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Supporting Information

Direct Catalytic Asymmetric Vinylogous Michael addition to Construct an All-Carbon Quaternary Center with 3-Alkenyl-oxindoles

Shuhui Lu[a], Zhifei Zhao[a], Yingzheng Ren[a], Guangfen Du[a]*, Jixing Zhao[b], Shi-Wu Li[a]*

[a]Key Laboratory for Green Processing of Chemical Engineering of Xinjiang Bingtuan , School of Chemitry and Chemical Engineering, Shihezi University, Xinjiang Uygur Autonomous Region 832000, People's Republic of China. [b]Analysis and Testing Cent er of Shihezi University.

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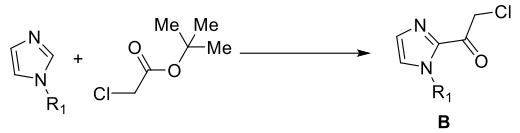
I General Information

All reactions were performed in Schlenk tubes at 50 ^{o}C using oven-dried glassware. Commercially obtained reagents were used without further purification, unless otherwise noted. Dry 1,2-dichloroethane (DCE) and THF were obtained from solvent distillation machine (Vigor VSPS-5) and stored under argon over 4 Å molecular sieves. Toluene was freshly distilled before use over sodium and benzophenone. Dichloromethane (DCM) was distilled over CaH_2. Methanol was used without further purification. Reactions were monitored by TLC analysis and plates were visualized with short-wave UV light (254 nm). The ^{1}H, ^{13}C NMR and ^{19}F spectra were obtained in $CDCl_3$ using a Bruker-BioSpin AVANCE III HD NMR spectrometer at 400 MHz, 100 MHz and 376 MHz respectively. Chemical shifts are reported in parts per million (δ value) calibrated against the residual solvent peak. HPLC analyses of the compounds were done using chiralcel IA-IF columns and chiralcel AD-H, AS-H, OJ-H and OD-H columns using hexane and isopropanol as eluent. High-resolution mass spectra were recorded on a Bruker Impact II UHR TOF LC/MS Mass Spectrometry. Crystal structure data were collected on a SuperNova, Dual, Cu at zero, Atlas diffractometer.

II Experimental Section

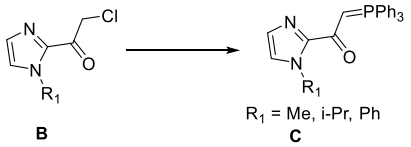
Δ-Rh or **Λ-Ir1** was prepared according to reported procedure.[1-2] 3-alkenyl-oxindoles and *α, α*-dicyanoalkenes were synthesized according to reported procedures.[2-4]

General route for the synthesis of 2a-2m



2-Chloro-1-(1-methyl-1H-imidazole-2-yl) ethanone **B**.

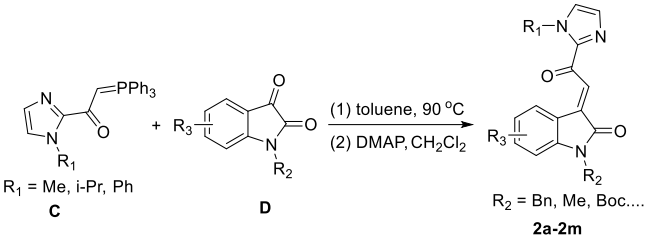
To a 100 mL vacuum flame dried RBF was added 2.62 g of N-methylimidazole (31.8 mmol, 1.0 equiv) and 80 mL of THF. The solution was cooled to -78 ^{o}C for 30 min before 12.2 mL of n-butyllithium in hexane (2.6 M, 31.8 mmol, 1.0 equiv) was added to the flask. The dry-ice/acetone bath was removed and the reaction was allowed to warm to rt over a 60 min. The reaction was cooled to -78 ^{o}C for 30 min before 5.70 mL of tert-butylchloroacetate (1.25 equiv) was added as a single portion. The reaction was stirred at -78 ^{o}C for 3.0 h. The reaction was quenched with 8 mL of H_2O and diluted with 100 mL of EtOAc and 100 mL of brine. The aqueous layer was separated and extracted 2x50 mL with EtOAc. The organic layers were combined and dried with Na_2SO_4. The drying agent was removed by filtration and the filtrate was concentrated in vacuo. The product was purified with a short SiO_2 column (70% EtOAc/hexanes) to produce 5.00 g (99% yield).



1-(1-methyl-1H-imidazole-2-yl)-2-(triphenylphosphoranylidene)-ethanone **C**.

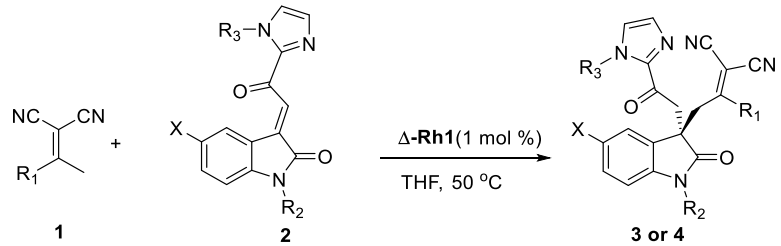
To a 100 mL vacuum flame dried RBF under dried N_2 was added 3.2 g of B (2-Chloro-1-(1- methyl-1H-imidazole-2-yl) ethanone, 19.6 mmol, 1.0 equiv), 50 mL of benzene, and 5.6 g of triphenylphosphine (21.6 mmol, 1.1 equiv). The reaction was refluxed for 16 h. The reaction was cooled to rt and then diluted with 160 mL of 1 N HCl and 200 mL of diethyl ether. The aqueous layer was separated and the corresponding organic

layer was extracted with 2x40mL 1 N HCl. The aqueous layers were combined and washed with 1x100 mL of diethyl ether. The aqueous layer was neutralized with sat. sodium carbonate. The aqueous layer was subsequently extracted with 3x100 mL EtOAc. The organic layers were combined and dried with Na_2SO_4. The drying agent was removed by filtration and the filtrate was concentrated in vacuo to produce 6.8 g (91% yield).



To a solution of Wittig reagent **C** (2.4 mmol, 1 equiv) in toluene (12.0 mL) at room temperature was added the corresponding isatin (2 equiv). The reaction was stirred at 90 °C overnight. After the solvent was removed in vacuo, the residue was purified by flash chromatography on silica gel (EtOAc/hexane = 1/4 to 1/3) to produce the unsaturated alkenes as a mixture of E:Z isomers. Then, to a solution of purified alkene in CH_2Cl_2 (0.2 M) at room temperature was added DMAP (0.1 equiv). The reaction was sealed and stored at -20 °C (fridge) for 24 hours. After isomerization, the solution was passed through a short silica column. The isomerization proceeded well to afford **2a-2m** with an improved E/Z value (E/Z > 50/1, as judged by 1H NMR).

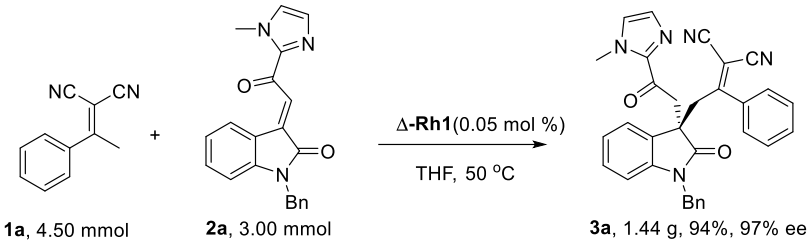
General procedure for Chiral-at-Metal Rh (III) Complex Catalyzed Vinylogous Michael addition of Malononitriles to 3-Alkenyl-oxindole



To an oven-dried 10 mL Schlenk tube equipped with a stir bar, **Λ-Rh1** (1 mol%) was added along with 3-Alkenyl-oxindole **2** (1.0 equiv, 0.1 mmol) and Malononitriles **1** (1.5 equiv, 0.15 mmol) in THF (0.5 mL). The reaction was stirring at 50 °C until consumption of the 3-Alkenyl-oxindole (monitored by TLC). The solution was directly

purified by silica gel column chromatography (EtOAc/Petroleum ether = 1:2-1:1) to afford **3** or **4**.

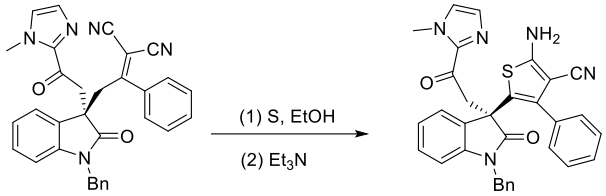
General procedure for gram-scale experiments with lower catalyst loading.



1a, 4.50 mmol **2a**, 3.00 mmol **3a**, 1.44 g, 94%, 97% ee

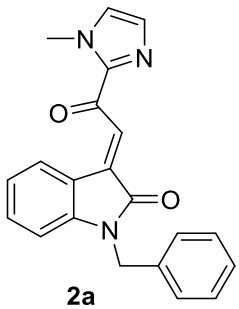
To an oven-dried 25 mL Schlenk tube equipped with a stir bar, **Δ-Rh1** (0.05 mol%, 1.18 mg) was added along with 3-alkenyl-oxindole **2a** (1.0 equiv, 3.00 mmol, 1029 mg) and *α, α*-dicyanoalkene **1a** (1.5 equiv, 4.50 mmol, 756 mg) in THF (8.0 mL). The reaction was stirring at 50 °C until consumption of the 3-alkenyl-oxindole **2a** (monitored by TLC). The solution was directly purified by silica gel column chromatography (EtOAc/Petroleum ether = 1:2-1:1) to afford **3a** (white solid, 1.44 g, 94% yield, 97% ee).

General procedure for synthetic transformation of the Michael product 3a.



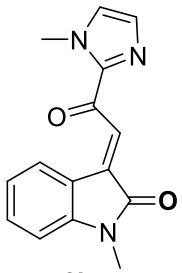
3a 5a

A 25 mL Pressure tube was charged with **3a** (0.1 mmol), sulfur (0.1 mmol), and triethylamine (0.1 mmol) in ethanol (0.5 mL, 1.0 M solution). The reaction was heated 60 °C for 12 h. Then, the reaction was cooled down to room temperature. Evaporation of ethanol left a residue that was purified by column chromatography (EtOAc/Petroleum ether =1:2-1:1) to afford **5a** (brown solid, 24 mg, 45% yield, 86% ee).



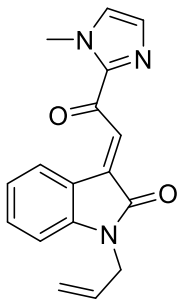
2a

Orange solid, 140 mg, 17% yield, mp = 172-174 ^{o}C. **^{1}H NMR (400 MHz, CDCl$_3$):** δ = 8.66 (d, J = 7.7 Hz, 1H), 8.53 (s, 1H), 7.30 (d, *J* = 4.2 Hz, 4H), 7.26-7.23 (m, 2H), 7.11 (s, 1H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.68 (d, *J* = 7.8 Hz, 1H), 4.96 (s, 2H), 4.13 (s, 3H). **^{13}C NMR (CDCl$_3$, 100 MHz):** δ = 180.9, 168.0, 145.6, 144.6, 136.6, 135.6, 132.6, 130.0, 128.8, 128.6, 127.9, 127.7, 127.5, 127.3, 122.6, 120.6, 109.1, 43.8, 36.5. **HRMS (ESI, m/z)** calcd for $C_{21}H_{17}N_3O_2Na^+$ $(M+Na)^+$: 366.12130, found: 366.12100.



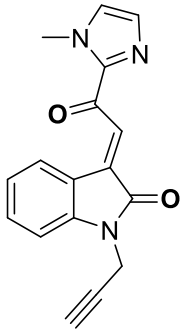
2b

Orange solid, 103 mg, 16% yield, mp = 194-196 ^{o}C. **^{1}H NMR (400 MHz, DMSO):** δ = 8.62 (d, *J* = 7.6 Hz, 1H), 8.26 (s, 1H), 7.65 (s, 1H), 7.47 (t, *J* = 7.0 Hz, 1H), 7.26 (s, 1H), 7.11-7.04 (m, 2H), 4.07 (s, 3H), 3.20 (s, 3H). **^{13}C NMR (DMSO, 100 MHz):** δ = 180.1, 167.6, 146.8, 144.5, 136.4, 133.7, 130.1, 130.0, 128.4, 126.9, 122.8, 120.0, 109.5, 36.6, 26.6. HRMS (ESI, *m*/*z*) calcd for $C_{15}H_{14}N_3O_2$ $[M+H]^+$: 268.1081, found: 268.1081.



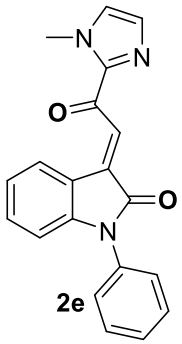
2c

Orange solid, 99 mg, 14% yield, mp = 206-207 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.68-8.66 (m, 1H), 8.47 (s, 1H),7.36-7.32 (m, 1H), 7.25 (m, 1H), 7.11 (s, 1H), 7.07-7.03 (m, 1H), 6.79 (d, *J* = 7.8 Hz, 1H), 5.89-5.80 (m, 1H), 5.27-5.20 (m, 2H), 4.39 (dt, J_1 = 5.3 Hz, J_2 = 1.6 Hz, 2H), 4.14 (s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.9, 167.6, 145.7, 144.6, 136.7, 132.6, 131.3, 130.0, 128.6, 127.9, 127.3, 122.5, 120.6, 117.6, 109.0, 42.4, 36.5. **HRMS (ESI, m/z)** calcd for $C_{17}H_{16}N_3O_2$ $[M+H]^+$: 294.1237, found: 294.1237.



2d

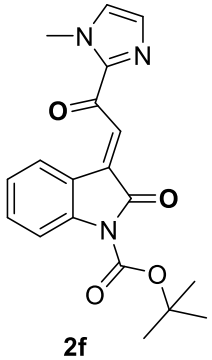
Orange solid, 120 mg, 17% yield, mp = 205-207 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.71- 8.69 (m, 1H), 8.48 (s, 1H), 7.44 -7.39 (m, 1H), 7.25 (d, *J* = 0.9 Hz, 1H), 7.12 - 7.08 (m, 2H), 7.04 -7.01 (m, 1H), 4.57 (d, *J* = 2.5 Hz, 2H), 4.14 (s, 3H), 2.24 (t, *J* = 2.5 Hz, 1H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.7, 167.0, 144.5, 136.3, 132.7, 130.1, 128.7, 127.9, 127.6, 123.0, 120.6, 109.1, 72.4, 36.5, 29.3. HRMS (ESI, *m*/*z*) calcd for $C_{17}H_{14}N_3O_2$ $[M+H]^+$: 292.1081, found: 292.1080.



2e

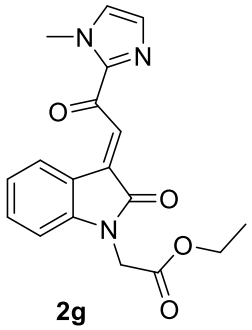
Orange solid, 87 mg, 11% yield, mp = 220-222 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.73 (d, *J* = 7.8 Hz, 1H), 8.54 (s, 1H), 7.56-7.51 (m, 2H), 7.44-7.40 (m, 3H), 7.33-7.29 (m, 1H), 7.27 (d, *J* = 0.8 Hz, 1H), 7.13 (s, 1H), 7.12-7.08 (m, 1H), 6.79 (d, *J* = 7.8 Hz, 3H), 4.16 (s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.9, 167.3, 146.4, 144.6, 136.6,

134.2, 132.6, 130.1, 129.7, 128.7, 128.2, 127.9, 127.8, 126.7, 123.0, 120.5, 109.4, 36.5. HRMS (ESI, *m*/*z*) calcd for $C_{20}H_{16}N_3O_2$ $[M+H]^+$: 330.1237, found: 330.1237.



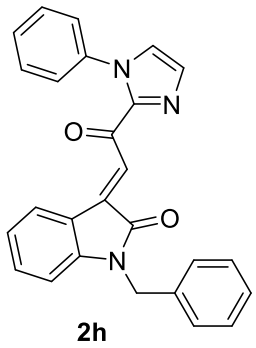
2f

Orange solid, 76 mg, 9% yield, mp = 172-173 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.80-8.77 (m, 1H), 8.49 (s, 1H), 7.47-7.42 (m, 1H), 7.24 (d, *J* = 0.6 Hz, 1H), 7.22-7.18 (m, 1H), 7.14-7.10 (m, 1H), 4.14 (s, 3H), 1.66 (s, 9H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.6, 166.0, 149.0, 144.6, 142.2, 135.3, 132.9, 130.1, 128.1, 128.0, 128.0, 124.4, 120.8, 114.9, 84.5, 36.5, 28.1. HRMS (ESI, *m*/*z*) calcd for $C_{19}H_{20}N_3O_4$ $[M+H]^+$: 354.1448, found: 354.1448.



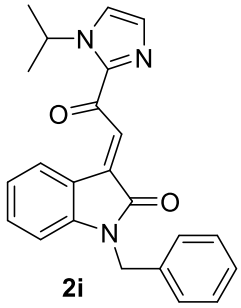
2g

Orange solid, 117 mg, 15% yield, mp = 162-165 °C. **^{1}H NMR (400 MHz, CDCl3):** δ = 8.72 (d, *J* = 7.7 Hz, 1H), 8.49 (s, 1H), 7.38-7.34 (m, 1H), 7.25 (d, *J* = 0.7 Hz, 1H), 7.12 (s, 1H), 7.11-7.07 (m, 1H), 6.69 (d, *J* = 7.8 Hz, 1H), 4.52 (s, 2H), 4,22 (q, *J* = 7.1 Hz, 2H), 4.14 (s, 3H), 1.26 (t, *J* = 7.1 Hz, 3H). **^{13}C NMR (CDCl3, 100 MHz):** δ = 180.8, 167.9, 167.5, 145.1, 144.6, 136.2, 132.7, 130.0, 128.8, 127.9, 127.6, 122.9, 120.6, 108.1, 61.8, 41.5, 36.5, 14.1. HRMS (ESI, m/z) calcd for $C_{17}H_{16}N_3O_4$ $[M+H]^+$: 326.1135, found: 326.1135.



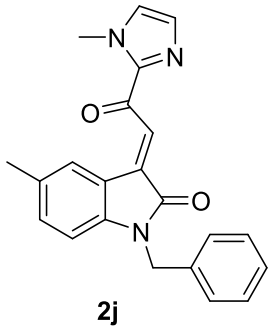
2h

Orange solid, 127 mg, 13% yield, mp = 164-165 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.54 (s, 1H), 8.44 (d, *J* = 7.6 Hz, 1H), 7.53-7.50 (m, 3H), 7.40-7.36 (m, 3H), 7.31-7.28 (m, 4H), 7.25 (d, *J* = 0.9 Hz, 1H), 7.23-7.19 (m, 1H), 6.93-6.89 (m, 1H), 6.65 (d, *J* = 7.8 Hz, 3H), 4.96 (s, 2H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.5, 167.6, 144.5, 143.9, 135.6, 135.2, 132.1, 130.2, 128.9, 128.9, 128.6, 128.1, 128.0, 127.8, 127.2, 121.8, 110.0, 44.0, 36.5. HRMS (ESI, *m*/*z*) calcd for $C_{26}H_{20}N_3O_2$ $[M+H]^+$: 406.1550, found: 406.1550.



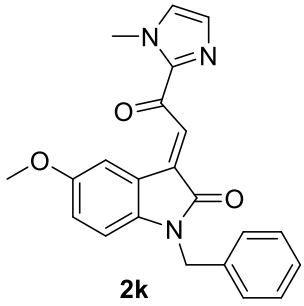
2i

Orange solid, 89 mg, 10% yield, mp = 179-181 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.63 (d, *J* = 7.7 Hz, 1H), 8.56 (s, 1H), 7.35 (d, *J* = 1.0 Hz, 1H), 7.31-7.29 (m, 5H), 7.28-7.23 (m, 2H), 7.04-7.00 (m, 1H), 6.69 (d, *J* = 7.7 Hz, 1H), 5.73 (ddd, J_1 = 20.1 Hz, J_2 = 13.4 Hz, J_3 = 6.7 Hz, 1H), 4.97 (s, 2H), 1.53 (d, *J* = 7.2 Hz, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 181.0, 168.1, 145.5, 143.9, 136.3, 135.7, 132.5, 130.5, 128.8, 128.4, 127.6, 127.3, 122.6, 122.0, 120.7, 109.1, 49.6, 43.8, 23.7. HRMS (ESI, *m*/*z*) calcd for $C_{23}H_{22}N_3O_2$ $[M+H]^+$: 372.1707, found: 372.1706.



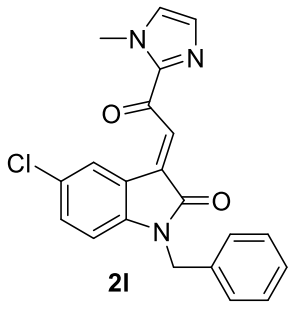
2j

Orange solid, 155 mg, 18% yield, mp = 226-228 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.51 (s, 1H), 8.48 (s, 1H), 7.30-7.28 (m, 4H), 7.27-7.22 (m, 2H), 7.11 (s, 1H), 7.06 (d, *J* = 8.8 Hz, 1H), 6.57 (d, *J* = 8.0 Hz, 1H), 4.94 (s, 2H), 4.16 (s, 3H), 2.34 (s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 181.0, 168.1, 144.6, 143.4, 137.0, 135.7, 133.1, 132.0, 130.0, 129.1, 128.7, 127.8, 127.6, 127.3, 127.2, 120.6, 108.9, 43.8, 36.5, 21.2. HRMS (ESI, *m*/*z*) calcd for $C_{22}H_{20}N_3O_2$ $[M+H]^+$: 358.1550, found: 358.1550.



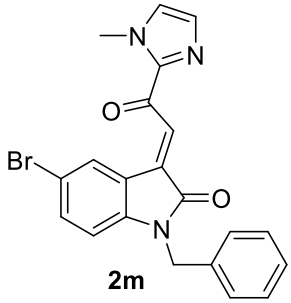
2k

Orange solid, 143 mg, 16% yield, mp = 203-206 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.53 (s, 1H), 8.39 (d, *J* = 2.6 Hz, 1H), 7.31-7.28 (m, 4H), 7.27-7.25 (m, 2H), 7.11 (s, 1H), 6.83-6.80 (m, 1H), 6.56 (d, *J* = 8.5 Hz, 1H), 4.94 (s, 2H), 4.14 (s, 3H), 3.82 (s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.8, 167.9, 155.6, 144.6, 139.4, 137.2, 135.7, 130.0, 128.8, 127.8, 127.7, 127.6, 127.3, 121.4, 117.9, 114.9, 109.4, 55.9, 43.9, 36.5. HRMS (ESI, *m*/*z*) calcd for $C_{22}H_{20}N_3O_3$ $[M+H]^+$: 374.1499, found: 374.1499.



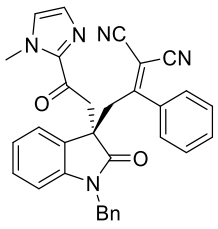
2l

Orange solid, 154 mg, 17% yield, mp = 219-220 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.71 (d, *J* = 2.2 Hz, 1H), 8.57 (s, 1H), 7.34-7.28 (m, 4H), 7.27 (d, *J* = 0.9 Hz, 1H), 7.23 (dd, J_1 = 8.4 Hz, J_2 = 2.2 Hz, 1H), 7.14 (s, 1H), 6.60 (d, *J* = 8.4 Hz, 1H), 4.95 (s, 2H), 4.16 (s, 3H), 3.82 (s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.5, 167.6, 144.5, 143.9, 135.6, 135.2, 132.1, 130.2, 128.9, 128.9, 128.6, 128.1, 128.0, 127.8, 127.2, 121.8, 110.0, 43.9, 36.5. HRMS (ESI, *m*/*z*) calcd for $C_{21}H_{17}ClN_3O_2$ $[M+H]^+$: 378.1004, found: 378.1004.



2m

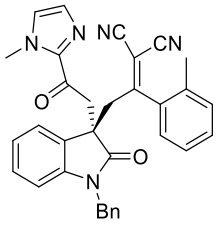
Orange solid, 152 mg, 15% yield, mp = 190-191 °C. **^{1}H NMR (400 MHz, $CDCl_3$):** δ = 8.85 (d, *J* = 2.0 Hz, 1H), 8.57 (s, 1H), 7.38 (dd, J_1 = 8.3 Hz, J_2 = 2.1 Hz, 1H), 7.33-7.27 (m, 5H), 7.14 (s, 1H), 6.56 (d, *J* = 8.4 Hz, 1H), 4.95 (s, 2H), 4.16(s, 3H). **^{13}C NMR ($CDCl_3$, 100 MHz):** δ = 180.4, 167.5, 144.5, 144.4, 135.5, 135.1, 135.0, 131.3, 130.2, 129.0, 128.9, 128.1, 127.8, 127.2, 122.2, 115.3, 110.5, 43.9, 36.5. HRMS (ESI, *m*/*z*) calcd for $C_{21}H_{17}BrN_3O_2$ $[M+H]^+$: 422.0499, found: 422.0499.



3a

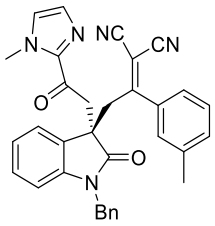
White solid, 48 mg, 94% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 40.59 min, tr (minor) = 11.41 min); $[\alpha]_D^{25}$ = -38.7 (c = 1, CH_2Cl_2); mp = 89.1-89.2 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.51-7.50 (m, 1H), 7.34-7.30 (m, 5H), 7.28-7.26 (m, 1H), 7.25-7.18 (m, 2H), 7.16-7.11 (m, 1H), 7.08 (s, 1H), 7.02-6.97 (m, 3H), 6.94 (s, 1H), 6.46 (d, *J* = 8.00 Hz, 1H), 4.58 (d, *J* = 16.00 Hz, 1H), 4.18 (d, *J* = 17.60 Hz, 1H), 3.76 (s, 3H), 3.74-3.65

(m, 3H), 3.55 (d, *J* = 15.60 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.0, 175.9, 173.8, 142.0, 141.2, 134.3, 132.0, 131.3, 128.4, 128.2, 127.9, 127.4, 127.4, 127.0, 126.4, 126.4, 126.3, 122.5, 121.6, 111.7, 111.3, 108.3, 86.9, 48.7, 44.7, 42.5, 42.4, 34.8. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{26}N_5O_2$ $[M+H]^+$: 512.2081, found: 512.2084.



3b

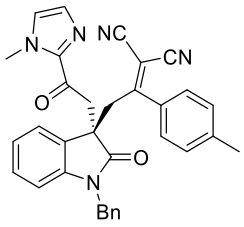
Brown oil, 48 mg, 91% yield, 96% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 33.25 min, tr (minor) = 8.21 min); $[\alpha]_D^{25}$ = -94.84 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.42-7.36(m, 1H), 7.35-7.26 (m, 4H), 7.25-7.16 (m, 3H), 7.15-6.91 (m, 5H), 6.60-6.50 (m, 1H), 6.06 (dd, *J* = 7.6, 1.6 Hz, 1H), 4.67 (dd, *J* = 19.6, 15.6 Hz, 1H), 4.14-4.04 (m, 1H), 3.90-3.79 (m, 2H), 3.79-3.75 (m, 3H), 3.66 (d, *J* = 16.0 Hz, 1H), 3.52 (dd, *J* = 17.6, 15.6 Hz, 1H), 2.33 (s, 2H), 1.67 (s, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.28, 177.96, 176.67, 175.11, 143.41, 142.44, 135.83, 135.36, 133.09, 131.12, 130.90, 129.15, 128.54, 128.47, 127.60, 127.31, 125.71, 125.43, 123.93, 123.59, 122.72, 90.56, 49.96, 45.95, 43.86, 41.82, 35.96, 20.27, 19.06. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{28}N_5O_2$ $[M+H]^+$: 526.2237, found: 526.2240.



3c

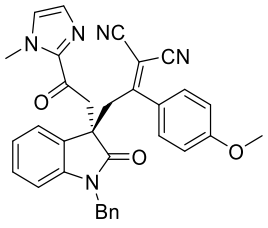
Yellow solid, 49 mg, 93% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 18.87 min, tr (minor) = 9.29 min); $[\alpha]_D^{25}$ = -163.46 (c = 1, CH_2Cl_2); mp = 145.1-145.2 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35-7.30 (m, 3H), 7.29-7.26 (m, 3H), 7.25-7.20 (m, 2H), 7.13 (td, *J* = 7.6, 1.2 Hz, 1H), 7.08 (d, *J* = 0.8 Hz, 1H), 6.98 (td, *J* = 7.2, 0.8 Hz, 1H), 6.94 (s,

1H), 6.83-6.78 (m, 1H), 6.72 (s, 1H), 6.46 (d, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 16.0 Hz, 1H), 4.17 (d, *J* = 17.6 Hz, 1H), 3.77 (s, 3H), 3.72-3.65 (m, 3H), 3.59 (d, *J* = 16.0 Hz, 1H), 2.33 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.1, 175.1, 143.2, 142.3, 138.3, 135.4, 133.1, 133.0, 129.2, 128.9, 128.5, 128.5, 128.3, 127.5, 127.5, 127.3, 125.1, 123.6, 122.5, 112.7, 112.4, 109.1, 87.6, 49.7, 45.7, 43.6, 43.5, 35.9, 21.2. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{28}N_5O_2$ $[M+H]^+$: 526.2237, found: 526.2238.



3d

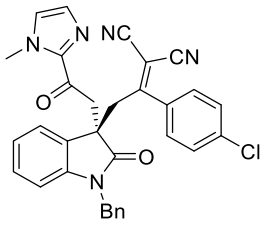
White solid, 47 mg, 90% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 31.03 min, tr (minor) = 9.34 min); $[\alpha]_D^{25}$ = -94.84 (c = 1, CH_2Cl_2); mp = 100.8-100.9 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.32 (d, *J* = 7.8 Hz, 3H), 7.28-7.21 (m, 3H), 7.20 (d, *J* = 8.0 Hz, 2H), 7.16-7.10 (m, 1H), 7.08 (s, 1H), 7.02-6.97 (m, 1H), 6.96-6.90 (m, 3H), 6.46 (d, *J* = 8.0 Hz, 1H), 4.59 (d, *J* = 15.6 Hz, 1H), 4.18 (d, *J* = 17.6 Hz, 1H), 3.77 (s, 3H), 3.72-3.66 (m, 3H), 3.54 (d, *J* = 16.0 Hz, 1H), 2.40 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.0, 174.8, 143.2, 143.0, 142.3, 135.3, 130.3, 129.2, 129.1, 128.9, 128.5, 128.5, 128.1, 127.5, 127.3, 123.6, 122.6, 112.9, 112.6, 109.3, 87.1, 49.8, 45.7, 43.5, 43.4, 35.9, 21.6. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{28}N_5O_2$ $[M+H]^+$: 526.2237, found: 526.2237.



3e

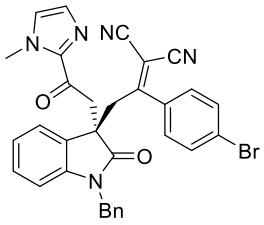
Brown solid, 39 mg, 72% yield, 93% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 43.62 min, tr (minor) = 10.57 min); $[\alpha]_D^{25}$ = -124.02 (c = 1, CH_2Cl_2); mp = 123.5-123.6 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35-7.30 (m, 3H), 7.29-7.26 (m, 1H), 7.25-7.18 (m, 2H), 7.15-7.10

(m, 1H), 7.08 (s, 1H), 7.05-6.98 (m, 3H), 6.94 (s, 1H), 6.89-6.84 (m, 2H), 6.46 (d, *J* = 7.6 Hz, 1H), 4.66 (d, *J* = 16.0 Hz, 1H), 4.19 (d, *J* = 17.6 Hz, 1H), 3.86 (s, 3H), 3.77 (s, 3H), 3.73-3.66 (m, 3H), 3.62 (d, *J* = 16.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.2, 174.0, 163.0, 143.0, 142.3, 135.3, 130.3, 129.2, 128.9, 128.6, 128.5, 127.5, 127.5, 127.3, 125.3, 123.6, 122.6, 113.9, 113.2, 113.0, 109.3, 85.8, 55.6, 49.9, 45.8, 43.6, 43.2, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{28}N_5O_3$ $[M+H]^+$: 542.2187, found: 542.2190.



3f

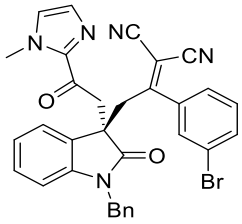
Gray solid, 53 mg, 97% yield, 98% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 50.34 min, tr (minor) = 10.59 min); $[\alpha]_D^{25}$ = -114.32 (c = 1, CH_2Cl_2); mp = 195.4-195.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36-7.26 (m, 7H), 7.26-7.21 (m, 1H), 7.15 (td, *J* = 8.0, 1.2 Hz, 1H), 7.08 (d, *J* = 1.2 Hz, 1H), 7.02-6.97 (m, 1H), 6.95 (s, 1H), 6.94-6.89 (m, 2H), 6.50 (d, *J* = 8.0 Hz, 1H), 4.67 (d, *J* = 15.6 Hz, 1H), 4.17 (d, *J* = 17.6 Hz, 1H), 3.78 (s, 3H), 3.76-3.63 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.0, 176.9, 173.4, 143.0, 142.2, 138.6, 135.1, 131.4, 129.4, 129.3, 129.0, 128.7, 128.6, 128.4, 127.6, 127.6, 127.4, 123.7, 122.7, 112.4, 112.1, 109.4, 88.3, 49.8, 45.8, 43.6, 43.3, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{25}ClN_5O_2$ $[M+H]^+$: 546.1691, found: 546.1694.



3g

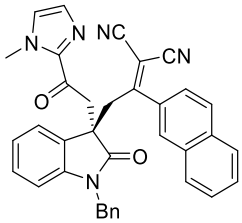
Brown solid, 56 mg, 95% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 50.25 min, tr (minor) = 10.74 min); $[\alpha]_D^{25}$ = -86.02 (c = 1, CH_2Cl_2); mp = 210.2-210.3 °C. ^{1}H NMR (400

MHz, $CDCl_3$): δ = 7.51-7.45 (m, 2H), 7.37-7.33 (m, 2H), 7.32-7.21(m, 4H), 7.14 (td, *J* = 7.6, 1.2 Hz, 1H), 7.08 (d, *J* = 0.8 Hz, 1H), 6.99 (td, *J* = 7.6, 0.8 Hz, 1H), 6.95 (s, 1H), 6.87-6.80 (m, 2H), 6.49 (d, *J* = 8.0 Hz, 1H), 4.67 (d, *J* = 16.0 Hz, 1H), 4.17 (d, *J* = 17.6 Hz, 1H), 3.77 (s, 3H), 3.75-3.62 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.0, 176.9, 173.5, 143.0, 142.2, 135.1, 131.8, 131.7, 129.5, 129.3, 129.0, 128.6, 128.4, 127.6, 127.6, 127.4, 127.1, 123.7, 122.7, 112.4, 112.1, 109.4, 88.3, 49.7, 45.8, 43.6, 43.3, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{25}BrN_5O_2$ $[M+H]^+$: 590.1186, found: 590.1187.



3h

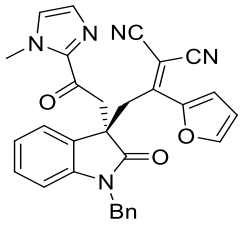
Brown oil, 56 mg, 95% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 20.64 min, tr (minor) = 10.52 min); $[\alpha]_D^{25}$ = -47.90 (c = 1, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ = 7.59-7.53 (m, 1H), 7.37 (d, *J* = 7.2 Hz, 2H), 7.32-7.19 (m, 5H), 7.16 (td, *J* = 7.6, 1.2 Hz, 1H), 7.08 (s, 1H), 7.01-6.89 (m, 4H), 6.57 (d, *J* = 8.0 Hz, 1H), 4.68 (d, *J* = 15.6 Hz, 1H), 4.16 (d, *J* = 17.6 Hz, 1H), 3.81 (d, *J* = 15.6 Hz, 1H), 3.78(s, 3H), 3.74-3.61 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.0, 176.9, 173.1, 143.0, 142.2, 135.2, 135.1, 134.8, 130.6, 130.0, 129.3, 129.2, 128.6, 128.3, 127.7, 127.6, 127.4, 126.5, 123.7, 122.7, 122.4, 112.2, 111.7, 109.4, 89.0, 49.7, 45.7, 43.7, 43.4, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{25}BrN_5O_2$ $[M+H]^+$: 590.1186, found: 590.1187.



3i

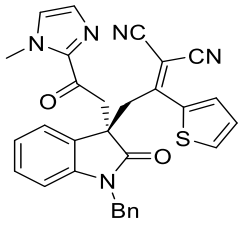
Yellow solid, 53 mg, 94% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 50.44 min, tr (minor) = 10.92 min); $[\alpha]_D^{25}$ = -87.22 (c = 1, CH_2Cl_2); mp = 218.8-218.9 °C. ^1H NMR (400

MHz, $CDCl_3$): δ = 7.87-7.76 (m, 3H), 7.65-7.54 (m, 2H), 7.37-7.25 (m, 2H), 7.19 -7.05 (m, 8H), 7.02-6.96 (m, 1H), 6.91 (s, 1H), 6.32 (d, *J* = 8.0 Hz, 1H), 4.19 (d, *J* = 17.2 Hz, 2H), 3.82 (dd, *J* = 14.0, 16.8 Hz, 2H), 3.74 (s, 3H), 3.70 (d, *J* = 17.2 Hz, 1H), 2.92 (d, *J* = 15.6 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.0, 175.0, 143.1, 142.2, 135.2, 134.7, 132.0, 130.3, 129.2, 129.0, 128.9, 128.7, 128.5, 128.4, 128.2, 127.7, 127.4, 127.3, 124.2, 123.6, 122.6, 112.8, 112.5, 109.2, 87.7, 49.7, 45.8, 43.4, 43.2, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{36}H_{28}N_5O_2$ $[M+H]^+$: 562.2237, found: 526.2239



3j

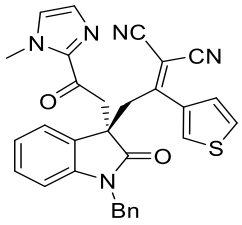
Yellow solid, 47 mg, 94% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 24.91 min, tr (minor) = 16.73 min); $[\alpha]_D^{25}$ = -15.78 (c = 1, CH_2Cl_2); mp = 174.2-174.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.58 (d, *J* = 1.8 Hz, 1H), 7.35-7.22 (m, 7H), 7.16-7.09 (m, 2H), 7.01-6.92 (m, 2H), 6.60 (d, J = 7.6 Hz, 1H), 6.56-6.50 (m, 1H), 4.92 (d, *J* = 16.0 Hz, 1H), 4.56 (d, *J* = 15.6 Hz, 1H), 4.30 (d, *J* = 18.0 Hz, 1H), 3.82-3.74 (m, 1H), 3.80 (s, 3H), 3.50 (dd, *J* = 13.2, 16.0 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.2, 177.9, 154.4, 148.3, 147.9, 143.2, 142.3, 135.6, 129.3, 128.9, 128.6, 127.5, 127.3, 127.2, 123.8, 122.4, 121.2, 113.9, 113.6, 113.3, 109.4, 80.4, 50.5, 45.2, 44.2, 40.7, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{30}H_{24}N_5O_3$ $[M+H]^+$: 502.1874, found: 502.1875.



3k

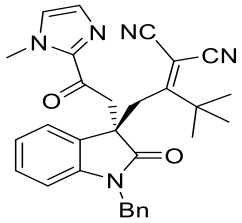
Brown solid, 38 mg, 74% yield, 96% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 45.69 min, tr (minor) = 16.85 min); $[\alpha]_D^{25}$ = -108.48 (c = 1, CH_2Cl_2); mp = 149.2-149.3 °C. ^{1}H NMR (400

MHz, $CDCl_3$): δ = 7.65 (dd, *J* = 5.2, 1.2 Hz, 1H), 7.47 (dd, *J* = 4.0, 1.2 Hz, 1H), 7.36-7.31 (m, 2H), 7.31-7.26(m, 3H), 7.26-7.23(m, 1H), 7.16-7.09 (m, 3H), 7.00-6.94 (m, 2H), 6.52 (d, *J* = 7.6 Hz, 1H), 4.83 (d, *J* = 16.0 Hz, 1H), 4.26 (d, *J* = 18.0 Hz, 1H), 4.04 (d, *J* = 16.0 Hz, 1H), 3.82 -3.75 (m, 1H), 3.78 (s, 3H), 3.62 (dd, *J* = 24.0, 13.6 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.5, 163.5, 143.0, 142.2, 135.6, 135.4, 133.8, 133.4, 129.3, 129.0, 128.5, 128.4, 127.4, 127.2, 123.7, 122.5, 113.4, 113.3, 109.4, 83.6, 50.5, 45.4, 44.5, 43.8, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{30}H_{24}N_5O_2S$ $[M+H]^+$: 518.1645, found: 518.1645.



3l

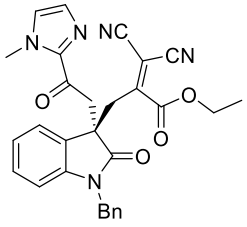
Brown oil, 44 mg, 85% yield, 94% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 51.10 min, tr (minor) = 17.22 min); $[\alpha]_D^{25}$ = -101.76 (c = 1, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ = 7.53-7.48 (m, 1H), 7.37-7.20 (m, 7H), 7.15-7.08 (m, 2H), 7.03-6.96 (m, 2H), 6.95 (s, 1H), 6.49 (d, *J* = 8.0 Hz, 1H), 4.81 (d, *J* = 16.0 Hz, 1H), 4.21 (d, *J* = 17.6 Hz, 1H), 3.83 (d, *J* = 16.0 Hz, 1H), 3.77 (s, 3H), 3.79-3.71 (m, 1H), 3.64 (dd, *J* = 22.8, 13.6 Hz, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 177.4, 167.1, 142.9, 142.2, 135.4, 134.2, 131.1, 129.3, 128.9, 128.5, 127.5, 127.5, 127.3, 127.0, 126.7, 123.5, 122.6, 113.1, 112.9, 109.3, 85.6, 50.1, 45.7, 43.8, 43.6, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{30}H_{24}N_5O_2S$ $[M+H]^+$: 518.1645, found: 518.1642.



3m

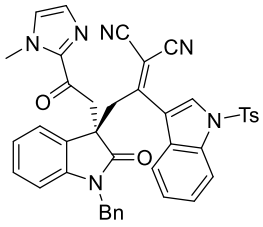
Brown oil, 30 mg, 61% yield, 80% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 28.68 min, tr (minor)

= 8.94 min); $[\alpha]_D^{25}$ = -41.86 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50 (d, *J* = 7.2 Hz, 2H), 7.35-7.26 (m, 3H), 7.26-7.22 (m, 1H), 7.19 (td, *J* = 7.6, 1.2 Hz, 1H), 7.10 (d, *J* = 1.2 Hz, 1H), 7.01-6.96 (m, 1H), 6.95 (s, 1H), 6.79 (d, *J* = 7.6 Hz, 1H), 5.16 (d, *J* = 15.6 Hz, 1H), 4.79 (d, *J* = 15.6 Hz, 1H), 4.45 (d, *J* = 17.2 Hz, 1H), 3.79-3.73 (m, 1H), 3.76 (s, 3H), 3.27 (s, 2H), 1.20 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 188.4, 187.4, 178.3, 143.4, 142.4, 135.5, 129.6, 129.4, 129.0, 128.6, 127.9, 127.6, 127.3, 124.2, 122.6, 113.6, 112.8, 109.7, 90.5, 50.6, 46.5, 44.6, 42.6, 38.8, 35.9, 29.4. HRMS (ESI, *m*/*z*) calcd for $C_{30}H_{30}N_5O_2$ $[M+H]^+$: 492.2394, found: 492.2392.



3n

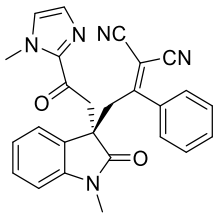
Brown oil, 11 mg, 21% yield, 85% ee (HPLC: chiralpak IC column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 20.10 min, tr (minor) = 17.06 min); $[\alpha]_D^{25}$ = +0.34 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48-7.42 (m, 2H), 7.39-7.34 (m, 2H), 7.31-7.26 (m, 1H), 7.22-7.14 (m, 2H), 7.11-7.08 (m, 1H), 6.99-6.94 (m, 2H), 6.73 (d, *J* = 8.0 Hz, 1H), 4.97 (dd, *J* = 15.6, 4.4 Hz, 2H), 4.28 (d, *J* = 17.6 Hz, 1H), 4.14-4.05 (m, 1H), 4.01-3.89 (m, 1H), 3.79(s, 3H), 3.71 (d, *J* = 17.6 Hz, 1H), 3.44 (d, *J* = 1.6 Hz, 2H), 1.19 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.0, 176.9, 162.3, 161.6, 143.5, 142.2, 135.5, 129.4, 129.2, 128.8, 128.1, 127.7, 127.5, 127.3, 123.9, 122.5, 110.6, 110.2, 109.7, 94.1, 63.8, 49.9, 44.8, 44.4, 40.7, 35.9, 13.5. HRMS (ESI, *m*/*z*) calcd for $C_{29}H_{26}N_5O_4$ $[M+H]^+$: 508.1979, found: 508.1980.



3o

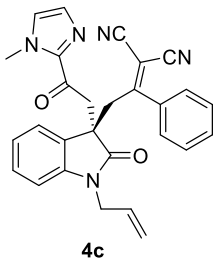
Yellow oil, 63 mg, 89% yield, 96% ee (HPLC: chiralpak AD-H column, 254 nm,

hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 18.49 min, tr (minor) = 11.13 min); $[\alpha]_D^{25}$ = +116.92 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.05 (d, *J* = 8.4 Hz, 2H), 7.97 (d, *J* = 8.4 Hz, 1H), 7.81 (s, 1H), 7.44-7.35 (m, 2H), 7.27-7.09 (m, 8H), 7.06 (td, *J* = 7.6, 0.8 Hz, 1H), 7.00-6.90 (m, 3H), 6.58 (d, *J* = 8.0 Hz, 1H), 6.07 (d, *J* = 8.0 Hz, 1H), 4.30 (d, *J* = 17.6 Hz, 1H), 3.85-3.75 (m, 2H), 3.73 (s, 3H), 3.59 (d, *J* = 13.2 Hz, 1H), 3.25 (d, *J* = 15.6 Hz, 1H), 2.01-1.94 (m, 4H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.9, 177.5, 166.0, 146.5, 142.3, 142.1, 134.9, 134.0, 133.5, 130.2, 129.3, 129.3, 128.7, 128.3, 128.3, 128.2, 127.4, 127.2, 127.0, 125.8, 125.6, 123.6, 123.5, 122.6, 121.5, 114.5, 113.3, 113.0, 112.3, 109.9, 87.1, 50.3, 45.6, 45.5, 42.1, 35.8, 21.2. HRMS (ESI, *m*/*z*) calcd for $C_{41}H_{33}N_6O_4S$ $[M+H]^+$: 705.2278, found: 705.2275.



4b

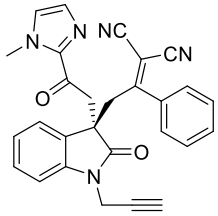
Orange solid, 42 mg, 96% yield, 96% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 54.04 min, tr (minor) = 8.98 min); $[\alpha]_D^{25}$ = -74.70 (c = 1, CH_2Cl_2); mp = 173.2-173.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35 (t, *J* = 7.6 Hz, 1H), 7.29-7.22 (m, 3H), 7.22-7.18 (m, 1H), 7.01-6.95 (m, 2H), 6.88 (d, *J* = 9.6 Hz, 3H), 6.54 (d, *J* = 8.0 Hz, 1H), 4.06 (d, *J* = 18.0 Hz, 1H), 3.67 (s, 3H), 3.66-3.53 (m, 3H), 2.47 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 176.9, 175.2, 144.0, 142.2, 132.8, 132.2, 129.2, 129.1, 128.4, 128.3, 128.0, 127.3, 123.5, 122.5, 112.7, 112.3, 108.2, 87.7, 49.5, 45.9, 43.0, 35.9, 25.7. HRMS (ESI, *m*/*z*) calcd for $C_{26}H_{22}N_5O_2$ $[M+H]^+$: 436.1768, found: 436.1767.



4c

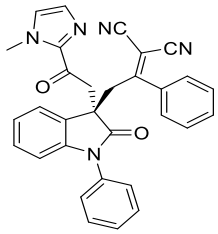
Gray solid, 45 mg, 98% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm,

hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 31.70 min, tr (minor) = 7.62 min); $[\alpha]_D^{25}$ = -115.02 (c = 1, CH_2Cl_2); mp = 165.1-165.2 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46 (t, *J* = 7.6 Hz, 1H), 7.34 (t, *J* = 7.6 Hz, 3H), 7.27-7.22 (m, 1H), 7.08-7.02 (m, 2H), 7.01-6.96 (m, 2H), 6.94 (s, 1H), 6.62 (d, *J* = 8.0 Hz, 1H), 5.64-5.53 (m, 1H), 5.34-5.27 (m, 1H), 5.16-5.11 (m, 1H), 4.15 (d, *J* = 17.6 Hz, 1H), 3.93-3.86 (m, 1H), 3.76 (s, 3H), 3.74-3.63 (m, 3H), 3.24-3.16 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 176.7, 175.0, 143.2, 142.2, 133.0, 132.3, 131.1, 129.2, 128.9, 128.4, 128.4, 128.0, 127.2, 123.5, 122.5, 117.6, 112.7, 112.3, 109.2, 87.8, 49.6, 46.0, 43.2, 42.1, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{28}H_{24}N_5O_2$ $[M+H]^+$: 462.1924, found: 462.1923.



4d

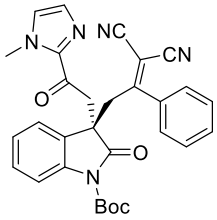
Brown solid, 38 mg, 82% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 35.41 min, tr (minor) = 9.05 min); $[\alpha]_D^{25}$ = -31.84 (c = 1, CH_2Cl_2); mp = 146.5-146.6 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.42 (t, *J* = 7.6 Hz, 1H), 7.33-7.26 (m, 4H), 7.08-7.02 (m, 2H), 7.00-6.95 (m, 2H), 6.94 (s, 1H), 6.88 (d, *J* = 7.6 Hz, 1H), 4.17-4.05 (m, 2H), 3.77 (s, 3H), 3.74-3.61 (m, 3H), 3.56 (dd, *J* = 17.6, 2.6 Hz, 1H), 2.21 (t, *J* = 2.5 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.9, 176.1, 174.6, 142.2, 133.1, 132.2, 129.2, 129.1, 128.4, 128.2, 127.9, 127.3, 123.8, 123.0, 112.6, 112.3, 109.2, 87.9, 76.4, 72.5, 49.6, 46.1, 43.0, 35.9, 29.0. HRMS (ESI, *m*/*z*) calcd for $C_{28}H_{22}N_5O_2$ $[M+H]^+$: 460.1768, found: 460.1769.



4e

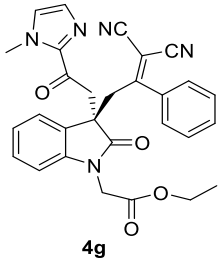
Brown solid, 48 mg, 96% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 55.70 min, tr (minor)

= 10.16 min); $[\alpha]_D^{25}$ = -87.64 (c = 1, CH_2Cl_2); mp = 150.1-150.2 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48 (t, *J* = 7.2 Hz, 1H), 7.42-7.36 (m, 4H), 7.35-7.25 (m, 2H), 7.20 (t, *J* = 8.0 Hz, 1H), 7.13-7.05 (m, 4H), 6.94 (s, 1H), 6.91 (d, *J* = 7.6 Hz, 2H), 6.65 (d, *J* = 8.0 Hz, 1H), 4.25 (d, *J* = 17.6 Hz, 1H), 3.85-3.74 (m, 2H), 3.78 (s, 3H), 3.69 (d, *J* = 17.6 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.2, 176.8, 175.0, 144.3, 142.2, 134.2, 133.4, 132.5, 129.3, 129.2, 129.0, 128.8, 128.3, 128.1, 127.9, 127.3, 126.1, 123.8, 123.0, 112.9, 112.4, 109.6, 88.2, 49.8, 47.1, 43.1, 36.0. HRMS (ESI, *m*/*z*) calcd for $C_{31}H_{24}N_5O_2$ $[M+H]^+$: 498.1924, found: 498.1923.



4f

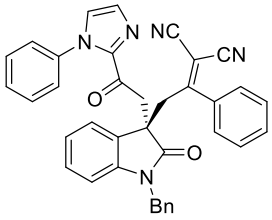
Brown solid, 51 mg, 97% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 17.35 min, tr (minor) = 5.20 min); $[\alpha]_D^{25}$ = -100.16 (c = 1, CH_2Cl_2); mp = 100.2-100.3 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.73-7.68 (m, 1H), 7.47-7.42 (m, 1H), 7.36-7.32 (m, 2H), 7.32-7.26 (m, 2H), 7.16 (td, *J* = 7.6, 1.2 Hz, 1H), 7.08 (d, *J* = 0.8 Hz, 1H), 6.98-6.93 (m, 3H), 4.20 (d, *J* = 18.0 Hz, 1H), 3.78-3.73 (m, 1H), 3.75 (s, 3H), 3.71-3.66 (m, 2H), 1.52 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.6, 176.1, 174.6, 148.3, 142.0, 140.4, 132.6, 132.6, 129.3, 129.3, 128.6, 128.0, 127.3, 127.3, 124.5, 123.0, 115.2, 112.6, 112.1, 88.1, 83.8, 49.9, 47.6, 44.2, 35.9, 28.0. HRMS (ESI, *m*/*z*) calcd for $C_{30}H_{28}N_5O_4$ $[M+H]^+$: 522.2136, found: 522.2136.



4g

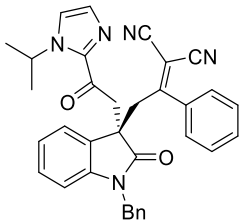
Brown oil, 37 mg, 73% yield, 93% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 30.05 min, tr (minor)

= 10.00 min); $[\alpha]_D^{25}$ = +2.60 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.44-7.38 (m, 1H), 7.33-7.26 (m, 2H), 7.25-7.18 (m, 2H), 7.06 (d, *J* = 0.8 Hz, 1H), 7.03-6.98 (m, 2H), 6.97-6.91 (m, 2H), 6.55 (d, *J* = 7.6, 1H), 4.20 (q, *J* = 7.2 Hz, 2H), 4.10 (d, *J* = 17.6 Hz, 1H), 4.01 (d, *J* = 17.6 Hz, 1H), 3.81 (s, 3H), 3.80-3.66 (m, 2H), 3.65-3.55 (m, 2H), 1.25 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.0, 176.8, 174.3, 167.2, 142.5, 142.3, 133.6, 132.0, 129.2, 128.9, 128.4, 128.1, 127.9, 127.3, 124.2, 122.9, 112.5, 112.4, 108.4, 88.2, 61.7, 49.7, 45.4, 43.1, 41.2, 36.0, 14.1. HRMS (ESI, *m*/*z*) calcd for $C_{29}H_{26}N_5O_4$ $[M+H]^+$: 508.1979, found: 508.1982.



4h

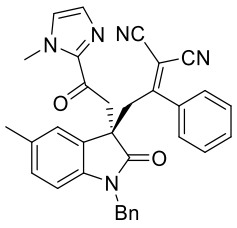
Brown solid, 56 mg, 97% yield, 94% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 35.85 min, tr (minor) = 12.70 min); $[\alpha]_D^{25}$ = -143.34 (c = 1, CH_2Cl_2); mp = 190.4-190.5 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.47 (t, *J* = 7.2 Hz, 1H), 7.40-7.33 (m, 3H), 7.29 (d, *J* = 6.8 Hz, 2H), 7.26-7.23 (m, 1H), 7.22 (s, 1H), 7.18-7.02 (m, 8H), 7.02-6.98 (m, 2H), 6.96 (d, *J* = 8.0 Hz, 2H), 6.34 (d, *J* = 8.0 Hz, 1H), 4.55 (d, *J* = 16.0 Hz, 1H), 4.29 (d, *J* = 16.8 Hz, 1H), 3.70 (s, 2H), 3.64 (d, *J* = 17.2 Hz, 1H), 3.42 (d, *J* = 16.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 185.6, 176.8, 174.7, 143.0, 142.3, 137.8, 135.0, 133.0, 132.3, 129.8, 128.9, 128.8, 128.5, 128.4, 128.2, 128.0, 127.4, 127.2, 127.1, 125.6, 123.5, 122.5, 112.7, 112.3, 109.5, 87.9, 50.0, 45.7, 43.7, 43.4. HRMS (ESI, *m*/*z*) calcd for $C_{37}H_{28}N_5O_2$ $[M+H]^+$: 574.2237, found: 574.2237.



4i

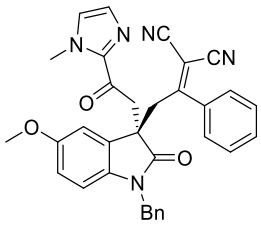
Brown solid, 37 mg, 68% yield, 92% ee (HPLC: chiralpak AD-H column, 254 nm,

hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 16.85 min, tr (minor) = 9.38 min); $[\alpha]_D^{25}$ = -76.86 (c = 1, CH_2Cl_2); mp = 143.9-144.0 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.51-7.45 (m, 1H), 7.37 (t, *J* = 8.0 Hz, 2H), 7.35-7.29 (m, 3H), 7.28-7.24 (m, 2H), 7.24-7.20 (m, 1H), 7.17 (d, *J* = 0.8 Hz, 1H), 7.15-7.10 (m, 2H), 7.03-6.95 (m, 3H), 6.45 (d, *J* = 8.0 Hz, 1H), 5.20-5.11 (m, 1H), 4.59 (d, *J* = 16.0 Hz, 1H), 4.21 (d, *J* = 17.2 Hz, 1H), 3.77-3.66 (m, 3H), 3.55 (d, *J* = 15.6 Hz, 1H), 1.30 (d, *J* = 6.4 Hz, 3H), 1.19 (d, *J* = 6.4 Hz, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.2, 177.0, 174.9, 143.0, 141.7, 135.4, 133.1, 132.3, 129.7, 128.9, 128.4, 128.0, 127.5, 127.4, 123.7, 122.5, 121.5, 112.7, 112.3, 109.3, 87.9, 50.0, 49.2, 46.3, 43.5, 43.5, 23.5, 23.2. HRMS (ESI, *m*/*z*) calcd for $C_{34}H_{30}N_5O_2$ $[M+H]^+$: 540.2394, found: 540.2398.



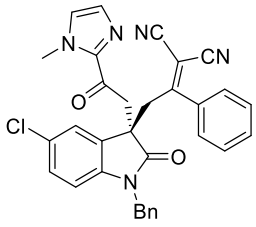
4j

Brown oil, 49 mg, 93% yield, 94% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 32.43 min, tr (minor) = 9.80 min); $[\alpha]_D^{25}$ = -91.56 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.51-7.45 (m, 1H), 7.37 (t, *J* = 7.6 Hz, 2H), 7.32 (d, *J* = 7.2 Hz, 2H), 7.29-7.26 (m, 1H), 7.26-7.18 (m, 2H), 7.10 (d, *J* = 7.2 Hz, 2H), 7.05-7.00 (m, 2H), 6.96-6.90 (m, 2H), 6.37 (d, *J* = 8.0 Hz, 1H), 4.54 (d, *J* = 15.6 Hz, 1H), 4.16 (d, *J* = 17.6 Hz, 1H), 3.78 (d, *J* = 2.0 Hz, 3H), 3.70 (d, *J* = 18.0 Hz, 3H), 3.58 (d, *J* = 15.6 Hz, 1H), 2.27 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 176.7, 174.8, 142.3, 140.5, 135.5, 133.2, 132.2, 129.2, 129.2, 128.5, 128.4, 128.4, 128.0, 127.5, 127.4, 127.2, 124.4, 112.7, 112.4, 109.0, 87.9, 49.9, 45.8, 43.7, 43.5, 35.9, 21.1. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{27}N_5O_2Na^+$ $[M+Na]^+$: 548.2057, found: 548.2055.



4k

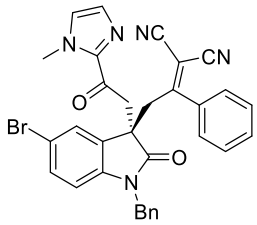
Yellow solid, 49 mg, 91% yield, 97% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 49.52 min, tr (minor) = 14.88 min); $[\alpha]_D^{25}$ = -100.42 (c = 1, CH_2Cl_2); mp = 165.9-166.0 ^oC. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.49 (t, *J* = 7.6 Hz, 1H), 7.38 (t, *J* = 8.0 Hz, 2H), 7.33-7.29 (m, 2H), 7.28-7.26 (m, 1H), 7.26-7.18 (m, 2H), 7.09 (s, 1H), 7.07-7.02 (m, 2H), 6.95 (d, *J* = 3.2 Hz, 2H), 6.66 (dd, *J* = 8.4, 2.4 Hz, 1H), 6.37 (d, *J* = 8.4 Hz, 1H), 4.55 (d, *J* = 16.0 Hz, 1H), 4.17 (d, *J* = 17.6 Hz, 1H), 3.78 (s, 3H), 3.75 (s, 3H), 3.72-3.66 (m, 3H), 3.53 (d, *J* = 16.0 Hz, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 187.1, 176.5, 174.9, 155.7, 142.3, 136.2, 135.4, 133.1, 132.3, 129.5, 129.2, 128.5, 128.4, 128.0, 127.5, 127.4, 127.3, 114.3, 112.9, 112.4, 110.0, 109.9, 87.9, 55.7, 50.3, 45.7, 43.5, 43.5, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{33}H_{28}N_5O_3$ $[M+H]^+$: 542.2187, found: 542.2186.



4l

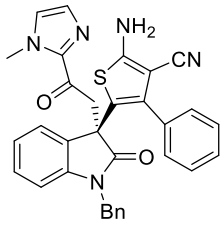
Brown oil, 44 mg, 80% yield, 94% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 25.88 min, tr (minor) = 9.68 min); $[\alpha]_D^{25}$ = -38.00 (c = 1, CH_2Cl_2). ^1H NMR (400 MHz, $CDCl_3$): δ = 7.47 (t, *J* = 7.2 Hz, 1H), 7.39-7.30 (m, 5H), 7.30-7.27 (m, 1H), 7.27-7.24 (m, 1H), 7.21 (d, *J* = 2.0 Hz, 1H), 7.10 (s, 1H), 7.09-7.02 (m, 3H), 6.97 (s, 1H), 6.41 (d, *J* = 8.4 Hz, 1H), 4.64 (d, *J* = 15.6 Hz, 1H), 4.13 (d, *J* = 18.0 Hz, 1H), 3.82-3.76 (m, 1H), 3.80 (s, 3H), 3.73-3.64 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.8, 176.5, 173.9, 142.0, 141.6, 134.9, 133.2, 132.4, 130.4, 129.4, 128.8, 128.6, 128.5, 128.0, 127.9, 127.7, 127.6, 127.4, 124.2, 112.4, 112.3, 110.2, 88.2, 49.9, 45.7, 43.8, 43.3, 35.9. HRMS (ESI, *m*/*z*) calcd

for $C_{32}H_{25}ClN_5O_2$ $[M+H]^+$: 546.1691, found: 546.1692.



4m

Brown oil, 55 mg, 94% yield, 95% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 29.45 min, tr (minor) = 10.22 min); $[\alpha]_D^{25}$ = -21.60 (c = 1, CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46 (t, *J* = 6.8 Hz, 1H), 7.37-7.31 (m, 5H), 7.31-7.23 (m, 3H), 7.20 (dt, *J* = 10.0, 1.6 Hz, 1H), 7.08 (s, 1H), 7.02 (d, *J* = 7.6 Hz, 2H), 6.96 (s, 1H), 6.36 (d, *J* = 8.4 Hz, 1H), 4.63 (d, *J* = 16.0 Hz, 1H), 4.13 (d, *J* = 18.0 Hz, 1H), 3.82 (d, *J* = 16.0 Hz, 1H), 3.77 (s, 3H), 3.73-3.61 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.8, 176.4, 173.9, 142.1, 142.0, 134.9, 133.3, 132.4, 131.7, 130.7, 129.4, 128.7, 128.6, 127.9, 127.7, 127.6, 127.5, 126.9, 115.2, 112.4, 112.3, 110.7, 88.2, 49.9, 45.7, 43.8, 43.4, 35.9. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{25}BrN_5O_2$ $[M+H]^+$: 590.1186, found: 590.1188.



5a

Brown solid, 24 mg, 45% yield, 86% ee (HPLC: chiralpak AD-H column, 254 nm, hexane/isopropanol = 70:30, flow rate 1.0 mL/min, tr (major) = 19.47 min, tr (minor) = 10.91 min); $[\alpha]_D^{25}$ = +2.59 (c = 1, CH_2Cl_2); mp = 219.7-219.8 ºC. ^{1}H NMR (400 MHz, $CDCl_3$): δ =δ 7.42 (d, *J* = 7.2 Hz, 2H), 7.32-7.22 (m, 4H), 7.18-7.03 (m, 6H), 6.97 (t, *J* = 8.0 Hz, 1H), 6.89 (s, 1H), 6.75 (t, *J* = 7.6 Hz, 1H), 6.39 (d, *J* = 8.0 Hz, 1H), 5.00 (s, 2H), 4.91 (d, *J* = 16.0 Hz, 1H), 4.51 (d, *J* = 16.8 Hz, 1H), 4.21 (d, *J* = 16.0 Hz, 1H), 3.77 (d, *J* = 16.8 Hz, 1H), 3.68 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 186.89, 176.68, 159.26, 143.26, 137.56, 135.74, 133.58, 131.32, 129.11, 128.48, 127.87, 127.77, 127.67, 127.44, 127.15, 124.58, 122.55, 122.31, 114.92, 109.19, 93.19, 51.04, 45.58,

44.35, 35.84. HRMS (ESI, *m*/*z*) calcd for $C_{32}H_{25}N_5O_2SNa^+$ $[M+Na]^+$: 566.1621, found: 566.1616.

III References

(1) Wang, C.; Chen, L.-A.; Huo, H.; Shen, X.; Harms, K.; Gong, L.; Meggers, E. *Chem. Sci.* **2015**, *6*, 1094-1100.

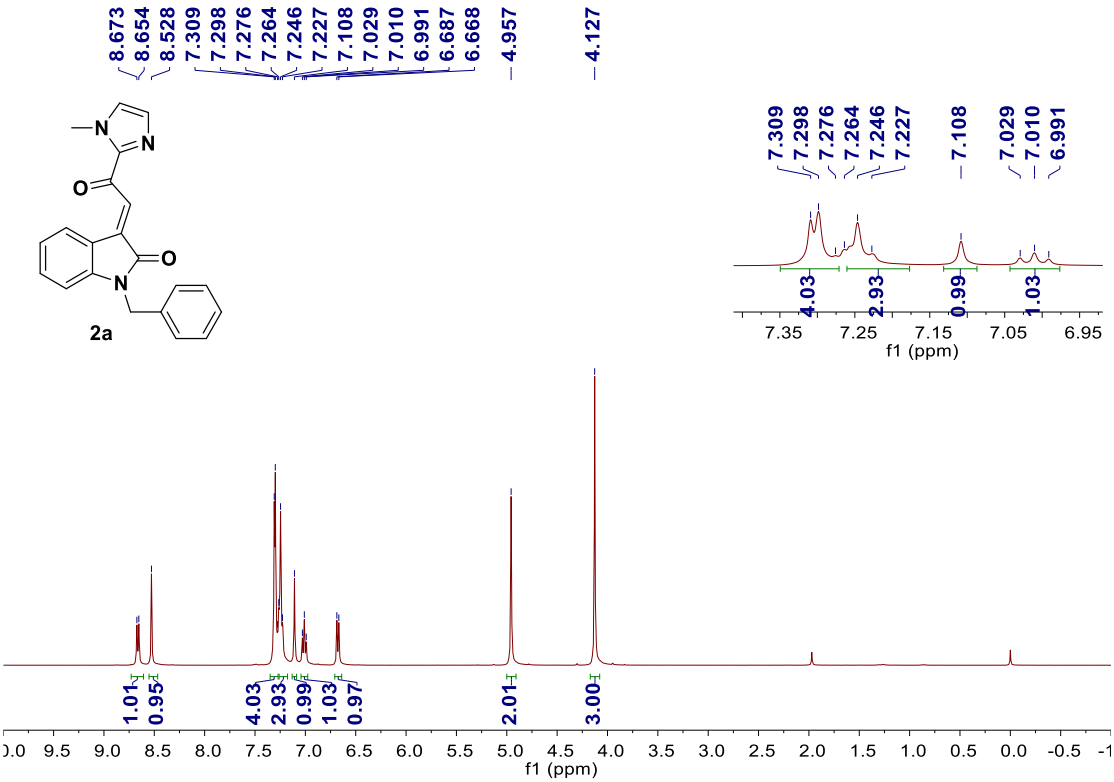
(2) Huo, H.; Fu, C.; Harms, K.; Meggers, E. *J. Am. Chem. Soc*. **2014**, *136*, 2990-2993.

(3) D. A. Evans.; K. R. Fandrick.; H. J. Song. *J. Am. Chem. Soc*. **2005**, *127*, 8942-8943.

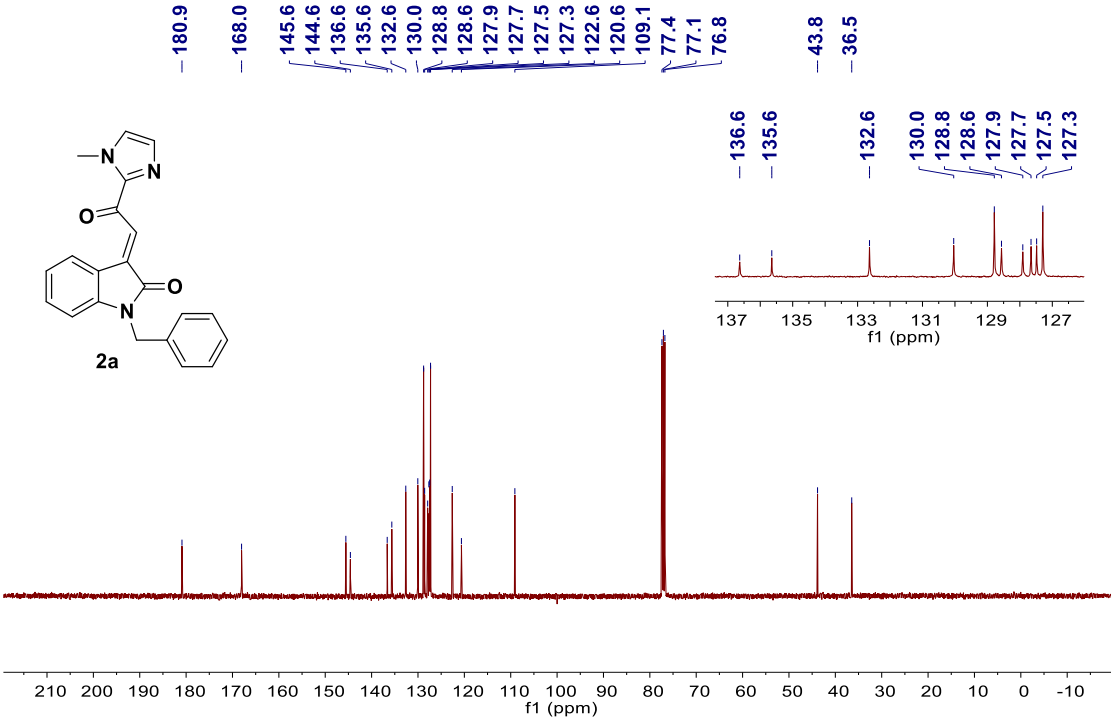
(4) Pan, H.; Han, M.-Y.; Li, P.-H.; Wang, L. *J. Org. Chem.* **2019**, *84*, 14281-14290.

IV NMR Spectrum

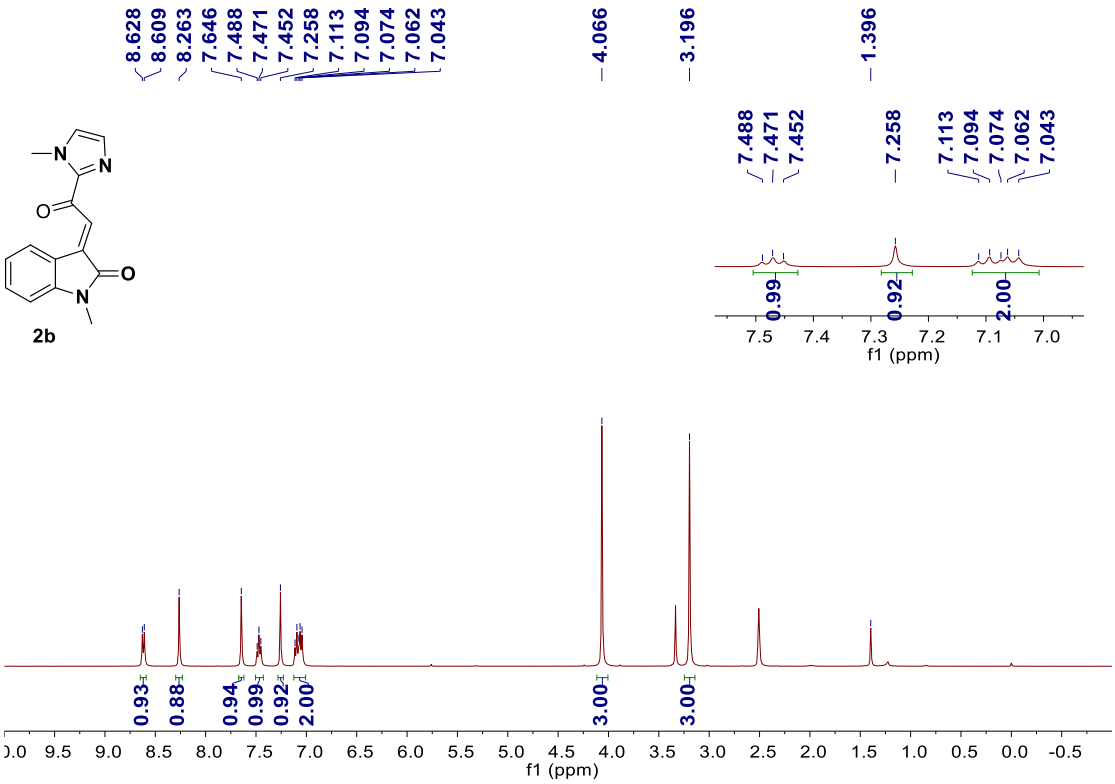
^{1}H-NMR-2a



^{13}C-NMR-2a



^{1}H-NMR-2b



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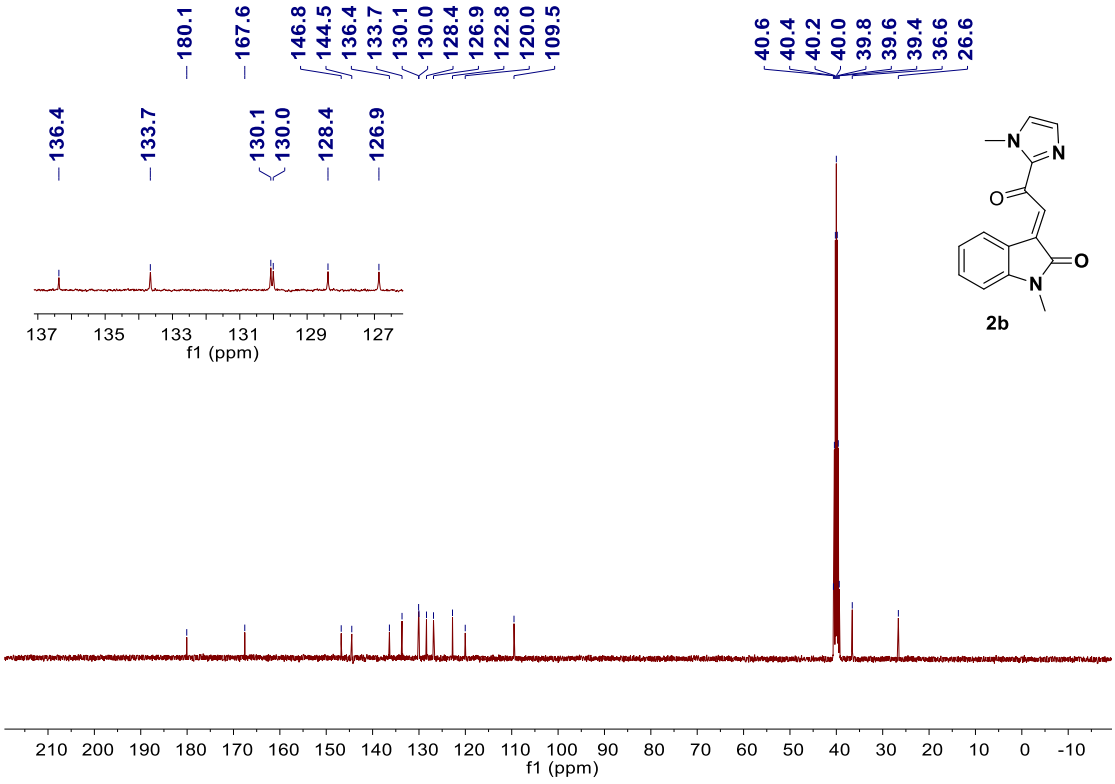

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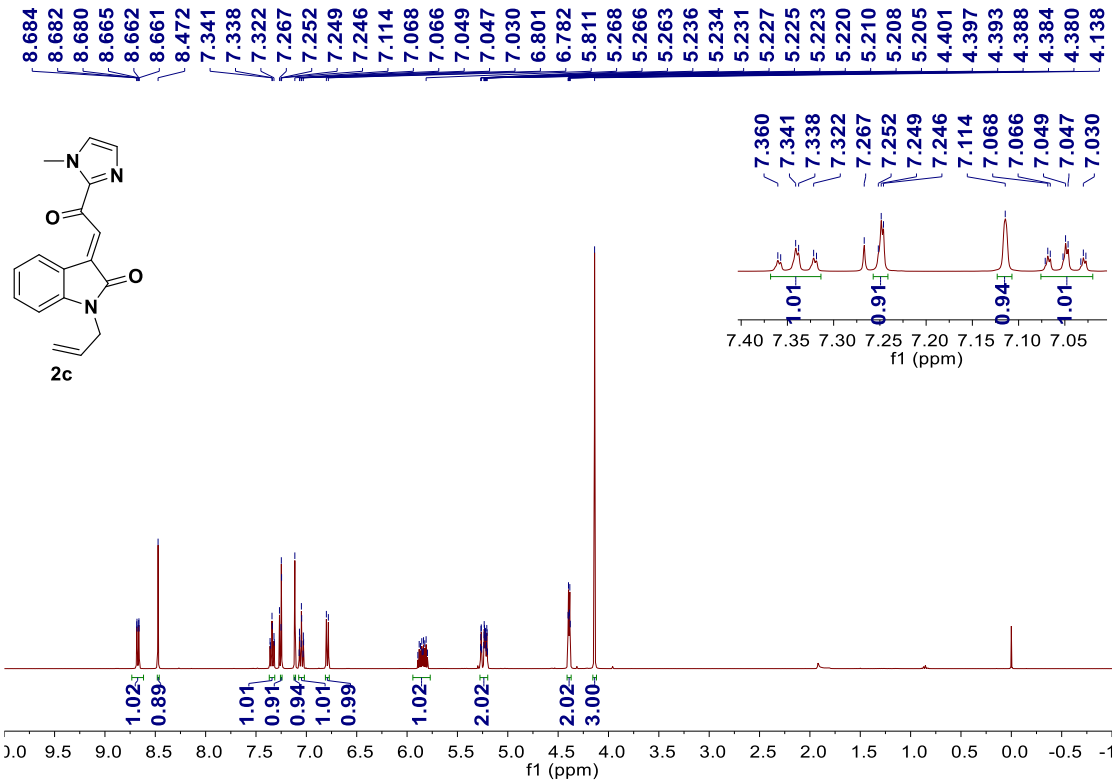

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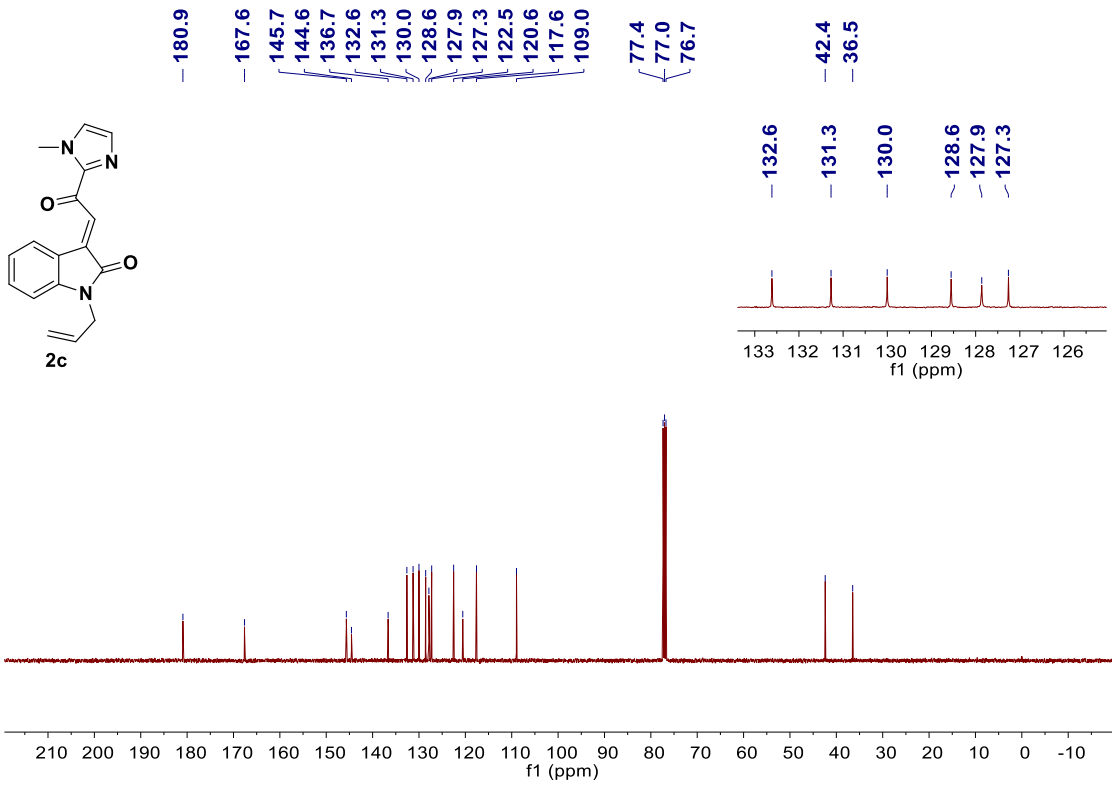

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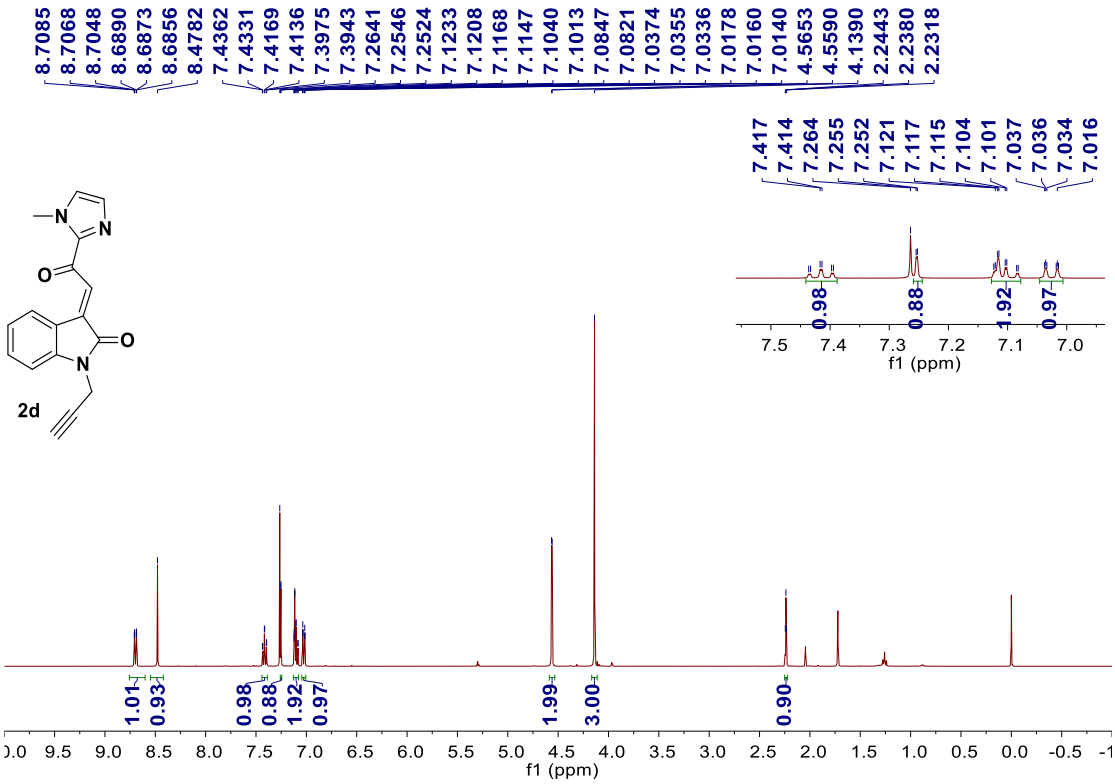

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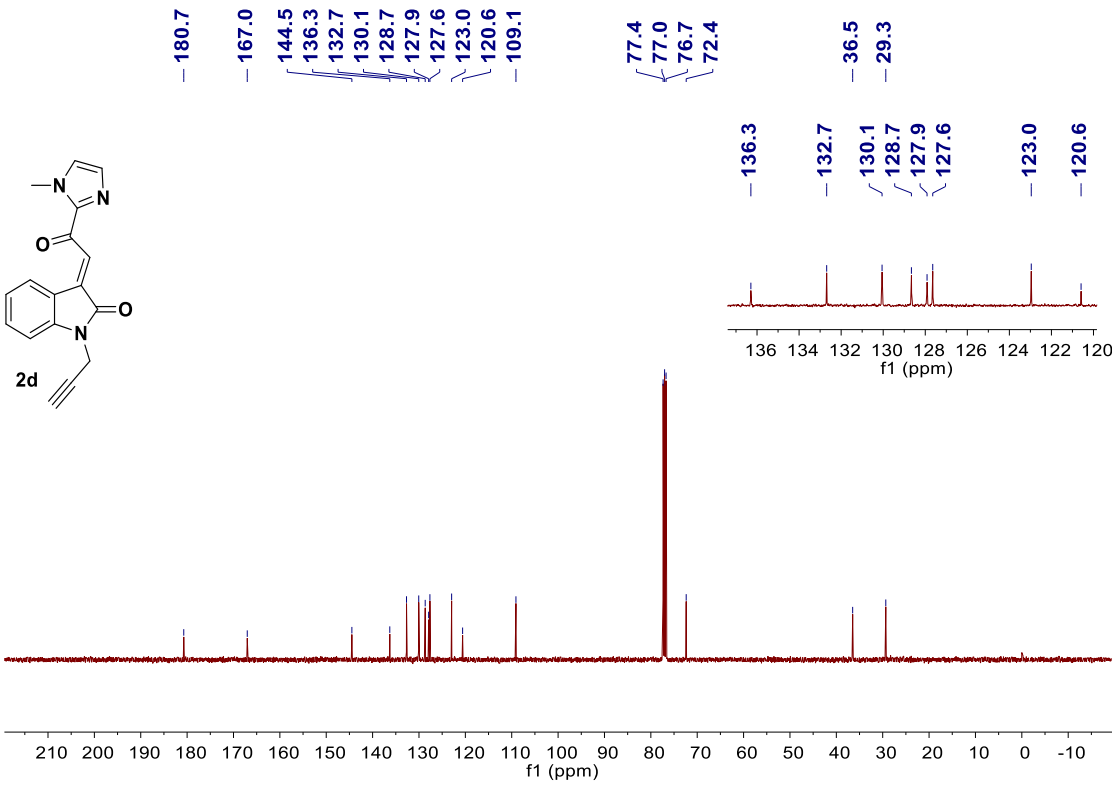
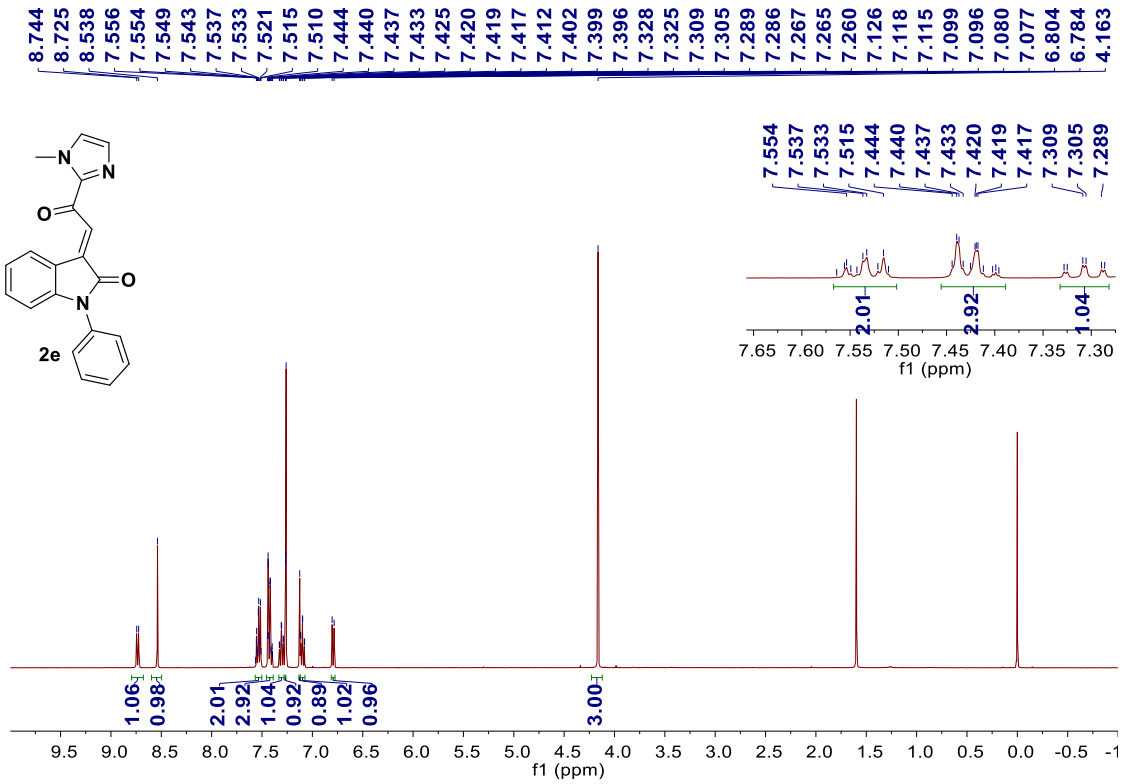


^{1}H-NMR-2e



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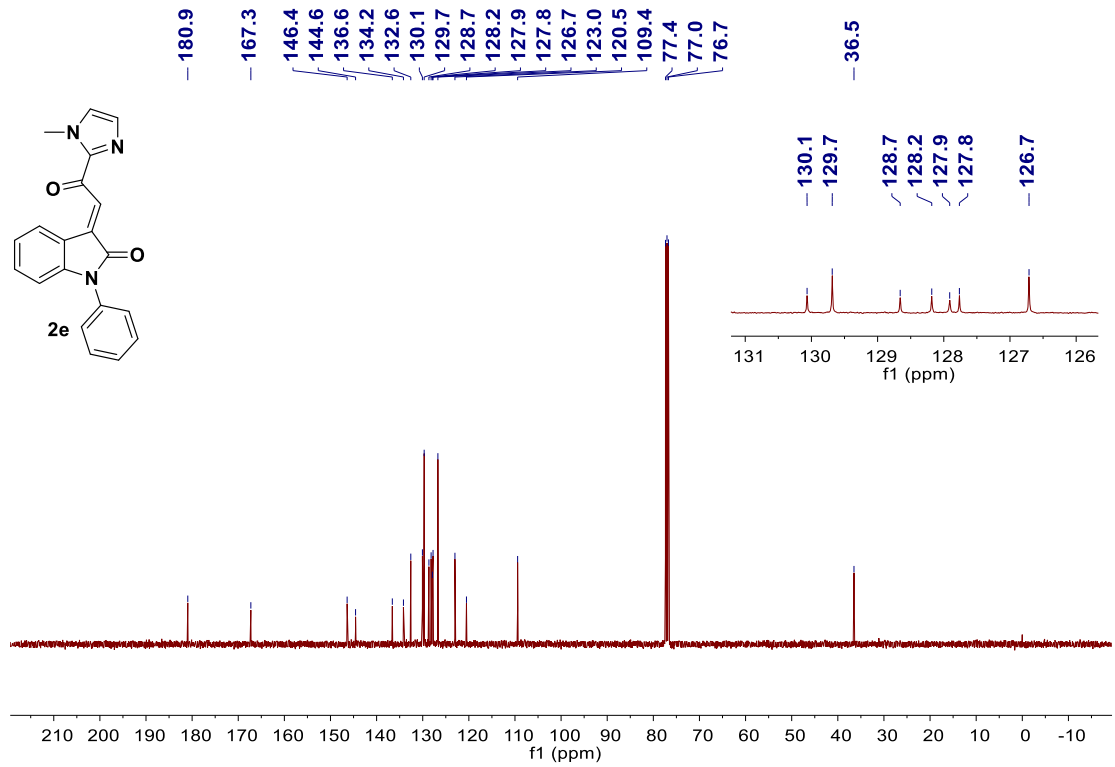

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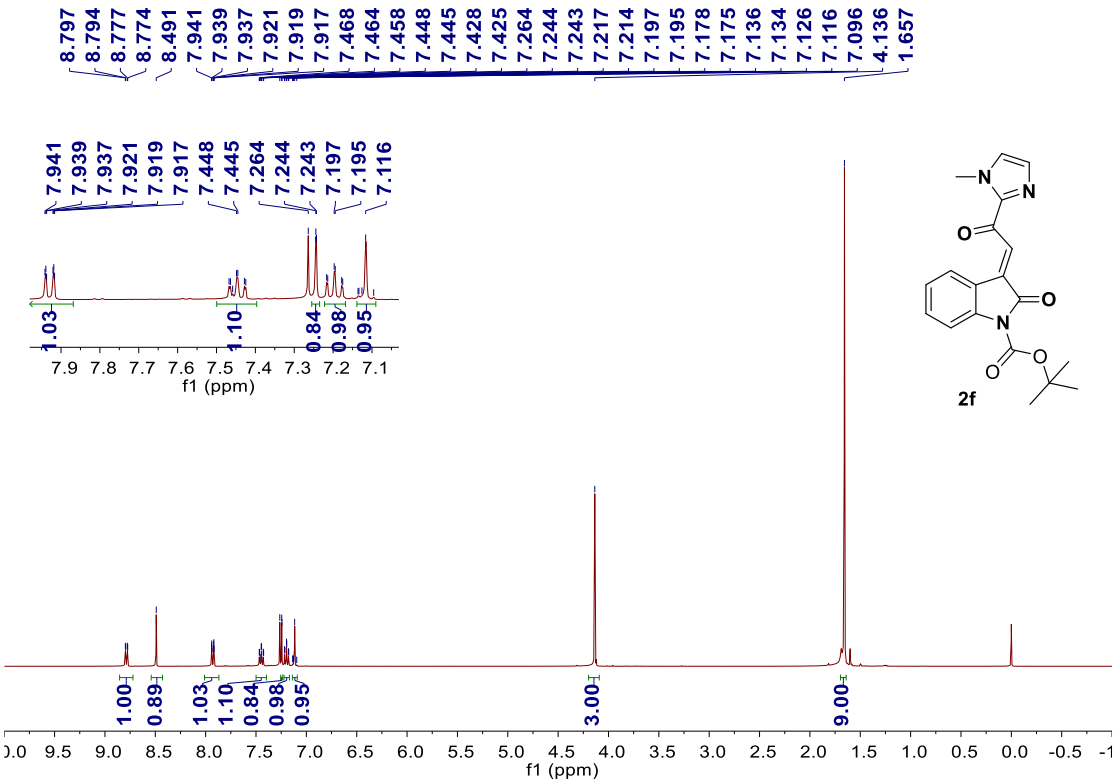

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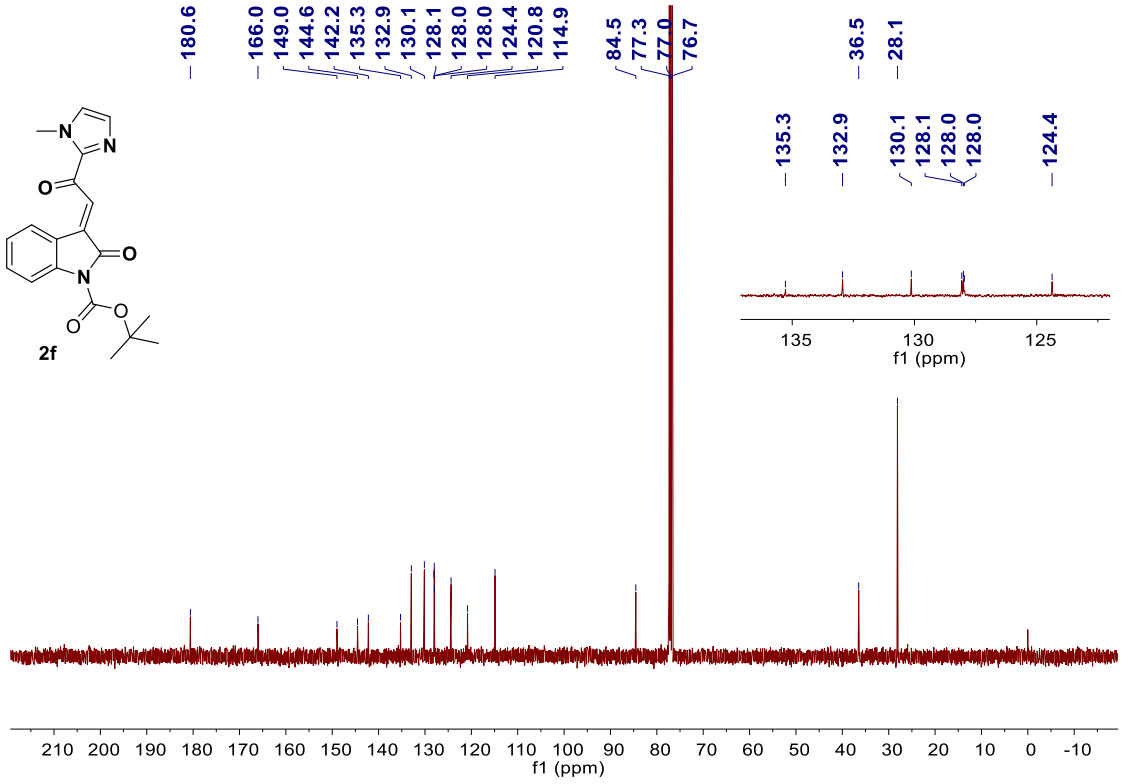

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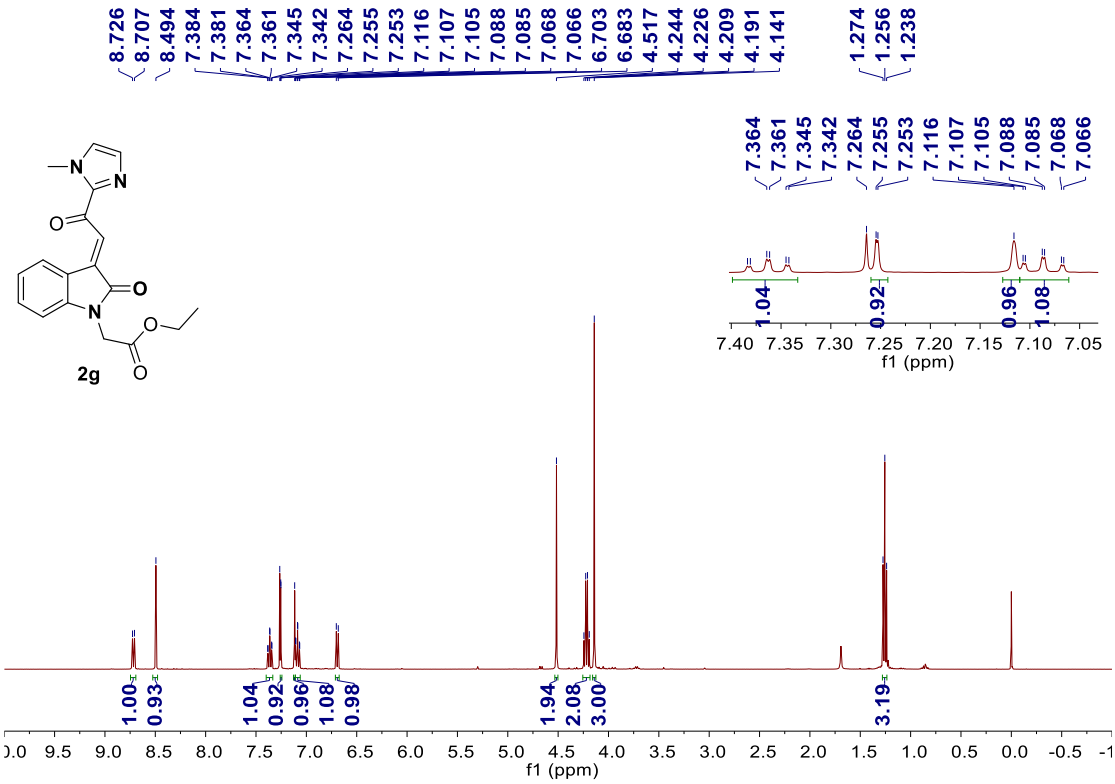

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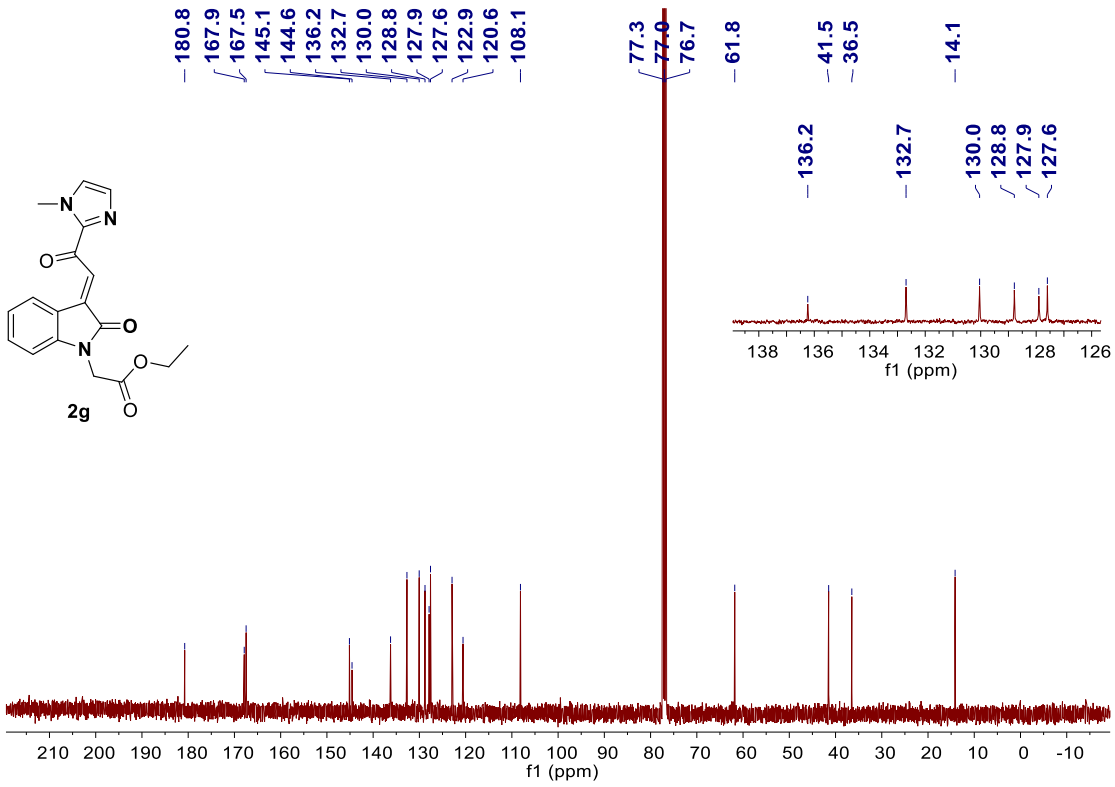

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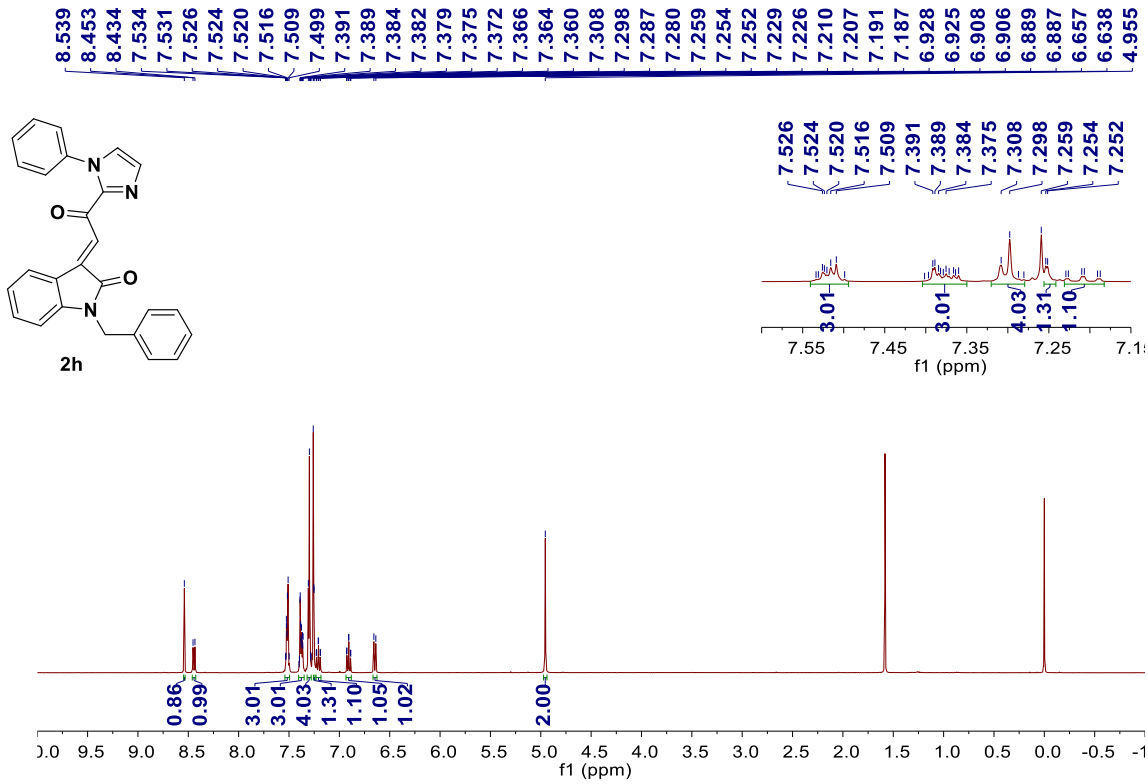

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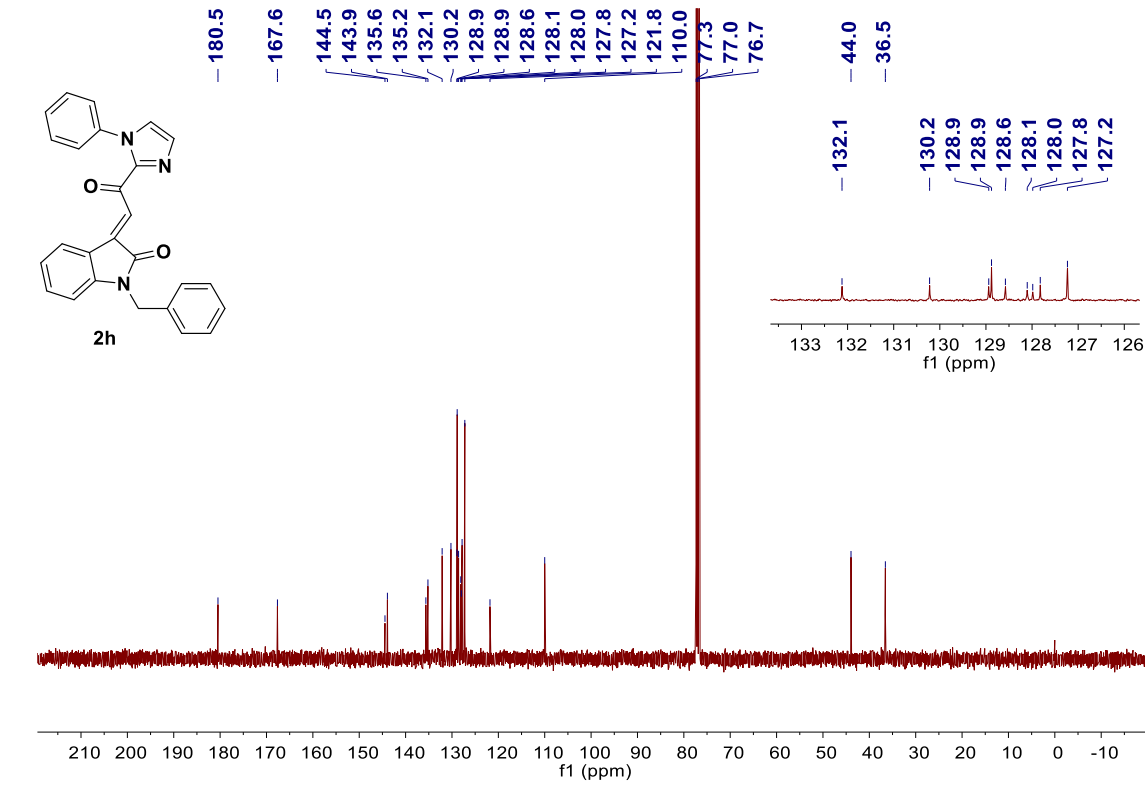

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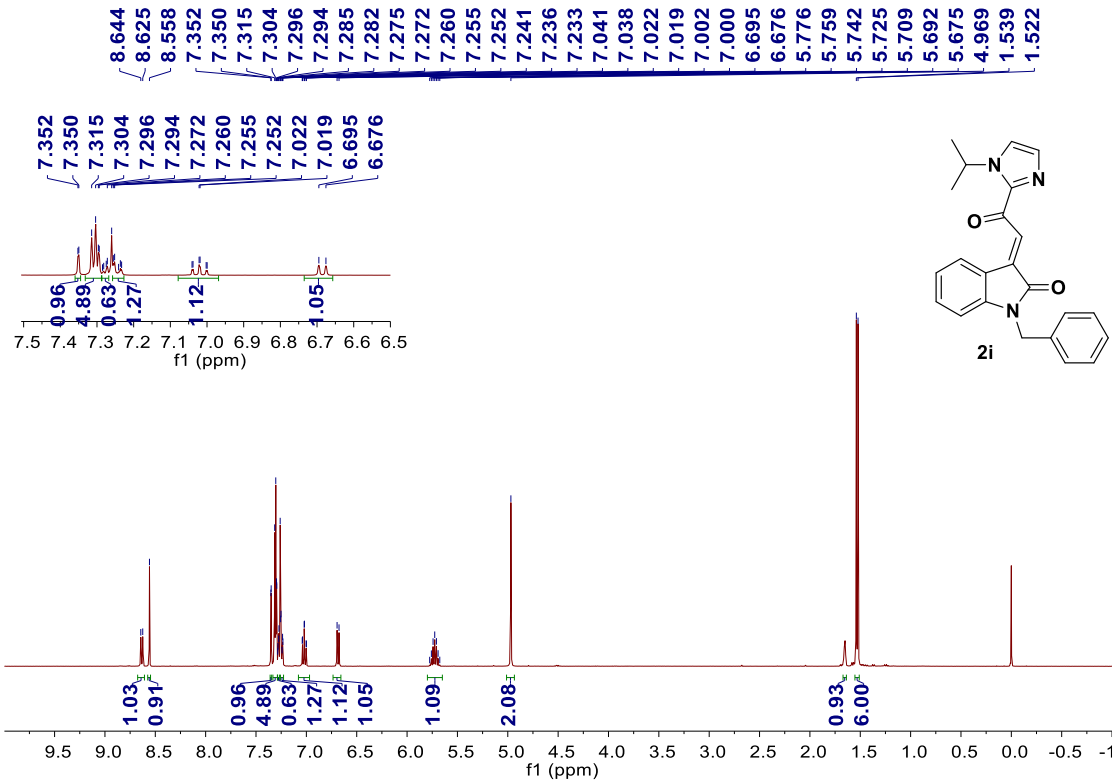

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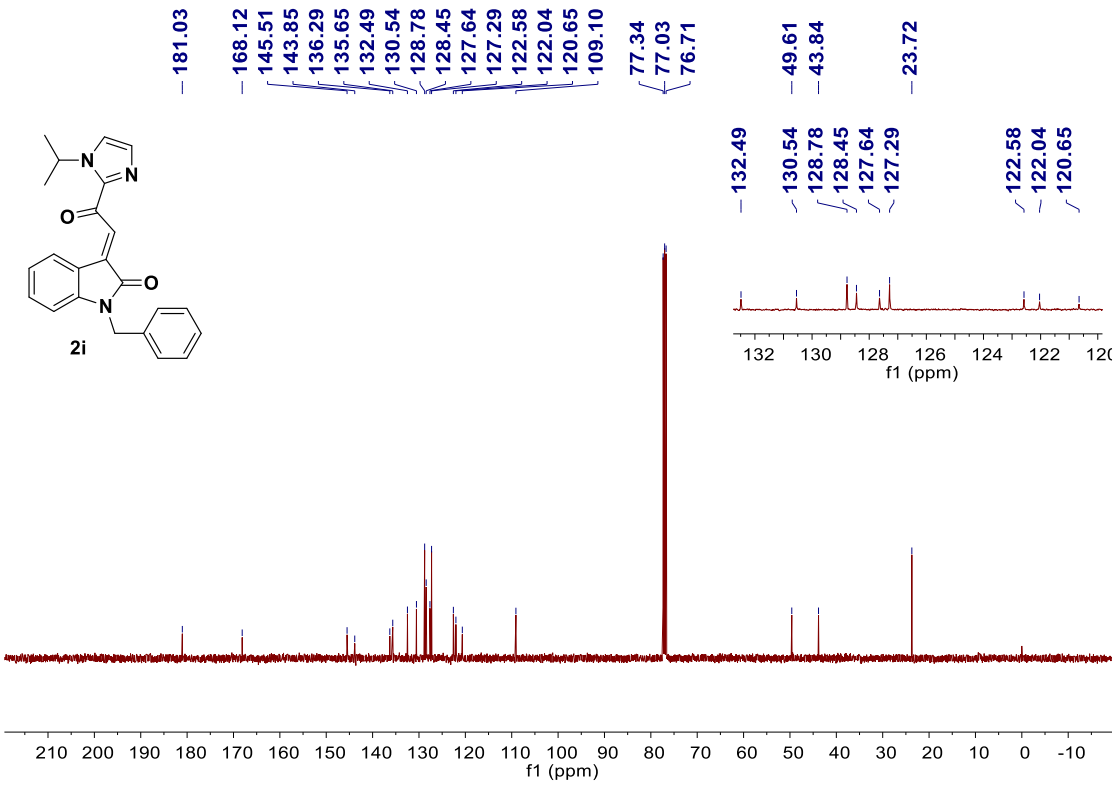

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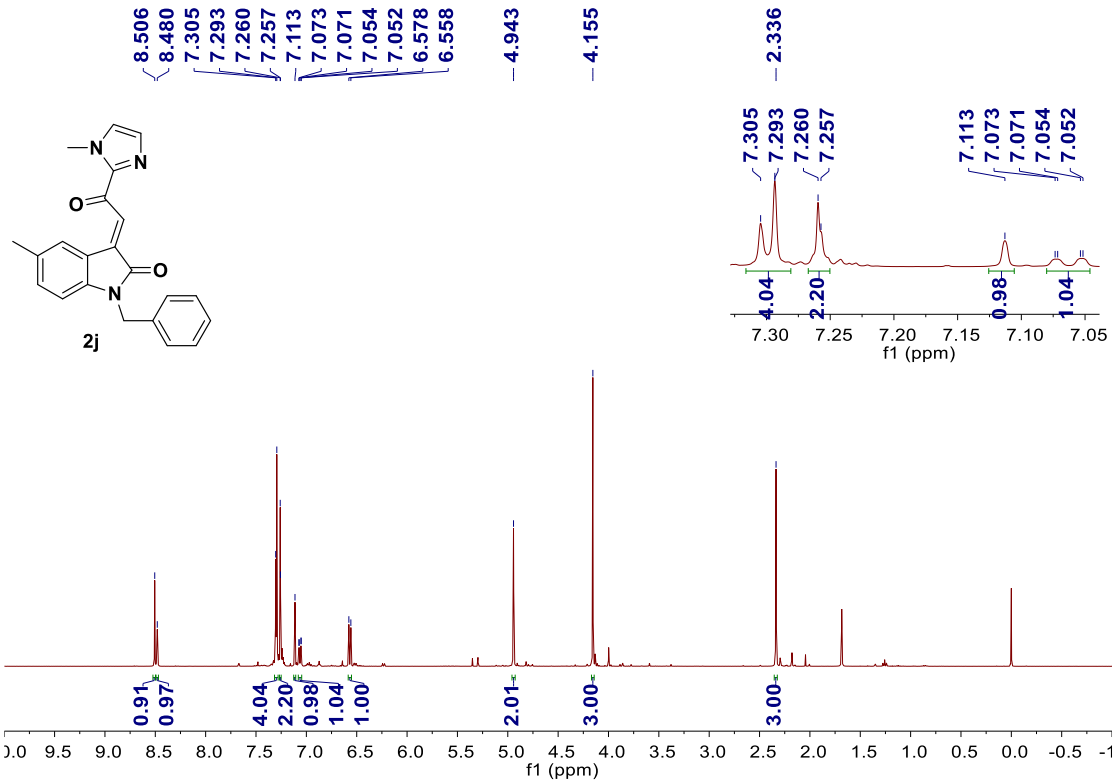

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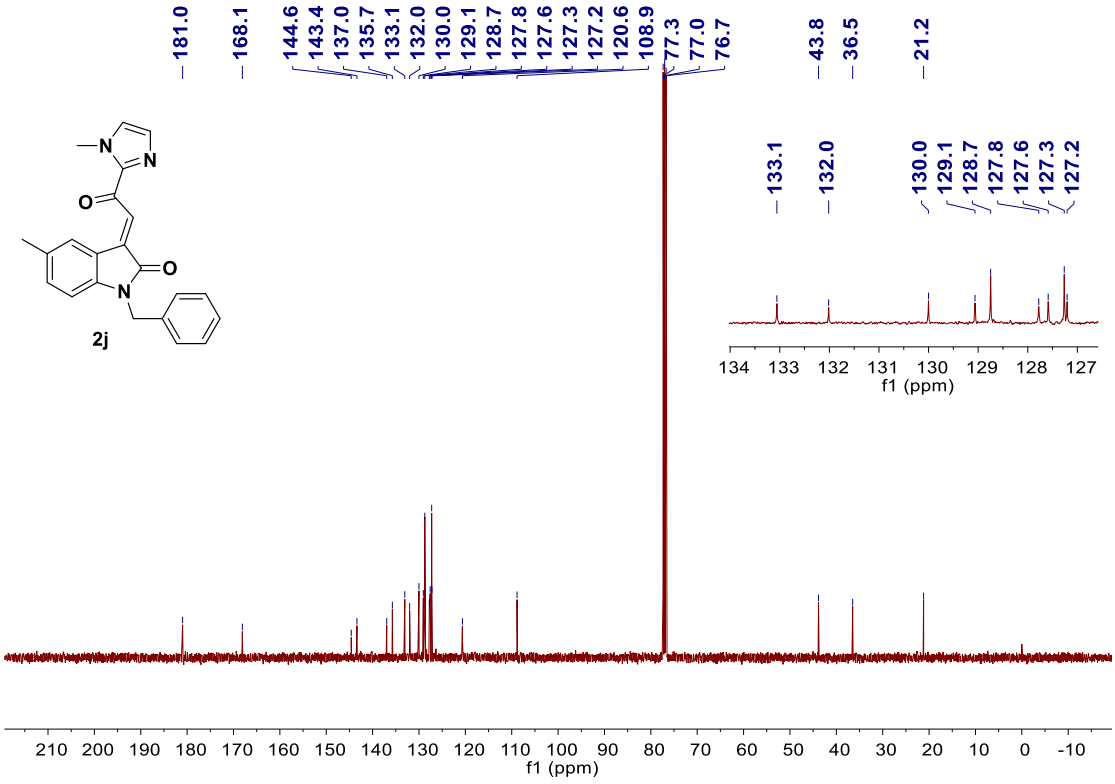

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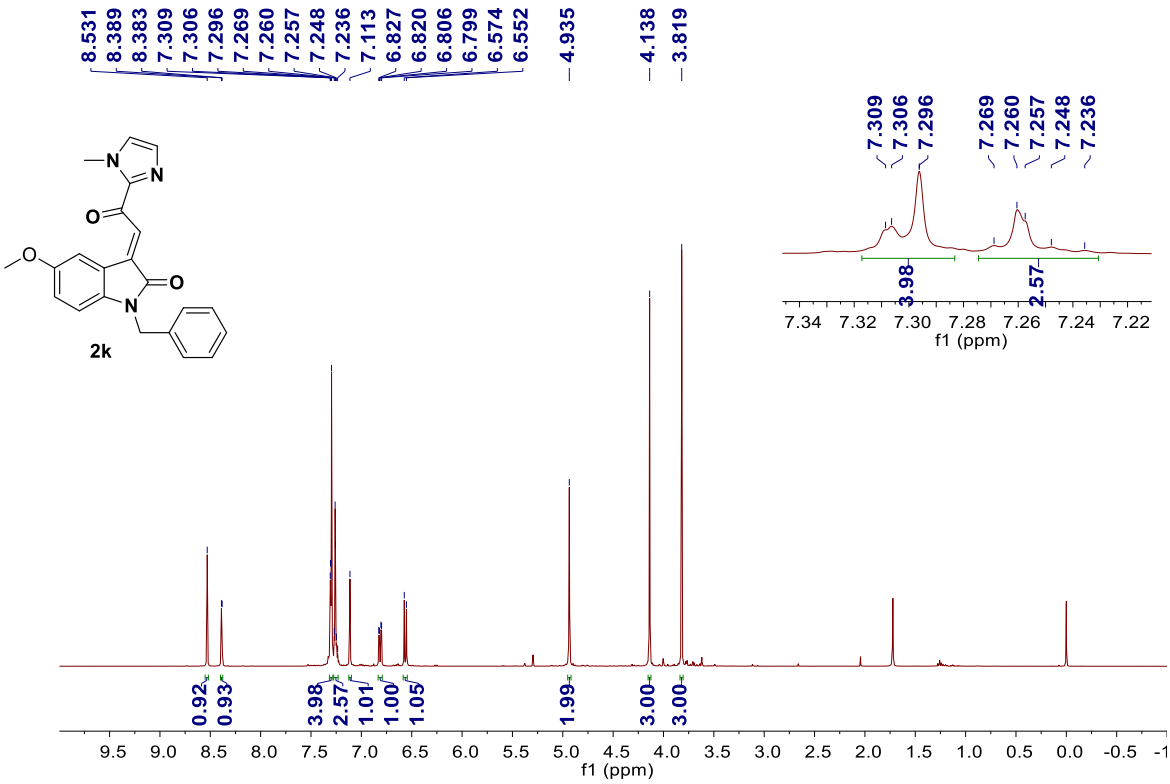

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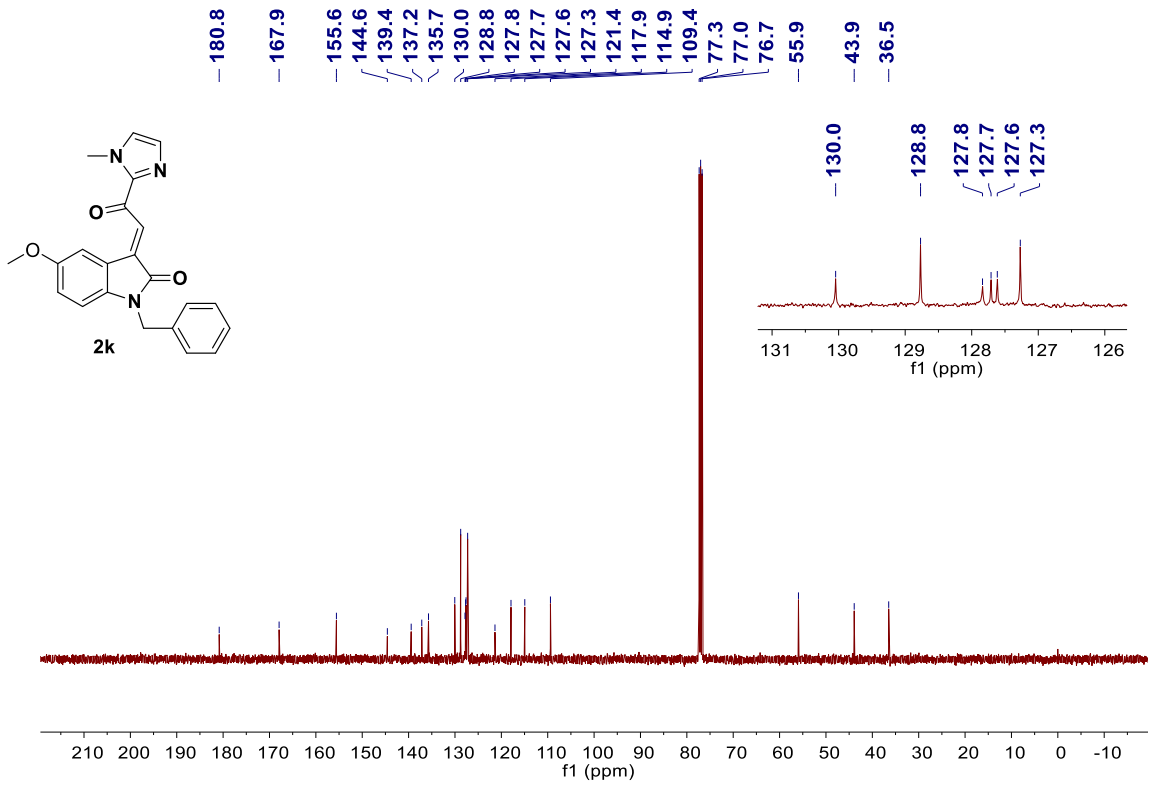

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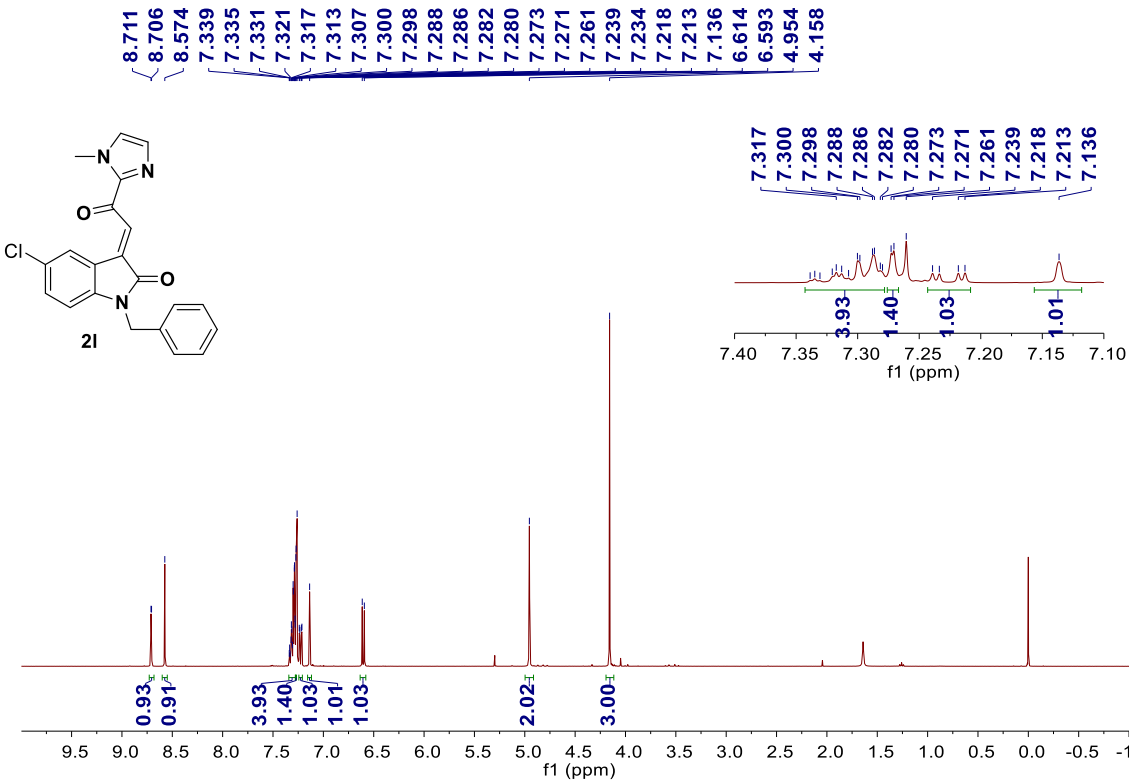

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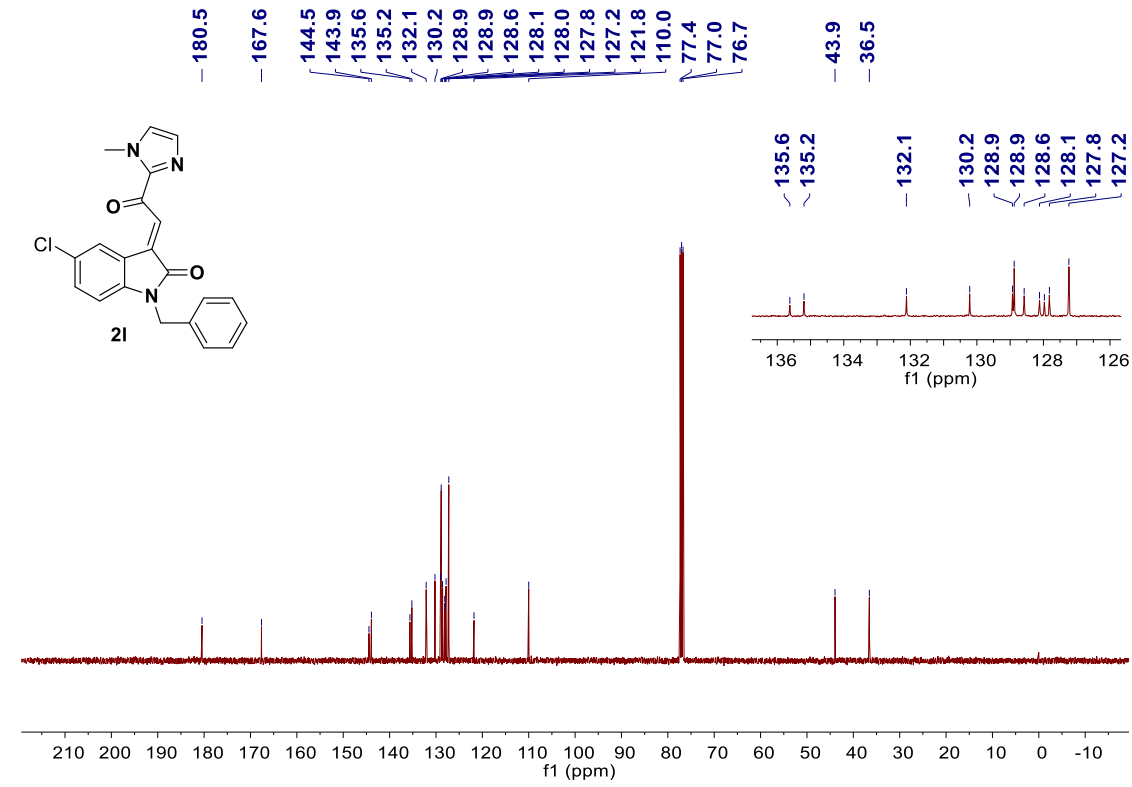

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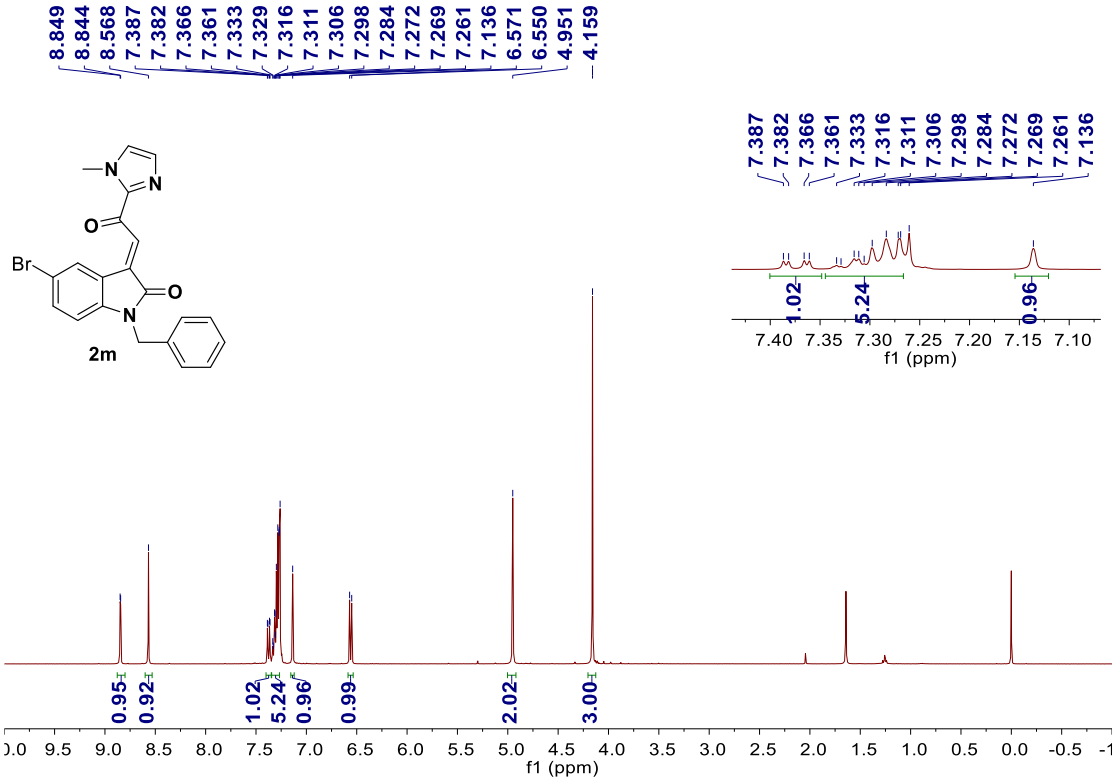

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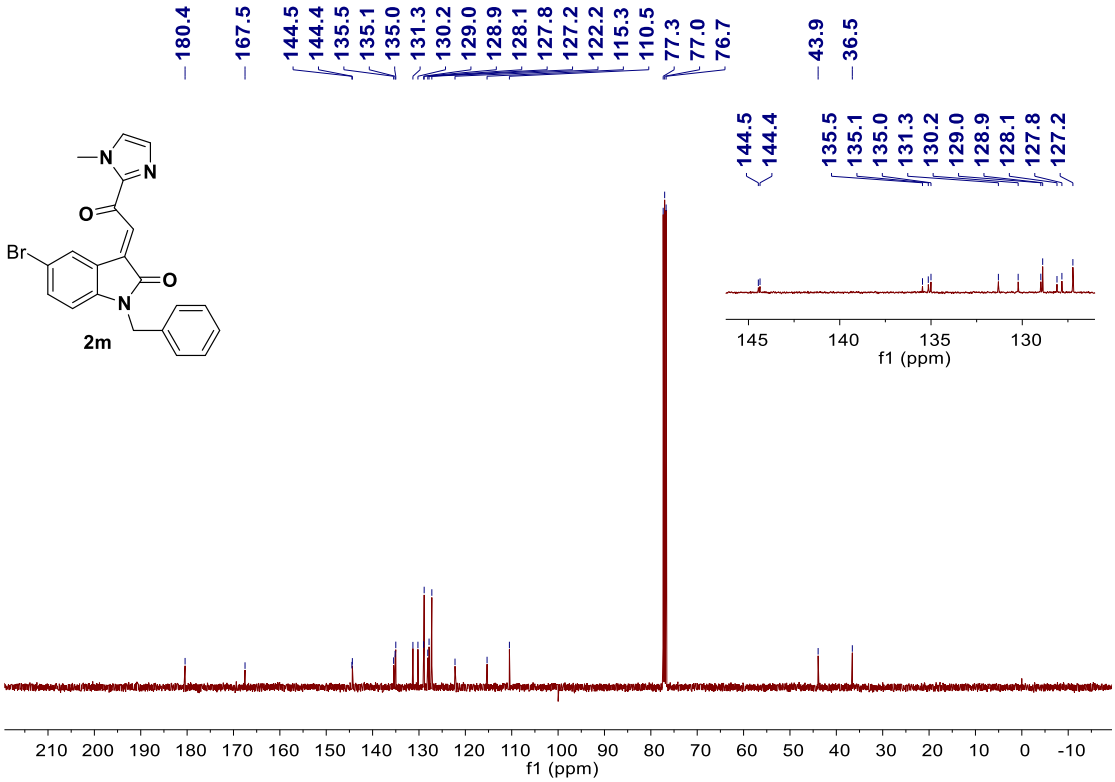

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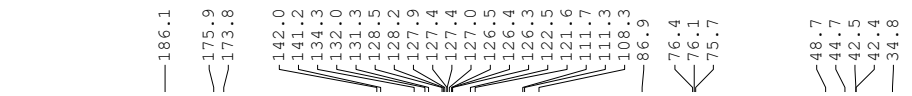

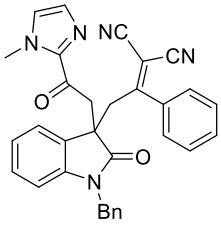

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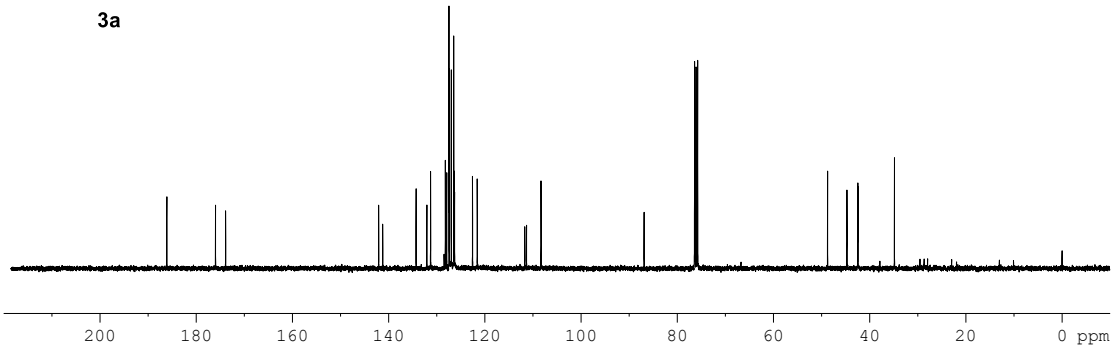

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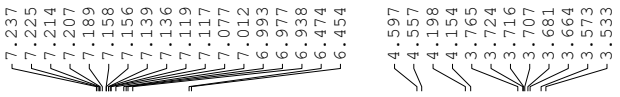

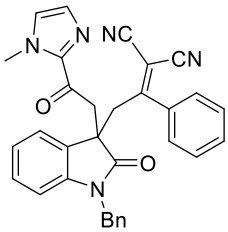

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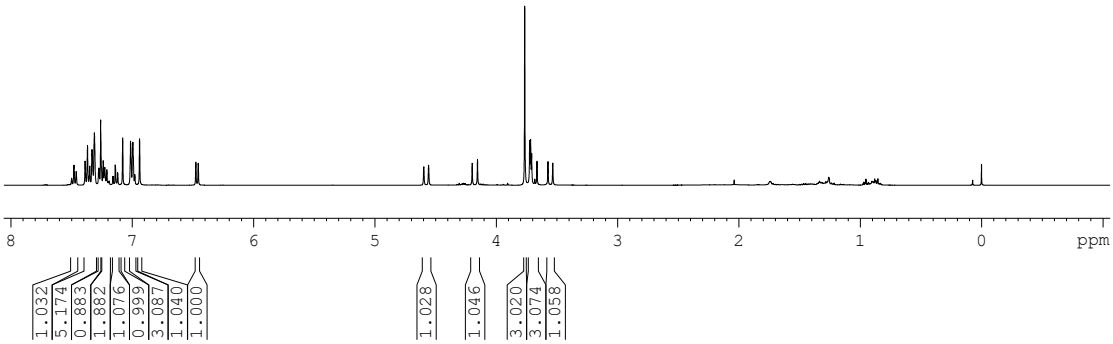
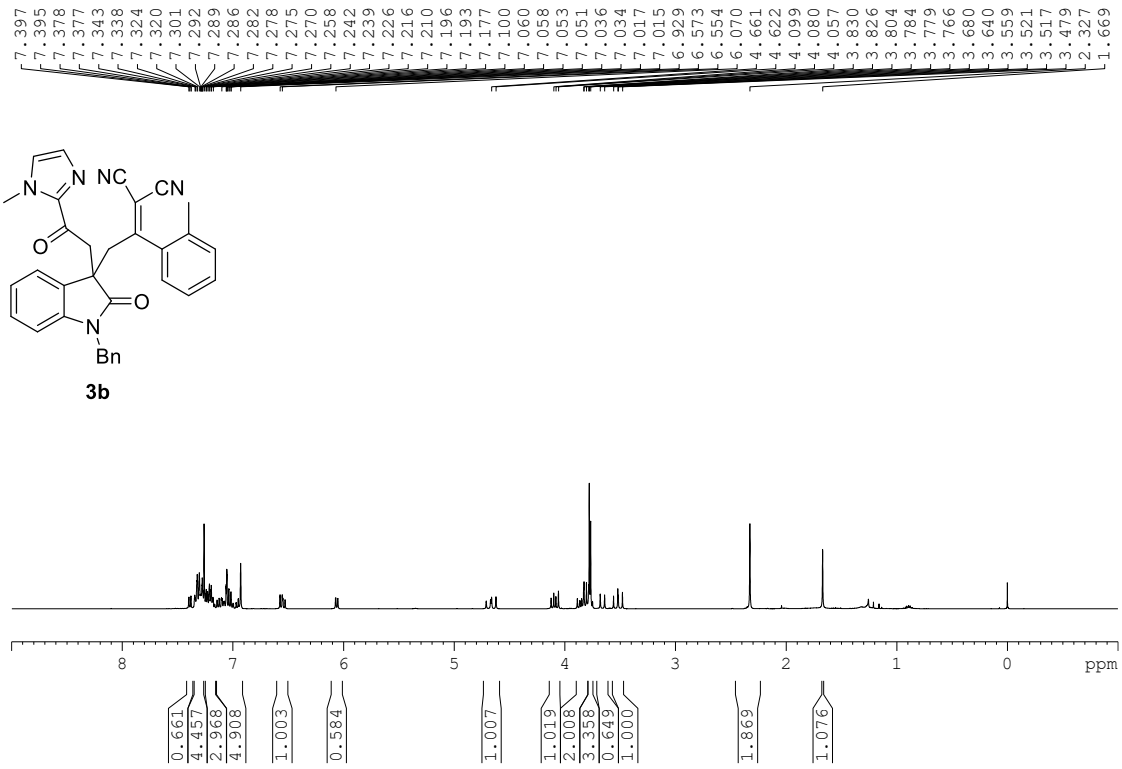
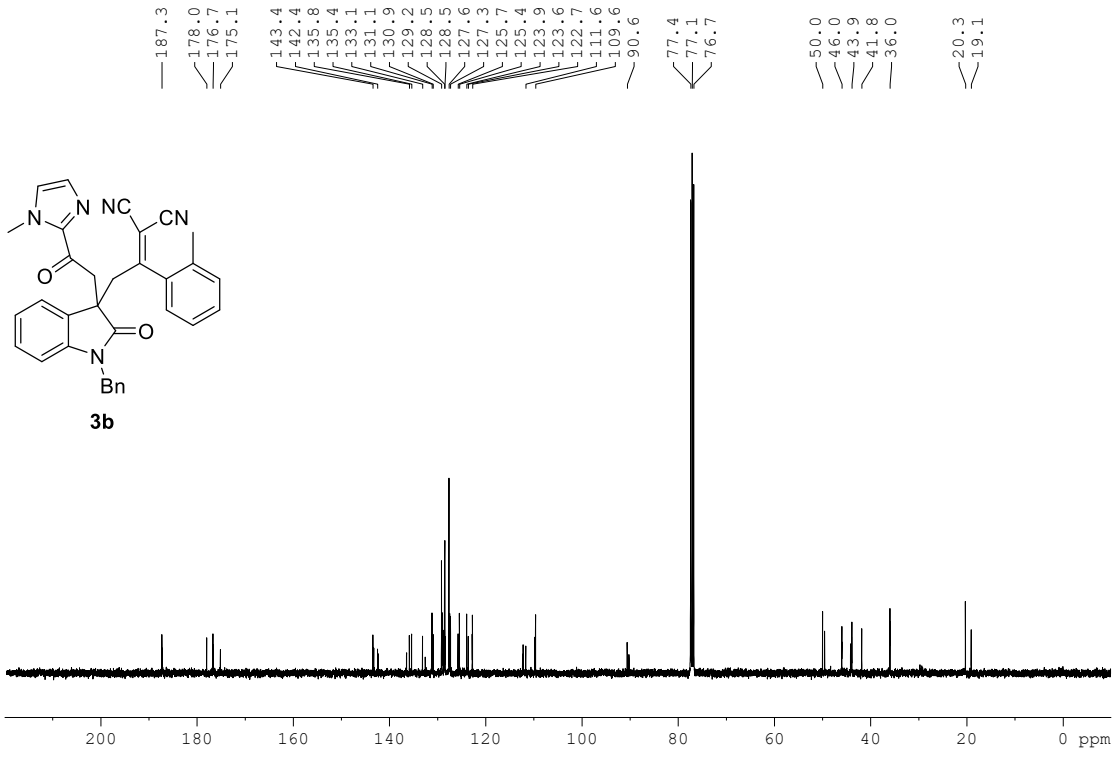


^{1}H-NMR-3b



3b

^{13}C NMR-3b



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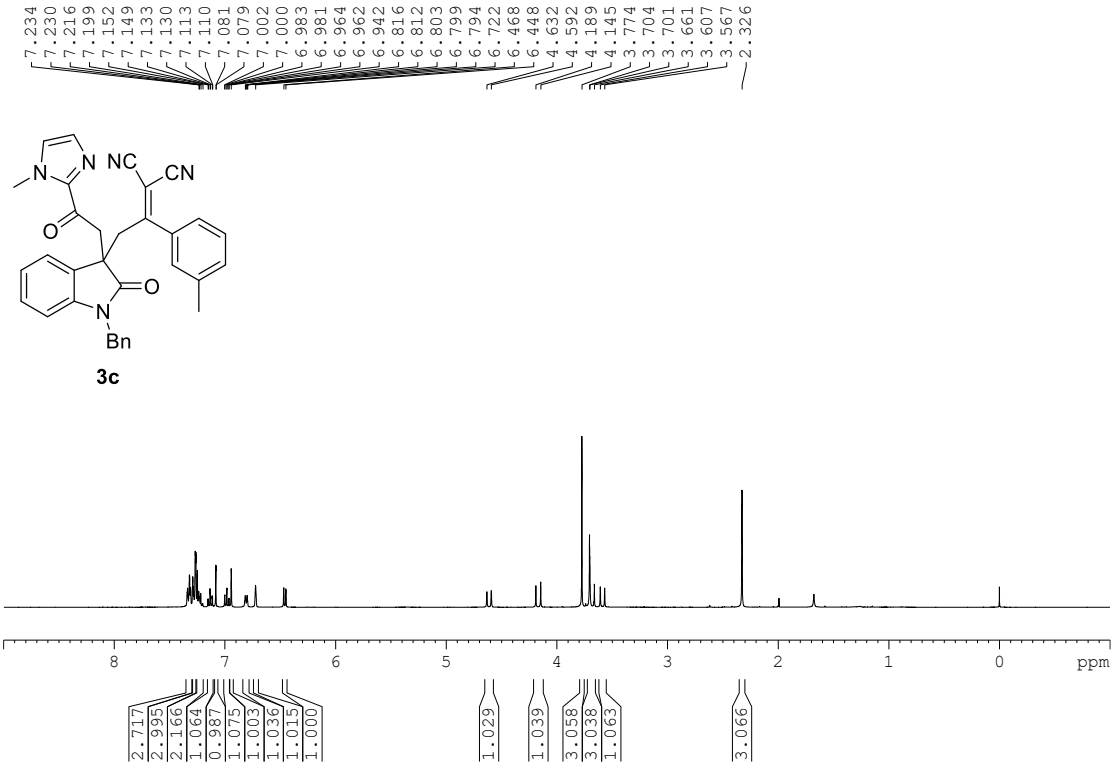

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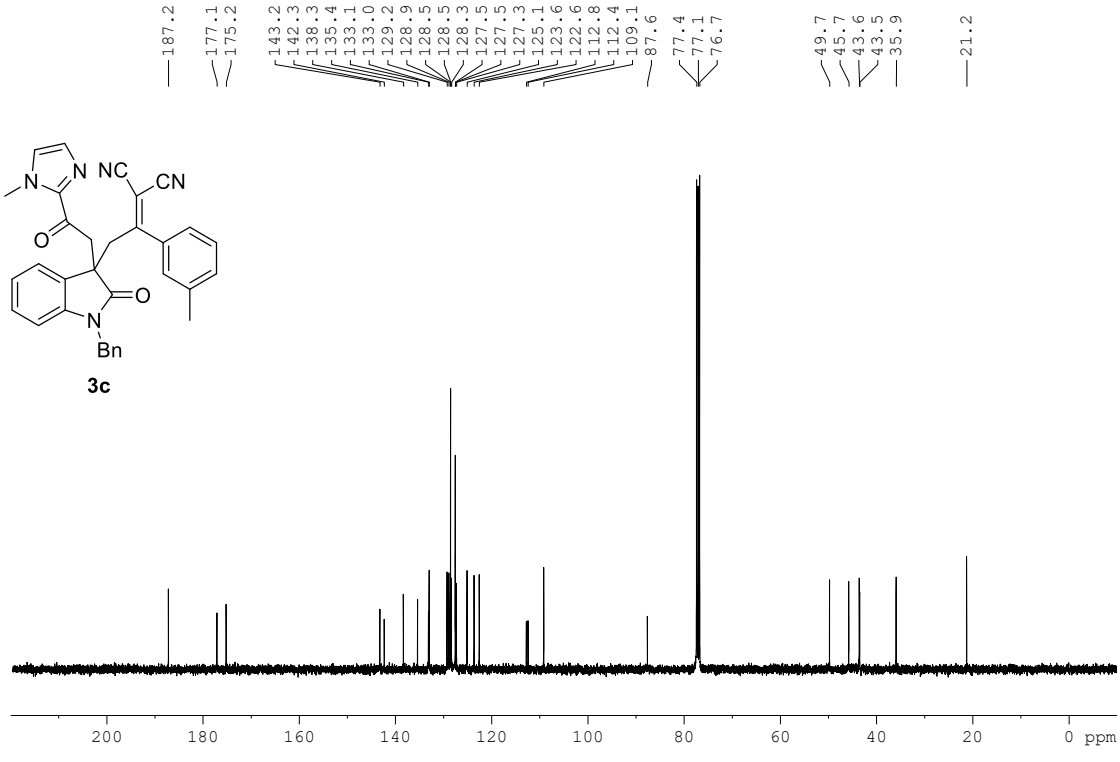
^{13}C NMR-3c



3c

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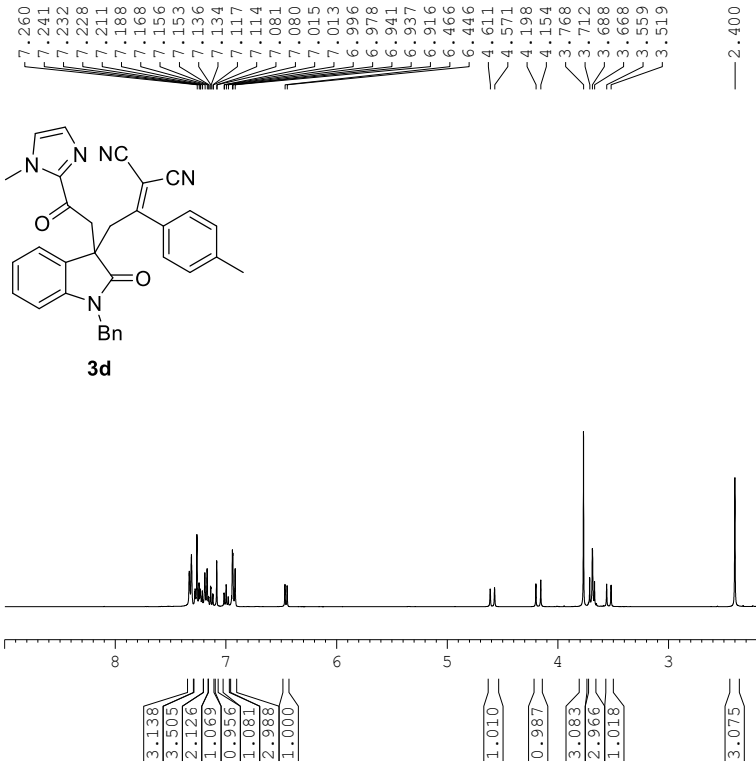

3d

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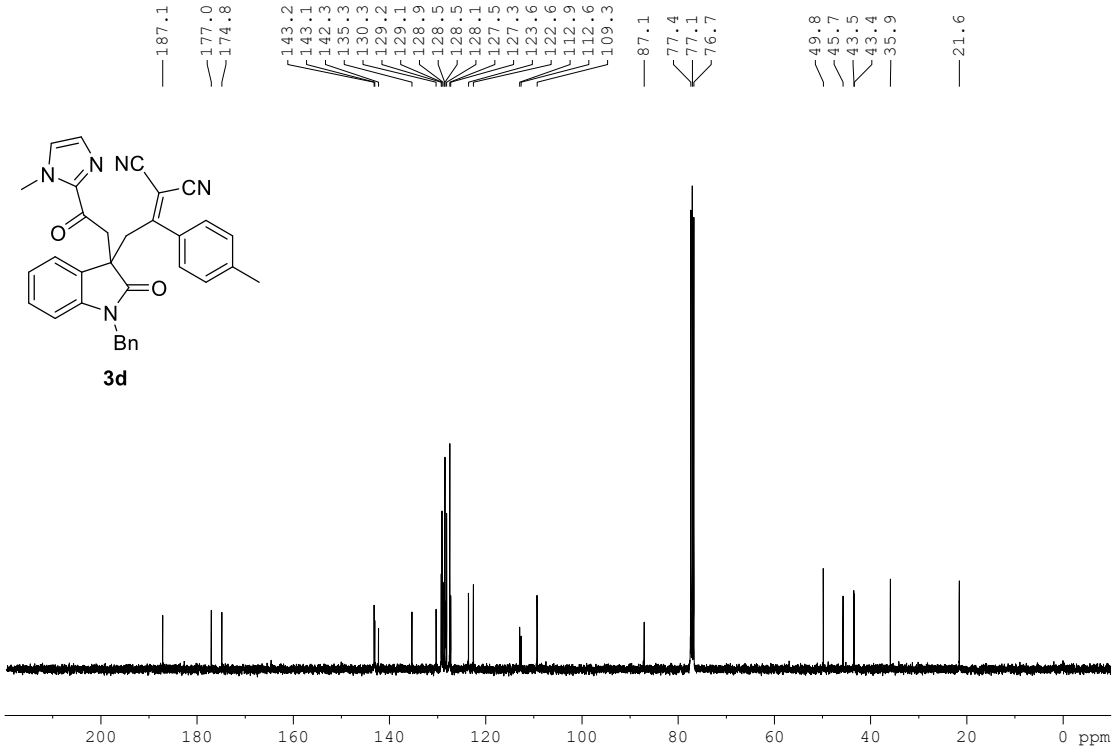

3d

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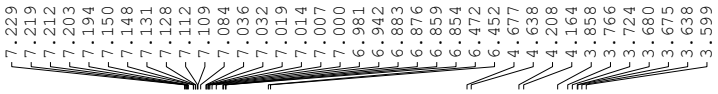

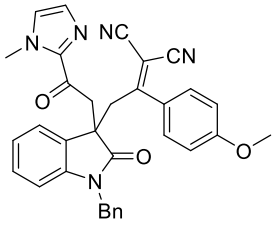

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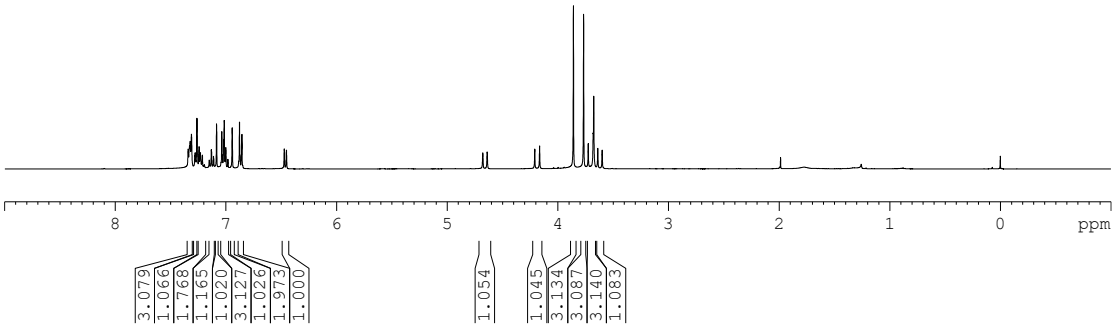
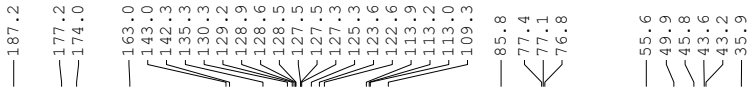
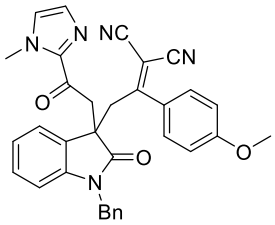


^{13}C NMR-3e





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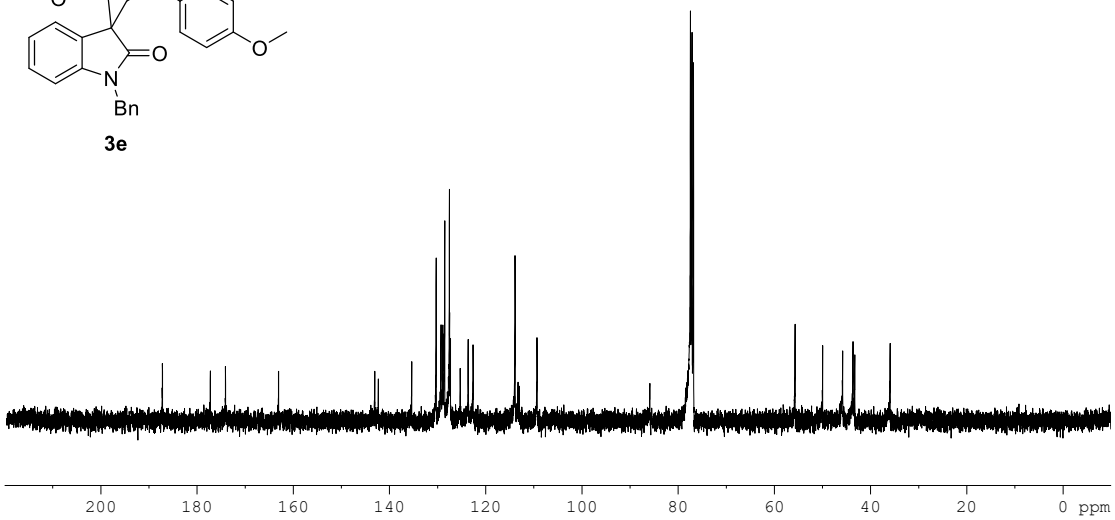

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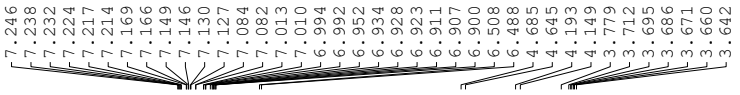

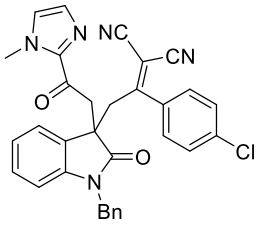

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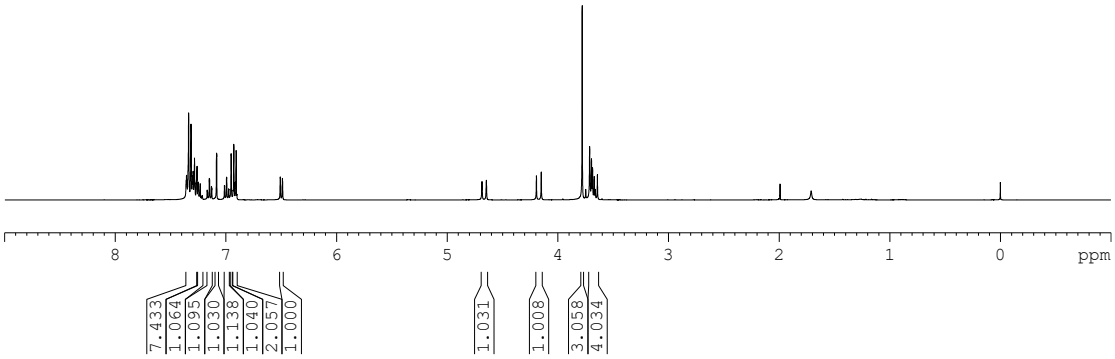

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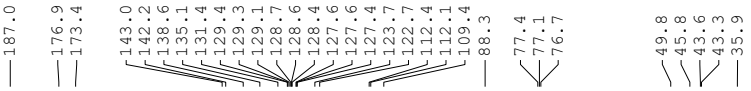

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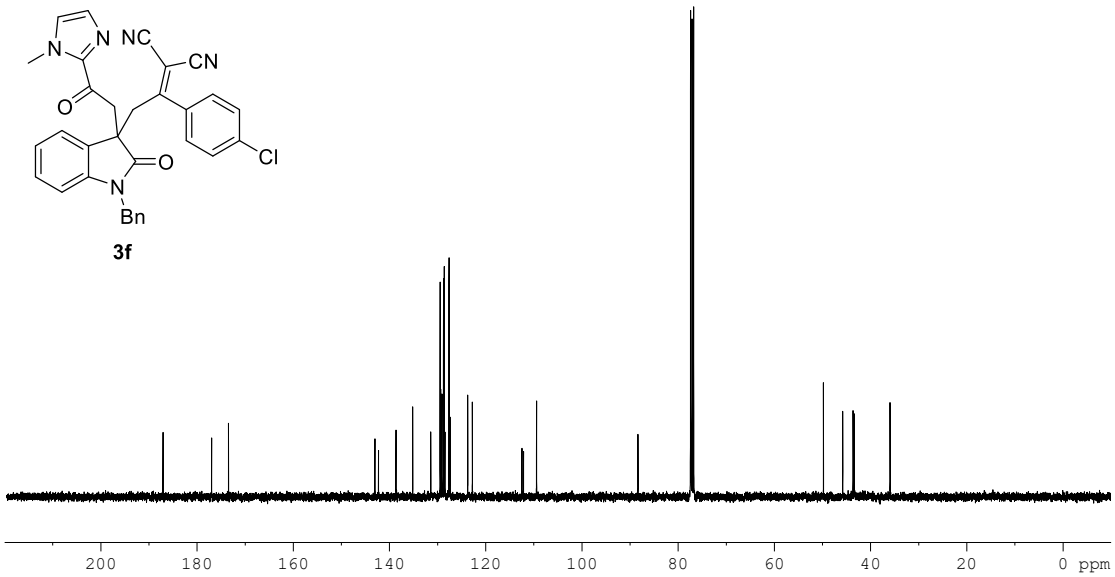

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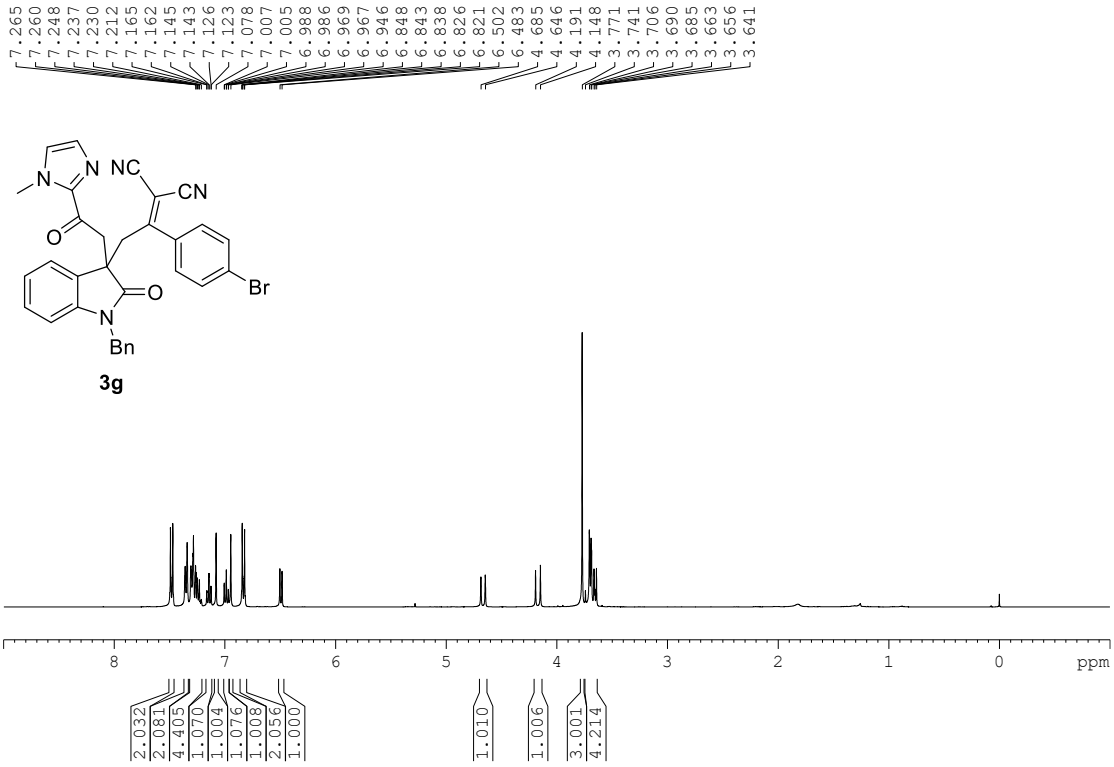

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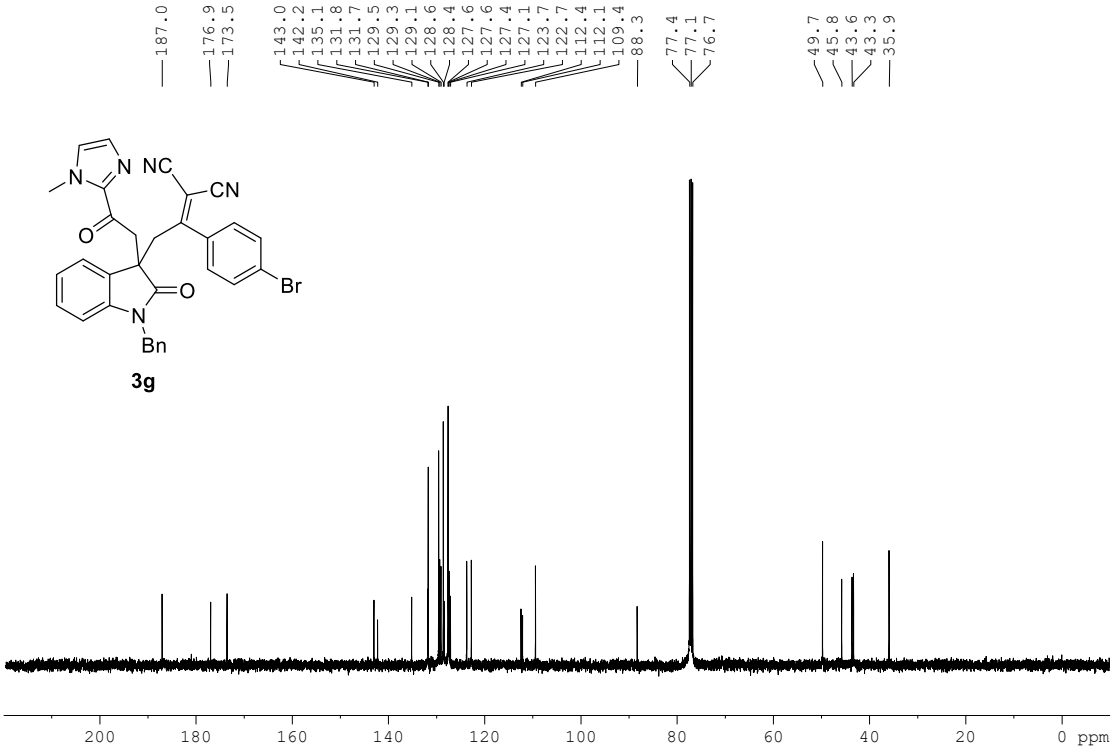

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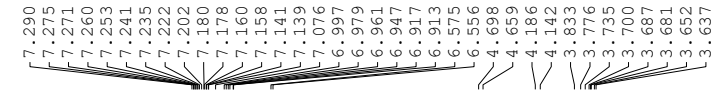

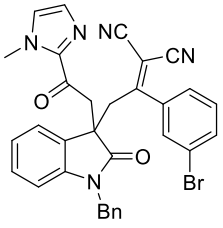

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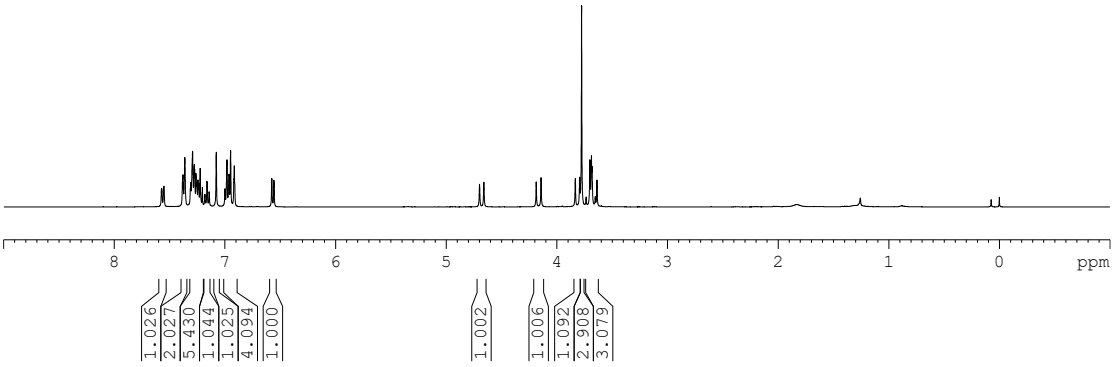

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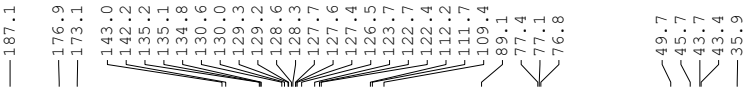

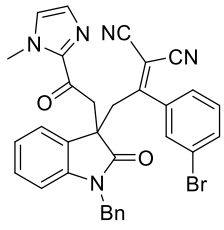

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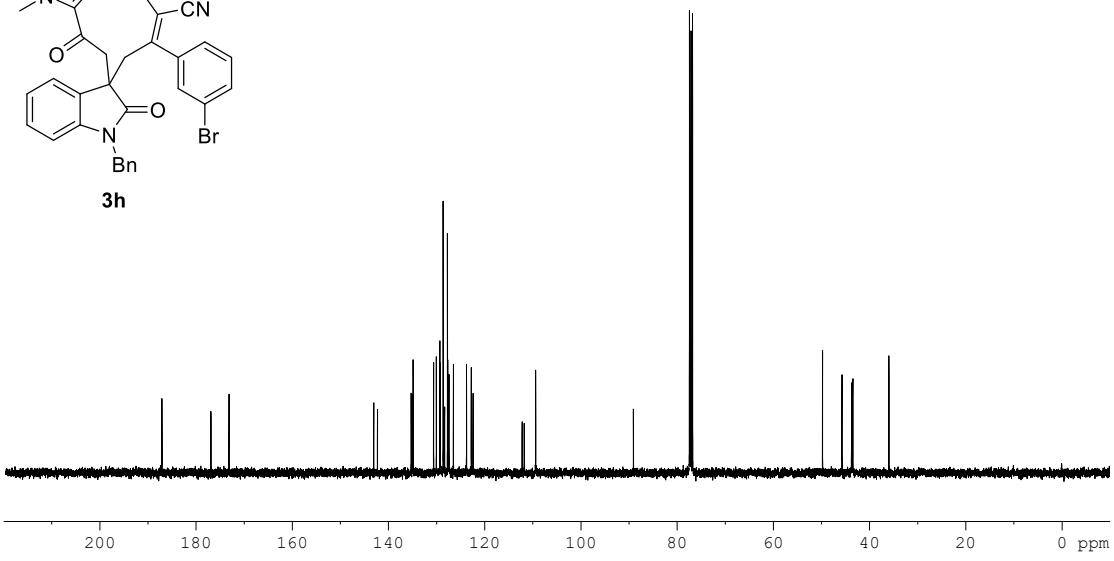

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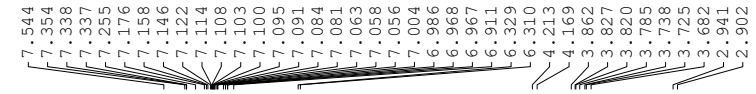

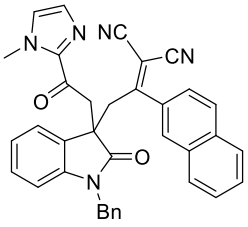

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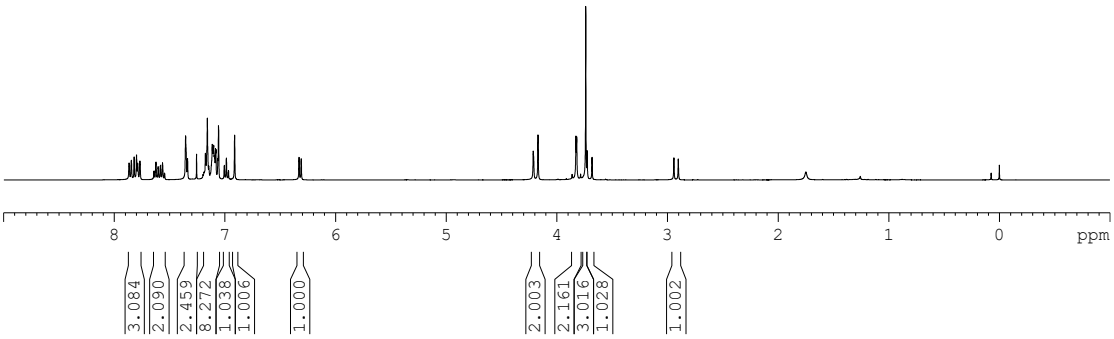

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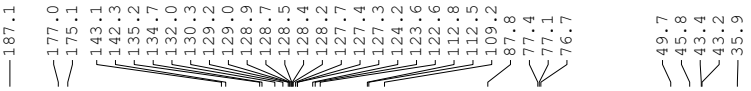

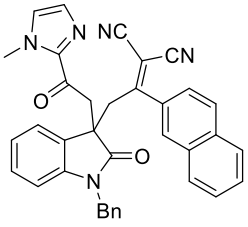

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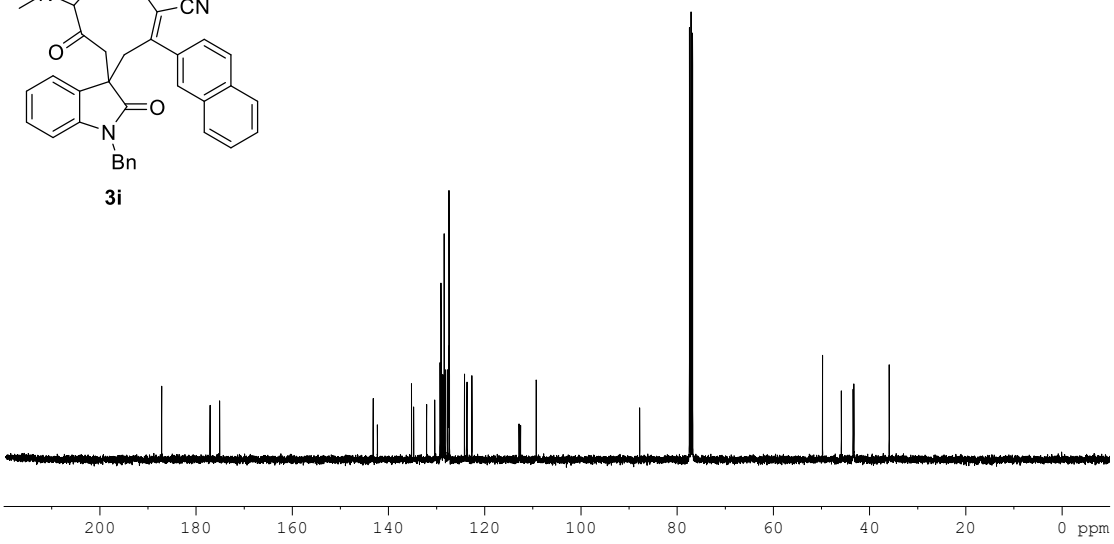

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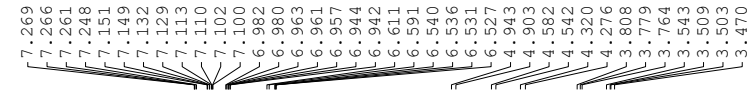

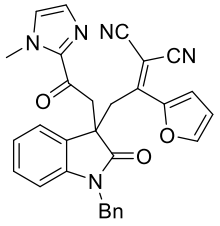

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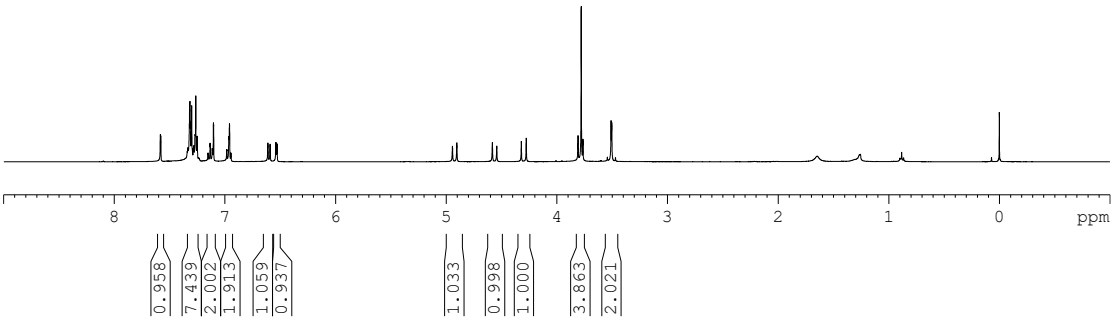

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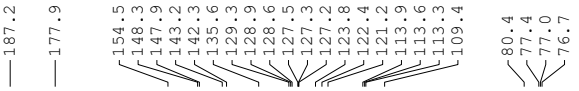

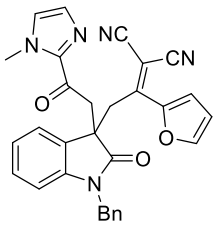

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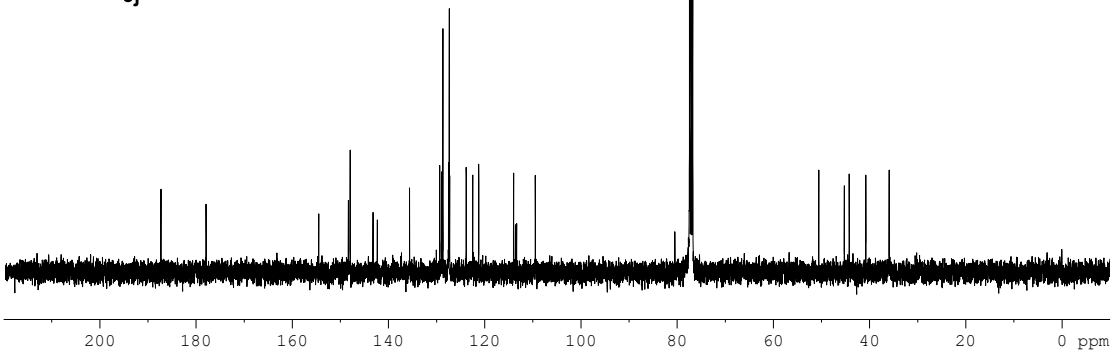

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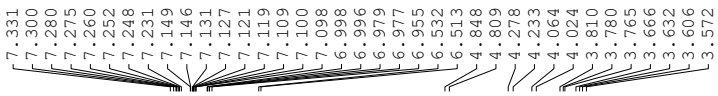

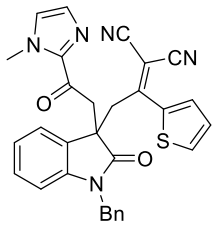

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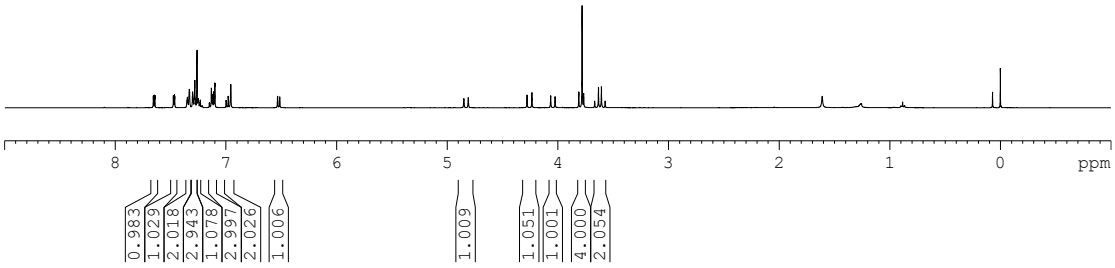

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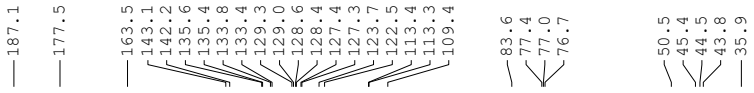

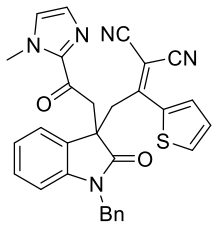

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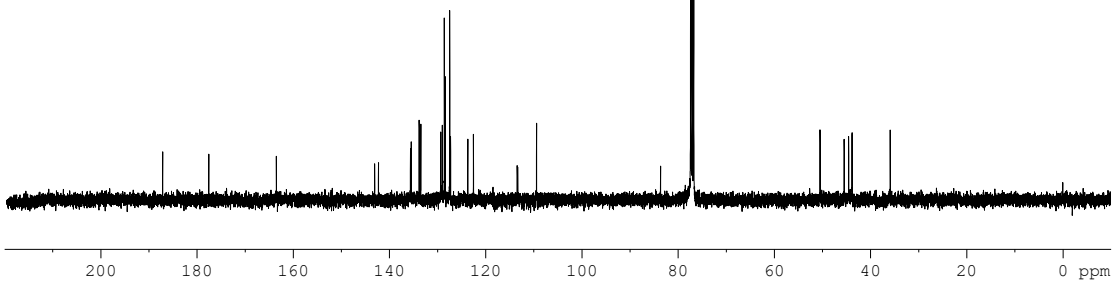

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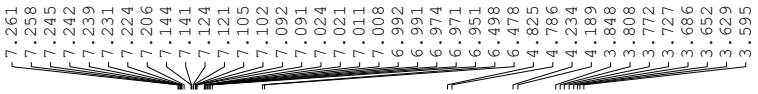

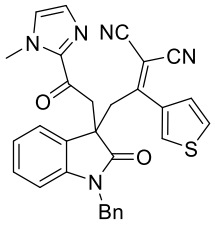

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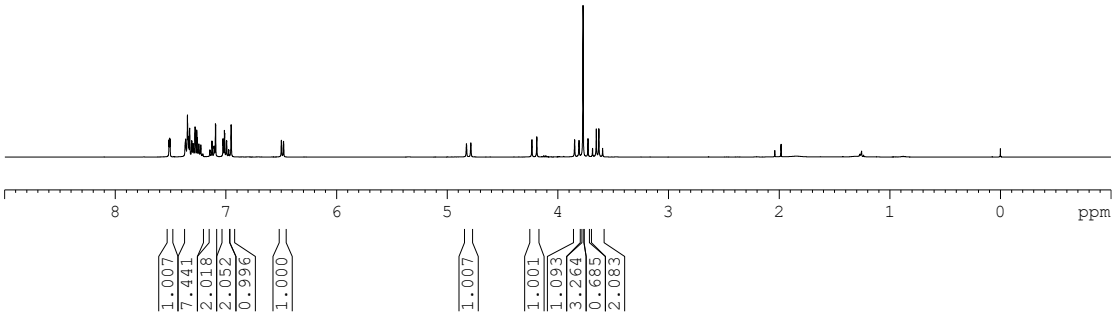

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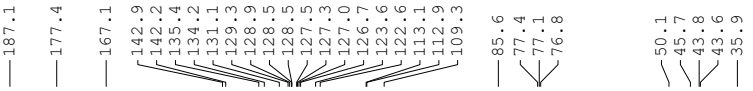

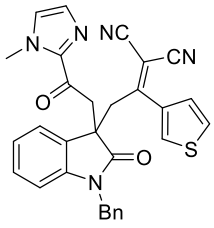

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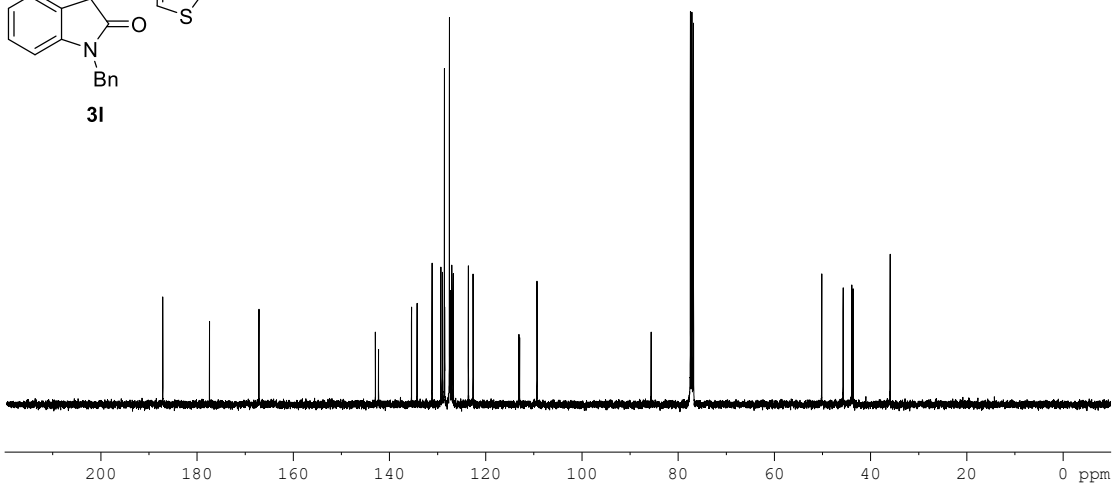

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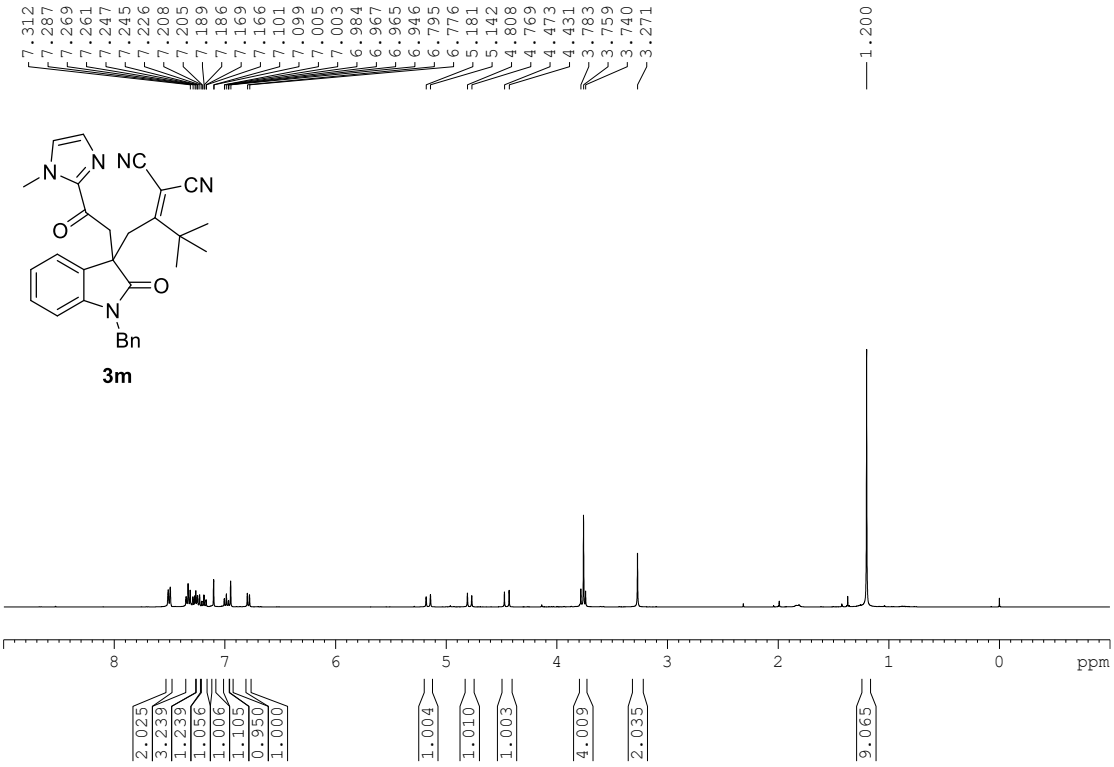
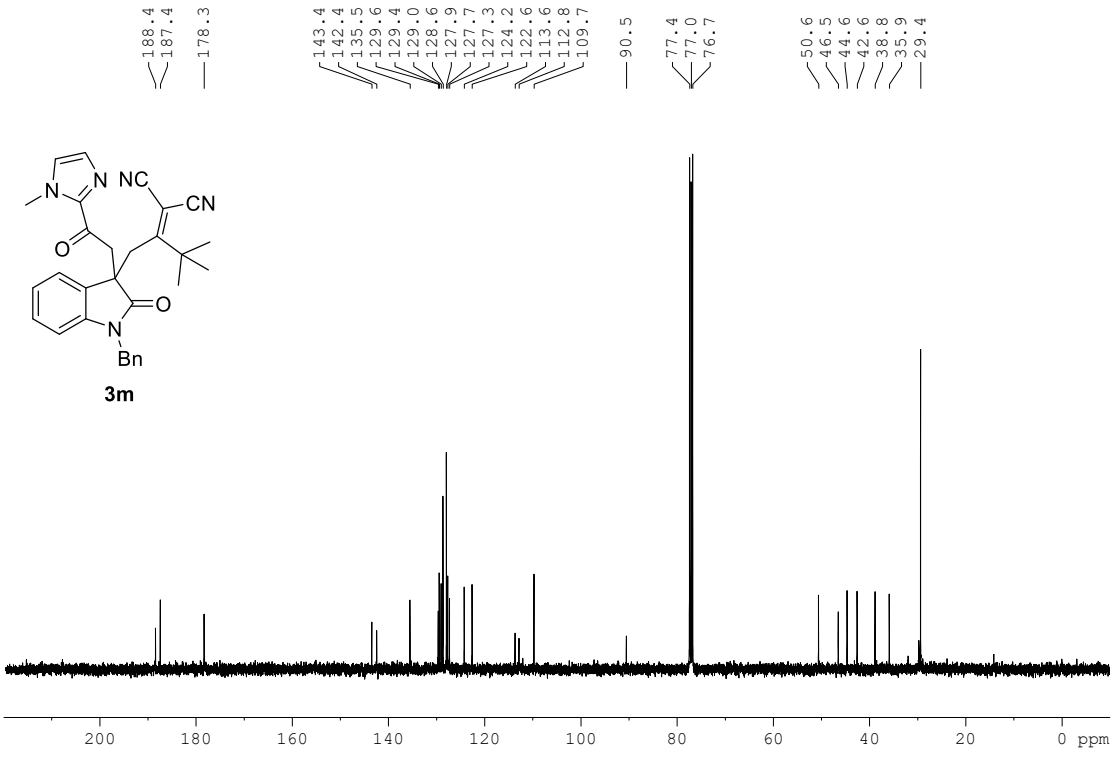


3m

^{13}C NMR-3m



3m

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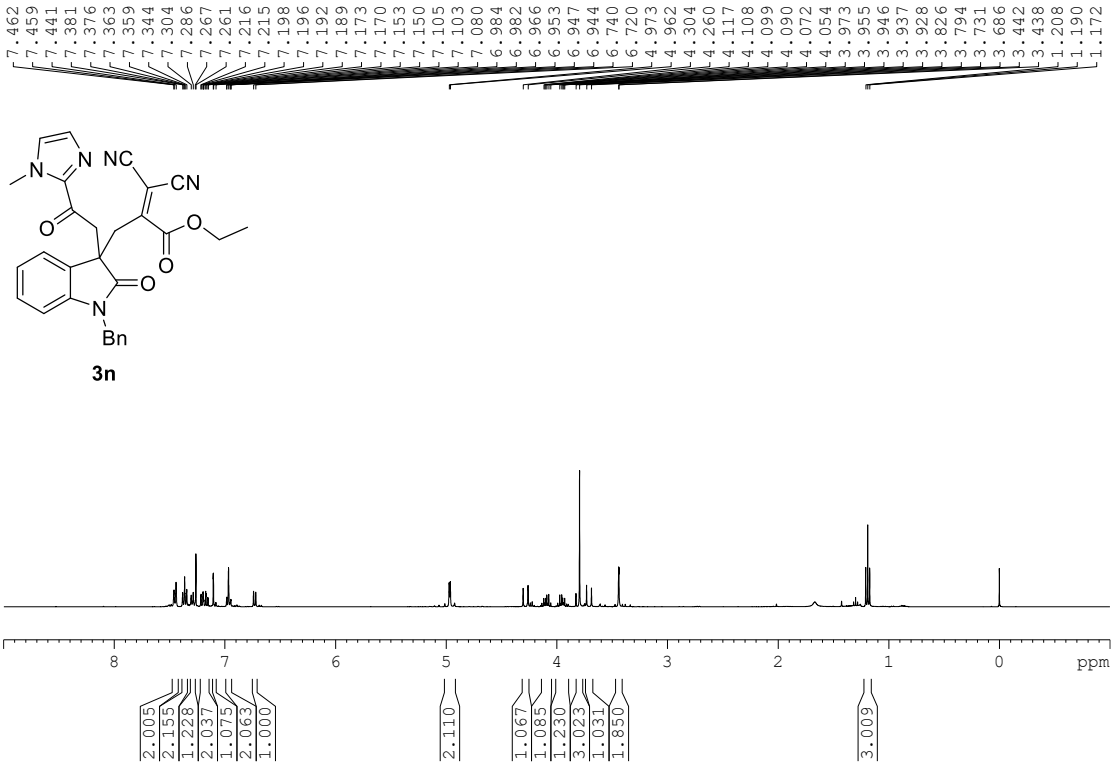

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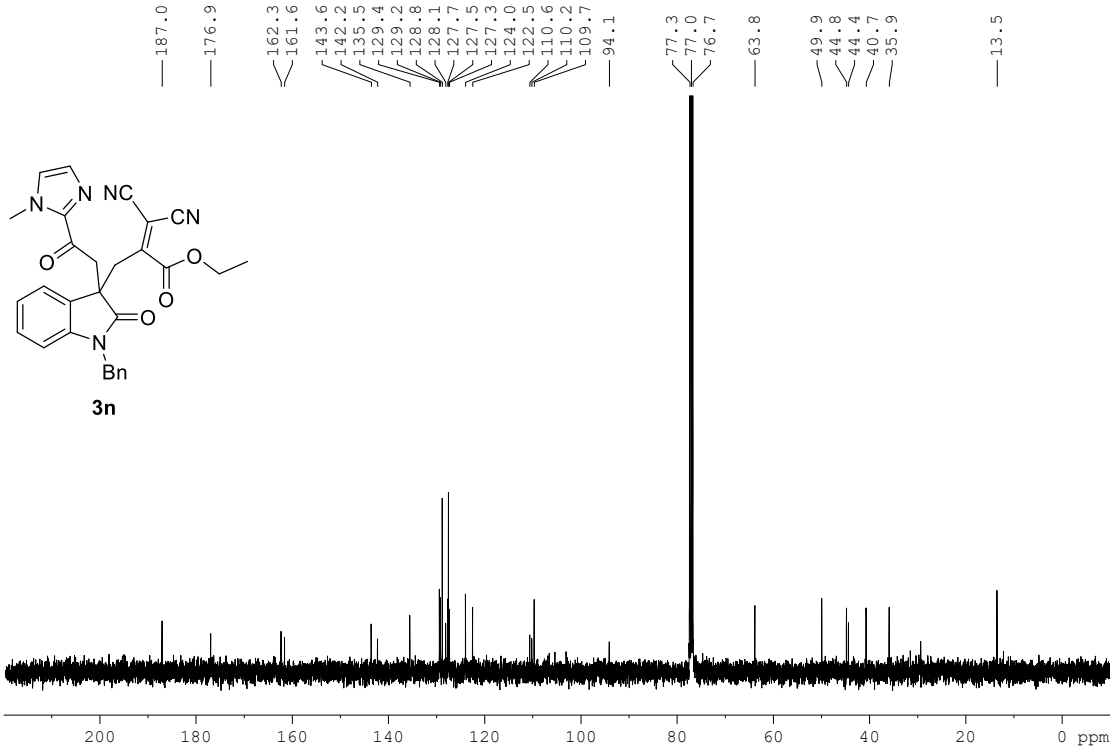

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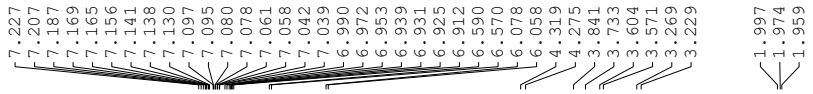

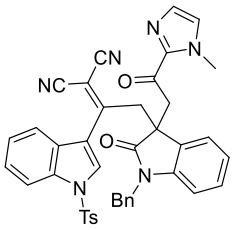

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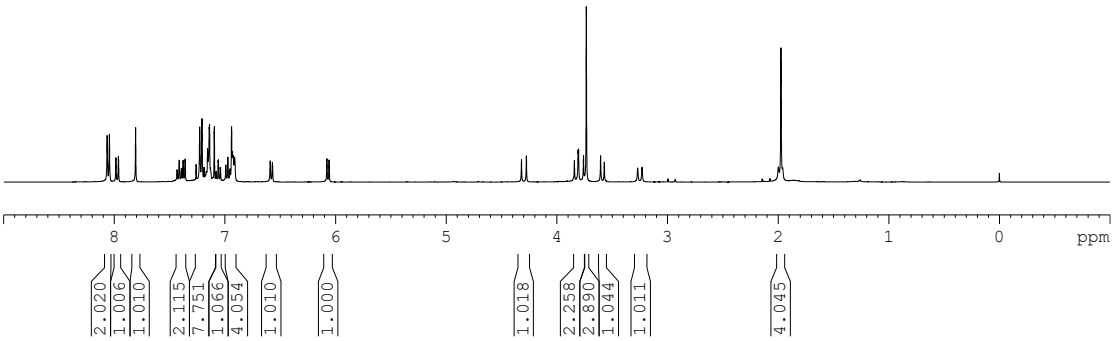

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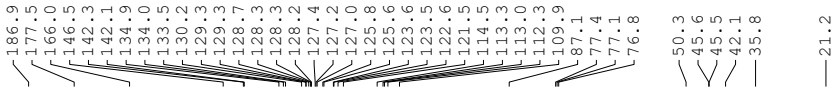

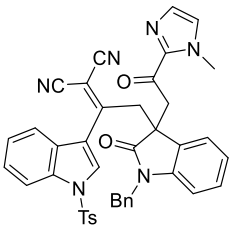

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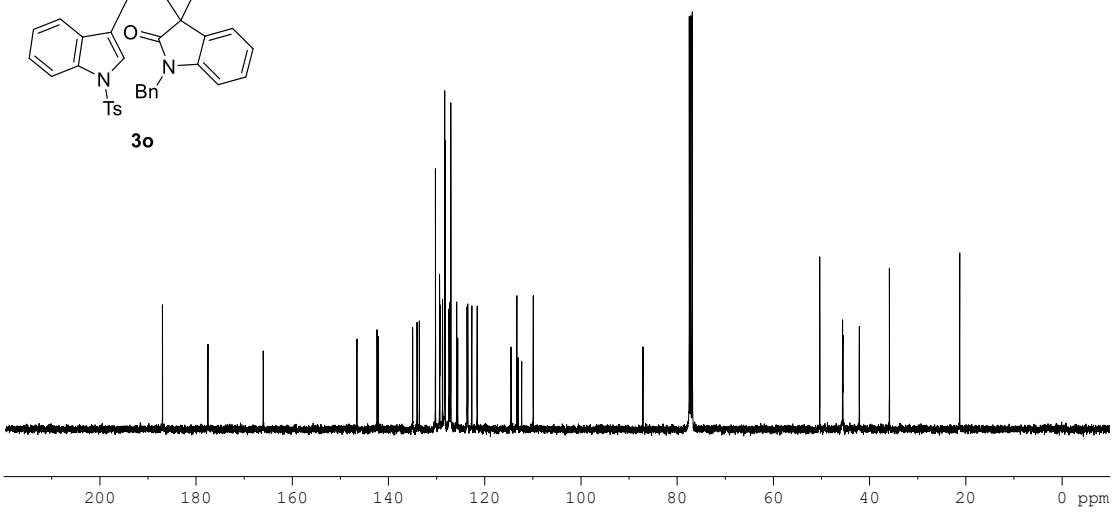
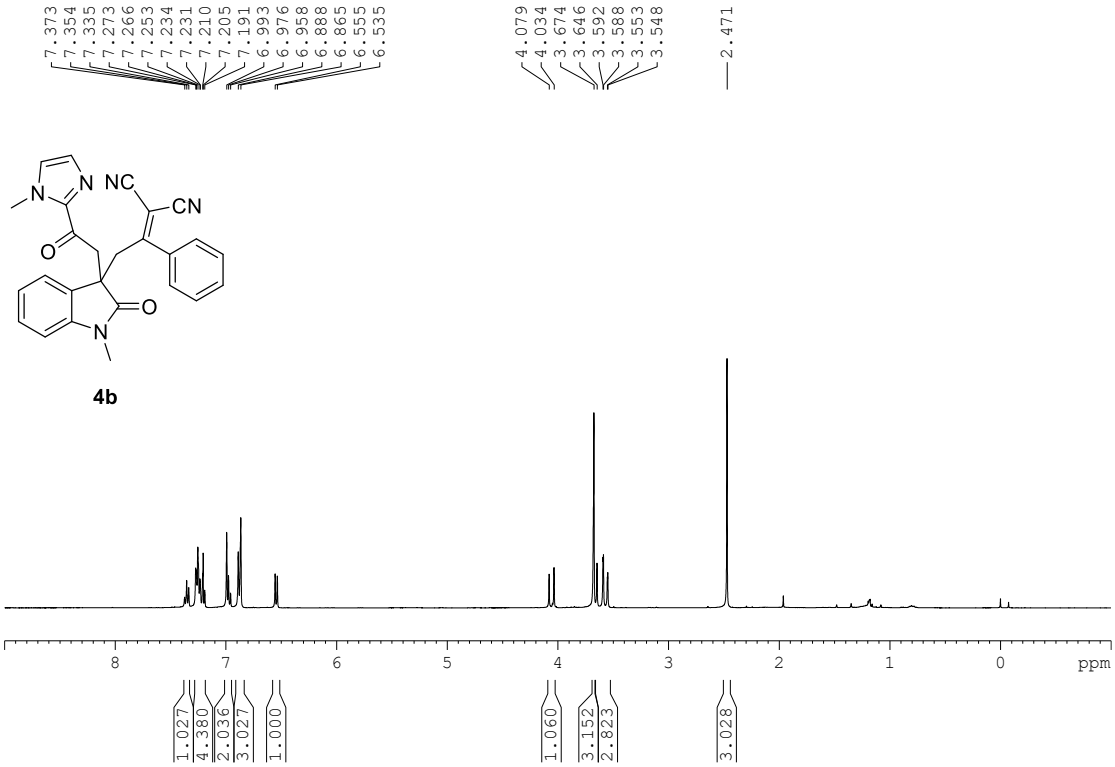
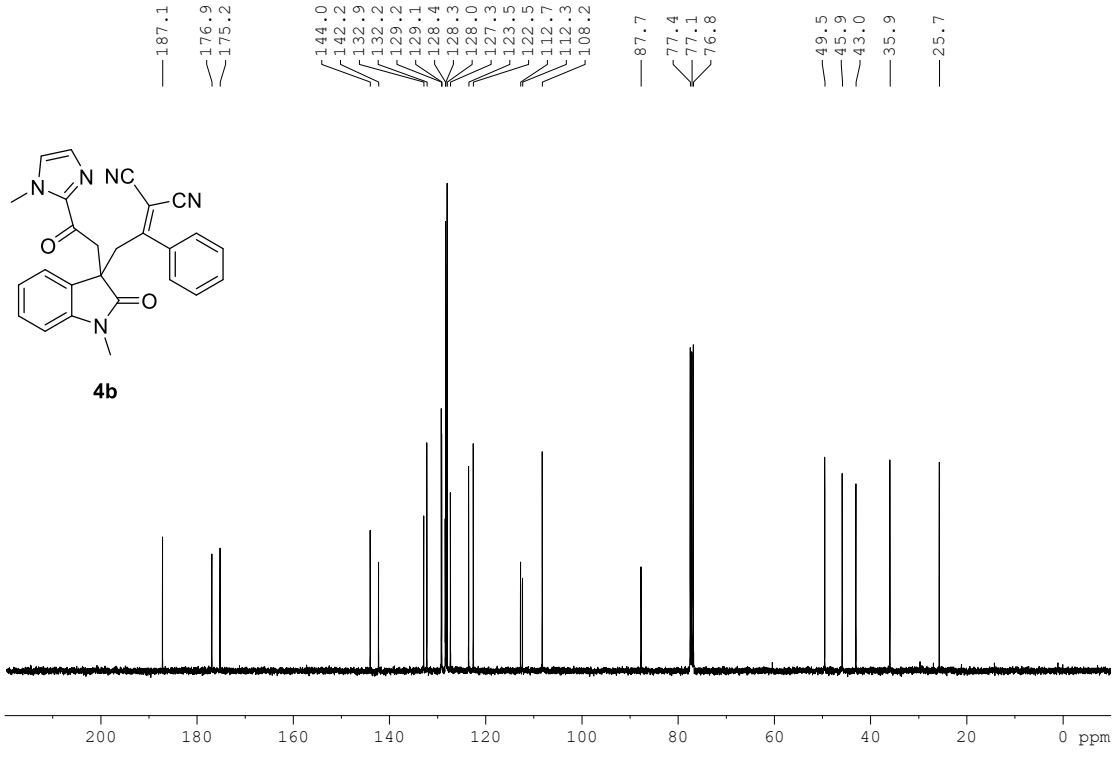


^{1}H-NMR-4b



^{13}C NMR-4b



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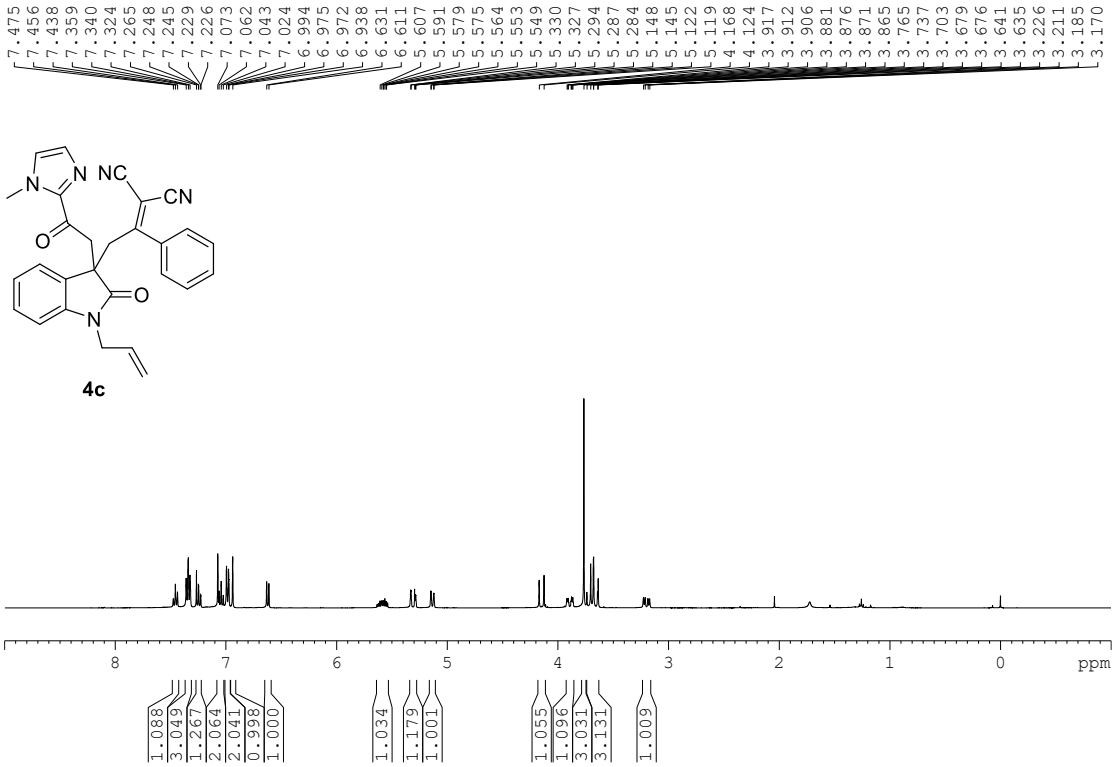

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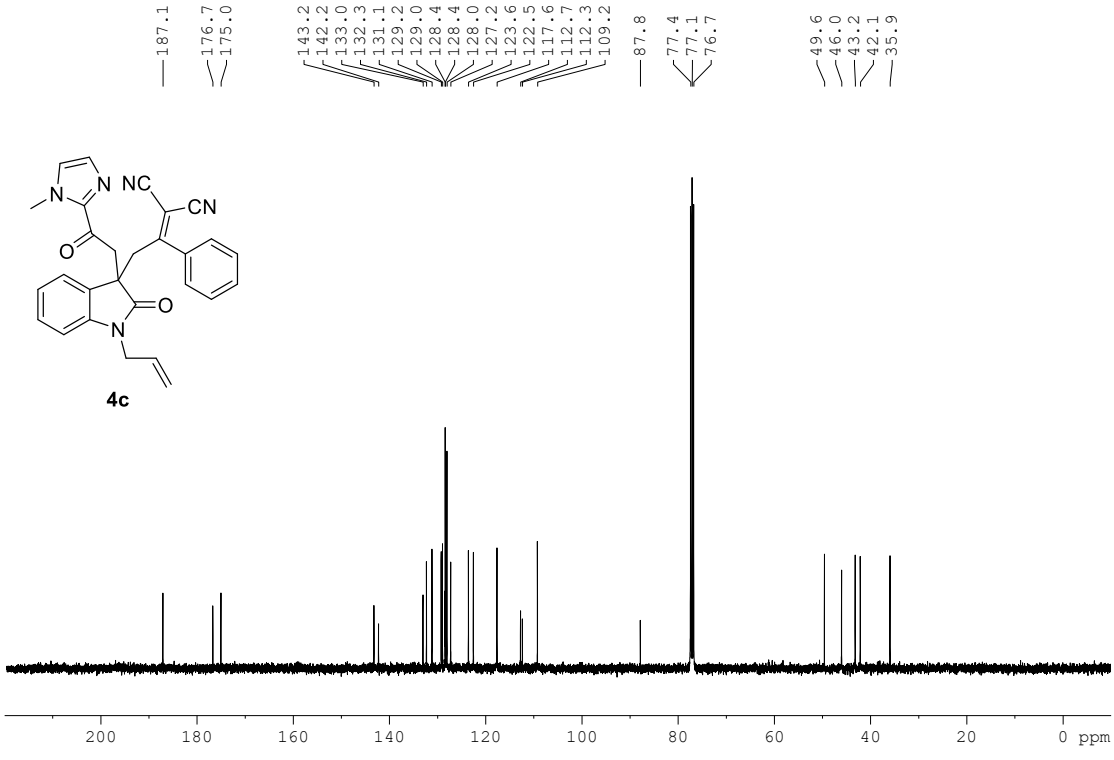

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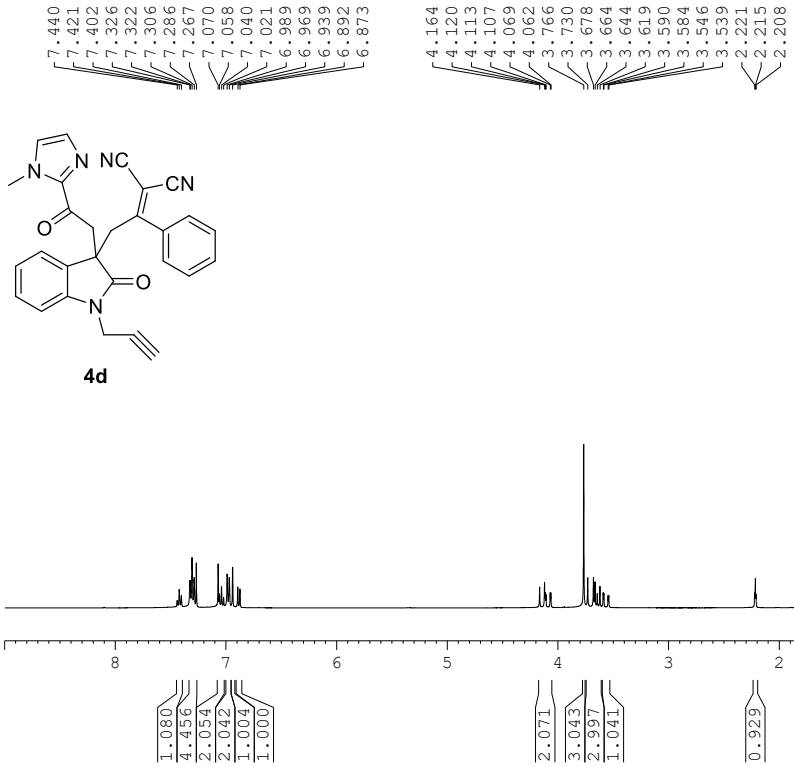

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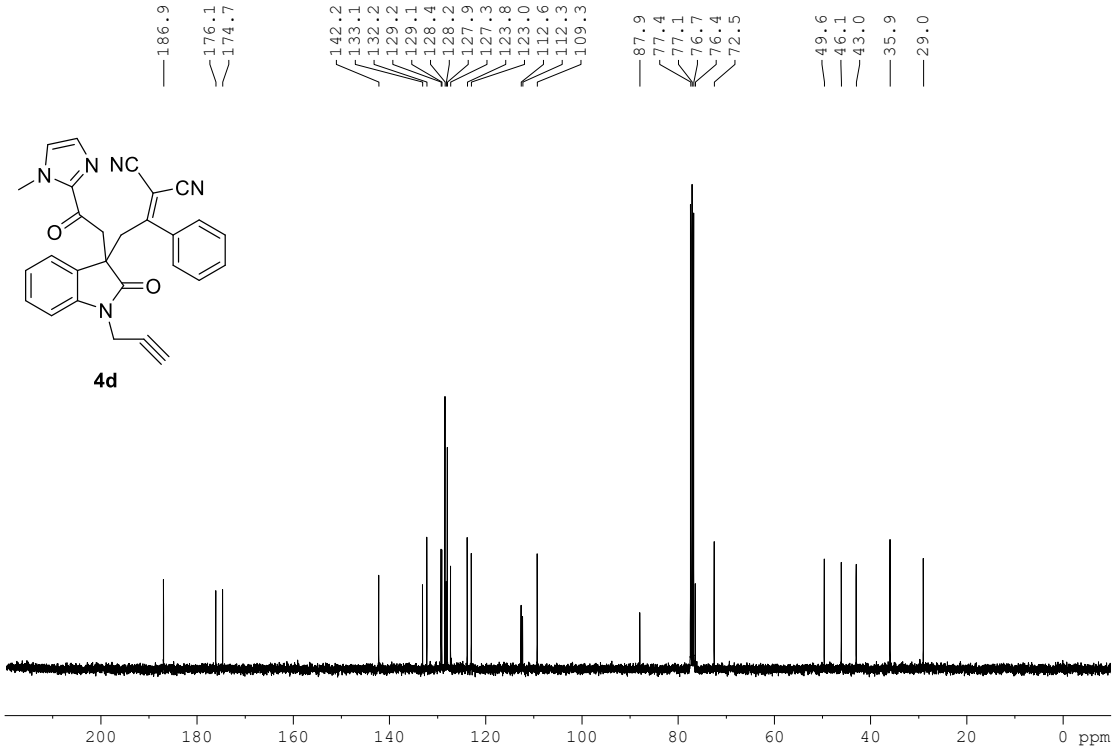
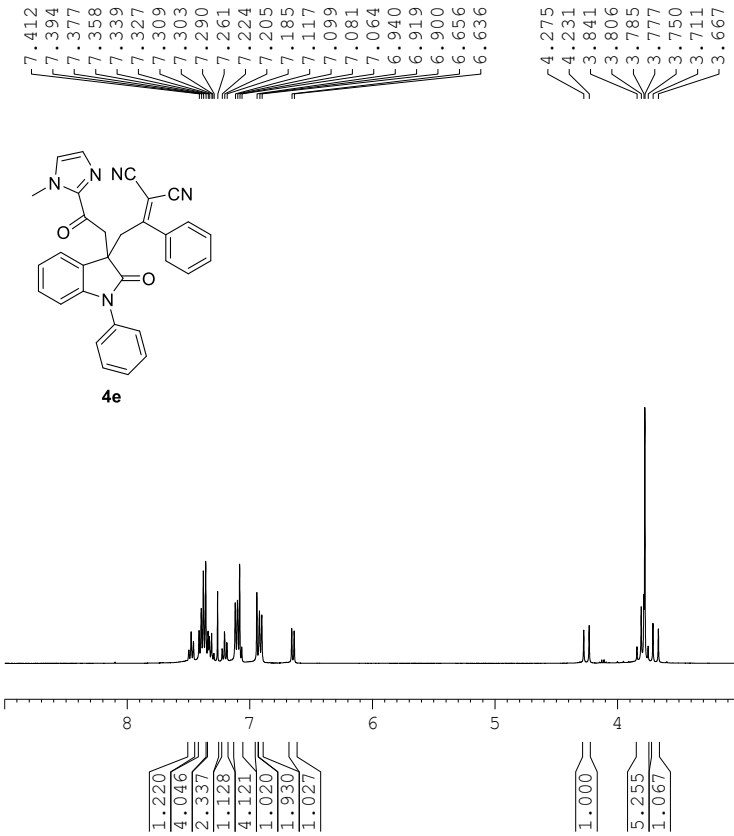


^{1}H-NMR-4e



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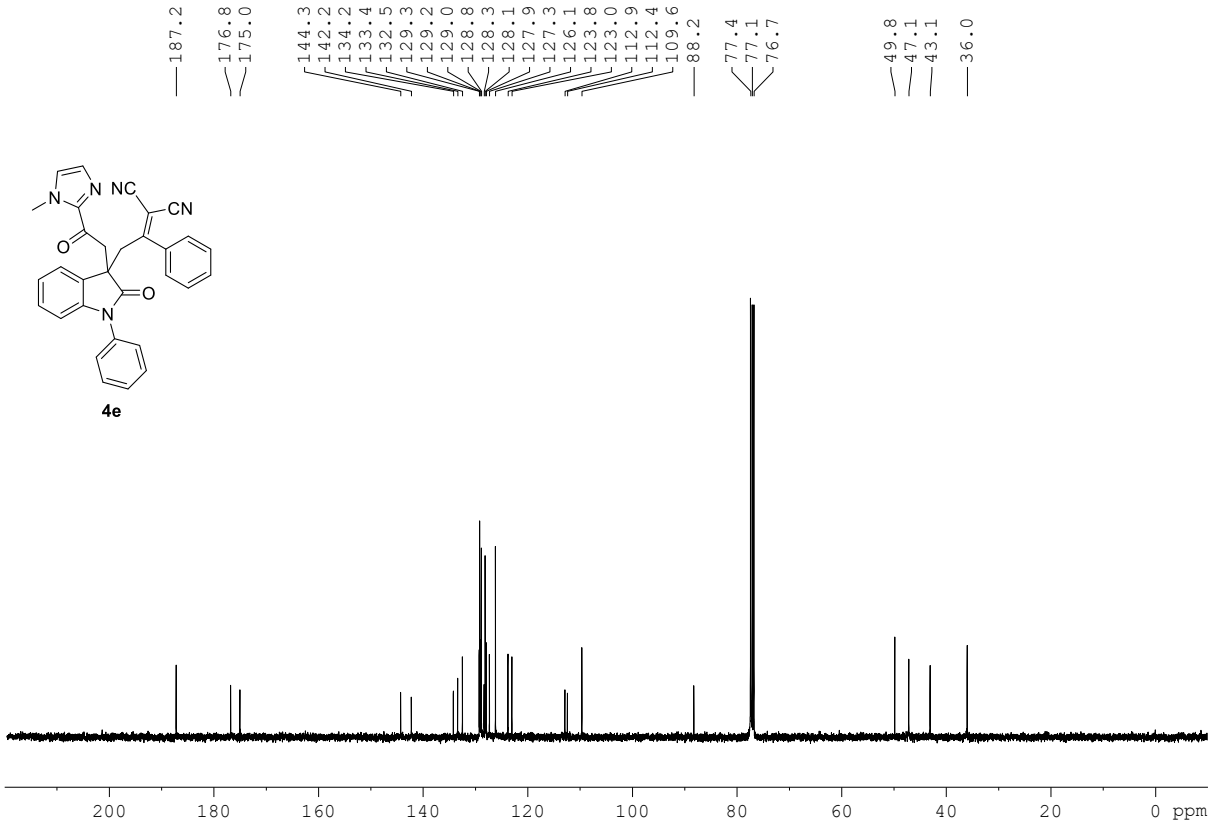

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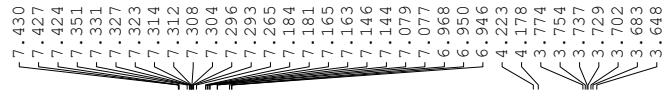

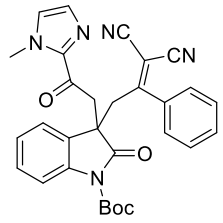

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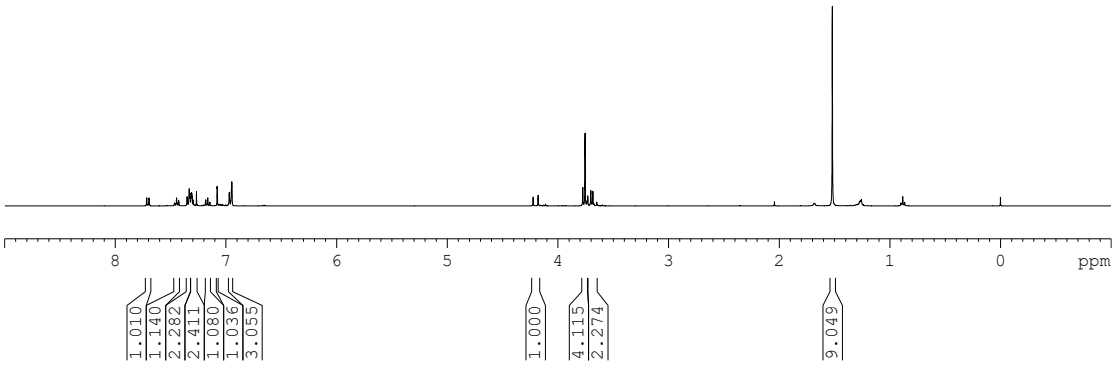

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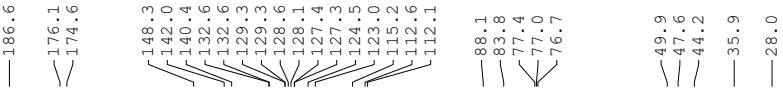

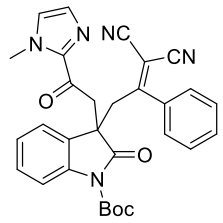

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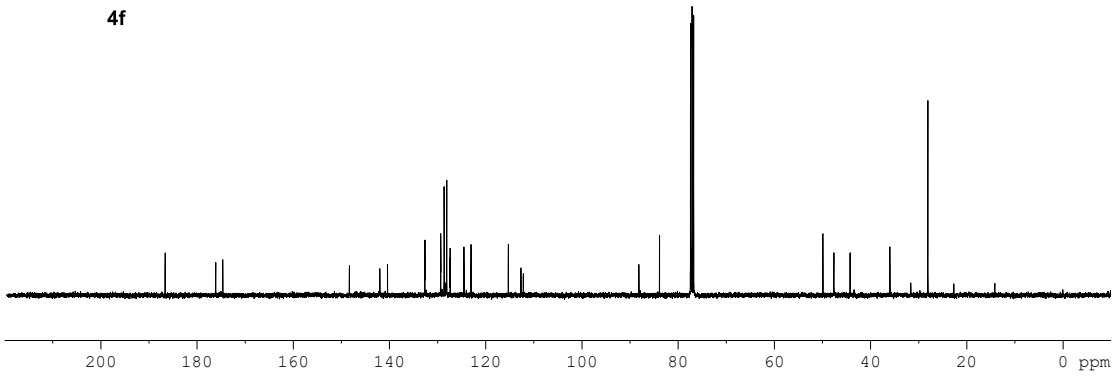

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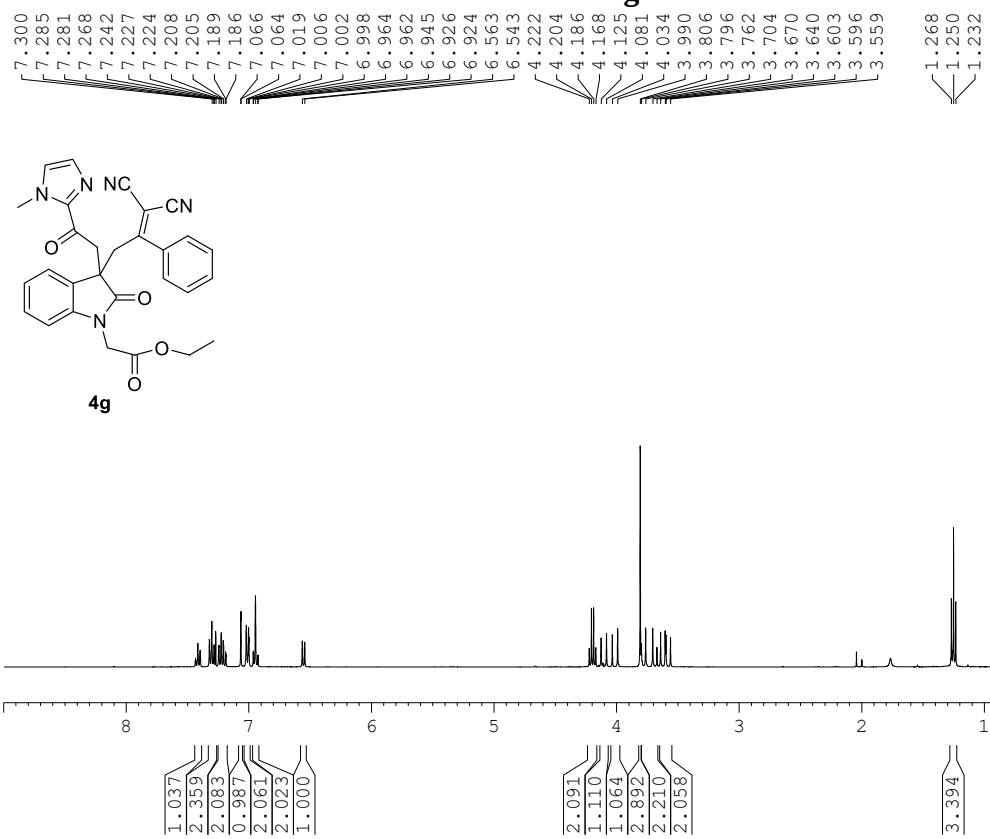

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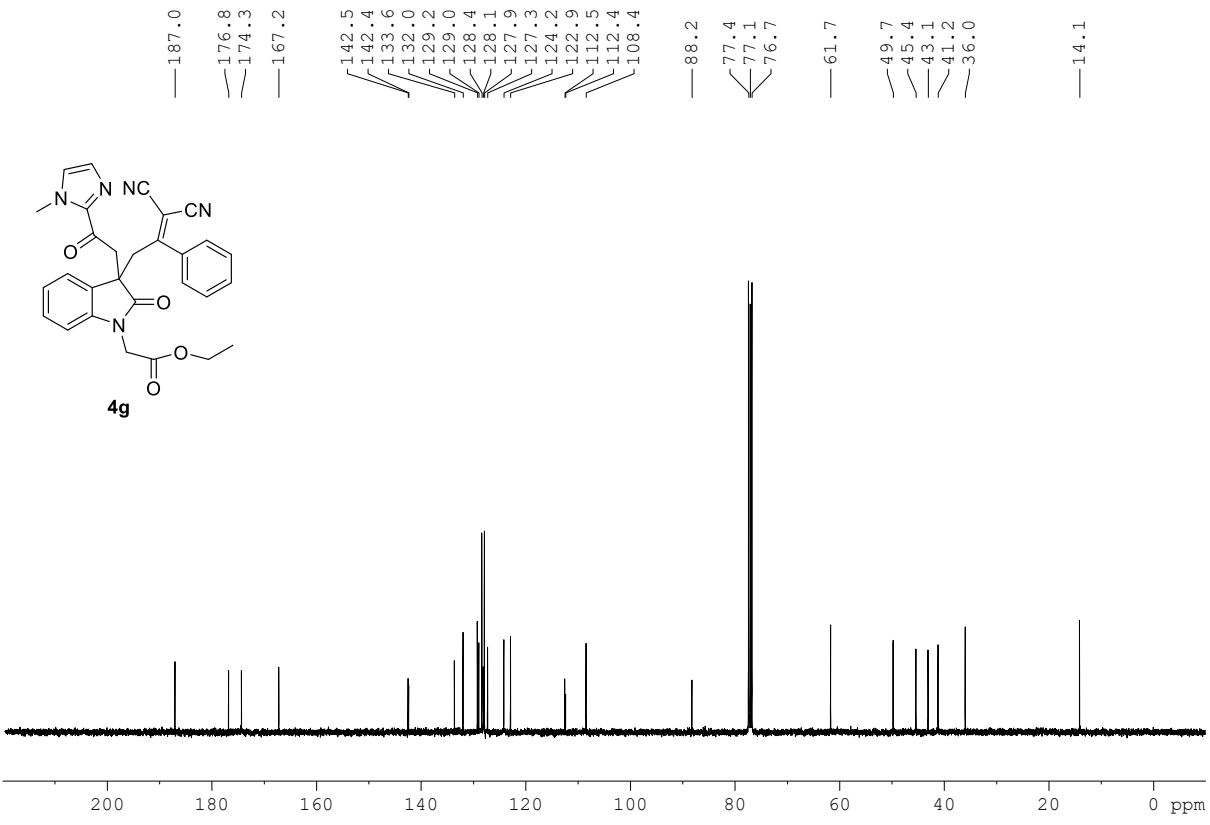

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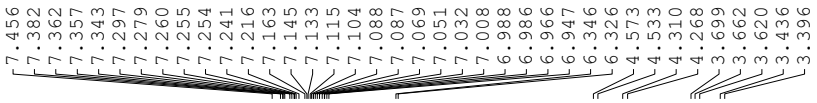

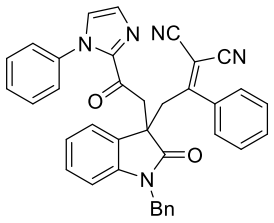

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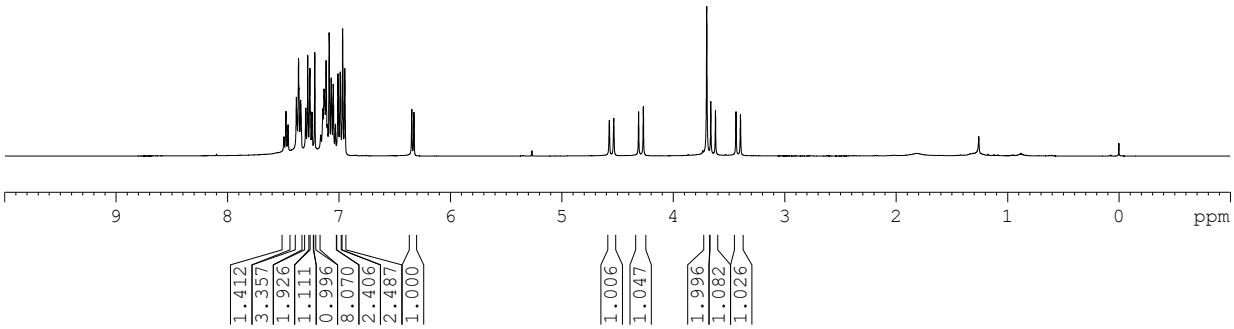

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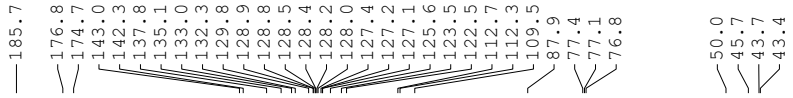

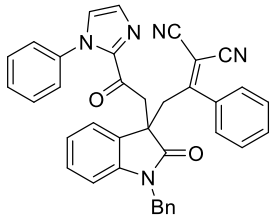

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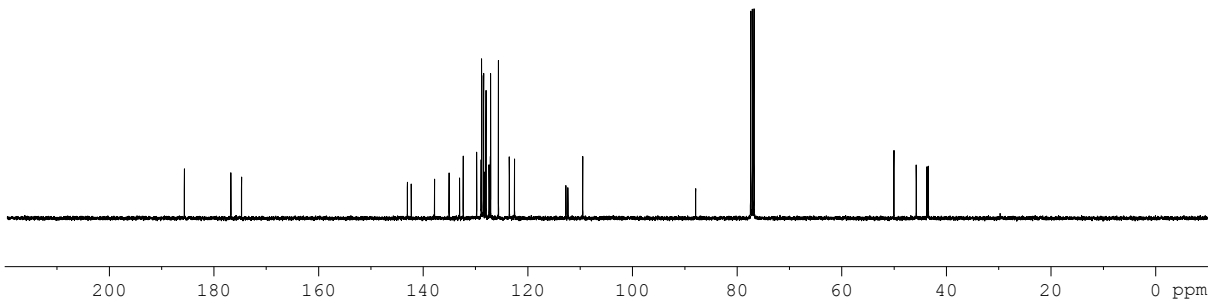

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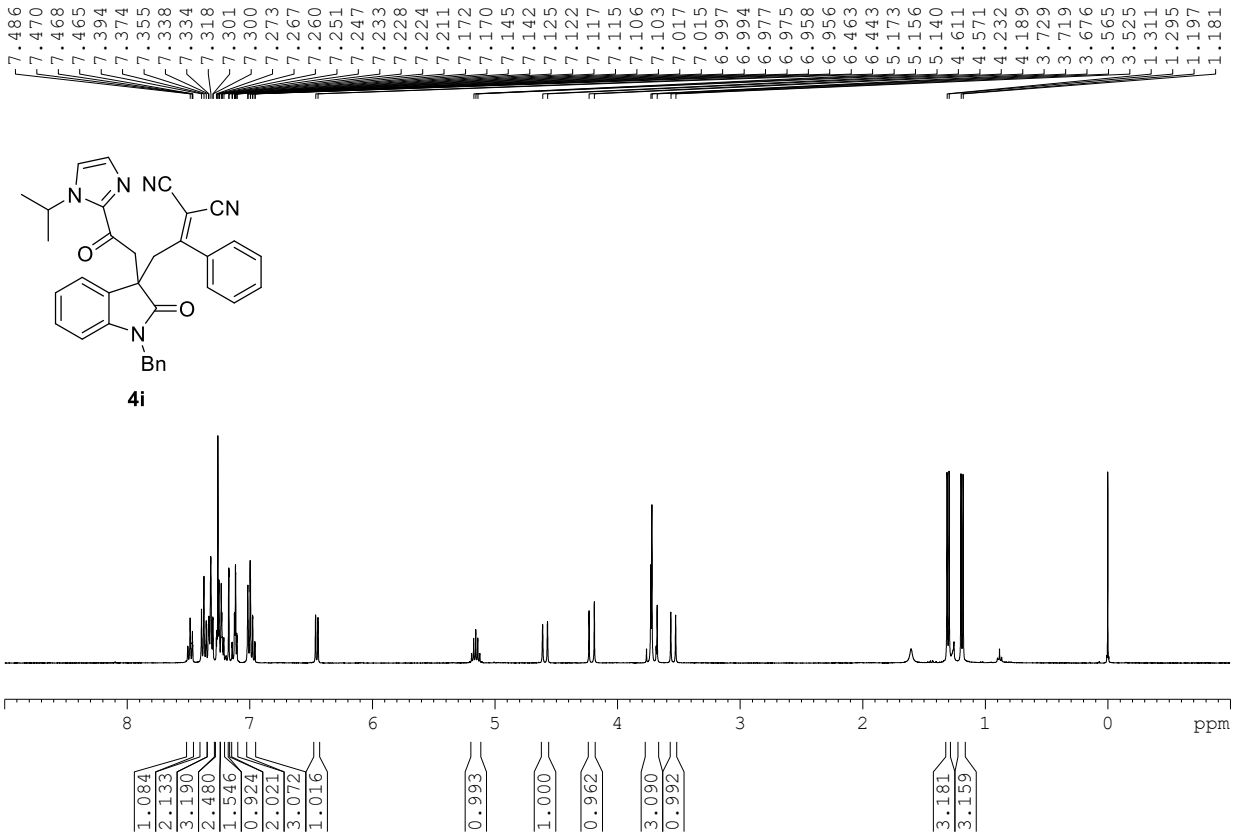

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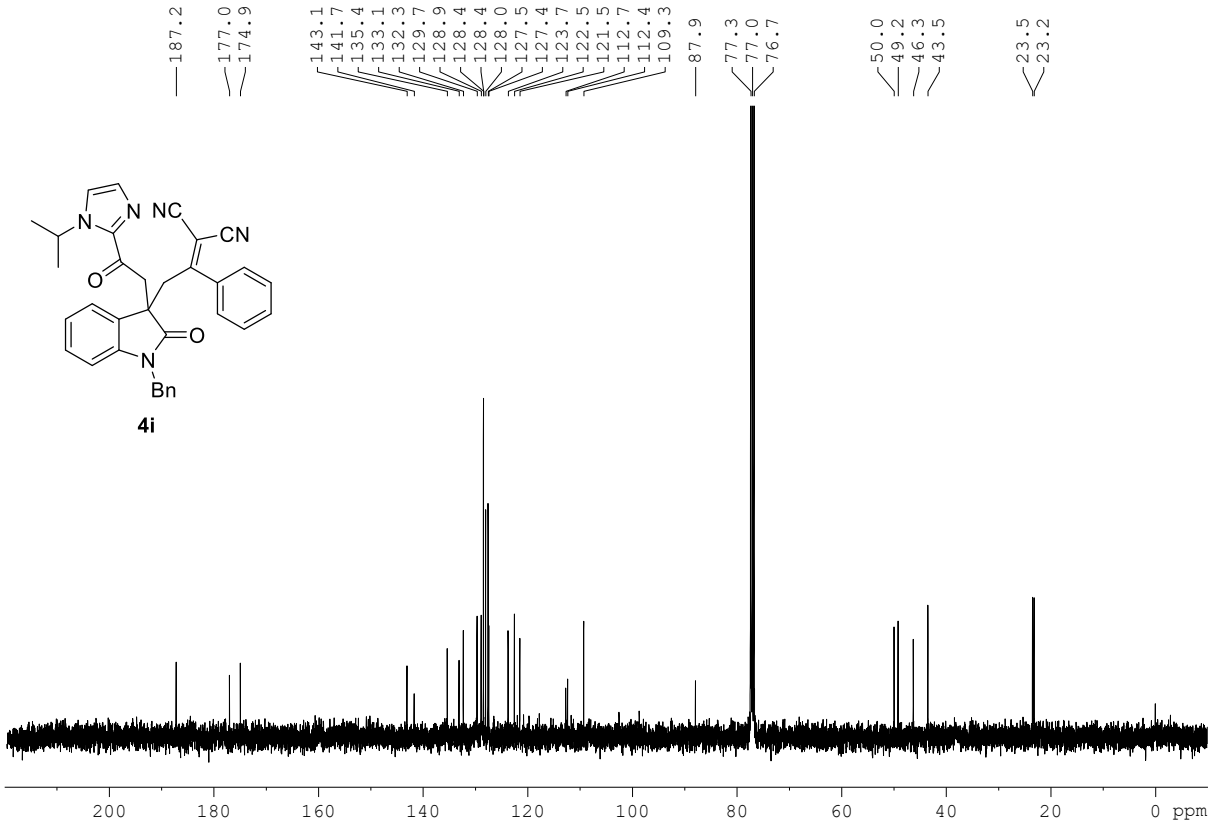
^{13}C NMR-4i



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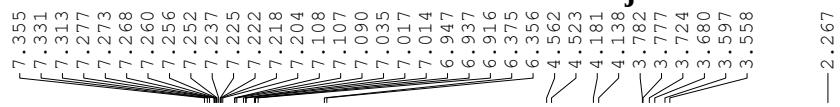

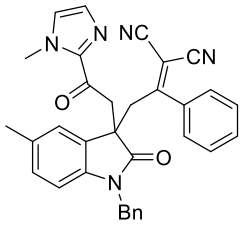

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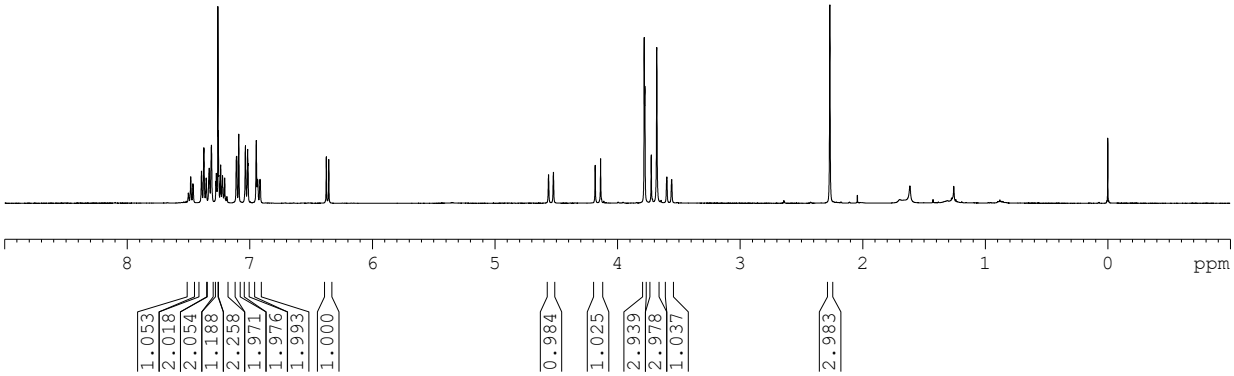

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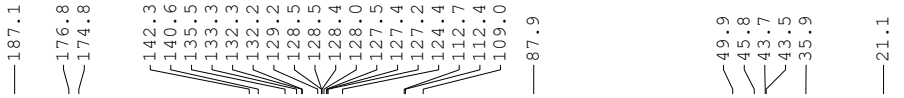

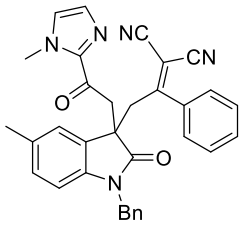

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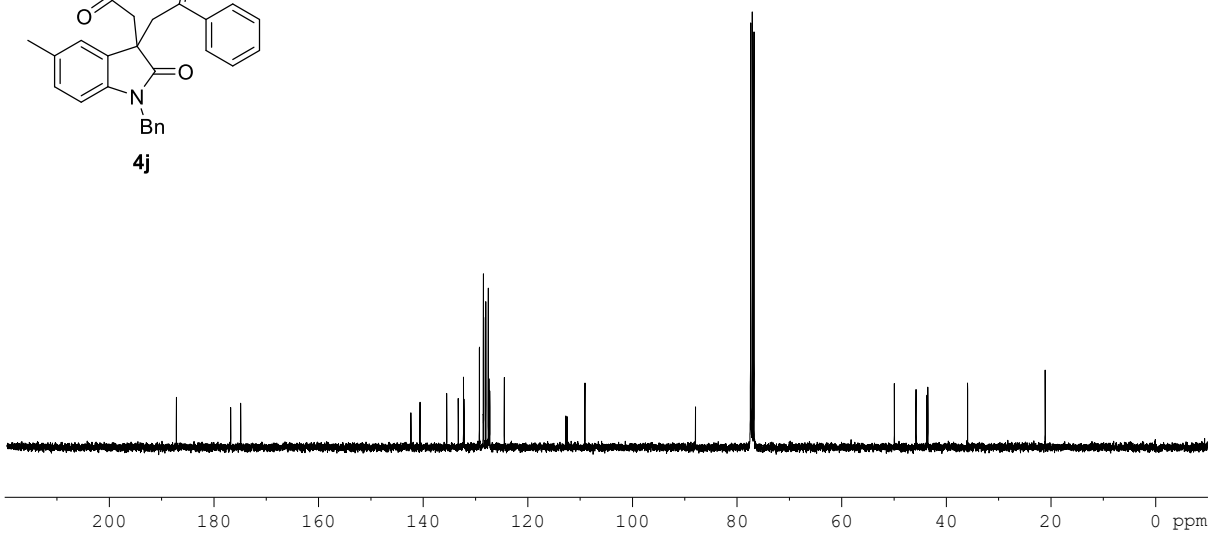

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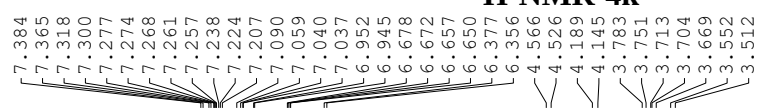

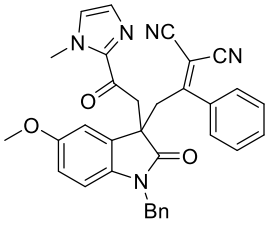

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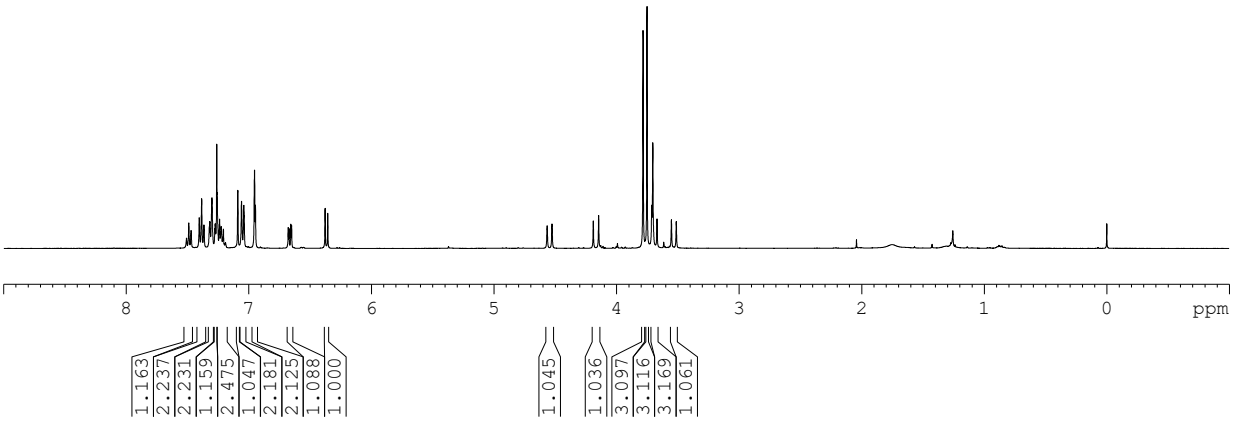

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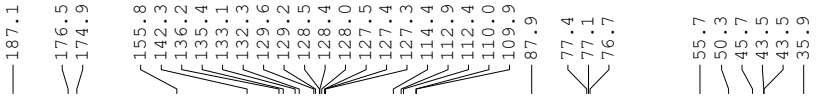

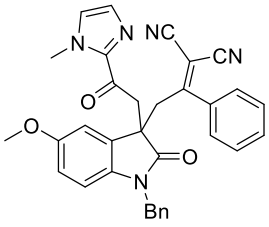

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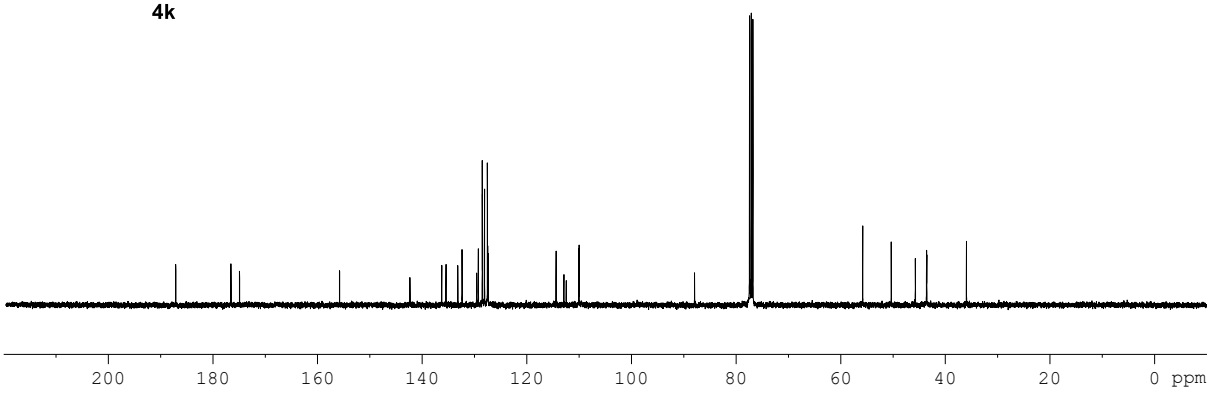

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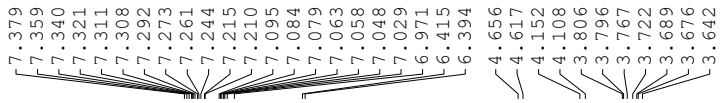

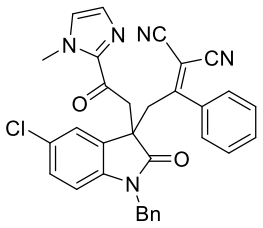

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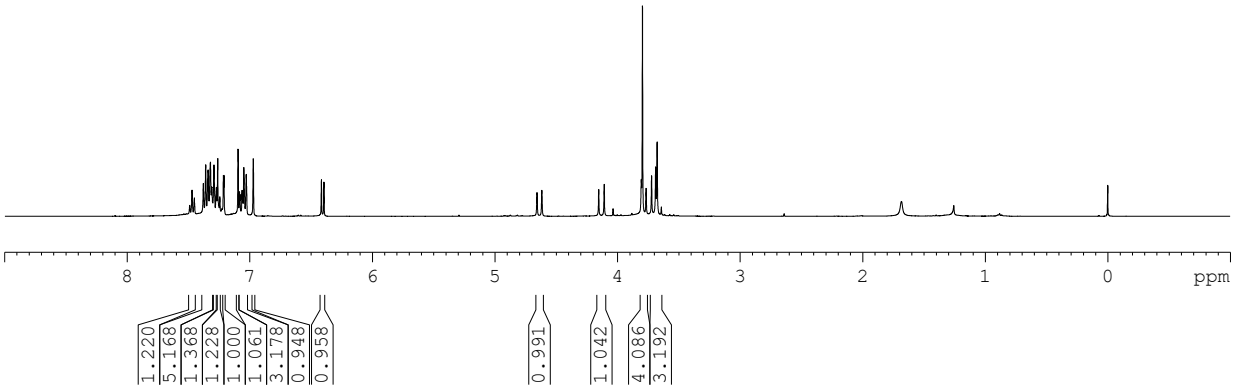

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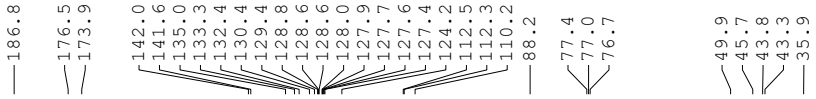

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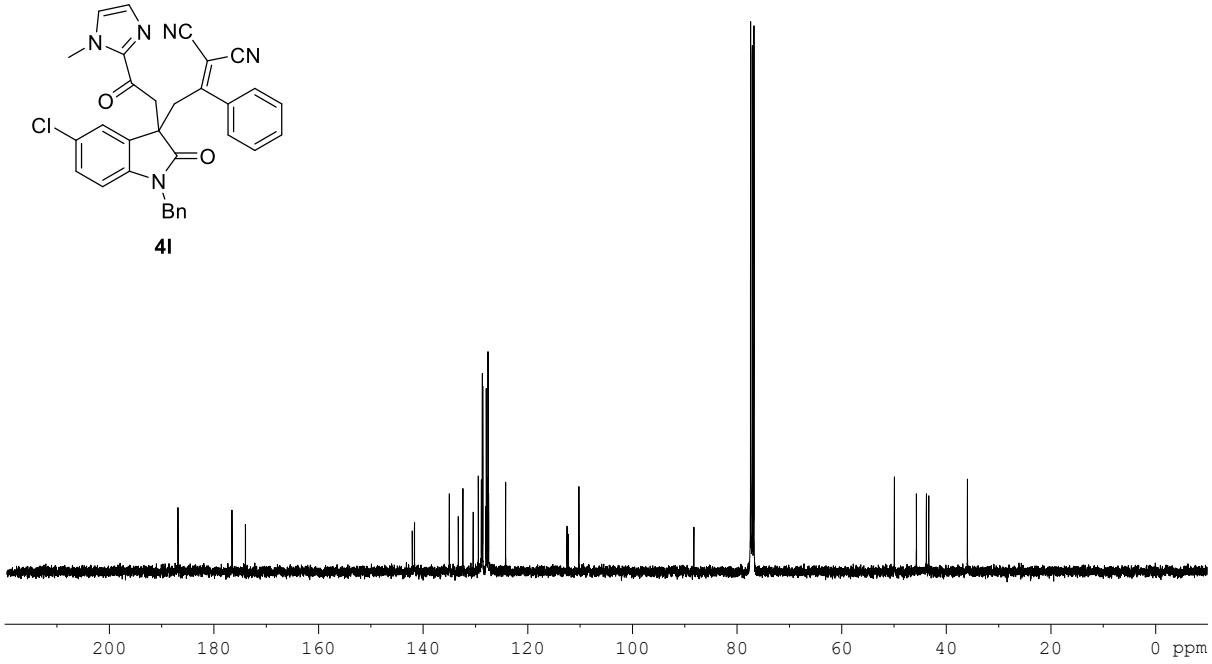

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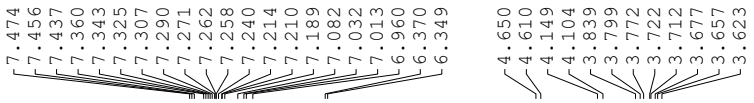

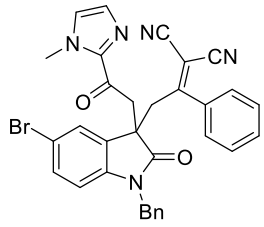

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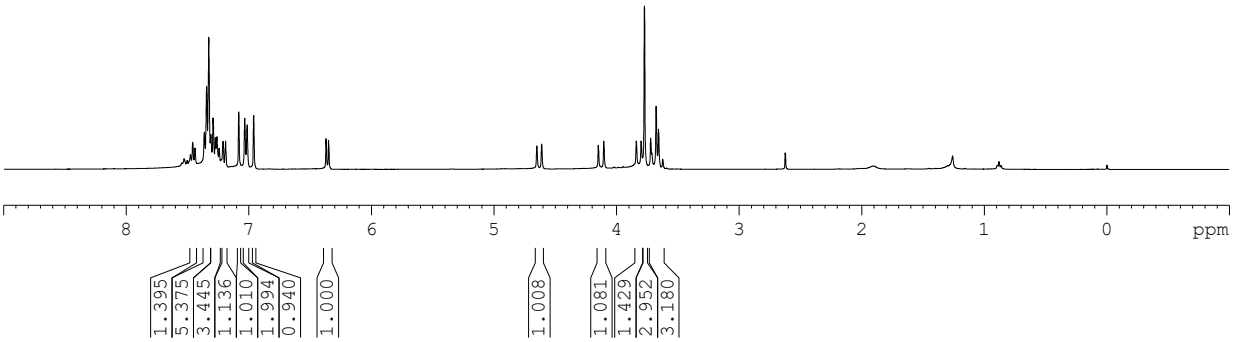

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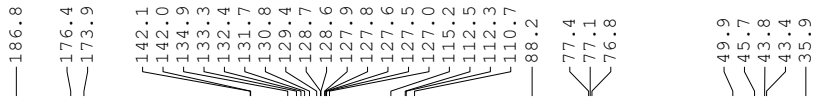

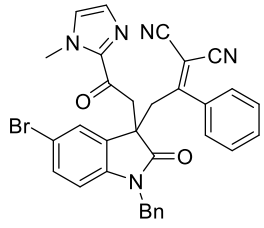

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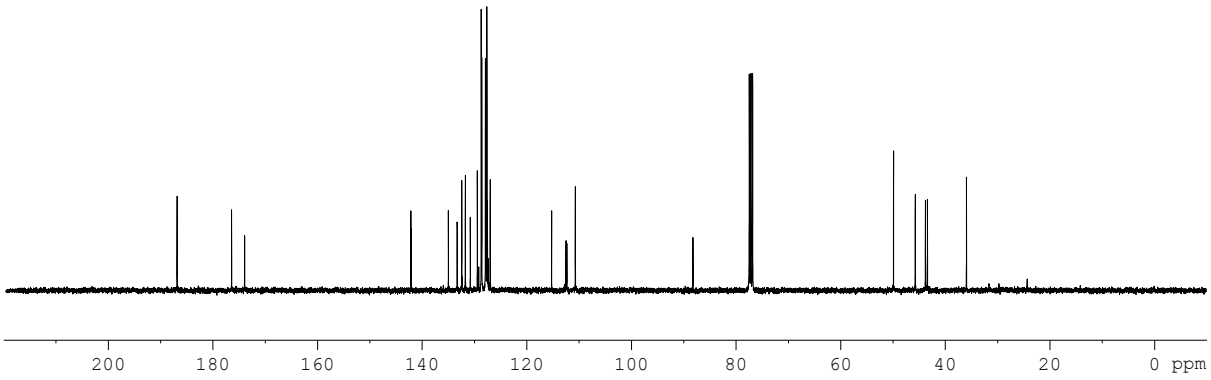

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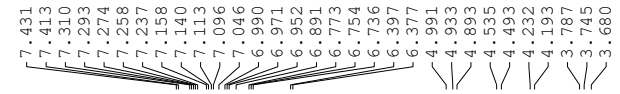

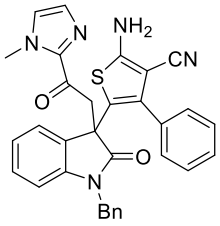

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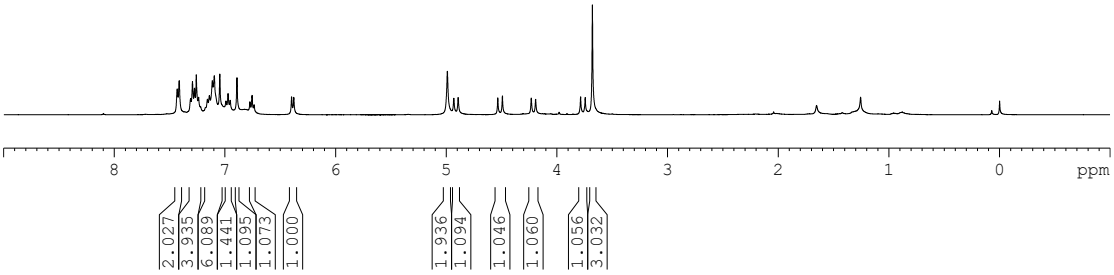

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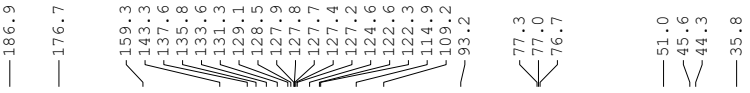

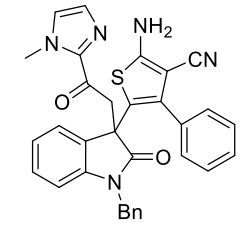

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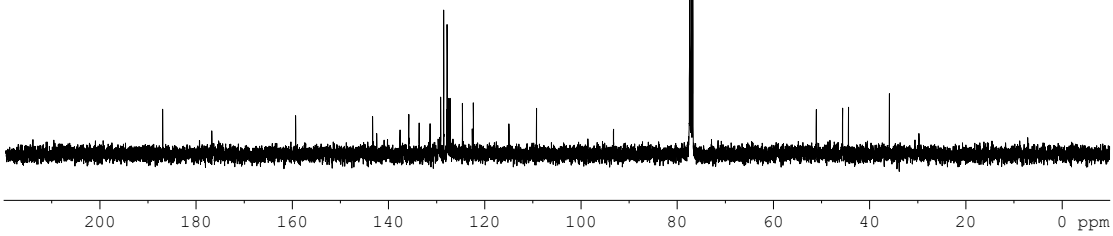
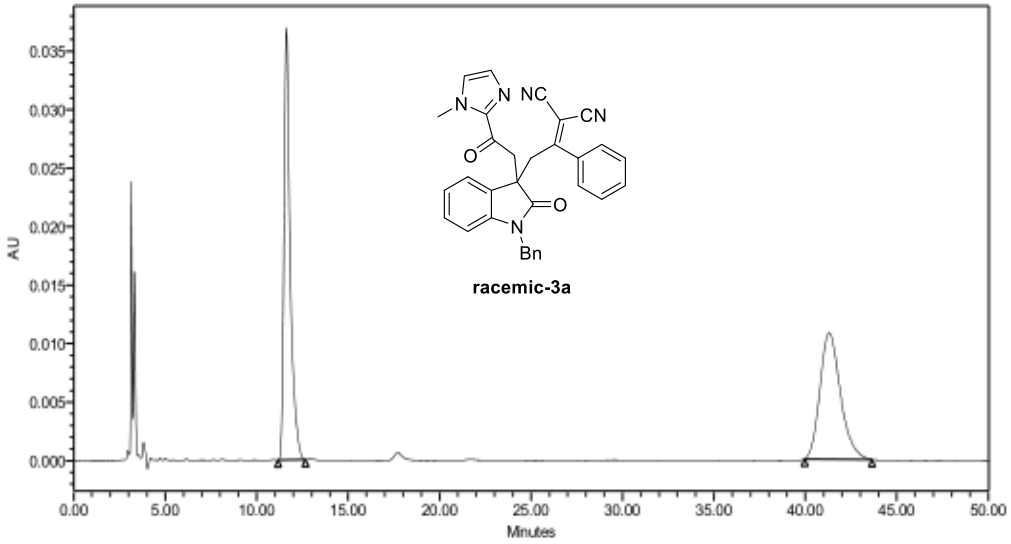


V Chiral HPLC analysis trace

racemic-3a



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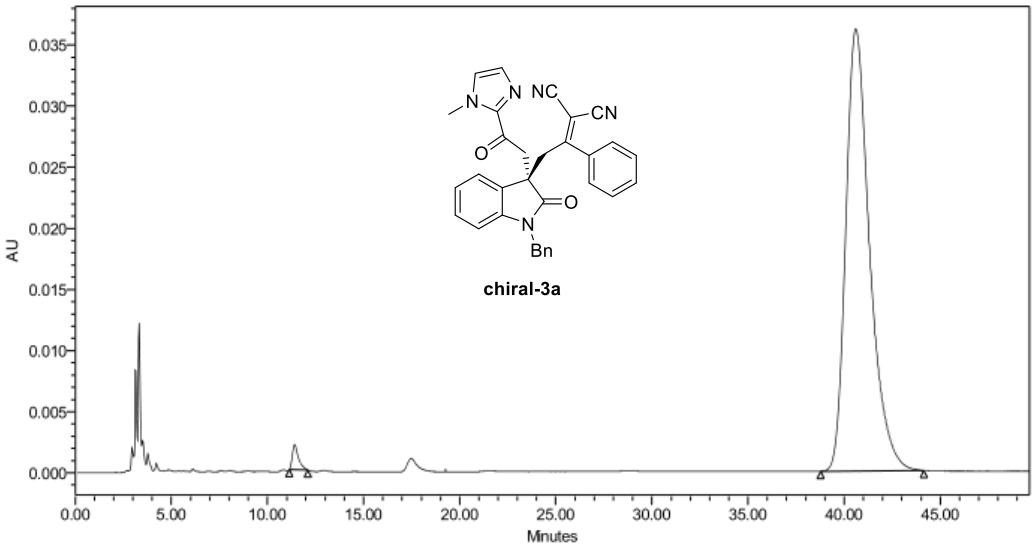
2	41.30	847195	49.40	10828

chiral-3a



	RT	Area	% Area	Height
1	11.41	45458	1.44	2049
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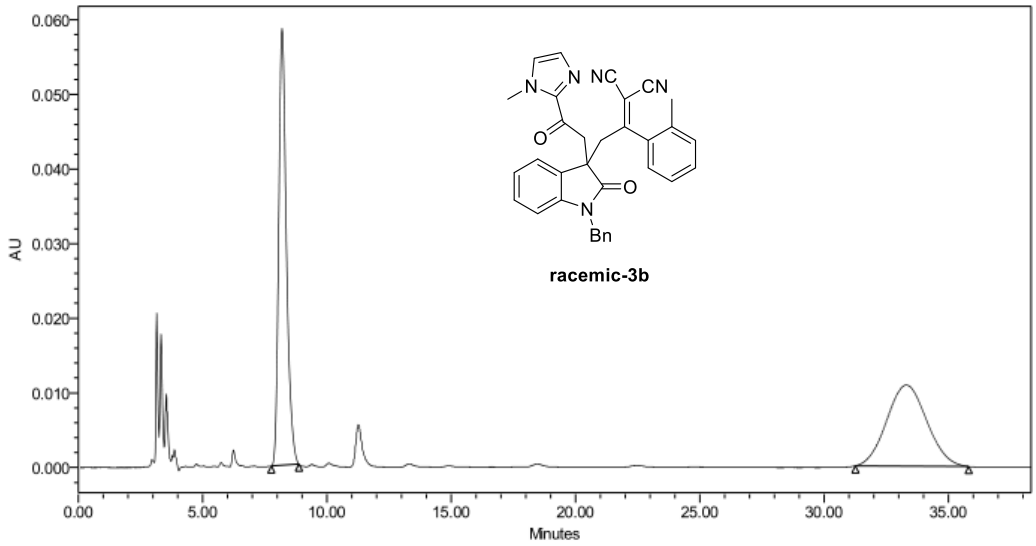
racemic-3b



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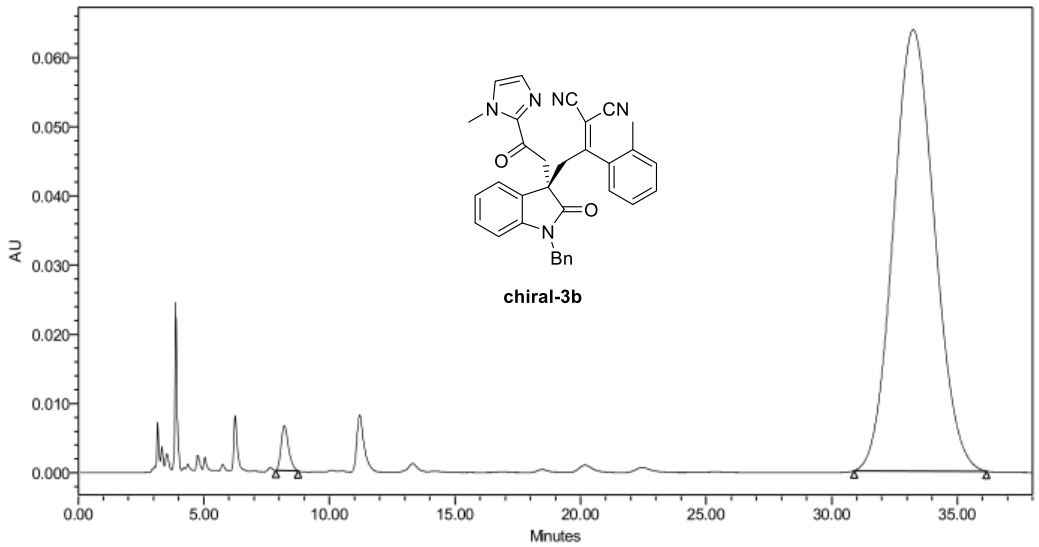
chiral-3b



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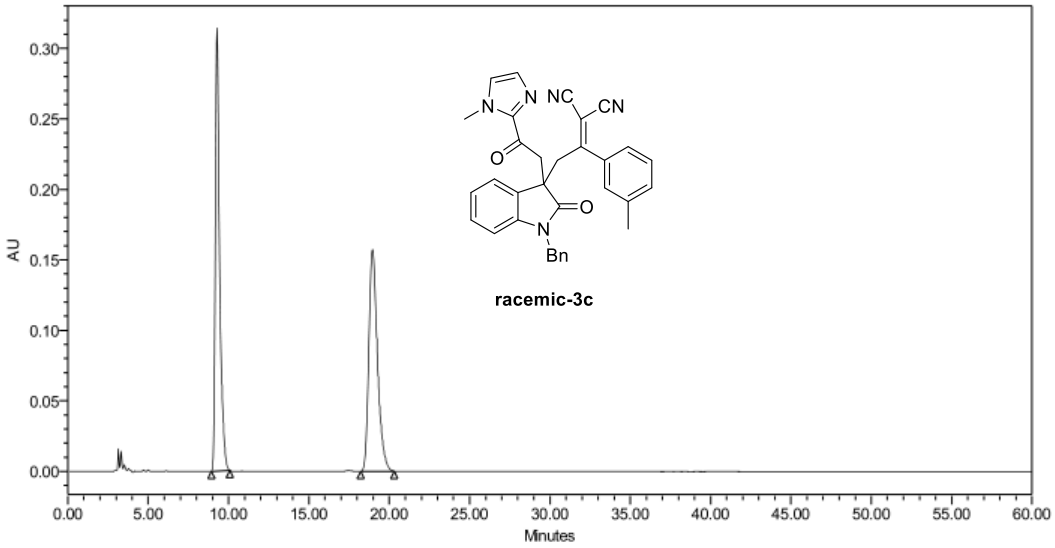
racemic-3c



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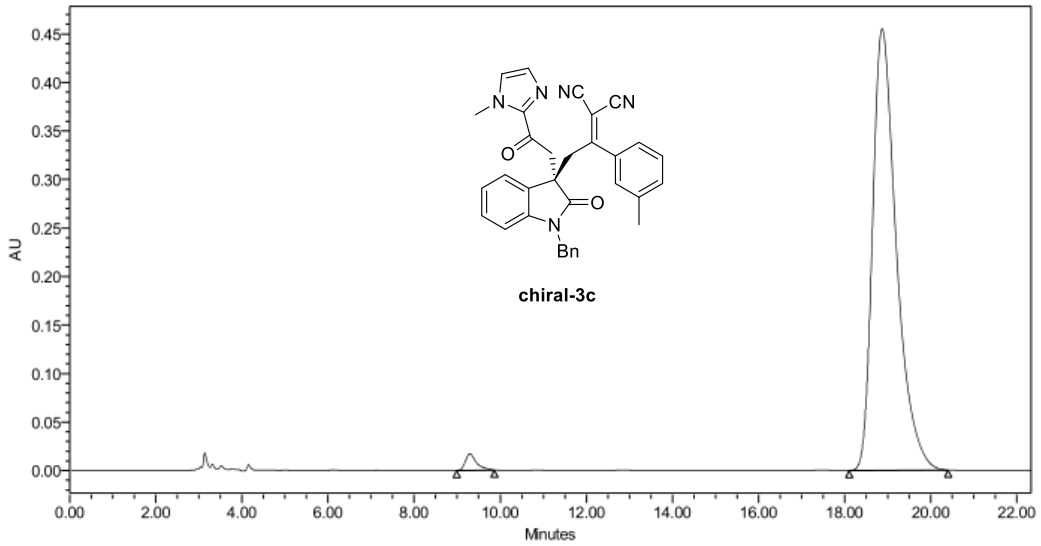
chiral-3c



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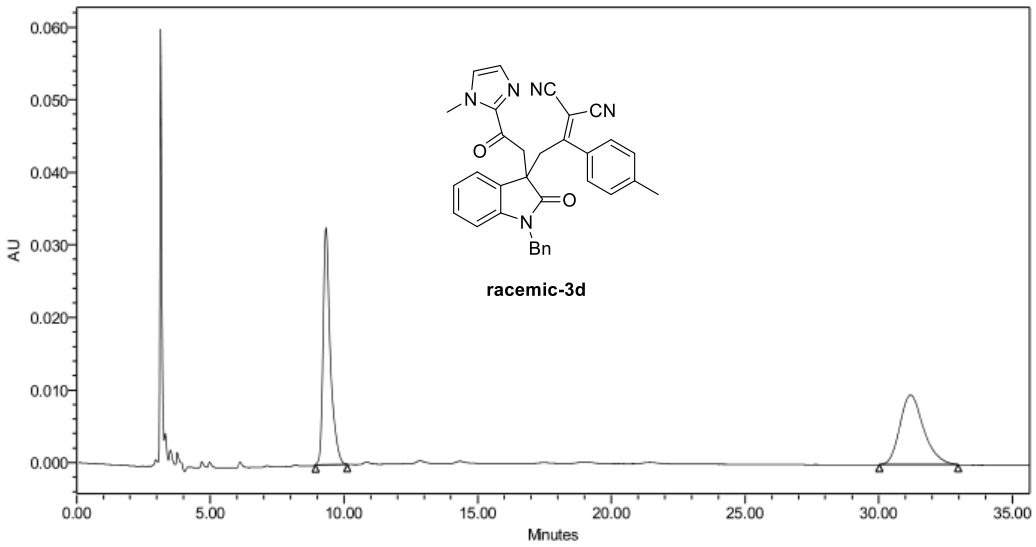
racemic-3d



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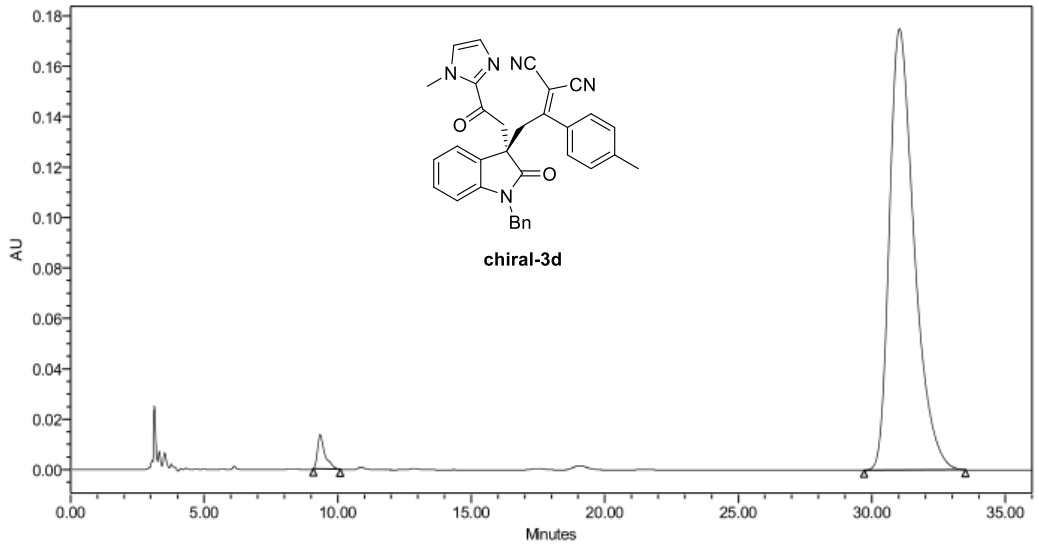
chiral-3d



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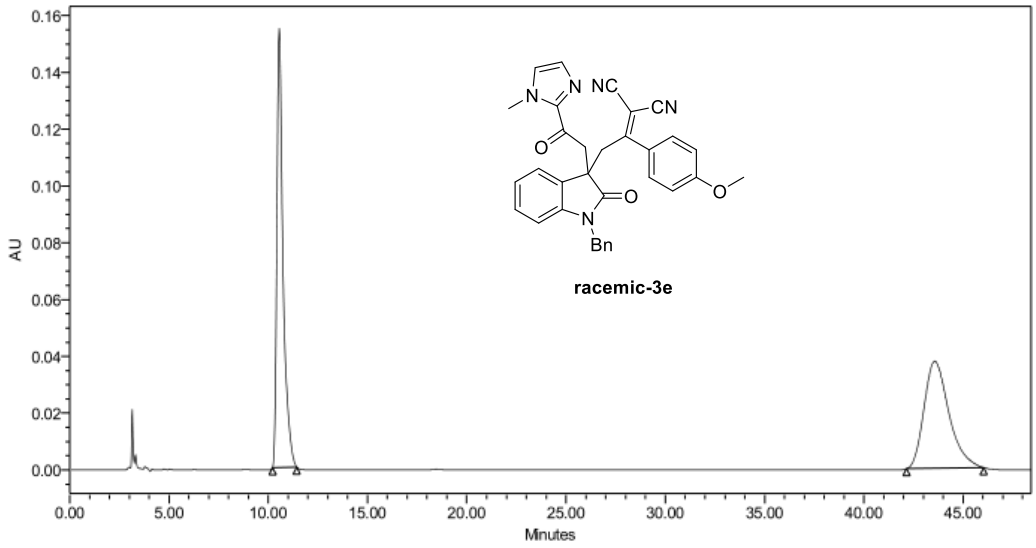
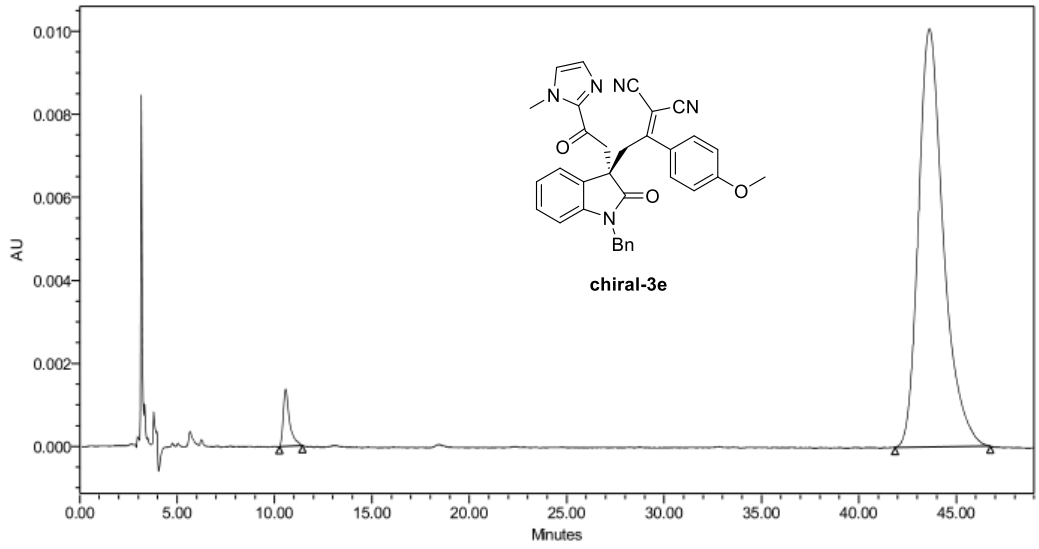
2	31.03	11355068	97.74	175081

racemic-3e



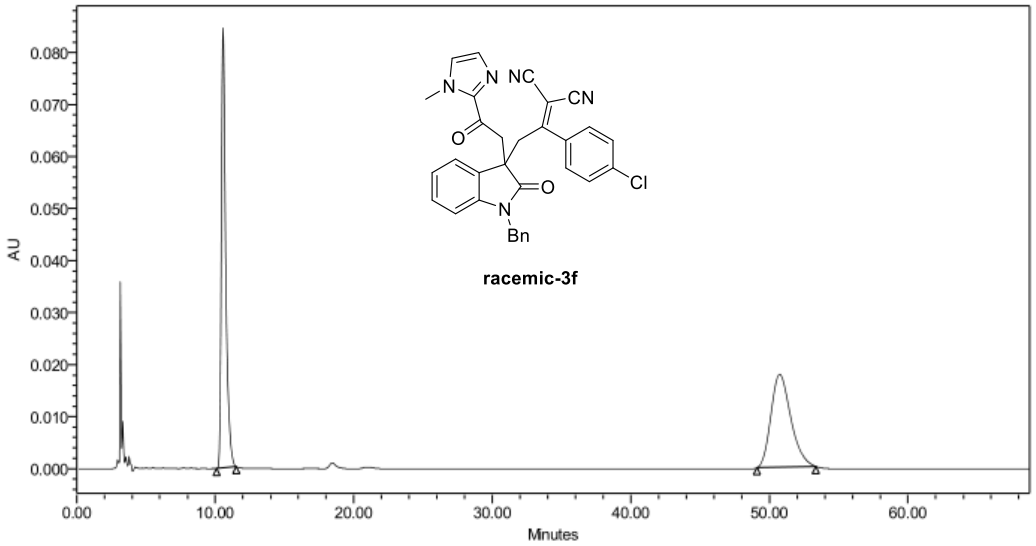
	RT	Area	% Area	Height
1	10.56	3366571	50.71	154578
2	43.57	3272250	49.29	37708

chiral-3e



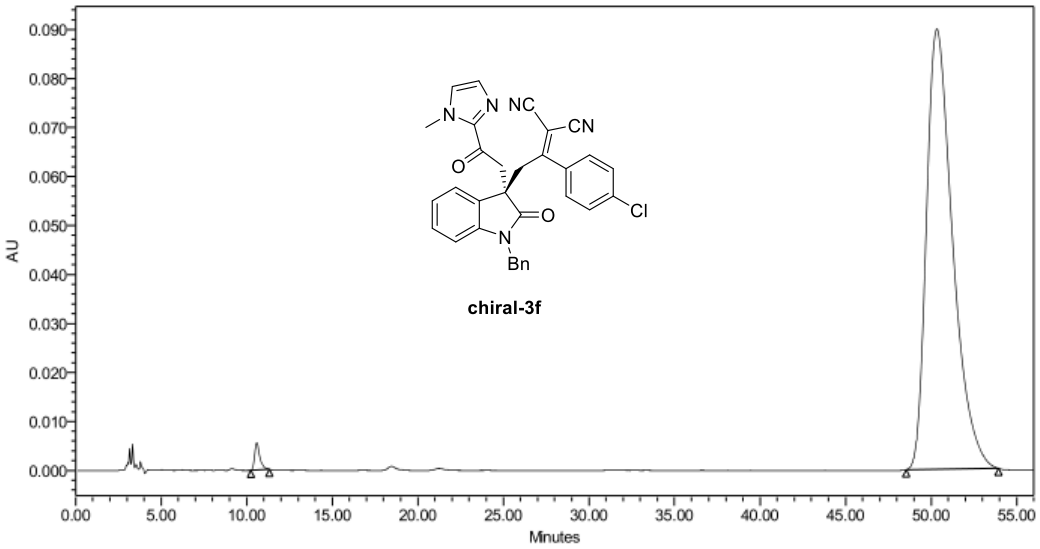
	RT	Area	% Area	Height
1	10.57	30583	3.30	1371
2	43.62	896348	96.70	10074

racemic-3f



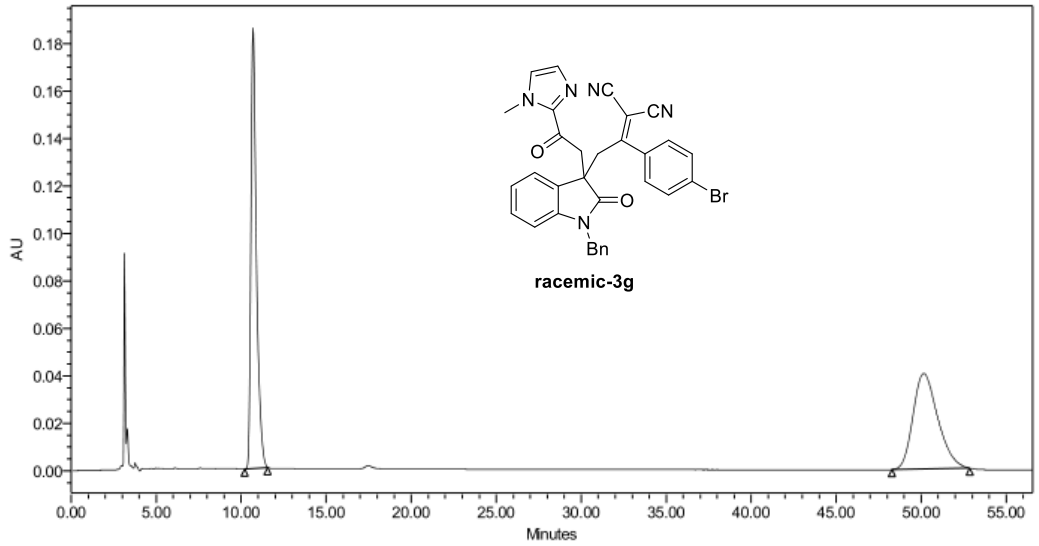
	RT	Area	% Area	Height
1	10.58	1836291	50.72	84524
2	50.74	1784047	49.28	17856

chiral-3f



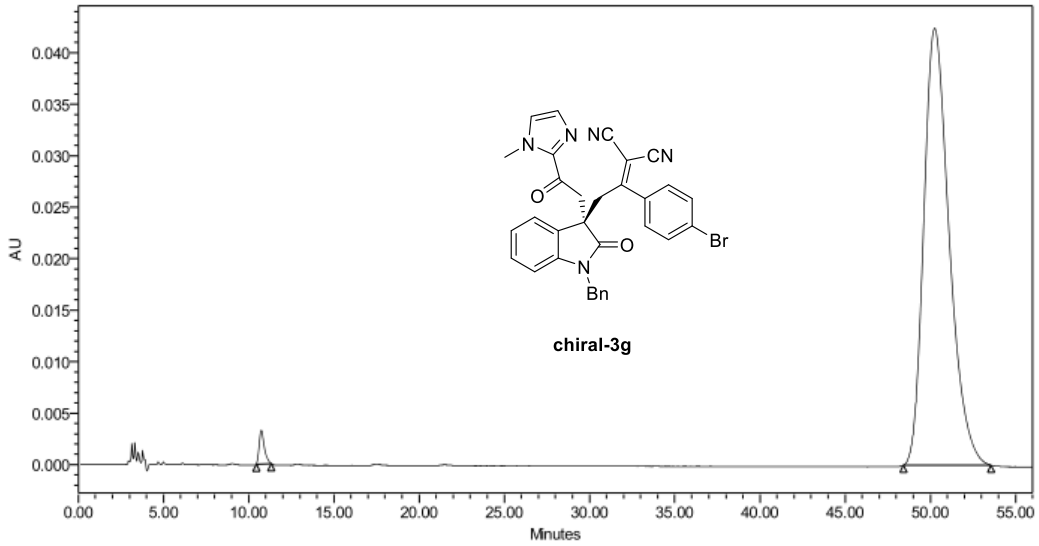
	RT	Area	% Area	Height
1	10.59	115142	1.19	5558
2	50.34	9559051	98.81	89897

racemic-3g



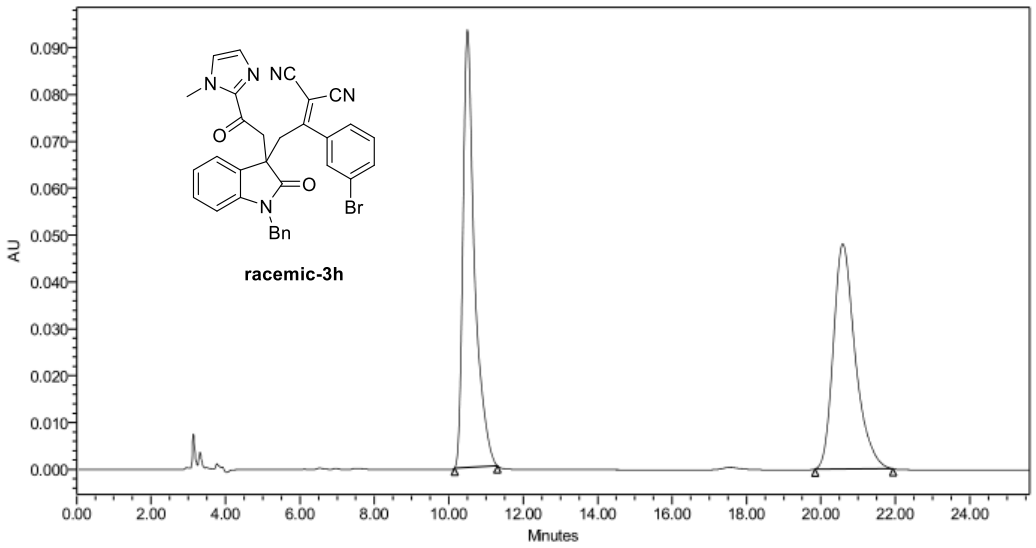
	RT	Area	% Area	Height
1	10.69	4183041	50.59	185509
2	50.15	4085316	49.41	40285

chiral-3g



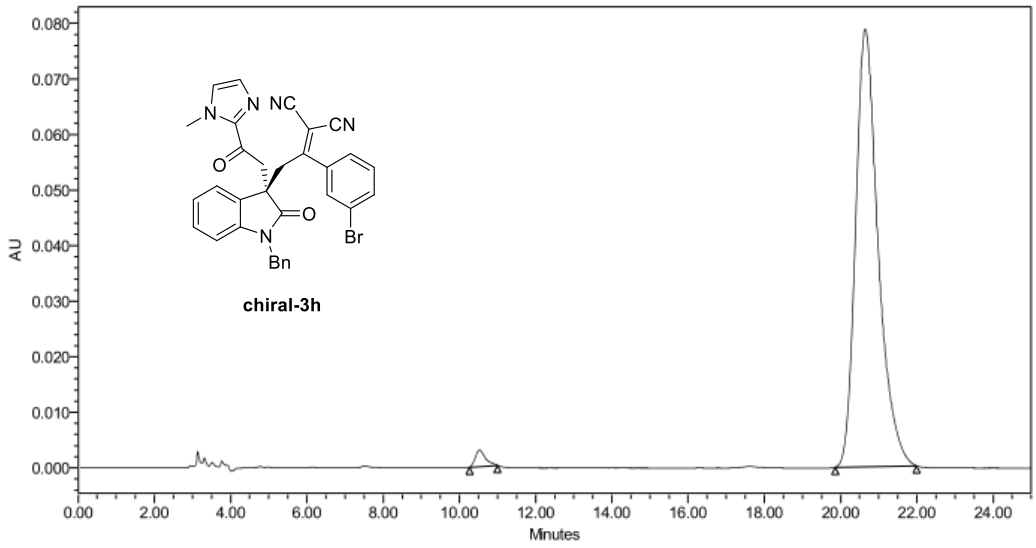
	RT	Area	% Area	Height
1	10.74	68028	1.52	3253
2	50.25	4395126	98.48	42450

racemic-3h



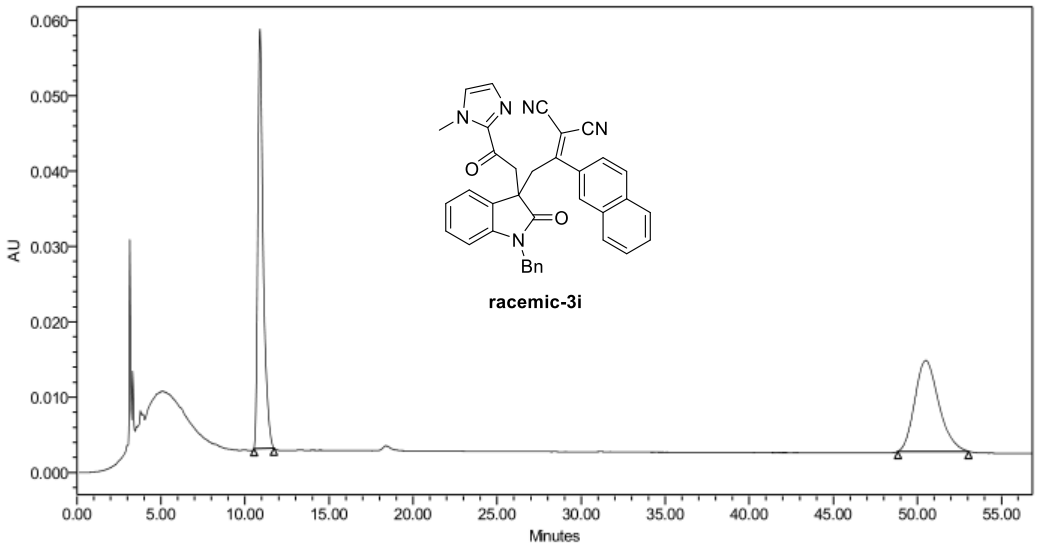
	RT	Area	% Area	Height
1	10.50	2011802	50.58	93377
2	20.58	1965816	49.42	48033

chiral-3h



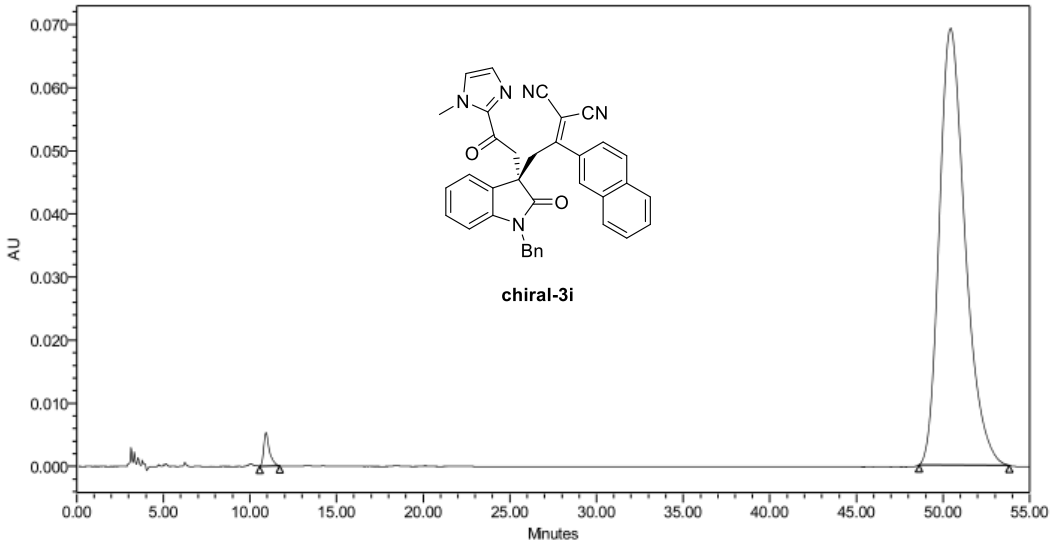
	RT	Area	% Area	Height
1	10.52	55211	1.67	2949
2	20.64	3245442	98.33	78738

racemic-3i



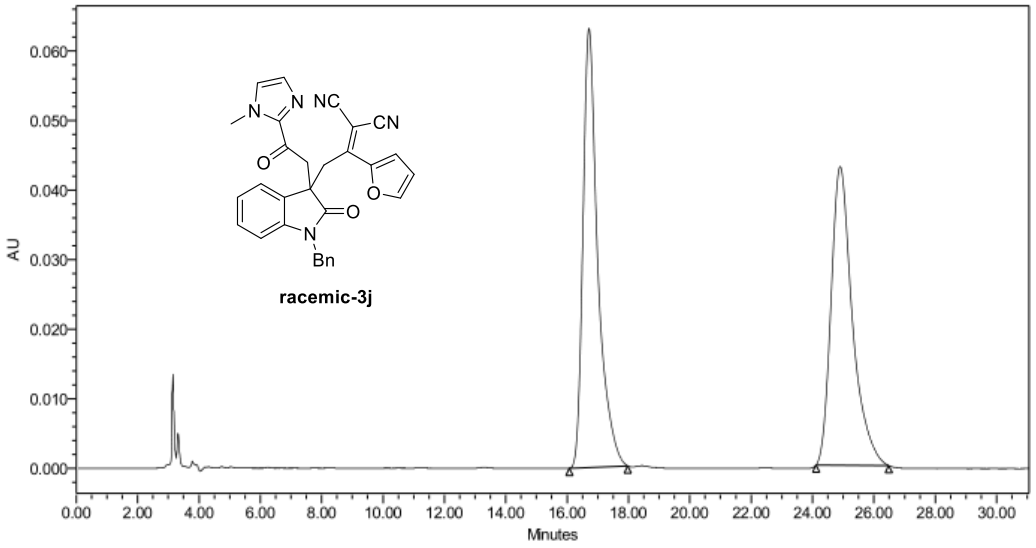
	RT	Area	% Area	Height
1	10.89	1239544	50.92	55638
2	50.50	1194599	49.08	12072

chiral-3i



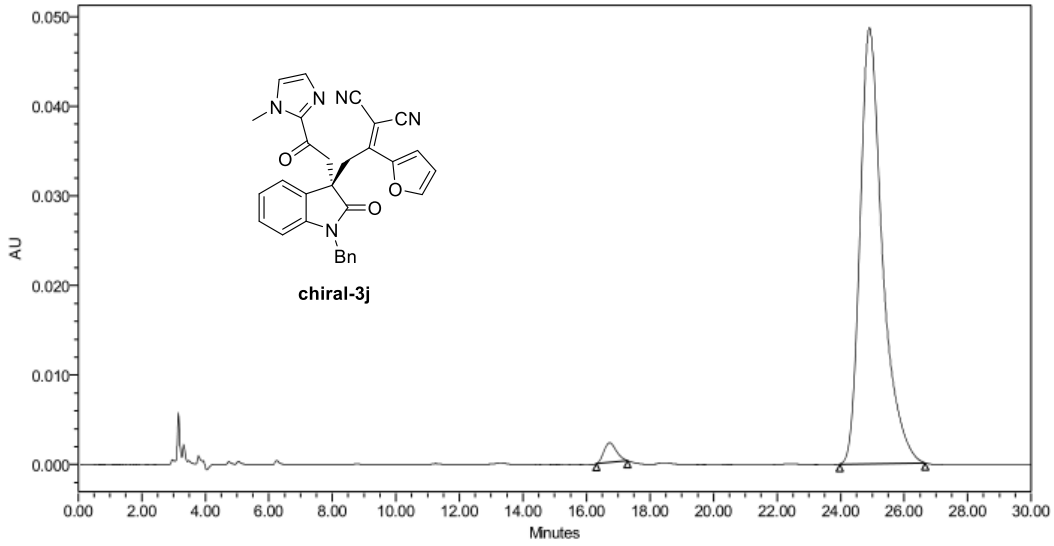
	RT	Area	% Area	Height
1	10.92	120280	1.65	5292
2	50.44	7153517	98.35	69225

racemic-3j



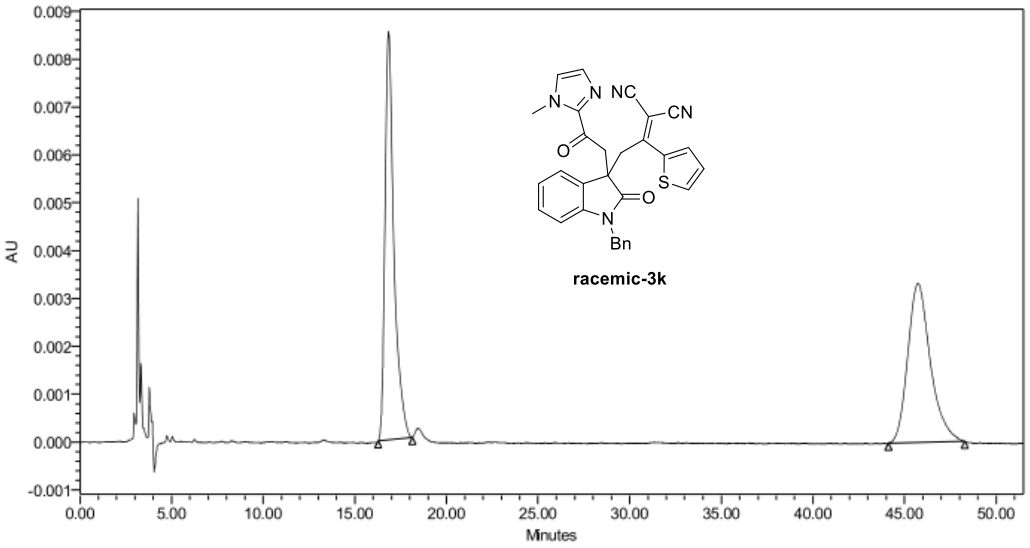
	RT	Area	% Area	Height
1	16.71	2115557	50.52	63157
2	24.89	2071830	49.48	42974

chiral-3j



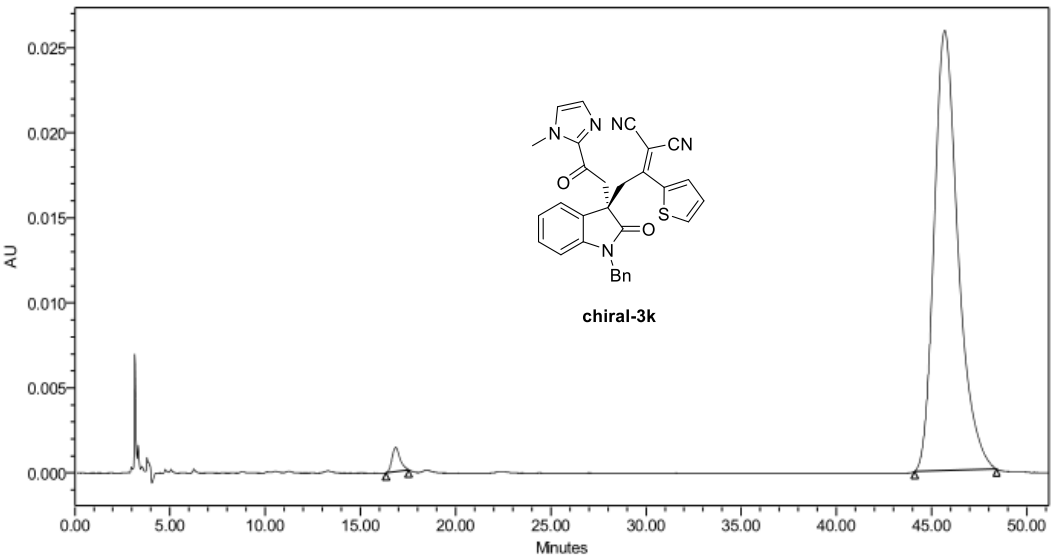
	RT	Area	% Area	Height
1	16.73	59592	2.44	2193
2	24.91	2385065	97.56	48675

racemic-3k



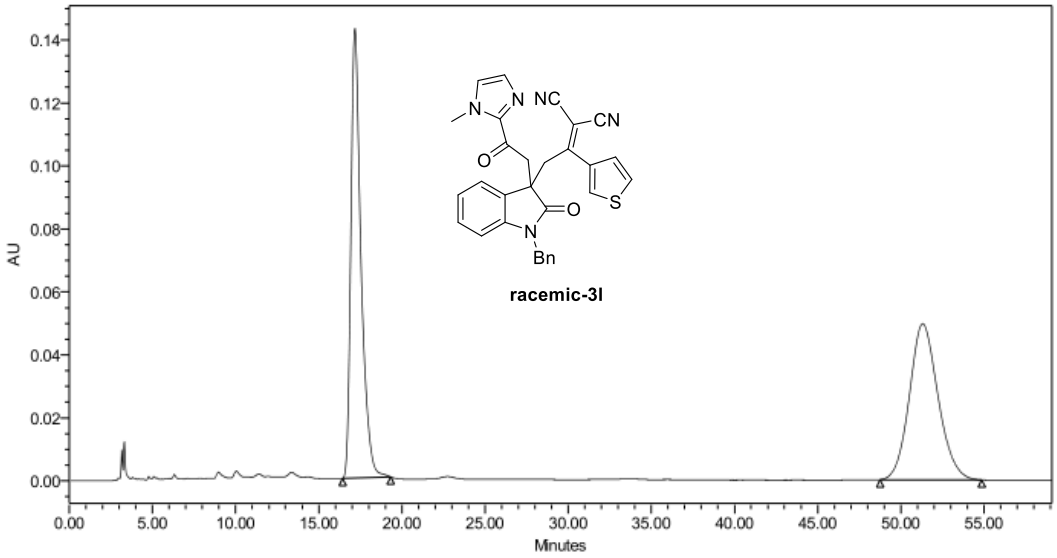
	RT	Area	% Area	Height
1	16.85	287629	50.05	8528
2	45.73	287022	49.95	3329

chiral-3k



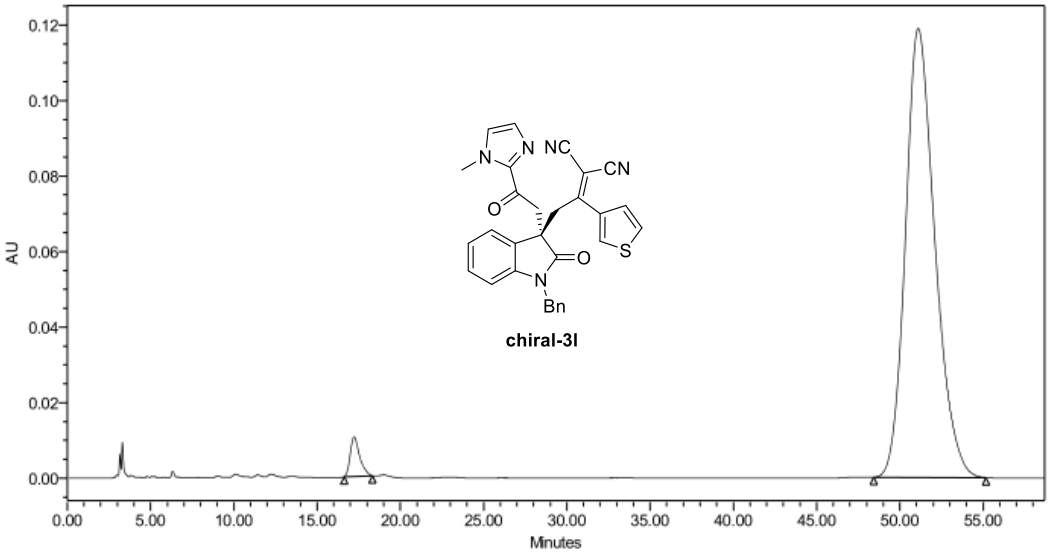
	RT	Area	% Area	Height
1	16.85	41887	1.82	1426
2	45.69	2255344	98.18	25865

racemic-3l



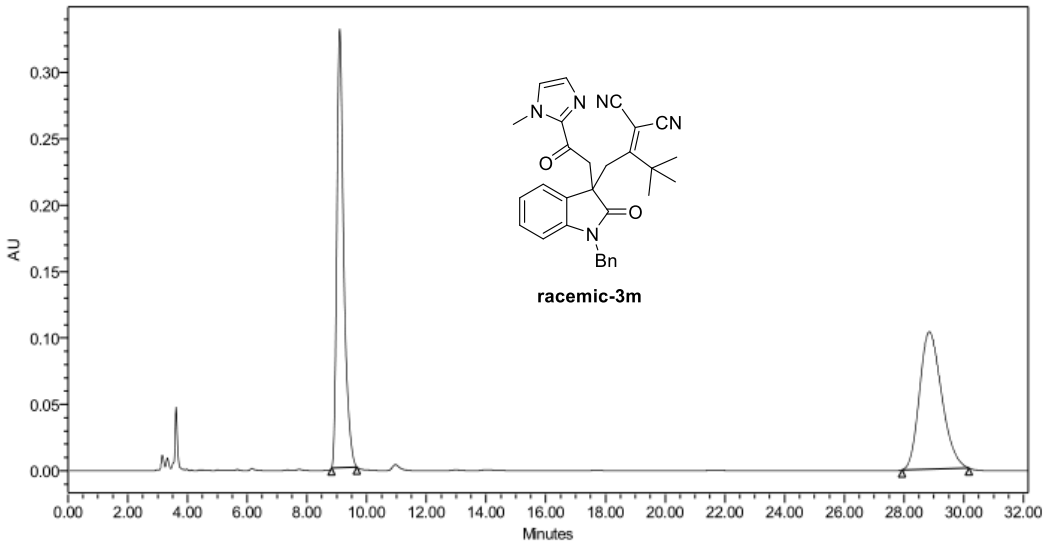
	RT	Area	% Area	Height
1	17.17	6071236	50.42	142759
2	51.31	5969892	49.58	49577

chiral-3l



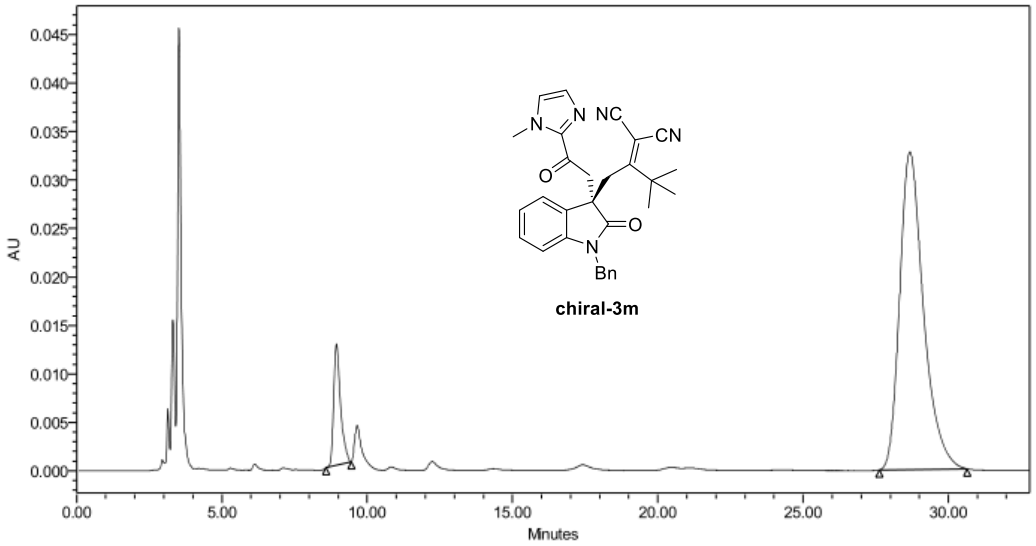
	RT	Area	% Area	Height
1	17.22	414505	2.74	10460
2	51.10	14686901	97.26	118916

racemic-3m



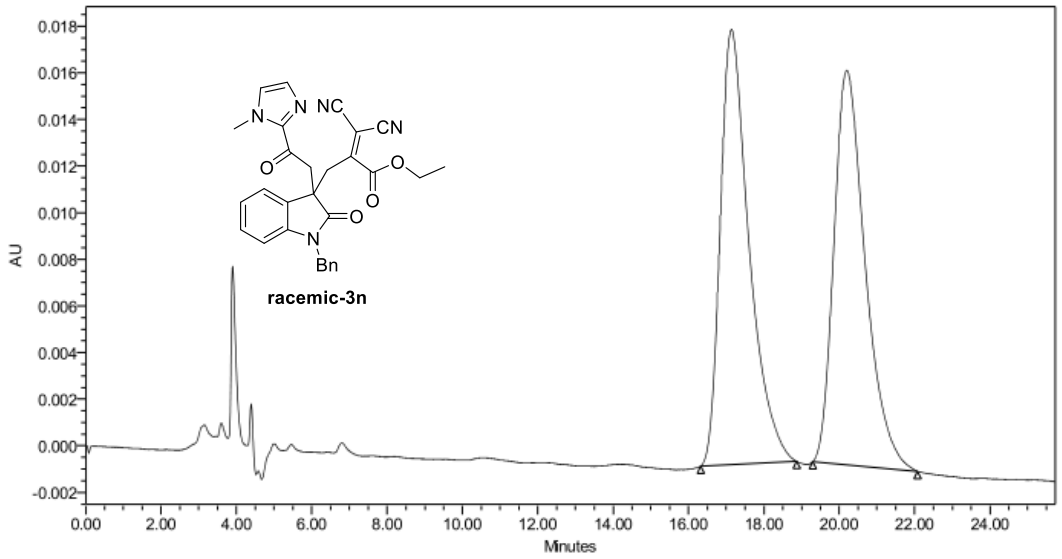
	RT	Area	% Area	Height
1	9.09	5362938	50.29	330115
2	28.85	5301092	49.71	103571

chiral-3m



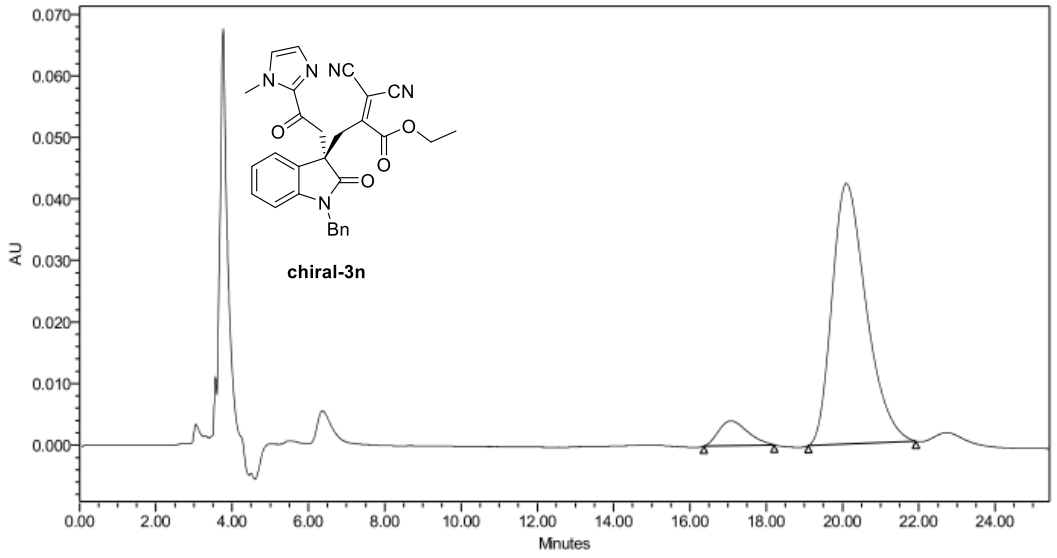
	RT	Area	% Area	Height
1	8.94	207294	10.00	12531
2	28.68	1865647	90.00	32772

racemic-3n



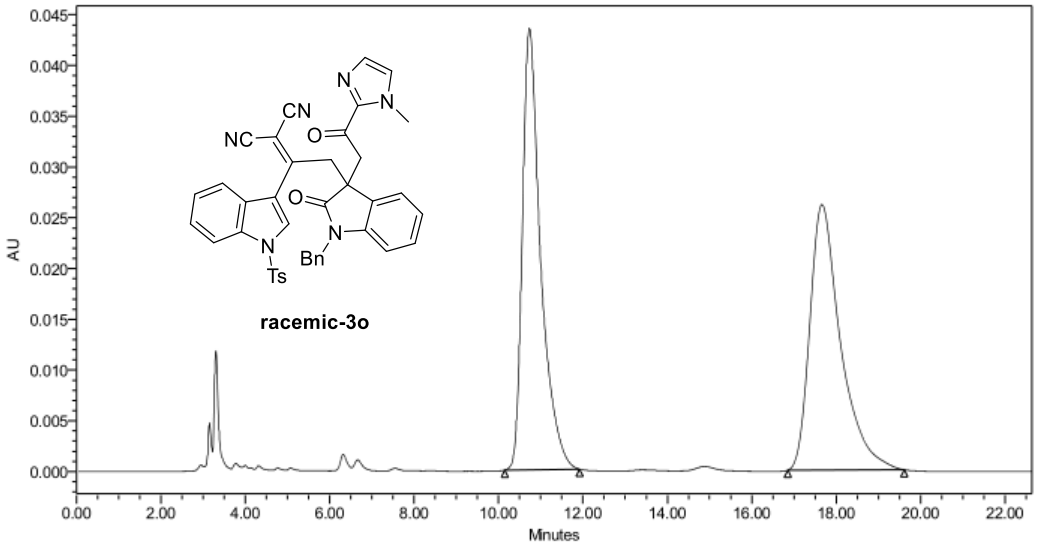
	RT	Area	% Area	Height
1	17.14	995015	50.39	18668
2	20.19	979612	49.61	16924

chiral-3n



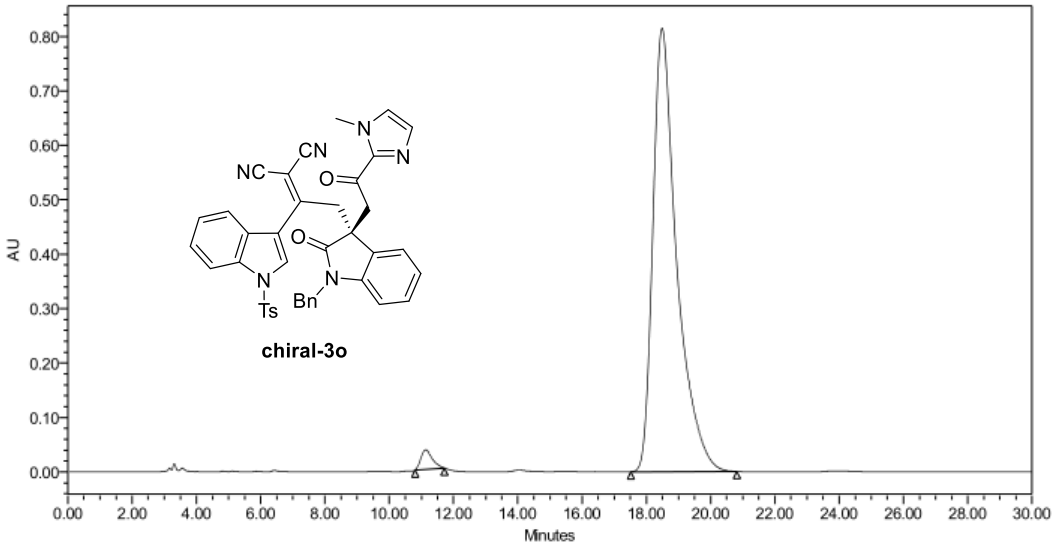
	RT	Area	% Area	Height
1	17.06	213146	7.47	4012
2	20.10	2640924	92.53	42377

racemic-3o



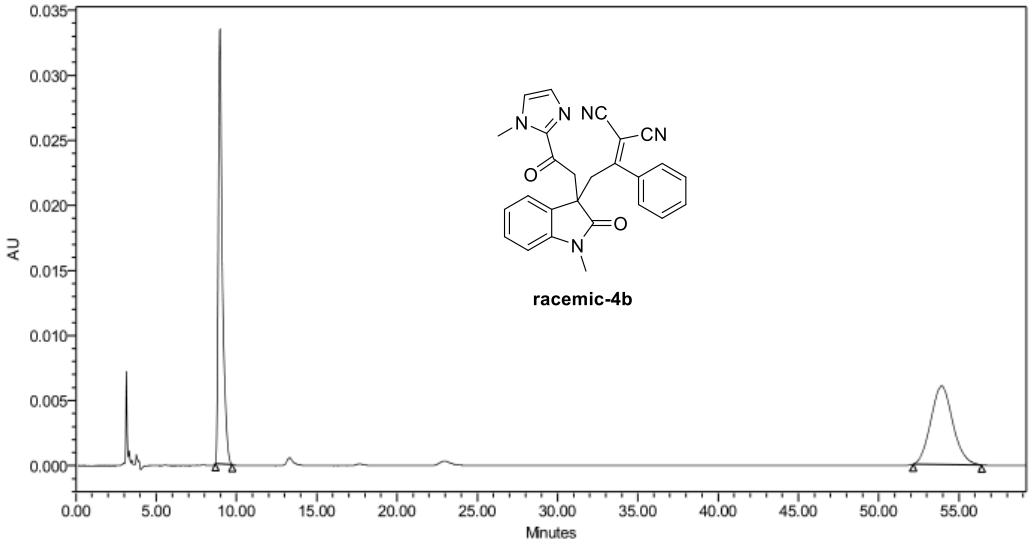
	RT	Area	% Area	Height
1	10.73	1318035	49.94	43494
2	17.66	1321159	50.06	26171

chiral-3o



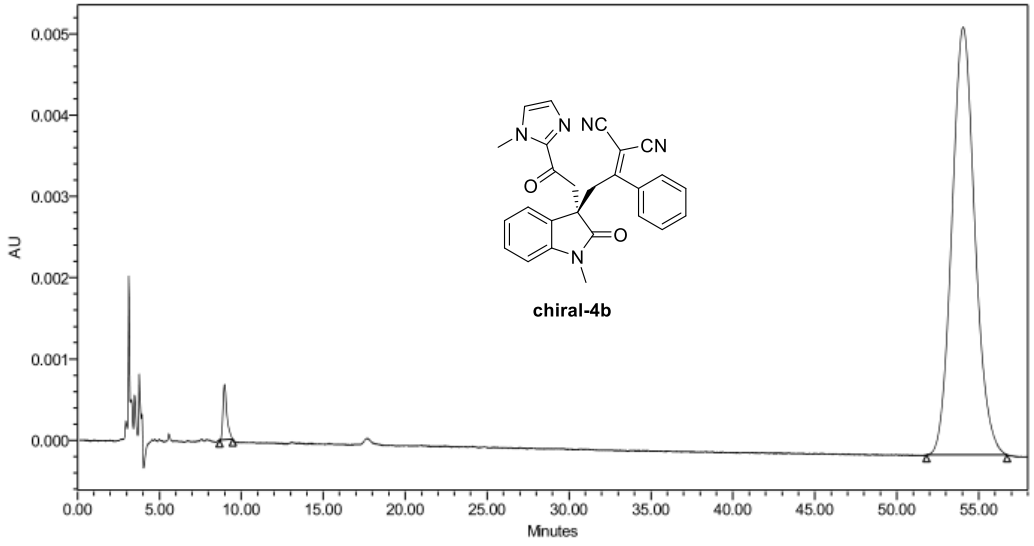
	RT	Area	% Area	Height
1	11.13	887898	2.06	35883
2	18.49	42307818	97.94	814383

racemic-4b



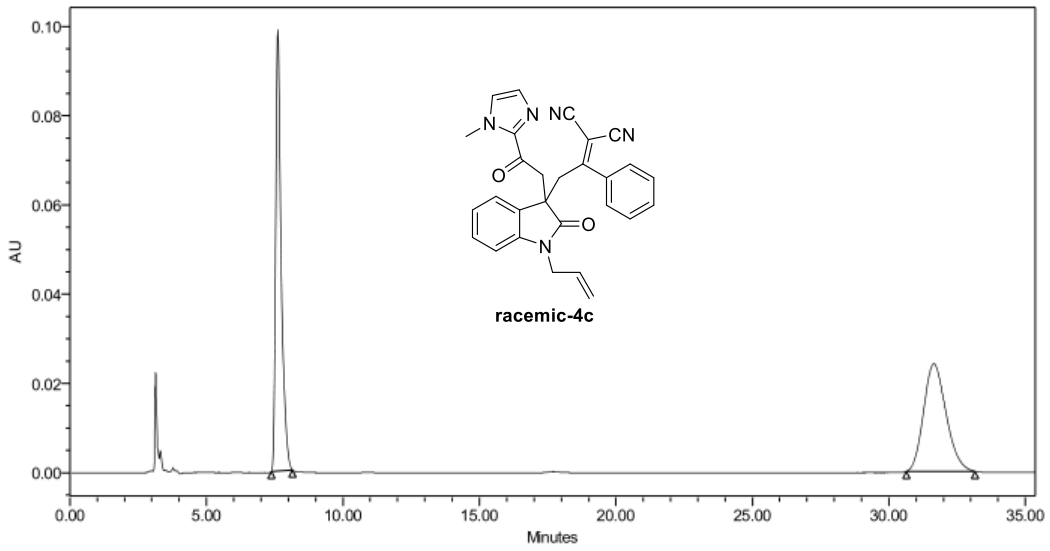
	RT	Area	% Area	Height
1	8.97	585540	50.48	33429
2	53.93	574461	49.52	6035

chiral-4b



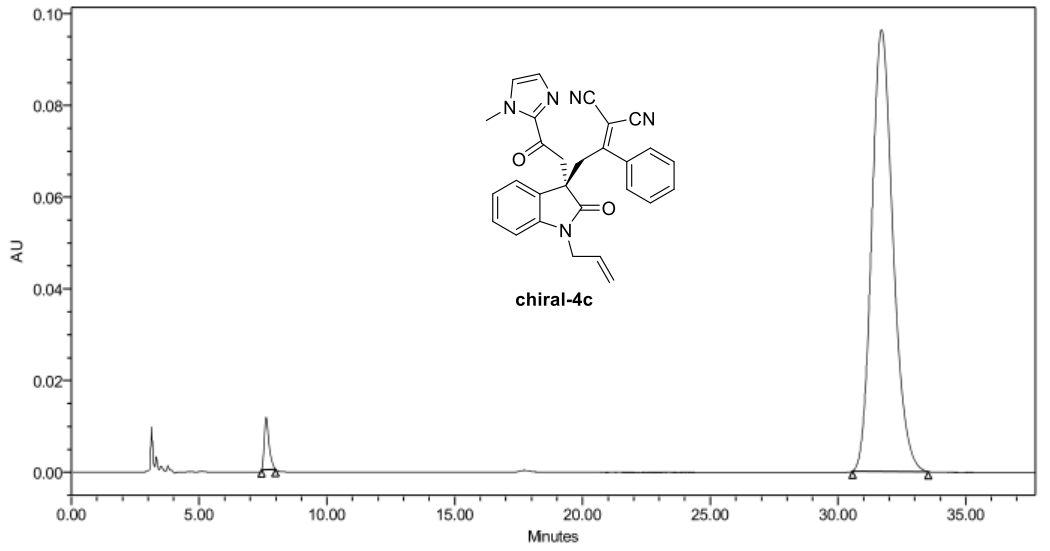
	RT	Area	% Area	Height
1	8.98	11078	2.12	678
2	54.04	510544	97.88	5262

racemic-4c



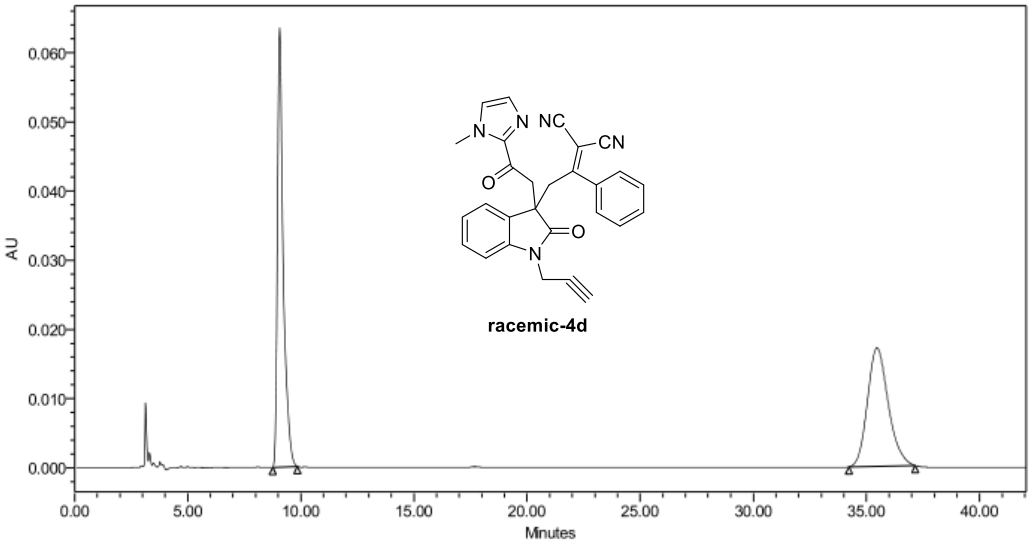
	RT	Area	% Area	Height
1	7.61	1393888	50.36	98834
2	31.65	1373744	49.64	24131

chiral-4c



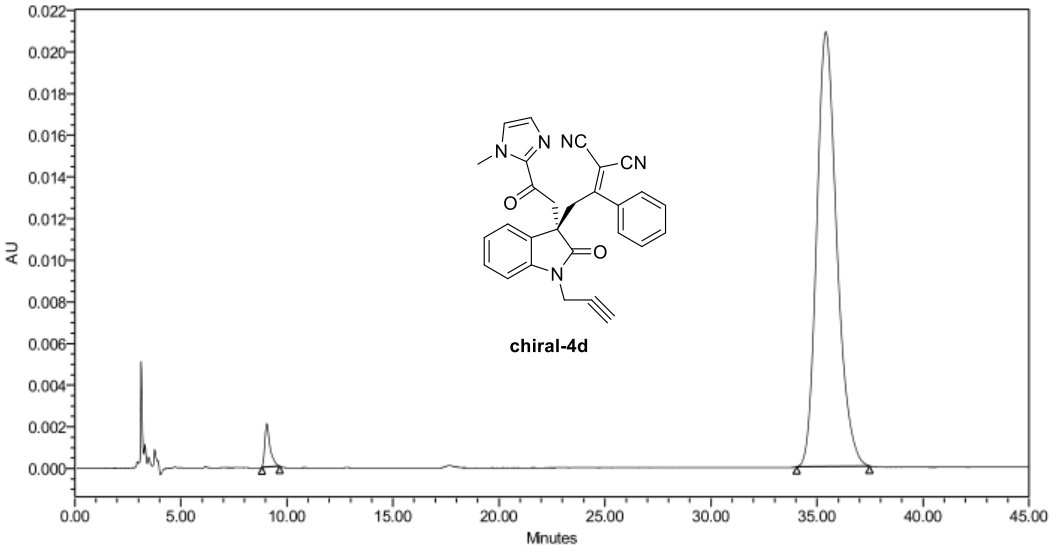
	RT	Area	% Area	Height
1	7.62	147472	2.58	11358
2	31.70	5575437	97.42	96286

racemic-4d



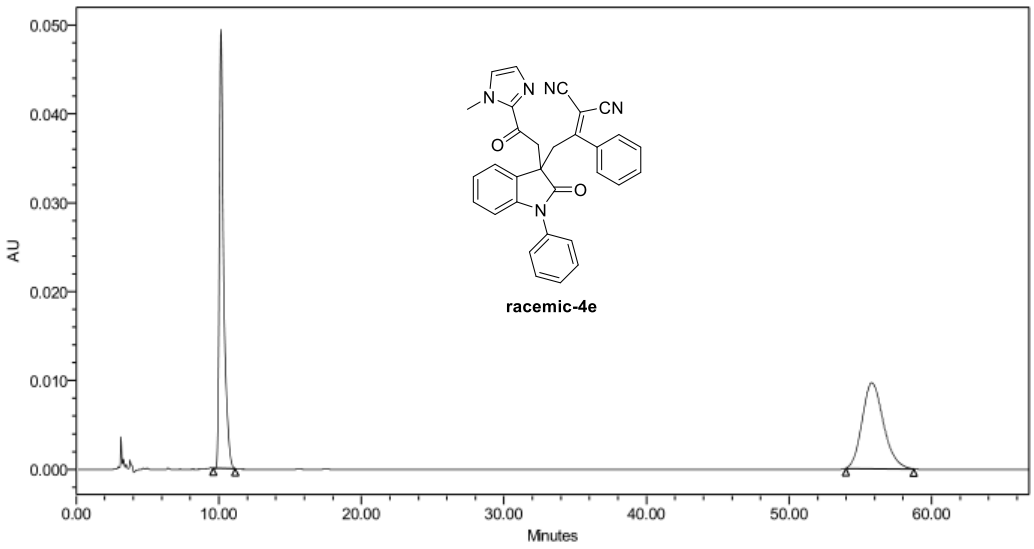
	RT	Area	% Area	Height
1	9.06	1132440	50.55	63448
2	35.46	1107896	49.45	17167

chiral-4d



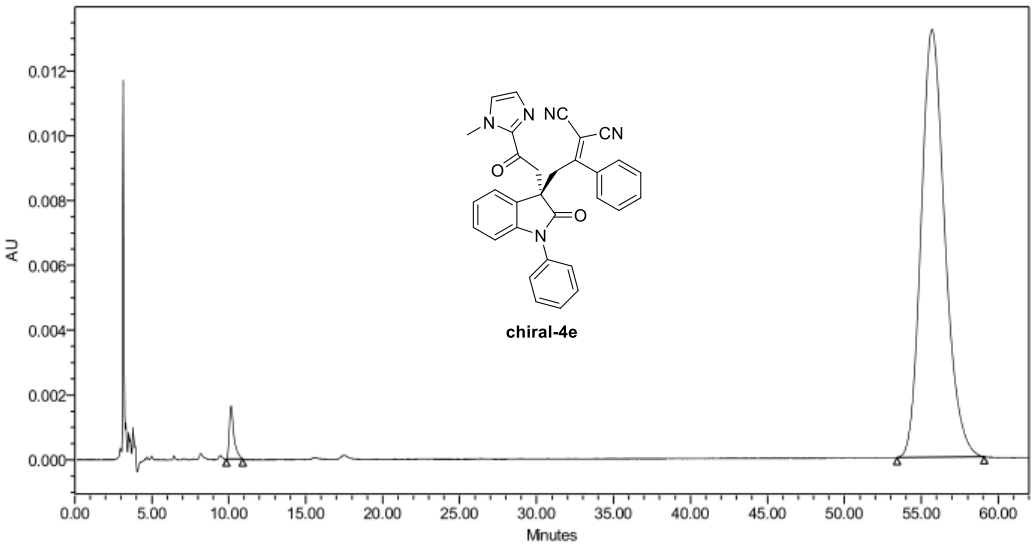
	RT	Area	% Area	Height
1	9.05	35661	2.54	2069
2	35.41	1370835	97.46	20882

racemic-4e



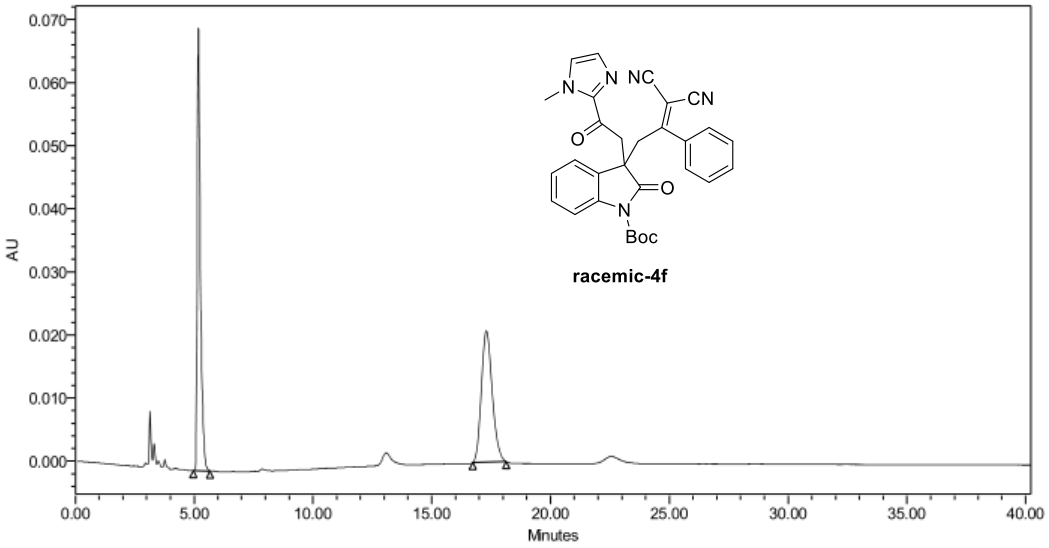
	RT	Area	% Area	Height
1	10.16	1039170	50.59	49365
2	55.79	1014970	49.41	9669

chiral-4e



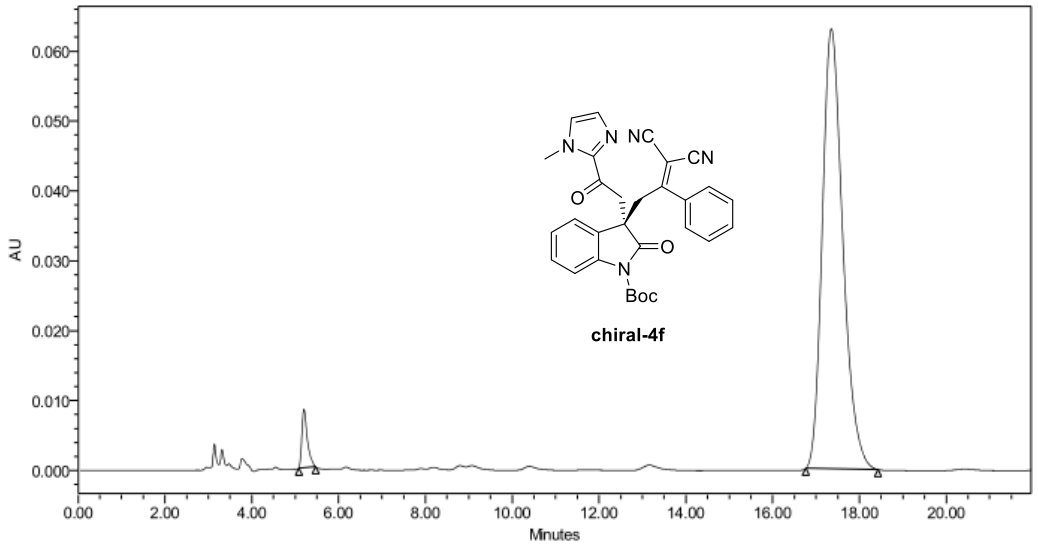
	RT	Area	% Area	Height
1	10.16	33843	2.35	1647
2	55.70	1408072	97.65	13212

racemic-4f



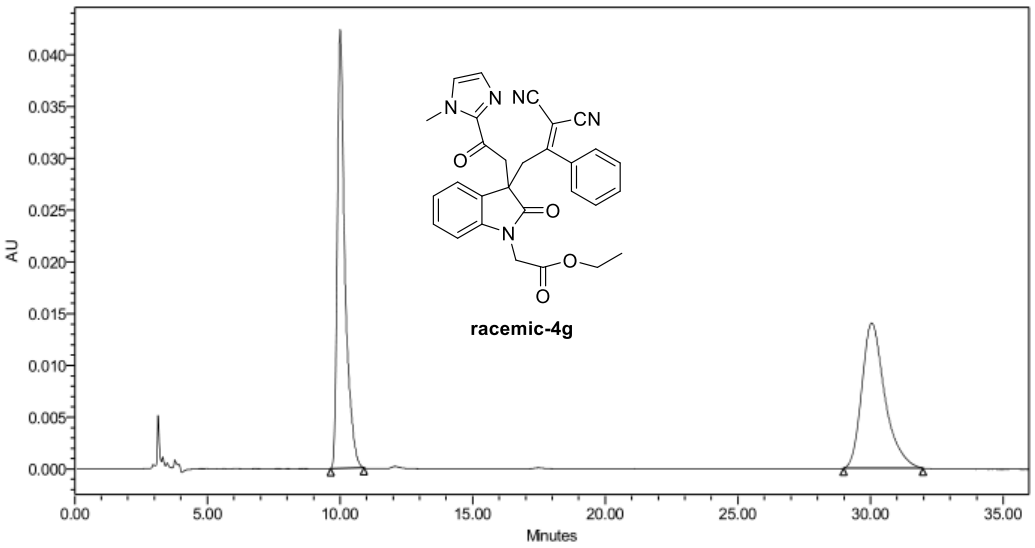
	RT	Area	% Area	Height
1	5.18	657802	49.91	70099
2	17.29	660195	50.09	20829

chiral-4f



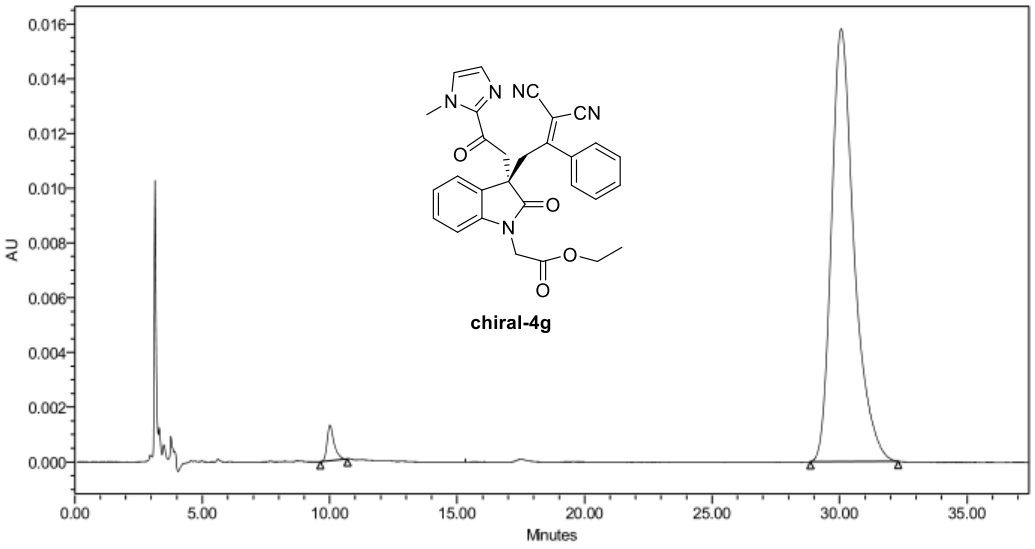
	RT	Area	% Area	Height
1	5.20	73435	3.45	8379
2	17.35	2058011	96.55	62957

racemic-4g



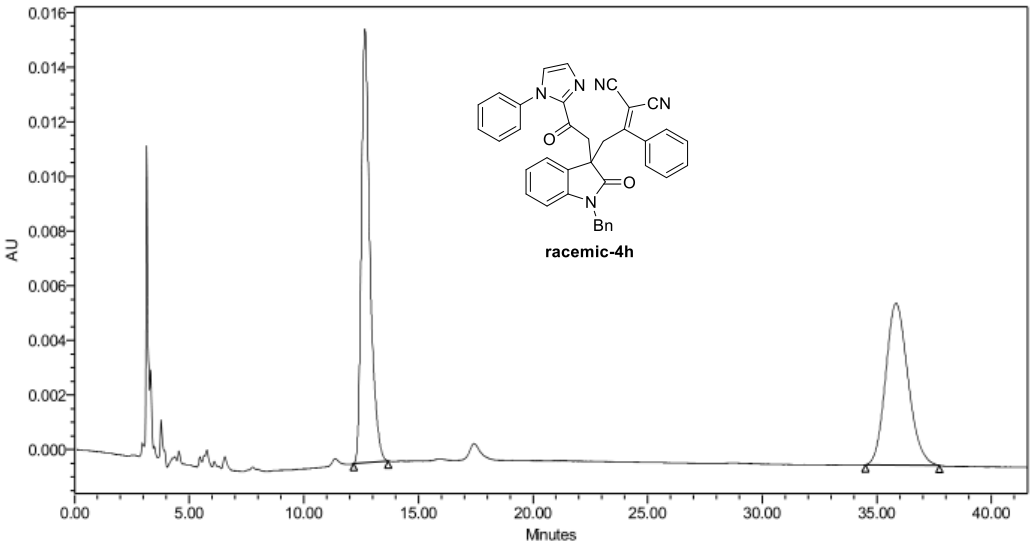
	RT	Area	% Area	Height
1	10.00	866508	50.41	42361
2	30.04	852335	49.59	14021

chiral-4g



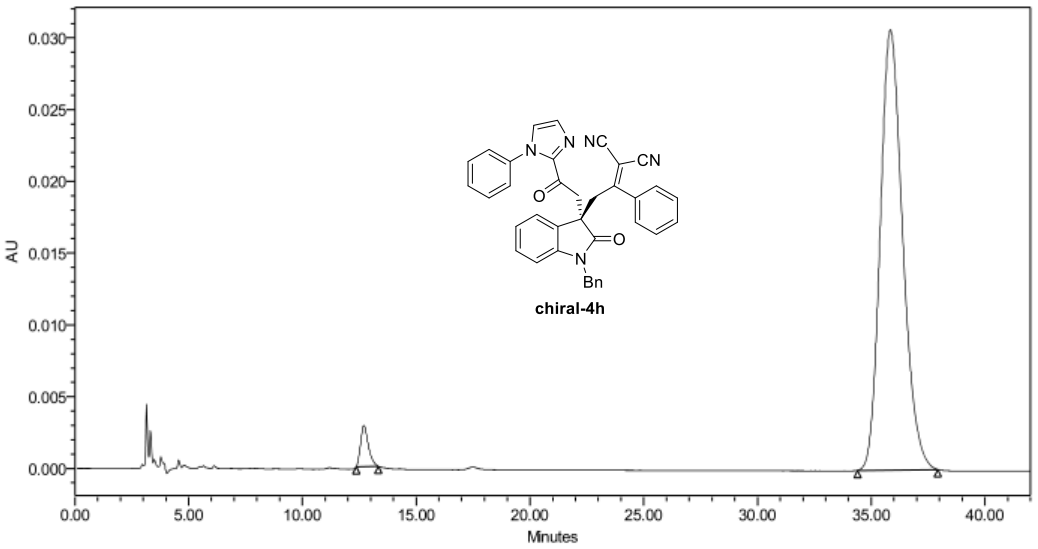
	RT	Area	% Area	Height
1	10.00	24987	2.50	1303
2	30.05	974633	97.50	15811

racemic-4h



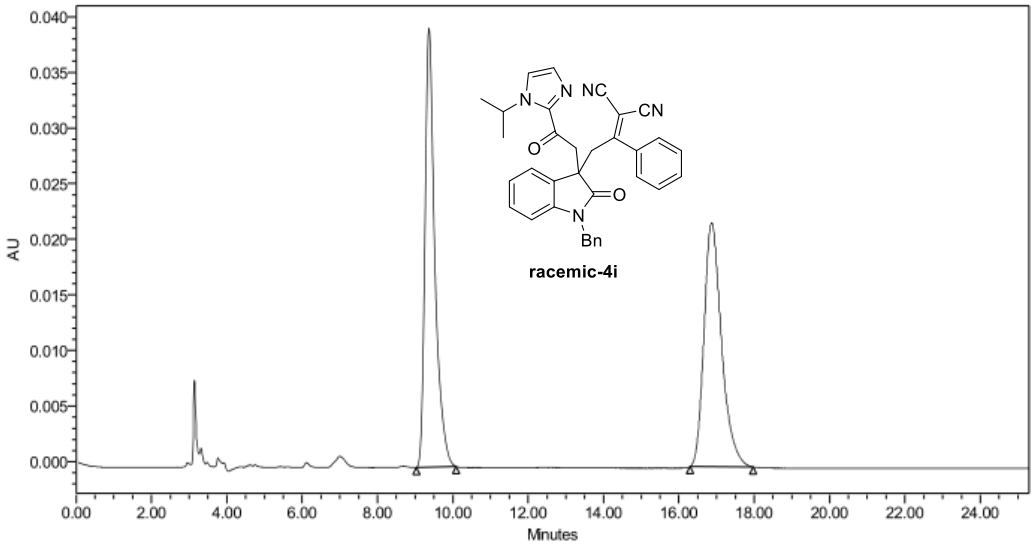
	RT	Area	% Area	Height
1	12.66	409815	50.35	15872
2	35.84	404182	49.65	5935

chiral-4h



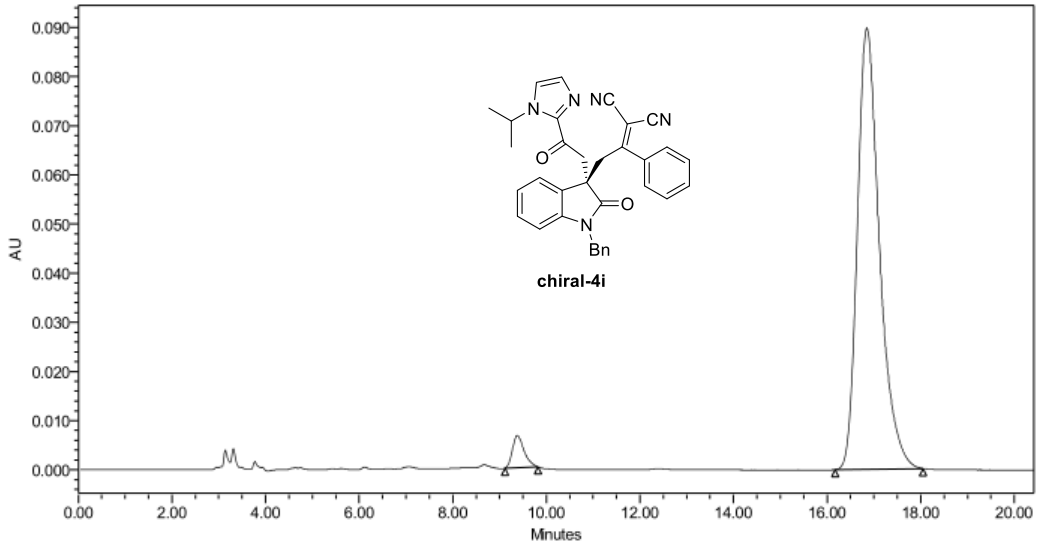
	RT	Area	% Area	Height
1	12.70	67111	3.07	2859
2	35.85	2119336	96.93	30672

racemic-4i



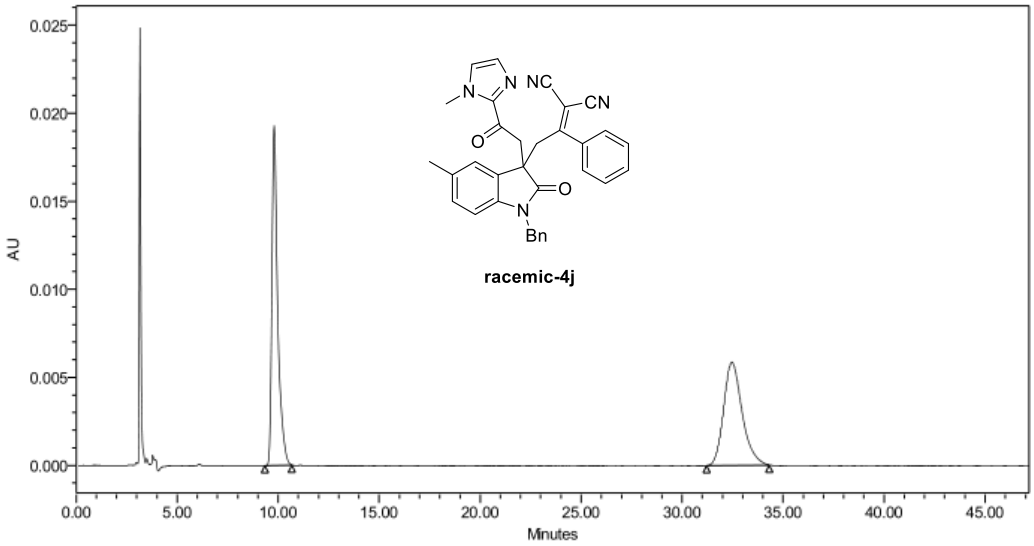
	RT	Area	% Area	Height
1	9.37	714410	50.11	39451
2	16.87	711259	49.89	21939

chiral-4i



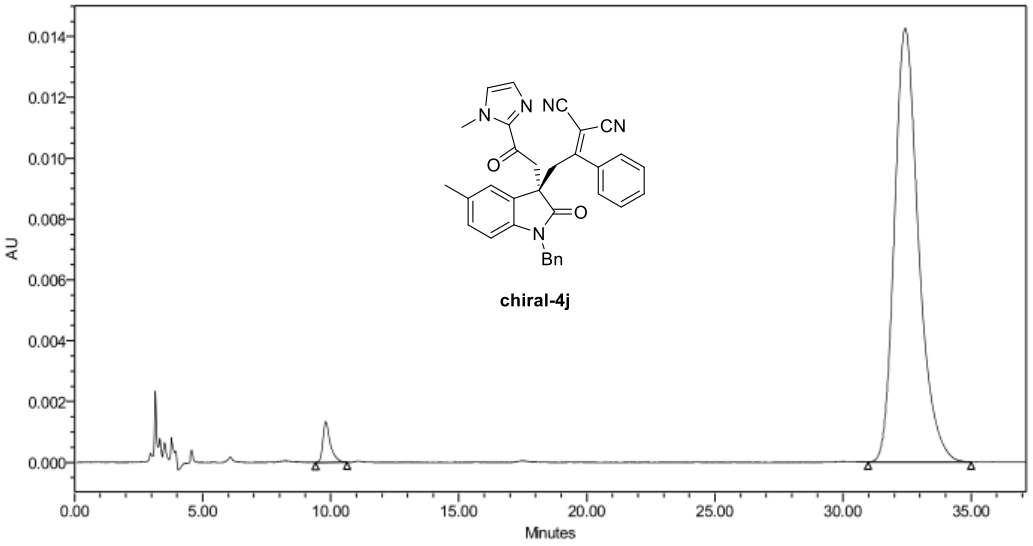
	RT	Area	% Area	Height
1	9.38	113975	3.71	6568
2	16.85	2957934	96.29	89837

racemic-4j



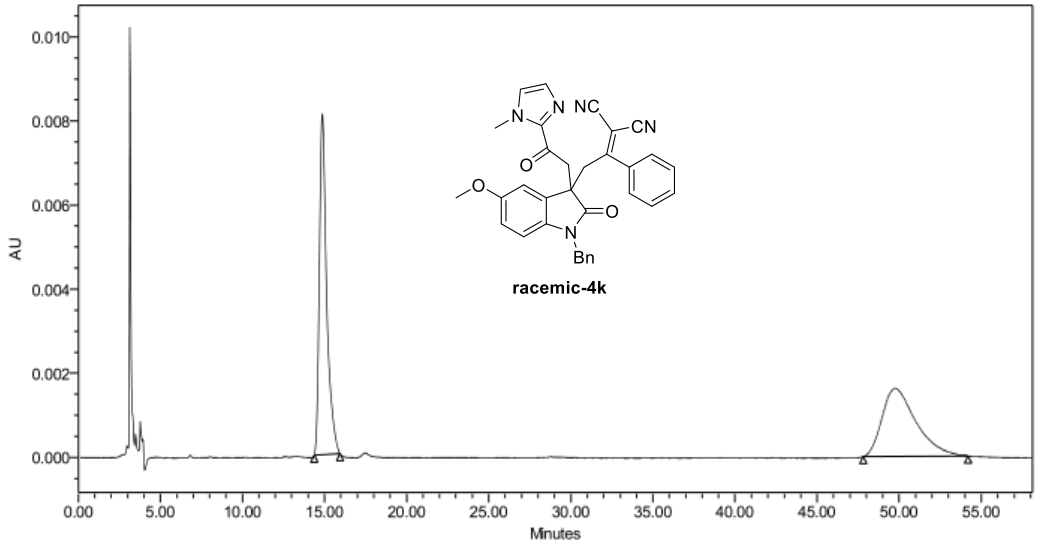
	RT	Area	% Area	Height
1	9.80	383338	50.44	19276
2	32.47	376645	49.56	5861

chiral-4j



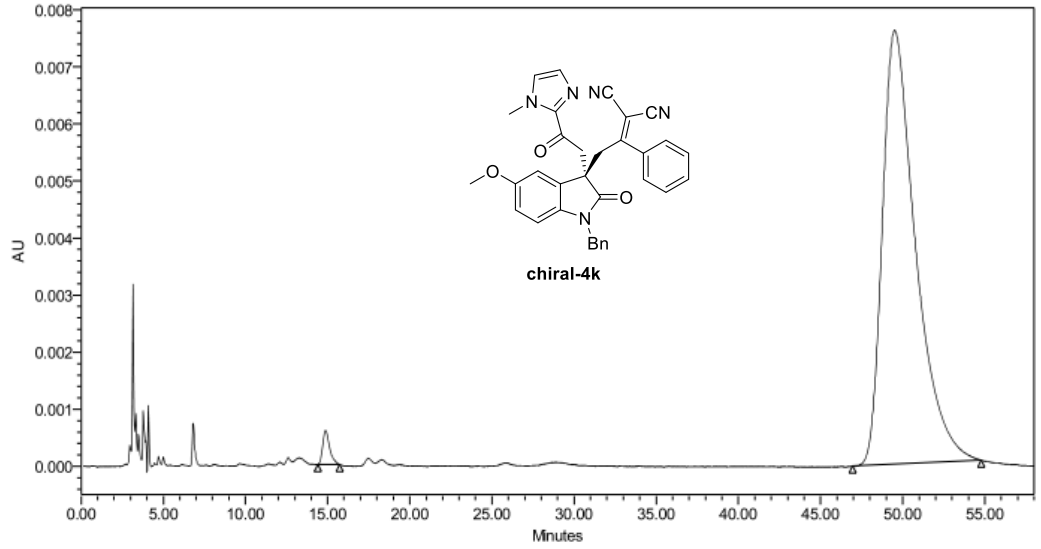
	RT	Area	% Area	Height
1	9.80	27079	2.82	1342
2	32.43	931496	97.18	14265

racemic-4k



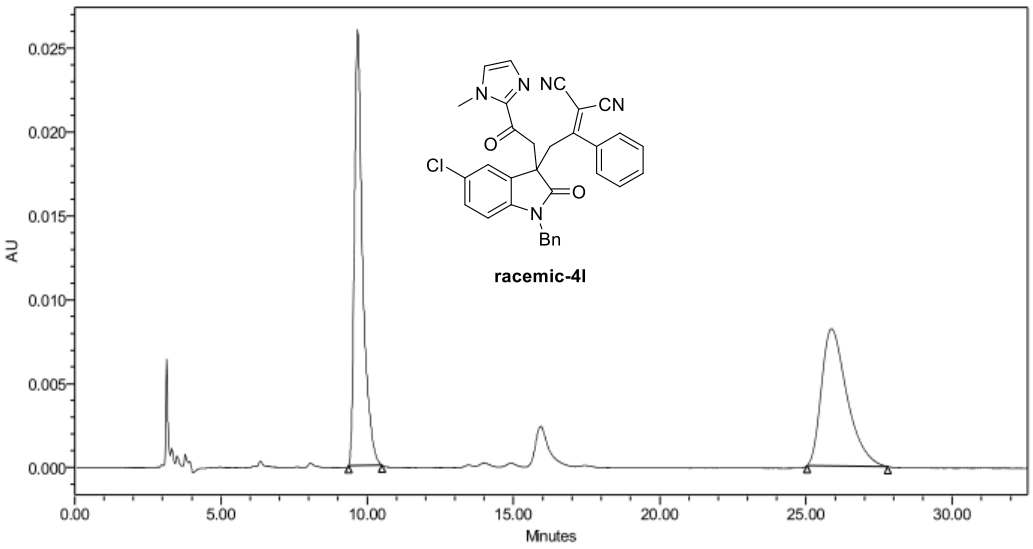
	RT	Area	% Area	Height
1	14.86	248950	51.75	8103
2	49.78	232079	48.25	1619

chiral-4k



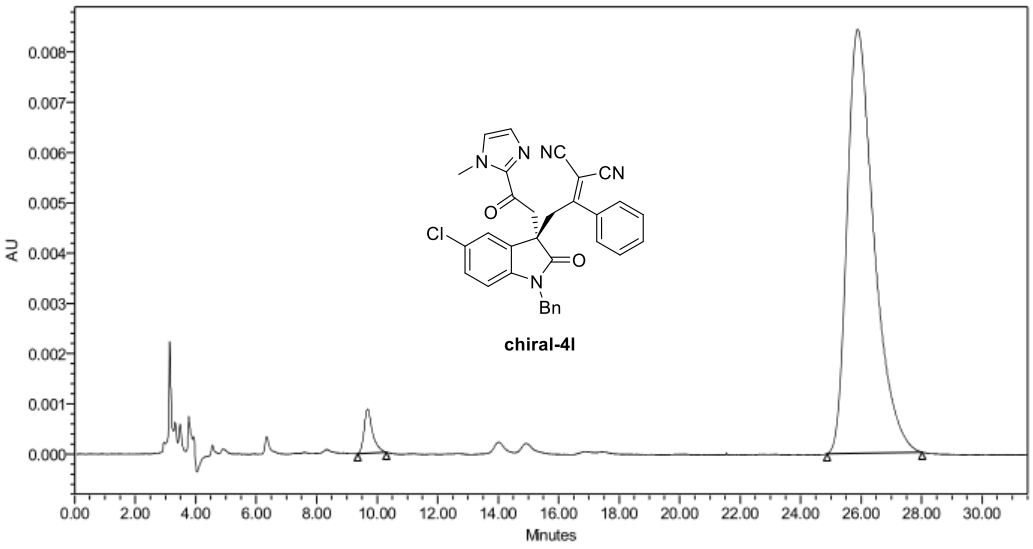
	RT	Area	% Area	Height
1	14.88	17311	1.59	593
2	49.52	1073410	98.41	7607

racemic-4l



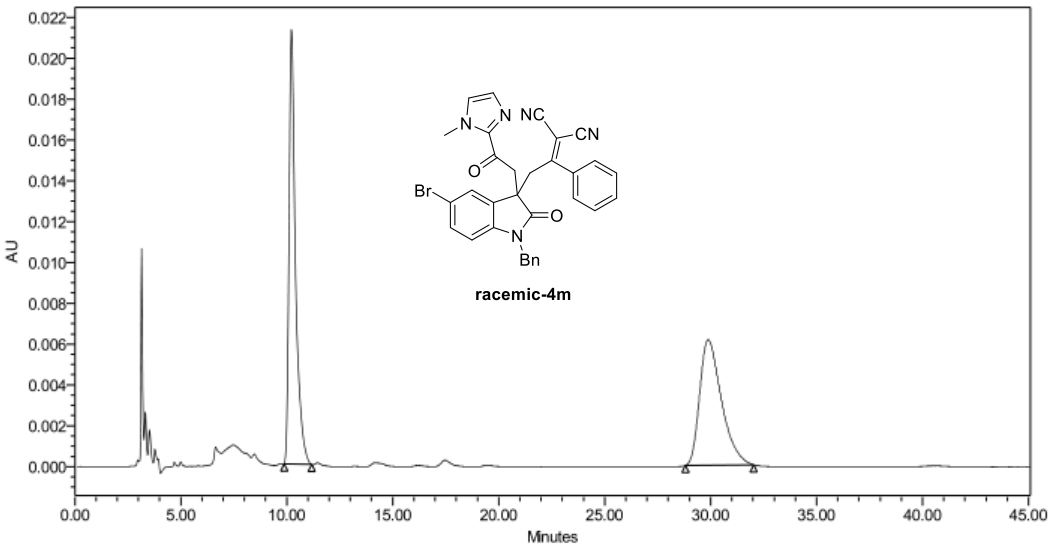
	RT	Area	% Area	Height
1	9.67	511744	50.73	25970
2	25.87	496934	49.27	8180

chiral-4l



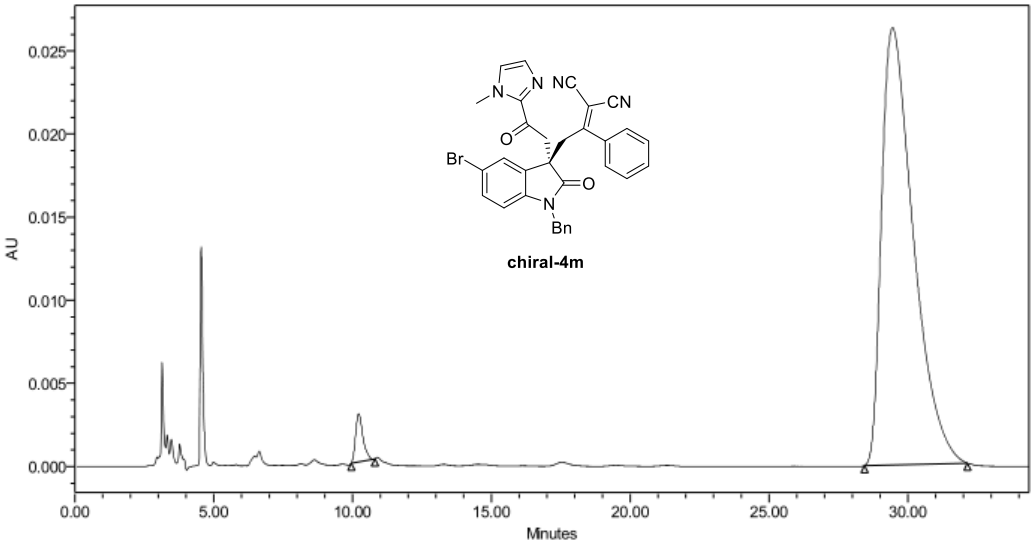
	RT	Area	% Area	Height
1	9.68	16887	3.13	876
2	25.88	522903	96.87	8440

racemic-4m



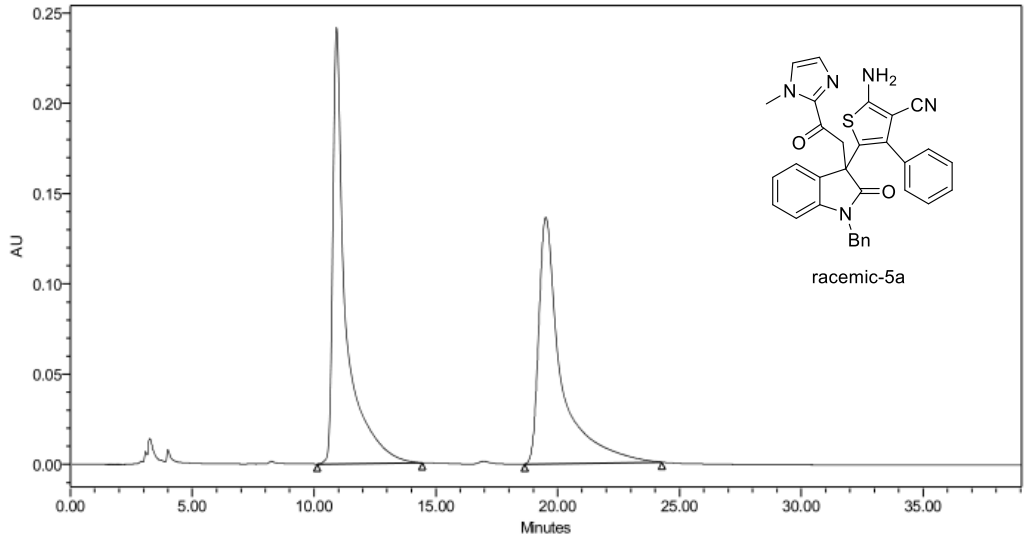
	RT	Area	% Area	Height
1	10.22	452360	50.63	21264
2	29.89	441057	49.37	6158

chiral-4m



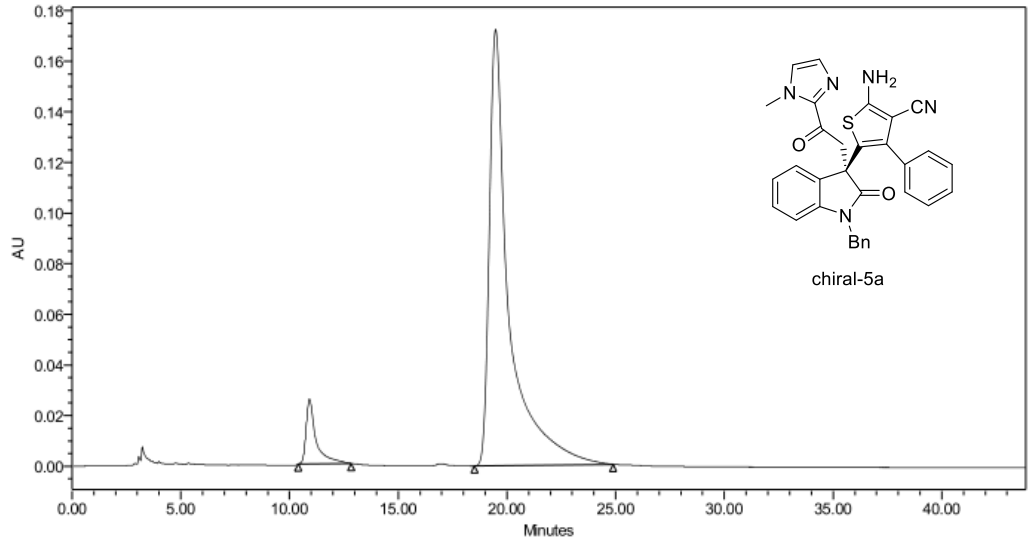
	RT	Area	% Area	Height
1	10.22	53067	2.46	2892
2	29.45	2103839	97.54	26310

racemic-5a



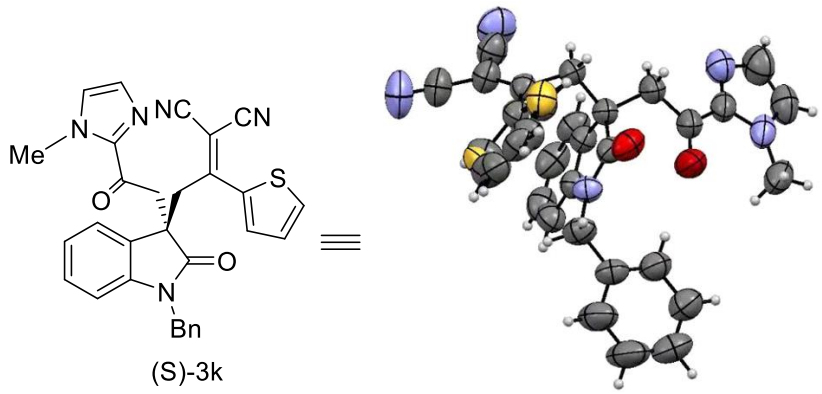
	RT	Area	% Area	Height
1	10.92	8976907	50.99	241568
2	19.51	8628674	49.01	136529

chiral-5a



	RT	Area	% Area	Height
1	10.91	811344	6.90	25711
2	19.47	10939187	93.10	172483

VI Single Crystal X-Ray Diffraction of 3k



(S)-3k

CCDC: 2130975

Table 1. Crystal data and structure refinement for 3k.

Identification code	3k	
Empirical formula	$C_{31}H_{24}Cl_3N_5O_2S$ $C_{30}H_{24}N_5O_2S$	
Formula weight	636.96	
Temperature	300.0 K	
Wavelength	1.54178 Å	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 13.8286(3) Å	α= 90°.
	b = 14.4943(3) Å	β= 90°.
	c = 15.4079(3) Å	γ = 90°.
Volume	3088.30(11) $Å^3$	
Z	4	
Density (calculated)	1.370 Mg/m^3	
Absorption coefficient	3.622 mm^{-1}	
F(000)	1312	
Crystal size	0.22 x 0.21 x 0.19 mm^3	
Theta range for data collection	4.187 to 68.430°.	
Index ranges	-16<=h<=16, -17<=k<=17, -18<=l<=18	
Reflections collected	101046	
Independent reflections	5671 [R(int) = 0.0889]	
Completeness to theta = 67.679°	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.7501 and 0.6859	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5671 / 126 / 446	

Goodness-of-fit on F^2	1.050
Final R indices [I>2sigma(I)]	R1 = 0.0565, wR2 = 0.1538
R indices (all data)	R1 = 0.0727, wR2 = 0.1736
Absolute structure parameter	0.026(8)
Extinction coefficient	0.0079(8)
Largest diff. peak and hole	0.206 and -0.217 e.$Å^{-3}$