

Supporting Information

Palladium-Catalyzed Hydroamination of Vinylidenecyclopropane-Diester with Pyrroles and Indoles: An Approach to Azaaromatic Vinylcyclopropanes

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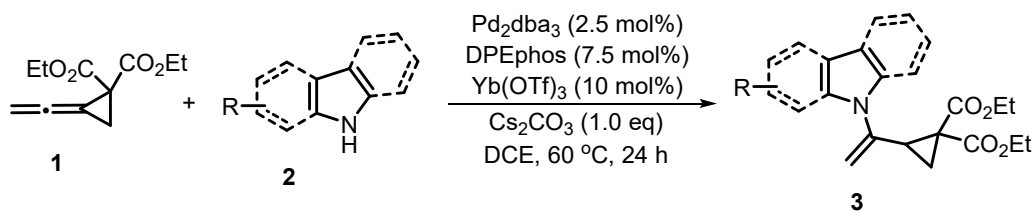
(A) General Information

Proton nuclear magnetic resonance (^1H NMR) spectra, carbon nuclear magnetic resonance (^{13}C NMR) spectra fluorine nuclear magnetic resonance (^{19}F NMR) were recorded at 400 MHz, 100 MHz and 367 MHz, respectively. Data are presented as follows: chemical shift (ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants in Hertz (Hz) and integration. Mass and High-resolution mass spectra (HRMS) spectra were recorded by ESI method. The employed solvents were dry up by standard methods when necessary. Commercially obtained reagents were used without further purification. Petroleum ether refers to the fraction with boiling point in the range 60-90 °C. For thin-layer chromatography (TLC), silica gel plates (Huanghai GF254) were used. Flash column chromatography was carried out using 300-400 mesh silica gel at increased pressure.

The preparation of vinylidenecyclopropane-diester **1**¹ followed the previous literature procedure.

1. Chen, J.; Gao, S.; Chen, M. *Org. Lett.* **2019**, *21*, 8800-8804.

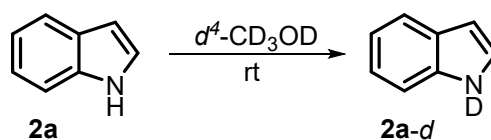
(B) General Procedure for Preparation of Products



Scheme S1

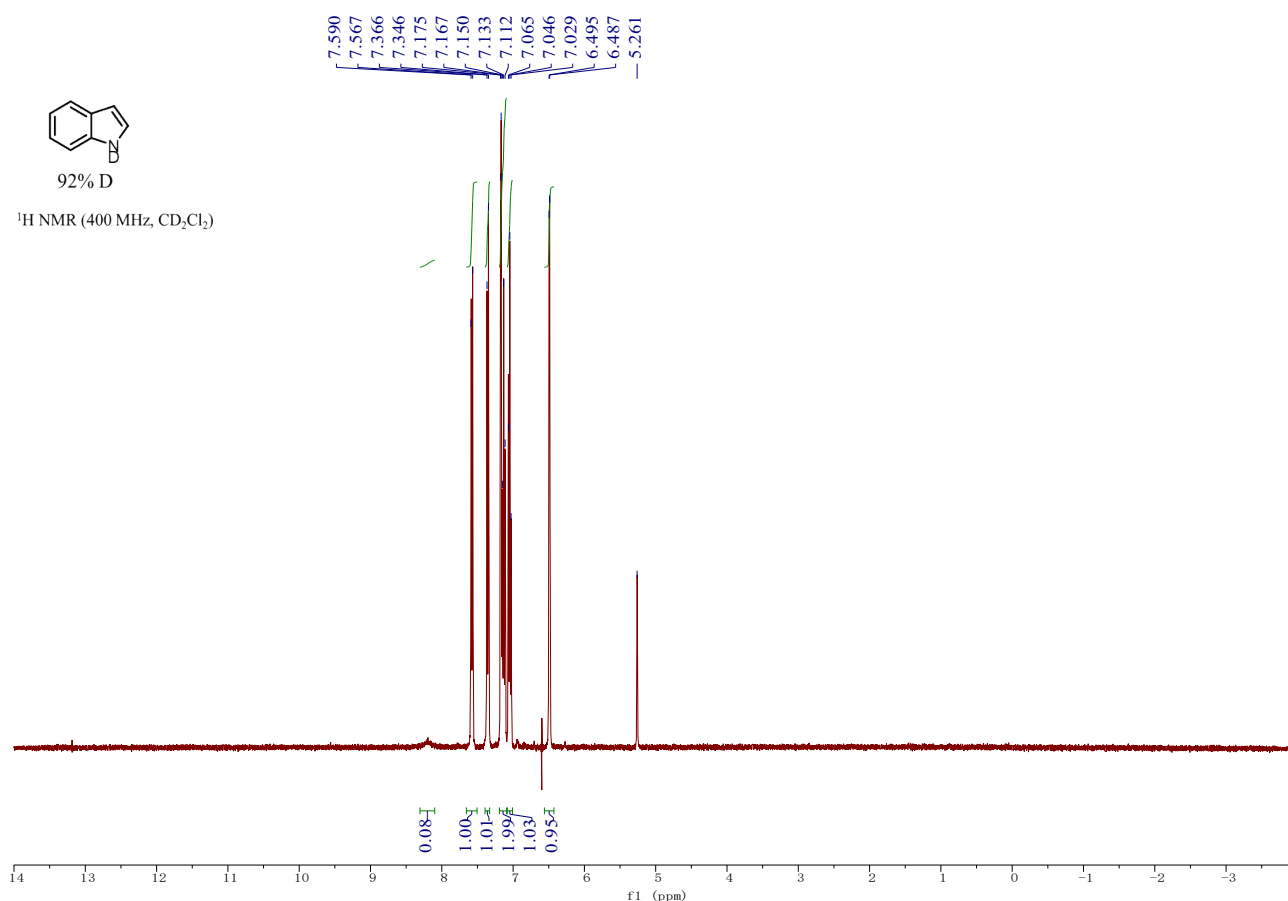
A dried 10 mL Sealed tube was charged with Pd₂dba₃ (0.0025 mmol, 2.5 mol%), DPEphos (0.0075 mmol, 7.5 mol%), Yb(OTf)₃ (0.001 mmol, 10 mol%), Cs₂CO₃ (0.1 mmol, 1.0 equiv) and azaaromatic substrates **2** (0.1 mmol, 1.0 equiv). Then the reaction tube was evacuated and backfilled with argon for 3 times, followed by addition of VDCP **1** (0.2 mmol, 2.0 equiv) and DCE (1.0 mL). The reaction mixture was stirred at 60 °C. After 24 h, the reaction mixture was concentrated under reduced pressure and purified by a flash silica gel chromatography (Petroleum Ether : Ethyl Acetate = 6 : 1, v/v) to afford the desired products.

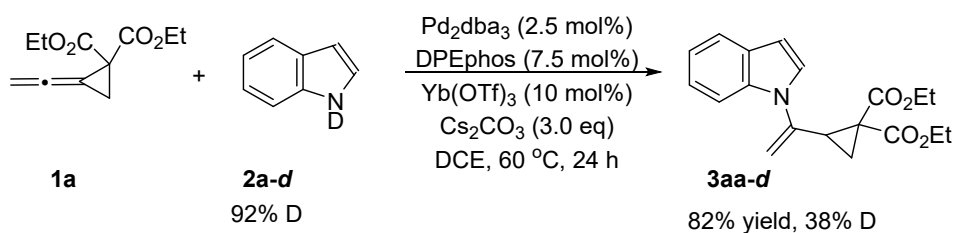
(C) Mechanistic Studies



Scheme S2

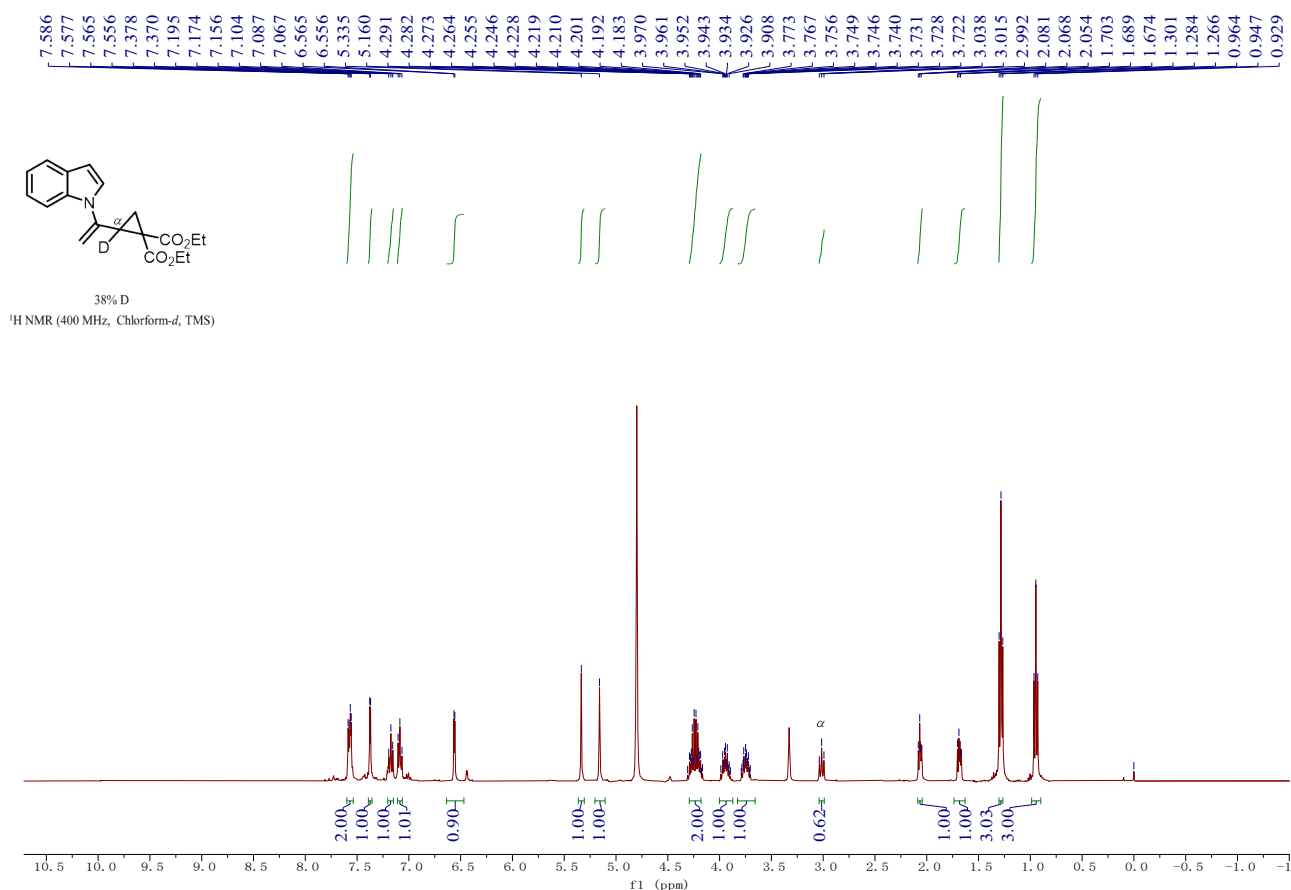
N-deuterium labeled indole **2a-D** was synthesized as following procedure: in a dried 10 mL schlenk tube, indole (1.0 g, 8.55 mmol) was dissolved in $d^4\text{-CD}_3\text{OD}$ (4.5 mL, 173 mmol) and the mixture was stirred at room temperature for 4 hours. Then the mixture was concentrated under vacuum to remove the solvent. $d^4\text{-CD}_3\text{OD}$ (4.5 mL) was added into the schlenk tube again and the mixture was stirred at room temperature for another 4 hours. Then, we repeat the same experimental handling for the third time. After that, the resulting mixture was concentrated under vacuum to give the desired product **2a-D** in quantitative yield along with 92% D content.



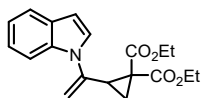


Scheme S3

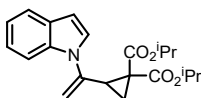
A dried 10 mL sealed tube was charged with Pd₂dba₃ (0.0025 mmol, 2.5 mol%), DPEphos (0.0075 mmol, 7.5 mol%), Yb(OTf)₃ (0.001 mmol, 10 mol%), Cs₂CO₃ (0.3 mmol, 3.0 equiv) and azaaromatic substrates **2a-d** (0.1 mmol, 1.0 equiv). Then the reaction tube was evacuated and backfilled with argon for 3 times, followed by addition of VDCP **1a** (0.2 mmol, 2.0 equiv) and DCE (1.0 mL). The reaction mixture was stirred at 60 °C. After 24 h, the reaction mixture was concentrated under reduced pressure and purified by a flash silica gel chromatography (Petroleum Ether : Ethyl Acetate = 6 : 1, v/v) to afford the desired product **3aa-d** in 82% yield (26.7 mg) along with 38% D content at the α -position of VCP product.



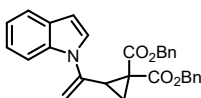
(D) Characterization Data of Products.



Diethyl 2-(1-(1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3aa). The title compound was achieved as yellow oil (26.9 mg, 82%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.60 (d, *J* = 8.5 Hz, 2H), 7.37 (d, *J* = 3.3 Hz, 1H), 7.27 – 7.17 (m, 1H), 7.14 – 7.12 (m, 1H), 6.58 (d, *J* = 3.4 Hz, 1H), 5.33 (s, 1H), 5.10 (s, 1H), 4.32 – 4.16 (m, 2H), 4.09 – 3.97 (m, 1H), 3.89 – 3.77 (m, 1H), 2.95 (t, *J* = 8.6 Hz, 1H), 2.06 (dd, *J* = 7.9, 5.3 Hz, 1H), 1.67 (dd, *J* = 9.2, 5.3 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.00 (t, *J* = 7.2 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.0, 166.1, 138.7, 135.6, 126.5, 122.3, 120.9, 120.4, 111.5, 106.2, 103.5, 61.9, 61.8, 37.3, 31.1, 18.3, 14.0, 13.7; IR (EtOH): ν 2986, 2901, 1727, 1645, 1521, 1475, 1456, 1369 cm⁻¹; HRMS (ESI) Calcd. for C₁₉H₂₁NO₄Na: 350.1363, Found: 350.1359.

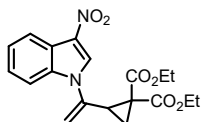


Diisopropyl 2-(1-(1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ba). The title compound was achieved as colorless oil (28.7 mg, 81%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.64 (d, *J* = 8.3 Hz, 1H), 7.60 (d, *J* = 7.8 Hz, 1H), 7.40 (d, *J* = 3.4 Hz, 1H), 7.21 (t, *J* = 7.2 Hz, 1H), 7.12 (t, *J* = 7.4 Hz, 1H), 6.57 (d, *J* = 3.4 Hz, 1H), 5.31 (s, 1H), 5.12 (hept, *J* = 6.3 Hz, 1H), 5.05 (s, 1H), 4.85 (hept, *J* = 6.3 Hz, 1H), 2.88 (t, *J* = 8.5 Hz, 1H), 2.02 (dd, *J* = 7.8, 5.2 Hz, 1H), 1.62 (dd, *J* = 9.2, 5.2 Hz, 1H), 1.30 (d, *J* = 6.2 Hz, 3H), 1.27 (d, *J* = 6.3 Hz, 3H), 1.19 (d, *J* = 6.2 Hz, 3H), 0.84 (d, *J* = 6.2 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.6, 165.6, 138.7, 135.6, 129.5, 126.7, 122.2, 120.9, 120.4, 111.7, 105.2, 103.4, 69.6, 69.5, 37.8, 30.9, 21.7, 21.5, 21.3, 17.8; IR (EtOH): ν 2987, 2901, 1720, 1644, 1456, 1405, 1394, 1313, 1208 cm⁻¹; HRMS (ESI) Calcd. for C₂₁H₂₅NO₄Na: 378.1676, Found: 378.1672.

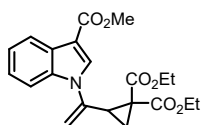


Dibenzyl 2-(1-(1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ca). The title compound

was achieved as colorless oil (19.9 mg, 44%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.60 (d, *J* = 7.7 Hz, 1H), 7.56 (d, *J* = 8.2 Hz, 1H), 7.35 – 7.09 (m, 11H), 6.99 (d, *J* = 7.3 Hz, 2H), 6.51 (d, *J* = 3.4 Hz, 1H), 5.216 (d, *J* = 12.4 Hz, 2H), 5.215 (s, 1H), 5.14 (d, *J* = 12.4 Hz, 1H), 5.05 (s, 1H), 4.93 (d, *J* = 12.1 Hz, 1H), 4.70 (d, *J* = 12.2 Hz, 1H), 3.01 (t, *J* = 8.5 Hz, 1H), 2.10 (dd, *J* = 7.9, 5.3 Hz, 1H), 1.72 (dd, *J* = 9.2, 5.3 Hz, 1H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.8, 165.8, 138.4, 135.6, 135.2, 134.9, 129.4, 128.6, 128.4, 128.3, 128.2, 128.1, 128.0, 126.5, 122.3, 121.0, 120.5, 111.6, 106.3, 103.6, 67.8, 67.6, 37.2, 31.7, 18.9; IR (EtOH): ν 2960, 2923, 1728, 1644, 1474, 1456, 1378, 1317, 1274, 1213, 1195, 1129, 1079 cm⁻¹; HRMS (ESI) Calcd. for C₂₉H₂₅NO₄Na: 474.1676, Found: 474.1683.

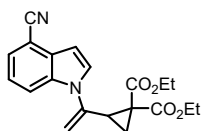


Diethyl 2-(1-(3-nitro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ab). The title compound was achieved as a yellow oil (14.4 mg, 39%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.32 (s, 1H), 8.30 (d, *J* = 11.5 Hz, 1H), 7.59 (d, *J* = 7.9 Hz, 1H), 7.43 – 7.36 (m, 2H), 5.53 (s, 1H), 5.43 (s, 1H), 4.38 – 4.18 (m, 2H), 4.18 – 4.07 (m, 1H), 4.03 – 3.91 (m, 1H), 2.91 (t, *J* = 8.4 Hz, 1H), 2.02 (dd, *J* = 7.8, 5.5 Hz, 1H), 1.74 (dd, *J* = 9.1, 5.5 Hz, 1H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.11 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.3, 165.8, 137.8, 135.0, 130.3, 129.0, 124.9, 124.5, 120.9, 120.8, 112.7, 112.1, 62.3, 62.1, 37.5, 30.2, 18.3, 13.9, 13.8; IR (EtOH): ν 2986, 2921, 1727, 1649, 1535, 1481, 1452, 1378 cm⁻¹; HRMS (ESI) Calcd. for C₁₉H₂₀N₂O₆Na: 395.1214, Found: 395.1208.

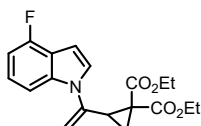


Diethyl 2-(1-(3-(methoxycarbonyl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ac). The title compound was achieved as colorless oil (19.2 mg, 50%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.21 – 8.18 (m, 1H), 8.01 (s, 1H), 7.59 – 7.51 (m, 1H), 7.32 – 7.24 (m, 2H), 5.43 (s, 1H), 5.29 (s, 1H), 4.34 – 4.14 (m, 3H), 4.15 – 4.02 (m, 1H), 3.92 (s, 3H), 3.91 – 3.81 (m, 1H), 2.95 (t, *J* = 8.0 Hz, 1H), 2.00 (dd, *J* = 7.8, 5.3 Hz, 1H), 1.70 (dd, *J* = 9.1, 5.3 Hz, 1H), 1.29 (t, *J*

= 7.2 Hz, 3H), 1.05 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.7, 166.0, 165.2, 138.5, 136.3, 132.9, 126.9, 123.4, 122.5, 121.7, 111.7, 110.4, 108.9, 62.1, 62.0, 61.1, 37.5, 30.6, 18.5, 14.0, 13.7; IR (EtOH): ν 2988, 2901, 1709, 1647, 1539, 1456, 1394, 1378 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{21}\text{H}_{23}\text{NO}_6\text{Na}$: 408.1418, Found: 408.1412.

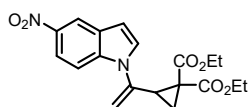


Diethyl 2-(1-(4-cyano-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ad). The title compound was achieved as colorless oil (33.1 mg, 94%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.80 (d, $J = 8.4$ Hz, 1H), 7.54 (d, $J = 3.4$ Hz, 1H), 7.49 (d, $J = 7.3$ Hz, 1H), 7.25 (t, $J = 8.0$ Hz, 1H), 6.81 (d, $J = 3.4$ Hz, 1H), 5.34 (s, 1H), 5.22 (s, 1H), 4.35 – 4.15 (m, 2H), 4.11 – 3.98 (m, 1H), 3.89 – 3.77 (m, 1H), 2.92 (t, $J = 8.5$ Hz, 1H), 2.04 (dd, $J = 7.8, 5.3$ Hz, 1H), 1.69 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.29 (t, $J = 7.1$ Hz, 3H), 1.03 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.8, 166.0, 138.4, 135.4, 130.6, 129.2, 125.7, 122.0, 116.1, 108.4, 103.4, 102.3, 62.1, 62.0, 37.3, 30.8, 18.4, 14.0, 13.8; IR (EtOH): ν 2988, 2901, 2224, 1723, 1647, 1514, 1482, 1514, 1482, 1432, 1394, 1370, 1327, 1280, 1205 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{20}\text{H}_{20}\text{N}_2\text{O}_4\text{Na}$: 375.1315, Found: 375.1320.

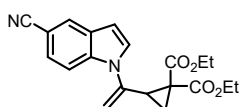


Diethyl 2-(1-(4-fluoro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ae). The title compound was achieved as yellow oil (29.4 mg, 85%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.50 (dd, $J = 8.6, 5.5$ Hz, 1H), 7.35 (d, $J = 3.4$ Hz, 1H), 7.28 (dd, $J = 10.7, 2.5$ Hz, 1H), 6.89 (td, $J = 9.0, 2.3$ Hz, 1H), 6.55 (d, $J = 3.4$ Hz, 1H), 5.29 (s, 1H), 5.11 (s, 1H), 4.34 – 4.13 (m, 2H), 4.12 – 4.00 (m, 1H), 3.92 – 3.82 (m, 1H), 2.91 (t, $J = 8.5$ Hz, 1H), 2.04 (dd, $J = 7.9, 5.3$ Hz, 1H), 1.67 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.29 (t, $J = 7.2$ Hz, 3H), 1.03 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.0, 166.0, 160.1 (d, $J = 237.8$ Hz), 138.8, 135.6 (d, $J = 12.2$ Hz), 127.1 (d, $J = 3.9$ Hz), 125.7, 121.5 (d, $J = 10.0$ Hz), 109.1 (d, $J = 24.6$ Hz), 106.5, 103.6, 98.2 (d, $J = 27.4$ Hz), 62.1, 61.9, 37.4, 31.0, 18.4, 14.0, 13.8; ^{19}F NMR (376 MHz, Chloroform-*d*, CFCl_3) δ -120.1 - -

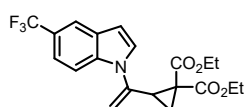
120.2 (m); IR (EtOH): ν 2985, 1723, 1645, 1616, 1483, 1450, 1394, 1369, 1319, 1277, 1203, 1133, 1039, 1023 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{19}\text{H}_{20}\text{NO}_4\text{FNa}$: 368.1269, Found: 368.1264.



Diethyl 2-(1-(5-nitro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3af). The title compound was achieved as yellow oil (28.8 mg, 77%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.57 (d, $J = 2.2$ Hz, 1H), 8.11 (dd, $J = 9.2, 2.3$ Hz, 1H), 7.60 (d, $J = 9.2$ Hz, 1H), 7.52 (d, $J = 3.4$ Hz, 1H), 6.76 (d, $J = 3.4$ Hz, 1H), 5.39 (s, 1H), 5.26 (s, 1H), 4.35 – 4.15 (m, 2H), 4.12 – 4.02 (m, 1H), 2.93 – 2.80 (m, 1H), 2.92 (t, $J = 8.4$ Hz, 1H), 2.05 (dd, $J = 7.8, 5.4$ Hz, 1H), 1.70 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.29 (t, $J = 7.1$ Hz, 3H), 1.05 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.7, 165.9, 142.1, 138.5, 138.4, 129.8, 128.5, 118.0, 117.8, 111.3, 109.1, 105.5, 62.2, 61.9, 37.4, 30.7, 18.4, 14.0, 13.9; IR (EtOH): ν 2982, 2930, 1726, 1651, 1515, 1464, 1394, 1369 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{19}\text{H}_{20}\text{N}_2\text{O}_6\text{Na}$: 395.1214, Found: 395.1206.

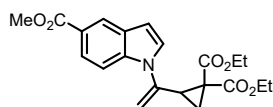


Diethyl 2-(1-(5-cyano-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ag). The title compound was achieved as colorless oil (29.1 mg, 83%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.96 (s, 1H), 7.62 (d, $J = 8.7$ Hz, 1H), 7.49 (d, $J = 3.4$ Hz, 1H), 7.44 (dd, $J = 8.6, 1.6$ Hz, 1H), 6.66 (d, $J = 3.4$ Hz, 1H), 5.35 (s, 1H), 5.23 (s, 1H), 4.34 – 4.14 (m, 2H), 4.11 – 3.99 (m, 1H), 3.90 – 3.78 (m, 1H), 2.91 (t, $J = 8.5$ Hz, 1H), 2.04 (dd, $J = 7.8, 5.4$ Hz, 1H), 1.69 (dd, $J = 9.2, 5.3$ Hz, 1H), 1.29 (t, $J = 7.1$ Hz, 3H), 1.03 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.8, 165.9, 138.4, 137.2, 129.0, 128.9, 126.4, 125.2, 112.2, 108.7, 104.1, 103.6, 62.1, 61.9, 37.4, 30.7, 18.4, 14.0, 13.8; IR (EtOH): ν 2987, 2901, 2221, 1725, 1647, 1607, 1471, 1333 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{20}\text{H}_{20}\text{N}_2\text{O}_4\text{Na}$: 375.1315, Found: 375.1309.



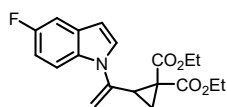
Diethyl 2-(1-(5-(trifluoromethyl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ah).

The title compound was achieved as yellow oil (31.0 mg, 78%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.90 (s, 1H), 7.65 (d, *J* = 8.8 Hz, 1H), 7.47 (d, *J* = 3.4 Hz, 1H), 7.44 (d, *J* = 8.9 Hz, 1H), 6.66 (d, *J* = 3.4 Hz, 1H), 5.35 (s, 1H), 5.19 (s, 1H), 4.34 – 4.13 (m, 2H), 4.10 – 3.98 (m, 1H), 3.89 – 3.78 (m, 1H), 2.93 (t, *J* = 8.5 Hz, 1H), 2.05 (dd, *J* = 7.8, 5.3 Hz, 1H), 1.69 (dd, *J* = 9.1, 5.3 Hz, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.01 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.9, 166.0, 143.3, 138.6, 136.9, 128.3, 125.1 (q, *J* = 271.5 Hz), 122.8 (q, *J* = 21.7 Hz), 119.0 (q, *J* = 3.6 Hz), 118.6 (q, *J* = 4.3 Hz), 111.66, 107.84, 104.22, 62.07, 61.87, 37.37, 30.87, 18.41, 14.01, 13.75; ¹⁹F NMR (376 MHz, Chloroform-*d*, CFC1₃) δ -60.6 (s); IR (EtOH): ν 2988, 2901, 1724, 1647, 1618, 1485, 1394, 1370, 1334, 1321, 1273, 1226, 1201 cm⁻¹; HRMS (ESI) Calcd. for C₂₀H₂₀NO₄F₃Na: 418.1237, Found: 428.1240.



Diethyl 2-(1-(5-(methoxycarbonyl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ai).

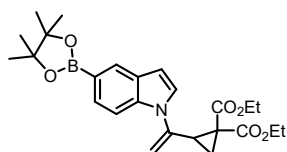
The title compound was achieved as colorless oil (31.1 mg, 81%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.36 (s, 1H), 7.90 (d, *J* = 8.5 Hz, 1H), 7.58 (d, *J* = 8.8 Hz, 1H), 7.42 (d, *J* = 3.3 Hz, 1H), 6.67 (d, *J* = 3.4 Hz, 1H), 5.36 (s, 1H), 5.18 (s, 1H), 4.34 – 4.14 (m, 2H), 4.10 – 3.98 (m, 1H), 3.93 (s, 3H), 3.88 – 3.75 (m, 1H), 2.94 (t, *J* = 8.6 Hz, 1H), 2.04 (dd, *J* = 7.9, 5.2 Hz, 1H), 1.68 (dd, *J* = 9.1, 5.3 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.01 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.9, 167.9, 166.0, 138.6, 138.1, 128.9, 128.0, 123.8, 123.6, 122.4, 111.1, 107.8, 104.7, 62.0, 61.9, 51.9, 37.3, 30.9, 18.5, 14.0, 13.8; IR (EtOH): ν 2986, 1717, 1647, 1610, 1447, 1394, 1284, 1204 cm⁻¹; HRMS (ESI) Calcd. for C₂₁H₂₃NO₆Na: 408.1418, Found: 408.1411.



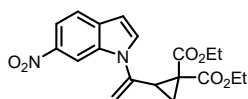
Diethyl 2-(1-(5-fluoro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3aj).

The title compound was achieved as light green oil (26.1 mg, 76%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.51 (dd, *J* = 9.1, 4.4 Hz, 1H), 7.40 (d, *J* = 3.4 Hz, 1H), 7.24 (dd, *J* = 9.2, 2.4 Hz, 1H), 6.94 (td, *J* = 9.1, 2.6 Hz, 1H), 6.53 (d, *J* = 3.3 Hz, 1H), 5.30 (s, 1H), 5.10 (s, 1H), 4.34 – 4.13 (m, 2H), 4.09 – 3.97 (m, 1H), 3.89 – 3.78 (m, 1H), 2.93 (t, *J* = 8.5 Hz, 1H), 2.04 (dd, *J* = 7.8, 5.3 Hz, 1H),

1.67 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.29 (t, $J = 7.1$ Hz, 3H), 1.01 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.0, 166.0, 158.1 (d, $J = 235.9$ Hz), 138.8, 132.2, 129.8 (d, $J = 10.1$ Hz), 128.0, 112.2 (d, $J = 9.5$ Hz), 110.5 (d, $J = 26.0$ Hz), 106.4, 105.7 (d, $J = 23.4$ Hz), 103.4 (d, $J = 4.5$ Hz), 62.0, 61.8, 37.3, 31.0, 18.4, 14.0, 13.8; ^{19}F NMR (376 MHz, Chloroform-*d*, CFCl_3) δ -124.1 - -124.2 (m); IR (EtOH): ν 2988, 2901, 1725, 1646, 1474, 1448, 1405, 1394, 1319, 1280, 1250, 1206, 1134, 1075, 1066, 1057 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{19}\text{H}_{20}\text{NO}_4\text{FNa}$: 368.1269, Found: 368.1272.

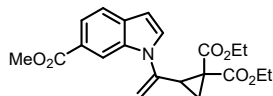


Diethyl 2-(1-(5-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ak). The title compound was achieved as colorless oil (34.4 mg, 76%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.13 (s, 1H), 7.65 (d, $J = 8.2$ Hz, 1H), 7.57 (d, $J = 8.4$ Hz, 1H), 7.35 (d, $J = 3.4$ Hz, 1H), 6.58 (d, $J = 3.4$ Hz, 1H), 5.33 (s, 1H), 5.11 (s, 1H), 4.33 – 4.13 (m, 2H), 4.10 – 3.99 (m, 1H), 3.90 – 3.78 (m, 1H), 2.94 (t, $J = 8.5$ Hz, 1H), 2.04 (dd, $J = 7.8, 5.2$ Hz, 1H), 1.66 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.28 (t, $J = 7.2$ Hz, 3H), 1.00 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.1, 166.1, 138.7, 137.6, 129.1, 128.8, 128.5, 126.8, 110.9, 106.7, 104.1, 83.5, 62.0, 61.8, 37.4, 31.0, 24.9, 18.4, 14.1, 13.8; ^{11}B NMR (128 MHz, Chloroform-*d*) δ 31.0 (br. s); IR (EtOH): ν 2987, 2901, 1727, 1644, 1607, 1521, 1436, 1393, 1370, 1356, 1320, 1298, 1278, 1205, 1135, 1074, 1066, 1027 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{25}\text{H}_{32}\text{BNO}_6\text{Na}$: 476.2215, Found: 476.2220.



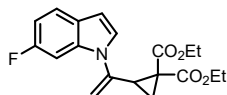
Diethyl 2-(1-(6-nitro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3al). The title compound was achieved as yellow oil (29.2 mg, 78%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.55 (s, 1H), 8.04 (dd, $J = 8.8, 2.0$ Hz, 1H), 7.67 (d, $J = 6.1$ Hz, 1H), 7.65 (s, 1H), 6.69 (d, $J = 3.3$ Hz, 1H), 5.39 (s, 1H), 5.24 (s, 1H), 4.36 – 4.17 (m, 3H), 4.18 – 4.07 (m, 1H), 4.01 – 3.89 m, 1H), 2.89 (t, $J = 8.0$ Hz, 1H), 2.07 (dd, $J = 7.8, 5.4$ Hz, 1H), 1.72 (dd, $J = 9.0, 5.4$ Hz, 1H), 1.30 (t, $J = 7.1$ Hz, 3H), 1.08 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.8, 165.9,

143.6, 138.3, 134.3, 134.0, 132.2, 120.9, 115.9, 108.5, 108.4, 104.1, 62.2, 62.0, 37.7, 30.7, 18.3, 14.0, 13.9; IR (EtOH): ν 2988, 2901, 1723, 1647, 1519, 1503, 1406, 1394, 1370, 1278, 1233, 1206, 1133, 1066 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{19}\text{H}_{20}\text{N}_2\text{O}_6\text{Na}$: 395.1214, Found: 395.1215.



Diethyl 2-(1-(6-(methoxycarbonyl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3am).

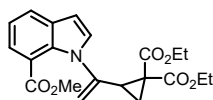
The title compound was achieved as colorless oil (30.9 mg, 80%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.32 (s, 1H), 7.83 (d, $J = 8.3$ Hz, 1H), 7.63 (d, $J = 8.3$ Hz, 1H), 7.53 (d, $J = 3.3$ Hz, 1H), 6.62 (d, $J = 3.3$ Hz, 1H), 5.40 (s, 1H), 5.20 (s, 1H), 4.34 – 4.13 (m, 2H), 4.14 – 4.02 (m, 1H), 3.93 (s, 3H), 3.92 – 3.84 (m, 1H), 2.93 (t, $J = 8.4$ Hz, 1H), 2.06 (dd, $J = 7.8, 5.3$ Hz, 1H), 1.69 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.28 (t, $J = 7.1$ Hz, 3H), 1.03 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.9, 168.0, 166.0, 138.3, 135.1, 132.9, 129.7, 124.0, 121.5, 120.5, 113.7, 107.8, 103.7, 62.0, 61.9, 51.9, 37.5, 31.0, 18.3, 14.0, 13.8; IR (EtOH): ν 2981, 1716, 1646, 1610, 1509, 1448, 1369, 1323, 1281, 1253, 1229, 1204, 1169, 1130, 1098 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{21}\text{H}_{23}\text{NO}_6\text{Na}$: 408.1418, Found: 408.1420.



Diethyl 2-(1-(6-fluoro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3an).

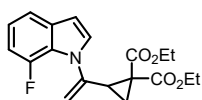
The title compound was achieved as yellow oil (29.9 mg, 87%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.50 (dd, $J = 8.6, 5.5$ Hz, 1H), 7.35 (d, $J = 3.4$ Hz, 1H), 7.28 (dd, $J = 10.4, 2.3$ Hz, 1H), 6.89 (td, $J = 9.0, 2.3$ Hz, 1H), 6.55 (d, $J = 3.4$ Hz, 1H), 5.29 (s, 1H), 5.11 (s, 1H), 4.34 – 4.13 (m, 2H), 4.13 – 4.00 (m, 1H), 3.93 – 1.81 (m, 1H), 2.91 (t, $J = 8.5$ Hz, 1H), 2.04 (dd, $J = 7.9, 5.3$ Hz, 1H), 1.67 (dd, $J = 9.2, 5.2$ Hz, 1H), 1.29 (t, $J = 7.2$ Hz, 3H), 1.03 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.0, 166.0, 160.1 (d, $J = 237.7$ Hz), 138.8, 135.6 (d, $J = 12.3$ Hz), 128.7 (d, $J = 57.6$ Hz), 127.0 (d, $J = 3.8$ Hz), 125.7, 121.5 (d, $J = 10.0$ Hz), 109.1 (d, $J = 24.5$ Hz), 106.5, 103.6, 98.2 (d, $J = 27.5$ Hz), 62.1, 61.9, 37.4, 31.0, 18.4, 14.0, 13.8; ^{19}F NMR (376 MHz, Chloroform-*d*, CFCl_3) δ -120.19 (ddd, $J = 15.0, 9.8, 5.5$ Hz); IR (EtOH): ν 2988, 2901, 1723, 1646, 1616, 1582, 1483, 1450, 1394, 1370, 1320, 1277, 1203, 1097, 1076, 1066, 1044 cm^{-1} ; HRMS (ESI)

Calcd. for C₁₉H₂₀NO₄FNa: 368.1269, Found: 368.1273.



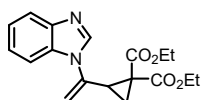
Diethyl 2-(1-(7-(methoxycarbonyl)-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ao).

The title compound was achieved as yellow oil (13.1 mg, 34%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.76 (d, *J* = 7.8 Hz, 1H), 7.61 (d, *J* = 7.4 Hz, 1H), 7.29 (d, *J* = 3.3 Hz, 1H), 7.16 (t, *J* = 7.6 Hz, 1H), 6.61 (d, *J* = 3.4 Hz, 1H), 5.04 (s, 1H), 5.01 (s, 1H), 4.29 – 4.07 (m, 4H), 3.89 (s, 3H), 2.91 (t, *J* = 8.7 Hz, 1H), 1.81 (dd, *J* = 8.1, 5.3 Hz, 1H), 1.63 (dd, *J* = 9.2, 5.2 Hz, 1H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.23 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.9, 168.0, 166.2, 141.8, 132.9, 130.9, 130.1, 125.3, 124.7, 119.6, 116.9, 108.5, 103.4, 61.9, 61.8, 51.6, 37.9, 31.2, 18.0, 14.1, 14.0; IR (EtOH): ν 2988, 2901, 1720, 1648, 1435, 1405, 1394, 1370, 1316, 1275, 1197, 1132, 1066 cm⁻¹; HRMS (ESI) Calcd. for C₂₁H₂₃NO₆Na: 408.1418, Found: 408.1411.

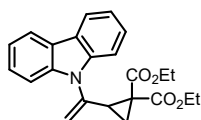


Diethyl 2-(1-(7-fluoro-1H-indol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ap).

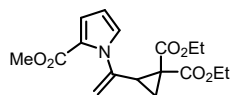
The title compound was achieved as yellow oil (32.7 mg, 95%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.37 (d, *J* = 7.8 Hz, 1H), 7.17 (d, *J* = 3.2 Hz, 1H), 7.04 (td, *J* = 7.8, 4.3 Hz, 1H), 6.90 (dd, *J* = 12.7, 7.8 Hz, 1H), 6.56 (t, *J* = 2.7 Hz, 1H), 5.25 (d, *J* = 3.8 Hz, 1H), 5.19 (s, 1H), 4.29 – 4.15 (m, 3H), 4.09 – 3.97 (m, 1H), 3.08 (t, *J* = 8.6 Hz, 1H), 1.88 (dd, *J* = 7.9, 5.3 Hz, 1H), 1.65 (dd, *J* = 9.3, 5.2 Hz, 1H), 1.26 (t, *J* = 7.1 Hz, 3H), 1.16 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.0, 166.4, 149.5 (d, *J* = 246.5 Hz), 139.7 (d, *J* = 1.7 Hz), 133.1 (d, *J* = 4.7 Hz), 129.2, 128.7 (d, *J* = 57.7 Hz), 120.6 (d, *J* = 6.8 Hz), 116.7 (d, *J* = 3.5 Hz), 111.3 (d, *J* = 4.0 Hz), 108.3 (d, *J* = 18.8 Hz), 103.6 (d, *J* = 2.0 Hz), 61.8, 61.7, 37.5, 31.3 (d, *J* = 5.7 Hz), 18.7, 14.0, 13.9; ¹⁹F NMR (376 MHz, Chloroform-*d*, CFC_l₃) δ -126.97 (d, *J* = 13.0 Hz); IR (EtOH): ν 2988, 2901, 1723, 1650, 1488, 1438, 1405, 1394, 1370, 1319, 1275, 1235, 1204, 1131, 1065, 1049 cm⁻¹; HRMS (ESI) Calcd. for C₁₉H₂₀NO₄FNa: 368.1269, Found: 368.1273.



Diethyl 2-(1-(1H-benzo[d]imidazol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3aq). The title compound was achieved as colorless oil (31.0 mg, 94%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.19 (s, 1H), 7.86 – 7.79 (m, 1H), 7.62 – 7.55 (m, 1H), 7.37 – 7.28 (m, 2H), 5.46 (s, 1H), 5.20 (s, 1H), 4.35 – 4.15 (m, 2H), 4.12 – 4.01 (m, 1H), 3.93 – 3.80 (m, 1H), 2.97 (t, *J* = 8.4 Hz, 1H), 2.05 (dd, *J* = 7.7, 5.4 Hz, 1H), 1.73 (dd, *J* = 9.1, 5.4 Hz, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.01 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.6, 165.9, 143.8, 141.7, 136.9, 132.9, 123.7, 122.9, 120.5, 111.4, 108.2, 62.2, 62.0, 37.4, 30.3, 18.2, 14.0, 13.7; IR (EtOH): ν 2988, 2901, 1728, 1648, 1496, 1455, 1370, 1209 cm⁻¹; HRMS (ESI) Calcd. for C₁₈H₂₁N₂O₄: 329.1496, Found: 329.1497.

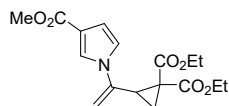


Diethyl 2-(1-(9H-carbazol-9-yl)vinyl)cyclopropane-1,1-dicarboxylate (3ar). The title compound was achieved as yellow oil (19.2 mg, 51%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 8.06 (d, *J* = 7.7 Hz, 2H), 7.51 (d, *J* = 8.2 Hz, 2H), 7.48 – 7.38 (m, 2H), 7.29 – 7.21 (m, 2H), 5.58 (s, 1H), 5.48 (s, 1H), 4.23 – 4.06 (m, 2H), 4.04 – 3.95 (m, 1H), 3.85 – 3.73 (m, 1H), 3.16 (t, *J* = 8.8 Hz, 1H), 1.91 (dd, *J* = 8.1, 5.1 Hz, 1H), 1.66 (dd, *J* = 9.3, 5.1 Hz, 1H), 1.22 (t, *J* = 7.1 Hz, 3H), 1.01 (t, *J* = 7.1 Hz, 3H); ¹³C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.1, 166.4, 140.0, 138.2, 125.8, 123.5, 120.1, 119.9, 114.5, 110.8, 61.9, 61.8, 37.7, 30.7, 20.2, 14.0, 13.7; IR (EtOH): ν 2988, 2901, 1717, 1451, 1406, 1394, 1229, 1066 cm⁻¹; HRMS (ESI) Calcd. for C₂₃H₂₃NO₄Na: 400.1519, Found: 400.1515.



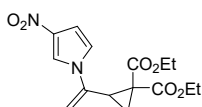
Diethyl 2-(1-(2-(methoxycarbonyl)-1H-pyrrol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3as). The title compound was achieved as yellow oil (32.7 mg, 98%). ¹H NMR (400 MHz, Chloroform-*d*, TMS) δ 6.99 (dd, *J* = 3.9, 1.8 Hz, 1H), 6.71 (t, *J* = 2.2 Hz, 1H), 6.13 (dd, *J* = 3.9, 2.6 Hz, 1H), 5.21 (s, 1H), 5.19 (s, 1H), 4.30 – 4.05 (m, 4H), 3.82 (s, 3H), 3.14 (t, *J* = 8.8 Hz, 1H), 1.73 (dd, *J* = 8.0, 5.1 Hz, 1H), 1.59 (dd, *J* = 9.4, 5.2 Hz, 1H), 1.26 (t, *J* = 6.9 Hz, 3H), 1.24 (t, *J* = 6.9 Hz, 3H); ¹³C

NMR (100 MHz, Chloroform-*d*, TMS) δ 168.9, 166.8, 160.9, 142.2, 129.5, 122.4, 118.8, 113.2, 108.5, 61.7, 61.6, 51.2, 37.3, 31.7, 18.9, 14.03, 13.96; IR (EtOH): ν 2984, 2899, 1709, 1652, 1532, 1439, 1413, 1263 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{17}\text{H}_{21}\text{NO}_6\text{Na}$: 358.1261, Found: 358.1255.

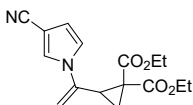


Diethyl 2-(1-(3-(methoxycarbonyl)-1H-pyrrol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3at).

The title compound was achieved as yellow oil (21.4 mg, 64%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.61 (s, 1H), 6.95 (t, $J = 2.7$ Hz, 1H), 6.62 (s, 1H), 5.19 (s, 1H), 4.75 (s, 1H), 4.38 – 4.18 (m, 2H), 4.08 – 3.96 (m, 2H), 3.81 (s, 3H), 2.87 (t, $J = 8.4$ Hz, 1H), 2.00 (dd, $J = 7.7, 5.4$ Hz, 1H), 1.66 (dd, $J = 9.0, 5.3$ Hz, 1H), 1.32 (t, $J = 7.1$ Hz, 3H), 1.02 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.8, 165.9, 165.0, 139.3, 123.8, 119.9, 117.2, 110.9, 102.5, 62.2, 61.8, 51.2, 36.9, 29.1, 17.8, 14.0, 13.7; IR (EtOH): ν 2987, 2901, 1720, 1644, 1547, 1495, 1406, 1066 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{17}\text{H}_{21}\text{NO}_6\text{Na}$: 358.1261, Found: 358.1256.

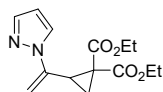


Diethyl 2-(1-(3-nitro-1H-pyrrol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3au). The title compound was achieved as yellow oil (20.9 mg, 65%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.85 (t, $J = 2.1$ Hz, 1H), 6.94 (t, $J = 3.0$ Hz, 1H), 6.80 – 6.77 (dd, $J = 3.4, 1.8$ Hz, 1H), 5.29 (d, $J = 2.2$ Hz, 1H), 4.90 (s, 1H), 4.39 – 4.20 (m, 1H), 4.14 – 3.98 (m, 2H), 2.82 (t, $J = 8.4$ Hz, 1H), 2.01 (dd, $J = 7.7, 5.5$ Hz, 1H), 1.71 (dd, $J = 9.0, 5.4$ Hz, 1H), 1.33 (t, $J = 7.1$ Hz, 3H), 1.07 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.5, 165.7, 139.0, 119.6, 119.5, 62.4, 62.0, 37.0, 28.7, 17.7, 14.0, 13.8; IR (EtOH): ν 2983, 2930, 1724, 1652, 1537, 1497, 1310, 1291 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{15}\text{H}_{18}\text{N}_2\text{O}_6\text{Na}$: 345.1057, Found: 345.1059.



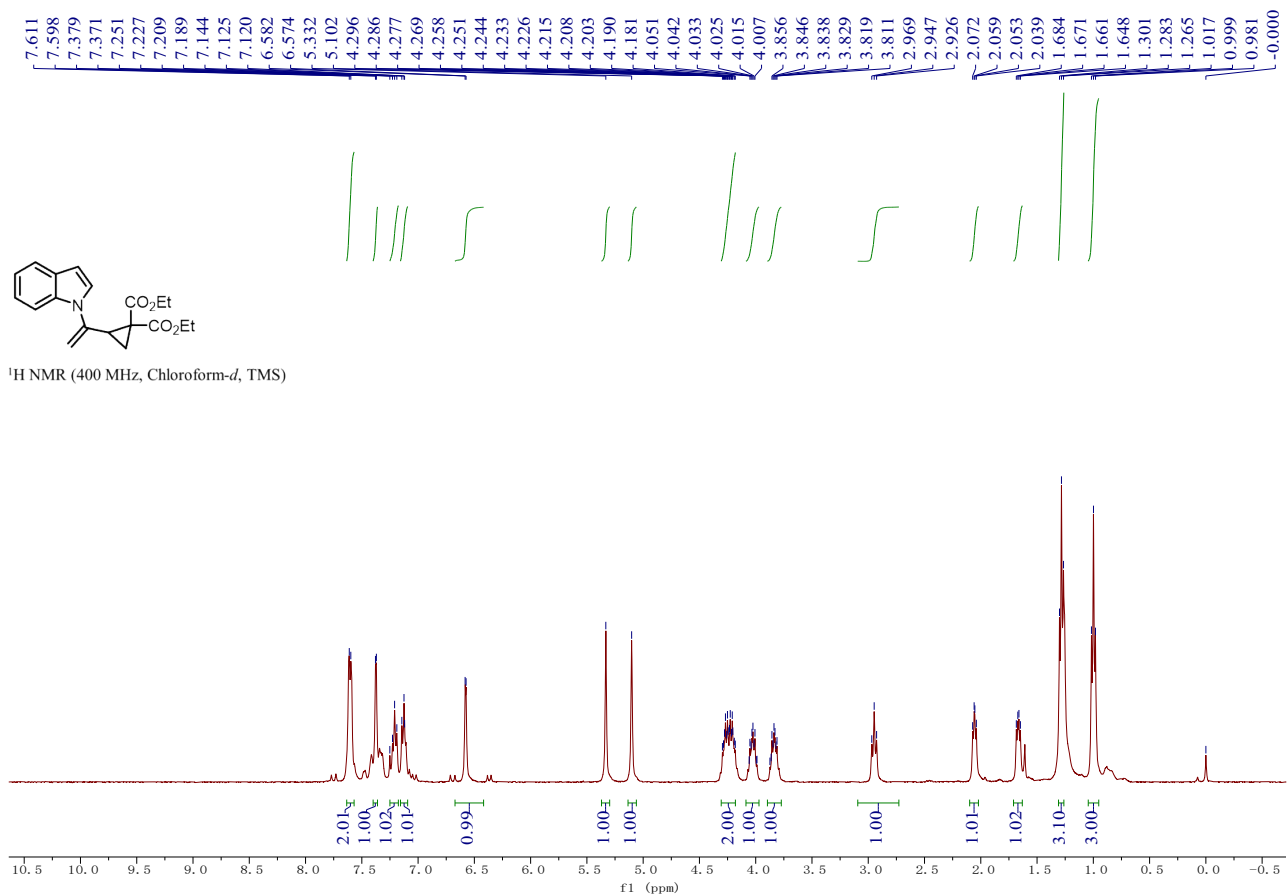
Diethyl 2-(1-(3-cyano-1H-pyrrol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3av). The title compound was achieved as yellow oil (23.0 mg, 76%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ

7.48 (s, 1H), 6.99 (s, 1H), 6.47 (s, 1H), 5.21 (s, 1H), 4.82 (s, 1H), 4.39 – 4.16 (m, 2H), 4.12 – 3.95 (m, 2H), 2.83 (t, $J = 8.4$ Hz, 1H), 2.01 (t, $J = 6.5$ Hz, 1H), 1.67 (dd, $J = 8.8, 5.9$ Hz, 1H), 1.32 (t, $J = 7.2$ Hz, 3H), 1.05 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 168.6, 165.7, 138.8, 126.0, 120.1, 116.2, 112.7, 103.6, 94.5, 62.3, 61.9, 36.9, 28.9, 17.7, 14.0, 13.8; IR (EtOH): ν 2983, 2938, 2227, 1723, 1651, 1538, 1500, 1280, 1203 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{16}\text{H}_{18}\text{N}_2\text{O}_4\text{Na}$: 325.1159, Found: 325.1164.



Diethyl 2-(1-(1H-pyrazol-1-yl)vinyl)cyclopropane-1,1-dicarboxylate (3aw). The title compound was achieved as colorless oil (14.4 mg, 52%). ^1H NMR (400 MHz, Chloroform-*d*, TMS) δ 7.78 (d, $J = 2.5$ Hz, 1H), 7.60 (s, 1H), 6.34 (s, 1H), 5.72 (s, 1H), 4.76 (s, 1H), 4.37 – 4.14 (m, 2H), 3.99 (q, $J = 7.1$ Hz, 2H), 3.02 (t, $J = 8.5$ Hz, 1H), 2.06 (dd, $J = 7.8, 5.3$ Hz, 1H), 1.69 (dd, $J = 9.1, 5.3$ Hz, 1H), 1.31 (t, $J = 7.1$ Hz, 3H), 0.96 (t, $J = 7.1$ Hz, 3H); ^{13}C NMR (100 MHz, Chloroform-*d*, TMS) δ 169.1, 166.0, 140.7, 138.9, 127.5, 106.6, 101.8, 62.1, 61.6, 36.6, 28.4, 17.8, 14.0, 13.7; IR (EtOH): ν 2987, 2894, 1724, 1651, 1520, 1394, 1315, 1207, 1133 cm^{-1} ; HRMS (ESI) Calcd. for $\text{C}_{14}\text{H}_{18}\text{N}_2\text{O}_4\text{Na}$: 301.1159, Found: 301.1160.

(E) Spectroscopic Data of Products (NMR Spectra).



δ 169.032
 δ 166.068

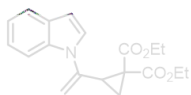
 δ 138.686
 δ 135.574
 δ 126.515
 δ 122.256
 δ 120.894
 δ 120.379
 δ 111.479
 δ 106.176
 δ 103.454

 δ 77.319
 δ 77.002
 δ 76.685

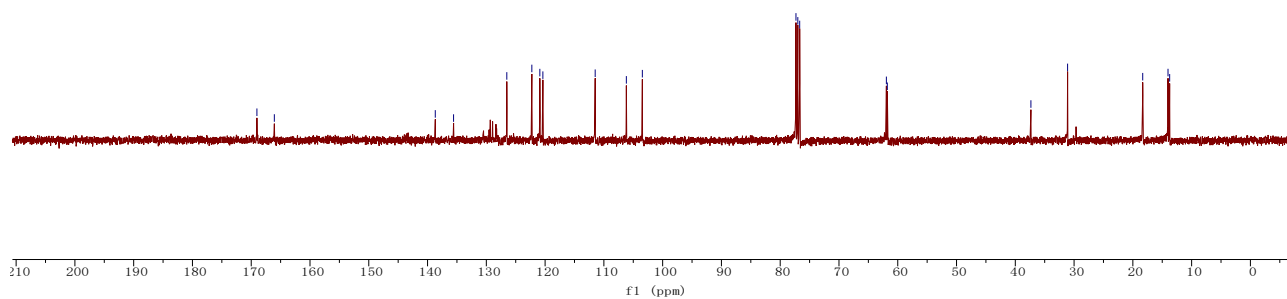
 δ 61.935
 δ 61.775

 δ 37.345
 δ 31.104

 δ 18.322
 δ 14.018
 δ 13.737

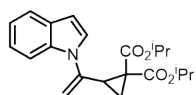


^{13}C NMR (100 MHz, Chloroform-*d*, TMS)

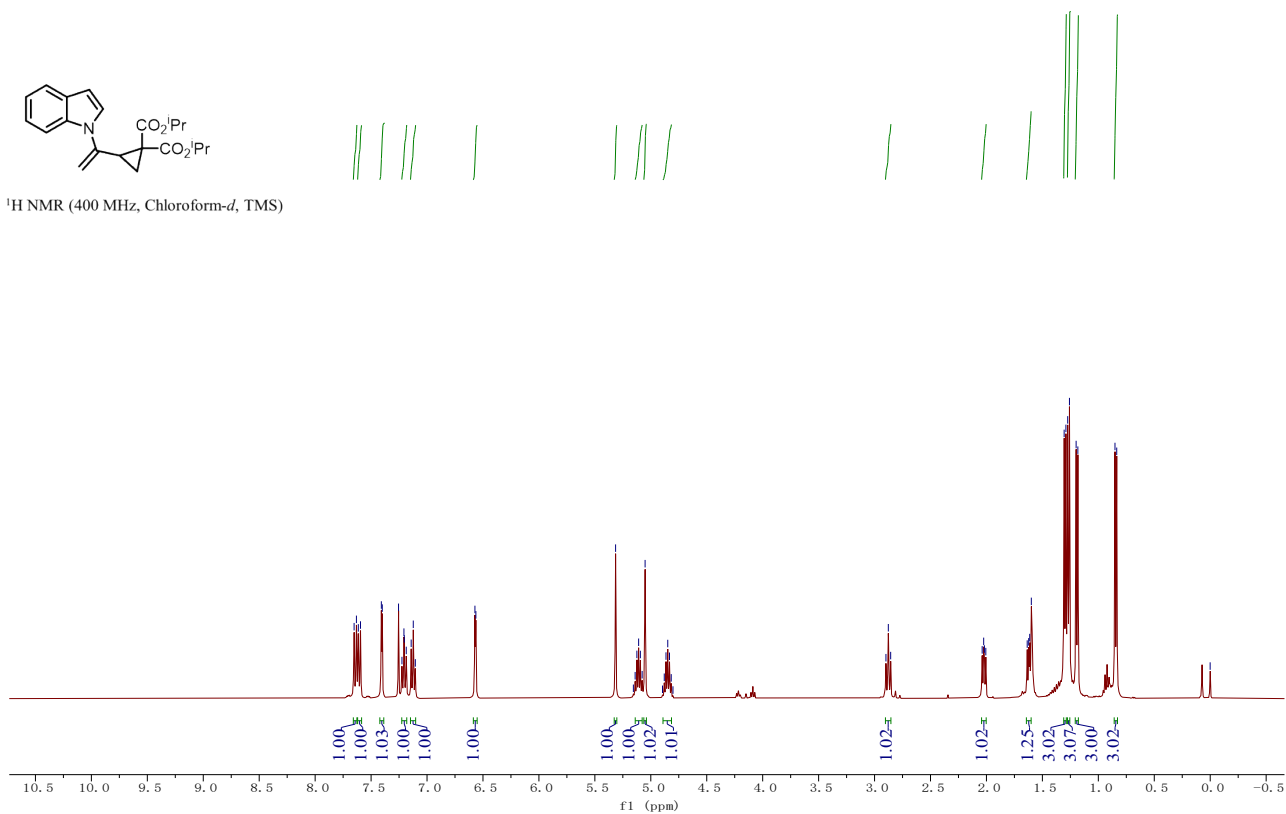


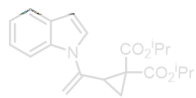
δ 7.652
 δ 7.631
 δ 7.614
 δ 7.595
 δ 7.408
 δ 7.400
 δ 7.255
 δ 7.224
 δ 7.206
 δ 7.203
 δ 7.186
 δ 7.142
 δ 7.123
 δ 7.105
 δ 6.572
 δ 6.563
 δ 5.315
 δ 5.156
 δ 5.140
 δ 5.124
 δ 5.109
 δ 5.093
 δ 5.077
 δ 5.051
 δ 4.895
 δ 4.880
 δ 4.864
 δ 4.848
 δ 4.833
 δ 4.817
 δ 4.802

 δ 2.898
 δ 2.877
 δ 2.856
 δ 2.038
 δ 2.025
 δ 2.018
 δ 2.006
 δ 1.636
 δ 1.623
 δ 1.613
 δ 1.599
 δ 1.306
 δ 1.290
 δ 1.274
 δ 1.258
 δ 1.198
 δ 1.183
 δ 0.851
 δ 0.836
 δ 0.001

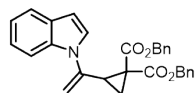
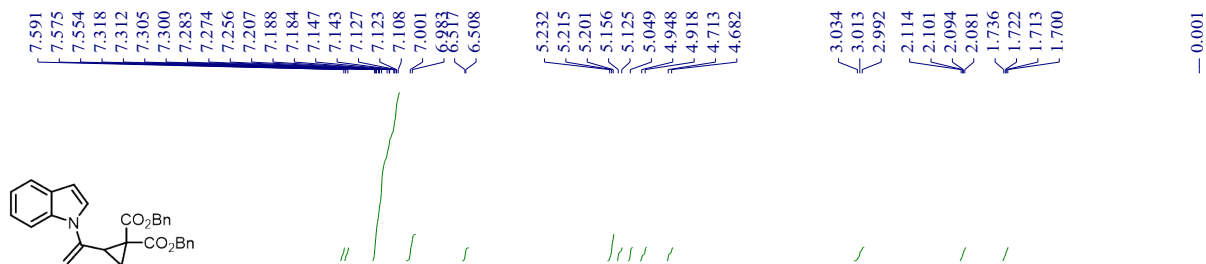
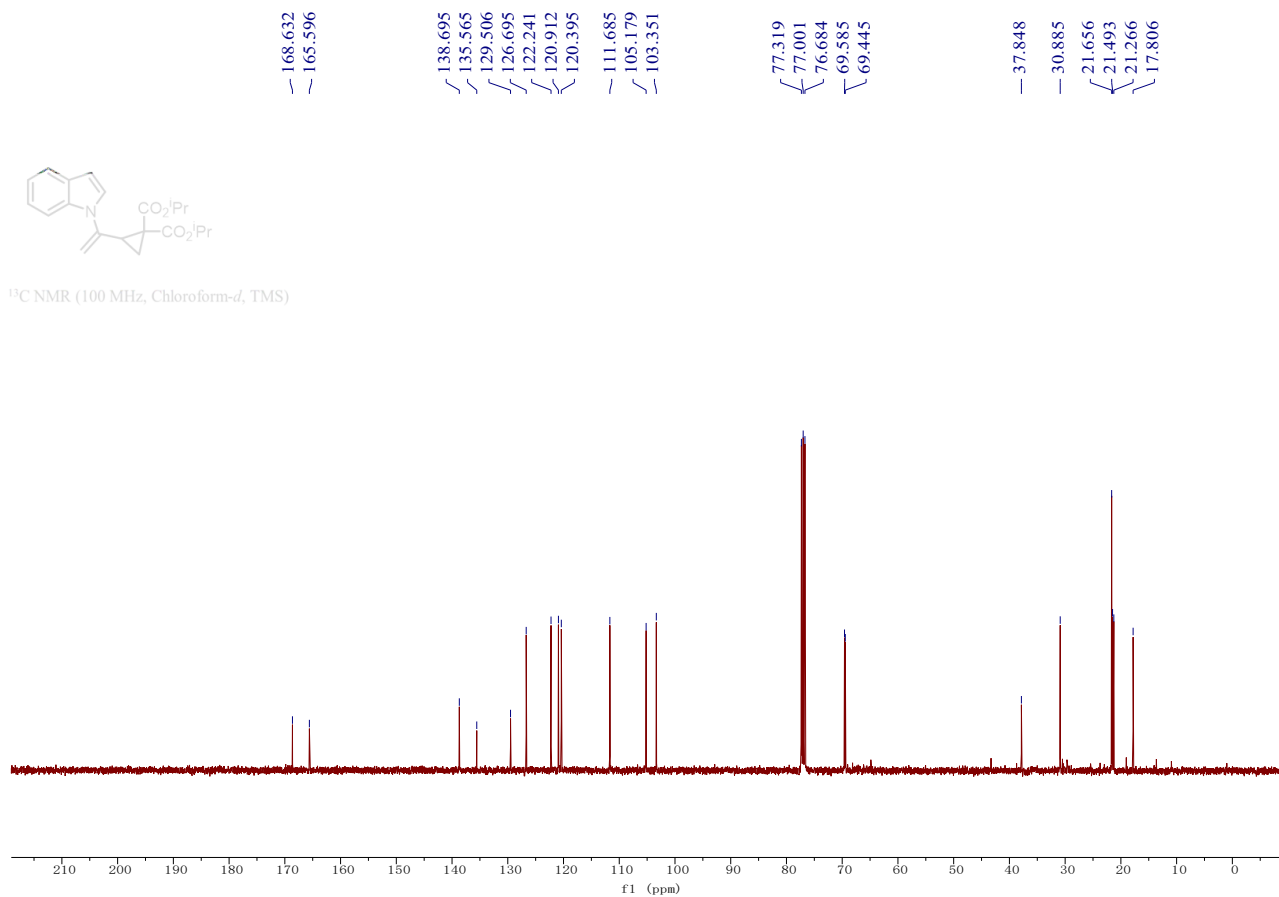


^1H NMR (400 MHz, Chloroform-*d*, TMS)

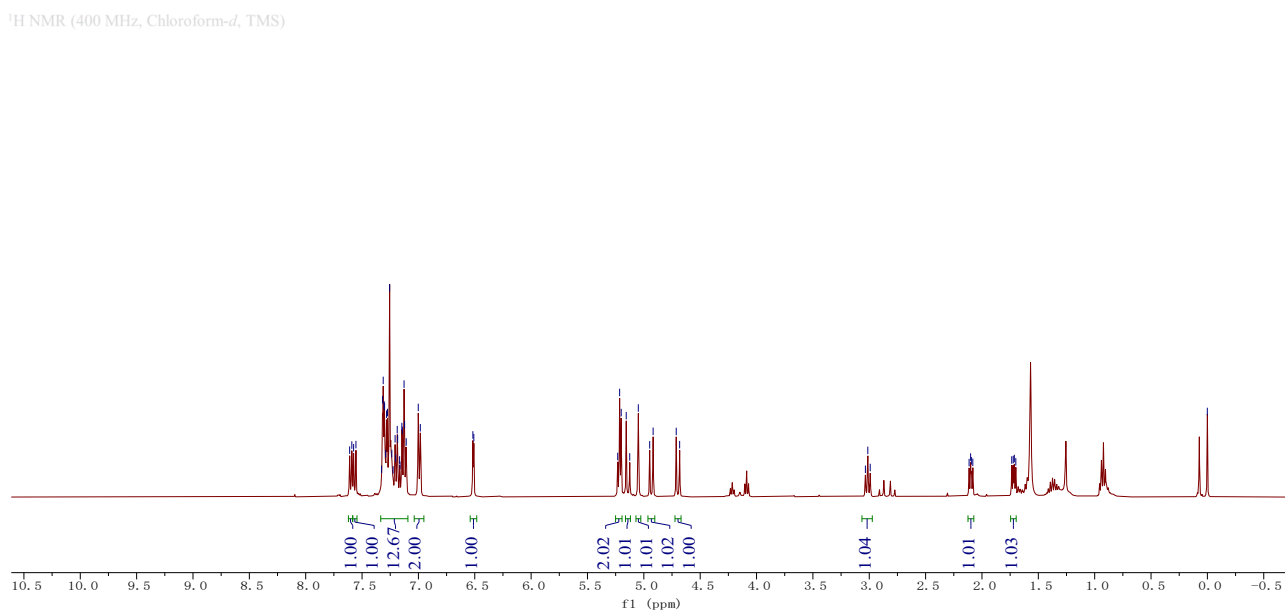


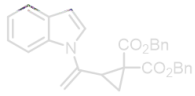


¹³C NMR (100 MHz, Chloroform-*d*, TMS)

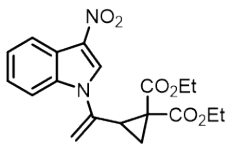
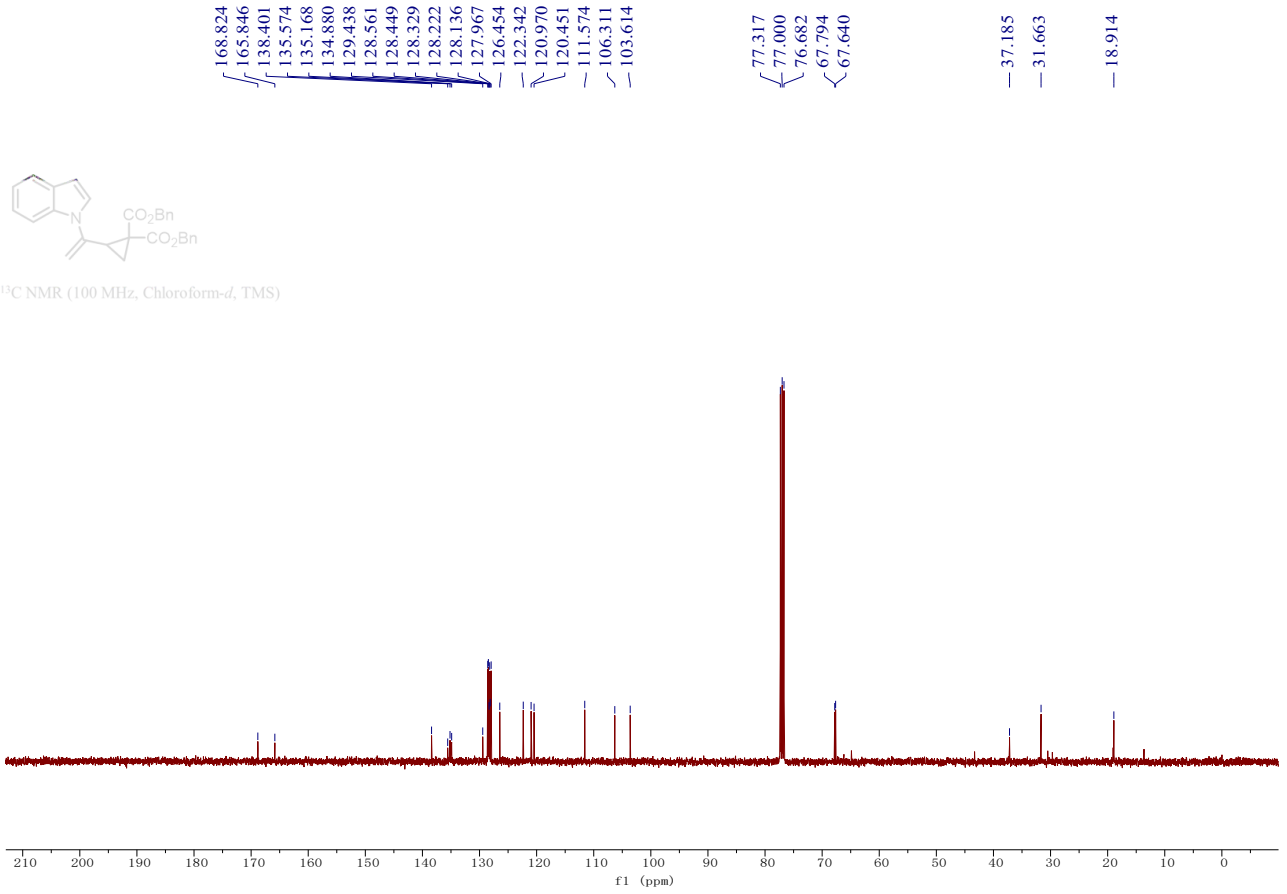


¹H NMR (400 MHz, Chloroform-*d*, TMS)

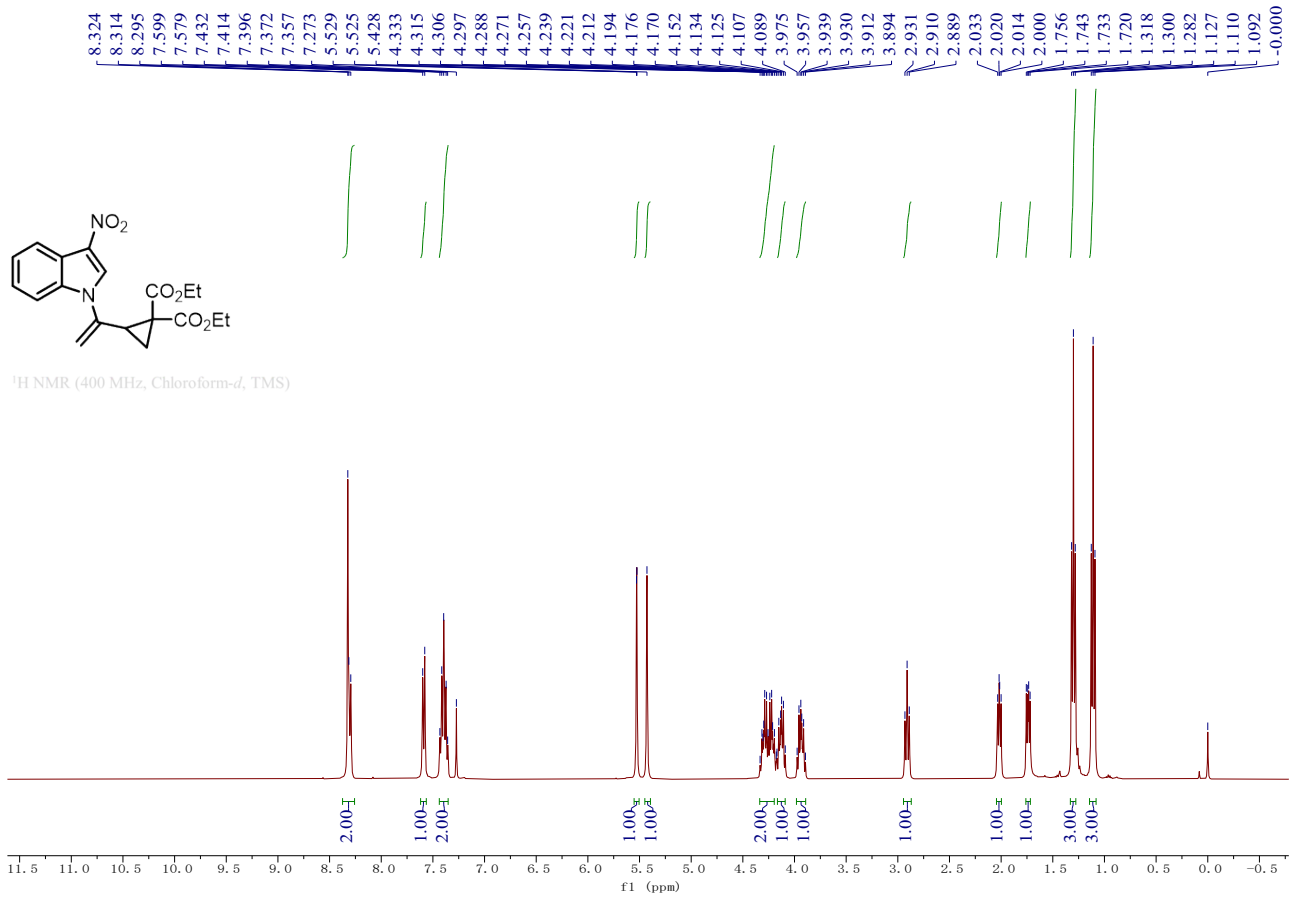


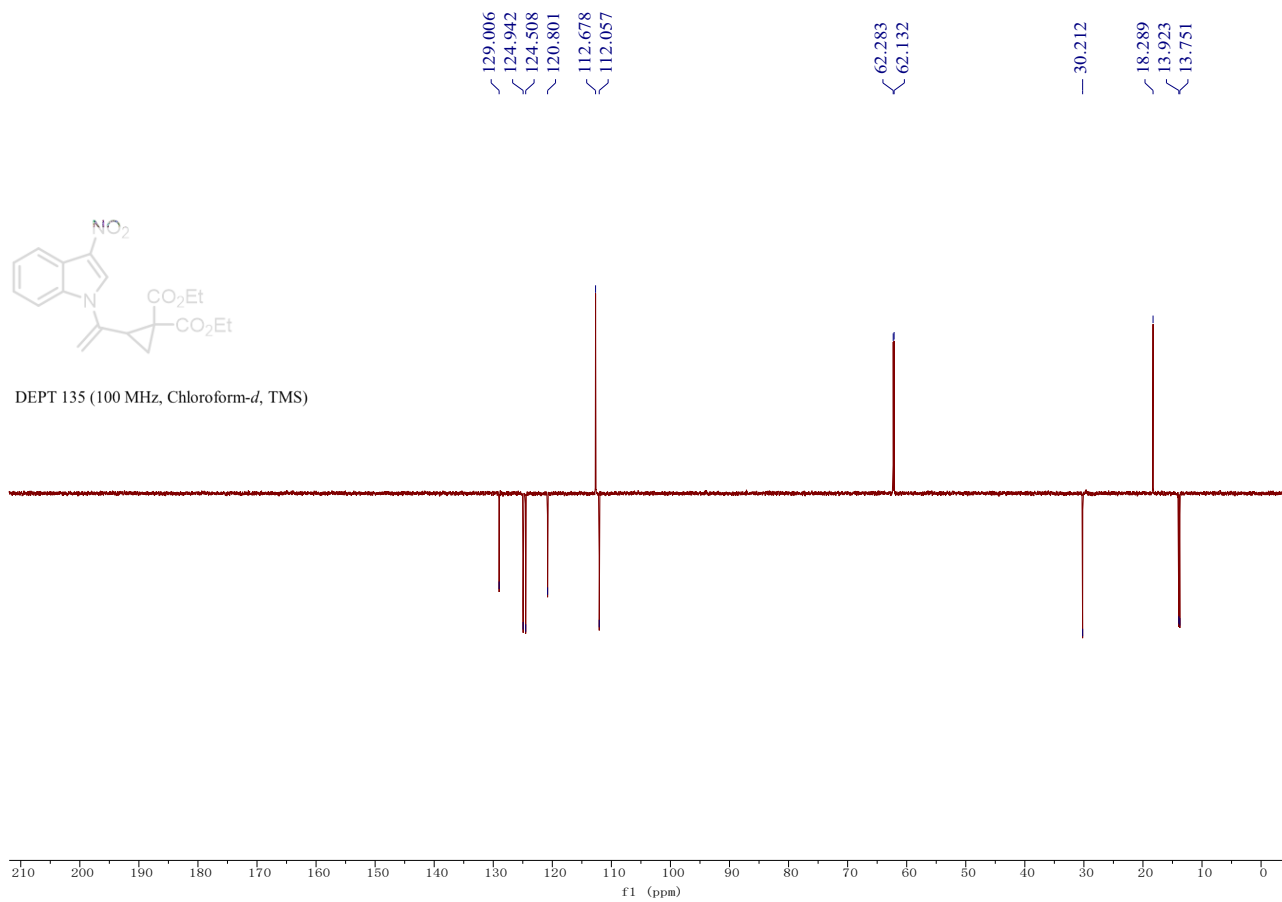
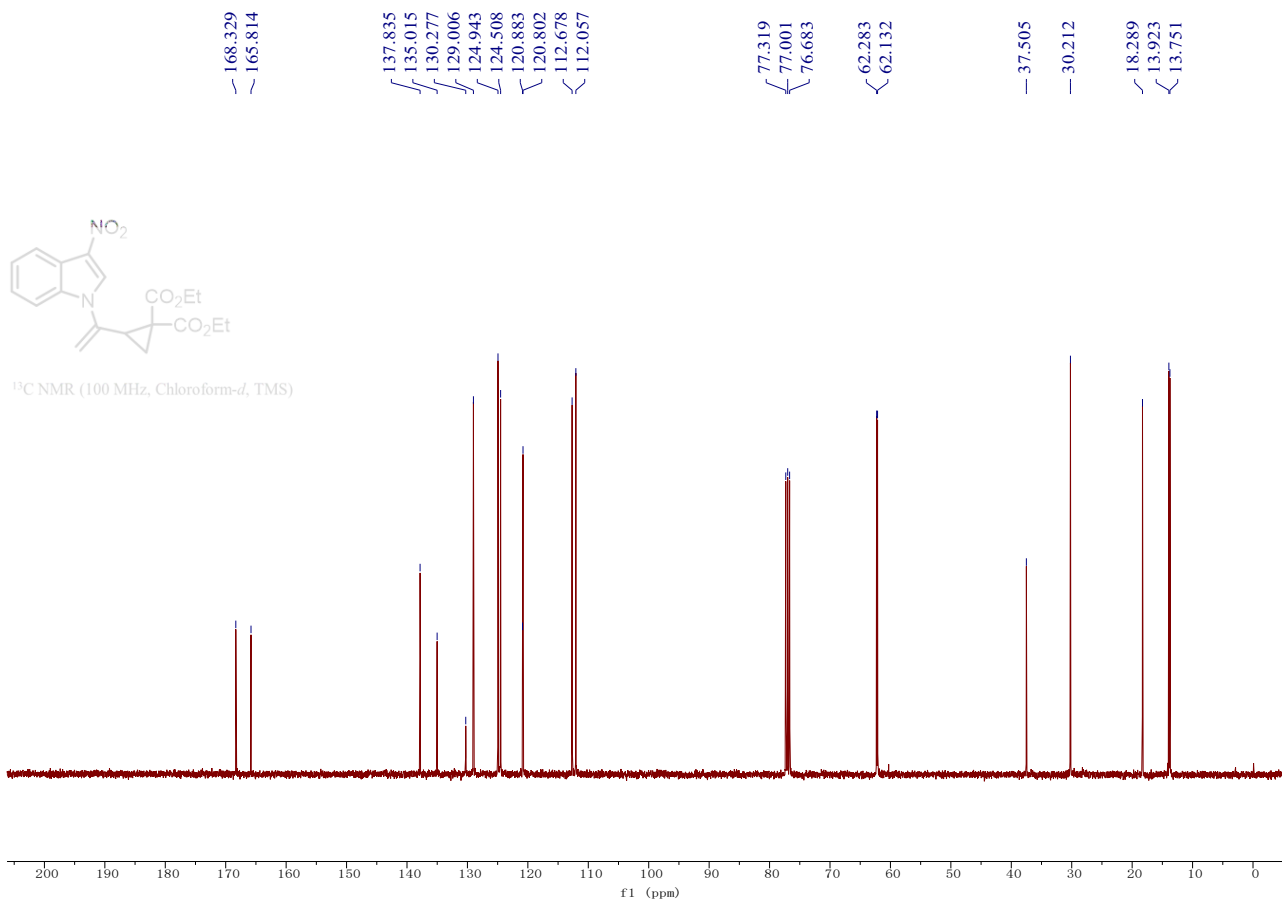


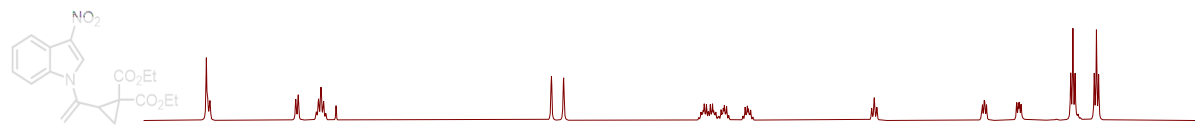
¹³C NMR (100 MHz, Chloroform-*d*, TMS)



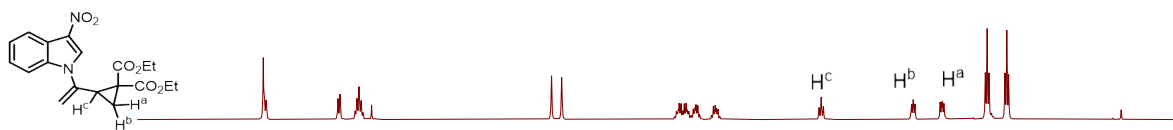
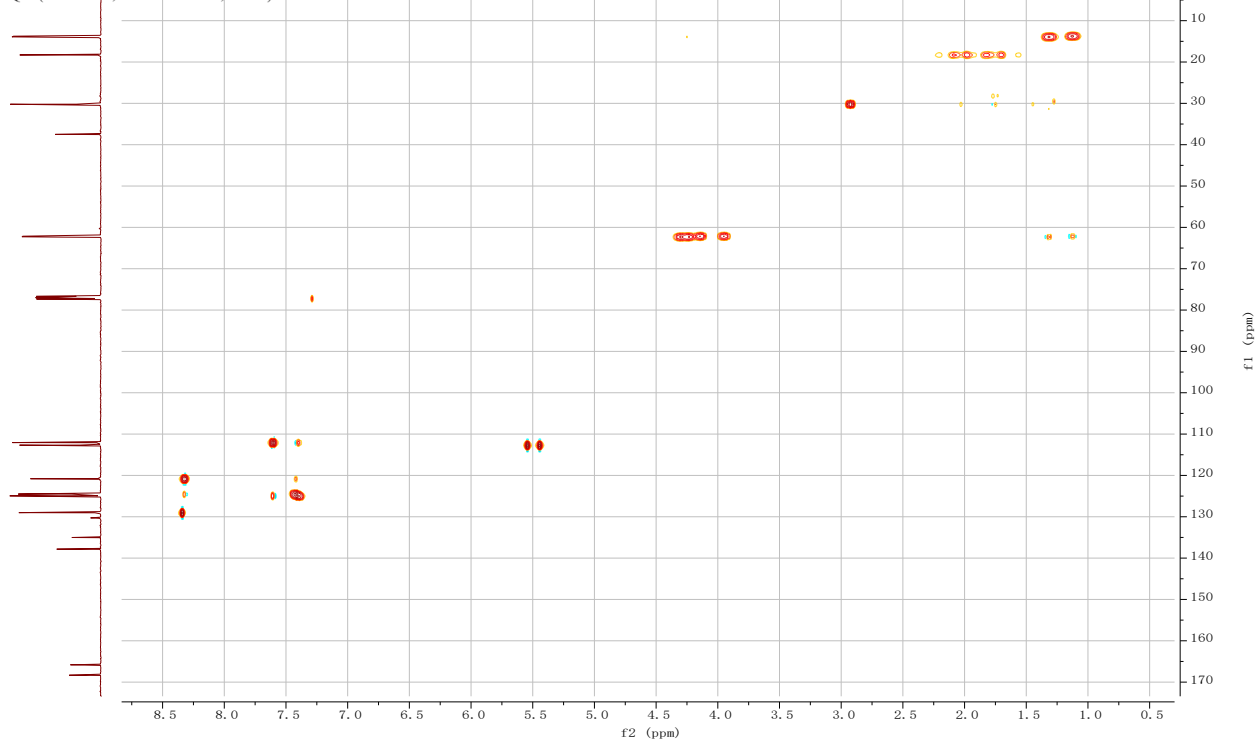
¹H NMR (400 MHz, Chloroform-*d*, TMS)



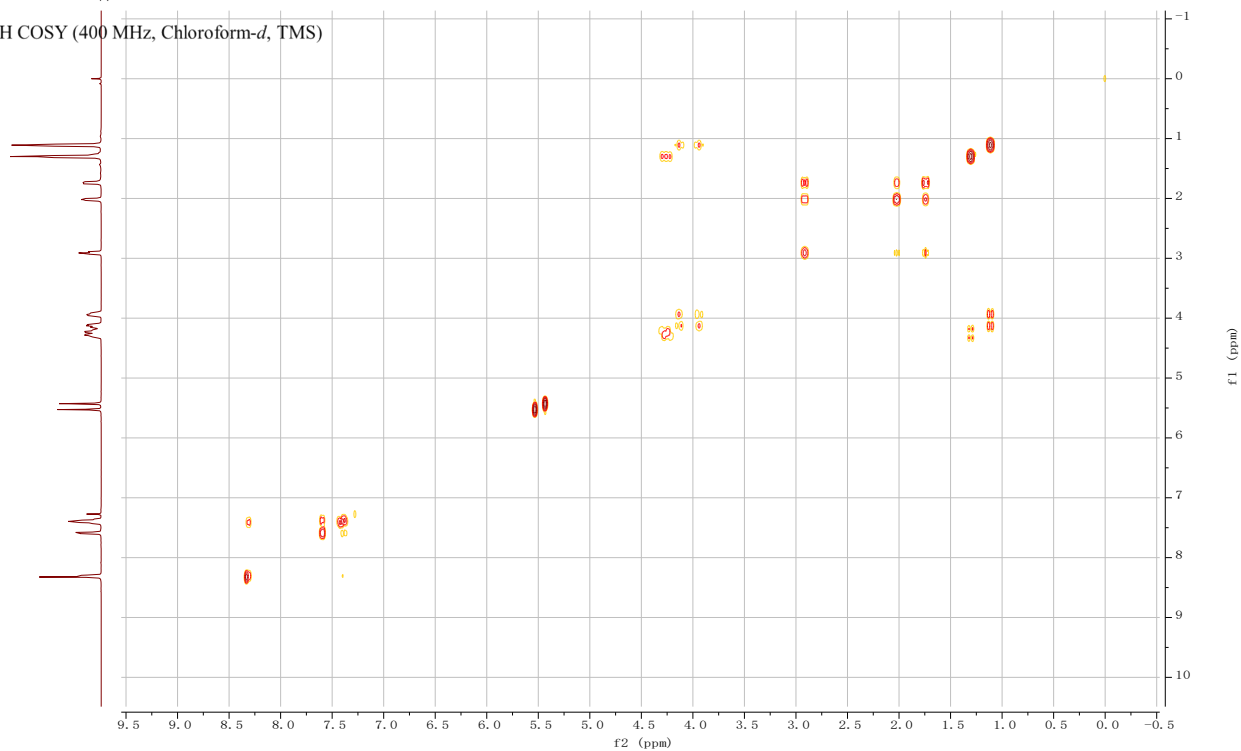


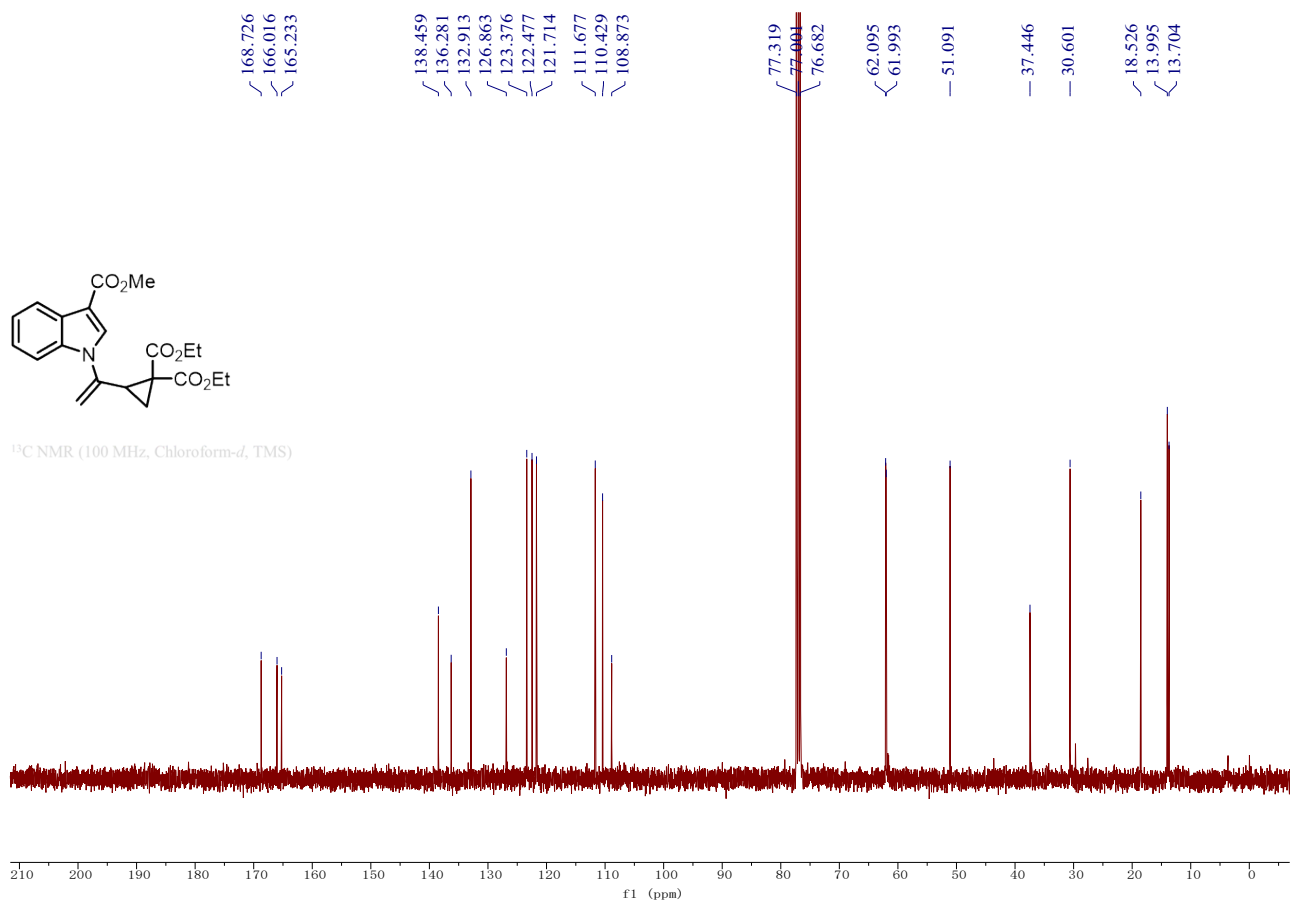
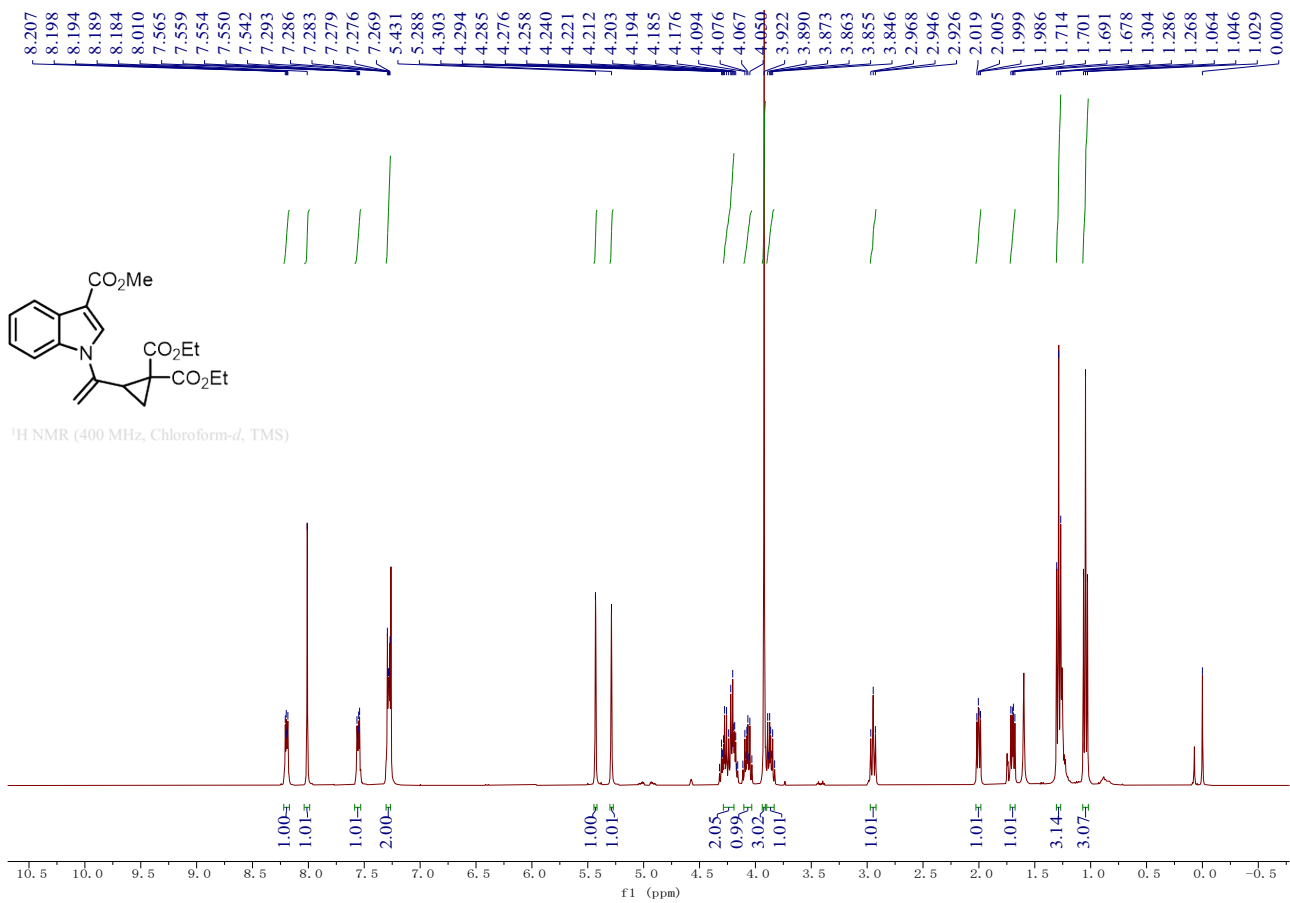


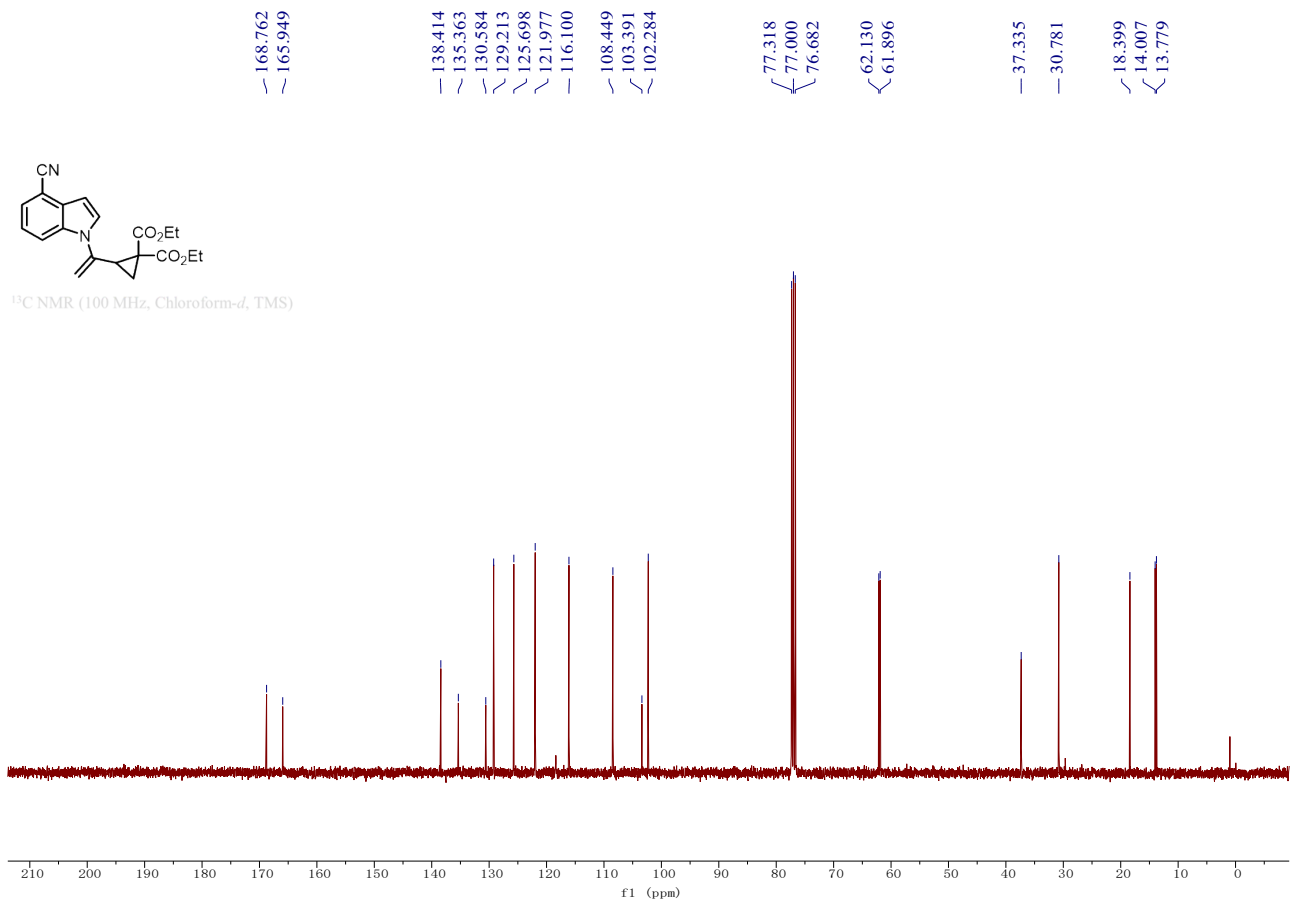
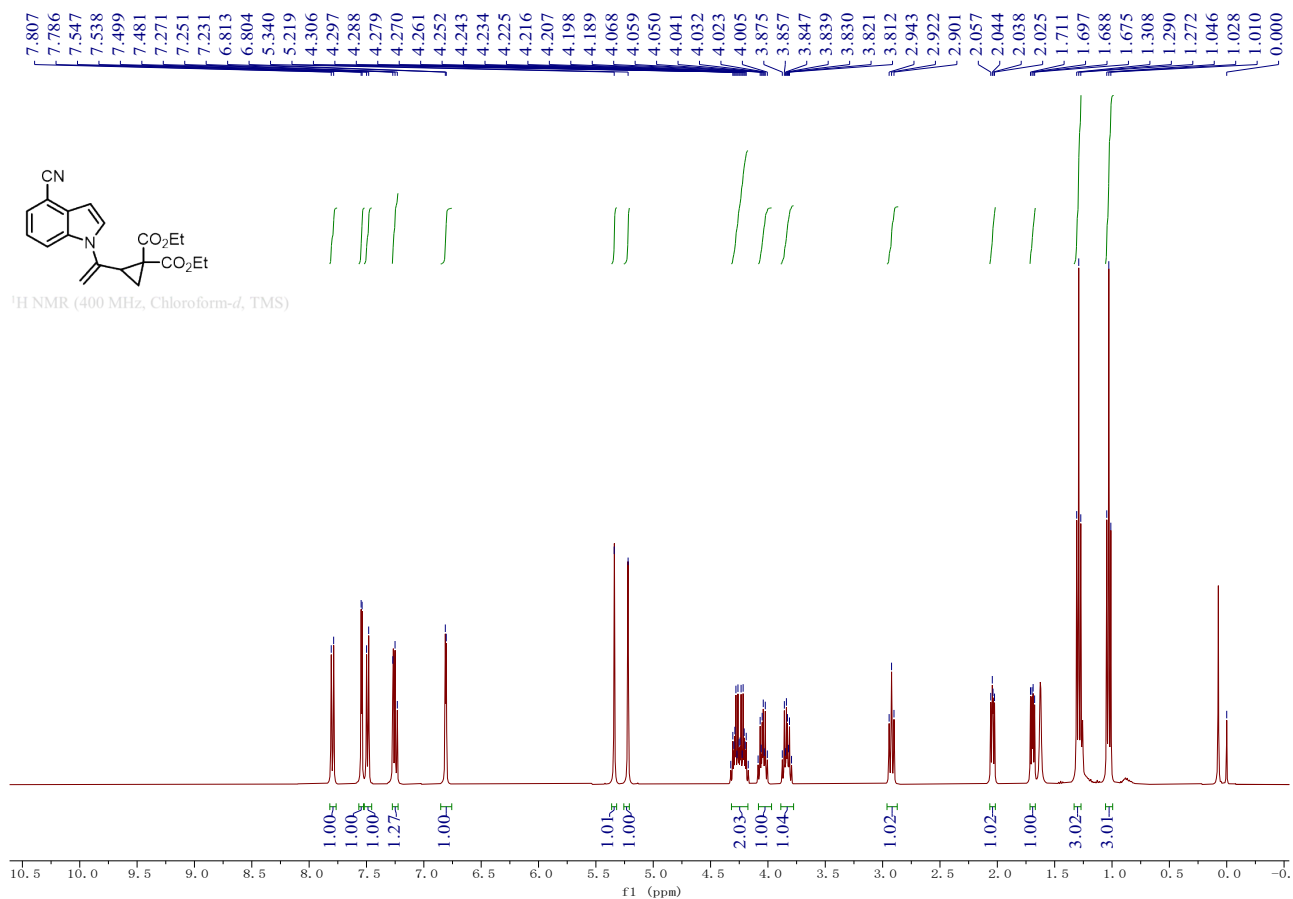
HSQC (400 MHz, Chloroform-*d*, TMS)

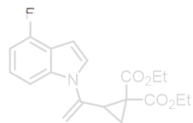


¹H-¹H COSY (400 MHz, Chloroform-*d*, TMS)

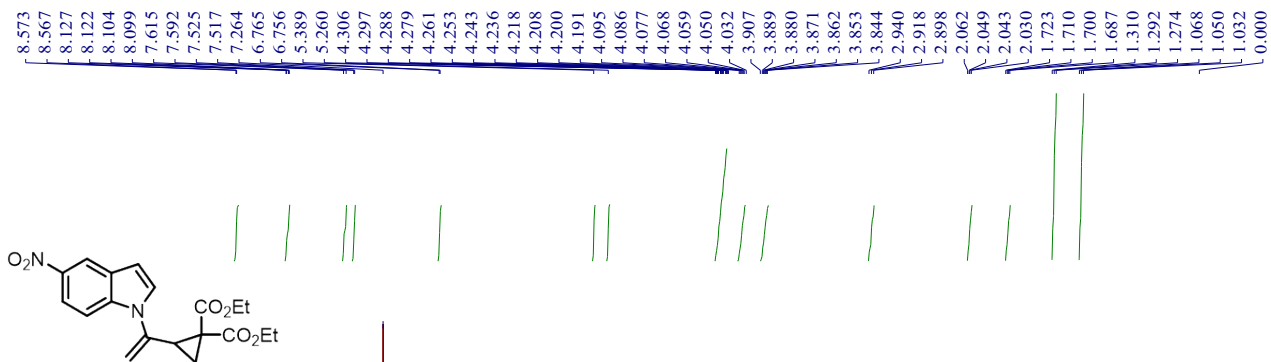
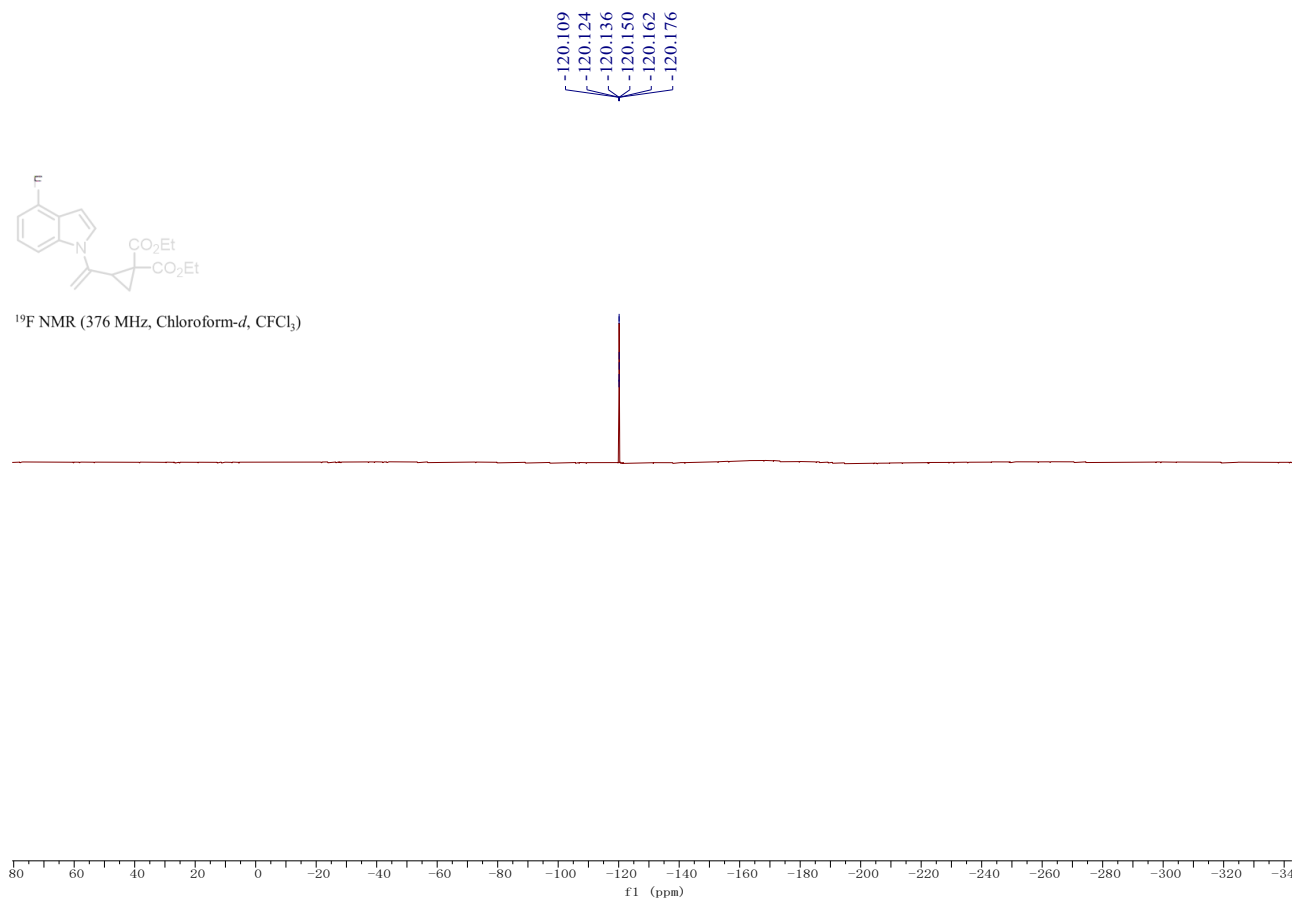




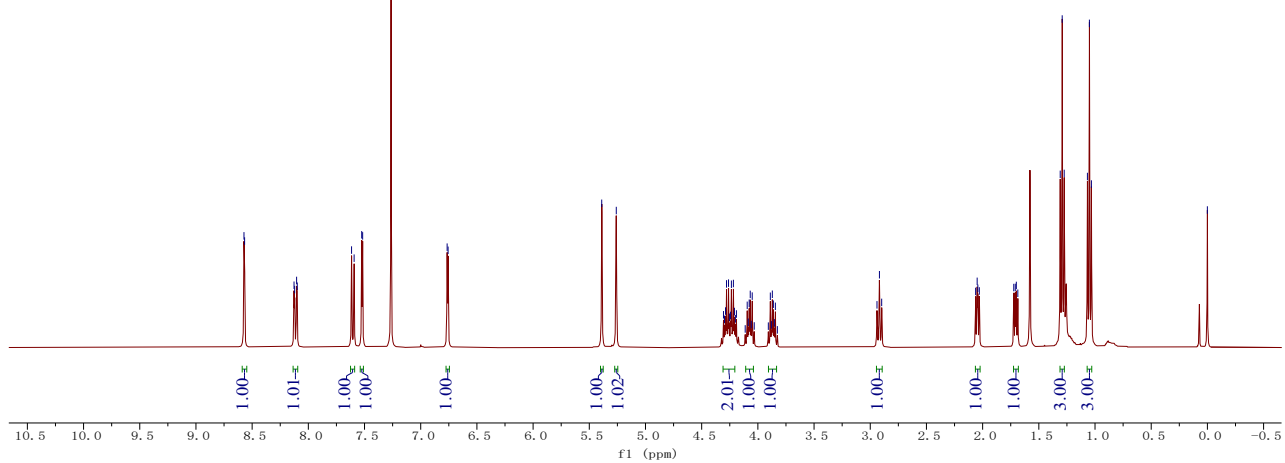


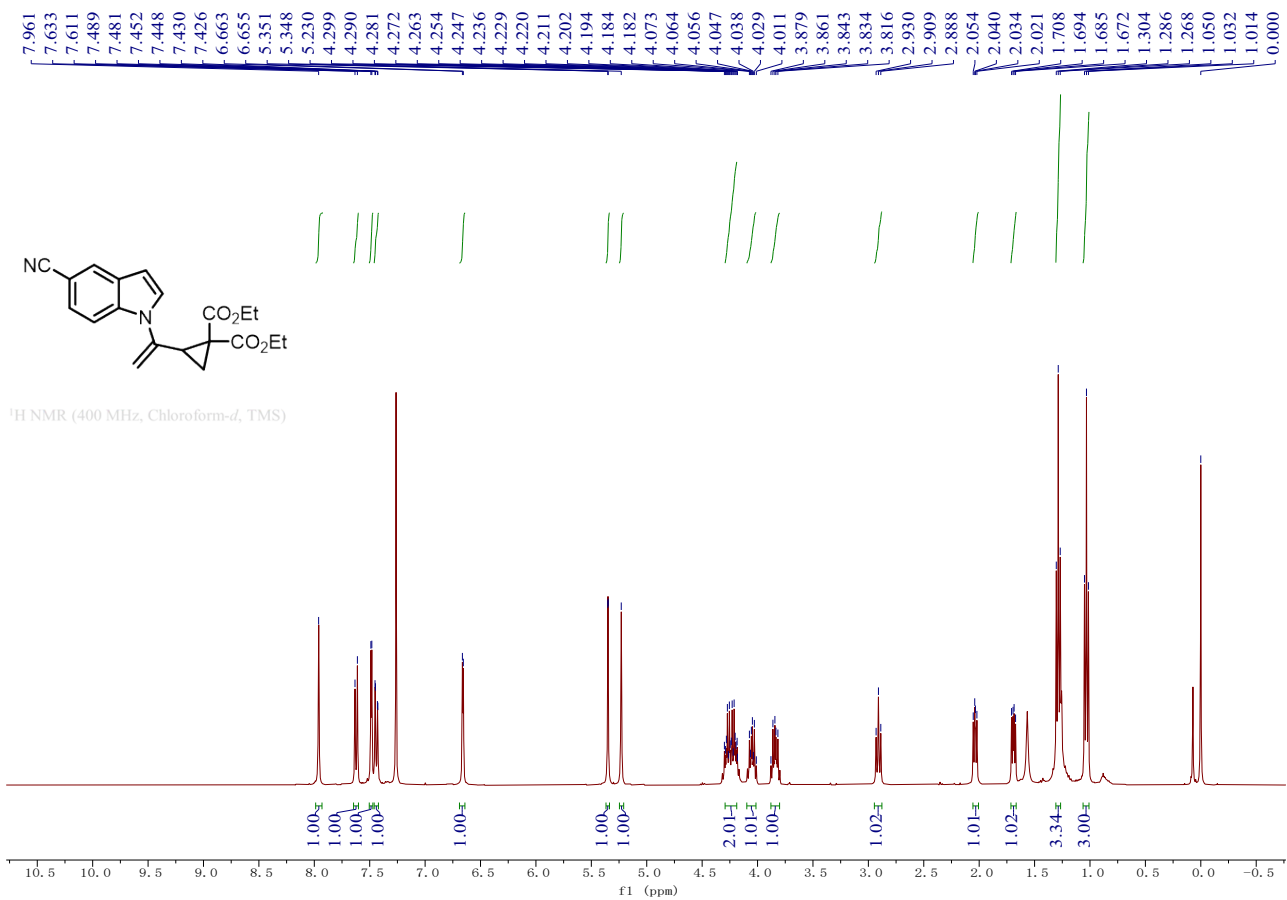
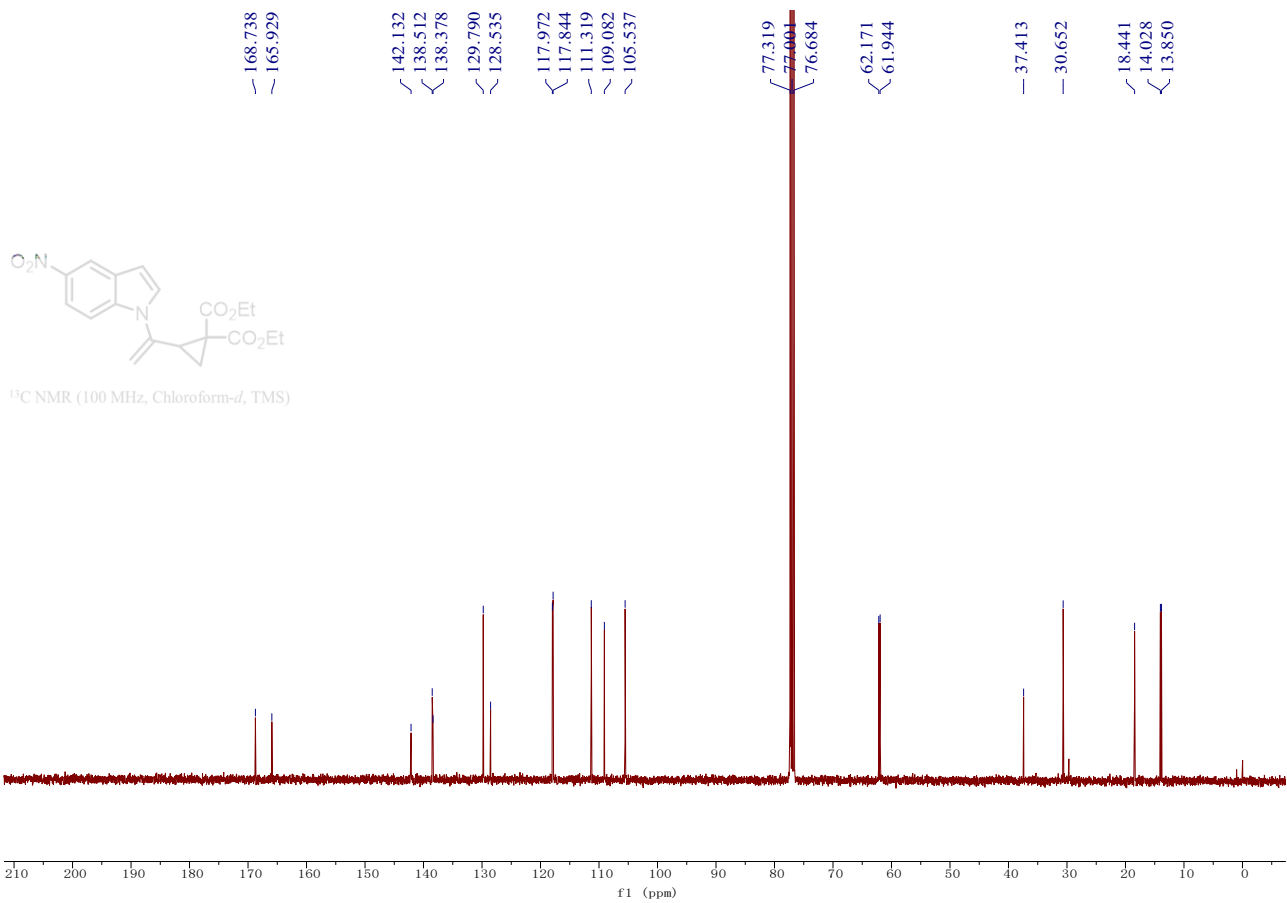


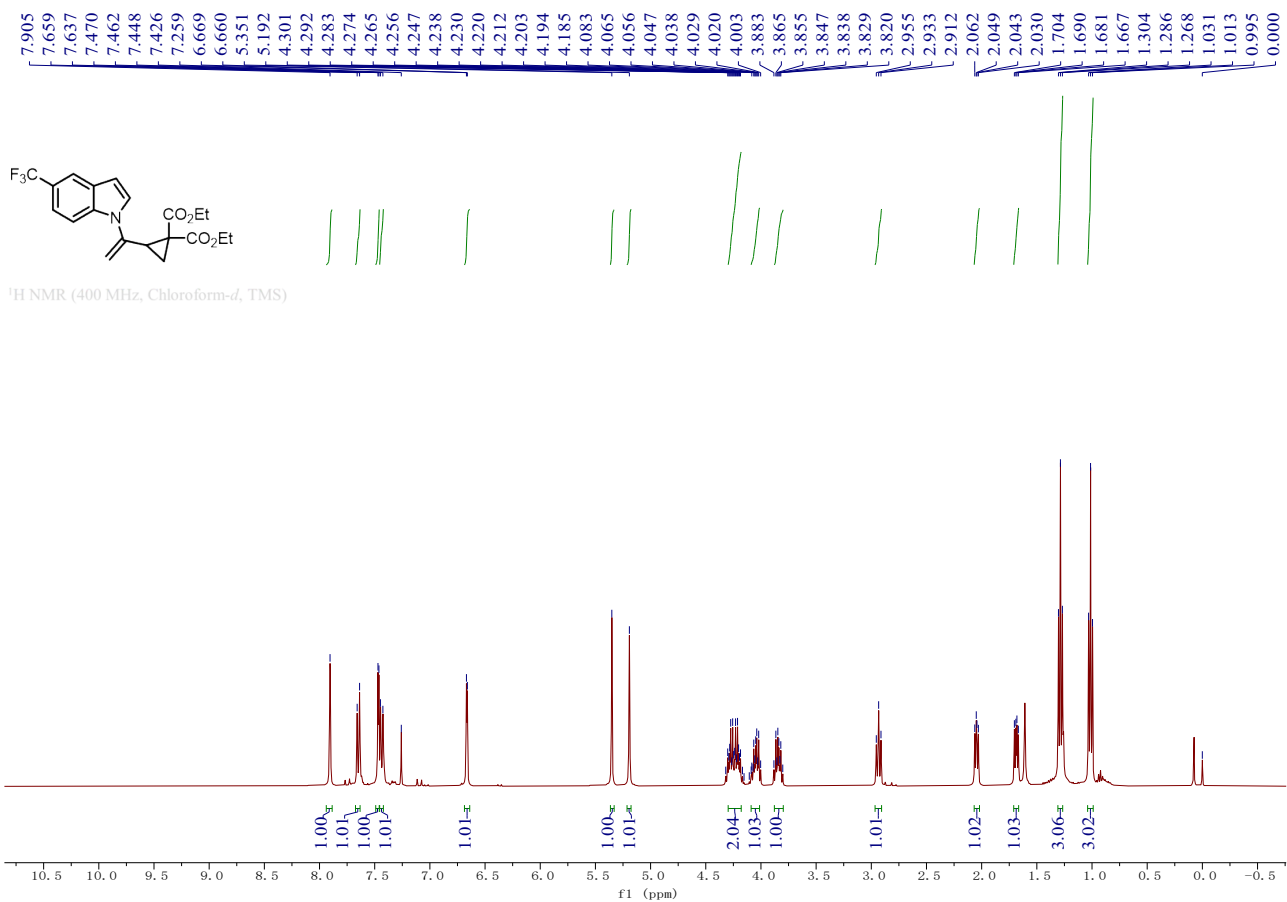
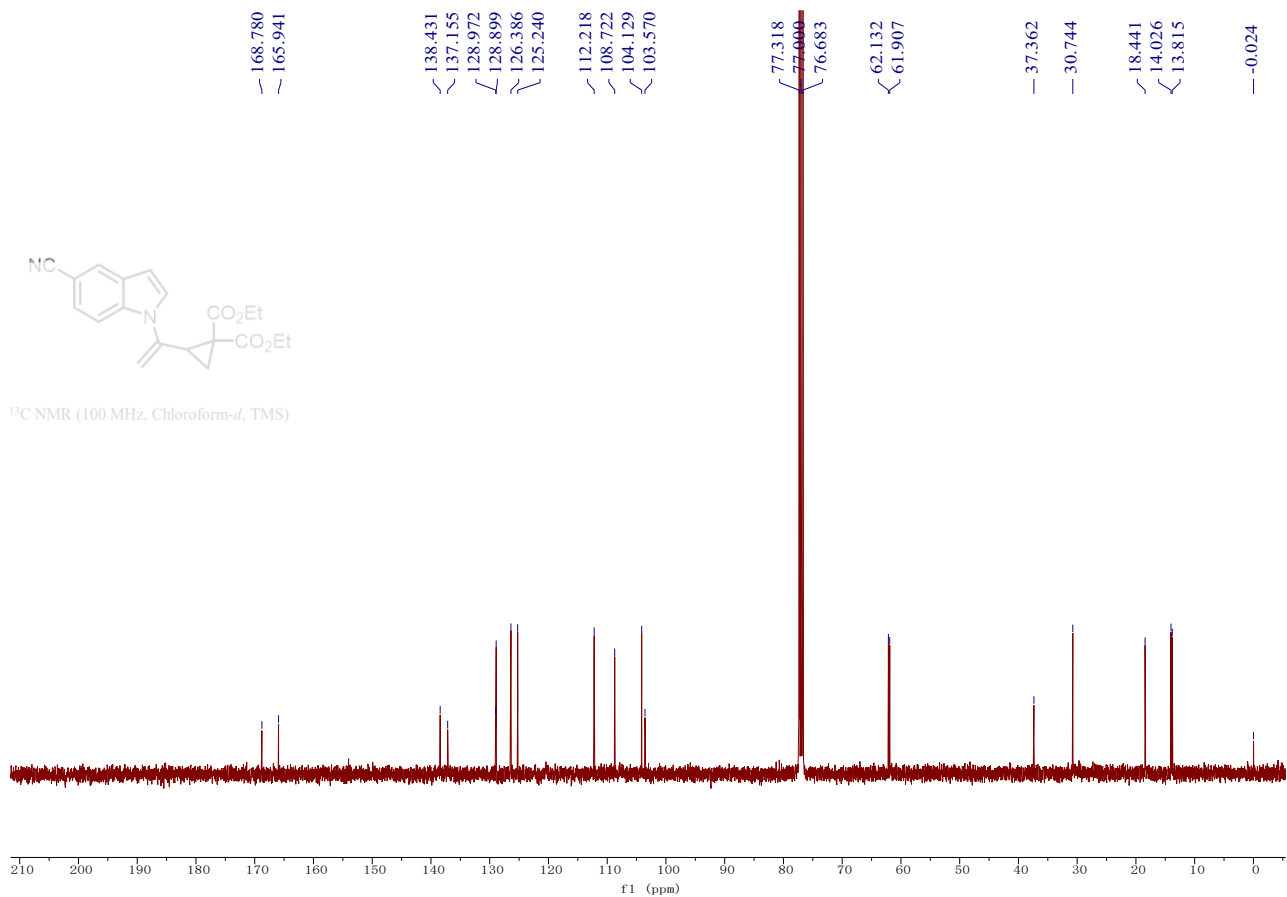
¹⁹F NMR (376 MHz, Chloroform-*d*, CFC1₃)

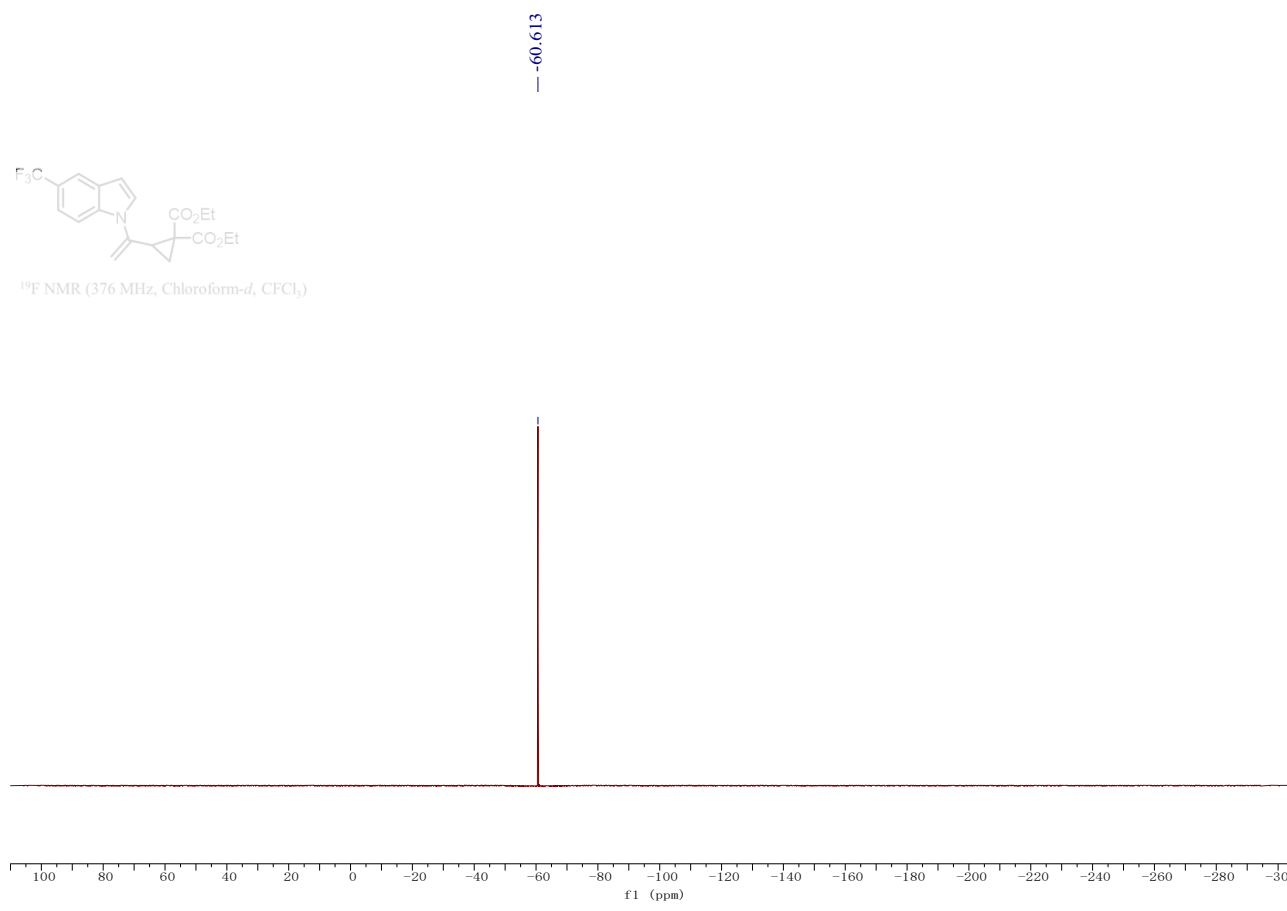
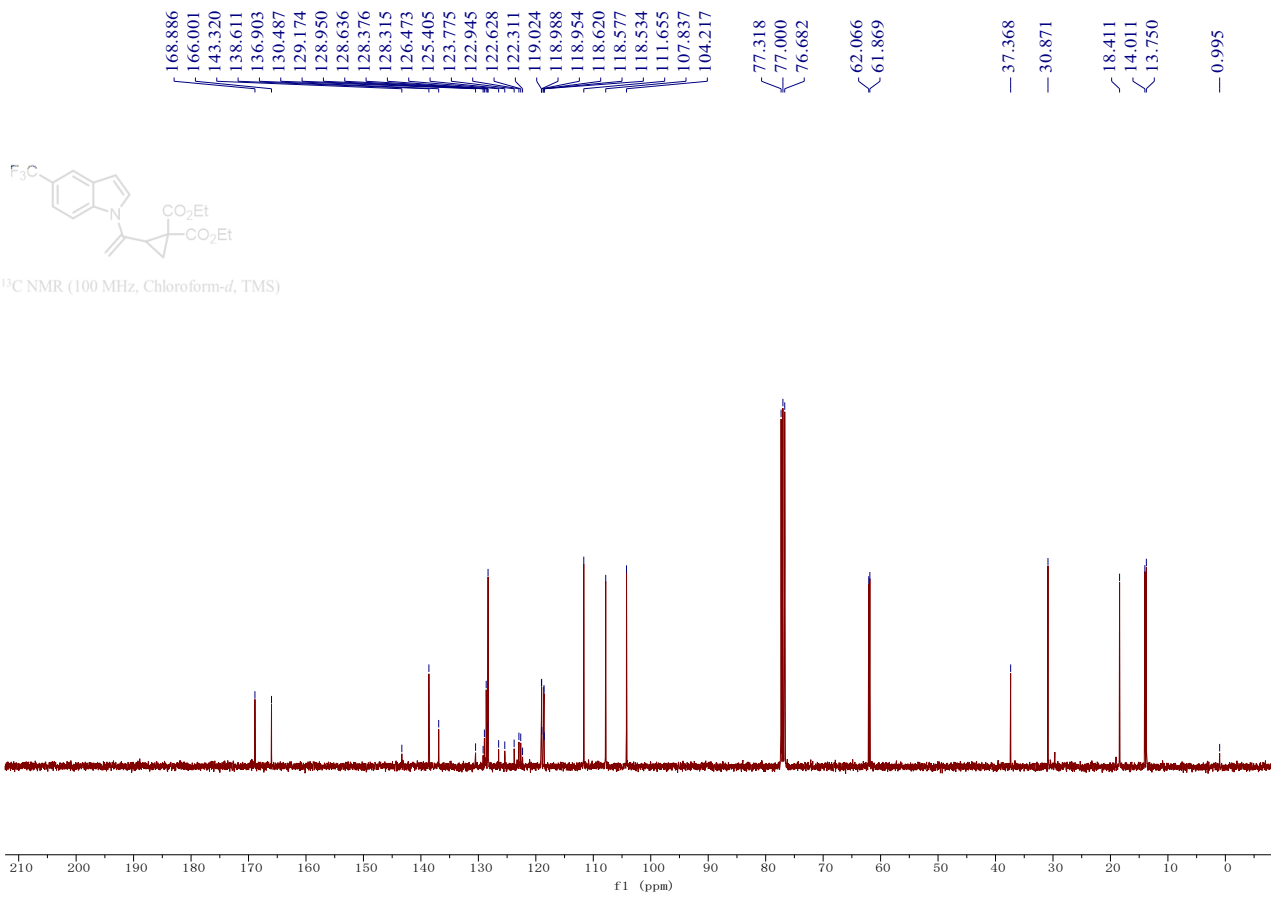


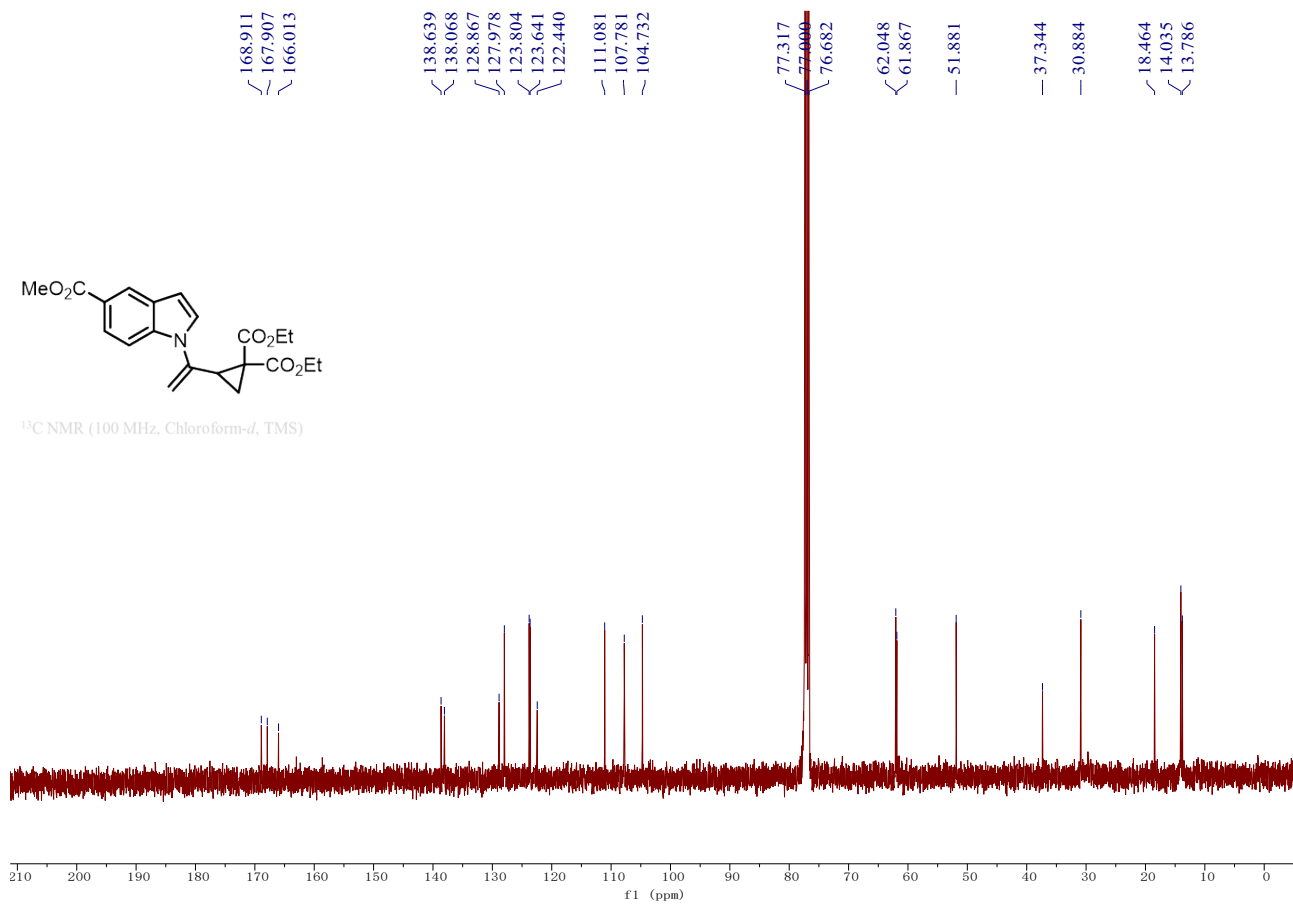
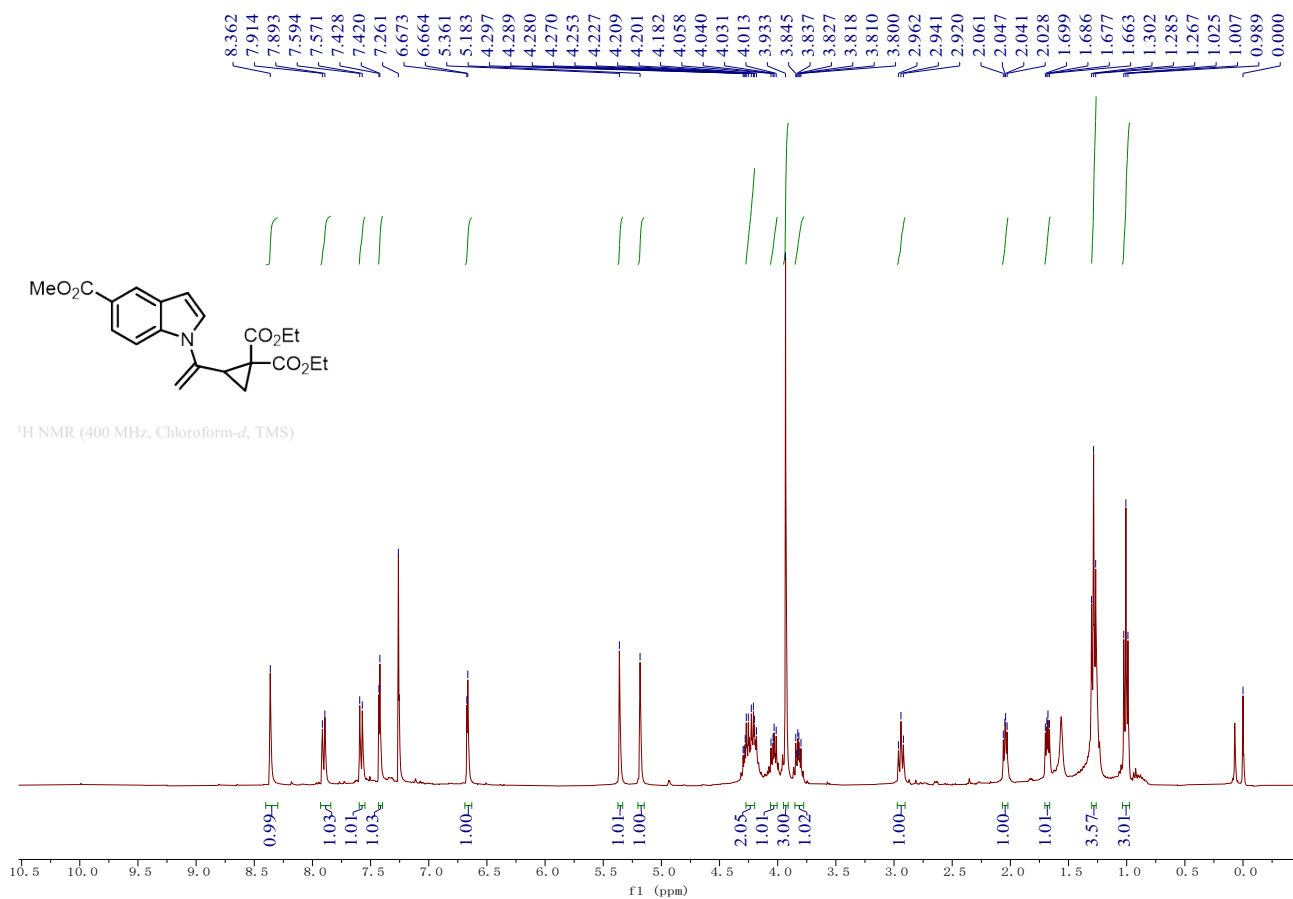
¹H NMR (400 MHz, Chloroform-*d*, TMS)

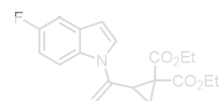




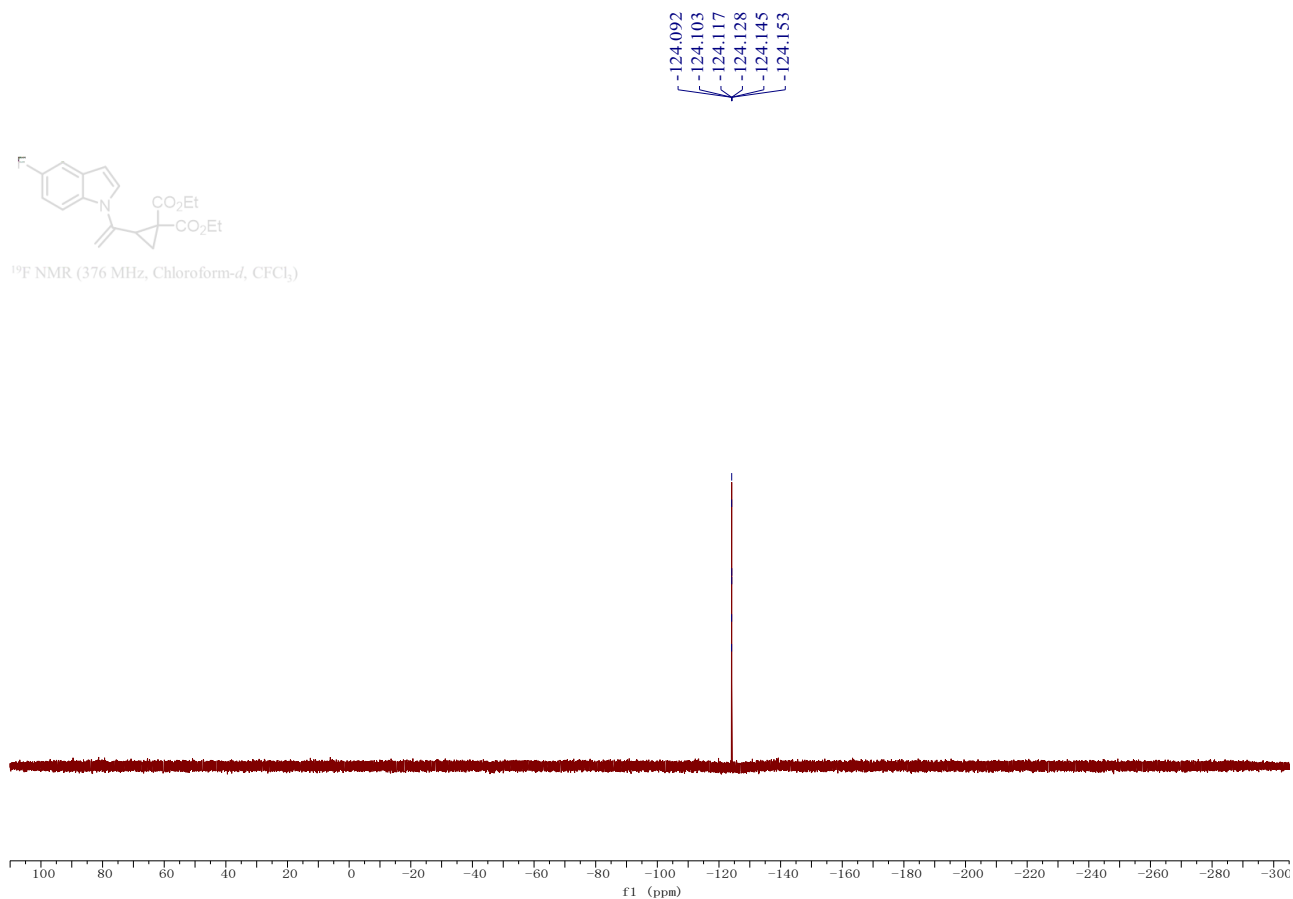




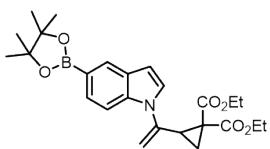




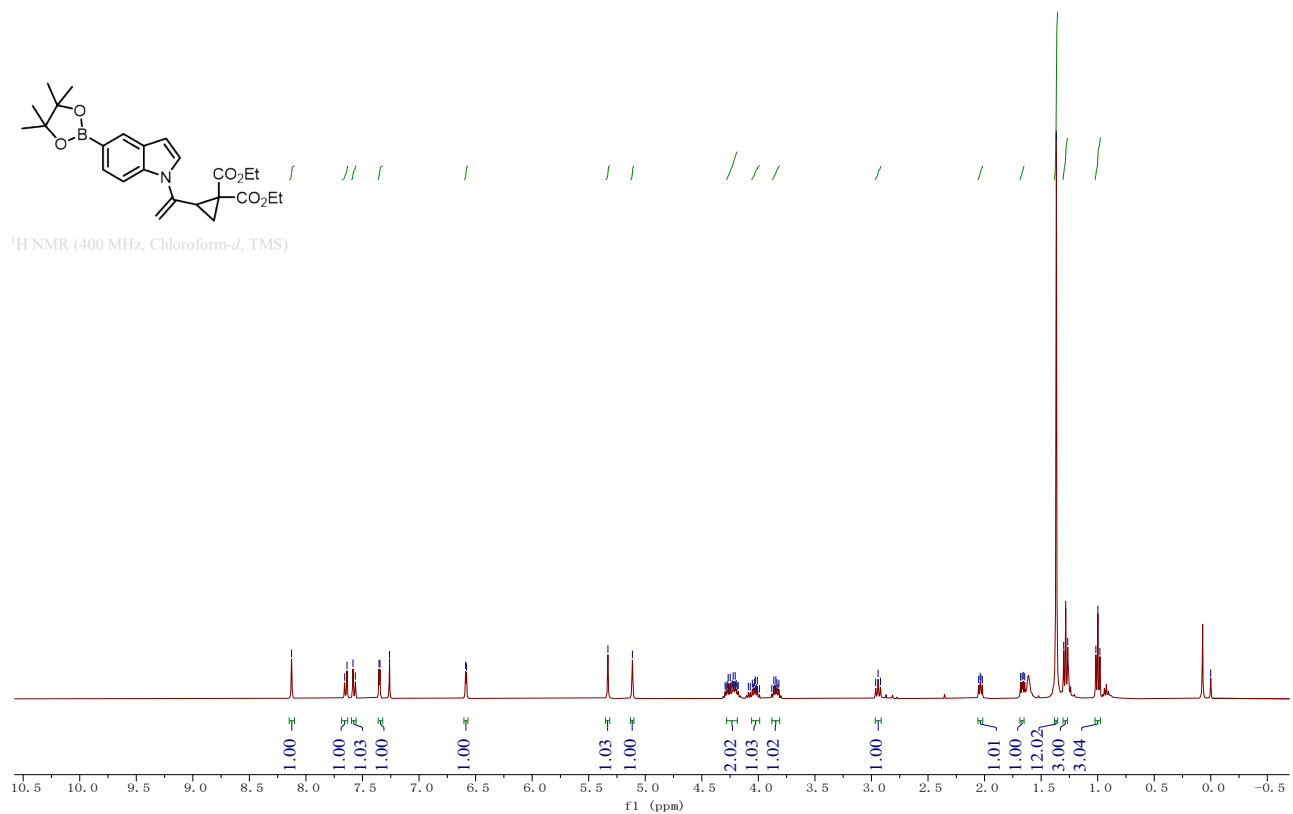
¹⁹F NMR (376 MHz, Chloroform-*d*, CFCl₃)



8.127
7.658
7.637
7.584
7.563
7.354
7.345
7.261
6.589
5.330
5.114
4.294
4.285
4.276
4.267
4.258
4.249
4.240
4.232
4.223
4.215
4.205
4.196
4.187
4.178
4.089
4.072
4.054
4.044
4.035
4.026
4.017
4.009
3.863
3.854
3.845
3.836
3.827
3.819
2.963
2.942
2.920
2.052
2.039
2.032
2.020
1.681
1.668
1.658
1.645
1.365
1.300
1.283
1.265
1.016
0.998
0.980
0.001



¹H NMR (400 MHz, Chloroform-*d*, TMS)



\swarrow 169.055
 \swarrow 166.112

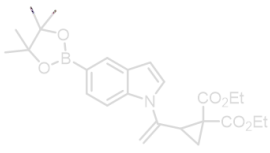
 \swarrow 138.746
 \swarrow 137.578
 \swarrow 129.103
 \swarrow 128.782
 \swarrow 128.455
 \swarrow 126.755

 \swarrow 110.906
 \swarrow 106.719
 \swarrow 104.073

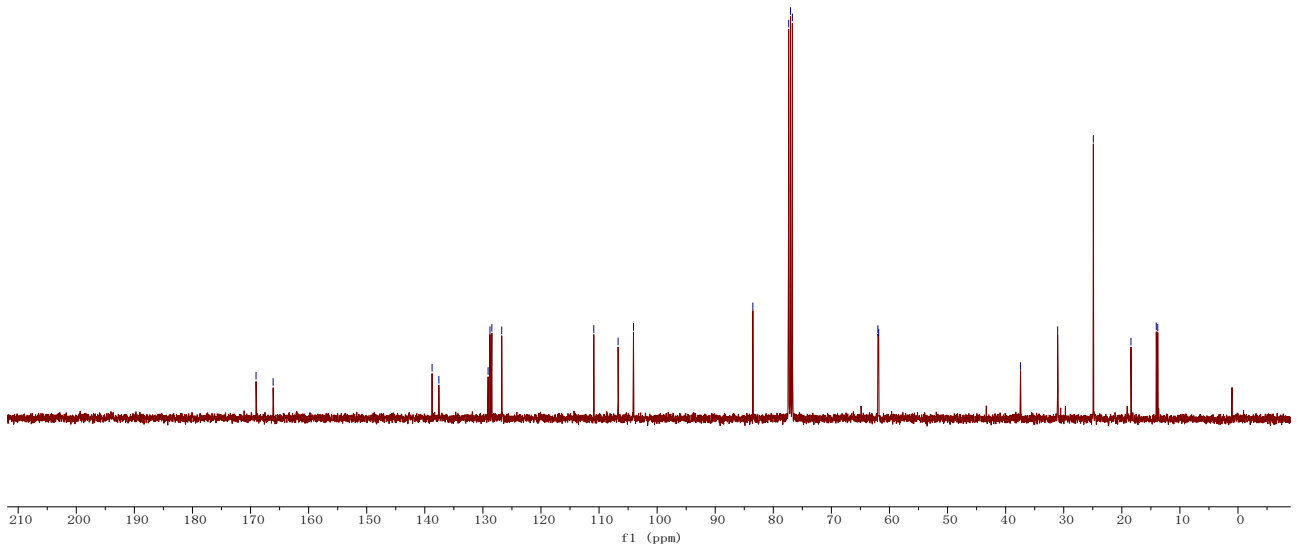
 \swarrow 83.518
 \swarrow 77.350
 \swarrow 77.032
 \swarrow 76.714

 \swarrow 61.995
 \swarrow 61.849

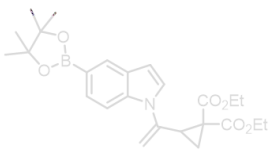
 \swarrow 37.438
 \swarrow 31.043
 \swarrow 24.902
 \swarrow 18.424
 \swarrow 14.065
 \swarrow 13.809



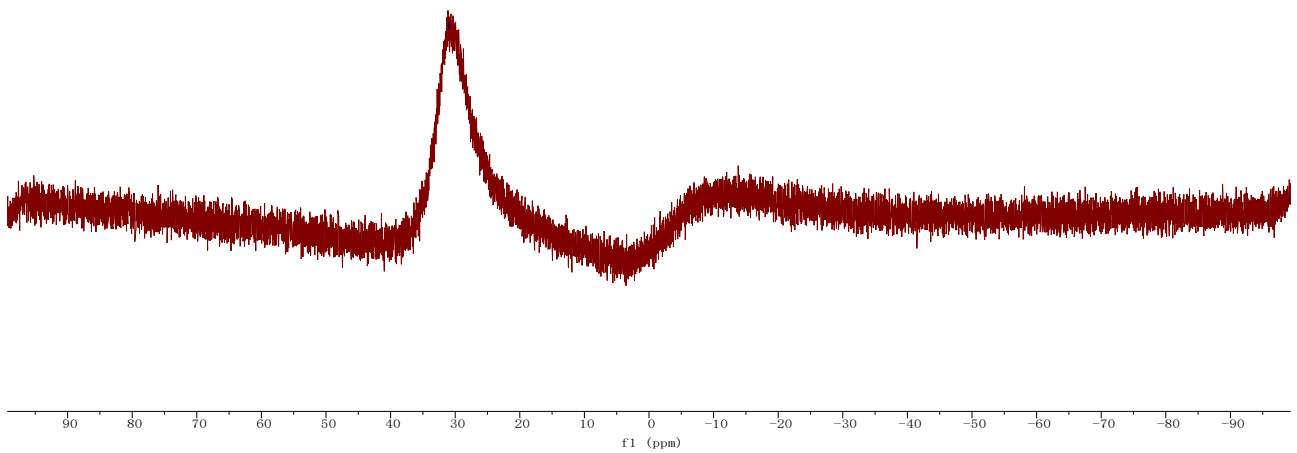
^{13}C NMR (100 MHz, Chloroform-*d*, TMS)

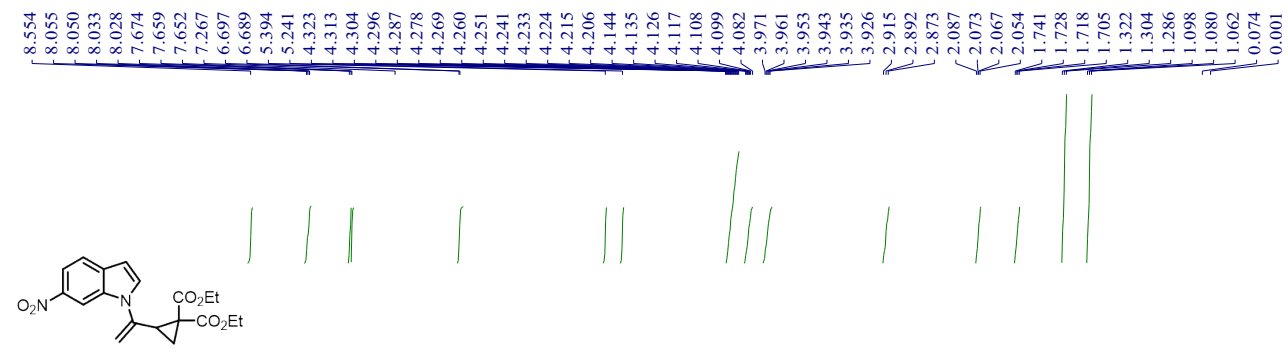


— 30.997

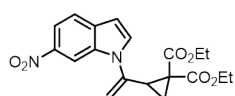
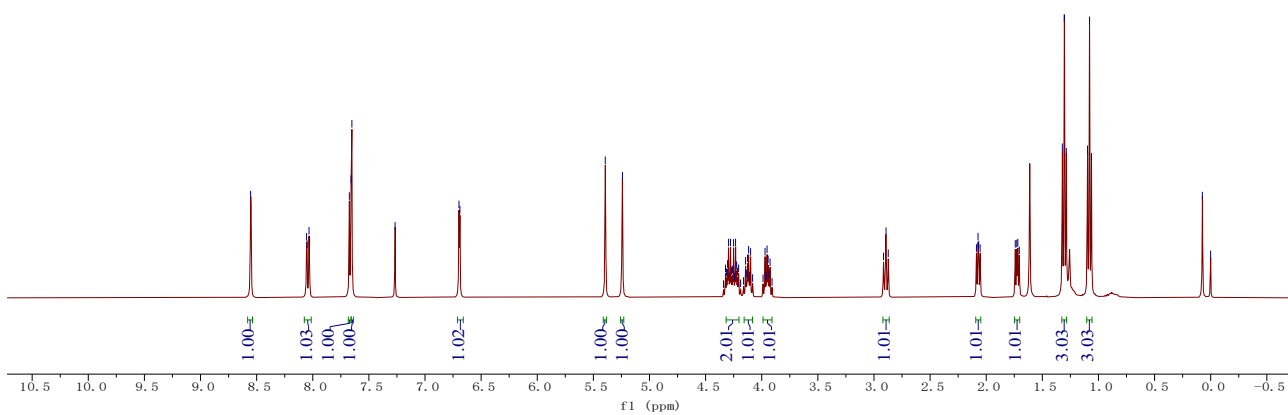


^{11}B NMR (128.4 MHz, Chloroform-*d*)

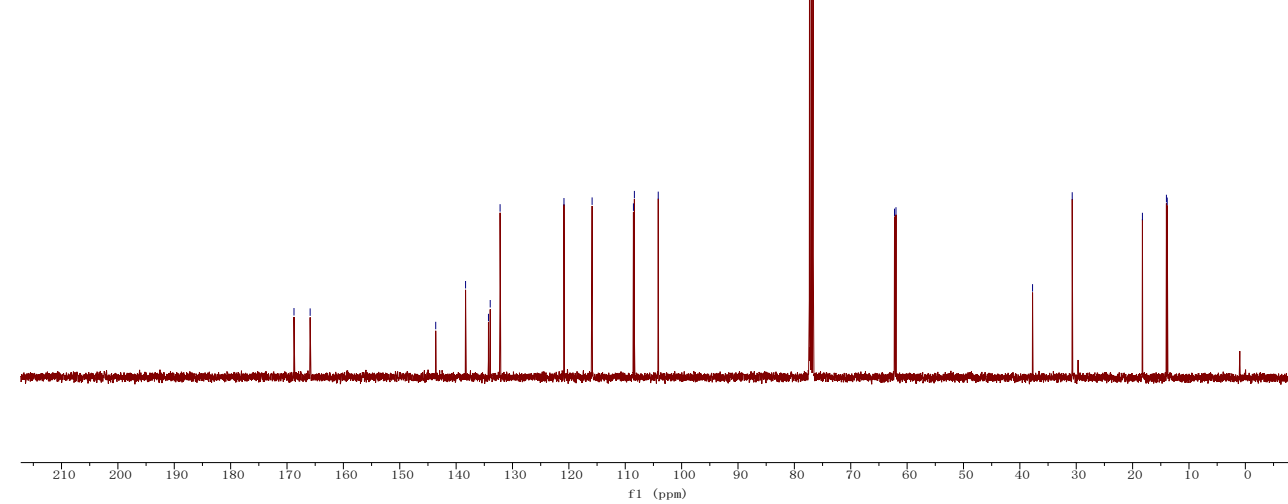


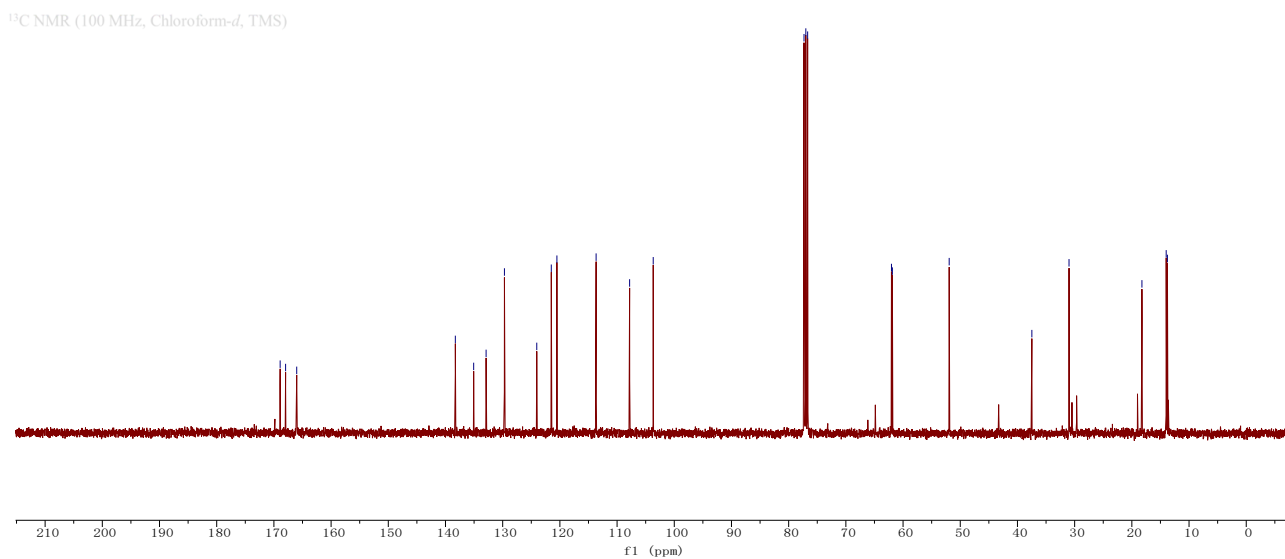
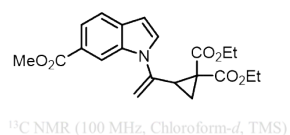
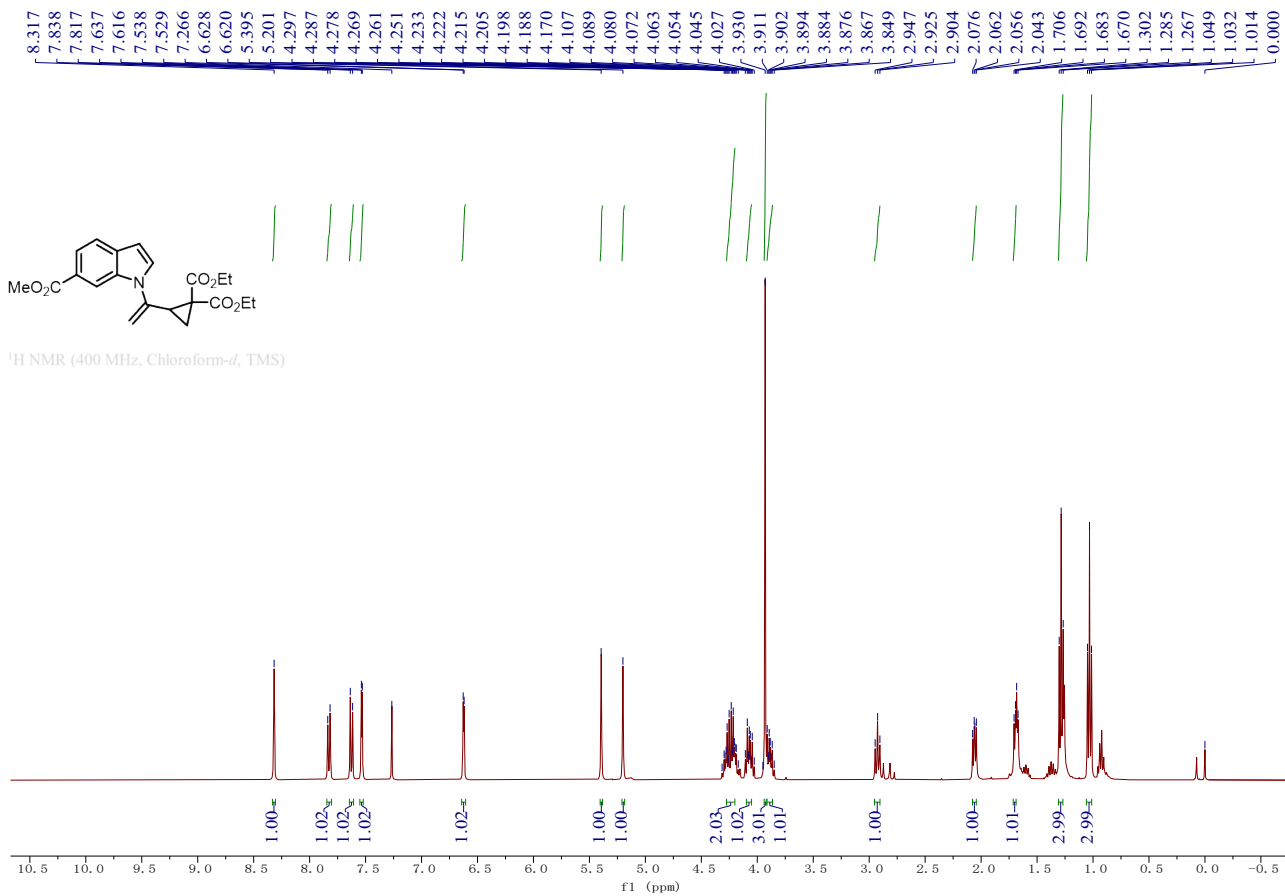


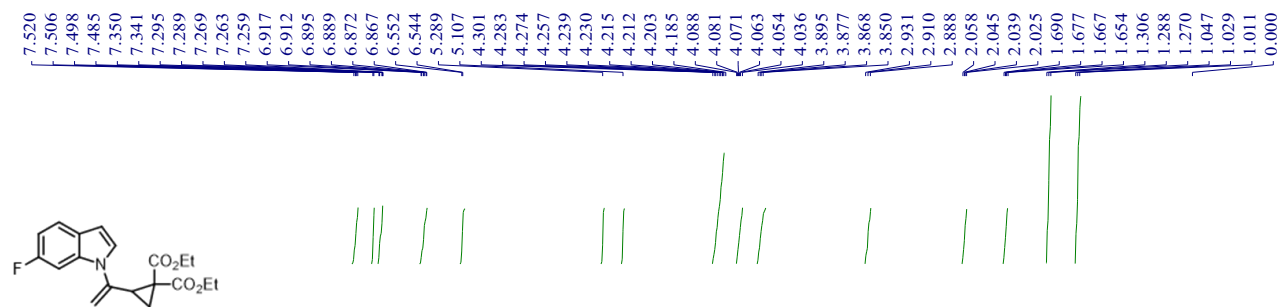
¹H NMR (400 MHz, Chloroform-d, TMS)



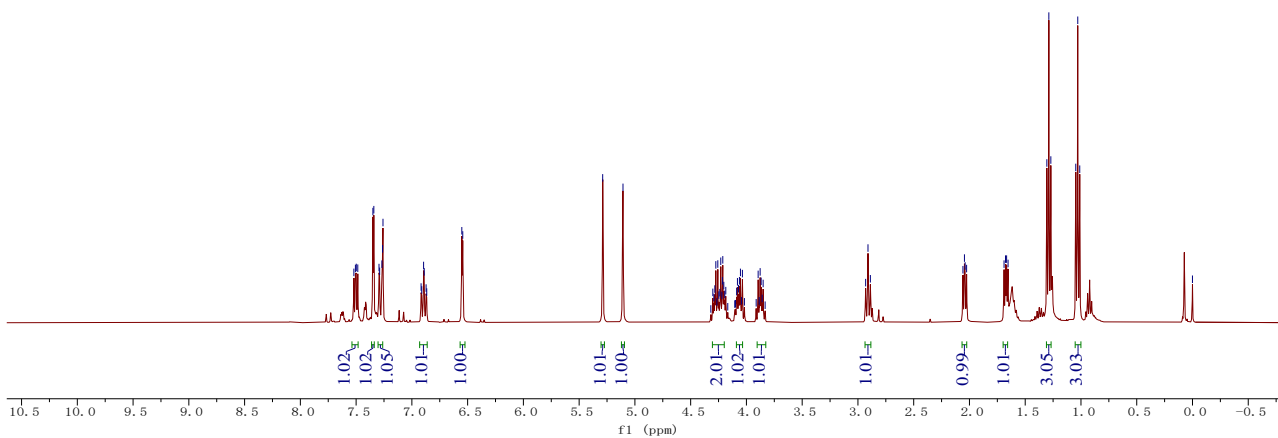
¹³C NMR (100 MHz, Chloroform-d, TMS)



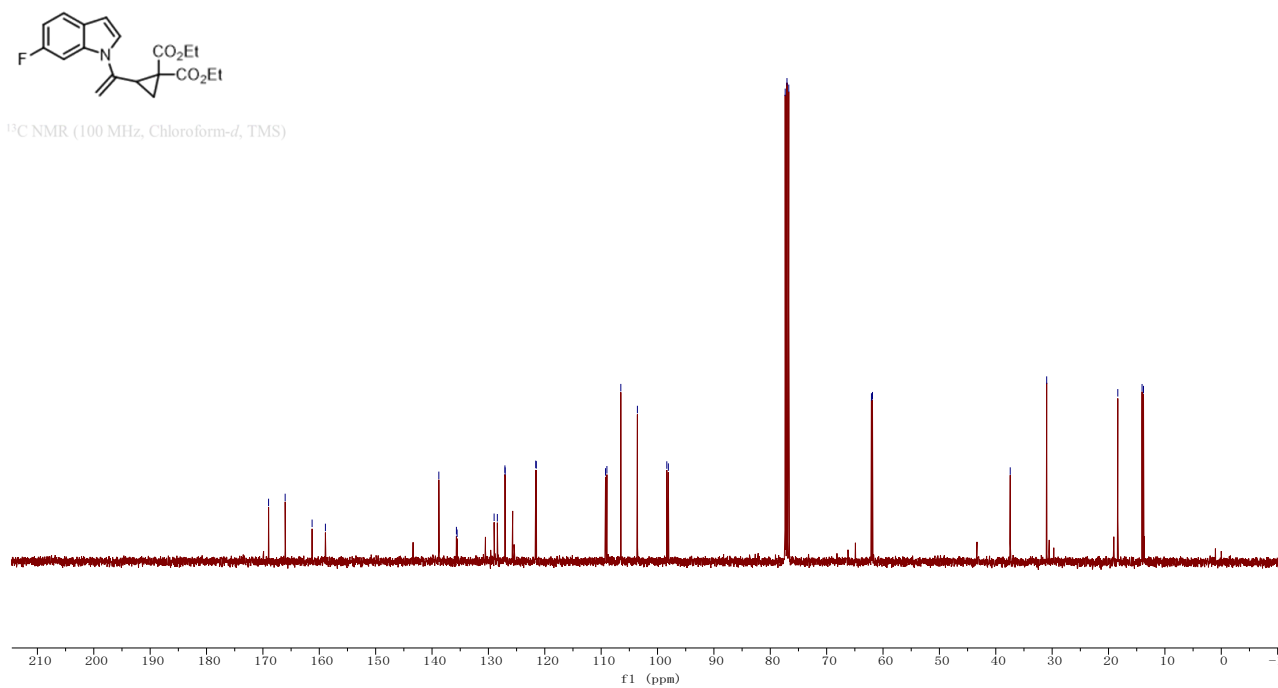


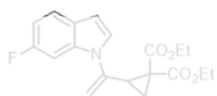


¹H NMR (400 MHz, Chloroform-*d*, TMS)

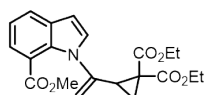
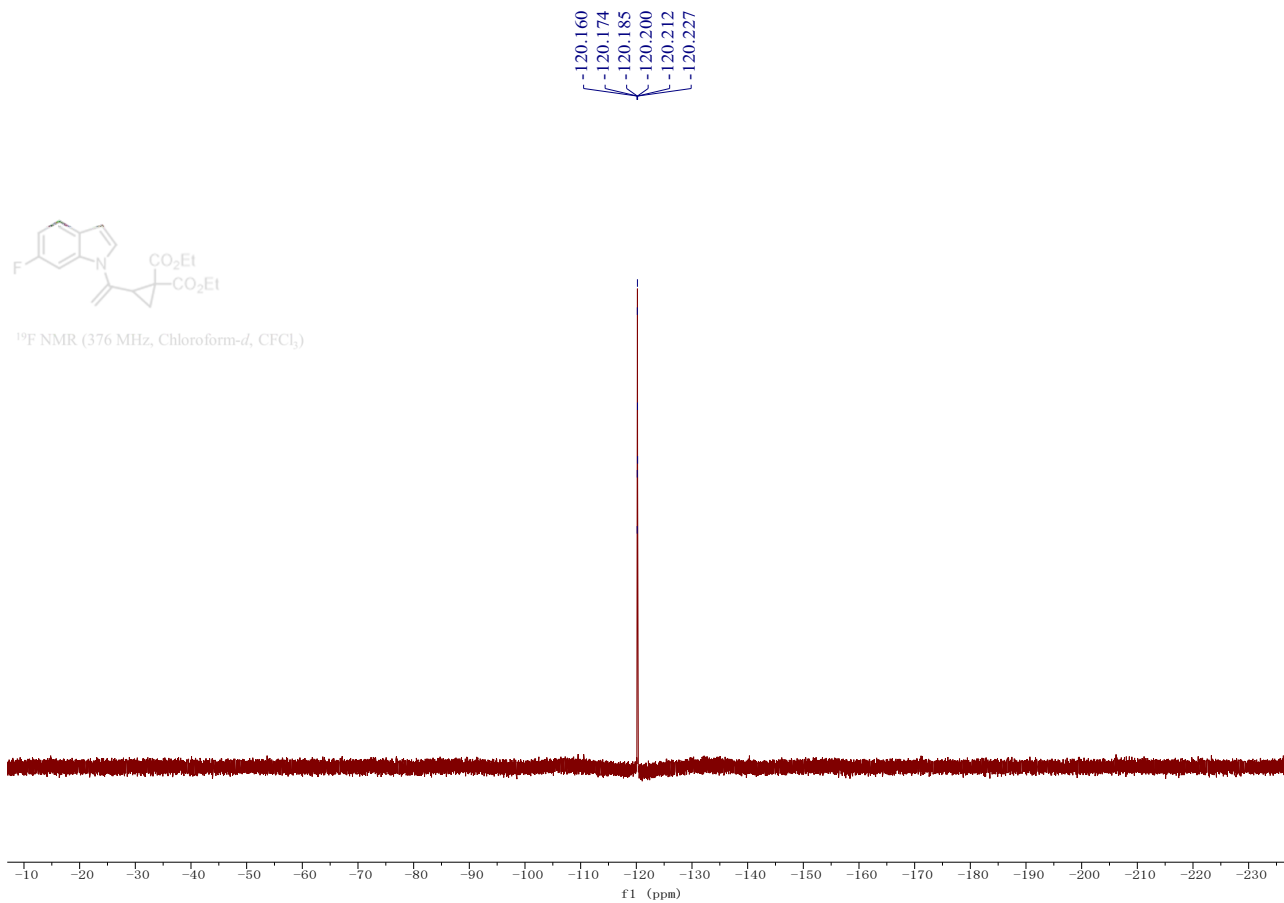


¹³C NMR (100 MHz, Chloroform-*d*, TMS)

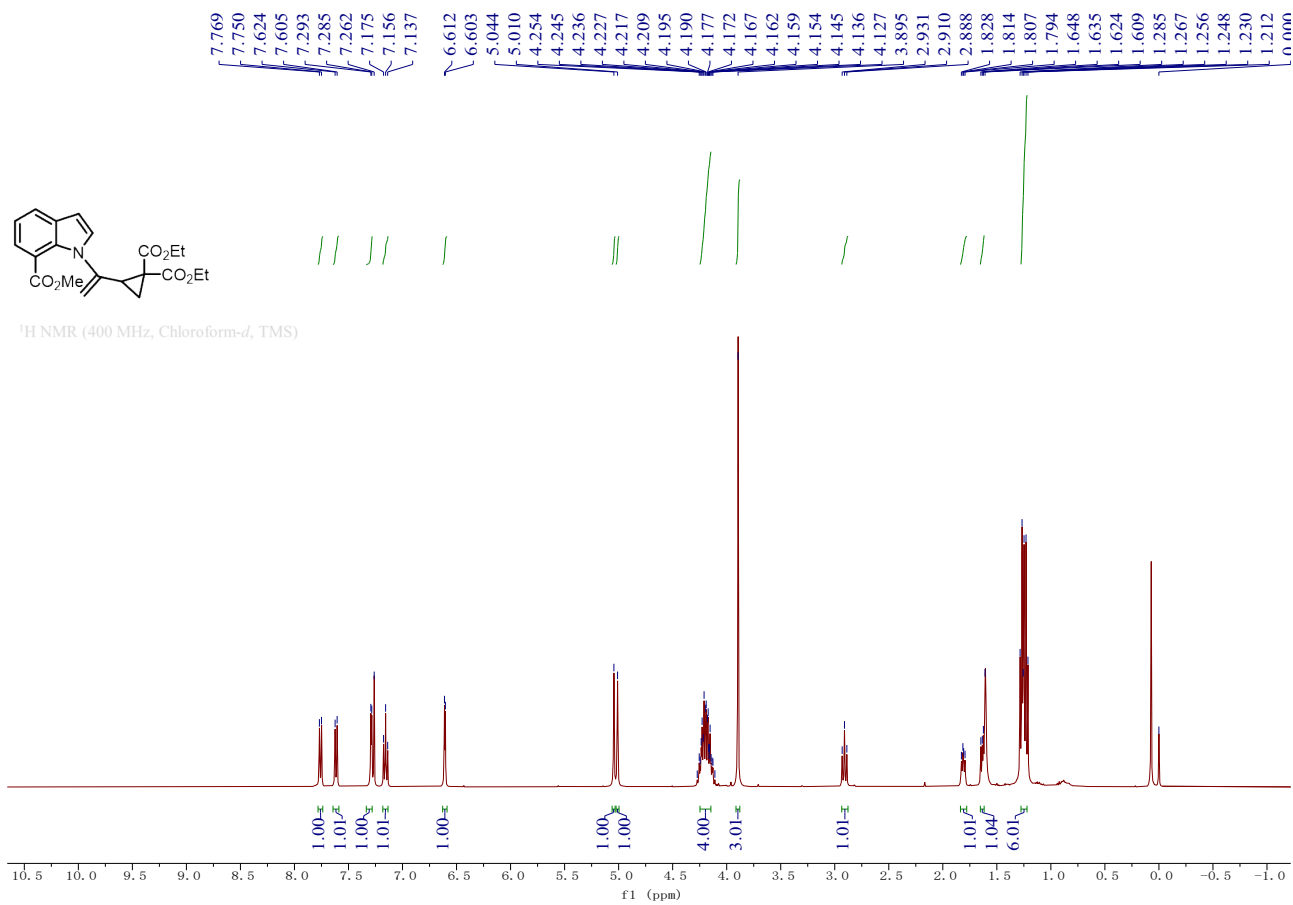


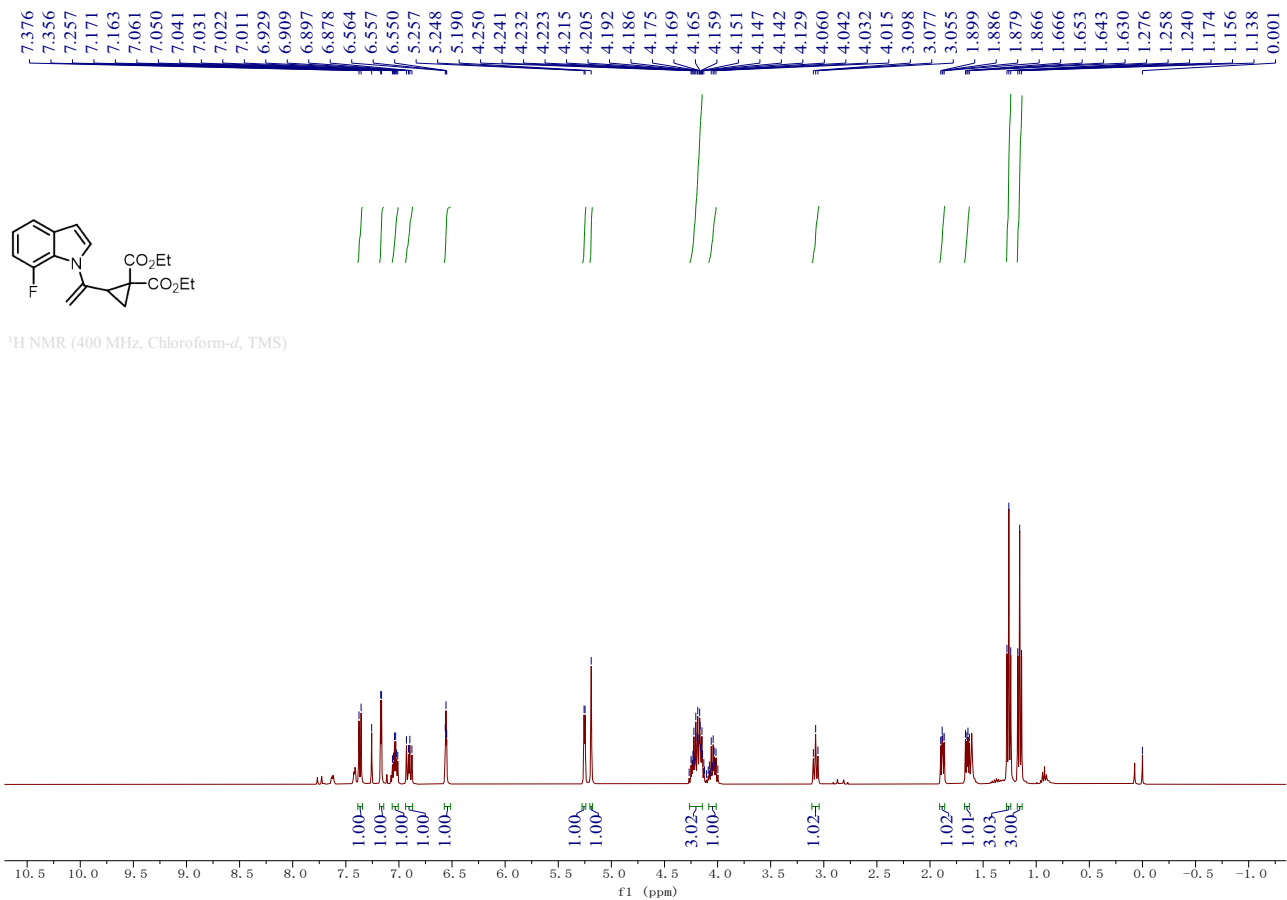
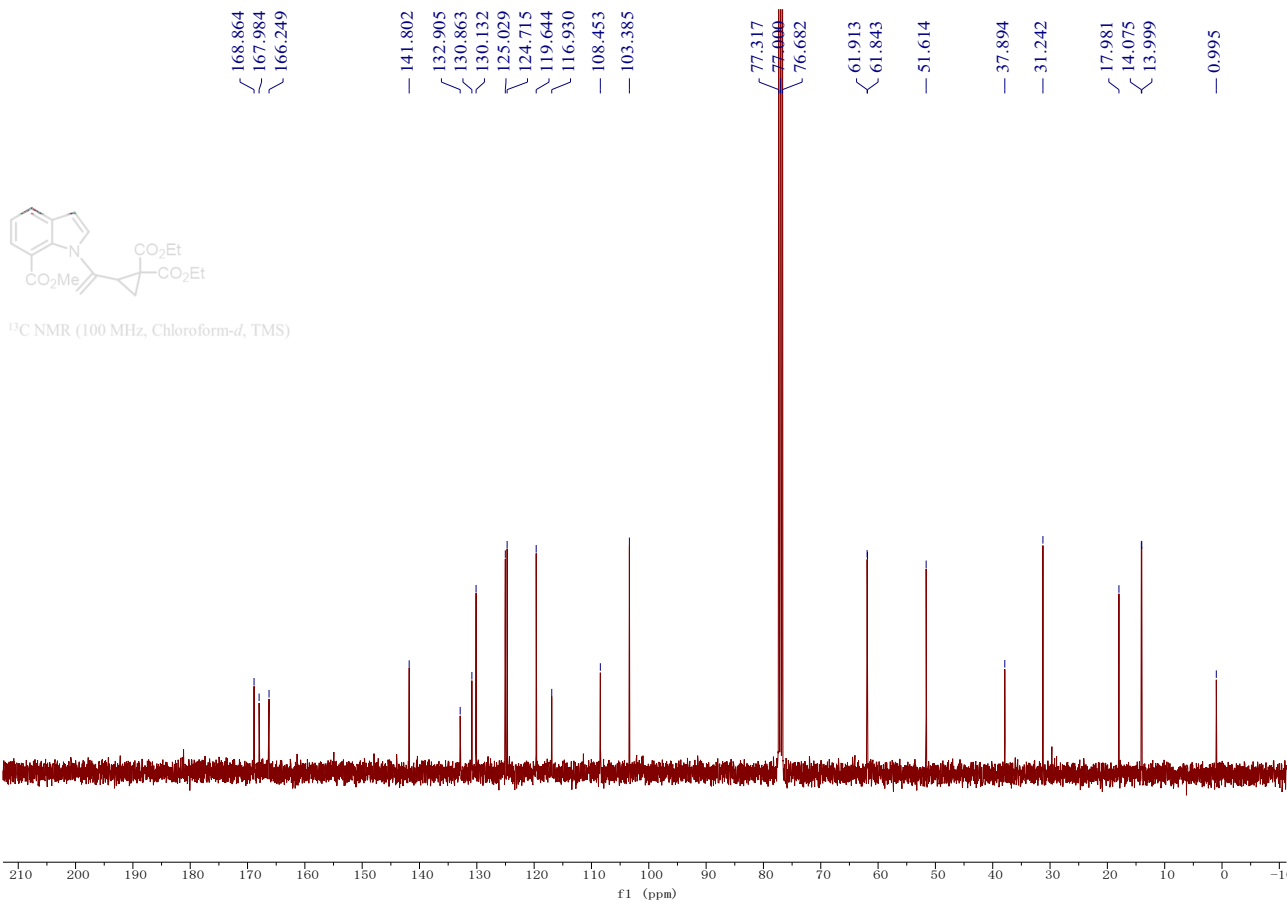


¹⁹F NMR (376 MHz, Chloroform-*d*, CFCl₃)

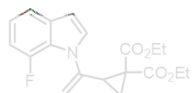


¹H NMR (400 MHz, Chloroform-*d*, TMS)

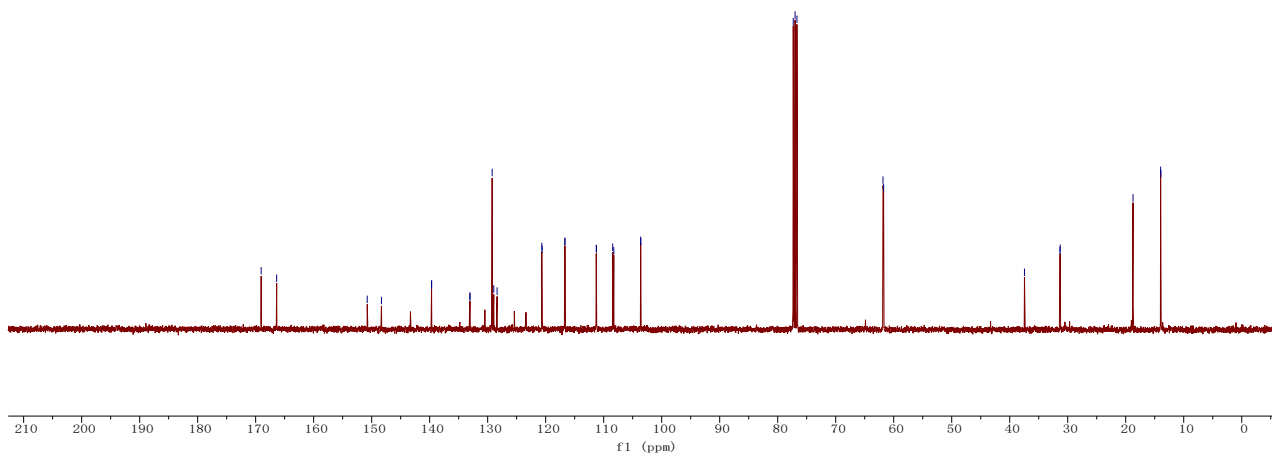




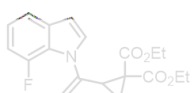
¹³C NMR (100 MHz, Chloroform-*d*, TMS) peaks (ppm):
 169.049, 166.381, 150.765, 148.315, 139.675, 139.658, 133.077, 133.031, 129.227, 128.949, 128.376, 120.671, 120.603, 116.700, 116.664, 111.281, 111.242, 108.446, 108.258, 103.622, 103.602, 77.319, 77.002, 76.684, 61.844, 61.740, 37.455, 31.348, 31.291, 18.741, 13.983, 13.932



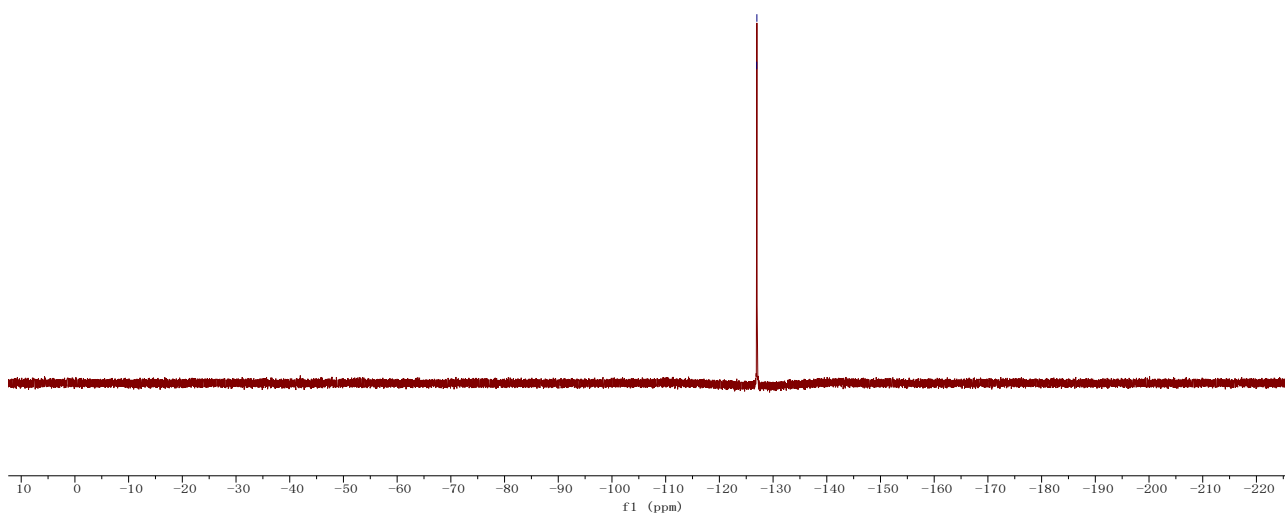
¹³C NMR (100 MHz, Chloroform-*d*, TMS)

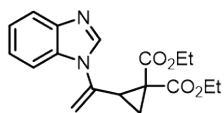
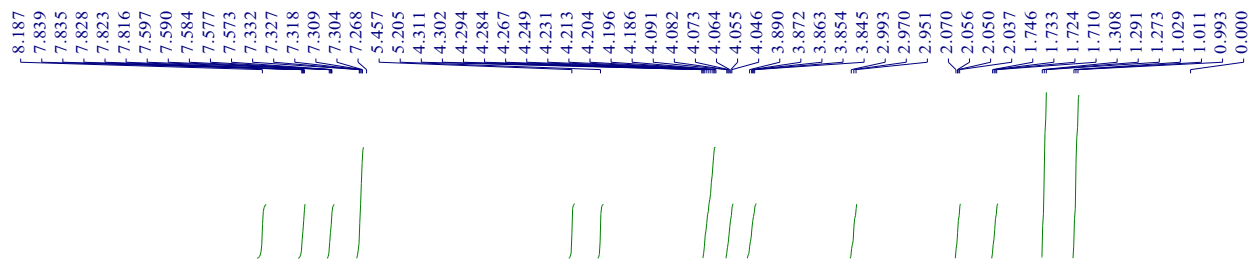


¹⁹F NMR (376 MHz, Chloroform-*d*, CFCl₃) peaks (ppm):
 -126.948, -126.983

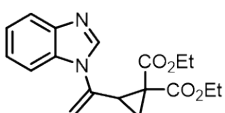
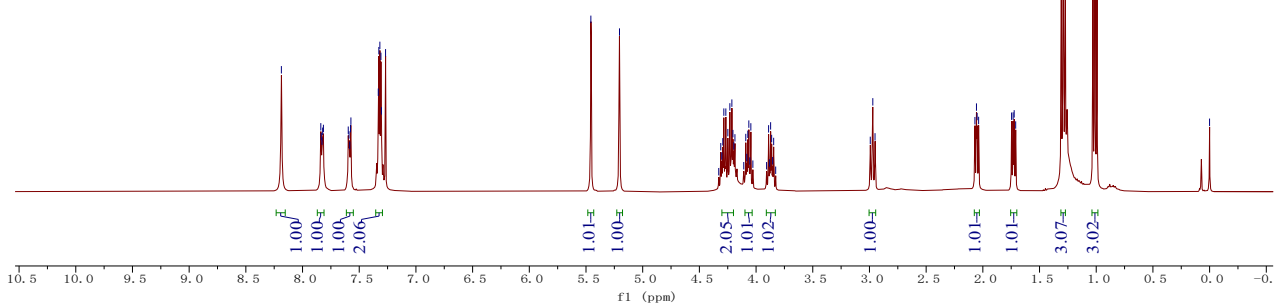


¹⁹F NMR (376 MHz, Chloroform-*d*, CFCl₃)

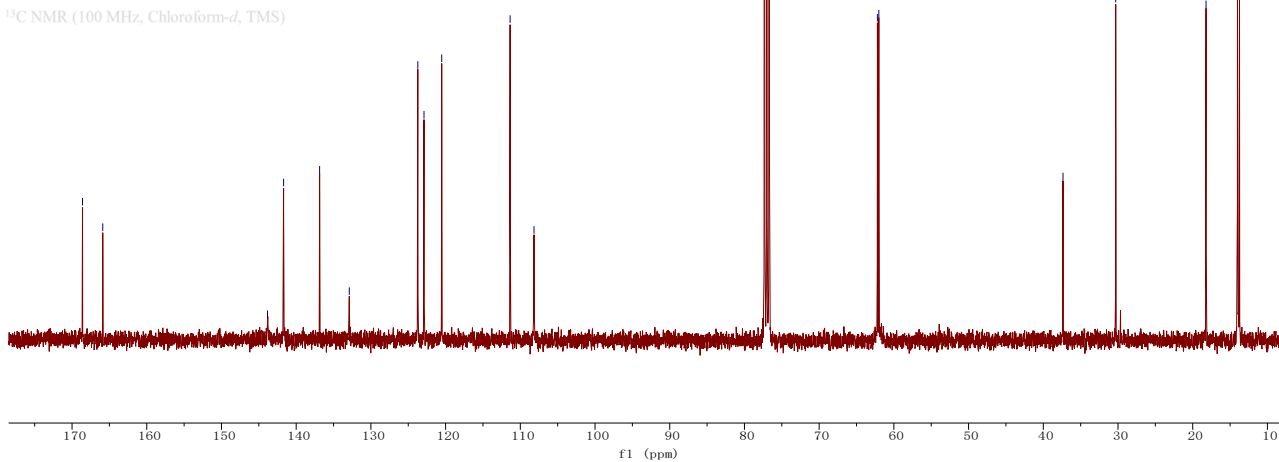


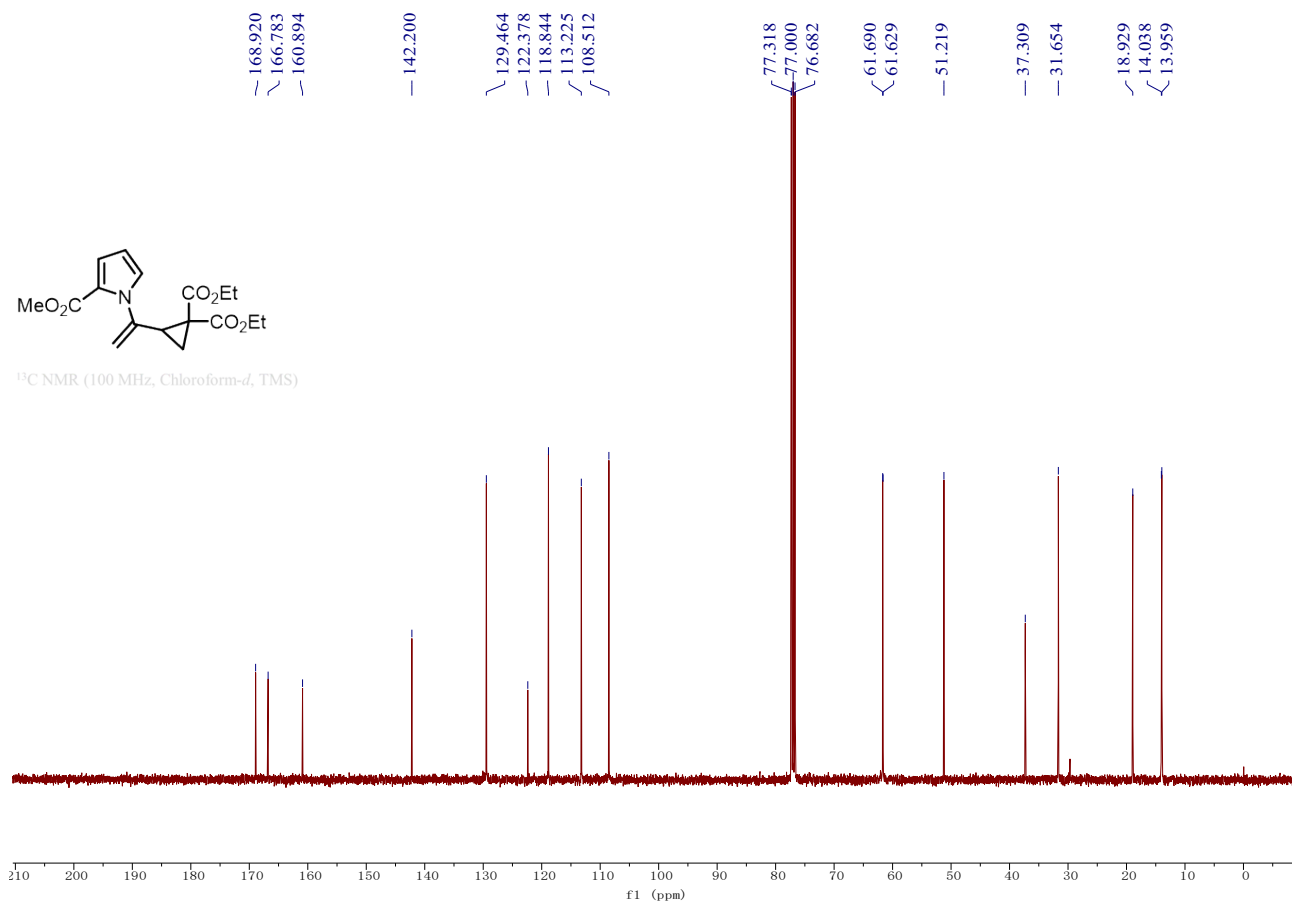
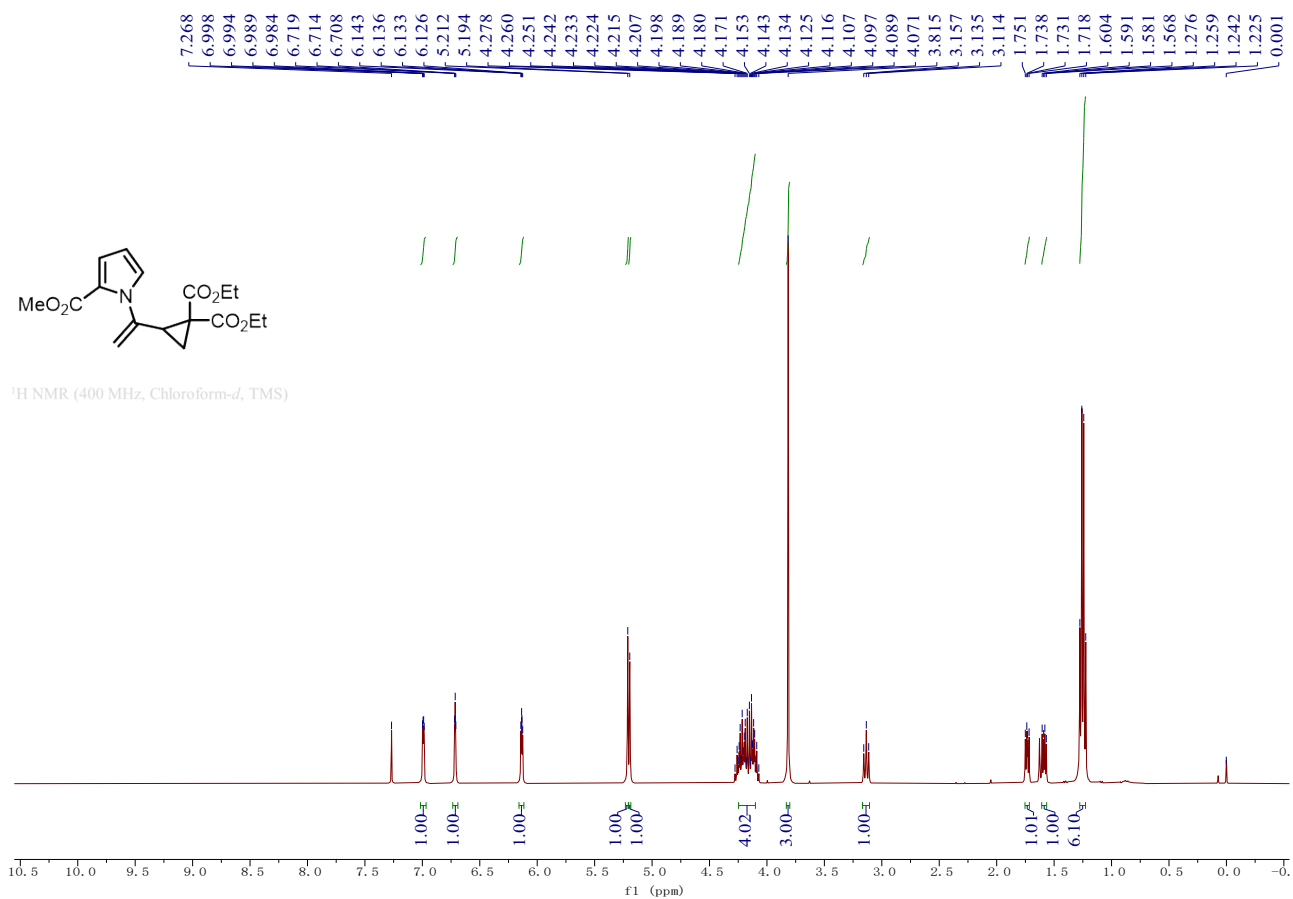


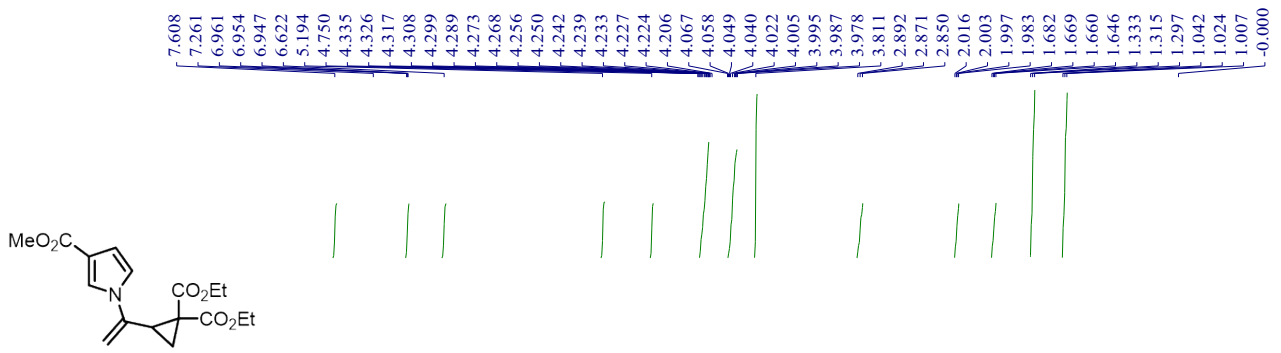
¹H NMR (400 MHz, Chloroform-*d*, TMS)



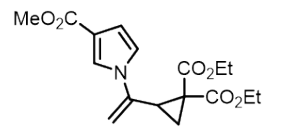
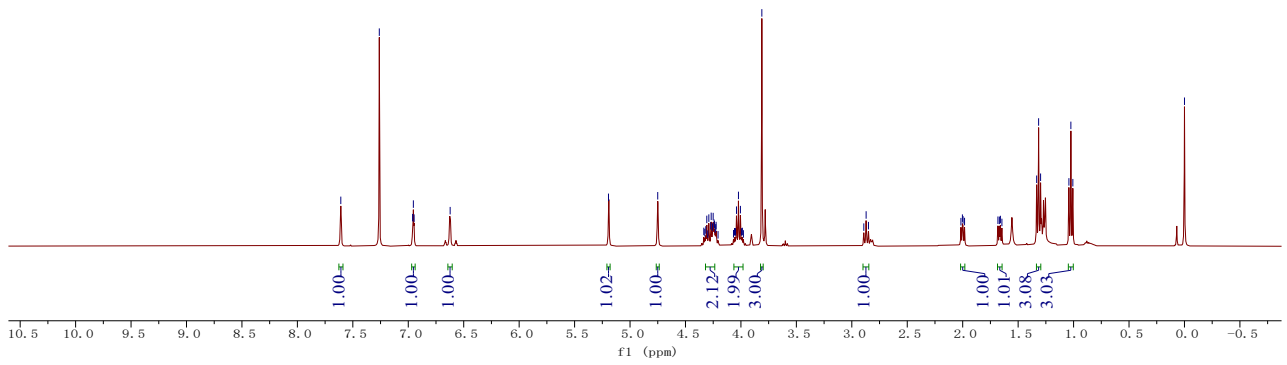
¹³C NMR (100 MHz, Chloroform-*d*, TMS)



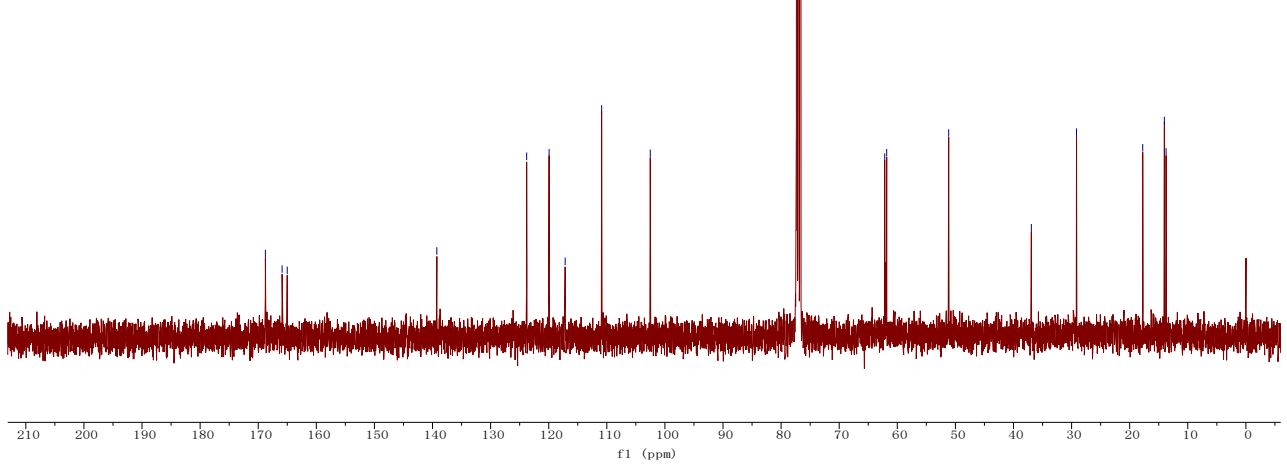


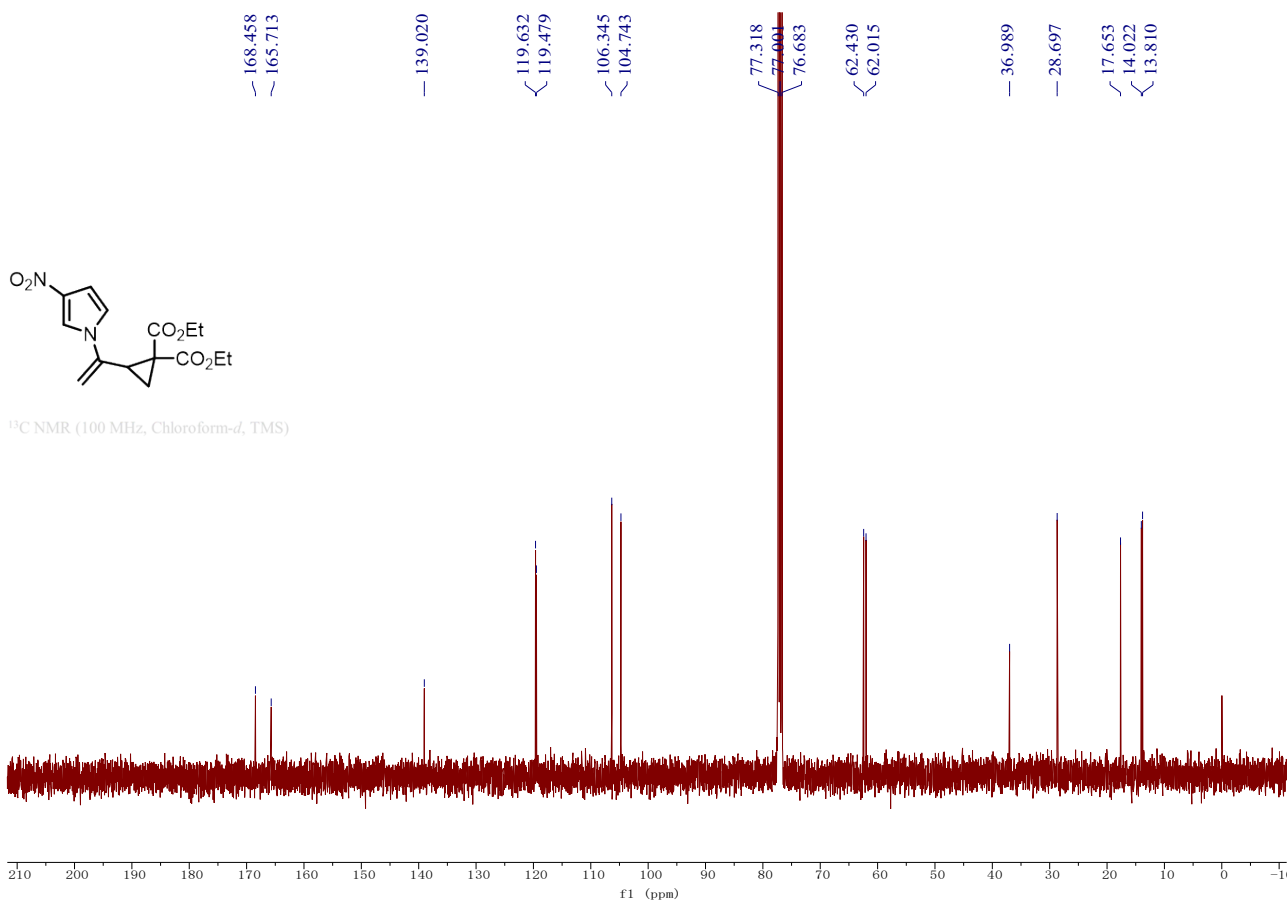
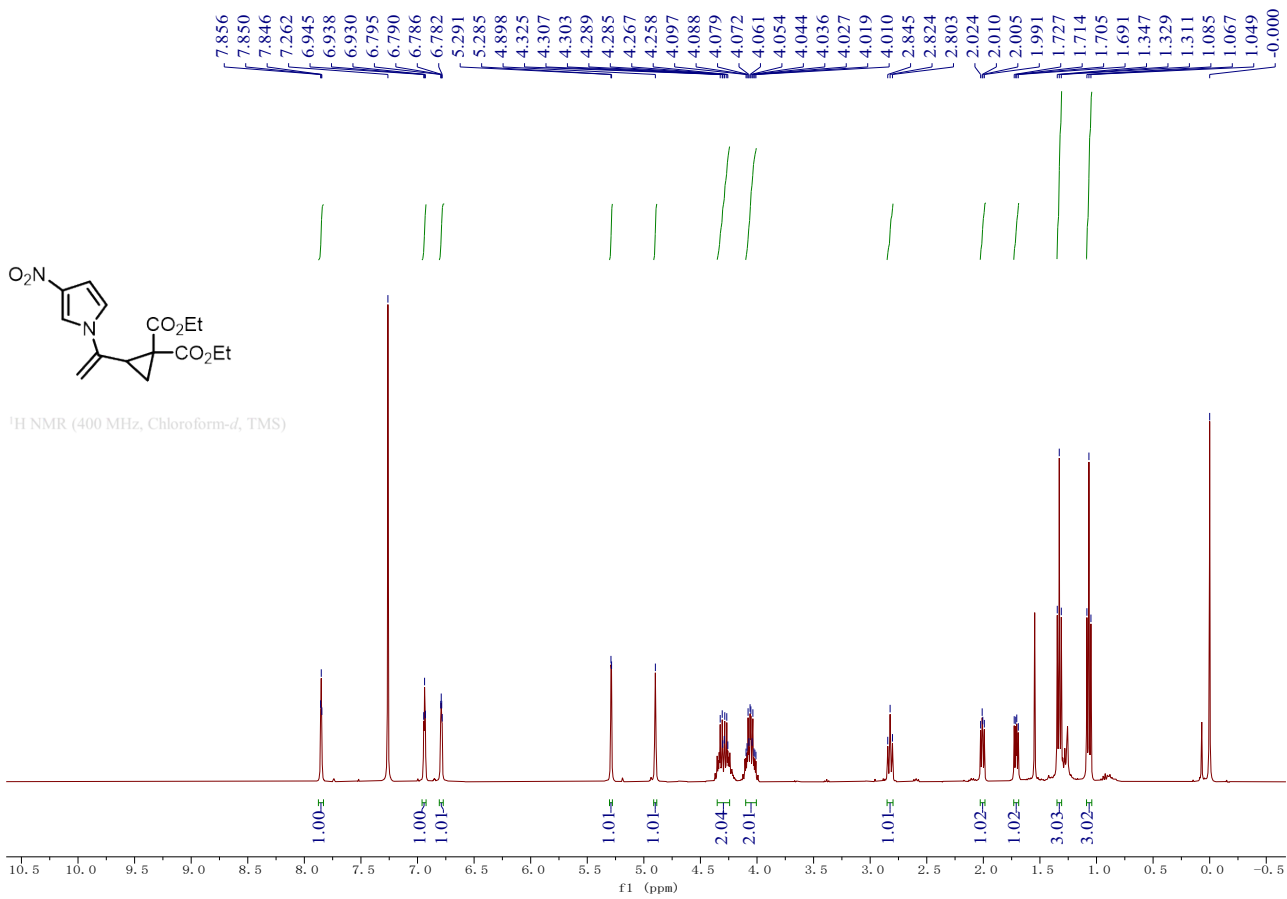


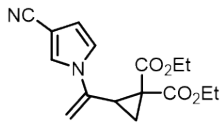
¹H NMR (400 MHz, Chloroform-*d*, TMS)



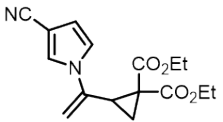
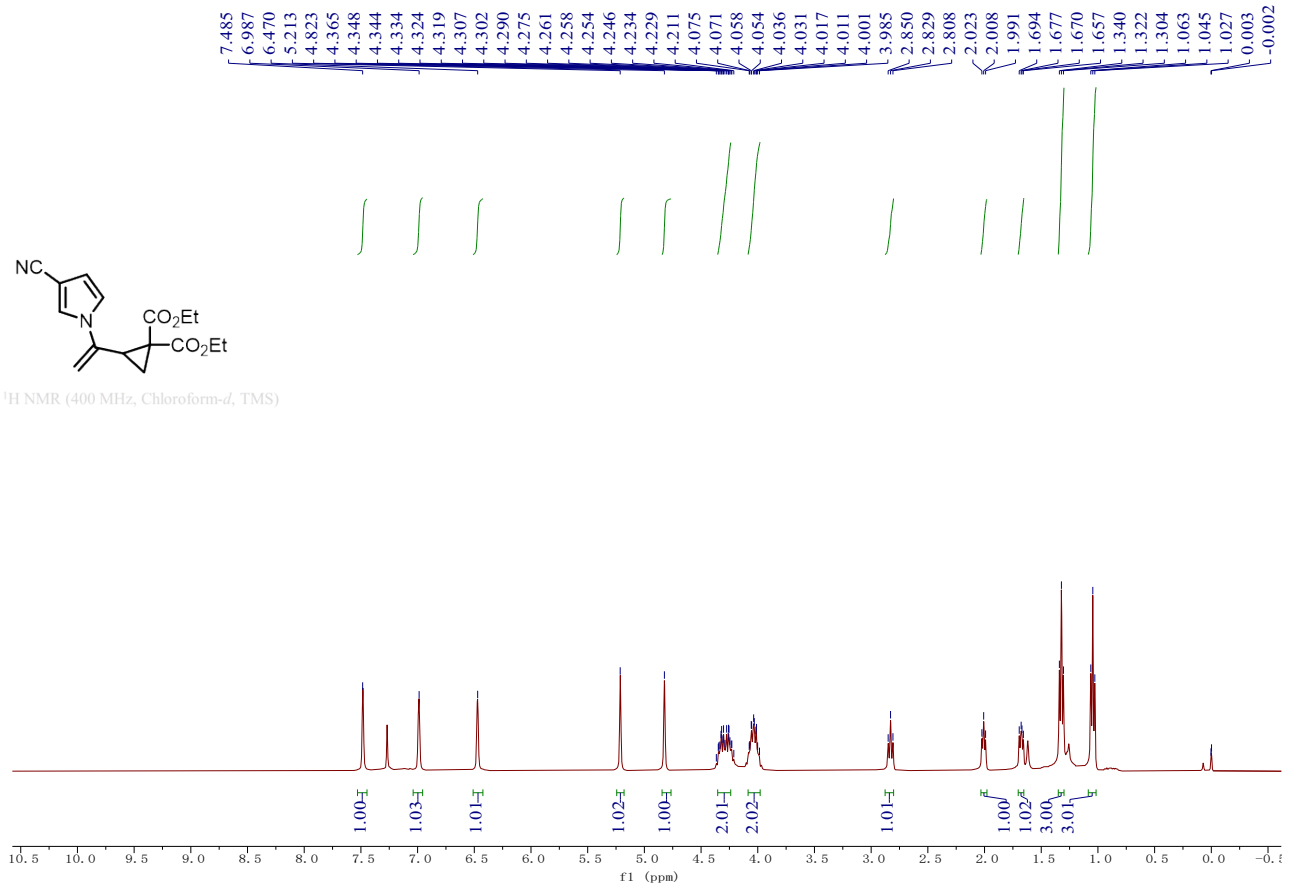
¹³C NMR (100 MHz, Chloroform-*d*, TMS)







¹H NMR (400 MHz, Chloroform-d, TMS)



¹³C NMR (100 MHz, Chloroform-d, TMS)

