A Synthesis of Multifunctionalized Indoles from [3+2] Annulation of 2-Bromocyclopropenes with Anilines

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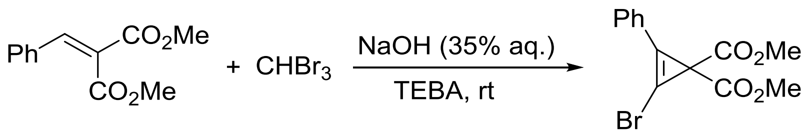
Supporting Information

Contents

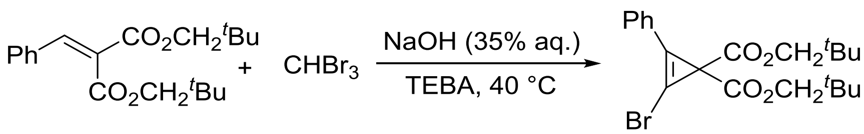
1. General Information

All reactions were carried out under Ar unless otherwise noted. All compounds and solvents were purified according to standard methods unless otherwise noted. ^{1}H NMR spectra were recorded on a Varian Mercury 400 MHz or Agilent Mercury 400 MHz spectrometer (^{1}H: 400 MHz and ^{13}C: 100 MHz) in chloroform-d or DMSO-d_6. ^{1}H and ^{13}C NMR spectra were internally referenced to the proton (^{1}H) of the internal TMS signal at 0.00 ppm or the solvent residue of DMSO at 2.54 ppm and the residual carbon nuclei (^{13}C) of the solvent at 77.0 or 40.0 ppm, respectively. Data for ^{1}H NMR were recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet or unresolved, coupling constant(s) in Hz, integration). IR spectra were recorded on a Bruker–Tensor 27; frequencies are given in reciprocal centimeters (cm^{-1}) and only selected absorbance is reported. High resolution mass spectra were recorded on Agilent Technologies 6224 TOF LC/MS (ESI) or Thermo Scientific Q Exactive HF Orbitrap-FTMS (ESI) mass spectrometers. Substrates are commercially available or were prepared according to the literatures[1-4].

2. Synthesis of Cyclopropenes

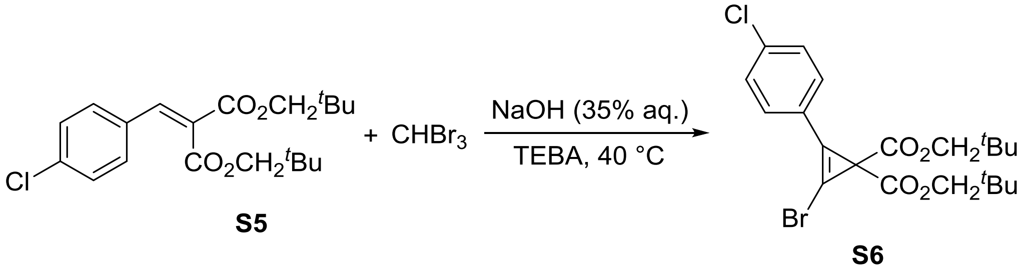


A mixture of **S1** (20.2 g, 91.8 mmol), $CHBr_3$ (80.2 mL, 918.0 mmol), 35% aq. NaOH (185.0 mL) and benzyltriethylammonium chloride (4.20 g, 18.4 mmol) was stirred at room temperature. After the completion of the reaction (monitored by ^{1}H NMR, in 4.0 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S2** (24.3 g, 85% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.62-7.59 (m, 2H), 7.46-7.44 (m, 3H), 3.77 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 130.5, 129.5, 128.9, 122.9, 112.5, 84.8, 52.6, 39.0; IR ν/ cm^{-1} 2957, 1738, 1428, 1057, 758; HRMS-ESI (*m/z*): calcd for $C_{13}H_{12}BrO_4^+$ ($[M+H]^+$): 310.9913; Found: 310.9919.

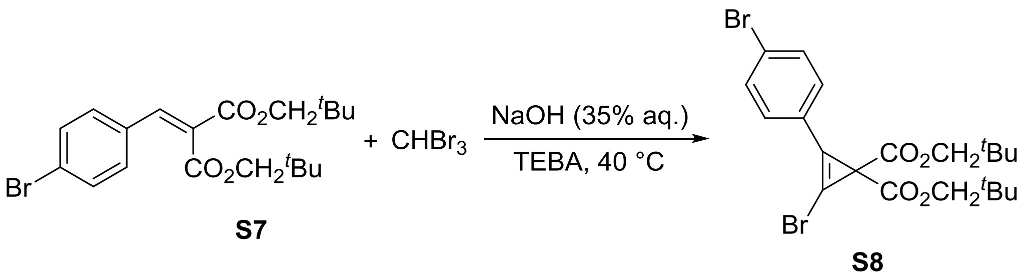


A mixture of **S3** (10.0 g, 30.0 mmol), $CHBr_3$ (26.2 mL, 300.0 mmol), 35% aq. NaOH (45.0 mL) and benzyltriethylammonium chloride (1.37 g, 6.0 mmol) was stirred at 40 ℃. After the completion of the reaction (monitored by TLC, in 4.0 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S4** (10.3 g, 81% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.63-7.61 (m, 2H), 7.45-7.42 (m, 3H), 3.87 (ABd, J_{AB} = 10.4 Hz, 2H), 3.84 (ABd, J_{BA} = 10.8 Hz, 2H), 0.89 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 130.5, 129.5, 128.9, 123.1, 112.8, 85.1, 74.5, 39.5, 31.4, 26.3; IR ν/ cm^{-1} 2958, 1731, 1241, 1051, 759; HRMS-ESI (*m/z*): calcd for

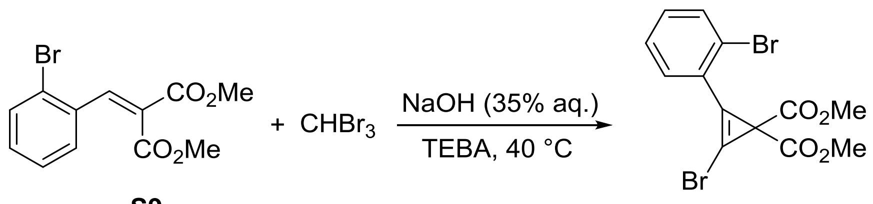
$C_{21}H_{28}BrO_4^+$ ($[M+H]^+$): 423.1165; Found: 423.1174.



A mixture of **S5** (2.0 g, 5.5 mmol), $CHBr_3$ (4.8 mL, 55.0 mmol), 35% aq. NaOH (12.0 mL) and benzyltriethylammonium chloride (0.25 g, 1.1 mmol) was stirred at 40 ℃. After the completion of the reaction (monitored by TLC, in 3.5 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S6** (2.1 g, 83% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.57-7.54 (m, 2H), 7.44-7.41 (m, 2H), 3.88 (ABd, J_{AB} = 10.4 Hz, 2H), 3.84 (ABd, J_{BA} = 10.4 Hz, 2H), 0.89 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 136.6, 130.6, 129.3, 121.7, 112.0, 86.0, 74.6, 39.4, 31.4, 26.2; IR ν/ cm^{-1} 2956, 1730, 1367, 1168, 743; HRMS-ESI (*m/z*): calcd for $C_{21}H_{27}BrClO_4^+$ ($[M+H]^+$): 457.0776; Found: 457.0779.

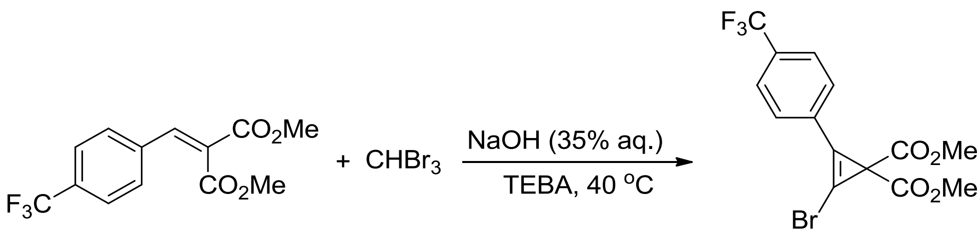


A mixture of **S7** (2.5 g, 6.1 mmol), $CHBr_3$ (5.3 mL, 61.0 mmol), 35% aq. NaOH (15.0 mL) and benzyltriethylammonium chloride (0.28 g, 1.2 mmol) was stirred at 40 ℃. After the completion of the reaction (monitored by TLC, in 4.0 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S8** (2.3 g, 76% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.60-7.57 (m, 2H), 7.50-7.47 (m, 2H), 3.88 (ABd, J_{AB} = 10.8 Hz, 2H), 3.84 (ABd, J_{BA} = 10.4 Hz, 2H), 0.89 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 132.2, 130.8, 125.0, 122.1, 112.1, 86.2, 74.6, 39.4, 31.4, 26.3; IR ν/ cm^{-1} 2955, 1729, 1367, 1168, 737; HRMS-ESI (*m/z*): calcd for $C_{21}H_{27}Br_2O_4^+$ ($[M+H]^+$): 501.0271; Found: 501.0272.



S9 **S10**

A mixture of **S9** (4.4 g, 14.8 mmol), $CHBr_3$ (13.0 mL, 148.0 mmol), 35% aq. NaOH (34.0 mL) and benzyltriethylammonium chloride (0.68 g, 3.0 mmol) was stirred at 40 ℃. After the completion of the reaction (monitored by TLC, in 1.5 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S10** (3.8 g, 65% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.65 (d, J = 8.0 Hz, 1H), 7.50 (d, J = 7.2 Hz, 1H), 7.37 (t, J = 7.4 Hz, 1H), 7.30 (t, J = 7.4 Hz, 1H), 3.77 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 133.4, 131.9, 131.7, 127.5, 124.8, 124.4, 111.2, 88.9, 52.6, 38.6; IR ν/ cm^{-1} 2955, 1720, 1250, 1063, 784, 736; HRMS-ESI (*m/z*): calcd for $C_{13}H_{11}Br_2O_4^+$ ($[M+H]^+$): 388.9019; Found: 388.9025.



S11 **S12**

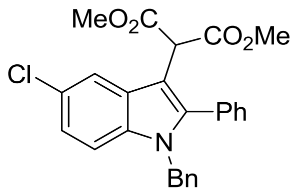
A mixture of **S11** (2.0 g, 7.0 mmol), $CHBr_3$ (6.1 mL, 70.0 mmol), 35% aq. NaOH (16.0 mL) and benzyltriethylammonium chloride (0.32 g, 1.4 mmol) was stirred at at 40 ℃. After the completion of the reaction (monitored by ^{1}H NMR, in 1.0 hours), water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **S12** (1.5 g, 55% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.74-7.69 (m, 4H), 3.79 (s, 6H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -63.1 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 131.9 (q, J_{C-F} = 32.6 Hz), 129.6, 126.4 (d, J_{C-F} = 1.2 Hz), 125.8 (q, J_{C-F} = 3.7 Hz), 124.9, 123.5 (q, J_{C-F} = 270.7 Hz), 111.7, 88.2, 52.6, 39.1; IR ν/ cm^{-1} 2960, 1730, 1438, 1319, 1246, 1053, 837, 747; HRMS-ESI (*m/z*): calcd for $C_{14}H_{10}BrF_3NaO_4^+$ ($[M+Na]^+$): 400.9607; Found: 400.9605.

3. General Procedure for the Synthesis of Indoles

For 3a-3r and 5a-5h. A mixture of $Ni(ClO_4)_2 \cdot 6H_2O$ (22.0 mg, 0.06 mmol) and the **L5** (5.2 mg, 0.036 mmol) in 1,2-dichloroethane (2.0 mL), with activated 4Å MS (500.0 mg) was stirred at room temperature for 4.0 h under nitrogen. Then, the cyclopropene **2** (0.3 mmol), the aromatic amine **1** or **4** (0.6 mmol) and 1,2-dichloroethane (1.0 mL) were added to the mixture of catalyst successively. The resulting suspension was allowed to stir at 80 ℃. Upon disappearance of **2** as confirmed by thin-layer chromatography, the reaction was filtered through a glass funnel with a thin layer (20 mm) of silica gel (100-200 mesh) with CH_2Cl_2 and EtOAc. The filtrate was concentrated under reduced pressure, and the residue was purified by flash chromatography (EtOAc/petroleum) to afford the product **3** or **5.**

For 5i. A mixture of $Ni(ClO_4)_2 \cdot 6H_2O$ (11.0 mg, 0.03 mmol) and the **L4** (8.1 mg, 0.036 mmol) in 1,2-dichloroethane (1.0 mL), with activated 4Å MS (500.0 mg) was stirred at room temperature for 5.0 h under nitrogen. Then, the cyclopropene **2b** (152.0 mg, 0.36 mmol), the aromatic amine **4i** (48.4 mg, 0.3 mmol) and 1,2-dichloroethane (2.0 mL) were added to the mixture of catalyst successively. The resulting suspension was allowed to stir at 80 ℃. Upon disappearance of **4i** as confirmed by thin-layer chromatography, the reaction was filtered through a glass funnel with a thin layer (20 mm) of silica gel (100-200 mesh) with CH_2Cl_2 and EtOAc. The filtrate was concentrated under reduced pressure, and the residue was purified by flash chromatography (EtOAc/petroleum) to afford the product **5i.**

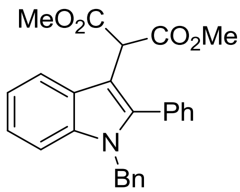
For 3s. A mixture of $Ni(ClO_4)_2 \cdot 6H_2O$ (0.29 g, 0.8 mmol) and the **L4** (0.22 g, 0.96 mmol) in 1,2-dichloroethane (20.0 mL), with activated 4Å MS (13.0 g) was stirred at room temperature for 9.0 h under nitrogen. Then, the cyclopropene **2b** (4.05 g, 9.6 mmol), the aromatic amine **1s** (0.86 g, 8.0 mmol) and 1,2-dichloroethane (20.0 mL) were added to the mixture of catalyst successively. The resulting suspension was allowed to stir at 80 ℃. Upon disappearance of **1s** as confirmed by thin-layer chromatography, the reaction was filtered through a glass funnel with a thin layer (20 mm) of silica gel (100-200 mesh) with CH_2Cl_2 and EtOAc. The filtrate was concentrated under reduced pressure, and the residue was purified by flash chromatography (EtOAc/petroleum) to afford the product **3s.**



dimethyl 2-(1-benzyl-5-chloro-2-phenyl-1*H*-indol-3-yl)malonate

3a

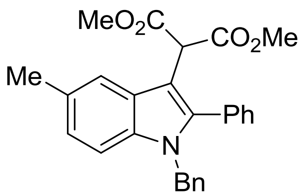
3a, white solid, 94 mg, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.78 (s, 1H), 7.44-7.40 (m, 3H), 7.36-7.33 (m, 2H), 7.26-7.20 (m, 3H), 7.12-7.07 (m, 2H), 6.90 (d, *J* = 6.4 Hz, 2H), 5.17 (s, 2H), 4.75 (s, 1H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 141.7, 137.3, 135.2, 130.7, 129.9, 129.2, 128.7, 127.6, 127.3, 126.1, 126.0, 122.7, 120.4, 111.4, 105.1, 52.7, 49.6, 47.9; IR ν/ cm^{-1} 2950, 1727, 1357, 1130, 730; HRMS-ESI (*m/z*): calcd for $C_{26}H_{23}ClNO_4^+$ ($[M+H]^+$): 448.1310; Found: 448.1309.



dimethyl 2-(1-benzyl-2-phenyl-1*H*-indol-3-yl)malonate

3b

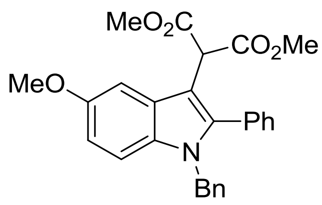
3b, white solid, 81 mg, 65% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.82-7.79 (m, 1H), 7.42-7.40 (m, 3H), 7.37-7.35 (m, 2H), 7.24-7.15 (m, 6H), 6.94 (d, *J* = 6.8 Hz, 2H), 5.19 (s, 2H), 4.81 (s, 1H), 3.71 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 140.3, 137.7, 136.7, 130.8, 130.3, 128.9, 128.6, 128.5, 127.1, 126.6, 126.0, 122.3, 120.8, 120.3, 110.4, 105.4, 52.6, 49.8, 47.7; IR ν/ cm^{-1} 2949, 1730, 1364, 1145, 725; HRMS-ESI (*m/z*): calcd for $C_{26}H_{24}NO_4^+$ ($[M+H]^+$): 414.1700; Found: 414.1704.



dimethyl 2-(1-benzyl-5-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3c

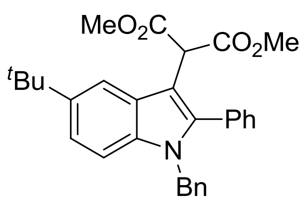
3c, white solid, 84 mg, 66% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.57 (s, 1H), 7.40-7.34 (m, 5H), 7.22-7.15 (m, 3H), 7.07-6.97 (m, 2H), 6.92 (d, J = 6.8 Hz, 2H), 5.16 (s, 2H), 4.79 (s, 1H), 3.70 (s, 6H), 2.46 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 140.4, 137.9, 135.1, 130.7, 130.4, 129.6, 128.8, 128.52, 128.48, 127.0, 126.8, 126.0, 123.9, 120.3, 110.0, 104.8, 52.6, 49.7, 47.7, 21.6; IR ν/ cm^{-1} 2950, 1731, 1361, 1174, 729; HRMS-ESI (*m/z*): calcd for $C_{27}H_{26}NO_4^+$ ($[M+H]^+$): 428.1856; Found: 428.1862.



dimethyl 2-(1-benzyl-5-methoxy-2-phenyl-1*H*-indol-3-yl)malonate

3d

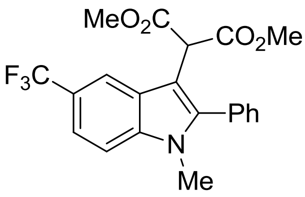
3d, white solid, 102 mg, 77% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.41-7.20 (m, 9H), 7.07-6.81 (m, 4H), 5.16 (s, 2H), 4.79 (s, 1H), 3.86 (s, 3H), 3.72 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 154.4, 140.9, 137.8, 131.9, 130.7, 130.4, 128.8, 128.6, 128.5, 127.1, 127.0, 126.0, 112.5, 111.1, 104.9, 102.5, 55.8, 52.6, 49.7, 47.8; IR ν/ cm^{-1} 2951, 1732, 1351, 1145, 734; HRMS-ESI (*m/z*): calcd for $C_{27}H_{26}NO_5^+$ ($[M+H]^+$): 444.1805; Found: 444.1818.



dimethyl 2-(1-benzyl-5-(tert-butyl)-2-phenyl-1*H*-indol-3-yl)malonate

3e

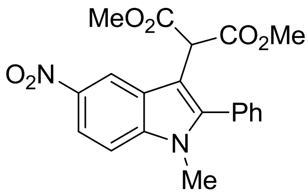
3e, white solid, 99 mg, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.78 (s, 1H), 7.41 (t, J = 3.2 Hz, 3H), 7.35-7.33 (m, 2H), 7.27-7.20 (m, 4H), 7.12 (d, J = 8.8 Hz, 1H), 6.98 (d, J = 6.8 Hz, 2H), 5.15 (s, 2H), 4.80 (s, 1H), 3.71 (s, 6H), 1.39 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 143.0, 140.4, 137.9, 135.0, 130.8, 130.6, 128.7, 128.5, 128.4, 127.1, 126.3, 126.2, 120.5, 116.6, 109.8, 105.3, 52.5, 49.8, 47.7, 34.6, 31.9; IR ν/ cm^{-1} 2954, 1734, 1362, 1150, 734; HRMS-ESI (*m/z*): calcd for $C_{30}H_{32}NO_4^+$ ($[M+H]^+$): 470.2326; Found: 470.2330.



dimethyl 2-(1-methyl-2-phenyl-5-(trifluoromethyl)-1H-indol-3-yl)malonate

3f

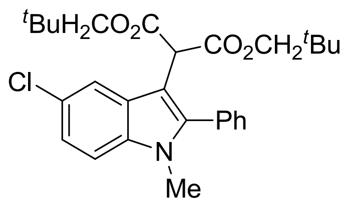
3f, white solid, 49 mg, 40% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 8.06 (s, 1H), 7.55-7.40 (m, 7H), 4.78 (s, 1H), 3.71 (s, 6H), 3.61 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -60.2 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 142.0, 138.4, 130.7, 129.8, 129.2, 128.8, 125.6, 125.3 (q, $J_{C\text{-}F}$ = 270.0 Hz), 122.5 (q, $J_{C\text{-}F}$ = 31.3 Hz), 118.8 (q, $J_{C\text{-}F}$ = 3.0 Hz), 118.6 (q, $J_{C\text{-}F}$ = 4.1 Hz), 109.9, 105.7, 52.7, 49.6, 31.2; IR ν/ cm^{-1} 2949, 1747, 1732, 1142, 1105, 846, 701; HRMS-ESI (*m/z*): calcd for $C_{21}H_{19}F_3NO_4^+$ ($[M+H]^+$): 406.1261; Found: 406.1259.



dimethyl 2-(1-methyl-5-nitro-2-phenyl-1H-indol-3-yl)malonate

3g

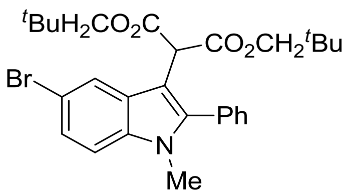
3g, yellow solid, 18 mg, 15% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 8.74 (d, *J* = 2.0 Hz, 1H), 8.17 (dd, *J* = 9.2, 2.0 Hz, 1H), 7.58-7.54 (m, 3H), 7.46-7.43 (m, 2H), 7.38 (m, 1H), 4.78 (s, 1H), 3.74 (s, 6H), 3.65 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 143.4, 142.1, 140.0, 130.6, 129.5, 129.2, 128.9, 125.6, 118.3, 117.7, 109.6, 107.3, 52.9, 49.5, 31.5; IR ν/ cm^{-1} 2853, 1734, 1319, 1150, 809, 750; HRMS-ESI (*m/z*): calcd for $C_{20}H_{19}N_2O_6^+$ ($[M+H]^+$): 383.1238; Found: 383.1234.



dineopentyl 2-(5-chloro-1-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3h

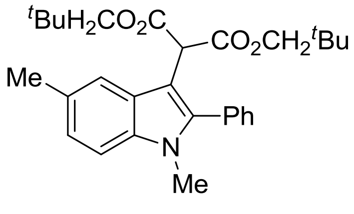
3h, white solid, 88 mg, 61% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.79 (d, J = 2.0 Hz, 1H), 7.54-7.49 (m, 3H), 7.44-7.42 (m, 2H), 7.25-7.17 (m, 2H), 4.74 (s, 1H), 3.85 (ABd, J_{AB} = 10.8 Hz, 2H), 3.82 (ABd, J_{BA} = 10.8 Hz, 2H), 3.57 (s, 3H), 0.87 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.6, 141.4, 135.7, 130.7, 130.1, 129.0, 128.6, 127.1, 125.6, 122.3, 120.8, 110.4, 104.8, 74.9, 50.0, 31.3, 31.1, 26.3; IR ν/ cm^{-1} 2954, 2917, 1752, 1732, 1470, 1143, 706; HRMS-ESI (*m/z*): calcd for $C_{28}H_{35}ClNO_4^+$ ($[M+H]^+$): 484.2249; Found: 484.2245.



dineopentyl 2-(5-bromo-1-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3i

3i, white solid, 99 mg, 62% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.95 (s, 1H), 7.52-7.42 (m, 5H), 7.31 (d, J = 8.4 Hz, 1H), 7.18 (d, J = 8.4 Hz, 1H), 4.74 (s, 1H), 3.87-3.81 (m, 4H), 3.55 (s, 3H), 0.88 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 141.3, 135.9, 130.7, 130.0, 129.0, 128.6, 127.7, 124.9, 123.8, 113.2, 110.8, 104.7, 74.9, 50.1, 31.2, 31.1, 26.3; IR ν/ cm^{-1} 2959, 1737, 1466, 1148, 702; HRMS-ESI (*m/z*): calcd for $C_{28}H_{35}BrNO_4^+$ ($[M+H]^+$): 528.1744; Found: 528.1744.

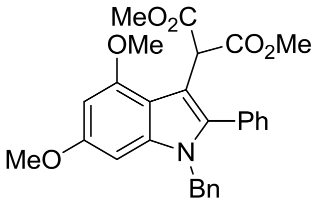


dineopentyl 2-(1,5-dimethyl-2-phenyl-1*H*-indol-3-yl)malonate

3j

3j, white solid, 97 mg, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.59 (s, 1H), 7.53-7.43 (m, 5H), 7.22 (d, J = 8.4 Hz, 1H), 7.06 (dd, J = 8.4, 1.2 Hz, 1H), 4.76

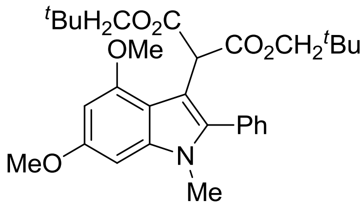
(s, 1H), 3.84 (ABd, J_{AB} = 10.4 Hz, 2H), 3.80 (ABd, J_{BA} = 10.4 Hz, 2H), 3.56 (s, 3H), 2.45 (s, 3H), 0.87 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 140.1, 135.7, 130.9, 130.8, 128.9, 128.53, 128.45, 126.4, 123.6, 121.0, 109.0, 104.5, 74.7, 50.1, 31.3, 30.9, 26.3, 21.5; IR ν/ cm^{-1} 2957, 1732, 1367, 1147, 701; HRMS-ESI (*m/z*): calcd for $C_{29}H_{38}NO_4^+$ ($[M+H]^+$): 464.2795; Found: 464.2799.



dimethyl 2-(1-benzyl-4,6-dimethoxy-2-phenyl-1*H*-indol-3-yl)malonate

3k

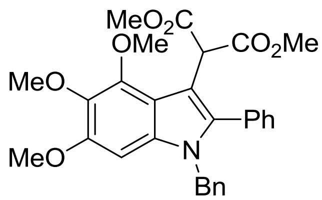
3k, white solid, 81 mg, 57% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.35-7.30 (m, 5H), 7.24-7.18 (m, 3H), 6.94 (d, *J* = 6.8 Hz, 2H), 6.23 (s, 2H), 5.22 (s, 1H), 5.08 (s, 2H), 3.84 (s, 3H), 3.72 (s, 3H), 3.56 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 157.5, 154.3, 137.9, 137.7, 137.1, 131.1, 130.5, 128.5, 128.0, 126.9, 125.9, 111.9, 105.4, 92.1, 86.3, 55.5, 55.0, 52.1, 50.2, 47.6; IR ν/ cm^{-1} 2950, 1734, 1338, 1151, 729; HRMS-ESI (*m/z*): calcd for $C_{28}H_{28}NO_6^+$ ($[M+H]^+$): 474.1911; Found: 474.1928.



dineopentyl 2-(4,6-dimethoxy-1-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3l

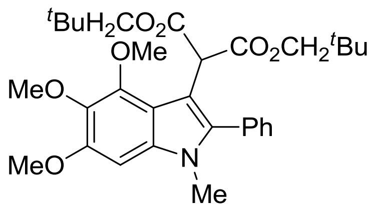
3l, white solid, 107 mg, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.41 (s, 5H), 6.38 (s, 1H), 6.21 (s, 1H), 5.13 (s, 1H), 3.85 (s, 3H), 3.81 (s, 3H), 3.77 (ABd, J_{AB} = 10.4 Hz, 2H), 3.55 (ABd, J_{BA} = 10.4 Hz, 2H), 3.46 (s, 3H), 0.83 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 157.4, 154.3, 138.3, 137.0, 131.1, 131.0, 128.2, 128.1, 111.6, 105.2, 91.8, 85.2, 74.3, 55.6, 54.9, 50.4, 31.1, 31.0, 26.3; IR ν/ cm^{-1} 2957, 1731, 1148, 1042, 704; HRMS-ESI (*m/z*): calcd for $C_{30}H_{40}NO_6^+$ ($[M+H]^+$): 510.2850; Found: 510.2851.



dimethyl 2-(1-benzyl-4,5,6-trimethoxy-2-phenyl-1*H*-indol-3-yl)malonate

3m

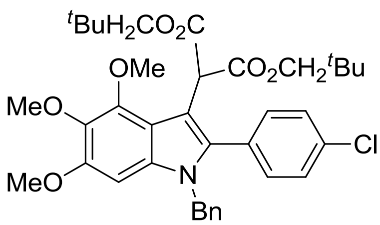
3m, white solid, 111 mg, 74% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.36-7.19 (m, 8H), 6.97 (d, *J* = 7.2 Hz, 2H), 6.37 (s, 1H), 5.14 (s, 1H), 5.06 (s, 2H), 4.00 (s, 3H), 3.84 (s, 3H), 3.75 (s, 3H), 3.60 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 151.4, 146.5, 138.2, 137.7, 136.5, 133.3, 131.1, 130.6, 128.7, 128.6, 128.2, 127.1, 126.1, 114.3, 105.3, 89.0, 61.0, 60.5, 56.3, 52.3, 50.0, 47.8; IR ν/ cm^{-1} 2957, 1741, 1366, 1125, 734; HRMS-ESI (*m/z*): calcd for $C_{29}H_{30}NO_7^+$ ($[M+H]^+$): 504.2017; Found: 504.2019.



dineopentyl 2-(4,5,6-trimethoxy-1-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3n

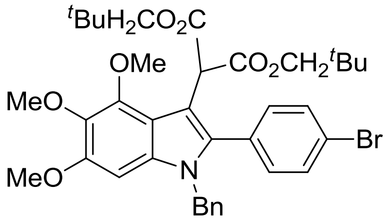
3n, white solid, 131 mg, 81% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.46-7.37 (m, 5H), 6.53 (s, 1H), 5.01 (s, 1H), 4.01 (s, 3H), 3.93 (s, 3H), 3.84 (s, 3H), 3.80 (ABd, J_{AB} = 10.4 Hz, 2H), 3.64 (ABd, J_{BA} = 10.8 Hz, 2H), 3.47 (s, 3H), 0.86 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 151.2, 146.5, 138.0, 136.2, 133.7, 131.0, 130.9, 128.3, 128.2, 113.9, 105.0, 88.0, 74.4, 60.9, 60.5, 56.2, 50.0, 31.1, 31.0, 26.3; IR ν/ cm^{-1} 2961, 1731, 1366, 1231, 766; HRMS-ESI (*m/z*): calcd for $C_{31}H_{42}NO_7^+$ ($[M+H]^+$): 540.2956; Found: 540.2956.



dineopentyl 2-(1-benzyl-2-(4-chlorophenyl)-4,5,6-trimethoxy-1*H*-indol-3-yl)malonate

3o

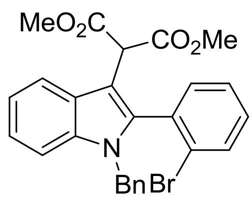
3o, white solid, 147 mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.31-7.21 (m, 7H), 6.90-6.88 (m, 2H), 6.36 (s, 1H), 5.06 (m, 3H), 4.01 (s, 3H), 3.82 (s, 3H), 3.77-3.75 (m, 5H), 3.65 (ABd, J_{BA} = 10.4 Hz, 2H), 0.84 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 151.5, 146.6, 137.6, 136.6, 136.3, 134.7, 133.4, 132.3, 129.2, 128.6, 128.5, 127.1, 125.8, 114.3, 106.4, 88.5, 74.5, 60.9, 60.5, 56.1, 50.0, 47.5, 31.1, 26.3; IR ν/ cm^{-1} 2956, 1731, 1367, 1122, 723; HRMS-ESI (*m/z*): calcd for $C_{37}H_{45}ClNO_7^+$ ($[M+H]^+$): 650.2879; Found: 650.2878.



dineopentyl 2-(1-benzyl-2-(4-bromophenyl)-4,5,6-trimethoxy-1*H*-indol-3-yl)malonate

3p

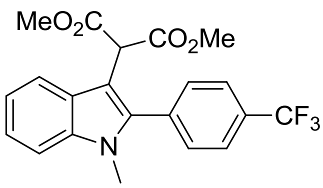
3p, white solid, 154 mg, 74% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.46 (d, *J* = 8.4 Hz, 2H), 7.25-7.15 (m, 5H), 6.90-6.88 (m, 2H), 6.35 (s, 1H), 5.07 (s, 1H), 5.06 (s, 2H), 4.01 (s, 3H), 3.82 (s, 3H), 3.77-3.75 (m, 5H), 3.64 (ABd, J_{BA} = 10.8 Hz, 2H), 0.84 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 151.5, 146.6, 137.6, 136.6, 136.3, 133.4, 132.6, 131.4, 129.6, 128.6, 127.1, 125.8, 123.0, 114.3, 106.4, 88.5, 74.5, 60.9, 60.5, 56.1, 50.0, 47.5, 31.1, 26.3; IR ν/ cm^{-1} 2956, 1730, 1368, 1122, 721; HRMS-ESI (*m/z*): calcd for $C_{37}H_{45}BrNO_7^+$ ($[M+H]^+$): 694.2374; Found: 694.2372.



dimethyl 2-(1-benzyl-2-(2-bromophenyl)-1*H*-indol-3-yl)malonate

3q

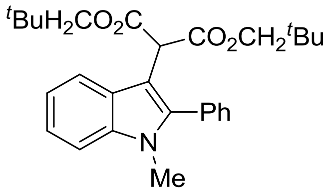
3q, white solid, 103 mg, 70% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.82-7.80 (m, 1H), 7.70-7.68 (m, 1H), 7.33-7.16 (m, 9H), 6.91-6.88 (m, 2H), 5.25 (ABd, J_{AB} = 16.8 Hz, 1H), 4.99 (ABd, J_{BA} = 16.4 Hz, 1H), 4.56 (s, 1H), 3.71 (s, 3H), 3.68 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 168.7, 138.5, 137.2, 136.5, 133.6, 132.8, 131.7, 130.9, 128.4, 127.3, 127.2, 126.4, 126.3, 125.9, 122.4, 120.9, 120.2, 110.3, 106.0, 52.6, 52.5, 49.7, 47.8; IR ν/ cm^{-1} 2948, 1742, 1455, 1291, 1134, 741; HRMS-ESI (*m/z*): calcd for $C_{26}H_{23}BrNO_4^+$ ($[M+H]^+$): 492.0805; Found: 492.0815.



dimethyl 2-(1-methyl-2-(4-(trifluoromethyl)phenyl)-1H-indol-3-yl)malonate

3r

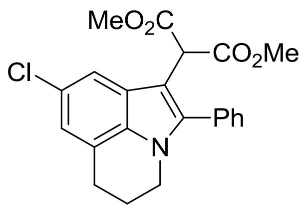
3r, white solid, 64 mg, 52% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.79-7.77 (m, 3H), 7.60-7.58 (m, 2H), 7.35 (d, *J* = 8.4 Hz, 1H), 7.28 (t, *J* = 7.6 Hz, 1H), 7.19 (t, *J* = 7.4 Hz, 1H), 4.75 (s, 1H), 3.68 (s, 6H), 3.58 (s, 3H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.6 (s, 3F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168,9, 138.3, 137.3, 134.3, 131.2, 130.7 (q, J_{C-F} = 31.6 Hz), 126.1, 125.5 (q, J_{C-F} = 3.3 Hz), 123.9 (q, J_{C-F} = 270.3 Hz), 122.6, 120.9, 120.4, 109.6, 105.5, 52.6, 49.6, 31.0; IR ν/ cm^{-1} 2955, 1724, 1322, 1162, 1107, 755; HRMS-ESI (*m/z*): calcd for $C_{21}H_{19}F_3NO_4^+$ ($[M+H]^+$): 406.1261; Found: 406.1258.



dineopentyl 2-(1-methyl-2-phenyl-1*H*-indol-3-yl)malonate

3s

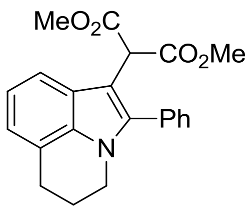
3s, white solid, 2.59 g, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.80 (d, *J* = 8.0 Hz, 1H), 7.52-7.44 (m, 5H), 7.34 (d, *J* = 8.4 Hz, 1H), 7.27-7.23 (m, 1H), 7.17-7.13 (m, 1H), 4.78 (s, 1H), 3.84 (ABd, J_{AB} = 10.4 Hz, 2H), 3.79 (ABd, J_{BA} = 10.4 Hz, 2H), 3.60 (s, 3H), 0.86 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 140.1, 137.2, 130.8, 130.6, 128.6, 128.5, 126.2, 122.0, 121.3, 119.8, 109.3, 105.1, 74.6, 50.1, 31.3, 30.9, 26.3; IR ν/ cm^{-1} 2952, 1750, 1401, 1296, 1150, 737; HRMS-ESI (*m/z*): calcd for $C_{28}H_{36}NO_4^+$ ($[M+H]^+$): 450.2639; Found: 450.2629.



dimethyl 2-(8-chloro-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5a

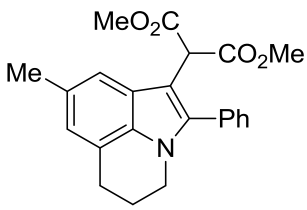
5a, white solid, 98 mg, 82% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.55-7.44 (m, 6H), 6.94 (s, 1H), 4.80 (s, 1H), 3.96 (t, *J* = 5.6 Hz, 2H), 3.73 (s, 6H), 2.97 (t, *J* = 6.0 Hz, 2H), 2.20-2.14 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 139.5, 132.6, 130.3, 129.8, 128.75, 128.68, 125.7, 125.0, 123.1, 119.6, 117.7, 103.7, 52.6, 49.5, 43.0, 24.7, 22.6; IR ν/ cm^{-1} 2950, 1732, 1362, 1144, 703; HRMS-ESI (*m/z*): calcd for $C_{22}H_{21}ClNO_4^+$ ($[M+H]^+$): 398.1154; Found: 398.1159.



dimethyl 2-(2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5b

5b, white solid, 83 mg, 76% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.57-7.43 (m, 6H), 7.07 (t, *J* = 7.6 Hz, 1H), 6.96 (d, *J* = 7.2 Hz, 1H), 4.85 (s, 1H), 3.98 (t, *J* = 5.6 Hz, 2H), 3.71 (s, 6H), 3.00 (t, *J* = 5.8 Hz, 2H), 2.21-2.15 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 138.4, 134.2, 130.4, 130.3, 128.6, 128.5, 124.4, 121.8, 120.1, 119.1, 118.3, 103.9, 52.5, 49.7, 43.1, 25.0, 22.8; IR ν/ cm^{-1} 2948, 1734, 1345, 1145, 748; HRMS-ESI (*m/z*): calcd for $C_{22}H_{22}NO_4^+$ ($[M+H]^+$): 364.1543; Found: 364.1549.

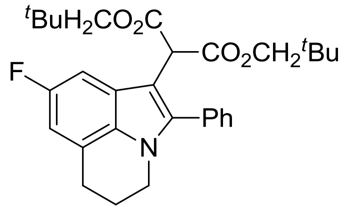


dimethyl 2-(8-methyl-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5c

5c, white solid, 98 mg, 86% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.52-7.42 (m, 5H), 7.34 (s, 1H), 6.80 (s, 1H), 4.82 (s, 1H), 3.96 (t, *J* = 5.6 Hz, 2H), 3.71 (s, 6H), 2.96 (t, *J* = 6.0 Hz, 2H), 2.45 (s, 3H), 2.19-2.13 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$)

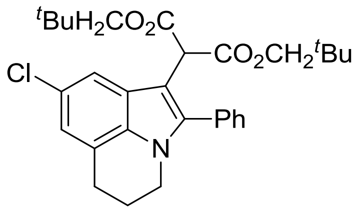
δ 169.4, 138.4, 132.6, 130.5, 130.4, 129.5, 128.5, 128.4, 124.5, 121.4, 120.9, 117.6, 103.4, 52.5, 49.7, 43.1, 24.9, 22.9, 21.9; IR ν/ cm^{-1} 2949, 1732, 1362, 1145, 735; HRMS-ESI (*m/z*): calcd for $C_{23}H_{24}NO_4^+$ ($[M+H]^+$): 378.1700; Found: 378.1705.



dineopentyl 2-(8-fluoro-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5d

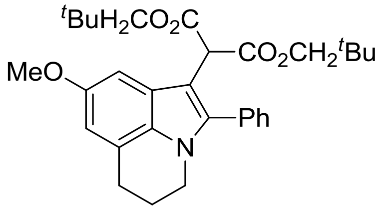
5d, white solid, 95 mg, 64% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.52-7.43 (m, 5H), 7.29-7.25 (m, 1H), 6.73-6.70 (m, 1H), 4.82 (s, 1H), 3.96 (t, J = 5.6 Hz, 2H), 3.87 (ABd, J_{AB} = 10.8 Hz, 2H), 3.82 (ABd, J_{BA} = 10.8 Hz, 2H), 2.96 (t, J = 6.0 Hz, 2H), 2.18-2.12 (m, 2H), 0.89 (s, 18H); ^{19}F NMR (376 MHz, $CDCl_3$) δ -123.8 (t, J = 10.0 Hz, 1F); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 158.2 (d, $J_{C\text{-}F}$ = 233.0 Hz), 139.6, 130.8, 130.4, 130.1, 128.6, 124.2 (d, $J_{C\text{-}F}$ = 11.3 Hz), 122.7 (d, $J_{C\text{-}F}$ = 9.6 Hz), 108.0 (d, $J_{C\text{-}F}$ = 26.2 Hz), 104.5 (d, $J_{C\text{-}F}$ = 5.3 Hz), 103.7 (d, $J_{C\text{-}F}$ = 24.9 Hz), 74.8, 49.9, 43.0, 31.3, 26.3, 25.0, 22.7; IR ν/ cm^{-1} 2957, 1735, 1369, 1152, 704; HRMS-ESI (*m/z*): calcd for $C_{30}H_{37}FNO_4^+$ ($[M+H]^+$): 494.2701; Found: 494.2702.



dineopentyl 2-(8-chloro-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5e

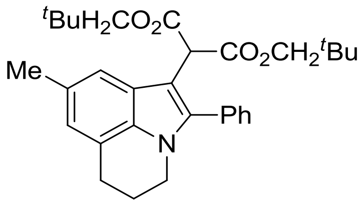
5e, white solid, 96 mg, 63% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.60 (d, J = 1.6 Hz, 1H), 7.53-7.44 (m, 5H), 6.91 (d, J = 1.2 Hz, 1H), 4.81 (s, 1H), 3.95 (t, J = 5.6 Hz, 2H), 3.87 (ABd, J_{AB} = 10.4 Hz, 2H), 3.83 (ABd, J_{BA} = 10.4 Hz, 2H), 2.95 (t, J = 6.0 Hz, 2H), 2.17-2.11 (m, 2H), 0.90 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 139.5, 132.7, 130.4, 129.9, 128.7, 128.6, 125.5, 125.0, 122.9, 119.5, 118.4, 104.1, 74.9, 49.9, 43.0, 31.3, 26.3, 24.8, 22.6; IR ν/ cm^{-1} 2958, 1726, 1366, 1006, 727; HRMS-ESI (*m/z*): calcd for $C_{30}H_{37}ClNO_4^+$ ($[M+H]^+$): 510.2406; Found: 510.2398.



dineopentyl 2-(8-methoxy-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5f

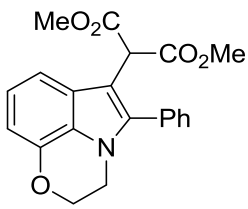
5f, white solid, 101 mg, 67% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.51-7.41 (m, 5H), 7.08 (d, *J* = 1.2 Hz, 1H), 6.63 (s, 1H), 4.85 (s, 1H), 3.95 (t, *J* = 5.6 Hz, 2H), 3.89 (ABd, J_{AB} = 10.8 Hz, 2H), 3.84 (s, 3H), 3.81 (ABd, J_{BA} = 10.4 Hz, 2H), 2.94 (t, *J* = 5.8 Hz, 2H), 2.16-2.11 (m, 2H), 0.90 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 154.5, 138.5, 130.5, 130.4, 129.7, 128.5, 128.3, 124.3, 122.5, 110.1, 104.0, 100.2, 74.5, 55.8, 49.9, 43.0, 31.3, 26.3, 24.9, 22.9; IR ν/ cm^{-1} 2956, 1739, 1366, 1137, 731; HRMS-ESI (*m/z*): calcd for $C_{31}H_{40}NO_5^+$ ($[M+H]^+$): 506.2901; Found: 506.2902.



dineopentyl 2-(8-methyl-2-phenyl-5,6-dihydro-4*H*-pyrrolo[3,2,1-*ij*]quinolin-1-yl)malonate

5g

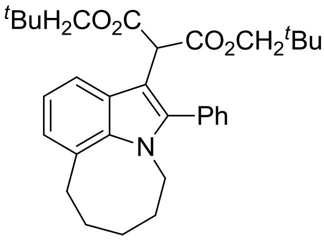
5g, white solid, 101 mg, 69% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.49-7.40 (m, 6H), 6.77 (s, 1H), 4.83 (s, 1H), 3.95 (t, *J* = 5.6 Hz, 2H), 3.86 (ABd, J_{AB} = 10.4 Hz, 2H), 3.80 (ABd, J_{BA} = 10.4 Hz, 2H), 2.95 (t, *J* = 6.0 Hz, 2H), 2.42 (s, 3H), 2.18-2.12 (m, 2H), 0.90 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 138.3, 132.8, 130.7, 130.5, 129.0, 128.5, 128.2, 124.5, 121.2, 120.8, 118.4, 103.8, 74.7, 50.0, 43.1, 31.3, 26.4, 24.9, 23.0, 21.8; IR ν/ cm^{-1} 2959, 1724, 1365, 1145, 703; HRMS-ESI (*m/z*): calcd for $C_{31}H_{40}NO_4^+$ ($[M+H]^+$): 490.2952; Found: 490.2954.



dimethyl 2-(5-phenyl-2,3-dihydro-[1,4]oxazino[2,3,4-*hi*]indol-6-yl)malonate

5h

5h, white solid, 51 mg, 47% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.54-7.45 (m, 5H), 7.32 (d, J = 8.4 Hz, 1H), 7.03 (t, J = 7.8 Hz, 1H), 6.70 (d, J = 7.6 Hz, 1H), 4.87 (s, 1H), 4.49 (t, J = 4.8 Hz, 2H), 4.13 (t, J = 4.8 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.1, 143.0, 137.8, 130.1, 129.5, 128.8, 128.7, 126.3, 125.4, 121.0, 113.7, 105.7, 105.3, 65.4, 52.6, 49.6, 42.9; IR ν/ cm^{-1} 2920, 1727, 1445, 1299, 1212, 1141, 732; HRMS-ESI (*m/z*): calcd for $C_{21}H_{20}NO_5^+$ ($[M+H]^+$): 366.1336; Found: 366.1345.

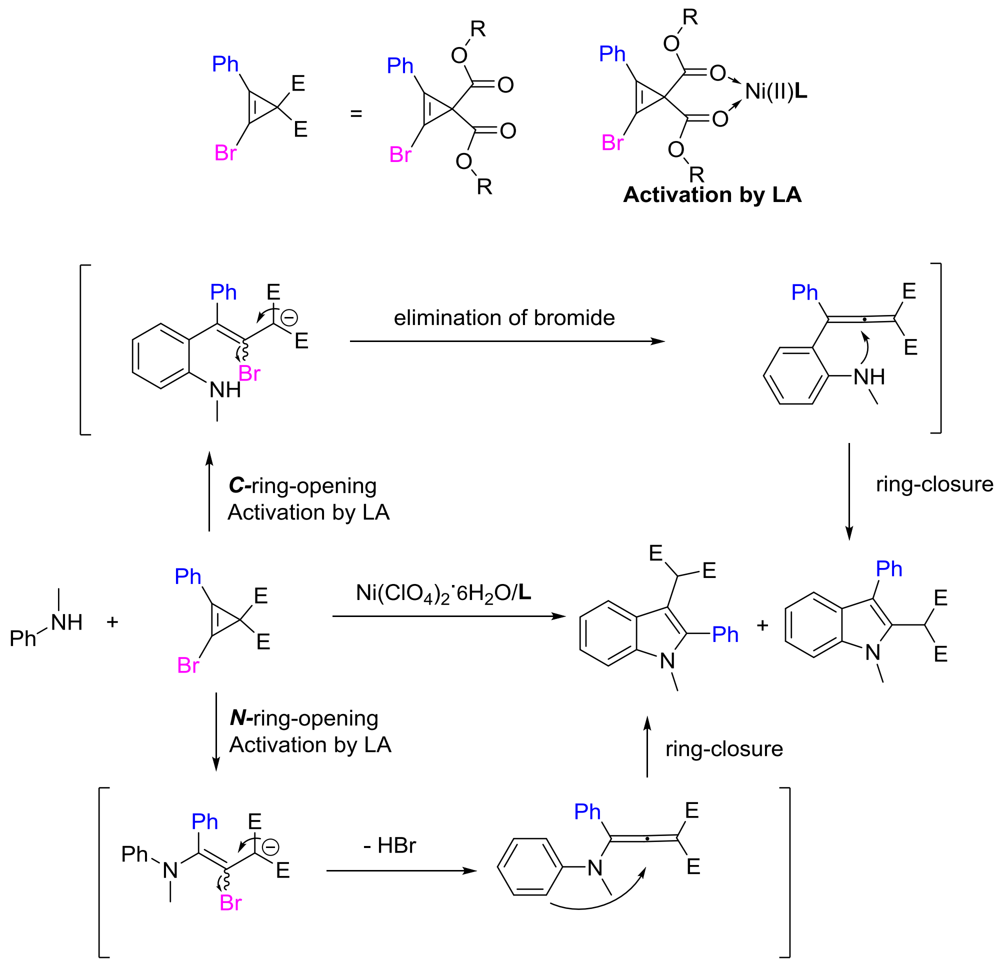


dineopentyl 2-(2-phenyl-5,6,7,8-tetrahydro-4H-azocino[3,2,1-*hi*]indol-1-yl)malonate

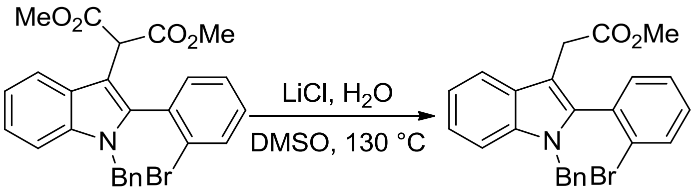
5i

5i, white solid, 48 mg, 32% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.64 (d, J = 8.0 Hz, 1H), 7.48-7.39 (m, 5H), 7.01 (t, J = 7.4 Hz, 1H), 6.88 (d, J = 6.8 Hz, 1H), 4.68 (s, 1H), 4.27 (s, 2H), 3.79 (s, 4H), 3.27 (s, 2H), 1.92-1.88 (m, 2H), 1.83-1.80 (m, 2H), 1.49-1.48 (m, 2H), 0.82 (s, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 140.0, 137.3, 131.2, 130.9, 128.7, 128.4, 126.1, 124.3, 124.0, 119.9, 119.2, 105.0, 74.5, 50.2, 44.2, 32.5, 31.3, 30.9, 29.7, 26.3, 21.3; IR ν/ cm^{-1} 2960, 1752, 1738 1366, 1140, 742; HRMS-ESI (*m/z*): calcd for $C_{32}H_{42}NO_4^+$ ($[M+H]^+$): 504.3108; Found: 504.3104.

4. Proposed Mechanism

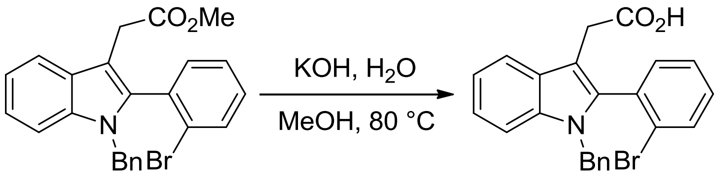


5. Chemical Transformation of the Products



3q **6**

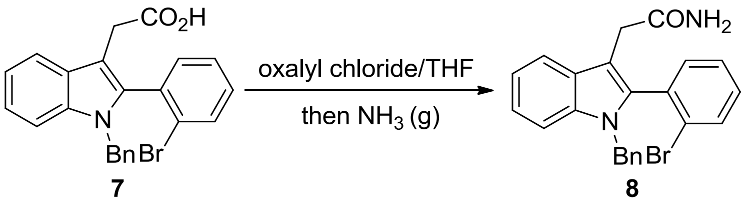
3q (257.3 mg, 0.52 mmol) was dissolved in DMSO (2.0 mL) and water (10.0 uL, 0.56 mmol), and then LiCl (45.0 mg, 1.04 mmol) was added under Ar. The reaction mixture was stirred for 13 h at 130 ℃, cooled to rt, quenched by the addition of 2.5 N NaOH, and extracted with Et_2O. The combined organic layers were washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **6** (188.4 mg, 84% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.70-7.67 (m, 2H), 7.30-7.15 (m, 9H), 6.89-6.86 (m, 2H), 5.25 (AB, J_{AB} = 16.4 Hz, 1H), 5.02 (AB, J_{BA} = 16.4 Hz, 1H), 3.68 (AB, J_{AB} = 15.6 Hz, 1H), 3.60 (s, 3H), 3.53 (AB, J_{BA} = 16.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 137.6 (2C), 136.3, 133.6, 132.8, 132.4, 130.5, 128.4, 127.5, 127.2, 127.1, 126.4, 125.8, 122.3, 119.9, 119.3, 110.3, 106.9, 51.8, 47.7, 30.8; IR ν/ cm^{-1} 2920, 1732, 1453, 1186, 1026, 739; HRMS-ESI (*m/z*): calcd for $C_{24}H_{24}BrN_2O_2^+$ ($[M+NH_4]^+$): 451.1016; Found: 451.1025.



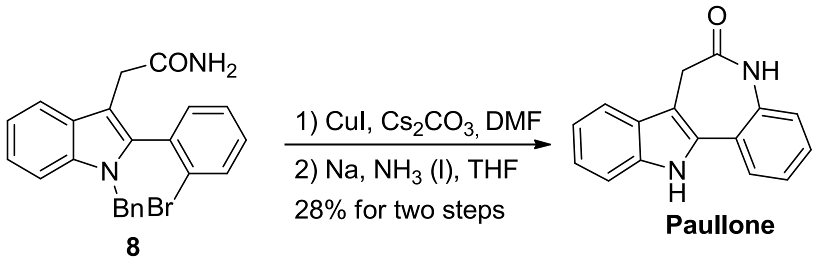
6 **7**

6 (120.0 mg, 0.28 mmol) was dissolved in MeOH (2.0 mL) and water (1.0 mL), and then KOH (157.0 mg, 2.8 mmol) was added under Ar. The reaction mixture was stirred for 2 h at 80 ℃, cooled to rt, quenched by the addition of 2.5 N HCl, and extracted with EA. The combined organic layers were washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **7** (107.9 mg, 92% yield) as white solid. ^{1}H

NMR (400 MHz, $CDCl_3$, TMS) δ 7.70-7.65 (m, 2H), 7.30-7.16 (m, 9H), 6.89-6.87 (m, 2H), 5.25 (AB, J_{AB} = 16.4 Hz, 1H), 5.02 (AB, J_{BA} = 16.4 Hz, 1H), 3.70 (AB, J_{AB} = 16.0 Hz, 1H), 3.53 (AB, J_{BA} = 16.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.7, 137.9, 137.5, 136.3, 133.6, 132.8, 132.1, 130.6, 128.4, 127.34, 127.29, 127.1, 126.4, 125.7, 122.4, 120.0, 119.3, 110.4, 106.3, 47.8, 30.7; IR ν/ cm^{-1} 3029, 1704, 1495, 1345, 1184, 1027, 740; HRMS-ESI (*m/z*): calcd for $C_{23}H_{19}BrNO_2^+$ ($[M+H]^+$): 420.0594; Found: 420.0599.

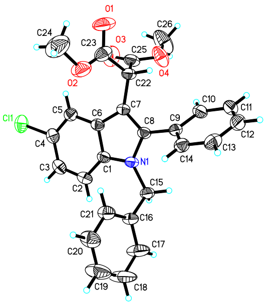


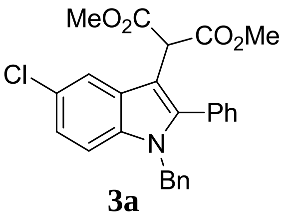
7 (95.0 mg, 0.23 mmol) was dissolved in THF (1.0 mL), and then oxalyl chloride (45.0 mg, 0.35 mmol) was added under Ar. The reaction mixture was stirred for 2 h at 50 ℃, cooled to rt, and pure NH_3 (g) was bubbled into the mixture for 20 min, and water was added and the mixture was extracted with DCM, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **8** (80.7 mg, 84% yield) as white solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS) δ 7.72-7.67 (m, 2H), 7.33-7.16 (m, 9H), 6.87-6.85 (m, 2H), 5.73 (s, 1H), 5.39 (s, 1H), 5.30 (AB, J_{AB} = 16.4 Hz, 1H), 5.02 (AB, J_{BA} = 16.4 Hz, 1H) , 3.60 (AB, J_{AB} = 17.6 Hz, 1H), 3.54 (AB, J_{BA} = 17.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.9, 138.0, 137.3, 136.5, 133.2, 132.9, 131.9, 130.9, 128.4, 127.6, 127.3, 127.0, 126.4, 125.6, 122.8, 120.2, 119.1, 110.5, 107.4, 47.8, 32.4; IR ν/ cm^{-1} 3458, 1668, 1457, 1343, 1186, 1026, 741; HRMS-ESI (*m/z*): calcd for $C_{23}H_{20}BrN_2O^+$ ($[M+H]^+$): 419.0754; Found: 419.0759.



8 (46.5 mg, 0.11 mmol), CuI (11.4 mg, 0.06 mmol), Cs_2CO_3 (91.3 mg, 0.28 mmol) was added in a Schlenk tube. The tube was evacuated and backfilled with argon before 0.5 mL DMF was added. The reaction mixture was stirred at 110 ℃ for 48 h. After the reaction mixture was cooled to rt, and water was added and the mixture was extracted with EtOAc, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to yield the corresponding product. Then to the solution of sodium (3.5 mg, 0.15 mmol) in liquid ammonia (1.0 mL) was add the corresponding product in THF (0.5 mL) at -78 ℃. The reaction was quenched by adding NH_4Cl after 20 min. Water was added and the mixture was extracted with EtOAc, and the organic layer was washed with brine and dried over Na_2SO_4. After concentration in vacuo, the residue was purified by column chromatography on silica gel to provide the **Paullone** (28% yield for two steps) as pale yellow solid. ^1H NMR (400 MHz, DMSO-d_6, TMS) δ 11.64 (s, 1H), 10.15 (s, 1H), 7.79-7.69 (m, 2H), 7.49-7.09 (m, 6H), 3.54 (s, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 172.1, 137.9, 135.9, 133.0, 128.5, 127.4, 127.0, 124.2, 123.4, 122.8, 122.6, 119.6, 118.5, 112.0, 108.1, 32.1; HRMS-ESI (*m/z*): calcd for $C_{16}H_{11}N_2O^-$ ($[M-H]^-$): 247.0877; Found: 247.0878. All the analytical data are consistent with the reported values[5].

6. X-ray Crystallographic Data

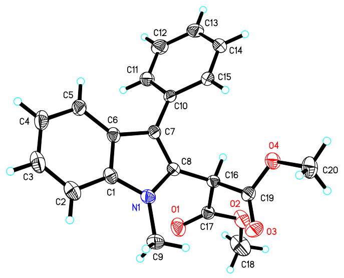


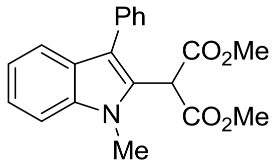


3a

Crystal data and structure refinement for **3a**

Empirical formula	C26 H22 Cl N O4	
Formula weight	447.89	
Temperature	296(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P 21/n	
Unit cell dimensions	a = 11.1236(3) Å	α= 90 °.
	b = 13.5248(4) Å	β= 98.4720(10) °.
	c = 15.1885(5) Å	γ = 90 °.
Volume	2260.09(12) Å^3	
Z	4	
Density (calculated)	1.316 Mg/m^3	
Absorption coefficient	0.202 mm^{-1}	
F(000)	936	
Crystal size	0.200 x 0.170 x 0.120 mm^3	
Theta range for data collection	2.606 to 24.998 °.	
Index ranges	-12<=h<=13, -15<=k<=16, -18<=l<=18	
Reflections collected	23223	
Independent reflections	3944 [R(int) = 0.0774]	
Completeness to theta = 25.242 °	96.5 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7456 and 0.4823	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3944 / 0 / 292	
Goodness-of-fit on F^2	1.038	
Final R indices [I>2sigma(I)]	R1 = 0.0689, wR2 = 0.1951	
R indices (all data)	R1 = 0.0875, wR2 = 0.2203	
Extinction coefficient	0.039(7)	
Largest diff. peak and hole	0.689 and -0.323 e.Å^{-3}	





3t'

Crystal data and structure refinement for **3t'**

Empirical formula	C20 H19 N O4	
Formula weight	337.36	
Temperature	293(2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	P 21/n	
Unit cell dimensions	a = 11.0608(10) Å	α= 90 °.
	b = 16.1061(16) Å	β= 101.078(2) °.
	c = 19.4870(19) Å	γ = 90 °.
Volume	3406.9(6) Å^3	
Z	8	
Density (calculated)	1.315 Mg/m^3	
Absorption coefficient	0.092 mm^{-1}	
F(000)	1424	
Crystal size	0.189 x 0.176 x 0.123 mm^3	
Theta range for data collection	1.971 to 25.496 °.	
Index ranges	-13<=h<=13, -19<=k<=19, -23<=l<=18	
Reflections collected	19593	
Independent reflections	6358 [R(int) = 0.0421]	
Completeness to theta = 25.242 °	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7456 and 0.6495	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	6358 / 0 / 457	
Goodness-of-fit on F^2	1.038	
Final R indices [I>2sigma(I)]	R1 = 0.0593, wR2 = 0.1554	
R indices (all data)	R1 = 0.0804, wR2 = 0.1721	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.355 and -0.195 e.Å^{-3}	

7. References

(1) Li, D.; Yang, T.; Su, H.; Yu, W. *Adv. Synth. Catal*. **2015**, 357, 2529 – 2539.

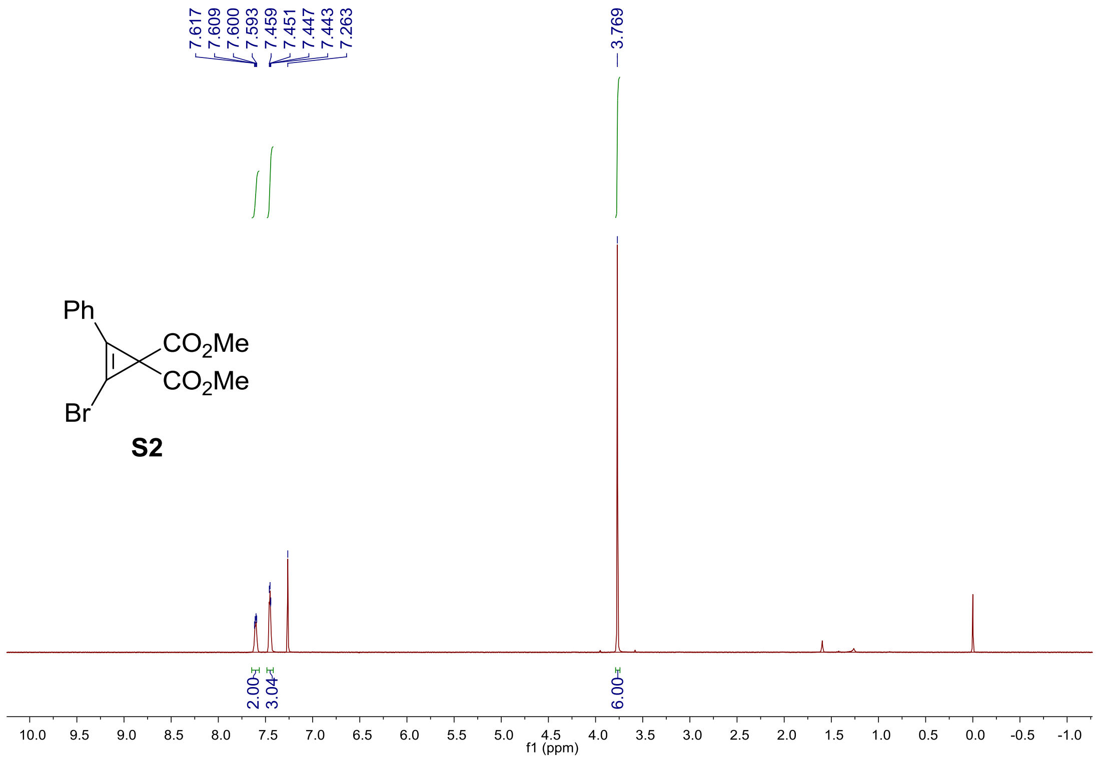
(2) Mazik, M.; Buthe, A. C. *Org. Biomol. Chem.*, **2008**, 6, 1558–1568.

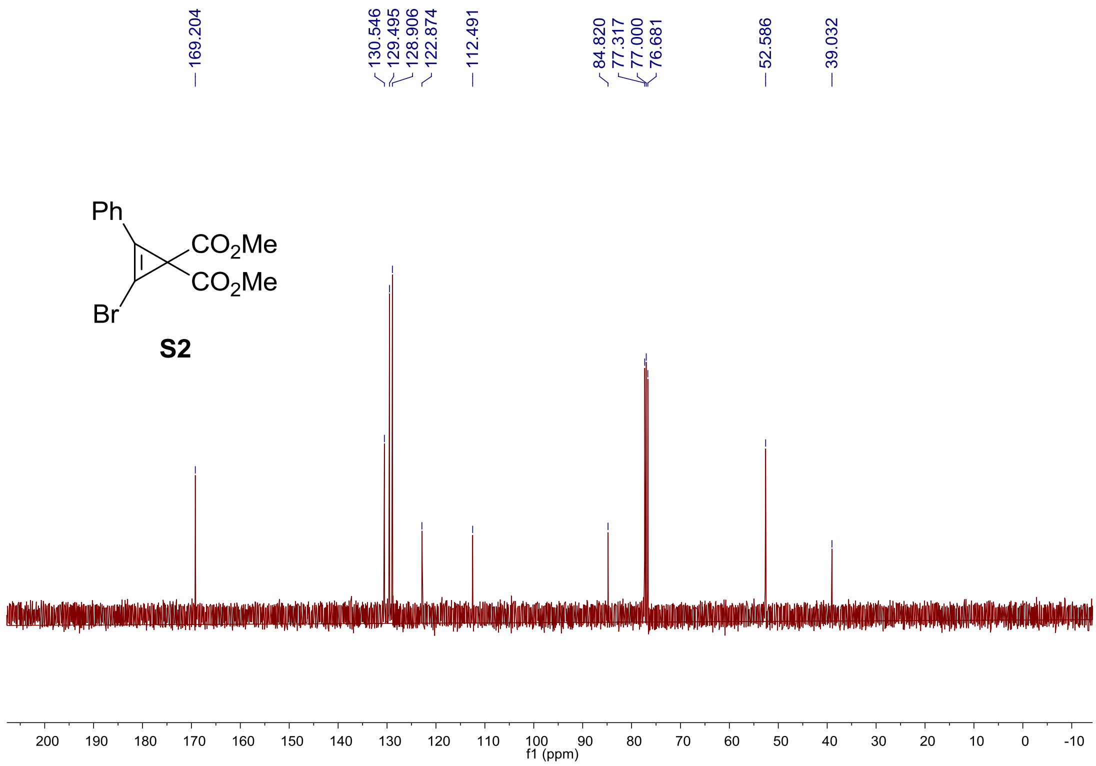
(3) Cho, H.; Iwama, Y.; Sugimoto, K.; Mori, S.; Tokuyama, H. *J. Org. Chem*. **2010**, 75, 627–636.

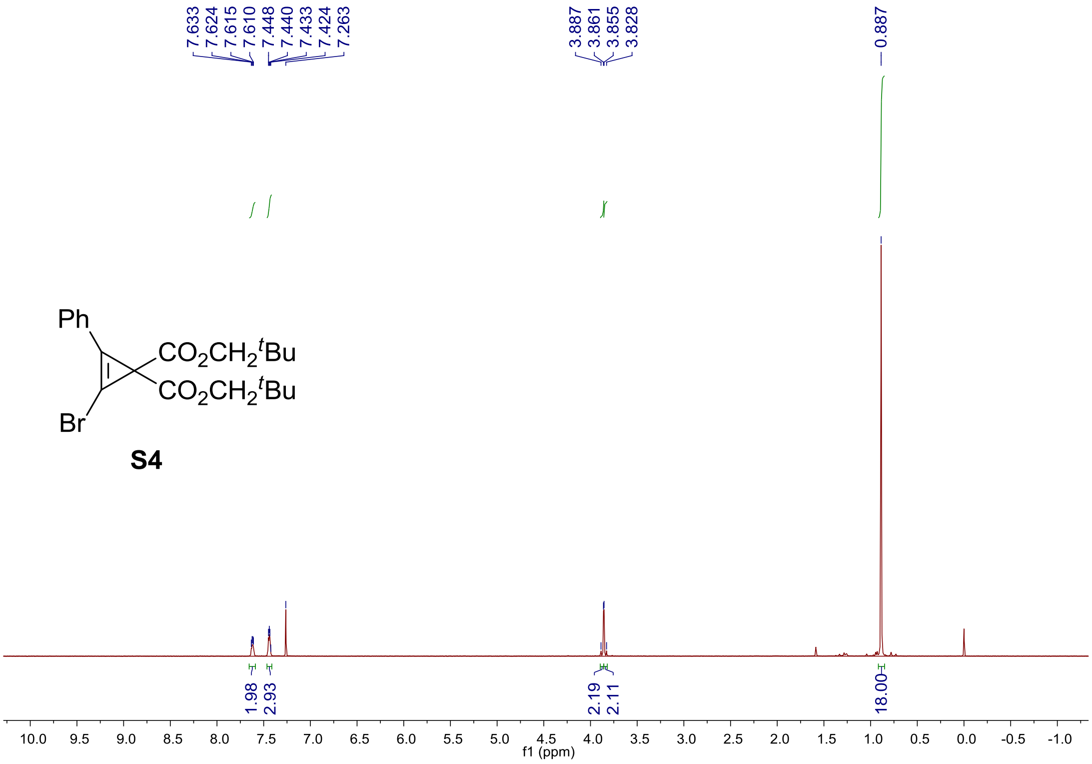
(4) Boitsov, V. M.; Kostikov, R. R.; Molchanov, A. P.; Stepakov, A. V.; Baird, M. S. *Russ. J. Org. Chem.* **2004**, Vol. 40, 1760-1763.

(5) Tobisu, M.; Fujihara, H.; Koh, K.; Chatani, N. *J. Org. Chem.*, **2010**, 75, 4841-4847.

8. Copies of NMR Spectra of Products







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7.615
7.610
7.448
7.440
7.433
7.424
7.263
3.887
3.861
3.855
3.828
0.887
1.98
2.93
2.19
2.11
18.00
f1 (ppm)
Ph
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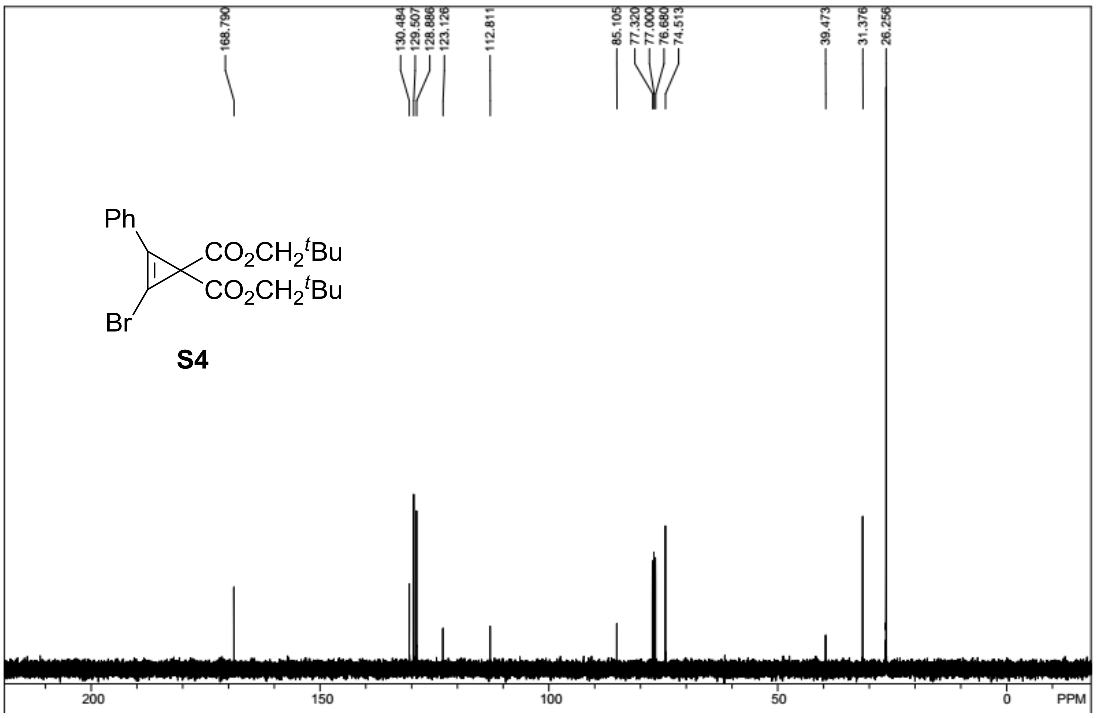
$CO_2CH_2{}^tBu$
Br
S4



168.790
130.484
129.507
128.886
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77.000
76.680
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39.473
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26.256
PPM
Ph
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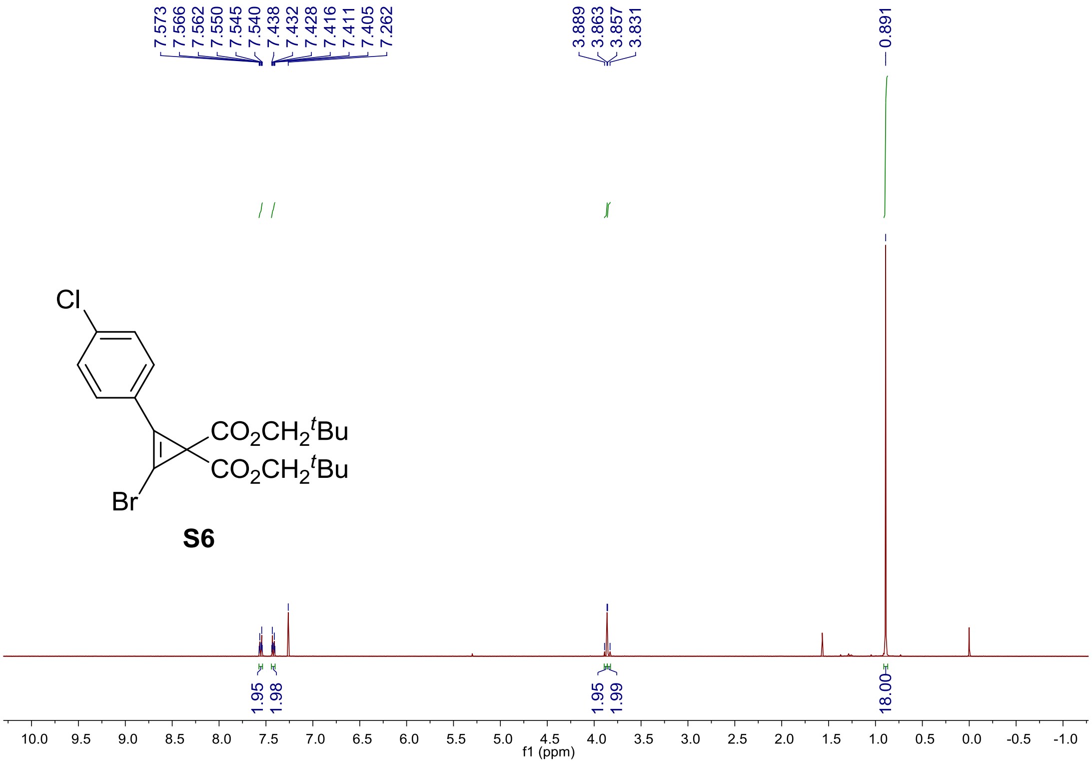
Br
S4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7.540
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7.428
7.416
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7.262
3.889
3.863
3.857
3.831
0.891
Cl
$CO_2CH_2{}^tBu$
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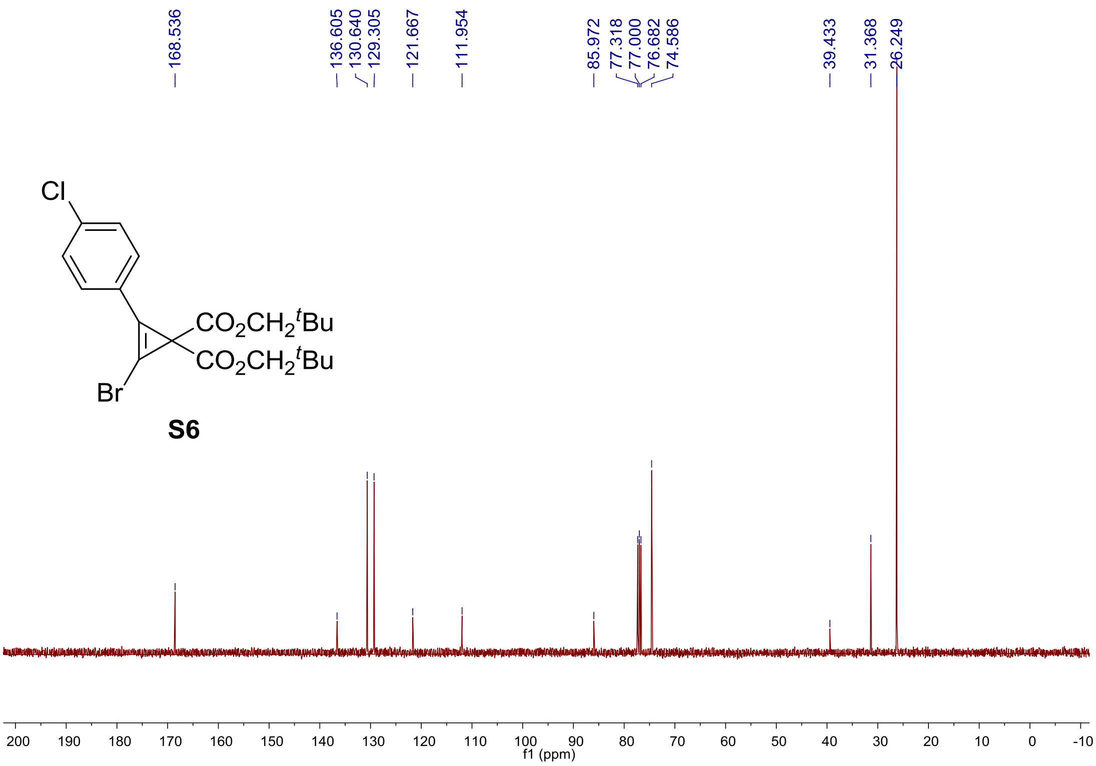
Br
S6
1.95
1.98
1.95
1.99
18.00
f1 (ppm)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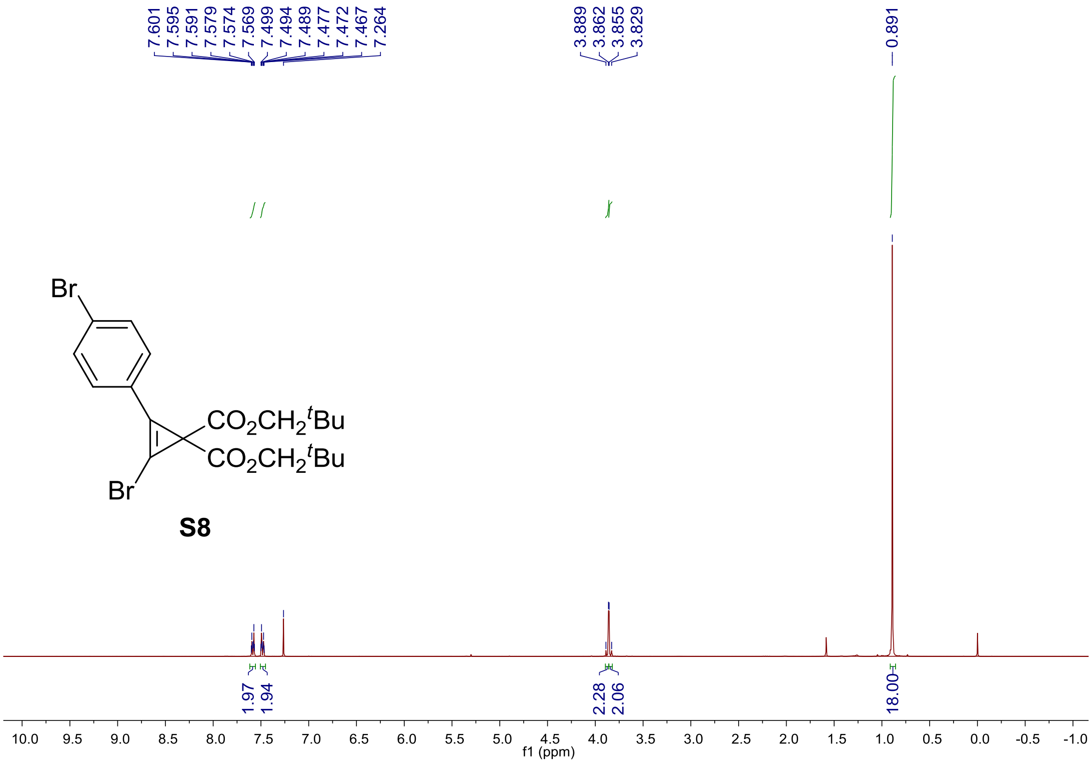
S6
f1 (ppm)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7.477
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7.467
7.264
3.889
3.862
3.855
3.829
0.891
Br
$CO_2CH_2{}^tBu$
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Br
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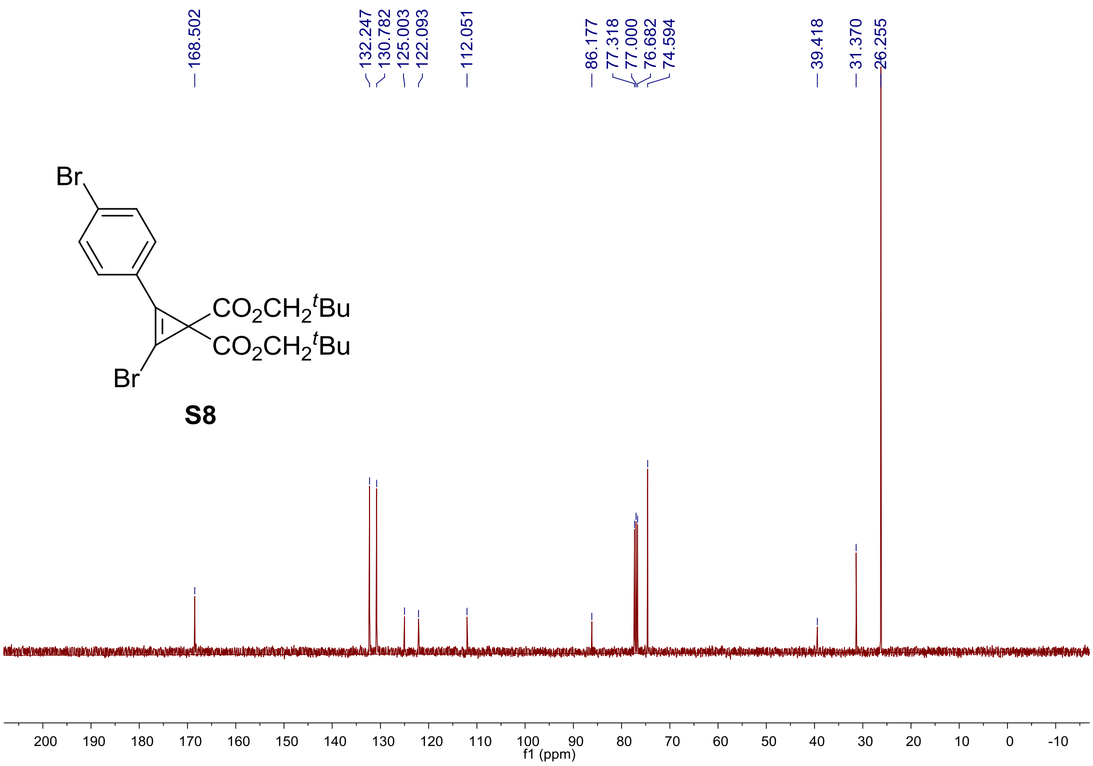
2.06
18.00
f1 (ppm)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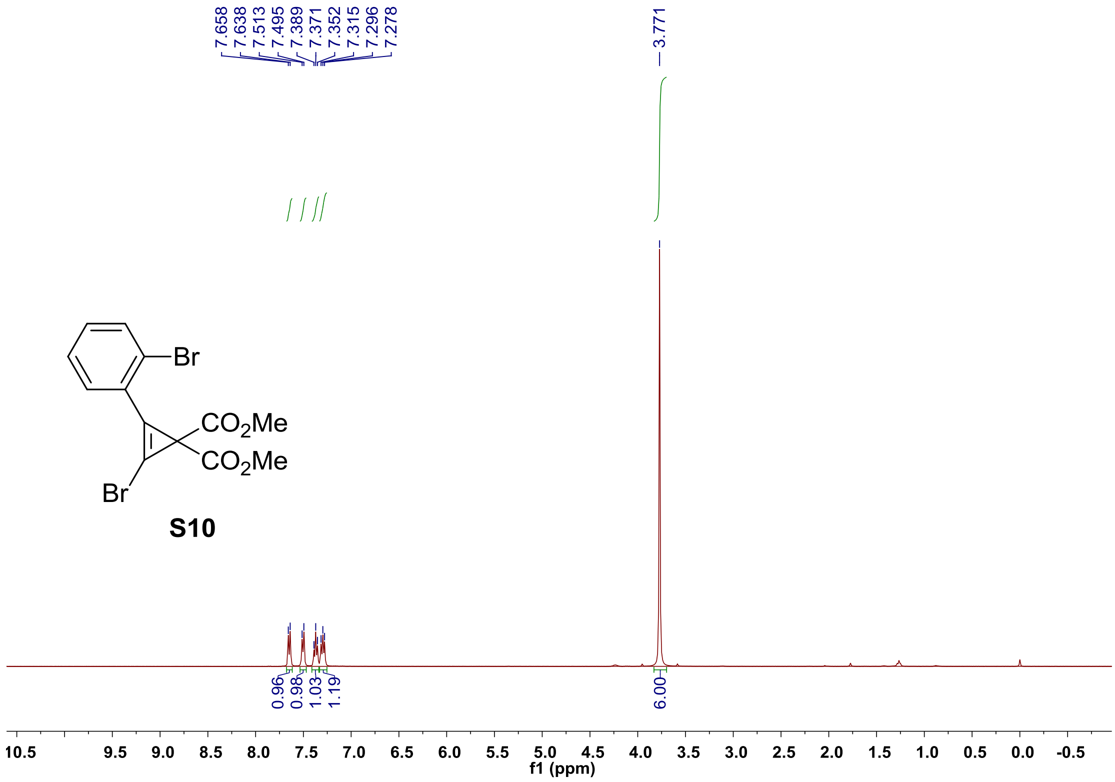
Br
S8
f1 (ppm)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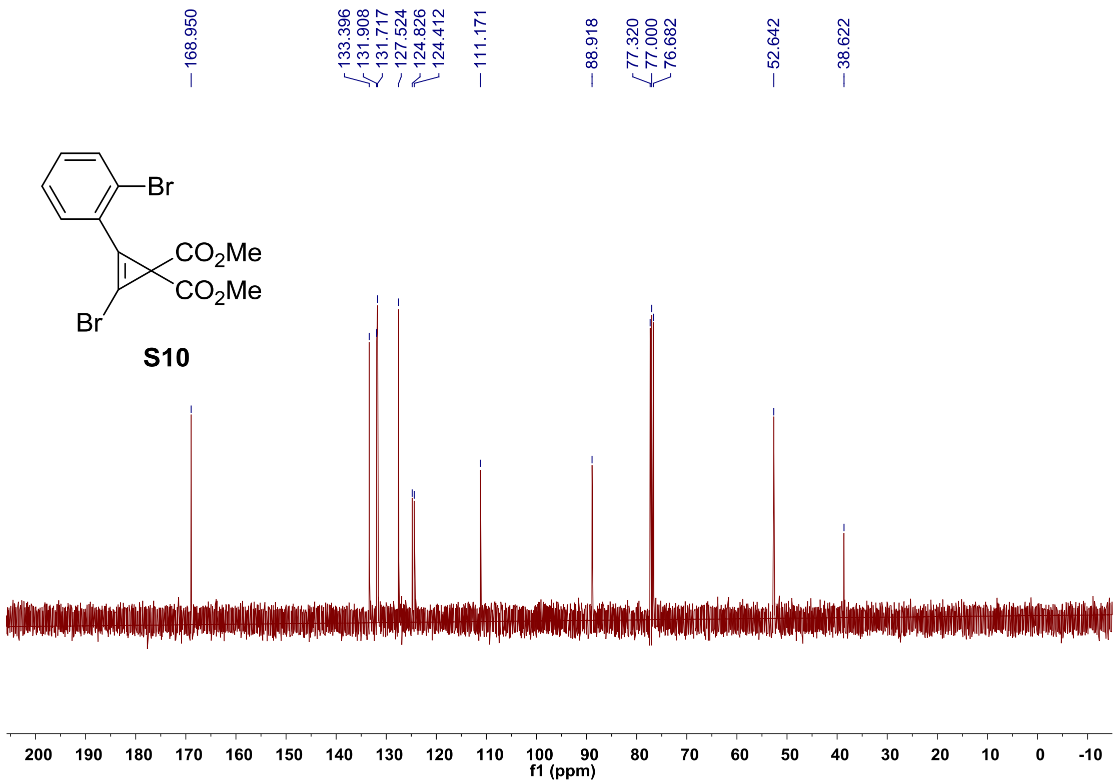
Br
CO_2Me
CO_2Me
Br
S10
0.96
0.98
1.03
1.19
6.00
10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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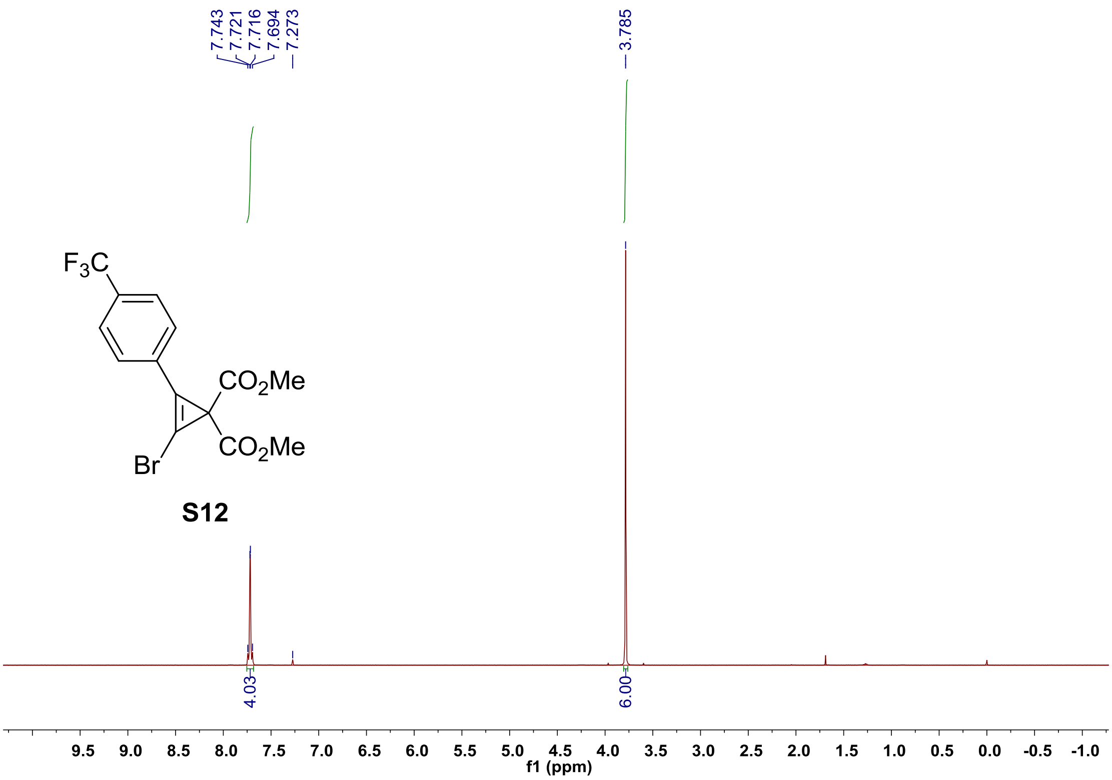
38.622
Br
CO_2Me
CO_2Me
Br
S10
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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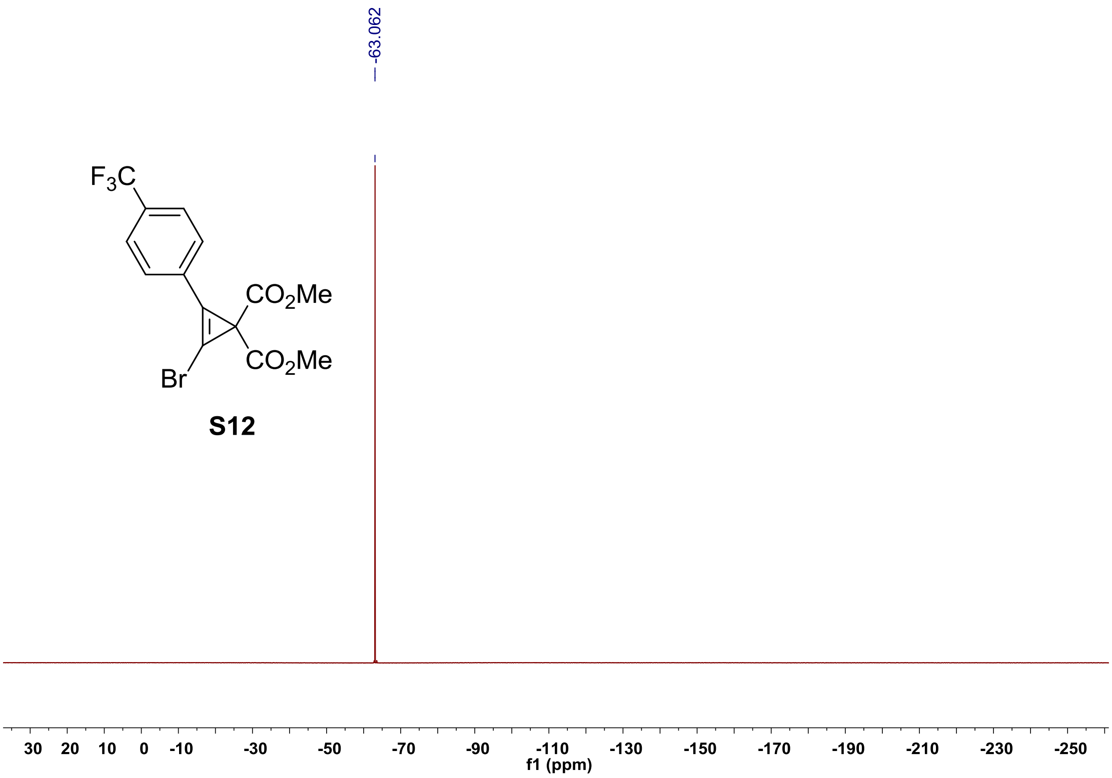
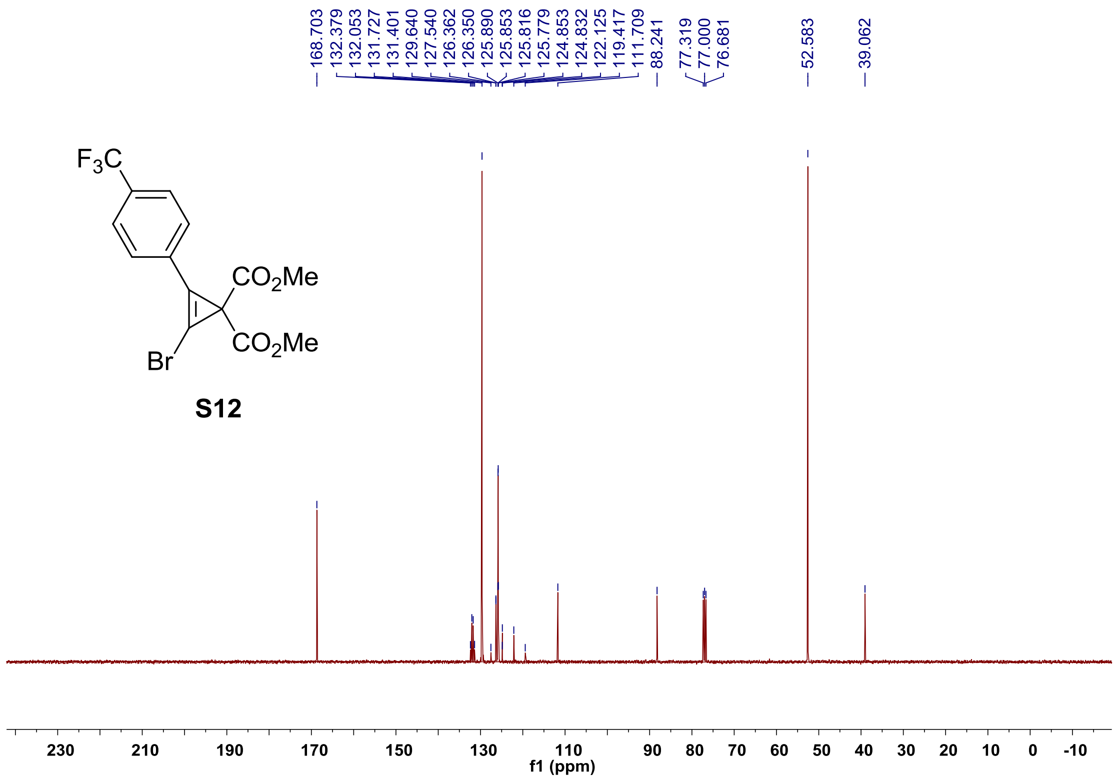
7.716
7.694
7.273
3.785
F3C
CO2Me
CO2Me
Br
S12
4.03
6.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


-63.062
F3C
CO2Me
CO2Me
Br
S12
30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230 -250
f1 (ppm)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132.053
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127.540
126.362
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125.890
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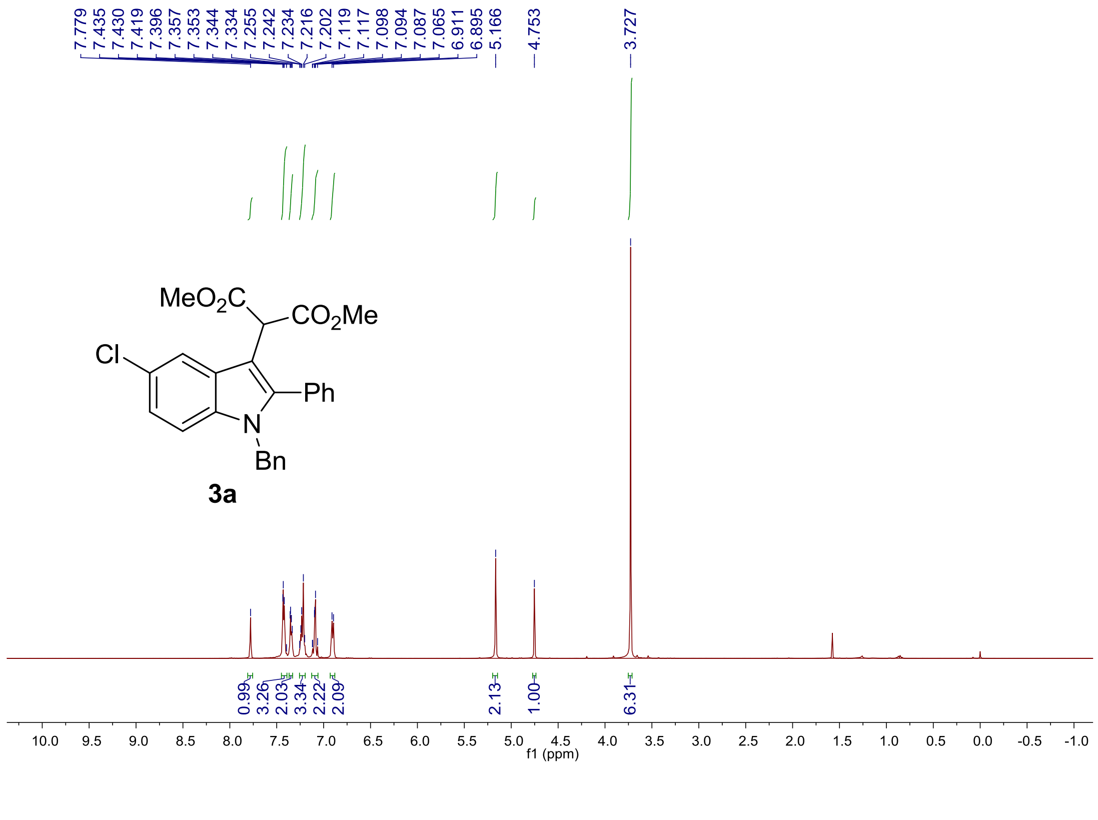
125.816
125.779
124.853
124.832
122.125
119.417
111.709
88.241
77.319
77.000
76.681
52.583
39.062
F3C
CO2Me
CO2Me
Br
S12
230 210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.430
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7.357
7.353
7.344
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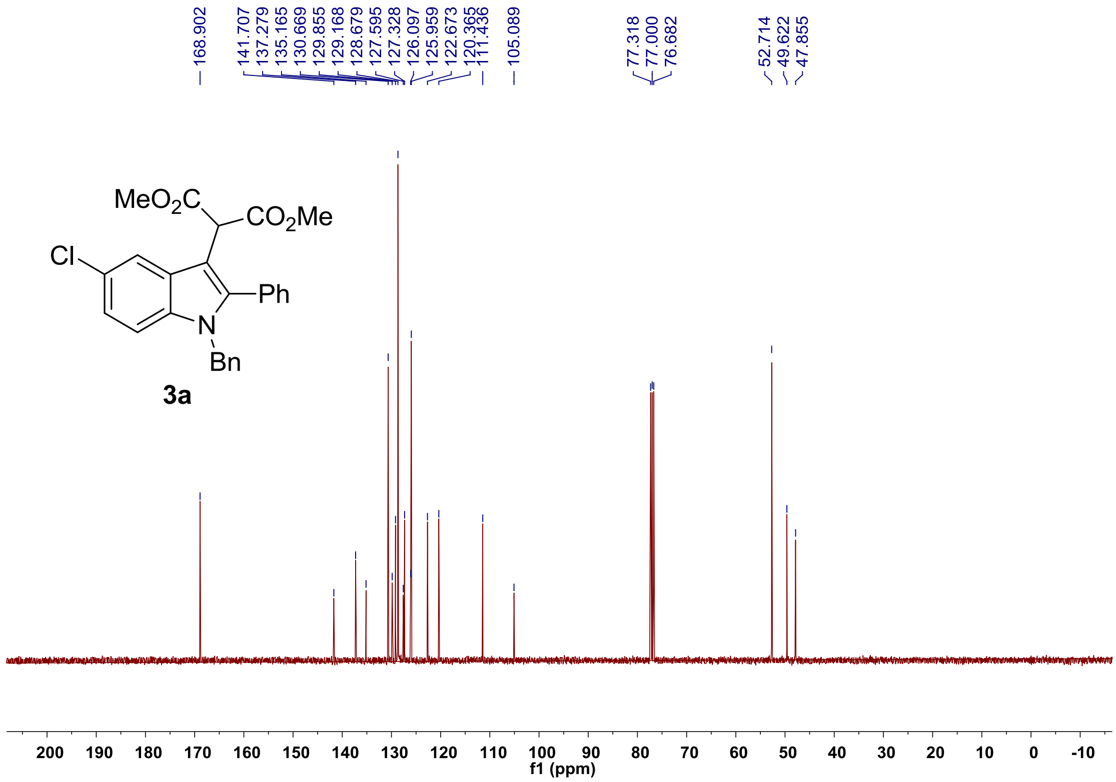
7.255
7.242
7.234
7.216
7.202
7.119
7.117
7.098
7.094
7.087
7.065
6.911
6.895
5.166
4.753
3.727
MeO2C
CO2Me
Cl
Ph
N
Bn
3a
0.99
3.26
2.03
3.34
2.22
2.09
2.13
1.00
6.31
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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141.707
137.279
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129.168
128.679
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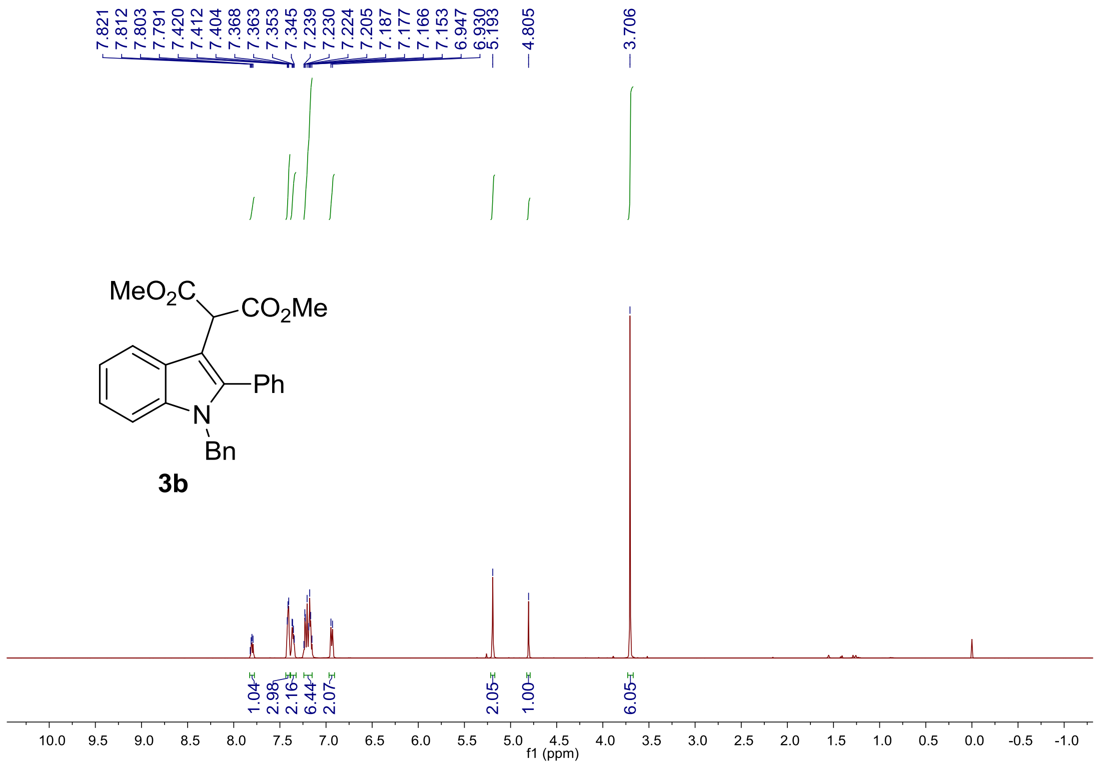
127.328
126.097
125.959
122.673
120.365
111.436
105.089
77.318
77.000
76.682
52.714
49.622
47.855
MeO2C
CO2Me
Cl
Ph
N
Bn
f1 (ppm)

3a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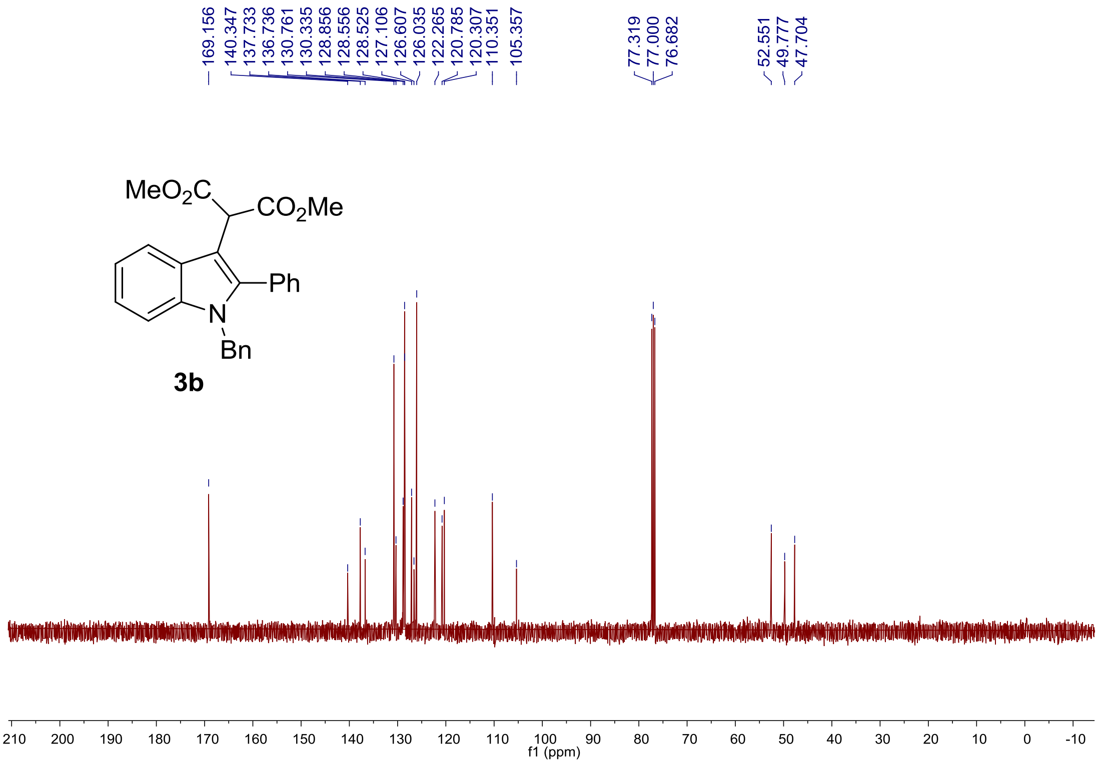
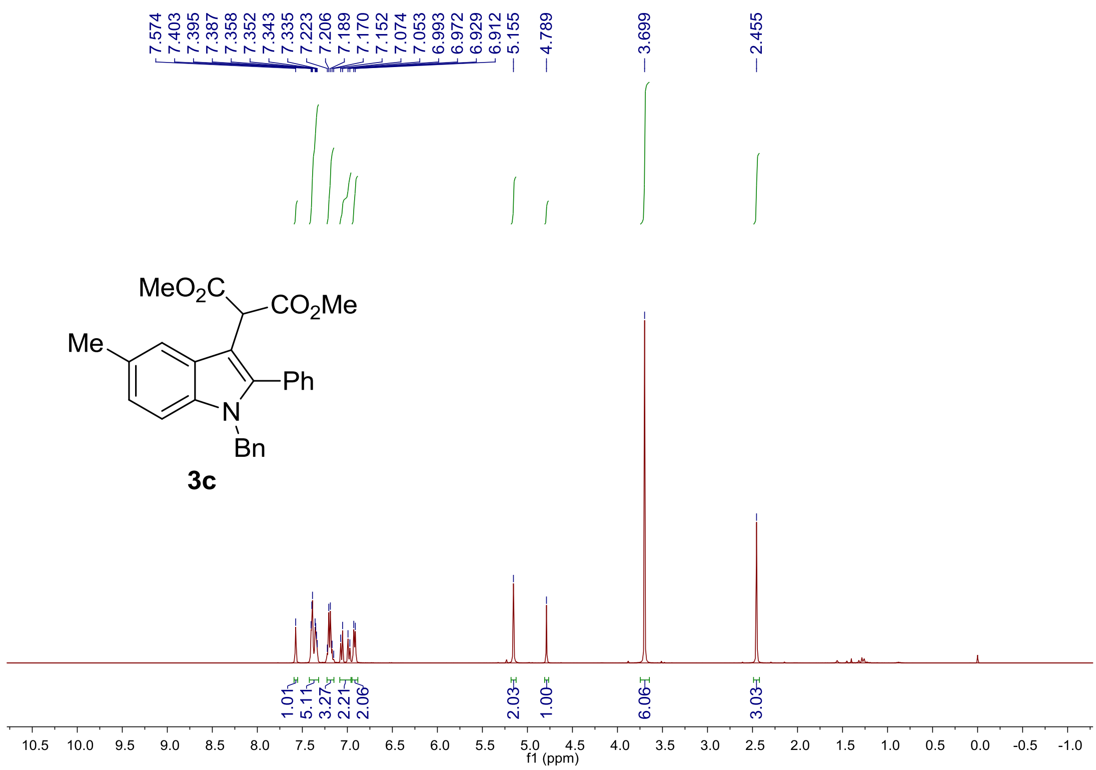
7.812
7.803
7.791
7.420
7.412
7.404
7.368
7.363
7.353
7.345
7.239
7.230
7.224
7.205
7.187
7.177
7.166
7.153
6.947
6.930
5.193
4.805
3.706
MeO2C
CO2Me
Ph
N
Bn
1.04
2.98
2.16
6.44
2.07
2.05
1.00
6.05
f1 (ppm)

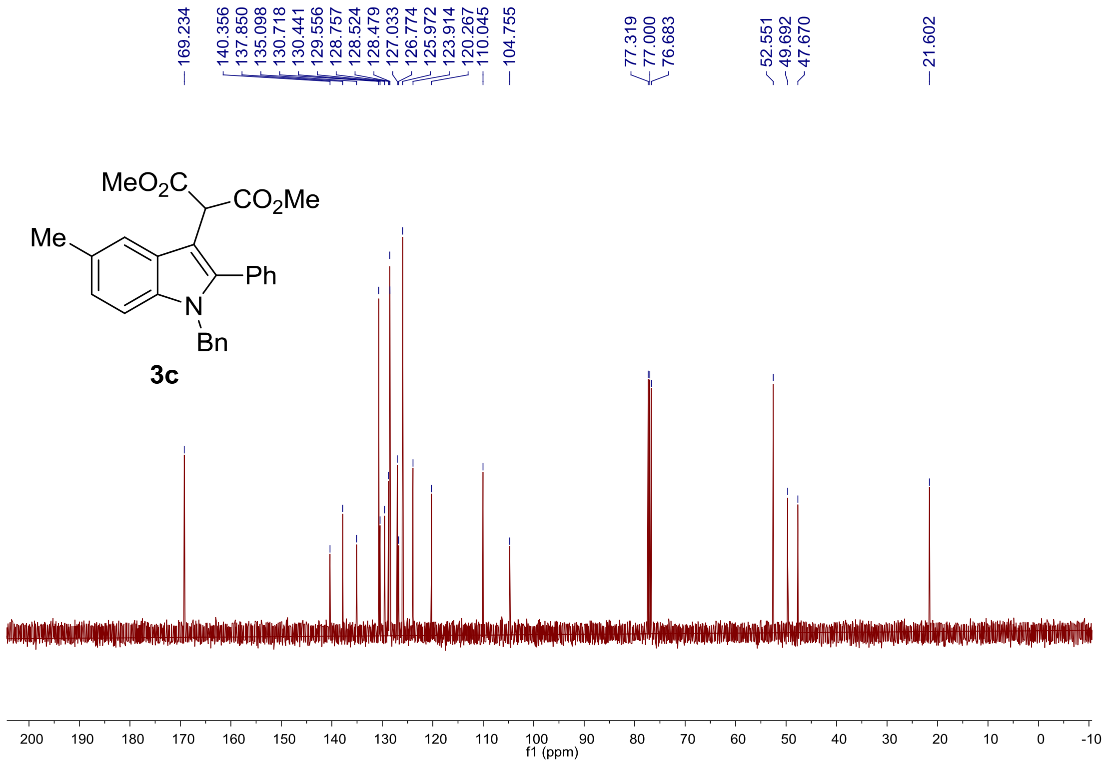
3b



3b



3c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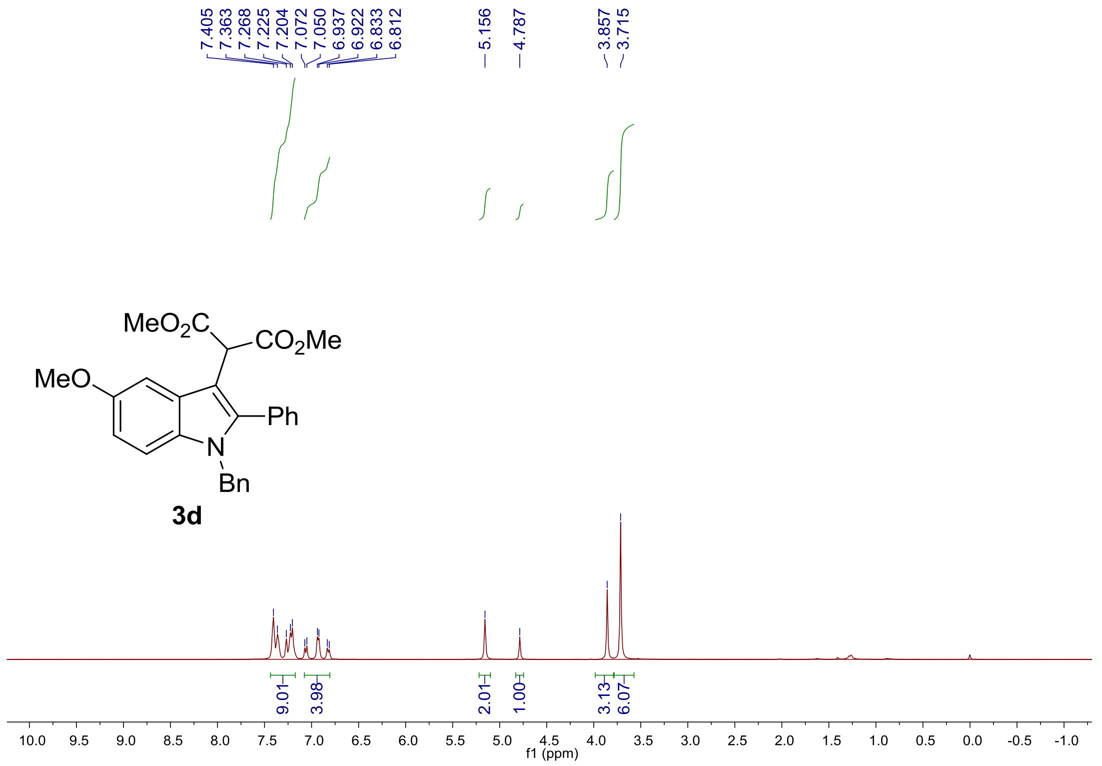
137.850
135.098
130.718
130.441
129.556
128.757
128.524
128.479
127.033
126.774
125.972
123.914
120.267
110.045
104.755
77.319
77.000
76.683
52.551
49.692
47.670
21.602
MeO2C
CO2Me
Me
Ph
N
Bn
f1 (ppm)

3c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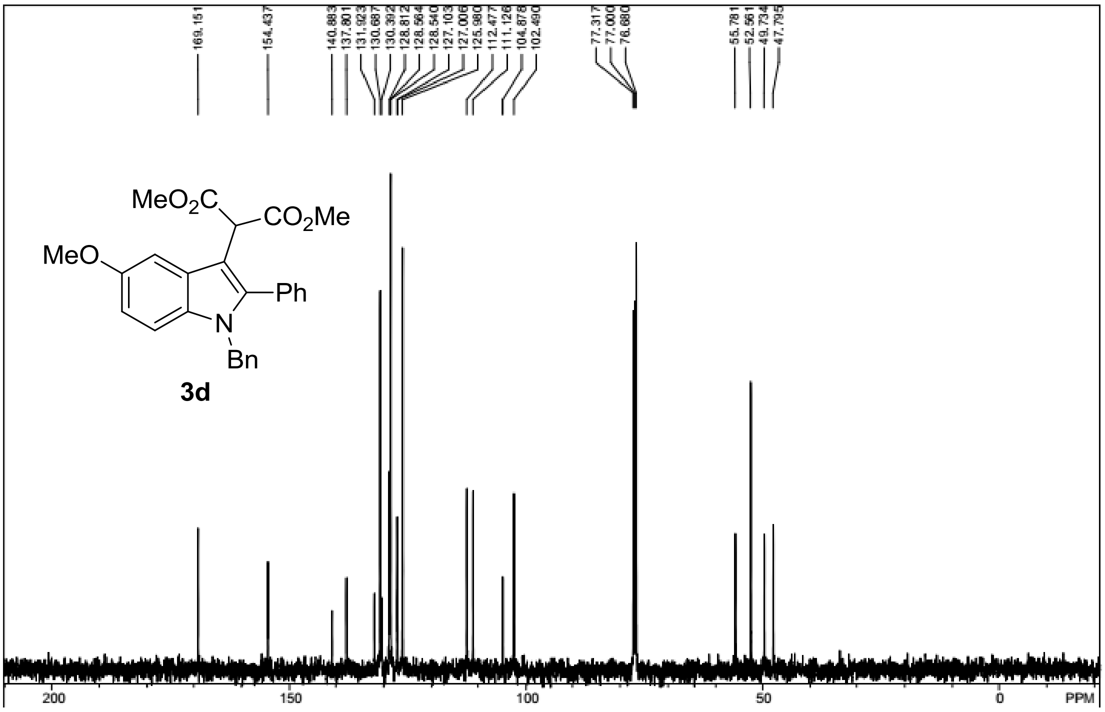
7.363
7.268
7.225
7.204
7.072
7.050
6.937
6.922
6.833
6.812
5.156
4.787
3.857
3.715
MeO2C
CO2Me
MeO
Ph
N
Bn
9.01
3.98
2.01
1.00
3.13
6.07
f1 (ppm)

3d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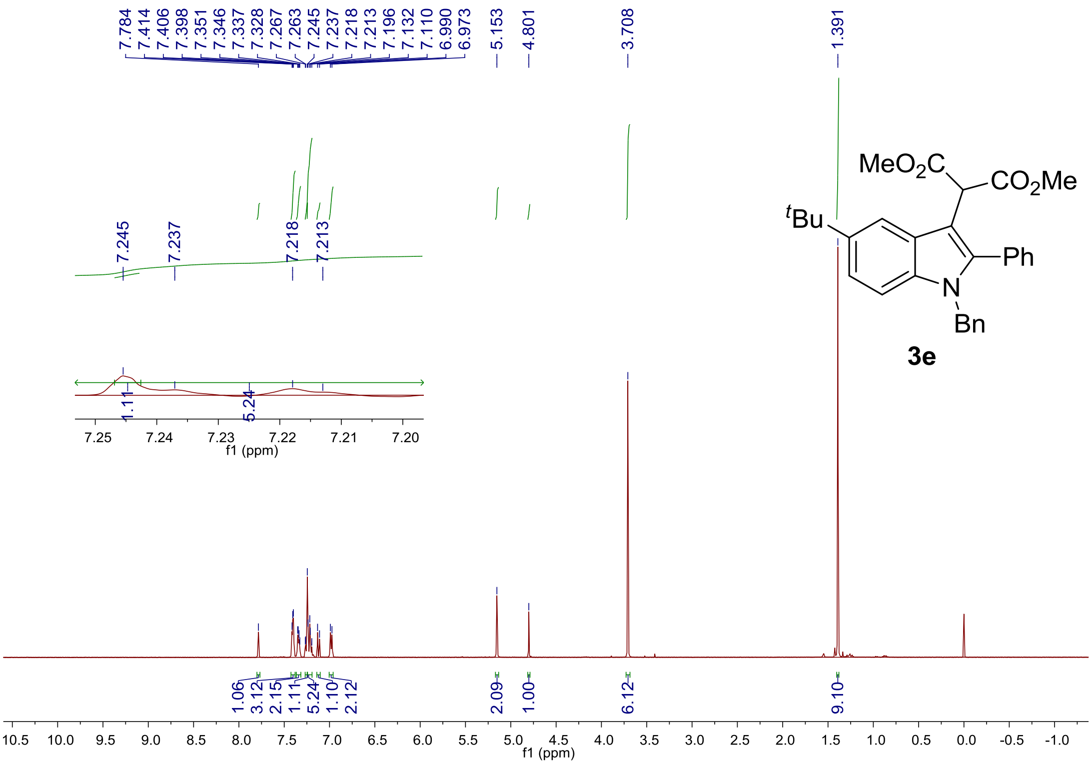
154.437
140.883
137.801
131.923
130.687
130.392
128.812
128.564
128.540
127.103
127.006
125.980
112.477
111.126
104.878
102.490
77.317
77.000
76.680
55.781
52.561
49.734
47.795
MeO2C
CO2Me
MeO
Ph
N
Bn
3d
200
150
100
50
0
PPM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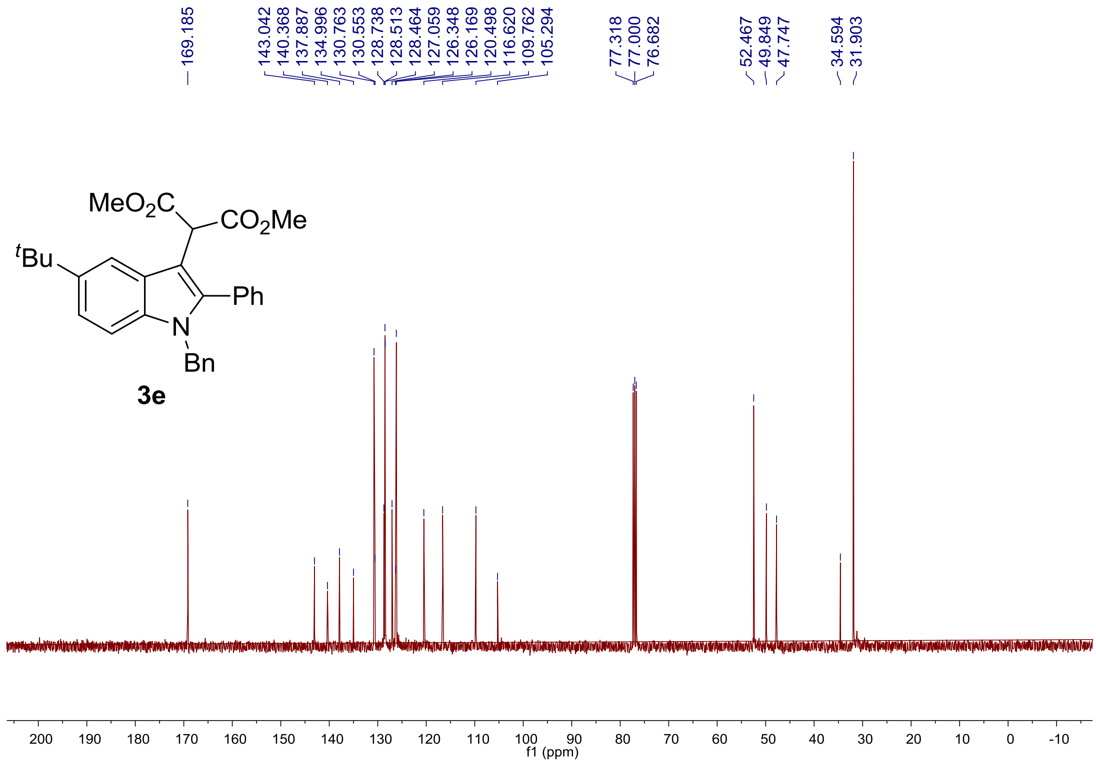
7.406
7.398
7.351
7.346
7.337
7.328
7.267
7.263
7.245
7.237
7.218
7.213
7.196
7.132
7.110
6.990
6.973
5.153
4.801
3.708
1.391
MeO2C
CO2Me
tBu
Ph
N
Bn
3e
1.11
5.24
7.25
7.24
7.23
7.22
7.21
7.20
f1 (ppm)
1.06
3.12
2.15
1.11
5.24
1.10
2.12
2.09
1.00
6.12
9.10
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)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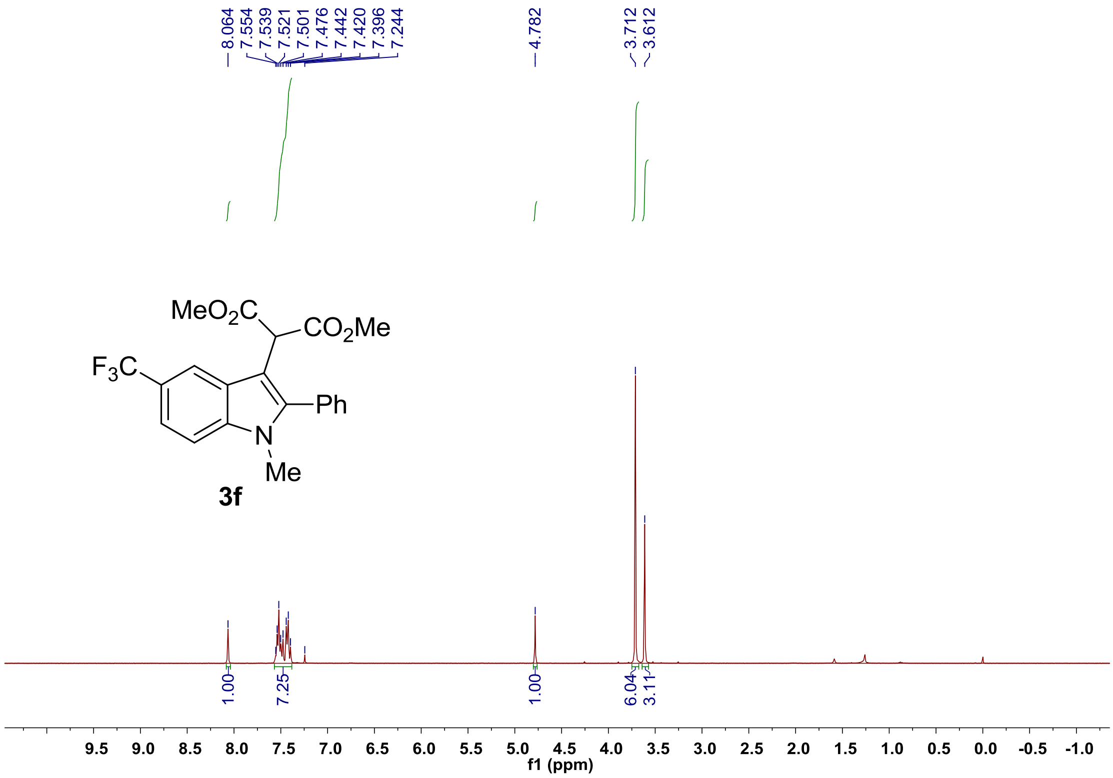
140.368
137.887
134.996
130.763
130.553
128.738
128.513
128.464
127.059
126.348
126.169
120.498
116.620
109.762
105.294
77.318
77.000
76.682
52.467
49.849
47.747
34.594
31.903
MeO2C
CO2Me
tBu
Ph
N
Bn
3e
f1 (ppm)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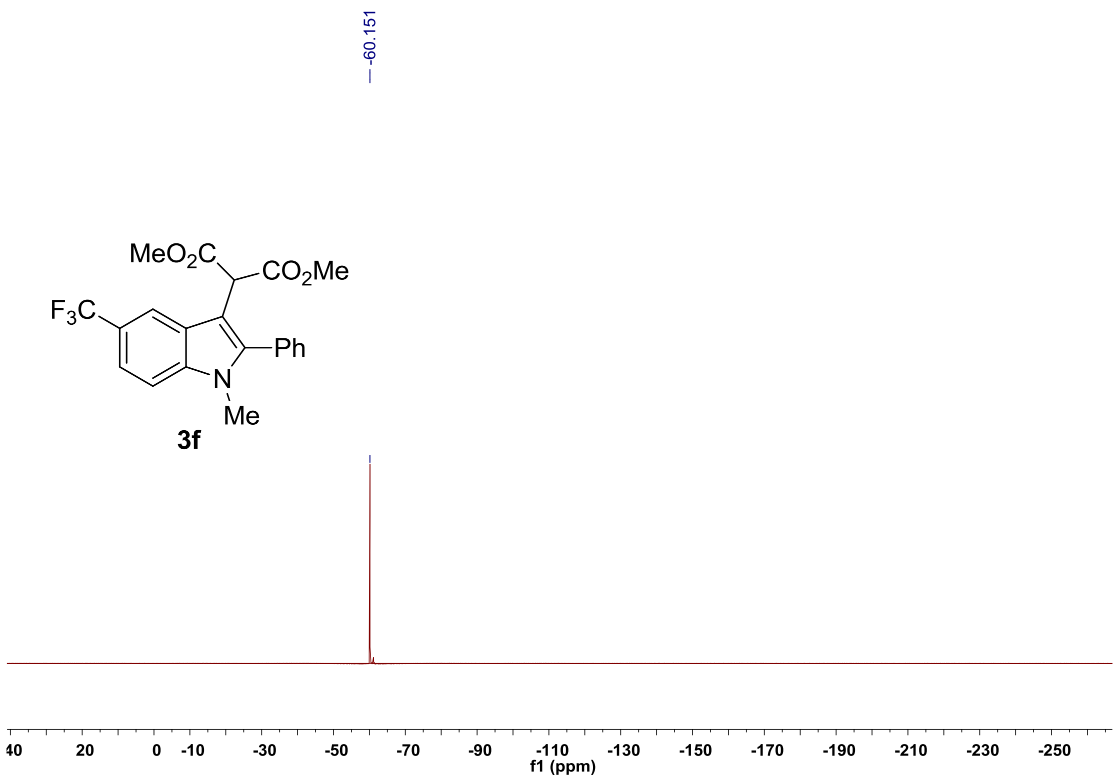
7.539
7.521
7.501
7.476
7.442
7.420
7.396
7.244
4.782
3.712
3.612
MeO2C
CO2Me
F3C
Ph
N
Me
3f
1.00
7.25
1.00
6.04
3.11
f1 (ppm)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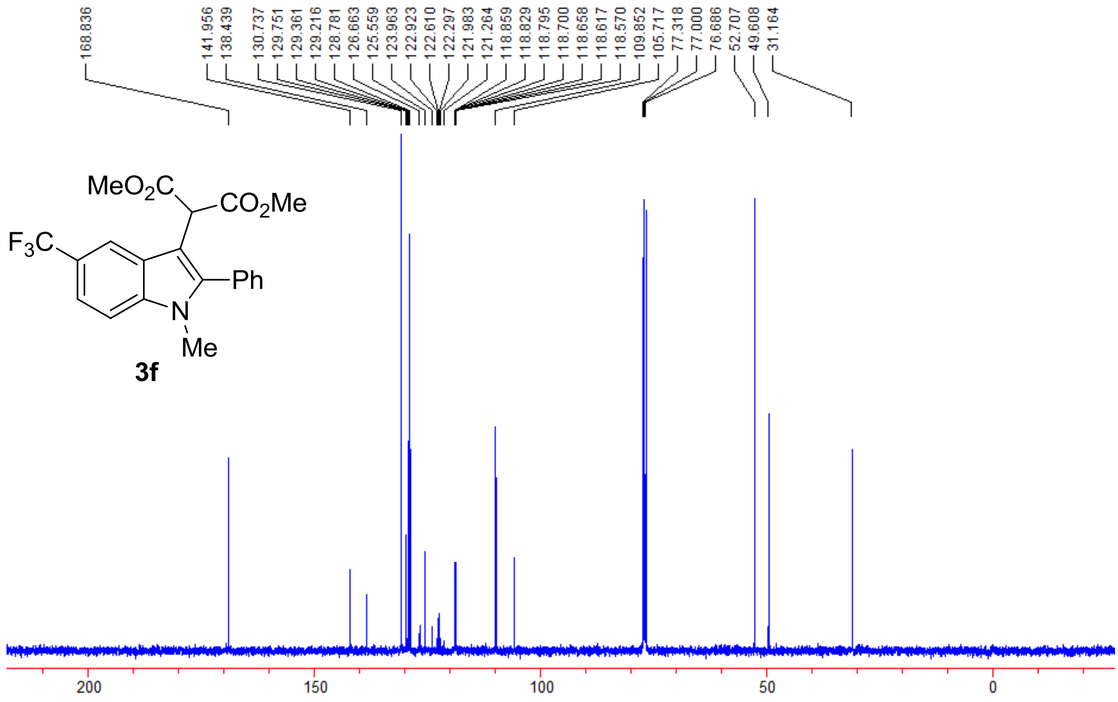
CO2Me
F3C
Ph
N
Me
3f
40
20
0
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
-230
-250
f1 (ppm)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129.216
128.781
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125.559
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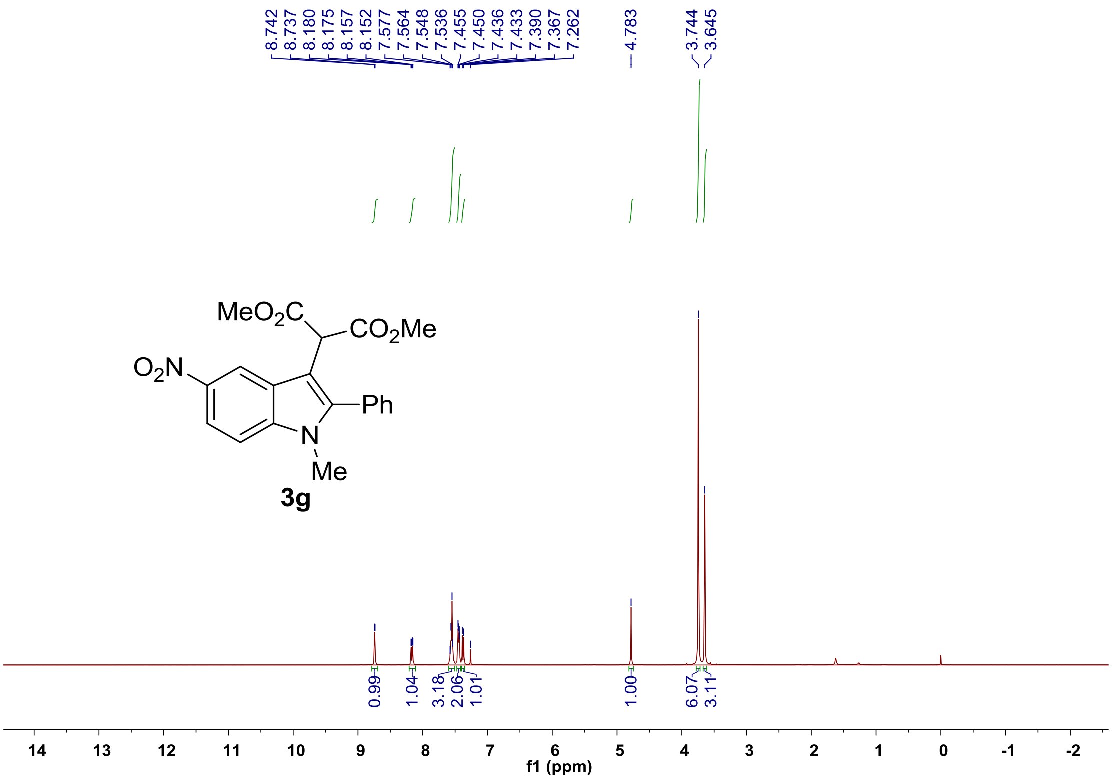
122.923
122.610
122.297
121.983
121.264
118.859
118.829
118.795
118.700
118.658
118.617
118.570
109.852
105.717
77.318
77.000
76.686
52.707
49.608
31.164
MeO2C
CO2Me
F3C
Ph
N
Me
3f
200
150
100
50
0



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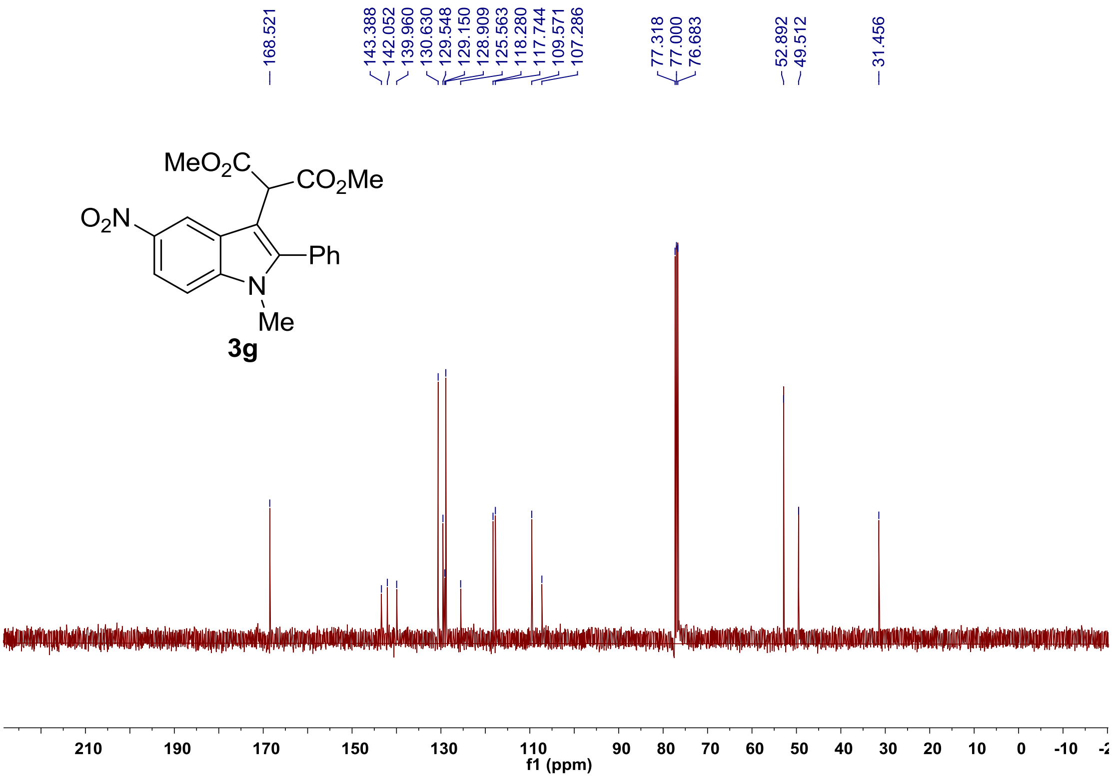
8.180
8.175
8.157
8.152
7.577
7.564
7.548
7.536
7.455
7.450
7.436
7.433
7.390
7.367
7.262
4.783
3.744
3.645
MeO2C
CO2Me
O2N
Ph
N
Me
3g
0.99
1.04
3.18
2.06
1.01
1.00
6.07
3.11
f1 (ppm)



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142.052
139.960
130.630
129.548
129.150
128.909
125.563
118.280
117.744
109.571
107.286
77.318
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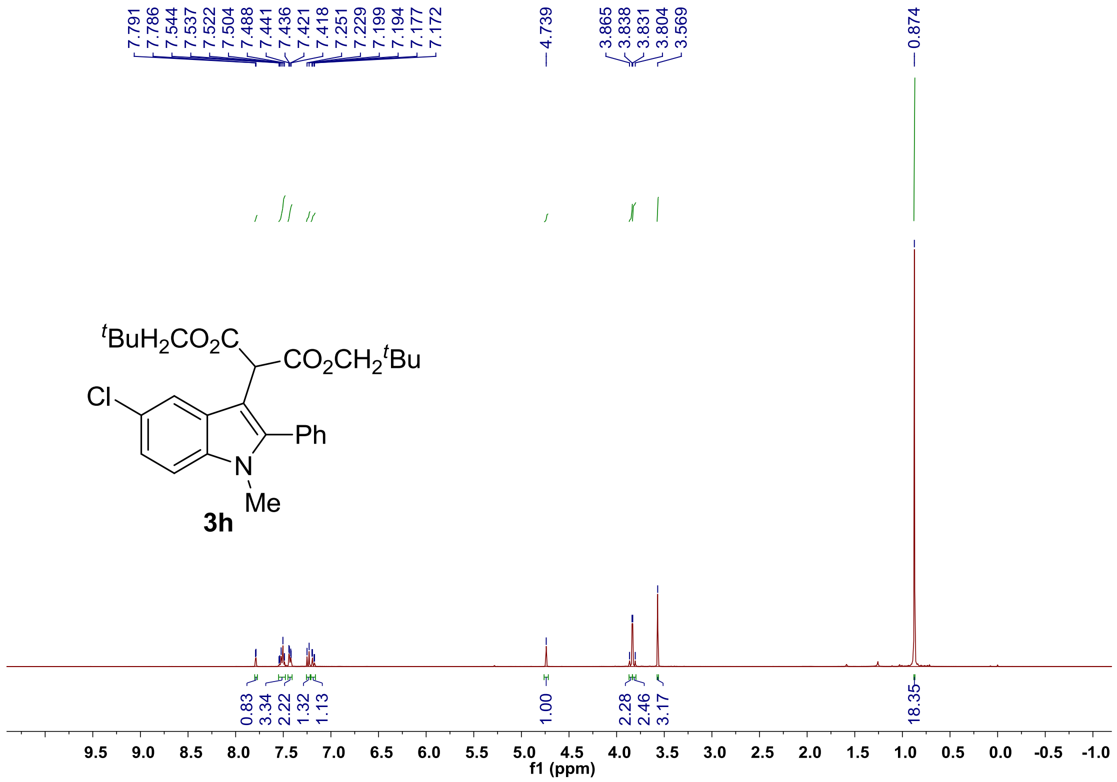
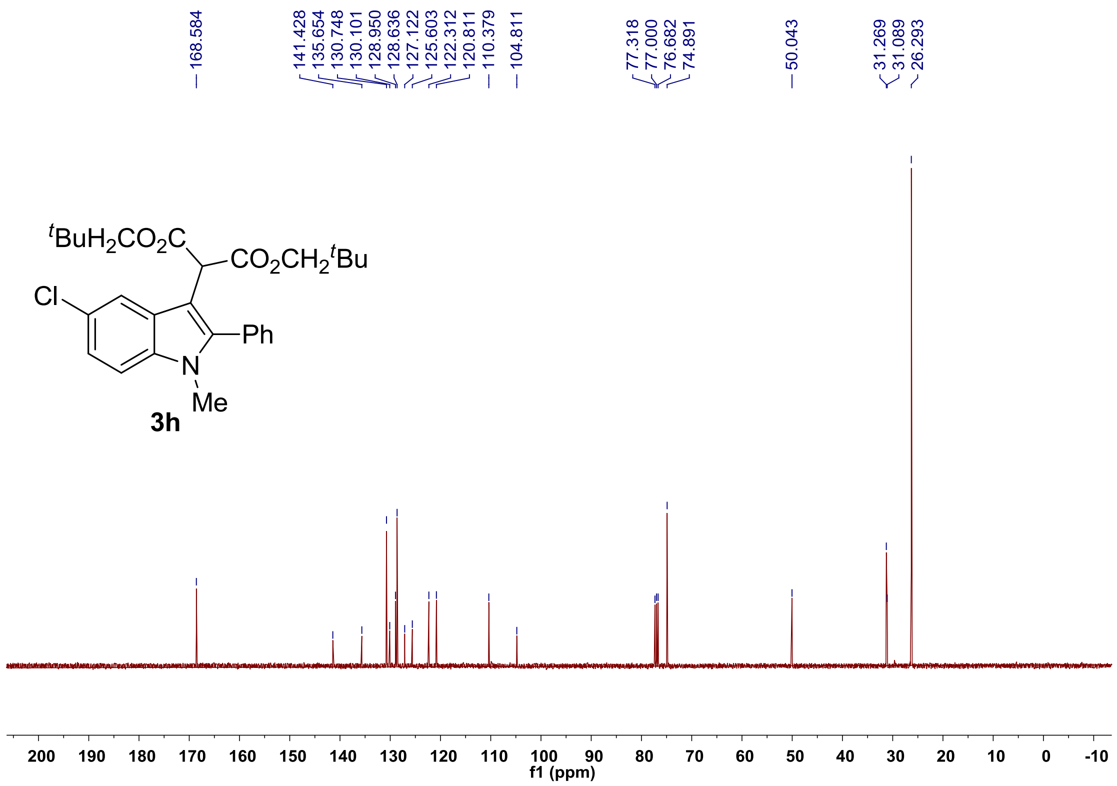
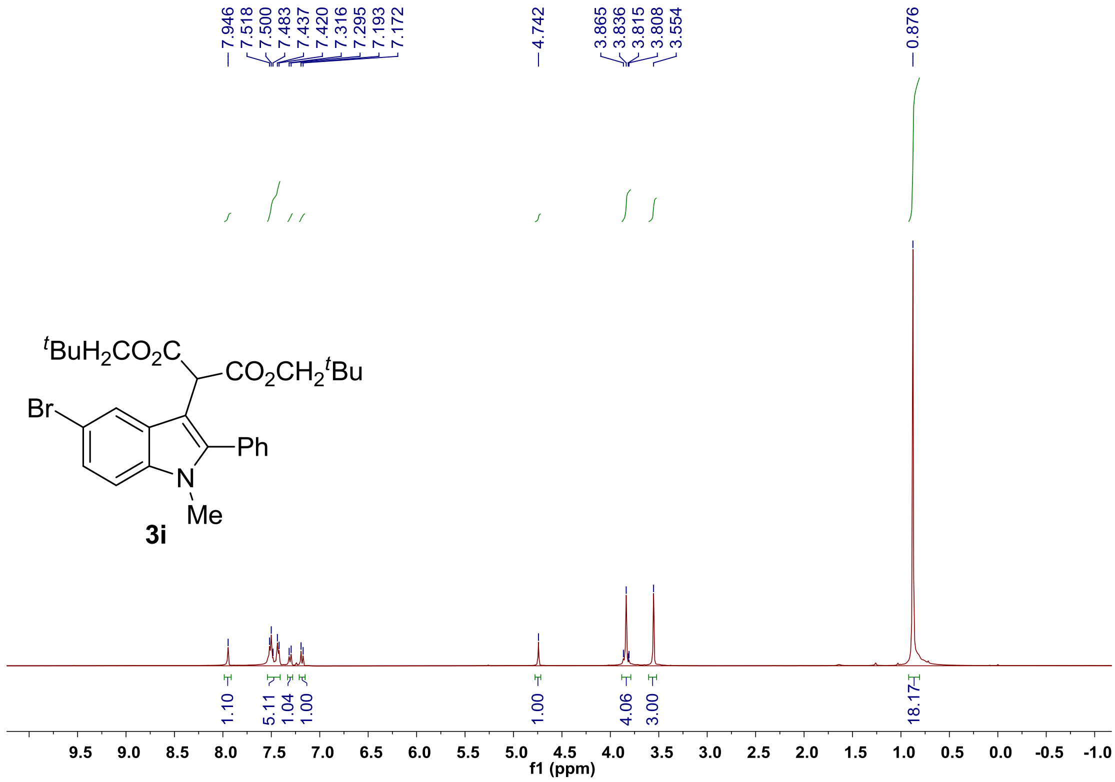
MeO2C
CO2Me
O2N
Ph
N
Me
3g
f1 (ppm)



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7.295
7.193
7.172
4.742
3.865
3.836
3.815
3.808
3.554
0.876
$^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
Br
Ph
N
Me
3i
1.10
5.11
1.04
1.00
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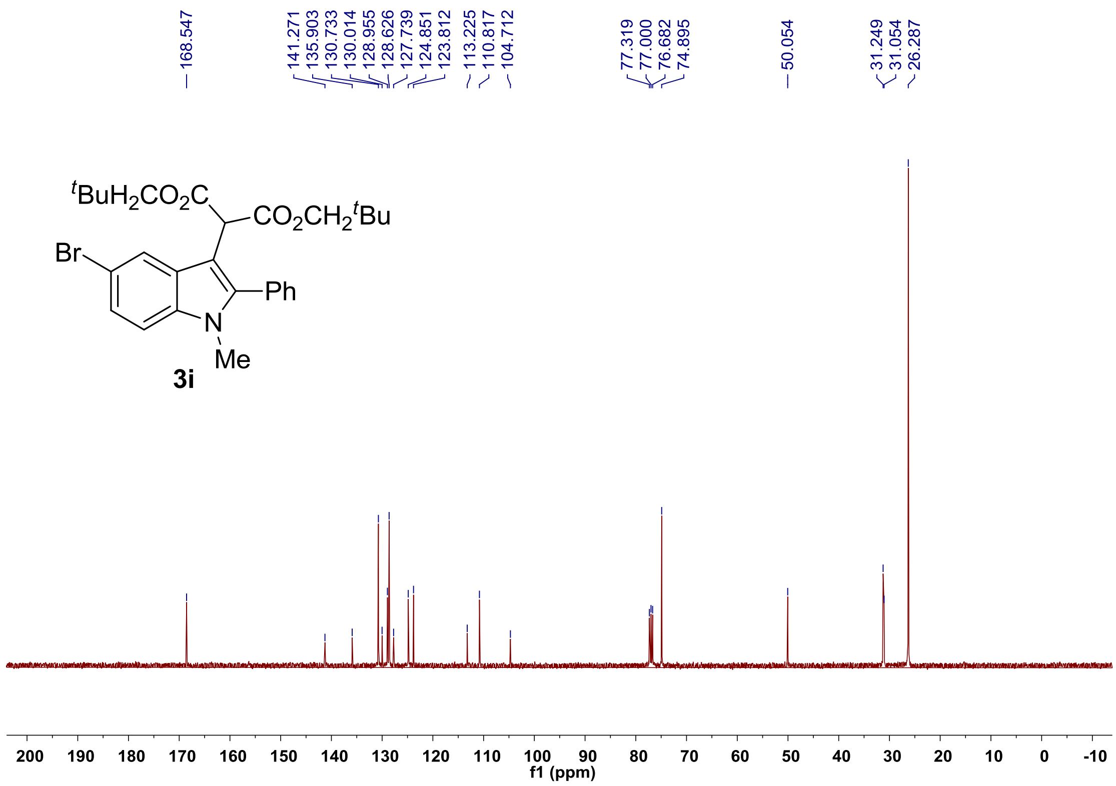
3.00
18.17
f1 (ppm)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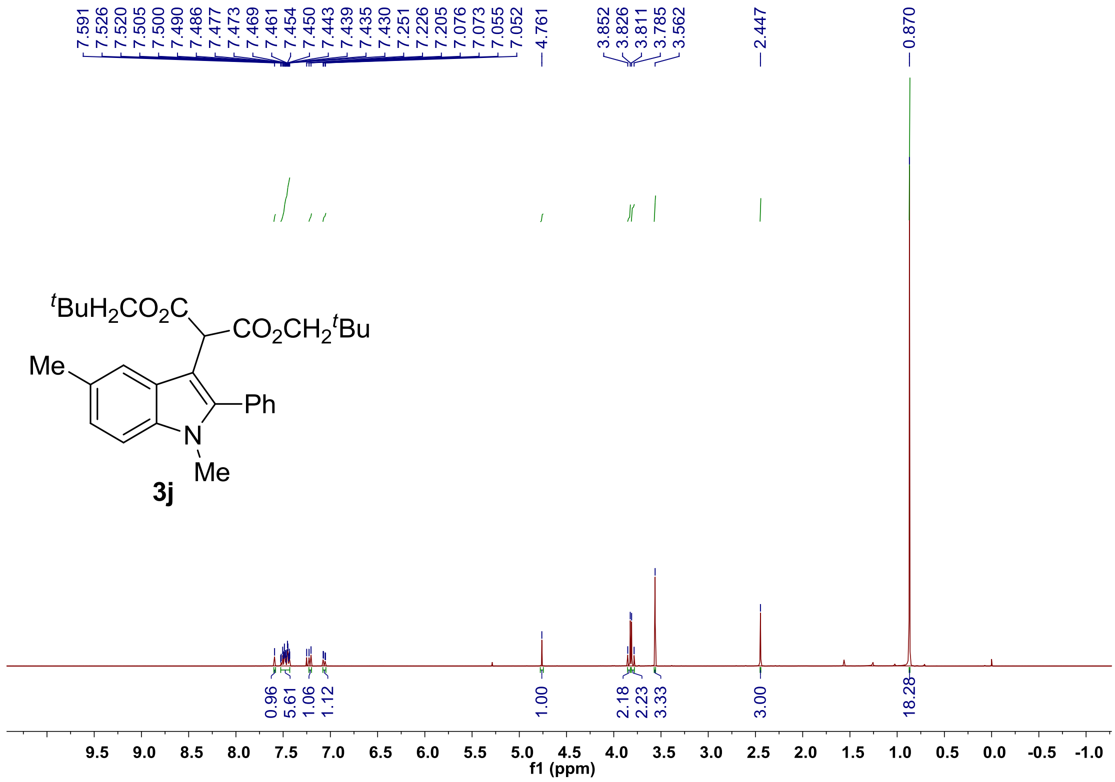
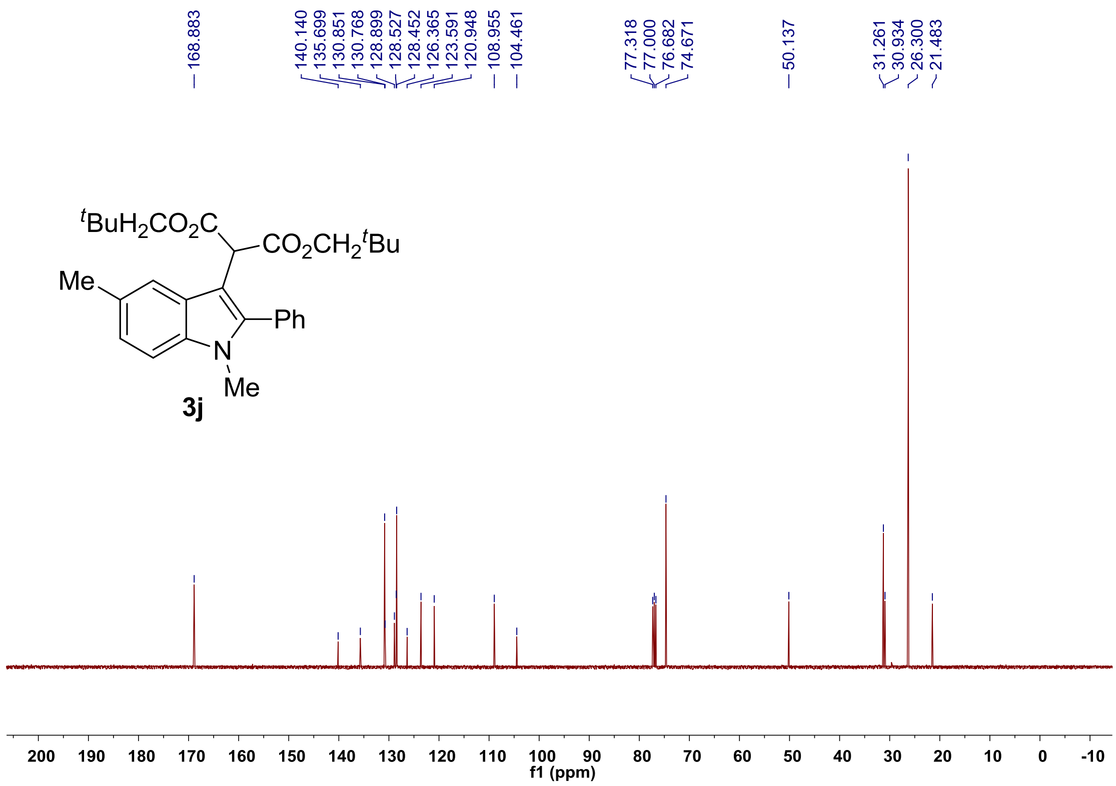
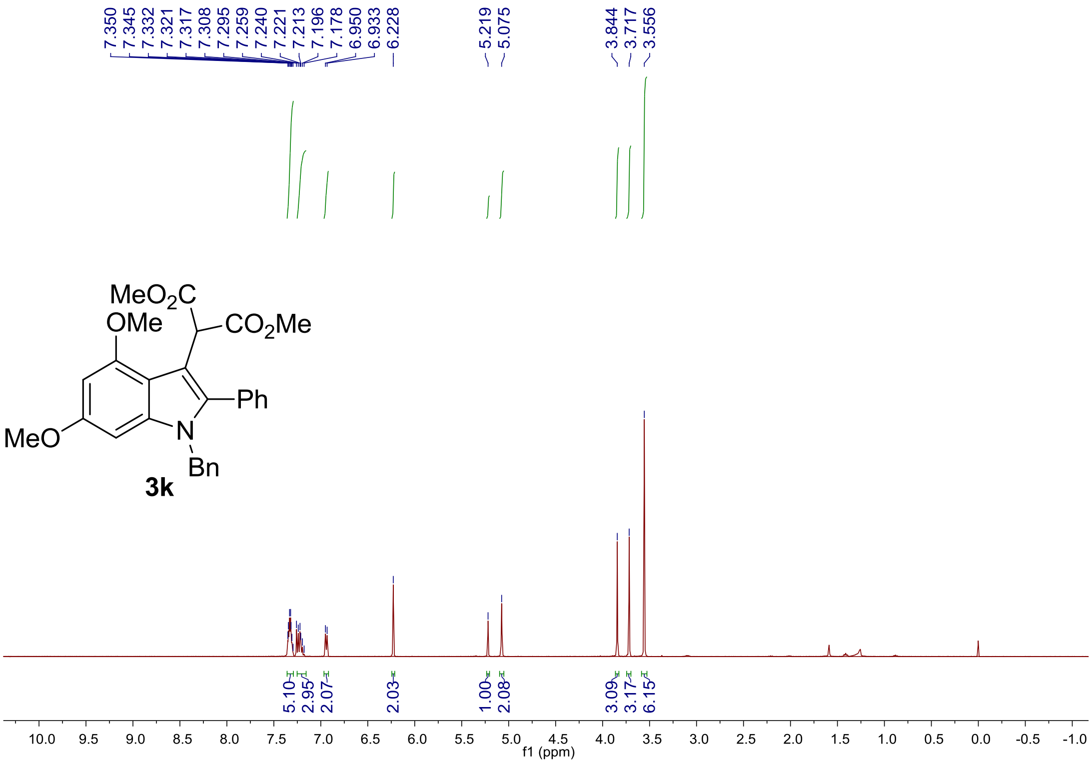
123.812
113.225
110.817
104.712
77.319
77.000
76.682
74.895
50.054
31.249
31.054
26.287
$^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
Br
Ph
N
Me
3i
f1 (ppm)



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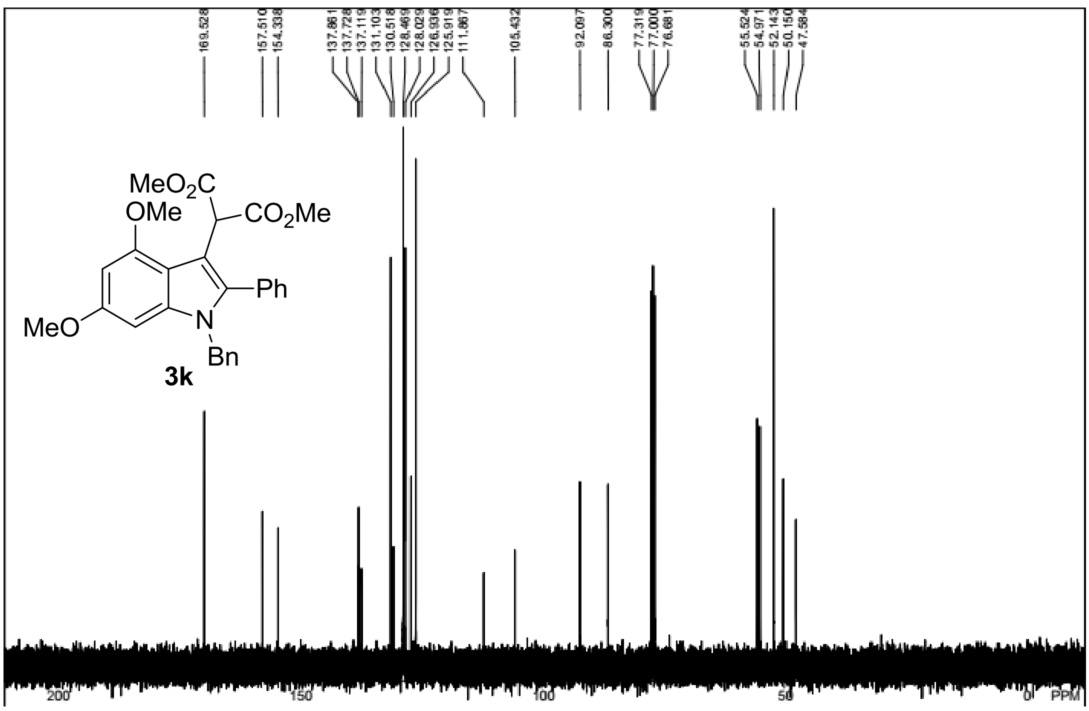
7.221
7.213
7.196
7.178
6.950
6.933
6.228
5.219
5.075
3.844
3.717
3.556
MeO2C
OMe
CO2Me
Ph
MeO
N
Bn
3k
5.10
2.95
2.07
2.03
1.00
2.08
3.09
3.17
6.15
f1 (ppm)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128.029
126.936
125.919
111.867
105.432
92.097
86.300
77.319
77.000
76.681
55.524
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50.150
47.584
MeO2C
OMe
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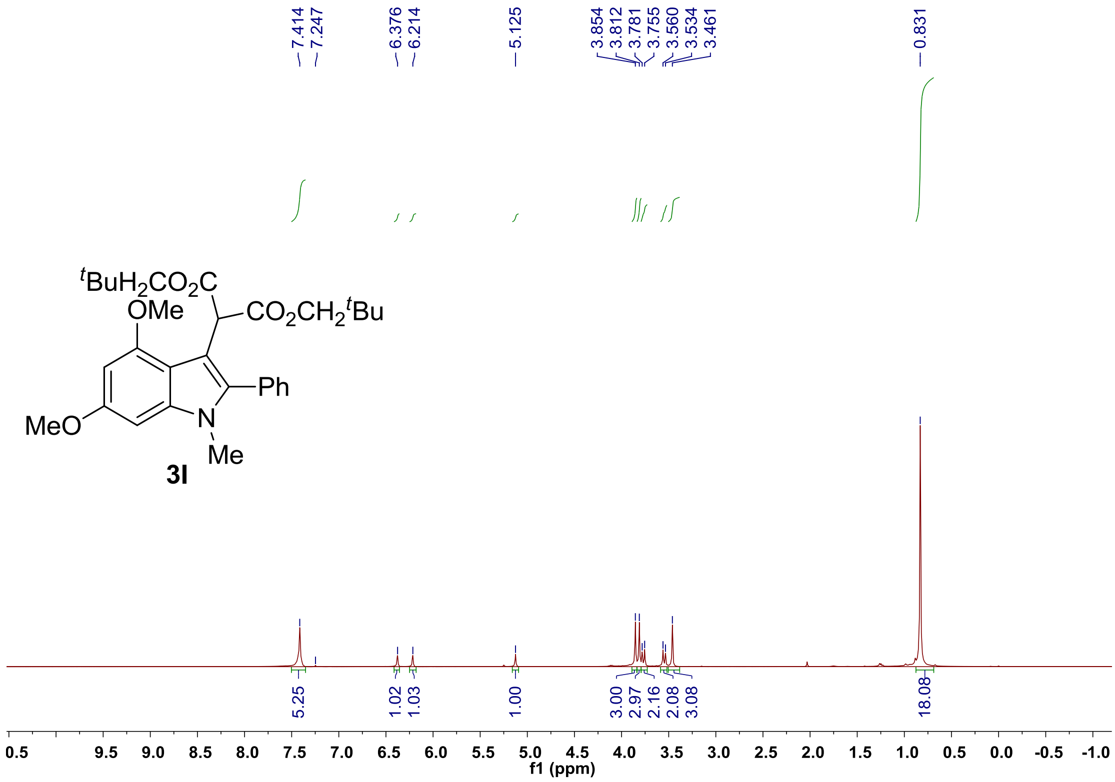
N
Bn
3k
PPM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3.854
3.812
3.781
3.755
3.560
3.534
3.461
0.831
^{t}BuH$_2$CO$_2$C
OMe
CO$_2$CH$_2$^{t}Bu
Ph
MeO
N
Me
3l
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1.03
1.00
3.00
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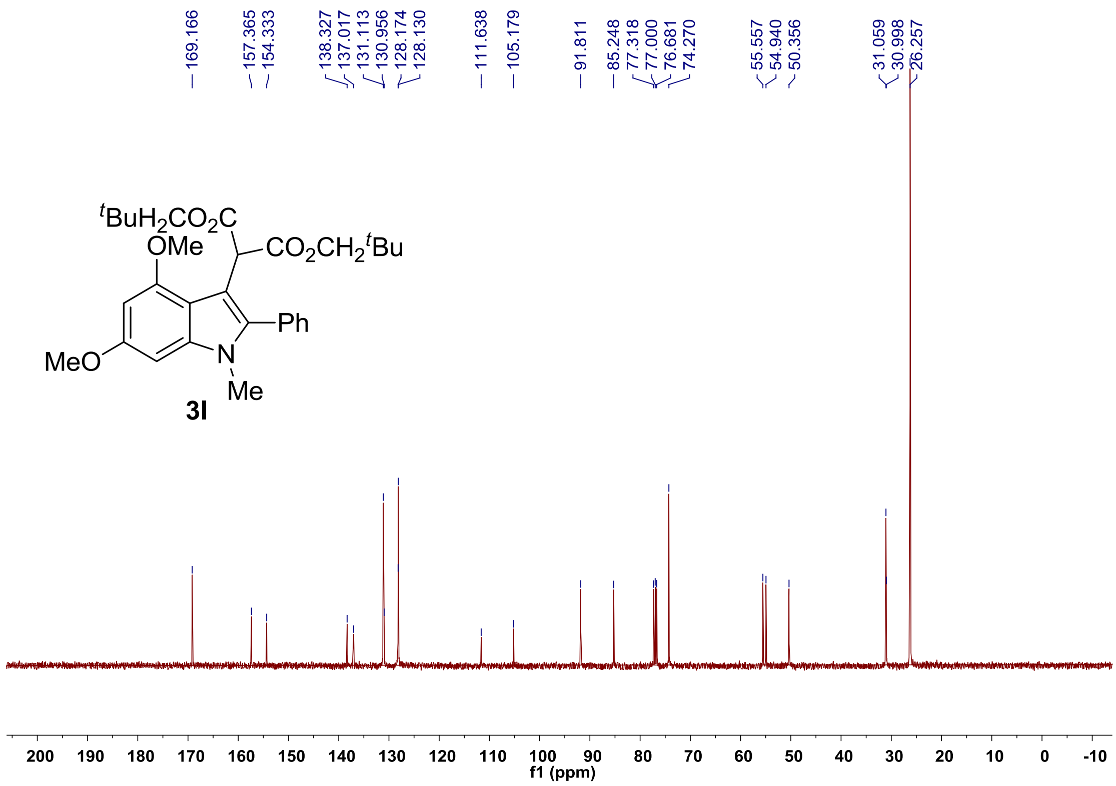
2.08
3.08
18.08
f1 (ppm)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111.638
105.179
91.811
85.248
77.318
77.000
76.681
74.270
55.557
54.940
50.356
31.059
30.998
26.257
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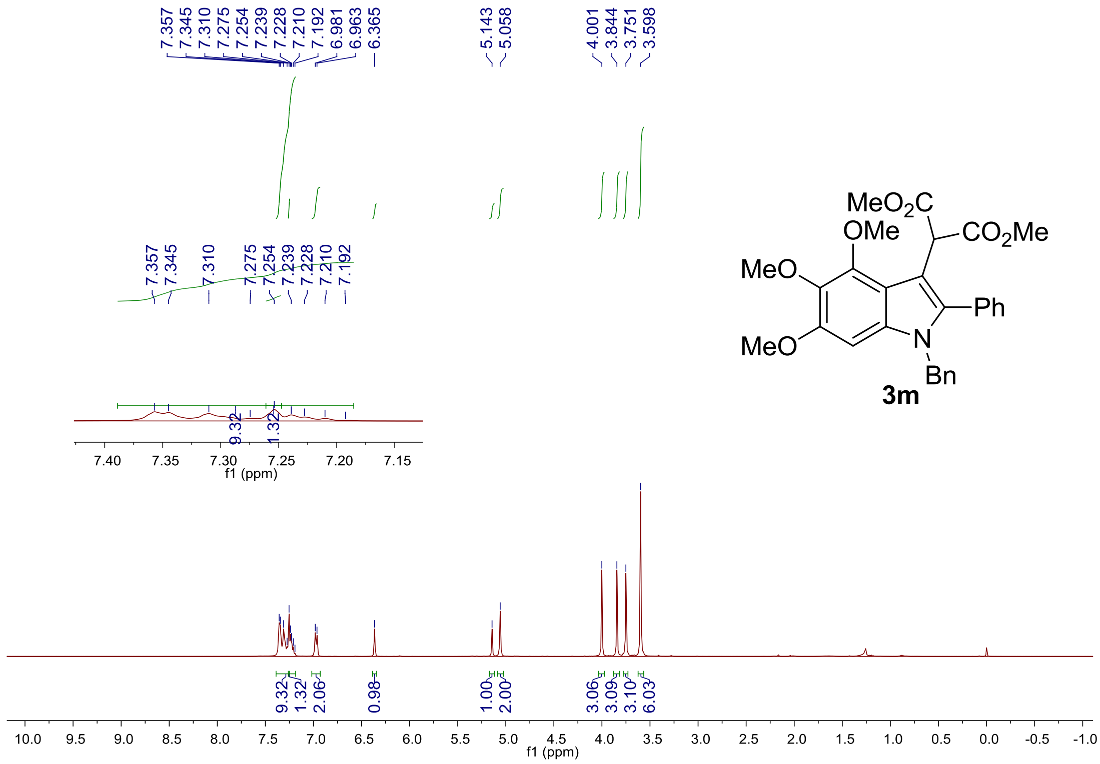
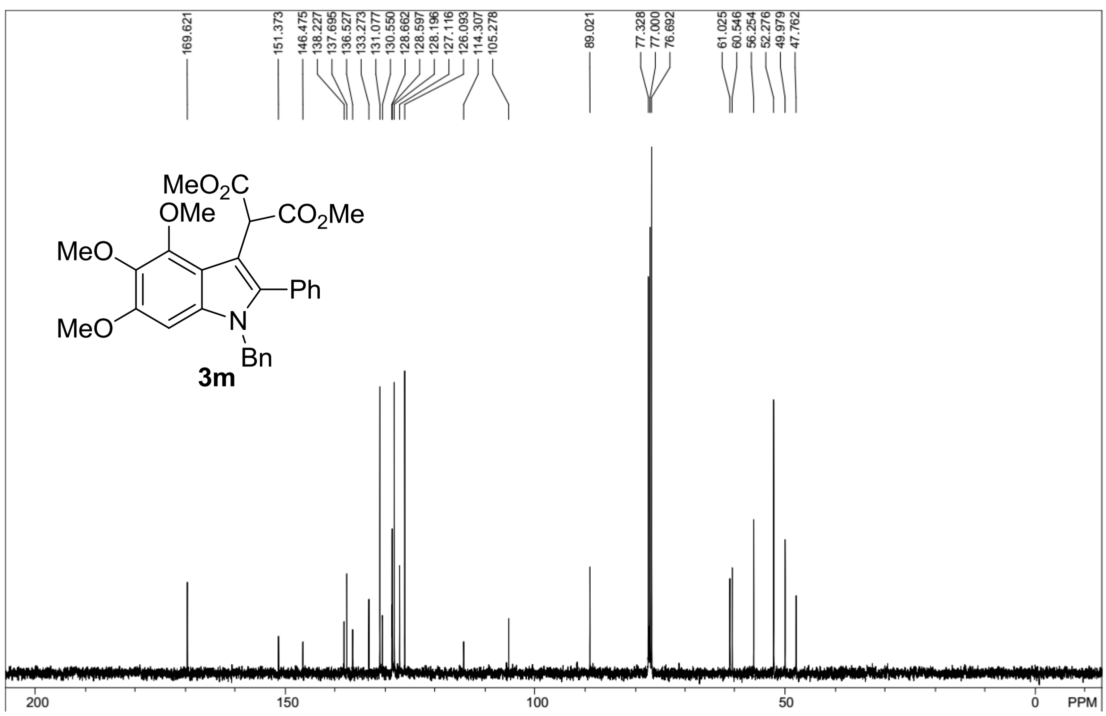
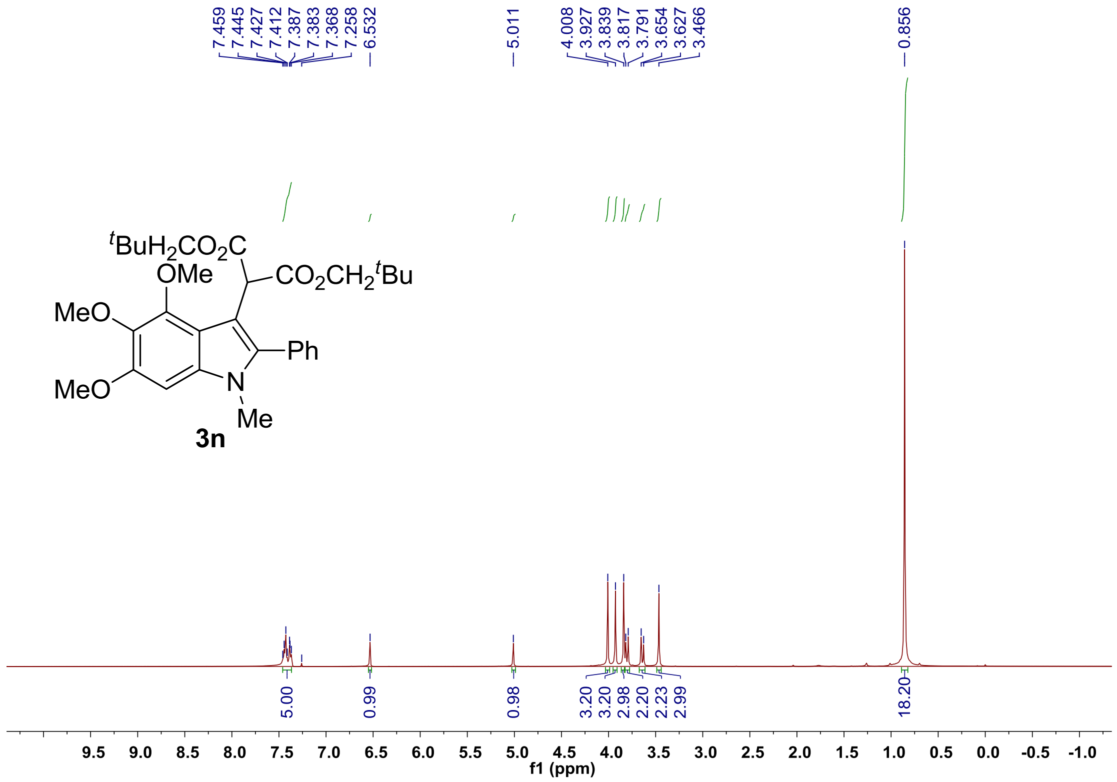
OMe
CO$_2$CH$_2$^{t}Bu
Ph
MeO
N
Me
3l
f1 (ppm)



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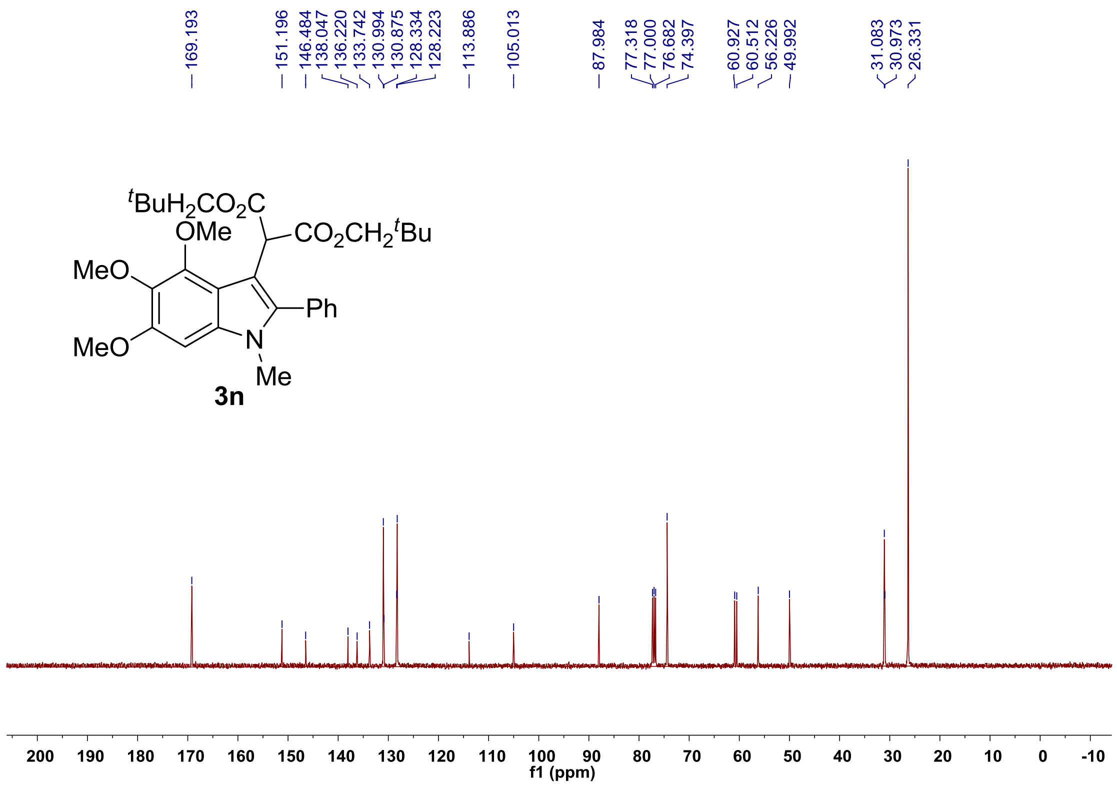
7.258
6.532
5.011
4.008
3.927
3.839
3.817
3.791
3.654
3.627
3.466
0.856
^{t}BuH$_2$CO$_2$C
OMe
CO$_2$CH$_2$^{t}Bu
MeO
MeO
Ph
N
Me
3n
5.00
0.99
0.98
3.20
3.20
2.98
2.20
2.23
2.99
18.20
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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130.875
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128.223
113.886
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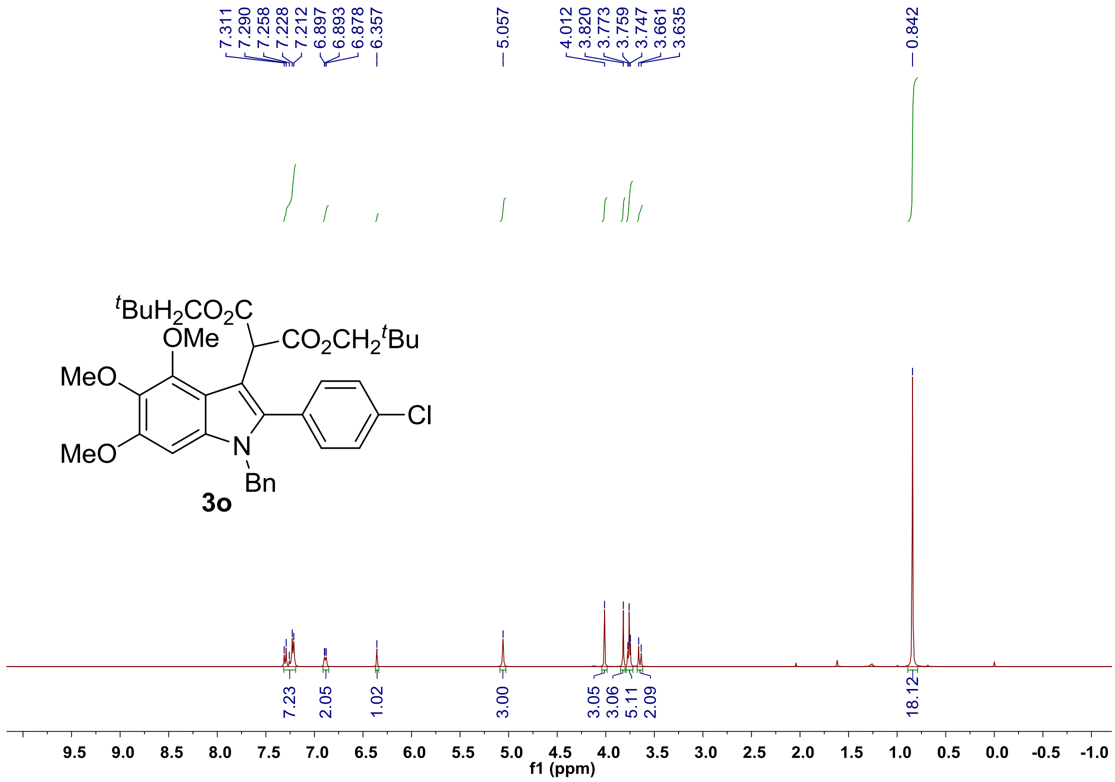
87.984
77.318
77.000
76.682
74.397
60.927
60.512
56.226
49.992
31.083
30.973
26.331
^{t}BuH$_2$CO$_2$C
OMe
CO$_2$CH$_2$^{t}Bu
MeO
MeO
Ph
N
Me
3n
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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3.773
3.759
3.747
3.661
3.635
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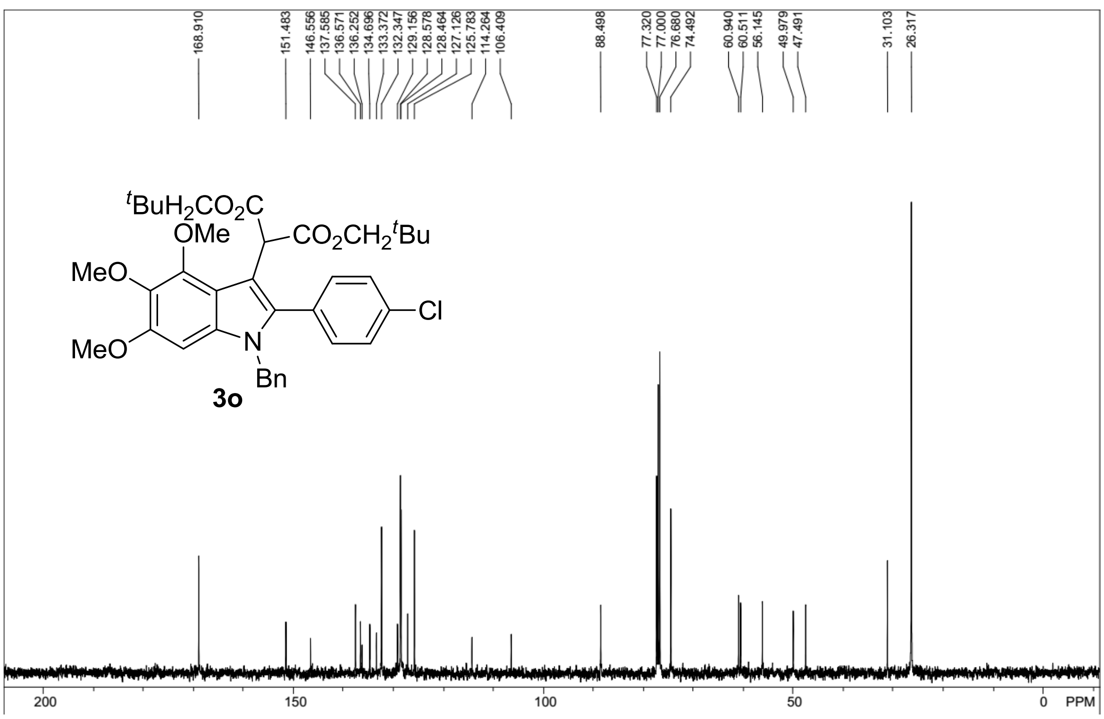
3.06
5.11
2.09
18.12
f1 (ppm)
3o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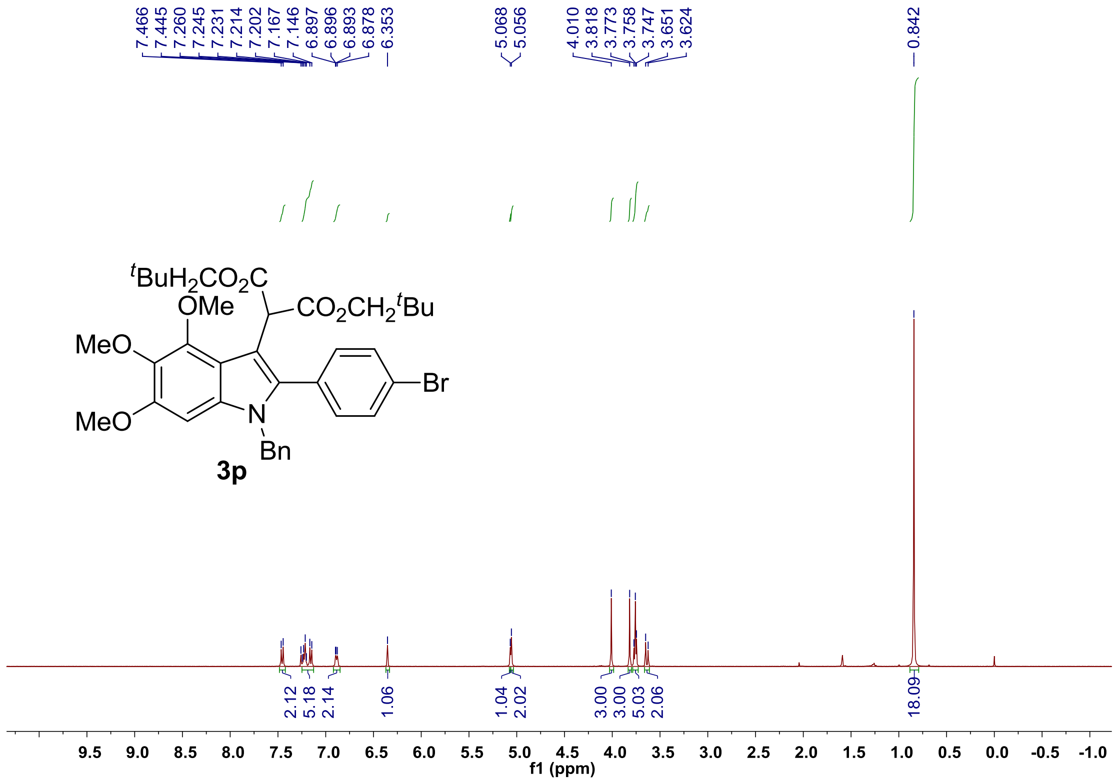
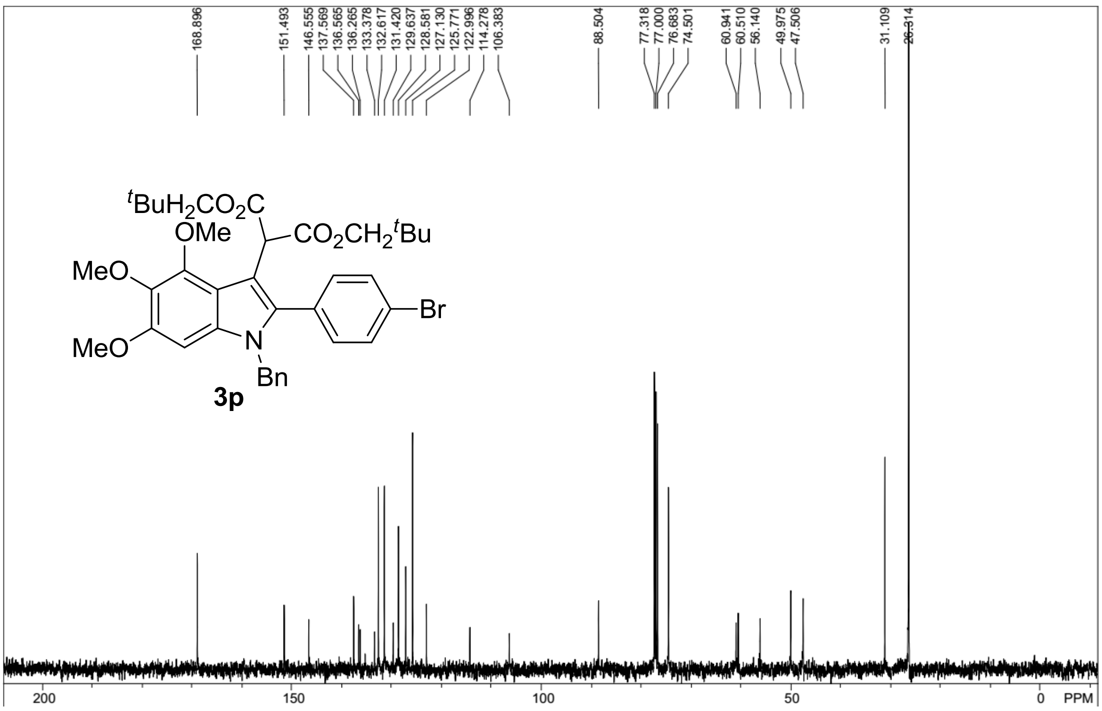
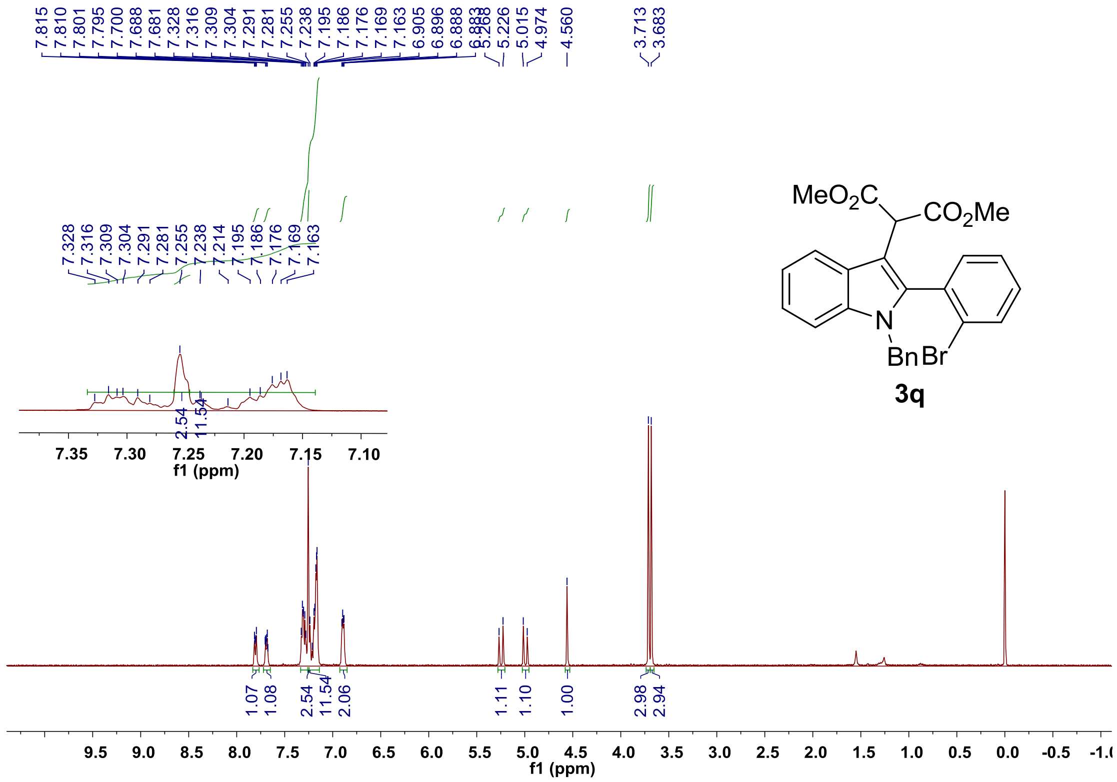
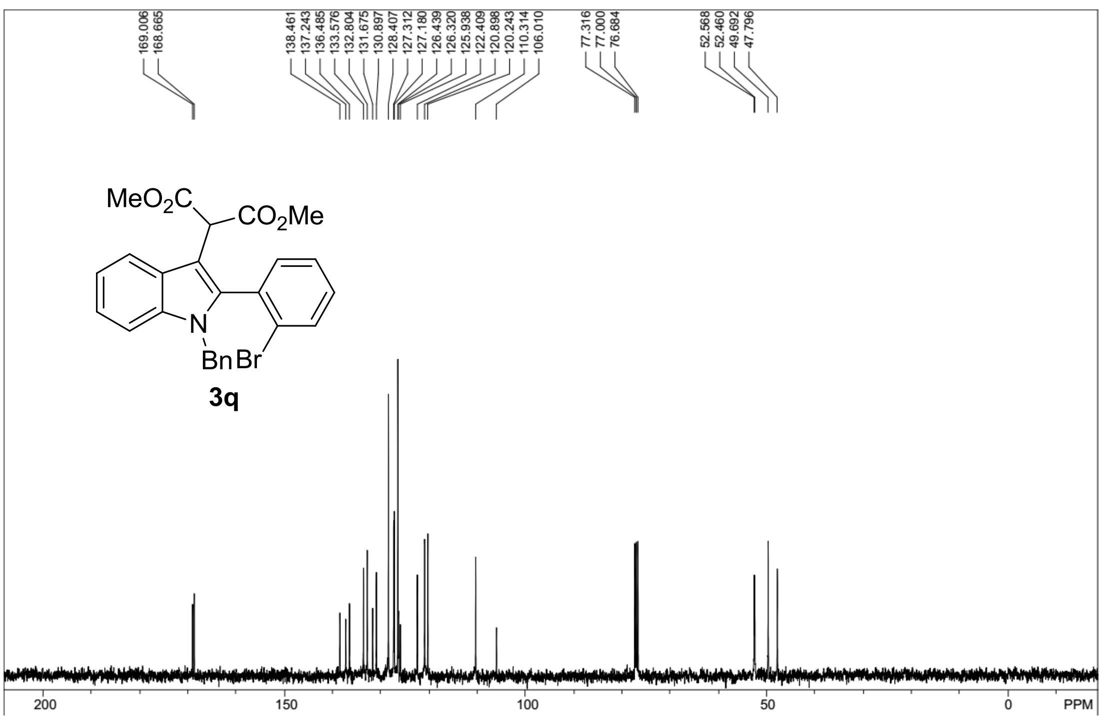
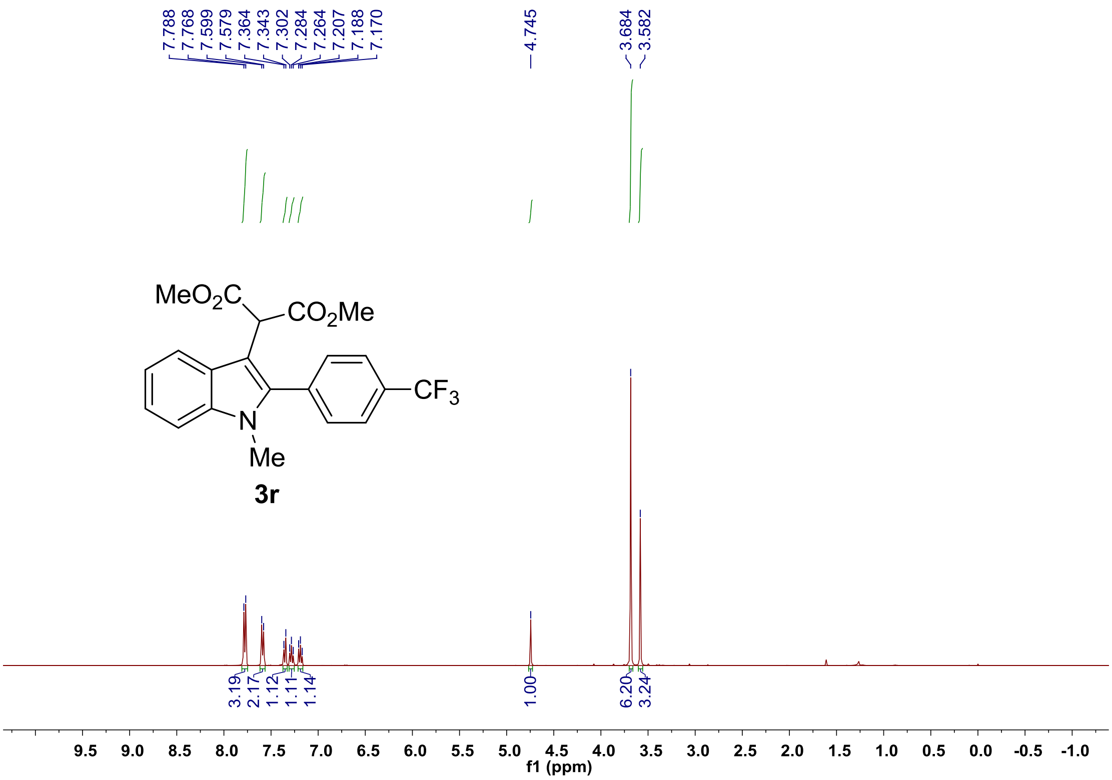
125.783
114.264
106.409
88.498
77.320
77.000
76.680
74.492
60.940
60.511
56.145
49.979
47.491
31.103
26.317
PPM
3o











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7.768
7.599
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7.343
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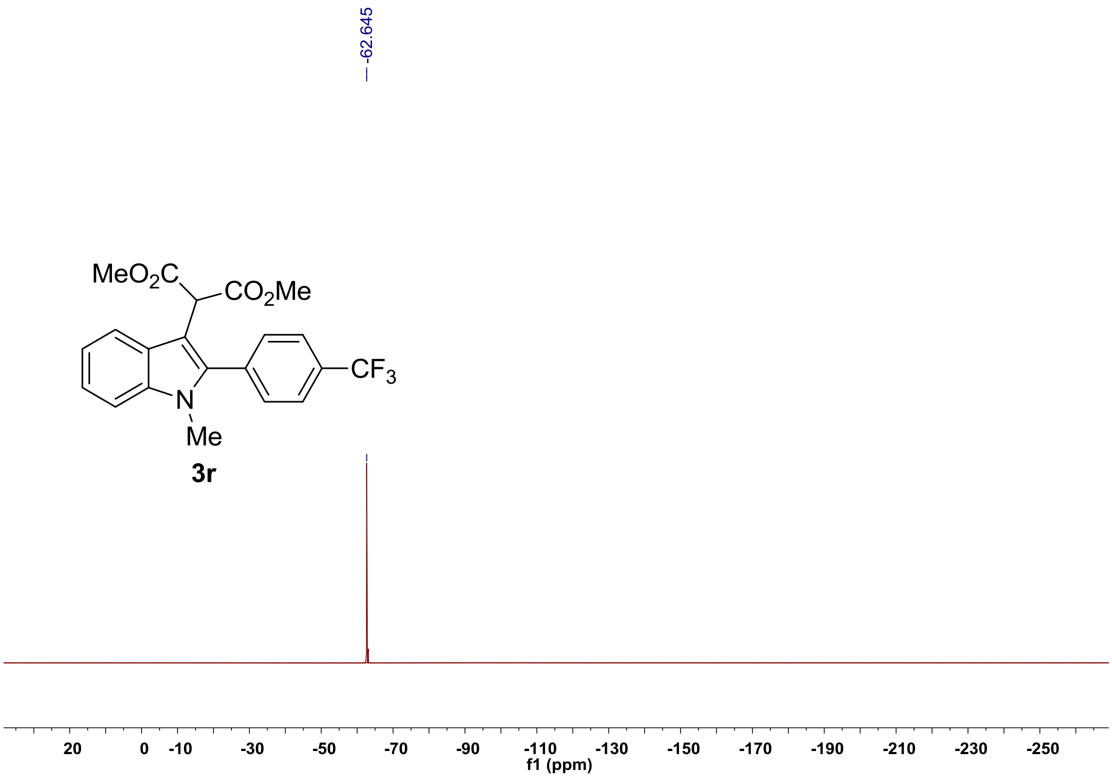
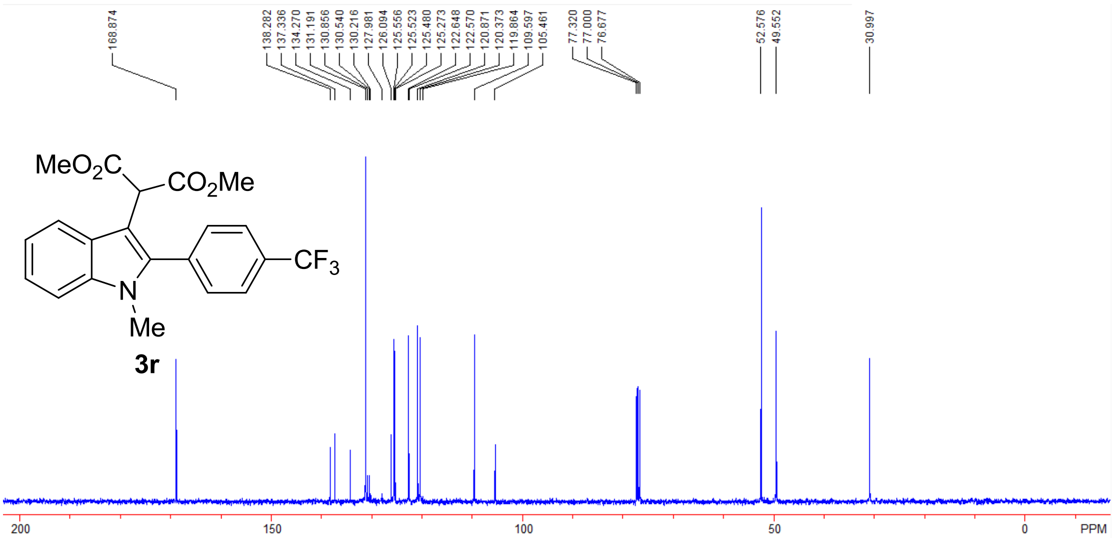
7.284
7.264
7.207
7.188
7.170
4.745
3.684
3.582
MeO2C
CO2Me
CF3
N
Me
3r
3.19
2.17
1.12
1.11
1.14
1.00
6.20
3.24
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)



-62.645
MeO2C
CO2Me
CF3
N
Me
3r
20 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230 -250
f1 (ppm)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CO2Me
CF3
N
Me
3r
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137.336
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131.191
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130.216
127.981
126.094
125.556
125.523
125.480
125.273
122.648
122.570
120.871
120.373
119.864
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77.000
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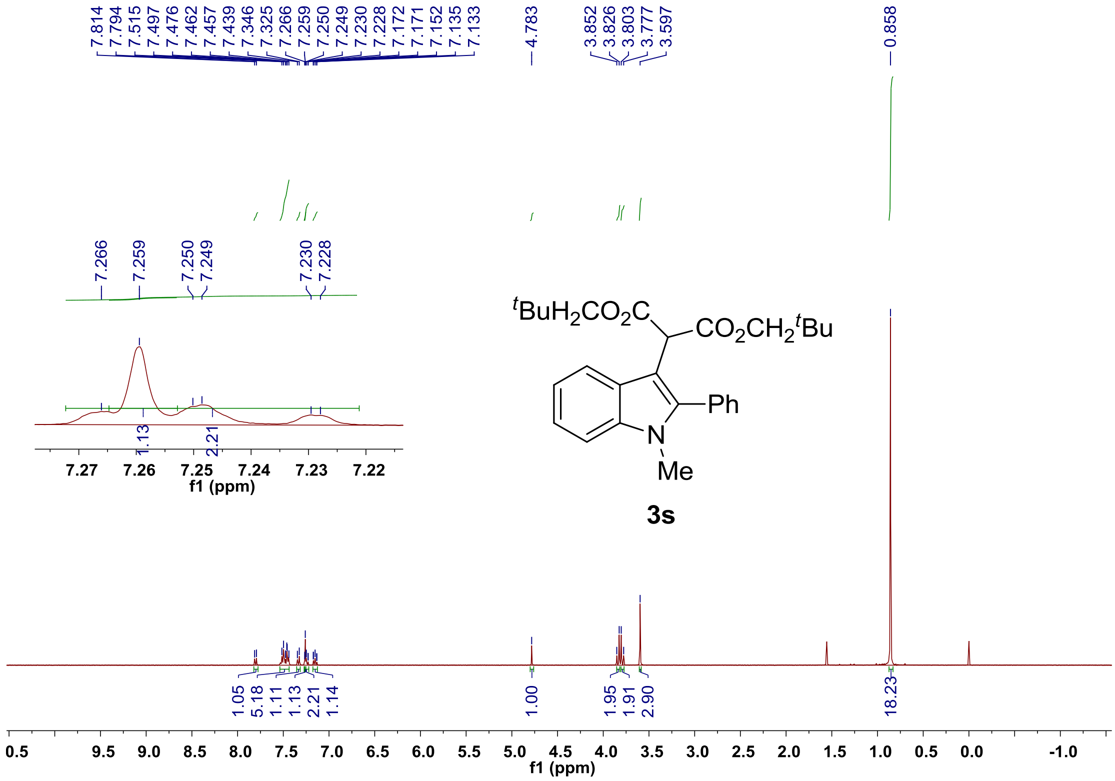
49.552
30.997
200
150
100
50
0
PPM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7.439
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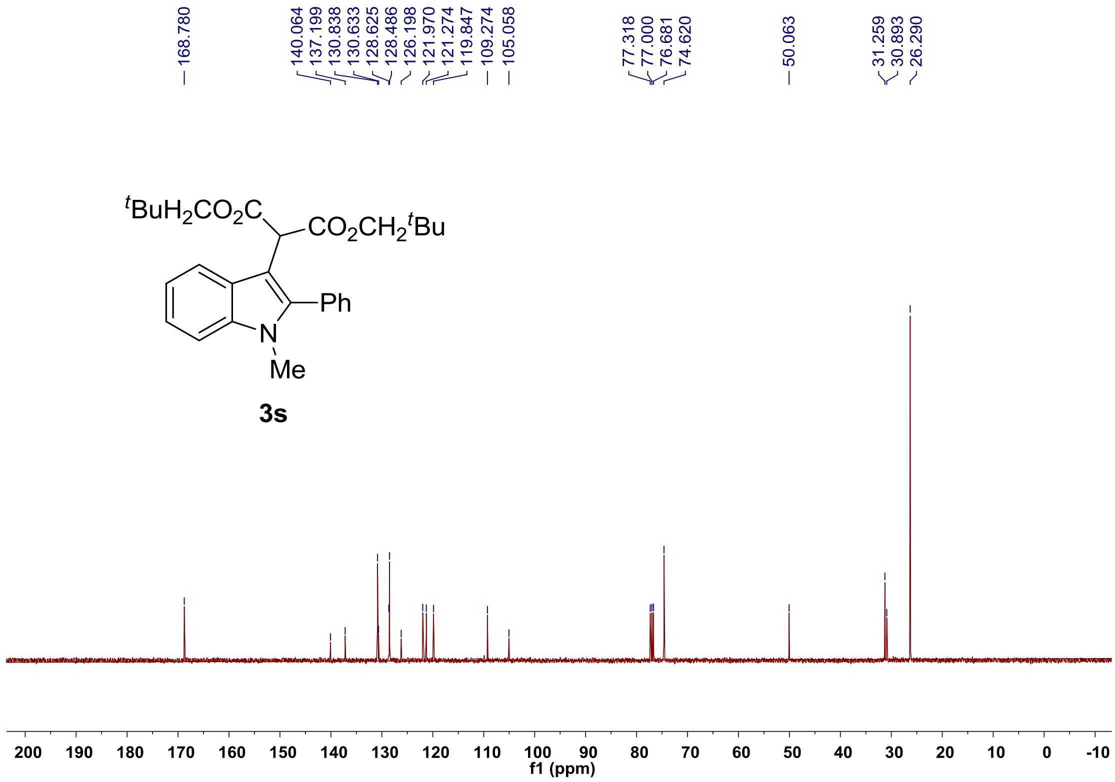
7.325
7.266
7.259
7.250
7.249
7.230
7.228
7.172
7.171
7.152
7.135
7.133
4.783
3.852
3.826
3.803
3.777
3.597
0.858
tBuH2CO2C
CO2CH2tBu
Ph
N
Me
3s
1.13
2.21
7.27
7.26
7.25
7.24
7.23
7.22
f1 (ppm)
1.05
5.18
1.11
1.13
2.21
1.14
1.00
1.95
1.91
2.90
18.23
f1 (ppm)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130.633
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128.486
126.198
121.970
121.274
119.847
109.274
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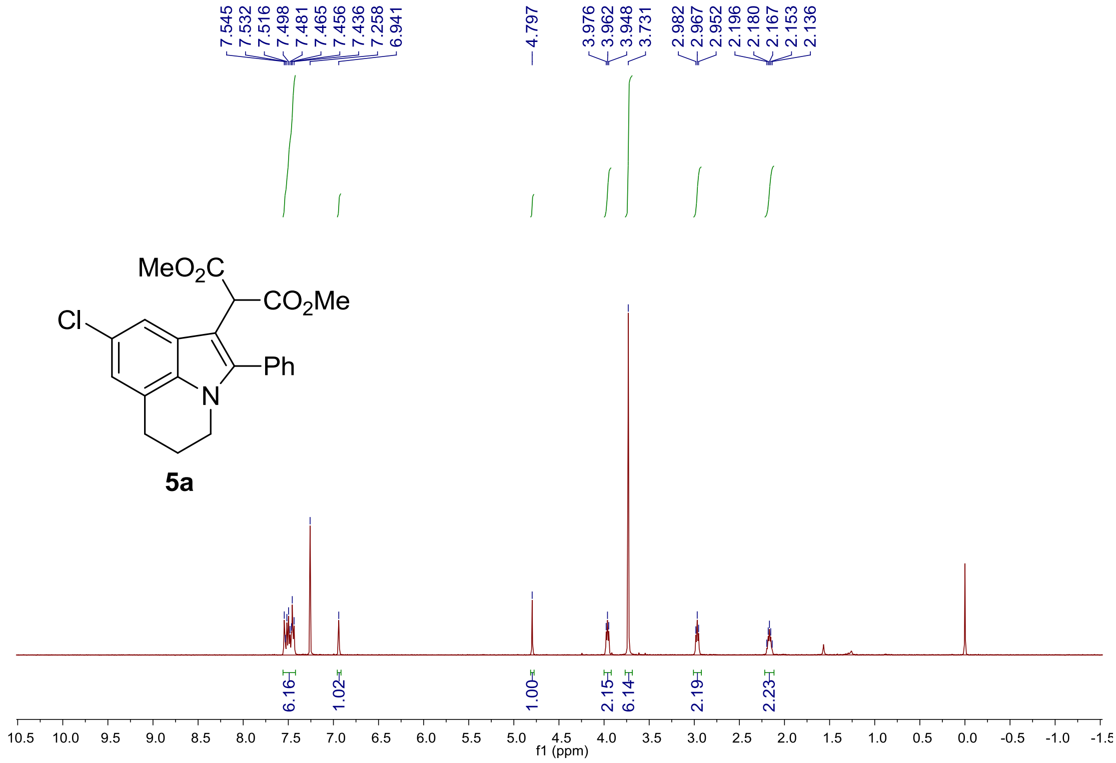
77.318
77.000
76.681
74.620
50.063
31.259
30.893
26.290
3s
f1 (ppm)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7.516
7.498
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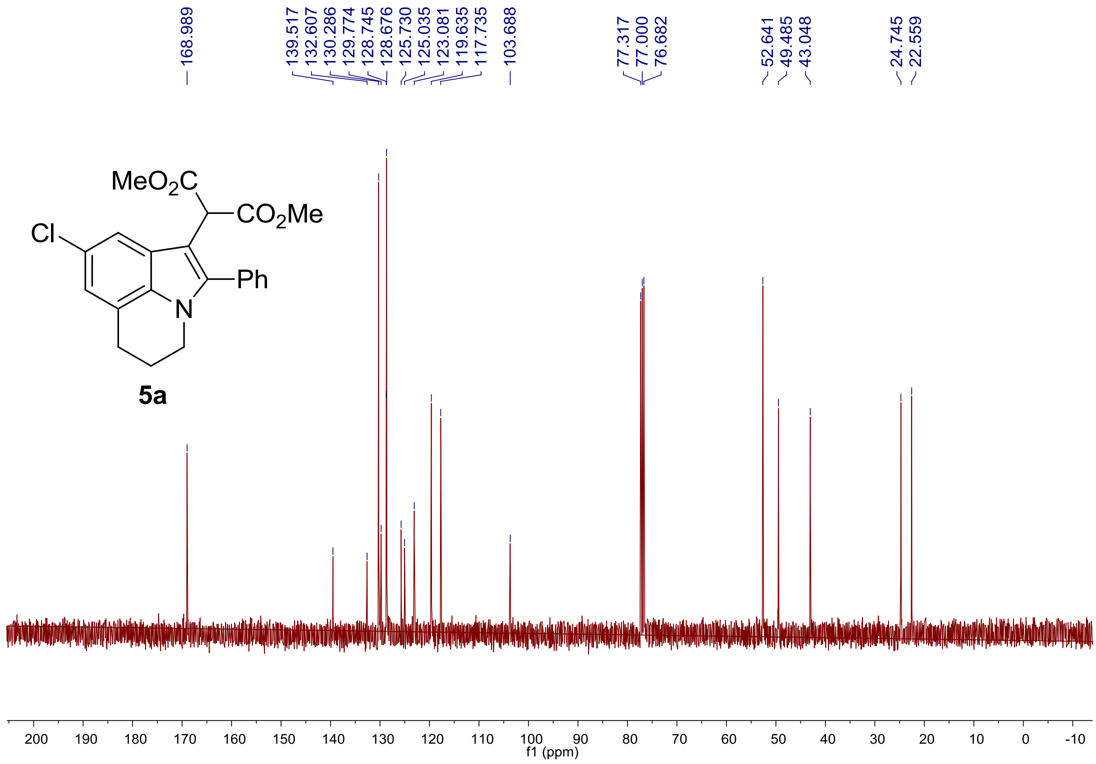
7.465
7.456
7.436
7.258
6.941
4.797
3.976
3.962
3.948
3.731
2.982
2.967
2.952
2.196
2.180
2.167
2.153
2.136
5a
6.16
1.02
1.00
2.15
6.14
2.19
2.23
f1 (ppm)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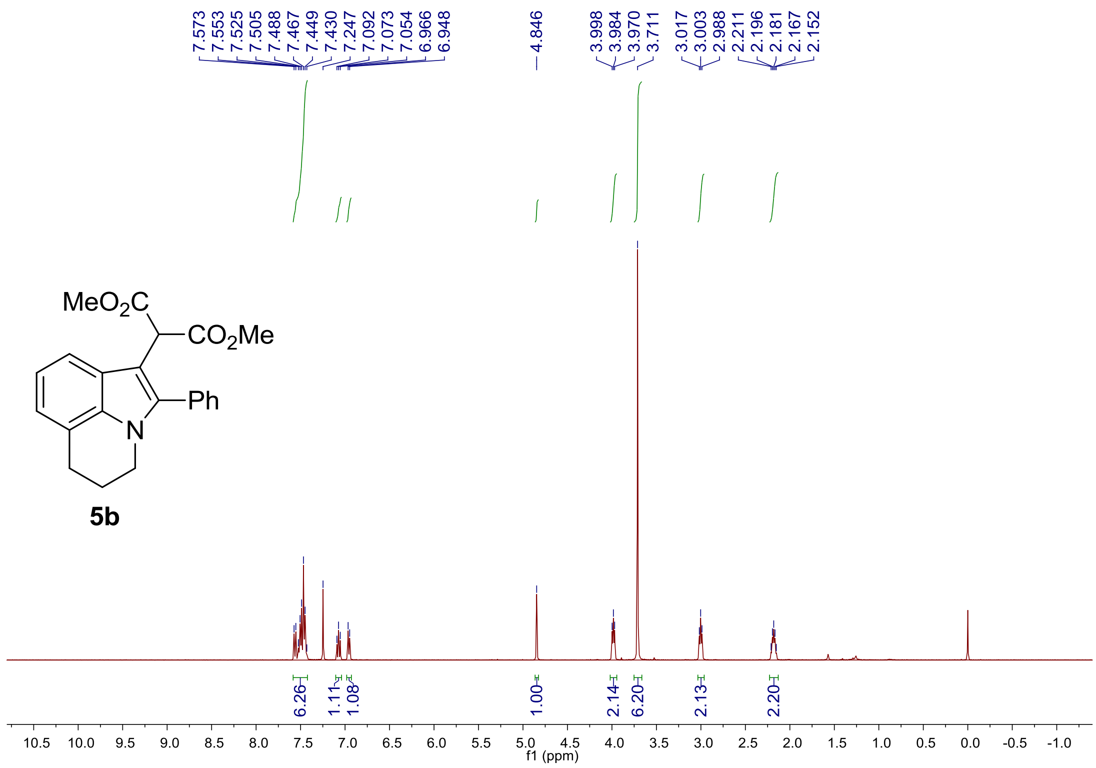
128.676
125.730
125.035
123.081
119.635
117.735
103.688
77.317
77.000
76.682
52.641
49.485
43.048
24.745
22.559
MeO2C
CO2Me
Cl
Ph
N
5a
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.525
7.505
7.488
7.467
7.449
7.430
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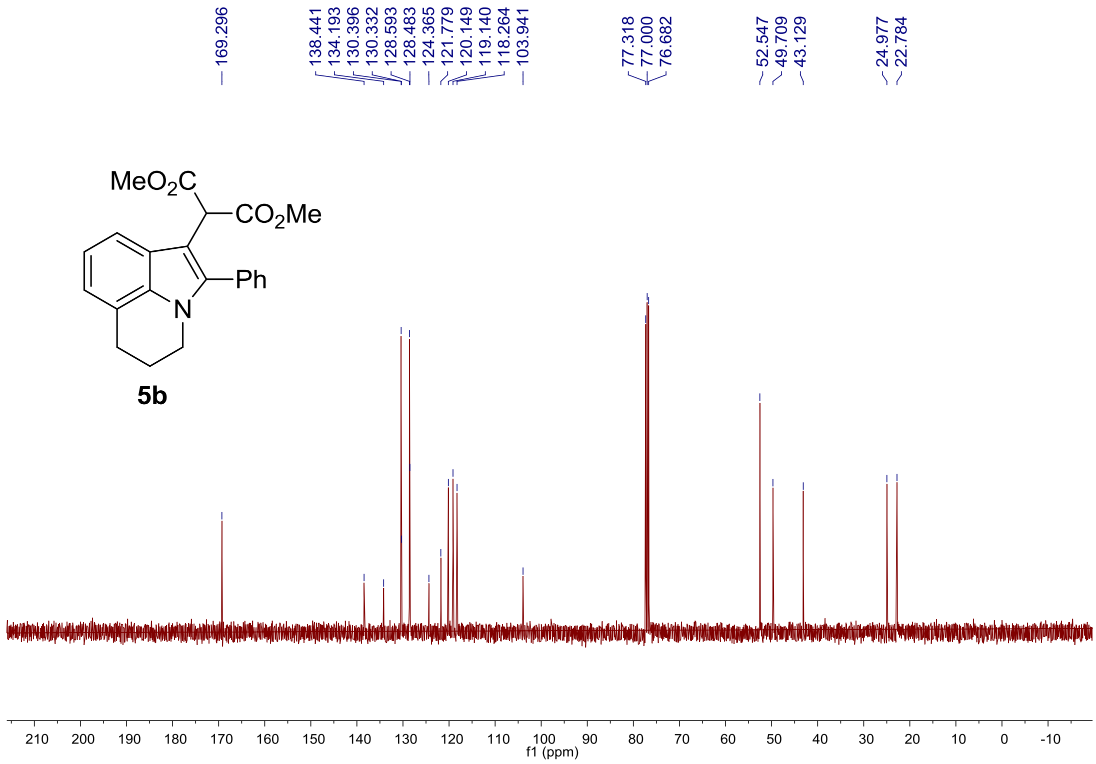
7.092
7.073
7.054
6.966
6.948
4.846
3.998
3.984
3.970
3.711
3.017
3.003
2.988
2.211
2.196
2.181
2.167
2.152
MeO2C
CO2Me
Ph
N
5b
6.26
1.11
1.08
1.00
2.14
6.20
2.13
2.20
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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124.365
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120.149
119.140
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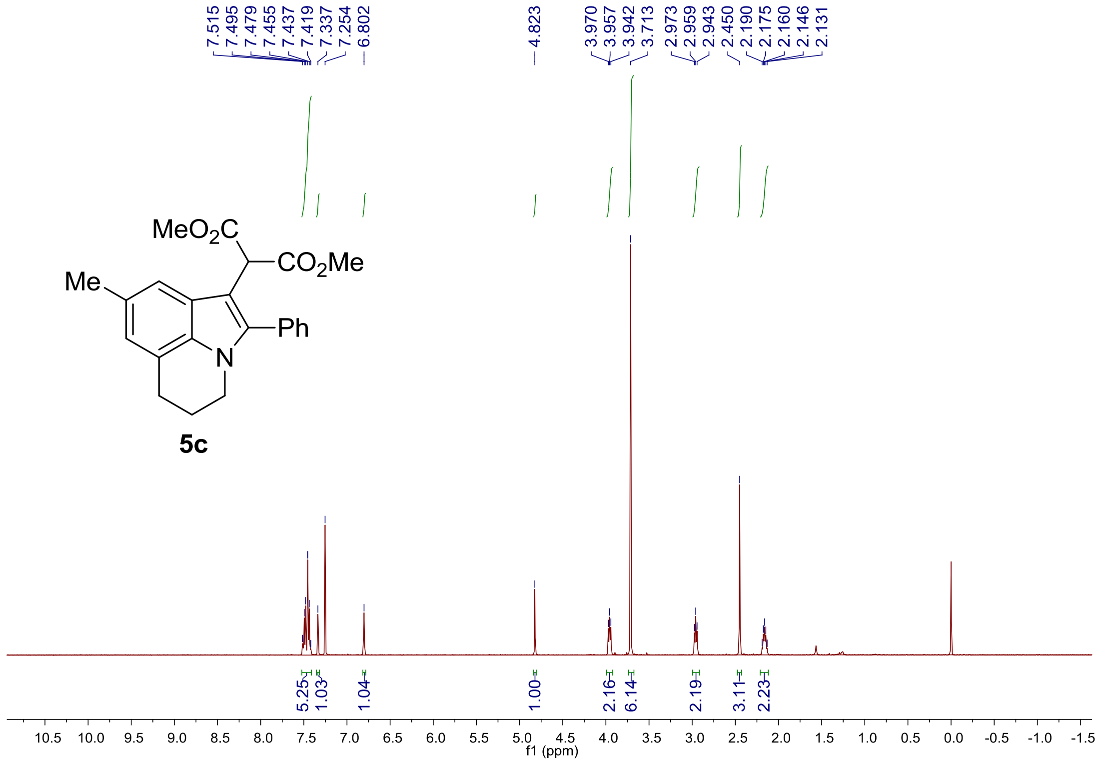
103.941
77.318
77.000
76.682
52.547
49.709
43.129
24.977
22.784
MeO2C
CO2Me
Ph
N
f1 (ppm)

5b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7.479
7.455
7.437
7.419
7.337
7.254
6.802
4.823
3.970
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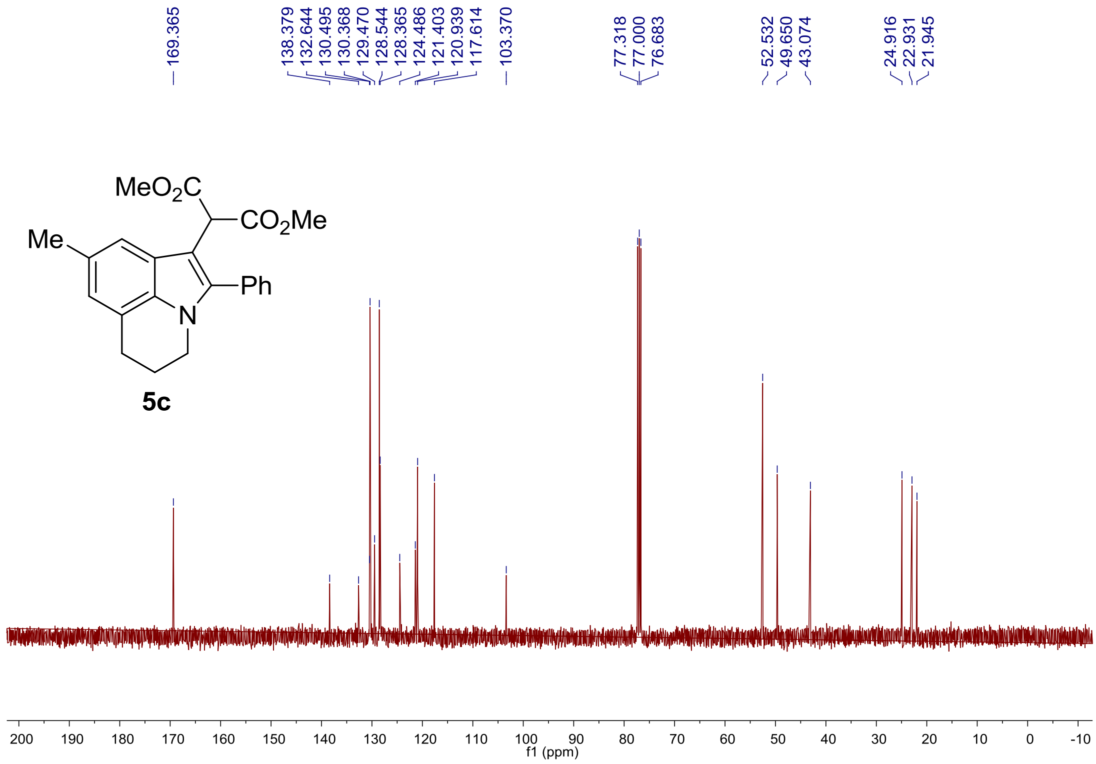
3.942
3.713
2.973
2.959
2.943
2.450
2.190
2.175
2.160
2.146
2.131
MeO2C
CO2Me
Me
Ph
N
5.25
1.03
1.04
1.00
2.16
6.14
2.19
3.11
2.23
f1 (ppm)

5c



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130.368
129.470
128.544
128.365
124.486
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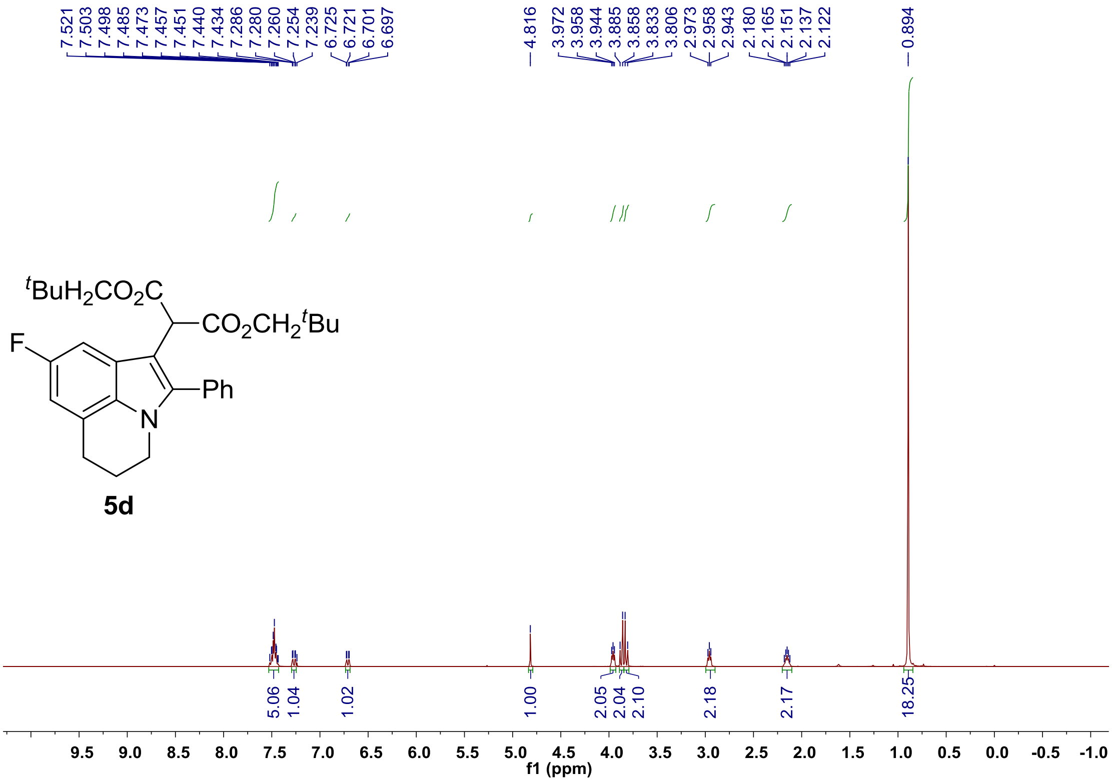
120.939
117.614
103.370
77.318
77.000
76.683
52.532
49.650
43.074
24.916
22.931
21.945
MeO_2C
CO_2Me
Me
Ph
N
5c
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



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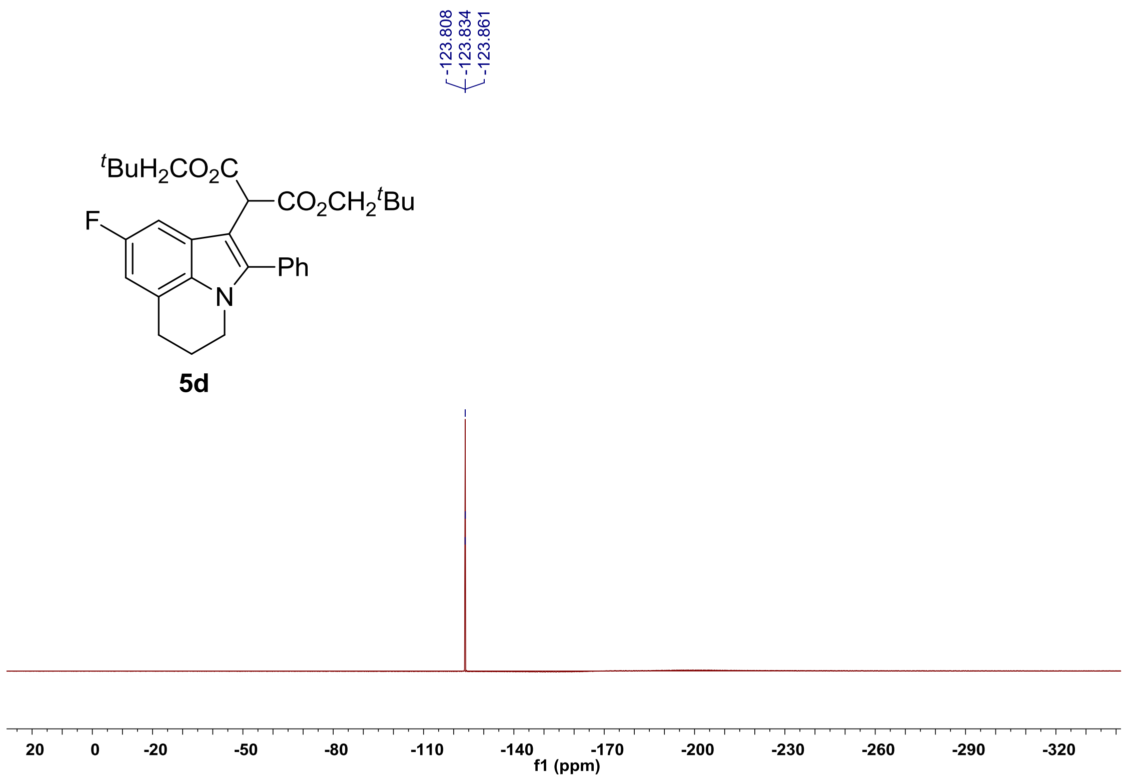
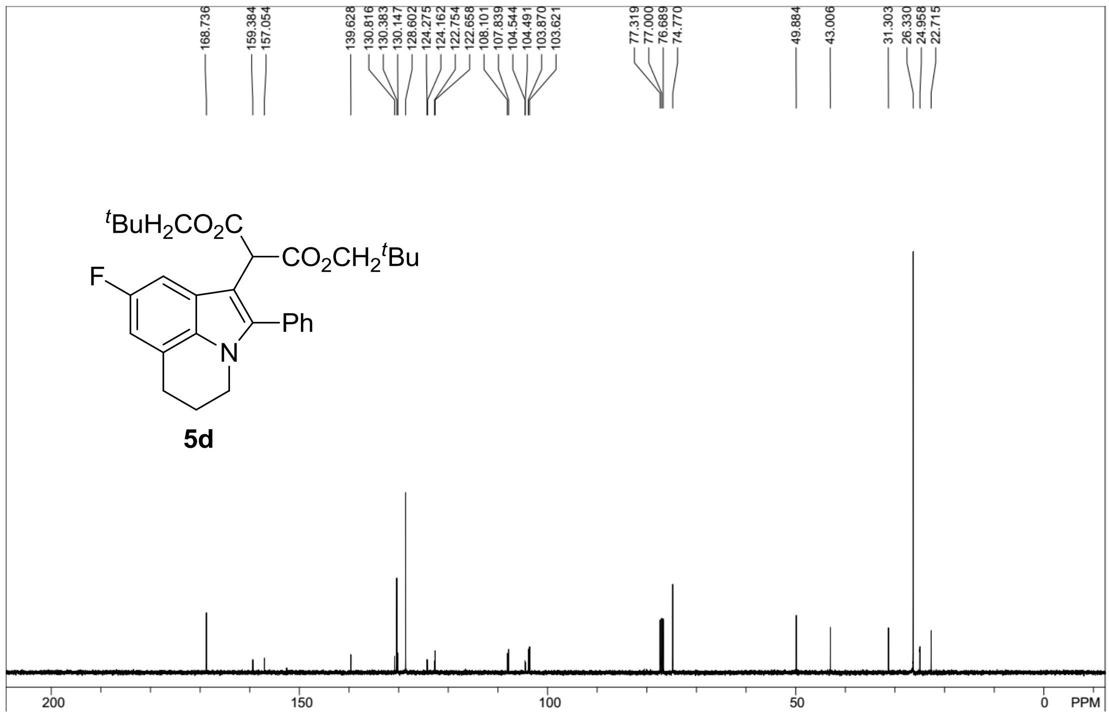
7.503
7.498
7.485
7.473
7.457
7.451
7.440
7.434
7.286
7.280
7.260
7.254
7.239
6.725
6.721
6.701
6.697
4.816
3.972
3.958
3.944
3.885
3.858
3.833
3.806
2.973
2.958
2.943
2.180
2.165
2.151
2.137
2.122
0.894
$^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
F
Ph
N
5d
5.06
1.04
1.02
1.00
2.05
2.04
2.10
2.18
2.17
18.25
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


-123.808
-123.834
-123.861
${}^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
F
Ph
N
5d
20 0 -20 -50 -80 -110 -140 -170 -200 -230 -260 -290 -320
f1 (ppm)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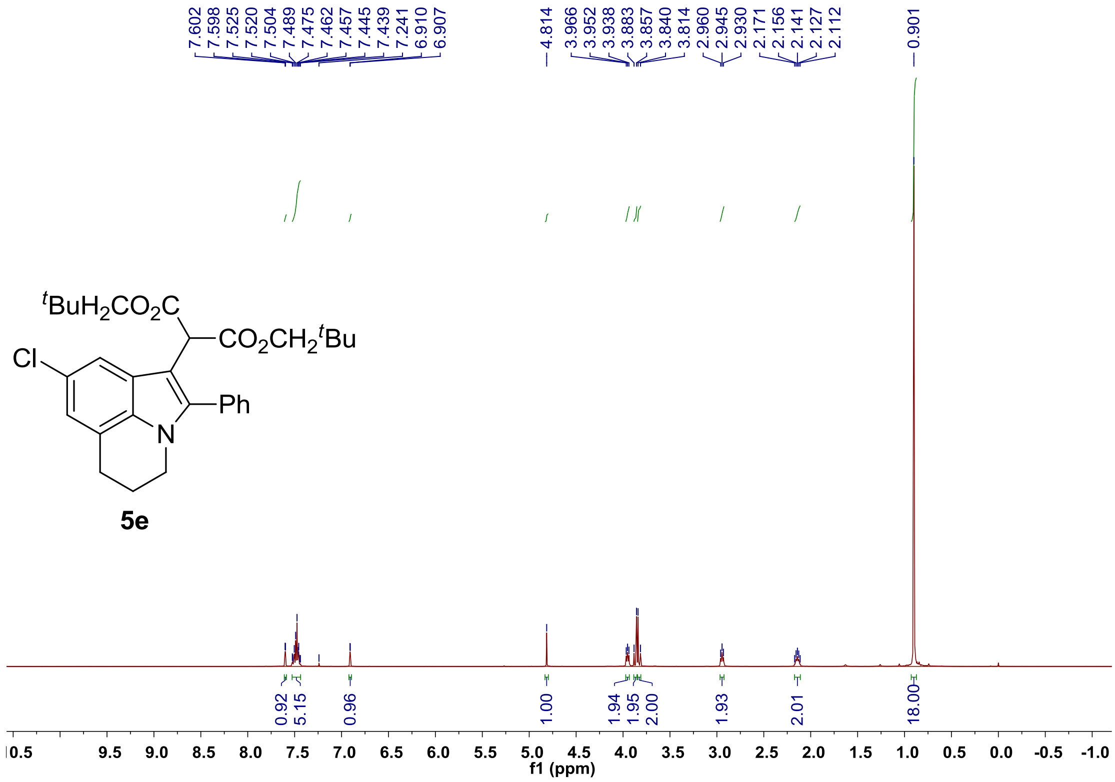
157.054
139.628
130.816
130.383
130.147
128.602
124.275
124.162
122.754
122.658
108.101
107.839
104.544
104.491
103.870
103.621
77.319
77.000
76.689
74.770
49.884
43.006
31.303
26.330
24.958
22.715
${}^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
F
Ph
N
5d
200 150 100 50 0 PPM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7.462
7.457
7.445
7.439
7.241
6.910
6.907
4.814
3.966
3.952
3.938
3.883
3.857
3.840
3.814
2.960
2.945
2.930
2.171
2.156
2.141
2.127
2.112
0.901
$^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
Cl
Ph
N
5e
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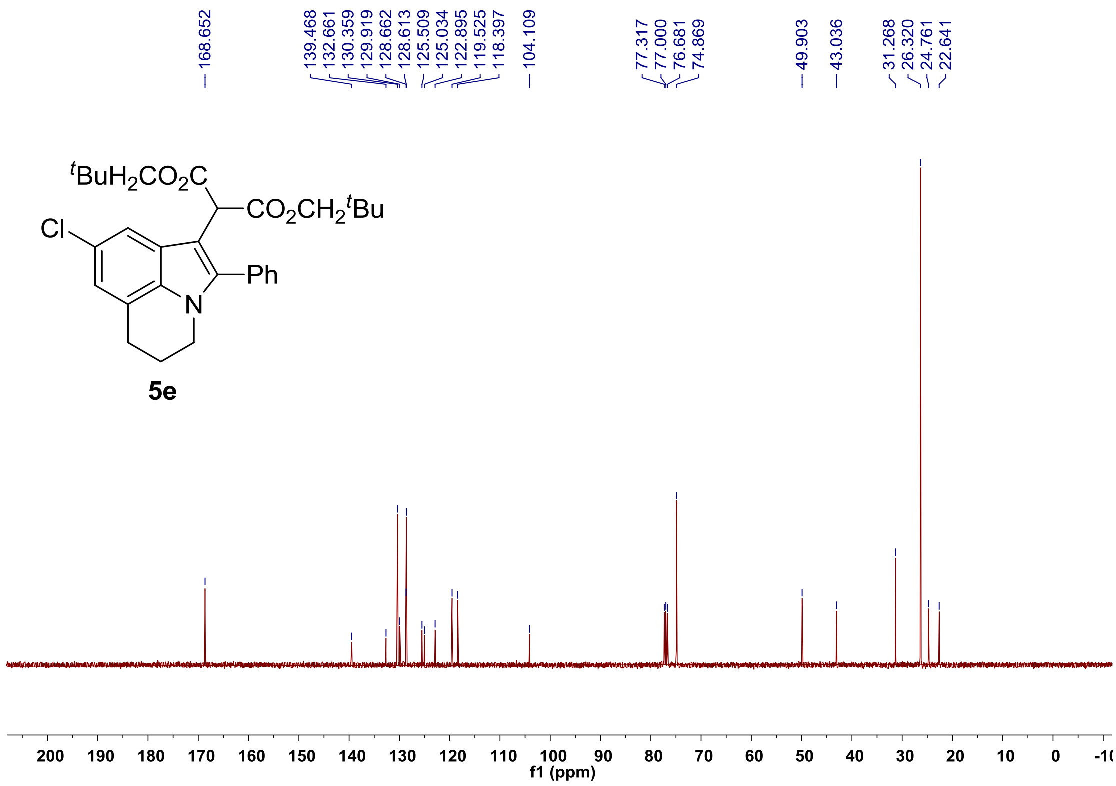
5.15
0.96
1.00
1.94
1.95
2.00
1.93
2.01
18.00
f1 (ppm)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122.895
119.525
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77.317
77.000
76.681
74.869
49.903
43.036
31.268
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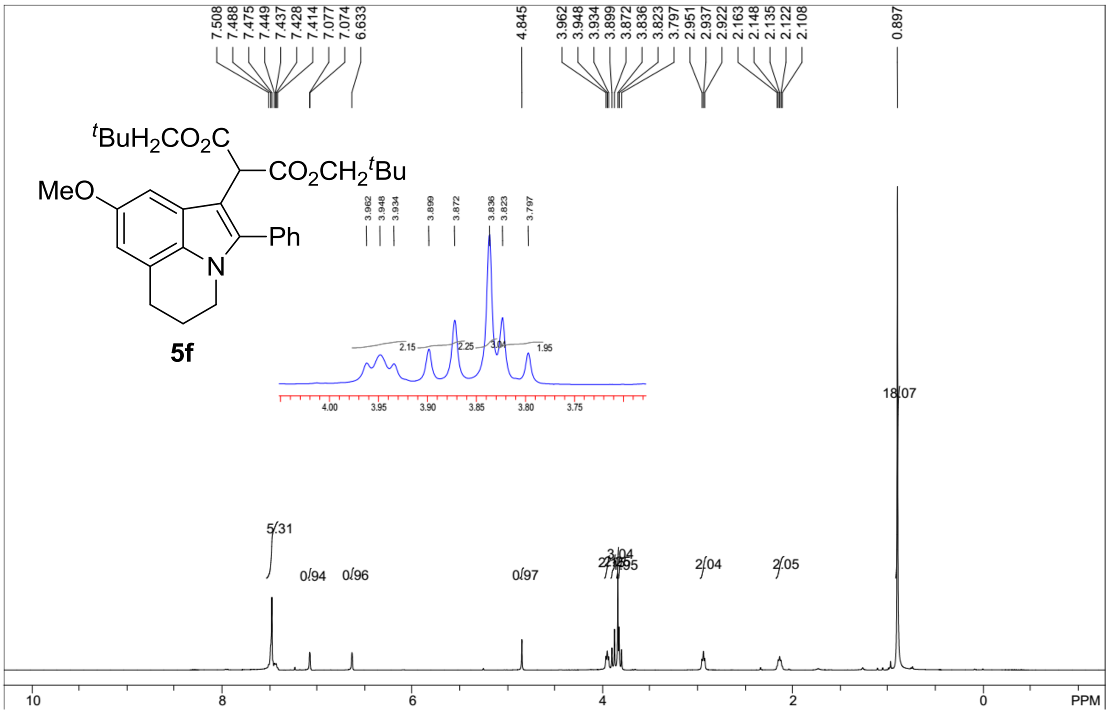
22.641
$^tBuH_2CO_2C$
$CO_2CH_2{}^tBu$
Cl
Ph
N
5e
f1 (ppm)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3.948
3.934
3.899
3.872
3.836
3.823
3.797
2.951
2.937
2.922
2.163
2.148
2.135
2.122
2.108
0.897
^{t}BuH$_2$CO$_2$C
CO$_2$CH$_2$^{t}Bu
MeO
Ph
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5f
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2.04
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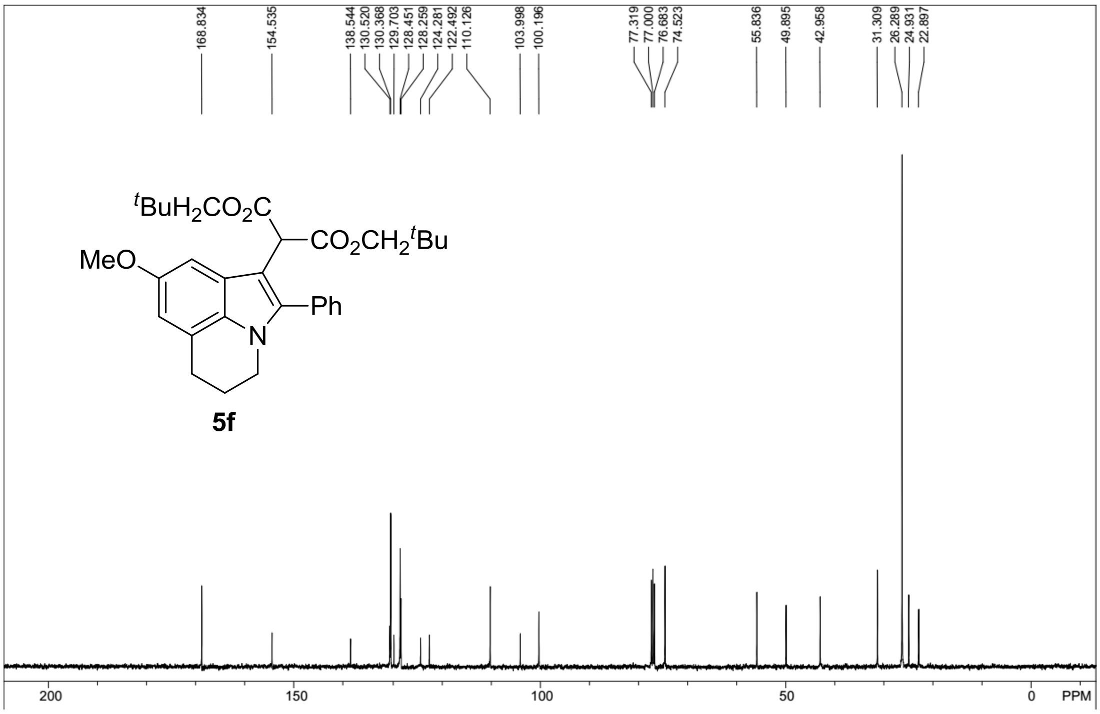
PPM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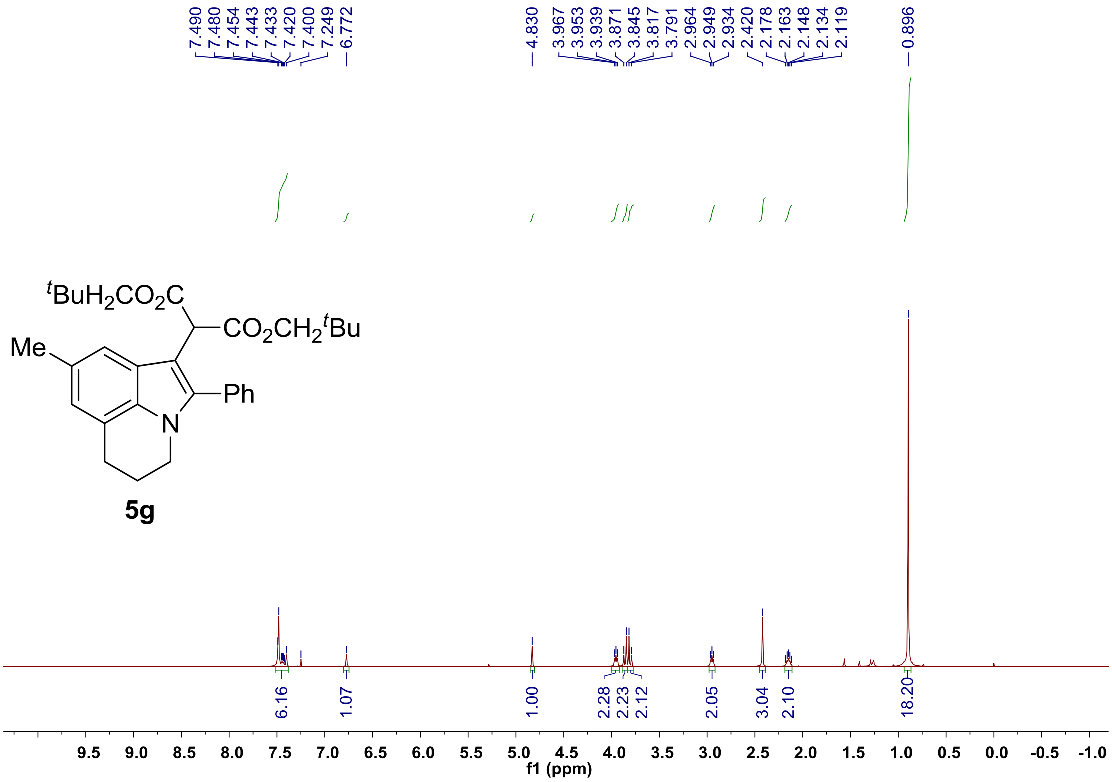
103.998
100.196
77.319
77.000
76.683
74.523
55.836
49.895
42.958
31.309
26.289
24.931
22.897
^{t}BuH$_2$CO$_2$C
CO$_2$CH$_2$^{t}Bu
MeO
Ph
N
5f
PPM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7.249
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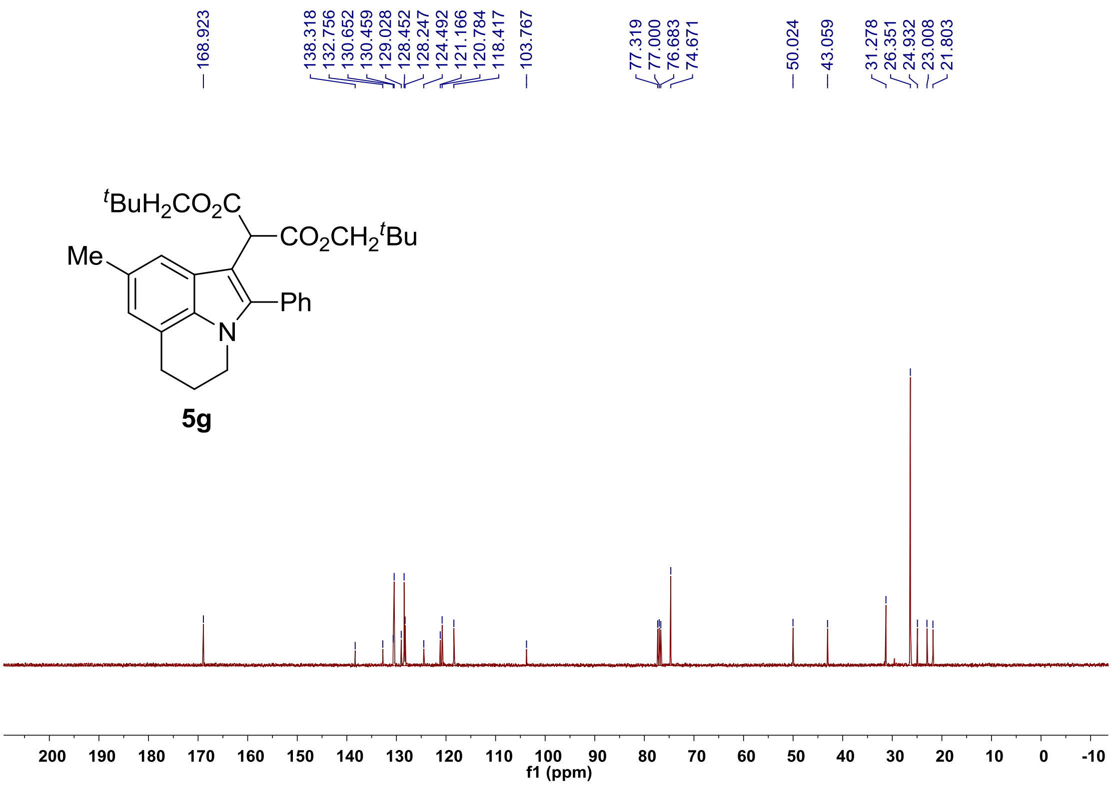
3.871
3.845
3.817
3.791
2.964
2.949
2.934
2.420
2.178
2.163
2.148
2.134
2.119
0.896
tBuH2CO2C
CO2CH2tBu
Me
Ph
N
5g
6.16
1.07
1.00
2.28
2.23
2.12
2.05
3.04
2.10
18.20
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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128.247
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121.166
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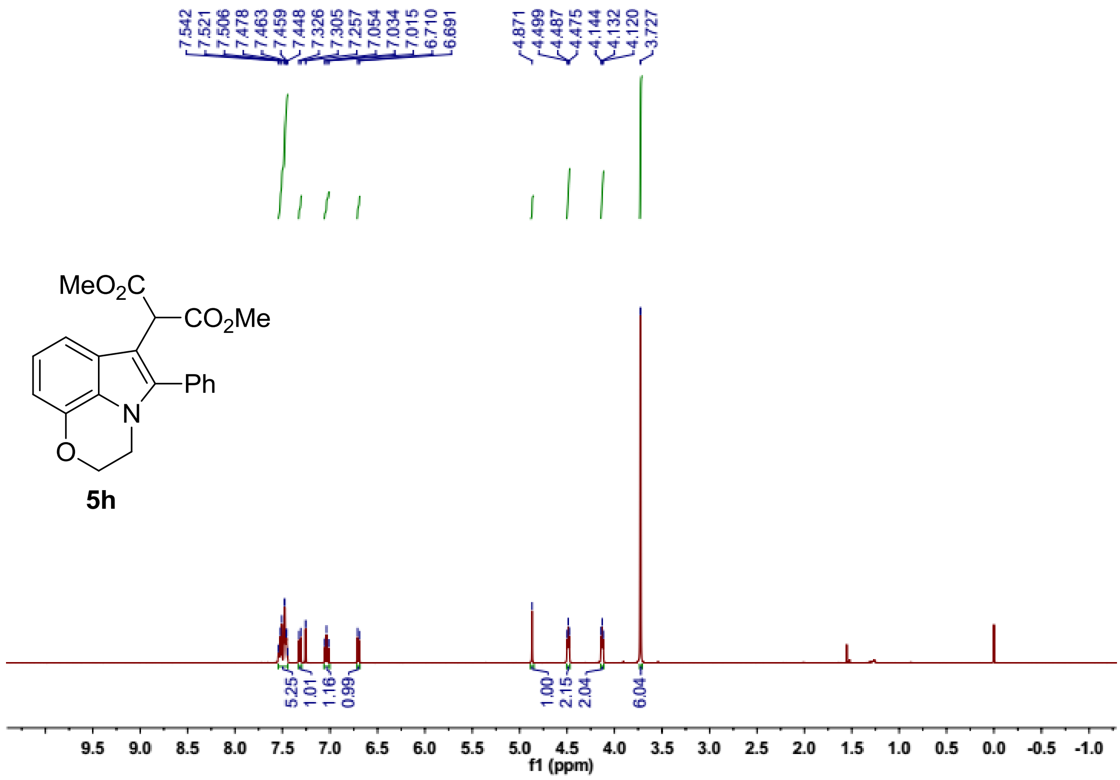
103.767
77.319
77.000
76.683
74.671
50.024
43.059
31.278
26.351
24.932
23.008
21.803
tBuH2CO2C
CO2CH2tBu
Me
Ph
N
5g
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.054
7.034
7.015
6.710
6.691
4.871
4.499
4.487
4.475
4.144
4.132
4.120
3.727
MeO2C
CO2Me
Ph
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O
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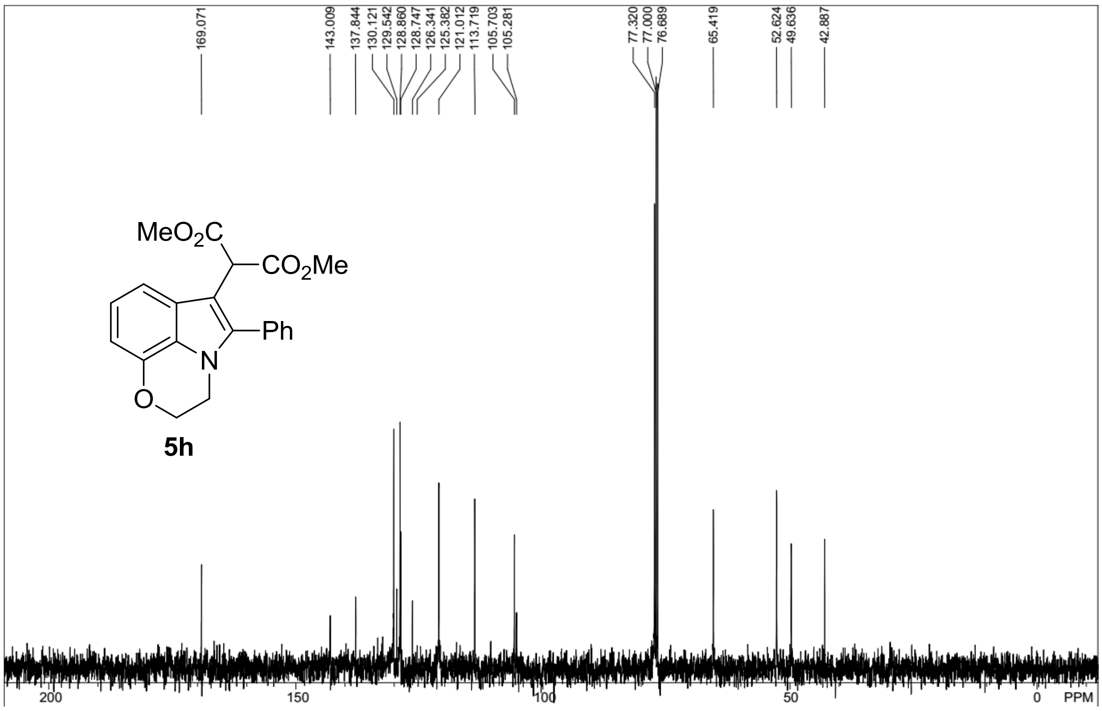
1.00
2.15
2.04
6.04
f1 (ppm)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105.281
77.320
77.000
76.689
65.419
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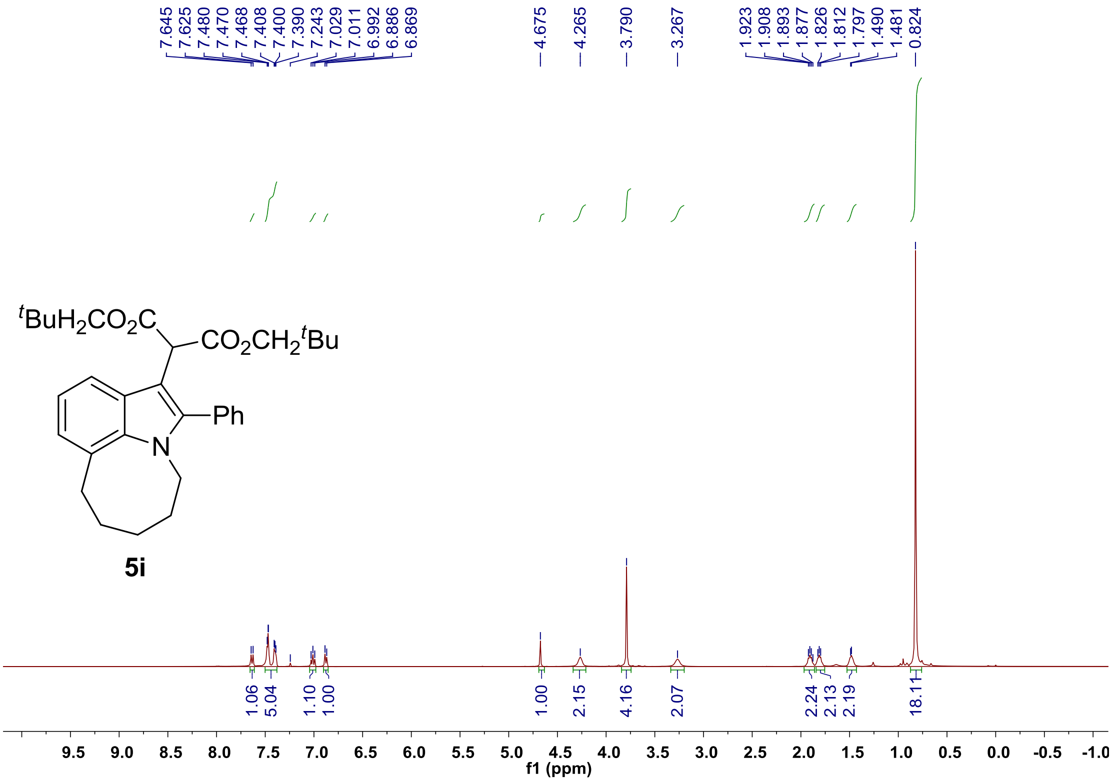
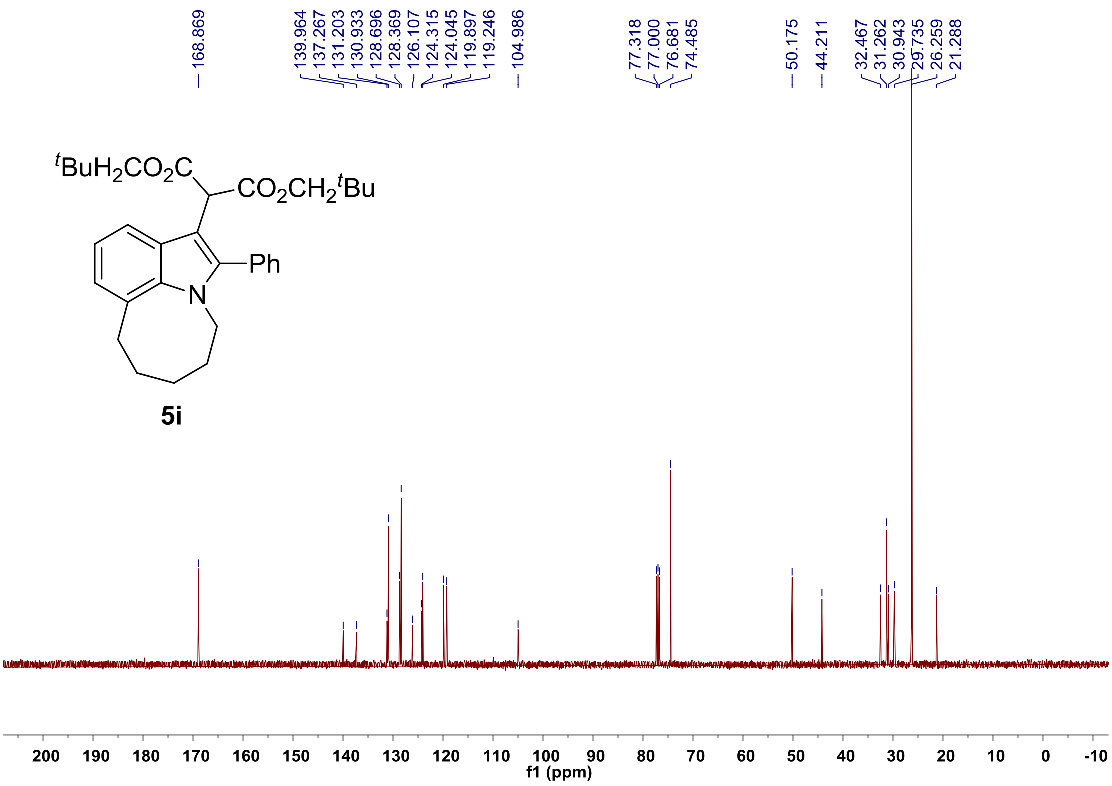
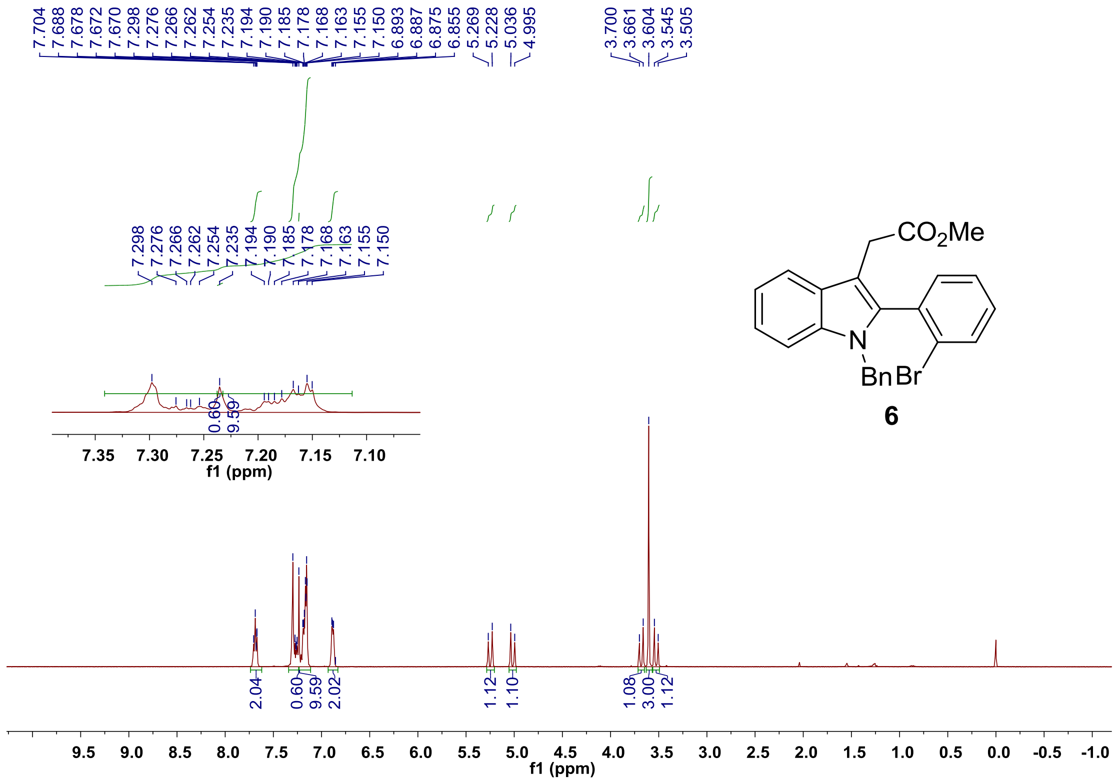
42.887
MeO2C
CO2Me
Ph
N
O
5h
200
150
100
50
0
PPM



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7.185
7.178
7.168
7.163
7.155
7.150
6.893
6.887
6.875
6.855
5.269
5.228
5.036
4.995
3.700
3.661
3.604
3.545
3.505
CO2Me
N
Bn Br
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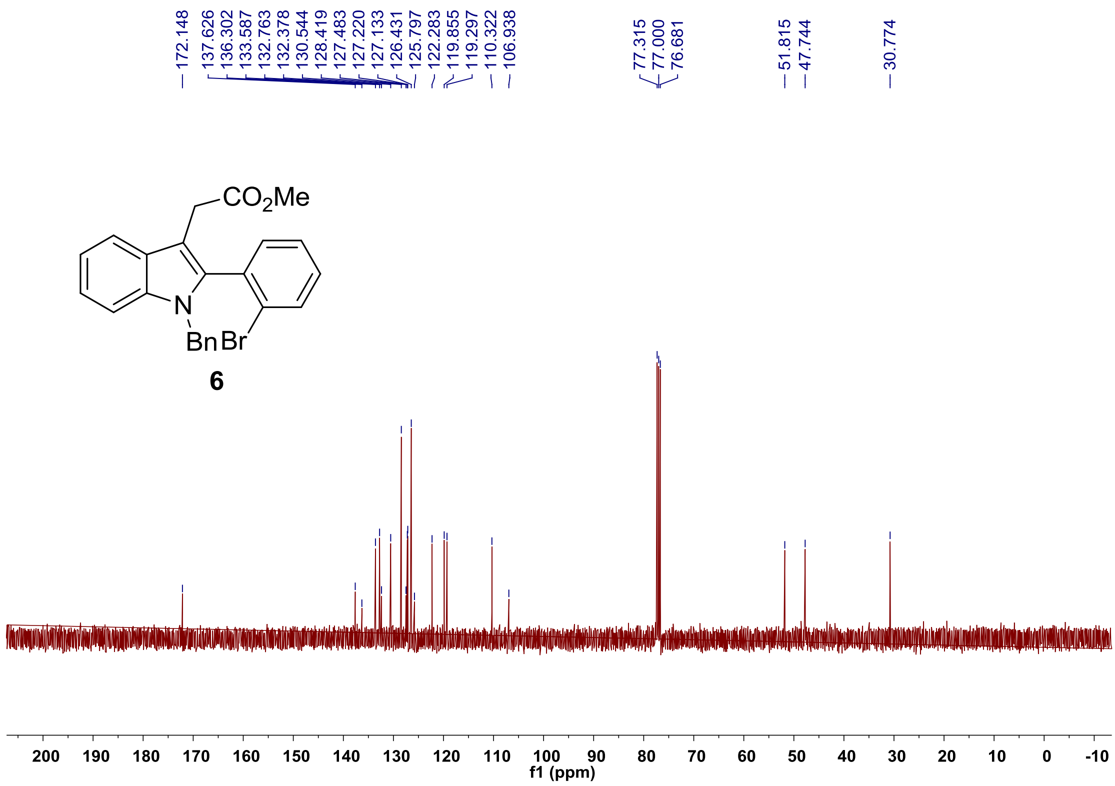
9.59
2.02
1.12
1.10
1.08
3.00
1.12
f1 (ppm)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127.220
127.133
126.431
125.797
122.283
119.855
119.297
110.322
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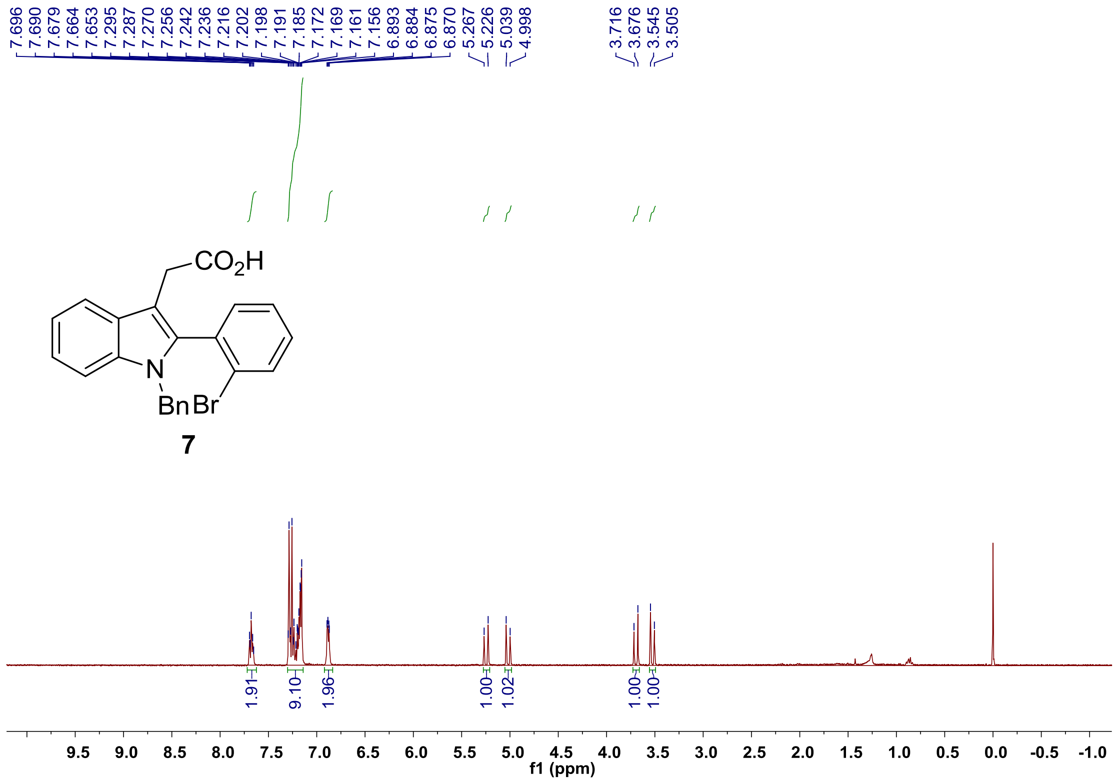
77.000
76.681
51.815
47.744
30.774
CO2Me
N
Bn Br
6
f1 (ppm)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Bn Br
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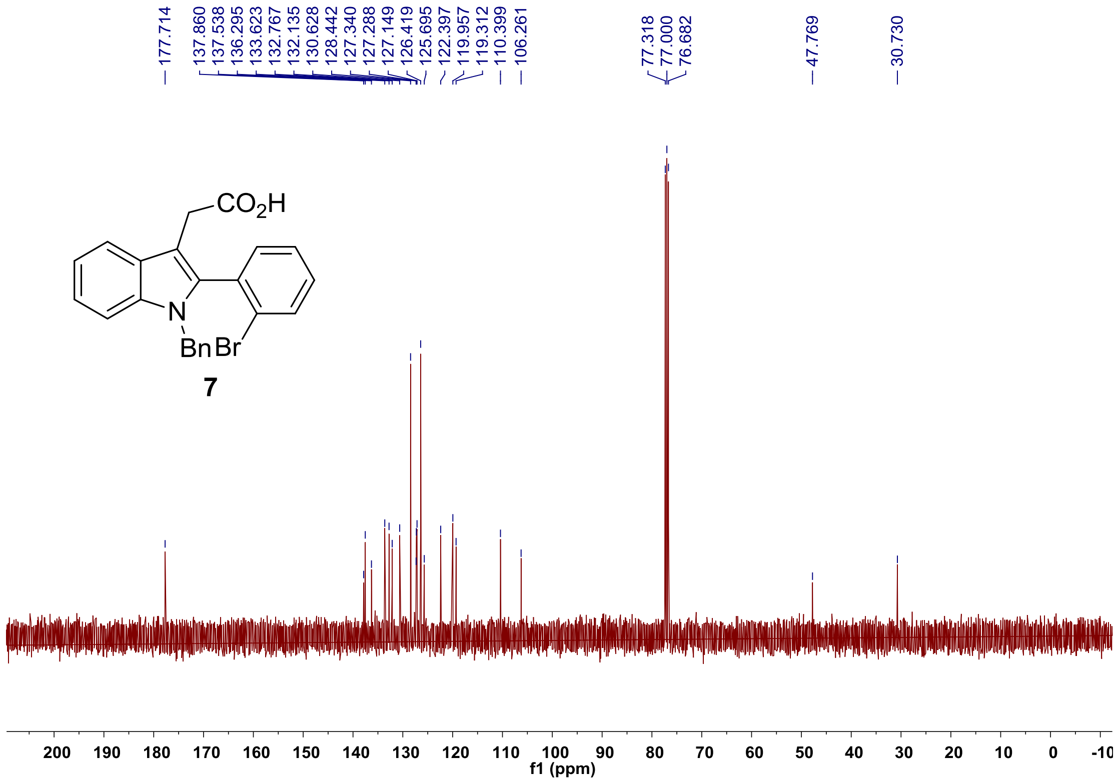
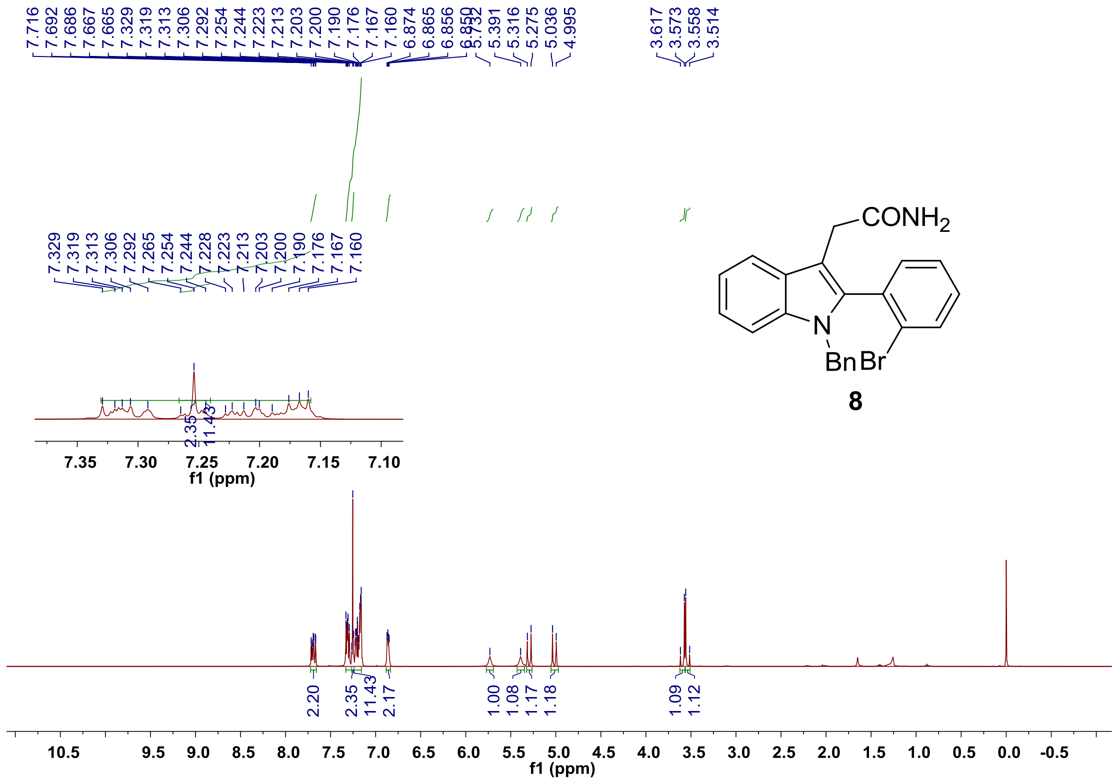
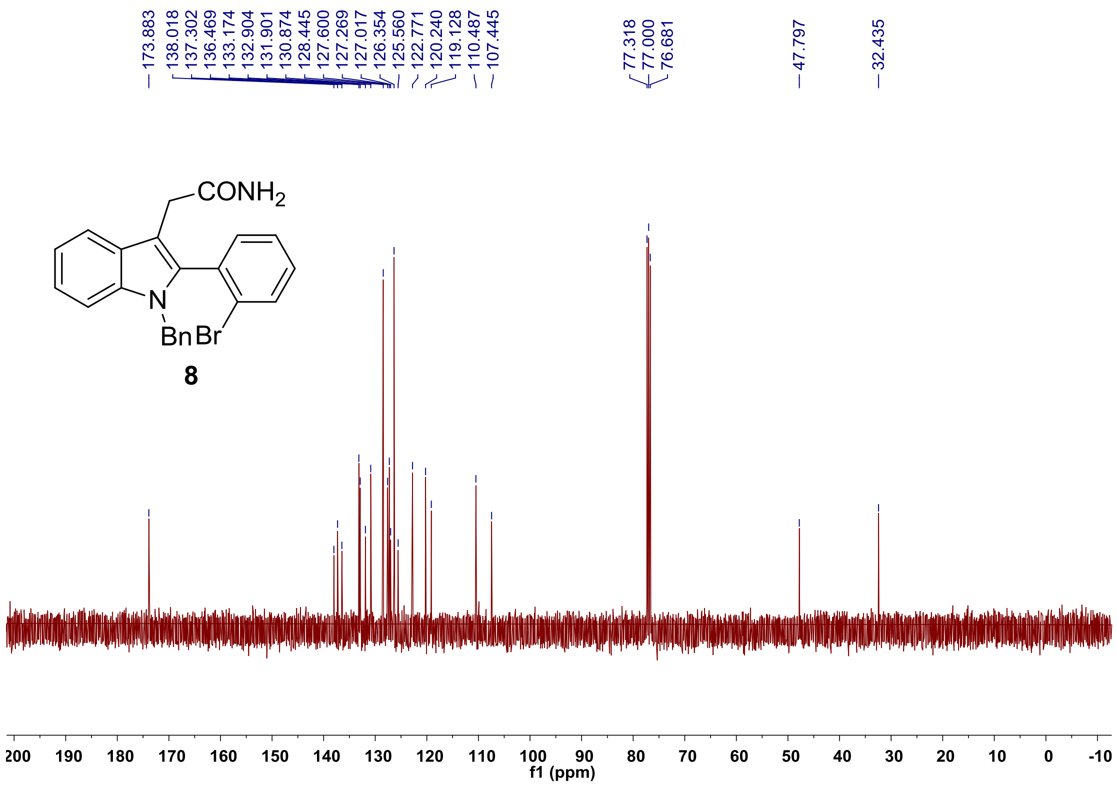
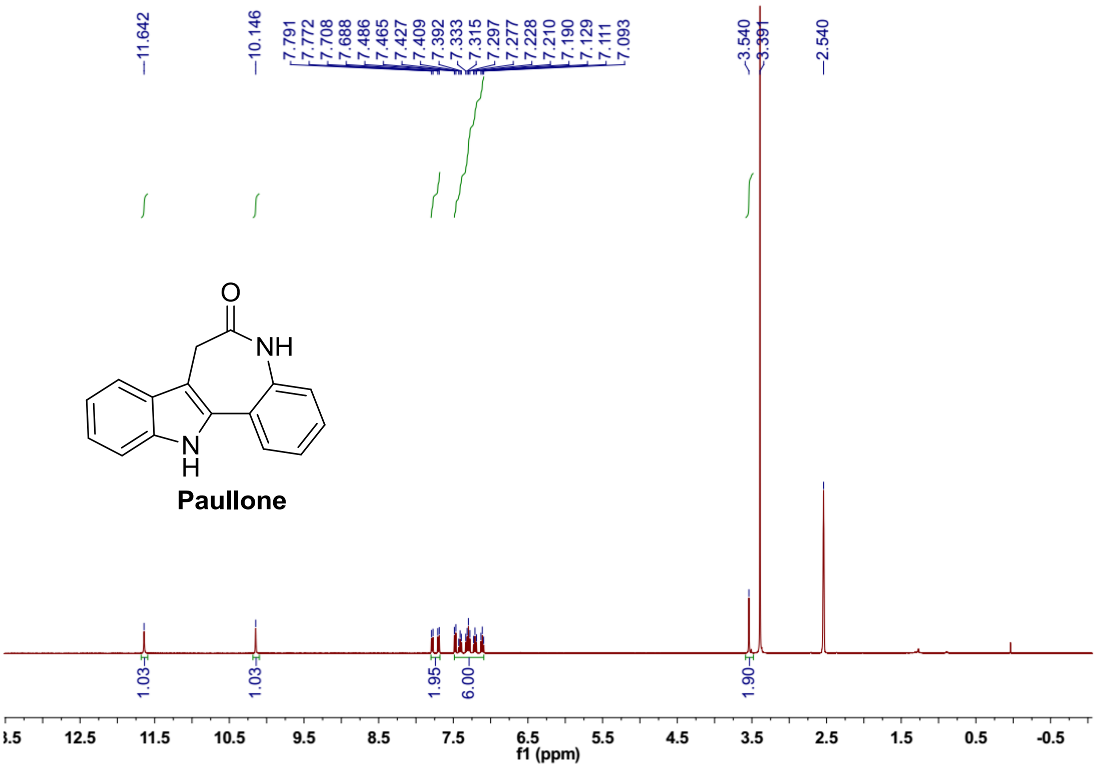
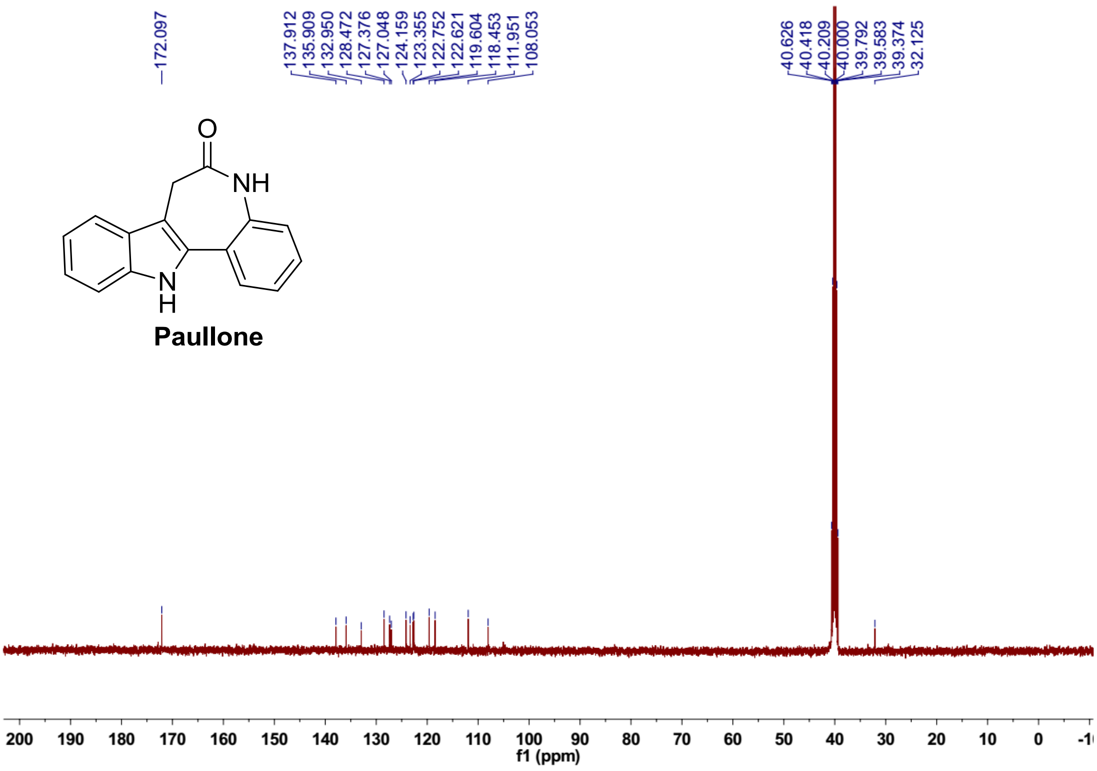

CO2H
N
Bn Br
7
f1 (ppm)


7.716 7.692 7.686 7.667 7.665 7.329 7.319 7.313 7.306 7.292 7.254 7.244 7.223 7.213 7.203 7.200 7.190 7.176 7.167 7.160 6.874 6.865 6.856 6.850 5.732 5.391 5.316 5.275 5.036 4.995
3.617 3.573 3.558 3.514
7.329 7.319 7.313 7.306 7.292 7.265 7.254 7.244 7.228 7.223 7.213 7.203 7.200 7.190 7.176 7.167 7.160
CONH2
N
Bn Br
8
2.35
11.43
7.35 7.30 7.25 7.20 7.15 7.10
f1 (ppm)
2.20 2.35 11.43 2.17 1.00 1.08 1.17 1.18 1.09 1.12
10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


173.883 138.018 137.302 136.469 133.174 132.904 131.901 130.874 128.445 127.600 127.269 127.017 126.354 125.560 122.771 120.240 119.128 110.487 107.445
77.318 77.000 76.681
47.797
32.435
CONH2
N
Bn Br
8
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


11.642
10.146
7.791
7.772
7.708
7.688
7.486
7.465
7.427
7.409
7.392
7.333
7.315
7.297
7.277
7.228
7.210
7.190
7.129
7.111
7.093
3.540
3.391
2.540
O
NH
N
H
Paullone
1.03
1.03
1.95
6.00
1.90
f1 (ppm)


172.097
137.912
135.909
132.950
128.472
127.376
127.048
124.159
123.355
122.752
122.621
119.604
118.453
111.951
108.053
40.626
40.418
40.209
40.000
39.792
39.583
39.374
32.125
O
NH
N
H
Paullone
f1 (ppm)