m, 1H), 3.91-3.83 (m, 1H), 3.06-3.00 (m, 1H), 2.87 (br, 1H), 1.25 (t, J = 8.0 Hz, 3H), 1.05 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.4, 158.4 (d, J = 242.0 Hz, 1C), 151.0 (d, J = 2.0 Hz, 1C), 142.2, 134.7, 129.3 (d, J = 8.0 Hz, 1C), 129.0, 128.6, 128.1, 124.0, 118.6 (d, J = 9.0 Hz, 1C), 115.7 (d, J = 23.0 Hz, 1C), 115.0 (d, J = 24.0 Hz, 1C), 83.1, 74.6, 62.6, 61.6, 57.8, 57.7, 42.3, 41.0, 13.7, 13.4; ^{19}F NMR (375 MHz, $CDCl_3$) δ -118.5. IR (KBr) ν 3357, 2937, 1733, 1638, 1494, 1206, 747 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}FN_3O_7$ $[M+H]^+$: 512.1828, found: 512.1827.



Diethyl 5-benzyl-9-chloro-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3l**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 89.7 mg, 85% yield; dr > 20:1; reaction time = 48 h; mp 86.7-87.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (s, 1H), 7.37-7.29 (m, 3H), 7.24 (t, J = 4.0 Hz, 2H), 7.19 (d, J = 4.0 Hz, 1H), 7.14 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 6.76 (d, J = 8.0 Hz, 1H), 4.82 (d, J = 8.0 Hz, 1H), 4.69 (d, J = 16.0 Hz, 1H), 4.58 (d, J = 8.0 Hz, 1H), 4.56 (s, 1H), 4.36 (d, J = 12.0 Hz, 1H), 4.27-4.15 (m, 2H), 4.06-3.98

(m, 1H), 3.86-3.78 (m, 1H), 3.06-3.00 (m, 1H), 2.81 (br, 1H), 1.22 (t, *J* = 8.0 Hz, 3H), 1.02 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.6, 168.4, 153.6, 142.1, 134.6, 129.6, 129.0, 128.9, 128.6, 128.4, 128.4, 128.1, 124.0, 118.8, 83.0, 74.5, 62.5, 61.6, 57.8, 57.4, 42.3, 40.9, 13.7, 13.3. IR (KBr) ν 3462, 3324, 2985, 1730, 1628, 1292, 1188, 755 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}ClN_3O_7$ $[M+H]^+$: 528.1532, found: 528.1531.

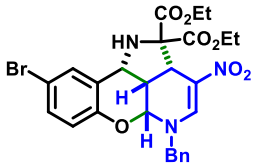


Diethyl

5-benzyl-7,9-dichloro-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate

(**3m**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 81.2 mg, 72% yield; dr > 20:1; reaction time = 48 h; mp 89.3-89.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 7.39-7.28 (m, 6H), 7.14 (d, *J* = 4.0 Hz, 1H), 4.87 (d, *J* = 8.0 Hz, 1H), 4.78 (d, *J* = 16.0 Hz, 1H), 4.64 (d, *J* = 16.0 Hz, 1H), 4.55 (d, *J* = 4.0 Hz, 1H), 4.37 (d, *J* = 8.0 Hz, 1H), 4.30-4.18 (m, 2H), 4.15-4.07 (m, 1H), 3.94-3.86 (m, 1H), 3.11-3.05 (m, 1H), 2.86 (br, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.09 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 168.3, 149.6, 142.1, 134.3, 130.9, 129.1, 129.0, 128.7, 128.4, 128.3, 127.0, 124.3, 123.5, 83.3, 74.5, 62.7, 61.8, 57.6, 57.5, 42.3, 40.9, 13.7, 13.4. IR (KBr) ν 3465, 3419, 1740, 1640, 1299, 1193, 789 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{26}Cl_2N_3O_7$ $[M+H]^+$: 562.1142, found: 562.1141.

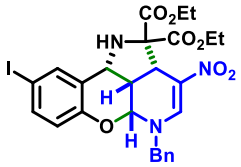


Diethyl 5-benzyl-9-bromo-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate

(**3n**)

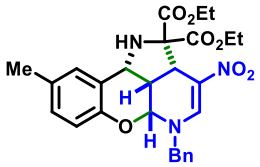
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 71.3 mg, 62% yield; dr > 20:1; reaction time = 48 h; mp 143.6-143.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 7.38-7.25 (m, 7H), 6.73 (d, *J* = 8.0 Hz, 1H), 4.83 (d, *J* = 12.0 Hz, 1H), 4.72 (d, *J* = 12.0 Hz, 1H), 4.61 (d, *J* = 8.0 Hz, 1H), 4.59 (s, 1H), 4.38 (d, *J* = 12.0 Hz, 1H), 4.27-4.19

(m, 2H), 4.08-4.00 (m, 1H), 3.88-3.80 (m, 1H), 3.09-3.03 (m, 1H), 2.83 (br, 1H), 1.24 (t, J = 8.0 Hz, 3H), 1.04 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.4, 154.1, 142.1, 134.6, 131.9, 131.5, 130.1, 129.1, 128.7, 128.1, 124.2, 119.3, 115.9, 82.9, 74.6, 62.6, 61.7, 57.8, 57.4, 42.4, 41.1, 13.8, 13.4. IR (KBr) ν 3418, 3325, 2984, 1727, 1628, 1293, 1188, 754 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}BrN_3O_7$ $[M+H]^+$: 572.1027, found: 572.1034.



Diethyl 5-benzyl-9-iodo-3-nitro-hexahydro-2H-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3o**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 100.2 mg, 81% yield; dr > 20:1; reaction time = 48 h; mp 132.3-132.8 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (s, 1H), 7.53 (d, J = 4.0 Hz, 1H), 7.49 (d, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 7.37-7.32 (m, 3H), 7.23-7.21 (m, 2H), 6.60 (d, J = 8.0 Hz, 1H), 4.81 (d, J = 8.0 Hz, 1H), 4.69 (d, J = 16.0 Hz, 1H), 4.58-4.54 (m, 2H), 4.38 (d, J = 8.0 Hz, 1H), 4.27-4.21 (m, 2H), 4.09-3.99 (m, 1H), 3.88-3.80 (m, 1H), 3.05-2.99 (m, 1H), 2.55 (s, 1H), 1.24 (t, J = 8.0 Hz, 3H), 1.04 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.5, 154.9, 142.1, 138.0, 137.4, 134.6, 130.5, 129.2, 128.8, 128.1, 124.2, 119.7, 86.4, 82.8, 74.6, 62.7, 61.3, 57.9, 57.2, 42.4, 41.2, 13.8, 13.5. IR (KBr) ν 3417, 2378, 1735, 1636, 1207, 753 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{27}IN_3O_7$ $[M+H]^+$: 620.0888, found: 620.0889.

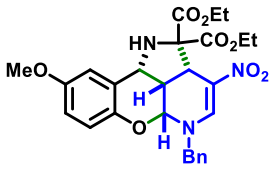


Diethyl

5-benzyl-9-methyl-3-nitro--hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3p**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 62.2 mg, 61% yield; dr > 20:1; reaction time = 48 h; mp 79.1-79.8 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (s, 1H), 7.36-7.29 (m, 3H), 7.25-7.23 (m, 2H), 7.03-6.98 (m, 2H), 6.74 (d, J = 8.0 Hz, 1H), 4.81 (d, J = 8.0 Hz, 1H), 4.71 (d, J = 16.0 Hz, 1H), 4.57 (d, J = 16.0 Hz, 1H), 4.55 (s, 1H), 4.41 (d,

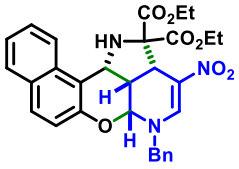
J = 8.0 Hz, 1H), 4.27-4.19 (m, 2H), 4.07-3.99 (m, 1H), 3.88-3.80 (m, 1H), 3.03-2.97 (m, 1H), 2.82 (br, 1H), 2.27 (s, 3H), 1.24 (t, *J* = 8.0 Hz, 3H), 1.02 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.0, 168.6, 152.9, 142.5, 134.9, 133.4, 129.7, 129.1, 128.7, 128.2, 127.8, 124.0, 117.3, 82.9, 74.7, 62.6, 61.7, 57.9, 57.9, 42.6, 41.5, 20.8, 13.9, 13.5, one carbon missing in the aromatic region. IR (KBr) ν 3416, 1728, 1630, 1196, 748 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_7$ $[M+H]^+$: 508.2078, found: 503.2079.



Diethyl

5-benzyl-9-methoxy-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3q**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 83.2 mg, 80% yield; dr > 20:1; reaction time = 48 h; mp 112.3-112.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.37-7.31 (m, 3H), 7.25-7.23 (m, 2H), 6.80-6.72 (m, 3H), 4.81 (d, *J* = 12.0 Hz, 1H), 4.71 (d, *J* = 16.0 Hz, 1H), 4.57 (d, *J* = 16.0 Hz, 1H), 4.51 (d, *J* = 4.0 Hz, 1H), 4.44 (d, *J* = 8.0 Hz, 1H), 4.26-4.21 (m, 2H), 4.08-4.00 (m, 1H), 3.91-3.83 (m, 1H), 3.74 (s, 3H), 3.01-2.95 (m, 1H), 2.88 (br, 1H), 1.24 (t, *J* = 8.0 Hz, 3H), 1.04 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.0, 168.6, 155.8, 148.9, 142.5, 134.9, 129.2, 128.8, 128.7, 128.2, 123.9, 118.4, 114.6, 113.3, 83.1, 74.8, 62.6, 61.7, 58.2, 57.9, 55.7, 42.5, 41.4, 13.9, 13.5. IR (KBr) ν 3471, 3417, 2982, 1735, 1631, 1299, 1198, 747 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_8$ $[M+H]^+$: 524.2027, found: 524.2028.

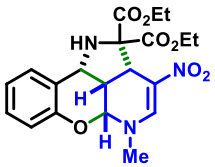


Diethyl

5-benzyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazacyclopenta[*no*]tetraphene-2,2-dicarboxylate (**3r**)

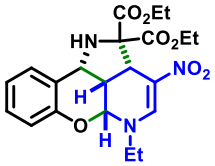
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 92.3 mg, 85% yield; dr > 20:1; reaction time = 48 h; mp 92.3-92.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 8.05 (d, *J* = 8.0 Hz, 1H), 7.78 (d, *J* = 8.0 Hz, 1H), 7.69 (d, *J* = 8.0 Hz, 1H), 7.53 (t,

J = 8.0 Hz, 1H), 7.40 (t, *J* = 8.0 Hz, 1H), 7.37-7.31 (m, 3H), 7.28 (t, *J* = 4.0 Hz, 2H), 7.00 (d, *J* = 8.0 Hz, 1H), 5.59 (d, *J* = 8.0 Hz, 1H), 4.75 (d, *J* = 12.0 Hz, 1H), 4.70 (d, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 12.0 Hz, 1H), 4.41 (d, *J* = 12.0 Hz, 1H), 4.27-4.16 (m, 2H), 3.98-3.90 (m, 1H), 3.71-3.62 (m, 1H), 3.20-3.14 (m, 1H), 2.89 (br, 1H), 1.20 (t, *J* = 8.0 Hz, 3H), 0.88 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 168.4, 152.6, 142.3, 134.8, 131.3, 130.4, 129.4, 128.9, 128.7, 128.5, 128.1, 127.3, 124.4, 121.9, 120.0, 117.9, 82.1, 74.3, 62.3, 61.3, 57.8, 53.2, 41.9, 40.8, 13.7, 13.1, one carbon missing in the aromatic region. IR (KBr) ν 3444, 3353, 1731, 1637, 1311, 1204, 731 cm^{-1}. HRMS (ESI) calcd for $C_{30}H_{30}N_3O_7$ $[M+H]^+$: 544.2078, found: 544.2079.



Diethyl 5-methyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3s**)

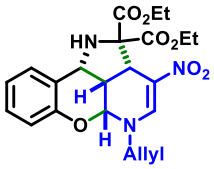
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 58.3 mg, 70% yield; dr > 20:1; reaction time = 48 h; mp 142.1-142.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (s, 1H), 7.28 (dd, J_1 = 4.0 Hz, J_2 = 8.0 Hz, 1H), 7.22 (t, *J* = 8.0 Hz, 1H), 7.05 (t, *J* = 8.0 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 4.90 (d, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 4.0 Hz, 1H), 4.41 (d, *J* = 8.0 Hz, 1H), 4.26-4.21 (m, 2H), 4.06-4.02 (m, 1H), 3.86-3.78 (m, 1H), 3.28 (s, 3H), 3.15-3.09 (m, 1H), 2.83 (br, 1H), 1.24 (t, *J* = 8.0 Hz, 3H), 1.02 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 168.5, 155.0, 143.1, 129.1, 128.7, 128.0, 123.87, 123.4, 117.6, 84.8, 74.6, 62.5, 61.6, 57.6, 42.0, 41.5, 41.3, 13.8, 13.4. IR (KBr) ν 3463, 2934, 1740, 1634, 1298, 1266, 1225, 759 cm^{-1}. HRMS (ESI) calcd for $C_{20}H_{24}N_3O_7$ $[M+H]^+$: 418.1609, found: 418.1609.



Diethyl 5-ethyl-3-nitro-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3t**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 55.1 mg, 64% yield; dr > 20:1; reaction time = 48 h; mp 104.6-104.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (s, 1H), 7.30 (d, *J* = 4.0 Hz, 1H), 7.24 (t, *J* = 8.0 Hz, 1H), 7.07 (t, *J* = 8.0 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 4.95 (d, *J* = 8.0 Hz, 1H), 4.71 (d, *J* = 4.0 Hz, 1H), 4.43 (d, *J* = 12.0 Hz,

1H), 4.31-4.20 (m, 2H), 4.10-4.02 (m, 1H), 3.89-3.81 (m, 1H), 3.67-3.58 (m, 1H), 3.54-3.45 (m, 1H), 3.14-3.08 (m, 1H), 2.84 (br, 1H), 1.35 (t, *J* = 8.0 Hz, 3H), 1.26 (t, *J* = 8.0 Hz, 3H), 1.05 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.1, 168.7, 155.3, 142.0, 129.2, 128.8, 128.2, 123.9, 123.5, 117.7, 83.9, 74.7, 62.6, 61.6, 57.9, 49.6, 42.3, 41.5, 15.0, 13.9, 13.5. IR (KBr) ν 3445, 2983, 1735, 1639, 1260, 1211, 760 cm^{-1}. HRMS (ESI) calcd for $C_{21}H_{26}N_3O_7$ $[M+H]^+$: 432.1765, found: 432.1765.

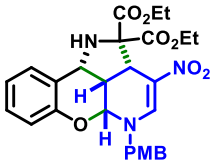


Diethyl

5-allyl-3-nitro-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate

(**3u**)

Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 67.5 mg, 76% yield; dr > 20:1; reaction time = 48 h; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09 (s, 1H), 7.23-7.13 (m, 2H), 7.02-6.97 (m, 1H), 6.81 (d, *J* = 9.0 Hz, 1H), 5.89-5.76 (m, 1H), 5.26 (s, 1H), 5.21 (d, *J* = 6.0 Hz, 1H), 4.87 (d, *J* = 9.0 Hz, 1H), 4.62 (d, *J* = 6.0 Hz, 1H), 4.33 (d, *J* = 9.0 Hz, 1H), 4.22-3.92 (m, 5H), 3.80-3.69 (m, 1H), 3.10-3.02 (m, 1H), 2.78 (br, 1H), 1.18 (t, *J* = 6.0 Hz, 3H), 0.96 (t, *J* = 6.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 168.3, 154.9, 142.0, 131.8, 128.8, 128.5, 127.9, 123.5, 123.5, 119.9, 117.3, 83.1, 74.3, 62.2, 61.3, 57.5, 56.5, 42.1, 41.0, 13.6, 13.2. IR (KBr) ν 3421, 2927, 1735, 1639, 1207, 765 cm^{-1}. HRMS (ESI) calcd for $C_{22}H_{26}N_3O_7$ $[M+H]^+$: 444.1760, found: 444.1762.

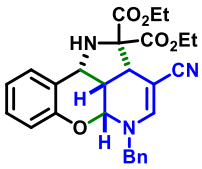


Diethyl

5-(4-methoxybenzyl)-3-nitro-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3v**)

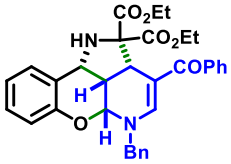
Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 71.1 mg, 70% yield; dr > 20:1; reaction time = 48 h; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.24-7.15 (m, 4H), 7.02 (t, *J* = 9.0 Hz, 1H), 6.90-6.83 (m, 3H), 4.86 (d, *J* = 8.0 Hz, 1H), 4.67-4.49

(m, 3H), 4.40 (d, *J* = 9.0 Hz, 1H), 4.26-4.19 (m, 2H), 4.05-3.97 (m, 1H), 3.84-3.76 (m, 4H), 3.04-2.96 (m, 1H), 2.78 (br, 1H), 1.22 (t, *J* = 9.0 Hz, 3H), 1.00 (t, *J* = 9.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.4, 159.7, 155.0, 142.3, 129.6, 129.0, 128.6, 128.0, 126.4, 123.7, 123.6, 117.4, 114.3, 82.5, 74.4, 62.4, 61.5, 57.6, 57.2, 55.1, 42.3, 41.2, 13.7, 13.3. IR (KBr) ν 3419, 2926, 1735, 1639, 1301, 764 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_6$ $[M+H]^+$: 524.2085, found: 524.2082.



Diethyl 5-benzyl-3-cyano-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3w**)

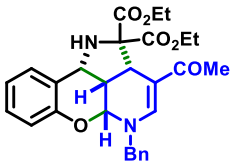
Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 57.2 mg, 60% yield; dr > 20:1; reaction time = 48 h; mp 87.6-88.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36-7.24 (m, 5H), 7.20 (d, *J* = 8.0 Hz, 2H), 7.05 (t, *J* = 8.0 Hz, 1H), 6.92 (d, *J* = 8.0 Hz, 2H), 4.64 (d, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 8.0 Hz, 1H), 4.49 (d, *J* = 16.0 Hz, 1H), 4.36 (d, *J* = 16.0 Hz, 1H), 4.31-4.16 (m, 3H), 4.14-4.06 (m, 1H), 4.03 (d, *J* = 8.0 Hz, 1H), 3.06-3.00 (m, 1H), 2.55 (br, 1H), 1.27 (t, *J* = 8.0 Hz, 3H), 1.17 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 168.3, 154.5, 146.0, 135.5, 129.0, 128.9, 128.4, 128.3, 128.0, 127.7, 123.5, 120.3, 117.8, 82.0, 78.8, 75.3, 62.5, 61.9, 56.8, 56.6, 41.3, 40.7, 13.8, 13.6. IR (KBr) ν 3445, 2985, 1735, 1638, 1201, 763 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{28}N_3O_5$ $[M+H]^+$: 474.2023, found: 474.2023.



Diethyl 3-benzoyl-5-benzyl-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3x**)

Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 29.1 mg, 26% yield; dr > 20:1; reaction time = 48 h; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63-7.61 (m, 2H), 7.42-7.27 (m, 7H), 7.23-7.11 (m, 4H), 7.05-7.00 (m, 1H), 6.88 (d, *J* = 6.0 Hz, 1H), 4.88 (d, *J* = 9.0 Hz, 1H), 4.62 (dd, J_1 = 3.0 Hz, J_2 = 9.0 Hz, 2H), 4.40-4.21 (m, 4H), 4.04-3.93 (m, 1H), 3.89-3.78 (m, 1H), 3.02-2.94 (m, 1H), 1.19 (t, *J* = 6.0 Hz, 3H), 0.95 (t, *J* = 6.0 Hz, 3H), one hydrogen for

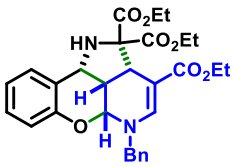
N-H was missing; ^{13}C NMR (75 MHz, $CDCl_3$) δ 194.1, 171.1, 168.8, 155.0, 148.5, 139.8, 135.9, 130.0, 128.8, 128.7, 128.6, 128.5, 128.0, 127.9, 127.7, 123.4, 117.4, 110.6, 83.2, 74.6, 62.4, 61.0, 57.3, 57.2, 41.5, 40.8, 13.8, 13.5, one carbon missing in the aromatic region. IR (KBr) ν 3430, 2924, 2856, 1637 cm^{-1}. HRMS (ESI) calcd for $C_{33}H_{33}N_2O_6$ $[M+H]^+$: 553.2333, found: 553.2332.



Diethyl

3-acetyl-5-benzyl-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**3y**)

Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 10.8 mg, 11% yield; dr > 20:1; reaction time = 48 h; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38-7.30 (m, 5H), 7.25-7.22 (m, 2H), 7.18 (dd, J_1 = 6.0 Hz, J_2 = 3.0 Hz, 1H), 7.04-6.99 (m, 1H), 6.87 (d, J = 9.0 Hz, 1H), 4.81 (d, J = 9.0 Hz, 1H), 4.68 (d, J = 15.0 Hz, 1H), 4.58 (d, J = 3.0 Hz, 1H), 4.50 (d, J = 15.0 Hz, 1H), 4.38-4.21 (m, 3H), 4.12 (d, J = 12.0 Hz, 1H), 4.05-3.94 (m, 1H), 3.83-3.72 (m, 1H), 2.98-2.90 (m, 1H), 2.23 (s, 3H), 1.29 (t, J = 6.0 Hz, 3H), 0.98 (t, J = 6.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 204.1, 194.7, 171.5, 168.9, 155.4, 144.4, 136.2, 128.9, 128.8, 128.7, 128.6, 128.2, 127.8, 123.4, 117.5, 83.4, 75.0, 62.3, 61.1, 57.7, 57.3, 41.5, 41.3, 24.3, 14.0, 13.5. IR (KBr) ν 3428, 2926, 1733, 1620, 1205, 759 cm^{-1}. HRMS (ESI) calcd for $C_{28}H_{31}N_2O_6$ $[M+H]^+$: 491.2023, found: 491.2021.

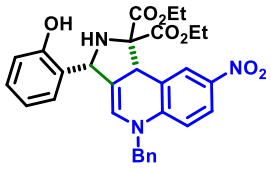


Triethyl

5-benzyl-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2,3-tricarboxylate (**3z**)

Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 10.6 mg, 10% yield; dr > 20:1; reaction time = 48 h; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.56 (s, 1H), 7.39-7.22 (m, 7H), 7.04 (t, J = 6.0 Hz, 1H), 6.94 (d, J = 9.0 Hz, 1H), 4.76 (d, J = 9.0 Hz, 1H), 4.70 (d, J = 15.0 Hz, 1H), 4.56 (d, J = 6.0 Hz, 1H), 4.50 (d, J = 15.0 Hz, 1H), 4.35-4.14 (m, 5H), 4.12-3.95 (m, 2H), 2.98-2.90 (m, 1H), 1.30 (t, J = 9.0 Hz, 6H), 1.12 (t, J = 6.0 Hz, 3H), one

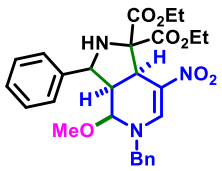
hydrogen for N-H was missing; ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.2, 169.3, 167.7, 155.7, 142.8, 136.4, 128.9, 128.8, 128.6, 128.6, 127.9, 127.7, 123.2, 117.8, 98.7, 83.5, 75.6, 61.9, 61.4, 59.4, 58.5, 56.9, 42.1, 41.8, 14.4, 13.9, 13.6. IR (KBr) ν 3420, 2925, 1732, 1623, 1208, 768 cm^{-1}. HRMS (ESI) calcd for $C_{29}H_{33}N_2O_7$ $[M+H]^+$: 521.1218, found: 521.1216.



Diethyl

5-benzyl-3-(2-hydroxyphenyl)-8-nitro-2,3,5,9b-tetrahydro-1*H*-pyrrolo[3,4-*c*]quinoline-1,1-dicarboxylate (**3aa**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 74.0 mg, 91% yield; dr > 20:1; reaction time = 2 h; mp 179.7-181.1 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.88 (s, 1H), 8.65 (s, 1H), 7.87 (d, *J* = 8.0 Hz, 1H), 7.31 (t, *J* = 8.0 Hz, 2H), 7.24-7.16 (m, 4H), 7.04 (d, *J* = 8.0 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 6.81 (t, *J* = 8.0 Hz, 1H), 6.57 (d, *J* = 8.0 Hz, 1H), 5.68 (s, 1H), 4.90 (s, 1H), 4.81 (s, 1H), 4.70-4.43 (m, 4H),3.99-3.83 (m, 2H), 3.76 (br, 1H), 1.52 (t, *J* = 8.0 Hz, 3H), 0.93 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 171.0, 170.2, 157.6, 144.3, 140.5, 135.8, 129.7, 129.7, 129.0, 127.7, 126.8, 126.6, 125.9, 124.3, 120.3, 119.0, 118.8, 117.7, 112.7, 111.6, 75.5, 63.4, 62.7, 62.4, 55.1, 45.8, 14.0, 13.4. IR (KBr) ν 3416, 2923, 1726, 1613, 1328, 755 cm^{-1}. HRMS (ESI) calcd for $C_{30}H_{30}N_3O_7$ $[M+H]^+$: 544.2078, found: 544.2078.

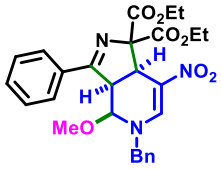


Diethyl

5-benzyl-4-methoxy-7-nitro-3-phenyl-2,3,3a,4,5,7a-hexahydro-1*H*-pyrrolo[3,4-*c*]pyridine-1,1-dicarboxylate (**3ab**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 50.6 mg, 50% yield; dr > 20:1; reaction time = 48 h; mp 182.3-182.7 ℃; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.98 (s, 1H), 7.34-7.29 (m, 5H), 7.24-7.18 (m, 3H), 7.04 (dd, J_1 = 6.0 Hz, J_2 = 3.0 Hz, 2H), 4.82 (d, *J* = 6.0 Hz, 1H), 4.65 (d, *J* = 9.0 Hz, 1H), 4.53 (d, *J* = 15.0 Hz, 1H), 4.36-4.12 (m,

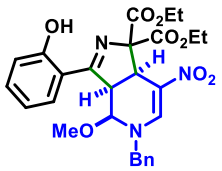
5H), 3.84 (d, *J* = 3.0 Hz, 1H), 2.89 (s, 3H), 2.30-2.24 (m, 1H), 1.29 (t, *J* = 9.0 Hz, 3H), 1.22 (t, *J* = 9.0 Hz, 3H), one hydrogen for N-H was missing; ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.1, 169.5, 141.1, 137.1, 135.4, 129.2, 128.5, 128.3, 127.4, 127.2, 126.2, 125.7, 85.3, 75.2, 64.2, 62.2, 61.7, 59.9, 54.9, 45.9, 42.8, 13.9, 13.6. IR (KBr) ν 3419, 2924, 2377, 1739, 1617, 753 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{32}N_3O_7$ $[M+H]^+$: 510.2076, found: 510.2078.



Diethyl

5-benzyl-4-methoxy-7-nitro-3-phenyl-3a,4,5,7a-tetrahydro-1*H*-pyrrolo[3,4-*c*]pyridine-1,1-dicarboxylate (**3ab'**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1 to 1:1); 21.7 mg, 21% yield; dr > 20:1; reaction time = 48 h; mp 198.1-198.8 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09 (s, 1H), 7.76-7.73 (m, 2H), 7.50-7.36 (m, 6H), 7.24-7.22 (m, 2H), 4.68-4.51 (m, 3H), 4.42-4.27 (m, 3H), 4.25-4.19 (m, 1H), 4.16-4.02 (m, 1H), 3.43 (dd, J_1 = 6.0 Hz, J_2 = 3.0 Hz, 1H), 2.98 (s, 3H), 1.33 (t, *J* = 9.0 Hz, 3H), 1.25 (t, *J* = 9.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.8, 169.9, 167.0, 140.7, 135.3, 132.3, 131.7, 129.3, 128.8, 128.8, 128.1, 127.7, 126.0, 87.2, 84.1, 62.7, 61.0, 59.6, 56.8, 49.7, 40.5, 13.9, 13.8. IR (KBr) ν 3445, 2929, 1738, 1618, 1298, 747 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{30}N_3O_7$ $[M+H]^+$: 508.2074, found: 508.2076.



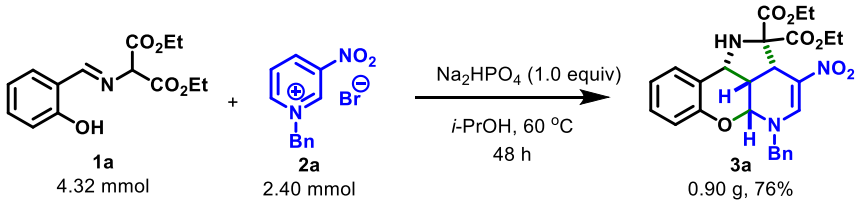
Diethyl

5-benzyl-3-(2-hydroxyphenyl)-4-methoxy-7-nitro-tetrahydro-1*H*-pyrrolo[3,4-*c*]pyridine-1,1-dicarboxylate (**4**)

Light yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 8.9 mg, 9% yield; dr > 20:1; reaction time = 48 h; mp 273.2-273.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.81 (s, 1H), 8.13 (s, 1H), 7.50-7.42 (m, 3H), 7.37 (t, *J* = 8.0 Hz, 1H), 7.27 (s, 2H), 7.06-7.00 (m, 2H), 6.80 (t, *J* = 8.0 Hz, 1H), 4.69 (d, *J* = 16.0 Hz, 1H), 6.66 (d, *J* = 4.0 Hz, 1H), 4.57 (d, *J* = 16.0

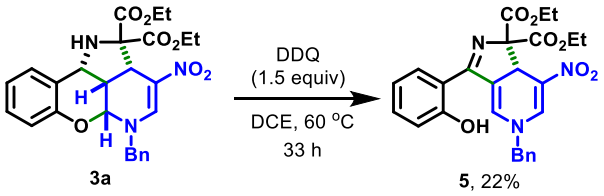
Hz, 1H), 4.39-4.29 (m, 3H), 4.27-4.21 (m, 1H), 4.08-4.00 (m, 1H), 3.48 (dd, J_1 = 4.0 Hz, J_2 = 12.0 Hz, 1H), 2.99 (s, 3H), 1.35 (t, J = 8.0 Hz, 3H), 1.25 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 177.0, 169.1, 165.8, 160.2, 142.3, 137.0, 133.9, 130.0, 128.9, 128.1, 128.0, 123.7, 119.1, 117.1, 115.3, 85.3, 84.0, 62.1, 60.5, 58.0, 55.5, 48.8, 39.2, 13.8, 13.6. IR (KBr) ν 3415, 2930, 1740, 1617, 1302, 1266, 770 cm^{-1}. HRMS (ESI) calcd for $C_{27}H_{29}N_3O_8$ $[M+H]^+$: 524.2027, found: 524.2027.

3. Scalable preparation of 3a

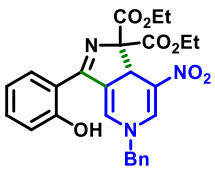


General procedure: To a solution of azomethine ylide **1a** (1.21 g, 4.32 mmol) and pyridinium salt **2a** (0.71 g, 2.40 mmol) in *i*-PrOH (12 mL) was added Na_2HPO_4 (0.34 g, 2.40 mmol) successively. After being stirred at 60 °C for 48 h, the mixture was concentrated in vacuum. The residue was purified via flash column chromatography on silica gel (petroleum ether/ ethyl acetate = 3:1 to 1:1) to afford the corresponding product **3a** as yellow solid in 76% yield (0.90 g).

4. Late-stage modifications



General procedure for the formation of 5: A solution of **3a** (98.7 mg, 0.20 mmol) and DDQ (68.1 mg, 0.3 mmol) in 2.0 mL of DCE was heated to 60 °C. The reaction mixture was stirred 33 h until the complete consumption of **3a** as monitored by thin layer chromatography. Then, the mixture was concentrated and purified with silica gel column chromatography to obtain **5** as yellow solid in 22% yield.

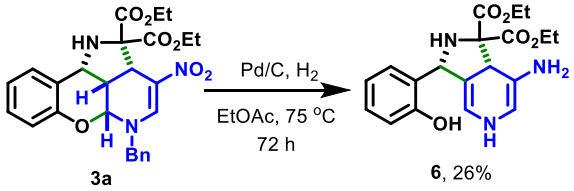


Diethyl

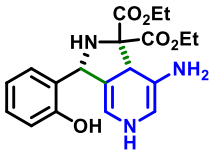
5-benzyl-3-(2-hydroxyphenyl)-7-nitro-5,7a-dihydro-1*H*-pyrrolo[3,4-*c*]pyridine-1,1-dicarboxylate

(**5**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 21.2 mg, 22% yield; dr > 20:1; reaction time = 33 h; mp 223.4-223.9 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.35 (s, 1H), 7.71 (s, 1H), 7.43-7.35 (m, 5H), 7.21 (d, *J* = 8.0 Hz, 2H), 7.05 (d, *J* = 12.0 Hz, 1H), 6.85 (t, *J* = 8.0 Hz, 1H), 6.57 (s, 1H), 5.01 (s, 1H), 4.60 (s, 2H), 4.39 (q, *J* = 8.0 Hz, 2H), 4.23-4.08 (m, 2H), 1.35 (t, *J* = 8.0 Hz, 3H), 1.18 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 172.8, 168.9, 165.8, 160.8, 137.2, 134.5, 133.6, 129.4, 129.1, 129.0, 128.3, 127.2, 126.2, 119.6, 118.8, 118.2, 114.3, 83.3, 62.7, 62.0, 58.3, 43.8, 14.0, 13.7. IR (KBr) ν 3420, 2929, 1735, 1594, 1296, 758 cm^{-1}. HRMS (ESI) calcd for $C_{26}H_{26}N_3O_7$ $[M+H]^+$: 492.1765, found: 492.1765.



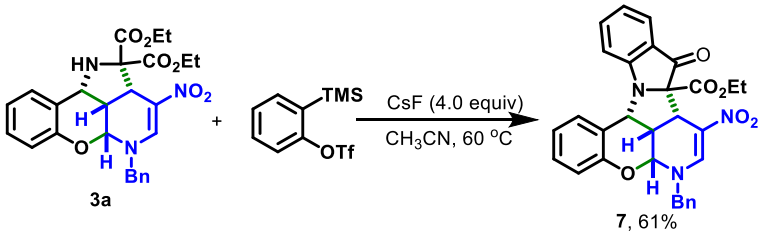
General procedure for the formation of 6: To a solution of compound **3a** (98.7 mg, 0.2 mmol) in EtOAc (2 mL) was added Pd/C (21.3 mg, 10% by weight on activated carbon). Hydrogenation was carried out under hydrogen atmosphere at 75 °C under atmospheric pressure for 72 h. Then, the reaction mixture was filtered and the filtrate was concentrated in vacuo. Purification of the residue by flash column chromatography afford the desired product **6** (19.6 mg, 26% yield).



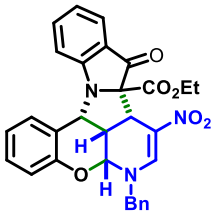
Diethyl 7-amino-3-(2-hydroxyphenyl)- tetrahydro-1*H*-pyrrolo[3,4-*c*]pyridine-1,1-dicarboxylate (**6**)

Yellow solid obtained by column chromatography (dichloromethane/methanol = 60:1 to 30:1); 19.6 mg, 26% yield; dr > 20:1; reaction time = 72 h; mp 115.7-116.3 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.27 (br, 1H), 8.01 (s, 2H), 7.20 (t, *J* = 8.0 Hz, 1H), 7.00 (t, *J* = 4.0 Hz, 1H), 6.91 (d, *J* = 8.0 Hz, 1H), 6.86 (d, *J* = 4.0 Hz, 1H), 6.78 (t, *J* = 8.0 Hz, 1H), 4.89 (s, 1H), 4.35-4.19 (m, 4H), 4.11 (s, 1H), 3.77 (br, 2H), 3.15 (br, 1H), 1.31-1.25 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.1, 156.9, 143.1, 138.3, 136.6, 129.6, 129.2, 122.9, 120.5, 119.9, 117.7, 62.5, 62.5, 62.4, 62.2,

29.7, 14.0, 13.9. IR (KBr) ν 3417, 2924, 1740, 1626, 1255, 758 cm^{-1}. HRMS (ESI) calcd for $C_{19}H_{24}N_3O_5$ $[M+H]^+$: 374.1710, found: 374.1711.



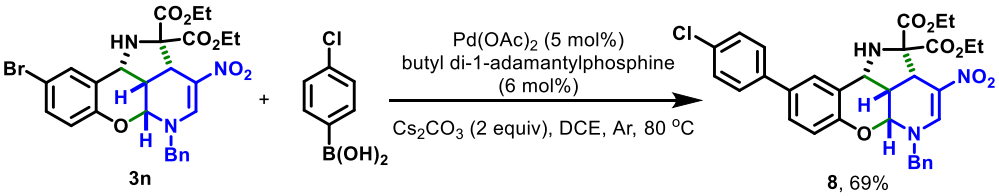
General procedure for the formation of 7: To a 5.0 mL vial were successively added **3a** (98.7 mg, 0.2 mmol), benzyne precursor (0.40 mmol), CsF (0.80 mmol) and 2.0 mL of CH_3CN. The resulting mixture was stirred at 60 °C for 5 h, and then the reaction mixture was directly subjected to flash column chromatography on silica gel (petroleum ether/ ethyl acetate) to afford the corresponding product **7**.



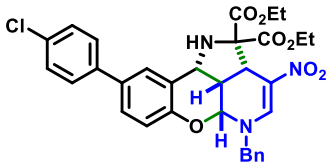
Ethyl

6-benzyl-8-nitro-9-oxo-5a1,6,8a,13c-tetrahydro-9*H*-5-oxa-6,13b-diazaindeno[1,2-*a*]aceanthrylene -8b(5a*H*)-carboxylate (**7**)

Yellow solid obtained by column chromatography (petroleum ether/ethyl acetate = 5:1); 63.8 mg, 61% yield; dr > 20:1; reaction time = 5 h; mp 130.2-130.7 °C; ^{1}H NMR (400 MHz, DMSO-d_6, $CDCl_3$) δ 8.59 (s, 1H), 7.68 (t, *J* = 8.0 Hz, 2H), 7.54 (d, *J* = 4.0 Hz, 1H), 7.47 (d, *J* = 8.0 Hz, 1H), 7.37-7.29 (m, 5H), 7.25 (t, *J* = 8.0 Hz, 1H), 7.12 (t, *J* = 8.0 Hz, 1H), 7.02 (t, *J* = 8.0 Hz, 1H), 6.77 (d, *J* = 8.0 Hz, 1H), 5.17 (d, *J* = 8.0 Hz, 1H), 4.83 (d, *J* = 4.0 Hz, 2H), 4.75 (d, *J* = 8.0 Hz, 1H), 3.81-3.69 (m, 3H), 3.55-3.49 (m, 1H), 0.80 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6, $CDCl_3$) δ 167.8, 167.1, 156.9, 143.1, 138.3, 136.6, 129.6, 129.2, 122.9, 120.5, 119.9, 117.7, 62.5, 62.5, 62.4, 62.2, 29.7, 14.0, 13.9. IR (KBr) ν 3417, 2924, 1740, 1626, 1255, 758 cm^{-1}. HRMS (ESI) calcd for $C_{19}H_{24}N_3O_5$ $[M+H]^+$: 374.1710, found: 374.1711.

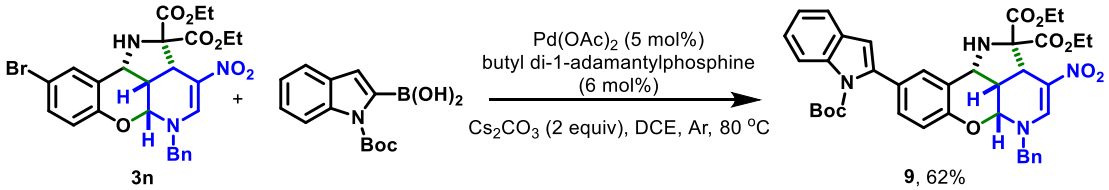


General procedure for the formation of 8: Under nitrogen atmosphere, compound **3n** (114.5 mg, 0.2 mmol), 4-chlorophenyl boronic acid (46.9 mg, 0.3 mmol, 1.5 equiv), Cs_2CO_3 (130.3 mg, 0.4 mmol, 2.0 equiv), $Pd(OAc)_2$ (0.05 equiv) and butyl di-1-adamantylphosphine (0.06 equiv) were successively added to a 15 mL dried tube, followed by addition of 2.0 mL DME. The resulting mixture was stirred at 80 °C for 24 h, and then the reaction mixture was directly subjected to silica gel column chromatography (petroleum ether/ ethyl acetate as eluent) to afford the corresponding product **8** as brown oil in 69% yield.



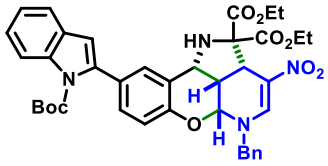
Diethyl 5-benzyl-9-(4-chlorophenyl)-3-nitro-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**8**)

Brown oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 83.5 mg, 69% yield; dr > 20:1; reaction time = 24 h; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 7.45-7.33 (m, 9H), 7.27 (d, J = 8.0 Hz, 2H), 6.94 (d, J = 8.0 Hz, 1H), 4.94 (dd, J_1 = 4.0 Hz, J_1 = 8.0 Hz, 1H), 4.75 (d, J = 12.0 Hz, 1H), 4.64-4.59 (m, 2H), 4.48 (d, J = 8.0 Hz, 1H), 4.26 (q, J = 8.0 Hz, 2H), 4.11-4.03 (m, 1H), 3.94-3.86 (m, 1H), 3.11-3.05 (m, 1H), 2.92 (s, 1H), 1.26 (t, J = 8.0 Hz, 3H), 1.06 (t, J = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 164.8, 162.0, 155.9, 144.3, 137.6, 136.2, 129.3, 128.9, 128.5, 128.4, 127.9, 127.7, 125.0, 123.6, 120.9, 120.7, 118.2, 117.8, 112.8, 84.1, 81.5, 60.7, 59.4, 56.9, 45.4, 38.0, 13.4. IR (KBr) ν 3440, 2927, 2377, 1742, 1642, 1304, 753 cm^{-1}. HRMS (ESI) calcd for $C_{30}H_{26}N_3O_6$ $[M+H]^+$: 524.1816, found: 524.1814.



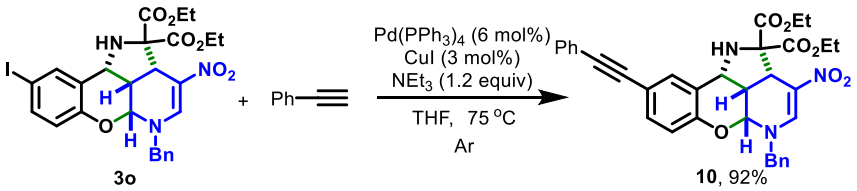
General procedure for the formation of 9: Under nitrogen atmosphere, compound **3n**

(114.5 mg, 0.2 mmol), *N*-Boc 2-indolyl boronic acid (78.3 mg, 0.3 mmol, 1.5 equiv), Cs_2CO_3 (130.3 mg, 0.4 mmol, 2.0 equiv), $Pd(OAc)_2$ (0.05 equiv) and butyl di-1-adamantylphosphine (0.06 equiv) were successively added to a 15 mL dried tube, followed by addition of 2.0 mL DME. The resulting mixture was stirred at 80 °C for 6 h, and then the reaction mixture was directly subjected to silica gel column chromatography (petroleum ether/ ethyl acetate as eluent) to afford the corresponding product **9** as brown oil in 62% yield.



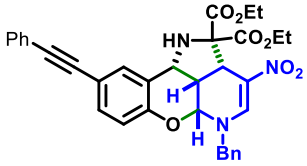
Diethyl 5-benzyl-9-(1-(tert-butoxycarbonyl)-1*H*-indol-2-yl)-3-nitro-1,2a,2a1,5,5a,10b-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylate (**9**)

Yellow oil obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 88.5 mg, 62% yield; dr > 20:1; reaction time = 6 h; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (s, 1H), 8.15 (d, *J* = 12.0 Hz, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.40-7.22 (m, 9H), 6.92 (d, *J* = 8.0 Hz, 1H), 6.53 (s, 1H), 4.89 (d, *J* = 8.0 Hz, 1H), 4.75 (d, *J* = 16.0 Hz, 1H), 4.61 (d, *J* = 8.0 Hz, 1H), 4.58 (d, *J* = 4.0 Hz, 1H), 4.55 (d, *J* = 8.0 Hz, 1H), 4.27 (q, *J* = 8.0 Hz, 2H), 4.14-4.06 (m, 1H), 3.98-3.90 (m, 1H), 3.08-3.02 (m, 1H), 2.91 (s, 1H), 1.38 (s, 9H), 1.27 (t, *J* = 8.0 Hz, 3H), 1.09 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 168.7, 154.7, 150.0, 142.2, 139.5, 137.2, 134.6, 130.5, 129.6, 129.1, 129.1, 128.7, 128.7, 128.2, 127.7, 124.3, 123.9, 122.9, 120.4, 117.1, 115.2, 110.2, 83.4, 83.0, 74.8, 62.5, 61.7, 57.8, 57.8, 42.2, 41.6, 27.7, 13.8, 13.5. IR (KBr) ν 3434, 2924, 1734, 1641, 1320, 750 cm^{-1}. HRMS (ESI) calcd for $C_{39}H_{41}N_4O_9$ $[M+H]^+$: 709.2868, found: 709.2882.



General procedure for the formation of 10: Under nitrogen atmosphere, compound **3o** (123.9 mg, 0.2 mmol), $Pd(PPh_3)_4$ (0.06 equiv), CuI (0.05 equiv), phenylacetylene (24.5 mg, 1.2 equiv) and NEt_3 (24.3 mg, 1.2 equiv) were successively added to a 15 mL dried tube, followed by addition of 2.0 mL THF. The resulting mixture was stirred at 75 °C for 24 h, and then the reaction mixture was directly subjected to silica gel column chromatography (petroleum ether/ ethyl

acetate as eluent) to afford the corresponding product **10** as brown solid in 92% yield.



Diethyl

5-benzyl-3-nitro-9-(phenylethynyl)-hexahydro-2*H*-6-oxa-1,5-diazaaceanthrylene-2,2-dicarboxylat e (**10**)

Brown solid obtained by column chromatography (petroleum ether/ethyl acetate = 3:1); 109.2 mg, 92% yield; dr > 20:1; reaction time = 24 h; mp 98.3-98.7 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.50-7.46 (m, 2H), 7.41 (d, *J* = 4.0 Hz, 1H), 7.38-7.31 (m, 7H), 7.25 (d, *J* = 4.0 Hz, 1H), 7.23 (d, *J* = 4.0 Hz, 1H), 6.82 (d, *J* = 8.0 Hz, 1H), 4.87 (d, *J* = 8.0 Hz, 1H), 4.71 (d, *J* = 16.0 Hz, 1H), 4.60 (s, 1H), 4.58 (d, *J* = 12.0 Hz, 1H), 4.41 (d, *J* = 8.0 Hz, 1H), 4.31-4.19 (m, 2H), 4.08-4.00 (m, 1H), 3.87-3.79 (m, 1H), 3.08-3.02 (m, 1H), 2.85 (s, 1H), 1.25 (t, *J* = 8.0 Hz, 3H), 1.03 (t, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.8, 168.5, 155.0, 142.2, 134.6, 132.5, 132.0, 131.5, 129.2, 128.7, 128.3, 128.3, 128.2, 128.1, 124.2, 123.0, 118.8, 117.7, 89.0, 88.4, 82.9, 74.6, 62.7, 61.7, 57.9, 57.4, 42.3, 41.1, 13.8, 13.5. IR (KBr) ν 3418, 2928, 1734, 1638, 1263, 751 cm^{-1}. HRMS (ESI) calcd for $C_{34}H_{32}N_3O_7$ $[M+H]^+$: 594.2235, found: 594.2242.

5. Crystal structures

5.1 Crystal structure of 3n

Preparation of the single crystals of **3n**: 15.0 mg of pure compound **3n** was dissolved in the combined solvents of dichloromethane and methanol (3 mL, v/v = 1:2) at room temperature. The bottle was sealed by a piece of plastic film with several tiny holes, thus allowing slow evaporation of the solvents at 0 ^{o}C. After about one day, several small particles were observed at the bottom of the bottle. The crystals were chosen and subjected to the single crystal X-ray diffraction analysis for the determination of the structure and relative configuration of **3n**. The data were collected by a Bruker D8 VENTURE PHOTON II CCD diffractometer at 273.0 K.

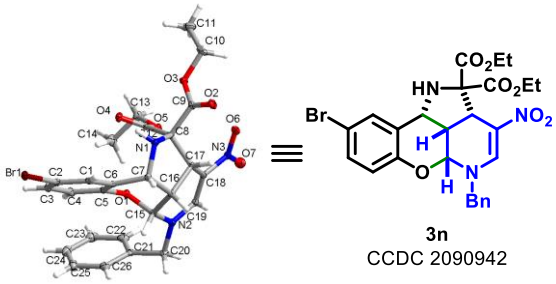


Table S1. Crystal data and structure refinement for **3n**.

Bond precision: C-C = 0.0029 A Wavelength = 0.71073

Cell: a = 11.194(5) b = 12.288(3) c = 18.063(6)

alpha = 90 beta = 95.088(14) gamma = 90

Temperature: 150 K

	Calculated	Reported
Volume	2474.8(15)	2474.7(16)
Space group	P 21/n	P 1 21/n 1
Hall group	-P 2yn	-P 2yn
Moiety formula	$C_{26}H_{26}BrN_3O_7$	$C_{26}H_{26}BrN_3O_7$
Sum formula	$C_{26}H_{26}BrN_3O_7$	$C_{26}H_{26}BrN_3O_7$
Mr	572.40	572.41
Dx,g cm-3	1.536	1.536
Z	4	4
Mu (mm-1)	1.714	1.714
F000	1176.0	1176.0
F000'	1175.40	
h,k,lmax	13,15,22	13,15,22
Nref	5060	5059
Tmin,Tmax	0.742,0.814	0.669,0.746
Tmin'	0.691	

Correction method= # Reported T Limits: Tmin=0.669 Tmax=0.746 AbsCorr =

MULTI-SCAN

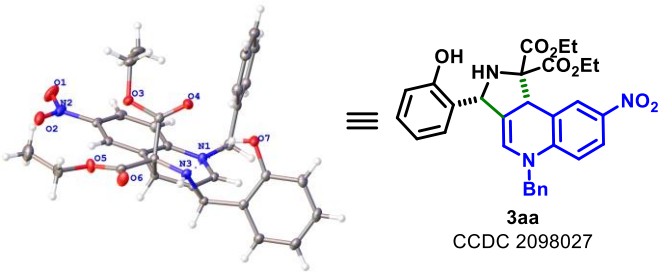
Data completeness= 1.000 Theta(max)= 26.368

R(reflections)= 0.0263(4318) wR_2(reflections)= 0.0603(5059)

S = 1.028 Npar = 340

5.2 Crystal structure of 3aa

Preparation of the single crystals of **3aa**: 15.0 mg of pure compound **3aa** was dissolved in the combined solvents of dichloromethane and methanol (3 mL, v/v = 1:2) at room temperature. The bottle was sealed by a piece of plastic film with several tiny holes, thus allowing slow evaporation of the solvents at 0 ^{o}C. After about one day, several small particles were observed at the bottom of the bottle. The crystals were chosen and subjected to the single crystal X-ray diffraction analysis for the determination of the structure and relative configuration of **3aa**. The data were collected by a SuperNova, Dual, Cu at zero, AtlasS2 diffractometer. The crystal was kept at 150.00(10) K during data collection.



3aa
CCDC 2098027

Table S2. Crystal data and structure refinement for **3aa**.

Identification code	**3aa**
Empirical formula	$C_{30}H_{29}N_3O_7$
Formula weight	543.56
Temperature/K	150.00(10)
Crystal system	triclinic
Space group	P-1
a/Å	8.9802(5)
b/Å	12.3650(6)
c/Å	12.6363(6)

α/°	109.475(4)
β/°	94.551(4)
γ/°	90.087(4)
Volume/Å^3	1318.10(12)
Z	2
ρ_{calc}g/cm^3	1.370
μ/mm^{-1}	0.099
F(000)	572.0
Crystal size/mm^3	0.13 × 0.1 × 0.08
Radiation	Mo Kα (λ = 0.71073)
2Θ range for data collection/°	3.996 to 49.994
Index ranges	-10 ≤ h ≤ 10, -14 ≤ k ≤ 13, -15 ≤ l ≤ 14
Reflections collected	9912
Independent reflections	4641 [R_{int} = 0.0303, R_{sigma} = 0.0467]
Data/restraints/parameters	4641/0/380
Goodness-of-fit on F^2	1.030
Final R indexes [I>=2σ (I)]	R_1 = 0.0414, wR_2 = 0.0938
Final R indexes [all data]	R_1 = 0.0561, wR_2 = 0.1039
Largest diff. peak/hole / e Å^{-3}	0.19/-0.18

5.3 Crystal structure of 4

Preparation of the single crystals of **4**: 10.0 mg of pure compound **4** was dissolved in the combined solvents of dichloromethane and methanol (2 mL, v/v = 1:1) at room temperature. The bottle was sealed by a piece of plastic film with several tiny holes, thus allowing slow evaporation of the solvents at 0 ^{o}C. After about two days, several small particles were observed at the bottom of the bottle. The crystals were chosen and subjected to the single crystal X-ray diffraction analysis for the determination of the structure and relative configuration of **4**. The data were collected by a Bruker D8 QUEST PHOTON II diffractometer at 273.0 K.

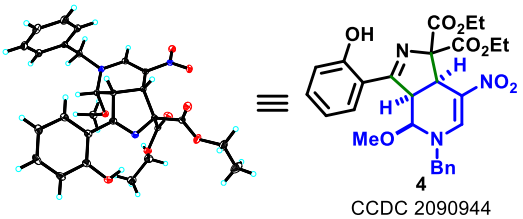


Table S3. Crystal data and structure refinement for **4**.

Identification code	global	
Empirical formula	$C_{27}H_{29}N_3O_8$	
Formula weight	523.53	
Temperature	100(2) K	
Wavelength	1.54178 Å	
Crystal system	Monoclinic	
Space group	P 1 21/n 1	
Unit cell dimensions	a = 8.0690(2) Å	α = 90 °.
	b = 11.2404(3) Å	β = 93.2810(10) °.
	c = 27.7333(8) Å	γ = 90 °.
Volume	2511.25(12) $Å^3$	
Z	4	
Density (calculated)	1.385 Mg/m^3	
Absorption coefficient	0.860 mm^{-1}	
F(000)	1104	
Crystal size	0.290 x 0.080 x 0.030 mm^3	
Theta range for data collection	3.19 to 72.20 °.	
Index ranges	-9<=h<=9, -13<=k<=13, -28<=l<=34	
Reflections collected	29794	
Independent reflections	4931 [R(int) = 0.0812]	
Completeness to theta = 72.20 °	99.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.97 and 0.85	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4931 / 0 / 347	

Goodness-of-fit on F^2	1.033
Final R indices [I>2sigma(I)]	R_1 = 0.0535, wR_2 = 0.1257
R indices (all data)	R_1 = 0.0696, wR_2 = 0.1361
Largest diff. peak and hole	1.307 and -0.740 e.$Å^{-3}$

5.4 Crystal structure of 7

Preparation of the single crystals of **7**: 8.0 mg of pure compound **7** was dissolved in the combined solvents of chloroform and methanol (1 mL, v/v = 2:1) at room temperature. The bottle was sealed by a piece of plastic film with several tiny holes, thus allowing slow evaporation of the solvents at 10 ^{o}C. After about two days, several small particles were observed at the bottom of the bottle. The crystals were chosen and subjected to the single crystal X-ray diffraction analysis for the determination of the structure and relative configuration of **7**. The data were collected by a SuperNova, Dual, Cu at zero, AtlasS2 diffractometer. The crystal was kept at 149.99(10) K during data collection.

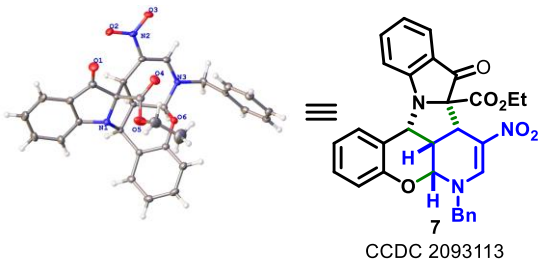


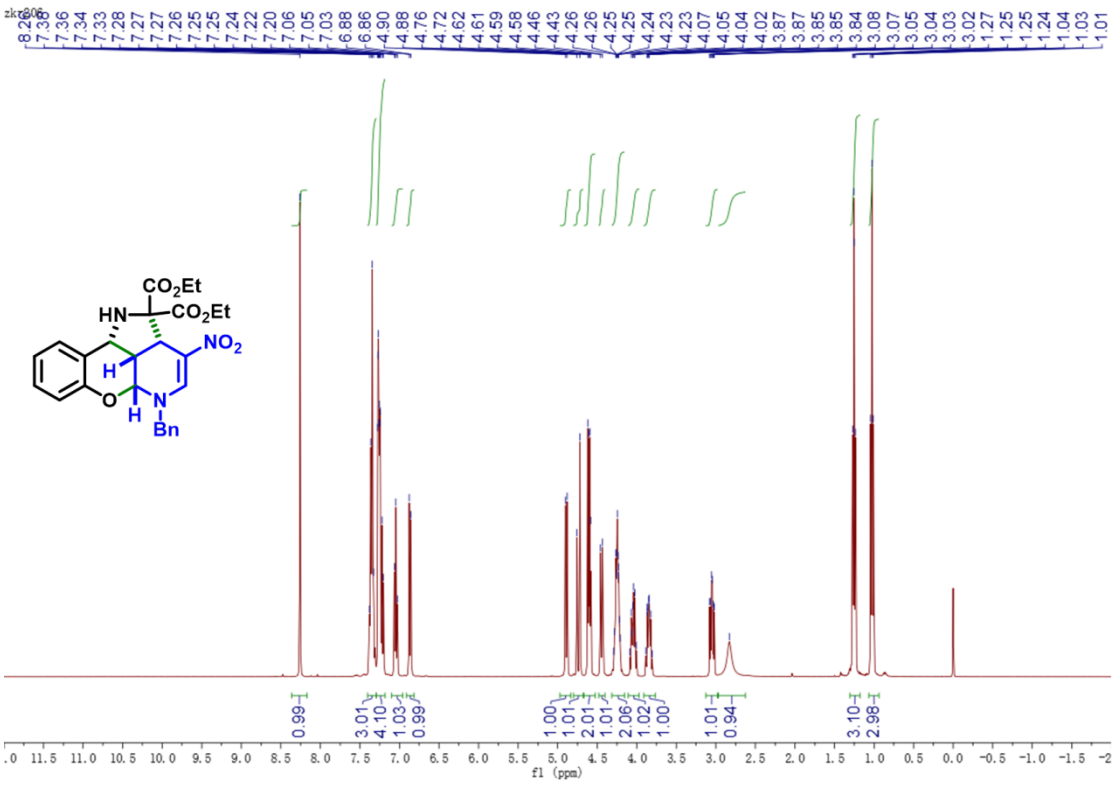
Table S4. Crystal data and structure refinement for **7**.

Identification code	**7**
Empirical formula	$C_{31}H_{26}Cl_3N_3O_6$
Formula weight	642.90
Temperature/K	149.99(10)
Crystal system	orthorhombic
Space group	$P2_12_12_1$
a/Å	8.9528(3)
b/Å	12.4499(5)
c/Å	26.0558(12)
α/°	90

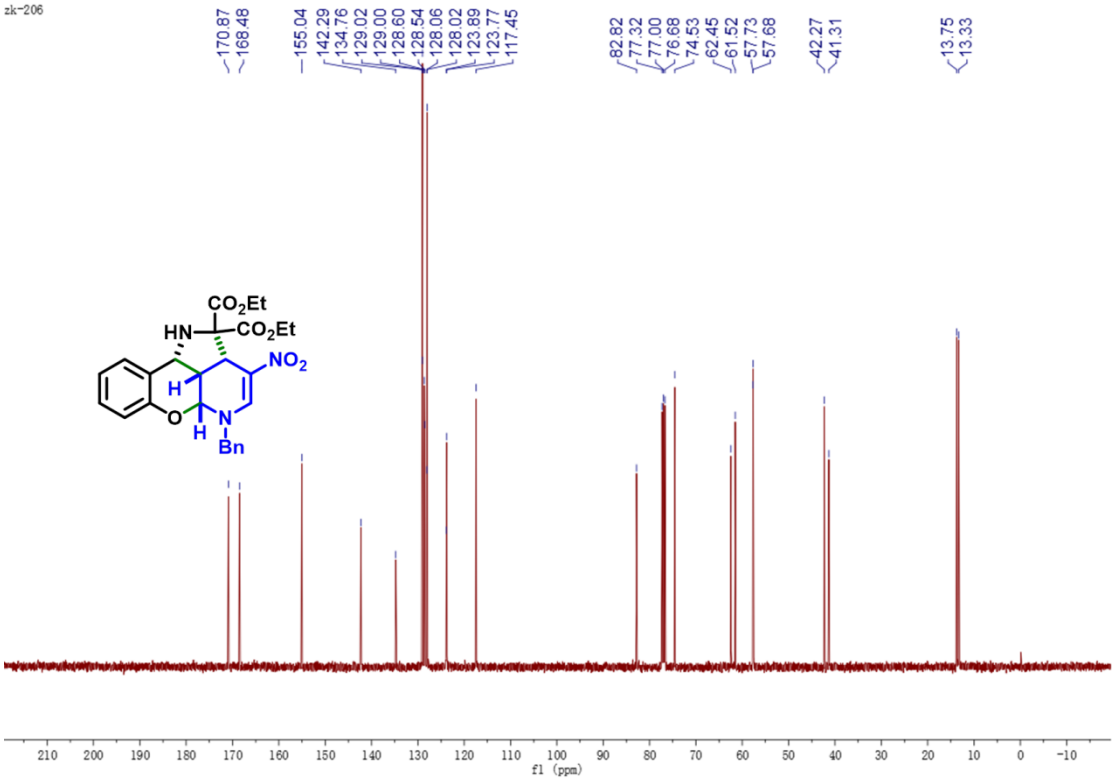
β/°	90
γ/°	90
Volume/Å^3	2904.2(2)
Z	4
ρ_{calc}g/cm^3	1.470
μ/mm^{-1}	3.287
F(000)	1328.0
Crystal size/mm^3	0.14 × 0.12 × 0.11
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	7.87 to 147.802
Index ranges	-7 ≤ h ≤ 10, -15 ≤ k ≤ 15, -31 ≤ l ≤ 23
Reflections collected	7183
Independent reflections	4952 [R_{int} = 0.0526, R_{sigma} = 0.0819]
Data/restraints/parameters	4952/38/409
Goodness-of-fit on F^2	1.050
Final R indexes [I>=2σ (I)]	R_1 = 0.0624, wR_2 = 0.1571
Final R indexes [all data]	R_1 = 0.0721, wR_2 = 0.1694
Largest diff. peak/hole / e Å^{-3}	0.50/-0.39
Flack parameter	0.01(2)

6. NMR spectra

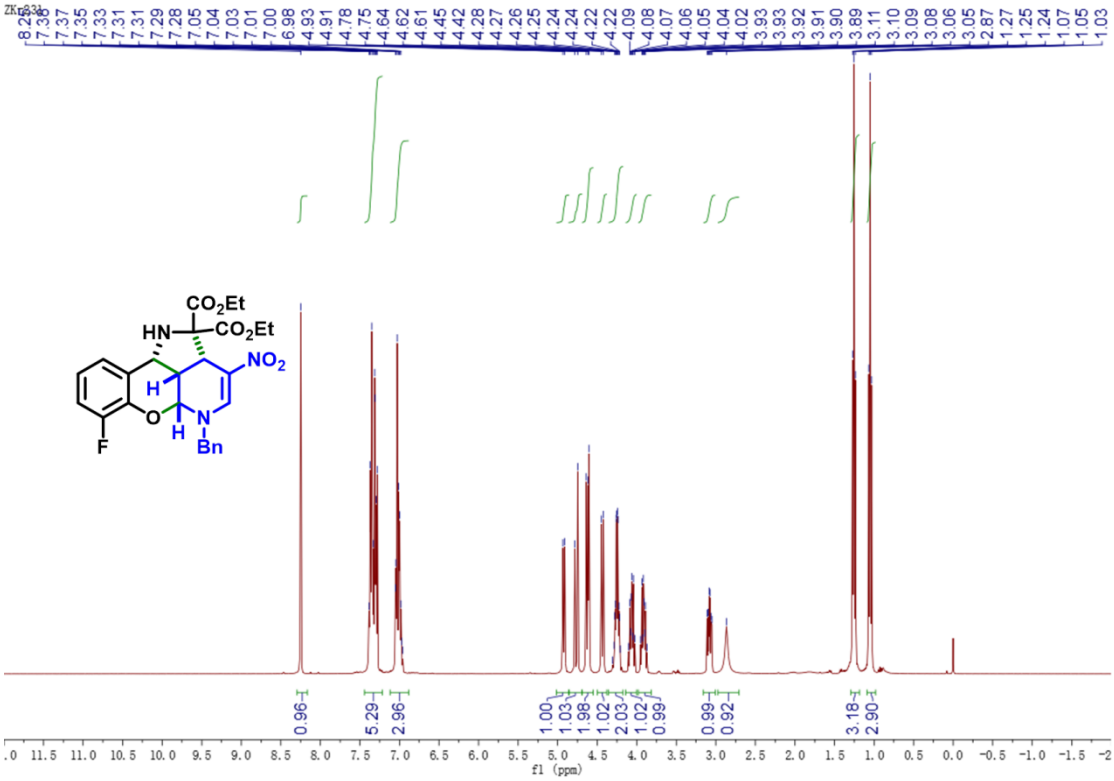
^{1}H NMR spectrum of **3a** (400 MHz, $CDCl_3$)



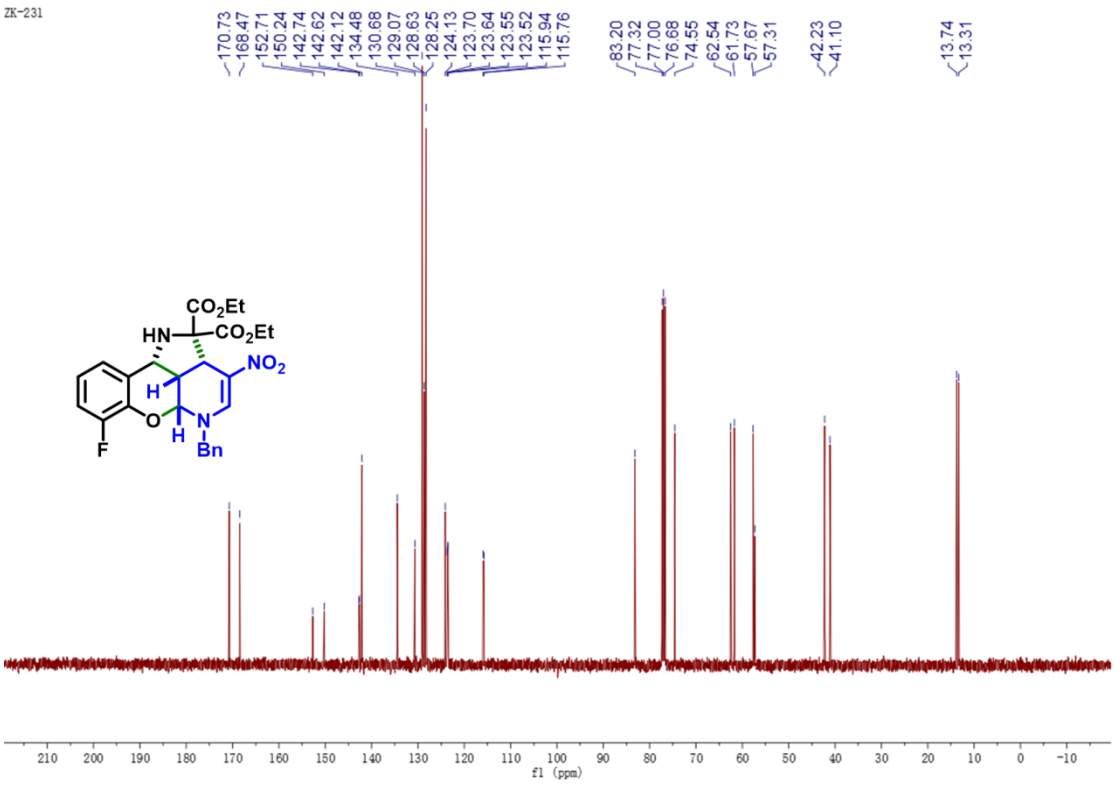
^{13}C NMR spectrum of **3a** (100 MHz, $CDCl_3$)



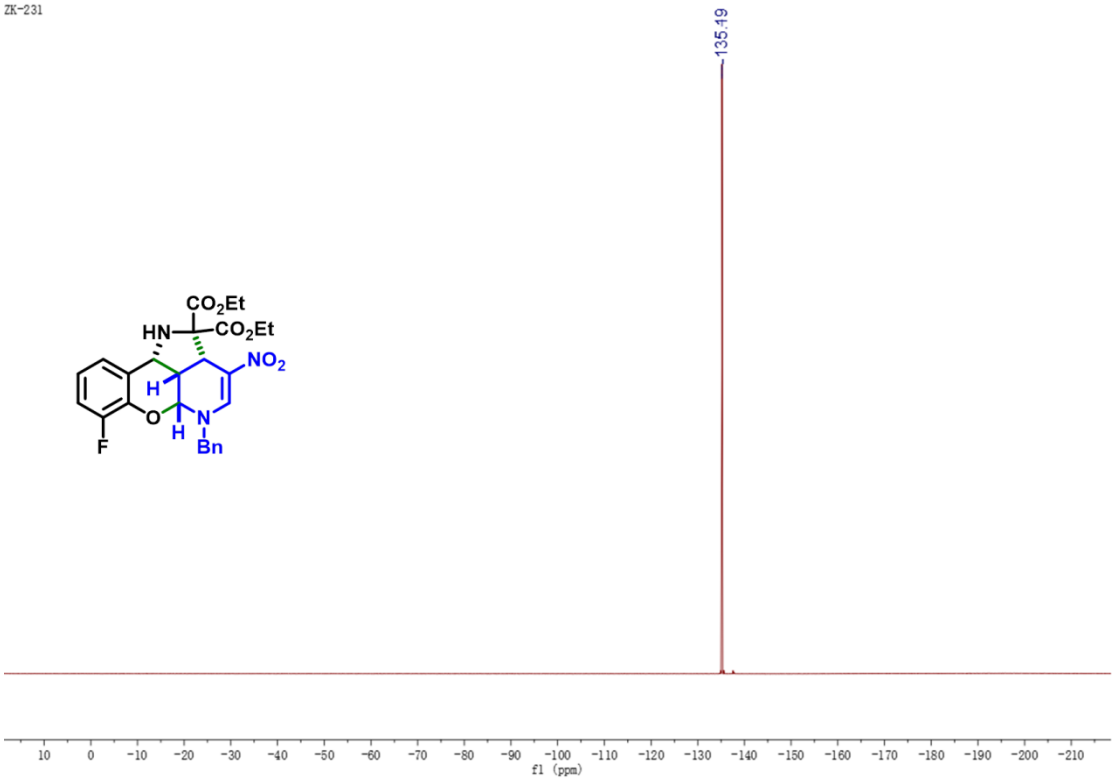
^{1}H NMR spectrum of **3b** (400 MHz, $CDCl_3$)



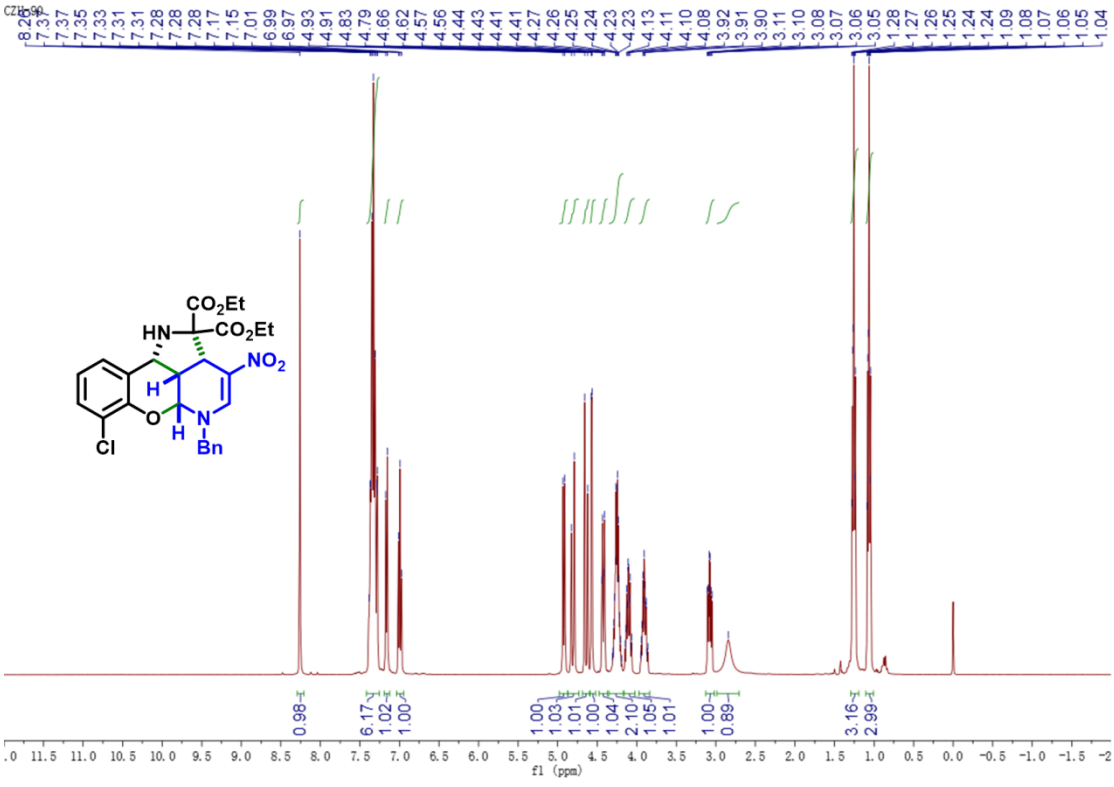
^{13}C NMR spectrum of **3b** (100 MHz, $CDCl_3$)



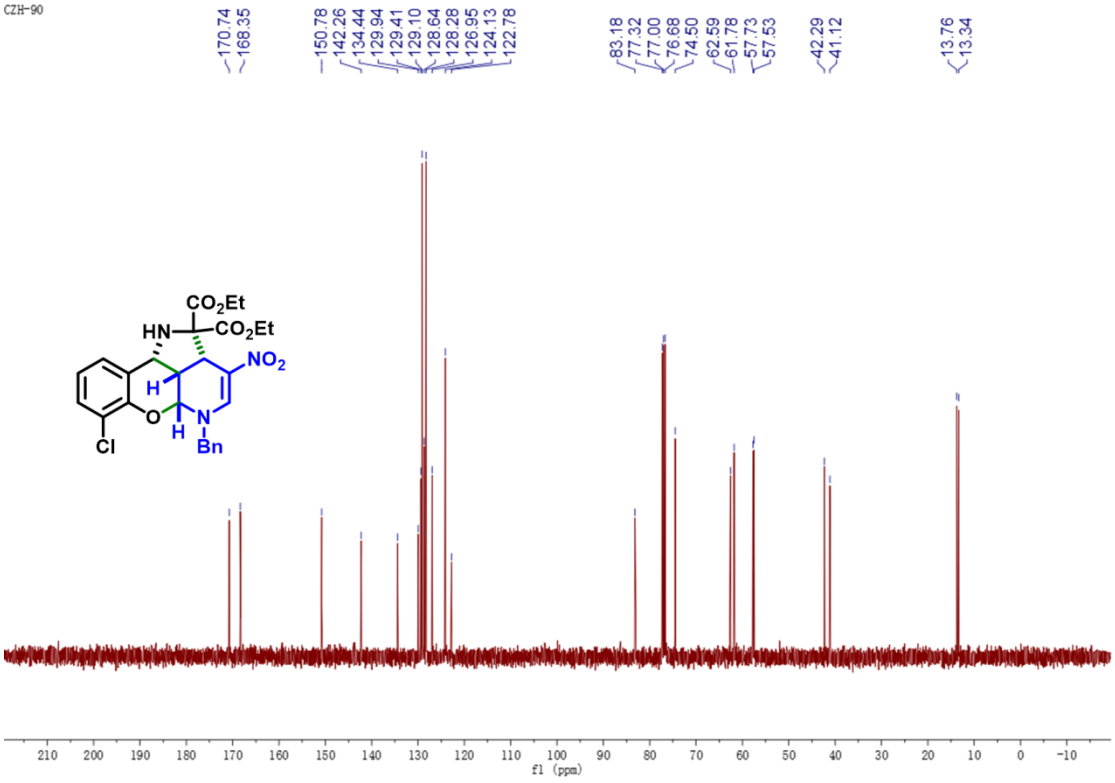
^{19}F NMR spectrum of **3b** (375 MHz, $CDCl_3$)



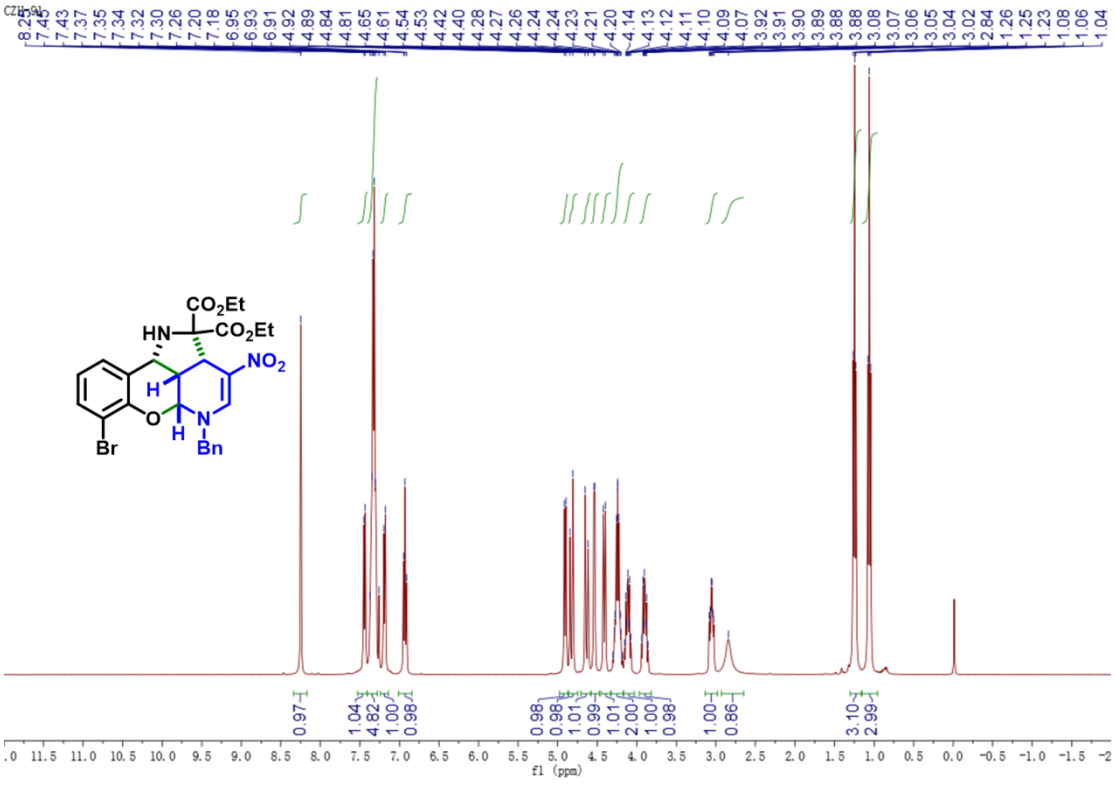
^{1}H NMR spectrum of **3c** (400 MHz, $CDCl_3$)



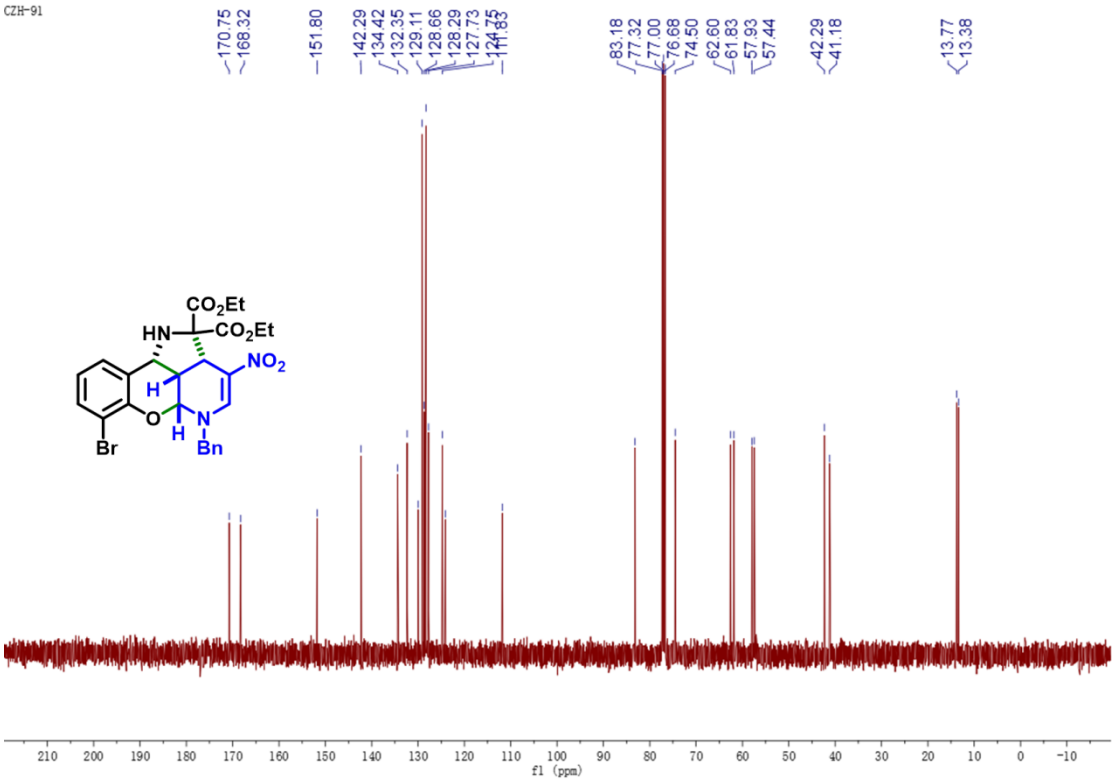
^{13}C NMR spectrum of **3c** (100 MHz, $CDCl_3$)



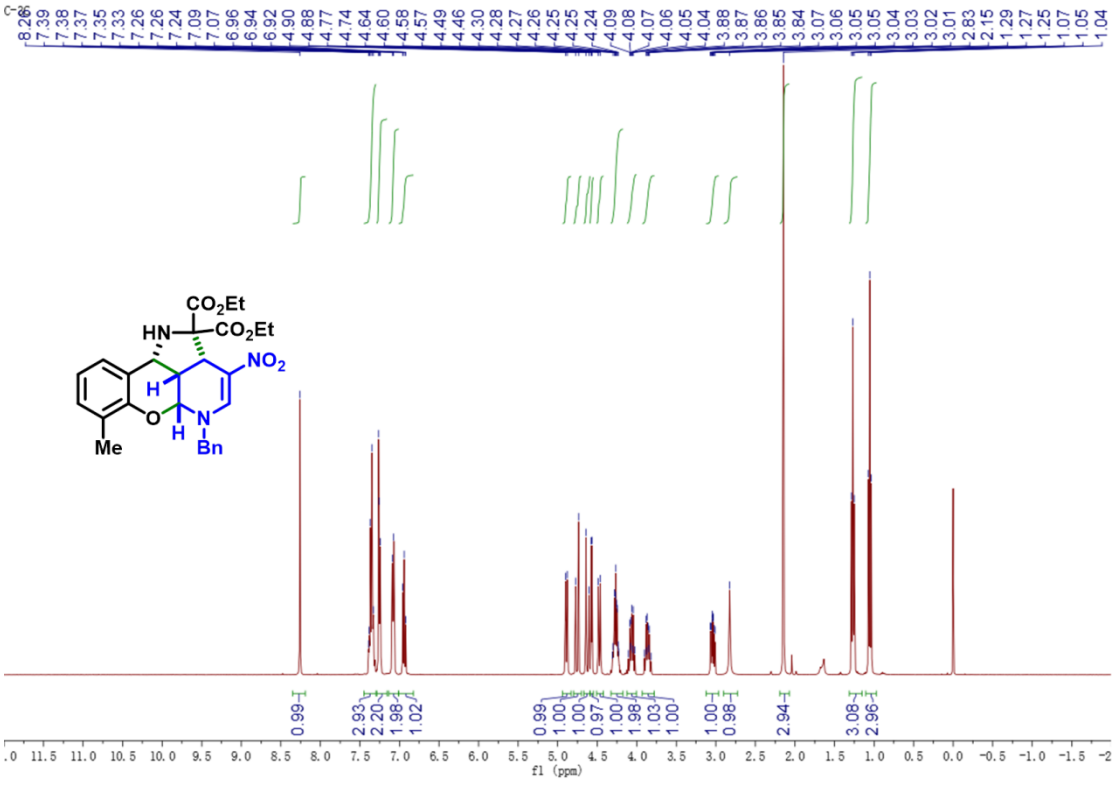
^{1}H NMR spectrum of **3d** (400 MHz, $CDCl_3$)



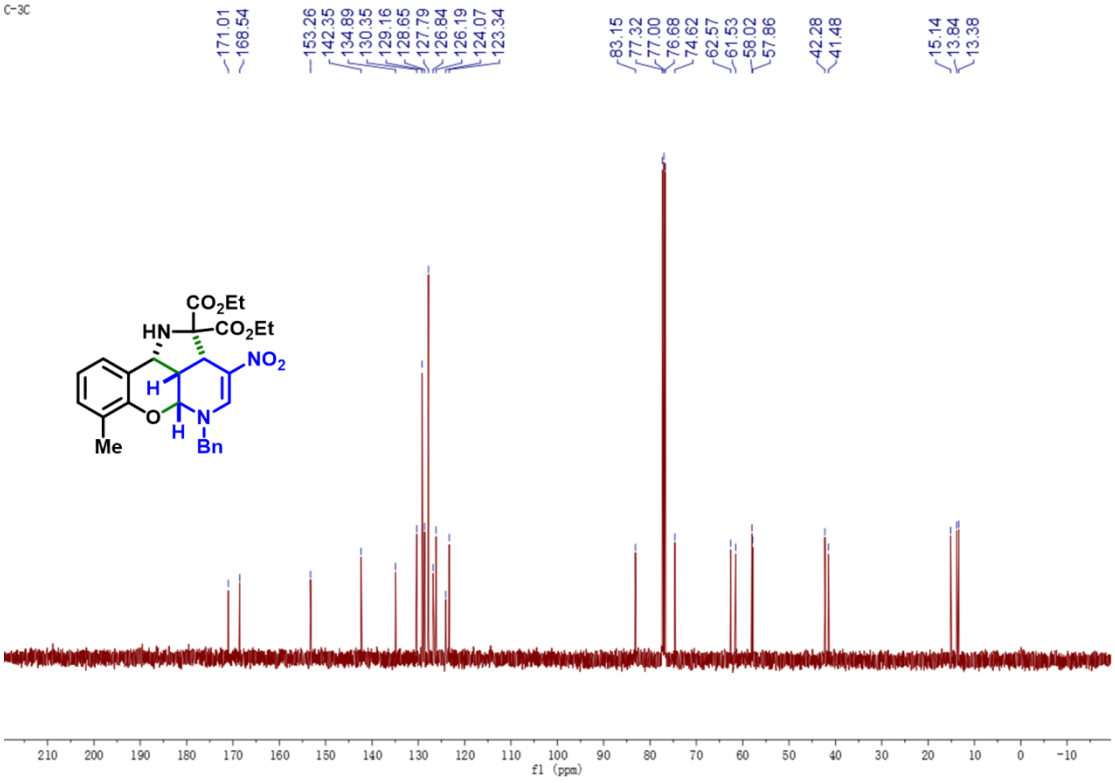
^{13}C NMR spectrum of **3d** (100 MHz, $CDCl_3$)



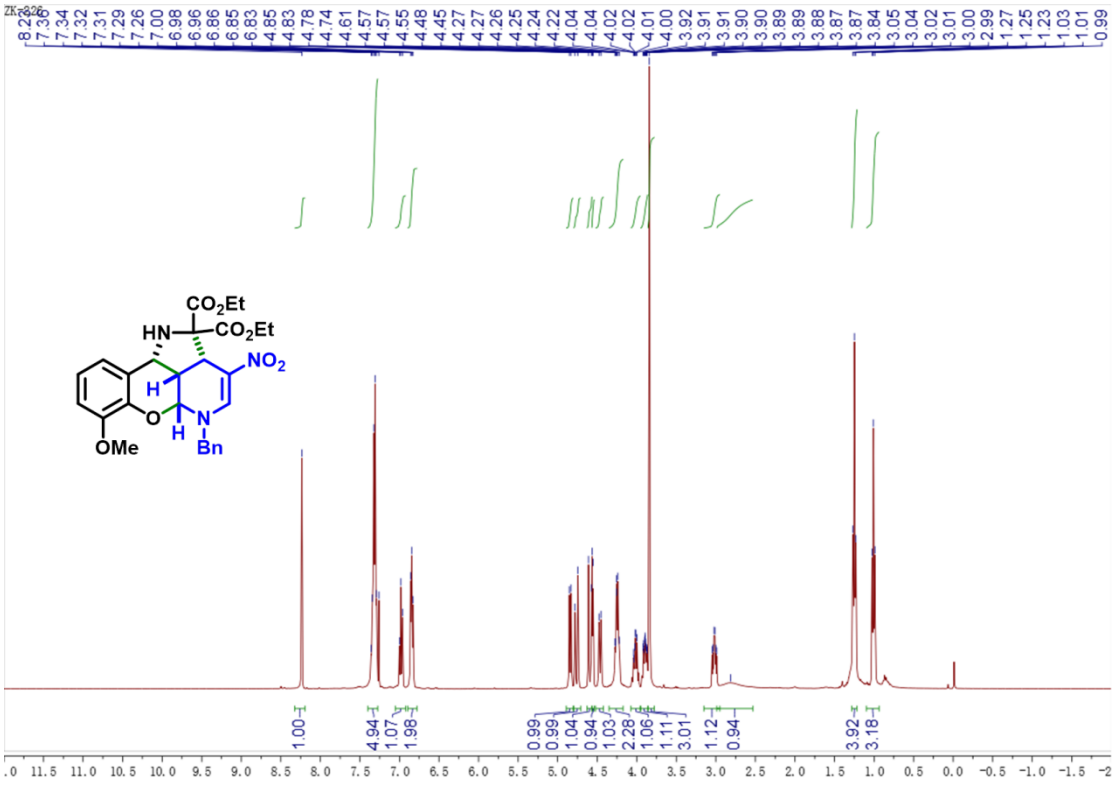
^{1}H NMR spectrum of **3e** (400 MHz, $CDCl_3$)



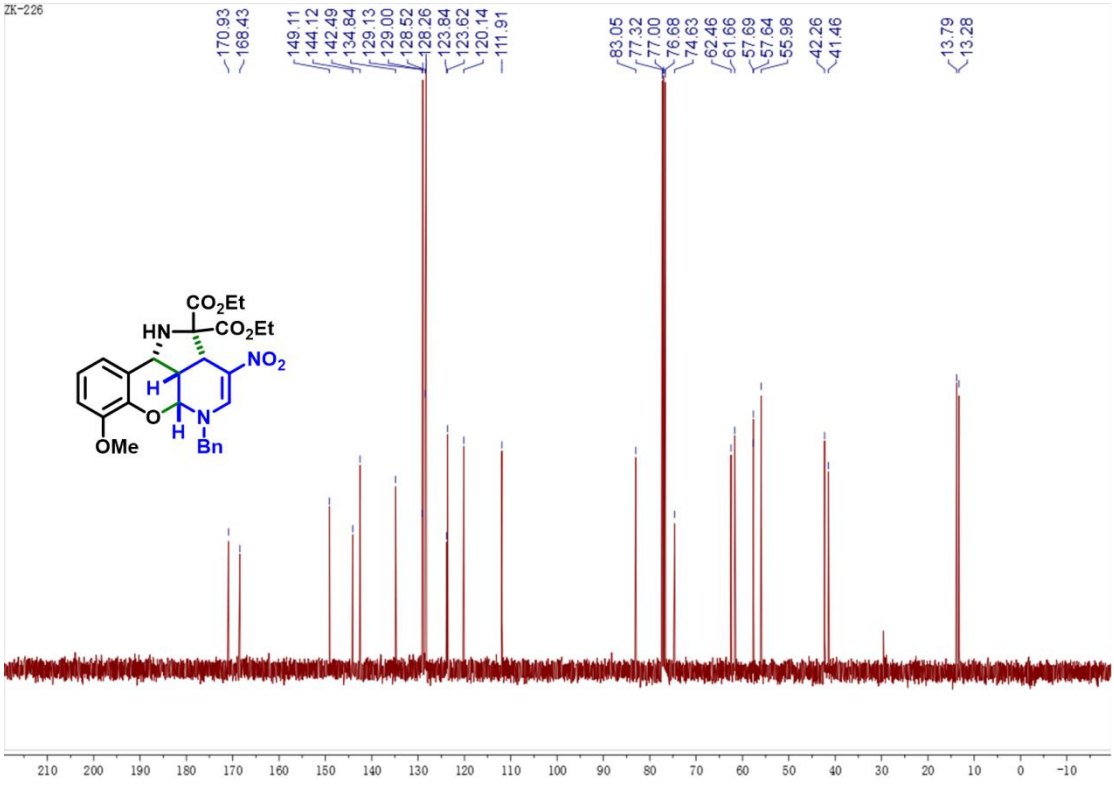
^{13}C NMR spectrum of **3e** (100 MHz, $CDCl_3$)



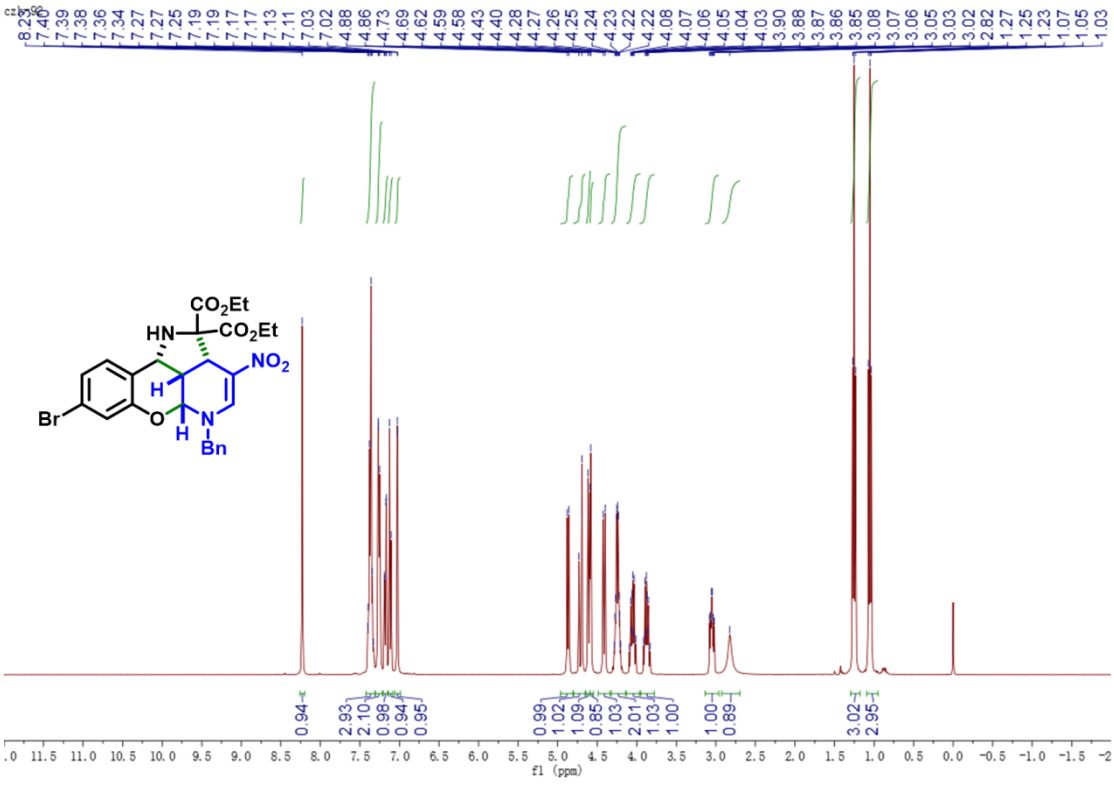
^{1}H NMR spectrum of **3f** (400 MHz, $CDCl_3$)



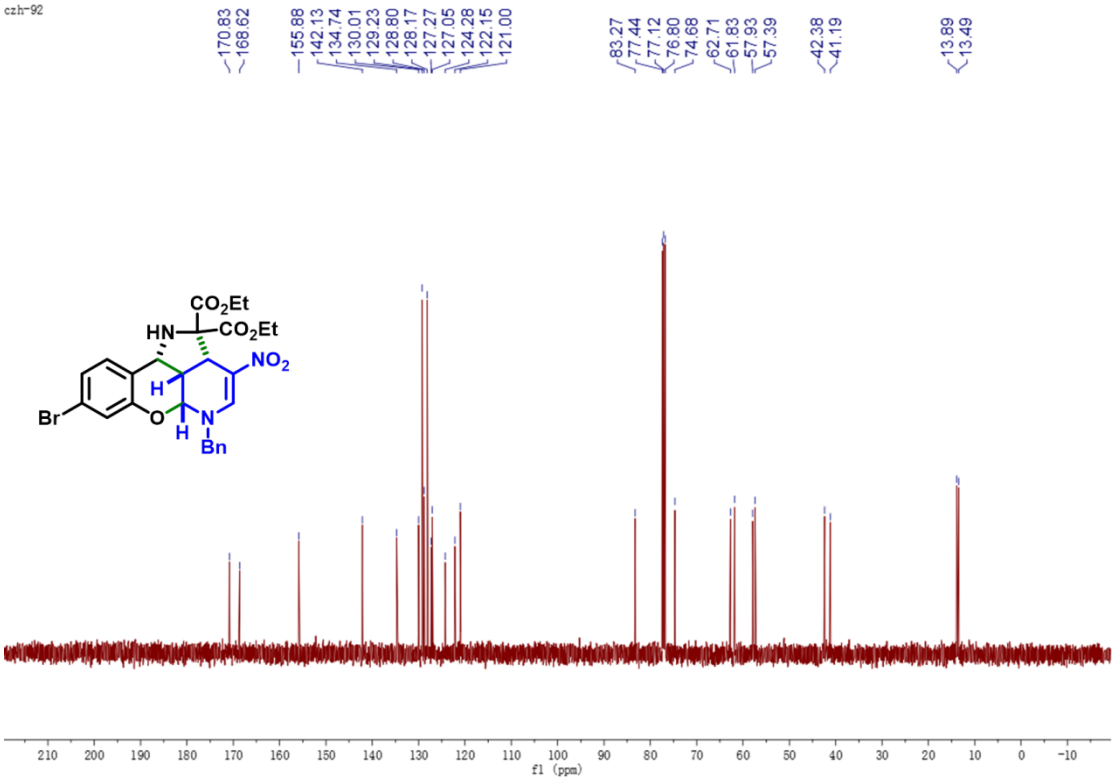
^{13}C NMR spectrum of **3f** (100 MHz, $CDCl_3$)



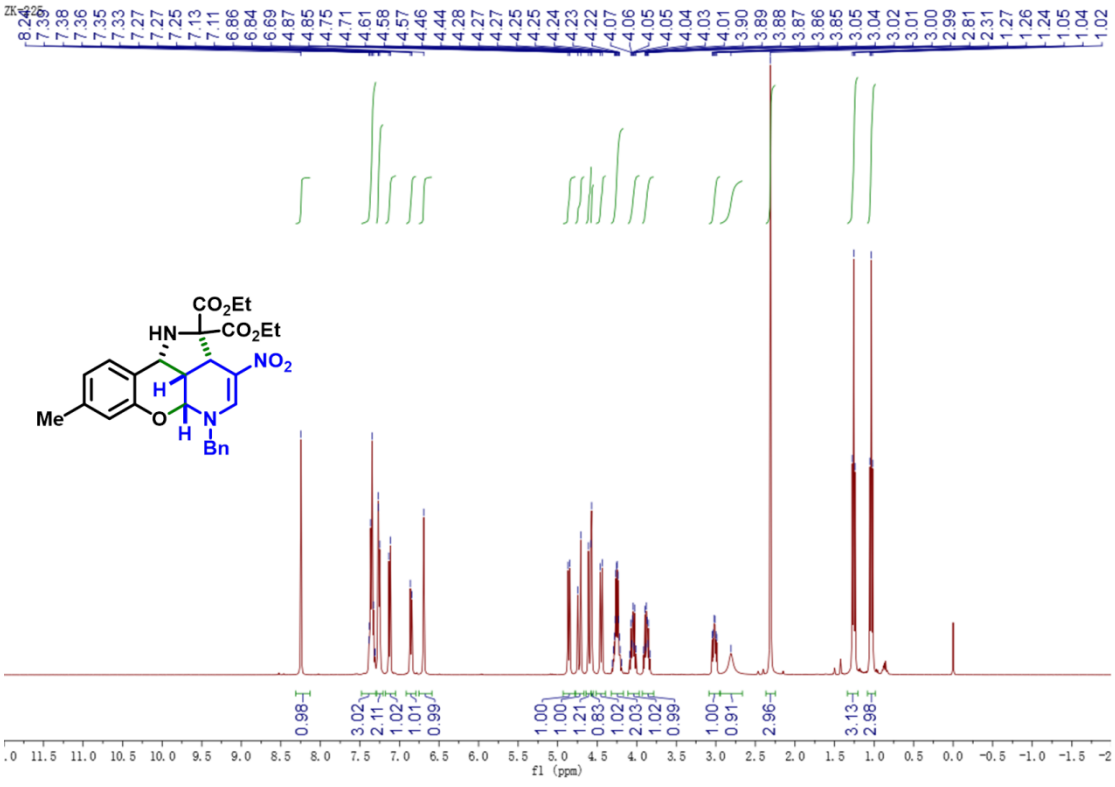
^{1}H NMR spectrum of **3g** (400 MHz, $CDCl_3$)



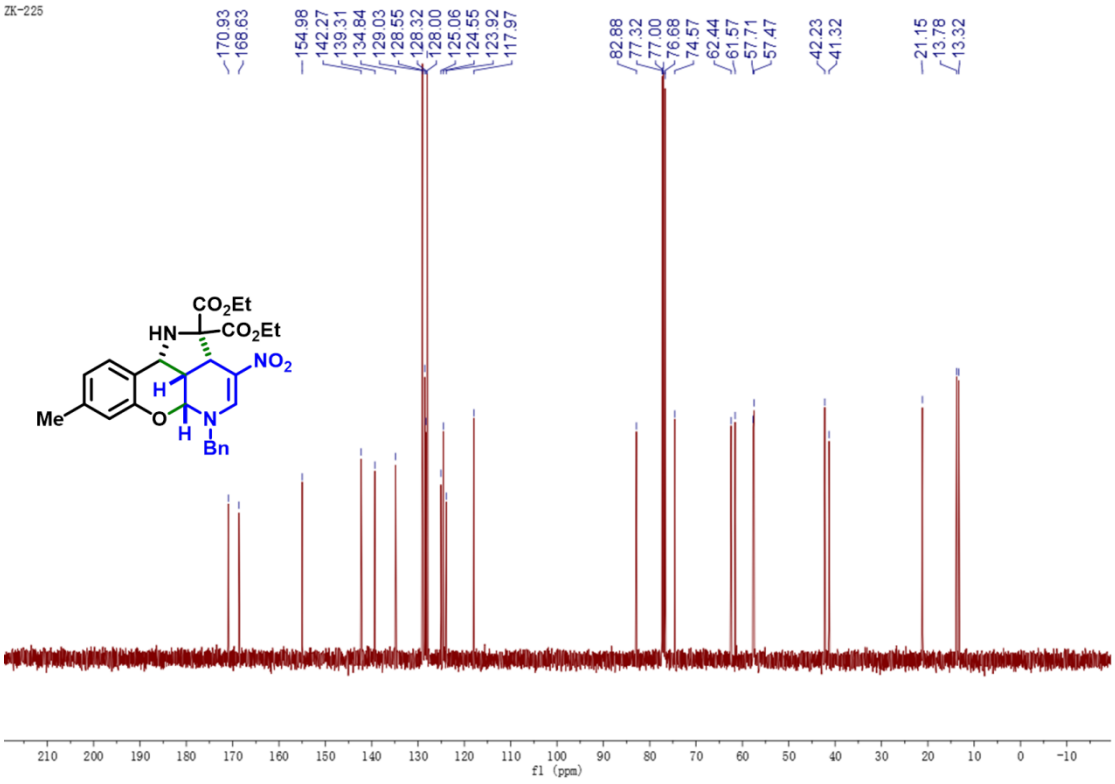
^{13}C NMR spectrum of **3g** (100 MHz, $CDCl_3$)



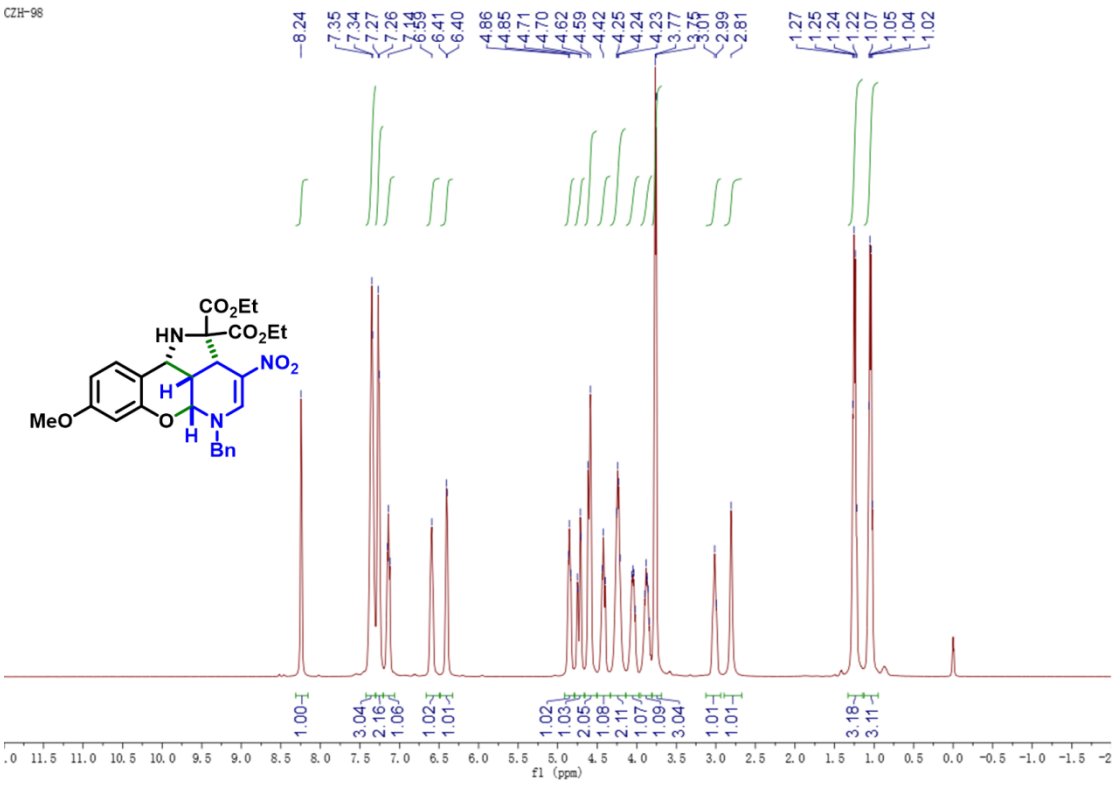
^{1}H NMR spectrum of **3h** (400 MHz, $CDCl_3$)



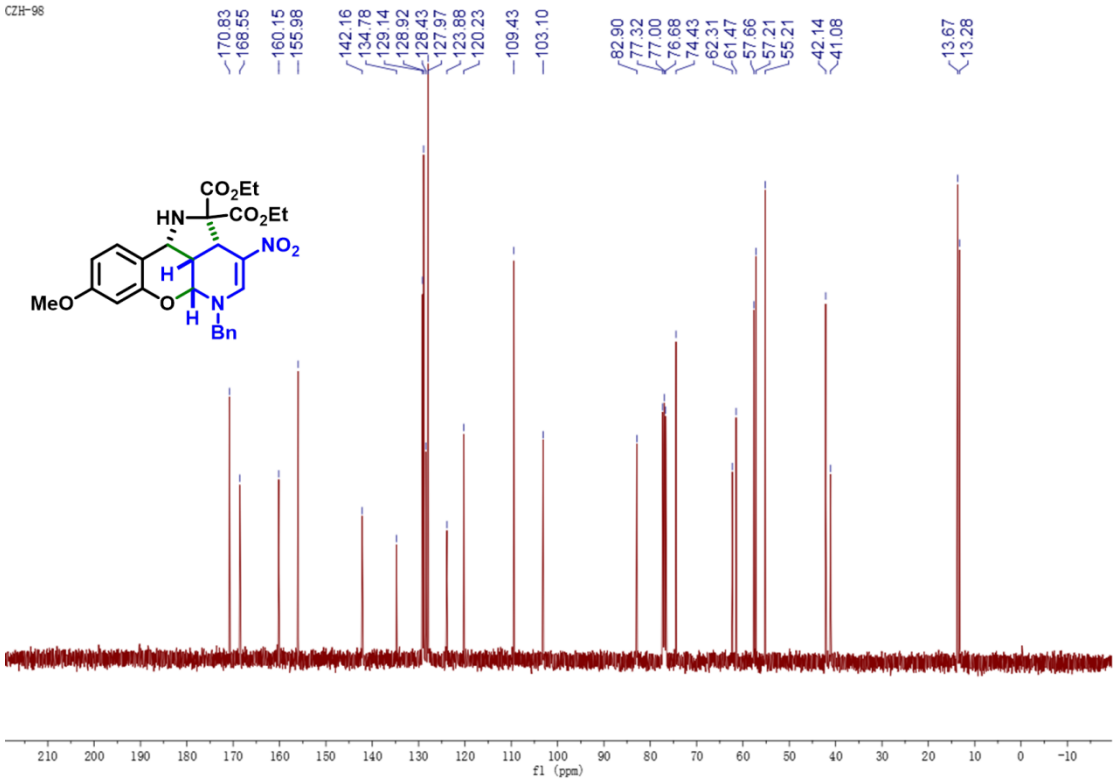
^{13}C NMR spectrum of **3h** (100 MHz, $CDCl_3$)



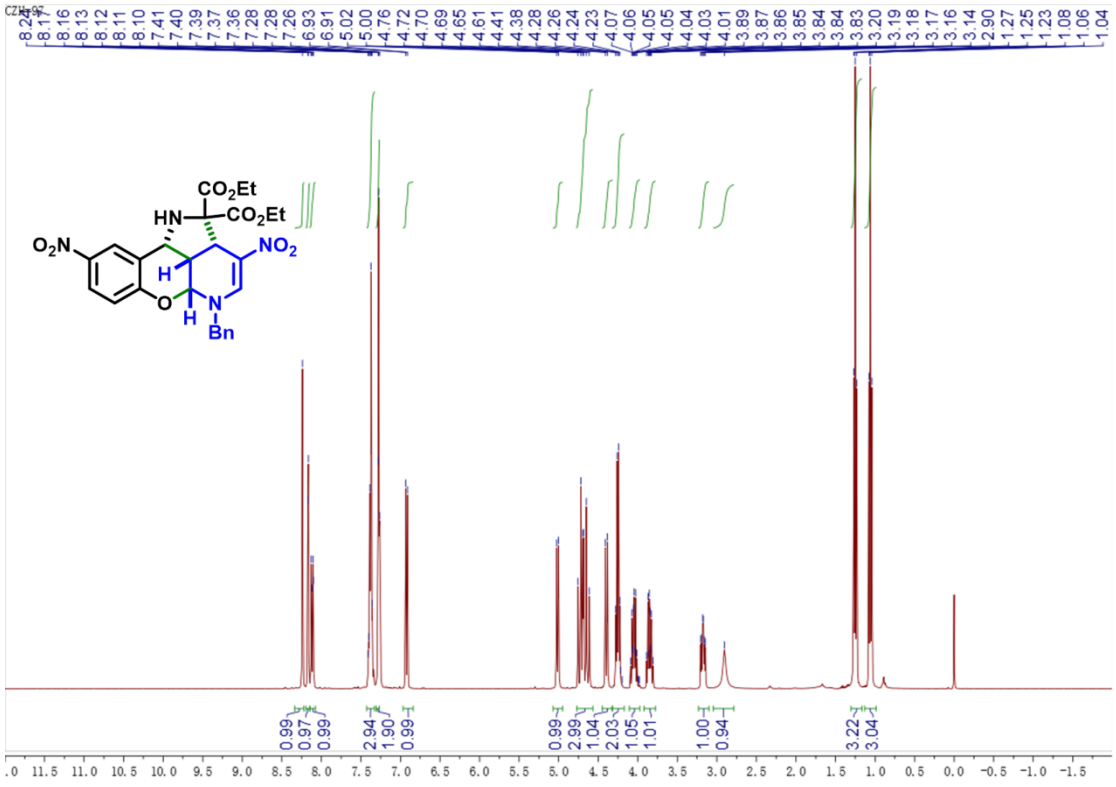
^{1}H NMR spectrum of **3i** (400 MHz, $CDCl_3$)



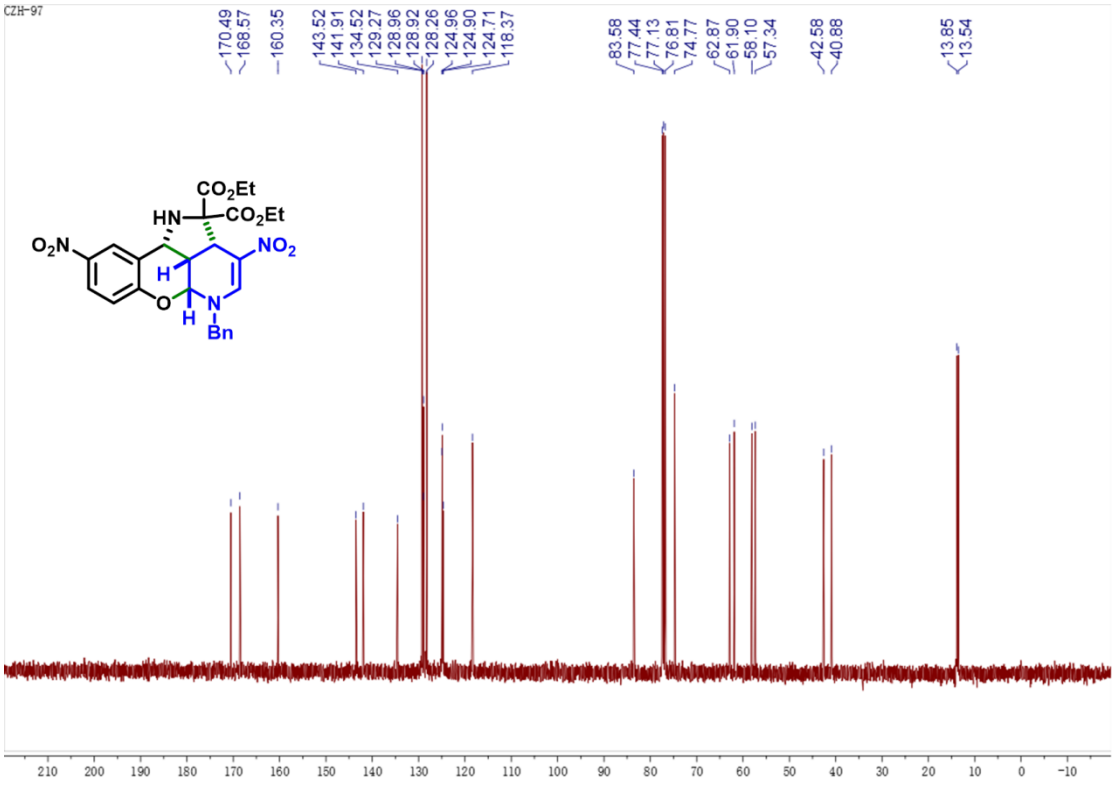
^{13}C NMR spectrum of **3i** (100 MHz, $CDCl_3$)



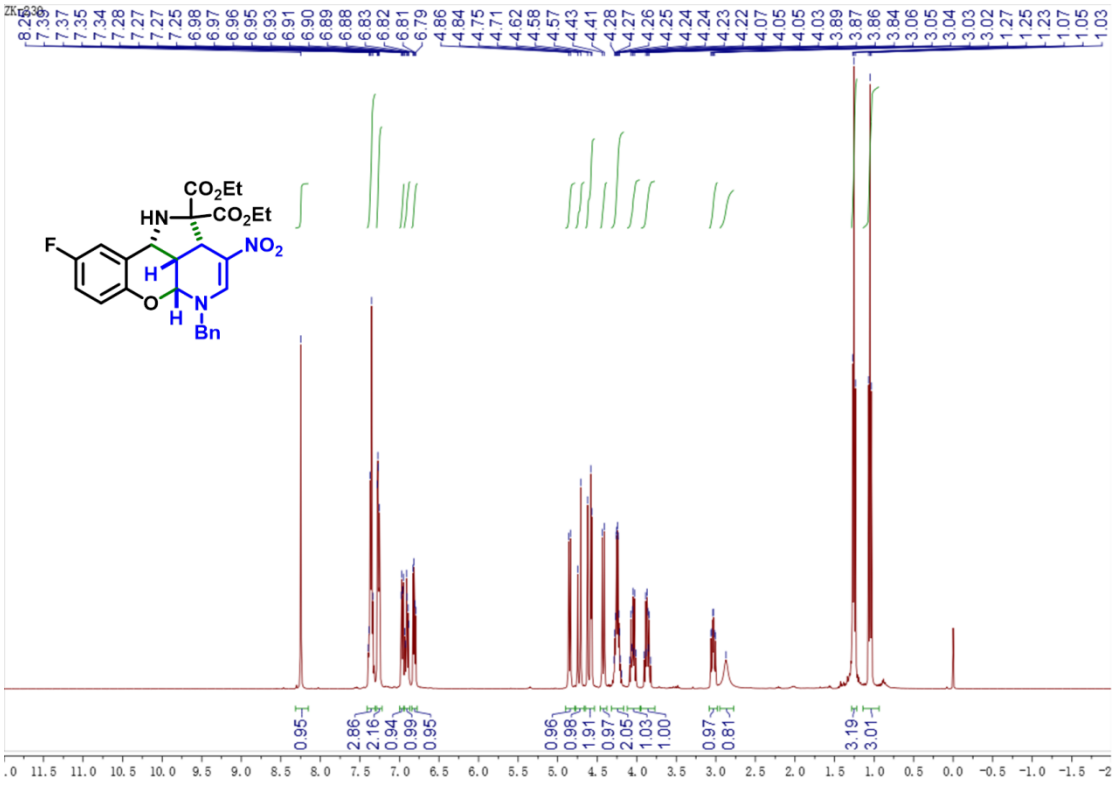
^{1}H NMR spectrum of **3j** (400 MHz, $CDCl_3$)



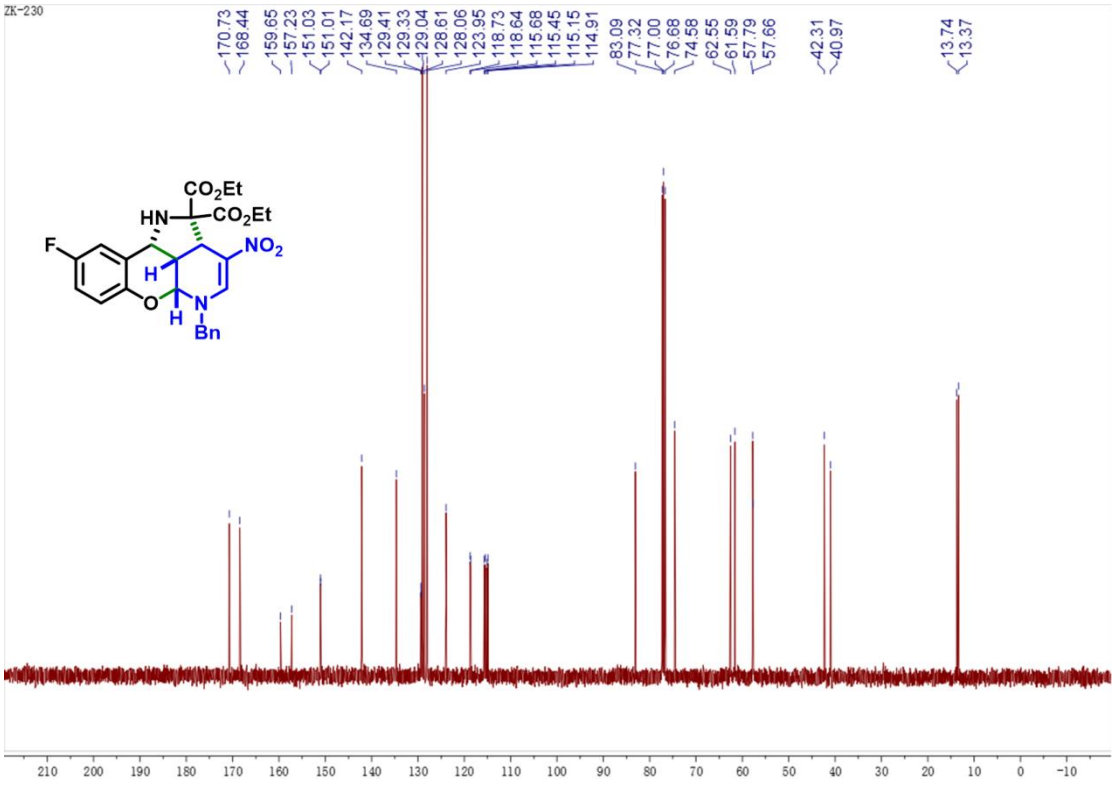
^{13}C NMR spectrum of **3j** (100 MHz, $CDCl_3$)



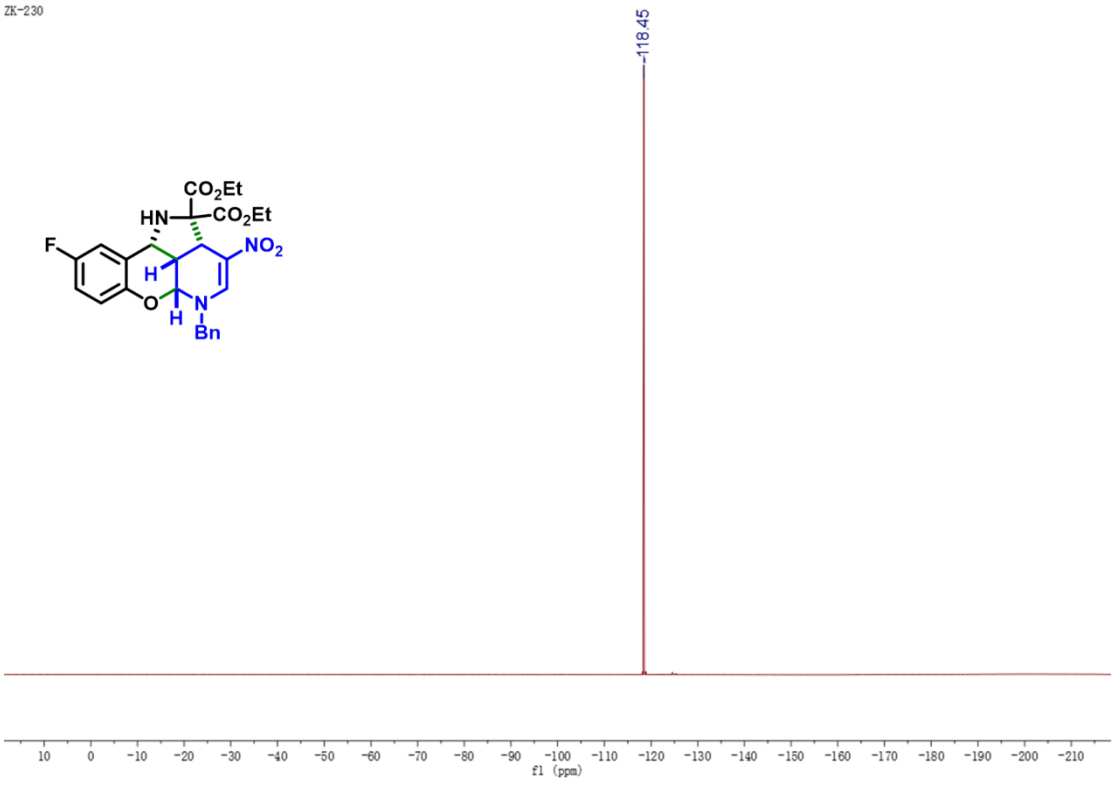
^{1}H NMR spectrum of **3k** (400 MHz, $CDCl_3$)



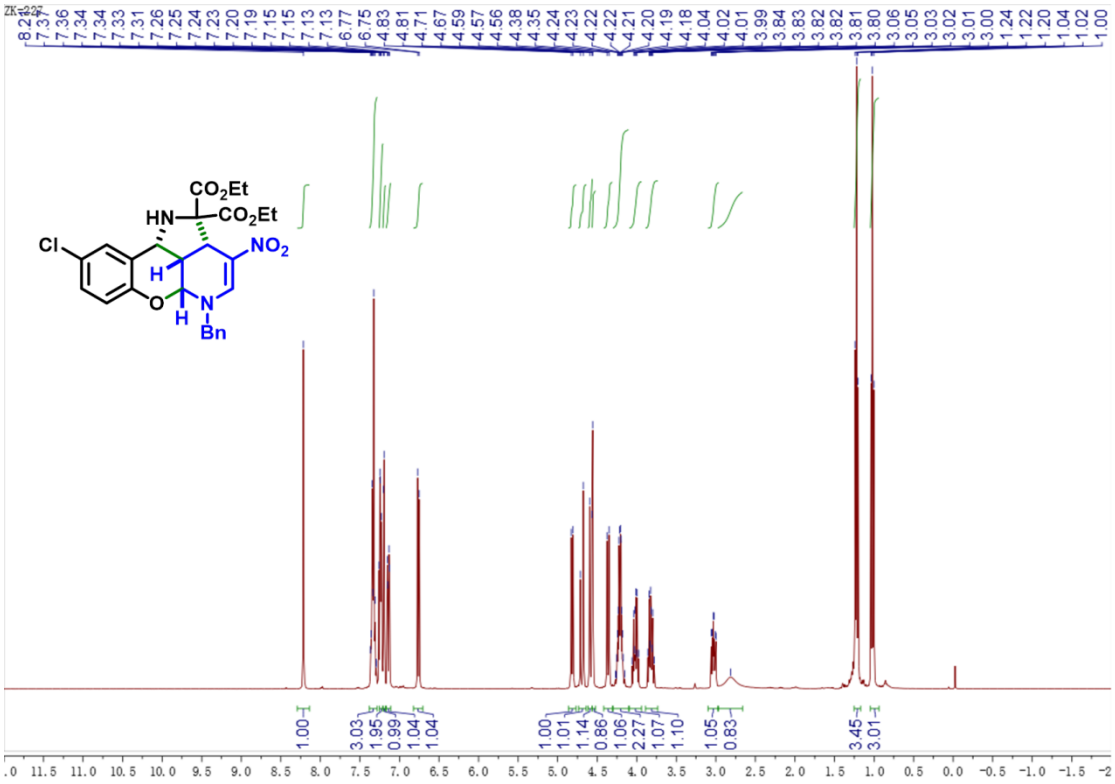
^{13}C NMR spectrum of **3k** (100 MHz, $CDCl_3$)



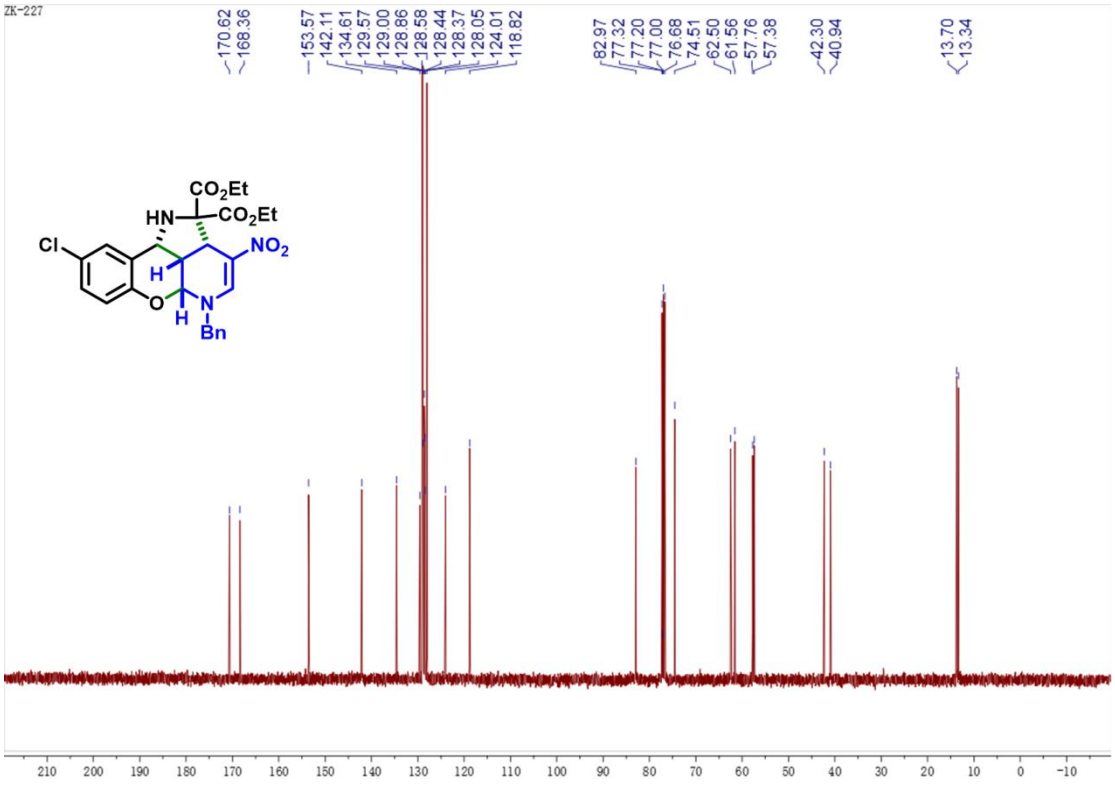
^{19}F NMR spectrum of **3k** (375 MHz, $CDCl_3$)



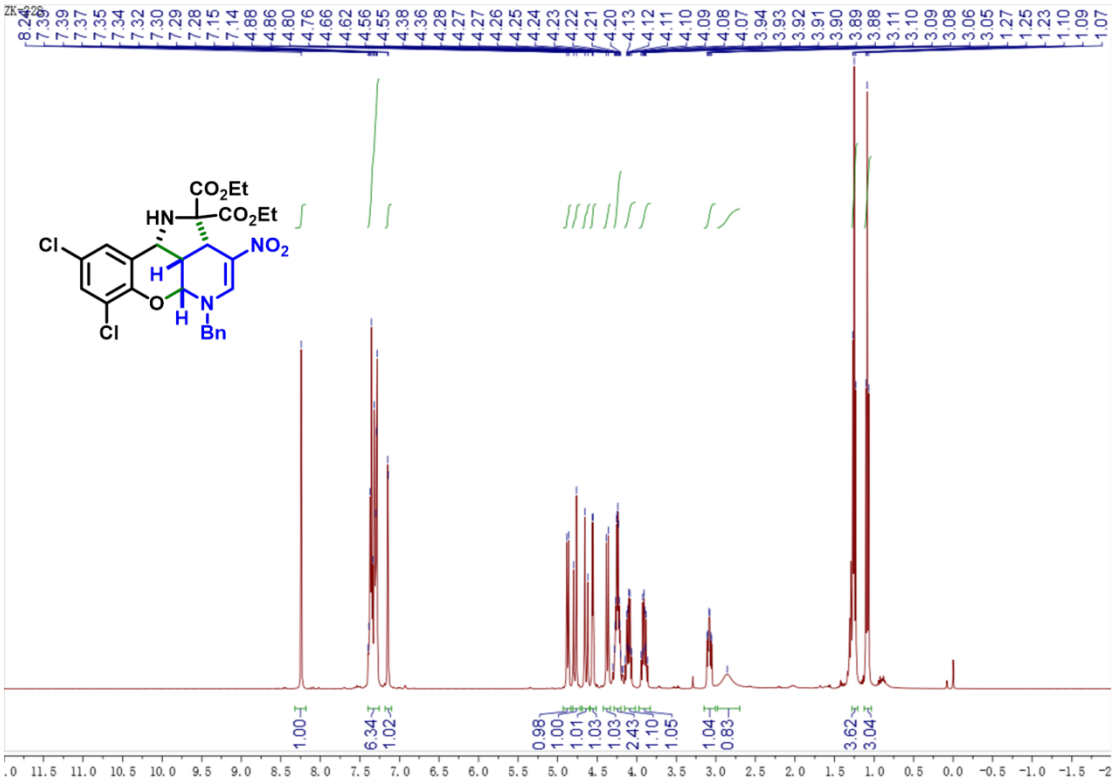
^{1}H NMR spectrum of **3l** (400 MHz, $CDCl_3$)



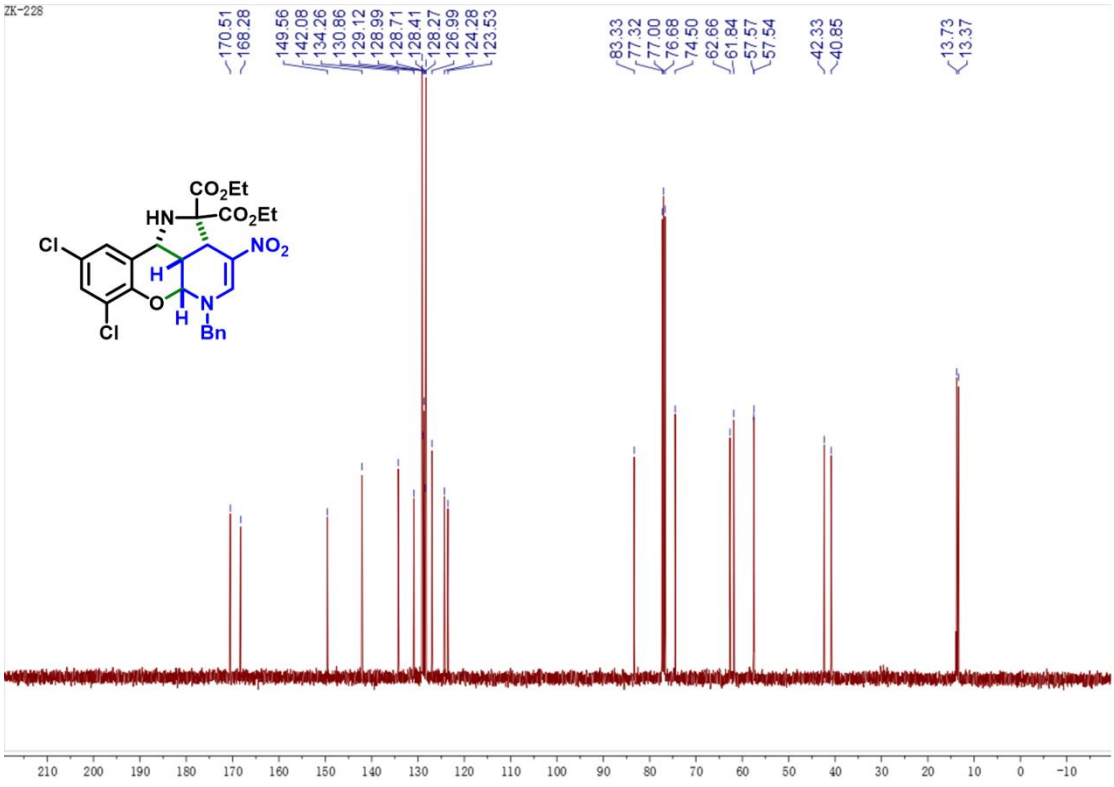
^{13}C NMR spectrum of **3l** (100 MHz, $CDCl_3$)



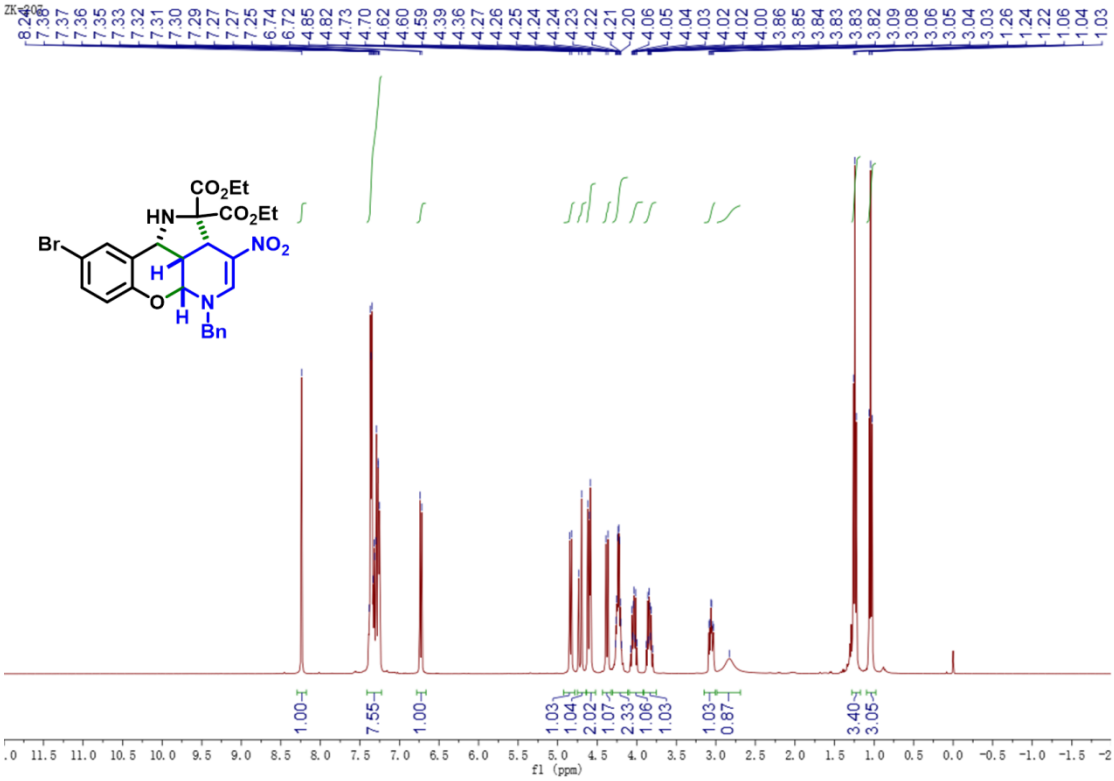
^{1}H NMR spectrum of **3m** (400 MHz, $CDCl_3$)



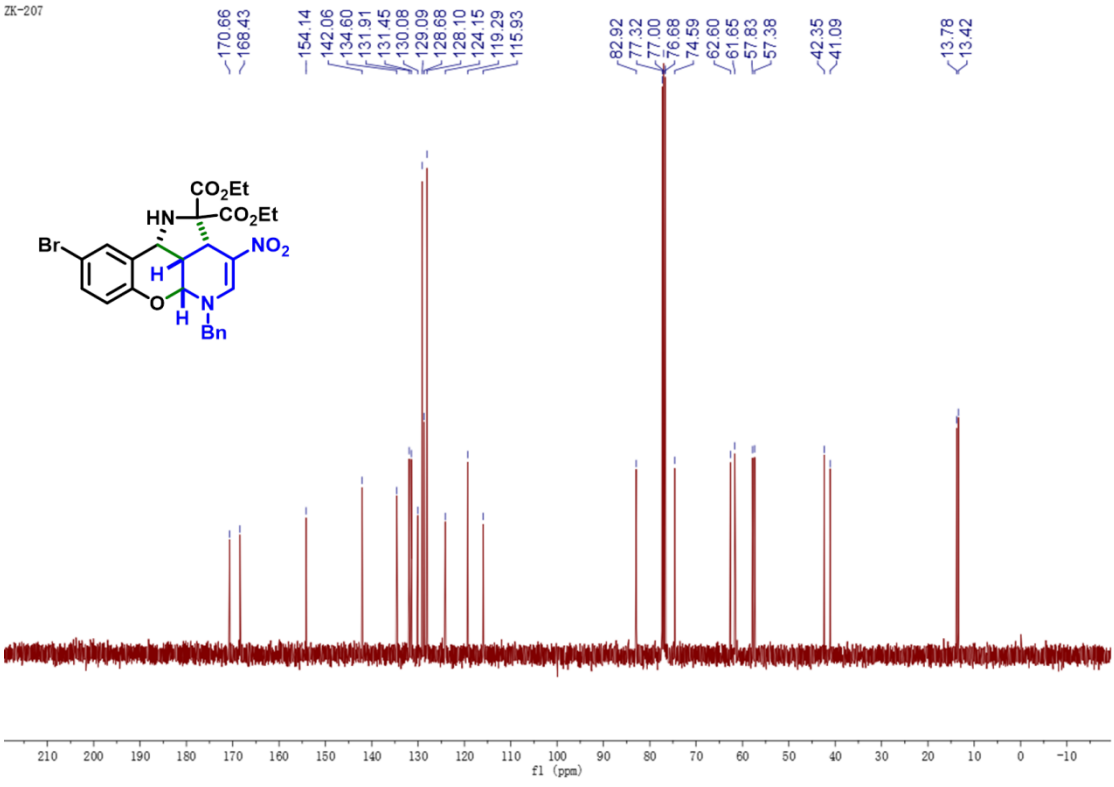
^{13}C NMR spectrum of **3m** (100 MHz, $CDCl_3$)



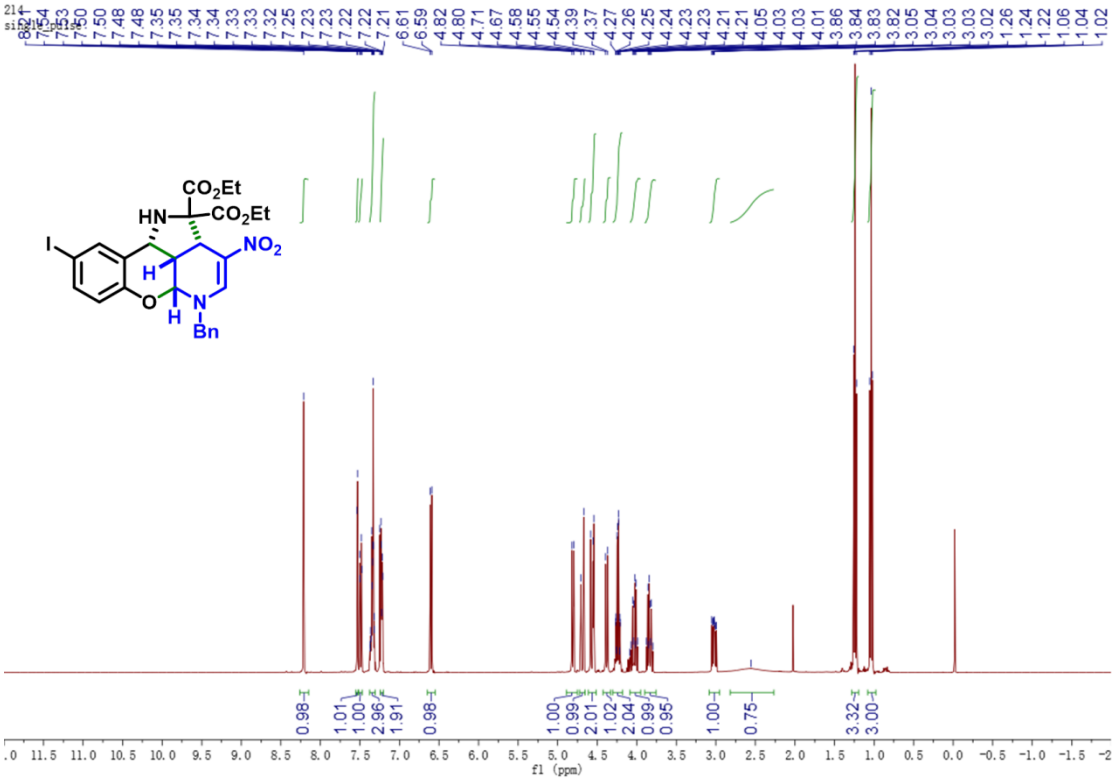
^{1}H NMR spectrum of **3n** (400 MHz, $CDCl_3$)



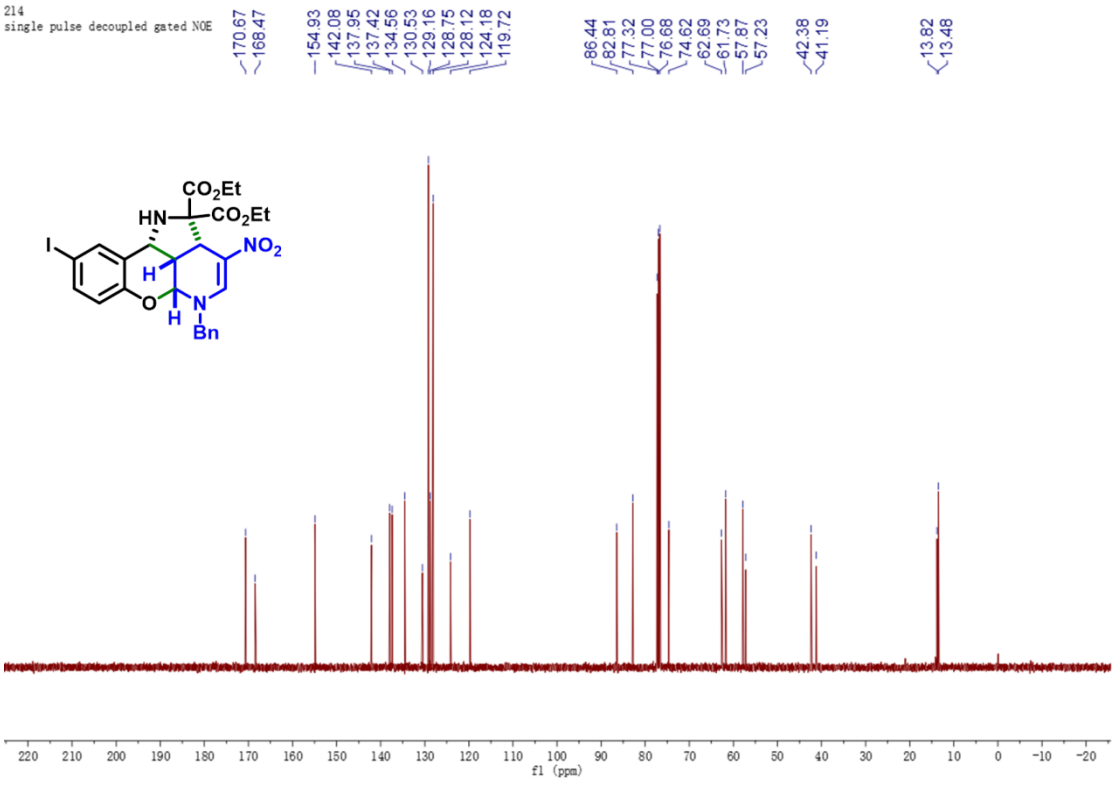
^{13}C NMR spectrum of **3n** (100 MHz, $CDCl_3$)



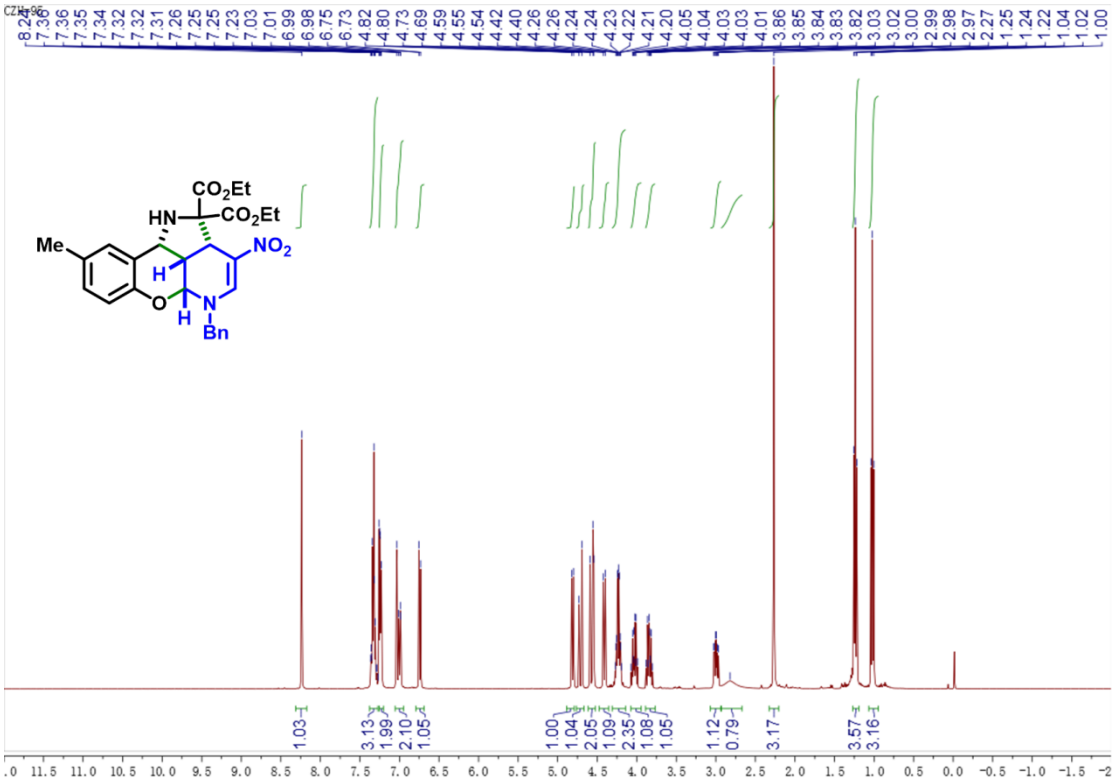
^{1}H NMR spectrum of **3o** (400 MHz, $CDCl_3$)



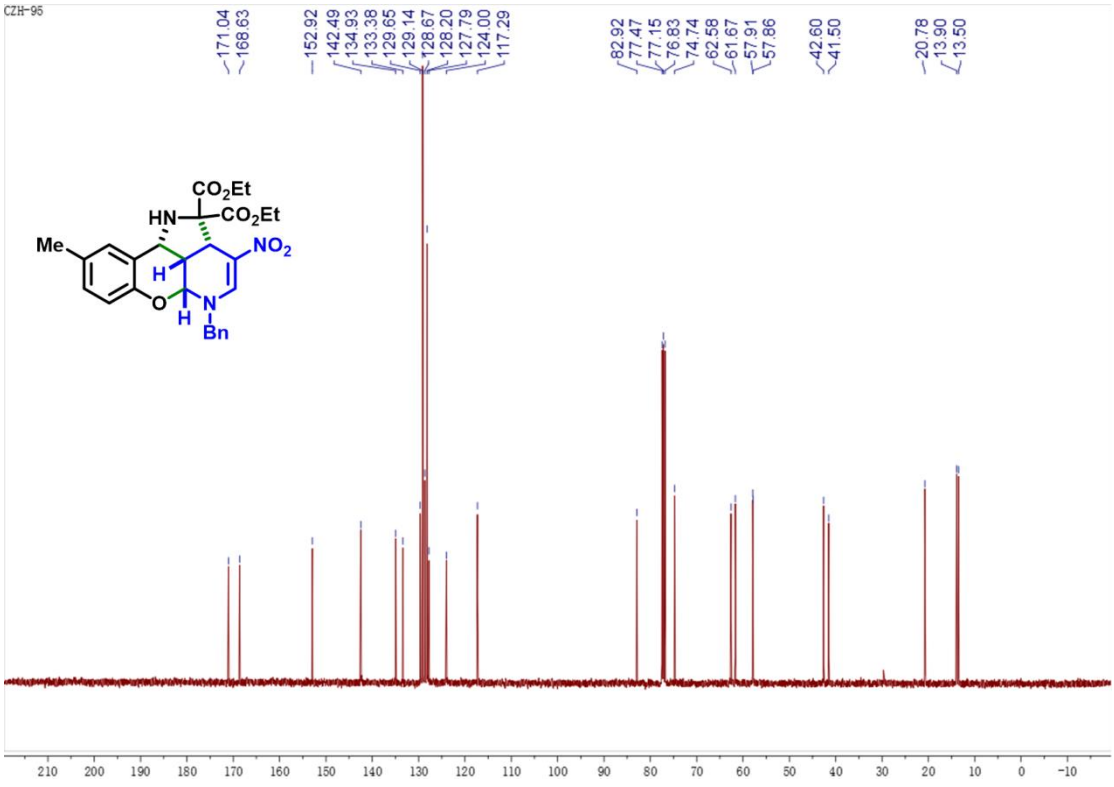
^{13}C NMR spectrum of **3o** (100 MHz, $CDCl_3$)



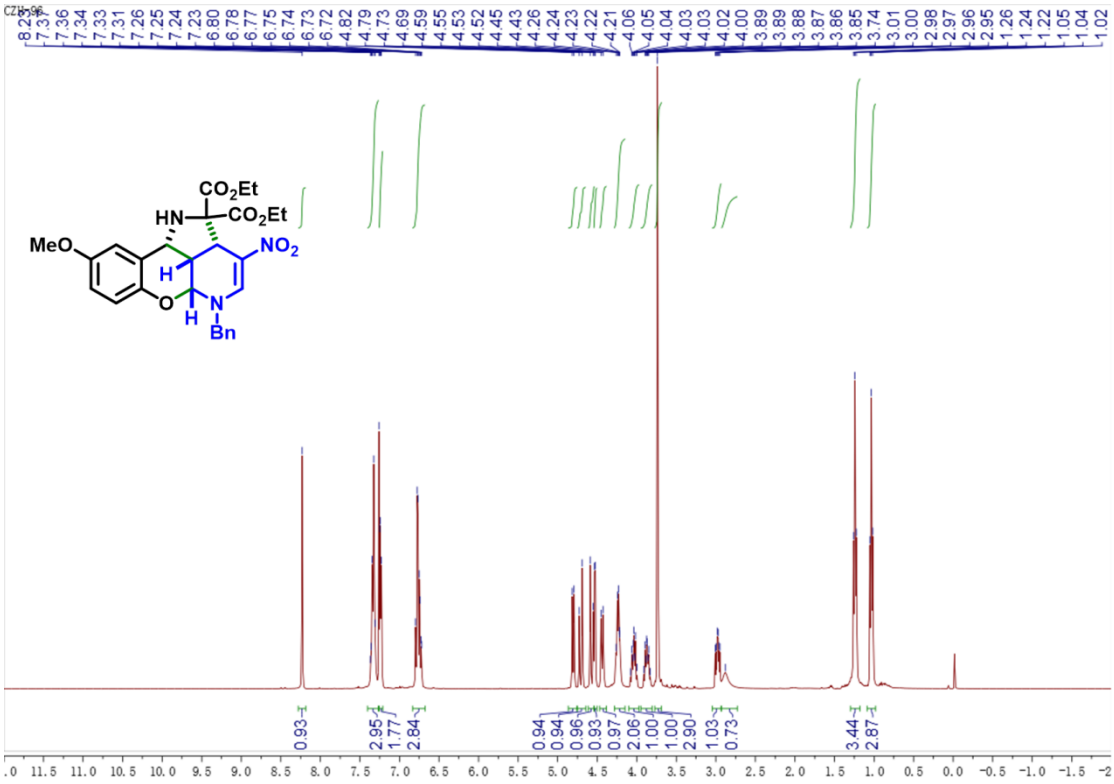
^{1}H NMR spectrum of **3p** (400 MHz, $CDCl_3$)



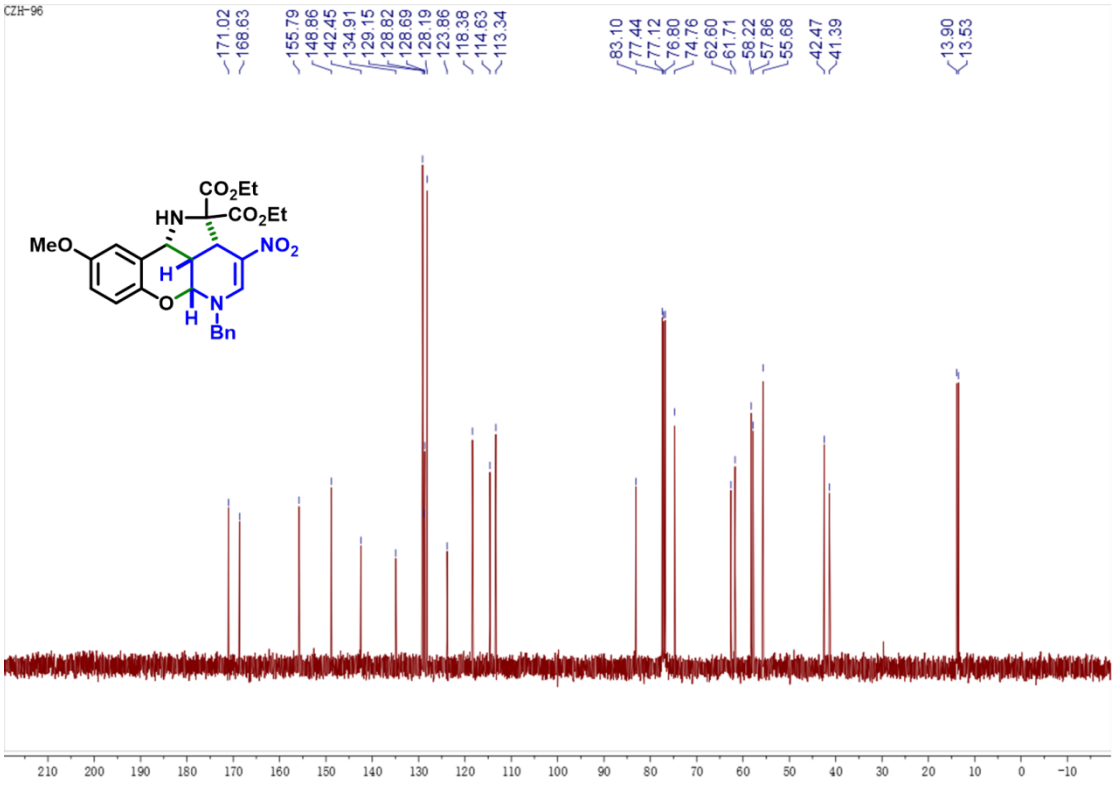
^{13}C NMR spectrum of **3p** (100 MHz, $CDCl_3$)



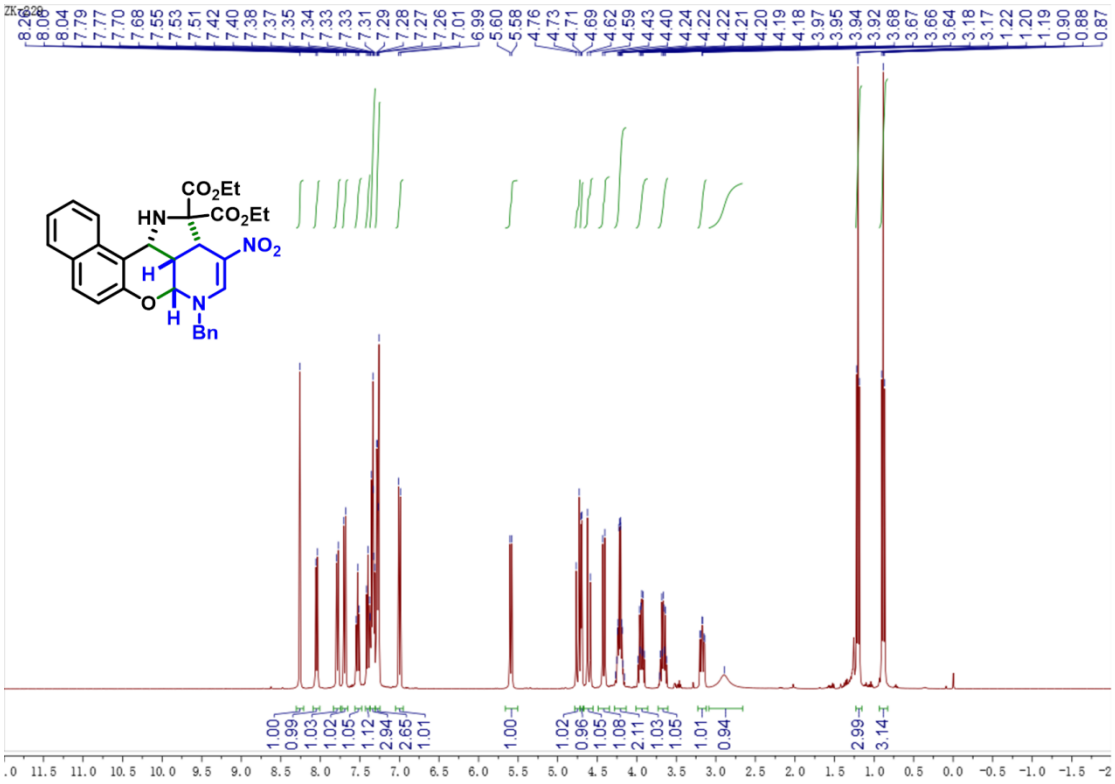
^{1}H NMR spectrum of **3q** (400 MHz, $CDCl_3$)



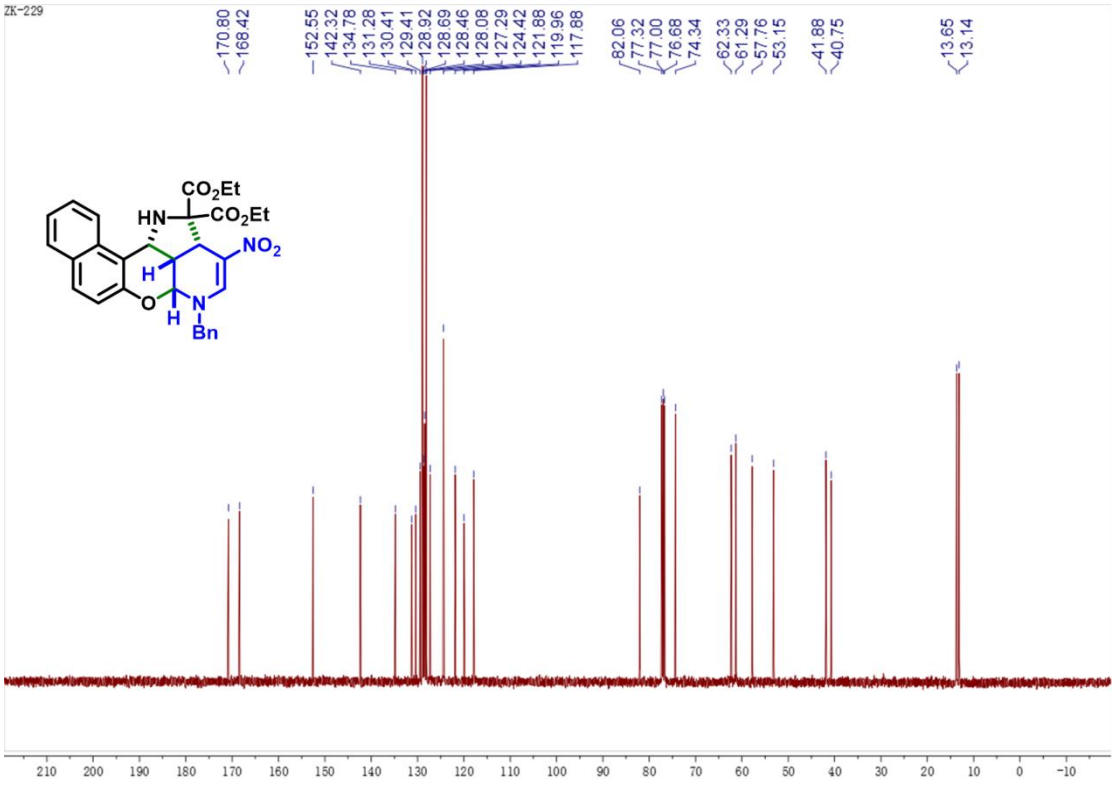
^{13}C NMR spectrum of **3q** (100 MHz, $CDCl_3$)



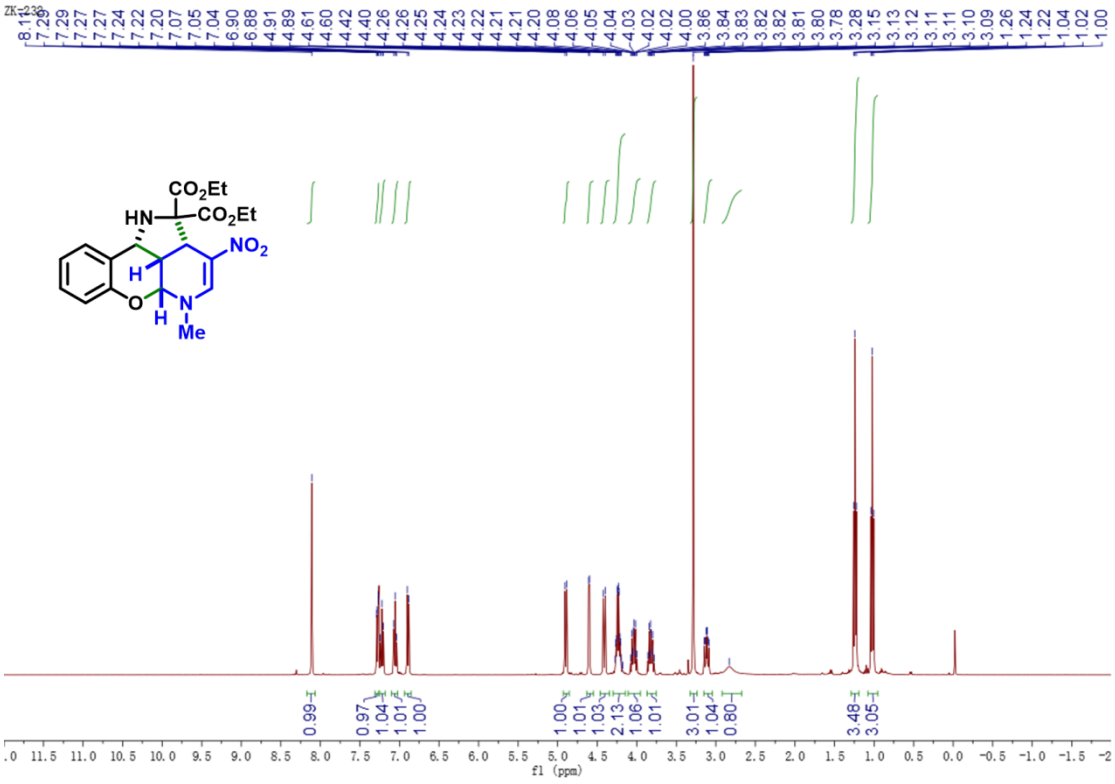
^{1}H NMR spectrum of **3r** (400 MHz, $CDCl_3$)



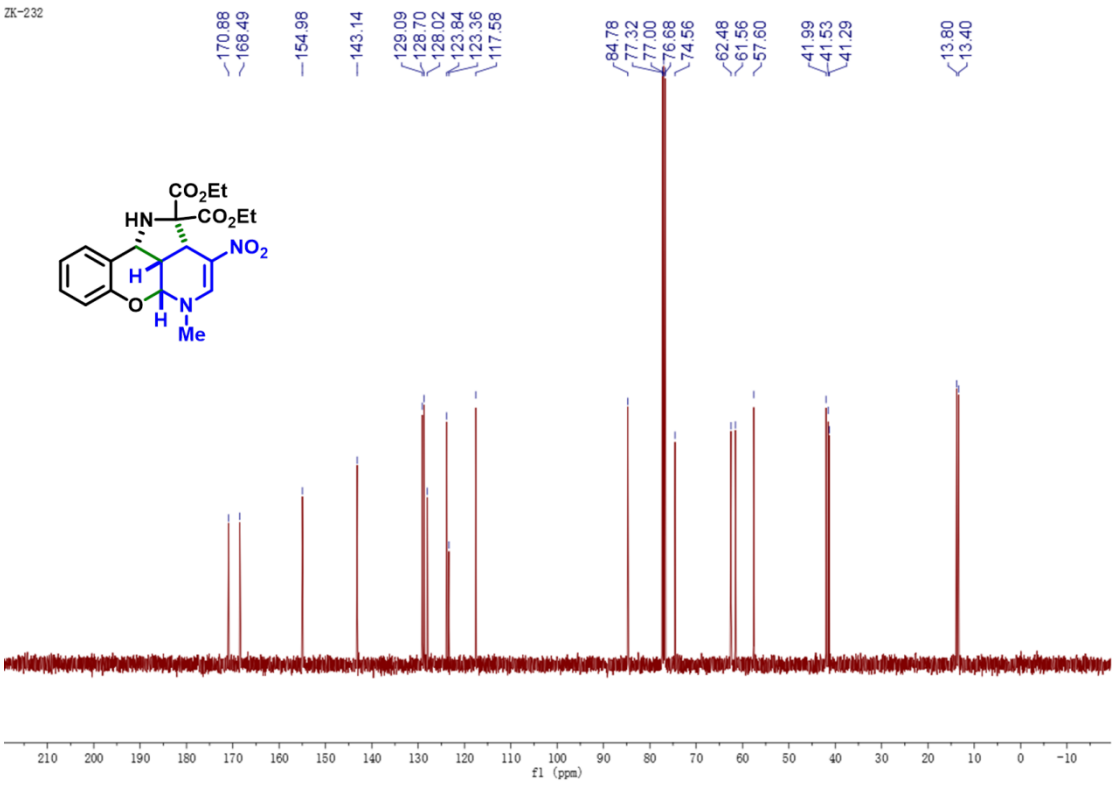
^{13}C NMR spectrum of **3r** (100 MHz, $CDCl_3$)



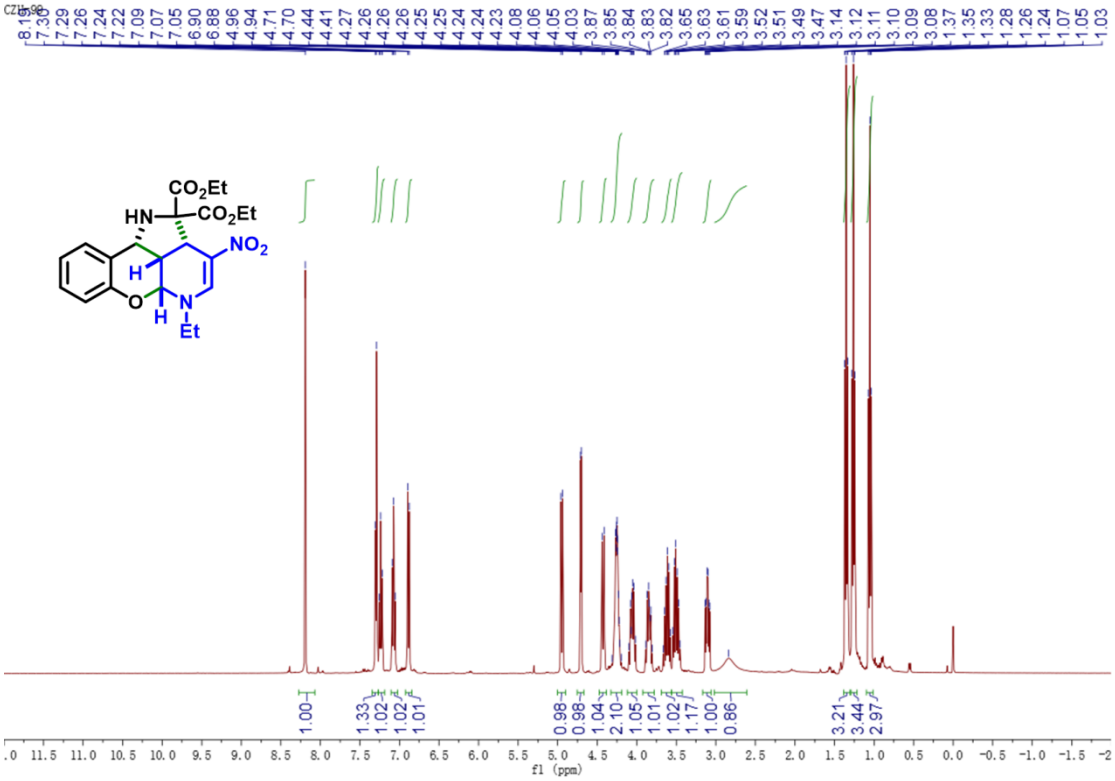
^{1}H NMR spectrum of **3s** (400 MHz, $CDCl_3$)



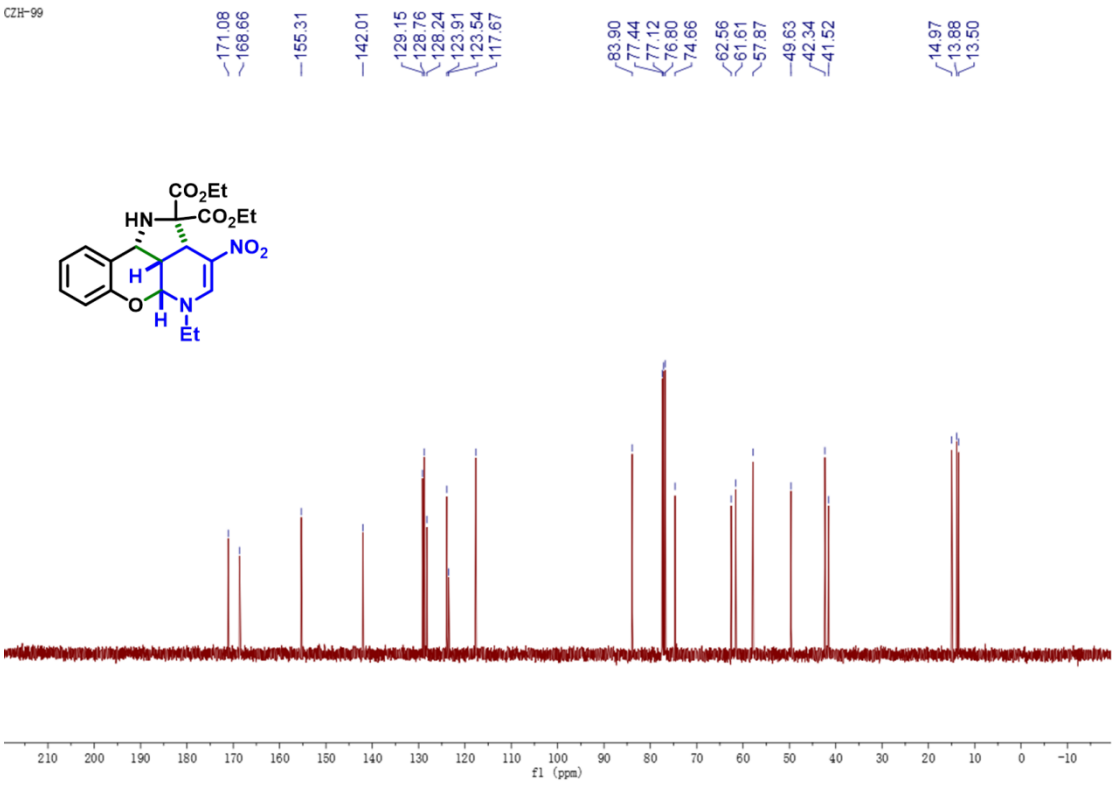
^{13}C NMR spectrum of **3s** (100 MHz, $CDCl_3$)



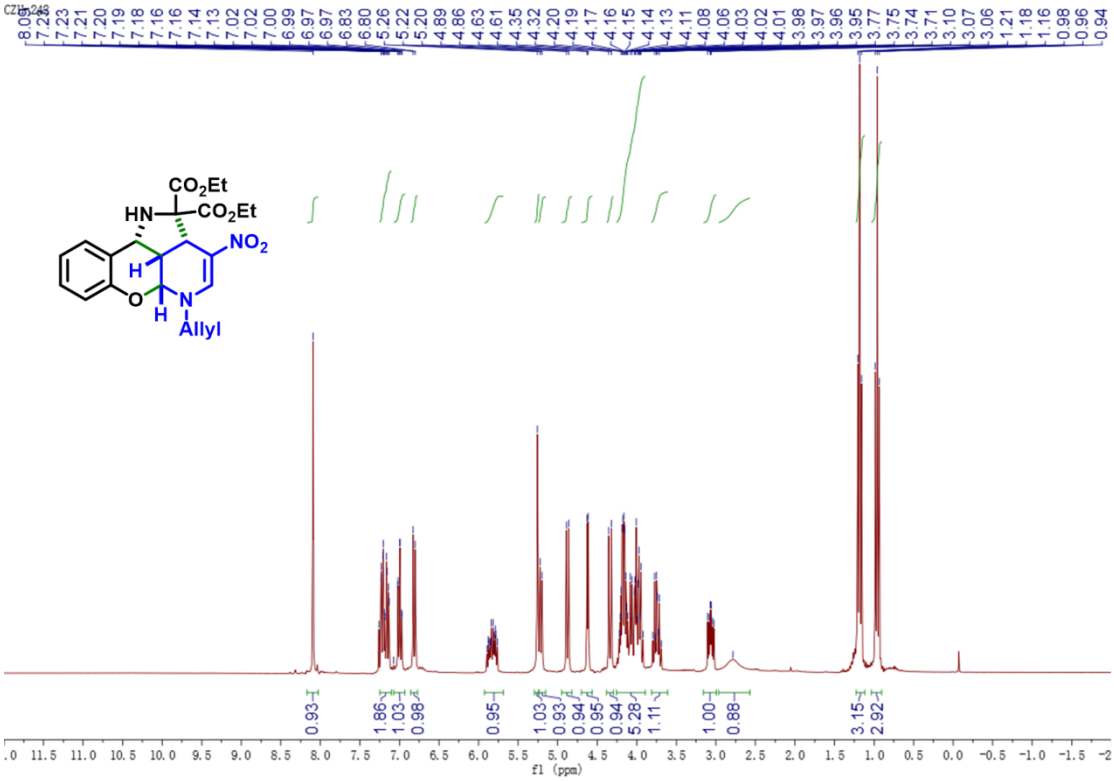
^{1}H NMR spectrum of **3t** (400 MHz, $CDCl_3$)



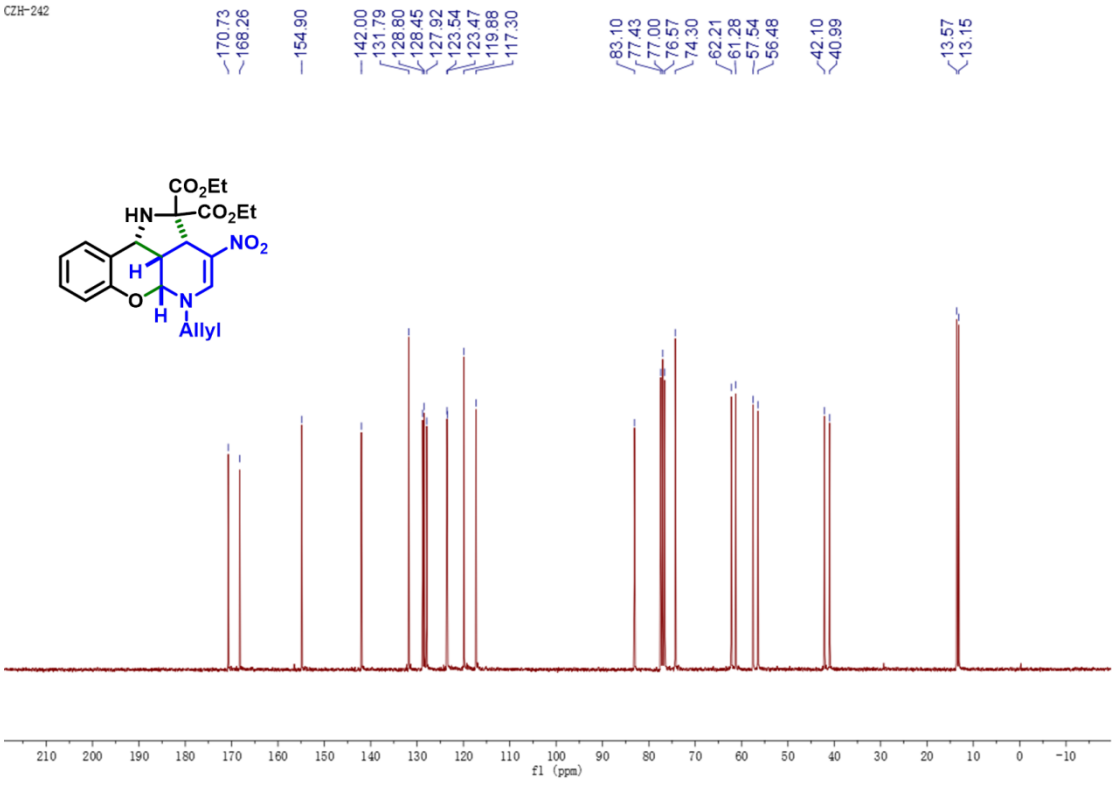
^{13}C NMR spectrum of **3t** (100 MHz, $CDCl_3$)



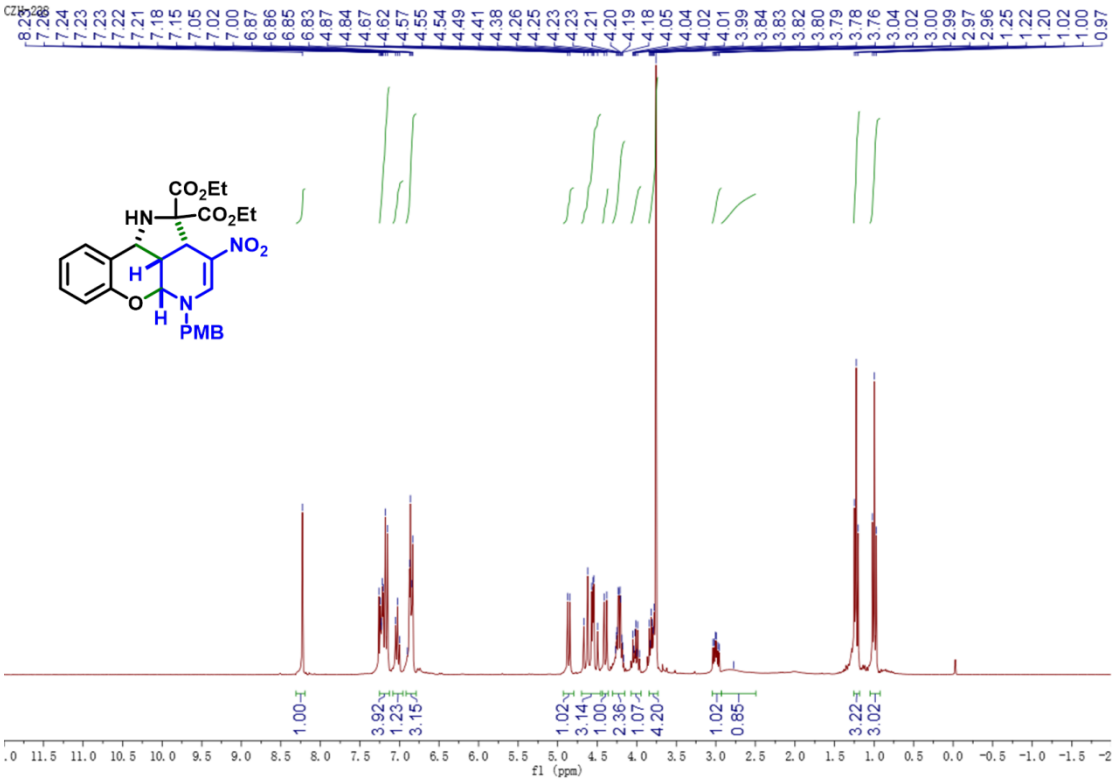
^{1}H NMR spectrum of **3u** (300 MHz, $CDCl_3$)



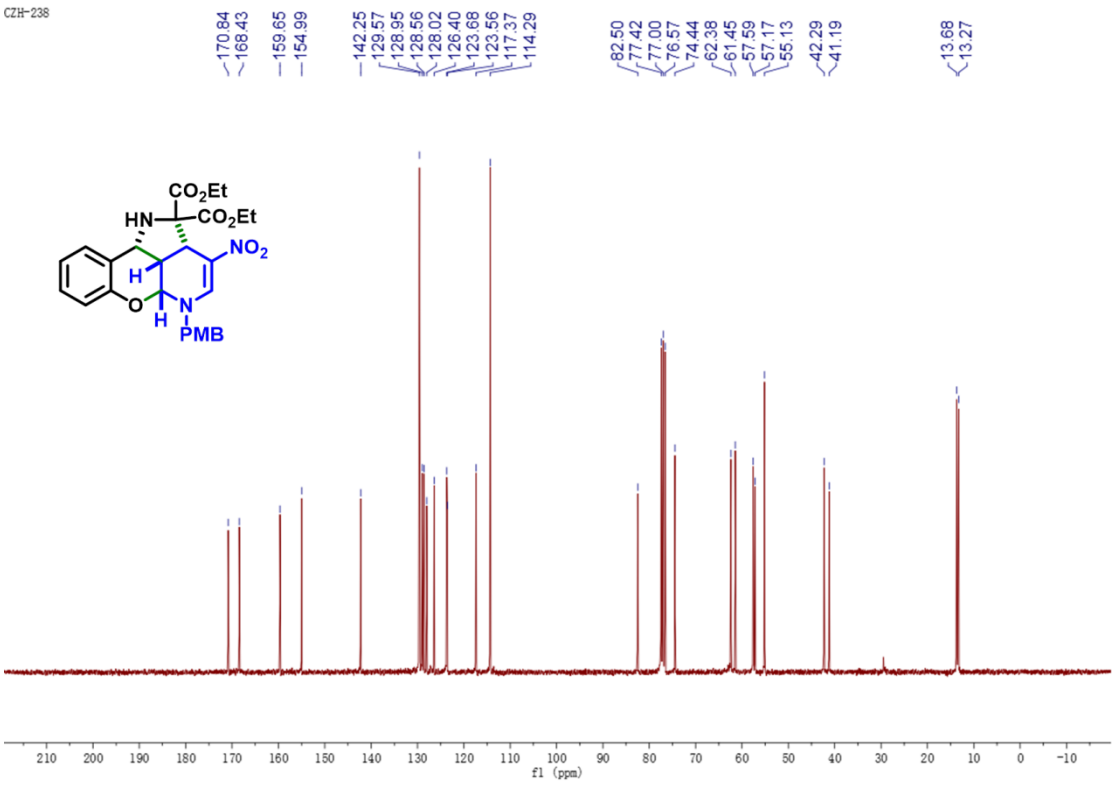
^{13}C NMR spectrum of **3u** (75 MHz, $CDCl_3$)



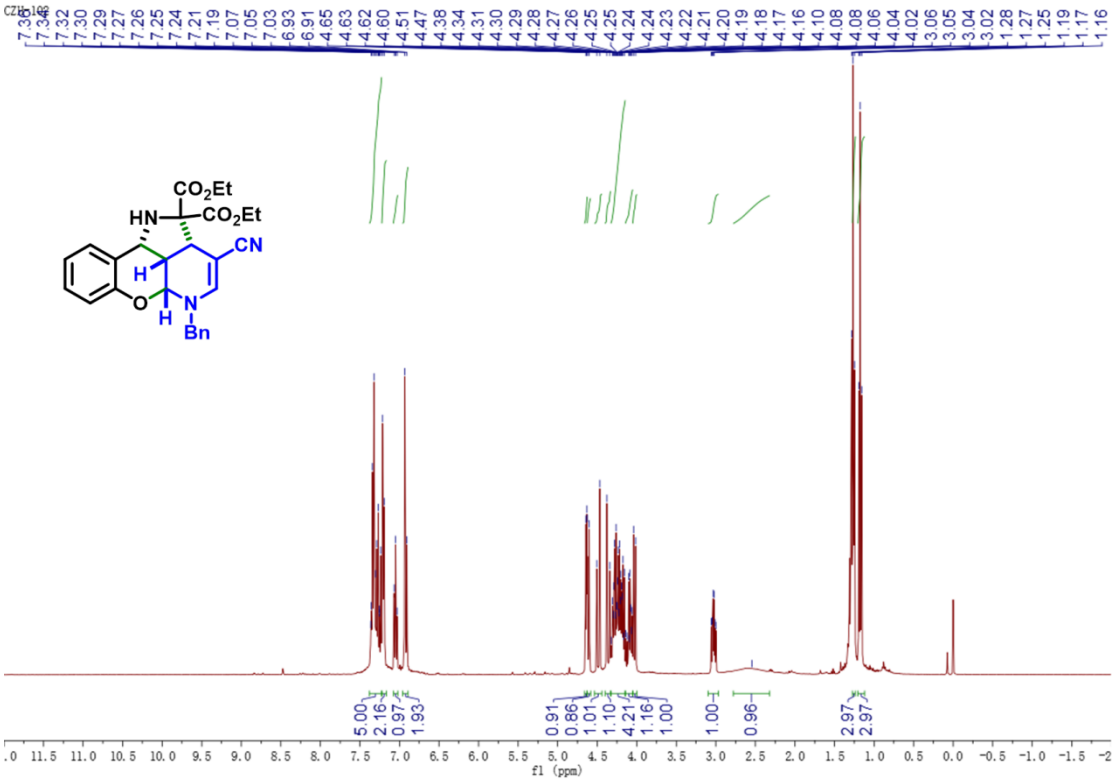
^{1}H NMR spectrum of **3v** (300 MHz, $CDCl_3$)



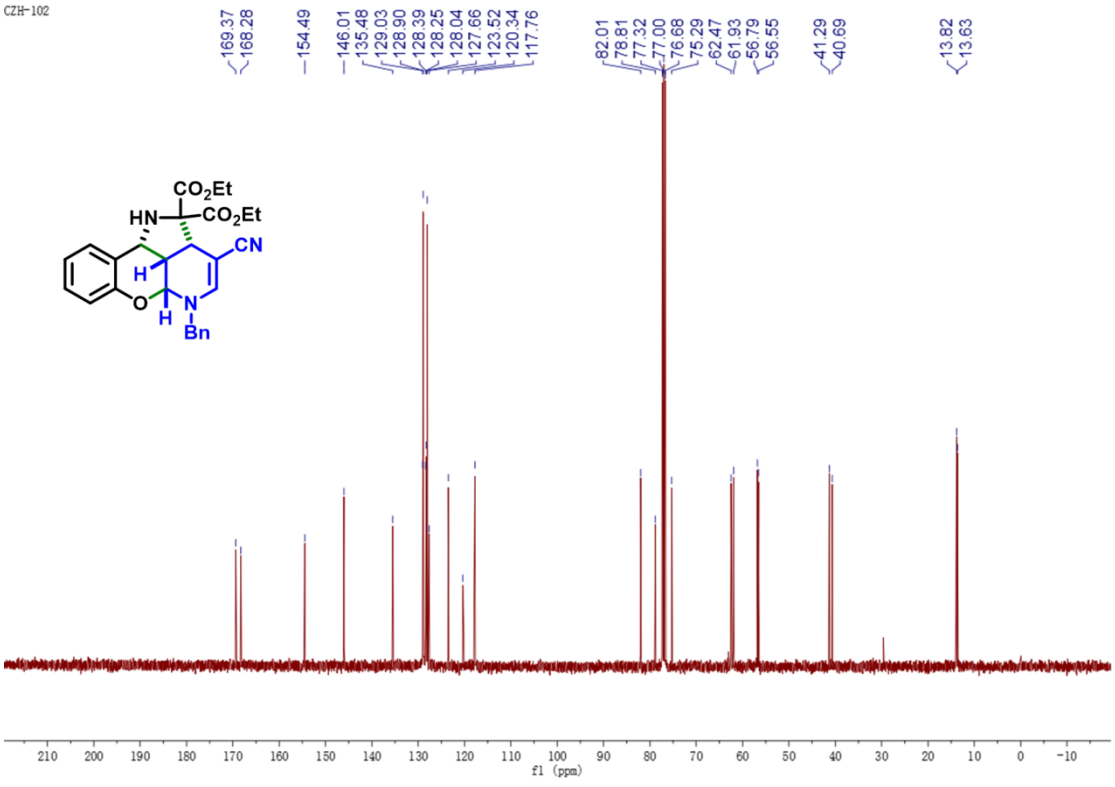
^{13}C NMR spectrum of **3v** (75 MHz, $CDCl_3$)



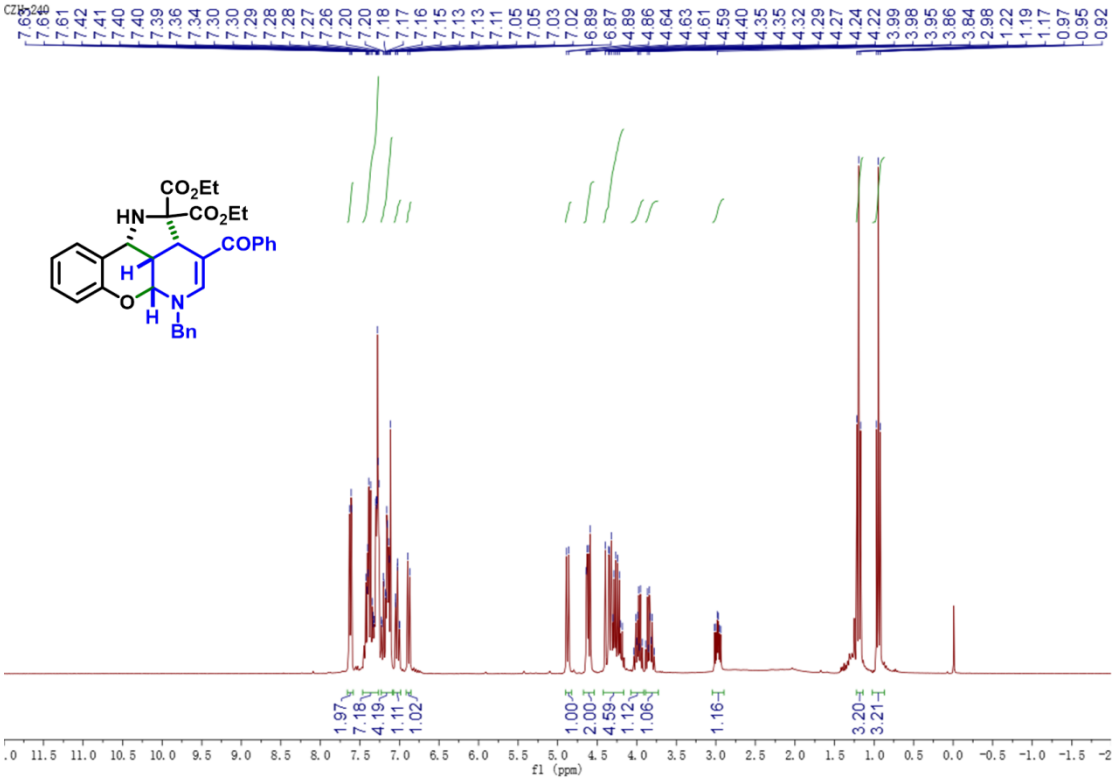
^{1}H NMR spectrum of **3w** (300 MHz, $CDCl_3$)



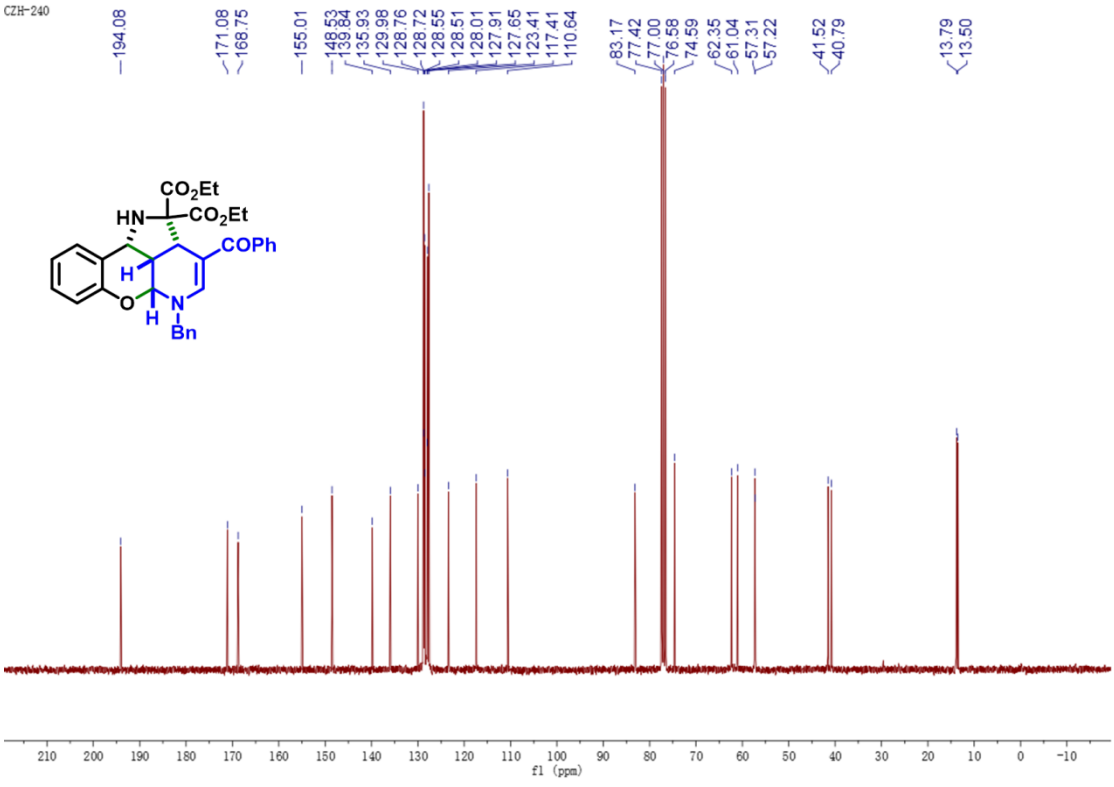
^{13}C NMR spectrum of **3w** (75 MHz, $CDCl_3$)



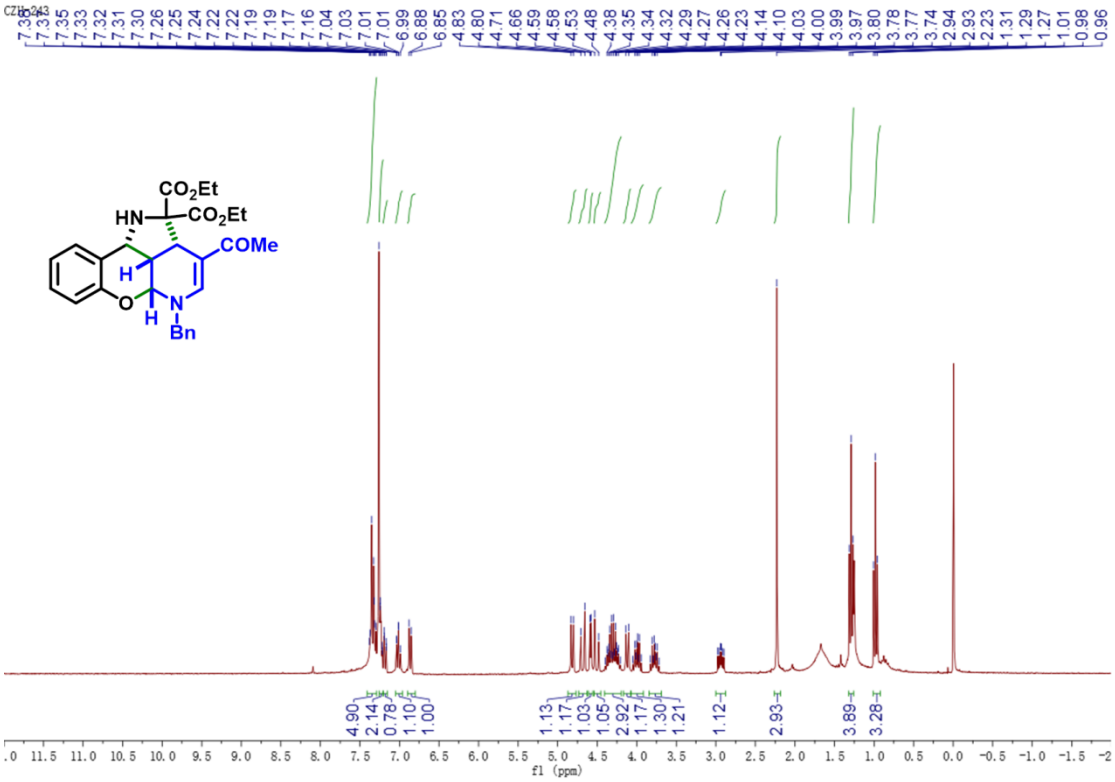
^{1}H NMR spectrum of **3x** (300 MHz, $CDCl_3$)



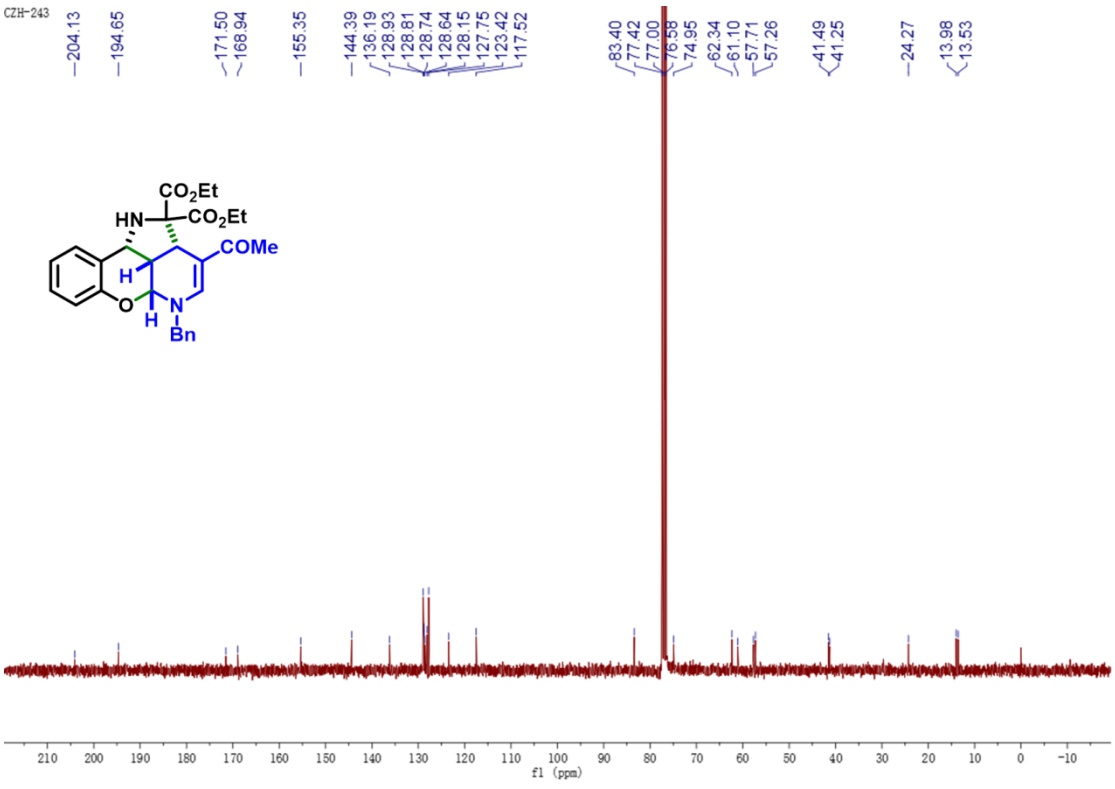
^{13}C NMR spectrum of **3x** (75 MHz, $CDCl_3$)



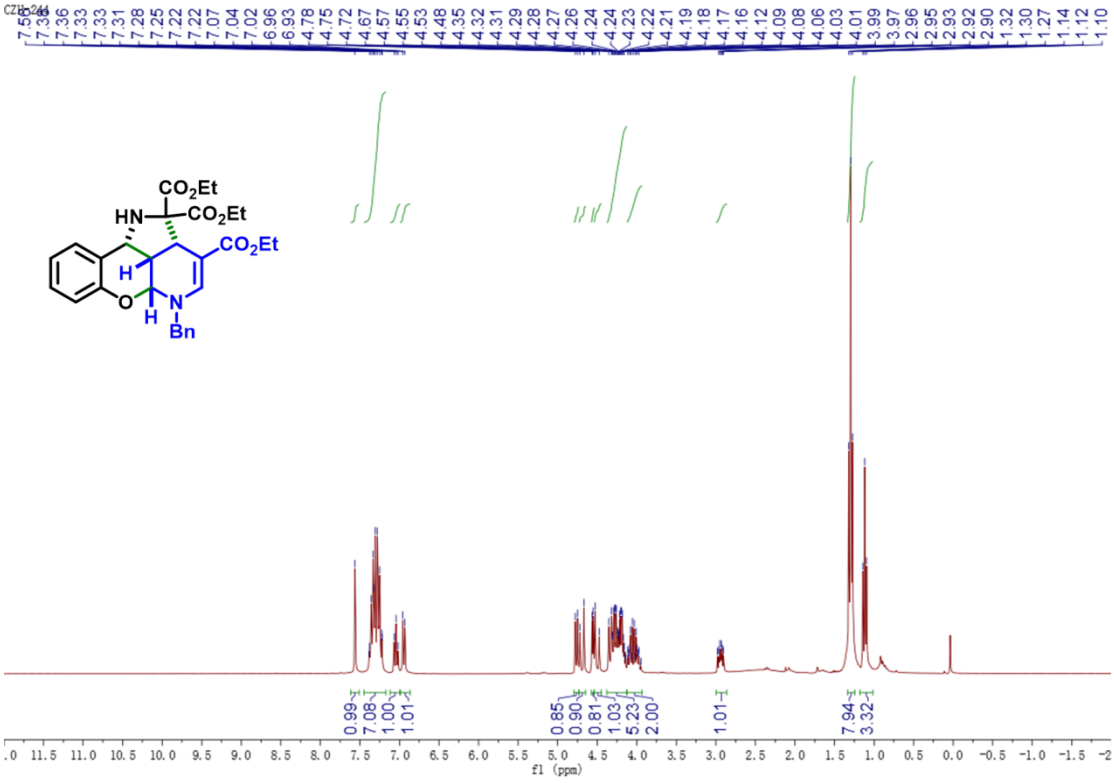
^{1}H NMR spectrum of **3y** (300 MHz, $CDCl_3$)



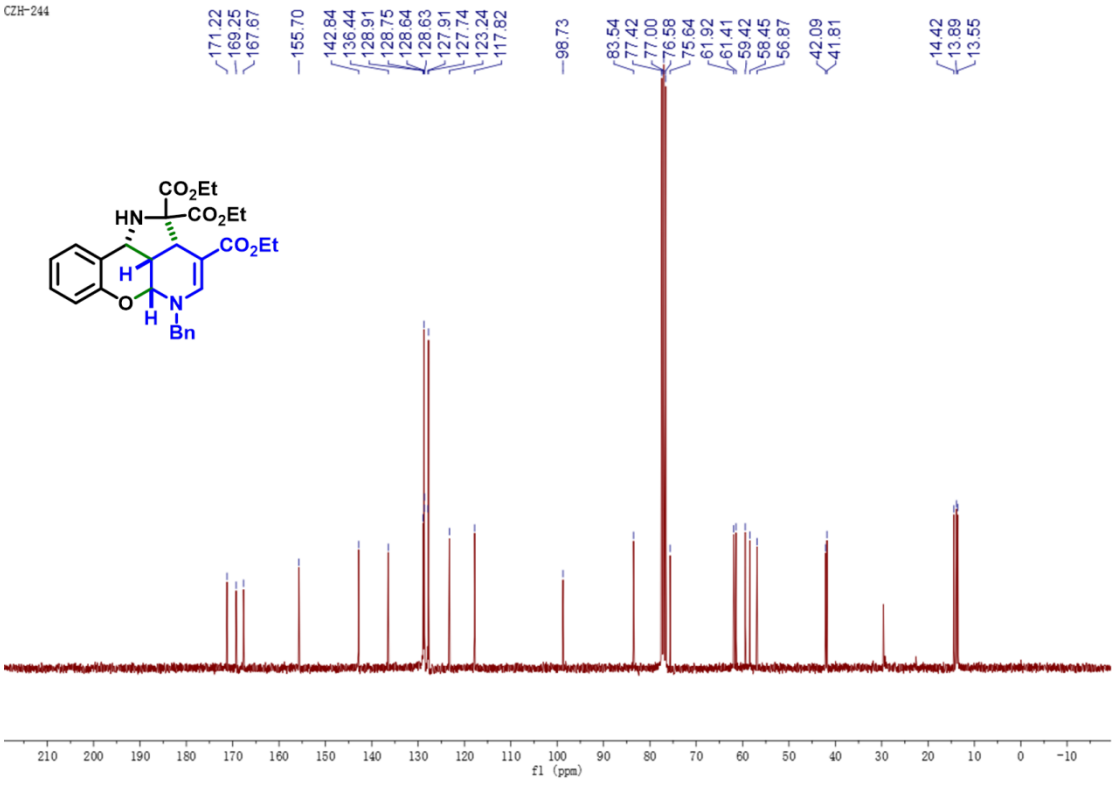
^{13}C NMR spectrum of **3y** (75 MHz, $CDCl_3$)



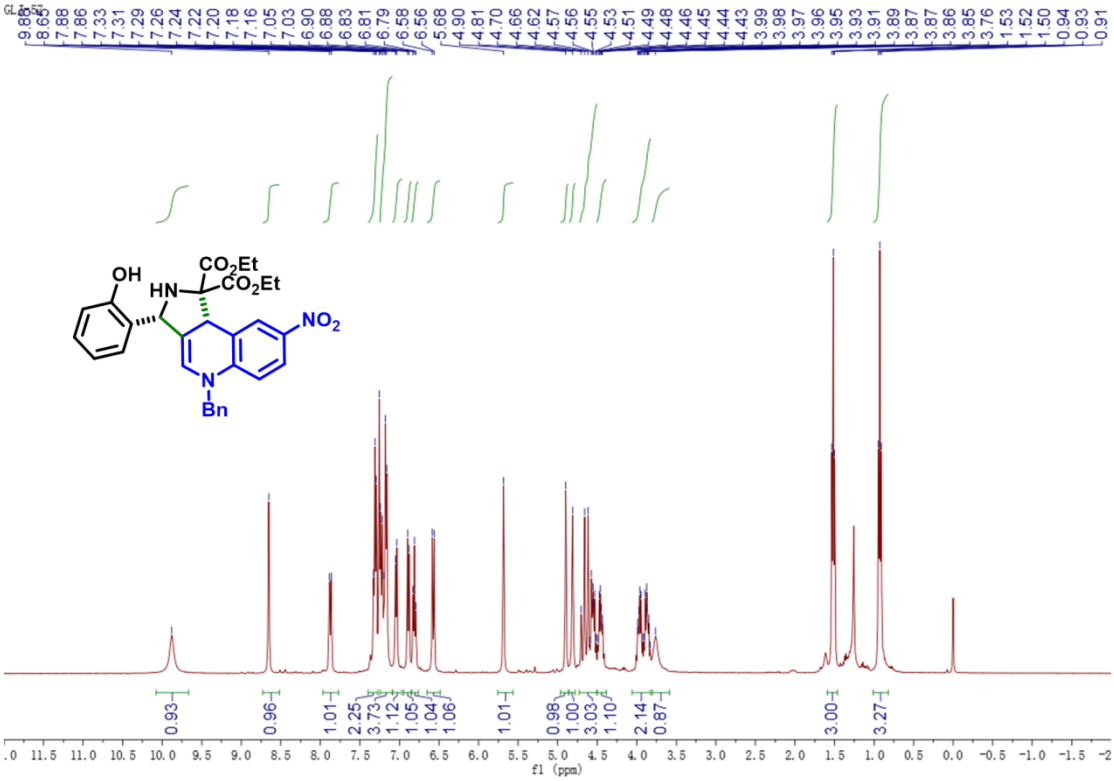
^{1}H NMR spectrum of **3z** (300 MHz, $CDCl_3$)



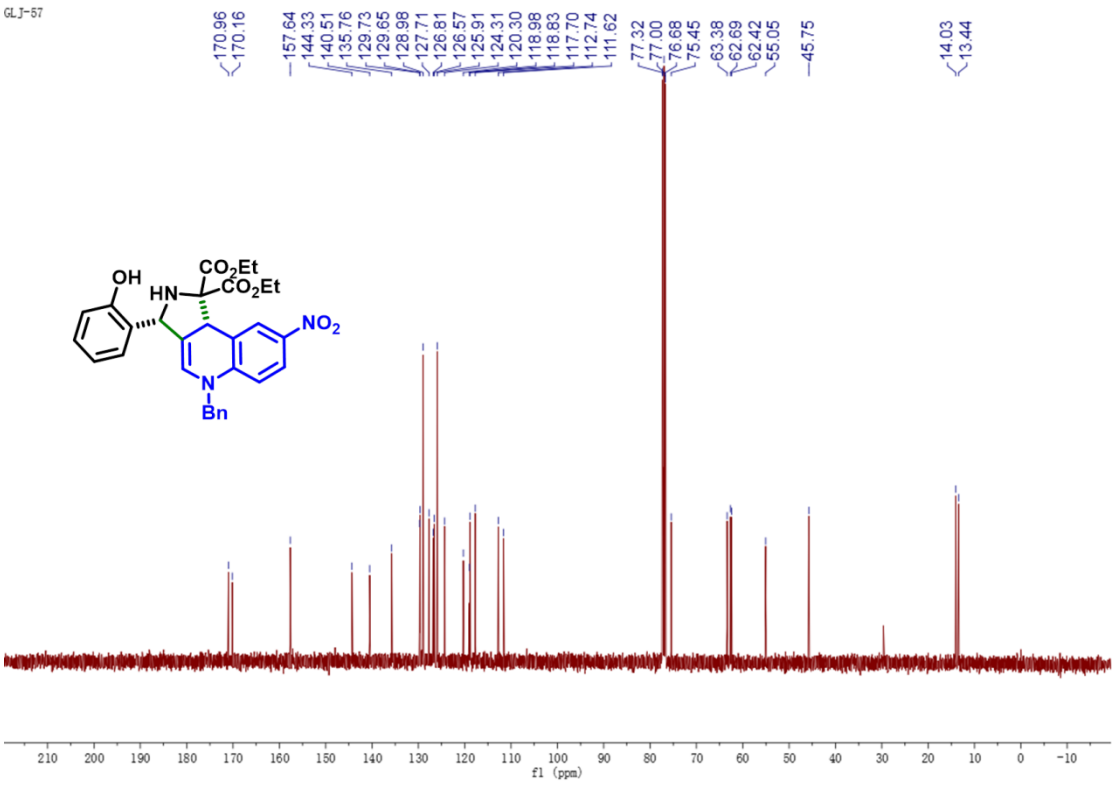
^{13}C NMR spectrum of **3z** (75 MHz, $CDCl_3$)



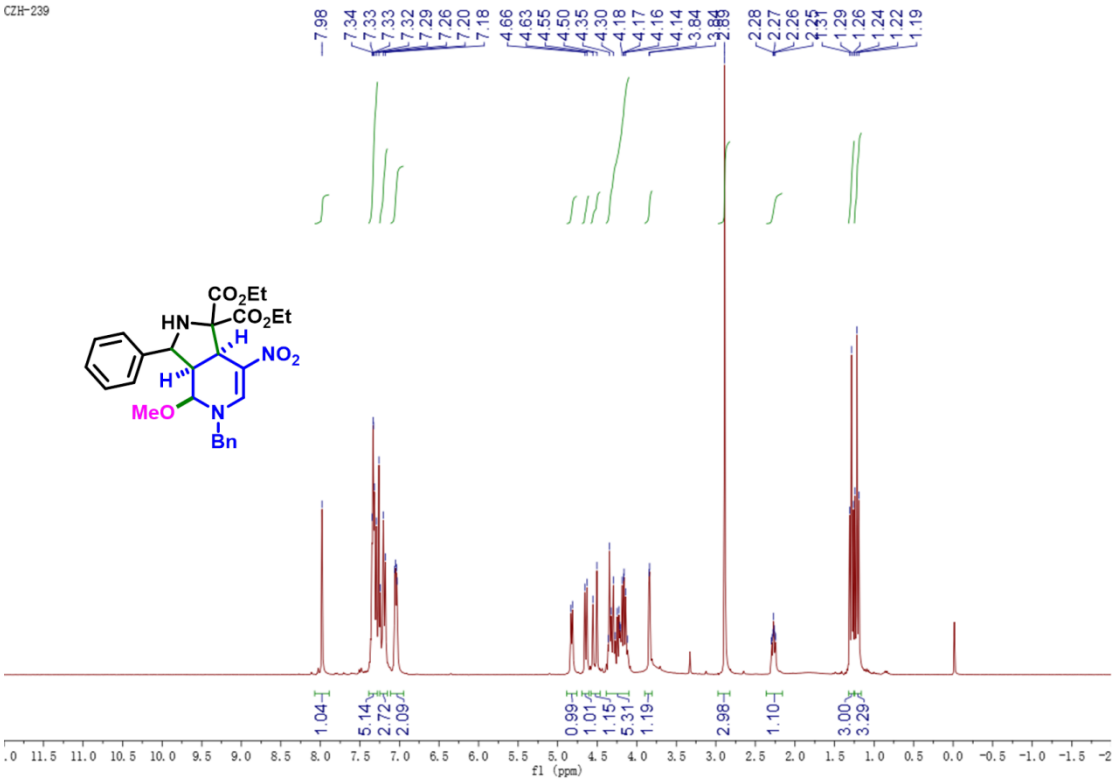
^{1}H NMR spectrum of **3aa** (400 MHz, $CDCl_3$)



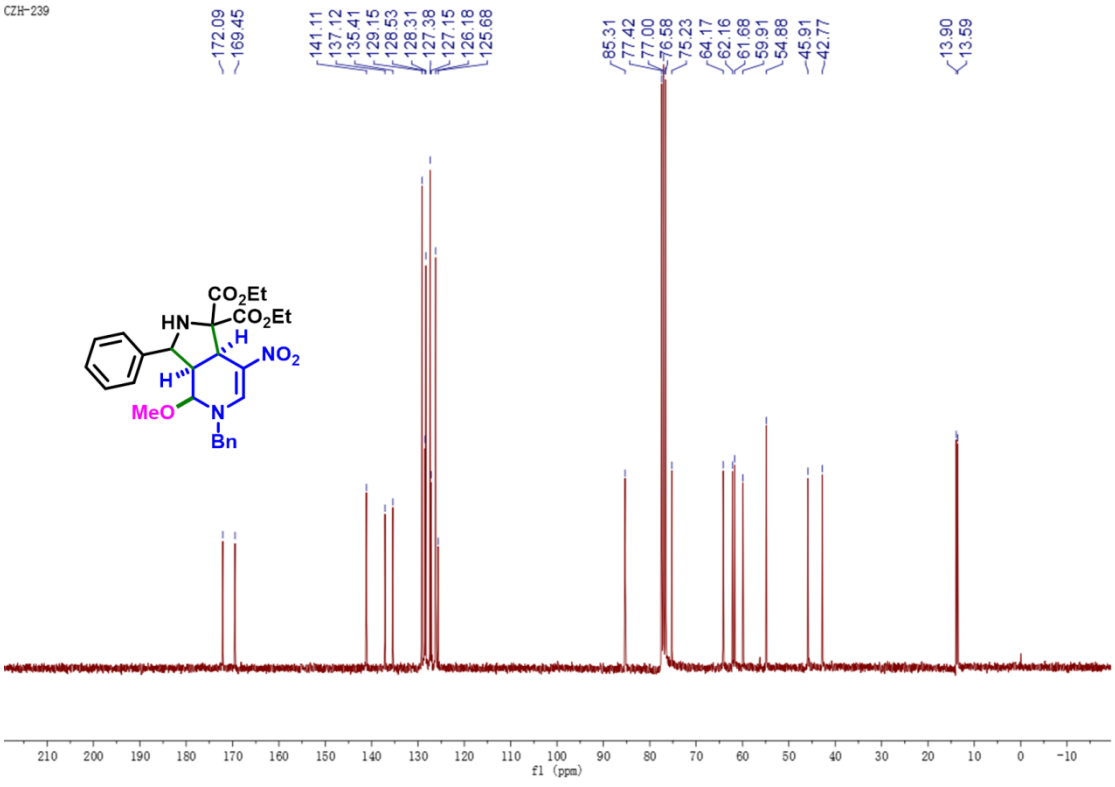
^{13}C NMR spectrum of **3aa** (100 MHz, $CDCl_3$)



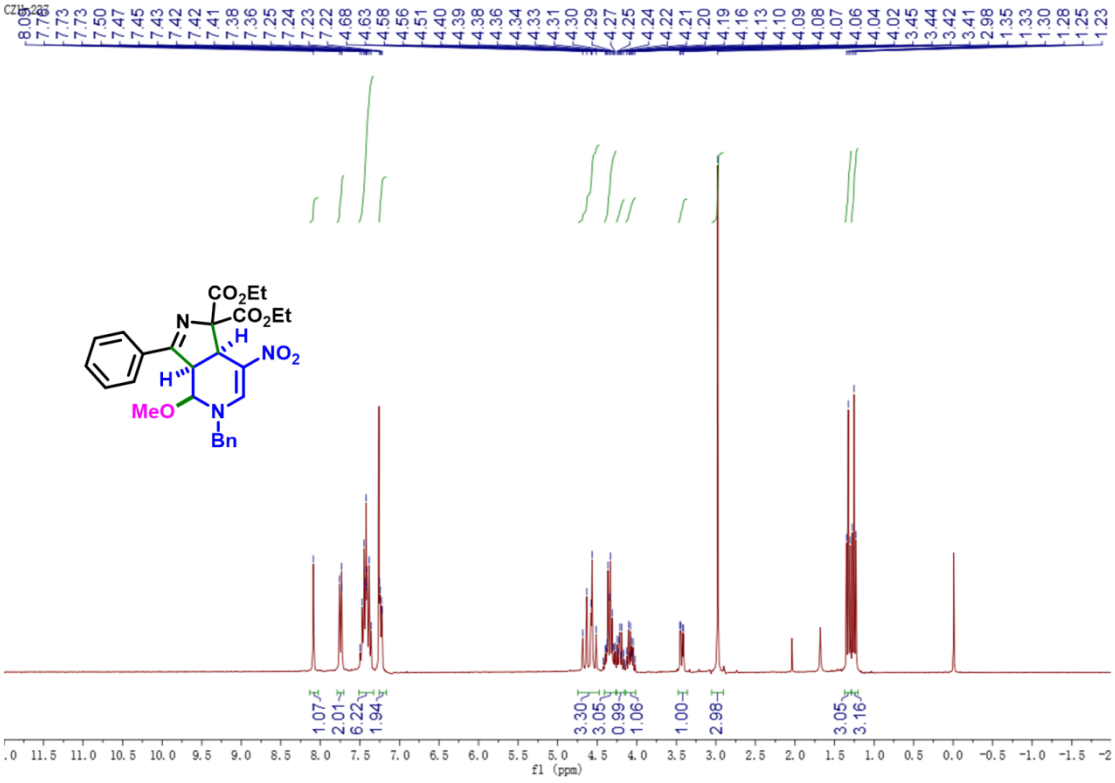
^{1}H NMR spectrum of **3ab** (300 MHz, $CDCl_3$)



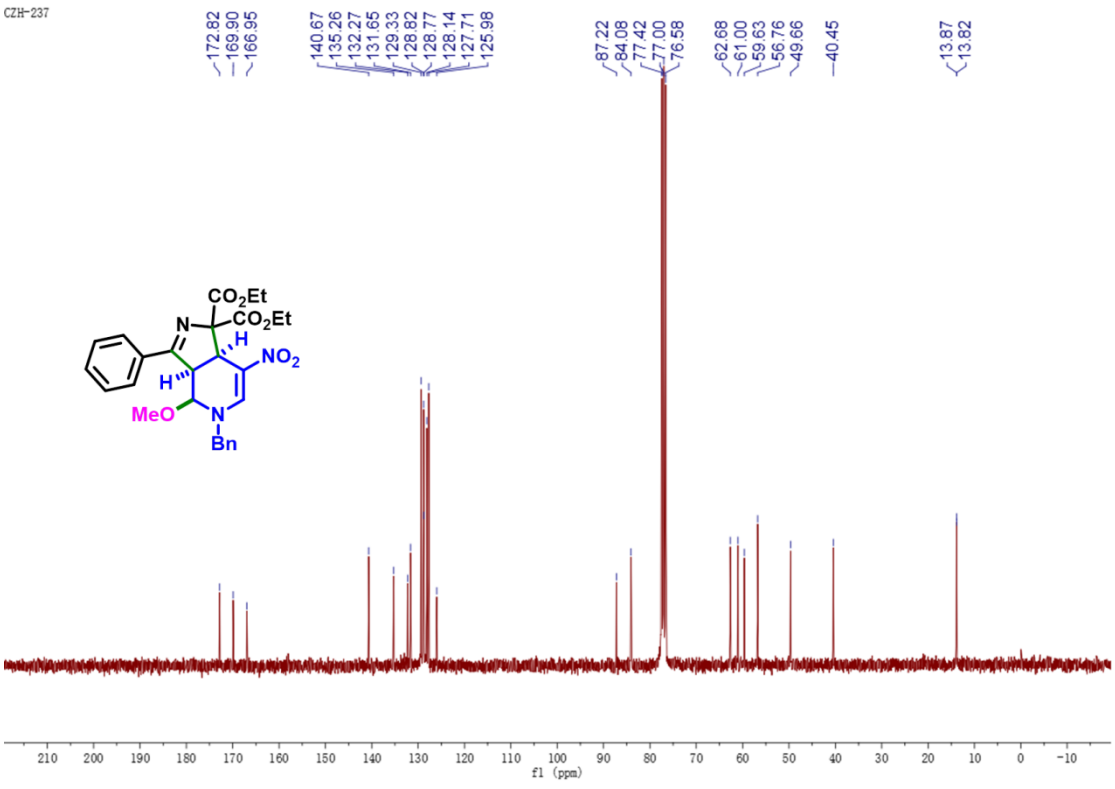
^{13}C NMR spectrum of **3ab** (75 MHz, $CDCl_3$)



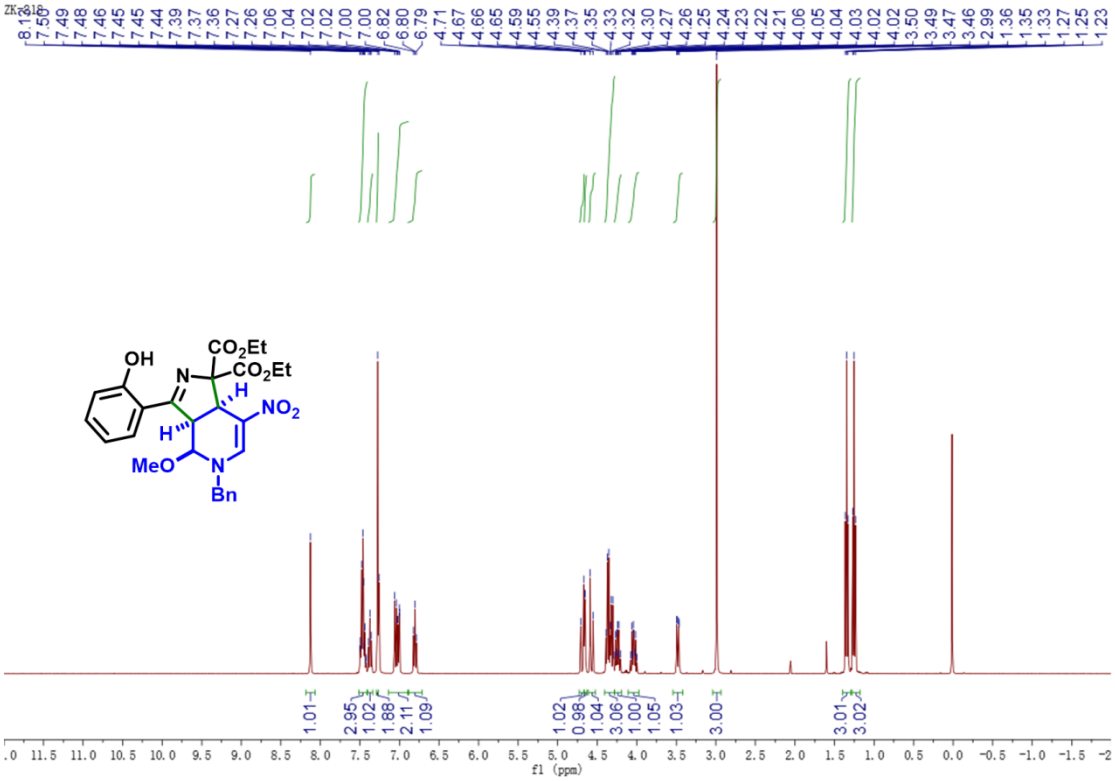
^{1}H NMR spectrum of **3ab'** (300 MHz, $CDCl_3$)



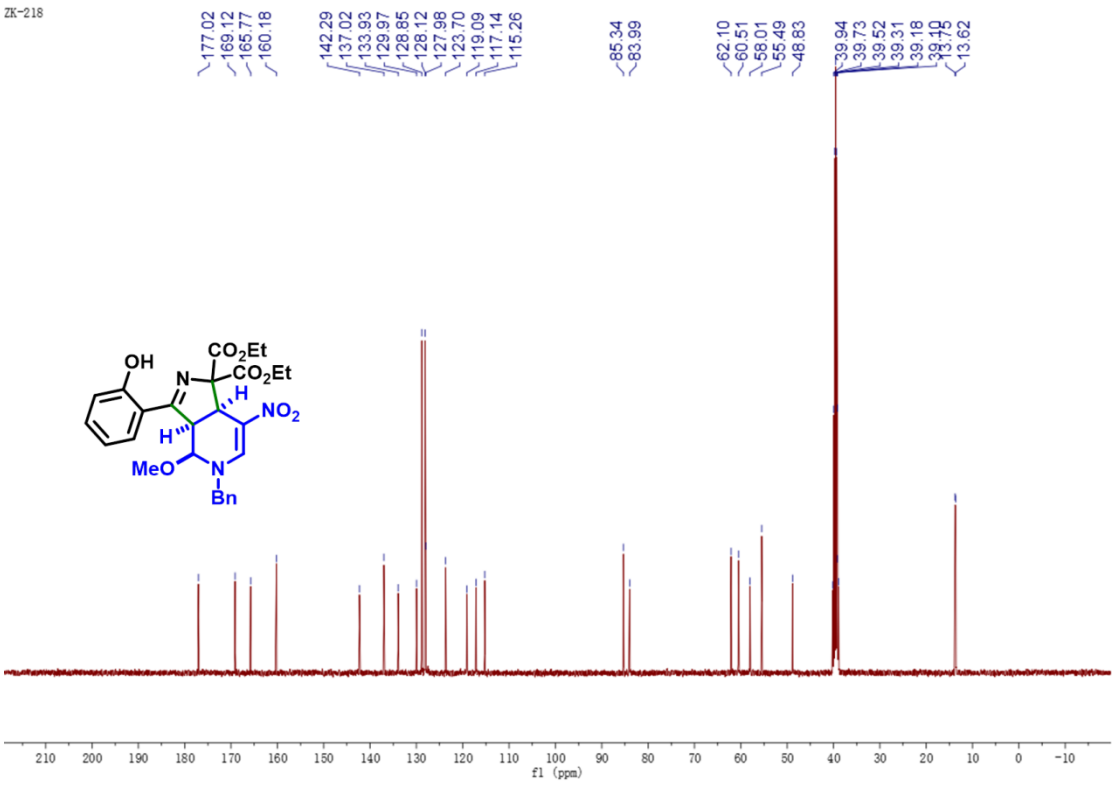
^{13}C NMR spectrum of **3ab'** (75 MHz, $CDCl_3$)



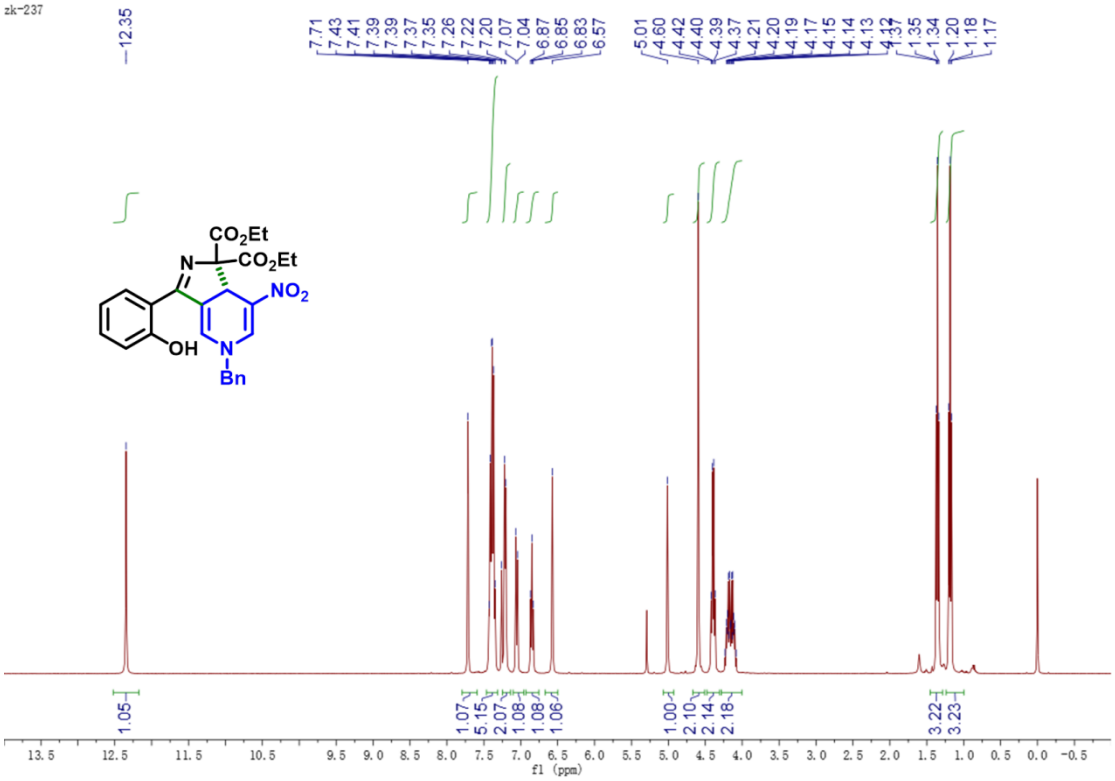
^{1}H NMR spectrum of **4** (400 MHz, $CDCl_3$)



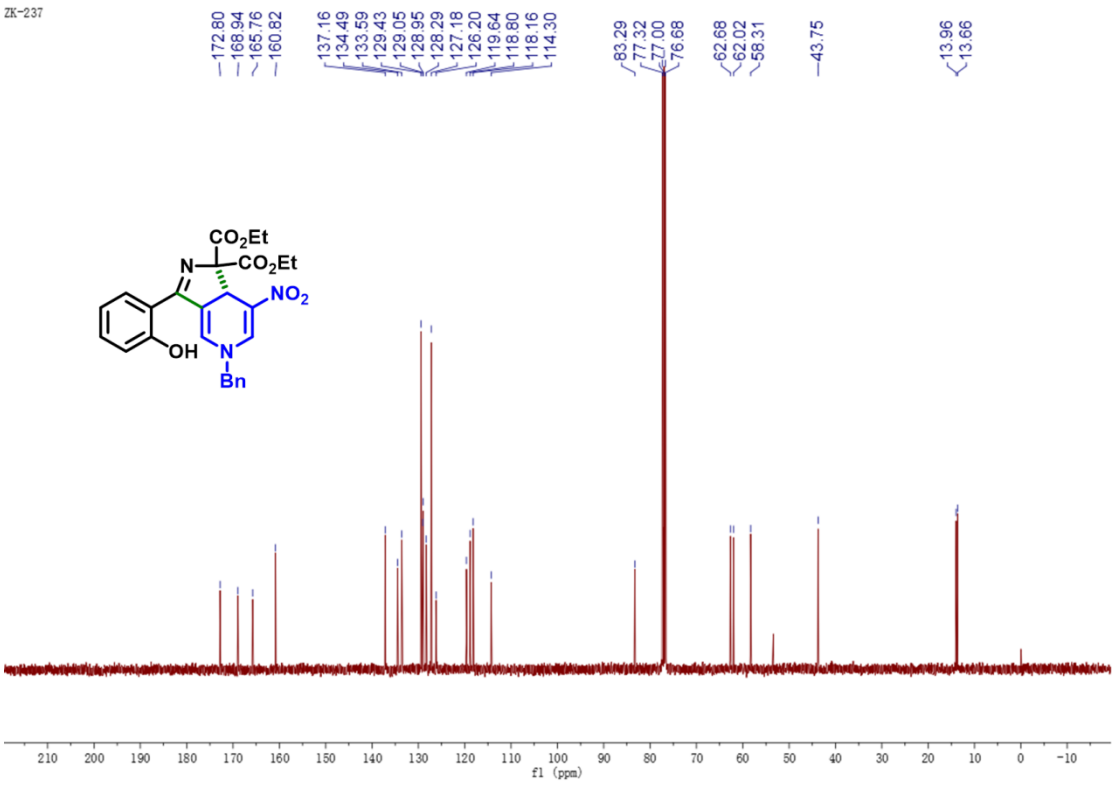
^{13}C NMR spectrum of **4** (100 MHz, DMSO-d_6)



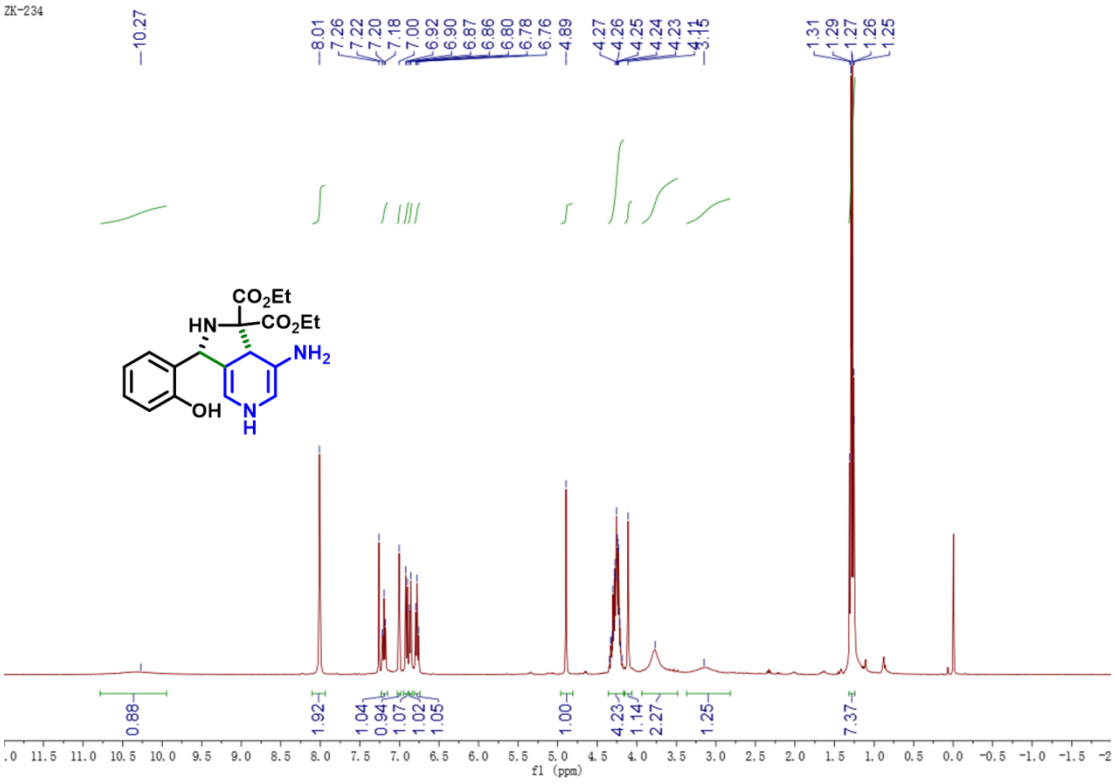
^{1}H NMR spectrum of **5** (400 MHz, $CDCl_3$)



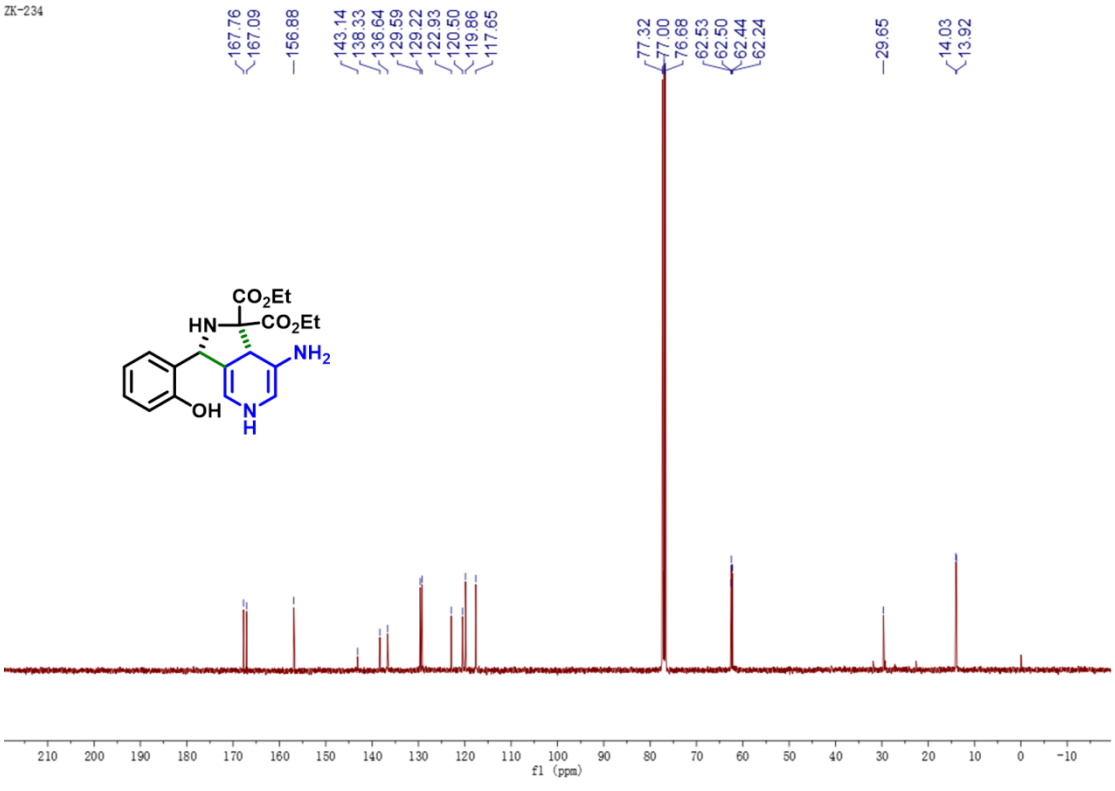
^{13}C NMR spectrum of **5** (100 MHz, $CDCl_3$)



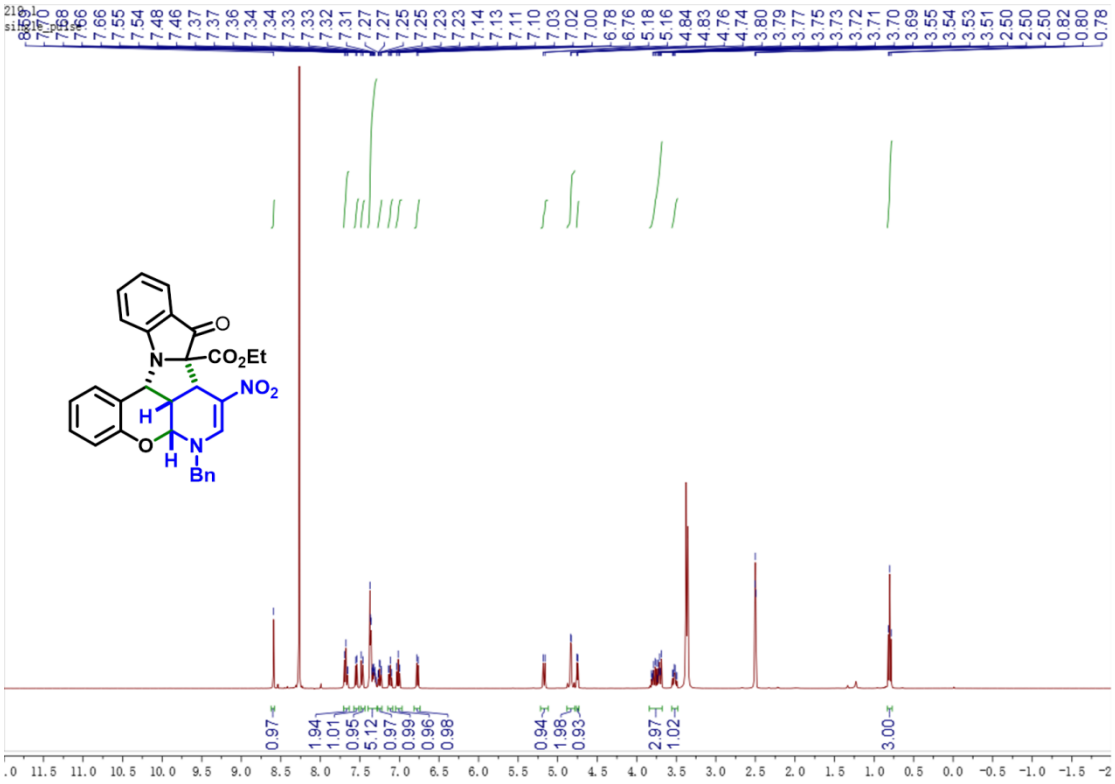
^{1}H NMR spectrum of **6** (400 MHz, $CDCl_3$)



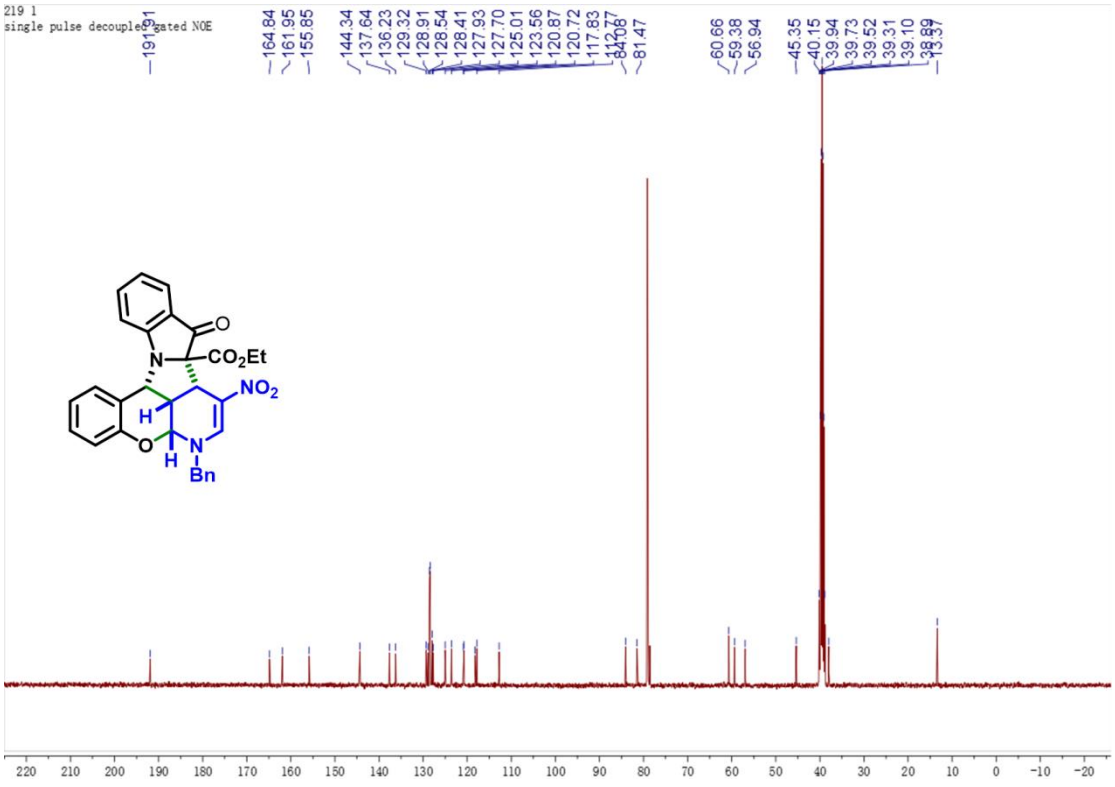
^{13}C NMR spectrum of **6** (100 MHz, $CDCl_3$)



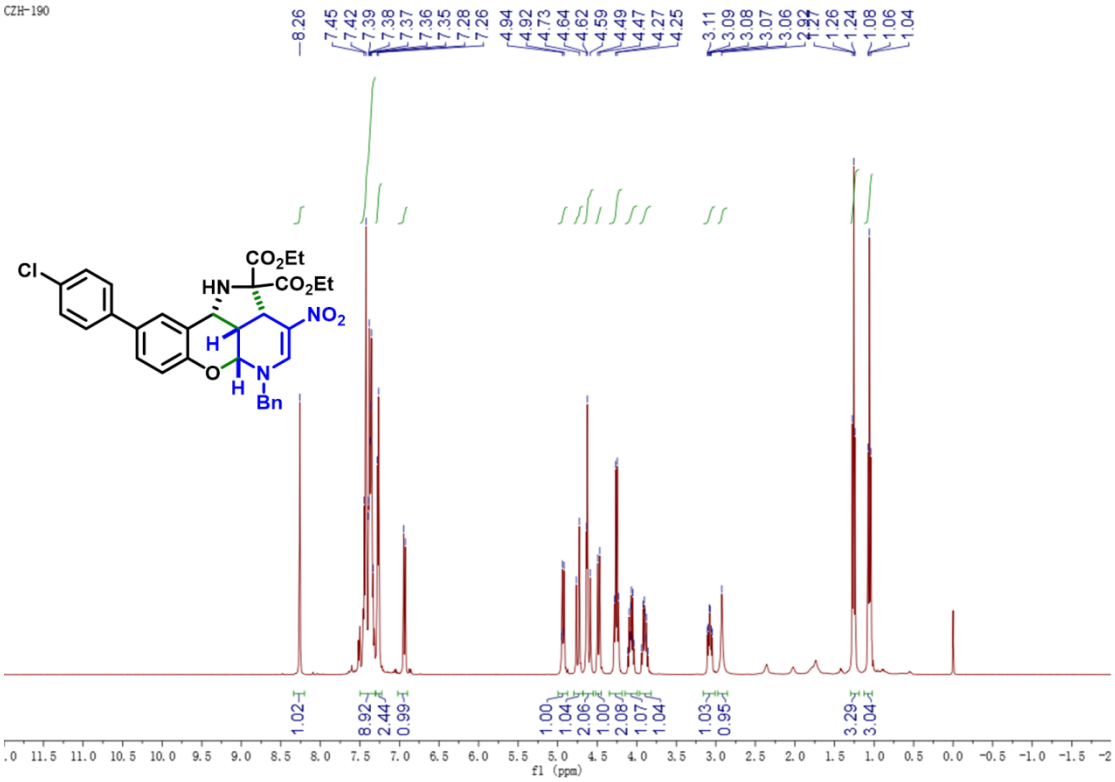
^{1}H NMR spectrum of **7** (400 MHz, DMSO-d_6, $CDCl_3$)



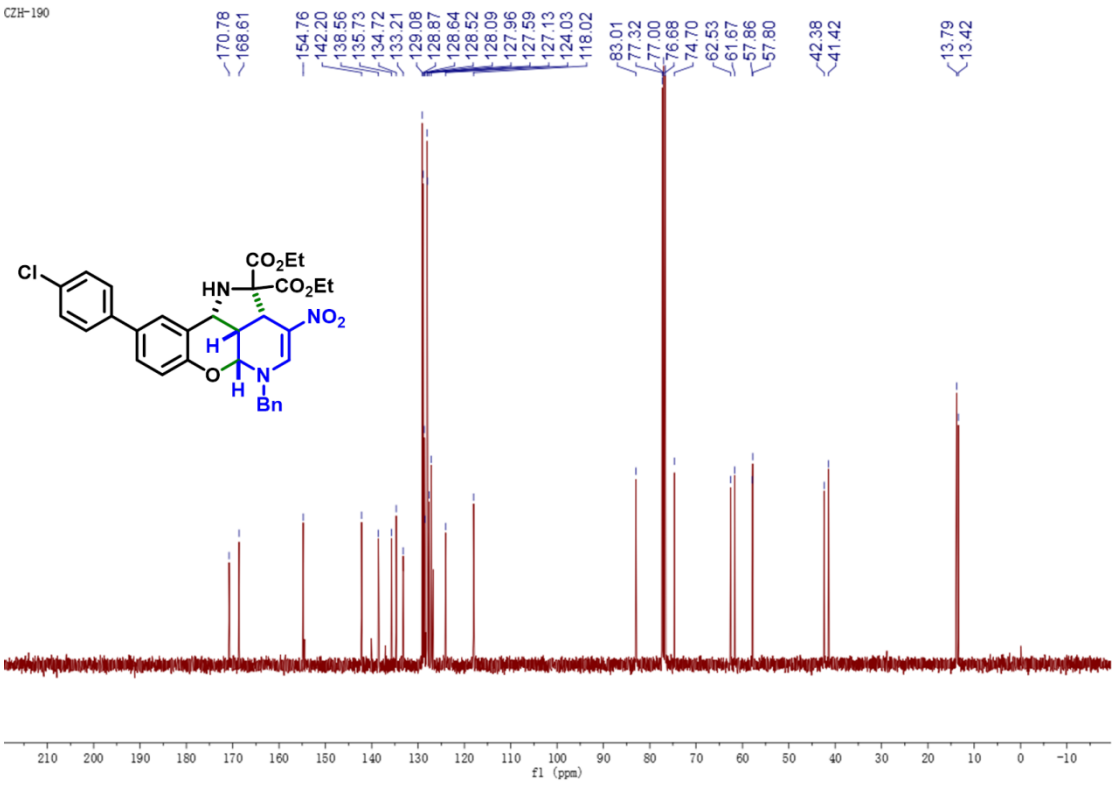
^{13}C NMR spectrum of **7** (100 MHz, DMSO-d_6, $CDCl_3$)



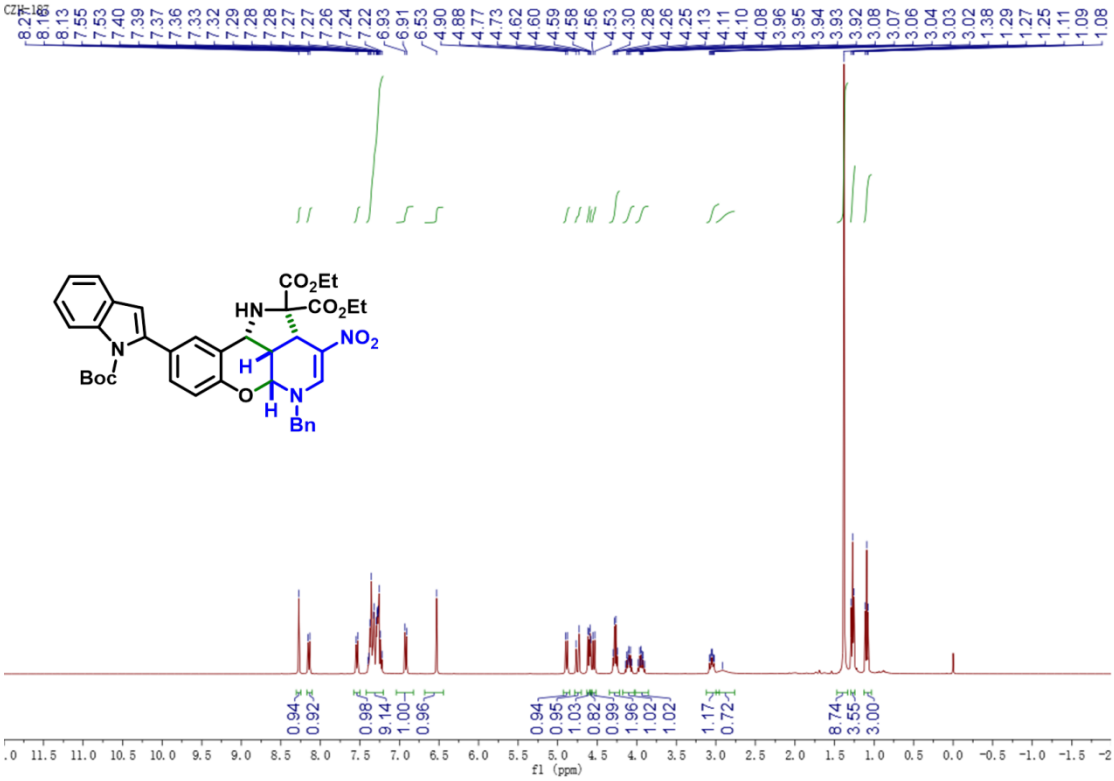
^{1}H NMR spectrum of **8** (400 MHz, $CDCl_3$)



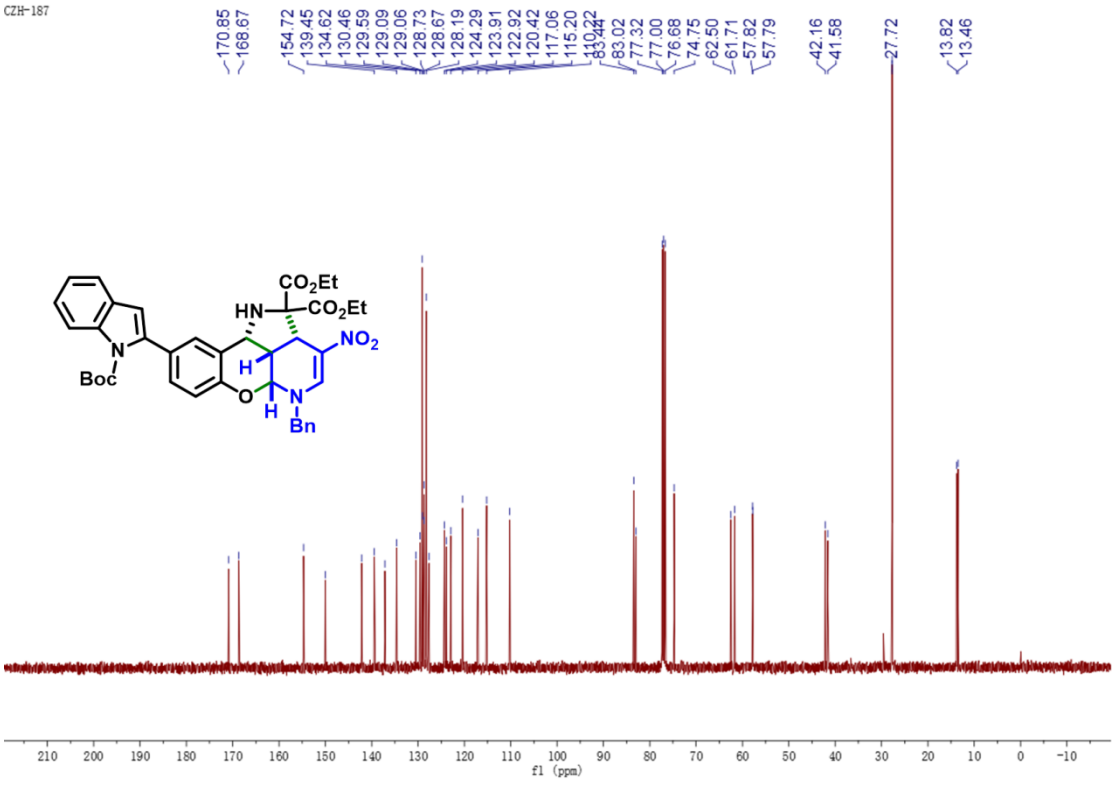
^{13}C NMR spectrum of **8** (100 MHz, $CDCl_3$)



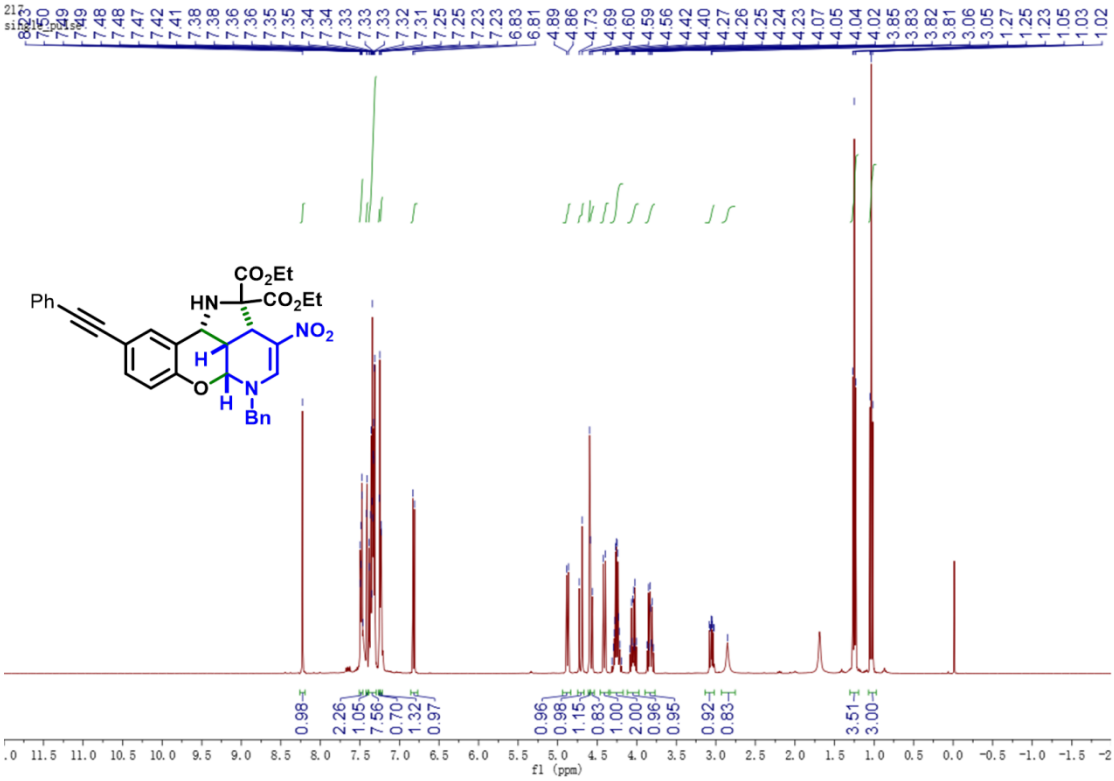
^{1}H NMR spectrum of **9** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of **9** (100 MHz, $CDCl_3$)



^{1}H NMR spectrum of **10** (400 MHz, $CDCl_3$)



^{13}C NMR spectrum of **10** (100 MHz, $CDCl_3$)