Experiment Section

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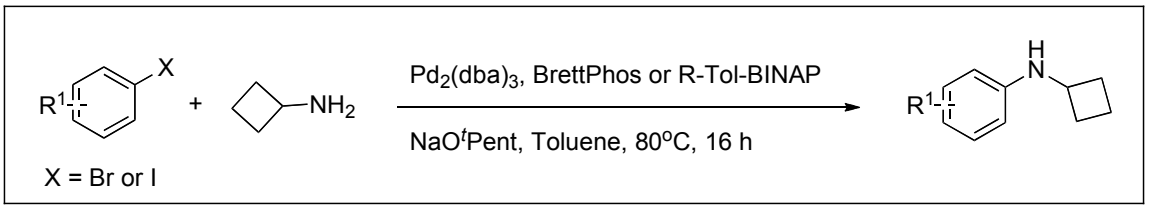
General Considerations

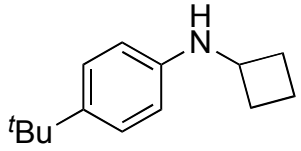
All reactions were carried out under a nitrogen atmosphere unless otherwise stated. Dry solvents were used as received except THF, CH_2Cl_2, Et_2O, and toluene. They were rigorously purged with argon for 2 h and then further purified by passing through two packed columns of neutral alumina (for THF and Et_2O) or through neutral alumina and copper (II) oxide (for toluene and CH_2Cl_2) under argon from a solvent purification system. A standard workup protocol consisted of extraction with diethyl ether, washing with brine, drying over Na_2SO_4, and removal of the solvent in vacuum. Column chromatography was carried out with silica gel (230-400 mesh). All new compounds were characterized by ^{1}H NMR, ^{13}C NMR, IR spectroscopy, high-resolution mass spectroscopy (HRMS), and melting point if solid. Nuclear magnetic resonance (NMR) spectra were obtained on a Bruker Avance DPX-300 and Bruker Avance DPX-400. Chemical shifts (δ) were reported in parts per million (ppm) relative to residual proton signals in $CDCl_3$ (7.26 ppm, 77.23 ppm) or CD_2Cl_2 (5.32 ppm, 54 ppm) at room temperature. IR spectra were recorded (thin film on NaCl plates) on a PerkinElmer Spectrum 100 series instrument. High resolution mass spectra were recorded on a Bruker Ultraflex II TOF/TOF mass spectrometer. Gas chromatography/mass spectroscopy (GC/MS) analyses were performed on an Agilent 6890N Network GC System/5973 inert Mass Selective Detector. Gas chromatography analyses were performed using a Shimadzu GC-2010 Plus instrument. Melting points (m.p.) were recorded using Stuart SMP10 Melting Point Apparatus and were uncorrected.

General procedure 1 (GP1): Preparation of N-cyclobutylanilines



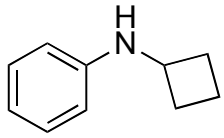
To an oven-dried schlenk tube equipped with a stir bar were added 0.02 mmol of $Pd_2(dba)_3$ and 0.06 mmol of ligand ((R)-Tol-BINAP or BrettPhos). Glove box was used to add 3 mmol of NaO^{t}Pent, followed by 2 mmol of aromatic halide, 2.2 mmol of cyclobutylamine, and 4 mL of toluene were then added to the reaction mixture and heated at 80^{o}C for 16 h. After completion, the reaction mixture was cooled to room temperature, diluted with diethyl ether, filtered over a short pad of silica gel, and concentrated in vacuum. Purification by flash chromatography on silica gel afforded *N*-cyclobutylaniline.

4-*tert*-Butyl-*N*-cyclobutylaniline (1a). Following **GP1** with 4-*tert*-butyl-bromobenzene (0.87 mL, 5 mmol) and BrettPhos (80.5 mg, 0.15 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as yellow oil (1.01 g, 99%). IR υ_{max} (cm^{-1}) 3400, 3045, 2959, 2866, 1614, 1518, 1472, 1361, 1319, 1192, 820; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.13 – 7.04 (m, 2H), 6.45 – 6.37 (m, 2H), 3.80 (tt, *J* = 8.1, 6.9 Hz, 1H), 3.61 (s, 1H), 2.36 – 2.23

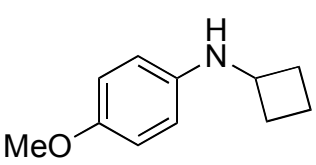


(m, 2H), 1.79 – 1.60 (m, 4H), 1.17 (d, J = 0.7 Hz, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 144.86, 140.04, 125.98, 112.67, 49.18, 33.83, 31.55, 31.37, 15.26; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{19}N$ 204.1747; found 204.1749.

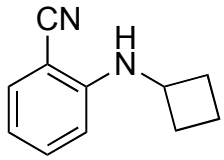
***N*-cyclobutylaniline (1b).** Following **GP1** with iodobenzene (0.56 mL, 5 mmol) and BrettPhos (80.5 mg, 0.15 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as colorless oil (570 mg, 78%). IR υ_{max} (cm^{-1}) 3400, 3050, 2934, 1603, 1504, 1315, 1270, 1167, 748; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.13 – 7.05 (m, 2H), 6.63 (tt, J = 7.3, 1.1 Hz, 1H), 6.49 (dq, J = 7.5, 1.0 Hz, 2H), 3.91 – 3.72 (m, 2H), 2.43 – 2.24 (m, 2H), 1.84 – 1.62 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 147.19, 129.27, 117.40, 113.06, 49.04, 31.28, 15.30; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{10}H_{13}N$ 148.1121; found 148.1126.



4-Trifluoromethyl-*N*-cyclobutylaniline (1c). 1c is prepared according to Ma's procedure[1]: An oven-dried schlenk tube was charged with CuI (48 mg, 0.25 mmol), K_2CO_3 (830 mg, 6 mmol), proline (69 mg, 0.6 mmol), cyclobutylamine (0.51 mL, 6 mmol), 4-iodobenzotrifluoride (0.74 mL, 5 mmol), DMSO (6 mL) and a stir bar. After purging with argon for a few seconds, the tube was sealed with a Teflon screw cap. The mixture was heated at 70 ^{o}C for 12 h. The reaction mixture was then cooled to room temperature, quenched with brine and diluted with diethyl ether. The organic layer was separated and the aqueous layer was extracted with diethyl ether. The combined organic layers were dried over Na_2SO_4, filtered, and concentrated under vacuum. Purification of the residual mass by silica gel flash chromatography (1:20 EtOAc/hexanes) afforded the product (1.01 g, 94%) as yellowish oil. IR υ_{max} (cm^{-1}) 3437, 3013, 2977, 2941, 1617, 1533, 1484, 1414, 1325, 1279, 1186, 1157, 1107, 1065, 825; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 – 7.32 (m, 2H), 6.63 – 6.46 (m, 2H), 4.30 (s, 1H), 4.03 – 3.86 (m, 1H), 2.55 – 2.33 (m, 2H), 1.97 – 1.71 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 149.61, 126.65, 125.26 (q, J^1 = 270.3 Hz), 118.86 (q, J^2 = 32.5 Hz), 111.99, 48.51, 30.99, 15.26; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{11}H_{12}F_3N$ 216.0995; found 216.0986.



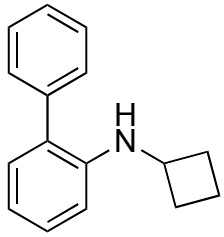
***N*-cyclobutyl-4-methoxyaniline (1d).** Following **GP1** with 1-bromo-4-methoxybenzene (0.68 mL, 5 mmol) and BrettPhos (80.5 mg, 0.15 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (1: 20 EtOAc/hexanes) as brown oil (0.76 g, 86%). IR υ_{max} (cm^{-1}) 3375, 2935, 2831, 1511, 1464, 1235, 1037, 819; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.71 – 6.66 (m, 2H), 6.48 – 6.43 (m, 2H), 3.81 – 3.73 (m, 1H), 3.66 (s, 3H), 2.37 – 2.26 (m, 2H), 1.77 – 1.63 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 152.17, 141.34, 127.84, 114.90, 114.45, 55.81, 49.89, 31.28, 15.22; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{11}H_{15}NO$ 178.1226; found 178.1221.



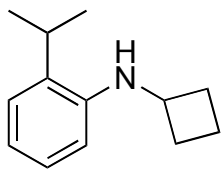
2-(cyclobutylamino)benzonitrile (1e). Following **GP1** with 2-bromobenzonitrile (0.364 g, 2 mmol) and (*R*)-Tol-BINAP (41 mg, 0.06 mmol, 3 mol%), the product was isolated after flash

chromatography on silica gel (1:20 EtOAc/hexanes) as colorless oil (279 mg, 81%). IR υ_{max} (cm^{-1}) 3357, 2976, 2936, 2212, 1603, 1576, 1511, 1461, 1324, 1267, 1169, 749; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.43 – 7.30 (m, 2H), 6.67 (dddd, *J* = 7.8, 7.3, 1.0, 0.4 Hz, 1H), 6.57 (ddt, *J* = 8.4, 1.0, 0.5 Hz, 1H), 3.97 (dq, *J* = 7.9, 7.1 Hz, 1H), 2.54 – 2.37 (m, 2H), 2.00 – 1.79 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 149.23, 134.20, 132.75, 117.96, 116.49, 111.09, 95.48, 77.34, 48.33, 30.88, 15.28; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{11}H_{12}N_2$ 173.1073; found 173.1077.

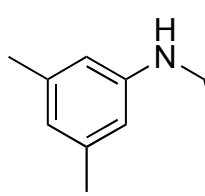
***N*-cyclobutyl-2-biphenylamine (1f).** Following **GP1** with 2-bromobiphenyl (0.86 mL, 5 mmol) and (*R*)-Tol-BINAP (102 mg, 0.15 mmol, 3 mol%), the product was isolated after a flash chromatography on silica gel (1:30 EtOAc/hexanes) as colorless oil (1.01 g, 91%). IR υ_{max} (cm^{-1}) 3417, 3065, 2979, 2963, 2934, 2880, 1603, 1581, 1507, 1448, 1460, 1312, 1285, 1168, 747; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.52 – 7.42 (m, 4H), 7.40 – 7.34 (m, 1H), 7.23 (ddd, *J* = 8.1, 7.3, 1.7 Hz, 1H), 7.10 (ddd, *J* = 7.5, 1.6, 0.4 Hz, 1H), 6.78 (td, *J* = 7.4, 1.2 Hz, 1H), 6.70 – 6.60 (m, 1H), 4.00 – 3.86 (m, 1H), 2.49 – 2.31 (m, 2H), 1.87 – 1.67 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.16, 139.73, 130.47, 129.49, 129.08, 128.85, 127.61, 127.34, 117.18, 111.23, 49.18, 31.35, 15.44; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{16}H_{17}N$ 224.1434; found 224.1444.



2-Isopropyl-*N*-cyclobutylaniline (1g). Following **GP1** with 1-bromo-2-isopropylbenzene (0.31 mL, 2 mmol) and (*R*)-Tol-BINAP (41 mg, 0.06 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (50:1 EtOAc/hexanes) as colorless oil (272 mg, 72%). IR υ_{max} (cm^{-1}) 3437, 3031, 2962, 2934, 2869, 1603, 1583, 1505, 1450, 1383, 1306, 1266, 1170, 1039, 743; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.24 – 7.06 (m, 2H), 6.86 – 6.70 (m, 1H), 6.56 (d, *J* = 8.1 Hz, 1H), 4.11 – 3.93 (m, 1H), 3.83 (s, 1H), 2.89 (h, *J* = 7.3, 6.8 Hz, 1H), 2.62 – 2.38 (m, 2H), 1.99 – 1.74 (m, 4H), 1.34 – 1.24 (m, 6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 144.08, 132.27, 126.86, 125.13, 117.51, 111.36, 49.38, 31.63, 27.33, 22.56, 15.56; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{19}N$ 190.1590; found 190.1587.



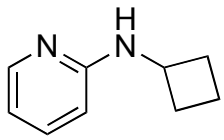
3,5-Dimethyl-*N*-cyclobutylaniline (1h). Following **GP1** with 5-bromo-m-xylene (0.27 mL, 2 mmol) and BrettPhos (32.2 mg, 0.06 mmol, 3 mol%), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as colorless oil (343 mg, 98%). IR υ_{max} (cm^{-1}) 3393, 3046, 2976, 2969, 2888, 1603, 1510, 1471, 1334, 1303, 1192, 821; ^1H NMR (300 MHz, Chloroform-*d*) δ 6.42 – 6.33 (m, 1H), 6.26 – 6.17 (m, 2H), 4.33 – 3.46 (m, 2H), 2.49 – 2.33 (m, 2H), 2.24 (s, 6H), 1.91 – 1.71 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.36, 139.09, 119.66, 111.23, 49.28, 31.54, 21.72, 15.45; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{12}H_{17}N$ 176.1434; found 176.1426.



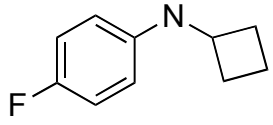
***N*-cyclobutyl-3-pyridinamine (1i).** Following **GP1** with 3-bromopyridine (0.2 mL, 2 mmol) and BrettPhos (32.2 mg, 0.06 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (2:1 EtOAc/hexanes)

as pale-yellow solid (238 mg, 80%). m.p. 51-52 °C; IR υ_{max} (cm^{-1}) 3266, 3093, 3037, 2976, 2936, 1587, 1519, 1482, 1415, 1313, 1246, 1161, 795; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.15 – 7.84 (m, 2H), 7.06 (dd, *J* = 8.4, 4.5 Hz, 1H), 6.80 (dd, *J* = 8.1, 2.7 Hz, 1H), 3.90 (p, *J* = 7.9, 7.4 Hz, 2H), 2.44 (tdd, *J* = 9.0, 5.3, 2.2 Hz, 2H), 1.84 (pd, *J* = 7.2, 3.4 Hz, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.39, 138.81, 136.21, 123.97, 118.99, 48.88, 31.19, 15.39; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_9H_{12}N_2$ 149.1073; found 149.1061.

***N*-cyclobutyl-2-pyridinamine (1j).** Following **GP1** with 2-bromopyridine (0.2 mL, 2 mmol) and BrettPhos (32.2 mg, 0.06 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (2:1 EtOAc/hexanes) as pale-yellow solid (160 mg, 54%). m.p. 40-42 °C; IR υ_{max} (cm^{-1}) 3251, 3031, 3015, 2976, 2939, 2854, 1609, 1573, 1446, 1336, 1291, 1155, 767; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06 (dt, *J* = 4.8, 1.4 Hz, 1H), 7.42 (ddd, *J* = 8.8, 7.2, 1.9 Hz, 1H), 6.56 (ddd, *J* = 7.1, 5.1, 1.0 Hz, 1H), 6.31 (d, *J* = 8.4 Hz, 1H), 4.83 (s, 1H), 4.12 (h, *J* = 7.5 Hz, 1H), 2.51 – 2.36 (m, 2H), 1.90 – 1.74 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.02, 148.28, 137.81, 113.04, 106.51, 47.52, 31.50, 15.39; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_9H_{12}N_2$ 149.1073; found 149.1074.

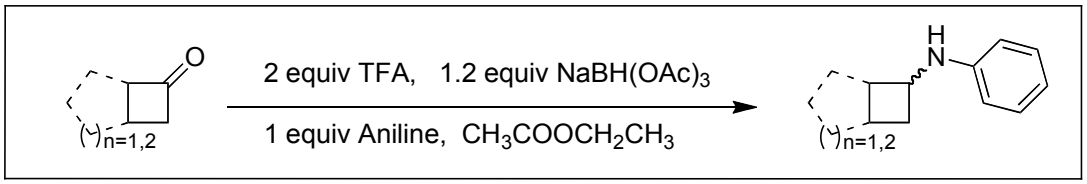


***N*-cyclobutyl-4-fluoroaniline (1k).** Following **GP1** with 1-bromo-4-fluorobenzene (0.22 mL, 2 mmol) and BrettPhos (32.2 mg, 0.06 mmol, 3 mol%), the product was isolated after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as yellow oil (0.27 g, 83%). IR υ_{max}(cm^{-1}) 3410, 2973, 2937, 1612, 1511, 1346, 1268, 1216, 1159, 820;^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.92 – 6.83 (m, 2H), 6.53 – 6.44 (m, 2H), 3.98 – 3.69 (m, 2H), 2.48 – 2.35 (m, 2H), 1.89 – 1.70 (m, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.06 (d, $^1J_{CF}$ = 234.7 Hz), 143.65, 115.85 (d, $^2J_{CF}$ = 22.3 Hz), 114.09 (d, $^3J_{CF}$ = 7.5 Hz), 49.80, 31.34, 15.43; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{10}H_{12}FN$ 166.1027; found 166.1020.



General procedure 2 (GP2): Synthesis of bicyclic cyclobutylaniline

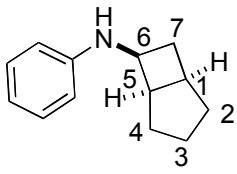
Bicyclo[3.2.0]heptan-6-one and bicyclo[4.2.0]octan-7-one were prepared according to Mollet's procedure.[2] Conversion of the bicyclic ketone to bicyclic cyclobutylaniline was accomplished via a reductive amination procedure developed by Davies.[3]



To a 25 mL round bottle flask equipped with a stir bar was added bicyclic ketone (3.6 mmol, 1.1 equiv.), aniline (3.27 mmol, 1 equiv.), trifluoroacetic acid (6.54 mmol, 2 equiv.) and ethyl acetate (6 mL). Sodium triacetoxyborohydride (3.9 mmol, 1.2 equiv.)

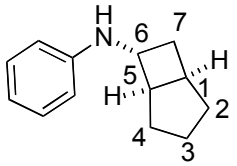
was added to the mixture in one portion and the reaction temperature rose to 40 °C. The reaction mixture continued to stir for another 30 minutes, and was monitored by TLC. The reaction mixture was then added with 10% sodium hydroxide solution to adjust the pH to 8-9, followed by the extraction with diethyl ether. The organic layer was then washed with water and brine, dried over sodium sulfate and concentrate. Column chromatography was used to purify the crude product to yield the desired bicyclic cyclobutylaniline with a distereoselectivity of 1:1.

(1S,5S,6R)-N-phenylbicyclo[3.2.0]heptan-6-amine (6a): Following **GP2** with



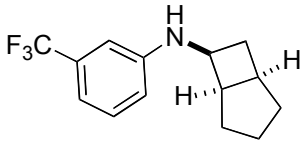
bicyclo[3.2.0]heptan-6-one (394 mg, 3.6 mmol), the product was isolated from two diastereomers (**6a** and **6b**, 1:1) after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as a colorless oil (243 mg, 36%). IR υ_{max} (cm^{-1}) 3367, 2943, 2861, 1618, 1601, 1500, 1315, 749; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.33 – 7.09 (m, 2H), 6.74 (q, *J* = 7.2, 6.7 Hz, 1H), 6.62 – 6.51 (m, 2H), 4.06 – 3.94 (m, 1H), 3.06 (qd, *J* = 7.9, 7.1, 2.5 Hz, 1H), 2.79 – 2.61 (m, 2H), 1.88 – 1.78 (m, 2H), 1.76 – 1.69 (m, 1H), 1.57 (dtd, *J* = 12.3, 6.0, 2.9 Hz, 2H), 1.45 (dddd, *J* = 12.4, 10.8, 6.0, 2.6 Hz, 1H), 1.38 – 1.29 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 129.23, 129.19, 117.18, 112.87, 46.45, 43.30, 33.77, 33.10, 33.07, 26.46, 25.97; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{17}N$ 188.1434; found 188.1439.

(1S,5S,6S)-N-phenylbicyclo[3.2.0]heptan-6-amine (6b): Following **GP2** with



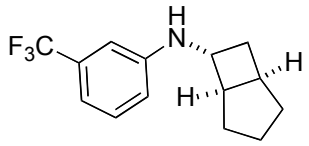
bicyclo[3.2.0]heptan-6-one (394 mg, 3.6 mmol), the product was isolated from two diastereomers (**6a** and **6b**, 1:1) after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as a colorless oil (228 mg, 34%). IR υ_{max} (cm^{-1}) 3398, 2942, 2852, 1602, 1503, 1314, 1269, 1177, 748; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.25 – 7.14 (m, 2H), 6.74 (tt, *J* = 7.3, 1.2 Hz, 1H), 6.58 – 6.48 (m, 2H), 3.41 (ddd, *J* = 7.0, 5.8, 3.6 Hz, 1H), 2.88 – 2.76 (m, 1H), 2.54 (td, *J* = 7.4, 3.6 Hz, 1H), 2.02 – 1.95 (m, 2H), 1.92 – 1.78 (m, 3H), 1.62 – 1.52 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 129.40, 117.67, 113.64, 113.63, 52.47, 46.72, 33.47, 33.39, 32.90, 32.31, 25.58; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{17}N$ 188.1434; found 188.1435.

(1S,5S,6R)-N-(4-iodophenyl)bicyclo[3.2.0]heptan-6-amine (6c): Following **GP2** with



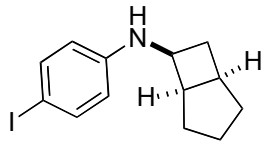
bicyclo[3.2.0]heptan-6-one (394 mg, 3.6 mmol) and *3-(trifluoromethyl)aniline* (716 mg, 3.27 mmol), the product was isolated from two diastereomers (**6c** and **6c'**, 1:1) after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as a colorless oil (287 mg, 28%). IR υ_{max} (cm^{-1}) 3401, 2941, 1590, 1491, 1314, 1179, 809; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.23 (t, *J* = 7.9 Hz, 1H), 6.88 (d, *J* = 7.7 Hz, 1H), 6.73 – 6.63 (m, 2H), 3.96 (q, *J* = 7.8, 7.2 Hz, 2H), 3.02 (q, *J* = 7.6 Hz, 1H), 2.74 – 2.56 (m, 2H), 1.75 (ddq, *J* = 24.1, 12.2, 5.8 Hz, 2H), 1.59 (dd, *J* = 13.6, 6.8 Hz, 1H), 1.53 – 1.46 (m, 2H), 1.43 – 1.37 (m, 1H), 1.36 – 1.24 (m, 1H); ^{13}C NMR (101 MHz, CD_2Cl2) δ 148.01, 131.71 (q, J^2 = 31.5 Hz), 129.57, 125.1 (q, J^1 = 272.2 Hz), 115.59, 112.94, 108.57, 46.13, 43.09, 33.83, 32.93, 32.71, 26.31, 25.83; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{16}IN$ 314.0400; found 314.0410.

(1S,5S,6S)-N-(4-iodophenyl)bicyclo[3.2.0]heptan-6-amine (6c'): Following **GP2** with



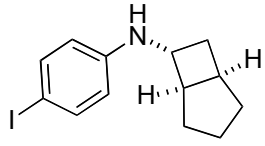
bicyclo[3.2.0]heptan-6-one (394 mg, 3.6 mmol) and *3-(trifluoromethyl)aniline* (716 mg, 3.27 mmol), the product was isolated from two diastereomers (**6c** and **6c'**, 1:1) after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as a colorless oil (273 mg, 27%). IR υ_{max} (cm^{-1}) 3369, 2930, 2857, 1589, 1490, 1179, 808; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.28 (t, J = 7.8 Hz, 1H), 6.97 – 6.90 (m, 1H), 6.75 – 6.63 (m, 2H), 4.29 – 4.15 (m, 1H), 3.41 (td, J = 5.9, 4.7, 2.5 Hz, 1H), 2.90 – 2.78 (m, 1H), 2.53 (td, J = 7.5, 3.6 Hz, 1H), 2.03 – 1.97 (m, 2H), 1.93 – 1.78 (m, 3H), 1.63 – 1.53 (m, 3H); ^{13}C NMR (75 MHz, CD_2Cl2) δ 147.58, 131.68 (q, J^2 = 31.4 Hz), 129.55, 125.08 (q, J^1 = 272.1 Hz), 116.19, 113.16, 109.03, 51.82, 46.47, 33.34, 32.86, 32.57, 31.99, 25.31; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{13}H_{16}IN$ 314.0400; found 314.0399.

(1S,5S,6R)-N-(3-(trifluoromethyl)phenyl)bicyclo[3.2.0]heptan-6-amine (6d):



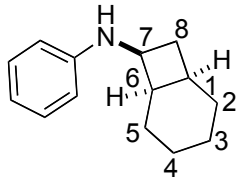
Following **GP2** with *bicyclo[3.2.0]heptan-6-one* (394 mg, 3.6 mmol) and *4-iodoaniline* (0.41 mL, 3.27 mmol), the product was isolated from two diastereomers (**6d** and **6d'**, 1:1) after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as a colorless oil (259 mg, 31%). IR υ_{max} (cm^{-1}) 3418, 2949, 2856, 1493, 1342, 1162, 1069, 767; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.46 – 7.31 (m, 2H), 6.38 – 6.24 (m, 2H), 3.95 – 3.82 (m, 1H), 2.98 (tdd, J = 8.6, 4.4, 1.6 Hz, 1H), 2.72 – 2.53 (m, 2H), 1.81 – 1.73 (m, 1H), 1.73 – 1.65 (m, 1H), 1.59 – 1.53 (m, 1H), 1.47 (ddd, J = 12.6, 6.3, 4.8 Hz, 2H), 1.41 – 1.33 (m, 1H), 1.31 – 1.24 (m, 1H); ^{13}C NMR (101 MHz, CD_2Cl2) δ 147.43, 137.61, 114.83, 76.89, 46.13, 43.16, 33.82, 32.96, 32.72, 26.34, 25.83; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{14}H_{16}F_3N$ 256.1308; found 256.1313.

(1S,5S,6S)-N-(4-(trifluoromethyl)phenyl)bicyclo[3.2.0]heptan-6-amine (6d'):



Following **GP2** with *bicyclo[3.2.0]heptan-6-one* (394 mg, 3.6 mmol) and *4-iodoaniline* (0.41 mL, 3.27 mmol), the product was isolated from two diastereomers (**6d** and **6d'**, 1:1) after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as a colorless oil (218 mg, 26%). IR υ_{max} (cm^{-1}) 3421, 2947, 2856, 1616, 1515, 1342, 1123, 787; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.46 – 7.34 (m, 2H), 6.36 – 6.23 (m, 2H), 3.35 (td, J = 6.7, 3.6 Hz, 1H), 2.88 – 2.72 (m, 1H), 2.50 (td, J = 7.4, 3.6 Hz, 1H), 1.99 – 1.93 (m, 2H), 1.91 – 1.82 (m, 2H), 1.81 – 1.74 (m, 1H), 1.56 (tdd, J = 7.3, 5.0, 2.3 Hz, 3H); ^{13}C NMR (101 MHz, CD_2Cl2) δ 147.00, 137.62, 115.32, 77.12, 51.85, 46.50, 33.35, 32.93, 32.58, 32.01, 25.29; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{14}H_{16}F_3N$ 256.1308; found 256.1311.

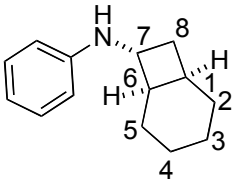
(1S,6S,7R)-N-phenylbicyclo[4.2.0]octan-7-amine (6e): Following **GP2** with



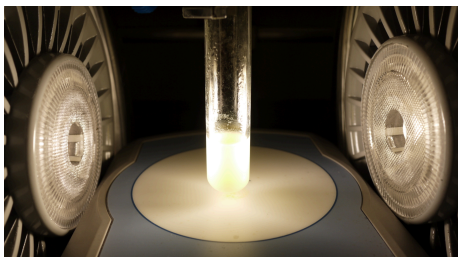
bicyclo[4.2.0]octan-7-one (440 mg, 3.6 mmol), the product was isolated from two diastereomers (**6e** and **6f**, 1:1) after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as a colorless oil (217 mg, 33%). IR υ_{max} (cm^{-1}) 3382, 2928, 2858, 1602, 1499, 1314, 1176, 749; ^{1}H NMR (400 MHz, Chloroform-d) δ 7.13 – 7.06 (m, 2H), 6.60 (m, 1H), 6.56 – 6.52 (m, 2H), 4.00 – 3.83 (m, 1H),

3.74 (dt, *J* = 9.5, 6.7 Hz, 1H), 2.57 (dddd, *J* = 14.9, 12.0, 9.4, 6.4 Hz, 1H), 2.28 – 2.13 (m, 2H), 1.90 – 1.82 (m, 1H), 1.62 – 1.51 (m, 3H), 1.51 – 1.42 (m, 3H), 1.35 – 1.27 (m, 1H), 1.06 – 1.00 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.47, 129.63, 117.27, 112.93, 48.48, 38.54, 31.25, 27.12, 26.44, 23.33, 22.45, 21.26; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{14}H_{19}N$ 202.1590; found 202.1597.

(1S,6S,7S)-N-phenylbicyclo[4.2.0]octan-7-amine (6f): Following **GP2** with *bicyclo[4.2.0]octan-7-one* (440 mg, 3.6 mmol), the product was isolated from two diastereomers (**6e** and **6f**, 1:1) after a flash chromatography on silica gel (1: 50 EtOAc/hexane) as a colorless oil (224 mg, 34%). IR υ_{max} (cm^{-1}) 3398, 2927, 2853, 1601, 1502, 1315, 1261, 748; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.14 – 6.99 (m, 2H), 6.60 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.56 – 6.46 (m, 2H), 3.89 (q, *J* = 7.4 Hz, 1H), 2.19 – 2.08 (m, 2H), 2.06 – 2.00 (m, 1H), 1.93 – 1.84 (m, 1H), 1.70 – 1.51 (m, 4H), 1.43 (dddt, *J* = 15.5, 11.3, 6.6, 2.2 Hz, 2H), 1.35 – 1.23 (m, 1H), 1.15 – 1.03 (m, 1H); ^{13}C NMR (101 MHz, CD_2Cl2) δ 148.43, 129.68, 117.43, 113.26, 50.07, 42.81, 36.12, 30.42, 27.40, 25.9; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{14}H_{19}N$ 202.1590; found 202.1593.



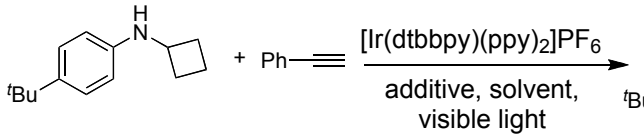
Catalyst optimization



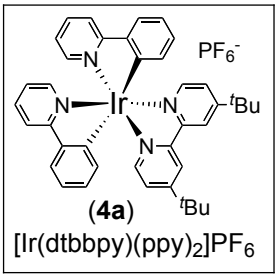
4-*tert*-Butyl-*N*-cyclobutylaniline (**1a**, 41 mg, 0.2 mmol), phenylacetylene (**2a**, 0.12 mL, 1.0 mmol), catalyst (2 mol%), and solvent (2 mL) were mixed together in a 10 mL test tube. The test tube was capped with a Teflon screw cap and then degassed using Freeze-Pump-Thaw (3 cycles). The degassed mixture was irradiated with two LED (18 watts) positioned 6 cm from the test tube for 14 h (unless noted). After that, the reaction mixture was diluted with Et_2O (2 mL) and *n*-dodecane (45 μL) was added as an internal standard. An aliquot (0.5 mL) was filtered through a syringe filter, diluted to 1 mL, and analyzed by GC.

- For entry 1, one LED light was used instead of two.
- For entries 3-6, nitromethane (CH_3NO_2), dimethylformamide (DMF), dimethyl sulfoxide (DMSO) and methanol (MeOH) were used as solvent respectively.
- For entry 7, the reaction was conducted without degassing via Freeze-Pump-Thaw cycles.
- For entry 11, no $[Ir(ppy)_2(dtbbpy)PF_6]$ **4a** was added.
- For entry 12, the reaction was conducted inside a dark cabinet.
- For entry 13, the reaction was conducted with one LED light at room temperature.

• For entry 14, the reaction was conducted in a 55 °C water bath with one LED light. For details, see the ***Temperature Control study*** shown below.



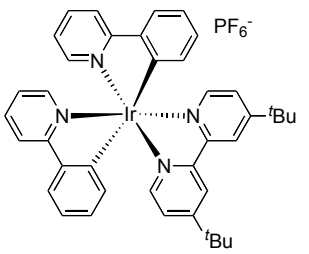
1a **2a** **3a**



(**4a**) [Ir(dtbbpy)(ppy)2]PF6

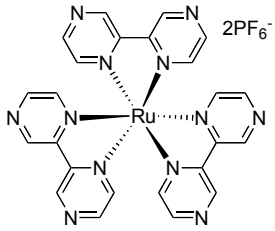
Entry[a]	Condition	t [h]	Conv. of **1 a**[%][b]	Yield of **3 a** [%][b]
1[c]	**4b** (2mol%), CH_3NO_2	16	11	9
2	**4b** (2mol%), CH_3NO_2	16	40	30
3	**4a** (2 mol%), CH_3NO_2	16	100	47
4	**4a** (2 mol%), DMF	16	90	86
5	**4a** (2 mol%), DMSO	16	100	90
6	**4a** (2 mol%), MeOH	12	100	97 (90)[d]
7	**4a** (2 mol%), Air, MeOH	16	100	42
8	**4b** (2mol%), MeOH	16	52	37
9	**4c** (2mol%), MeOH	16	82	60
10	**4d** (2mol%), MeOH	16	11	8
11	without **4a,** MeOH	16	7	3
12	**4a** (2mol%), MeOH, light bulb off	16	10	7
13[c]	**4a** (2 mol%), MeOH	16	29	27
14[e]	**4a** (2 mol%), MeOH	12	70	68

[a] Reaction conditions: **1a** (0.2 mmol, 0.1 M in degassed solvent), **2a** (1mmol), irradiation with two 18 W LED lightbulb at room temperature.
[b] Yields determined by GC analysis using dodecane as an internal standard unless noted. [c] One 18 W LED light. [d] Isolated yield by silica gel column chromatography.[e] One 18 W LED light, reaction tube in a 55 °c water bath.



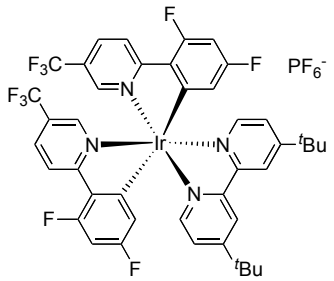
$[Ir(ppy)_2(dtbbpy)PF_6]$

4a



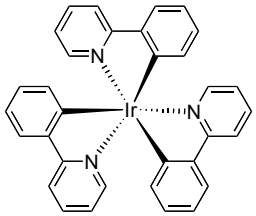
$[Ru(bpz)_3](PF_6)_2$

4b



$[Ir[(dF(CF_3)ppy)_2(dtbbpy)]PF_6]$

4c



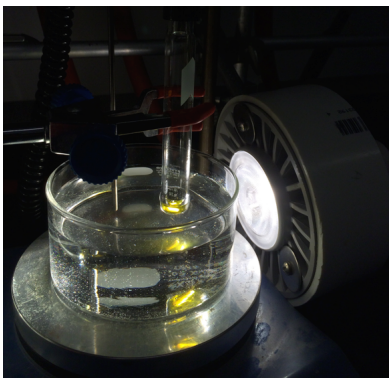
$Ir(ppy)_3$

4d

Conducting the experiment without degassing the reaction mixture led to significant decrease in the yield (entry 7). This observation is consistent with what we witnessed in the [3+2] annulation of cyclopropylanilines and alkynes.[4a] We previously showed that upon exposure to air under the optimized conditions, cyclopropylanilines underwent ring opening and then reacted with oxygen to form an endoperoxide byproduct.[4b] Presumably a similar process occurred with cyclobutylanilines, which resulted in the lower yield.

Temperature control study:

An oven-dried test tube equipped with a stir bar was charged with $Ir(dtbbpy)(ppy)_2PF_6$ (2 mol%), cyclobutylaniline **1a** (0.2 mmol), alkyne **2a** (1 mmol) and MeOH (2 mL). The test tube was capped with a Teflon screw cap and followed by degassing using Freeze-Pump-Thaw sequence three times. The reaction mixture was then put into a PYREX 100 x 50 water bath which was preheated to 55 °C and irradiated with 1 LED (18 watts) positioned 6 cm from the test tube. After 12 h, the reaction was stopped and analyzed by GC with dodecane as internal standard. The GC analysis showed that **3a** was formed in 68% GC yield (71% conversion of **1a**).

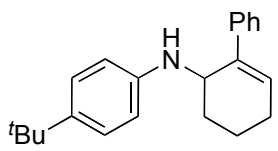


General Procedure 3 (GP3); Visible light catalyzed [4+2] annulation reaction

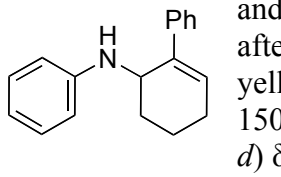
An oven-dried test tube equipped with a stir bar was charged with $Ir(dtbbpy)(ppy)_2PF_6$ (2 mol%) and cyclobutylaniline derivative (0.2 mmol), alkyne derivative (0.6 mmol) (phenylacetylene was used in 1 mmol scale) , and MeOH (2 mL). The test tube was capped with a Teflon screw cap and followed by degassing using Freeze-Pump-Thaw sequence three times. The reaction mixture was then irradiated with two LED (18 watts) positioned 6 cm from the test tube. After the reaction was complete as monitored by TLC, the mixture was dilute with diethyl ether and filtered through a short pad of silica gel. The solution was concentrated and the residue was purified by silica gel flash chromatography to afford the corresponding annulation product.

Compounds in Table 2

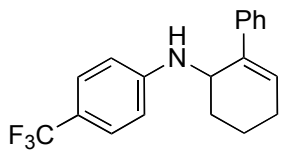
4-tert-butyl-N-(2-phenylcyclohex-2-enyl)aniline **(3a):** Following **GP3** with **1a** (41 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol) , the product was isolated after flash chromatography on silica gel (1: 30 EtOAc/hexanes) as brown oil (55 mg, 90%). IR υ_{max} (cm^{-1}) 3424, 3024, 2950, 2904, 2862, 1612, 1517, 1473, 1361, 1320, 1252, 1193, 818; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.43 (d, *J* = 7.5 Hz, 2H), 7.30 – 7.22 (m, 2H), 7.22 – 7.17 (m, 3H), 6.61 (d, *J* = 8.2 Hz, 2H), 6.39 – 6.26 (m, 1H), 4.48 (d, *J* = 3.3 Hz, 1H), 2.38 – 2.10 (m, 3H), 1.65 (dd, *J* = 13.8, 10.0 Hz, 3H), 1.28 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 144.51, 140.52, 139.90, 137.28, 129.07, 128.58, 127.13, 126.26, 125.73, 112.89, 48.41, 34.04, 31.77, 27.45, 26.20, 17.20; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{22}H_{27}N$ 306.2216; found 306.2214.



N-(2-phenylcyclohex-2-enyl)aniline **(3b):** Following **GP3** with **1b** (30 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after flash chromatography on silica gel (1: 50 EtOAc/hexanes) as yellow oil (37 mg, 76%). IR υ_{max} (cm^{-1}) 3400, 3020, 2927, 2864, 1598, 1500, 1424, 1310, 1251, 1161, 750; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.50 –7.44 (m, 2H), 7.34 – 7.26 (m, 2H), 7.26 – 7.17 (m, 3H), 6.71 (tq, *J* = 7.3, 0.9 Hz, 1H), 6.68 – 6.61 (m, 2H), 6.38 (dd, *J* = 5.0, 3.0 Hz, 1H), 4.51 (d, *J* = 2.5 Hz, 1H), 3.84 (d, *J* = 20.8 Hz, 1H), 2.53 – 2.14 (m, 3H), 1.88 – 1.62 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 147.03, 140.20, 137.05, 129.35, 128.81, 128.44, 127.02, 125.47, 116.92, 112.84, 48.01, 27.46, 26.01, 17.09; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{19}H_{21}N$ 250.1590; found 250.1594.



N-(2-phenylcyclohex-2-enyl)-4-(trifluoromethyl)aniline **(3c):** Following **GP3** with **1c** (43 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after flash chromatography on silica gel (1: 20 EtOAc/hexanes) as yellow solid (50 mg, 79%). m.p. 75-77 °C; IR υ_{max} (cm^{-1}) 3414, 3047, 2933, 2873, 1614, 1528, 1485, 1322, 1259, 1109, 1058, 823; ^1H NMR (400 MHz, Benzene-d_6) δ 7.35 – 7.27 (m, 4H), 7.15 – 7.09 (m, 2H), 7.09 – 7.03 (m, 1H), 6.12 (ddd, *J* = 4.8, 2.3, 1.5 Hz, 1H), 6.03 (d, *J* = 8.5 Hz, 2H), 4.22 – 4.12 (m, 1H), 3.56 (d, *J* = 7.3 Hz, 1H), 2.04 – 1.70 (m, 3H), 1.42 – 1.29 (m, 3H); ^{13}C NMR (101 MHz, C_6D_6) δ 149.97, 140.42, 136.99, 129.25, 129.14, 127.89, 127.36 (q, J^3 = 3.8 Hz), 126.38 (q, J^1 = 270.1 Hz), 125.94,



119.03 (q, J^2 = 32.4 Hz), 112.47, 48.06, 27.85, 26.41, 17.59; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{19}H_{18}F_3N$ 318.1464; found 318.1464.

4-methoxy-N-(2-phenylcyclohex-2-enyl)aniline **(3d):** Following **GP3** with **1d** (36 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 50 EtOAc/hexanes) as brown oil (16 mg, 28%). IR υ_{max} (cm^{-1}) 3405, 3026, 2931, 2859, 2830, 1608, 1510, 1442, 1402, 1237, 1174, 1036, 818; ^{1}H NMR (300 MHz, Chloroform-*d*) δ 7.55 – 7.41 (m, 2H), 7.34 – 7.20 (m, 3H), 6.88 – 6.74 (m, 2H), 6.69 – 6.56 (m, 2H), 6.41 – 6.28 (m, 1H), 4.48 – 4.35 (m, 1H), 3.76 (s, 3H), 2.41 – 2.06 (m, 3H), 1.69 (dd, *J* = 3.5, 1.7 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 151.88, 141.14, 140.31, 137.20, 128.73, 128.41, 126.97, 125.51, 114.98, 114.34, 55.85, 49.12, 27.45, 26.01, 17.01; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{19}H_{21}NO$ 280.1696; found 280.1701.

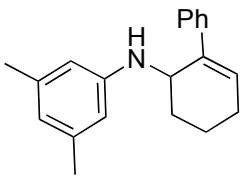
2-(2-phenylcyclohex-2-enylamino)benzonitrile **(3e):** Following **GP3** with **1e** (35 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 20 EtOAc/hexanes) as brown oil (46 mg, 84%). IR υ_{max} (cm^{-1}) 3420, 3024, 2932, 2867, 2832, 2209, 1602, 1574, 1505, 1449, 1442, 1318, 1284, 1165, 1070, 751; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.69 – 7.35 (m, 5H), 7.35 – 7.23 (m, 2H), 6.85 (d, *J* = 8.5 Hz, 1H), 6.68 (t, *J* = 7.5 Hz, 1H), 6.38 (dd, *J* = 4.9, 2.9 Hz, 1H), 4.63 (d, *J* = 21.9 Hz, 2H), 2.47 – 2.01 (m, 3H), 1.90 – 1.52 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 149.12, 139.94, 136.12, 134.27, 133.09, 129.99, 128.50, 127.25, 125.50, 117.77, 116.37, 110.79, 96.07, 48.09, 27.56, 25.79, 16.93. HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{19}H_{18}N_2$ 275.1543; found 275.1524.

N-(2-phenylcyclohex-2-enyl)biphenyl-2-amine **(3f):** Following **GP3** with **1f** (45 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 50 EtOAc/hexanes) as white solid (54 mg, 83%). m.p. 125-128 °C; IR υ_{max} (cm^{-1}) 3419, 3053, 2921, 1595, 1504, 1486, 1434, 1310, 1282, 760; ^{1}H NMR (300 MHz, Chloroform-*d*) δ 7.36 – 7.21 (m, 9H), 7.09 – 6.97 (m, 3H), 6.88 (d, *J* = 8.2 Hz, 1H), 6.75 (t, *J* = 7.3 Hz, 1H), 6.17 (t, *J* = 3.9 Hz, 1H), 4.49 (t, *J* = 3.4 Hz, 1H), 2.12 (ddd, *J* = 14.1, 5.8, 2.8 Hz, 3H), 1.82 – 1.42 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 143.74, 140.67, 139.26, 137.41, 130.50, 129.14, 129.02, 128.78, 128.69, 128.39, 127.87, 127.00, 126.92, 125.94, 116.73, 110.47, 49.09, 28.06, 25.87, 17.44; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{24}H_{23}N$ 326.1903; found 326.1907.

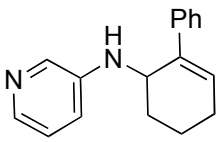
2-isopropyl-N-(2-phenylcyclohex-2-enyl)aniline **(3g):** Following **GP3** with **1g** (38 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as yellow oil (44 mg, 76%). IR υ_{max} (cm^{-1}) 3441, 3029, 2958, 2932, 2865, 1602, 1582, 1503, 1448, 1358, 1306, 1253, 757; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.47 – 7.42 (m, 2H), 7.30 – 7.24 (m, 2H), 7.23 – 7.18 (m, 1H), 7.18 – 7.11 (m, 2H), 6.82 (dt, *J* = 8.0, 0.9 Hz, 1H), 6.74 (td, *J* = 7.5, 1.2 Hz, 1H), 6.41 – 6.35 (m, 1H), 4.55 (d, *J* = 3.7 Hz, 1H), 2.66 (hept, *J*

= 6.8 Hz, 1H), 2.40 – 2.15 (m,3H), 1.79 – 1.67 (m, 3H), 1.22 (d, *J* = 6.8 Hz, 3H), 0.97 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.61, 140.28, 137.34, 131.96, 128.81, 128.42, 127.01, 126.75, 125.54, 125.10, 116.72, 110.03, 48.22, 27.57, 27.11, 26.06, 22.15, 17.39; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{21}H_{25}N$ 292.2060; found 292.2065.

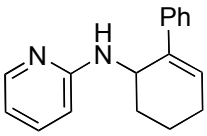
3,5-dimethyl-N-(2-phenylcyclohex-2-enyl)aniline (**3h**)**:** Following **GP3** with **1h** (35 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 50 EtOAc/hexanes) as yellow oil (46 mg, 87%). IR υ_{max} (cm^{-1}) 3417, 3031, 2935, 2860, 1598, 1507, 1496, 1443, 1339, 1189, 819; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.53 – 7.40 (m, 2H), 7.34 – 7.26 (m, 2H), 7.24 – 7.17 (m, 1H), 6.42 – 6.32 (m, 2H), 6.29 (s, 2H), 4.49 (t, *J* = 3.0 Hz, 1H), 2.43 – 2.09 (m, 9H), 1.81 – 1.57 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.11, 140.42, 139.16, 137.23, 128.90, 128.59, 127.13, 125.63, 119.15, 110.92, 48.02, 27.61, 26.19, 21.75, 17.22; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{20}H_{23}N$ 278.1903; found 278.1905.



N-(2-phenylcyclohex-2-enyl)pyridin-3-amine (**3i**)**:** Following **GP3** with **1i** (30 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 5 EtOAc/hexanes) as yellow solid (37 mg, 73%). m.p. 132-134 °C; IR υ_{max} (cm^{-1}) 3255, 3086, 3028, 2927, 2859, 2213, 1580, 1506, 1481, 1415, 1318, 1296, 786; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.08 (d, *J* = 2.7 Hz, 1H), 7.88 (d, *J* = 5.0 Hz, 1H), 7.40 – 7.33 (m, 2H), 7.31 – 7.26 (m, 2H), 7.25 – 7.19 (m, 2H), 7.13 – 7.04 (m, 1H), 6.35 (dd, *J* = 5.0, 3.0 Hz, 1H), 4.47 (d, *J* = 10.0 Hz, 2H), 2.40 – 2.16 (m, 2H), 2.12 – 2.01 (m, 1H), 1.83 – 1.63 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.40, 140.08, 137.86, 136.77, 135.55, 129.59, 128.68, 127.40, 125.63, 124.16, 119.10, 48.10, 27.55, 26.08, 17.26; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{17}H_{18}N_2$ 251.1543; found 251.1542.

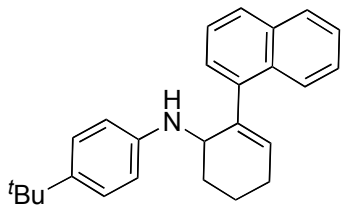


N-(2-phenylcyclohex-2-enyl)pyridin-2-amine (**3j**)**:** Following **GP3** with **1j** (30 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.12 mL, 1 mmol), the product was isolated after a flash chromatography on silica gel (1: 5 EtOAc/hexanes) as yellow solid (39 mg, 78%). m.p. 83-84 °C; IR υ_{max} (cm^{-1}) 3425, 3020, 2931, 1600, 1570, 1484, 1442, 755; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.00 (ddt, *J* = 5.1, 1.8, 0.8 Hz, 1H), 7.33 (ddt, *J* = 7.0, 1.3, 0.7 Hz, 2H), 7.30 – 7.23 (m, 1H), 7.21 – 7.14 (m, 2H), 7.13 – 7.05 (m, 1H), 6.44 (ddt, *J* = 7.0, 5.1, 0.9 Hz, 1H), 6.29 – 6.20 (m, 2H), 4.88 – 4.80 (m, 1H), 4.54 (d, *J* = 8.0 Hz, 1H), 2.27 – 2.07 (m, 2H), 2.07 – 1.97 (m, 1H), 1.76 – 1.67 (m, 1H), 1.63 (ttd, *J* = 10.6, 6.1, 5.3, 3.4 Hz, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.51, 147.93, 140.12, 137.34, 137.13, 129.16, 128.37, 127.01, 125.61, 112.48, 107.56, 46.35, 28.55, 26.02, 17.44. HRMS (ESI) m/z $[M+H]^+$, calc'd for C17H18N2. FTMS (ESI) m/z $[M+H]^+$, calc'd for $C_{17}H_{18}N_2$ 251.1543; found 251.1542.

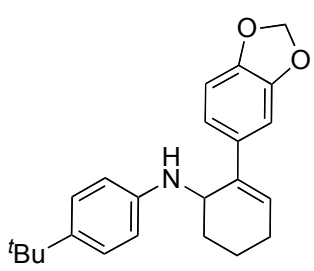


Compounds in Table 3

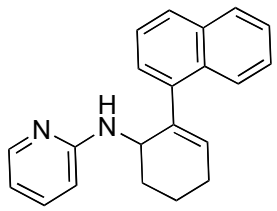
4-tert-butyl-N-(2-(naphthalen-1-yl)cyclohex-2-enyl)aniline **(5a):** Following **GP3** with **1a** (41 mg, 0.2 mmol) and 1-ethynylnaphthalene (**2b**) (91 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as yellow oil (50, 71%). IR υ_{max} (cm^{-1}) 3395, 3043, 2926, 1603, 1514, 1463, 1391, 1296, 1248, 1191, 816, 774; ^1H NMR (400 MHz, Benzene-d_6) δ 8.16 (d, J = 8.4 Hz, 1H), 7.64 (d, J = 8.1 Hz, 1H), 7.52 (dd, J = 8.3, 1.3 Hz, 1H), 7.37 (ddt, J = 8.3, 6.8, 1.2 Hz, 1H), 7.34 – 7.24 (m, 2H), 7.20 (ddd, J = 8.1, 6.9, 1.0 Hz, 1H), 7.05 – 6.94 (m, 2H), 6.33 – 6.23 (m, 2H), 5.80 (t, J = 3.9 Hz, 1H), 4.37 (d, J = 4.4 Hz, 1H), 3.54 (s, 1H), 2.11 – 1.89 (m, 3H), 1.78 – 1.58 (m, 2H), 1.46 (ddt, J = 12.7, 6.1, 3.2 Hz, 1H), 1.21 (d, J = 1.0 Hz, 9H); ^{13}C NMR (101 MHz, C_6D_6) δ 145.00, 140.43, 139.40, 138.12, 134.15, 132.39, 131.27, 128.62, 127.29, 125.76, 125.71, 125.45, 125.38, 125.22, 113.08, 51.74, 33.47, 31.40, 28.08, 25.43, 17.32; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{26}H_{29}N$ 356.2373; found 356.2369.



N-(2-(benzo[d][1,3]dioxol-5-yl)cyclohex-2-enyl)-4-tert-butylaniline **(5b):** Following **GP3** with **1a** (41 mg, 0.2 mmol) and 5-ethynylbenzo[*d*][1,3]dioxole (**2c**) (88 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as brown oil (40 mg, 57%). IR υ_{max} (cm^{-1}) 3406, 2926, 2857, 1724, 1610, 1516, 1238, 1037, 801; ^1H NMR (400 MHz, Chloroform-*d*) δ 7.24 – 7.18 (m, 2H), 6.97 (d, J = 1.8 Hz, 1H), 6.93 (dd, J = 8.1, 1.9 Hz, 1H), 6.72 (d, J = 8.2 Hz, 1H), 6.62 – 6.55 (m, 2H), 6.19 (dd, J = 4.9, 3.0 Hz, 1H), 5.92 (q, J = 1.5 Hz, 2H), 4.43 – 4.32 (m, 1H), 2.31 – 2.12 (m, 3H), 1.65 (tdd, J = 13.1, 6.4, 3.2 Hz, 3H), 1.29 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.89, 146.77, 144.73, 139.78, 137.16, 135.26, 128.04, 126.28, 119.31, 112.71, 108.32, 106.47, 101.10, 48.53, 34.04, 31.79, 27.44, 26.15, 17.16; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{23}H_{27}NO_2$ 350.2115; found 350.2121.



N-(2-(naphthalen-1-yl)cyclohex-2-enyl)pyridin-2-amine **(5c):** Following **GP3** of the annulation with **1j** (30 mg, 0.2 mmol) and 1-ethynylnaphthalene (**2b**) (91 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 5 EtOAc/hexanes) as yellow solid (43 mg, 72%). m.p. 99-102 °C; IR υ_{max} (cm^{-1}) 3289, 3026, 2862, 2852, 1596, 1569, 1484, 1442, 1394, 1326, 1282, 799; ^1H NMR (400 MHz, Chloroform-*d*) δ 8.05 (dd, J = 7.9, 1.8 Hz, 1H), 7.95 (dd, J = 4.8, 2.1 Hz, 1H), 7.84 (dd, J = 7.7, 1.9 Hz, 1H), 7.77 – 7.70 (m, 1H), 7.57 – 7.44 (m, 2H), 7.43 – 7.32 (m, 2H), 7.21 (ddd, J = 8.7, 7.1, 1.9 Hz, 1H), 6.42 (dd, J = 7.1, 5.0 Hz, 1H), 6.13 (d, J = 8.4 Hz, 1H), 6.01 (dd, J = 4.5, 3.0 Hz, 1H), 4.72 (s, 2H), 2.44 – 2.25 (m, 2H), 2.21 – 2.02 (m, 2H), 1.97 – 1.81 (m, 2H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 157.82, 147.81, 140.23, 137.56, 136.87, 133.75, 132.13, 132.01, 128.29, 127.12, 125.85, 125.83, 125.55, 125.40, 125.16, 112.33, 106.92, 49.66, 28.85, 25.62, 17.80; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{21}H_{20}N_2$ 301.1700; found 301.1702.



Methyl 6-(biphenyl-2-ylamino)cyclohex-1-enecarboxylate **(5d):** Following **GP3** with **1f** (45 mg, 0.2 mmol) and methyl propiolate (**2d**) (51 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 10 EtOAc/hexanes) as colorless oil (26 mg, 42%). IR υ_{max} (cm^{-1}) 3435, 3046, 2934,2858, 1715, 1646, 1600, 1506, 1489, 1436, 1244, 1060, 753; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.50 – 7.32 (m, 5H), 7.32 – 7.24 (m, 1H), 7.08 (ddd, *J* = 12.5, 6.2, 2.2 Hz, 2H), 6.98 (d, *J* = 8.1 Hz, 1H), 6.80 (td, *J* = 7.4, 1.2 Hz, 1H), 4.52 (d, *J* = 4.0 Hz, 1H), 3.74 (s, 3H), 2.31 – 2.18 (m, 1H), 2.18 – 2.04 (m, 2H), 1.69 – 1.56 (m, 1H), 1.45 (ddddd, *J* = 31.3, 13.4, 10.9, 4.8, 2.7 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.45, 144.11, 143.22, 139.74, 131.12, 130.58, 129.47, 129.06, 128.89, 128.54, 127.33, 117.40, 112.01, 51.98, 46.36, 27.18, 25.87, 16.46; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{20}H_{21}NO_2$ 308.1645; found 308.1641.

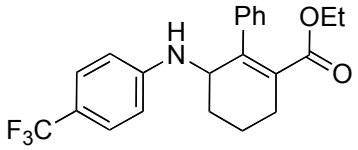
4-tert-butyl-N-(2-(thiophen-3-yl)cyclohex-2-enyl)aniline **(5e):** Following **GP3** with **1a** (41 mg, 0.2 mmol) and 3-ethynylthiophene (**2e**) (65 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as yellow oil (41 mg, 66%). IR υ_{max} (cm^{-1}) 3424, 3026, 2946, 2934, 2860, 1611, 1516, 1360, 1299, 1252, 1193, 818; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.17 – 7.11 (m, 4H), 7.09 (qd, *J* = 2.8, 1.2 Hz, 1H), 6.57 – 6.43 (m, 2H), 6.27 (ddd, *J* = 4.6, 3.2, 1.6 Hz, 1H), 4.27 (d, *J* = 3.3 Hz, 1H), 3.70 (s, 1H), 2.26 – 2.03 (m, 3H), 1.74 – 1.45 (m, 3H), 1.22 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 144.85, 142.04, 139.83, 132.87, 127.64, 126.37, 125.46, 125.30, 119.51, 112.53, 48.97, 34.05, 31.80, 27.52, 25.91, 17.21; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{20}H_{25}NS$ 312.1780; found 312.1790.

4-tert-butyl-N-(3-methyl-2-phenylcyclohex-2-enyl)aniline **(5f):** Following **GP3** with **1a** (41 mg, 0.2 mmol) and prop-1-ynylbenzene (**2f**) (70 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as yellow oil (39 mg, 61%). IR υ_{max} (cm^{-1}) 3415, 3031, 2950, 2864, 1613, 1517, 1470, 1441, 1301, 1259, 1193, 1033, 816; ^{1}H NMR (300 MHz, Chloroform-*d*) δ 7.44 – 7.30 (m, 2H), 7.29 – 7.13 (m, 5H), 6.55 (d, *J* = 8.2 Hz, 2H), 4.29 – 4.17 (m, 1H), 2.29 – 2.07 (m, 3H), 1.89 – 1.68 (m, 3H), 1.66 (s, 3H), 1.31 (d, *J* = 1.1 Hz, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 145.15, 142.22, 139.46, 134.57, 133.49, 129.11, 128.22, 126.55, 126.08, 112.75, 52.10, 33.95, 31.92, 31.74, 27.81, 21.31, 18.02; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{23}H_{29}N$ 320.2373; found 320.2374.

N-(3-butyl-2-(3-(trifluoromethyl)phenyl)cyclohex-2-enyl)-3,5-dimethylaniline **(5g):** Following **GP3** with **1h** (35 mg, 0.2 mmol) and 1-(hex-1-ynyl)-3-(trifluoromethyl)benzene (**2g**) (136 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 20 EtOAc/hexanes) as yellow oil (34 mg, 42%). IR υ_{max} (cm^{-1}) 3402, 3022, 2932, 2860, 1600, 1329, 1162, 1124, 1093, 1072; ^{1}H NMR (300 MHz, Benzene-d_6) δ 7.56 (s, 1H), 7.16 (s, 12H), 6.88 (t, *J* = 7.8 Hz, 1H), 6.32 (s, 1H), 6.07 (s, 2H), 4.07

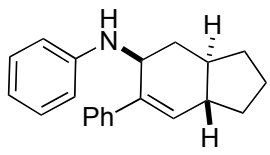
(d, J = 4.2 Hz, 1H), 3.34 (s, 1H), 2.11 (s, 6H), 2.08 – 1.96 (m, 1H), 1.83 (ddt, J = 20.8, 7.4, 3.9 Hz, 4H), 1.58 – 1.42 (m, 3H), 1.31 – 1.18 (m, 2H), 1.15 – 0.99 (m, 2H), 0.75 (dd, J = 7.9, 6.4 Hz, 3H); ^{13}C NMR (75 MHz, CD_2Cl2) δ 147.74, 143.93, 140.36, 139.19, 133.22, 133.03, 130.41 (q, J^2 = 31.8 Hz), 128.96, 126.31 (q, J^3 = 3.8 Hz), 124.96 (q, J^1 = 272.3 Hz), 123.57 (q, J^3 = 3.8 Hz), 119.35, 111.44, 52.64, 34.52, 31.11, 29.41, 28.52, 23.05, 21.66, 18.51, 14.14; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{25}H_{30}F_3N$ 402.2403; found 402.2399.

Ethyl 2-phenyl-3-(4-(trifluoromethyl)phenylamino)cyclohex-1-enecarboxylate (**5h**)**:** Following **GP3** with **1c** (43 mg, 0.2 mmol) and ethyl 3-phenylpropiolate (**2h**) (104 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 10 EtOAc/hexanes) as yellow solid (72 mg, 92%). m.p. 145-148 °C; IR υ_{max} (cm^{-1}) 3396, 2938, 2921, 1700, 1612, 1529, 1318, 1266, 1109, 1063, 1052, 865; ^{1}H NMR (300 MHz, Chloroform-*d*) δ 7.38 – 7.30 (m, 2H), 7.25 (dtd, J = 7.9, 5.3, 3.5 Hz, 5H), 6.60 – 6.47 (m, 2H), 4.40 (d, J = 3.1 Hz, 1H), 3.92 (q, J = 7.1 Hz, 2H), 2.73 – 2.55 (m, 1H), 2.44 – 2.25 (m, 1H), 2.18 – 2.02 (m, 1H), 1.90 – 1.64 (m, 3H), 0.86 (t, J = 7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.01, 149.28, 141.67, 140.35, 133.28, 128.22, 127.70, 127.41, 126.74 (q, J^3 = 3.8 Hz), 125.05 (q, J^1 = 270.3 Hz), 118.9 (q, J^2 = 32.6 Hz), 112.06, 60.61, 51.29, 27.41, 26.93, 17.03, 13.52; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{22}H_{22}F_3NO_2$ 390.1675; found 390.1682.



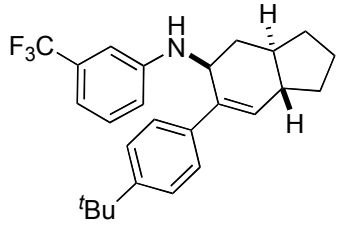
Compounds in Table 4

(3aS,5R,7aR)-N,6-diphenyl-2,3,3a,4,5,7a-hexahydro-1H-inden-5-amine (**7a**) (major isomer)**:** Following **GP3** with **6a** (38 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.07 mL, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as colorless oil (51 mg, 88%). IR υ_{max} (cm^{-1}) 3392, 2934, 2864, 1599, 1502, 1247, 747; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.40 – 7.34 (m, 2H), 7.33 – 7.27 (m, 2H), 7.27 – 7.20 (m, 1H), 7.18 – 7.12 (m, 2H), 6.66 (tt, J = 7.3, 1.1 Hz, 1H), 6.63 – 6.58 (m, 2H), 6.37 (t, J = 1.9 Hz, 1H), 4.81 (dddd, J = 9.0, 6.9, 3.6, 2.0 Hz, 1H), 2.82 (ddd, J = 12.4, 6.9, 2.5 Hz, 1H), 2.11 (ddddd, J = 12.3, 8.8, 7.0, 3.6, 1.9 Hz, 1H), 2.00 (ttd, J = 11.2, 5.9, 5.4, 2.8 Hz, 1H), 1.91 – 1.71 (m, 3H), 1.61 (dddt, J = 14.5, 10.5, 6.1, 2.4 Hz, 1H), 1.48 (td, J = 12.5, 9.3 Hz, 1H), 1.39 – 1.24 (m, 2H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 148.08, 141.33, 140.02, 132.84, 129.69, 128.55, 127.34, 126.94, 117.40, 113.52, 53.43, 46.00, 44.19, 36.93, 30.32, 30.23, 22.68; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{21}H_{23}N$ 290.1903; found 290.1908.



7a (major isomer) has also been obtained by following **GP3** with **6b** (38 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.07 mL, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes) as colorless oil (52 mg, 90%).

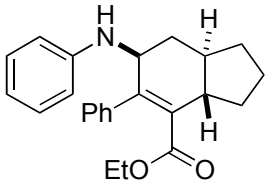
(3aS,5R,7aR)-6-(4-tert-butylphenyl)-N-(3-(trifluoromethyl)phenyl)-2,3,3a,4,5,7a-hexahydro-1H-inden-5-amine (**7b**) (major isomer)**:** Following **GP3** with **6c** (51 mg, 0.2 mmol) and 1-*tert*-



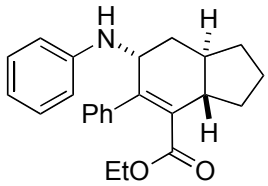
butyl-4-ethynylbenzene (**2i**) (95 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 40 EtOAc/hexanes) as colorless oil (70 mg, 85%). IR υ_{max} (cm^{-1}) 3407, 2953, 2866, 1612, 1593, 1341, 1119, 832; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.23 – 7.11 (m, 5H), 6.84 – 6.74 (m, 1H), 6.73 – 6.70 (m, 1H), 6.67 – 6.62 (m, 1H), 6.25 (t, J = 1.9 Hz, 1H), 4.71 (s, 1H), 3.79 (s, 1H), 2.69 (ddd, J = 12.4, 6.9, 2.4 Hz, 1H), 1.98 (ddddd, J = 12.2, 10.4 , 7.0, 3.4, 1.9 Hz, 1H), 1.91 – 1.84 (m, 1H), 1.77 – 1.60 (m, 3H), 1.53 – 1.42 (m, 2H), 1.41 – 1.31 (m, 1H), 1.20 (d, J = 0.4 Hz, 10H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 149.96, 147.84, 138.53, 137.40, 132.11, 131.15 (q, J^2 = 31.5 Hz), 129.60, 125.88, 125.00, 124.51 (q, J^1 = 272.3 Hz), 116.10, 112.94, 108.88, 52.63, 45.36, 43.52, 36.02, 34.30, 31.00, 29.73, 29.68, 22.10; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{26}H_{30}F_3N$ 414.2403; found 414.2404.

Following **GP3** with **6a** (38 mg, 0.2 mmol) and ethyl 3-phenylpropiolate (**2h**) (104 mg, 0.6 mmol), the products (two isomers, **7c** and **7c'**) were isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes).

(3aR,6R,7aS)-ethyl 5-phenyl-6-(phenylamino)-2,3,3a,6,7,7a-hexahydro-1H-indene-4-carboxylate (**7c**) major isomer, colorless oil (57 mg, 78%). IR υ_{max} (cm^{-1}) 3364, 2947, 2877, 1712, 1600, 1499, 1307, 1157, 752; ^{1}H NMR (400 MHz, Chloroform-d) δ 7.26 – 7.19 (m, 3H), 7.17 – 7.12 (m, 2H), 7.11 – 7.04 (m, 2H), 6.70 – 6.61 (m, 1H), 6.52 – 6.42 (m, 2H), 4.61 (ddd, J = 9.6, 6.9, 3.9 Hz, 1H), 3.92 (qd, J = 7.1, 4.6 Hz, 2H), 2.69 (ddd, J = 12.7, 6.8, 2.4 Hz, 1H, 2.43 (dddd, J = 12.4, 10.8, 6.8, 3.9 Hz, 1H), 2.00 (dtd, J = 11.4, 7.3, 3.5 Hz, 1H), 1.86 (dddd, J = 11.5, 8.8, 5.5, 3.2 Hz, 1H), 1.82 – 1.65 (m, 3H), 1.58 (td, J = 12.7, 9.9 Hz, 1H), 1.40 – 1.21 (m, 3H), 0.90 (t, J = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.31, 147.18, 142.69, 139.41, 135.55, 129.16, 128.15, 127.62, 127.50, 117.56, 113.65, 60.35, 56.35, 45.83, 43.22, 36.06, 29.98, 28.23, 21.88, 13.85; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{24}H_{27}NO_2$ 362.2115; found 362.2121.



(3aR,6R,7aR)-ethyl 5-phenyl-6-(phenylamino)-2,3,3a,6,7,7a-hexahydro-1H-indene-4-carboxylate (7**c'**) minor isomer, colorless oil (14 mg, 20%). IR υ_{max} (cm^{-1}) 3401, 2934, 2875, 1712, 1600, 1501, 1314, 1245, 747; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.37 – 7.31 (m, 2H), 7.31 – 7.24 (m, 2H), 7.16 – 7.08 (m, 2H), 6.65 (tt, J = 7.4, 1.1 Hz, 1H), 6.57 – 6.50 (m, 2H), 4.44 (s, 1H), 4.06 – 3.85 (m, 3H), 2.28 (dt, J = 12.4, 1.6 Hz, 1H), 2.19 (dddd, J = 13.2, 11.5, 6.3, 2.9 Hz, 1H), 2.02 – 1.91 (m, 1H), 1.89 – 1.78 (m, 4H), 1.76 – 1.66 (m, 2H), 1.57 – 1.43 (m, 1H), 1.38 – 1.26 (m, 2H), 0.98 (t, J = 7.1 Hz, 2H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 169.32, 147.32, 141.06, 140.83, 137.04, 129.73, 128.57, 128.42, 127.90, 117.74, 113.35, 60.75, 54.62, 46.82, 39.56, 33.58, 29.67, 28.53, 23.01, 14.17; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{24}H_{27}NO_2$ 362.2115; found 362.2121.



Following **GP3** with **6d** (63 mg, 0.2 mmol) and ethyl 3-phenylpropiolate (**2h**) (104 mg, 0.6 mmol), the products (two isomers **7d** and **7d'**) were isolated after a flash chromatography on silica gel (1: 20 EtOAc/hexanes).

(3aR,6R,7aS)-ethyl 6-(4-iodophenylamino)-5-phenyl-2,3,3a,6,7,7a-hexahydro-1H-indene-4-carboxylate (**7d**) major isomer, colorless oil (70 mg, 71%). IR υ_{max} (cm^{-1}) 3379, 2925, 2855, 1716, 1603, 1503, 1244, 1026, 750; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.35 – 7.26 (m, 2H), 7.26 – 7.17 (m, 3H), 7.17 – 7.07 (m, 2H), 6.30 – 6.19 (m, 2H), 4.59 (ddd, *J* = 10.3, 7.0, 3.9 Hz, 1H), 3.98 – 3.82 (m, 2H), 2.60 (ddd, *J* = 12.7, 6.9, 2.5 Hz, 1H), 2.38 (dddd, *J* = 12.3, 10.8, 6.9, 3.9 Hz, 1H), 2.04 – 1.91 (m, 1H), 1.85 (dddd, *J* = 12.6, 8.2, 4.3, 2.5 Hz, 1H), 1.74 (tddd, *J* = 16.4, 12.9, 7.7, 3.5 Hz, 3H), 1.52 (td, *J* = 12.6, 9.9 Hz, 1H), 1.35 – 1.22 (m, 3H), 0.92 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 169.31, 147.45, 142.41, 140.02, 138.06, 136.25, 128.48, 128.01, 127.80, 115.87, 77.73, 60.67, 56.31, 46.18, 43.63, 36.06, 30.31, 28.65, 22.23, 14.14; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{24}H_{26}INO_2$ 488.1081; found 488.1084.

(3aR,6R,7aR)-ethyl 6-(4-iodophenylamino)-5-phenyl-2,3,3a,6,7,7a-hexahydro-1H-indene-4-carboxylate (**7d'**) minor isomer, colorless oil (17 mg, 18%). IR υ_{max} (cm^{-1}) 3412, 2926, 2863, 1694, 1582, 1483, 1308, 1231, 1170, 869; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.33 (dq, *J* = 9.3, 2.6, 2.1 Hz, 2H), 7.30 – 7.17 (m, 5H), 6.34 – 6.27 (m, 2H), 4.39 – 4.29 (m, 1H), 4.03 (d, *J* = 8.4 Hz, 1H), 3.90 (q, *J* = 7.1 Hz, 2H), 2.21 (d, *J* = 1.5 Hz, 2H), 1.96 – 1.86 (m, 1H), 1.84 – 1.74 (m, 3H), 1.63 (ddd, *J* = 11.8, 9.8, 5.6 Hz, 2H), 1.51 – 1.38 (m, 1H), 1.33 – 1.24 (m, 1H), 0.93 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 169.21, 146.96, 140.79, 140.32, 138.26, 137.29, 128.52, 128.49, 128.00, 115.61, 77.85, 60.79, 54.59, 46.76, 39.55, 33.51, 29.63, 28.48, 22.98, 14.16; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{24}H_{26}INO_2$ 488.1081; found 488.1092.

Following **GP3** with **6e** (40 mg, 0.2 mmol) and phenylacetylene (**2a**) (0.07 mL, 0.6 mmol), the products (two isomers, **7e** and **7e'**) were isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes).

(2S,4aR,8aR)-N,3-diphenyl-1,2,4a,5,6,7,8,8a-octahydronaphthalen-2-amine (**7e**) major isomer, colorless oil (49 mg, 80%). IR υ_{max} (cm^{-1}) 3409, 2919, 2843, 1661, 1599, 1427, 1111, 1027, 743; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.33 – 7.28 (m, 2H), 7.28 – 7.22 (m, 2H), 7.21 – 7.16 (m, 1H), 7.14 – 7.05 (m, 2H), 6.61 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.57 – 6.51 (m, 2H), 5.90 (t, *J* = 1.9 Hz, 1H), 4.72 (d, *J* = 7.1 Hz, 1H), 3.45 (s, 1H), 2.46 – 2.35 (m, 1H), 1.90 (dddd, *J* = 11.2, 5.8, 3.8, 2.2 Hz, 1H), 1.86 (tt, *J* = 3.3, 1.7 Hz, 1H), 1.79 (ddddd, *J* = 13.8, 11.0, 4.4, 2.9, 1.6 Hz, 2H), 1.68 (dq, *J* = 15.3, 2.8 Hz, 1H), 1.45 – 1.31 (m, 4H), 1.13 (tdq, *J* = 16.9, 8.9, 4.6, 4.0 Hz, 2H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 147.76, 140.41, 138.74, 134.97, 129.13, 127.92, 126.70, 126.44, 116.72, 112.83, 51.66, 42.90, 40.19, 38.41, 32.77, 32.76, 26.73, 26.39; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{22}H_{25}N$ 304.2060; found 304.2066.

(2R,4aR,8aR)-N,3-diphenyl-1,2,4a,5,6,7,8,8a-octahydronaphthalen-2-amine (**7e'**) minor isomer, colorless oil (9 mg, 14%). IR υ_{max} (cm^{-1}) 3377, 2916, 2848, 1599, 1502, 1442, 1250, 1224, 747; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ

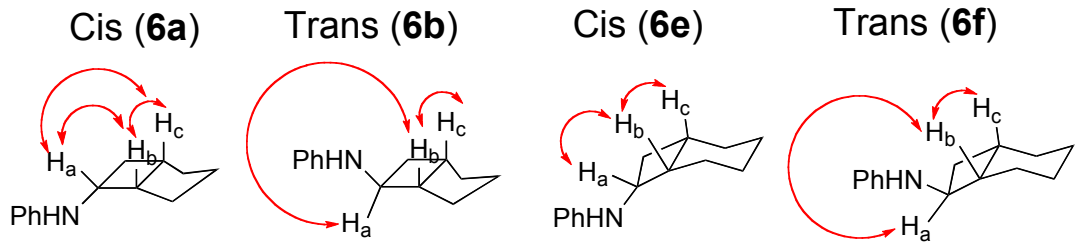
7.45 – 7.40 (m, 2H), 7.30 – 7.24 (m, 2H), 7.22 – 7.17 (m, 1H), 7.16 – 7.10 (m, 2H), 6.63 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.61 – 6.56 (m, 2H), 6.17 – 6.08 (m, 1H), 4.52 (d, *J* = 4.5 Hz, 1H), 3.82 (s, 1H), 2.01 (dt, *J* = 13.0, 2.0 Hz, 1H), 1.88 (dtd, *J* = 12.9, 3.4, 1.7 Hz, 1H), 1.82 – 1.76 (m, 3H), 1.63 – 1.57 (m, 1H), 1.52 – 1.45 (m, 1H), 1.37 (dddd, *J* = 24.3, 12.3, 6.2, 2.9 Hz, 3H), 1.22 – 1.10 (m, 2H). ^{13}C NMR (101 MHz, CD_2Cl2) δ 147.64, 140.61, 136.91, 136.89, 134.74, 129.80, 128.86, 127.55, 126.21, 117.27, 113.01, 111.07, 48.98, 43.85, 36.01, 35.72, 33.40, 33.34, 27.51, 27.25; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{22}H_{25}N$ 304.2060; found 304.2061.

Following **GP3** with **6f** (40 mg, 0.2 mmol) and 5-ethynylbenzo[*d*][1,3]dioxole (**2c**) (88 mg, 0.6 mmol), the products (two isomers, **7f** and **7f'**) were isolated after a flash chromatography on silica gel (1: 30 EtOAc/hexanes).

(2S,4aR,8aR)-3-(benzo[d][1,3]dioxol-5-yl)-N-phenyl-1,2,4a,5,6,7,8,8a-octahydronaphthalen-2-amine (**7f**) major isomer, colorless oil (51 mg, 73%). IR υ_{max} (cm^{-1}) 3407, 2917, 2856, 1600, 1435, 1245, 1039, 752; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.18 – 7.10 (m, 2H), 6.86 – 6.78 (m, 2H), 6.74 (d, *J* = 7.9 Hz, 1H), 6.65 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.61 – 6.54 (m, 2H), 5.97 – 5.91 (m, 2H), 5.84 (t, *J* = 1.9 Hz, 1H), 4.64 (dq, *J* = 9.9, 4.4, 3.3 Hz, 1H), 3.50 (s, 1H), 2.47 – 2.37 (m, 1H), 1.96 – 1.89 (m, 1H), 1.87 (dt, *J* = 3.2, 1.6 Hz, 1H), 1.86 – 1.78 (m, 2H), 1.73 – 1.66 (m, 1H), 1.47 – 1.33 (m, 4H), 1.21 – 1.06 (m, 2H); ^{13}C NMR (101 MHz, CD_2Cl_2) δ 148.30, 147.97, 147.04, 138.94, 135.26, 134.70, 129.70, 120.37, 117.32, 113.45, 108.24, 107.57, 101.63, 52.45, 43.37, 40.71, 39.02, 33.36, 33.32, 27.30, 26.97; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{23}H_{25}NO_2$ 348.1958; found 348.1958.

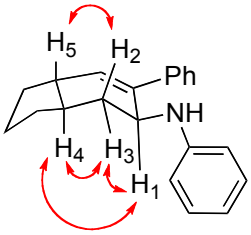
(2R,4aR,8aR)-3-(benzo[d][1,3]dioxol-5-yl)-N-phenyl-1,2,4a,5,6,7,8,8a-octahydronaphthalen-2-amine (**7f'**) minor isomer, colorless oil (10 mg, 16%). IR υ_{max} (cm^{-1}) 3409, 3081, 2918, 2849, 1599, 1501, 1444, 1104, 1029, 745; ^{1}H NMR (400 MHz, Methylene Chloride-d_2) δ 7.20 – 7.07 (m, 2H), 6.98 – 6.85 (m, 2H), 6.71 (d, *J* = 8.1 Hz, 1H), 6.63 (tt, *J* = 7.3, 1.1 Hz, 1H), 6.59 (m, 2H), 6.03 – 5.94 (m, 1H), 5.94 – 5.88 (m, 2H), 4.41 (s, 1H), 3.79 (s, 1H), 2.03 – 1.93 (m, 1H), 1.90 – 1.86 (m, 1H), 1.84 (dq, *J* = 4.8, 2.4, 1.9 Hz, 1H), 1.81 – 1.75 (m, 2H), 1.63 – 1.56 (m, 1H), 1.52 – 1.42 (m, 1H), 1.39 – 1.27 (m, 3H), 1.14 (ddt, *J* = 15.6, 9.4, 3.5 Hz, 2H); ^{13}C NMR (101 MHz, CD_2Cl2) δ 148.36, 147.63, 147.28, 136.65, 135.19, 133.84, 129.82, 119.71, 117.31, 113.03, 108.47, 106.78, 101.71, 49.40, 43.80, 36.00, 35.74, 33.37, 27.48, 27.25; HRMS (ESI) m/z $[M+H]^+$, calc'd for $C_{23}H_{25}NO_2$ 348.1958; found 348.1954.

Diastereomer Identification; key NOESY signals

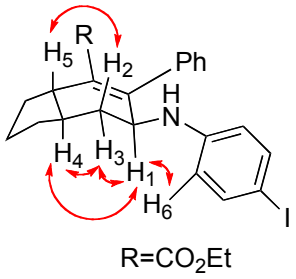


	NOESY crosspeak		NOESY crosspeak	
H_a-H_b	Strong	Weak	Strong	Weak
H_b-H_c	Strong	Strong	Strong	Strong

(7a)



(7d)



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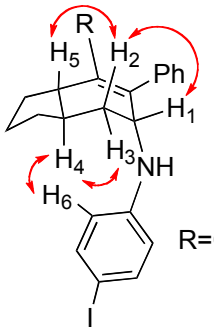
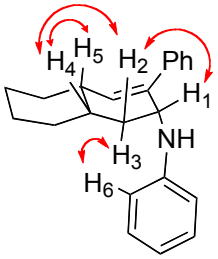
(7d')

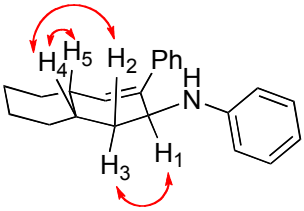


$R=CO_2Et$

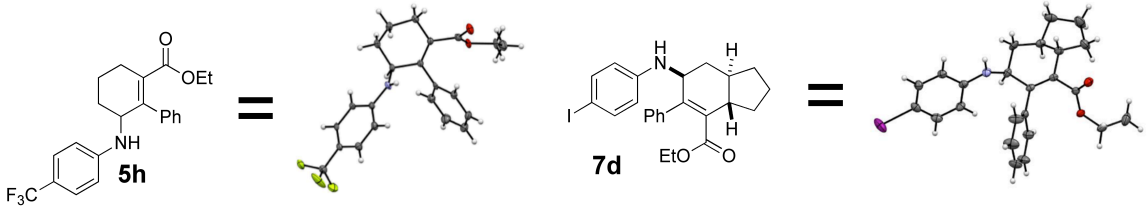
(7e)



(7e')

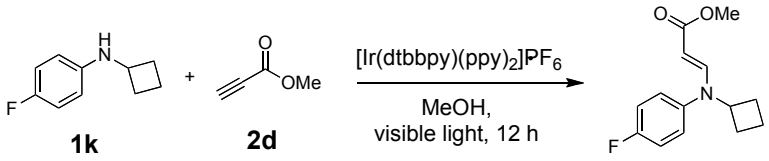


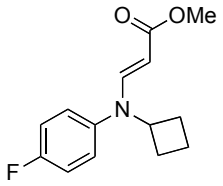
Crystal data for (5h) and (7d):



For the X-ray data collection, structure solution and Refinement:
The crystal was mounted on a glass fiber and transferred to a Bruker Kappa APEX II CCD diffractometer. The APEX2 software program[5] was used for determination of the unite cell parameters and data collection. The data were collected at 100 K using a Oxford Cryostream Plus system. The raw frame data were processed using APEX2 program. The absorption correction was applied using the program SADABS.[6] Subsequent calculations were carried out using the SHELXTL program.[7]

1, 4 Addition reaction of 4-fluoro-N-cyclobutylaniline (1k) to methyl propiolate (2d)

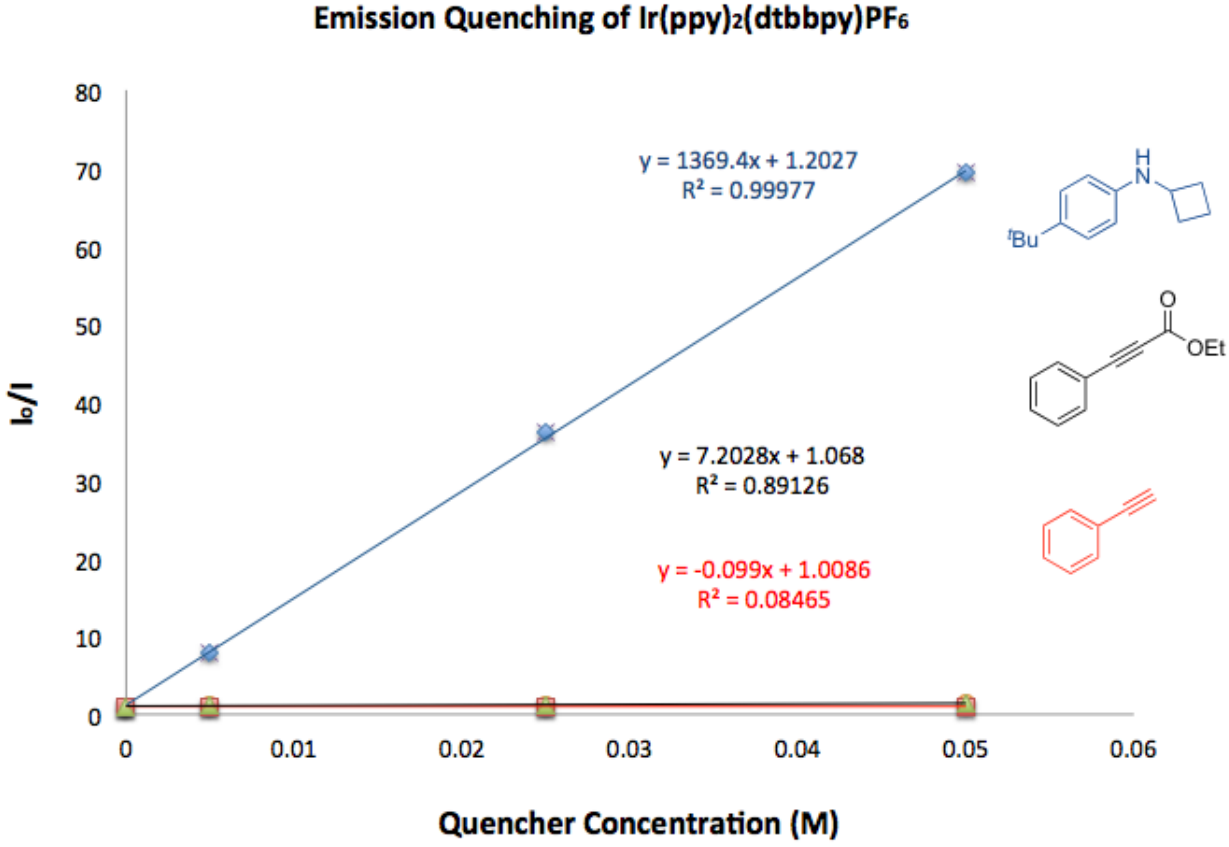


(E)-methyl 3-(cyclobutyl(4-fluorophenyl)amino)acrylate (**3k**): Following **GP3** with **1k** 

(33 mg, 0.2 mmol) and methyl propiolate (**2d**) (51 mg, 0.6 mmol), the product was isolated after a flash chromatography on silica gel (1: 10 EtOAc/hexanes) as colorless oil (19 mg, 38%). IR υ_{max} (cm^{-1}) 3386, 2974, 2945, 1692, 1615, 1594, 1507, 1243, 1151, 800; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.65 (dd, *J* = 13.3, 0.5 Hz, 1H), 7.14 – 6.97 (m, 4H), 4.56 (d, *J* = 13.3 Hz, 1H), 4.23 – 4.02 (m, 1H), 2.36 – 2.17 (m, 2H), 2.04 – 1.87 (m, 2H), 1.72 – 1.57 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.00, 161.42 (d, $^{1}J_{CF}$ = 246.8 Hz), 149.92, 138.18, 128.98 (d, $^{3}J_{CF}$ = 8.5 Hz), 116.52 (d, $^{2}J_{CF}$ = 22.7 Hz), 88.12, 56.86, 50.86, 29.46, 14.51; FTMS (ESI) m/z $[M+H]^{+}$, calc'd for $C_{14}H_{16}FNO_2$ 250.1238; found 250.1237.

Stern-Volmer Quenching study

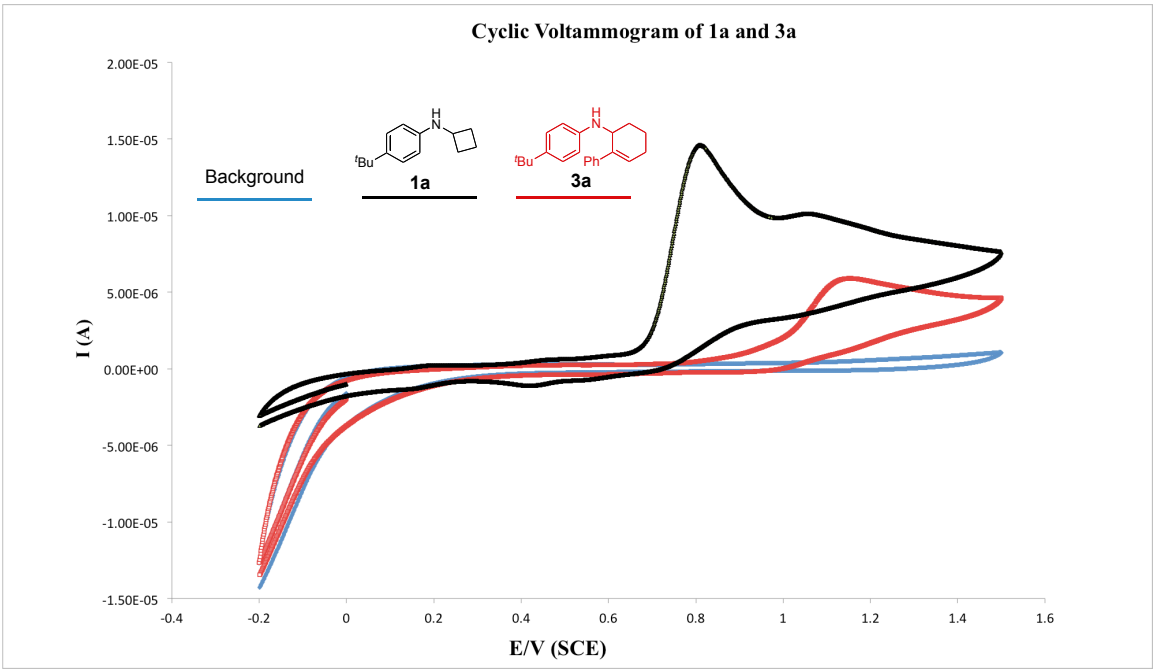
Fluorescence quenching studies were conducted using a Photon Technology Fluorescence Spectrophotometer. In each experiment, a solution of 5.0 x 10^{-4} M $Ir(ppy)_2(dtbbpy)PF_6$ in MeOH was mixed with a MeOH solution of a quencher of various concentration in a screw-top 1.0 cm quartz cuvette. After degassing by sparging with argon for ten minutes, the resulting solution was irradiated at 460 nm, and fluorescence was measured at 575 nm. Plots were constructed according to the Stern-Volmer equation: $I_0/I = 1 + k_q\tau_0[Q]$.



(Plots for two alkynes overlap.)

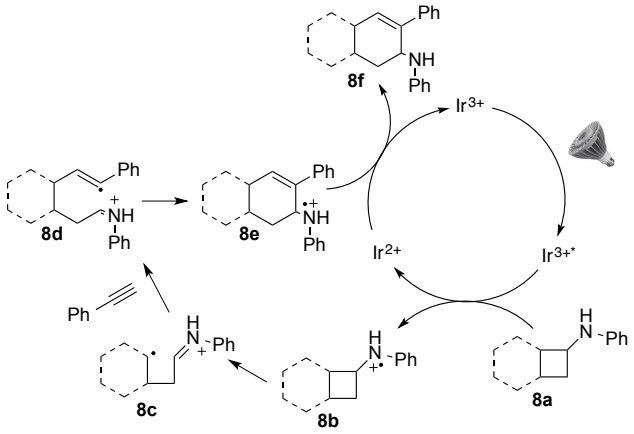
Cyclic Voltammograms of 1a and 3a

Cyclic voltammograms were recorded on a CH Instruments-Electrochemical Analyzer using a three-electrode cell at room temperature under an argon atmosphere. The reference electrode was a saturated calomel electrode (SCE), which was separated from the solution by a bridge compartment filled with the same supporting electrolyte solution used in the cell. A platinum disc (2.0 mm diameter) was used as the working electrode and a platinum wire as the auxiliary electrode. Tetrabutylammonium hexafluorophosphate (0.1 M in CH_3CN) was used as the supporting electrolyte. Voltammograms were taken in a solution of 4-*tert*-butyl-*N*-cyclobutylaniline (**1a**) in CH_3CN (c ~ 2.10-3mol.L^{-1}). The peak potentials for the irreversible oxidation of **1a** and **3a** were measured as 0.8 V vs. SCE and 1.14 V vs. SCE respectively.



Proposed catalytic cycle for the [4+2] annulation

A proposed catalytic cycle for the [4+2] annulation is shown in Scheme 2. Exposure of $[Ir(dtbbpy)(ppy)_2](PF_6)$ **4a** to two white LEDs produces the photoexcited $[Ir(dtbbpy)(ppy)_2]^{1+}$*, which is reductively quenched by cyclobutylaniline **8a** to generate $[Ir(dtbbpy)(ppy)_2]$ with the concomitant formation of amine radical cation **8b**. Subsequent ring opening generates distonic radical iminium ion **8c**, which undergoes intermolecular addition to phenylacetylene **2a** to yield vinyl radical **8d**. Intramolecular addition of the vinyl radical to the iminiun ion in **8d** closes the six-membered ring and produces amine radical cation **8e**. Finally, reduction of amine radical cation **8e** by $[Ir(dtbbpy)(ppy)_2]$ furnishes product **8f** and regenerates $[Ir(dtbbpy)(ppy)_2]^{1+}$, thus completing the catalytic cycle.

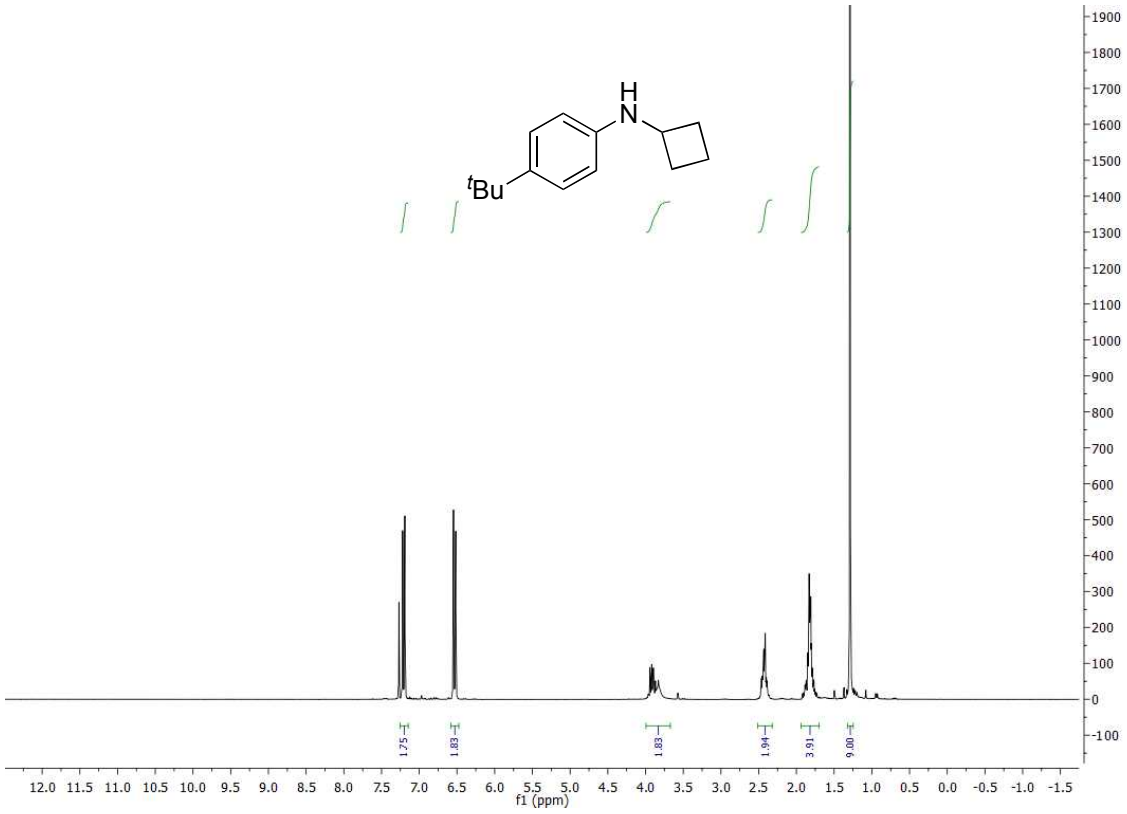


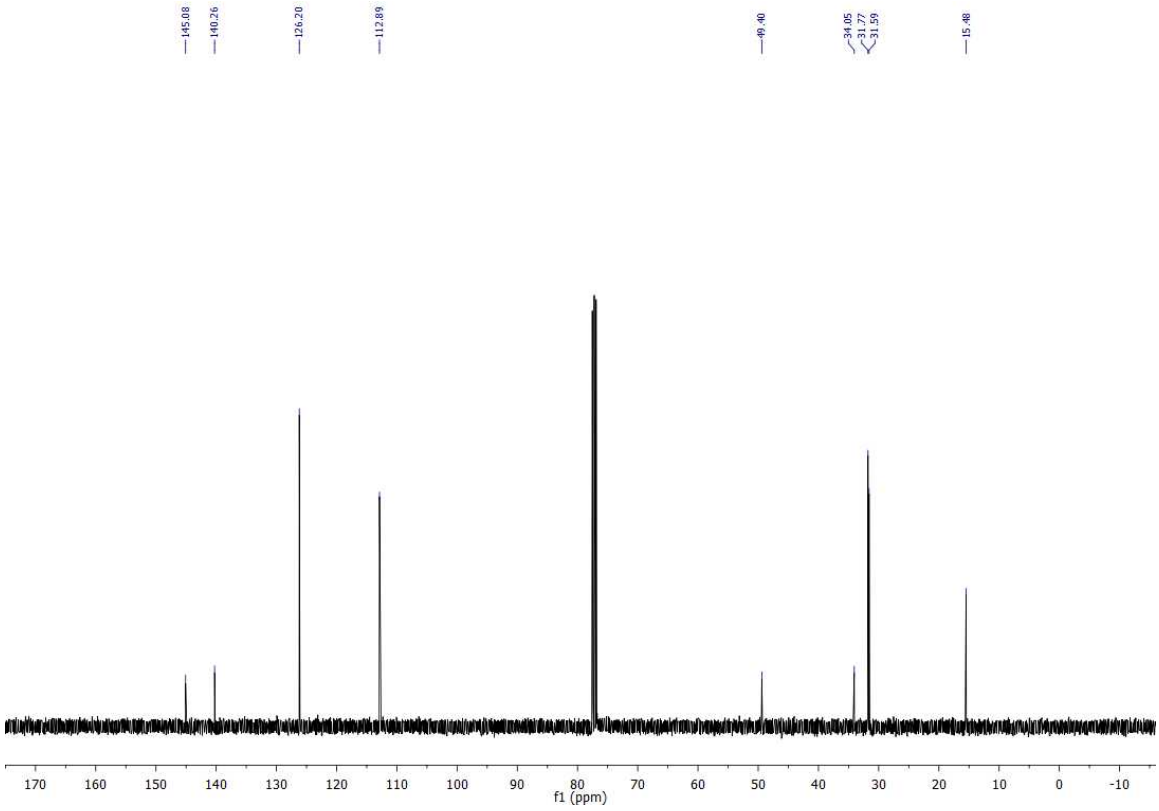
We have measured the oxidation peak potential of **1a** to be 0.8 V vs. SCE, which is more positive than the reduction potential of the photoexcited **4a** (Ir^{3+}*/Ir^{2+}: 0.66 V vs. SCE). Although thermodynamically unfavorable, such SET processes have been reported as long as there is overlap between the substrate's oxidation (or reduction) peak potential and the redox potential of the photocatalyst's excited state.[8] Furthermore, if the SET processes are subsequently coupled with an irreversible chemical reaction, they will more likely proceed to completion.[8] In our case, presumably the irreversible C-C bond cleavage drives the unfavorable ET process to completion. Stern-Volmer quenching studies revealed that cyclobutylaniline **1a** quenches the photoexcited **4a** while alkynes **2a** and **2h** showed little quenching (see page 21 of SI).

References:

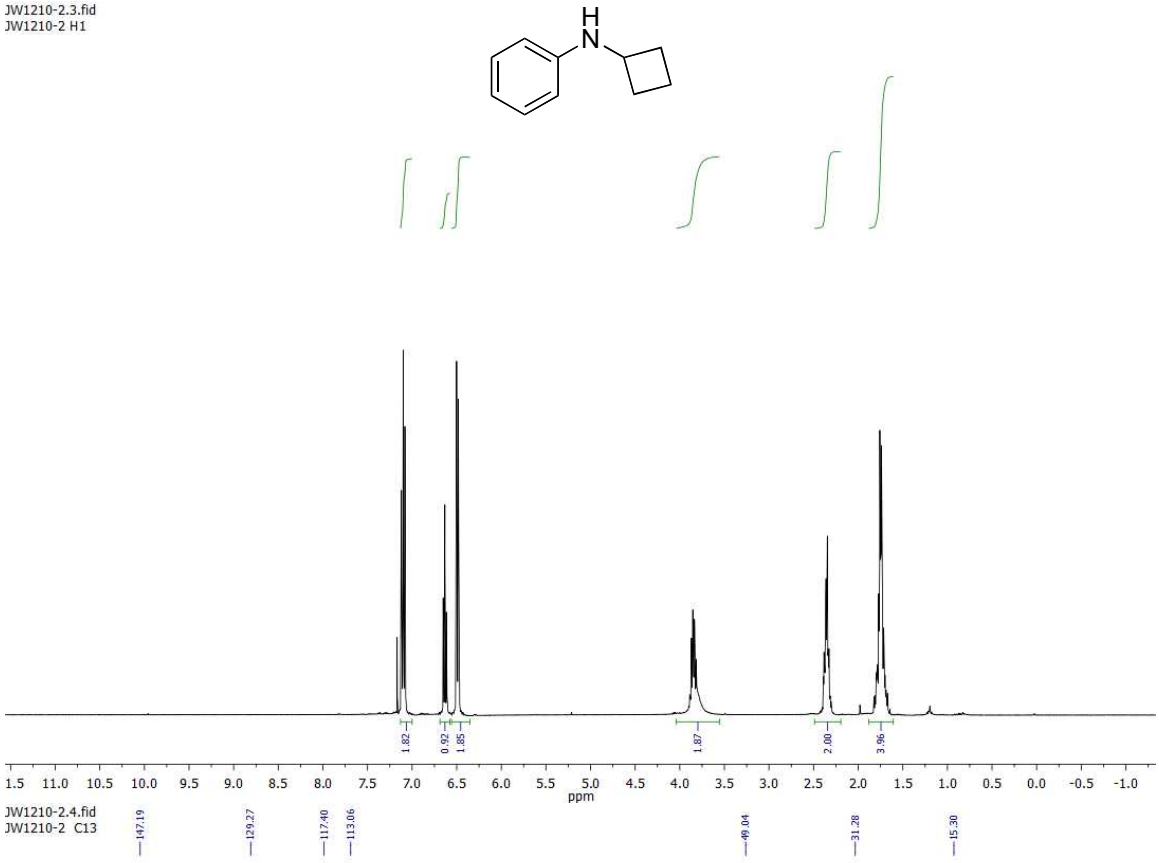
[1] D. Ma, Q. Cai, H. Zhang, *Org. Lett*. **2003**, *5*, 2453-2455.
[2] L. Ghosez, R. Montaigne, A. Roussel, H. Vanlierde, P, Mollet. *Tetrahedron.* **1971**, *27*, 615-633.
[3] M. McLaughlin, M. Palucki, I. W. Davies, *Org. Lett*. **2006**, *8*, 3307-3310.
[4] a) T. H. Nguyen, S. Maity, N. Zheng, *Beilstein J. Org. Chem.* **2014**, *10*, 975-980; b) S. Maity, M. Zhu, R. S. Shinabery, N. Zheng, *Angew. Chem.* **2012**, *124*, 226-230; *Angew. Chem. Int. Ed*. **2012**, 51, 222-226.
[5] APEX2 v2011.2-0, Bruker AXS, Inc., Madison, WI 2010.
[6] Sheldrick, G. M. SADABS, Version 2.05, Bruker AXS, Inc.; Madison, WI 2001.
[7] Sheldrick, G. M. SHELXTL, Version 6.12, Bruker AXS, Inc.; Madison, WI 2001.
[8] a) Y. Yasu; T. Koike, M. Akita, *Adv. Synth. Catal*. **2012**, *354*, 3414-3420; b) D. N. Primer, I. Karakaya, J. C. Tellis, G. A. Molander, *J. Am. Chem. Soc*. **2015**, *137*, 2195-2198.

NMR data

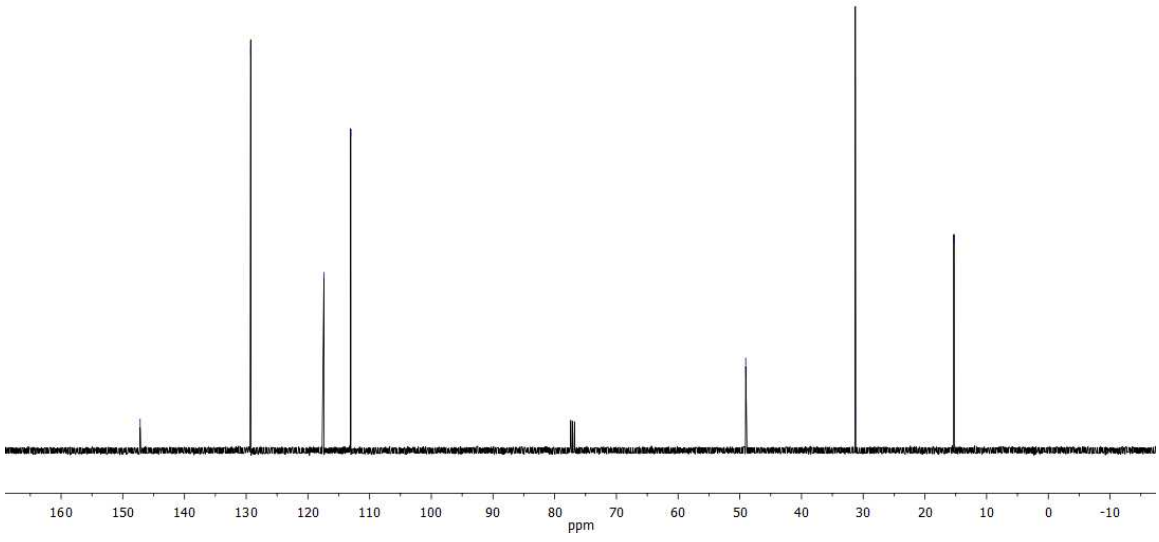

H
N
tBu
1.75
1.83
1.83
1.94
3.91
9.00
f1 (ppm)

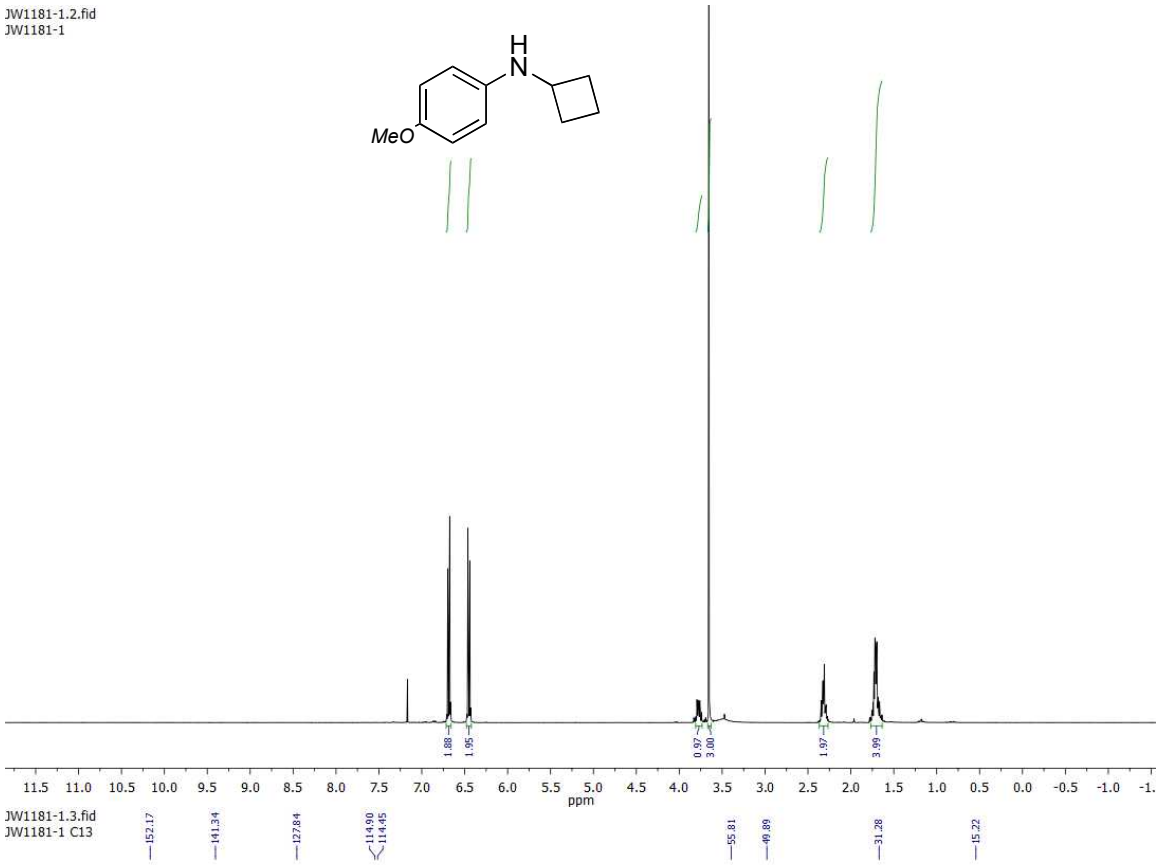

145.08
140.26
126.20
112.89
49.40
34.05
31.77
31.59
15.48
f1 (ppm)

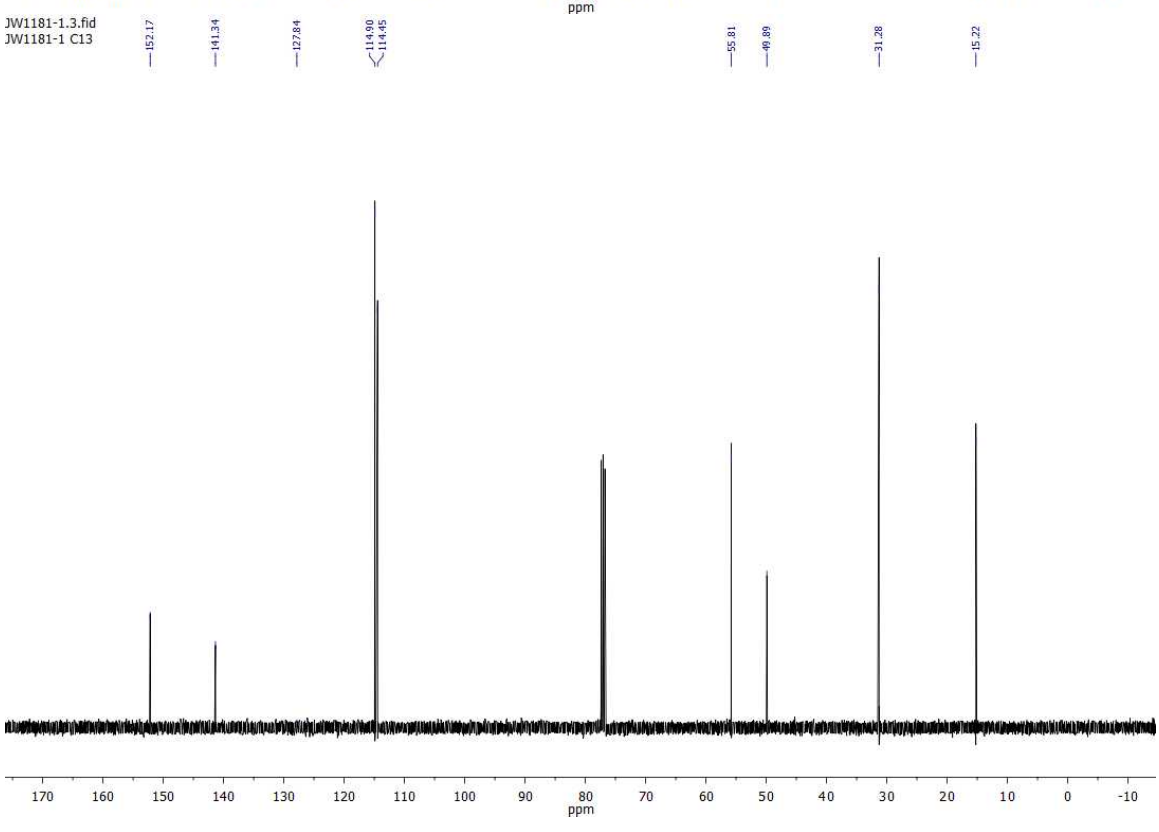
JW1210-2.3.fid
JW1210-2 H1



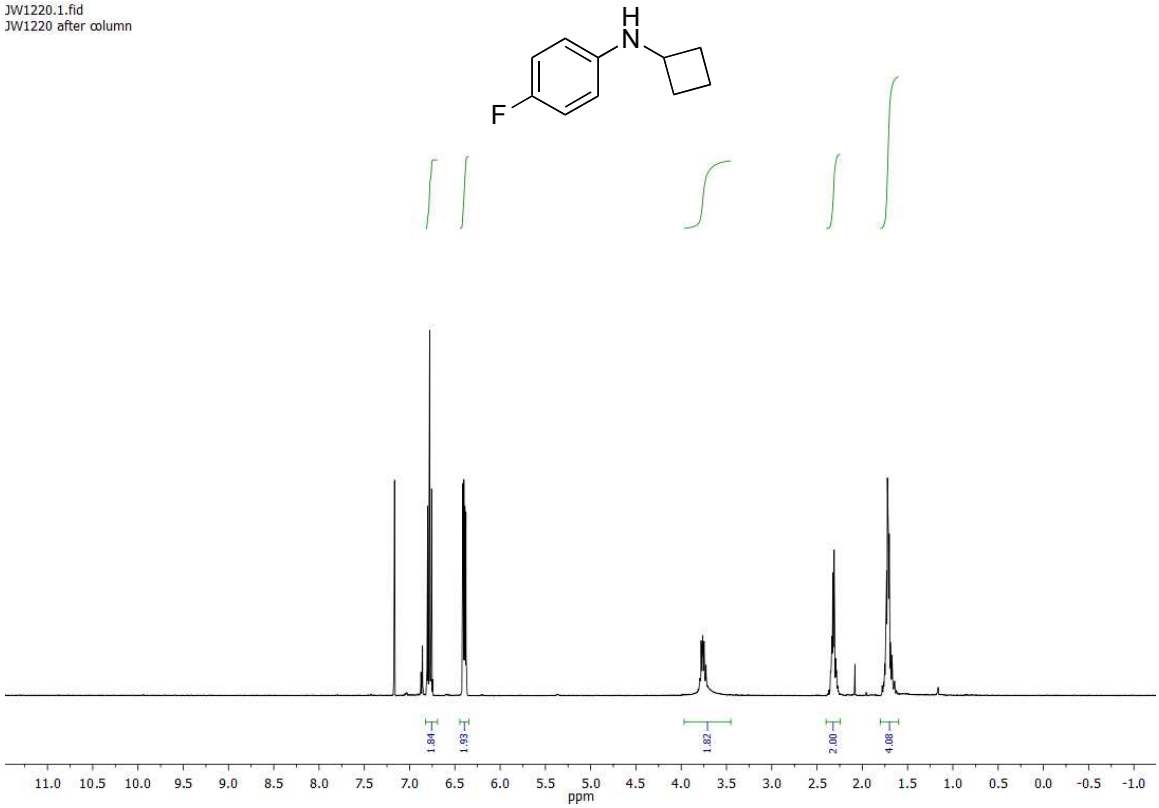
JW1210-2.4.fid
JW1210-2 C13



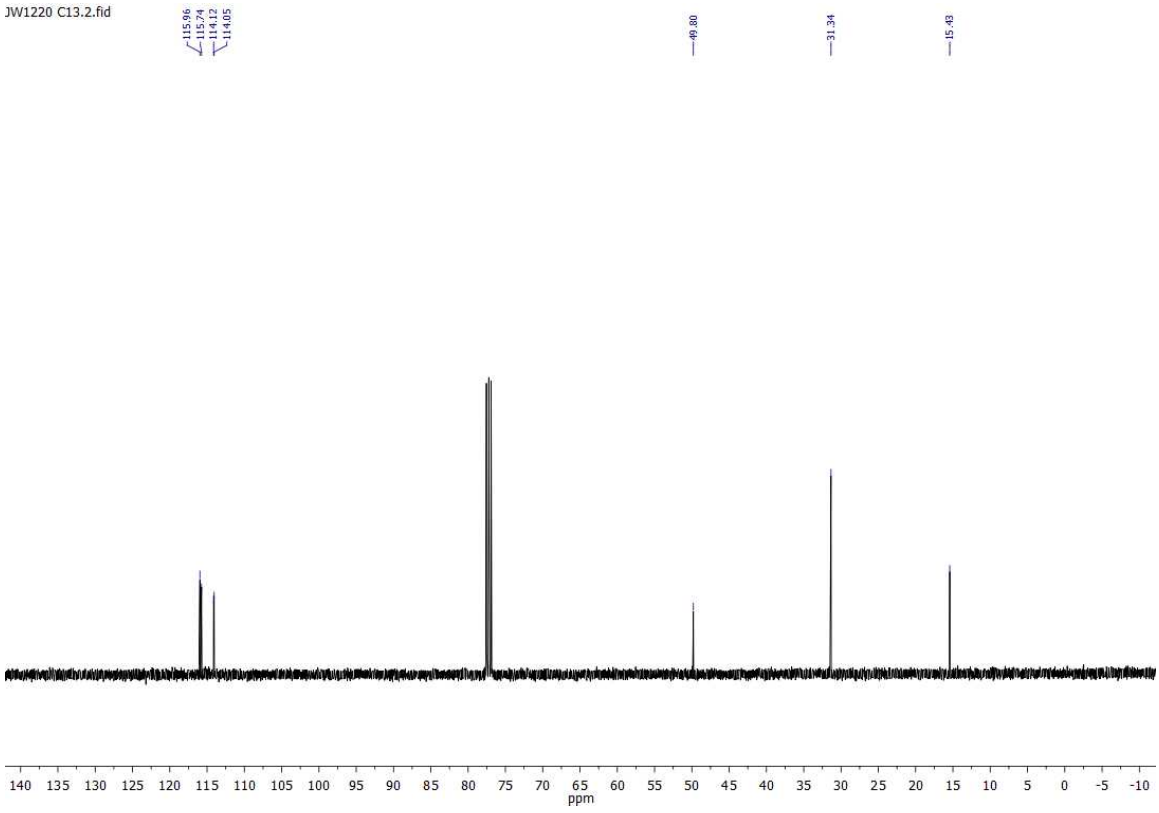

JW1181-1.2.fid
JW1181-1
H
N
MeO
1.88
1.95
0.97
3.00
1.97
3.99
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.
ppm

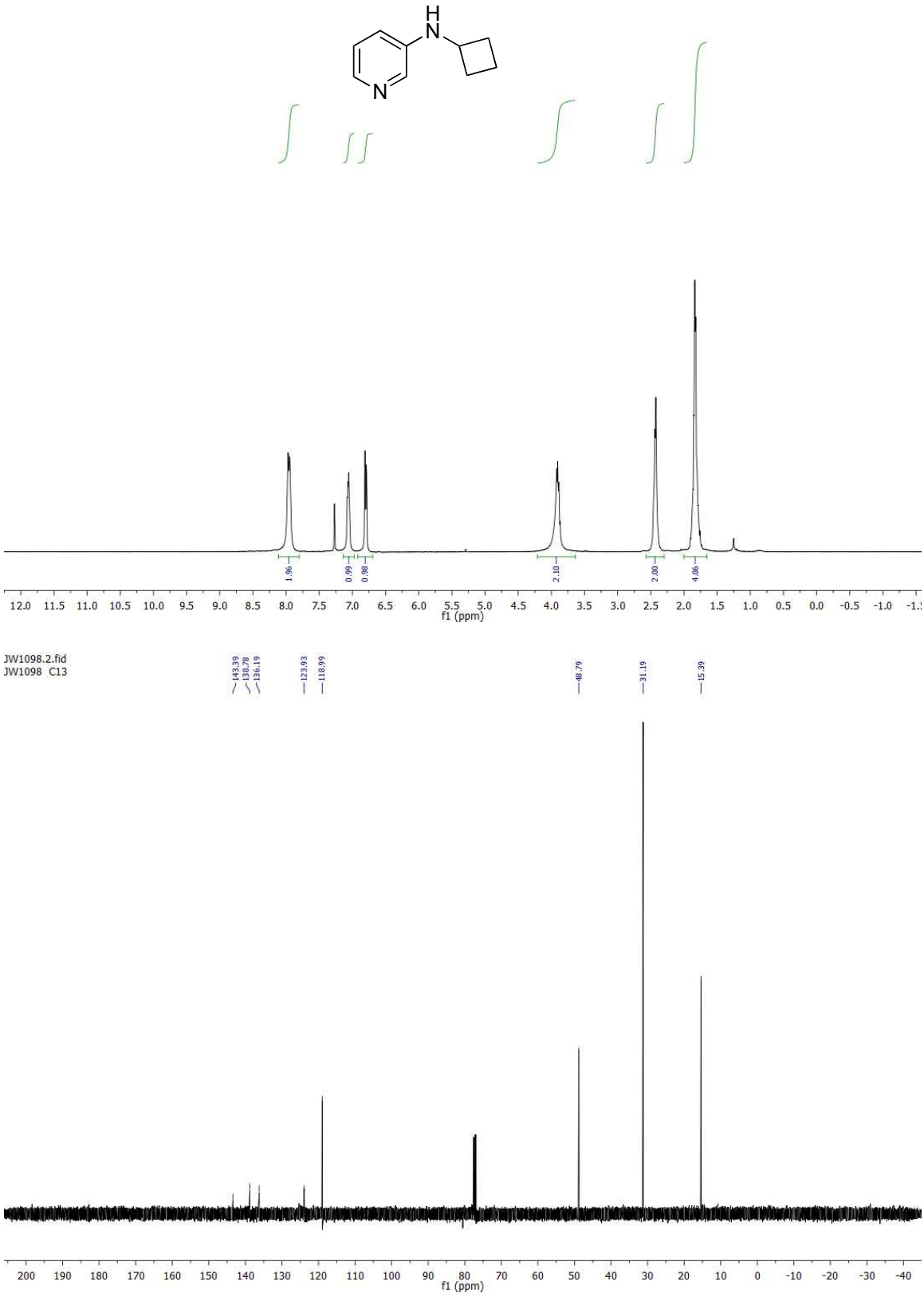

JW1181-1.3.fid
JW1181-1 C13
152.17
141.34
127.84
114.90
114.45
55.81
49.89
31.28
15.22
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

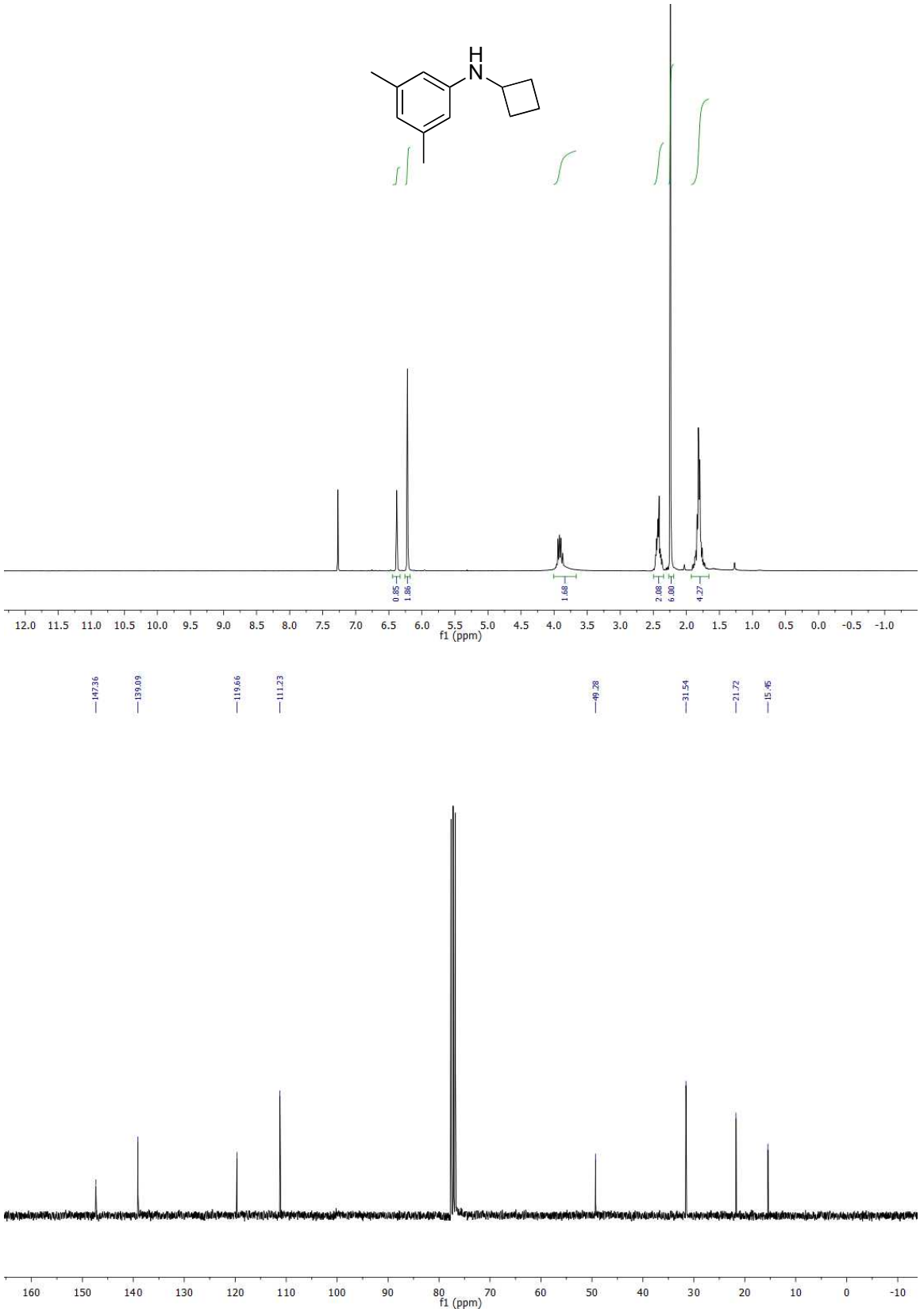
JW1220.1.fid
JW1220 after column



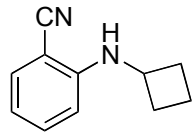
JW1220 C13.2.fid

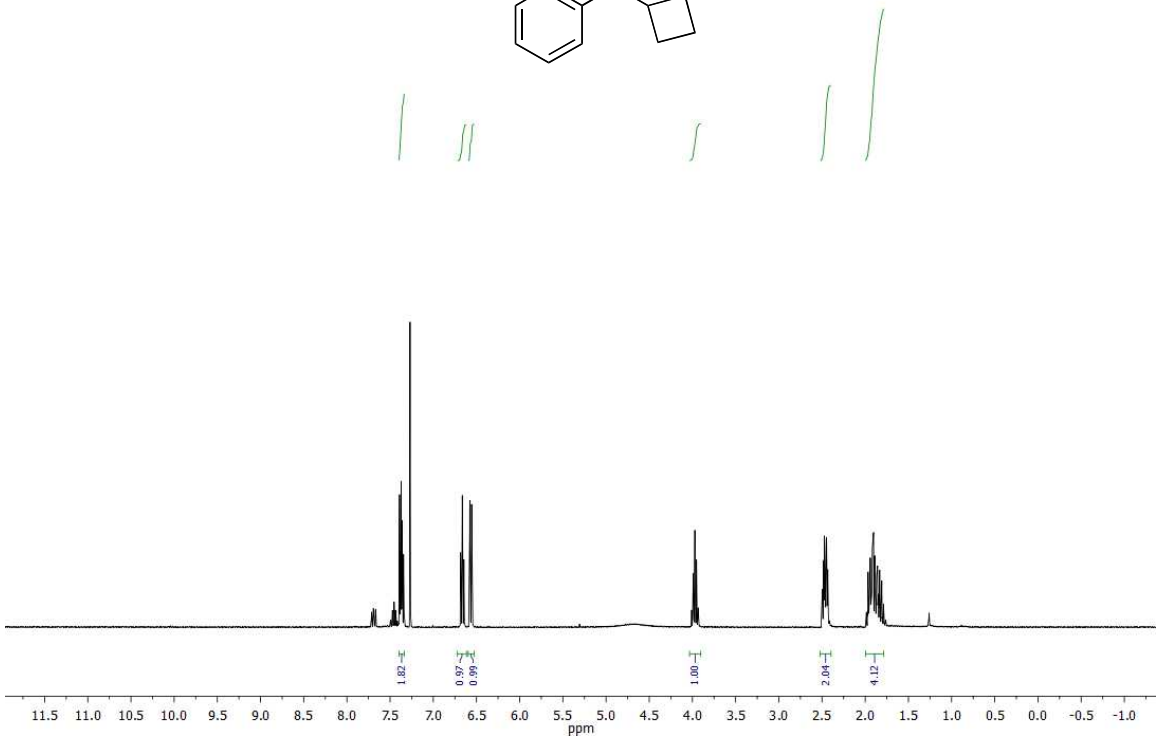



H
N
N
1.96
0.99
0.98
2.10
2.00
4.06
f1 (ppm)
JW1098.2.fid
JW1098 C13
143.39
138.78
136.19
123.93
118.99
48.79
31.19
15.39
f1 (ppm)

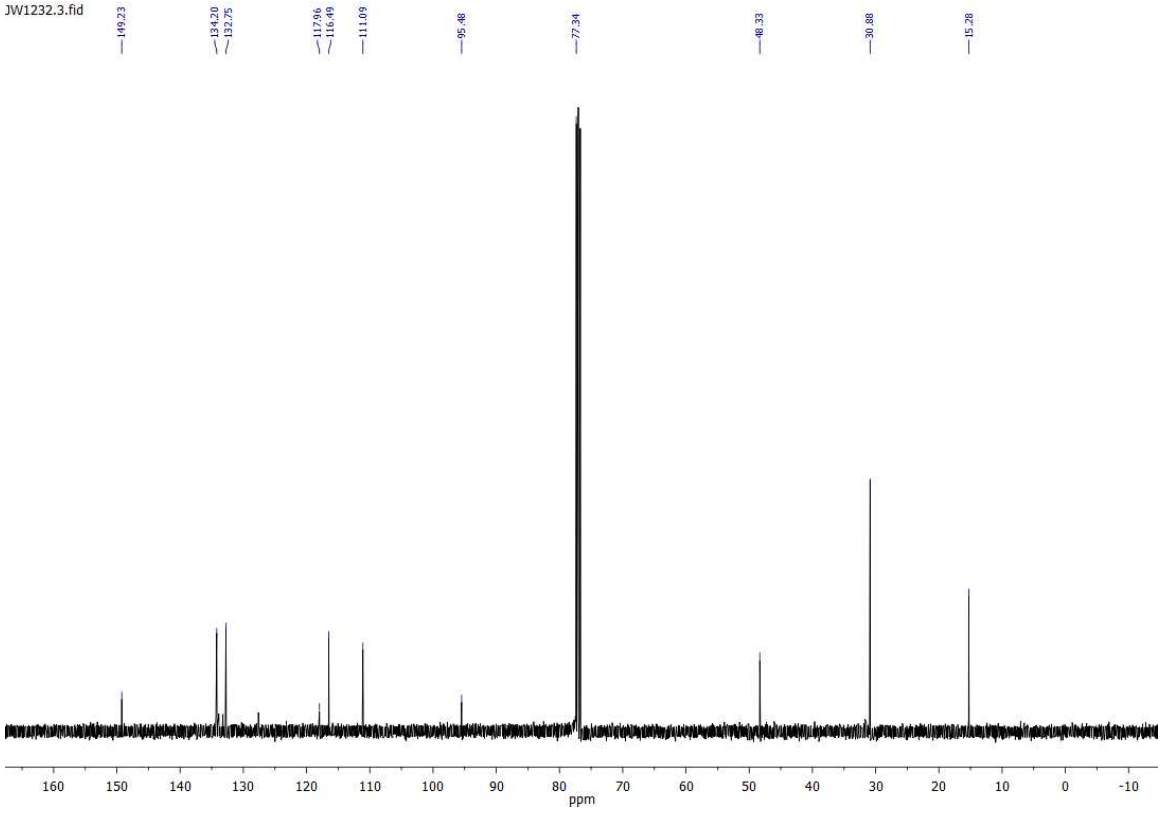

H
N
0.85
1.86
1.68
2.08
6.00
4.27
f1 (ppm)
147.36
139.09
119.66
111.23
49.28
31.54
21.72
15.45
f1 (ppm)

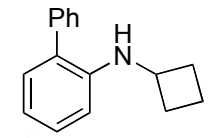
JW1232.1.fid
JW1232 H1

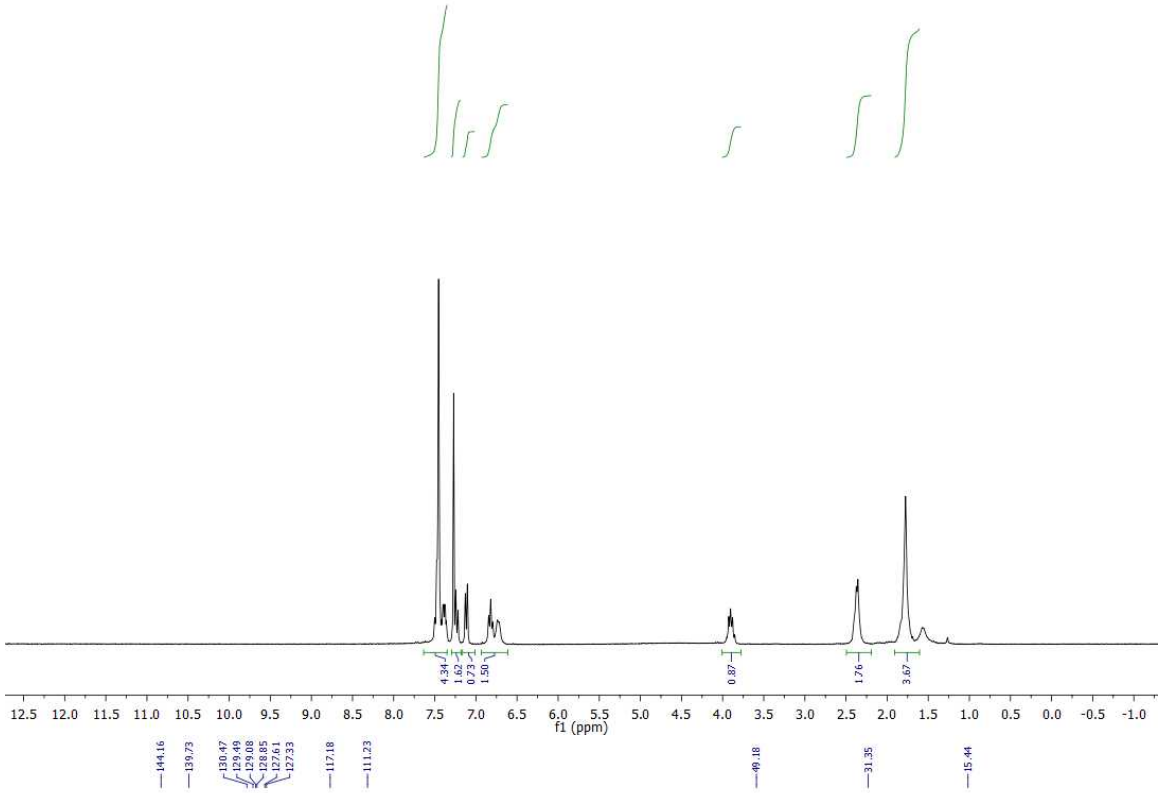


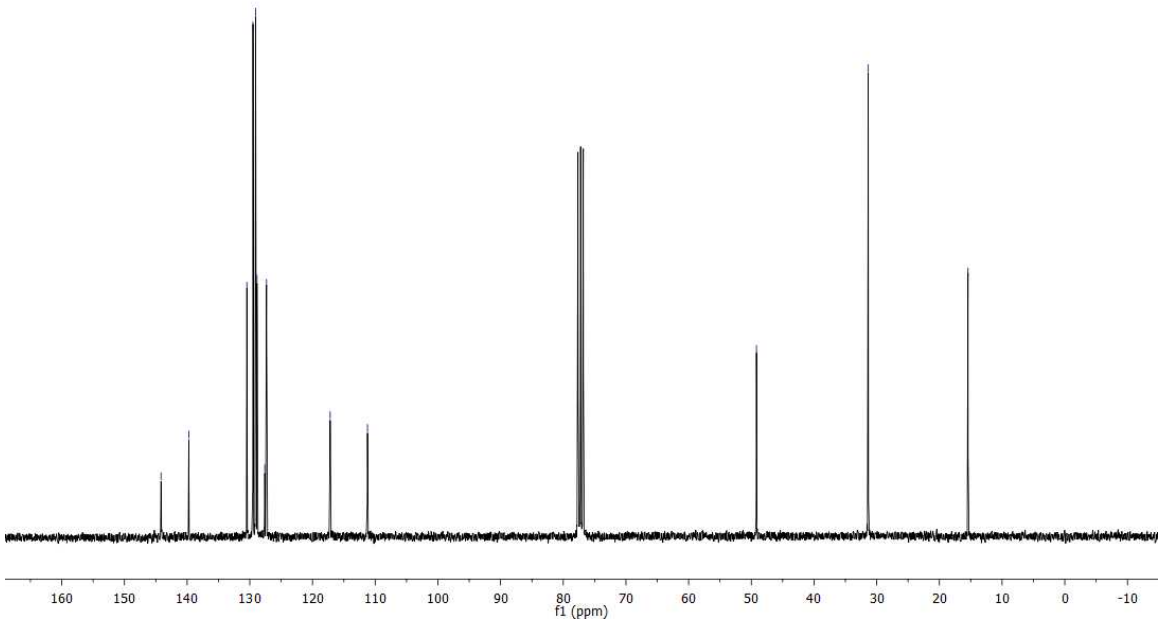


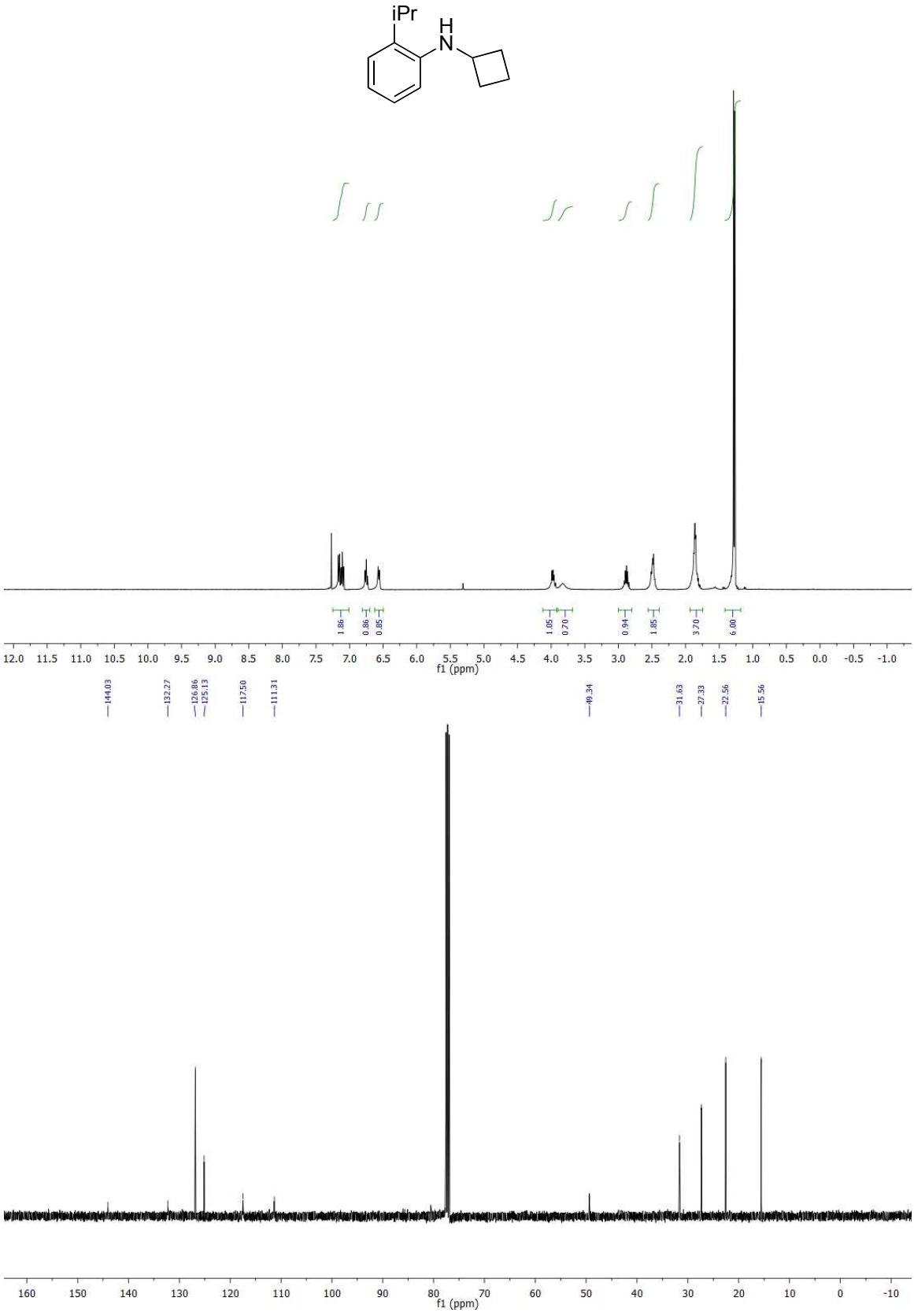
JW1232.3.fid

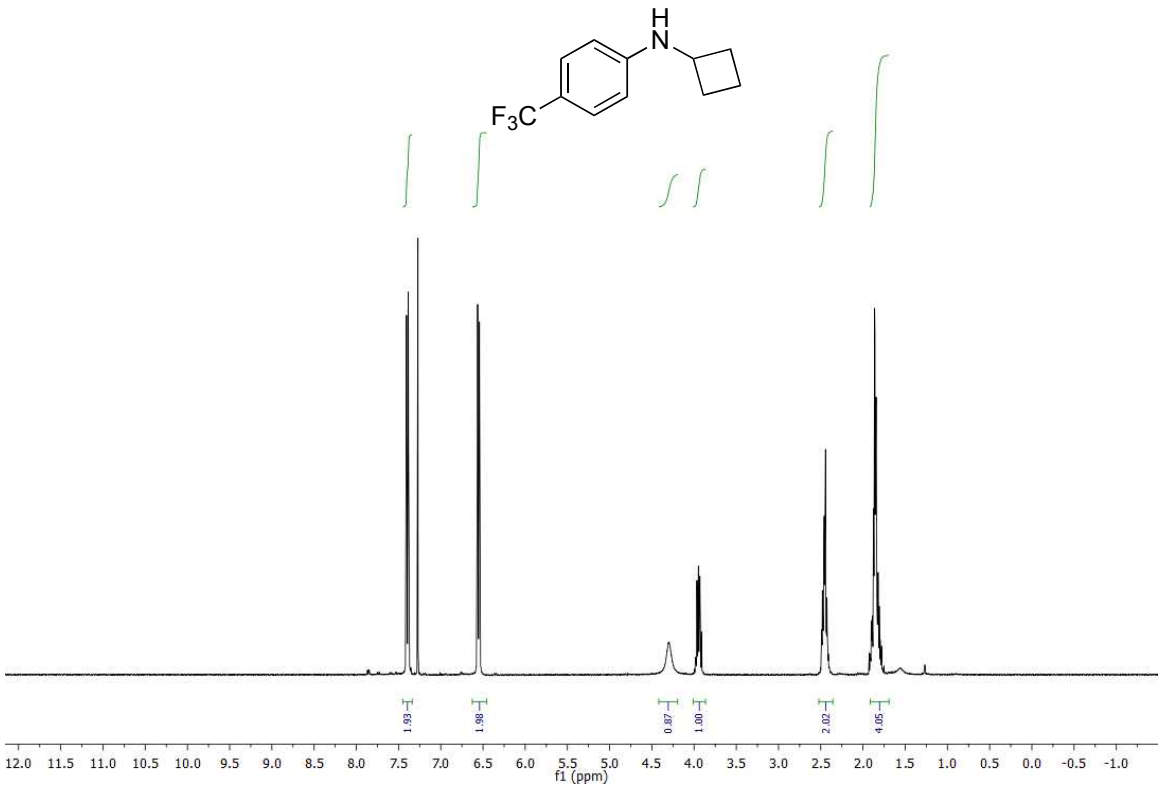


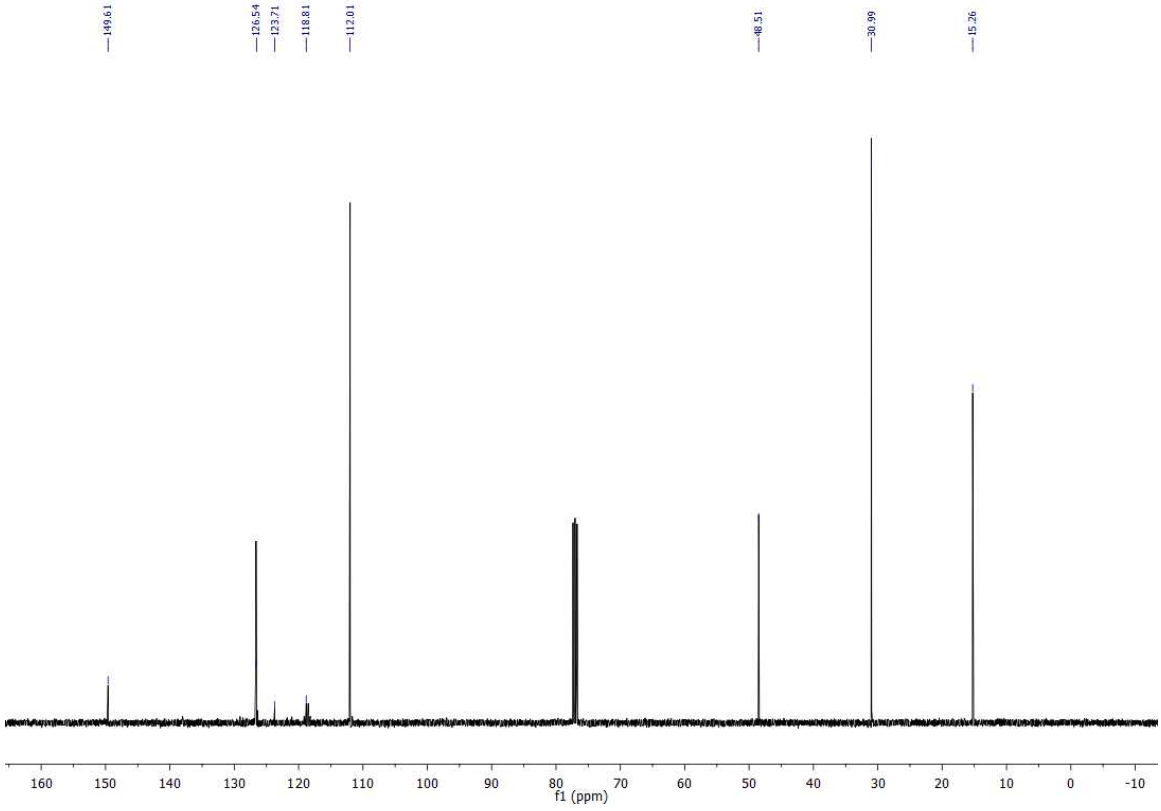

Ph
H
N

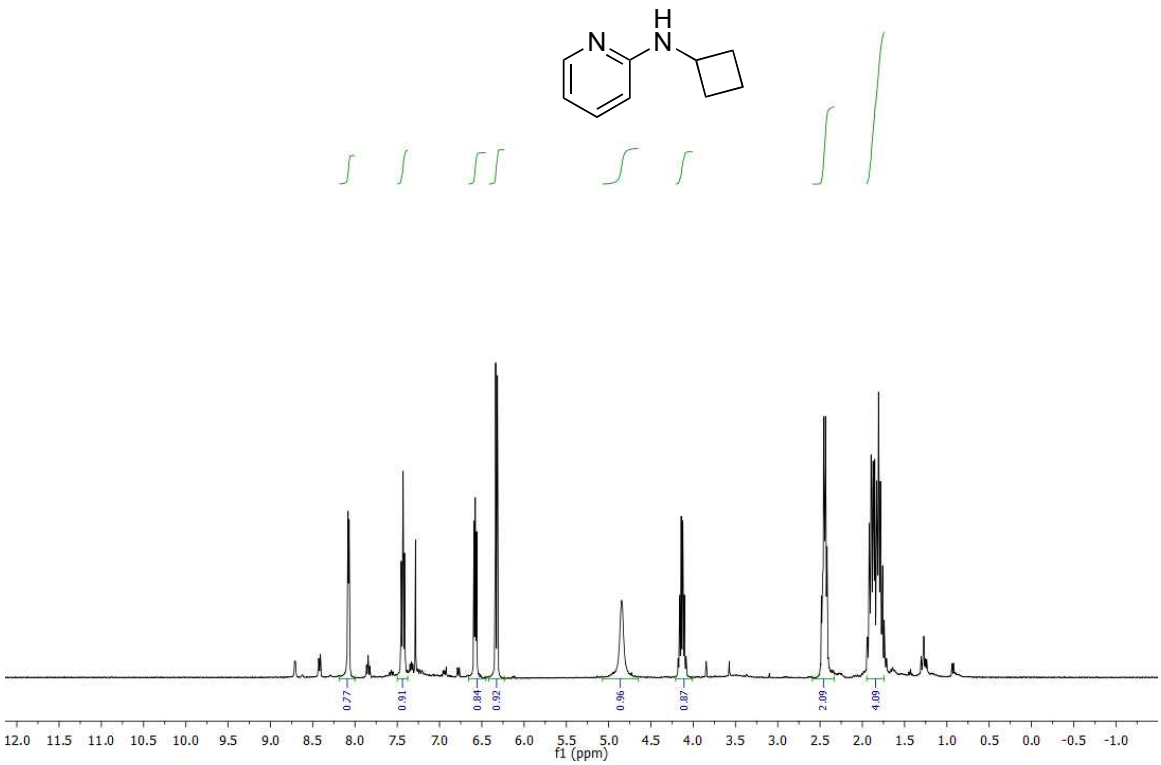

4.34
1.62
0.73
1.50
0.87
1.76
3.67
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)
144.16
139.73
130.47
129.49
129.08
128.85
127.61
127.33
117.18
111.23
49.18
31.35
15.44


160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

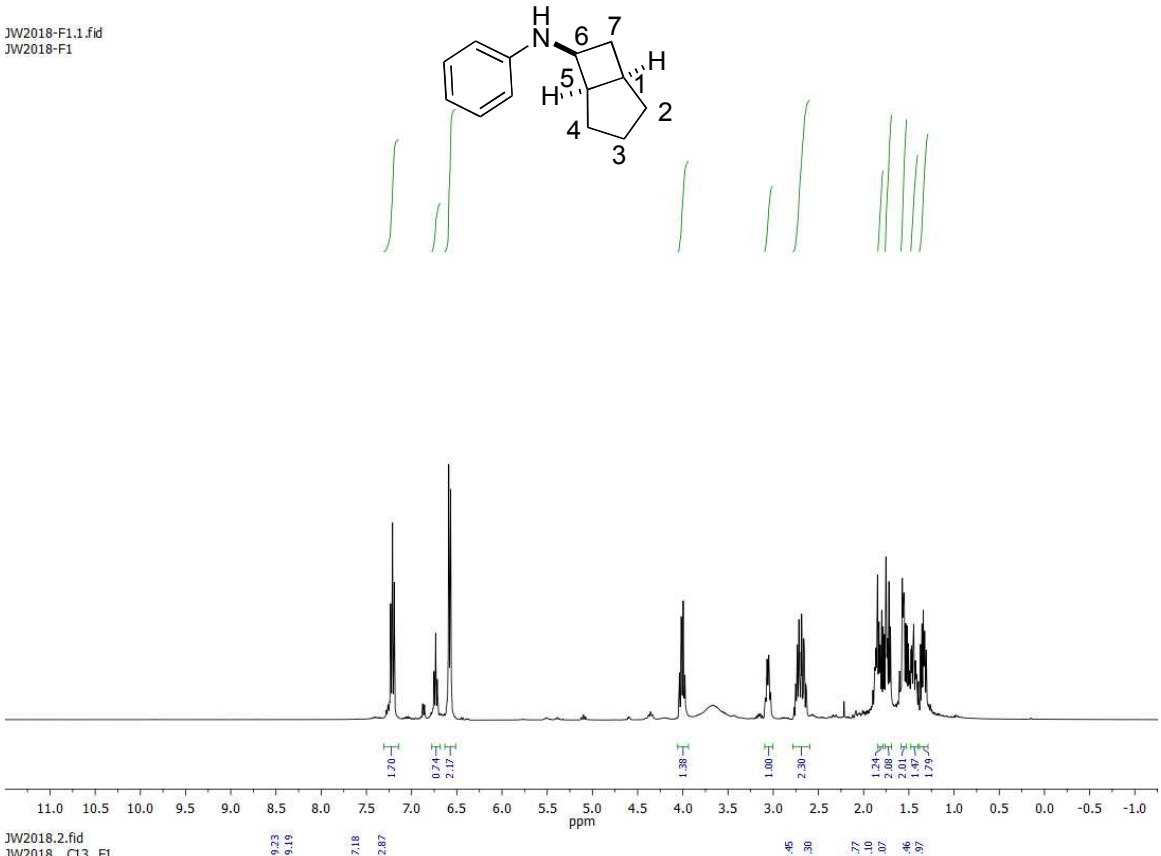

iPr
H
N
1.86
0.86
0.85
1.05
0.70
0.94
1.85
3.70
6.00
f1 (ppm)
144.03
132.27
126.86
125.13
117.50
111.31
49.34
31.63
27.33
22.56
15.56
f1 (ppm)


H
N
F3C
1.93
1.98
0.87
1.00
2.02
4.05
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

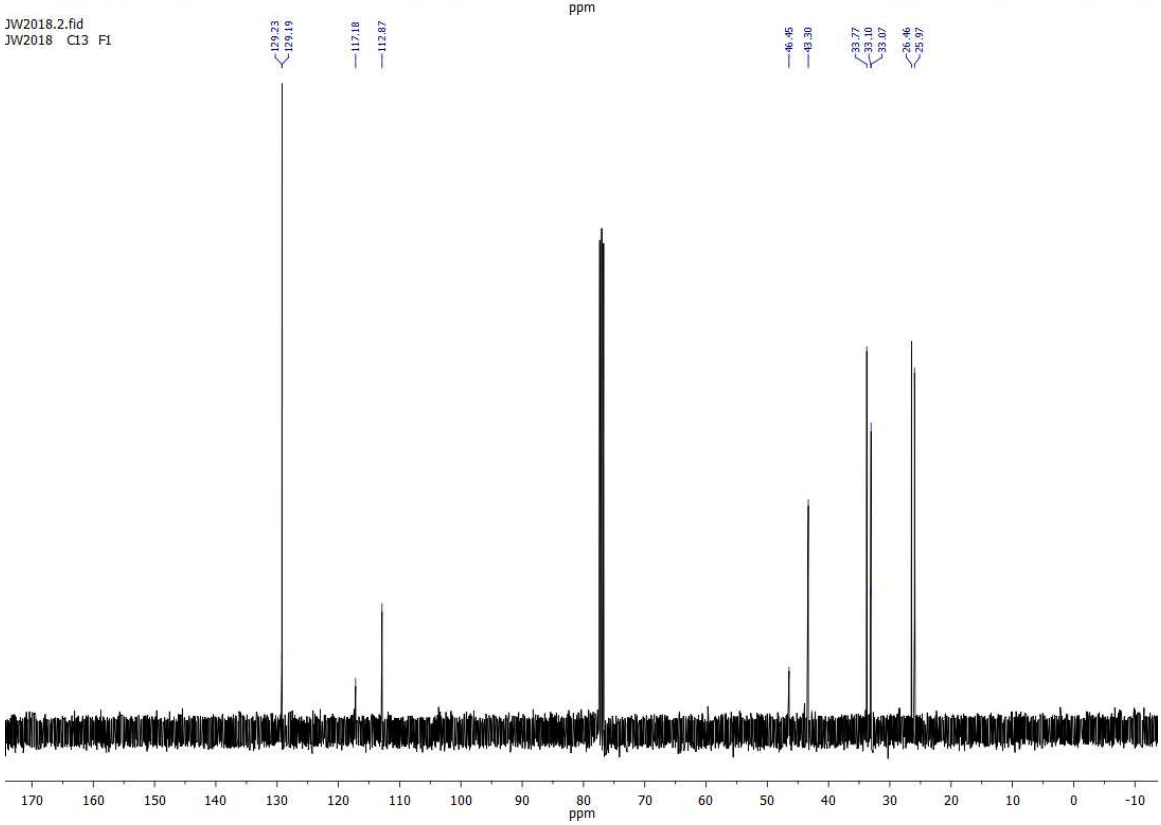

149.61
126.54
123.71
118.81
112.01
48.51
30.99
15.26
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


N
H
N
0.77
0.91
0.84
0.92
0.96
0.87
2.09
4.09
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)
158.02
148.28
137.81
113.04
106.51
47.52
31.50
15.39
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

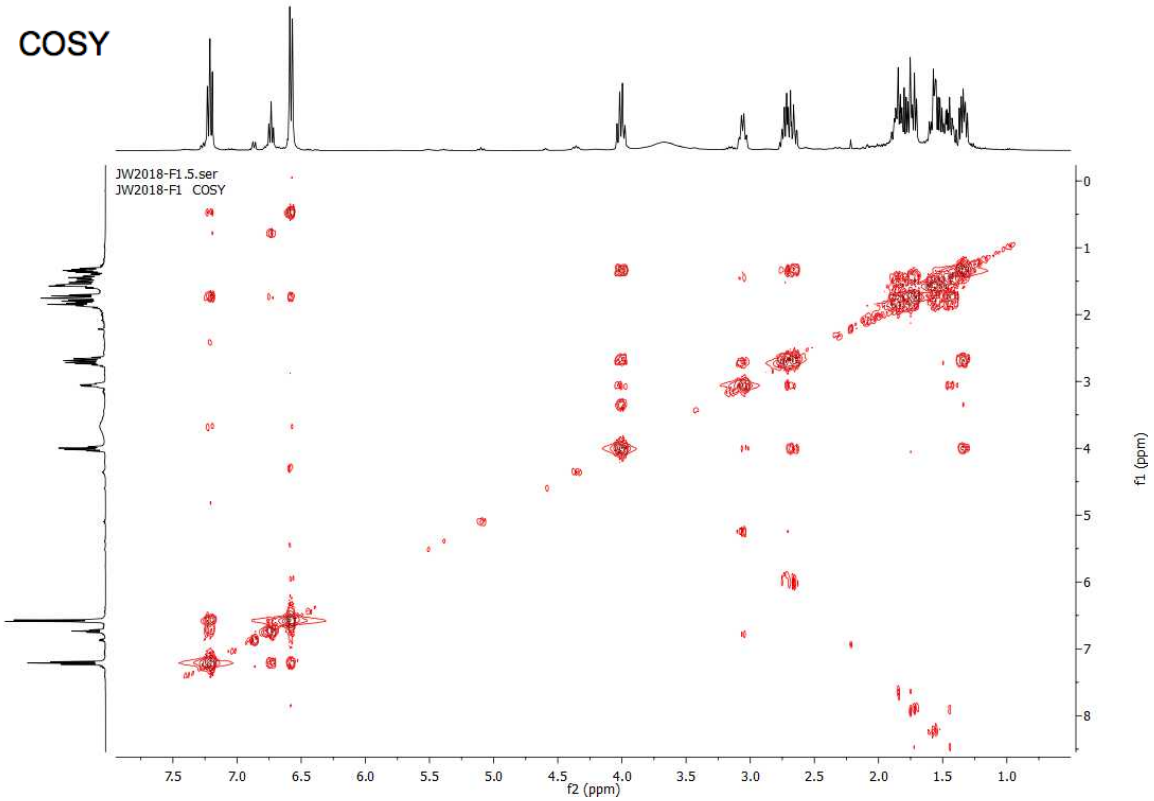
JW2018-F1.1.fid
JW2018-F1



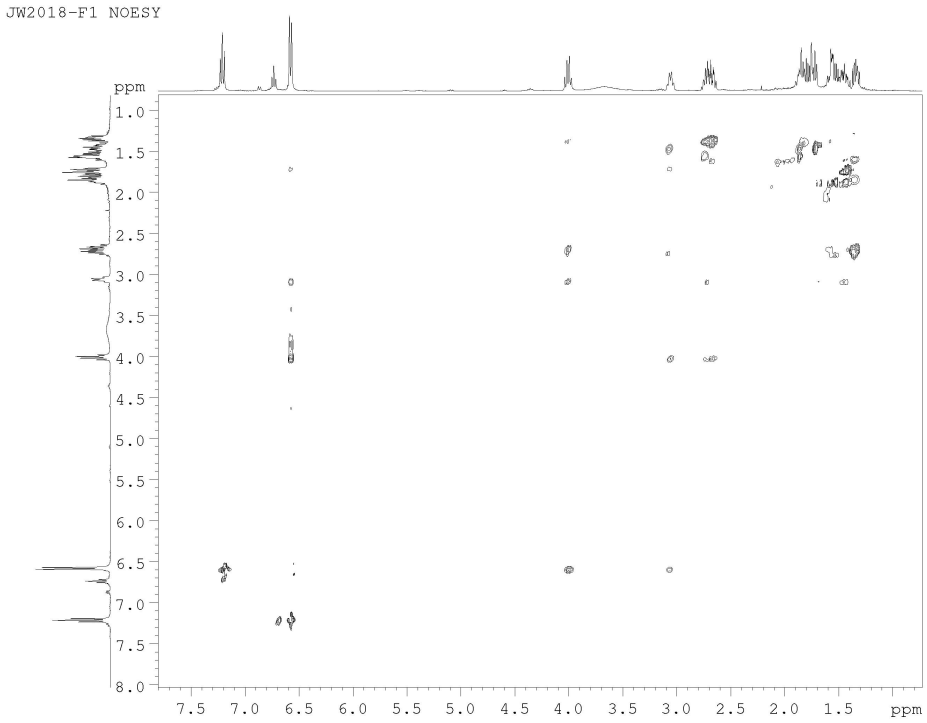
JW2018.2.fid
JW2018 C13 F1

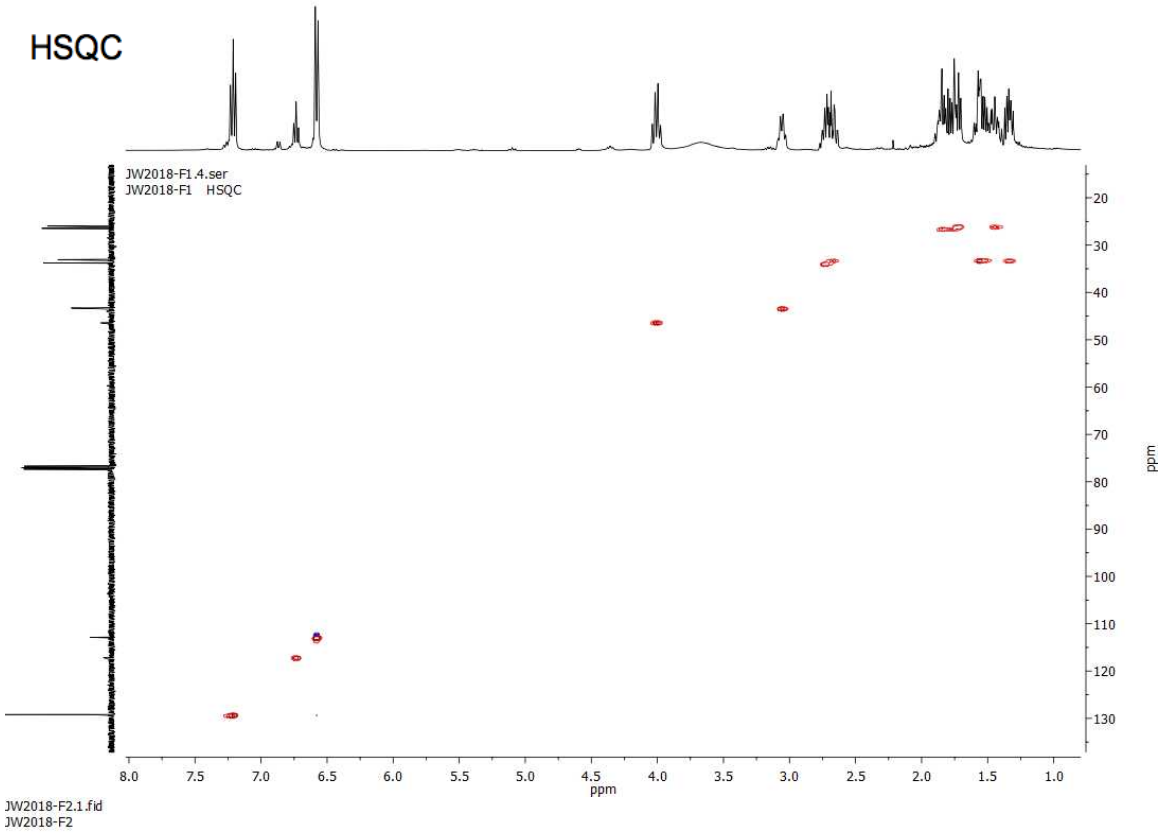


COSY


JW2018-F1.5.ser
JW2018-F1 COSY
f2 (ppm)
f1 (ppm)

NOESY


JW2018-F1 NOESY
ppm
ppm


HSQC
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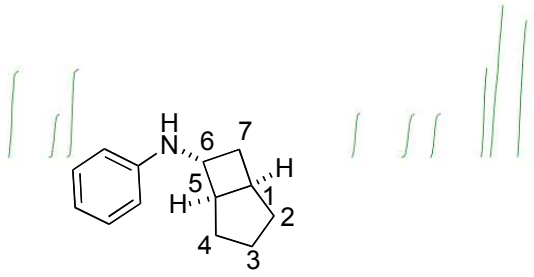
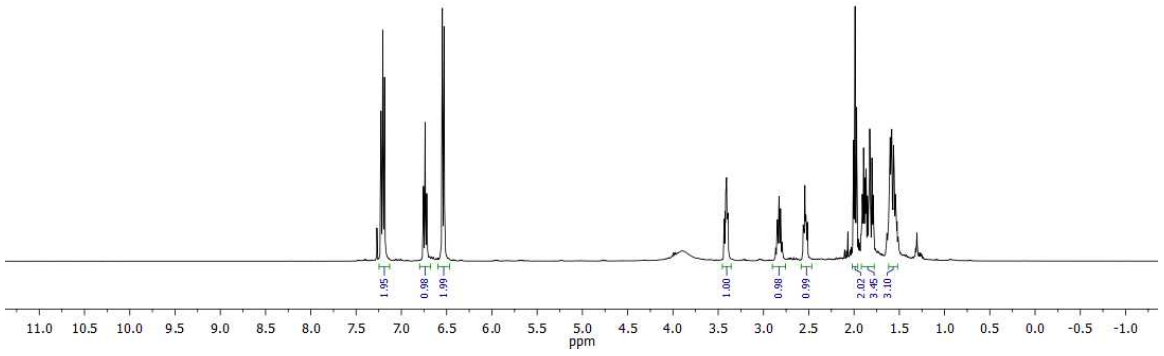
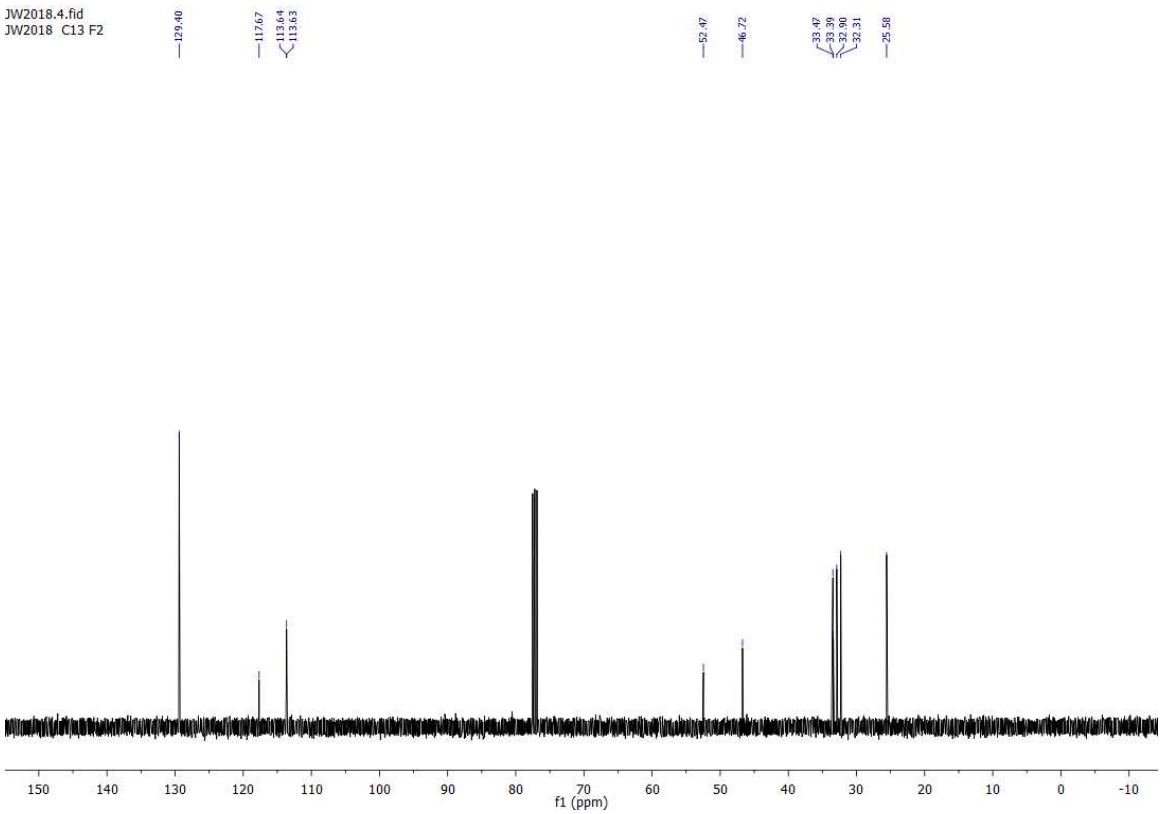
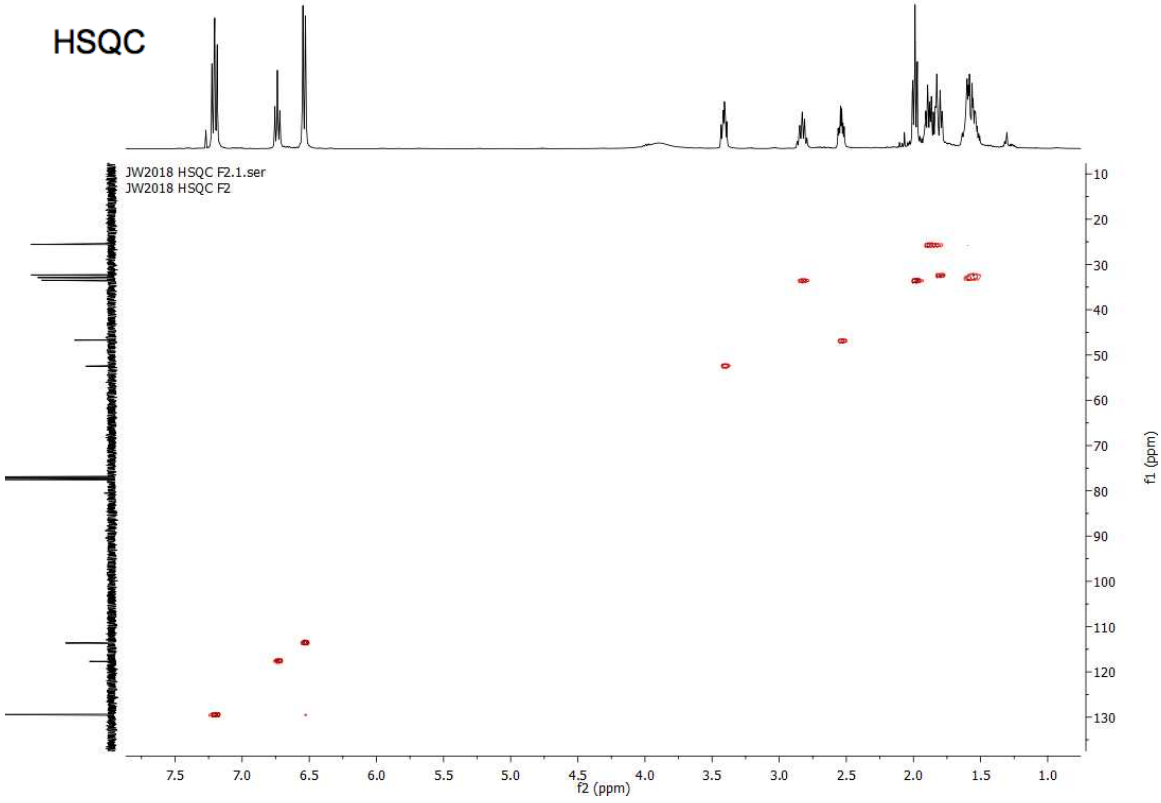
JW2018-F1 HSQC
ppm
JW2018-F2.1.fid
JW2018-F2

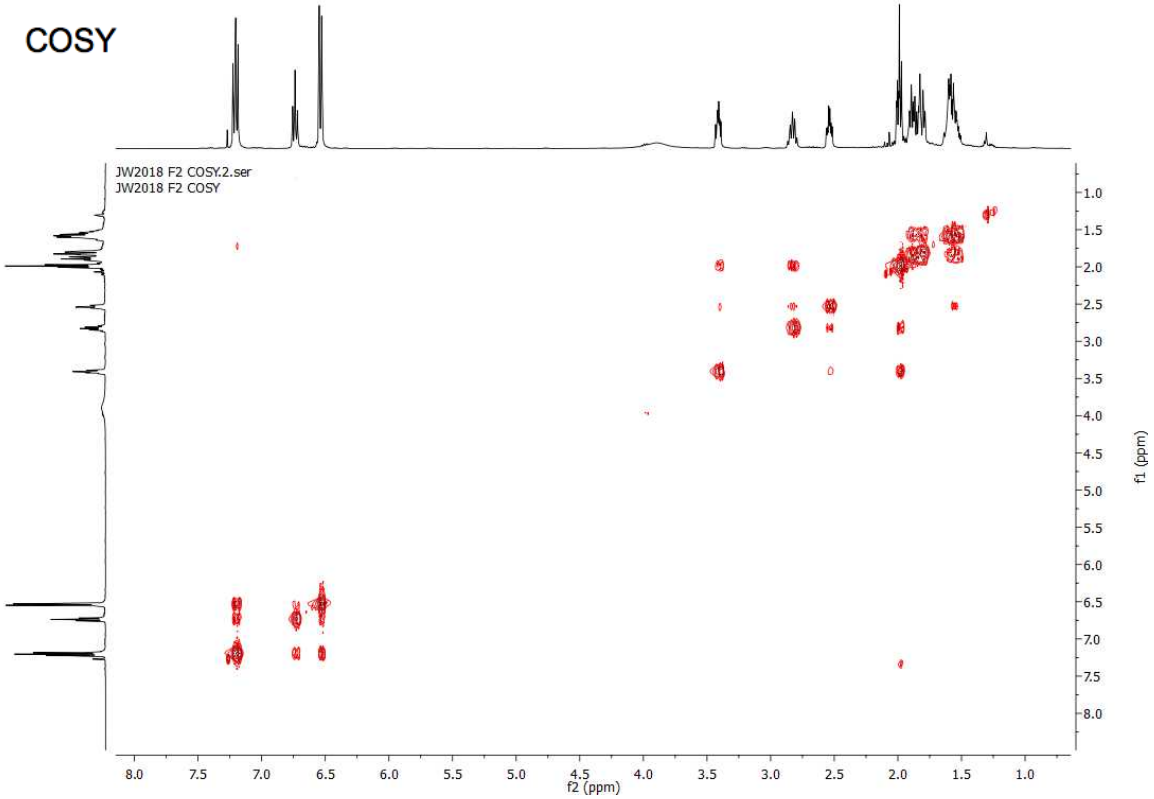

H
N
6
7
H
5
1
H
2
4
3


1.95
0.98
1.99
1.00
0.98
0.99
2.02
3.45
3.10
ppm

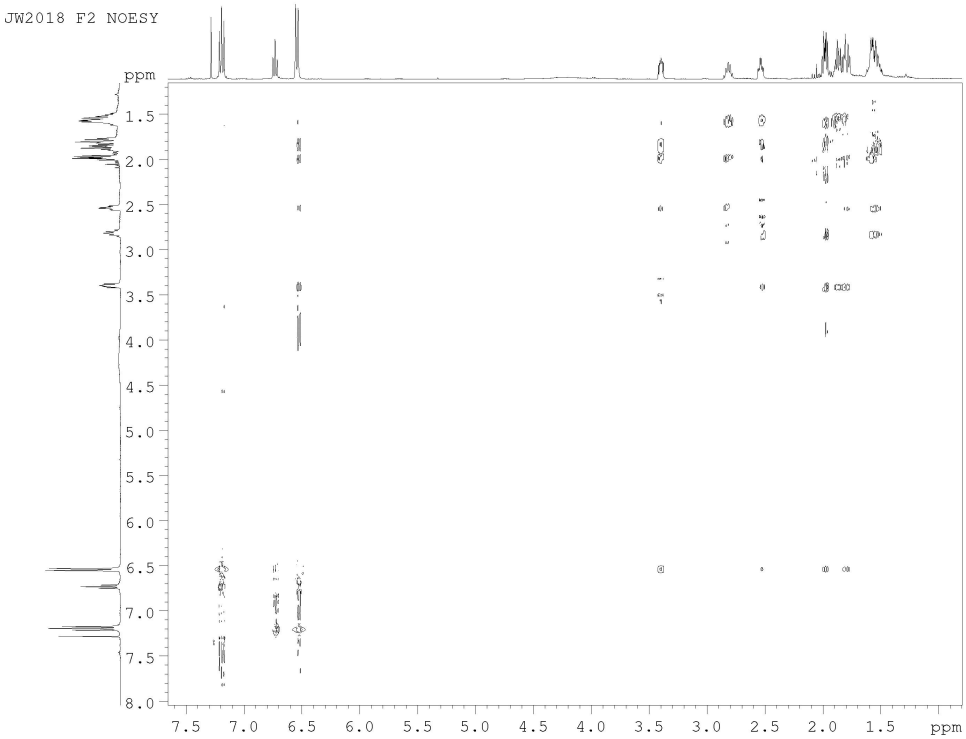

JW2018.4.fid
JW2018 C13 F2
129.40
117.67
113.64
113.63
52.47
46.72
33.47
33.39
32.90
32.31
25.58
f1 (ppm)


HSQC
JW2018 HSQC F2.1.ser
JW2018 HSQC F2
f2 (ppm)
f1 (ppm)

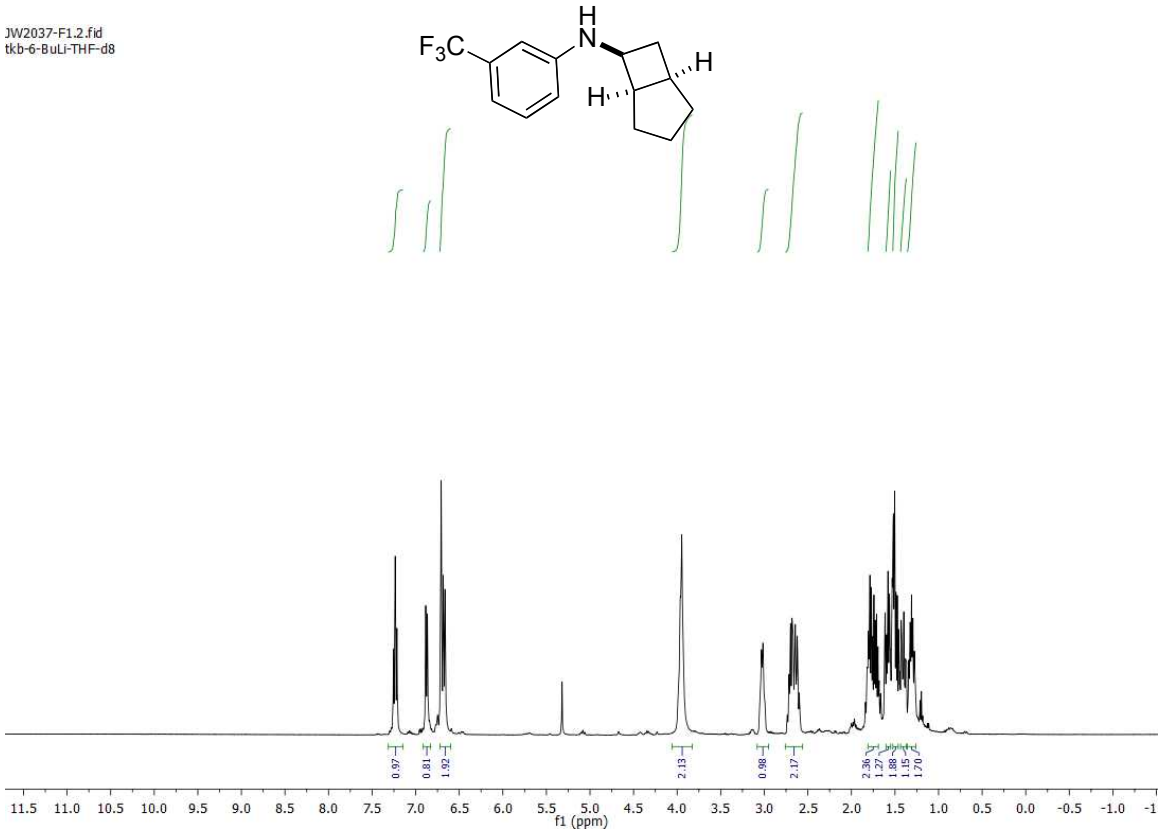
COSY


JW2018 F2 COSY.2.ser
JW2018 F2 COSY
f2 (ppm)
f1 (ppm)

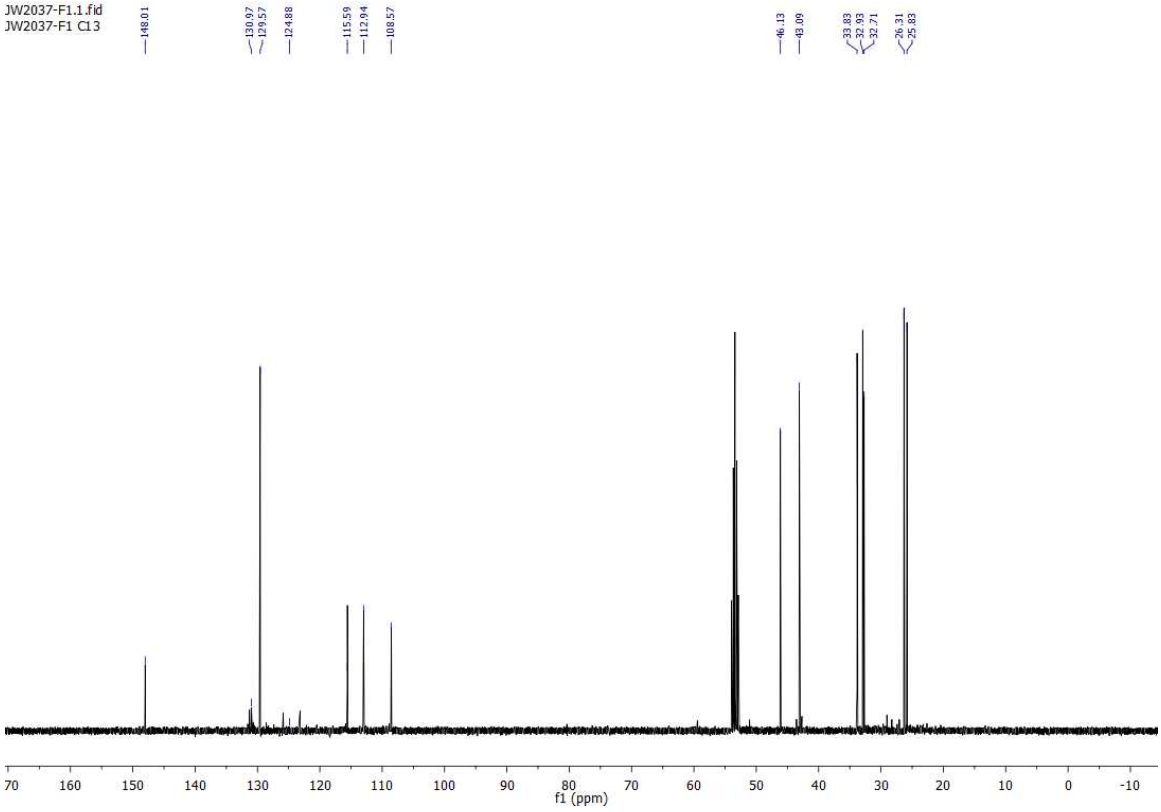
NOESY


JW2018 F2 NOESY
ppm
ppm

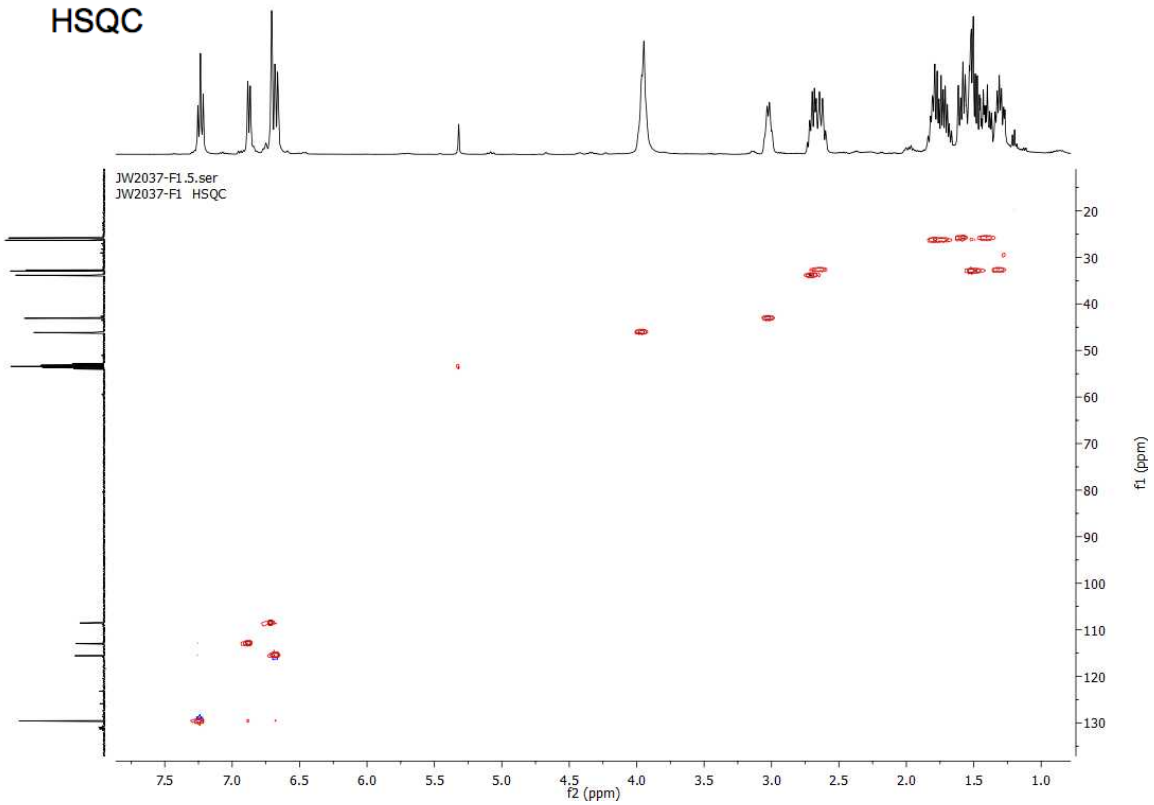
JW2037-F1.2.fid
tkb-6-BuLi-THF-d8



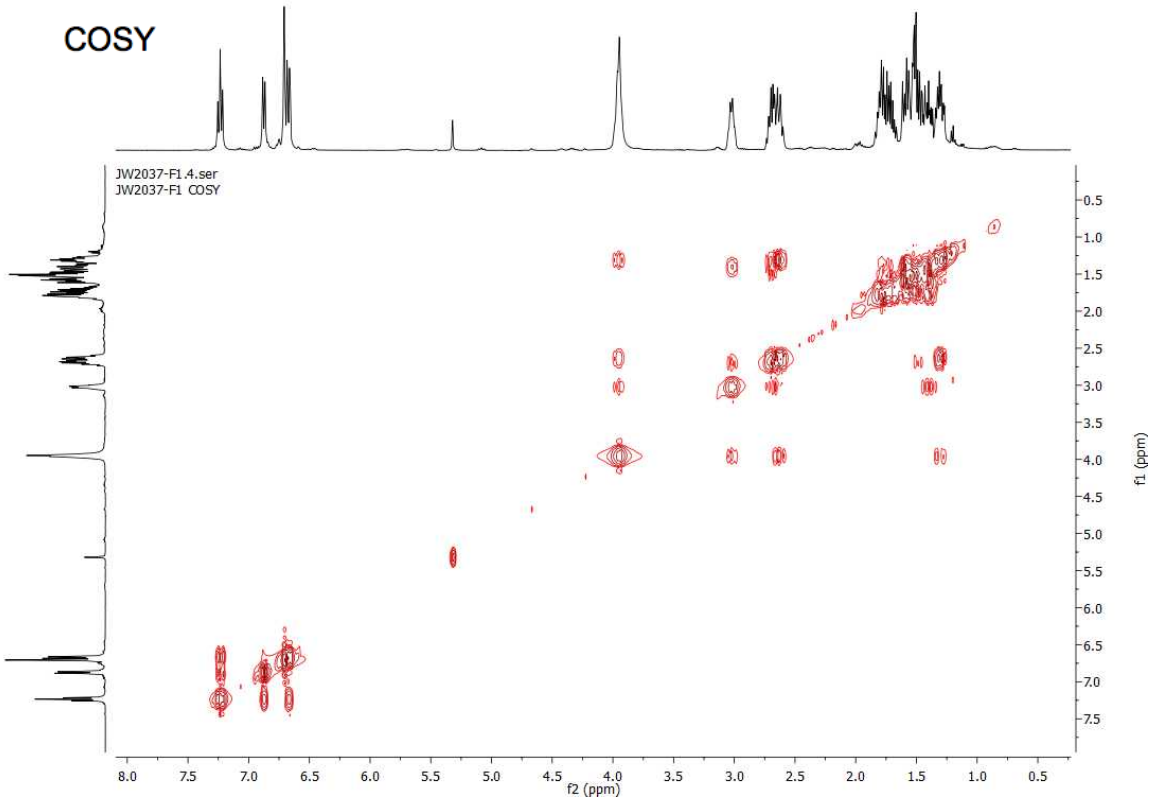
JW2037-F1.1.fid
JW2037-F1 C13

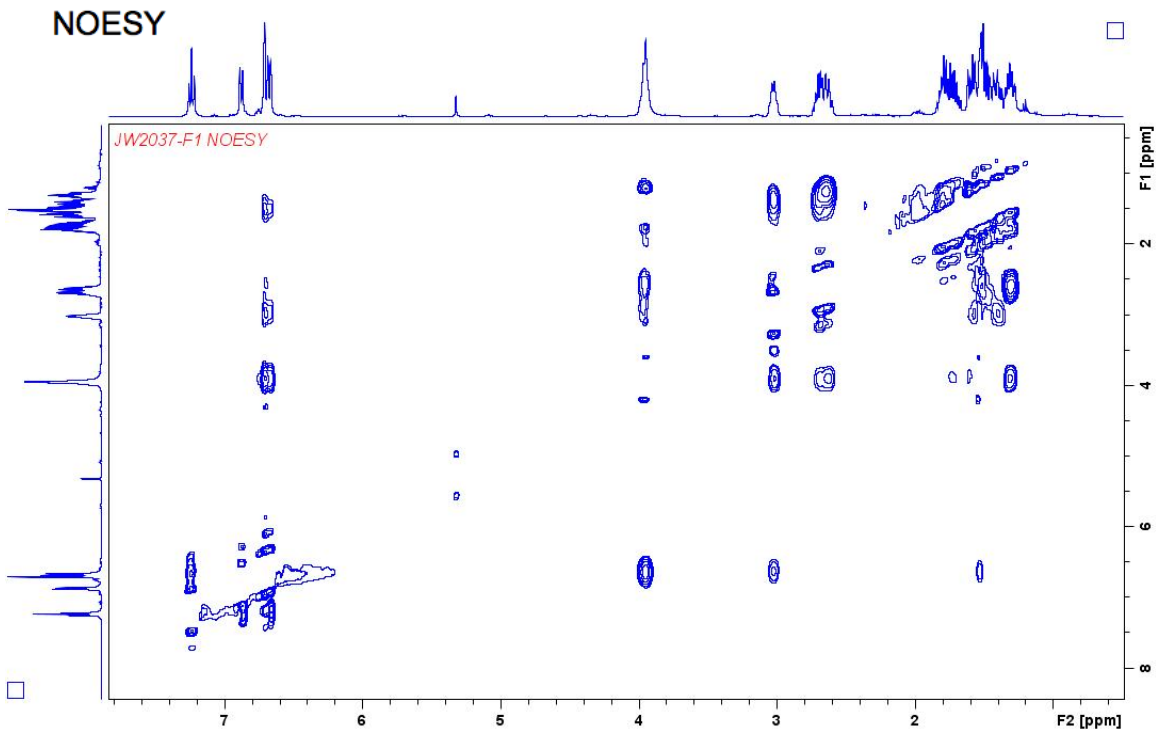


HSQC

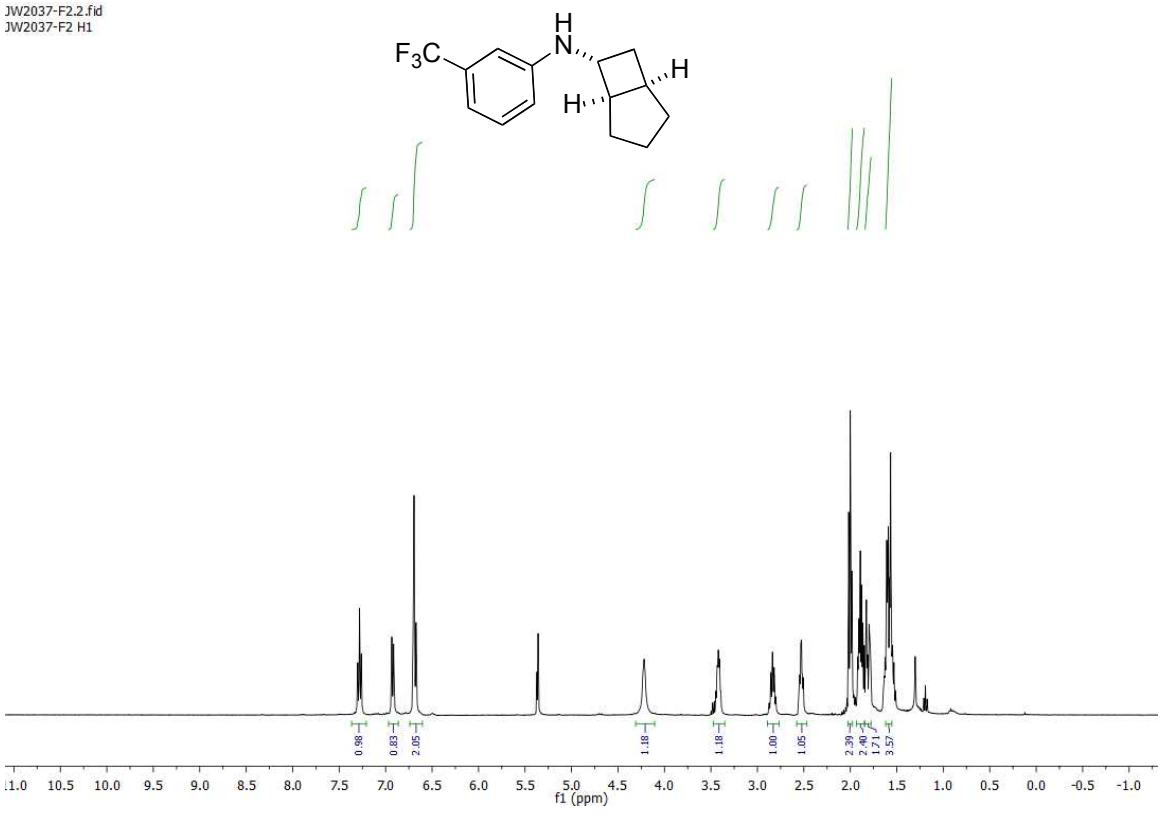

JW2037-F1.5.ser
JW2037-F1 HSQC
f2 (ppm)
f1 (ppm)

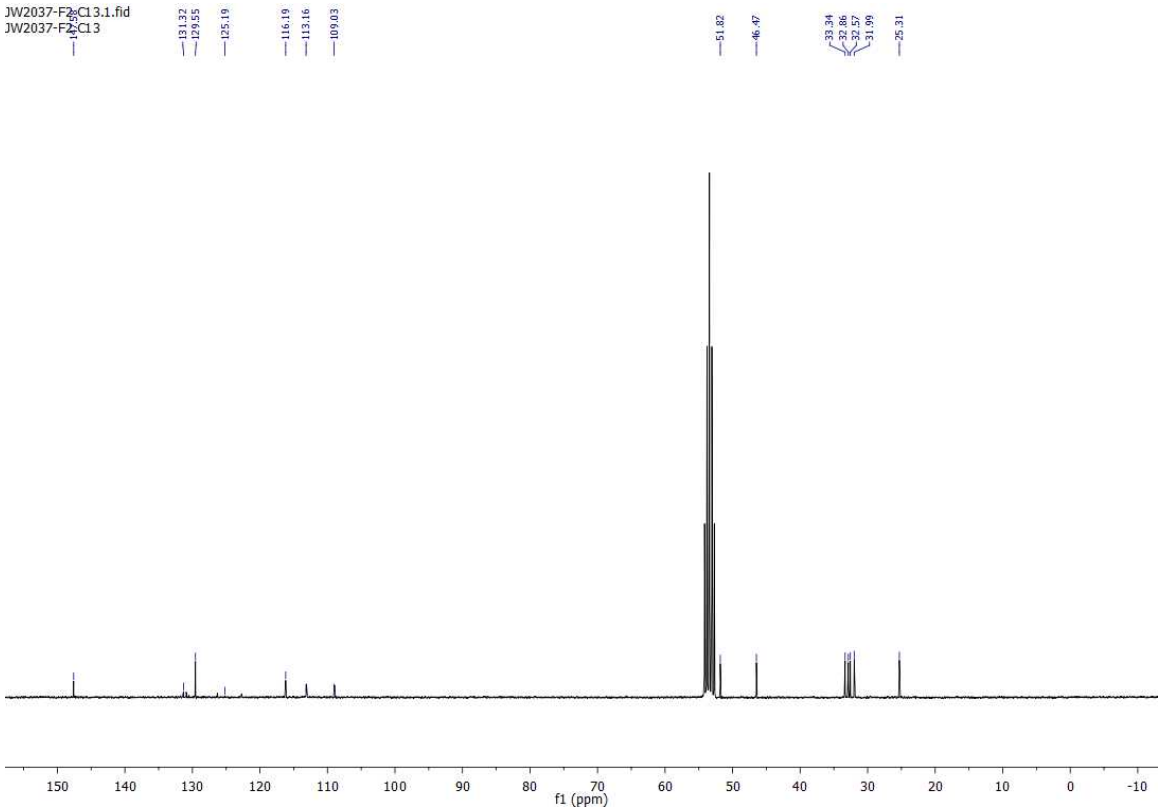
COSY

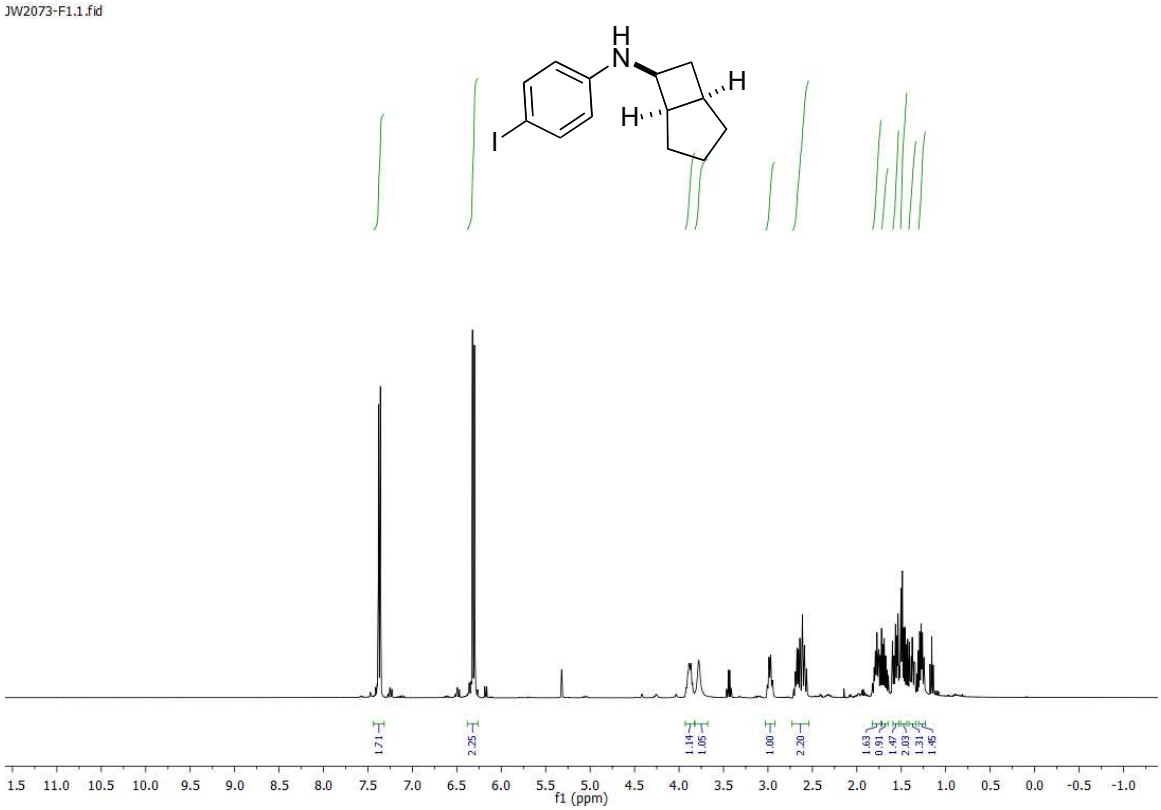

JW2037-F1.4.ser
JW2037-F1 COSY
f2 (ppm)
f1 (ppm)

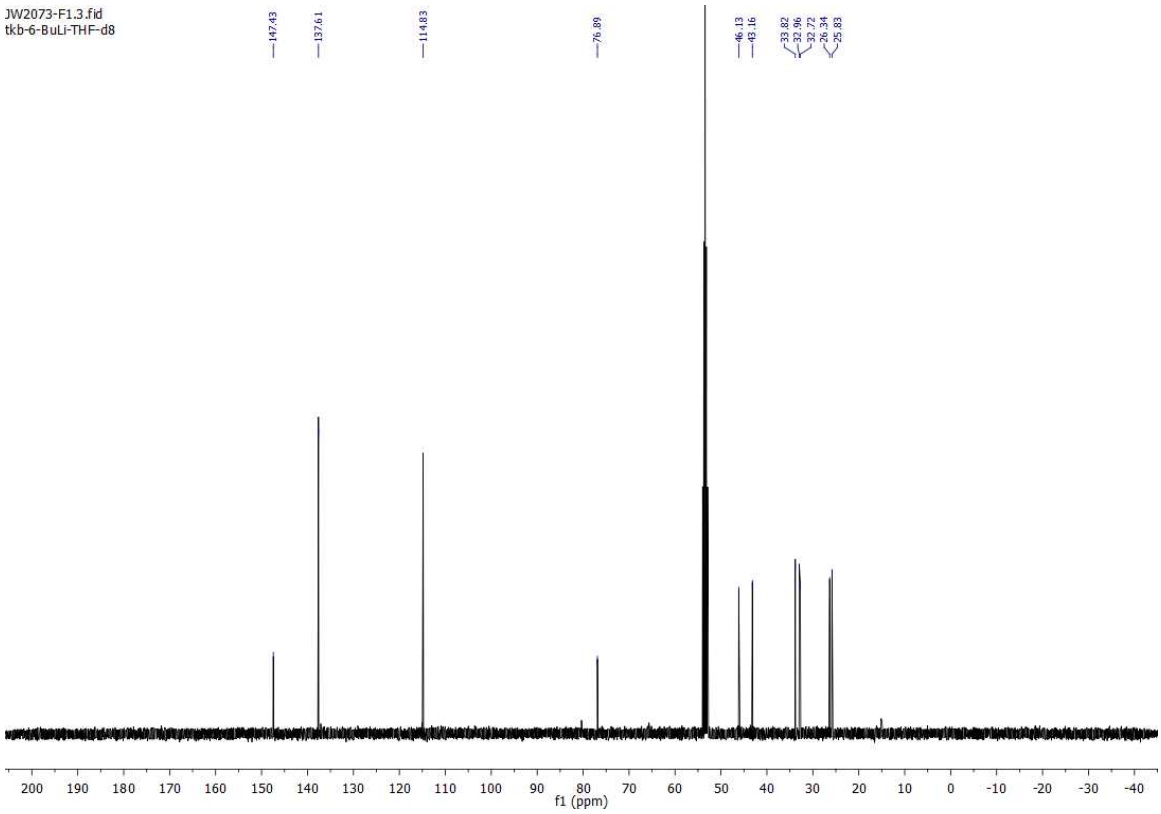


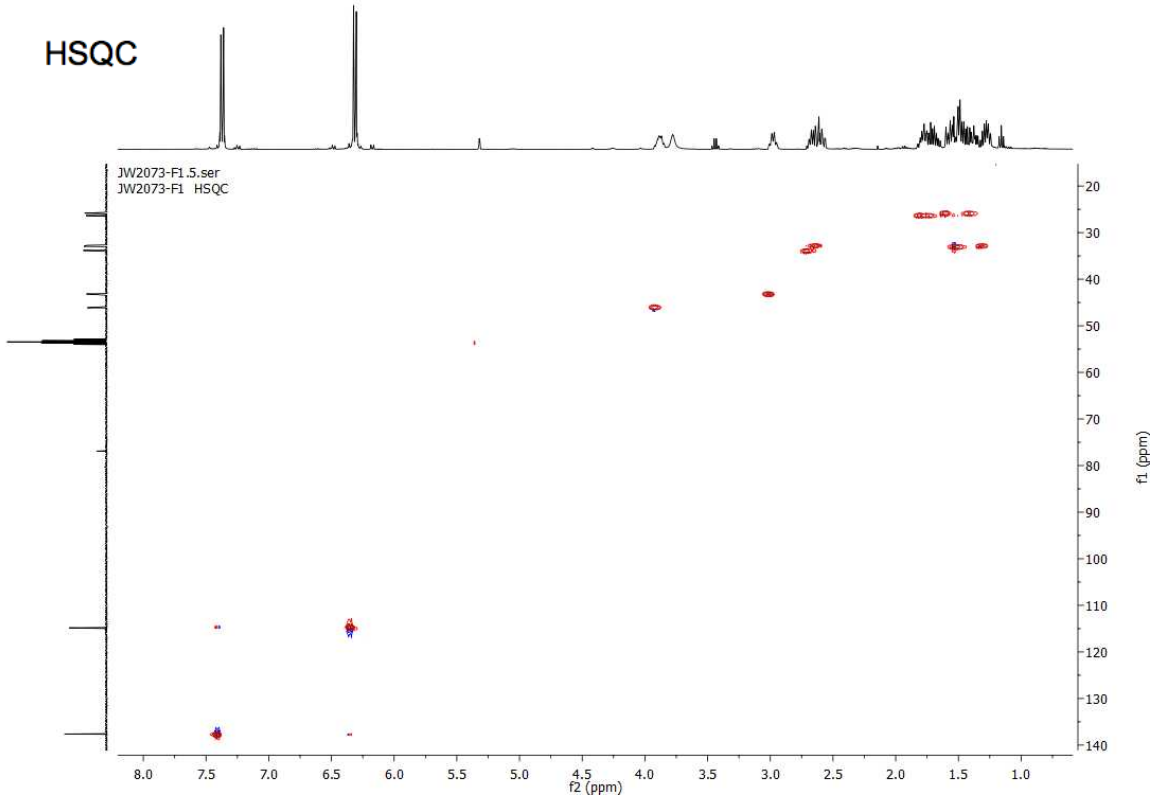
JW2037-F2.2.fid
JW2037-F2 H1

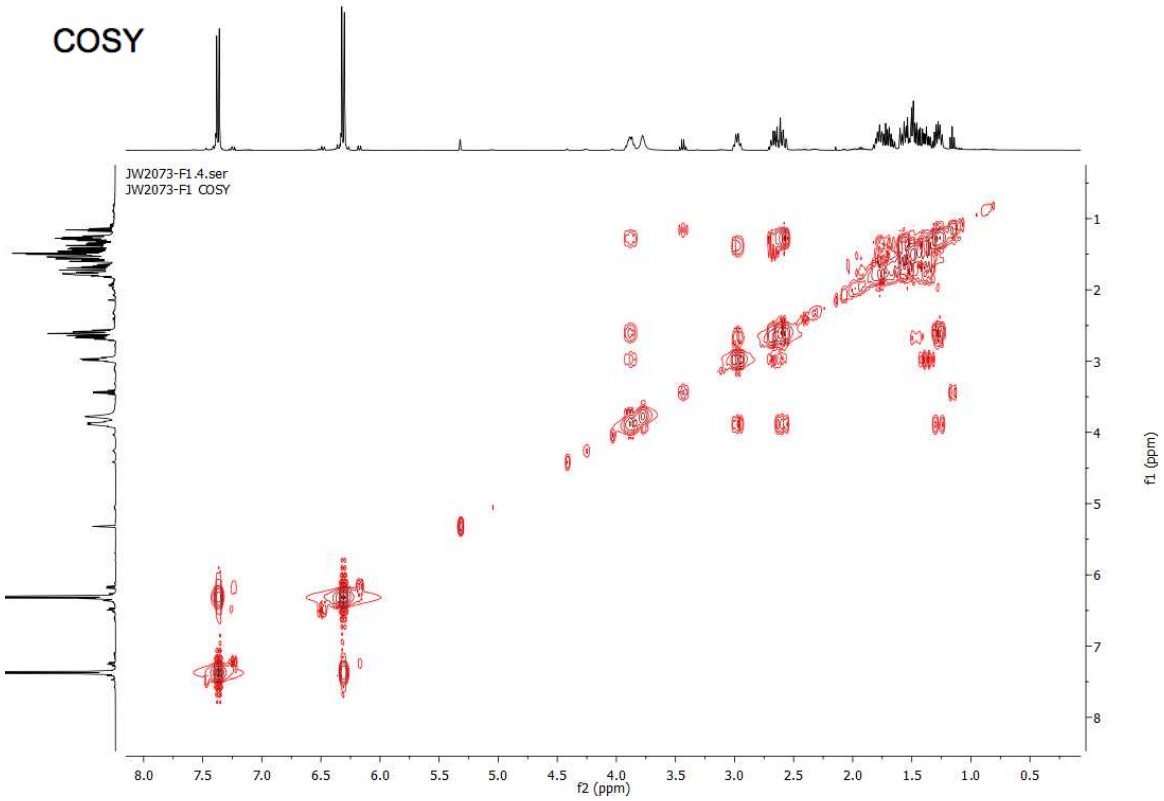


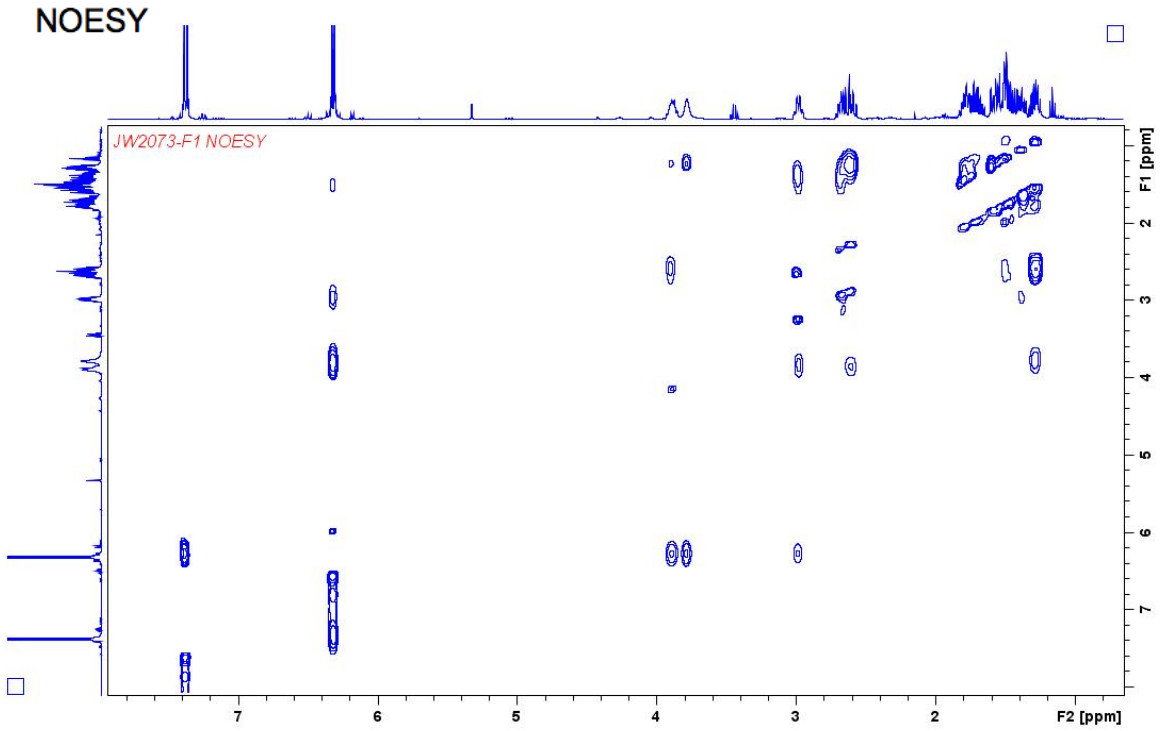

JW2037-F2-C13.1.fid
JW2037-F2-C13
147.58
131.32
129.55
125.19
116.19
113.16
109.03
51.82
46.47
33.34
32.86
32.57
31.99
25.31
150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

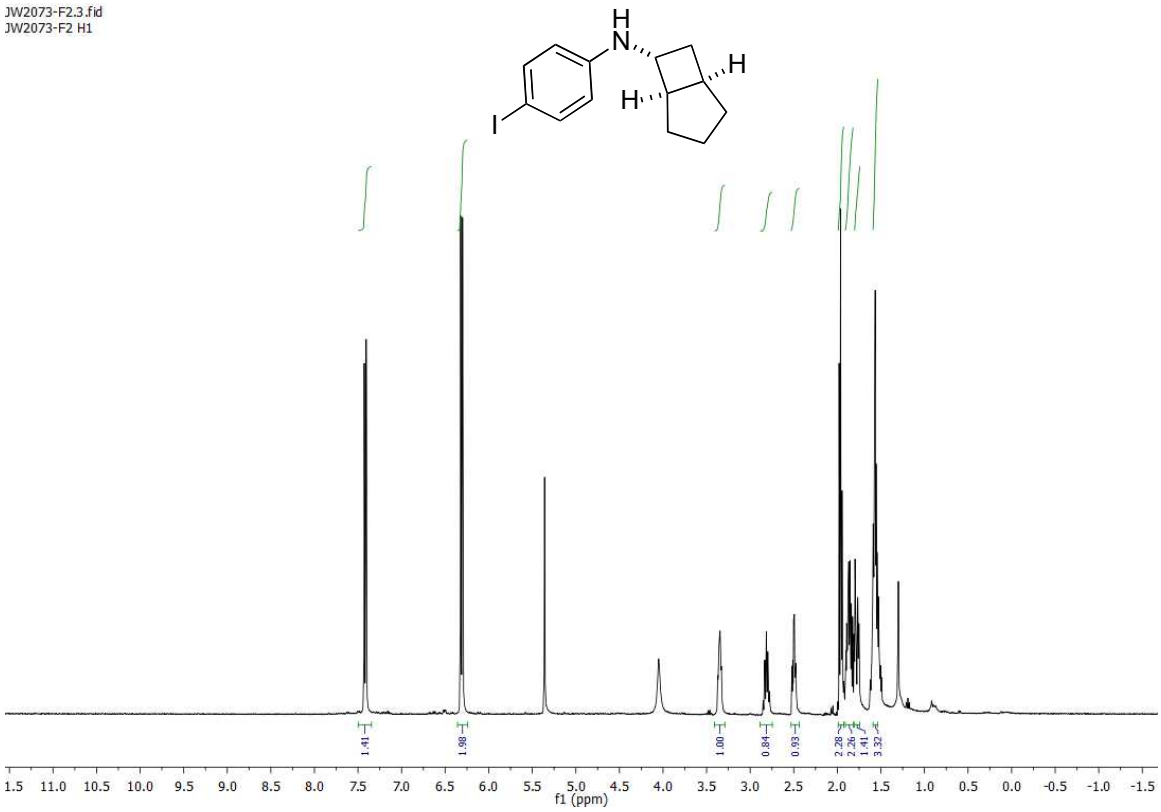

JW2073-F1.1.fid
H
N
H
H
I
1.71
2.25
1.14
1.05
1.00
2.20
1.63
0.91
1.47
2.03
1.31
1.45
1.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

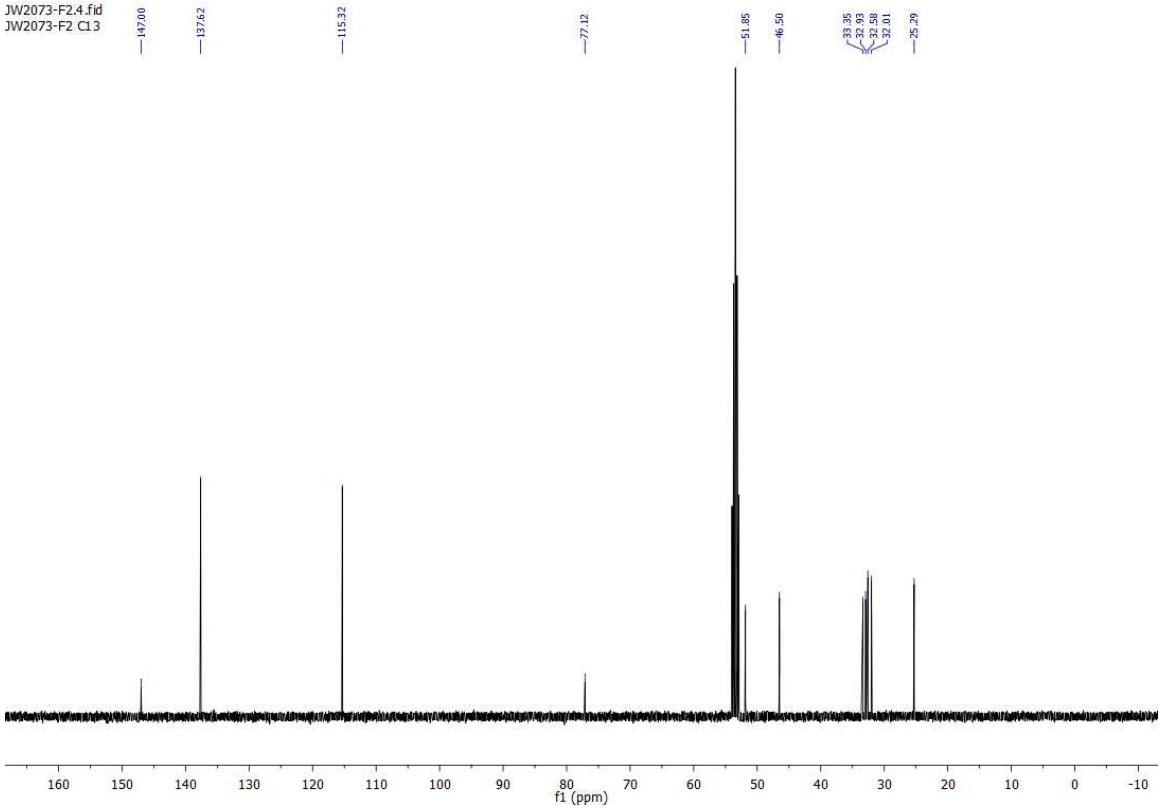

JW2073-F1.3.fid
tkb-6-BuLi-THF-d8
147.43
137.61
114.83
76.89
46.13
43.16
33.82
32.96
32.72
26.34
25.83
f1 (ppm)

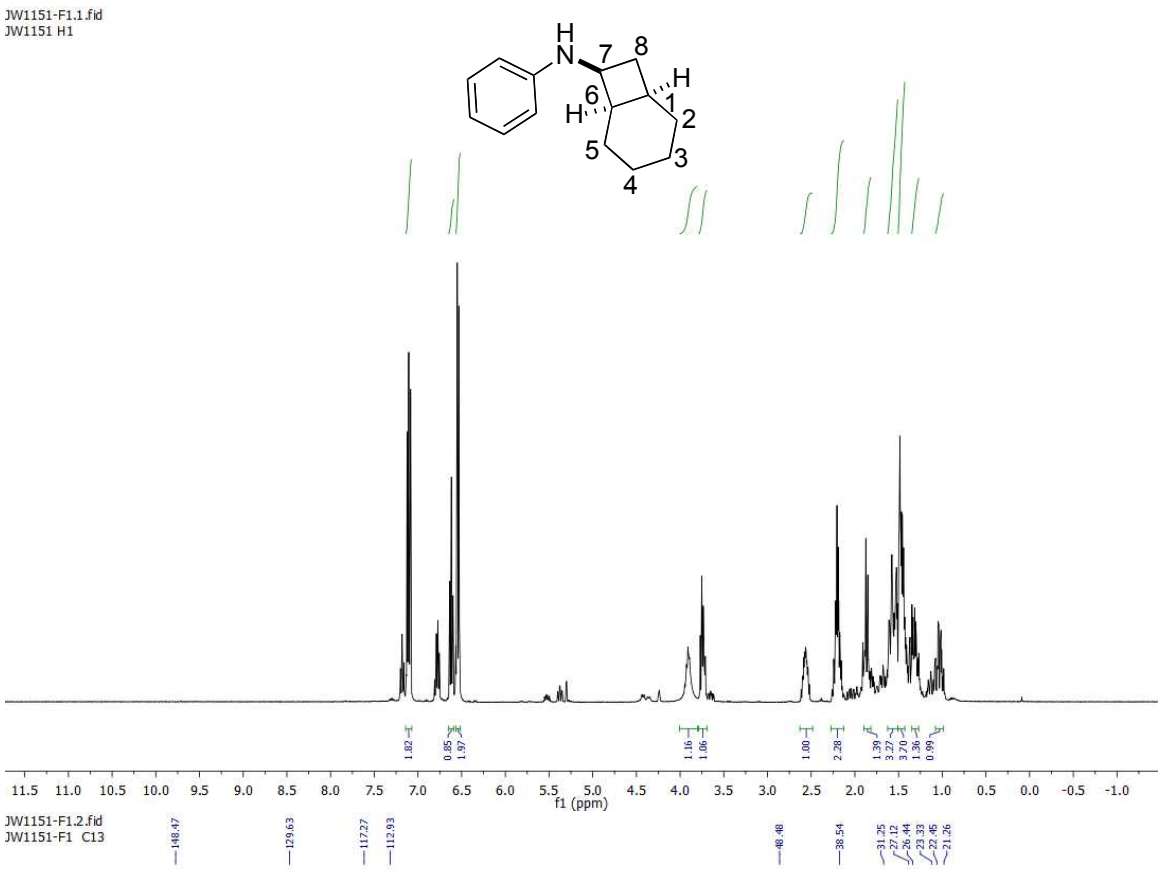

HSQC
JW2073-F1.5.ser
JW2073-F1 HSQC
f2 (ppm)
f1 (ppm)


COSY
JW2073-F1.4.ser
JW2073-F1 COSY
f1 (ppm)
f2 (ppm)

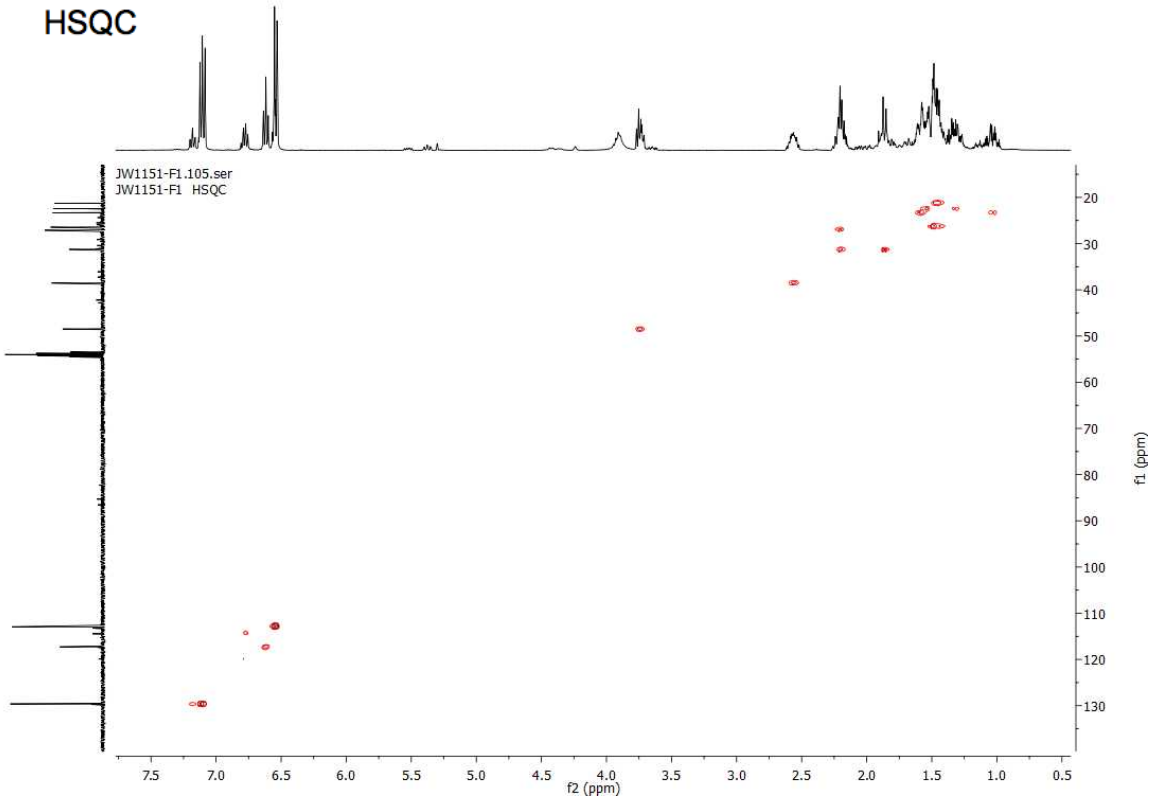

NOESY
JW2073-F1 NOESY
F1 [ppm]
F2 [ppm]


JW2073-F2.3.fid
JW2073-F2 H1
H
N
H
H
I
1.41
1.98
1.00
0.84
0.93
2.28
2.26
1.41
3.32
1.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)

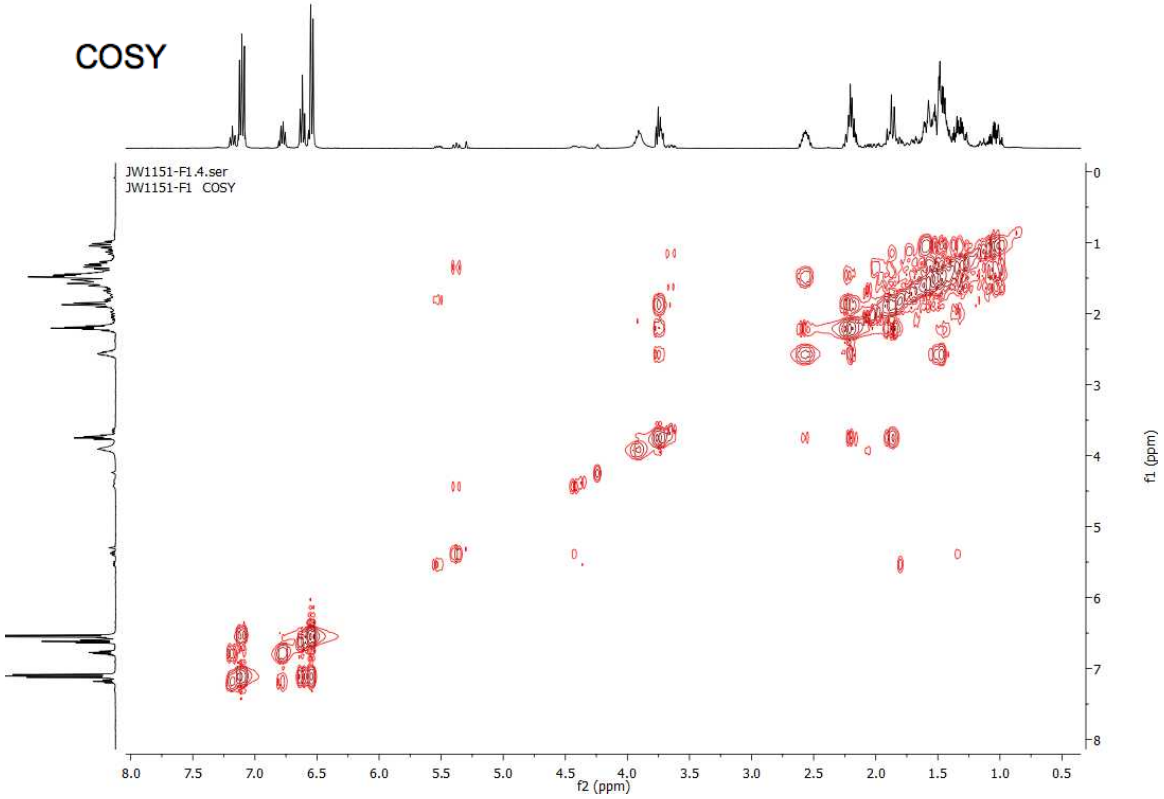

JW2073-F2.4.fid
JW2073-F2 C13
147.00
137.62
115.32
77.12
51.85
46.50
33.35
32.93
32.58
32.01
25.29
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


JW1151-F1.1.fid
JW1151 H1
H
N
7
8
H
6
H
1
2
5
3
4
1.82
0.85
1.97
1.16
1.06
1.00
2.28
1.39
3.27
3.70
1.36
0.99
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)
JW1151-F1.2.fid
JW1151-F1 C13
148.47
129.63
117.27
112.93
48.48
38.54
31.25
27.12
26.44
23.33
22.45
21.26
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

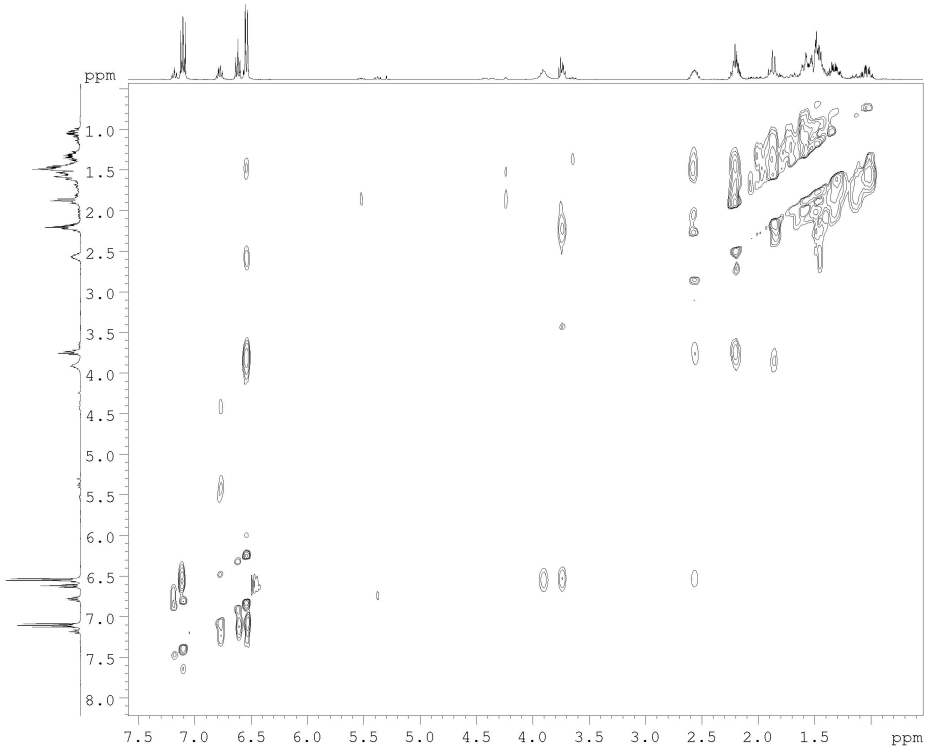
HSQC

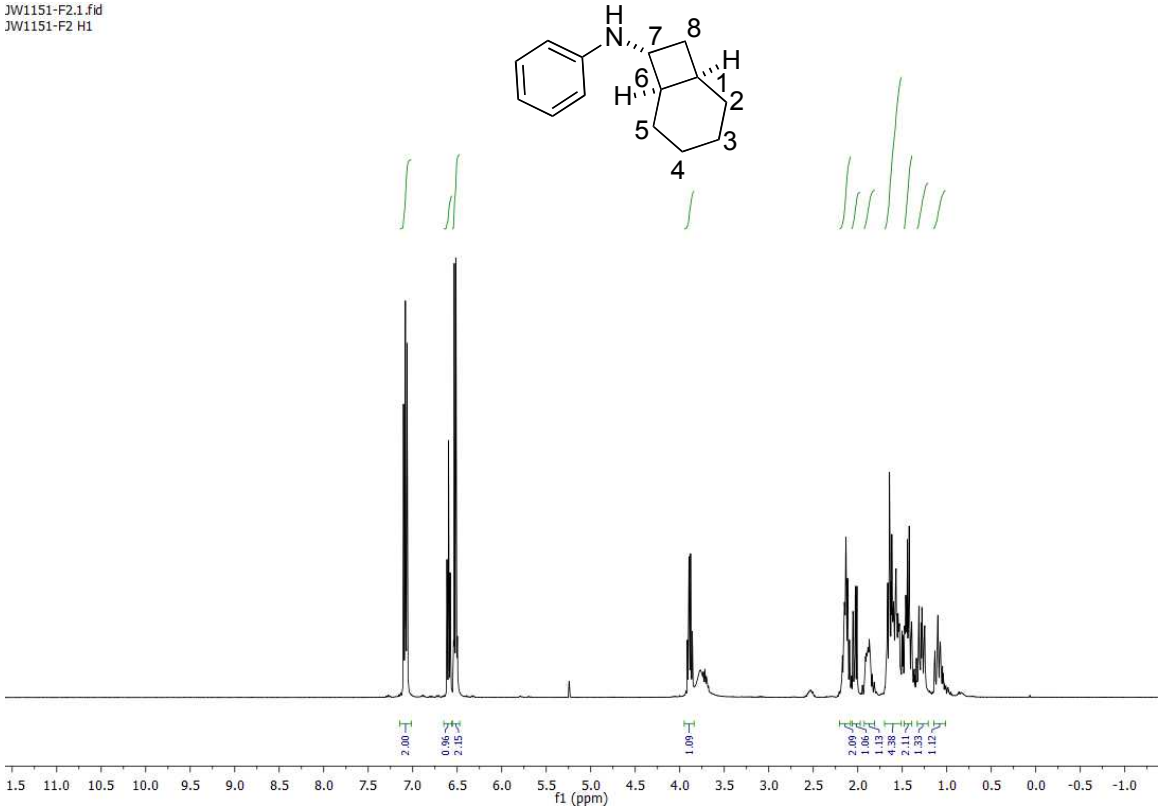

JW1151-F1.105.ser
JW1151-F1 HSQC
f2 (ppm)
f1 (ppm)

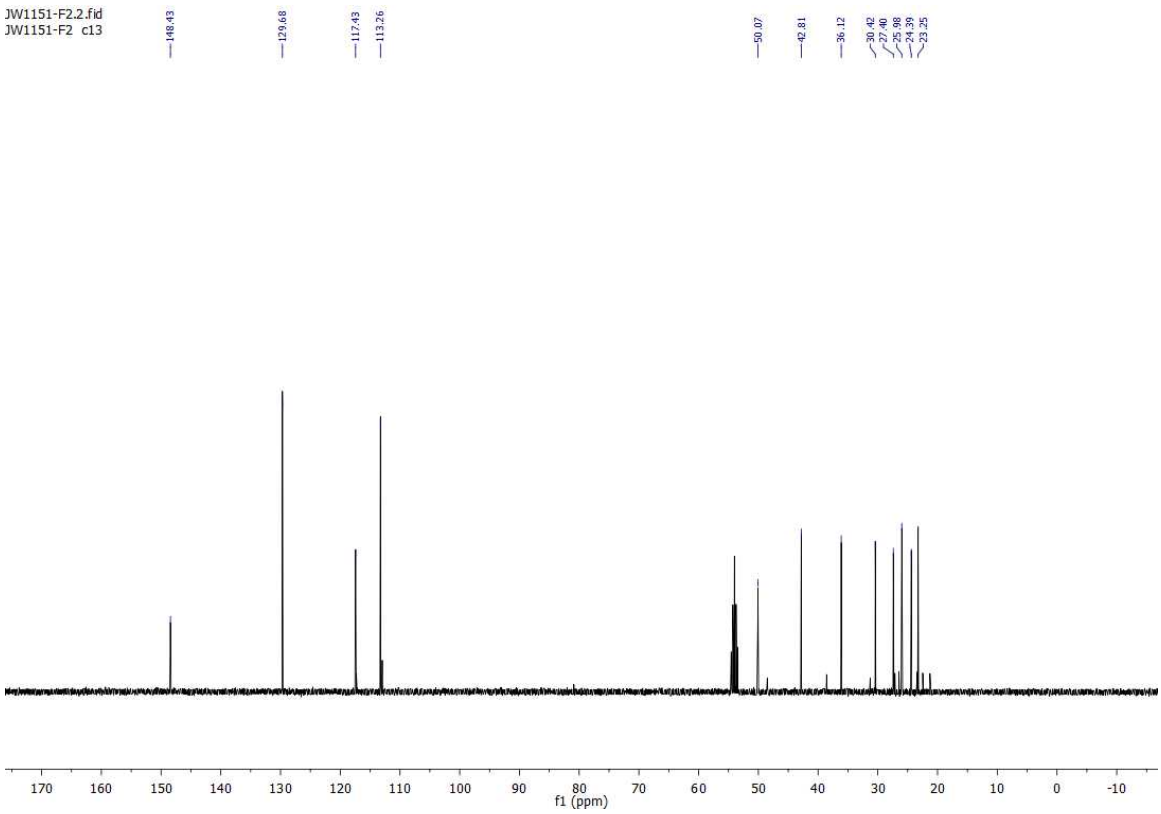
COSY

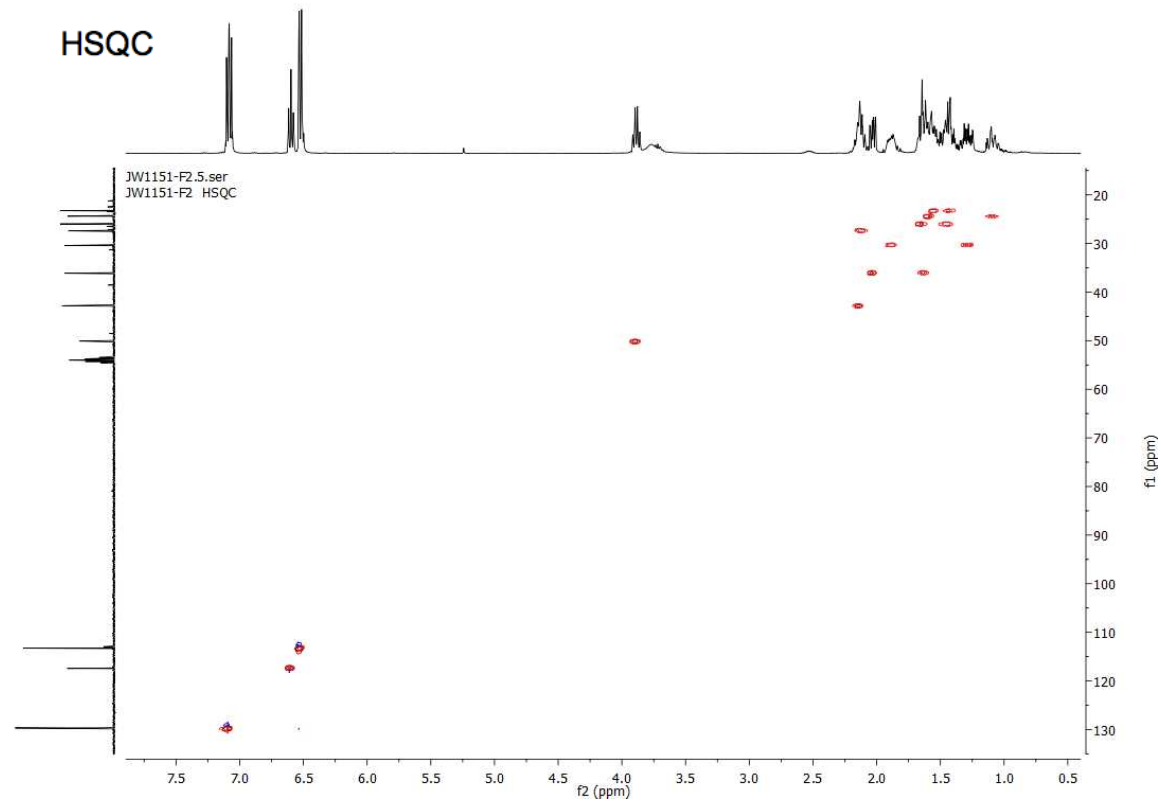

JW1151-F1.4.ser
JW1151-F1 COSY
f2 (ppm)
f1 (ppm)

NOESY

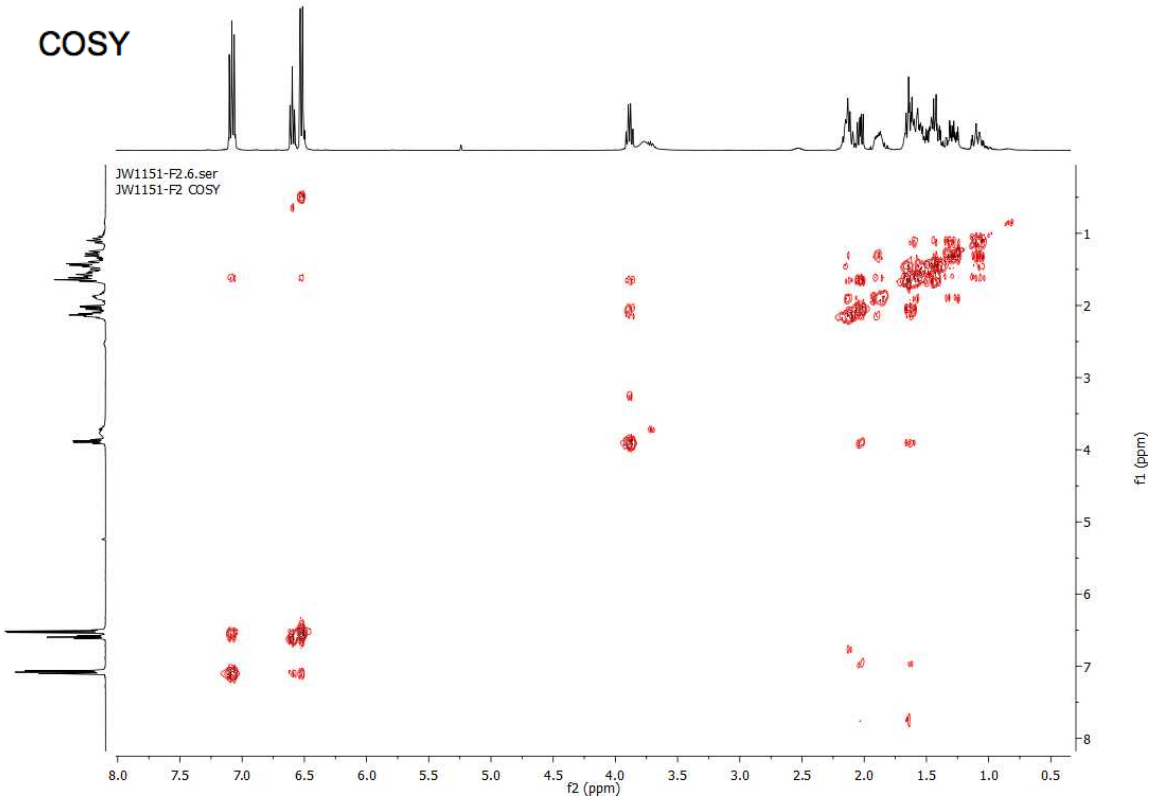

ppm
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 ppm


JW1151-F2.1.fid
JW1151-F2 H1
H
N
7
8
H
1
2
3
4
5
6
H
2.00
0.96
2.15
1.09
2.09
1.06
1.13
4.38
2.11
1.33
1.12
1.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

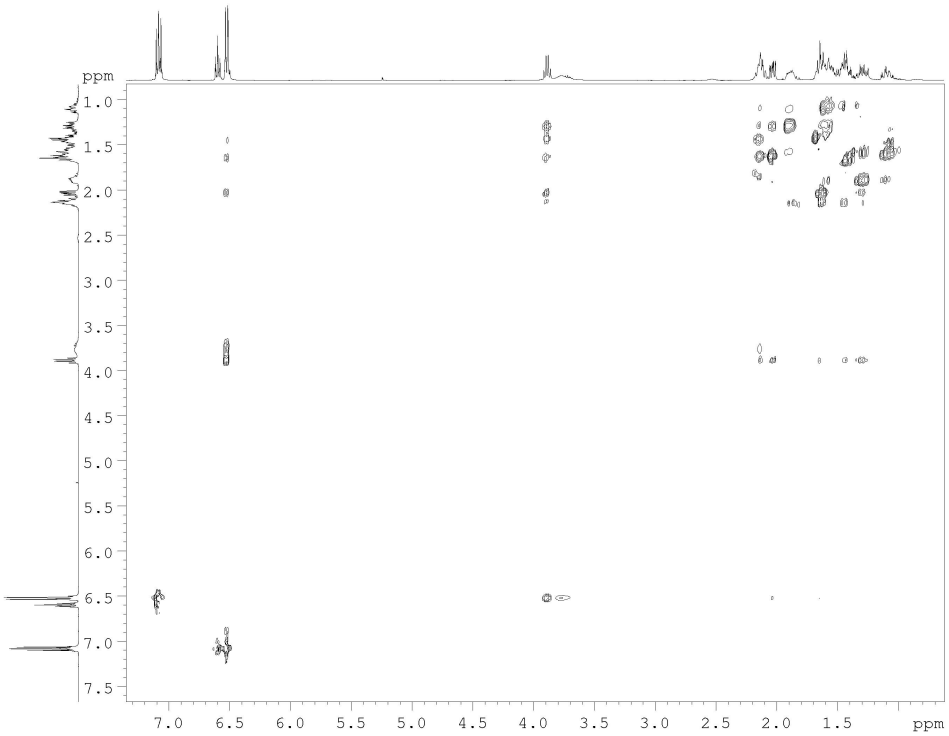

JW1151-F2.2.fid
JW1151-F2 c13
148.43
129.68
117.43
113.26
50.07
42.81
36.12
30.42
27.46
25.98
24.39
23.25
f1 (ppm)

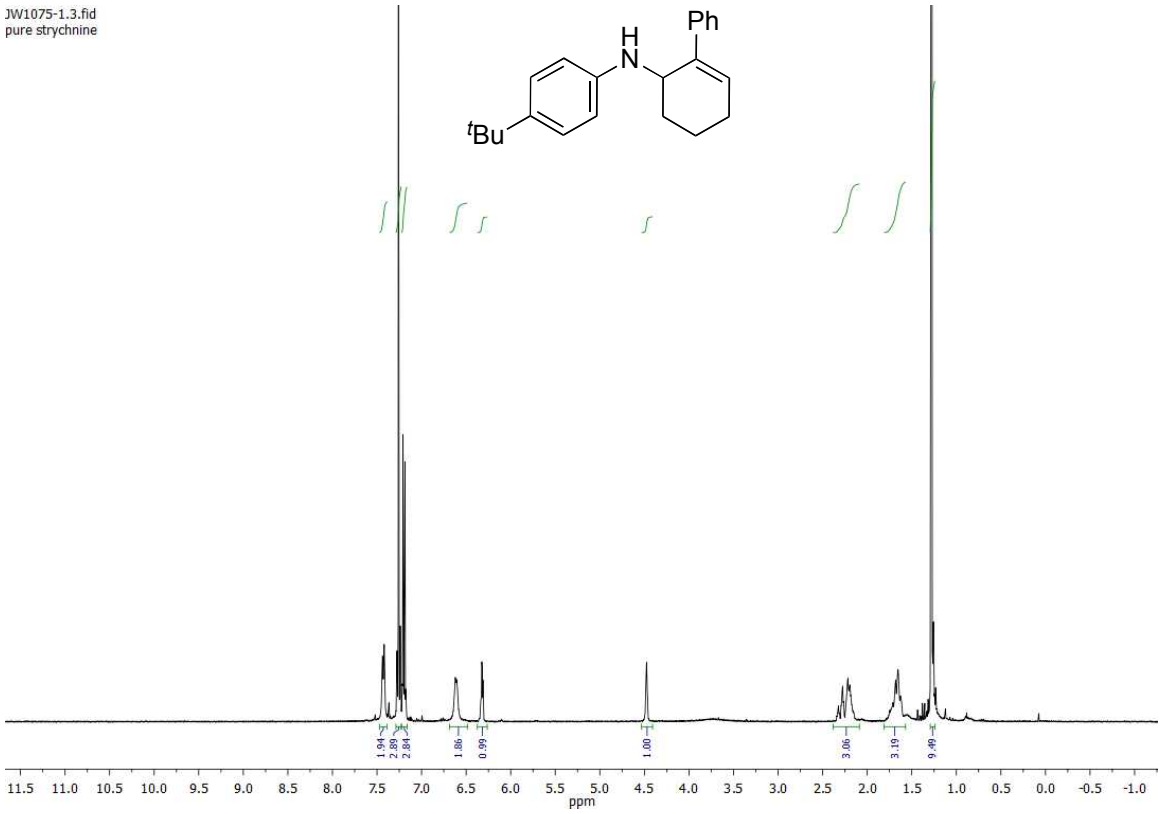

HSQC
JW1151-F2.5.ser
JW1151-F2 HSQC
f2 (ppm)
f1 (ppm)

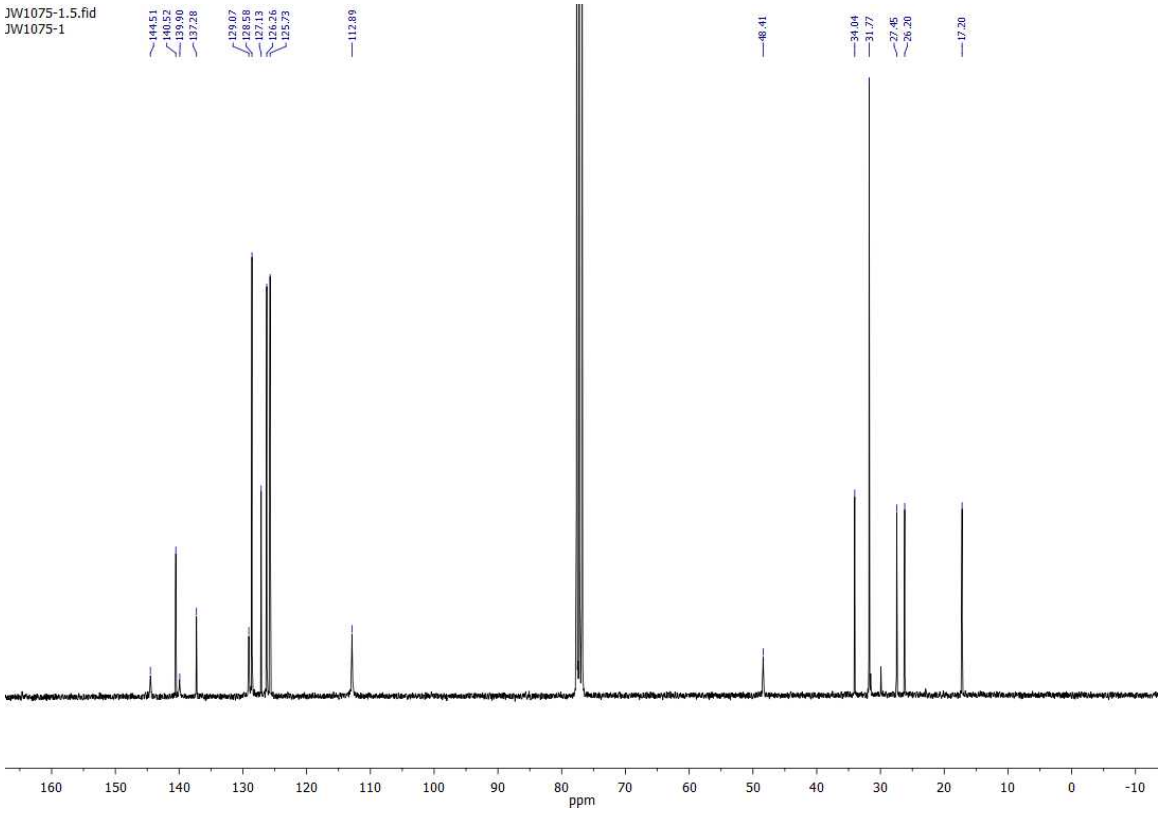
COSY



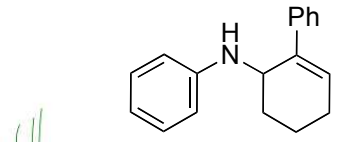
NOESY

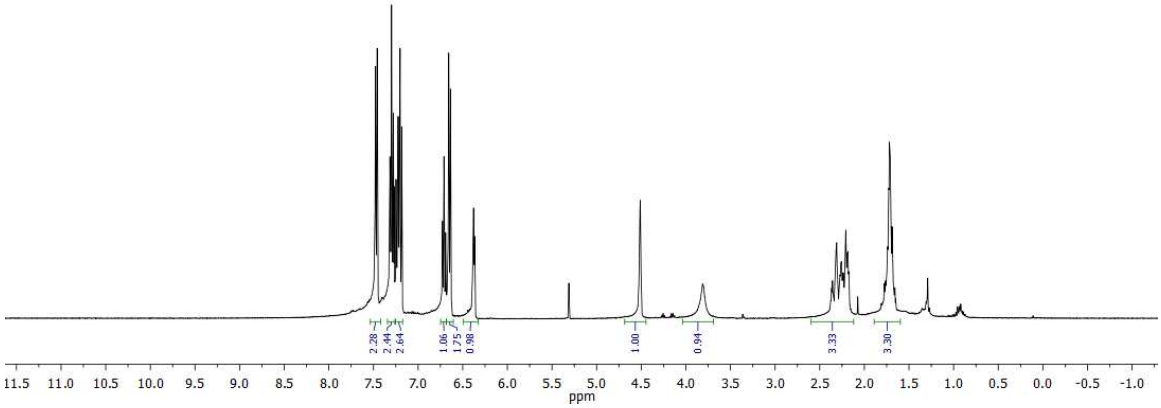



JW1075-1.3.fid
pure strychnine
Ph
H
N
tBu
1.94
2.00
2.84
1.86
0.99
1.00
3.06
3.19
9.49
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm

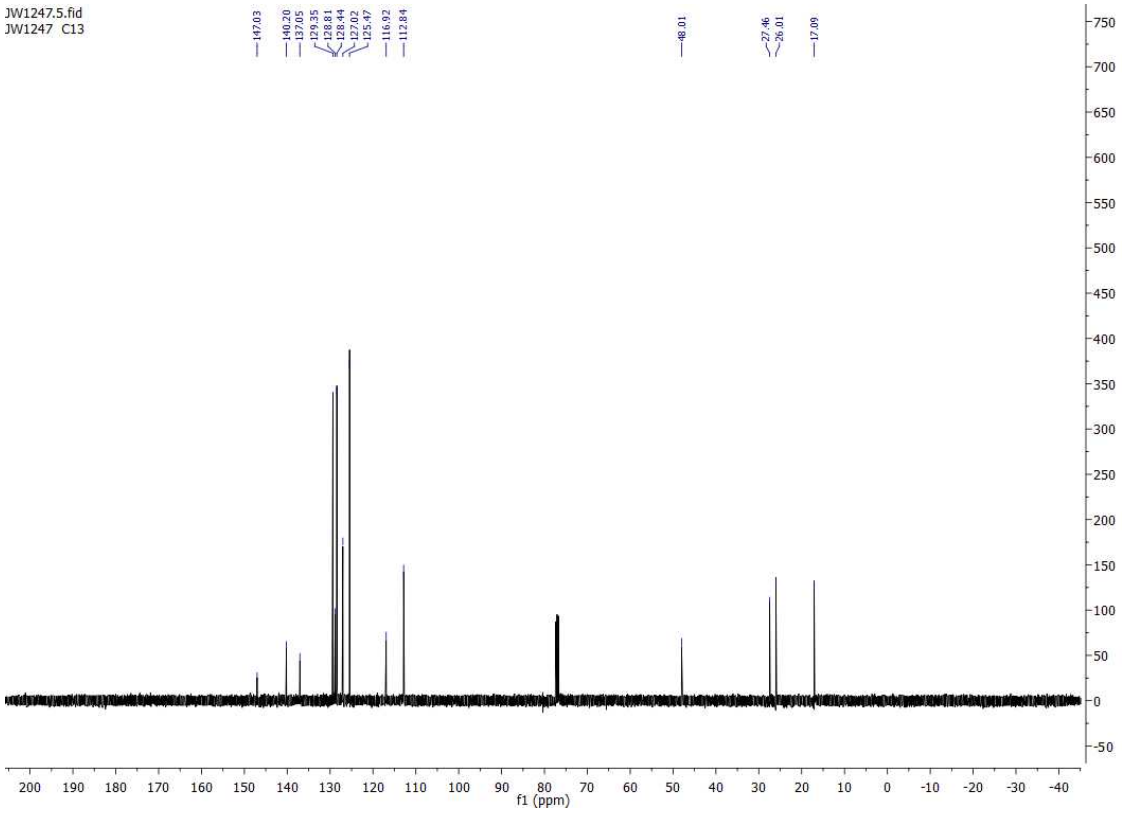

JW1075-1.5.fid
JW1075-1
144.51
140.52
139.90
137.28
129.07
128.58
127.13
126.26
125.73
112.89
48.41
34.04
31.77
27.45
26.20
17.20
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

JW1247.4.fid
JW1247 H1

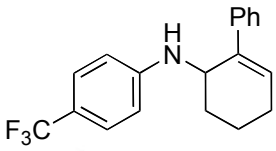


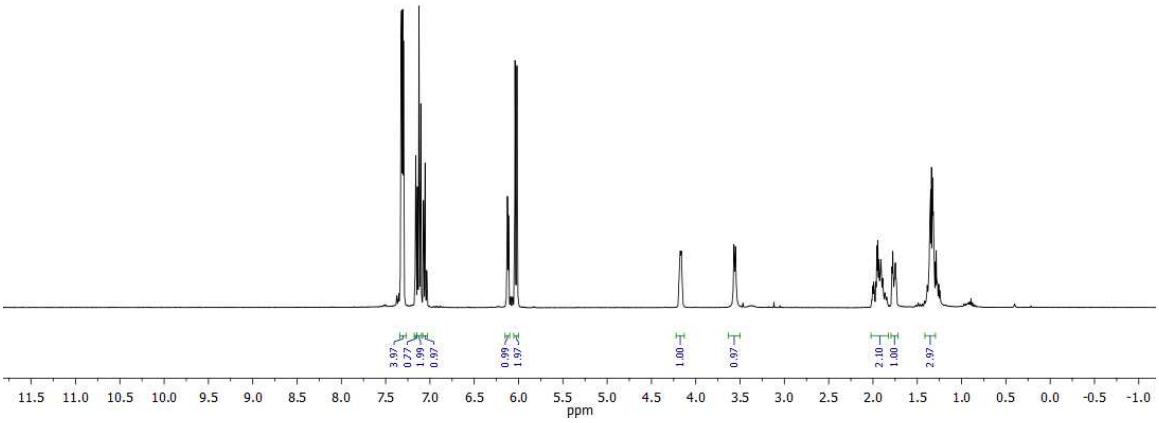


JW1247.5.fid
JW1247 C13

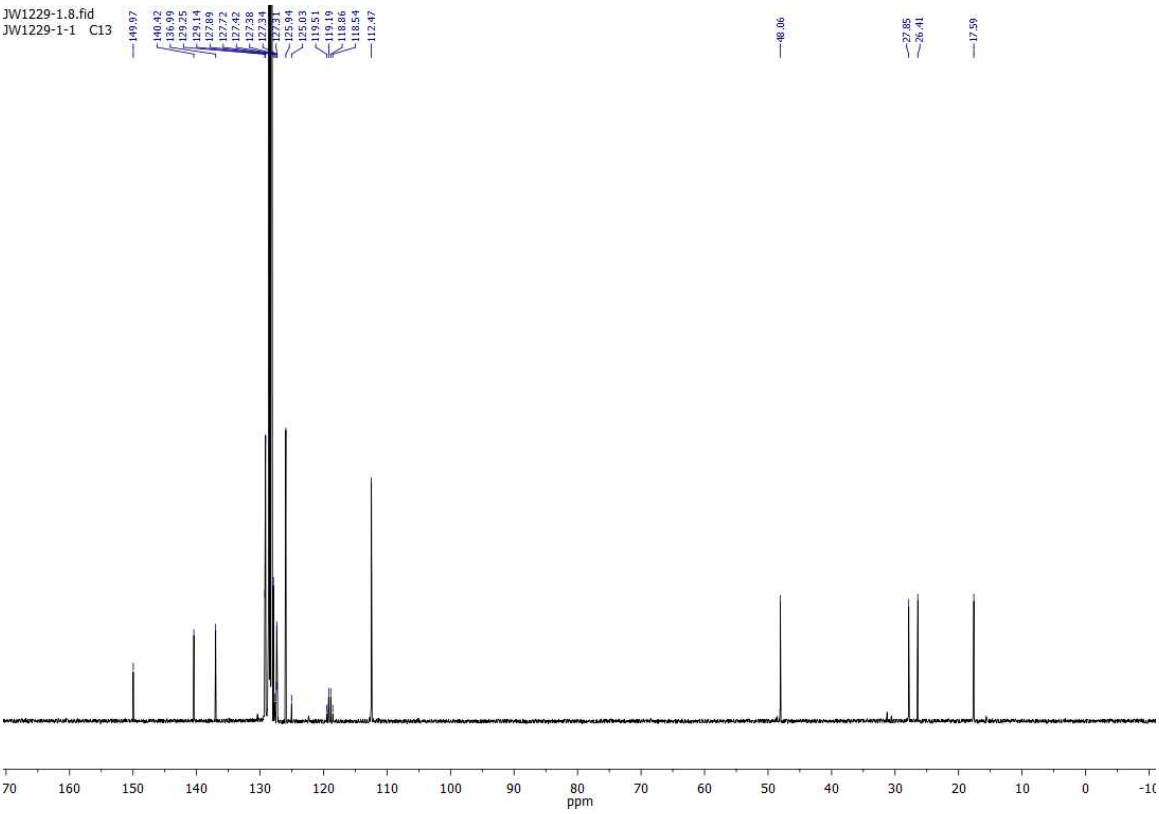


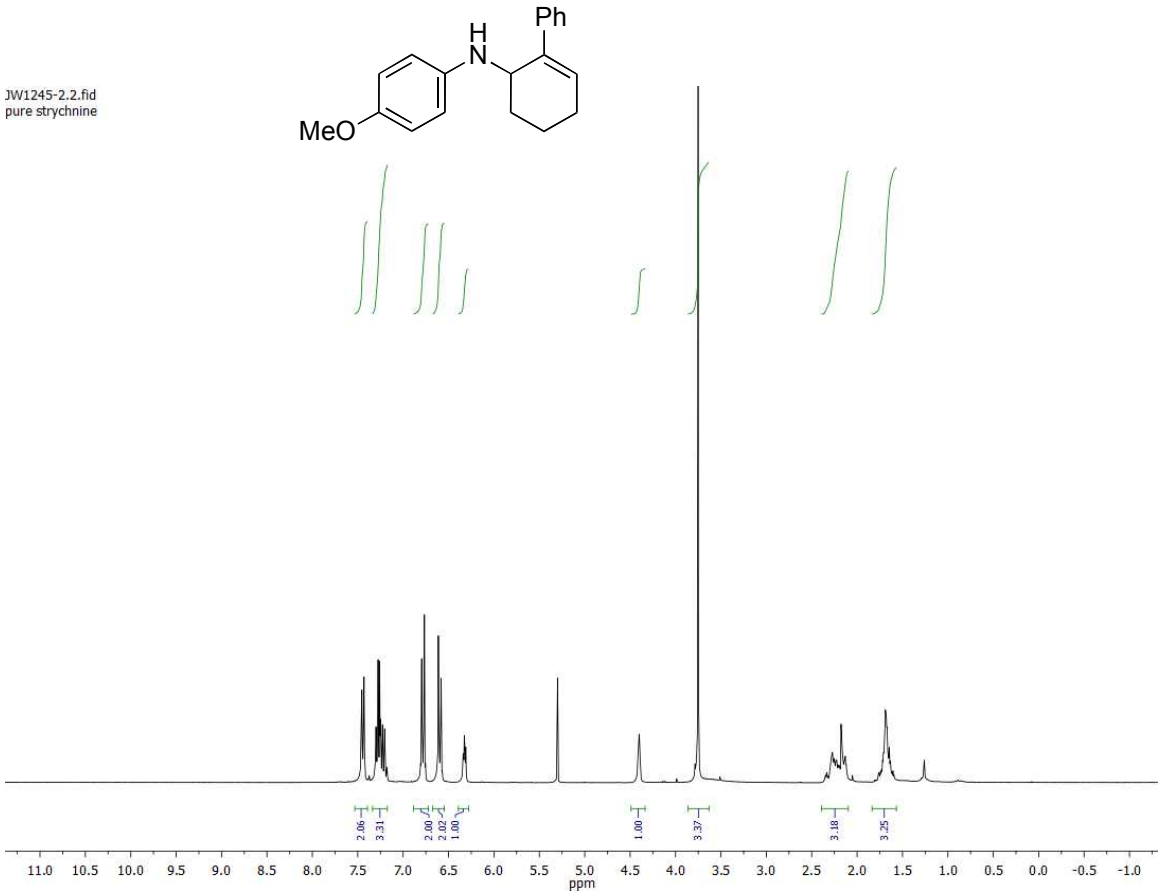
JW1229-1.7.fid
JW1229-1-1 H1

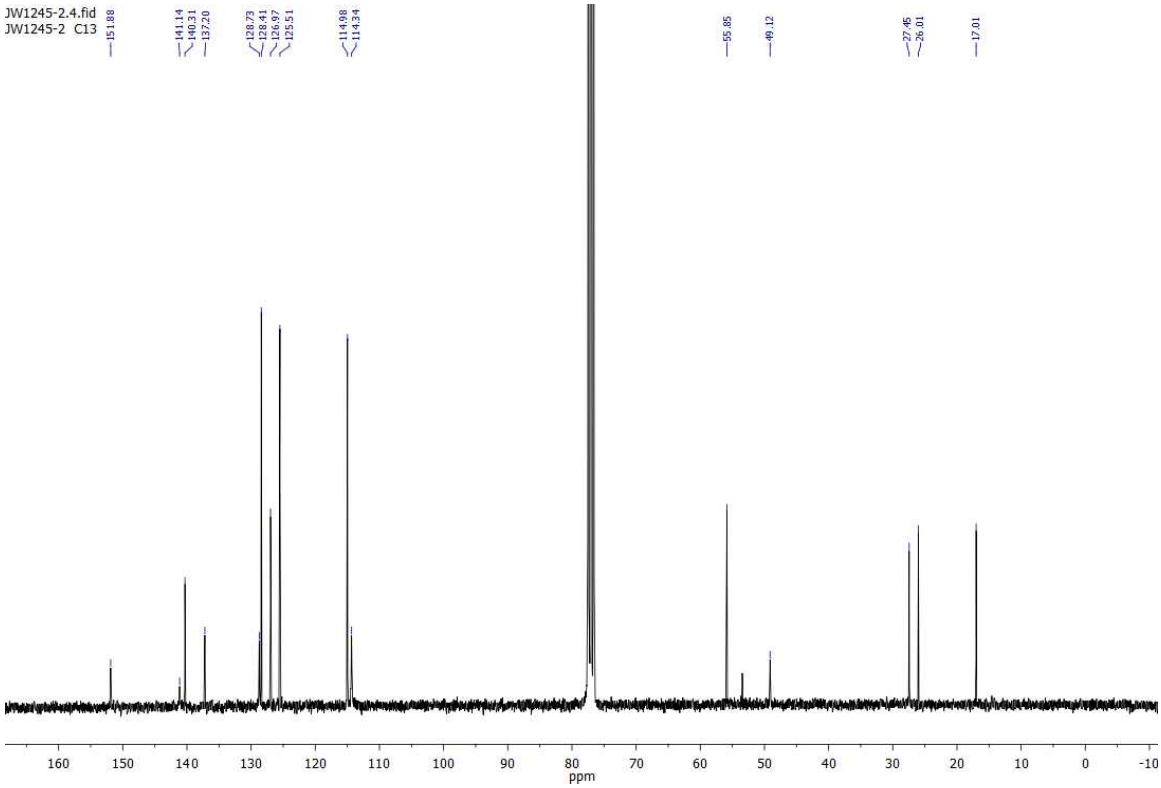




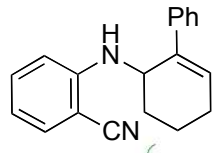
JW1229-1.8.fid
JW1229-1-1 C13

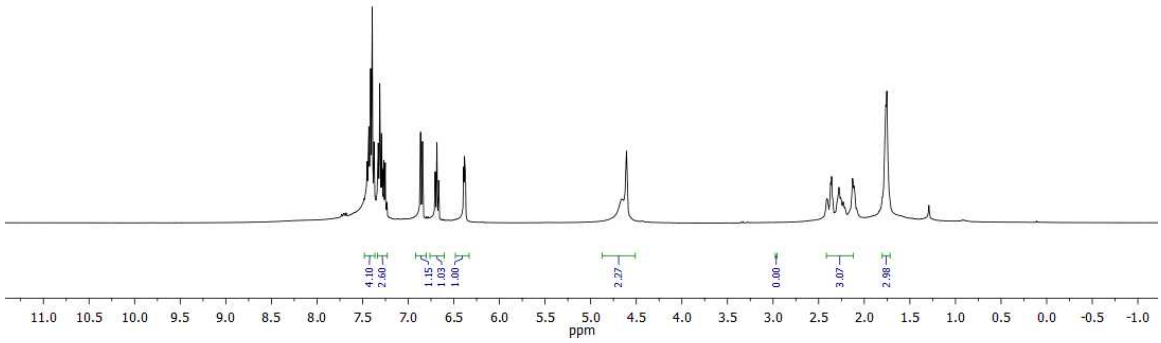



JW1245-2.2.fid
pure strychnine
Ph
H
N
MeO
2.06
3.31
2.00
2.02
1.00
1.00
3.37
3.18
3.25
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm

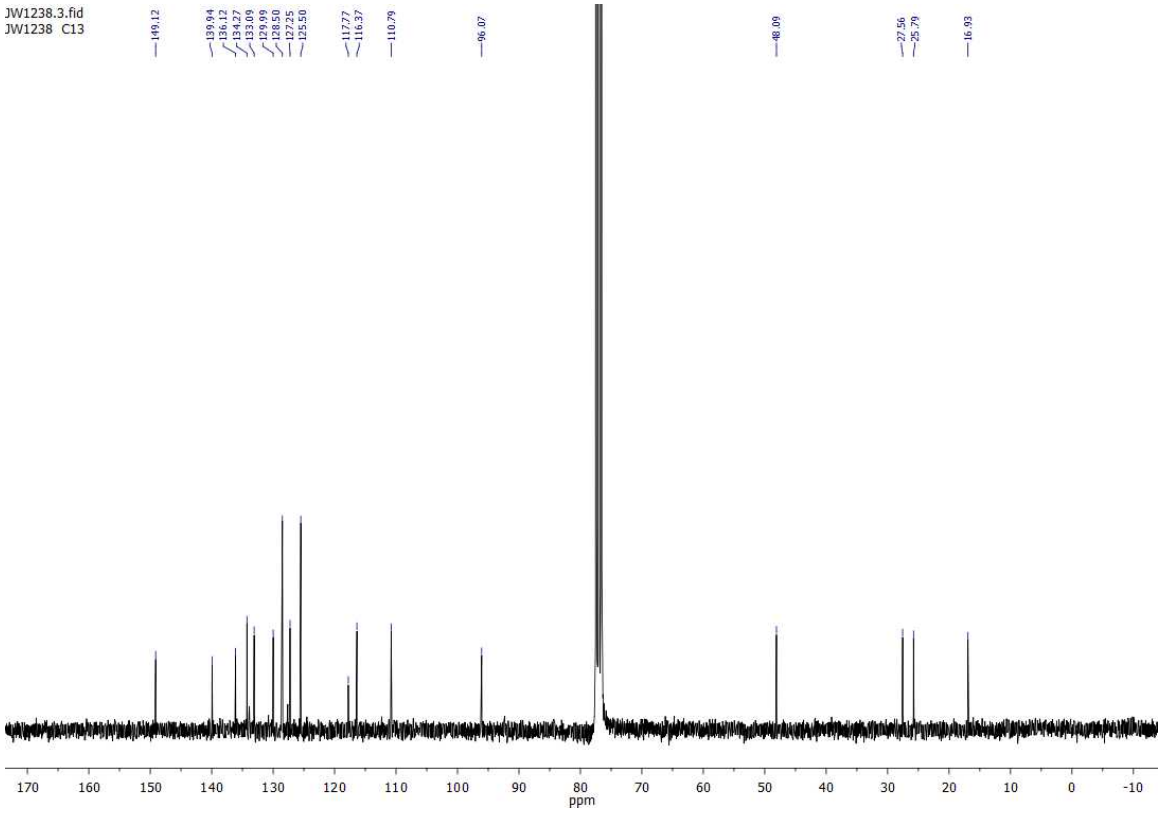

JW1245-2.4.fid
JW1245-2 C13
151.88
141.14
140.31
137.20
128.73
128.41
126.97
125.51
114.98
114.34
55.85
49.12
27.45
26.01
17.01
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

JW1238.5.fid
JW1238 H1

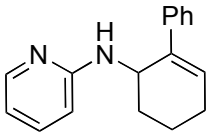


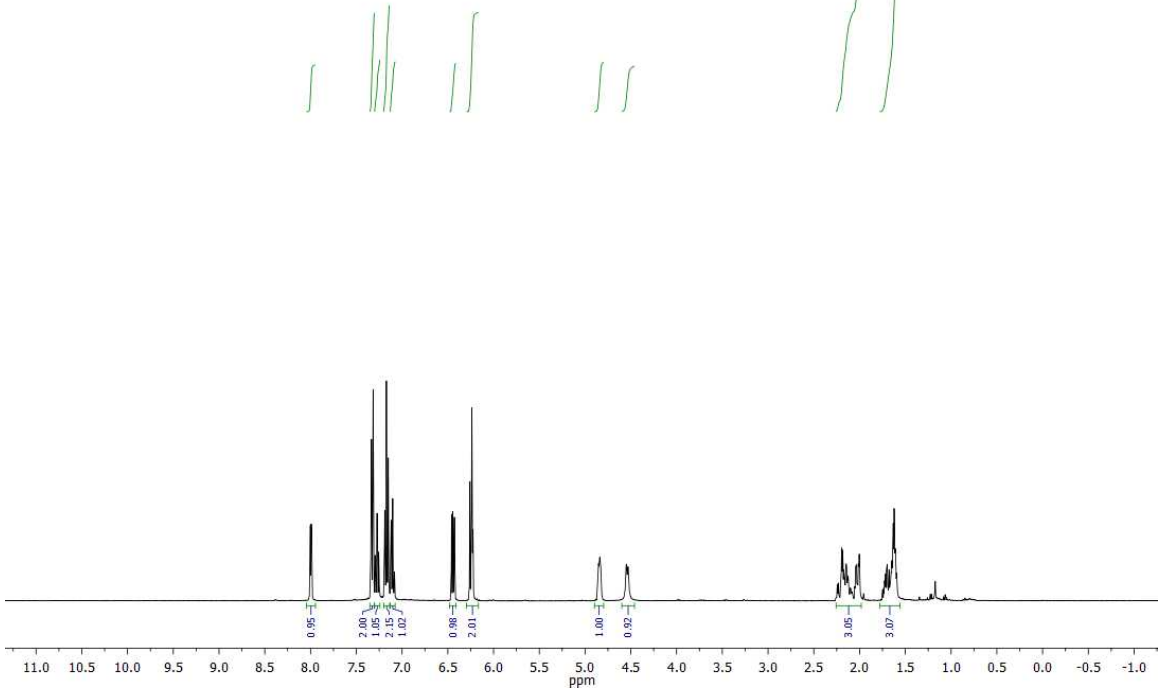


JW1238.3.fid
JW1238 C13



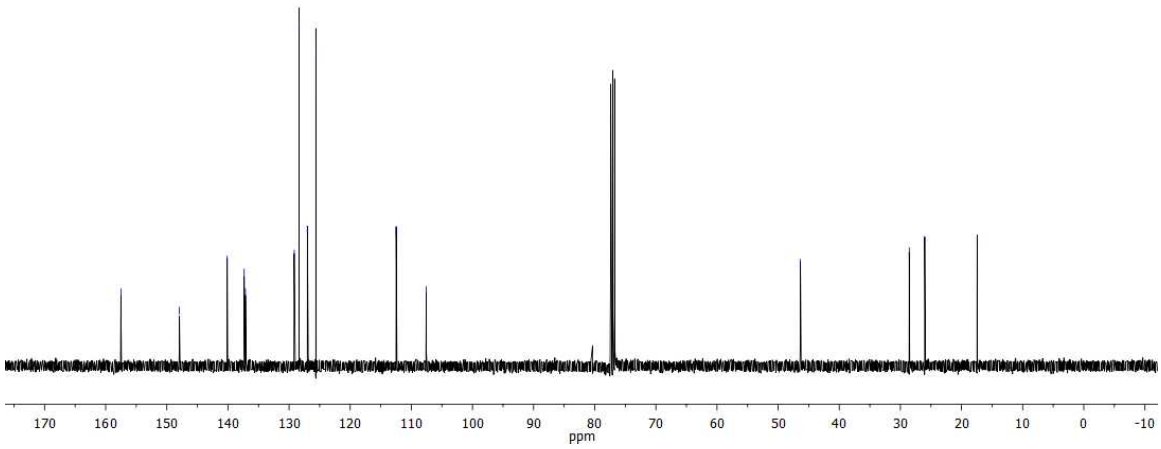
JW1299.1.fid
JW1299 H1



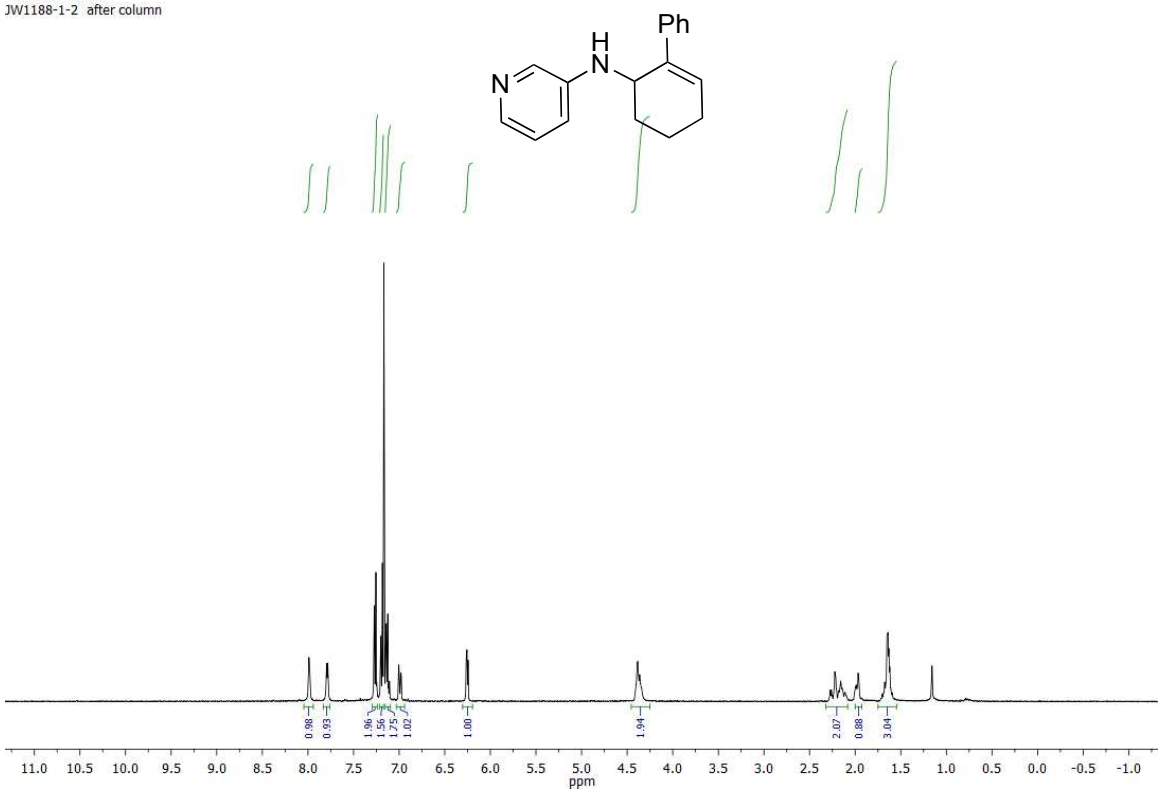


JW1299.2.fid
JW1299 C13

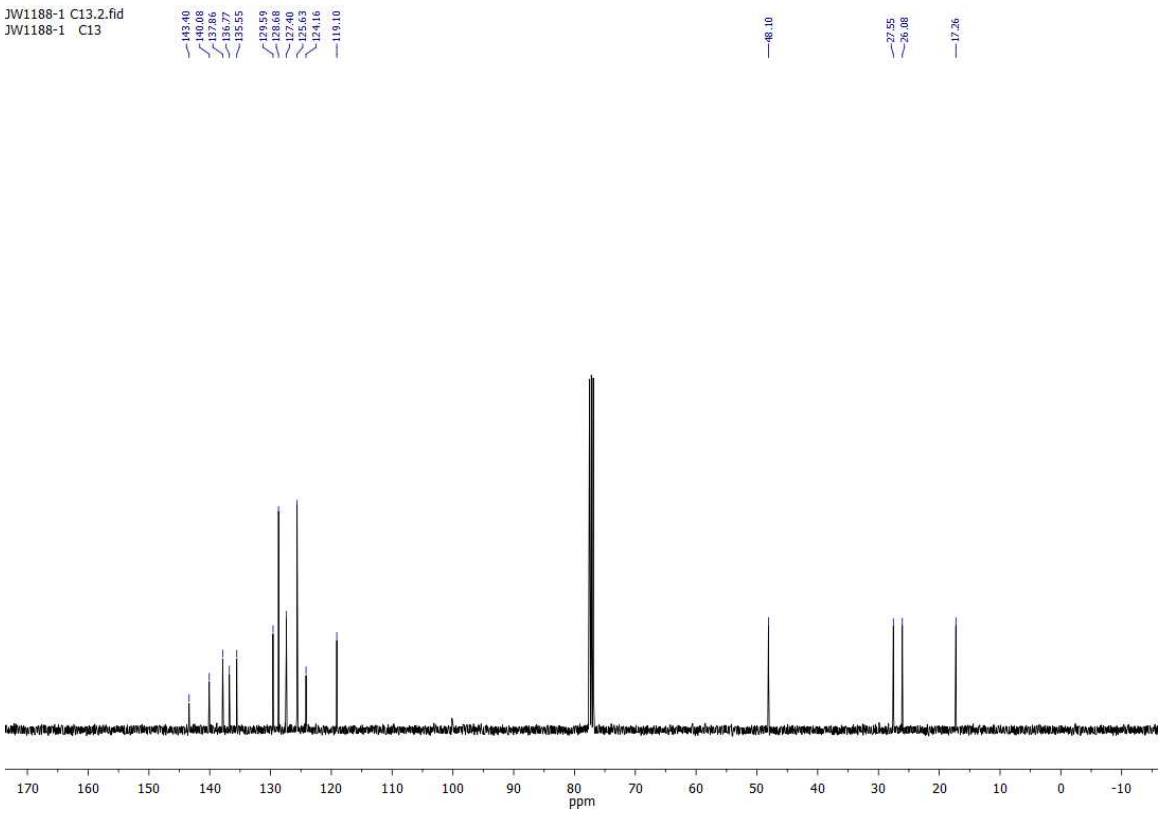
157.51
147.93
140.12
137.34
137.13
129.16
128.37
127.01
125.61
112.48
107.56
46.35
28.55
26.02
17.44

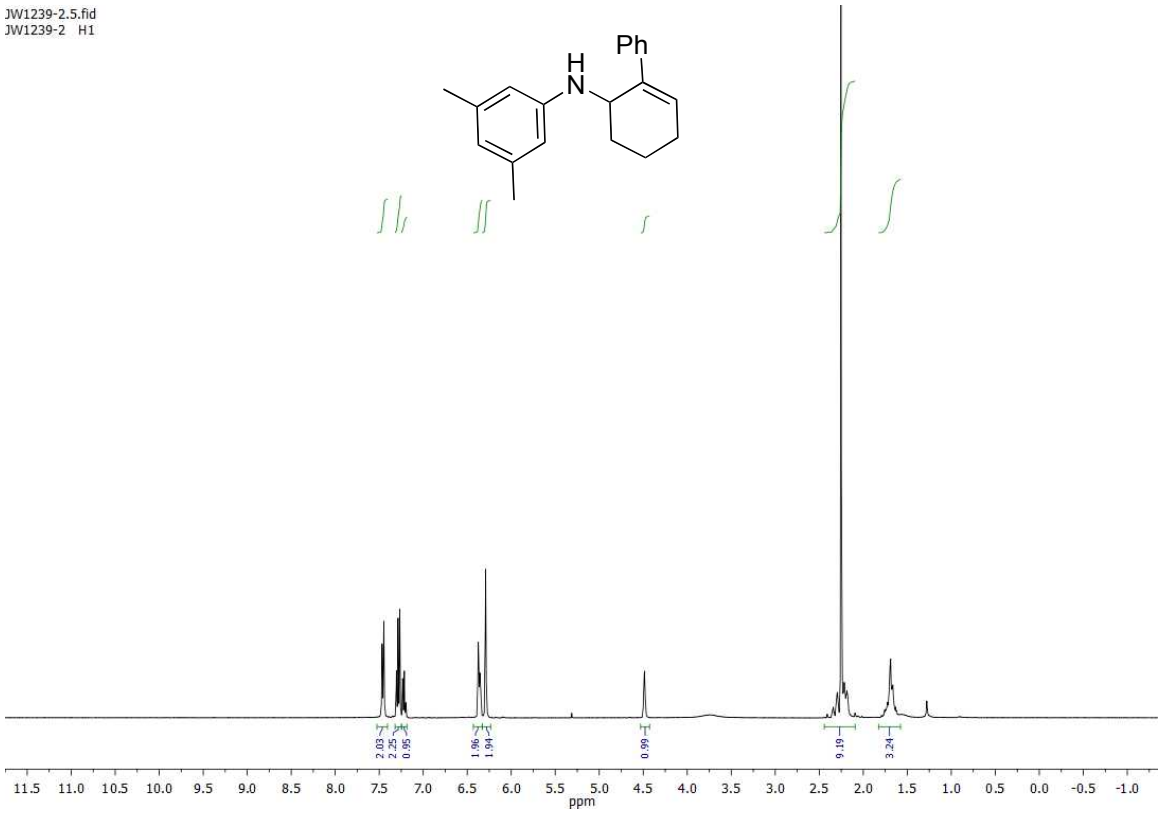


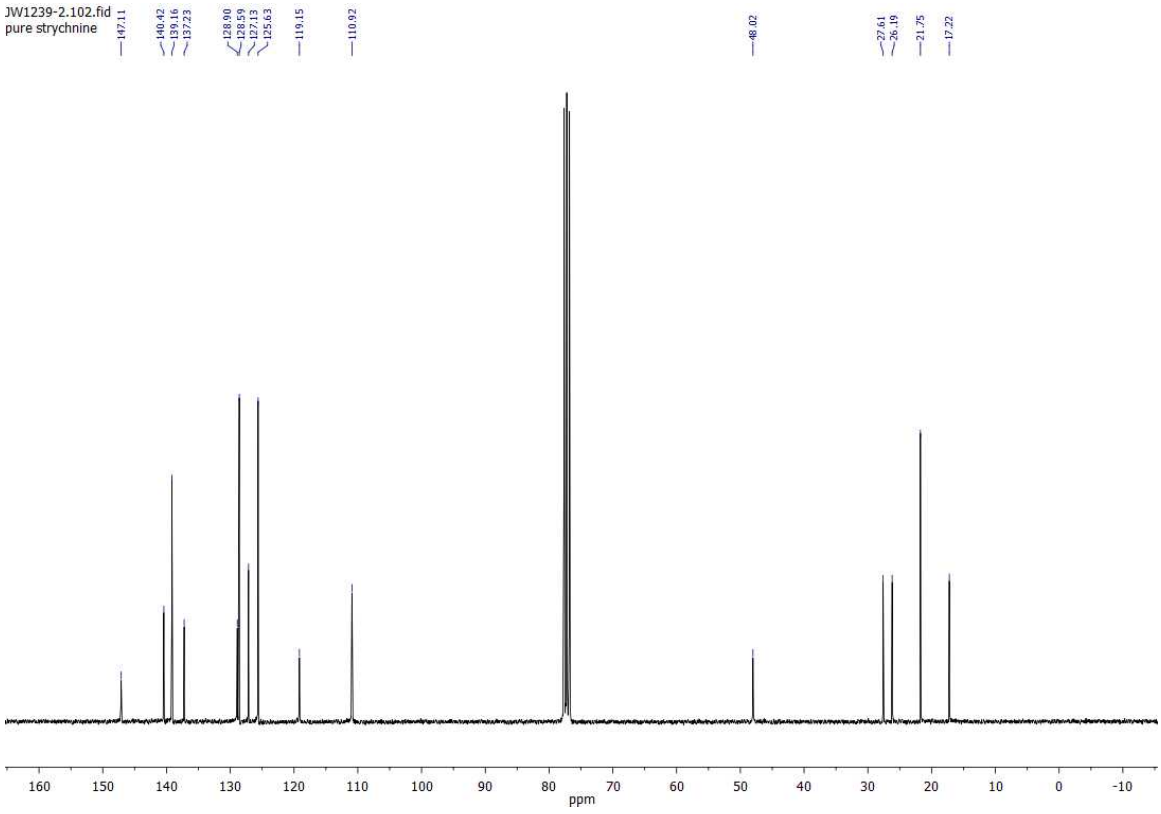
JW1188-1-2.1.fid
JW1188-1-2 after column



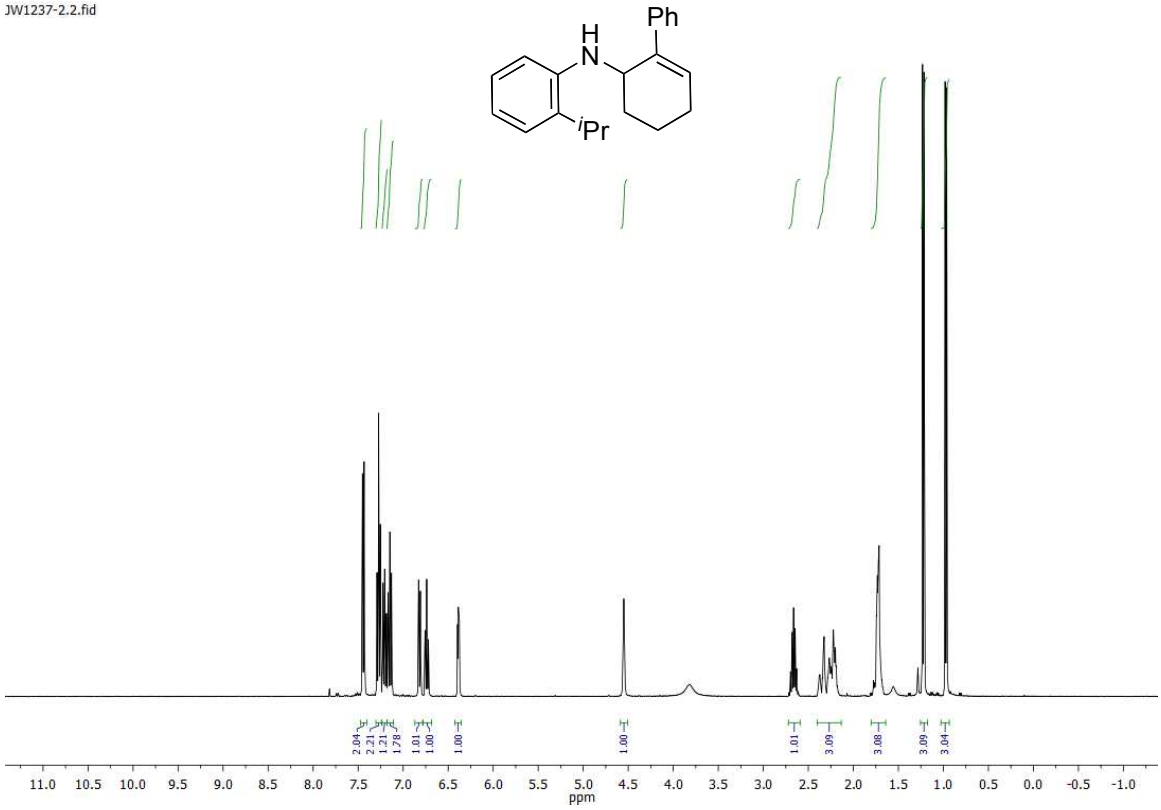
JW1188-1 C13.2.fid
JW1188-1 C13

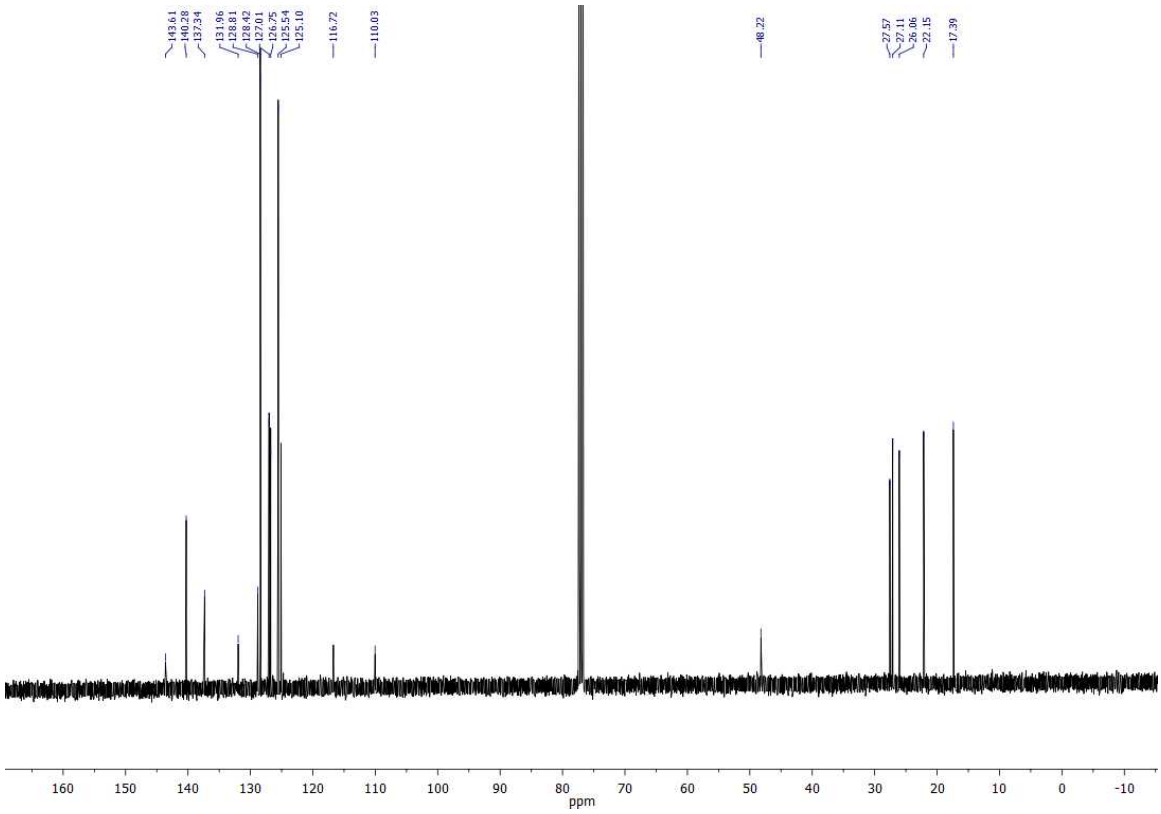



JW1239-2.5.fid
JW1239-2 H1
Ph
H
N
2.03
2.25
0.95
1.96
1.94
0.99
9.19
3.24
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm

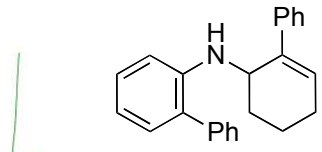

JW1239-2.102.fid
pure strychnine
147.11
140.42
139.16
137.23
128.90
128.59
127.73
125.63
119.15
110.92
48.02
27.61
26.19
21.75
17.22
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

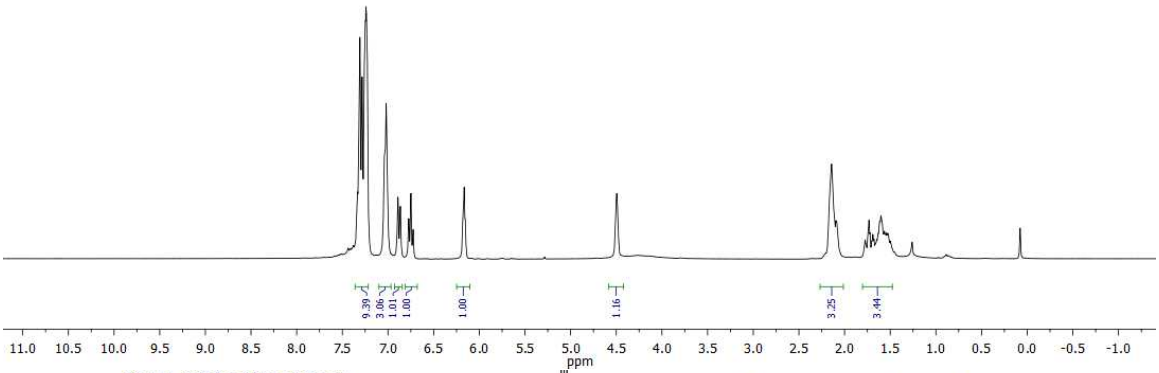
JW1237-2.2.fid

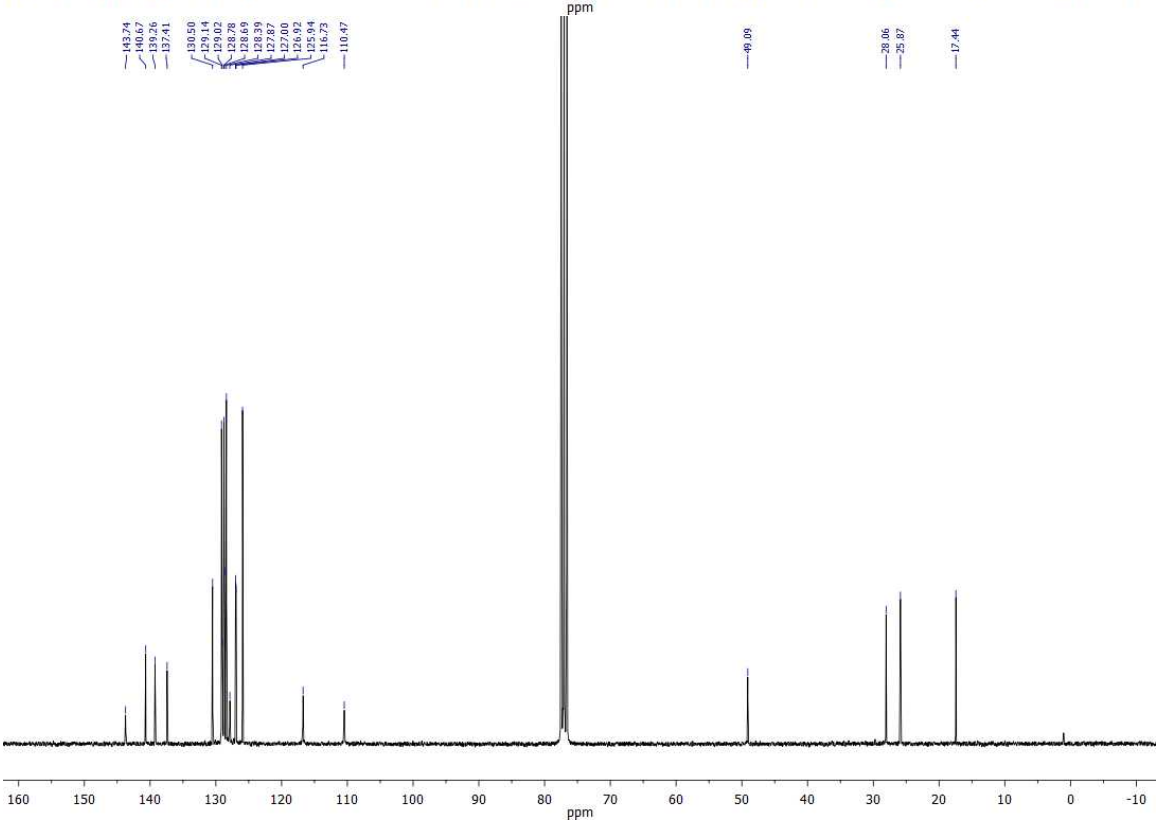


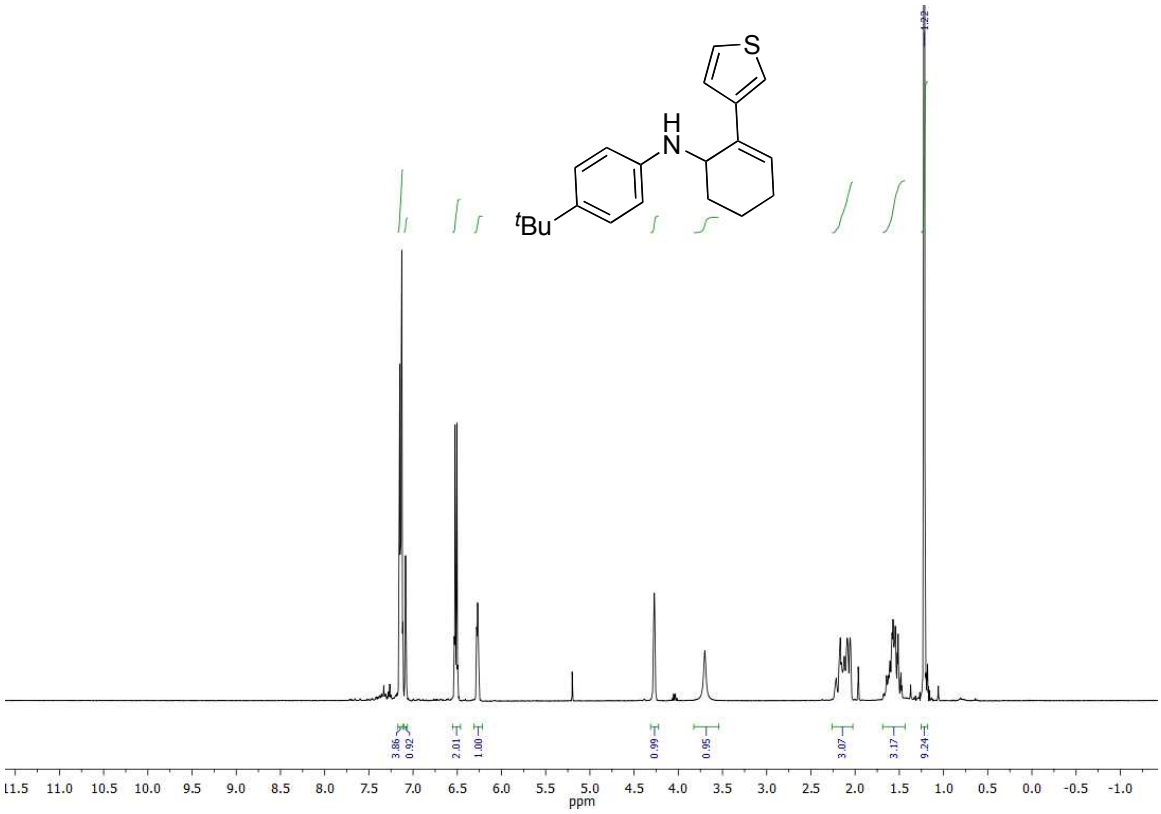


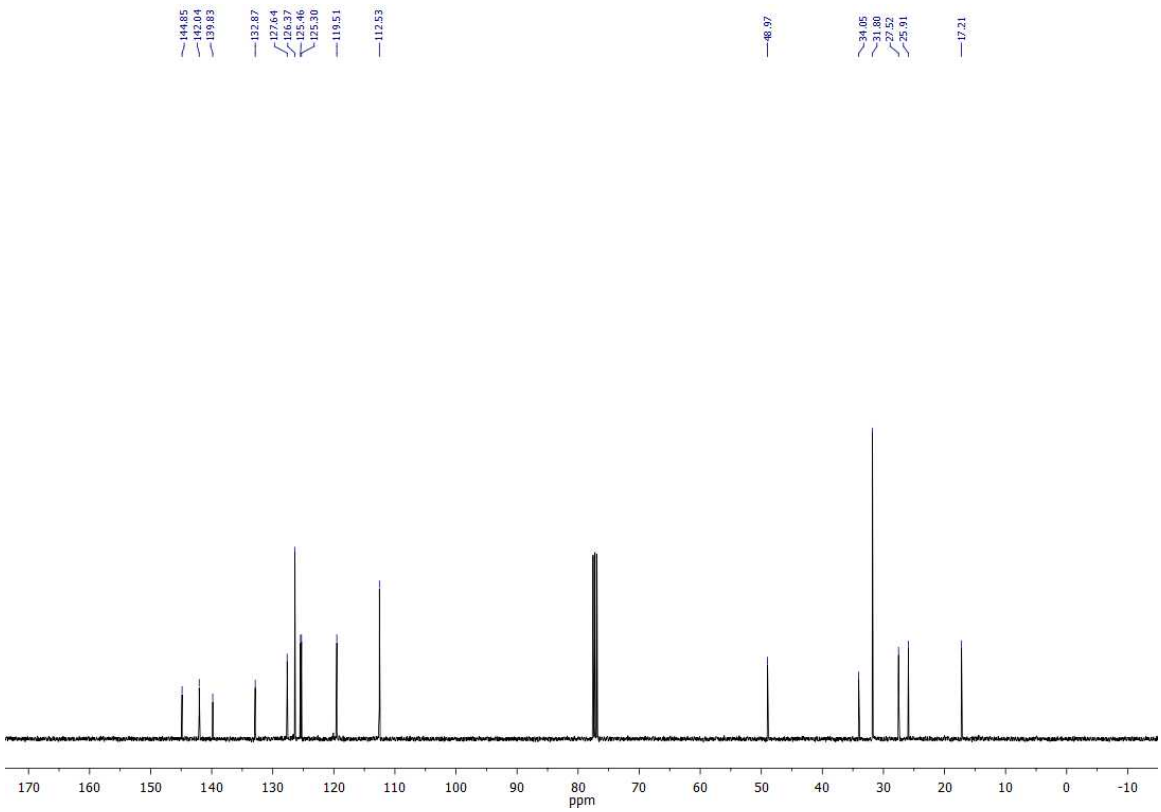
JW1184-1-2.1.fid
JW1184-1-2 after column

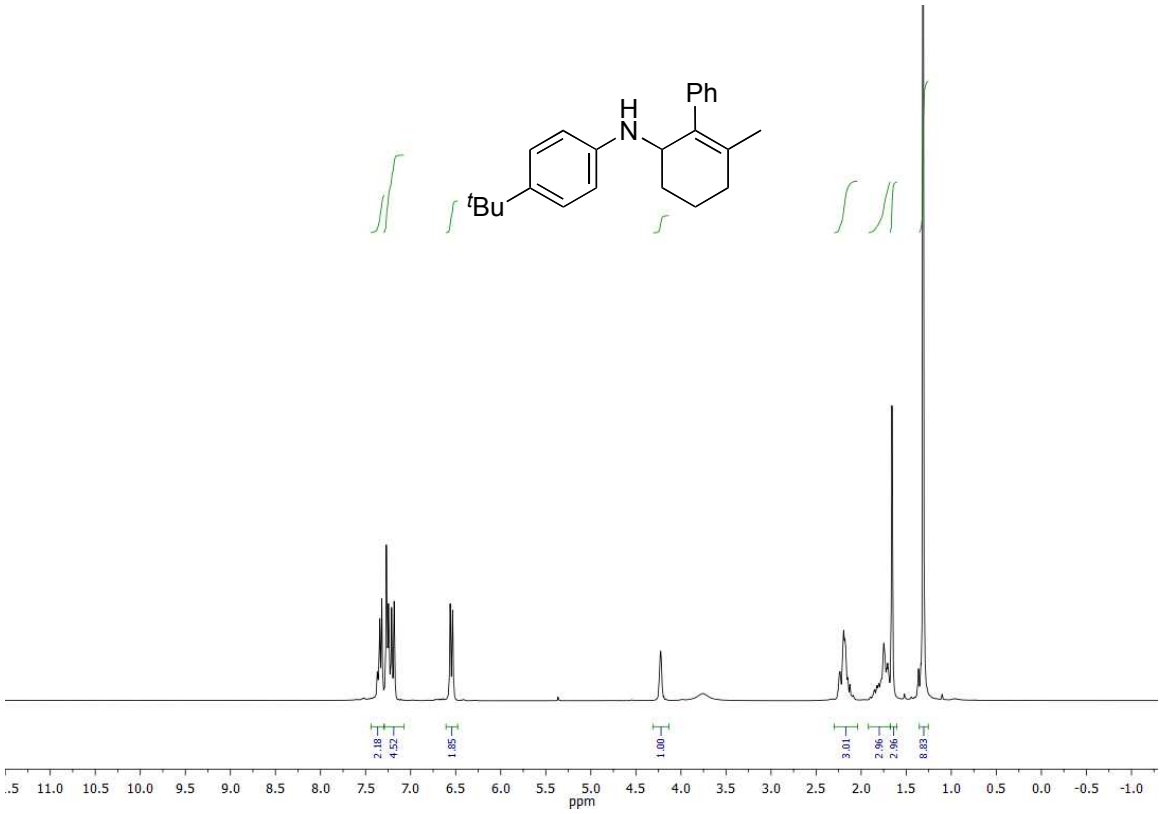


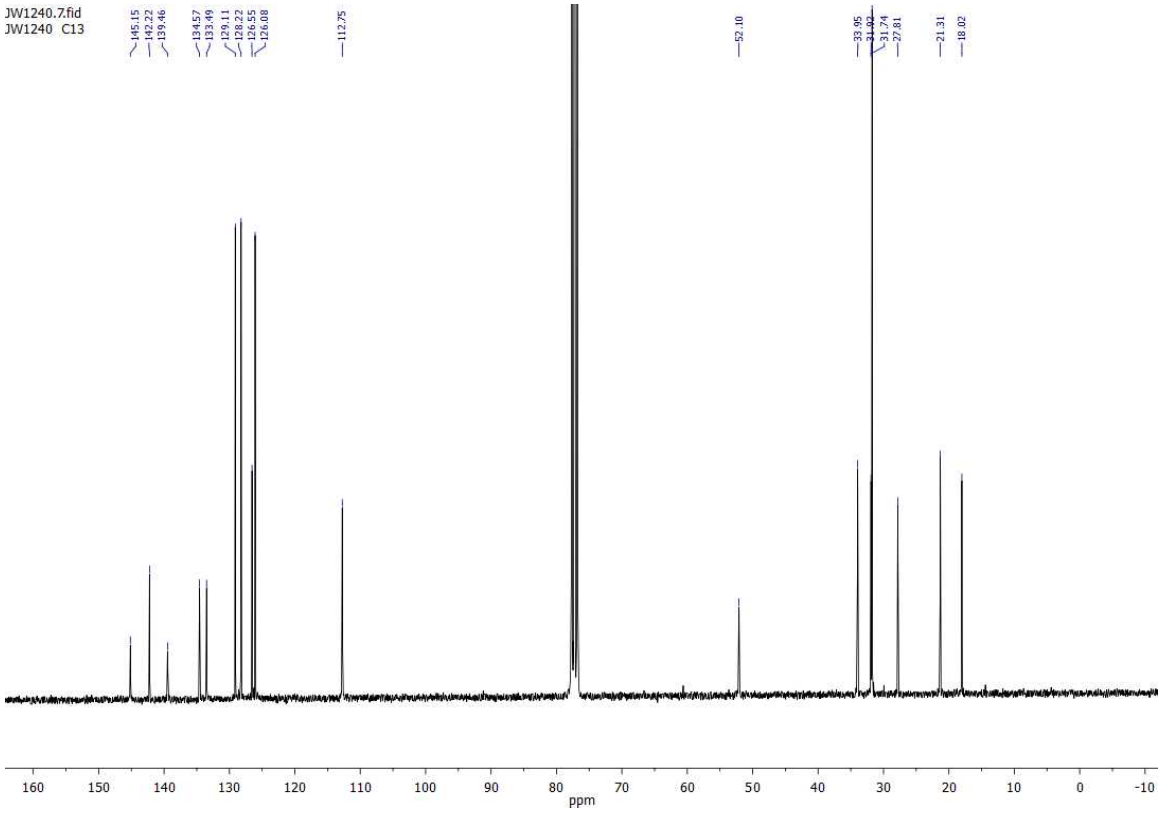


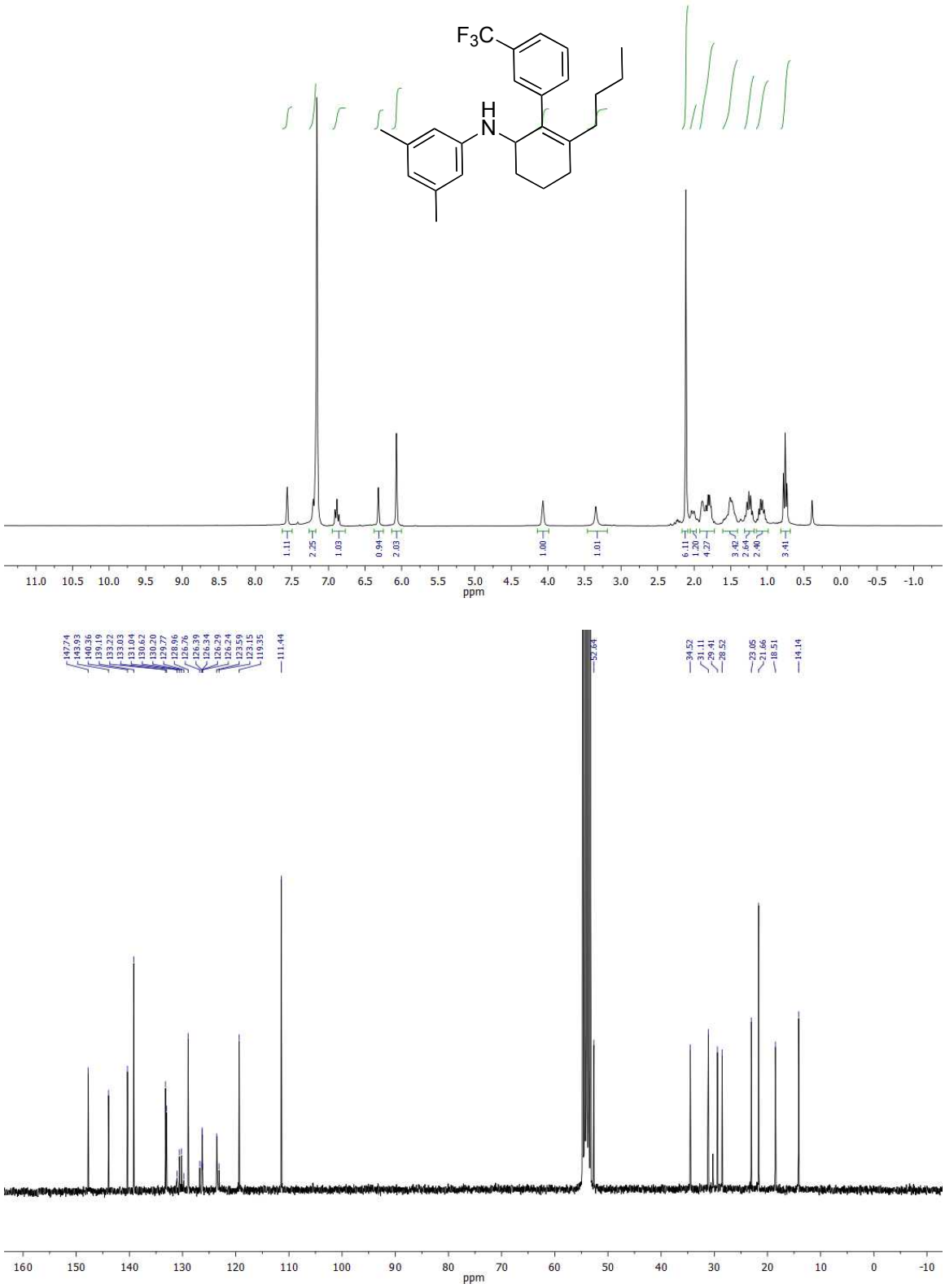


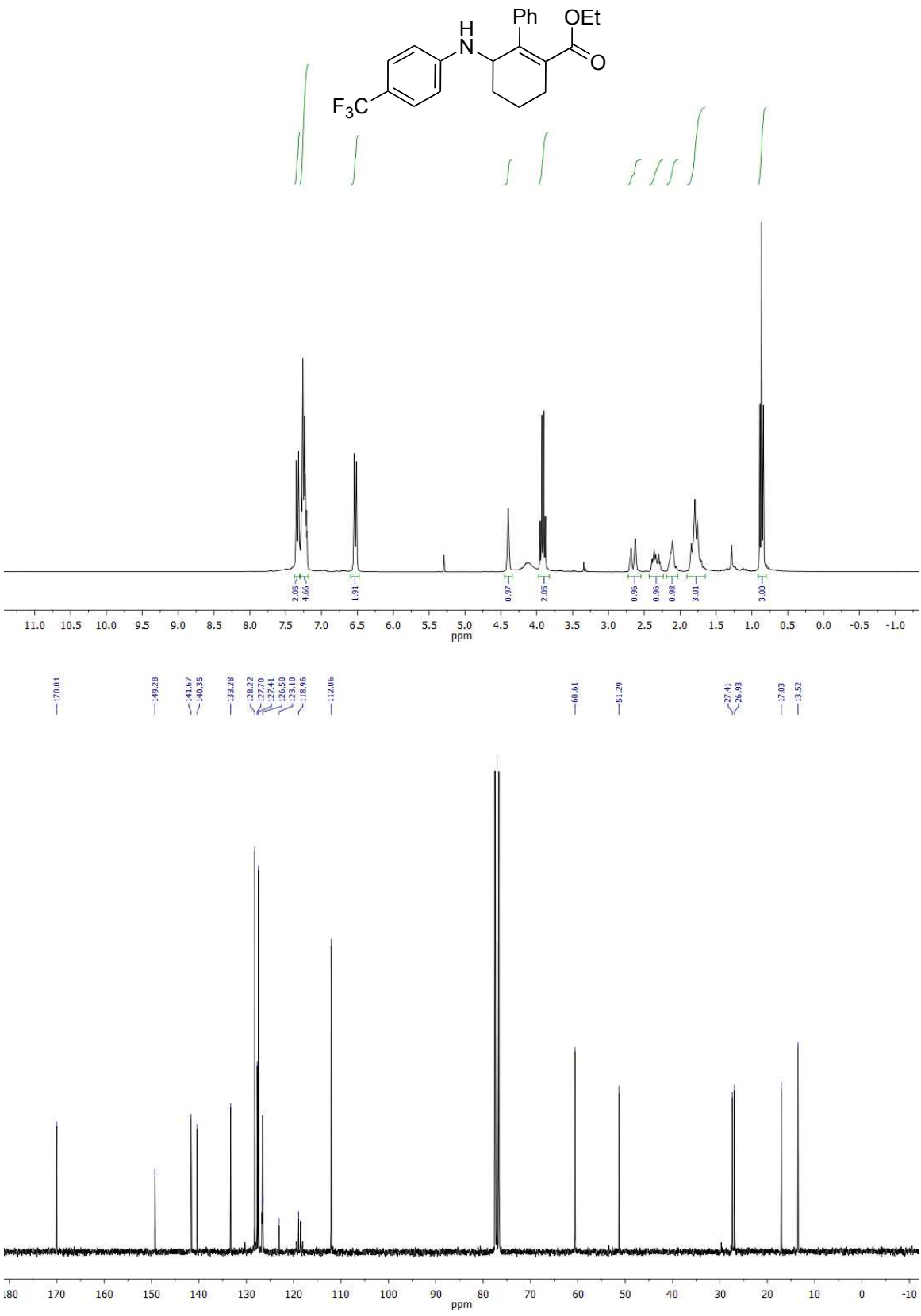

S
H
N
tBu
3.86
0.92
2.01
1.00
0.99
0.95
3.07
3.17
9.24
ppm

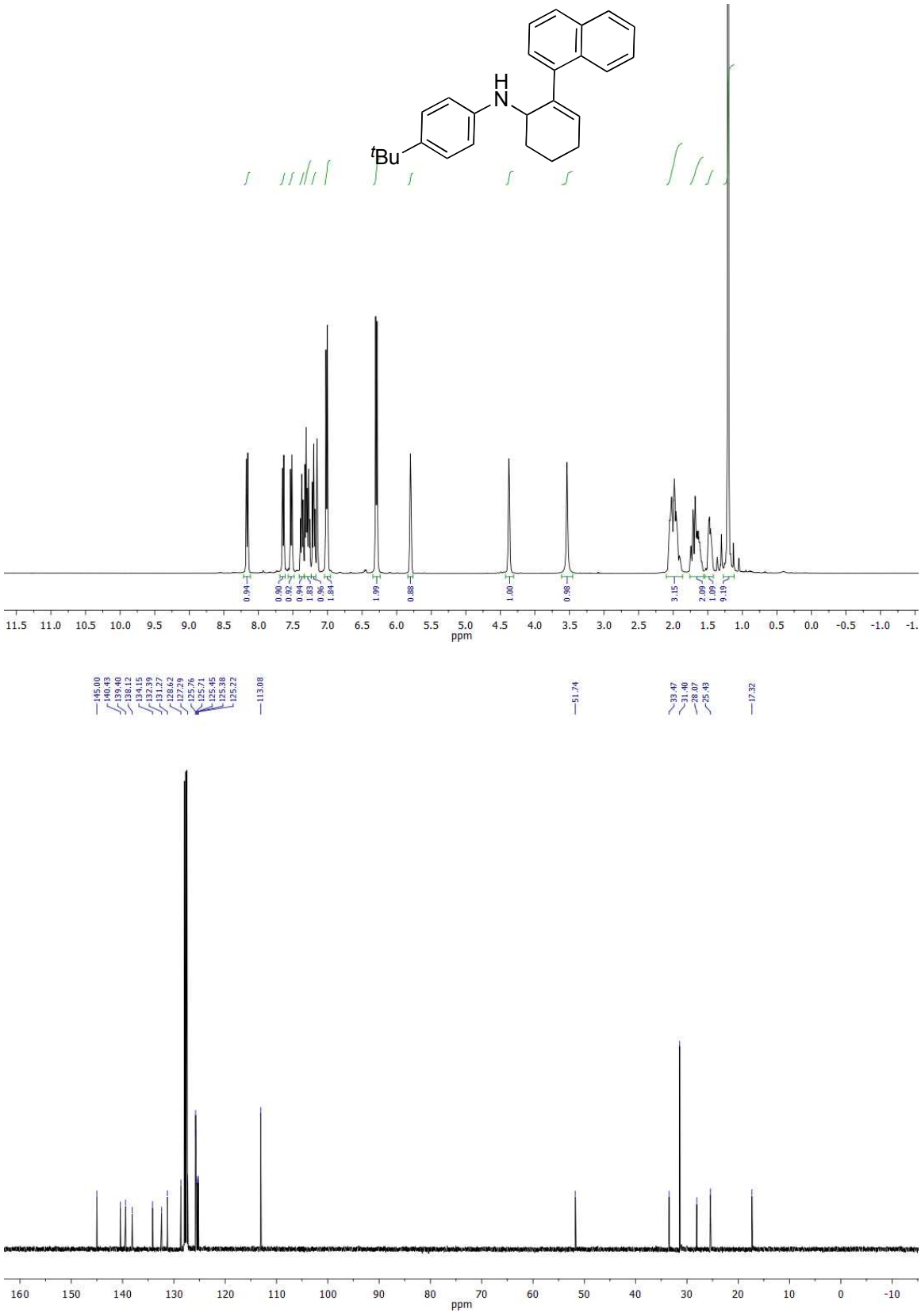

144.85
142.04
139.03
132.87
127.64
126.37
125.46
125.30
119.51
112.53
48.97
34.05
31.80
27.52
25.91
17.21
ppm

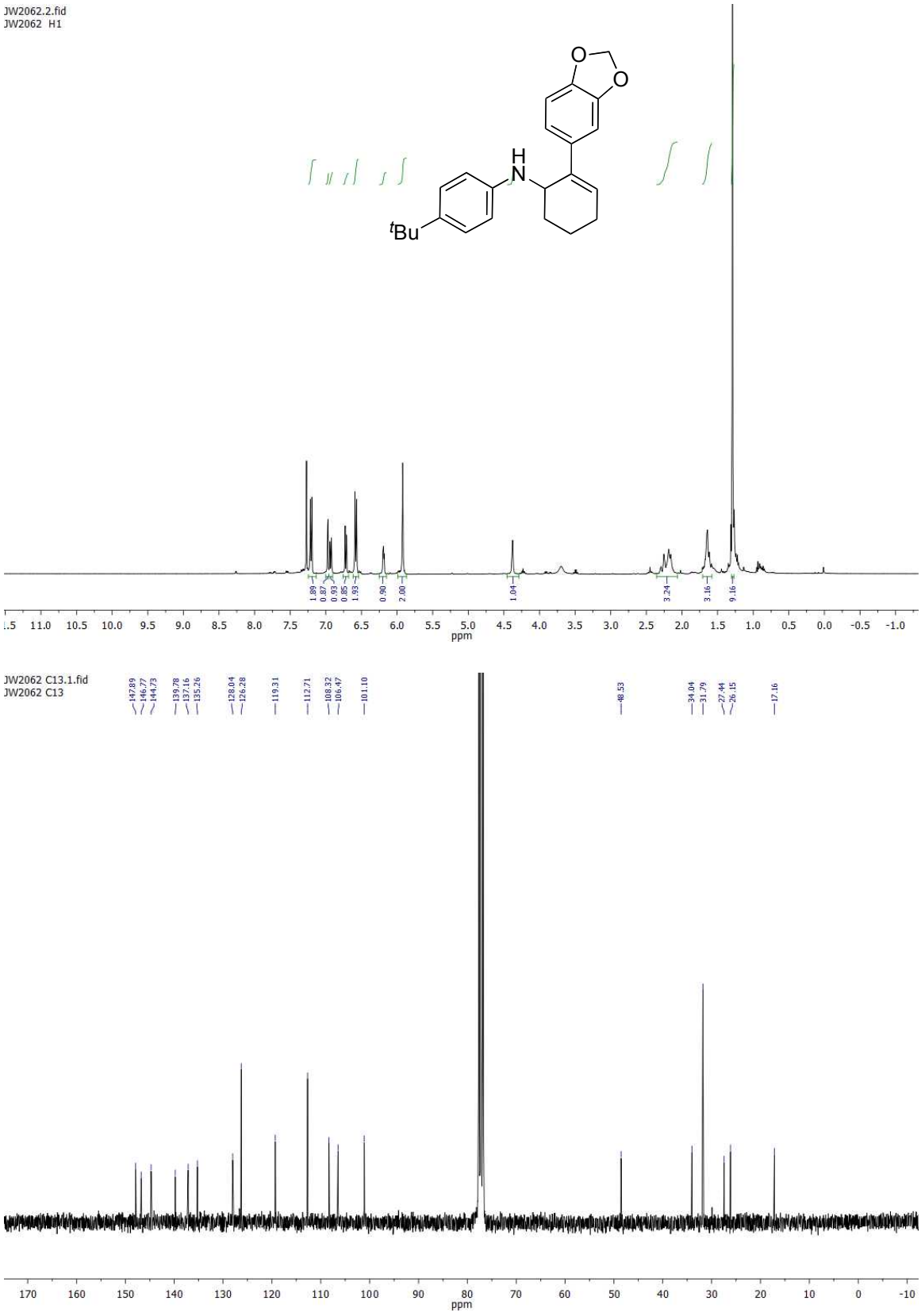

Ph
H
N
tBu
2.18
4.52
1.85
1.00
3.01
2.96
2.96
8.83
ppm

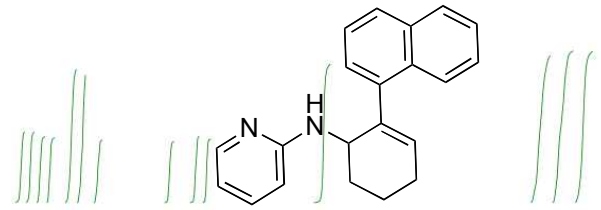

JW1240.7.fid
JW1240 C13
145.15
142.22
139.46
134.57
133.49
129.11
128.22
126.55
126.08
112.75
52.10
33.95
31.74
27.81
21.31
18.02
ppm

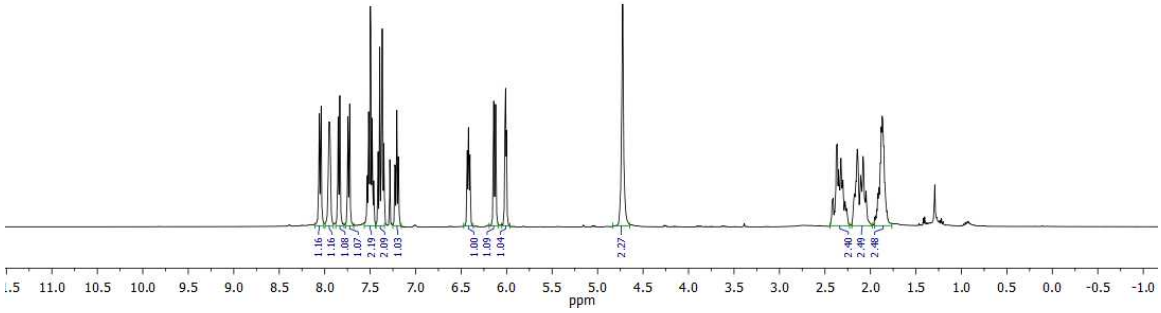

F3C
H
N
1.11
2.25
1.03
0.94
2.03
1.00
1.01
6.11
1.20
4.27
3.42
2.64
2.40
3.41
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm
147.74
143.93
140.36
139.19
133.22
133.03
131.04
130.62
130.20
129.77
128.96
126.76
126.39
126.34
126.24
126.24
123.59
123.15
119.35
111.44
52.64
34.52
31.11
29.41
28.52
23.05
21.66
18.51
14.14
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

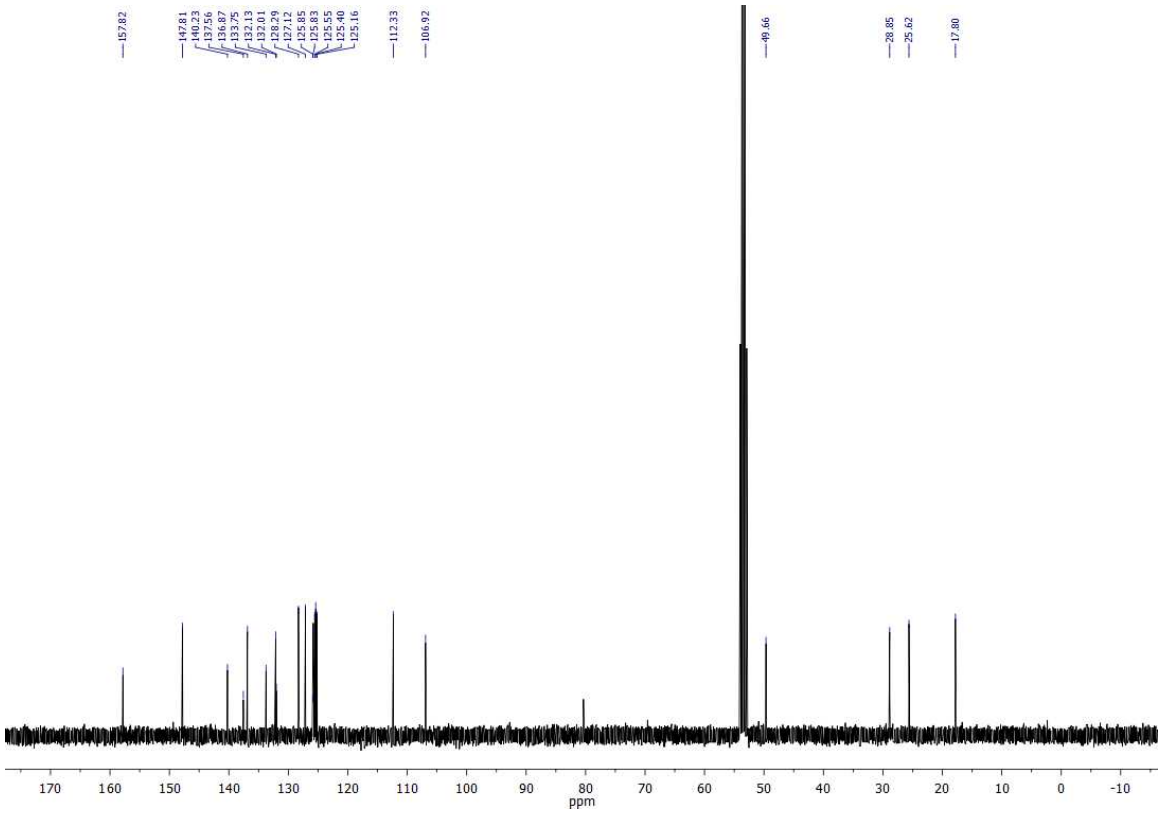

Ph
OEt
H
N
O
F3C
2.05
4.66
1.91
0.97
2.05
0.96
0.86
0.98
3.01
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm
170.01
149.28
141.67
140.35
133.28
128.22
127.70
127.41
126.50
123.10
118.96
112.06
60.61
51.29
27.41
26.93
17.03
13.52
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

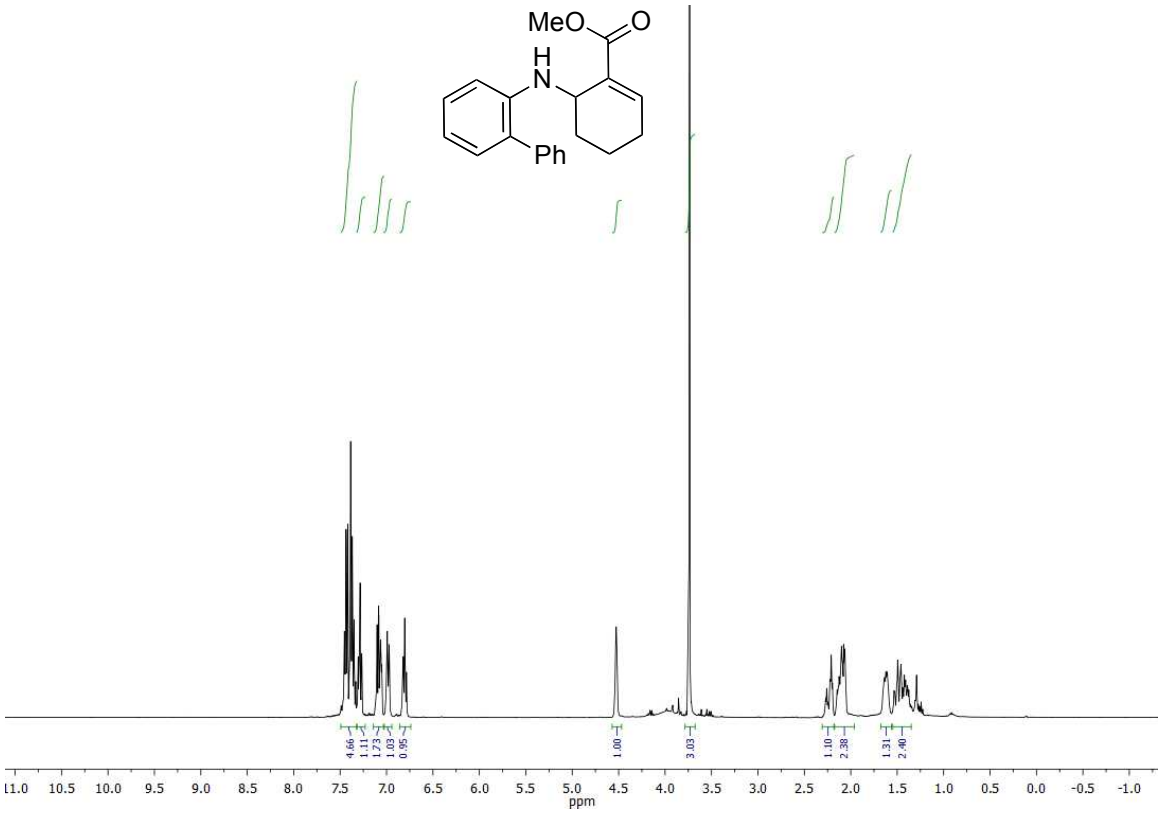

H
N
tBu
0.94
0.90
0.92
0.94
1.83
0.96
1.84
1.99
0.88
1.00
0.98
3.15
2.09
1.09
9.19
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.
ppm
145.00
140.43
139.40
138.12
134.15
132.39
131.27
128.62
127.29
125.76
125.71
125.41
125.38
125.22
113.08
51.74
33.47
31.40
28.07
25.43
17.32
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm

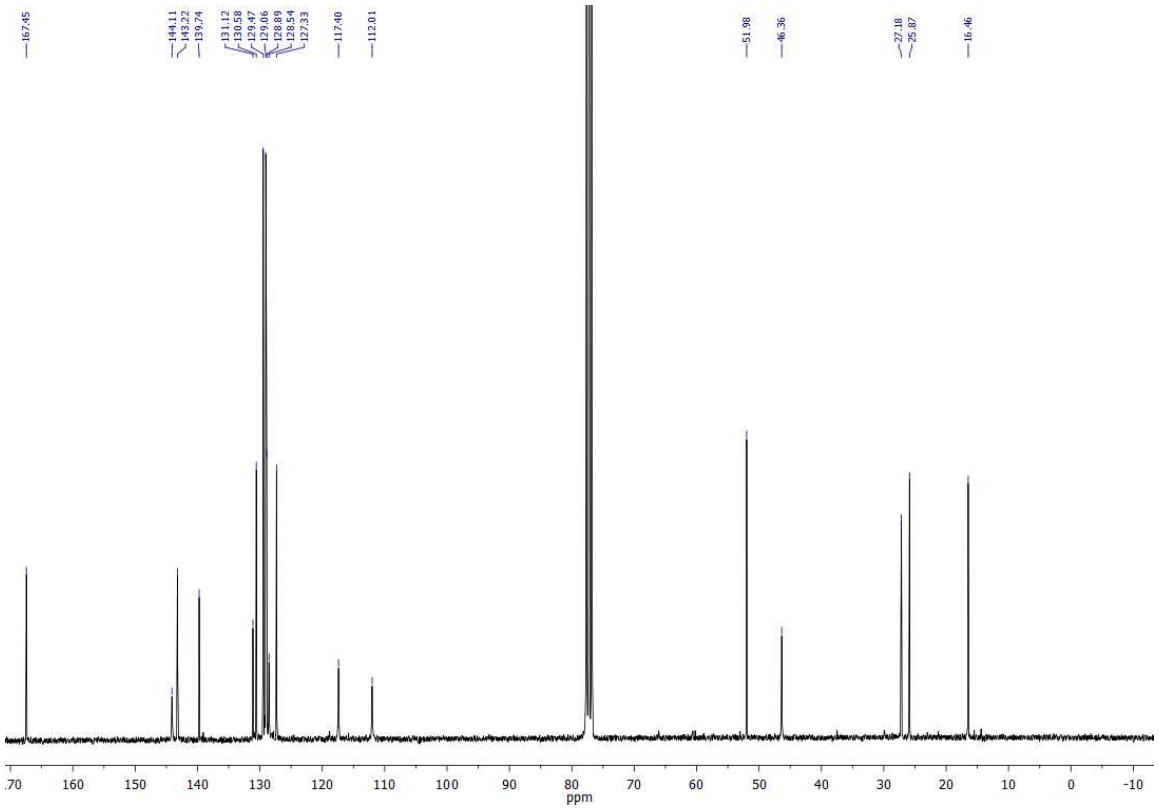

JW2062.2.fid
JW2062 H1
O
O
H
N
tBu
1.89
0.87
0.93
0.85
1.93
0.90
2.00
1.04
3.24
3.16
9.16
ppm
JW2062 C13.1.fid
JW2062 C13
147.89
146.77
144.73
139.78
137.16
135.26
128.04
126.28
119.31
112.71
108.32
106.47
101.10
48.53
34.04
31.79
27.44
26.15
17.16
ppm

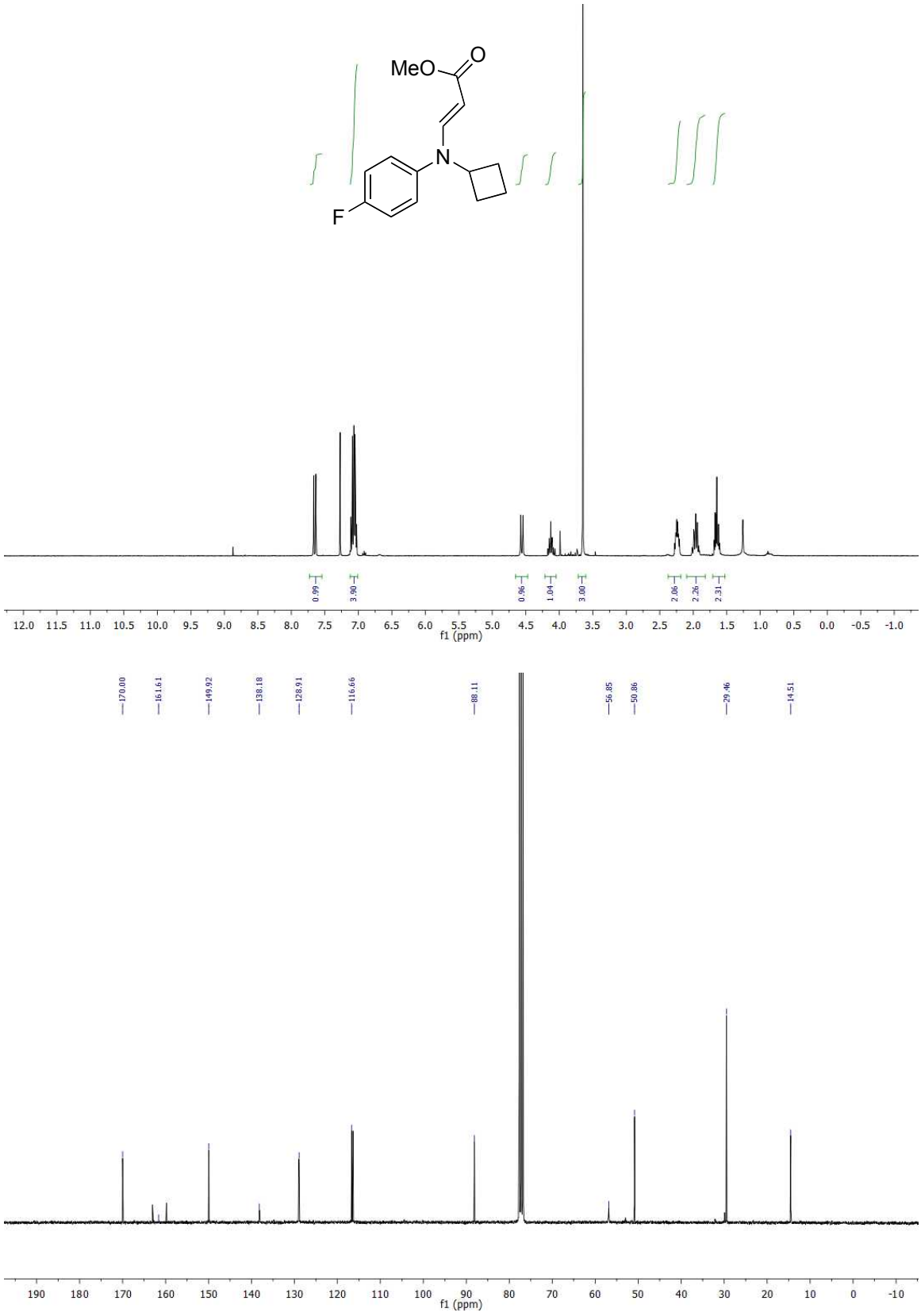

N
H
N


1.16
1.16
1.08
1.07
2.19
2.09
1.03
1.00
1.09
1.04
2.27
2.40
2.49
2.48
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
ppm

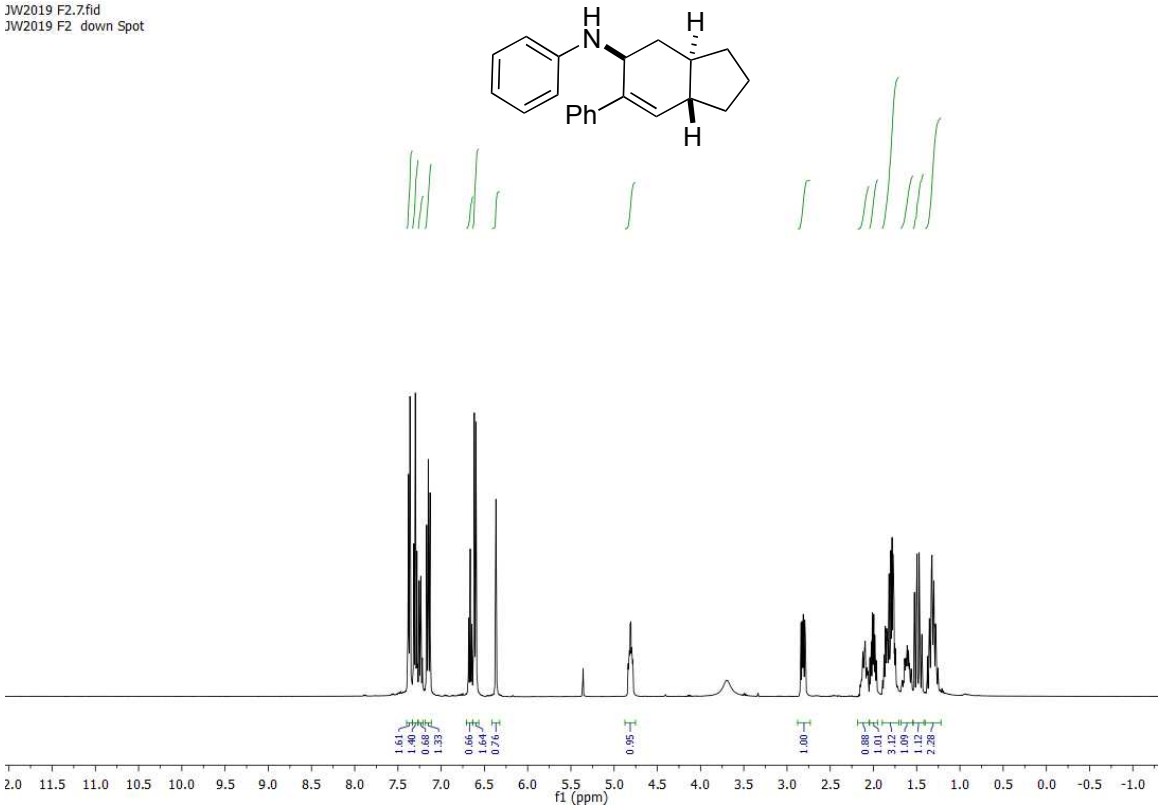

157.82
147.81
140.23
137.56
136.87
133.75
132.13
132.01
128.29
127.12
125.85
125.83
125.55
125.40
125.16
112.33
106.92
49.66
28.85
25.62
17.80
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
ppm


MeO
O
H
N
Ph
4.66
1.11
1.73
1.03
0.95
1.00
3.03
1.10
2.38
1.31
2.40
ppm

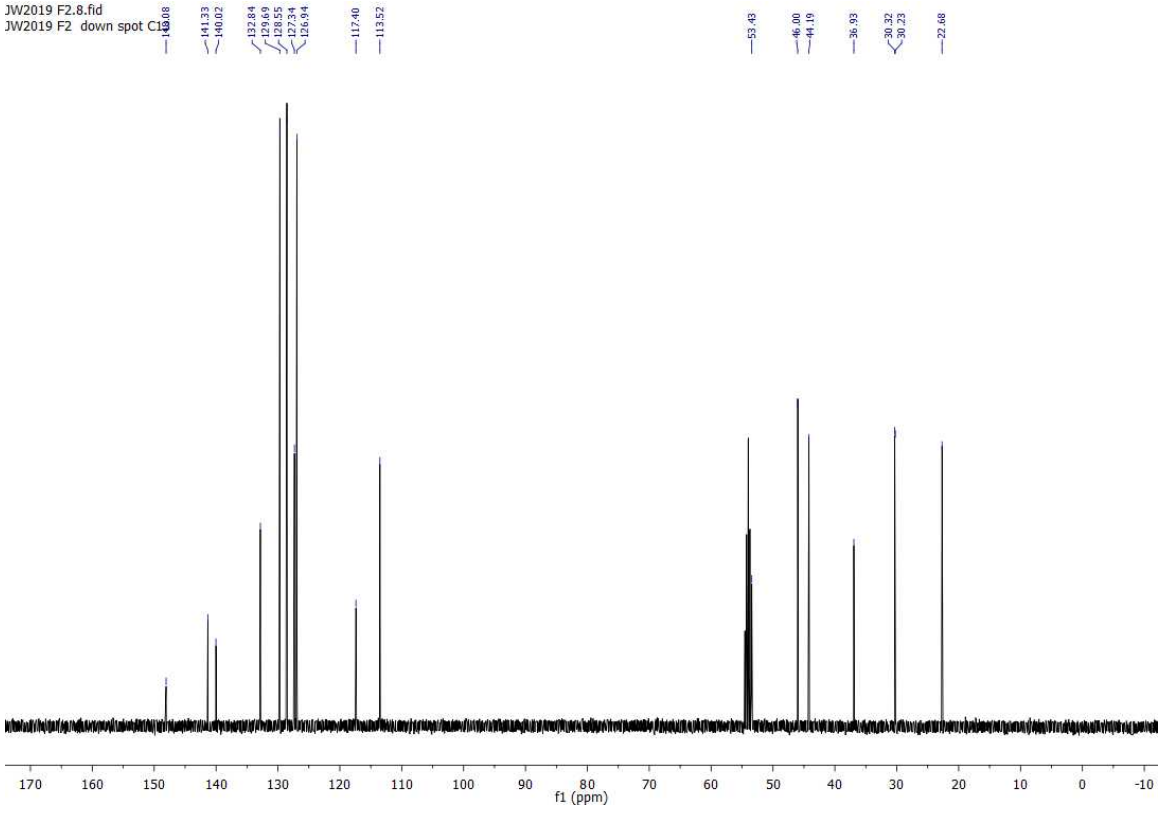

167.45
144.11
143.22
139.74
131.12
130.58
129.47
129.06
128.89
128.54
127.33
117.40
112.01
51.98
46.36
27.18
25.87
16.46
ppm


MeO
O
N
F
0.99
3.90
0.86
1.04
3.00
2.06
2.26
2.31
f1 (ppm)
170.00
161.61
149.92
138.18
128.91
116.66
88.11
56.85
50.86
29.46
14.51
f1 (ppm)

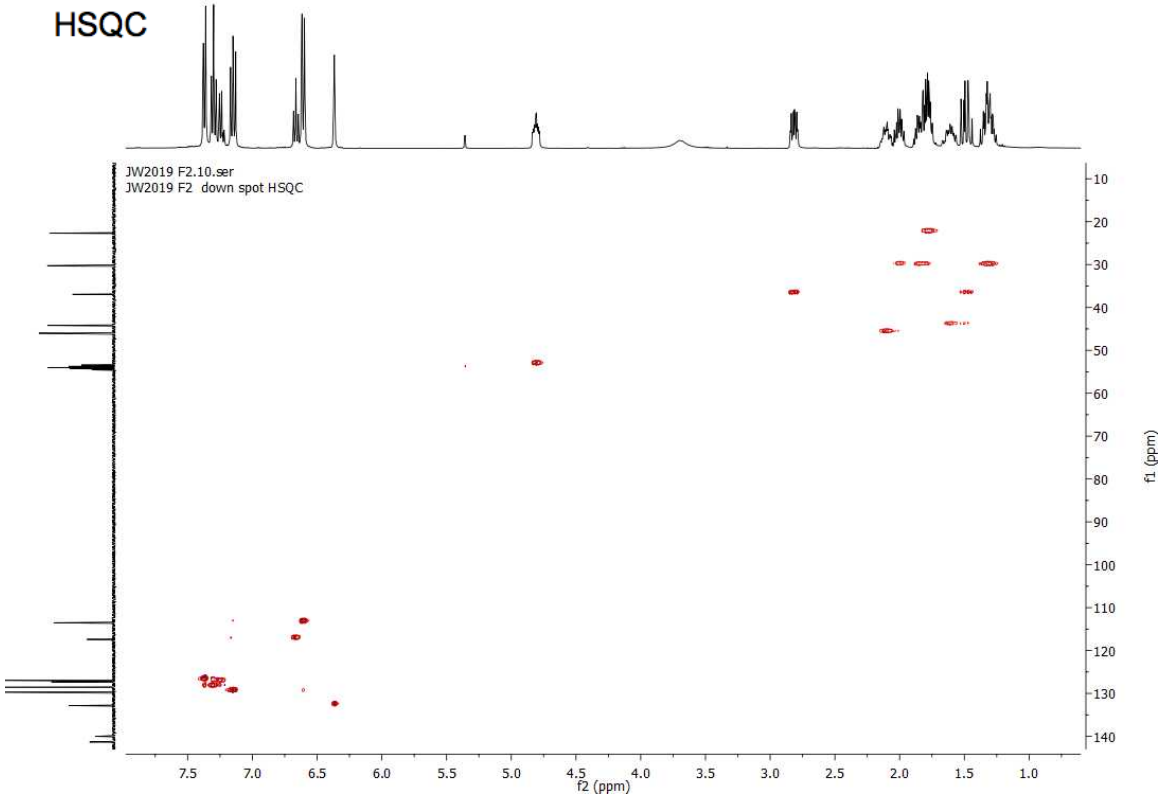
JW2019 F2.7.fid
JW2019 F2 down Spot



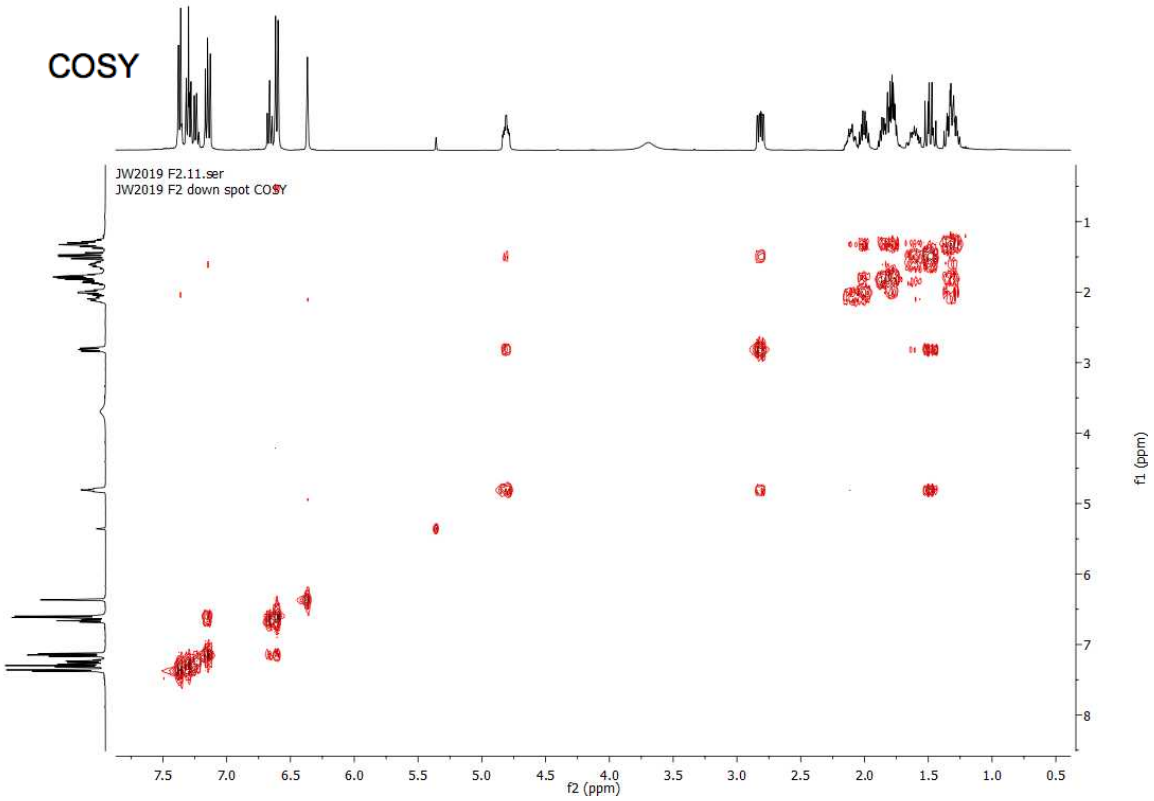
JW2019 F2.8.fid
JW2019 F2 down spot C13



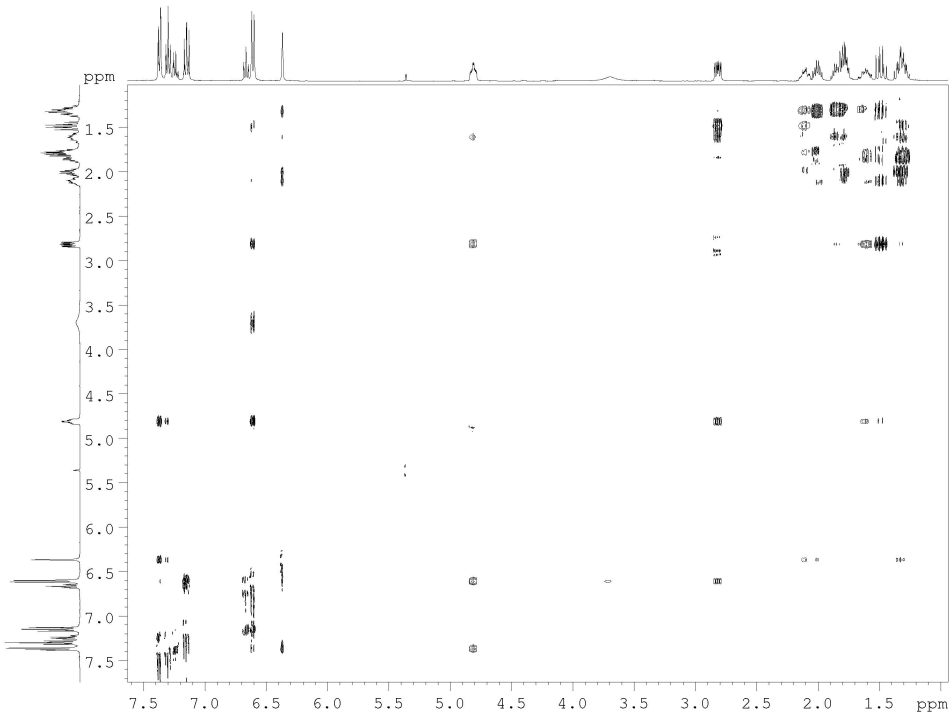
HSQC


JW2019 F2.10.ser
JW2019 F2 down spot HSQC
f2 (ppm)
f1 (ppm)

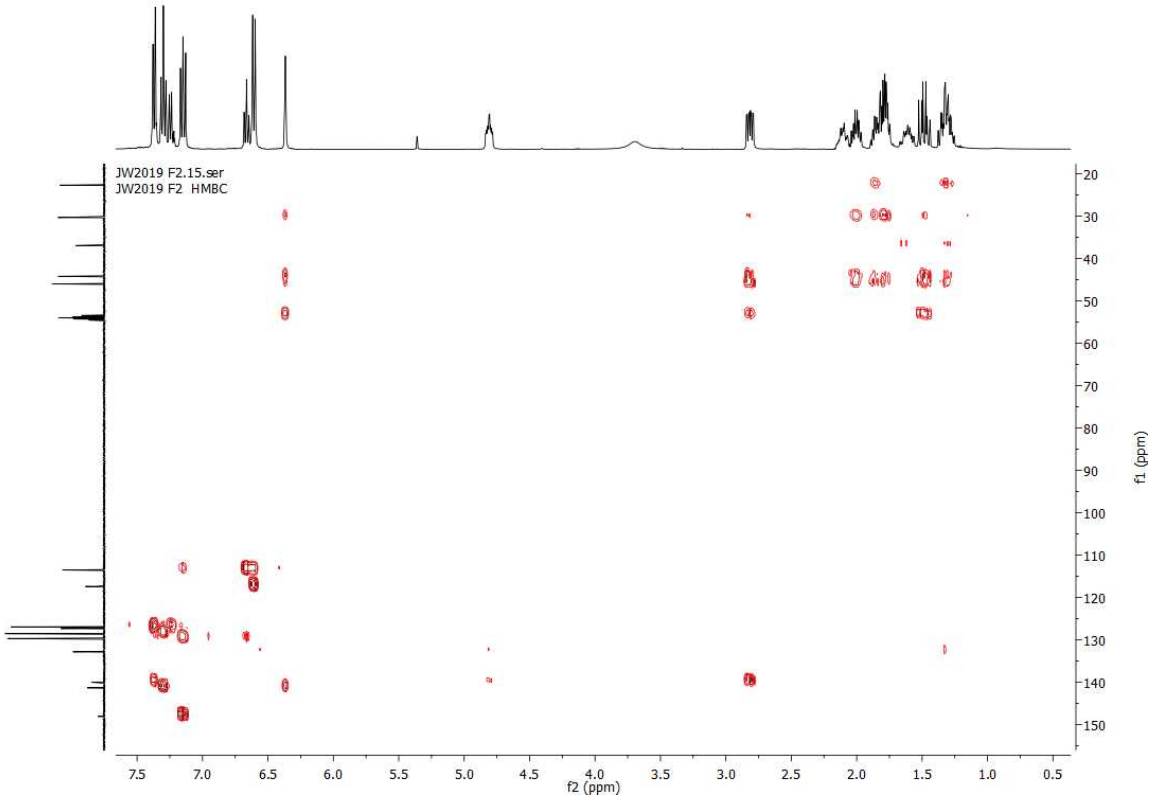
COSY

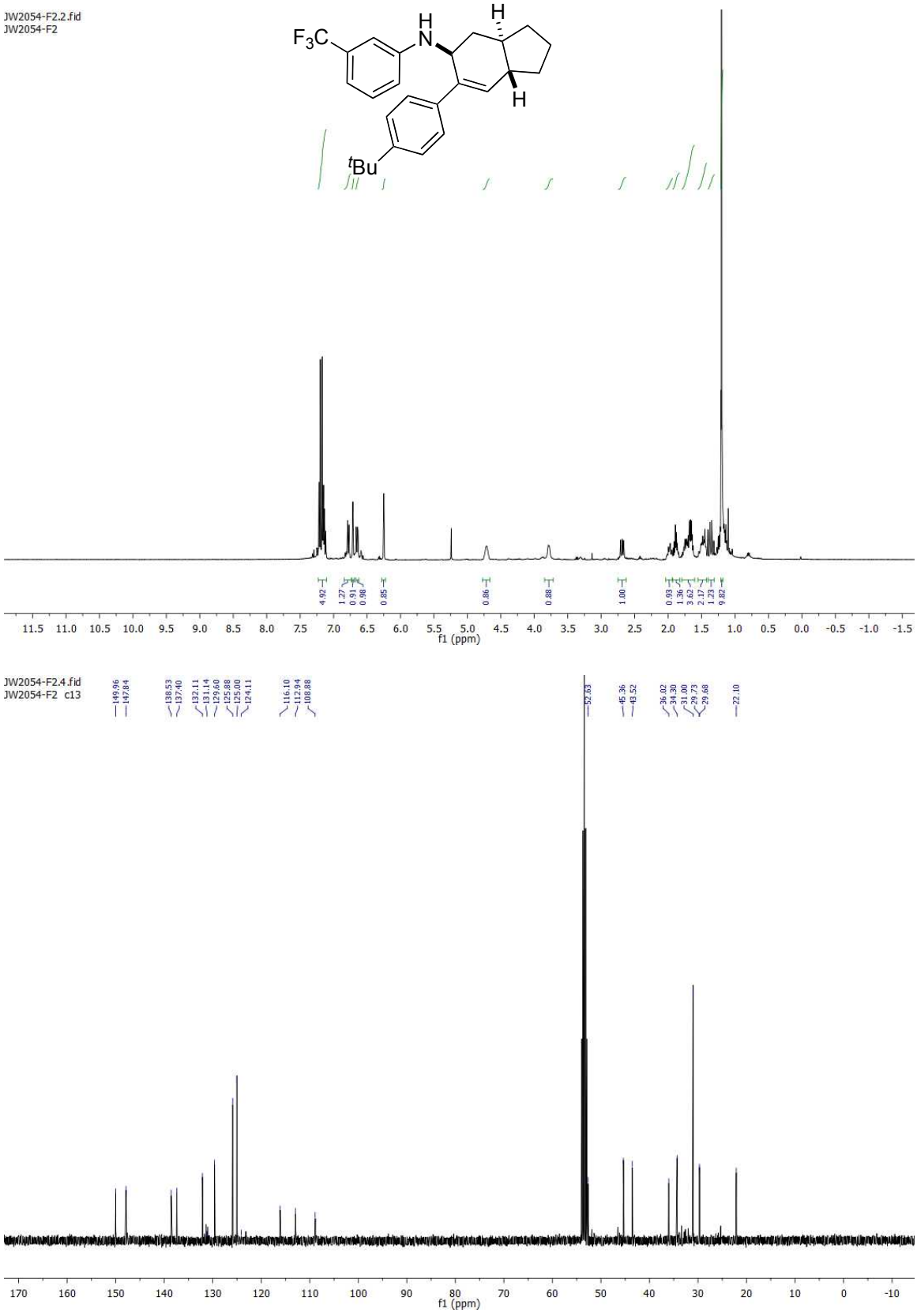

JW2019 F2.11.ser
JW2019 F2 down spot COSY
f2 (ppm)
f1 (ppm)

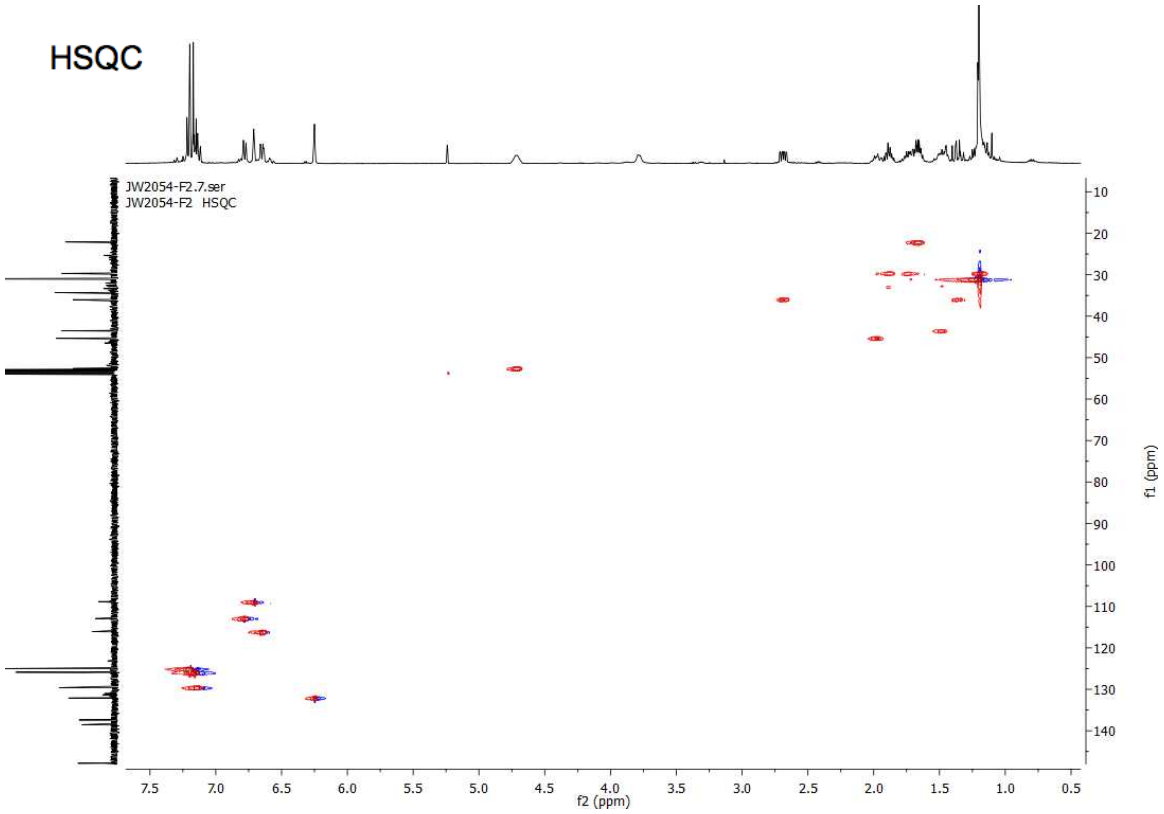
NOESY

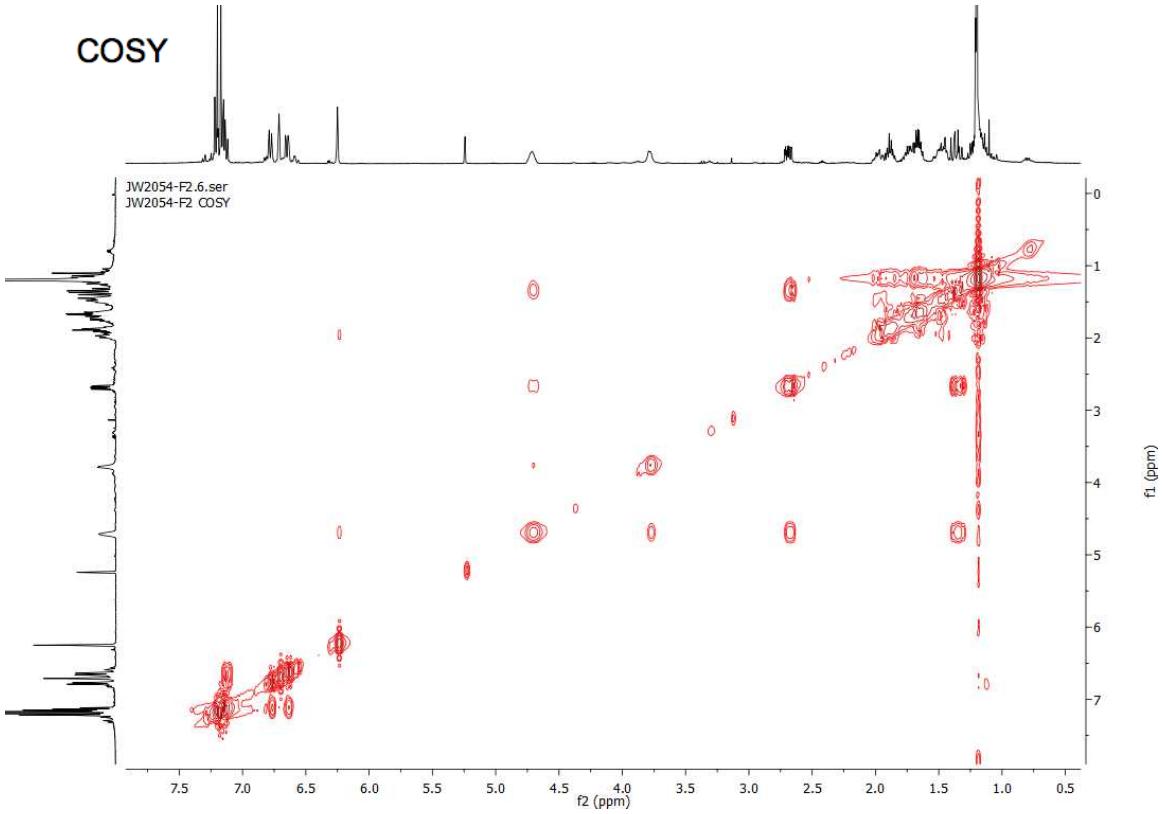

ppm
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 ppm

HMBC

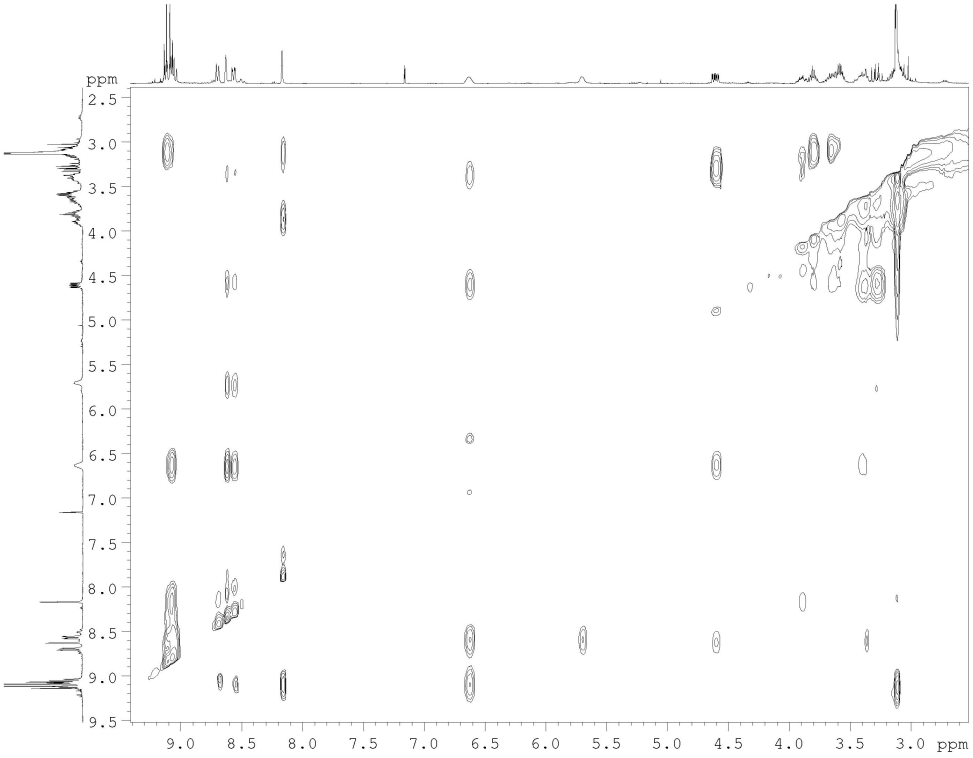

JW2019 F2.15.ser
JW2019 F2 HMBC
20
30
40
50
60
70
80
90
100
110
120
130
140
150
f1 (ppm)
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f2 (ppm)


JW2054-F2.2.fid
JW2054-F2
F3C
H
N
H
H
tBu
4.92
1.27
0.91
0.98
0.85
0.86
0.88
1.00
0.93
1.36
3.62
2.17
1.23
9.82
f1 (ppm)
JW2054-F2.4.fid
JW2054-F2 c13
149.96
147.84
138.53
137.40
132.11
131.14
129.60
125.88
125.00
124.11
116.10
112.94
108.88
52.63
45.36
43.52
36.02
34.30
31.00
29.73
29.68
22.10
f1 (ppm)

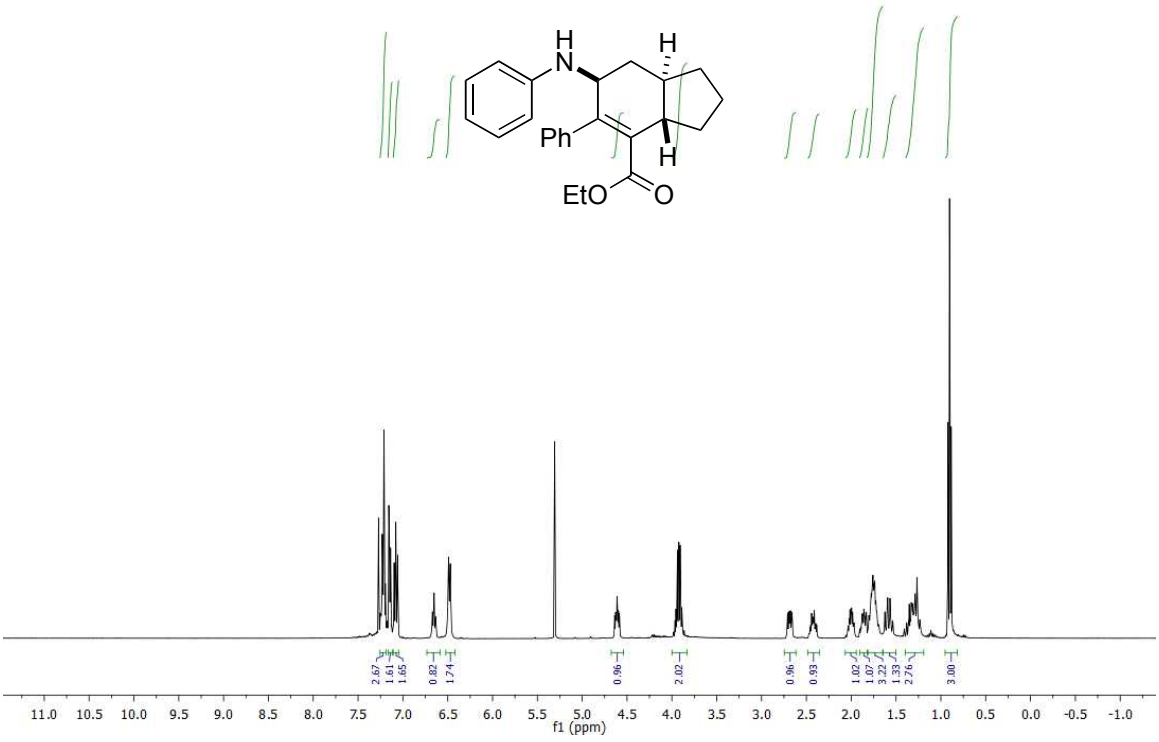

HSQC
JW2054-F2.7.ser
JW2054-F2 HSQC
f2 (ppm)
f1 (ppm)

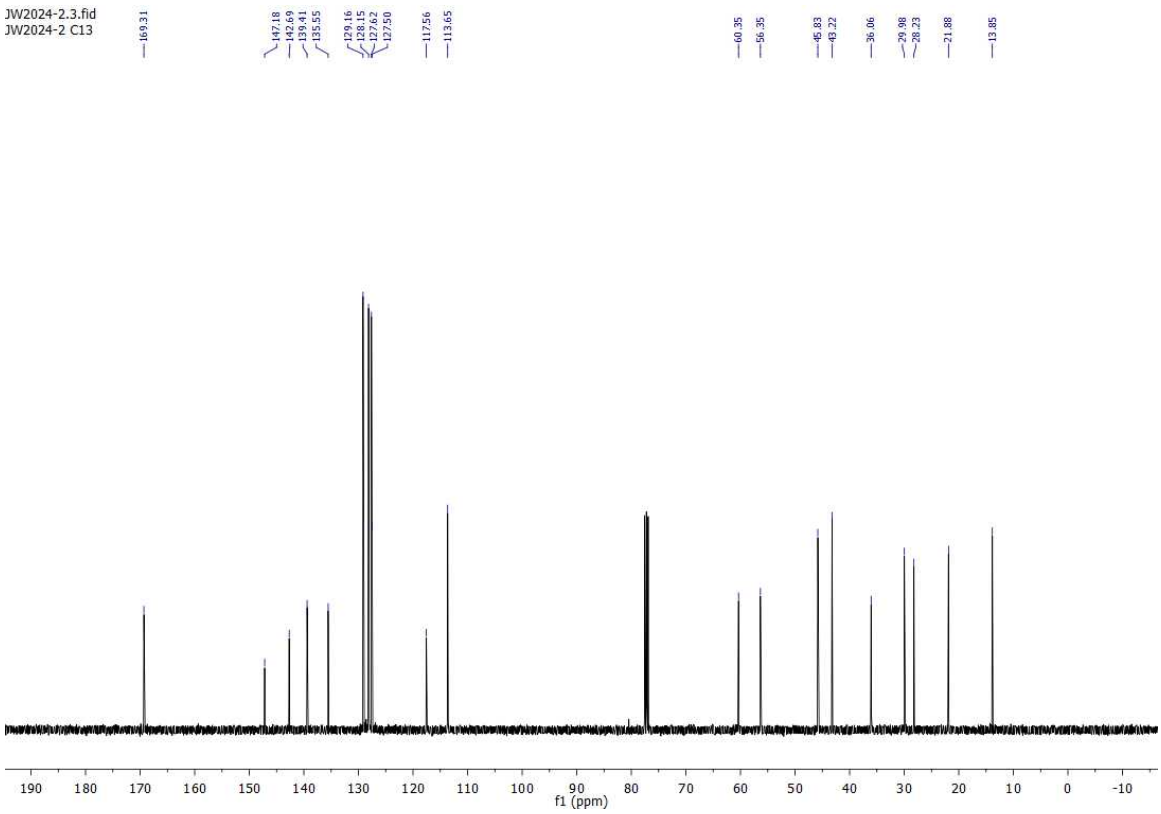

COSY
JW2054-F2.6.ser
JW2054-F2 COSY
f2 (ppm)
f1 (ppm)

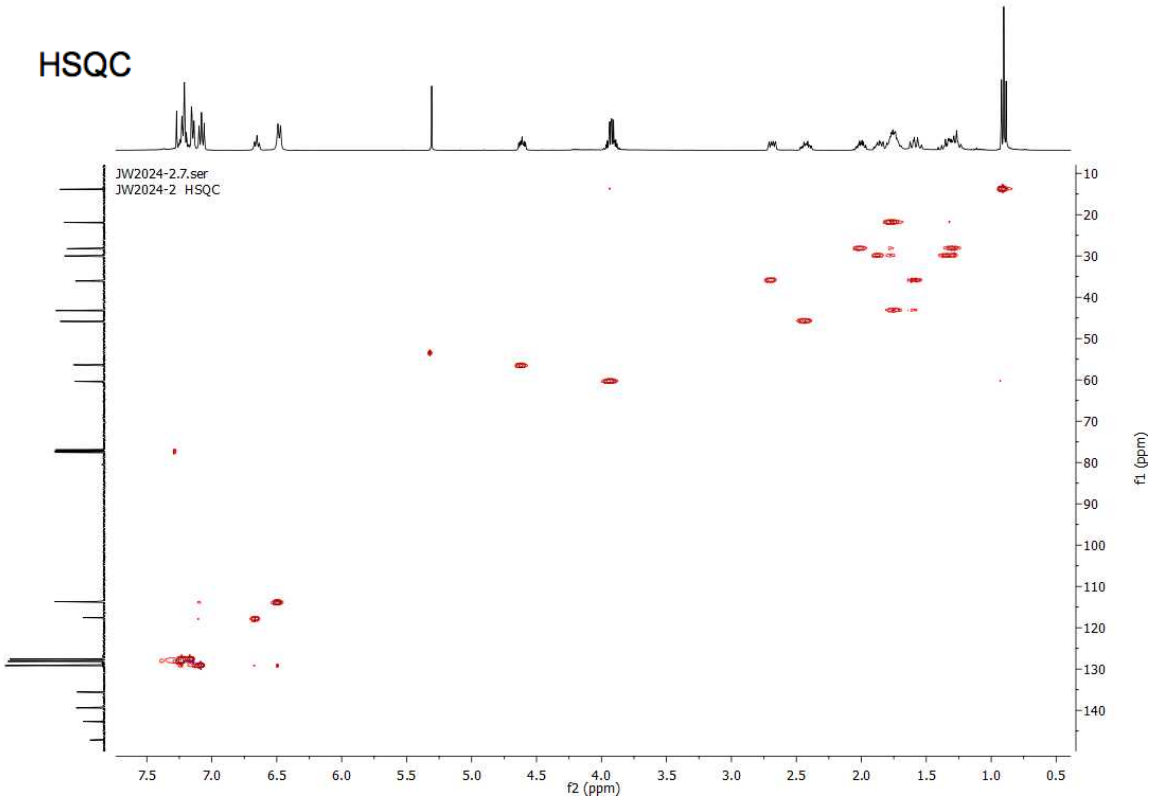
NOESY



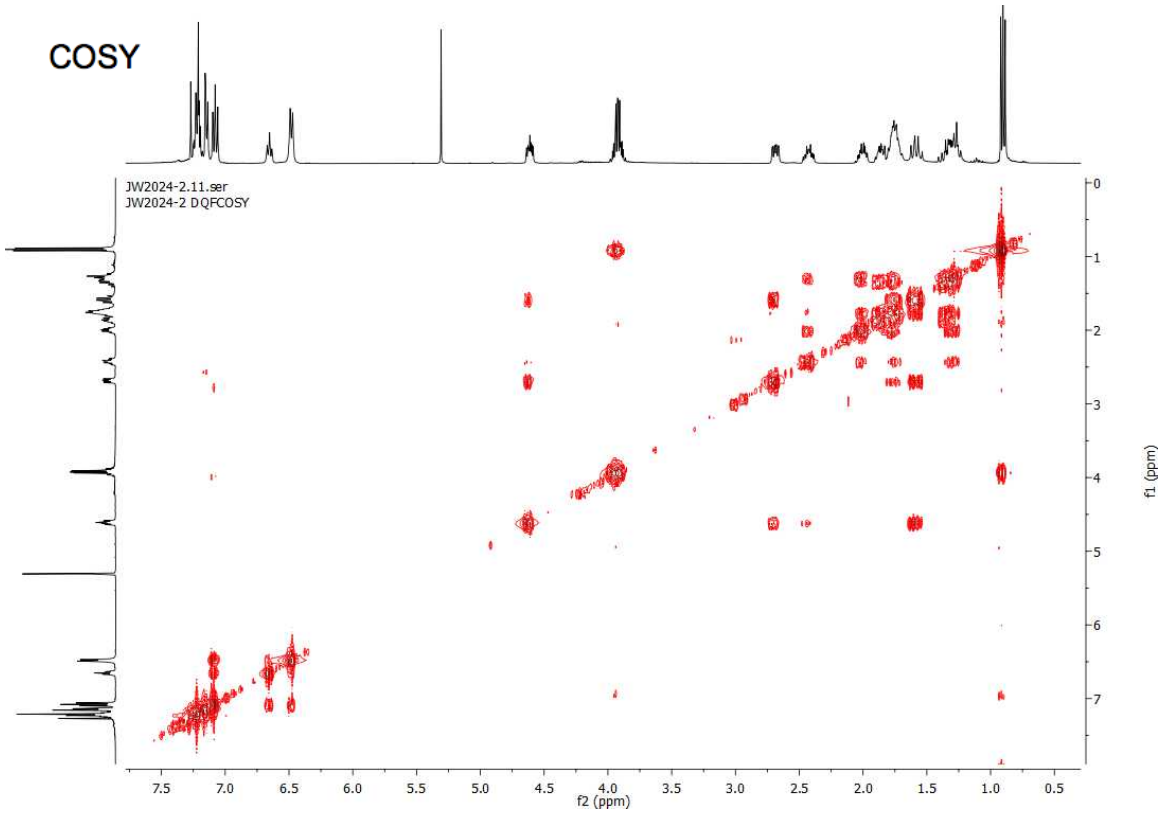
JW2024-2.6.fid
JW2024-2 H1



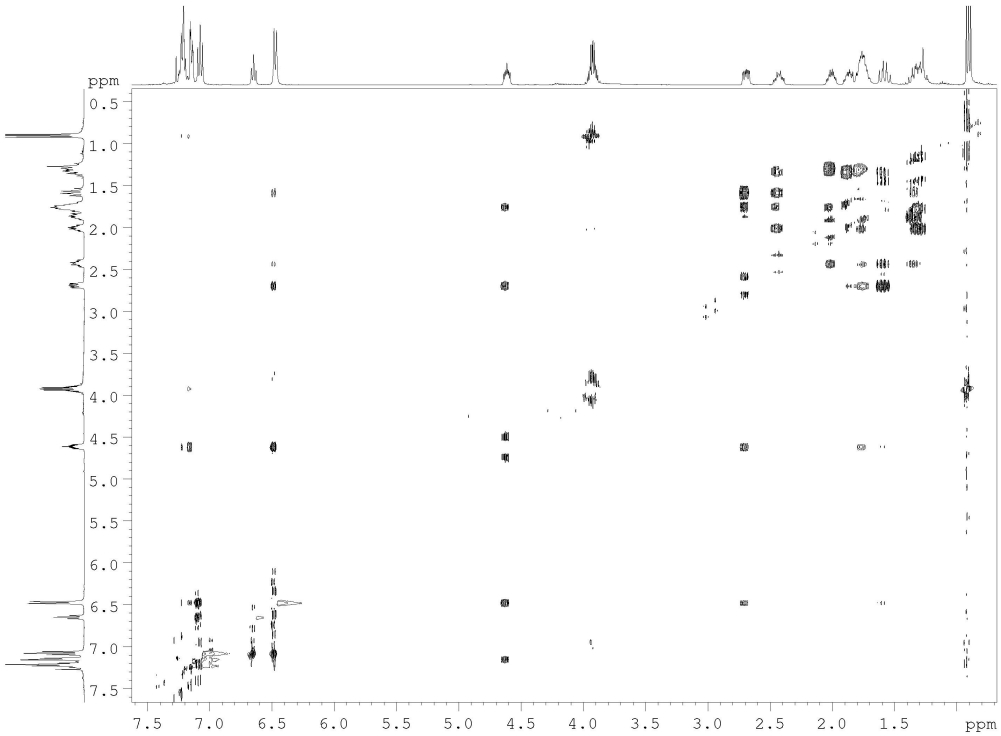

JW2024-2.3.fid
JW2024-2 C13
169.31
147.18
142.69
139.41
135.55
129.16
128.15
127.62
127.50
117.56
113.65
60.35
56.35
45.83
43.22
36.06
29.98
28.23
21.88
13.85
f1 (ppm)


HSQC
JW2024-2.7.ser
JW2024-2 HSQC
f2 (ppm)
f1 (ppm)

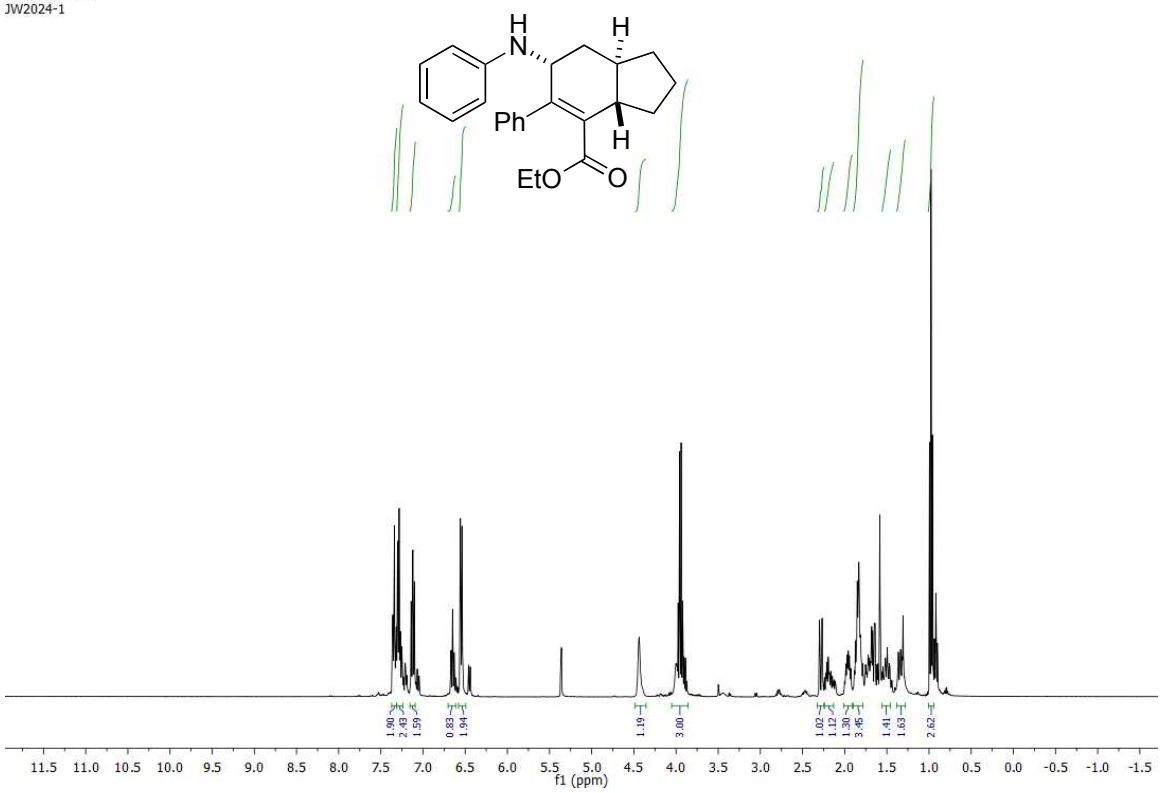
COSY



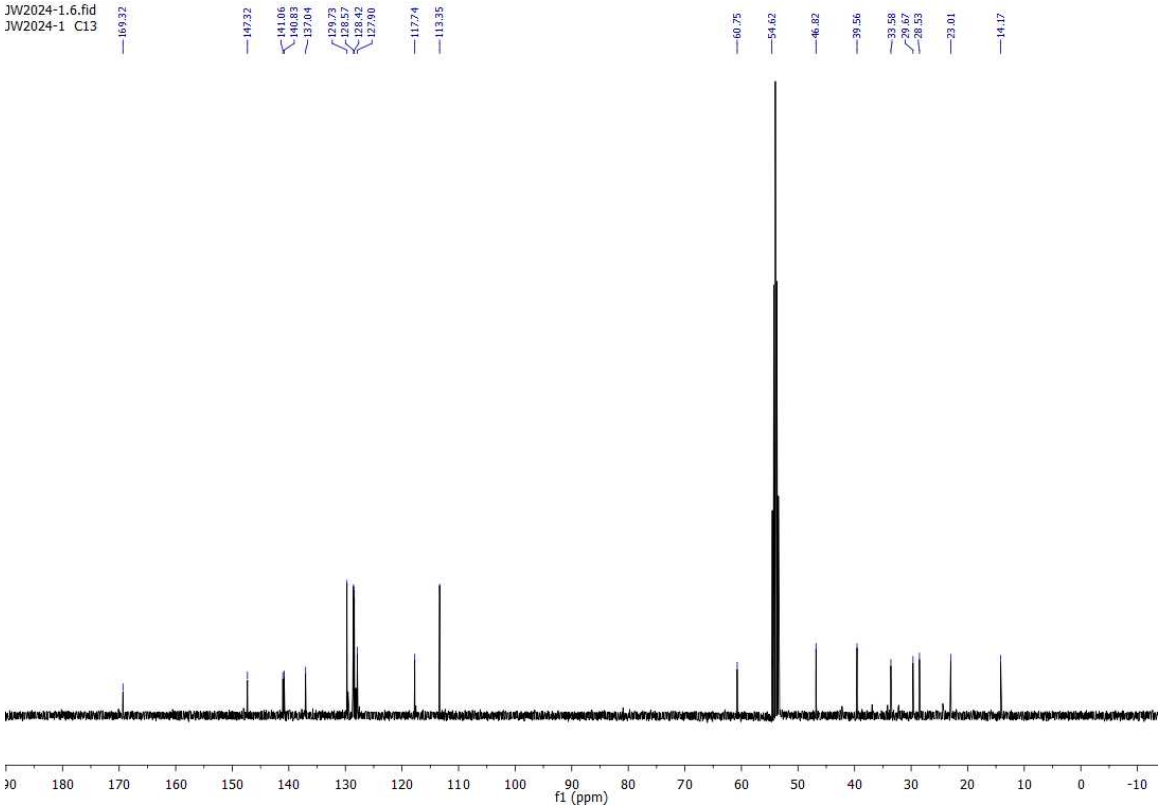
NOESY



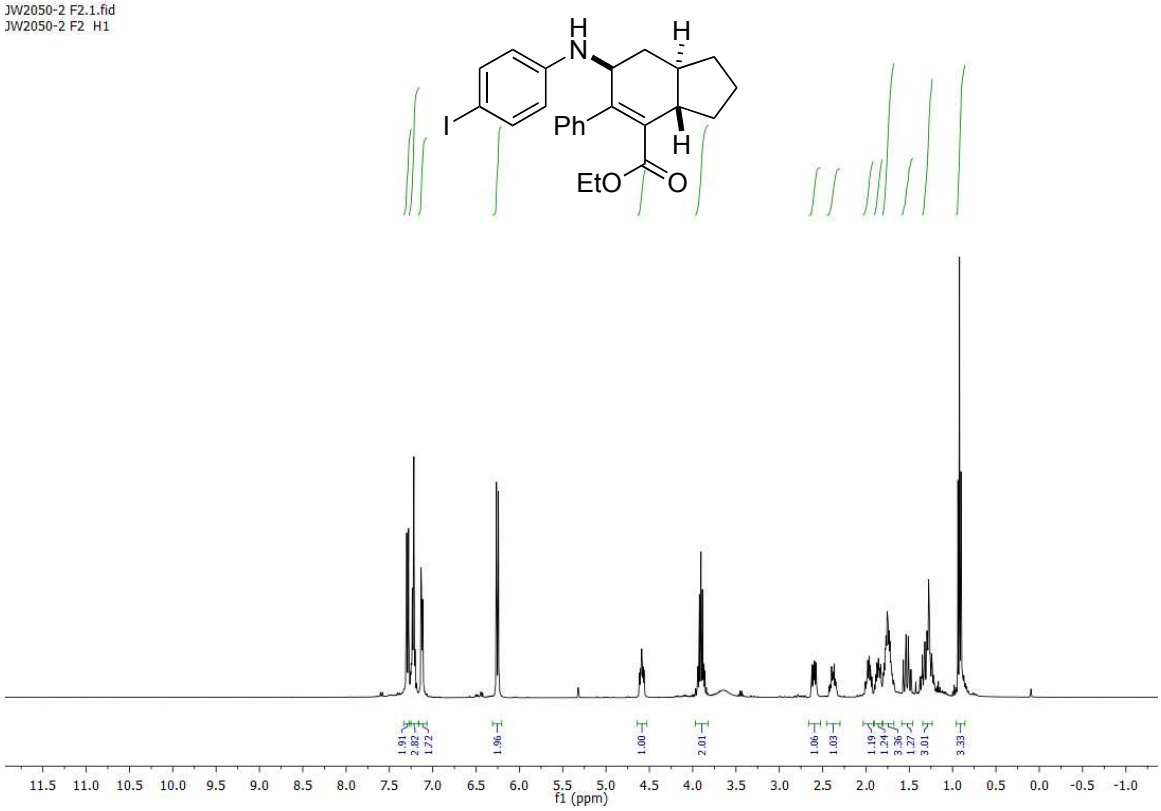
JW2024-1.5.fid
JW2024-1



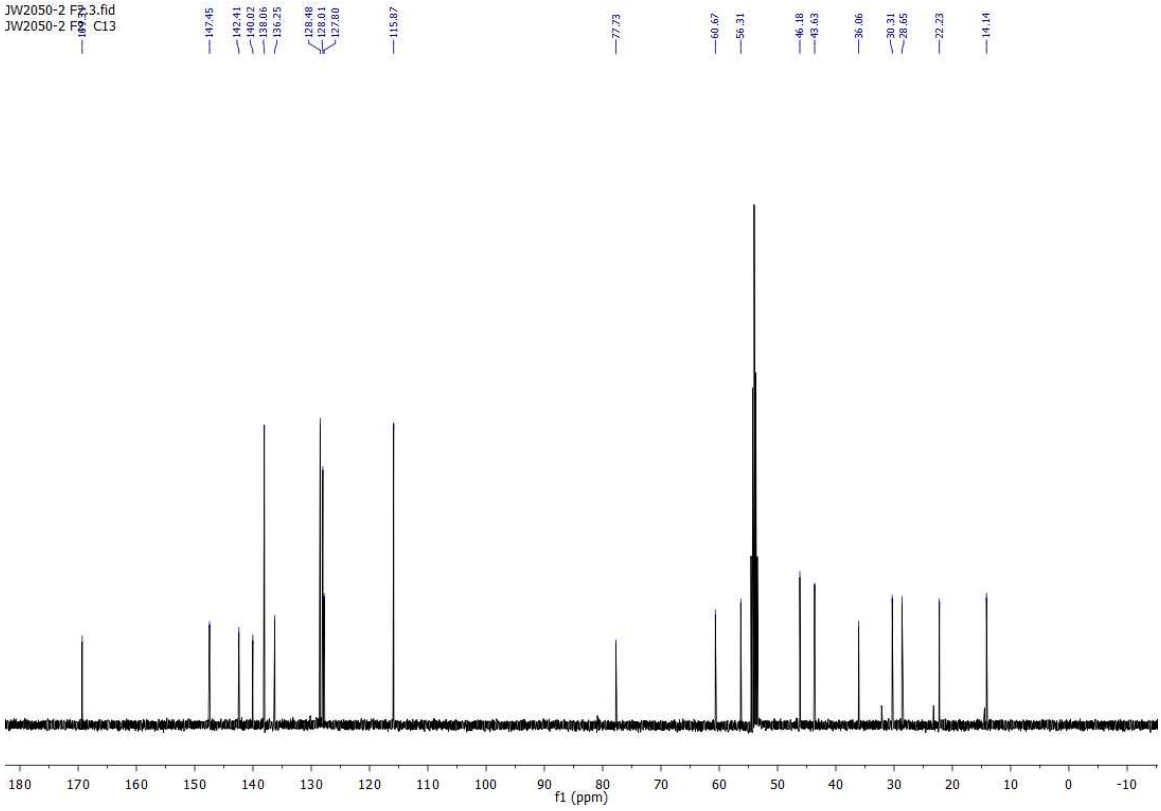
JW2024-1.6.fid
JW2024-1 C13



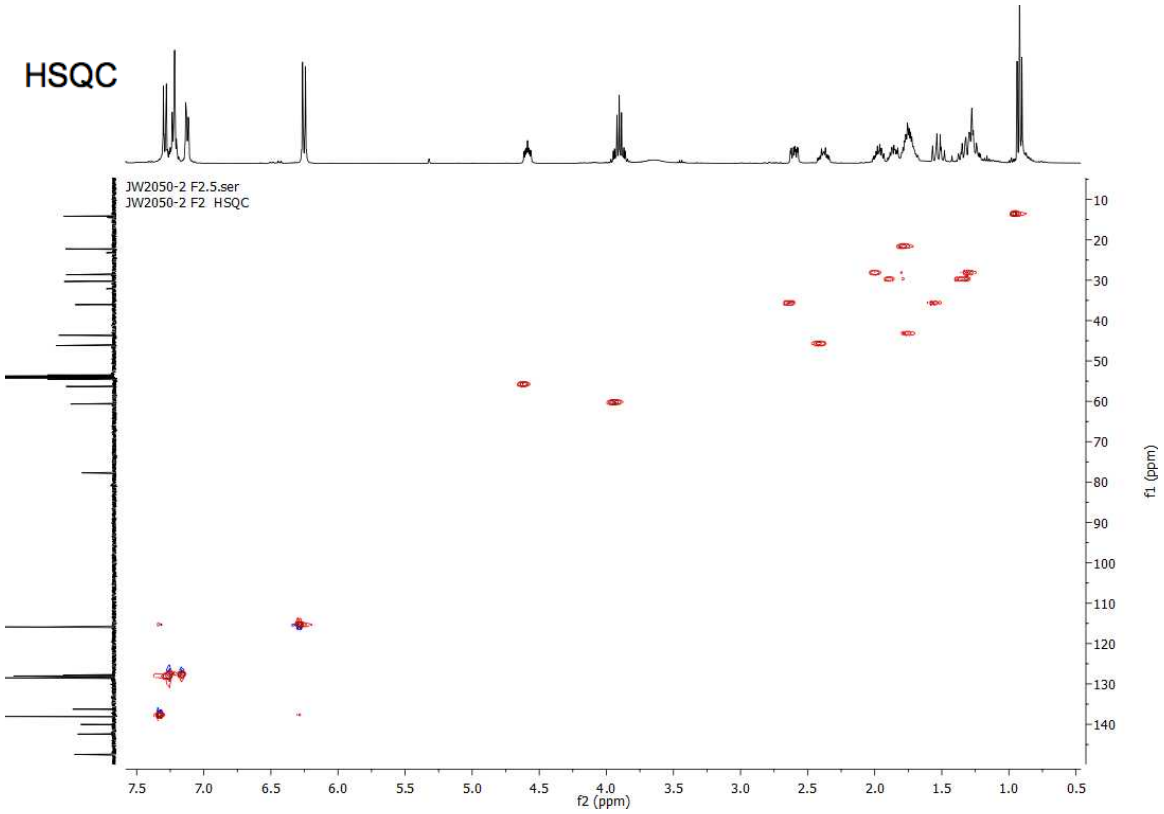
JW2050-2 F2.1.fid
JW2050-2 F2 H1



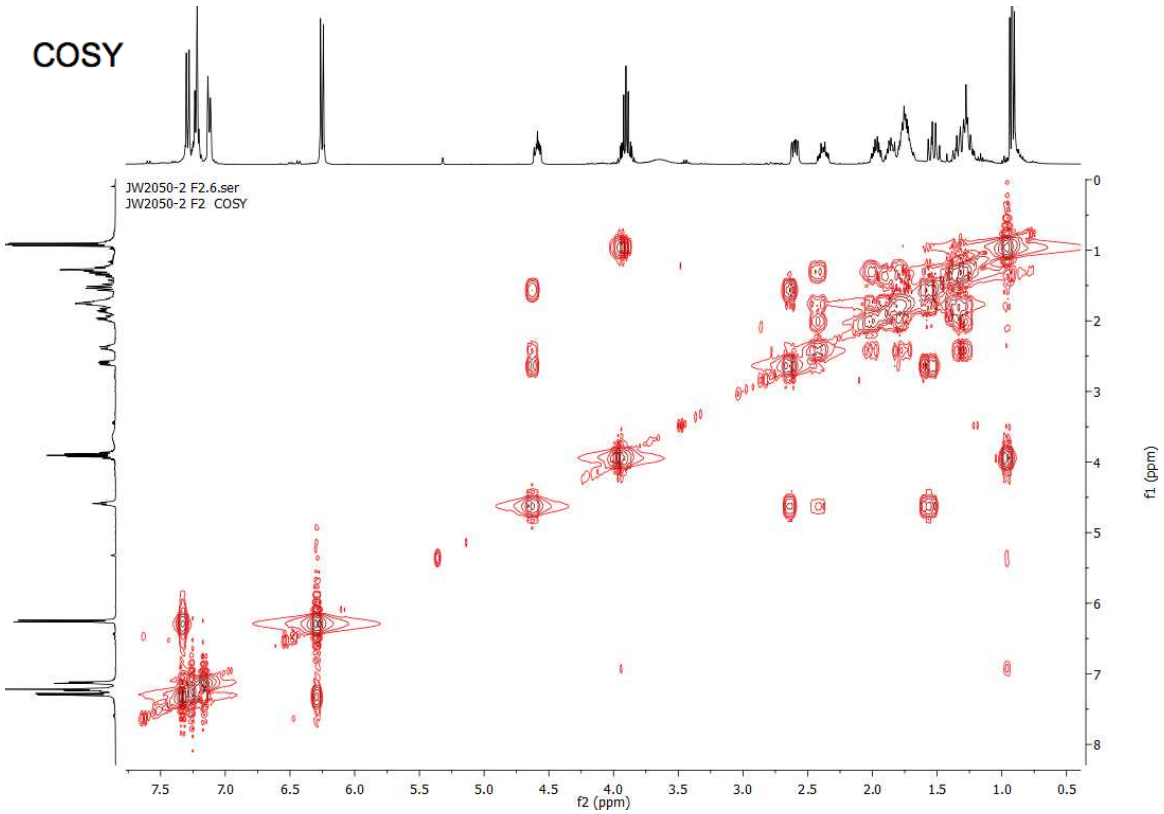
JW2050-2 F2.3.fid
JW2050-2 F2 C13



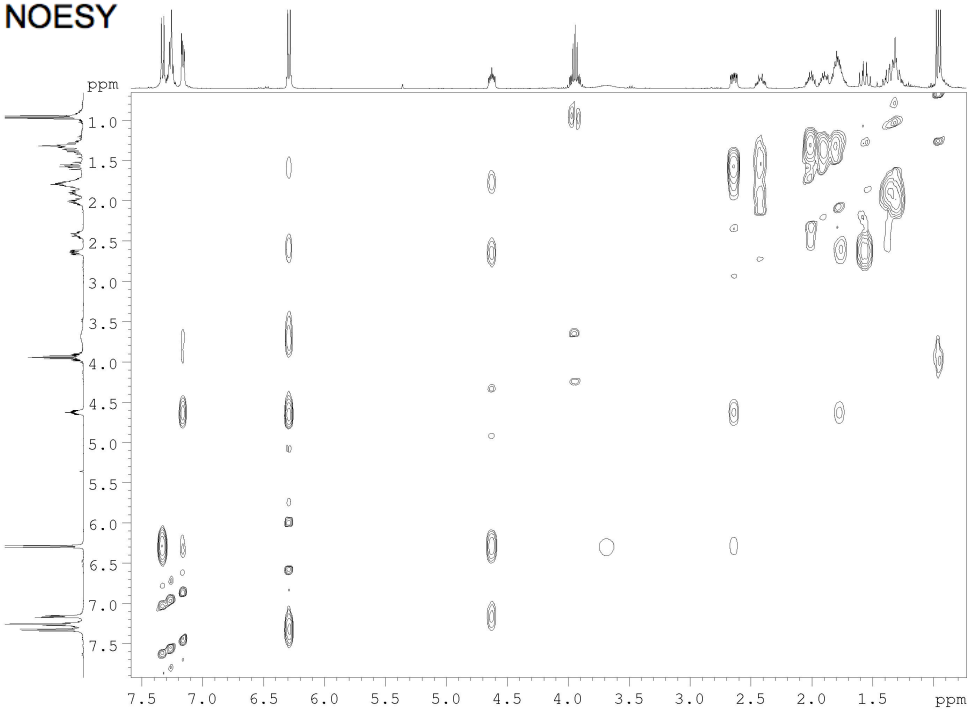
HSQC

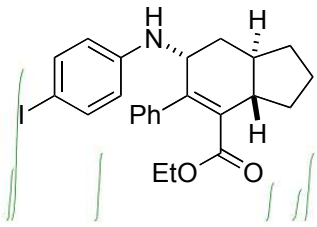

JW2050-2 F2.5.ser
JW2050-2 F2 HSQC
f2 (ppm)
f1 (ppm)

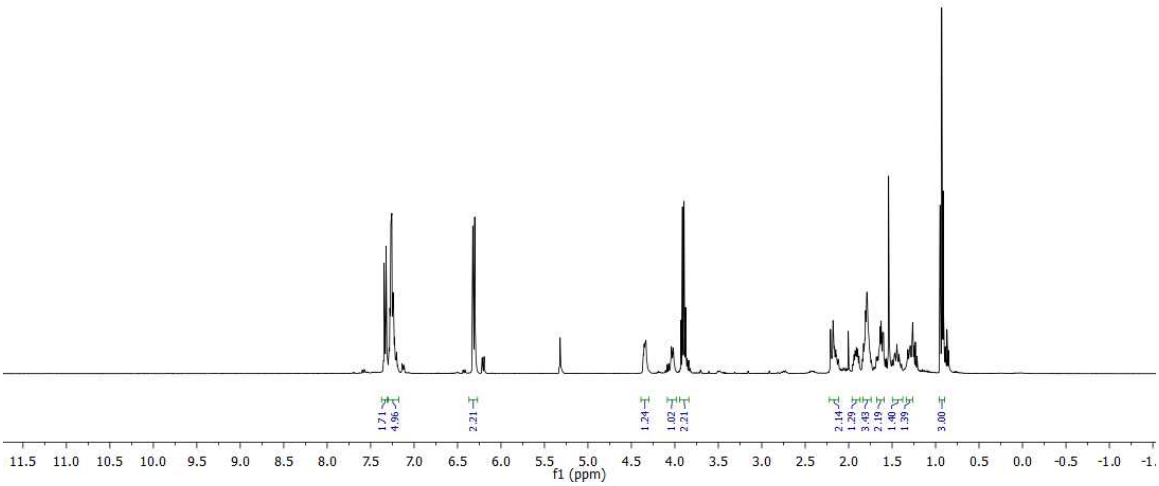
COSY

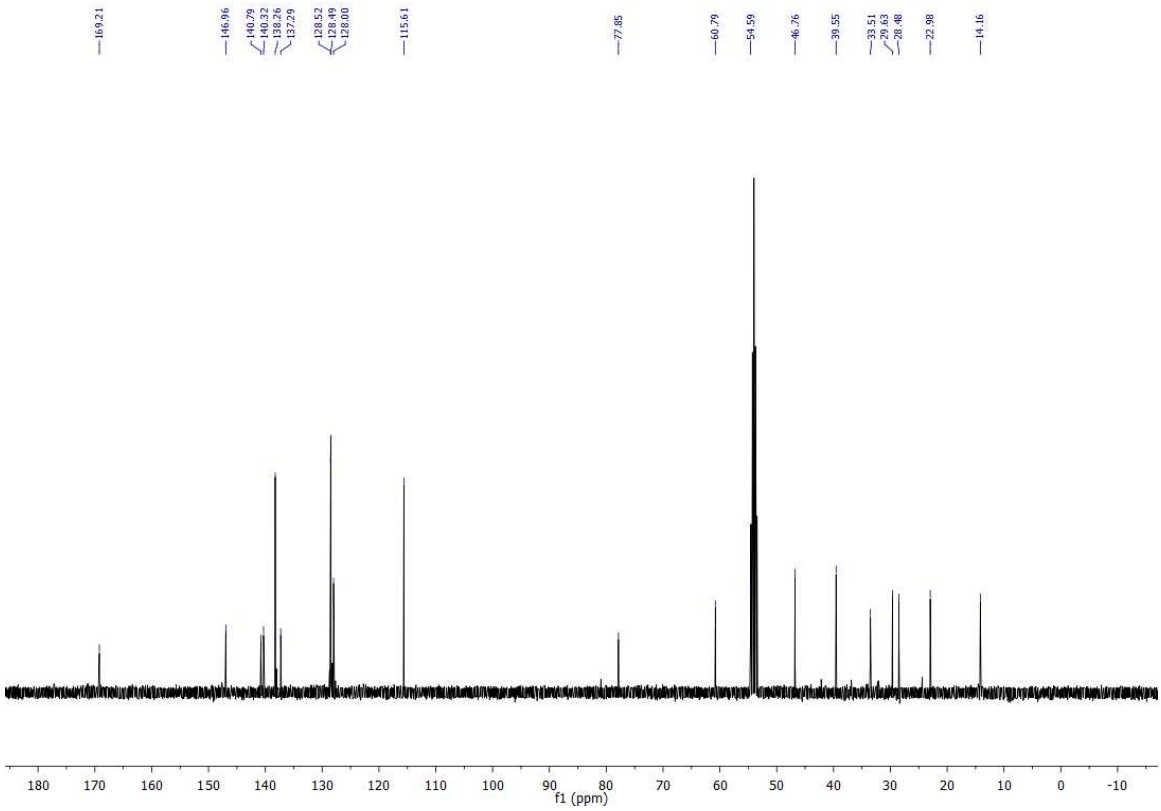

JW2050-2 F2.6.ser
JW2050-2 F2 COSY
f2 (ppm)
f1 (ppm)

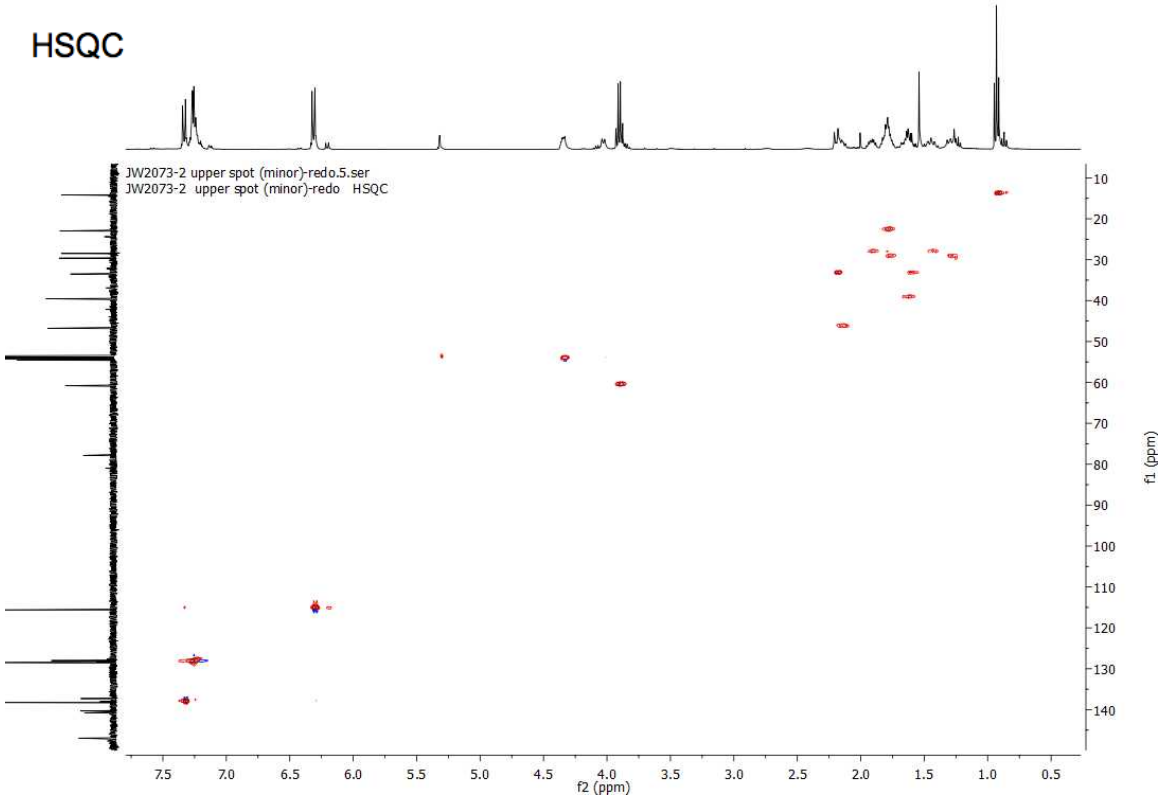
NOESY


ppm
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 ppm

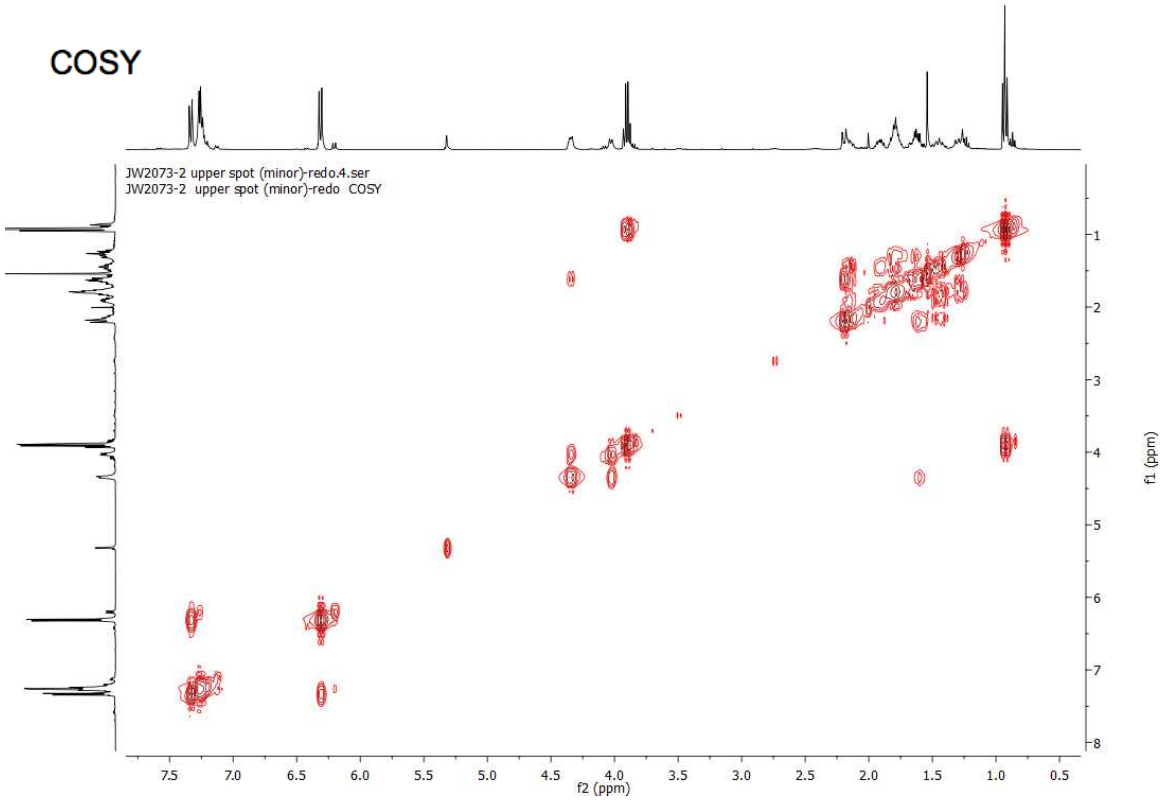

H
N
H
I
Ph
H
EtO
O


1.71
4.96
2.21
1.24
1.02
2.21
2.14
1.29
3.43
2.19
1.40
1.39
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.
f1 (ppm)

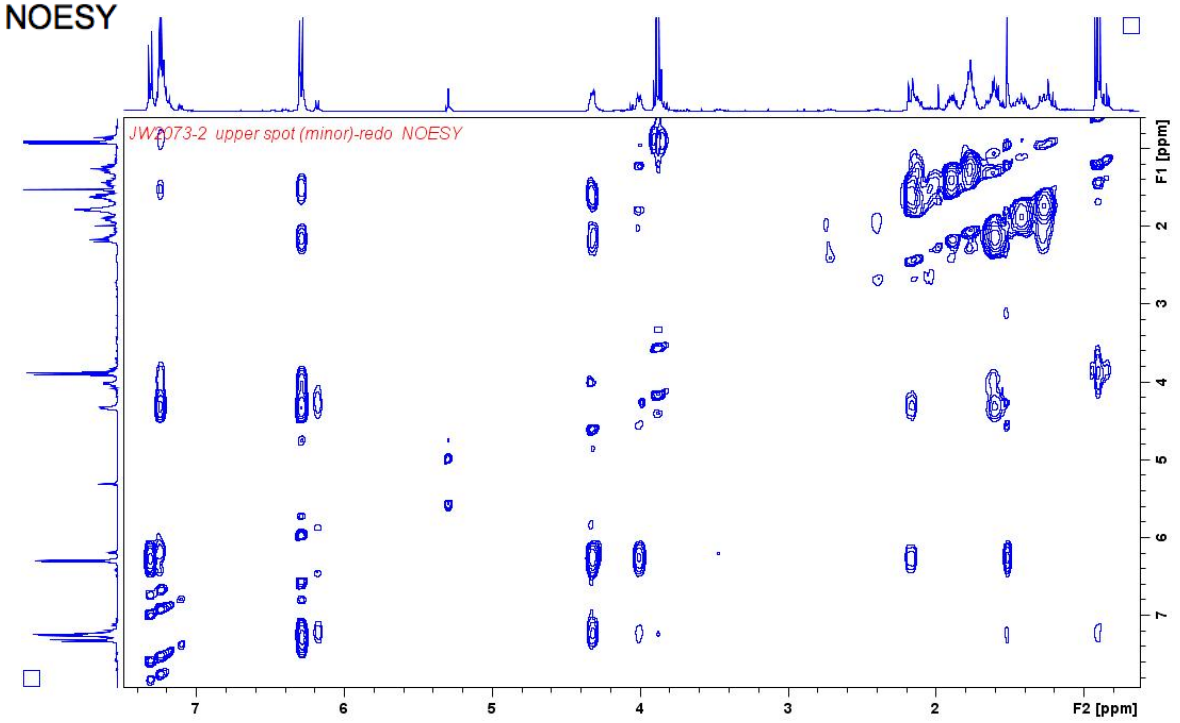

169.21
146.96
140.79
140.32
138.26
137.29
128.52
128.49
128.00
115.61
77.85
60.79
54.59
46.76
39.55
33.51
29.63
28.40
22.98
14.16
f1 (ppm)


HSQC
JW2073-2 upper spot (minor)-redo.5.ser
JW2073-2 upper spot (minor)-redo HSQC
f2 (ppm)
f1 (ppm)

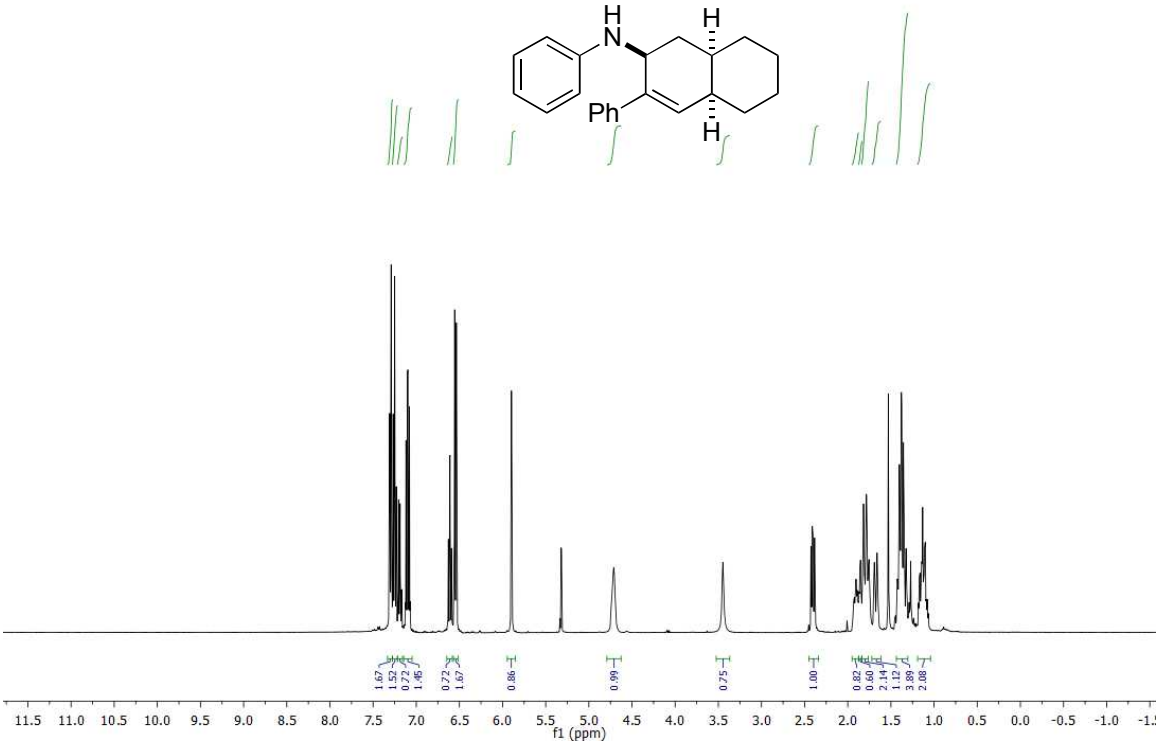
COSY


JW2073-2 upper spot (minor)-redo.4.ser
JW2073-2 upper spot (minor)-redo COSY
f2 (ppm)
f1 (ppm)

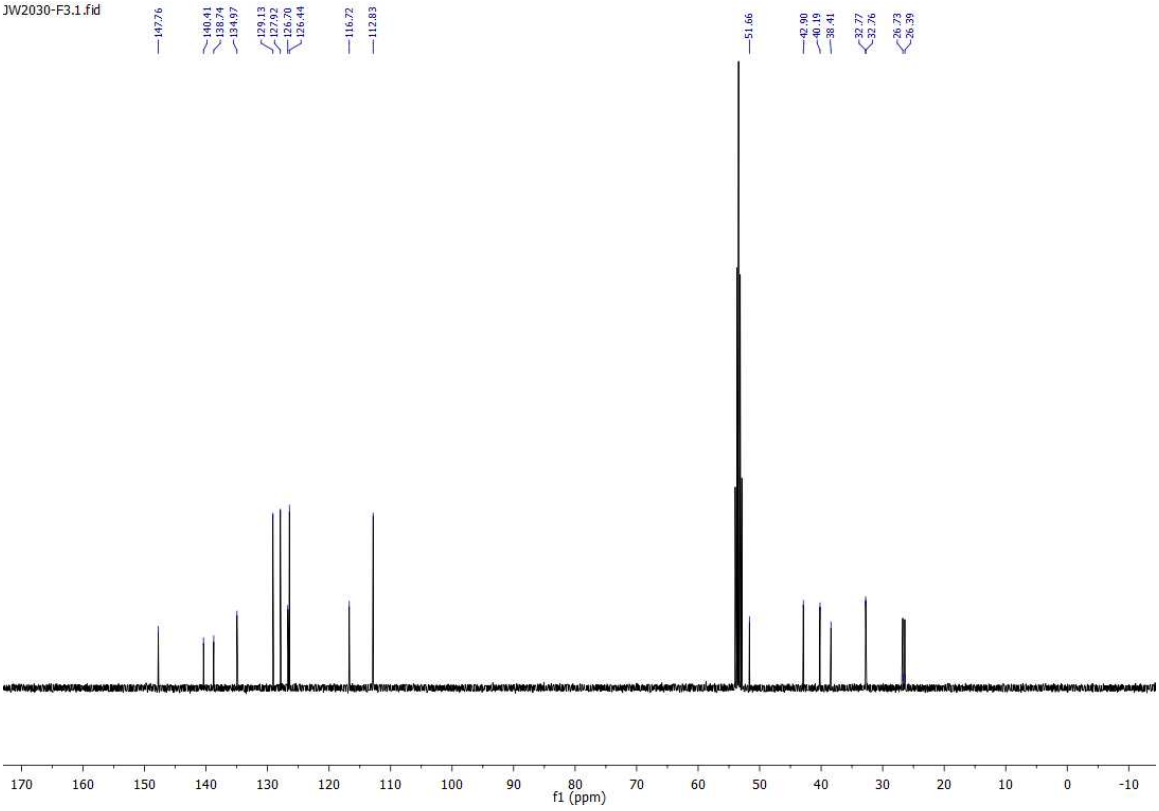
NOESY

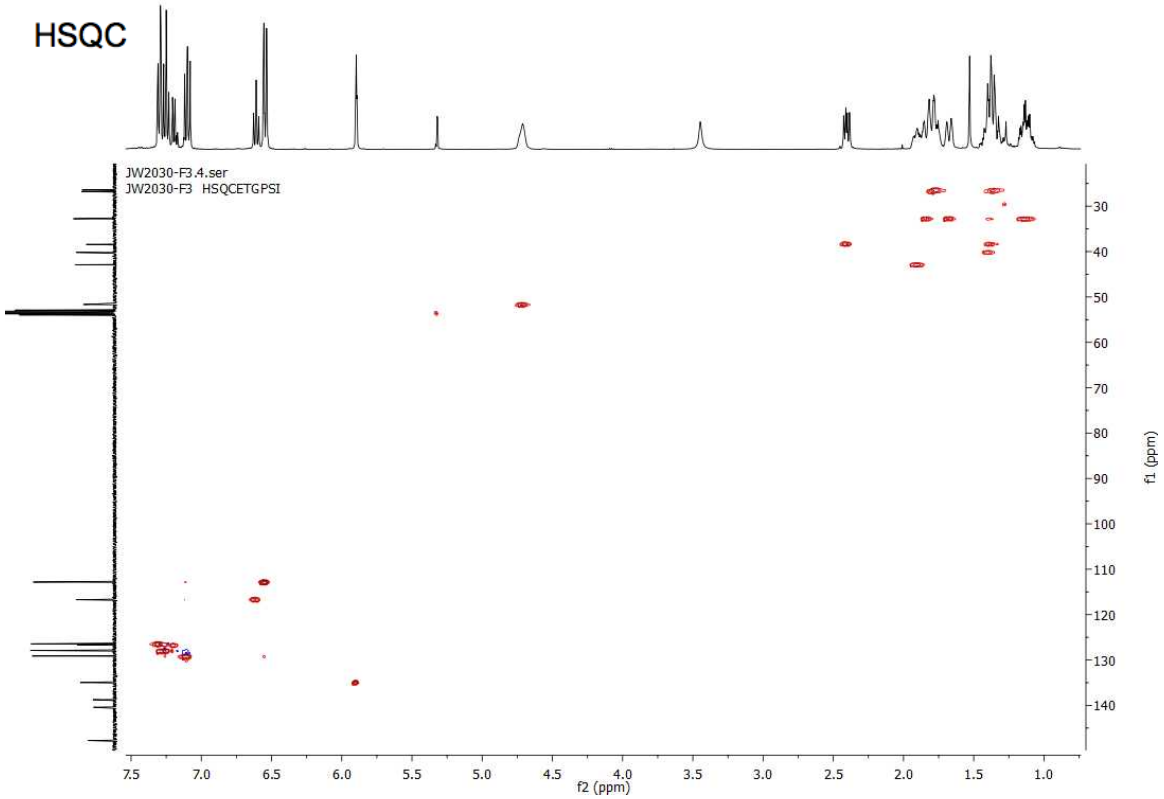

JW2073-2 upper spot (minor)-redo NOESY
F2 [ppm]
F1 [ppm]

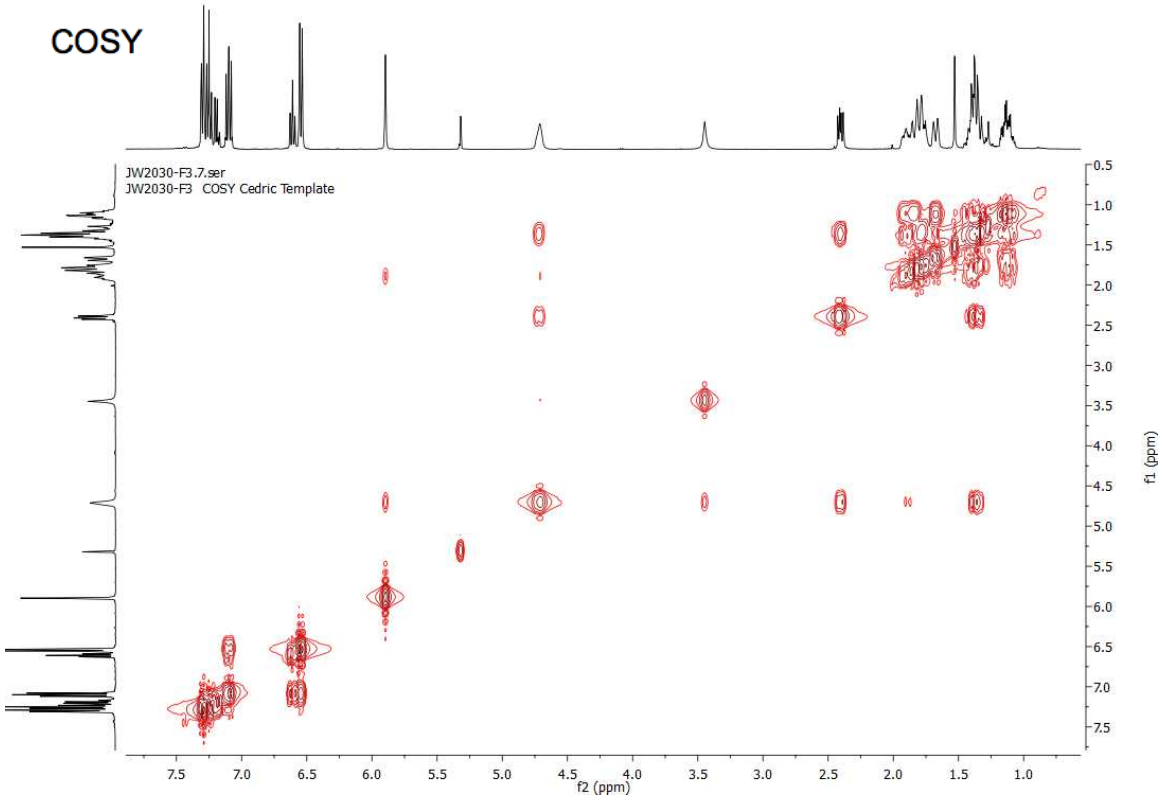
JW2030-F3.2.fid
JW2030-F3 H1



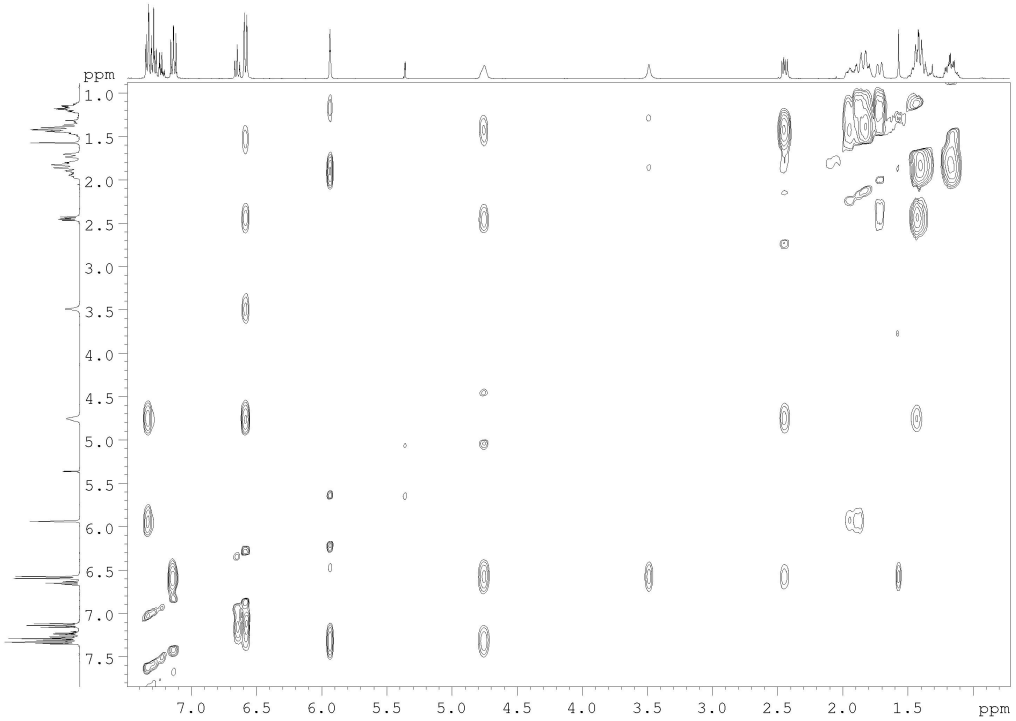
JW2030-F3.1.fid



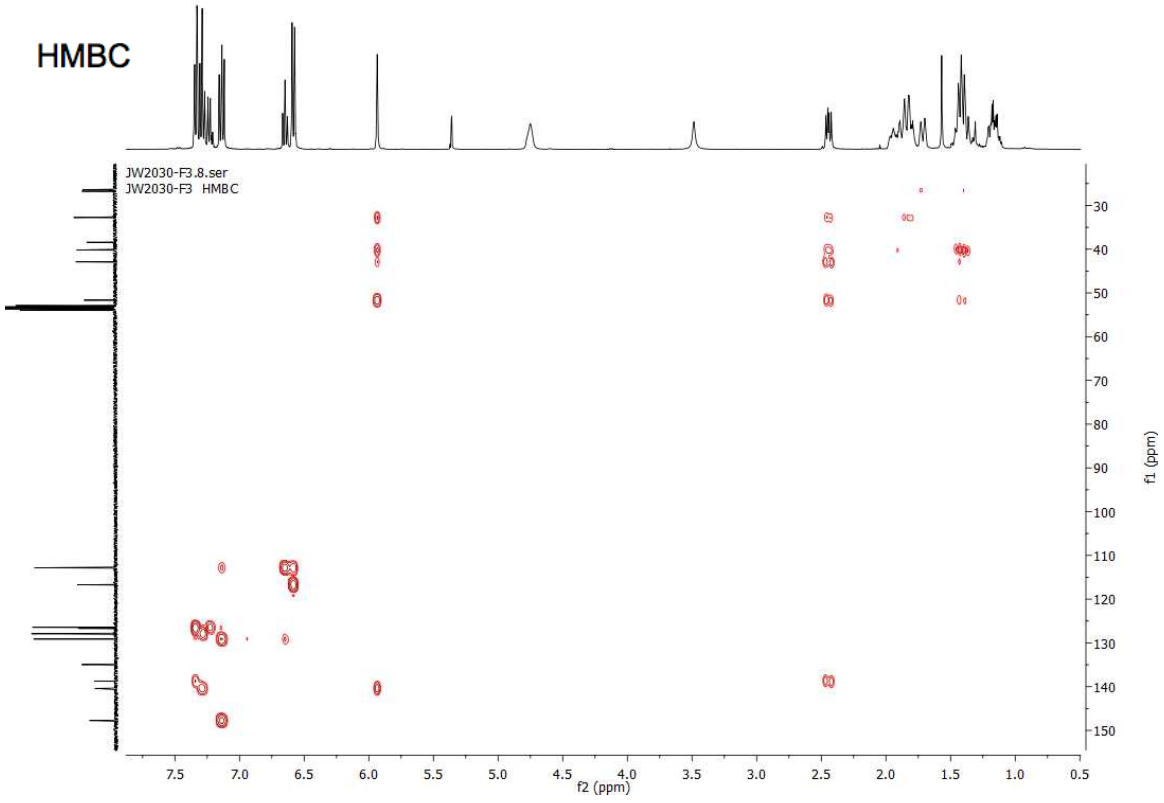

HSQC
JW2030-F3.4.ser
JW2030-F3 HSQCETGPSI
f2 (ppm)
f1 (ppm)

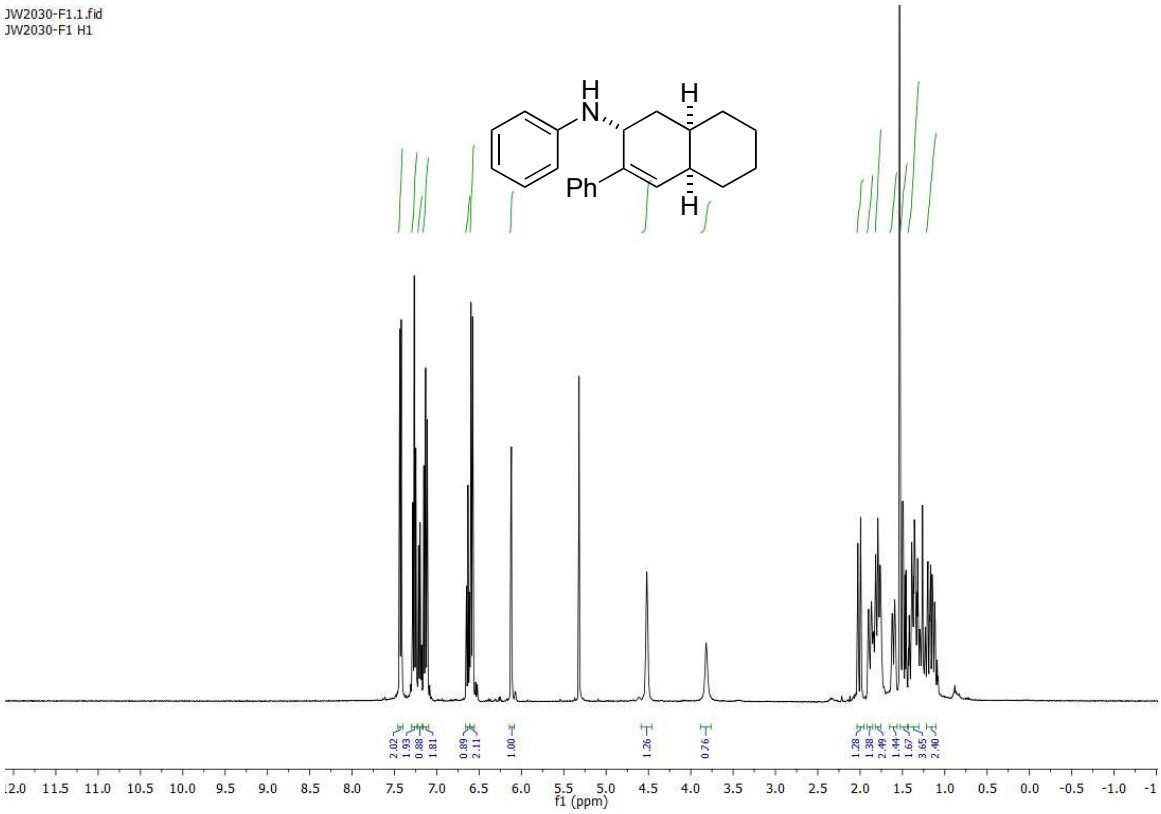

COSY
JW2030-F3.7.ser
JW2030-F3 COSY Cedric Template
f2 (ppm)
f1 (ppm)

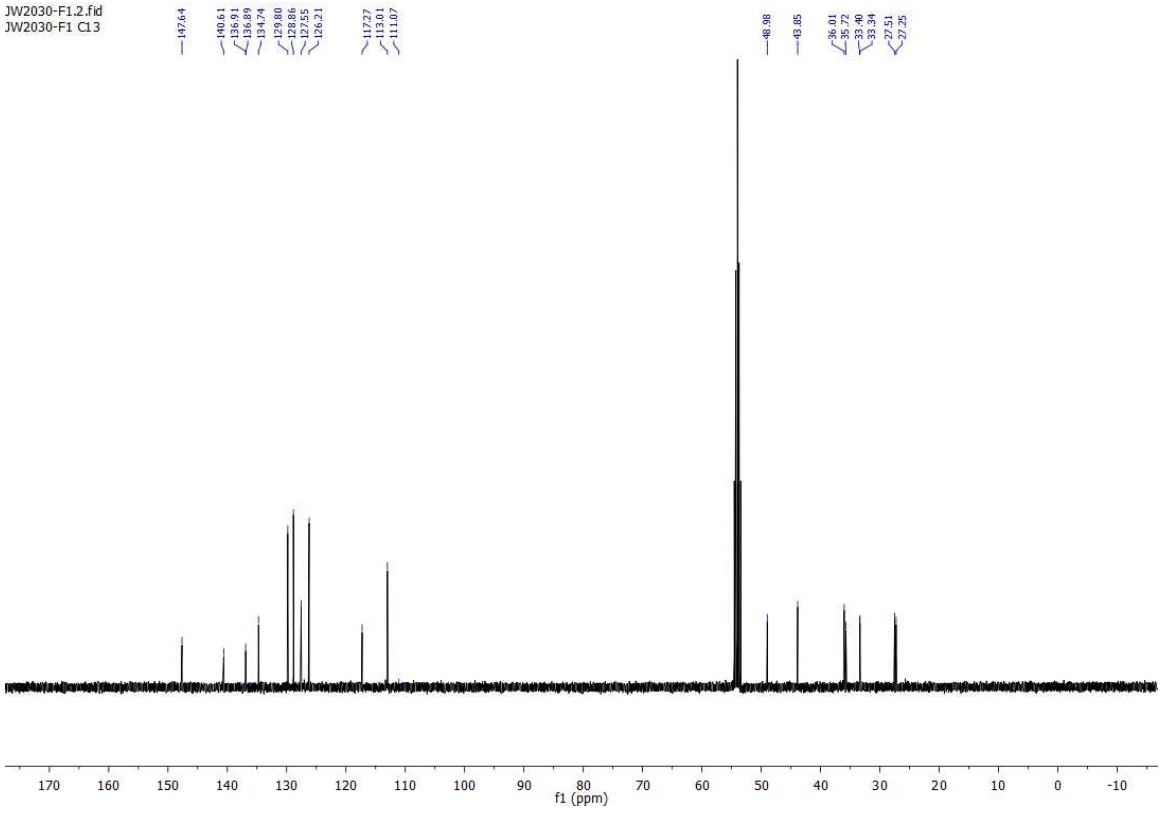
NOESY


ppm
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
ppm

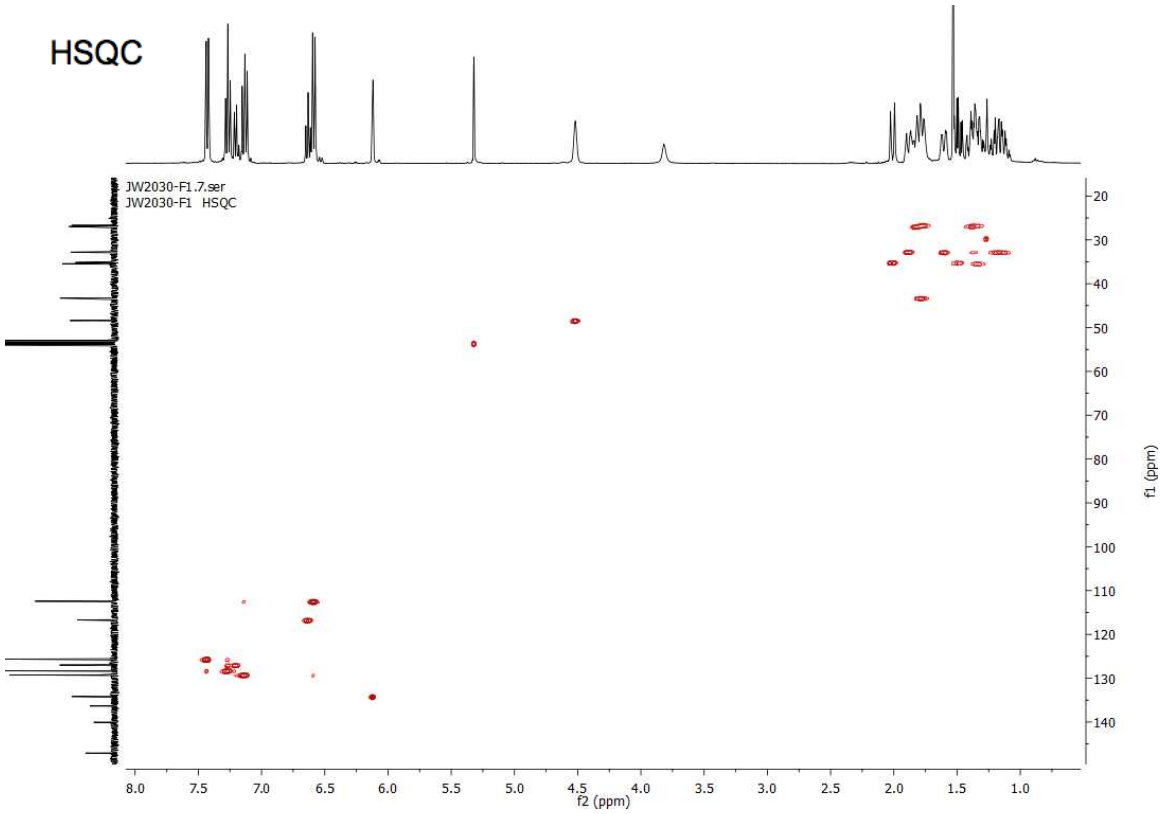
HMBC


JW2030-F3.8.ser
JW2030-F3 HMBC
30
40
50
60
70
80
90
100
110
120
130
140
150
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f2 (ppm)

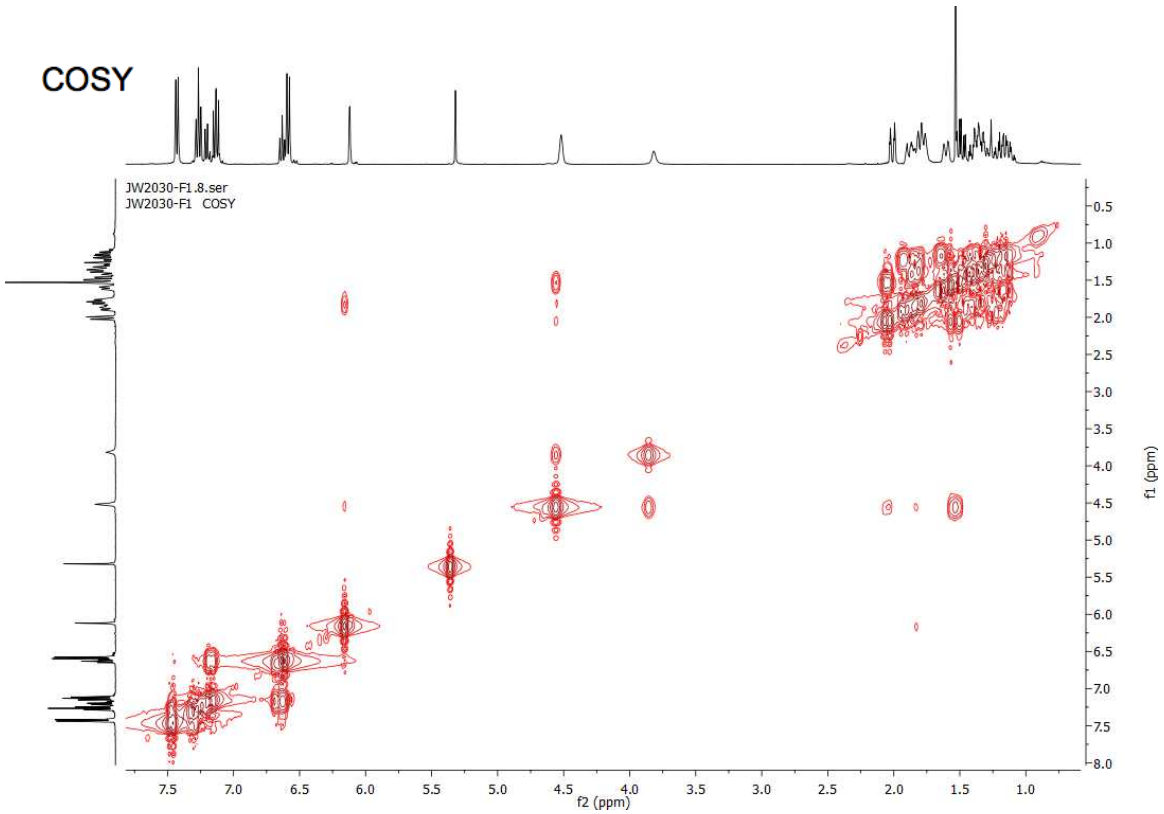

JW2030-F1.1.fid
JW2030-F1 H1
H
N
H
Ph
H
2.02
1.93
0.88
1.81
0.89
2.11
1.00
1.26
0.76
1.28
1.38
2.49
1.44
1.67
3.65
2.40
f1 (ppm)


JW2030-F1.2.fid
JW2030-F1 C13
147.64
140.61
136.91
136.89
134.74
129.80
128.86
127.55
126.21
117.27
113.01
111.07
48.98
43.85
36.01
35.72
33.40
33.34
27.51
27.25
f1 (ppm)

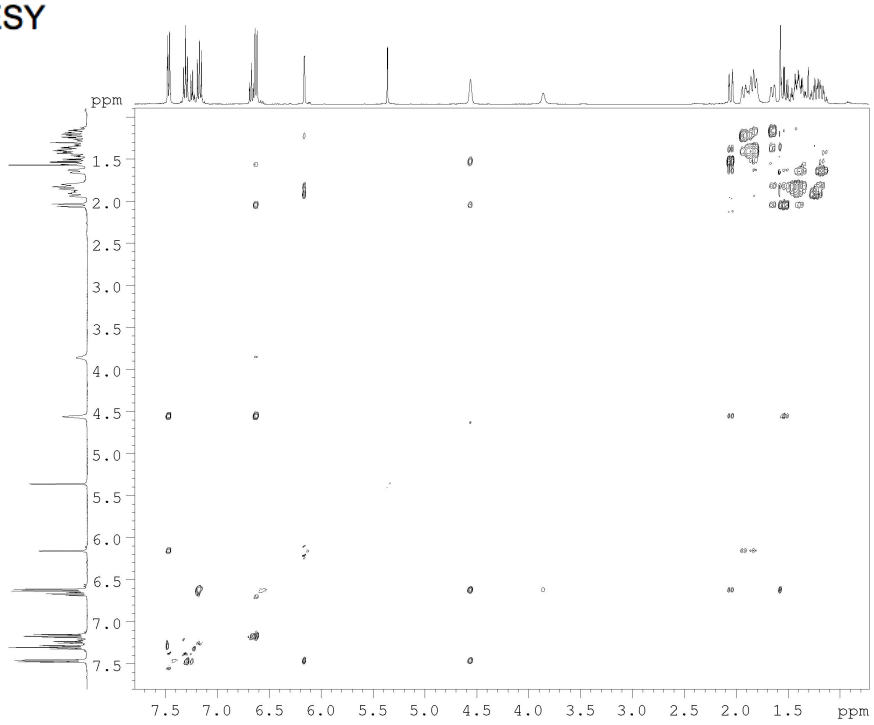
HSQC


JW2030-F1.7.ser
JW2030-F1 HSQC
f2 (ppm)
f1 (ppm)

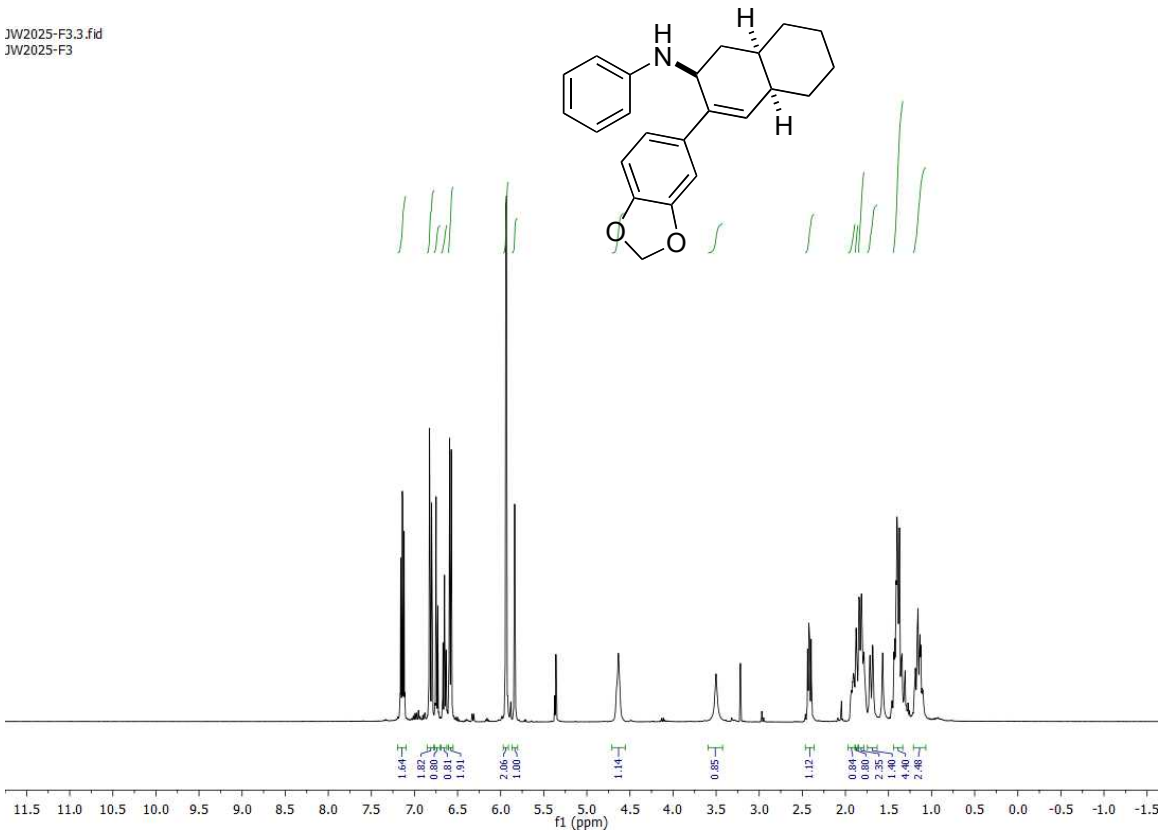
COSY

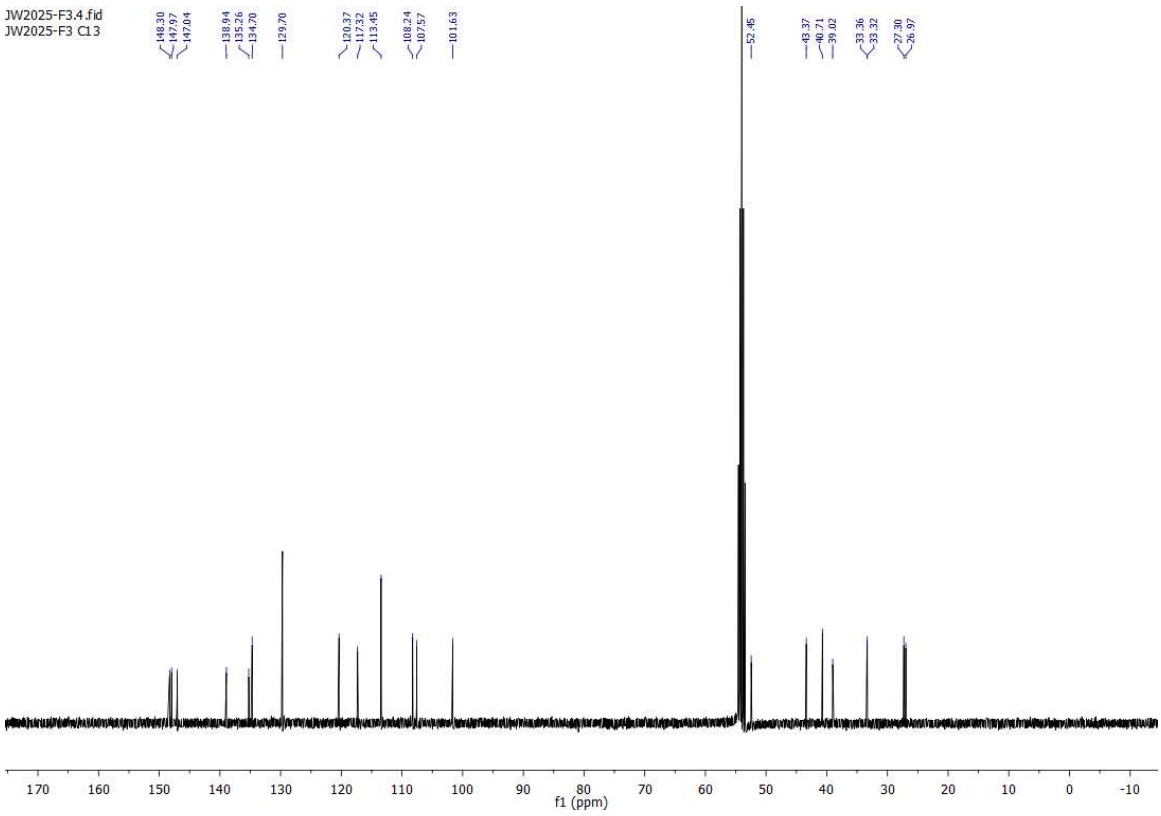

JW2030-F1.8.ser
JW2030-F1 COSY
f2 (ppm)
f1 (ppm)

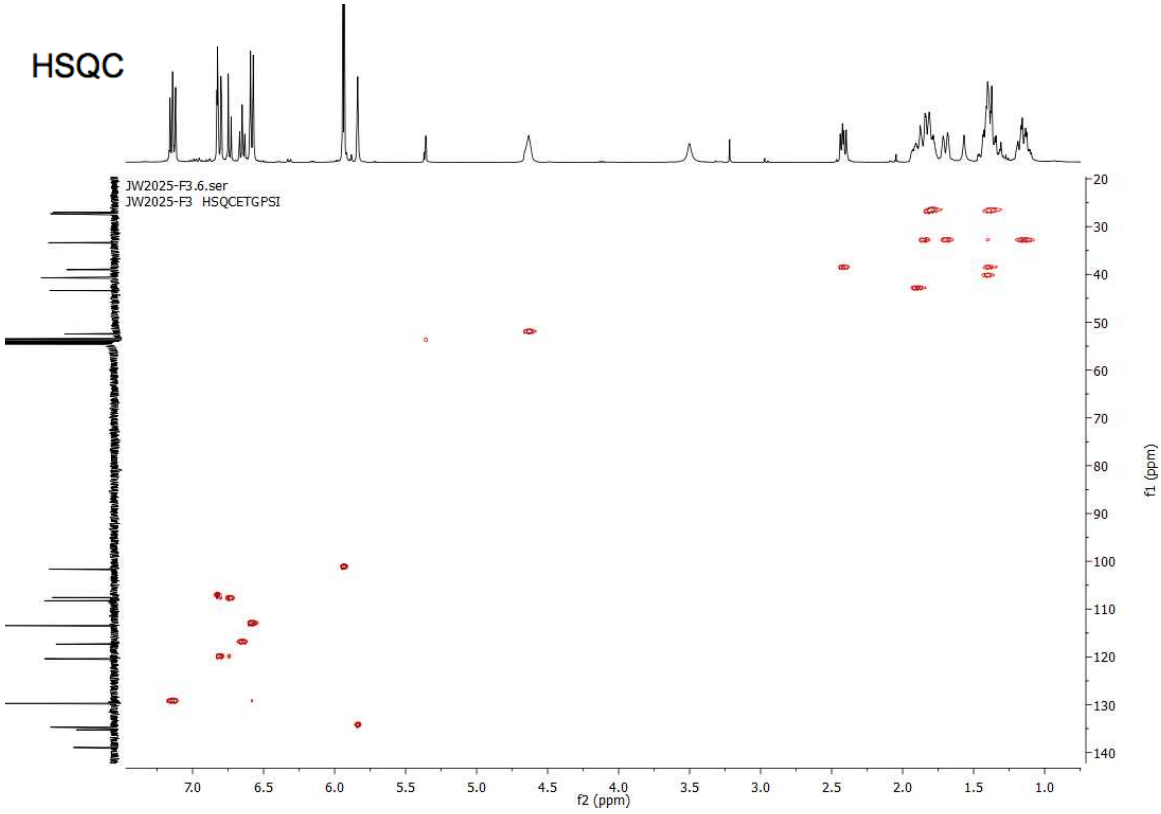
NOESY



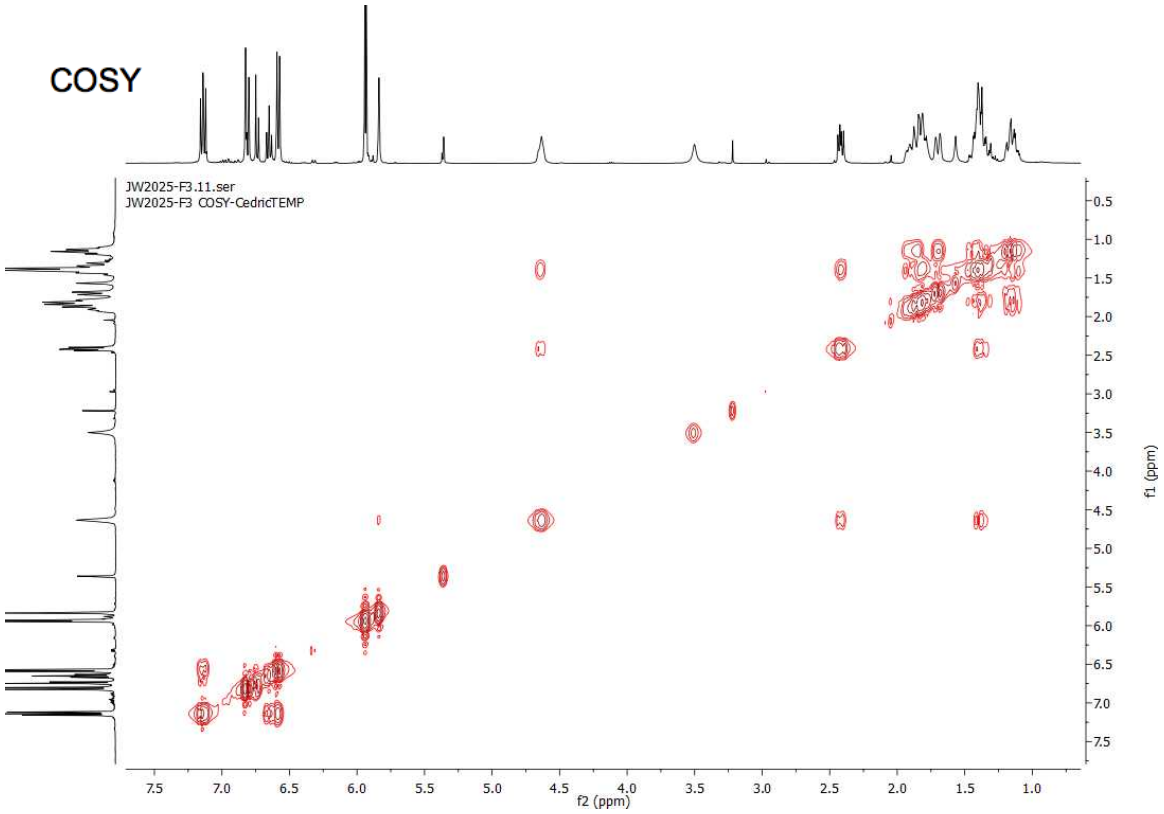
JW2025-F3.3.fid
JW2025-F3



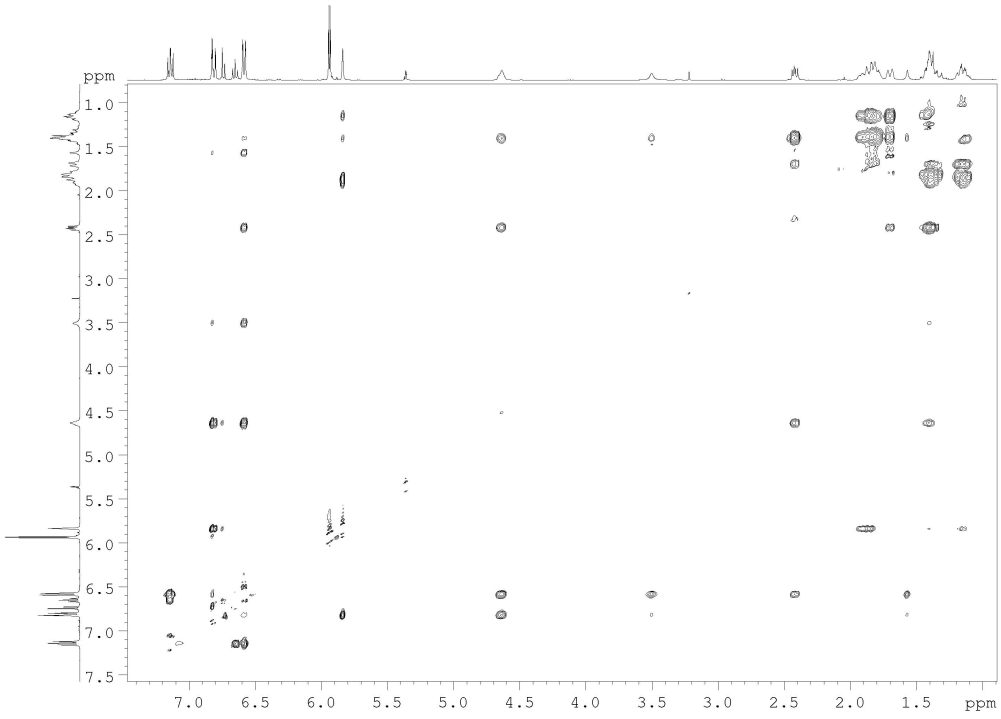

JW2025-F3.4.fid
JW2025-F3 C13
148.30
147.97
147.04
138.94
135.26
134.70
129.70
120.37
117.32
113.45
108.24
107.57
101.63
52.45
43.37
40.71
39.02
33.36
33.32
27.30
26.97
f1 (ppm)

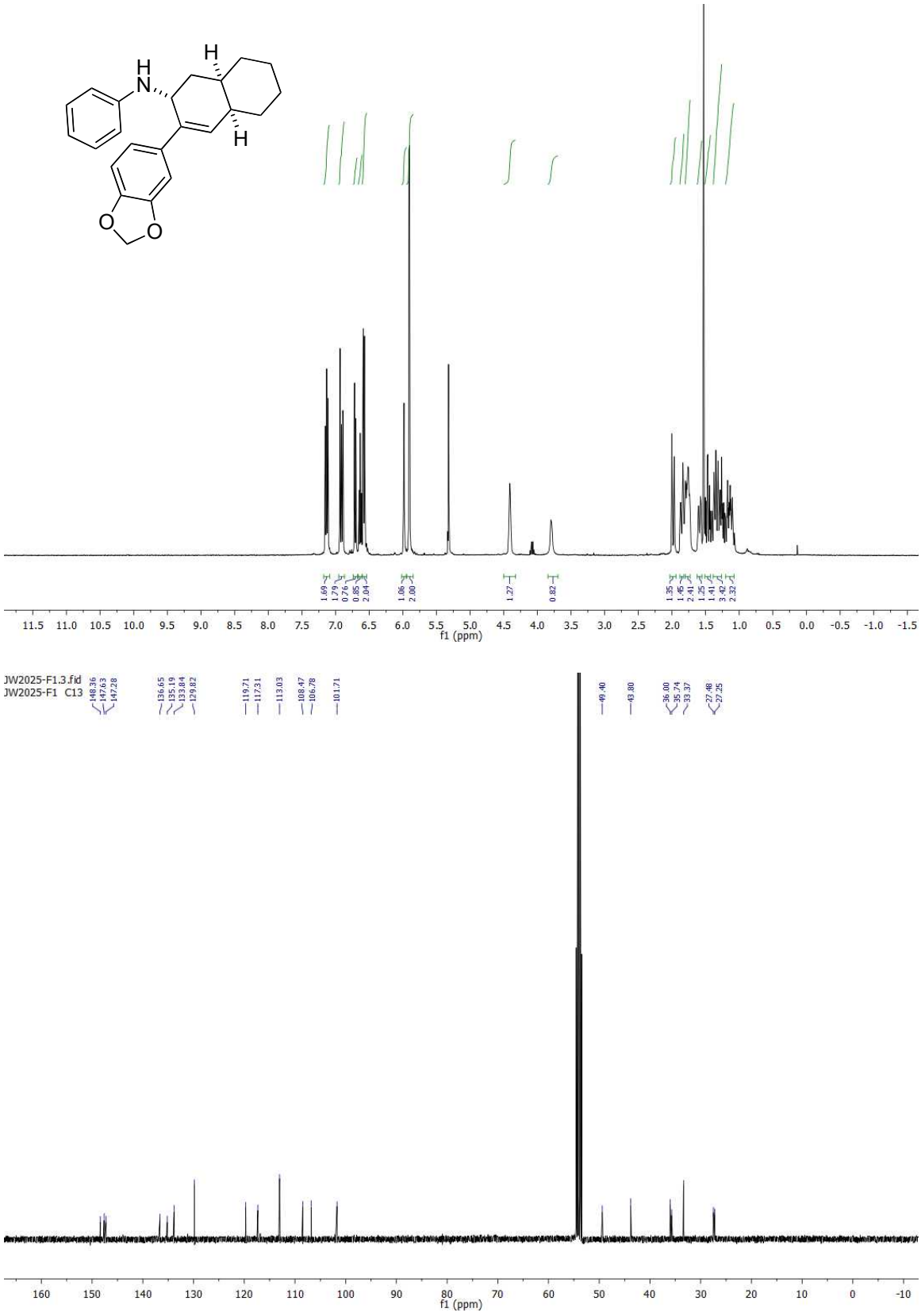

HSQC
JW2025-F3.6.ser
JW2025-F3 HSQCETGPSI
f2 (ppm)
f1 (ppm)

COSY

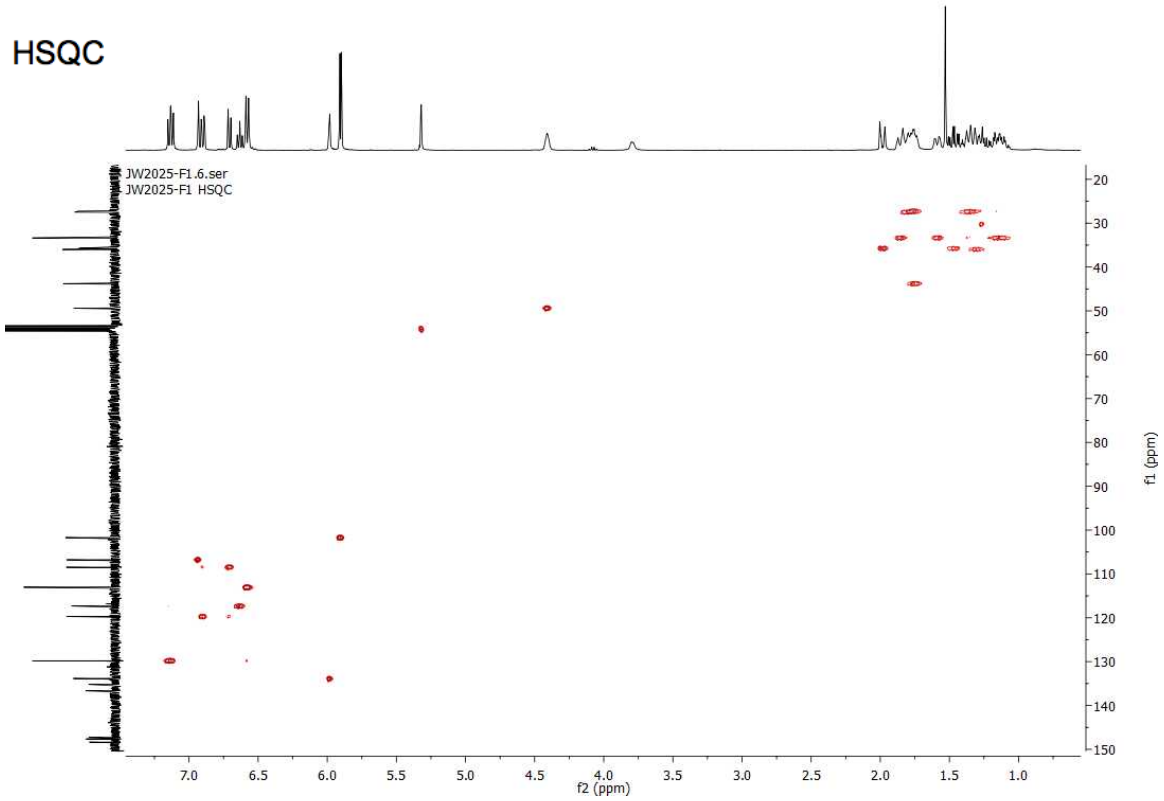

JW2025-F3.11.ser
JW2025-F3 COSY-CedricTEMP
f2 (ppm)
f1 (ppm)

NOESY

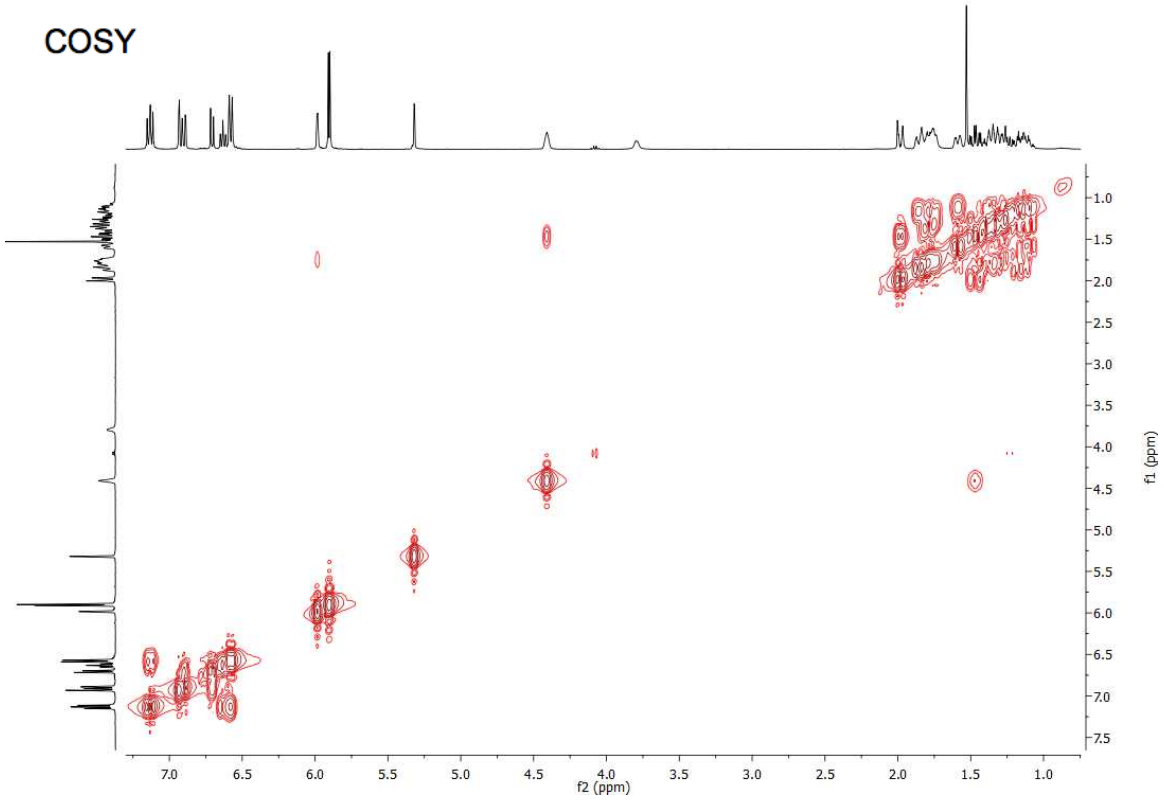

ppm
ppm


H
N
H
H
O
O
1.69
1.79
0.75
0.85
2.04
1.06
2.00
1.27
0.82
1.35
1.45
2.41
1.35
1.41
3.42
2.32
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)
JW2025-F1.3.fid
JW2025-F1 C13
148.36
147.63
147.28
136.65
135.19
133.84
129.82
119.71
117.31
113.03
108.47
106.78
101.71
49.40
43.80
36.00
35.74
33.37
27.48
27.25
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

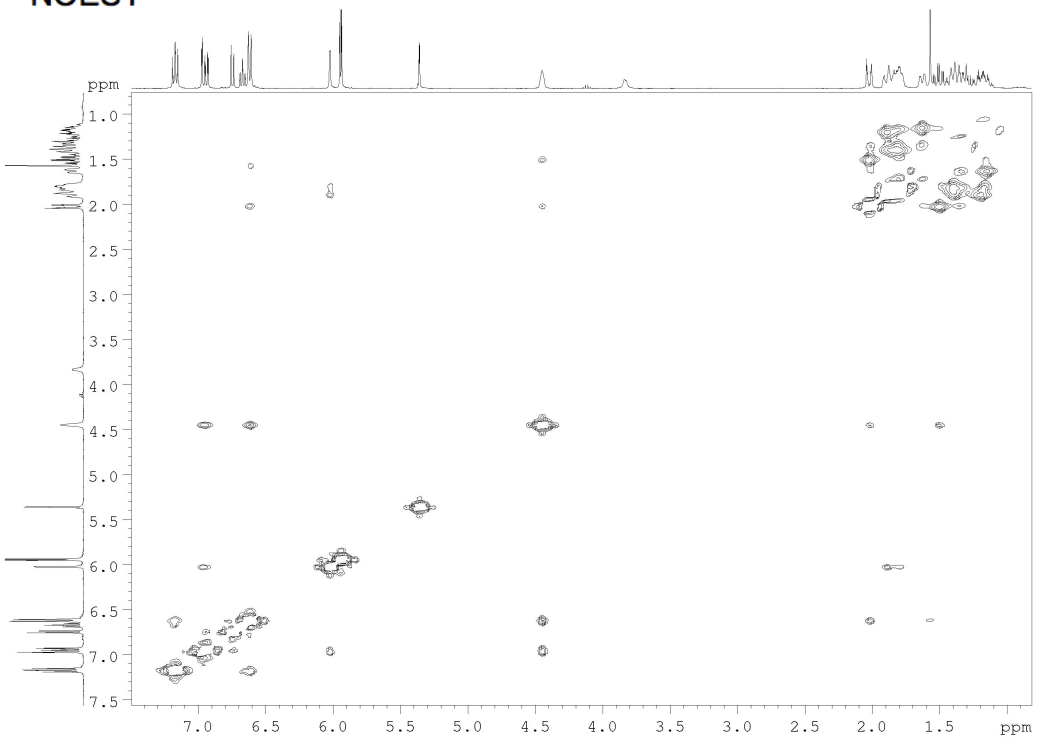
HSQC



COSY



NOESY


ppm
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
ppm