Copper Catalyzed C-H Functionalization for Direct Mannich Reactions

Magnus Rueping* and Nikita Tolstoluzhsky

Magnus.Rueping@RWTH-Aachen.de

Supporting Information

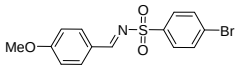
CONTENT

1. General experimental details. Unless otherwise noted, all commercially available compounds were used as provided without further purification. All known imines as well as the new compounds **2e**, **2g** were prepared according to the literature.[1] All azaarenes except 2-(4-methoxyphenyl)-4-methylpyridine **6**,[2] are commercially available compounds. Solvents for chromatography were technical grade and distilled prior to use. Tetrahydrofuran used in reactions was reagent grade and distilled from sodium. Analytical thin-layer chromatography (TLC) was performed on Merck silica gel aluminum plates with F-254 indicator, visualized by irradiation with UV light. Column chromatography was performed using silica gel Merck 60 (particle size 0.063–0.2 mm), Sigma-Aldrich Co. Solvent mixtures are understood as volume/volume. ^{1}H- and ^{13}C-NMR were recorded on a Bruker AV 300 and Varian Inova 400 NMR spectrometer with $CDCl_3$ as solvent. Data are reported in the following order: chemical shift (δ) in ppm; multiplicities are indicated as br s (broadened singlet), s (singlet), d (doublet), t (triplet), m (multiplet); coupling constants (J) are in Hertz (Hz). Mass spectra (MS-ESI) were conducted on VG-Plattform II (Fisons Instruments) (column: Hypersil ODS 150 x 0.32 mm, 3μm). IR spectra were recorded on a Jasco FT/IR-420 and a Perkin Elmer Spectrum 100 spectrometer and are reported in terms of frequency of absorption (cm^{-1}).

2. General procedure for the synthesis. Under Argon, $Cu(OTf)_2$ (5.4 mg, 5 mol %), 1,10-phenanthroline (2.7 mg, 5 mol %), azaarene **1a** (81 mg, 0.76 mmol) and imine **2a** (79 mg, 0.304 mmol) were mixed in a screw cap vial and then dry THF (0.2 mL) was added. The mixture was stirred at 120 °C in a closed reaction vessel. The reaction was monitored by TLC. After completion of the reaction, the solvent was evaporated under reduced pressure and the residue purified by column chromatography on silica gel to give the desired product.

3. Experimental characterization data for products.

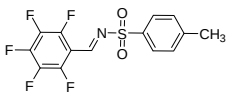
4-bromo-N-(4-methoxybenzylidene)benzenesulfonamide 2e:



2e

The title compound was prepared according to the literature[1] and purified by recrystallization from EtOAc-Penatane, 90% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.89 (s, 3H), 6.97 (d, *J* = 8.9 Hz, 2H), 7.67 (d, *J* = 8.6 Hz, 2H), 7.80–7.93 (m, 4H), 8.95 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 55.71, 114.77, 125.00, 128.42, 129.34, 132.35, 133.92, 137.92, 165.57, 169.94; MS (ESI) calcd for $C_{14}H_{12}BrNO_3S$ [M+1]: 356.0, found: 356.0; IR (solid): ν = 1596, 1508, 1321, 1251, 1151, 1084, 1013, 803, 734 cm^{-1}.

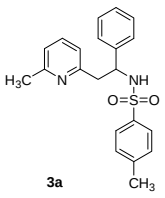
4-methyl-N-((perfluorophenyl)methylene)benzenesulfonamide 2g:



2g

The title compound was prepared according to the literature[1] and purified by recrystallization from EtOAc-Penatane, 40% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.45 (s, 3H), 7.37 (d, *J* = 8.2 Hz, 2H), 7.89 (d, *J* = 8.2 Hz, 2H), 9.20 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.70, 128.41, 129.98, 133.87, 145.41, 158.53; ^{19}F NMR (282 MHz, CDCl3) δ -135.94, -142.32, -159.74; MS (ESI) calcd for $C_{14}H_8F_5NO_2S$ [M+1]: 350.0, found: 349.8; IR (solid): ν = 2325, 1651, 1598, 1492, 1418, 1319, 1161, 1086, 1014, 965, 831, 730, 684 cm^{-1}.

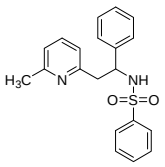
4-methyl-N-(2-(6-methylpyridin-2-yl)-1-phenylethyl)benzenesulfonamide 3a:



3a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-6:1), 80% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.33 (s, 3H), 2.58 (s, 3H), 2.91-3.05 (m, 2H), 4.58 (t, *J*=7.9 Hz, 1H), 6.75 (d, *J*=7.6 Hz, 1H), 6.98–7.08 (m, 3H), 7.14–7.2 (m, 5H), 7.38–7.47 (m, 3H), 7.52 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.4, 24.2, 43.6, 58.1, 121.0, 121.7, 126.7, 126.9, 127.2, 128.2, 129.1, 137.5, 137.6, 141.0, 142.5, 156.8, 157.5; MS (ESI) calcd for $C_{21}H_{22}N_2O_2S$ [M+1]: 367.1, found: 367.0; IR (solid): ν = 2923, 1595, 1457, 1330, 1157, 1090, 1044, 939, 794, 697 cm^{-1}.

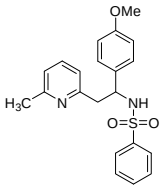
N-(2-(6-methylpyridin-2-yl)-1-phenylethyl)benzenesulfonamide 3b:



3b

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 80% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.48 (s, 3H), 2.89 (d, *J* = 6.5 Hz, 2H), 4.53 (t, *J* = 6.5 Hz, 1H), 6.65 (d, *J* = 7.6 Hz, 1H), 6.90 (d, *J* = 7.7 Hz, 1H), 7.02–7.11 (m, 5H), 7.12–7.20 (m, 2H), 7.25–7.34 (m, 2H), 7.47 (dd, *J* = 8.4, 1.2 Hz, 2H), 7.54 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.30, 43.67, 58.16, 120.95, 121.65, 126.70, 126.87, 127.28, 128.19, 128.47, 131.87, 137.36, 140.52, 140.91, 156.81, 157.58; MS (ESI) calcd for $C_{20}H_{20}N_2O_2S$ [M+1]: 353.1, found: 353.1; IR (solid): ν = 3382, 1592, 1454, 1321, 1156, 1091, 950, 753, 691 cm^{-1}.

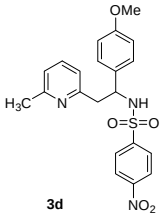
N-(1-(4-methoxyphenyl)-2-(6-methylpyridin-2-yl)ethyl)benzenesulfonamide 3c:



3c

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-6:1), 60% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1H NMR (300 MHz, $CDCl_3$) δ 2.58 (s, 3H), 2.89–3.03 (m, 2H), 3.73 (s, 3H), 4.56 (dd, *J* = 8.2, 4.8 Hz, 1H), 6.67 (d, *J* = 8.8 Hz, 2H), 6.76 (d, *J* = 7.6 Hz, 1H), 7.00 (d, *J* = 7.7 Hz, 1H), 7.07 (d, *J* = 8.8 Hz, 2H), 7.21–7.28 (m, *J* = 7.6 Hz, 2H), 7.34–7.46 (m, 2H), 7.51–7.61 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.19, 43.66, 55.21, 57.68, 113.58, 121.03, 121.71, 126.89, 127.87, 128.42, 131.79, 133.00, 137.53, 140.63, 156.88, 157.50, 158.75; MS (ESI) calcd for $C_{21}H_{22}N_2O_3S$ [M+1]: 383.1, found: 383.0; IR (solid): ν = 3382, 1589, 1512, 1453, 1321, 1246, 1156, 1092, 1032, 950, 831, 753, 688 cm^{-1}.

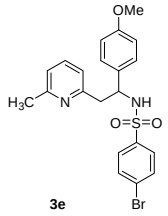
N-(1-(4-methoxyphenyl)-2-(6-methylpyridin-2-yl)ethyl)-4-nitrobenzenesulfonamide 3d:



3d

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 61% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1H NMR (300 MHz, $CDCl_3$) δ 2.55 (s, 3H), 2.88–3.09(m, 2H), 3.64 (s, 3H), 4.61 (dd, *J* = 8.9, 4.4 Hz, 1H), 6.55 (d, *J* = 8.7 Hz, 2H), 6.79 (d, *J* = 7.6 Hz, 1H), 6.91 (d, *J* = 8.7 Hz, 2H), 7.01 (d, *J* = 7.8 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 1H), 7.57 (d, *J* = 8.6 Hz, 2H), 7.97 (d, *J* = 8.6 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.07, 43.05, 55.23, 58.03, 113.58, 121.23, 122.03, 123.46, 128.09, 128.13, 132.00, 137.92, 146.90, 149.25, 156.73, 157.49, 159.10; MS (ESI) calcd for $C_{21}H_{21}N_3O_5S$ [M+1]: 428.1, found: 428.0; IR ($CDCl_3$): ν = 3581, 3379, 3025, 1604, 1525, 1458, 1346, 1249, 1161, 1093, 1034, 956, 834, 753, 687, 616, 557 cm^{-1}.

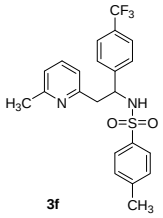
4-bromo-N-(1-(4-methoxyphenyl)-2-(6-methylpyridin-2-yl)ethyl)benzenesulfonamide 3e:



3e

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 75% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.51 (s, 3H), 2.85–2.95 (m, 2H), 3.68 (s, 3H), 4.46–4.57 (m, 1H), 6.60 (d, *J* = 8.7 Hz, 2H), 6.72 (d, *J* = 7.6 Hz, 1H), 6.89–7.02 (m, 3H), 7.28 (s, 4H), 7.38 (t, *J* = 7.7 Hz, 1H), 7.65 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 24.24, 43.53, 55.26, 57.80, 113.58, 121.04, 121.75, 126.53, 128.00, 128.50, 131.54, 132.53, 137.54,139.93, 156.89, 157.58, 158.91; MS (ESI) calcd for $C_{21}H_{21}BrN_2O_3S$ [M+1]: 463.0, found: 462.8; IR (solid): ν =3258, 2923, 2854, 1734, 1613, 1579, 1512, 1453, 1326, 1250, 1154, 1065, 960, 818, 737 cm^{-1}.

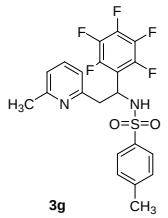
4-methyl-N-(2-(6-methylpyridin-2-yl)-1-(4-(trifluoromethyl)phenyl)ethyl)benzene-sulfonamide 3f:



3f

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 80% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.23 (s, 3H), 2.49 (s, 3H), 2.80-2.90 (m, 2H), 4.58 (t, *J* = 6.4 Hz, 1H), 6.67 (d, *J* = 7.6 Hz, 1H), 6.89–6.99 (m, 3H), 7.20 (d, *J* = 8.8 Hz, 2H), 7.26–7.40 (m, 5H), 7.66 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.27, 24.23, 43.13, 57.64, 121.01, 121.83, 125.08 (q, J^{F} = 3.7 Hz), 126.91, 127.19, 129.15, 137.28, 137.50, 142.88, 145.01, 156.24, 157.71; ^{19}F NMR (282 MHz, $CDCl_3$) δ -62.62; MS (ESI) calcd for $C_{22}H_{21}F_3N_2O_2S$ [M+1]: 435.1, found: 435.1; IR (solid): ν = 2927, 1595, 1459, 1322, 1158, 919, 819, 712, 661 cm^{-1}.

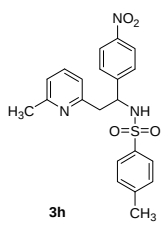
4-methyl-N-(2-(6-methylpyridin-2-yl)-1-(perfluorophenyl)ethyl)benzene-sulfonamide 3g:



3g

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 79% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.34 (s, 3H), 2.48 (s, 3H), 3.02 (dd, *J* = 14.0, 5.5 Hz, 1H), 3.29 (dd, *J* = 13.9, 9.1 Hz, 1H), 4.95–5.10 (m, 1H), 6.70 (br s, 1H), 6.82 (d, *J* = 7.6 Hz, 1H), 6.99 (d, *J* = 7.7 Hz, 1H), 7.10 (d, *J* = 7.9 Hz, 2H), 7.43 (t, *J* = 7.7 Hz, 1H), 7.50 (d, *J* = 8.3 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.30, 24.13, 41.04, 48.68, 120.54, 121.90, 126.89, 129.19, 136.44, 137.28, 143.39, 155.21, 158.07; ^{19}F NMR (282 MHz, $CDCl_3$) δ -142.39, -154.93, -162.05; MS (ESI) calcd for $C_{21}H_{17}F_5N_2O_2S$ [M+1]: 457.1, found: 457.1; IR (solid): ν = 3068, 2327, 1651, 1595, 1503, 1460, 1409, 1362, 1312, 1150, 998, 944, 856, 803, 708, 660 cm^{-1}.

4-methyl-N-(2-(6-methylpyridin-2-yl)-1-(4-nitrophenyl)ethyl)benzenesulfonamide 3h:

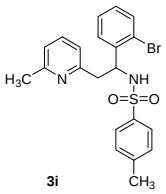


3h

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-2:1), 97% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.33 (s, 3H), 2.56 (s, 3H), 2.91–3.03 (m, 2H), 4.67 (t, *J* = 6.3 Hz, 1H), 6.72 (d, *J* = 7.6 Hz, 1H), 7.02 (d, *J* = 7.7 Hz, 1H), 7.08 (d, *J* = 8.4 Hz, 2H), 7.34–7.42 (m, 3H), 7.43–7.50 (m, 2H), 7.86 (br s, 1H), 8.02 (d, *J* = 8.8 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.39, 24.20, 42.75, 57.36, 121.06,

122.02, 123.45, 126.89, 127.65, 129.32, 137.08, 137.67, 143.20, 147.05, 148.67, 155.79, 157.76; MS (ESI) calcd for $C_{21}H_{21}N_3O_4S$ [M+1]: 412.1, found: 412.1; IR (solid): ν = 2923, 1597, 1518, 1458, 1337, 1155, 1062, 942, 854, 814, 666 cm^{-1}.

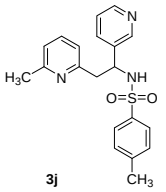
N-(1-(2-bromophenyl)-2-(6-methylpyridin-2-yl)ethyl)-4-methylbenzenesulfonamide 3i:



3i

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-2:1), 88% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.32 (s, 3H), 2.59 (s, 3H), 2.84 (dd, *J* = 13.9, 9.3 Hz, 1H), 3.00 (dd, *J* = 13.9, 3.7 Hz, 1H), 4.87 (d, *J* = 7.6 Hz, 1H), 6.74 (d, *J* = 7.6 Hz, 1H), 7.00 (d, *J* = 7.7 Hz, 1H), 7.06 (d, *J* = 8.6 Hz, 3H), 7.15 (td, *J* = 7.6, 1.3 Hz, 1H), 7.37 (d, *J* = 7.7 Hz, 1H), 7.39–7.43 (m, 1H), 7.47 (d, *J* = 8.2 Hz, 3H), 7.56 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.41, 24.20, 41.66, 57.29, 120.83, 121.75, 121.91, 127.00, 127.48, 128.68, 128.93, 129.16, 132.50, 136.60, 137.58, 140.18, 142.74, 156.43, 157.42; MS (ESI) calcd for $C_{21}H_{21}BrN_2O_2S$ [M+1]: 447.1, found: 447.0; IR (solid): ν = 2923, 1597, 1518, 1458, 1337, 1155, 1062, 942, 854, 814, 666 cm^{-1}.

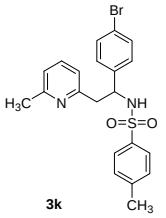
4-methyl-N-(2-(6-methylpyridin-2-yl)-1-(pyridin-3-yl)ethyl)benzenesulfonamide 3j:



3j

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-0:1), 89% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.31 (s, 3H), 2.54 (s, 3H), 4.62 (s, 1H), 2.91–3.02 (m, 2H), 6.72 (d, *J* = 7.5 Hz, 1H), 6.99 (d, *J* = 7.7 Hz, 1H), 7.07 (d, *J* = 7.9 Hz, 3H), 7.39 (t, *J* = 7.7 Hz, 1H), 7.45 (d, *J* = 8.0 Hz, 2H), 7.52 (s, 1H), 7.84 (s, 1H), 8.40 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.53, 24.39, 43.20, 55.75, 121.04, 121.80, 123.15, 126.85, 129.26, 134.46, 136.81, 137.10, 137.43, 142.88, 148.16, 148.41, 156.07, 157.62; MS (ESI) calcd for $C_{20}H_{21}N_3O_2S$ [M+1]: 368.1, found: 368.0; IR (solid): ν = 3070, 2869, 1578, 1458, 1426, 1329, 1153, 1067, 947, 814, 715, 667 cm^{-1}.

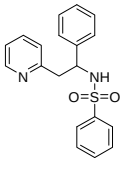
N-(1-(4-bromophenyl)-2-(6-methylpyridin-2-yl)ethyl)-4-methylbenzenesulfonamide 3k:



3k

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-2:1), 88% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.28 (s, 3H), 2.50 (s, 3H), 2.81–2.93 (m, 2H), 4.48 (t, *J* = 6.2 Hz, 1H), 6.67 (d, *J* = 7.7 Hz, 1H), 6.89–7.05 (m, 5H), 7.13–7.25 (m, 2H), 7.30–7.40 (m, 3H), 7.57 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.41, 24.17, 43.16, 57.46, 121.08, 121.12, 121.82, 126.93, 128.52, 129.16, 131.23, 137.41, 137.59, 140.07, 142.80, 156.37, 157.60; MS (ESI) calcd for $C_{21}H_{21}BrN_2O_2S$ [M+1]: 447.1, found: 447.0; IR (solid): ν = 3121, 1594, 1459, 1329, 1158, 1089, 1040, 925, 822, 729, 669 cm^{-1}.

N-(1-phenyl-2-(pyridin-2-yl)ethyl)benzenesulfonamide 4a:

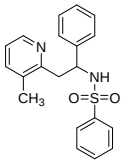


4a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (8:1-2:1), 50% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.96–3.08 (m, 2H), 4.70 (dt, *J* = 7.1, 5.3 Hz, 1H), 6.88 (d, *J* = 7.7 Hz, 1H), 7.08–7.16 (m, 6H), 7.26 (t, *J* = 7.6 Hz,

2H), 7.33 (d, *J* = 5.1 Hz, 1H), 7.35–7.41 (m, 1H), 7.47 (td, *J* = 7.7, 1.8 Hz, 1H), 7.56–7.62 (m, 2H), 8.48 (d, *J* = 4.2 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 43.96, 57.92, 121.98, 124.05, 126.61, 126.92, 127.26, 128.20, 128.54, 131.92, 136.88, 140.70, 148.82, 157.56; MS (ESI) calcd for $C_{19}H_{18}N_2O_2S$ [M+1]: 339.1, found: 339.0; IR (solid): ν = 3063, 2856, 1596, 1444, 1311, 1148, 1061, 966, 862, 754, 684 cm^{-1}.

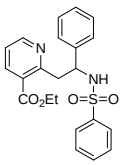
N-(2-(3-methylpyridin-2-yl)-1-phenylethyl)benzenesulfonamide 5a:



5a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-6:1), 79% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.96 (s, 3H), 2.98–3.07 (m, 2H), 4.63 (dd, *J* = 9.8, 6.1 Hz, 1H), 7.03 (dd, *J* = 7.6, 4.8 Hz, 1H), 7.10–7.15 (m, 5H), 7.20–7.31 (m, 3H), 7.33–7.44 (m, 2H), 7.55 (dd, *J* = 8.4, 1.2 Hz, 2H), 8.32 (d, *J* = 4.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 18.54, 40.43, 57.06, 122.06, 126.51, 126.84, 127.25, 128.17, 128.47, 131.84, 131.97, 138.33, 140.39, 140.96, 145.98, 155.80; MS (ESI) calcd for $C_{20}H_{20}N_2O_2S$ [M+1]: 353.1, found: 353.0; IR (solid): ν = 3026, 2852, 2712, 1582, 1447, 1319, 1155, 1062, 963, 799, 754, 688 cm^{-1}.

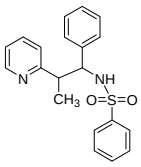
Ethyl 2-(2-phenyl-2-(phenylsulfonamido)ethyl)nicotinate 6a:



6a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-4:1), 62% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.31 (t, *J* = 7.1 Hz, 3H), 3.25–3.41 (m, 2H), 4.29 (q, *J* = 7.1 Hz, 2H), 4.67–4.87 (m, 1H), 6.69 (d, *J* = 5.7 Hz, 1H), 7.05–7.20 (m, 6H), 7.21–7.32 (m, 3H), 7.36 (dd, *J* = 8.4, 1.3 Hz, 2H), 8.00 (dd, *J* = 7.9, 1.4 Hz, 1H), 8.49 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.20, 43.17, 58.10, 61.94, 121.78, 126.45, 126.64, 127.25, 128.34, 128.46, 131.63, 138.68, 140.41, 141.71, 151.60, 158.52, 166.67; MS (ESI) calcd for $C_{22}H_{22}N_2O_4S$ [M+1]: 411.1, found: 411.0; IR (solid): ν = 3118, 2924, 1716, 1572, 1444, 1324, 1263, 1160, 1083, 942, 767, 692 cm^{-1}.

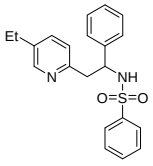
N-(1-phenyl-2-(pyridin-2-yl)propyl)benzenesulfonamide 7a:



7a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-4:1), 58% yield. (D/R isomers ratio 9:1 according to NMR) ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.12–1.24 (m, 3H), 3.10–3.28 (m, 1H), 4.49–4.62 (m, 1H), 6.75 (d, *J* = 7.8 Hz, 1H), 6.81–6.91 (m, 2H), 6.96–7.07 (m, 4H), 7.14–7.24 (m, 3H), 7.27–7.34 (m, 1H), 7.40 (td, *J* = 7.7, 1.8 Hz, 1H), 7.50–7.59 (m, 2H), 8.46 (d, *J* = 4.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 15.34, 45.88, 62.32, 121.90, 122.48, 126.85, 127.00, 127.33, 127.65, 128.42, 131.82, 136.66, 138.73, 140.19, 148.43, 161.56; MS (ESI) calcd for $C_{20}H_{20}N_2O_2S$ [M+1]: 353.1, found: 353.0; IR (solid): ν = 3296, 1591, 1445, 1317, 1156, 1089, 917, 752, 693 cm^{-1}.

N-(2-(5-ethylpyridin-2-yl)-1-phenylethyl)benzenesulfonamide 8a:

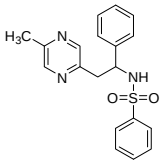


8a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-5:1), 54% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.16 (td, *J* = 7.6, 1.1 Hz, 3H), 2.53 (q, *J* = 7.6 Hz, 2H), 2.93 (d, *J* = 6.5 Hz, 2H), 4.58 (s, 1H), 6.76 (d, *J* = 7.9

Hz, 1H), 7.06 (s, 5H), 7.14–7.21 (m, 2H), 7.23–7.35 (m, *J* = 16.5, 7.8 Hz, 3H), 7.50 (d, *J* = 8.4 Hz, 2H), 8.26 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 15.14, 25.66, 43.40, 58.09, 123.65, 126.65, 126.93, 127.24, 128.18, 128.45, 131.83, 136.44, 137.59, 140.60, 140.82, 148.27, 154.69; MS (ESI) calcd for $C_{21}H_{22}N_2O_2S$ [M+1]: 367.1, found: 367.0; IR (solid): ν = 3055, 2854, 1576, 1488, 1444, 1314, 1150, 1063, 969, 839, 755, 689 cm^{-1}.

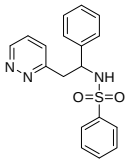
N-(2-(5-methylpyrazin-2-yl)-1-phenylethyl)benzenesulfonamide 9a:



9a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (6:1-2:1), 49% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.40 (s, 3H), 3.01 (d, *J* = 6.6 Hz, 2H), 4.72 (q, *J* = 6.5 Hz, 1H), 6.55 (d, *J* = 6.6 Hz, 1H), 6.96–7.13 (m, 5H), 7.19 (t, *J* = 7.5 Hz, 2H), 7.27–7.40 (m, 1H), 7.47–7.60 (m, 2H), 7.99 (s, 1H), 8.19 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.15, 41.18, 57.70, 126.45, 126.87, 127.53, 128.41, 128.61, 132.04, 132.12, 140.08, 140.49, 143.36, 143.87, 149.60, 151.99; MS (ESI) calcd for $C_{19}H_{19}N_3O_2S$ [M+1]: 354.1, found: 354.0; IR (solid): ν = 3072, 2872, 1692, 1491, 1446, 1313, 1150, 1062, 968, 844, 756, 691 cm^{-1}.

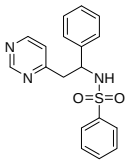
N-(1-phenyl-2-(pyridazin-3-yl)ethyl)benzenesulfonamide 10a:



10a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (5:1-2:1-1:1-1:2), 58% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.30 (qd, *J* = 14.2, 6.9 Hz, 2H), 4.79 (td, *J* = 7.9, 5.3 Hz, 1H), 6.81 (d, *J* = 7.3 Hz, 1H), 7.05 (s, 5H), 7.09–7.27 (m, 4H), 7.26–7.37 (m, 1H), 7.45–7.58 (m, 2H), 8.94 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 43.14, 57.73, 126.52, 126.83, 126.93, 127.56, 127.75, 128.44, 128.64, 132.02,139.94, 140.49, 149.96, 160.18; MS (ESI) calcd for $C_{18}H_{17}N_3O_2S$ [M+1]: 340.1, found: 340.0; IR (solid): ν = 3060, 2864, 1580, 1477, 1318, 1152, 1065, 945, 807, 747, 689 cm^{-1}.

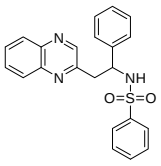
N-(1-phenyl-2-(pyrimidin-4-yl)ethyl)benzenesulfonamide 11a:



11a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (5:1-0:1), 50% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.00– 3.20 (m, 2H), 4.83 (dd, *J* = 13.0, 6.9 Hz, 1H), 6.74 (d, *J* = 6.9 Hz, 1H), 6.98 (s, 1H), 7.05–7.18 (m, 5H), 7.22–7.33 (m, 2H), 7.41 (ddd, *J* = 6.8, 3.9, 1.2 Hz, 1H), 7.54–7.68 (m, 2H), 8.53 (s, 1H), 9.05 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 44.13, 57.11, 126.42, 126.84, 127.65, 128.47, 128.72, 132.25, 139.80, 140.34, 156.93, 157.93, 166.06; MS (ESI) calcd for $C_{18}H_{17}N_3O_2S$ [M+1]: 340.1, found: 340.0; IR (solid): ν = 3078, 2865, 1585, 1451, 1392, 1310, 1148, 1059, 958, 861, 821, 758, 687 cm^{-1}.

N-(1-phenyl-2-(quinoxalin-2-yl)ethyl)benzenesulfonamide 12a:

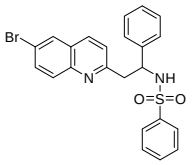


12a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (6:1-1:1), 76% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.16–3.33 (m, 2H), 4.80 (q, *J* = 6.6 Hz, 1H), 6.56 (d, *J* = 6.4 Hz, 1H), 6.95–7.04 (m, 2H), 7.05–7.19 (m, 6H), 7.38–7.51 (m, 2H), 7.59–7.76 (m, 2H), 7.87–8.04 (m, 2H), 8.37 (s, 1H); ^{13}C NMR (75 MHz,

$CDCl_3$): δ 42.40, 57.63, 126.50, 126.64, 127.71, 128.45, 128.55, 128.89, 129.23, 129.69, 130.37, 132.01, 140.07, 140.25, 141.41, 145.63, 152.76; MS (ESI) calcd for $C_{22}H_{19}N_3O_2S$ [M+1]: 390.1, found: 390.0; IR (solid): ν = 3267, 3061, 2926, 1494, 1448, 1315, 1151, 1092, 1051, 983, 948, 902, 835, 754, 721, 689 cm^{-1}.

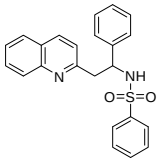
N-(2-(6-bromoquinolin-2-yl)-1-phenylethyl)benzenesulfonamide 13a:



13a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-6:1), 63% yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.14 (d, *J* = 6.6 Hz, 2H), 4.69 (dd, *J* = 11.9, 6.5 Hz, 1H), 6.96 (d, *J* = 8.4 Hz, 1H), 6.99–7.16 (m, 8H), 7.17–7.24 (m, 1H), 7.40–7.46 (m, 2H), 7.69–7.80 (m, 2H), 7.81–7.90 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 44.40, 57.83, 120.53, 122.87, 126.61, 126.72, 127.51, 127.96, 128.39, 129.60, 130.00, 131.84, 133.65, 136.51, 140.29, 140.63, 158.46; MS (ESI) calcd for $C_{23}H_{19}BrN_2O_2S$ [M+1]: 469.0, found: 468.9; IR (solid): ν = 3255, 3064, 1593, 1489, 1450, 1319, 1157, 1091, 1056, 945, 880, 826, 722, 688 cm^{-1}.

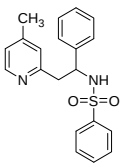
N-(1-phenyl-2-(quinolin-2-yl)ethyl)benzenesulfonamide 14a:



14a

Under Argon, $Cu(OTf)_2$ (5.4 mg, 5 mol %), 1,10-phenanthroline (2.7 mg, 5 mol %), quinaldine **3l** (0.32 mmol), imine **2a** (79 mg, 0.304 mmol) and iPr_2NEt 1.5 eq. were mixed in a screw cap vial and then dry THF (0.2 mL) was added. The mixture was stirred at 120 °C and monitored by TLC, after the completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by column chromatography: first column Hexane-EtOAc (10:1-5:1), second column Hexane-2-Propanol (25:1), 55 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 3.03–3.27 (m, 2H), 4.64 (dt, *J* = 8.0, 5.0 Hz, 1H), 6.90–7.03 (m, 3H), 7.04–7.26 (m, 6H), 7.34–7.44 (m, 3H), 7.44–7.52 (m, 1H), 7.60– 7.75 (m, 2H), 7.89 (d, *J* = 8.4 Hz, 1H), 8.04 (d, *J* = 8.9 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 44.41, 57.95, 121.85, 126.63, 126.67, 126.75, 126.89, 127.43, 127.59, 131.75, 128.32, 128.35, 128.51, 130.20, 137.43, 140.17, 140.96, 146.75, 158.00; MS (ESI) calcd for $C_{23}H_{20}N_2O_2S$ [M+1]: 389.1, found: 389.0; IR (solid): ν = 3054, 2862, 1601, 1565, 1504, 1434, 1324, 1260, 1158, 1055, 956, 821, 755, 723, 690 cm^{-1}.

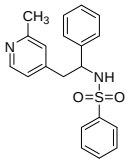
N-(2-(4-methylpyridin-2-yl)-1-phenylethyl)benzenesulfonamide 15a:



15a

The title compound and **4nb** was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-7:1) for **3nb** and Hexane-EtOAc (7:1-1:1) for **4nb**, 23 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.15 (s, 3H), 2.92 (d, J = 6.1 Hz, 2H), 4.57 (s, 1H), 6.68 (s, 1H), 6.90 (s, 1H), 7.07 (s, 5H), 7.13–7.25 (m, 3H), 7.27–7.41 (m, 2H), 7.45–7.55 (m, 2H), 8.28 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 21.16, 43.20, 58.16, 126.64, 126.87, 127.36, 128.26, 128.45, 131.80, 140.59, 147.13, 149.87, 156.68; MS (ESI) calcd for $C_{20}H_{20}N_2O_2S$ [M+1]: 353.1, found: 353.0; IR (solid): ν = 3060, 2855, 2718, 1610, 1446, 1317, 1153, 1090, 1061, 967, 824, 754, 690 cm^{-1}.

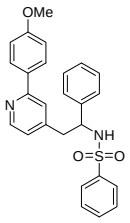
N-(2-(2-methylpyridin-4-yl)-1-phenylethyl)benzenesulfonamide 15b:



15b

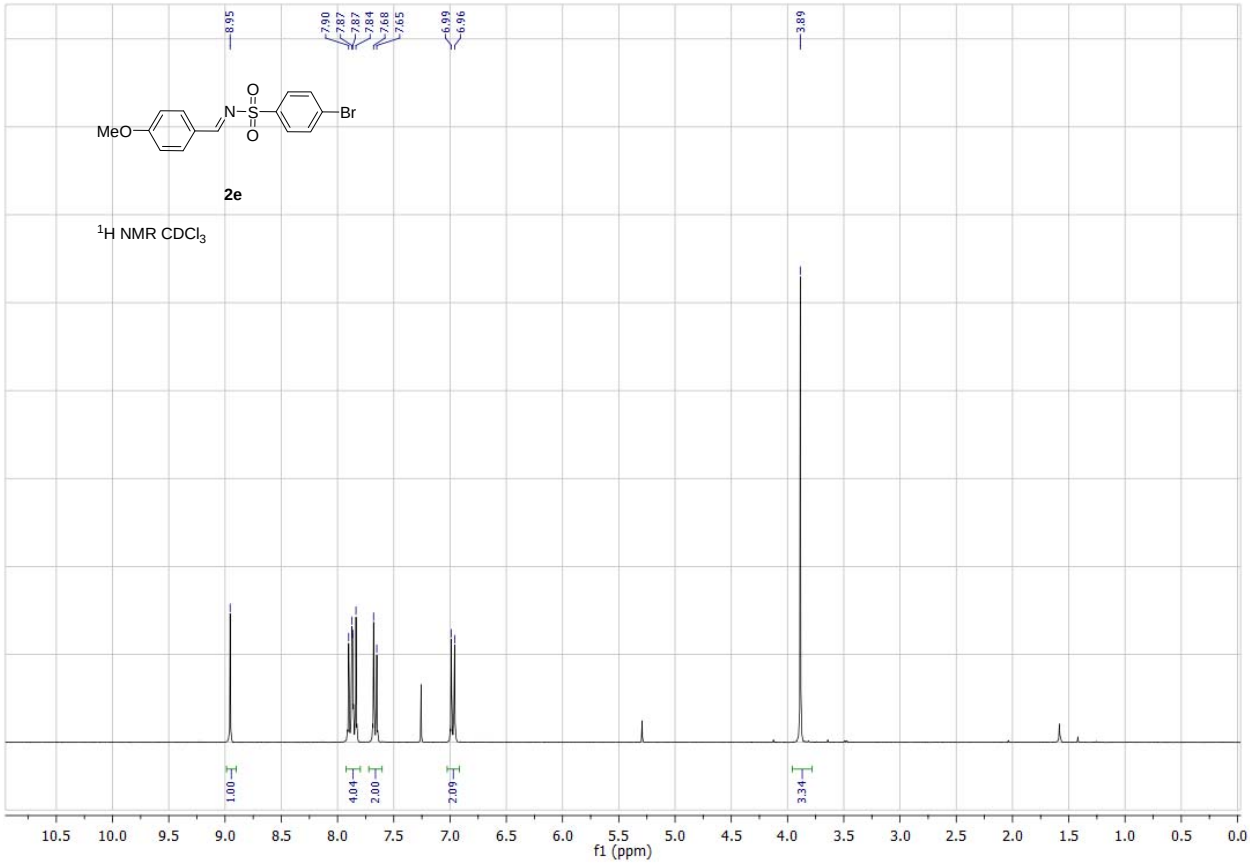
The title compound and **3nb** was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-7:1) for **3nb** and Hexane-EtOAc (7:1-1:1) for **4nb**, 55 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.35 (s, 3H), 2.92 (qd, J = 13.8, 7.4 Hz, 2H), 4.50 (q, J = 7.5 Hz, 1H), 6.01 (d, J = 7.7 Hz, 1H), 6.66 (d, J = 3.9 Hz, 1H), 6.73 (s, 1H), 6.92–7.00 (m, 2H), 7.00–7.11 (m, 3H), 7.12–7.24 (m, 2H), 7.28–7.40 (m, 1H), 7.44–7.58 (m, 2H), 8.14 (s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.74, 43.15, 58.72, 121.96, 124.53, 126.54, 126.75, 127.77, 128.50, 128.69, 132.31,139.58, 140.15, 147.17, 148.08, 157.76; MS (ESI) calcd for $C_{20}H_{20}N_2O_2S$ [M+1]: 353.1, found: 353.0; IR ($CDCl_3$): ν = 3278, 3064, 2858, 1608, 1449, 1323, 1159, 1091, 957, 912, 754, 580, 548 cm^{-1}.

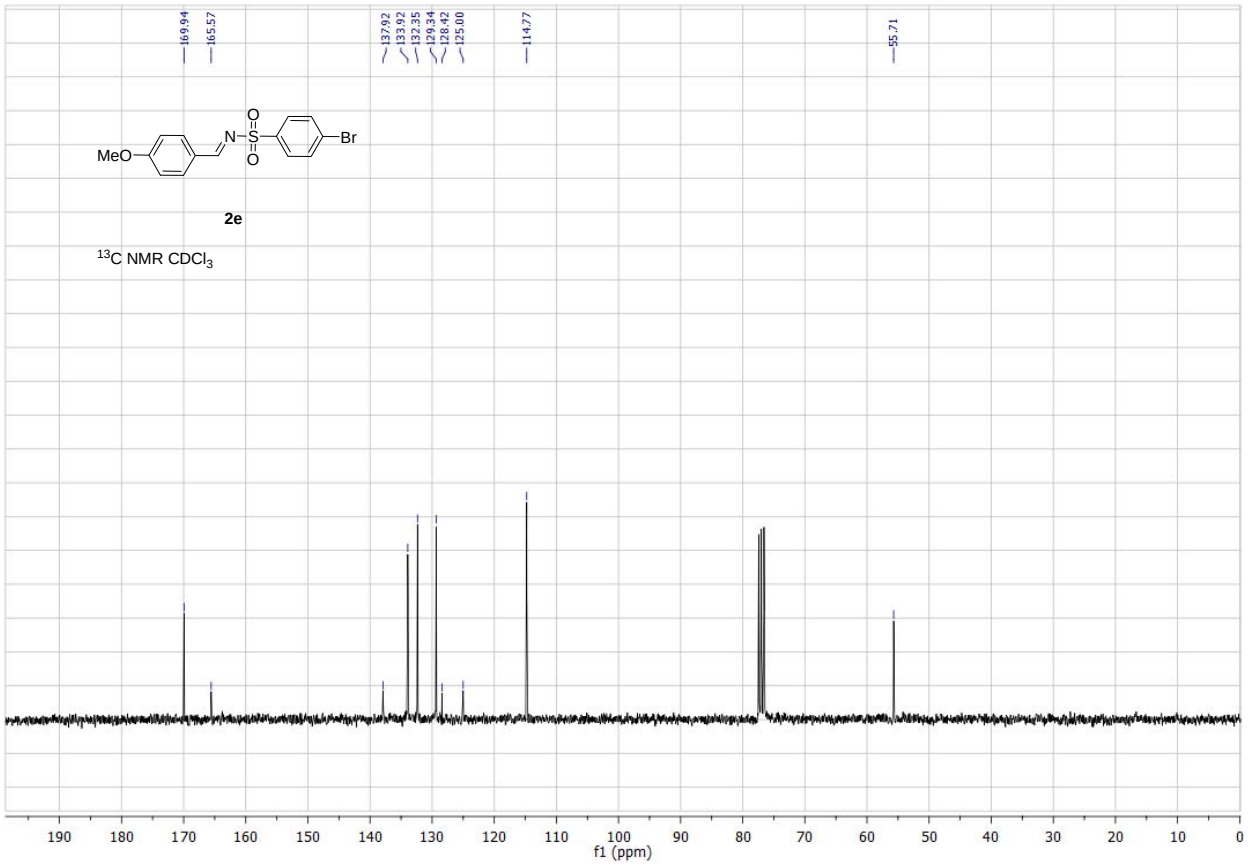
N-(2-(2-(4-methoxyphenyl)pyridin-4-yl)-1-phenylethyl)benzenesulfonamide 16a:

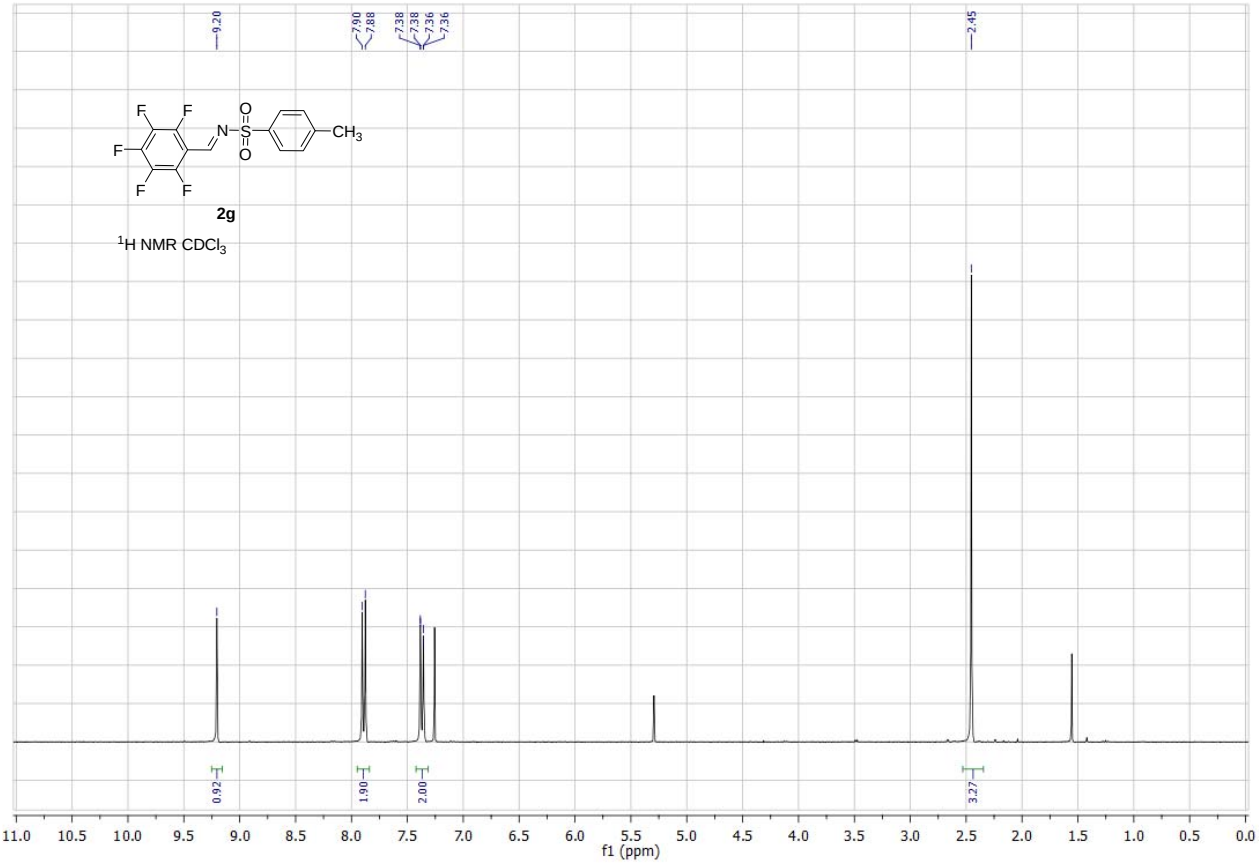


16a

The title compound was prepared according to the General Procedure and purified by column chromatography Hexane-EtOAc (10:1-6:1), 48 % yield. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.97 (qd, J = 13.8, 7.3 Hz, 2H), 3.77 (s, 3H), 4.54 (q, J = 7.4 Hz, 1H), 5.73 (d, J = 7.5 Hz, 1H), 6.68 (d, J = 5.1, 1.2 Hz, 1H), 6.87 (d, J = 8.8 Hz, 2H), 6.94–7.01 (m, 2H), 7.04–7.10 (m, 3H), 7.11–7.19 (m, 3H), 7.28 (t, J = 7.4 Hz, 1H), 7.50 (d, J = 7.3 Hz, 2H), 7.73 (d, J = 8.7 Hz, 2H), 8.30 (d, J = 5.1 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 43.40, 55.34, 58.64, 114.09, 120.88, 122.35, 126.57, 126.75, 127.81, 128.29, 128.57, 128.72, 131.15, 132.37, 139.61, 140.00, 146.81, 148.99, 156.76, 160.58; MS (ESI) calcd for $C_{26}H_{24}N_2O_3S$ [M+1]: 445.2, found: 445.1; IR ($CDCl_3$): ν = 3268, 3029, 2930, 1721, 1606, 1514, 1459, 1318, 1248, 1160, 1071, 962, 841, 756, 584 cm^{-1}.

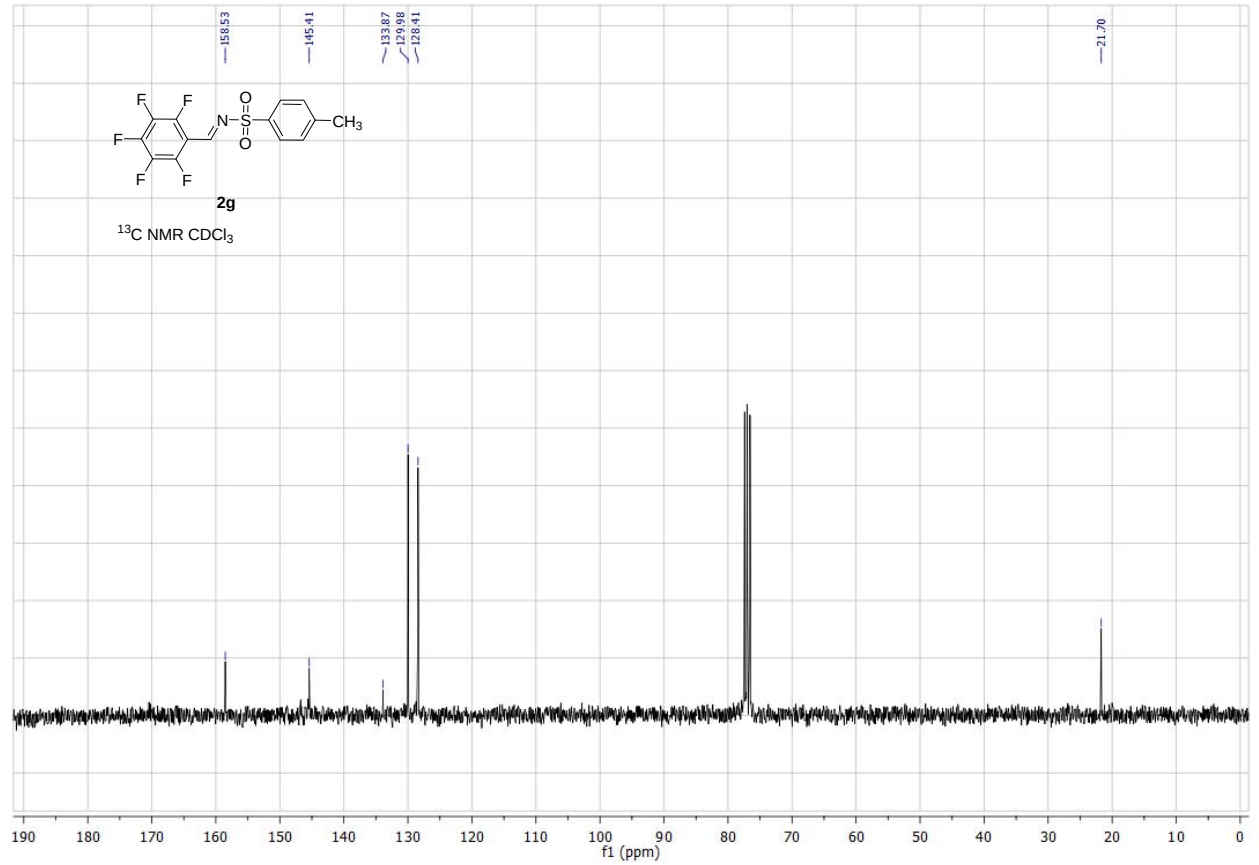

8.95
7.90
7.87
7.87
7.84
7.68
7.65
6.99
6.96
3.89
MeO
N
S
O
O
Br
2e
1H NMR CDCl3
1.00
4.04
2.00
2.09
3.34
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


169.94
165.57
137.92
133.92
132.35
129.34
128.42
125.00
114.77
55.71
MeO
N
S
O
O
Br
2e
13C NMR CDCl3
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



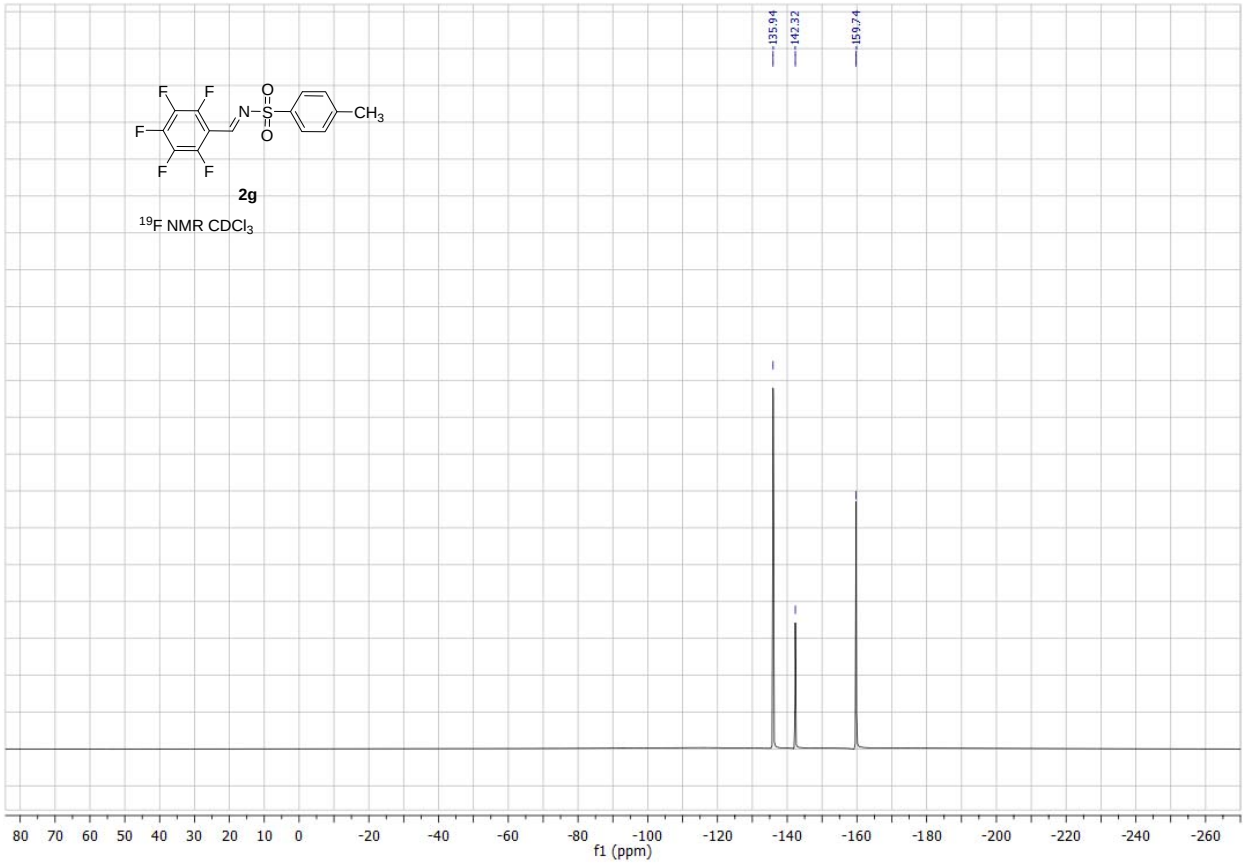
2g

^{1}H NMR $CDCl_3$



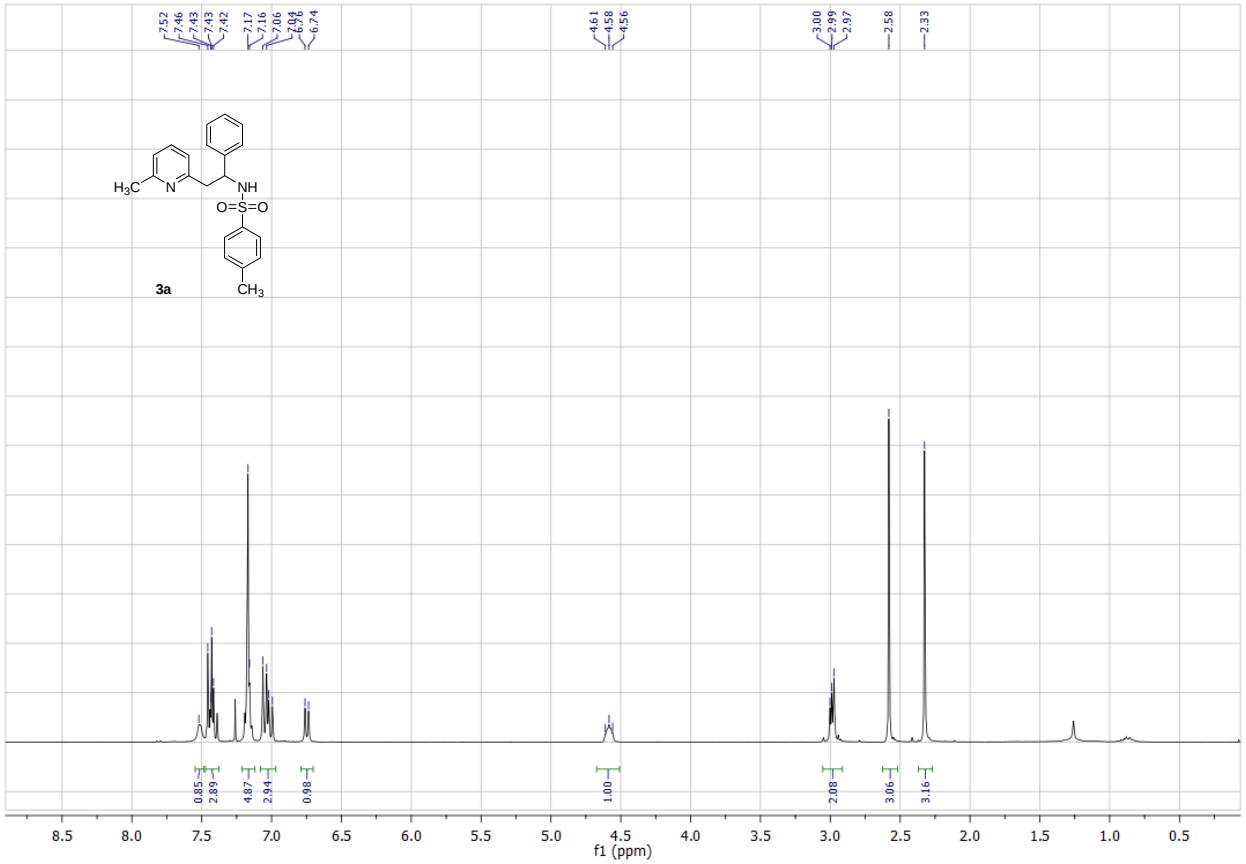
2g

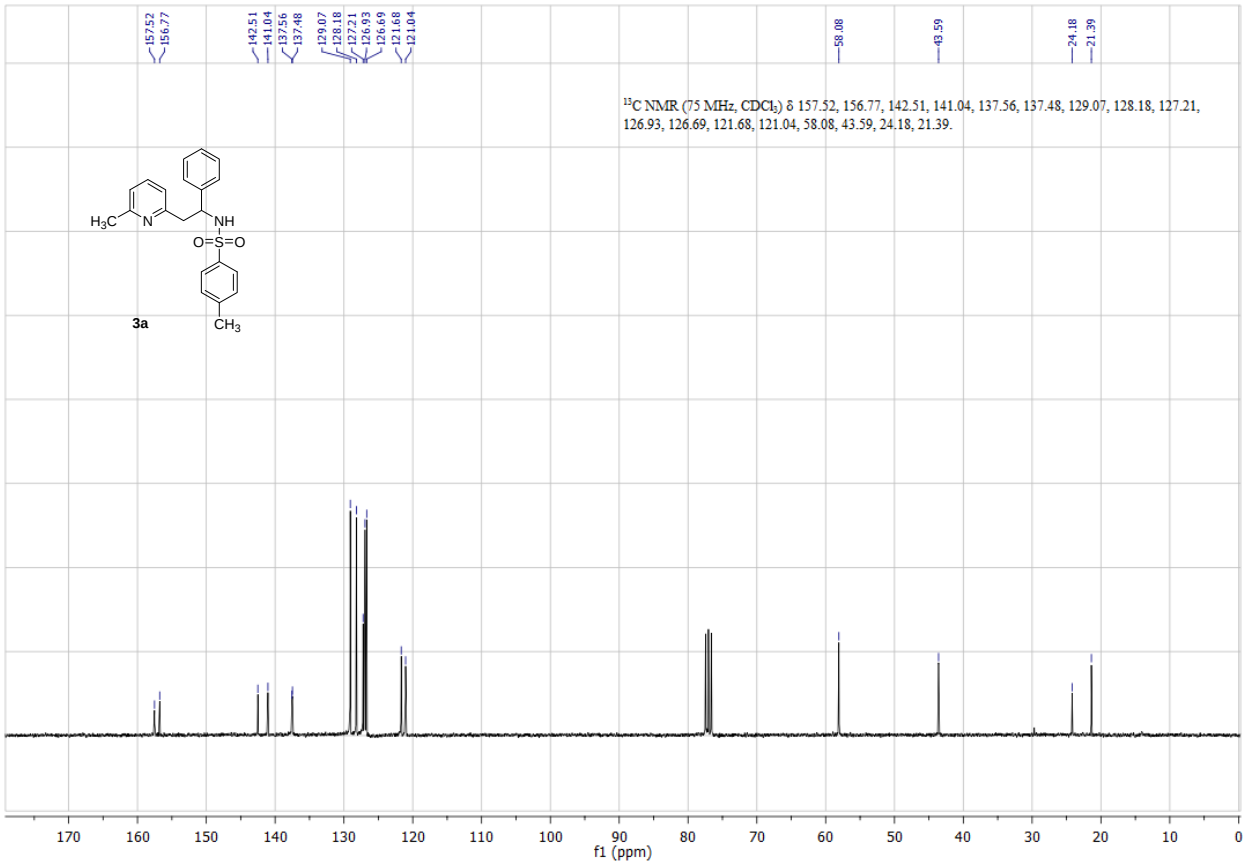
^{13}C NMR $CDCl_3$

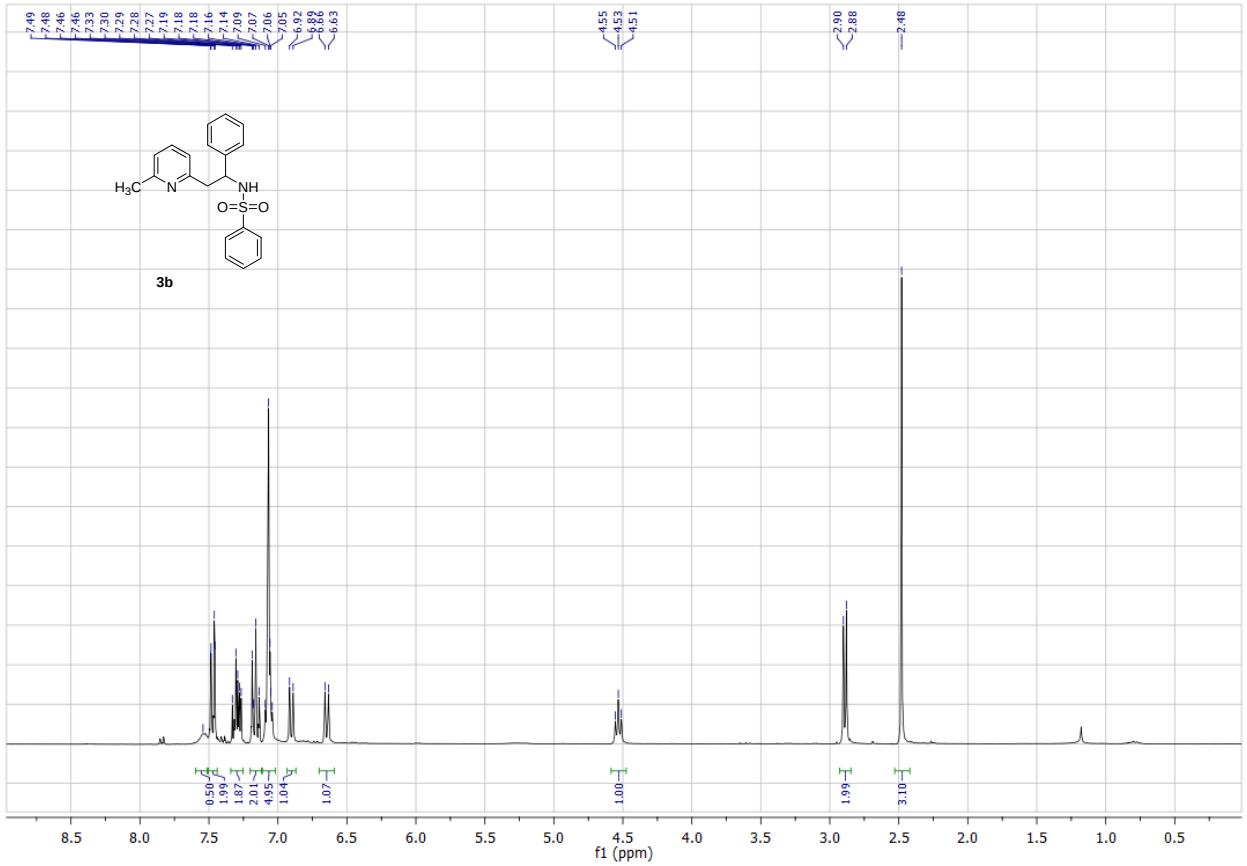


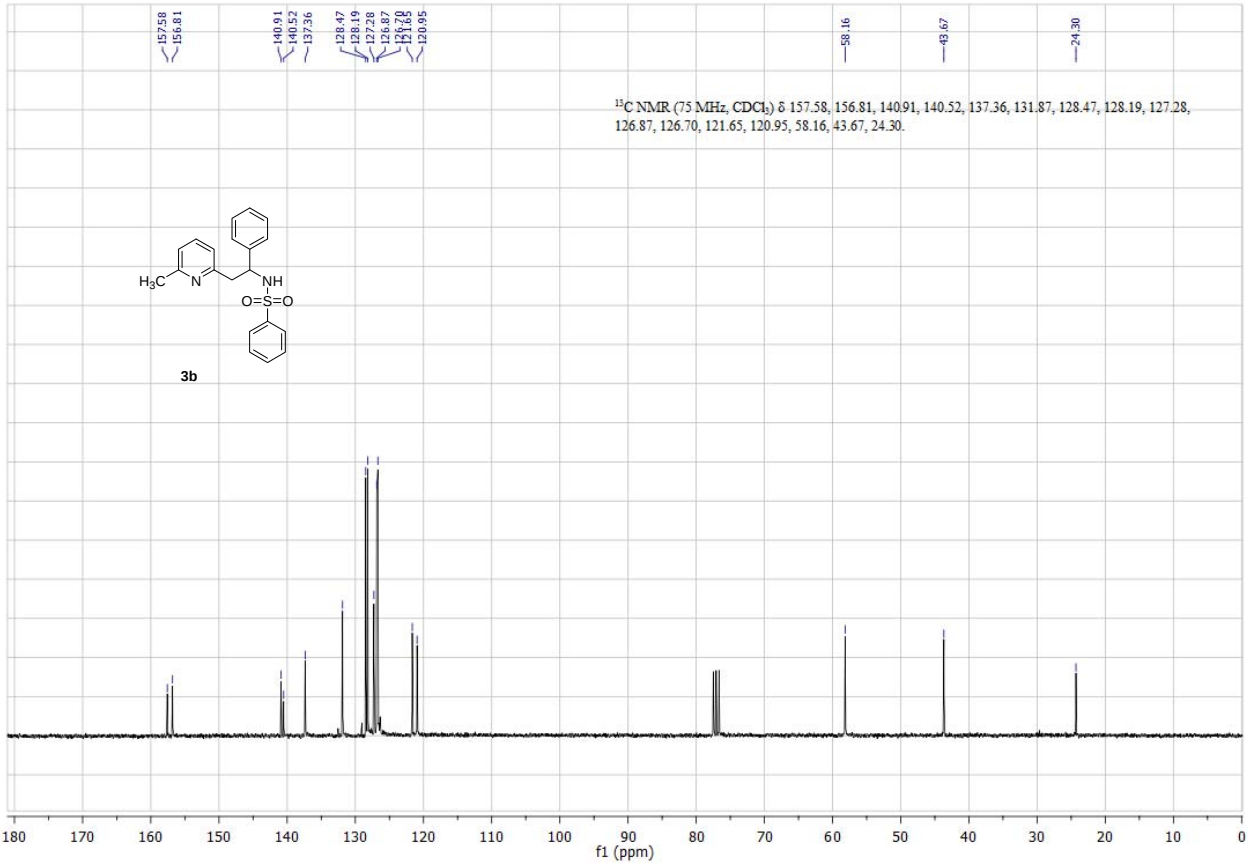
2g

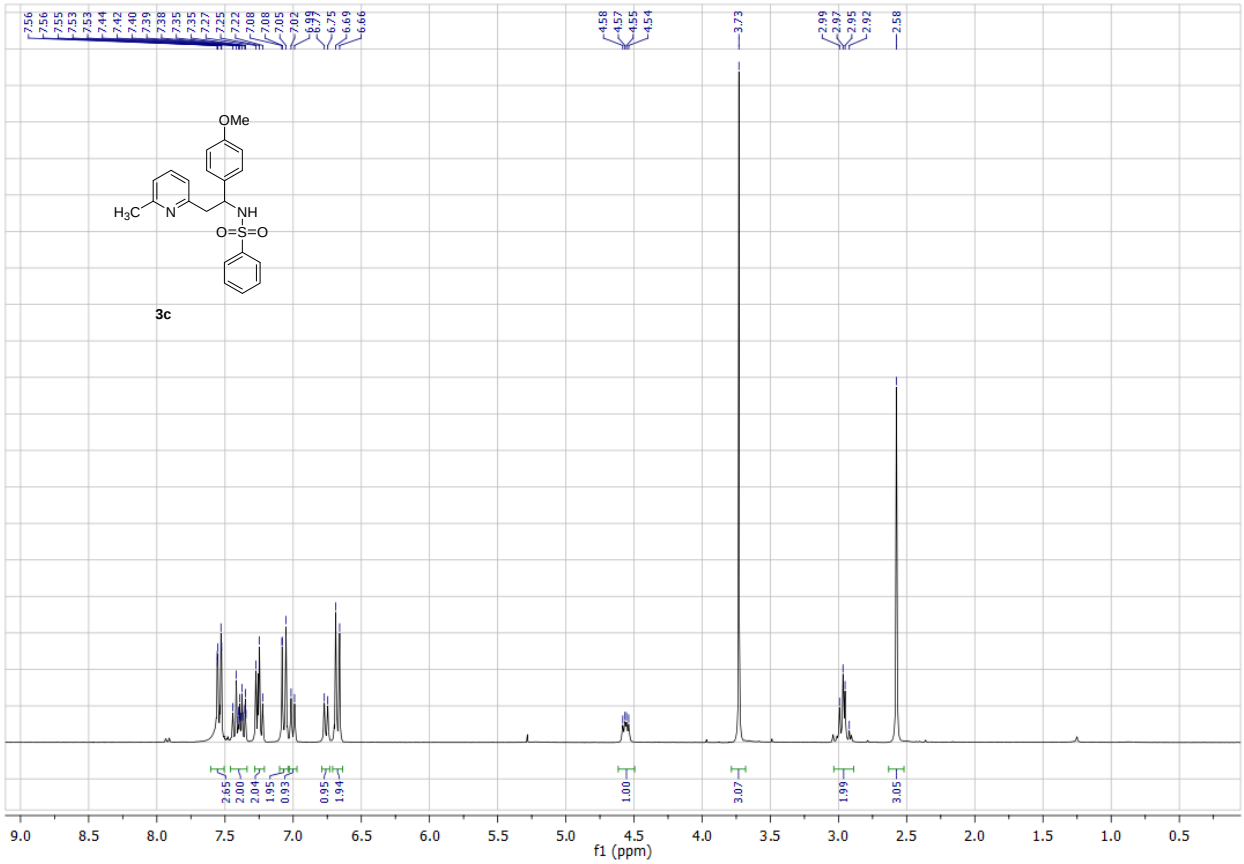
^{19}F NMR $CDCl_3$

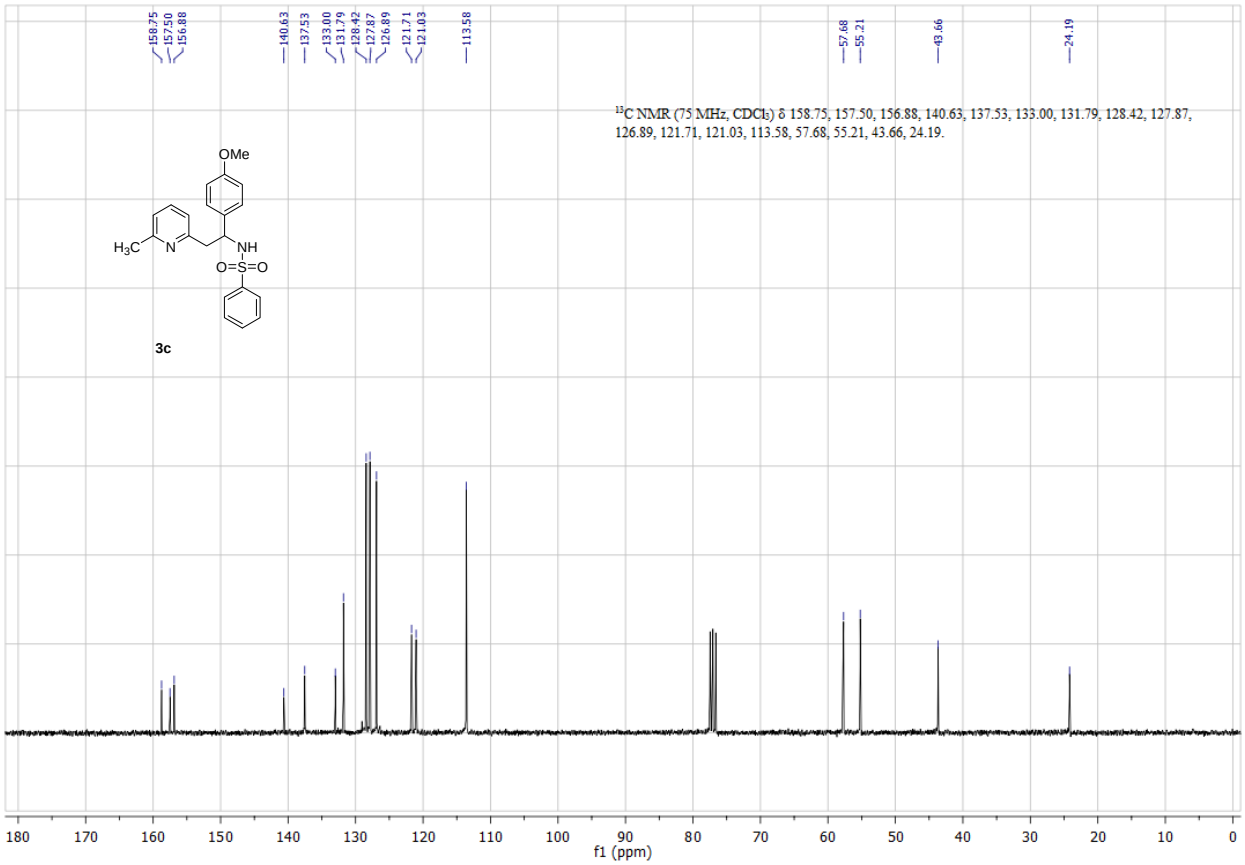

7.52
7.46
7.43
7.43
7.42
7.17
7.16
7.06
7.04
6.74
4.61
4.58
4.56
3.00
2.99
2.97
2.58
2.33
H3C
N
NH
O=S=O
CH3
3a
0.85
2.89
4.87
2.94
0.98
1.00
2.08
3.06
3.16
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

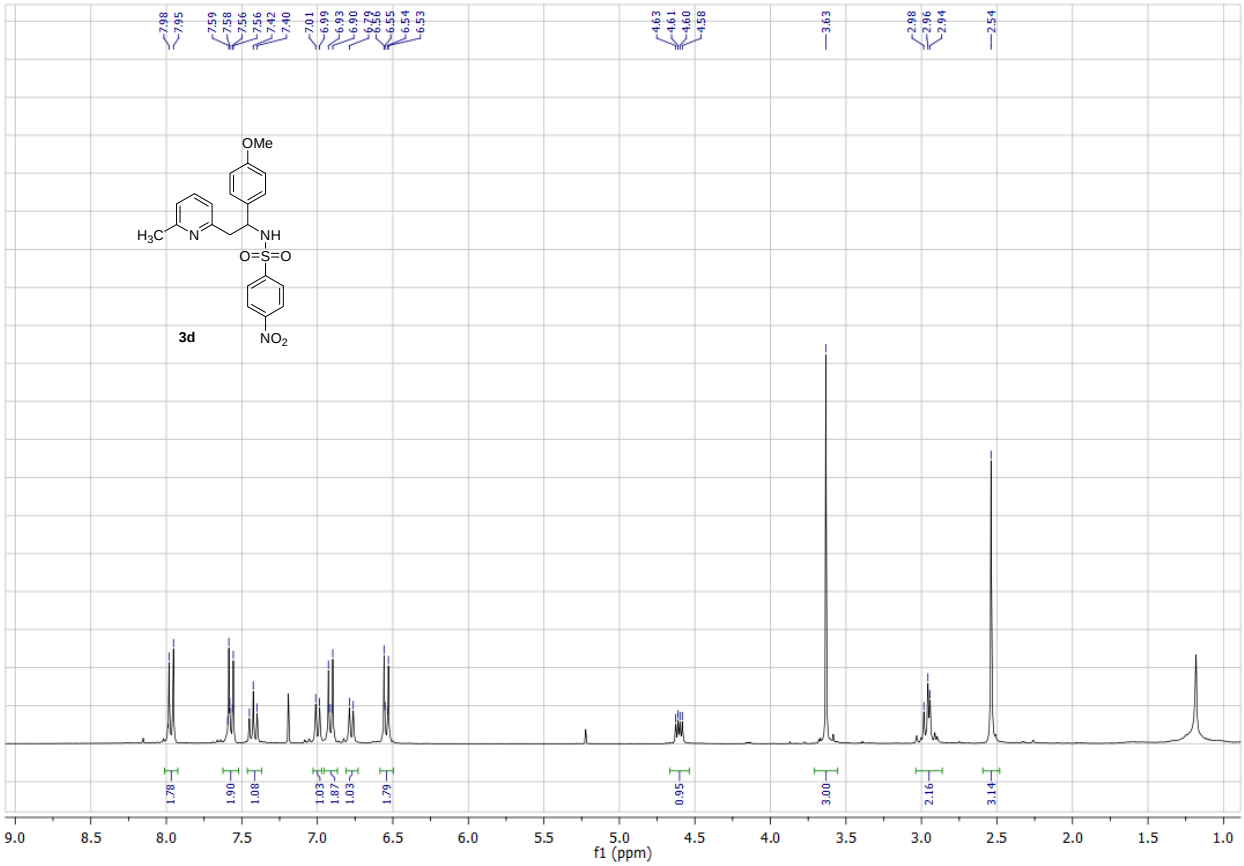

157.52
156.77
142.51
141.04
137.56
137.48
129.07
128.18
127.21
126.93
126.69
121.68
121.04
58.08
43.59
24.18
21.39
13C NMR (75 MHz, CDCl3) δ 157.52, 156.77, 142.51, 141.04, 137.56, 137.48, 129.07, 128.18, 127.21, 126.93, 126.69, 121.68, 121.04, 58.08, 43.59, 24.18, 21.39.
H3C
N
NH
O=S=O
CH3
3a
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

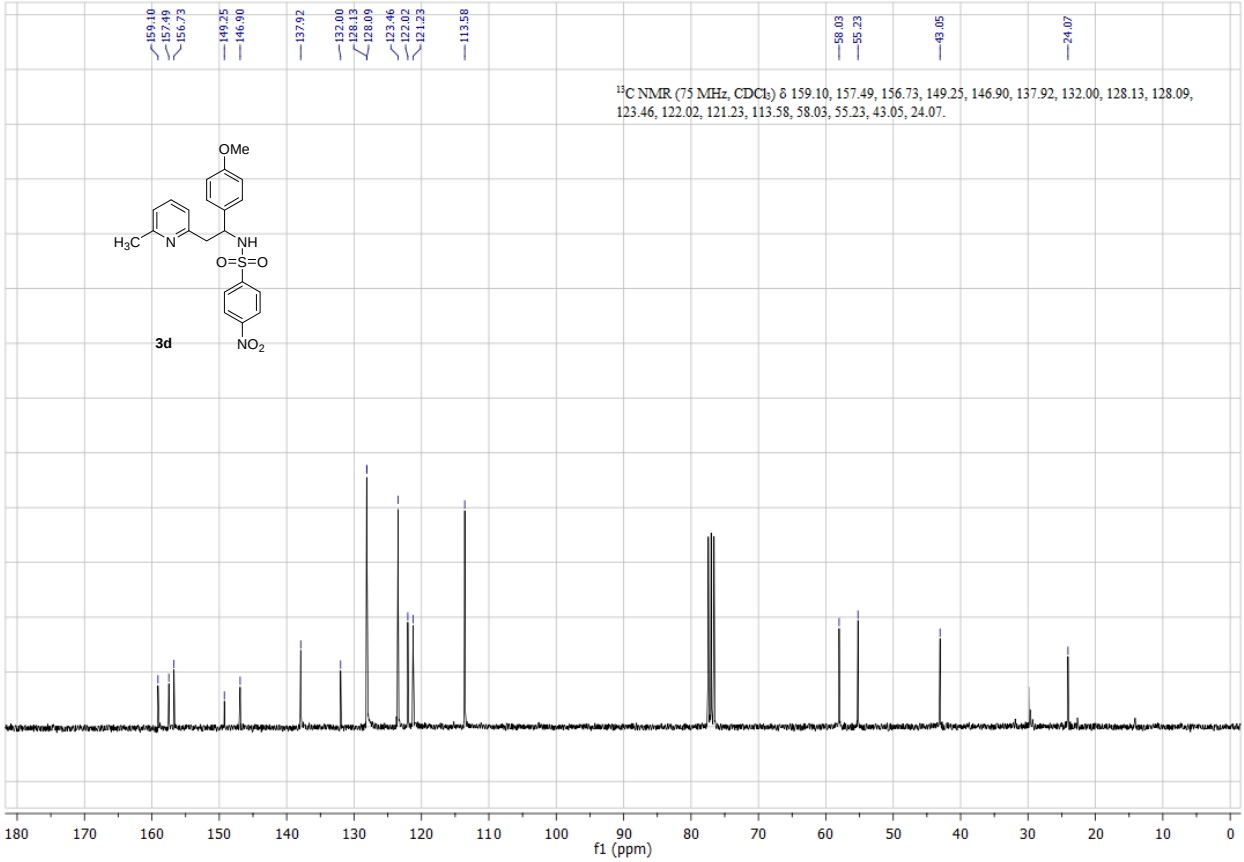

7.49
7.48
7.46
7.46
7.33
7.30
7.29
7.28
7.27
7.19
7.18
7.18
7.16
7.14
7.09
7.07
7.06
7.05
6.92
6.89
6.86
6.63
4.55
4.53
4.51
2.90
2.88
2.48
H3C
N
NH
O=S=O
3b
0.50
1.99
1.87
2.01
4.95
1.04
1.07
1.00
1.99
3.10
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

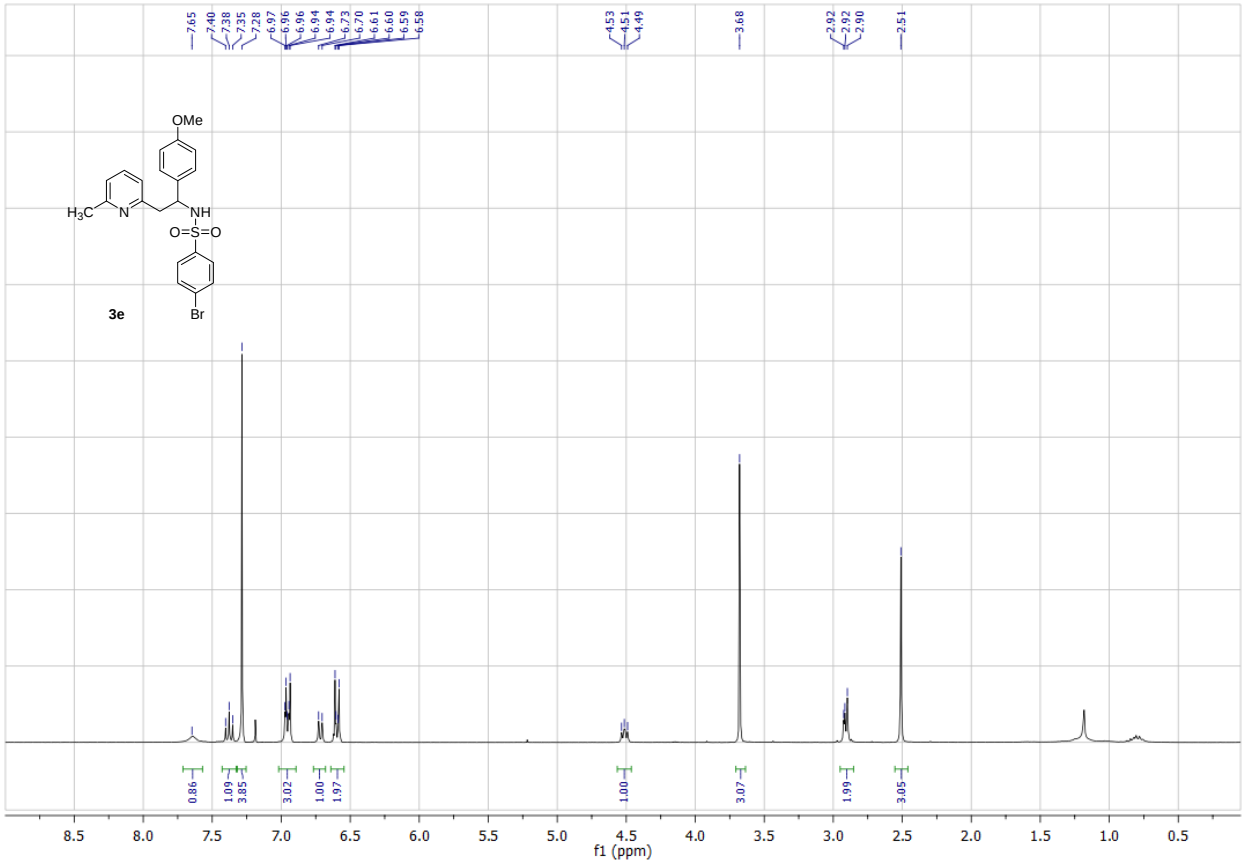

157.58
156.81
140.91
140.52
137.36
128.47
128.19
127.28
126.87
126.70
121.65
120.95
58.16
43.67
24.30
13C NMR (75 MHz, CDCl3) δ 157.58, 156.81, 140.91, 140.52, 137.36, 131.87, 128.47, 128.19, 127.28, 126.87, 126.70, 121.65, 120.95, 58.16, 43.67, 24.30.
H3C
N
NH
O=S=O
3b
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

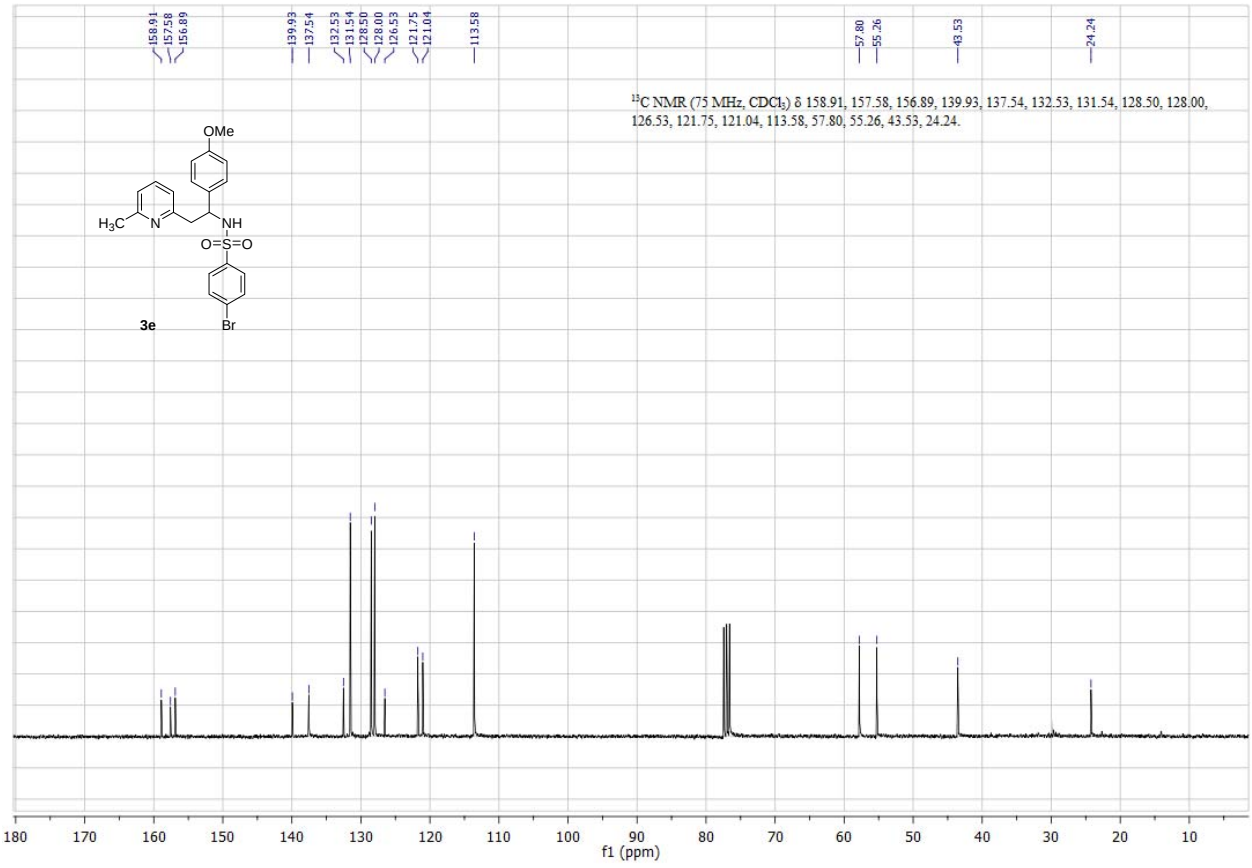

OMe
H3C
N
NH
O=S=O
3c
f1 (ppm)

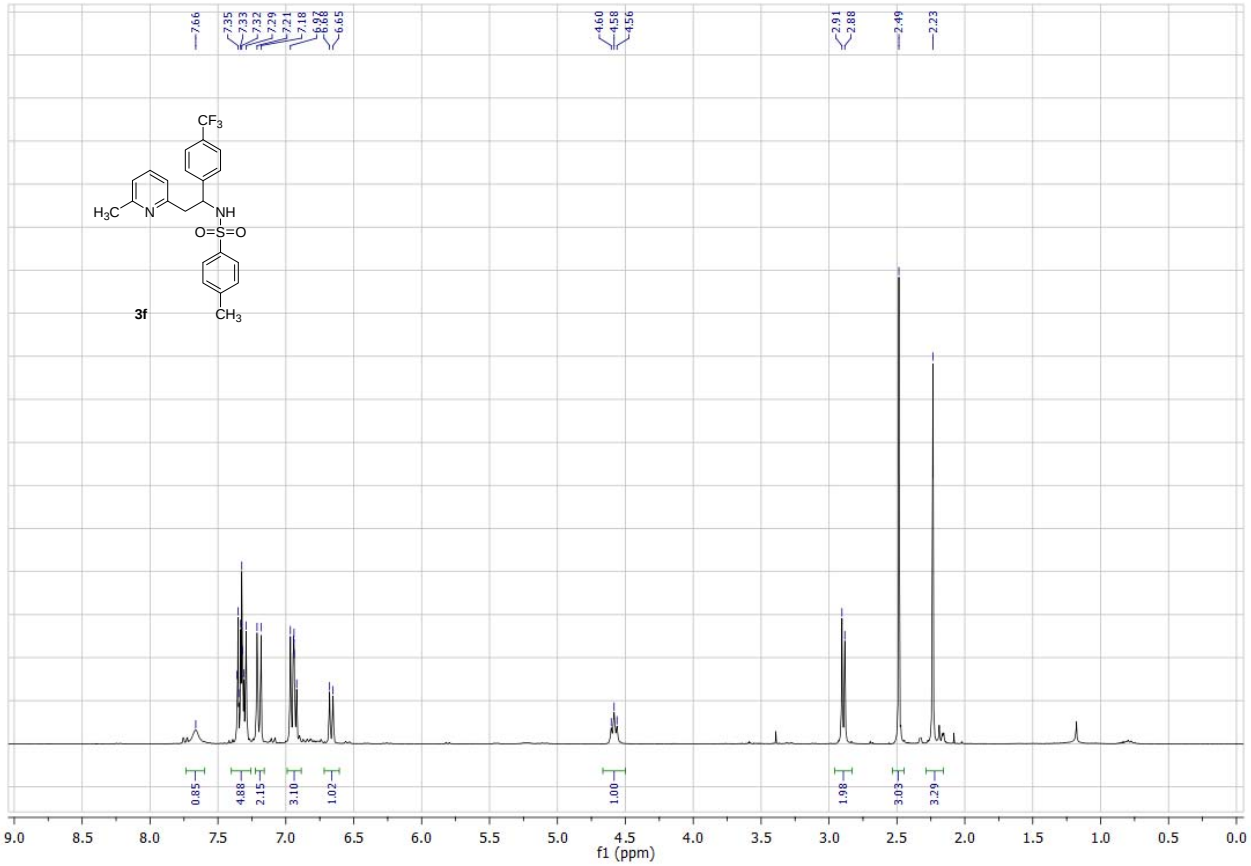

OMe
H3C
N
NH
O=S=O
3c
13C NMR (75 MHz, CDCl3) δ 158.75, 157.50, 156.88, 140.63, 137.53, 133.00, 131.79, 128.42, 127.87, 126.89, 121.71, 121.03, 113.58, 57.68, 55.21, 43.66, 24.19.
f1 (ppm)

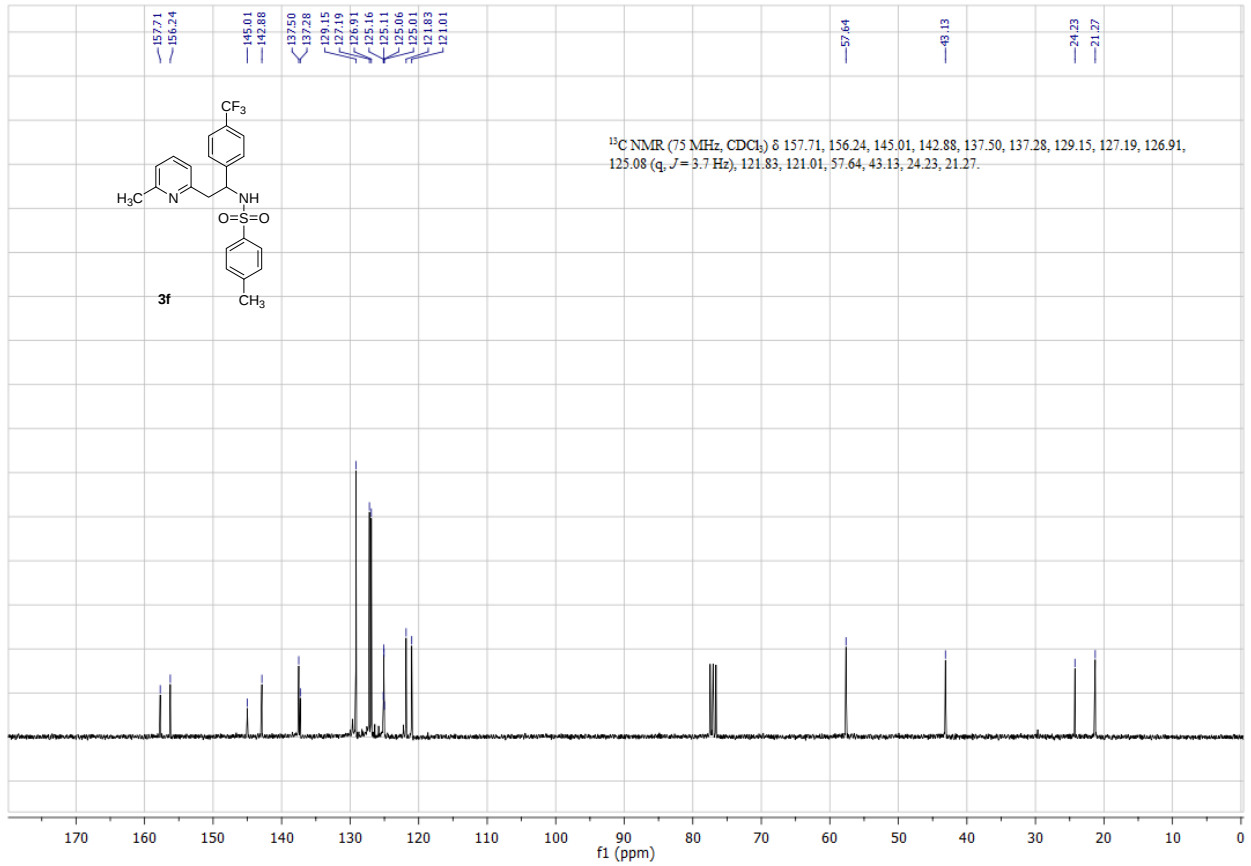

7.98
7.95
7.59
7.58
7.56
7.56
7.42
7.40
7.01
6.99
6.93
6.90
6.79
6.56
6.55
6.54
6.53
4.63
4.61
4.60
4.58
3.63
2.98
2.96
2.94
2.54
OMe
H3C
N
NH
O=S=O
NO2
3d
1.78
1.90
1.08
1.03
1.87
1.03
1.79
0.95
3.00
2.16
3.14
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f1 (ppm)


159.10
157.49
156.73
149.25
146.90
137.92
132.00
128.13
128.09
123.46
122.02
121.23
113.58
58.03
55.23
43.05
24.07
13C NMR (75 MHz, CDCl3) δ 159.10, 157.49, 156.73, 149.25, 146.90, 137.92, 132.00, 128.13, 128.09, 123.46, 122.02, 121.23, 113.58, 58.03, 55.23, 43.05, 24.07.
OMe
H3C
N
NH
O=S=O
NO2
3d
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

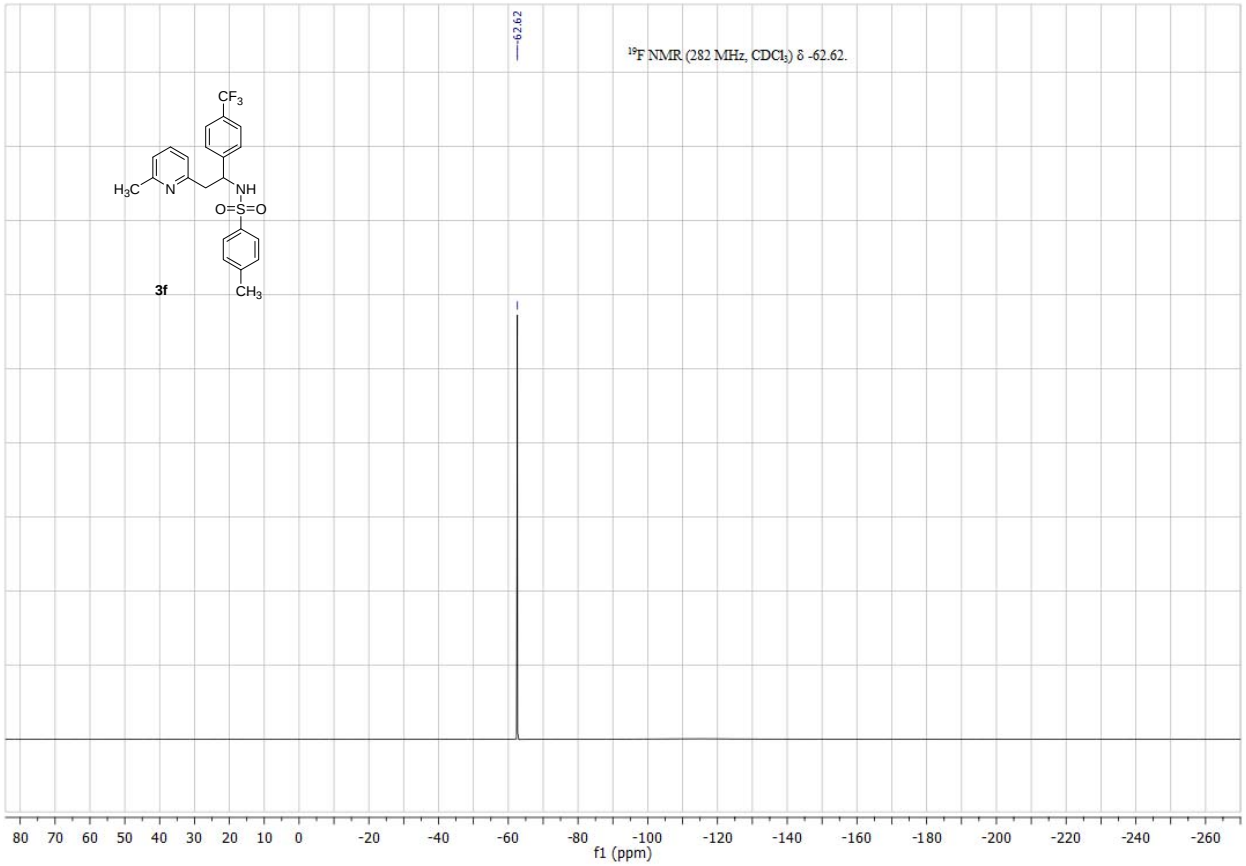

7.65
7.40
7.38
7.35
7.28
6.97
6.96
6.96
6.94
6.94
6.73
6.70
6.61
6.60
6.59
6.58
4.53
4.51
4.49
3.68
2.92
2.92
2.90
2.51
OMe
H3C
N
NH
O=S=O
Br
3e
0.86
1.09
3.85
3.02
1.00
1.97
1.00
3.07
1.99
3.05
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

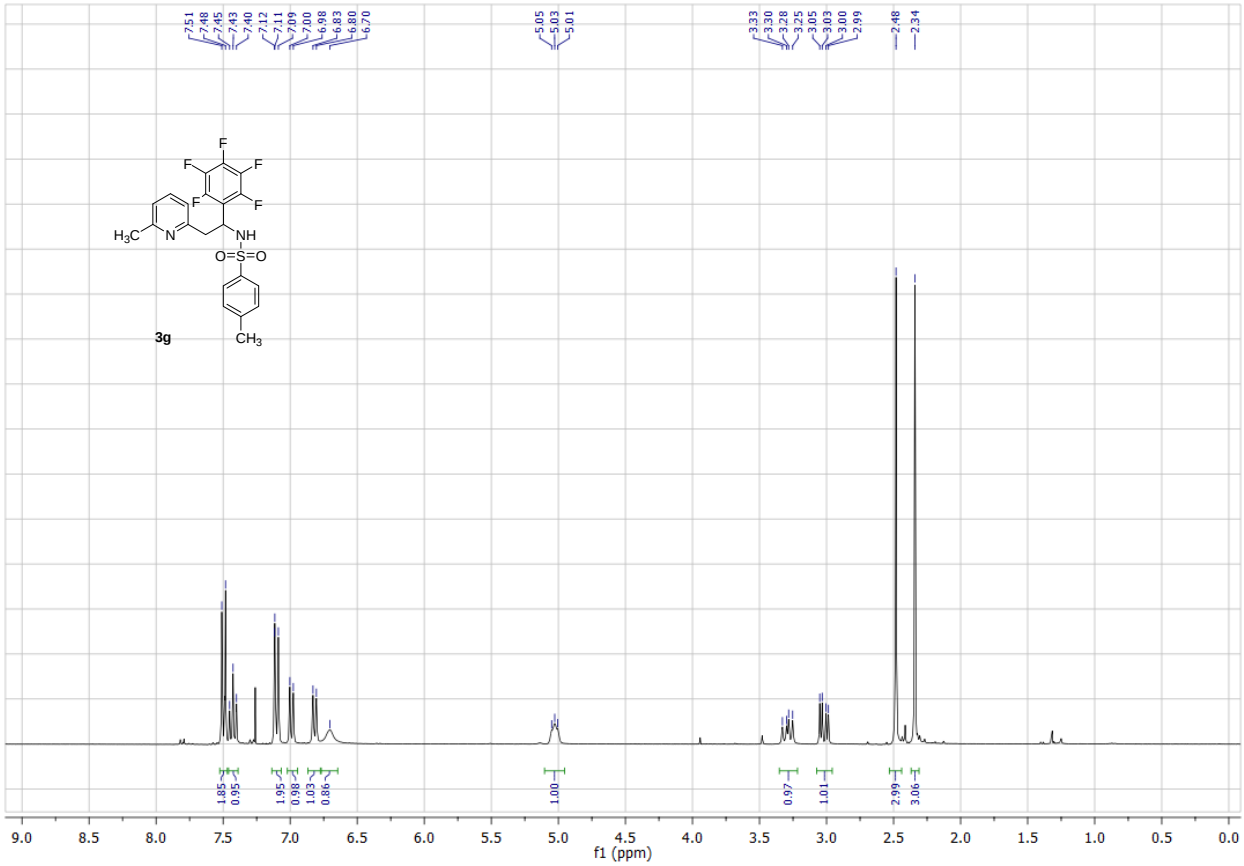

158.91
157.58
156.89
139.93
137.54
132.53
131.54
128.50
128.00
126.53
121.75
121.04
113.58
57.80
55.26
43.53
24.24
13C NMR (75 MHz, CDCl3) δ 158.91, 157.58, 156.89, 139.93, 137.54, 132.53, 131.54, 128.50, 128.00, 126.53, 121.75, 121.04, 113.58, 57.80, 55.26, 43.53, 24.24.
OMe
H3C
N
NH
O=S=O
Br
3e
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

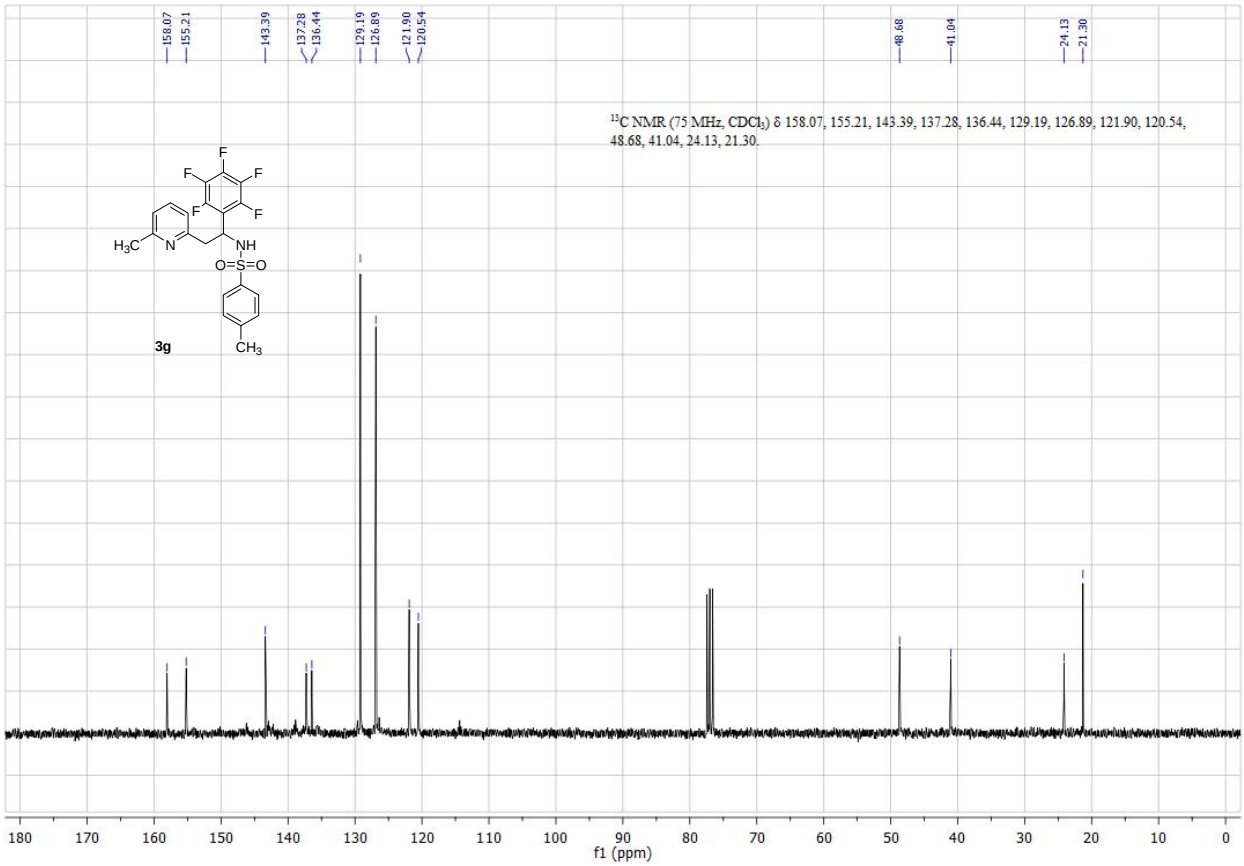


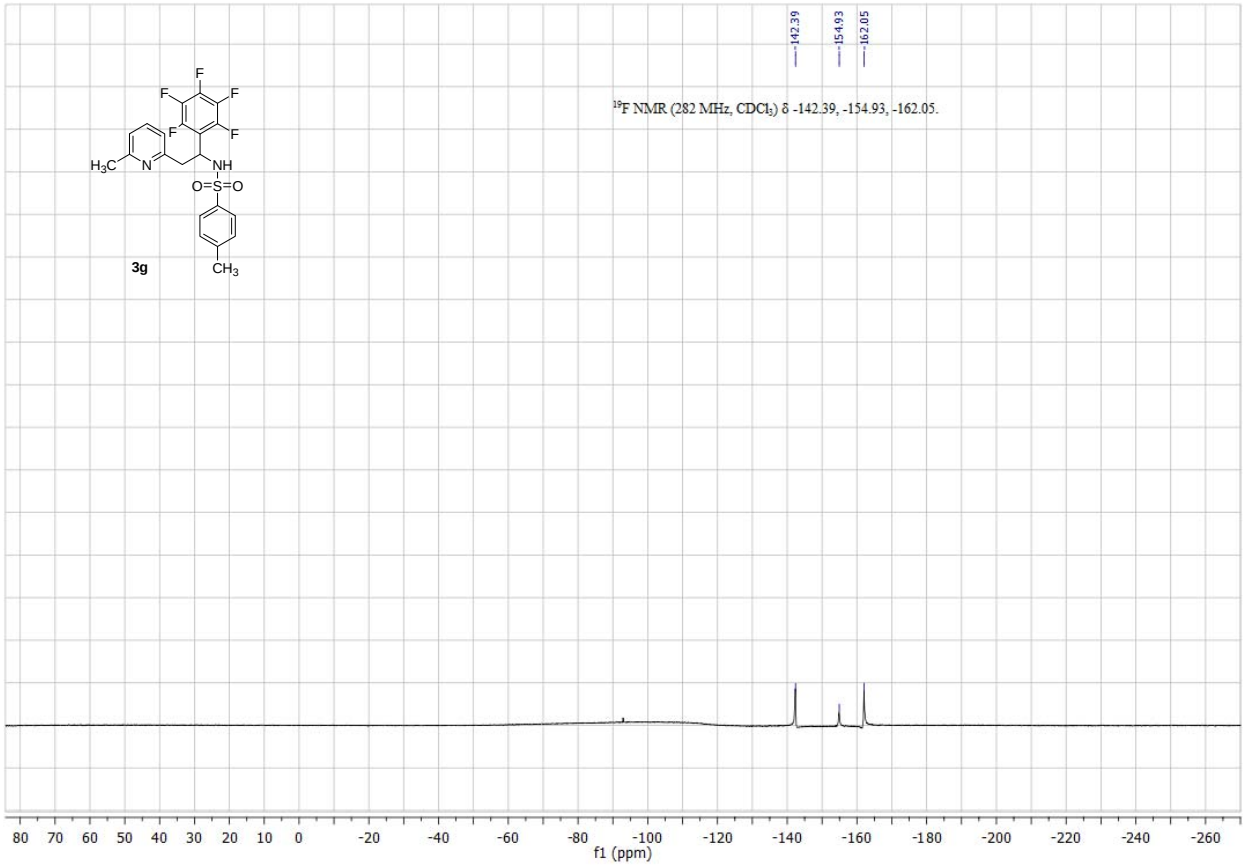


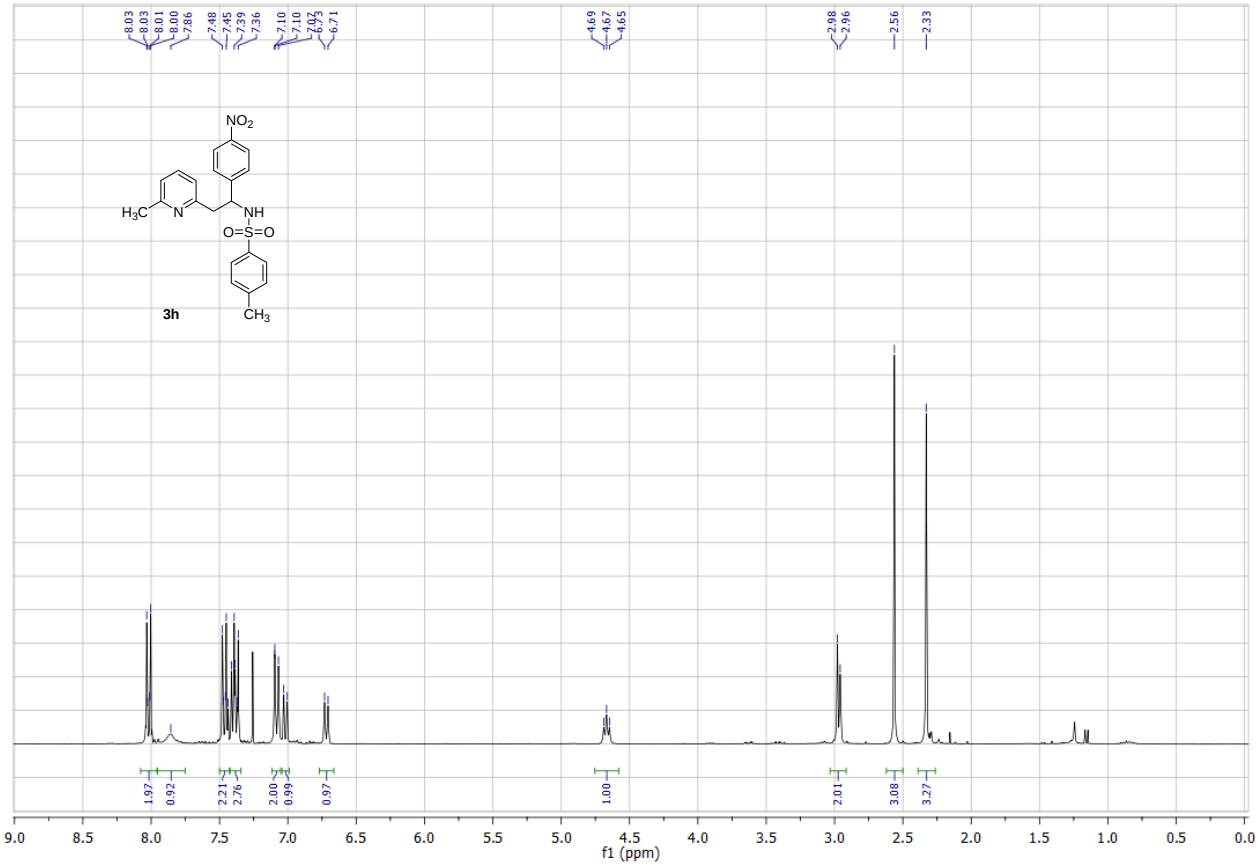
^{13}C NMR (75 MHz, $CDCl_3$) δ 157.71, 156.24, 145.01, 142.88, 137.50, 137.28, 129.15, 127.19, 126.91, 125.08 (q, J = 3.7 Hz), 121.83, 121.01, 57.64, 43.13, 24.23, 21.27.

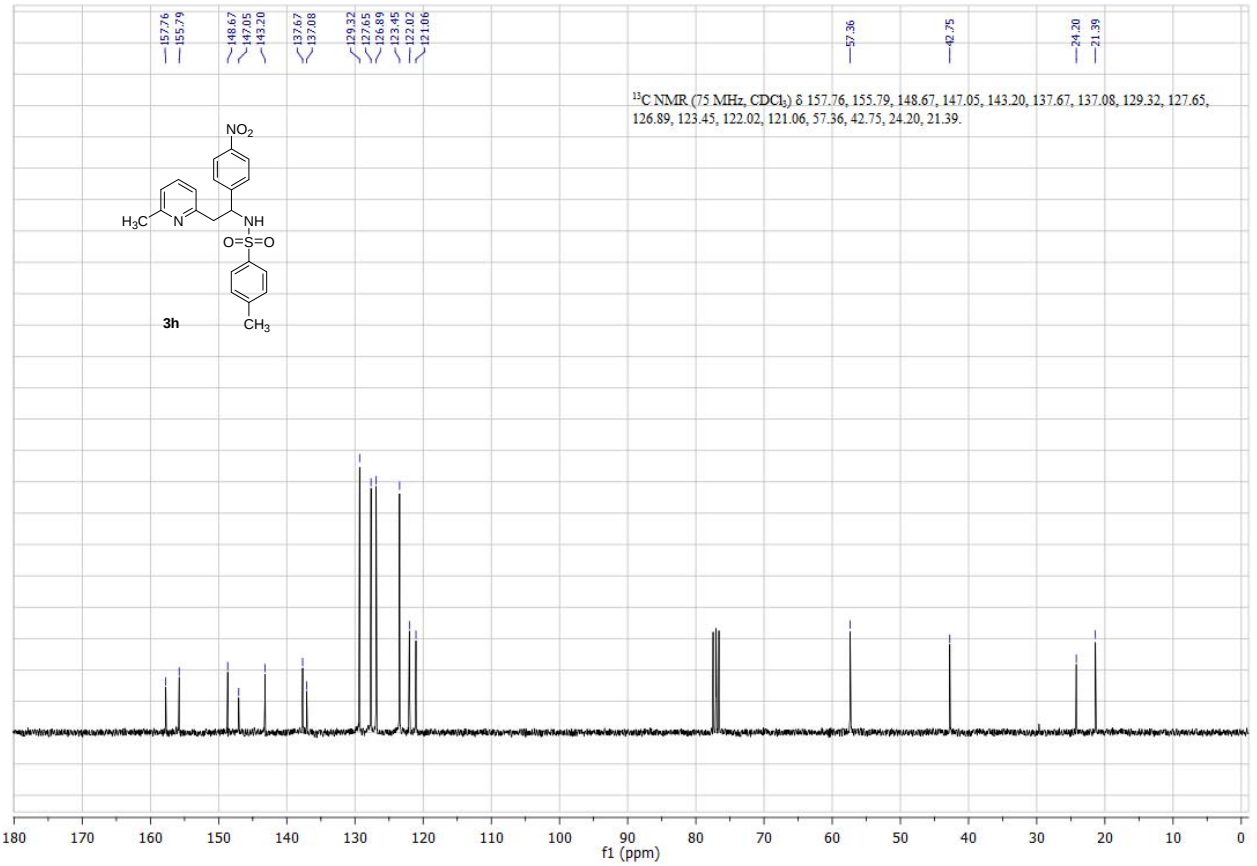

-62.62
^{19}F NMR (282 MHz, $CDCl_3$) δ -62.62.
CF_3
H_3C
N
NH
O=S=O
CH_3
3f
80 70 60 50 40 30 20 10 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260
f1 (ppm)

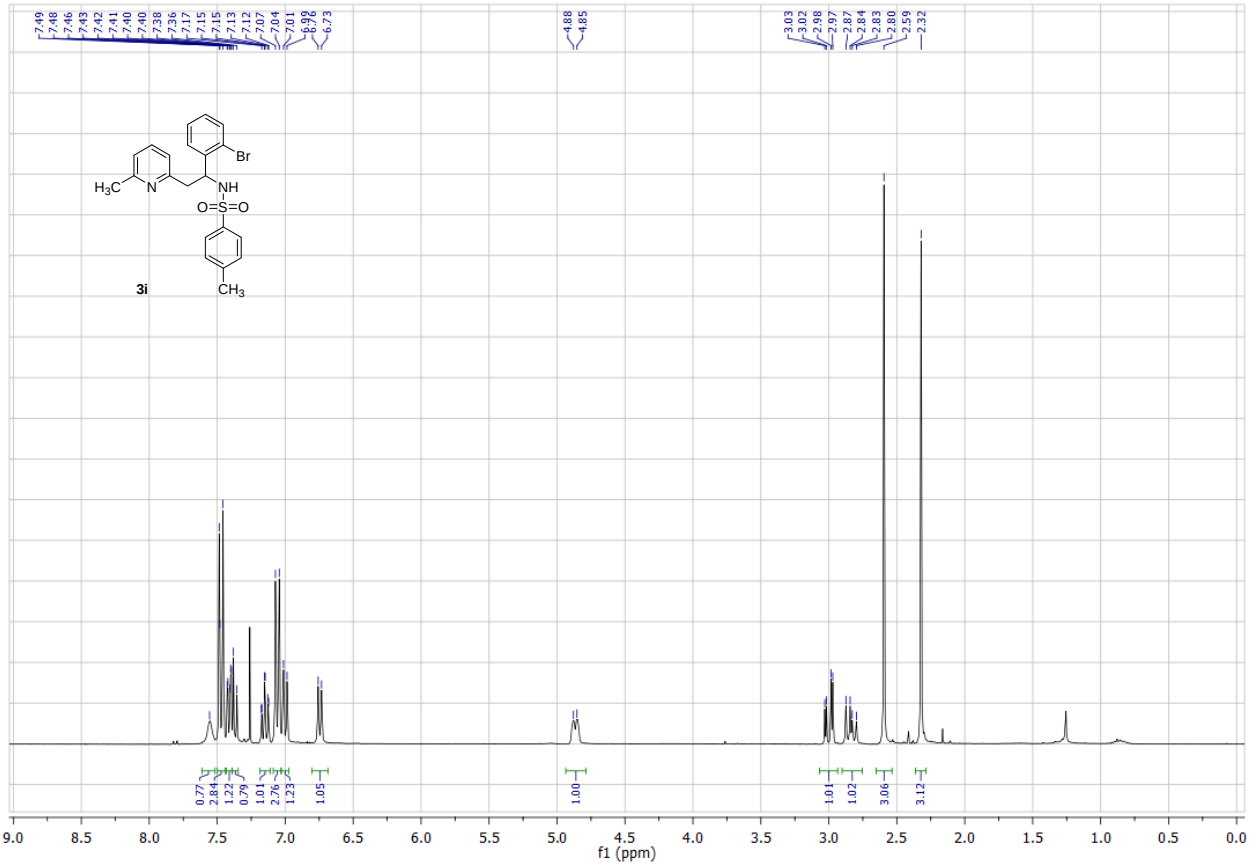

7.51
7.48
7.45
7.43
7.40
7.12
7.11
7.09
7.00
6.98
6.83
6.80
6.70
5.05
5.03
5.01
3.33
3.30
3.28
3.25
3.05
3.03
3.00
2.99
2.48
2.34
F
F
F
F
F
H3C
N
NH
O=S=O
CH3
3g
1.85
0.95
1.95
0.98
1.03
0.86
1.00
0.97
1.01
2.99
3.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

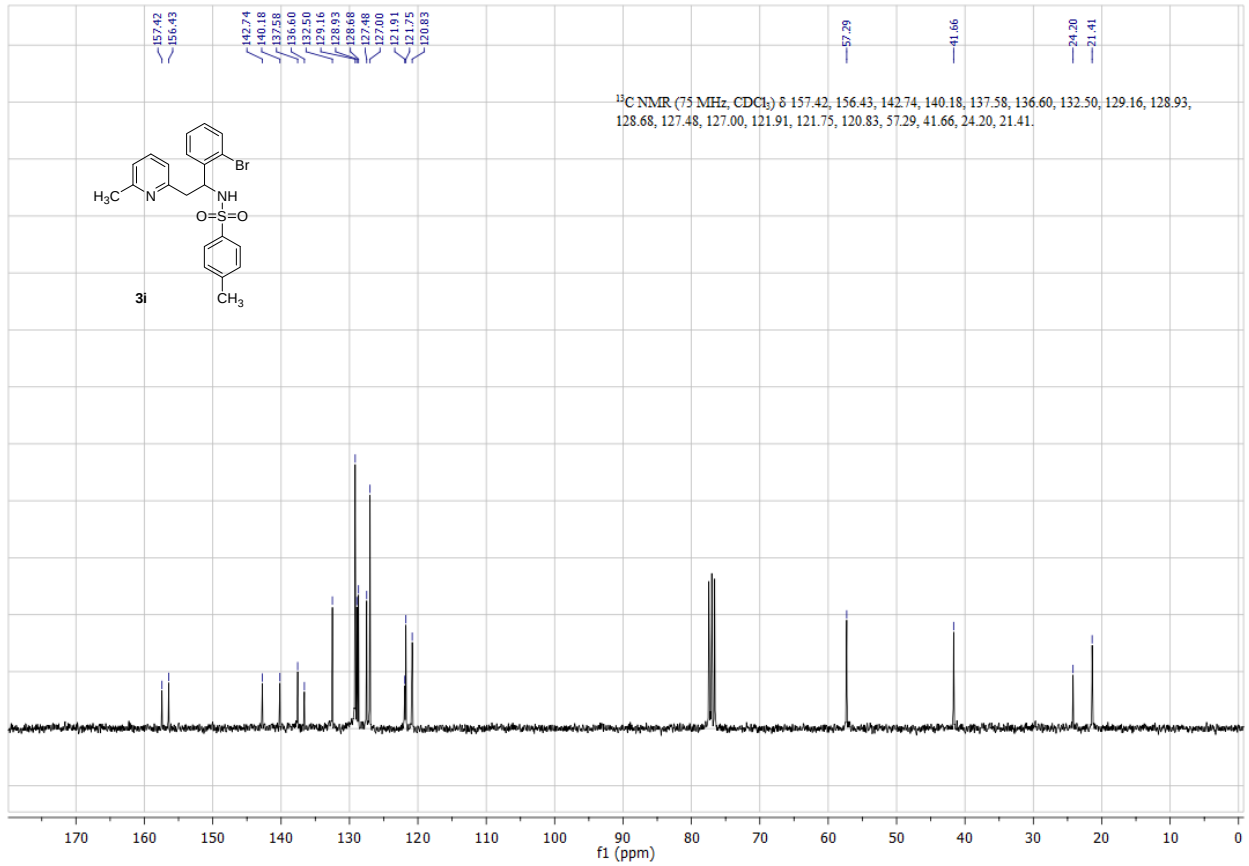

158.07
155.21
143.39
137.28
136.44
129.19
126.89
121.90
120.54
48.68
41.04
24.13
21.30
13C NMR (75 MHz, CDCl3) δ 158.07, 155.21, 143.39, 137.28, 136.44, 129.19, 126.89, 121.90, 120.54, 48.68, 41.04, 24.13, 21.30.
F
F
F
F
F
H3C
N
NH
O=S=O
CH3
3g
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

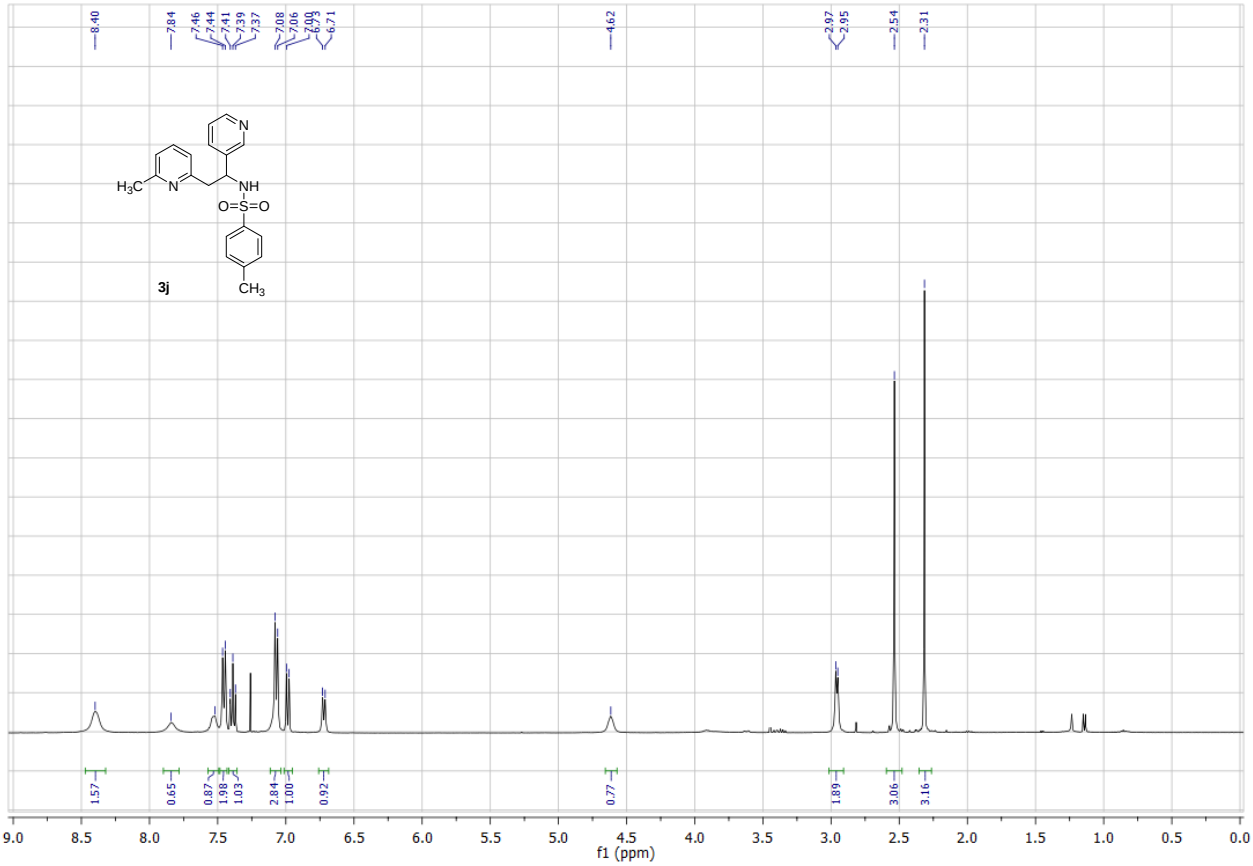

142.39
154.93
162.05
^{19}F NMR (282 MHz, CDCl$_3$) δ -142.39, -154.93, -162.05.
F
F
F
F
F
H$_3$C
N
NH
O=S=O
CH$_3$
3g
80 70 60 50 40 30 20 10 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260
f1 (ppm)

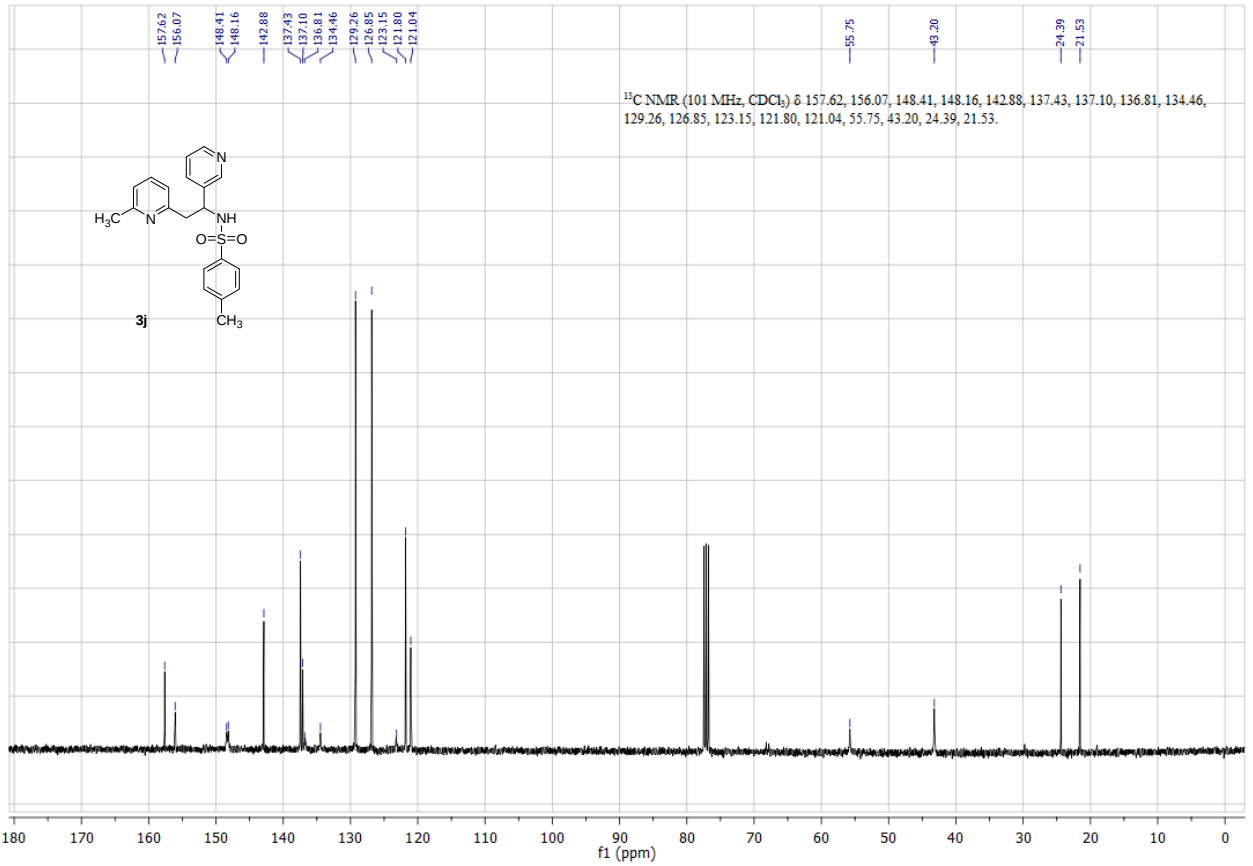

8.03
8.03
8.01
8.00
7.86
7.48
7.45
7.39
7.36
7.10
7.10
7.02
6.73
6.71
4.69
4.67
4.65
2.98
2.96
2.56
2.33
NO2
H3C
N
NH
O=S=O
CH3
3h
1.97
0.92
2.21
2.76
2.00
0.99
0.97
1.00
2.01
3.08
3.27
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

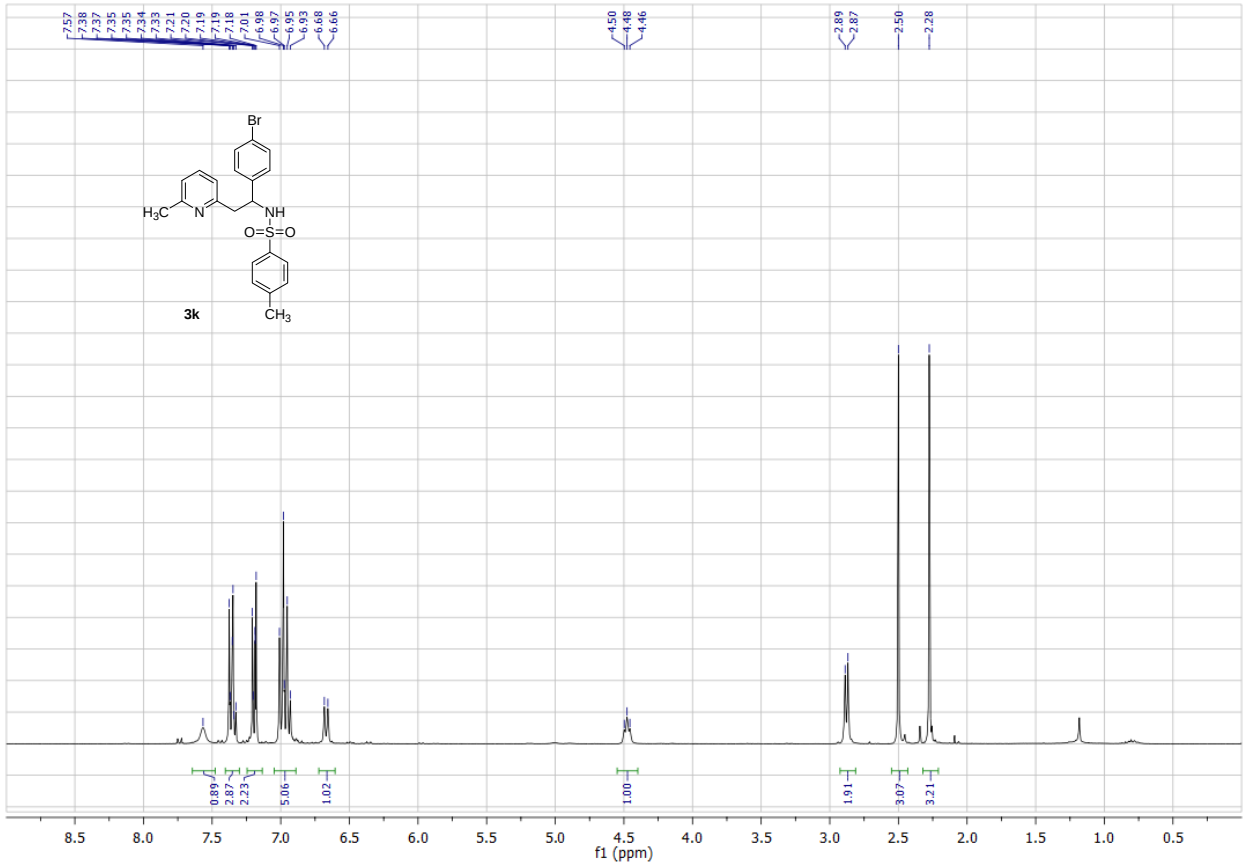

157.76
155.79
148.67
147.05
143.20
137.67
137.08
129.32
127.65
126.89
123.45
122.02
121.06
57.36
42.75
24.20
21.39
13C NMR (75 MHz, CDCl3) δ 157.76, 155.79, 148.67, 147.05, 143.20, 137.67, 137.08, 129.32, 127.65, 126.89, 123.45, 122.02, 121.06, 57.36, 42.75, 24.20, 21.39.
NO2
H3C
N
NH
O=S=O
CH3
3h
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

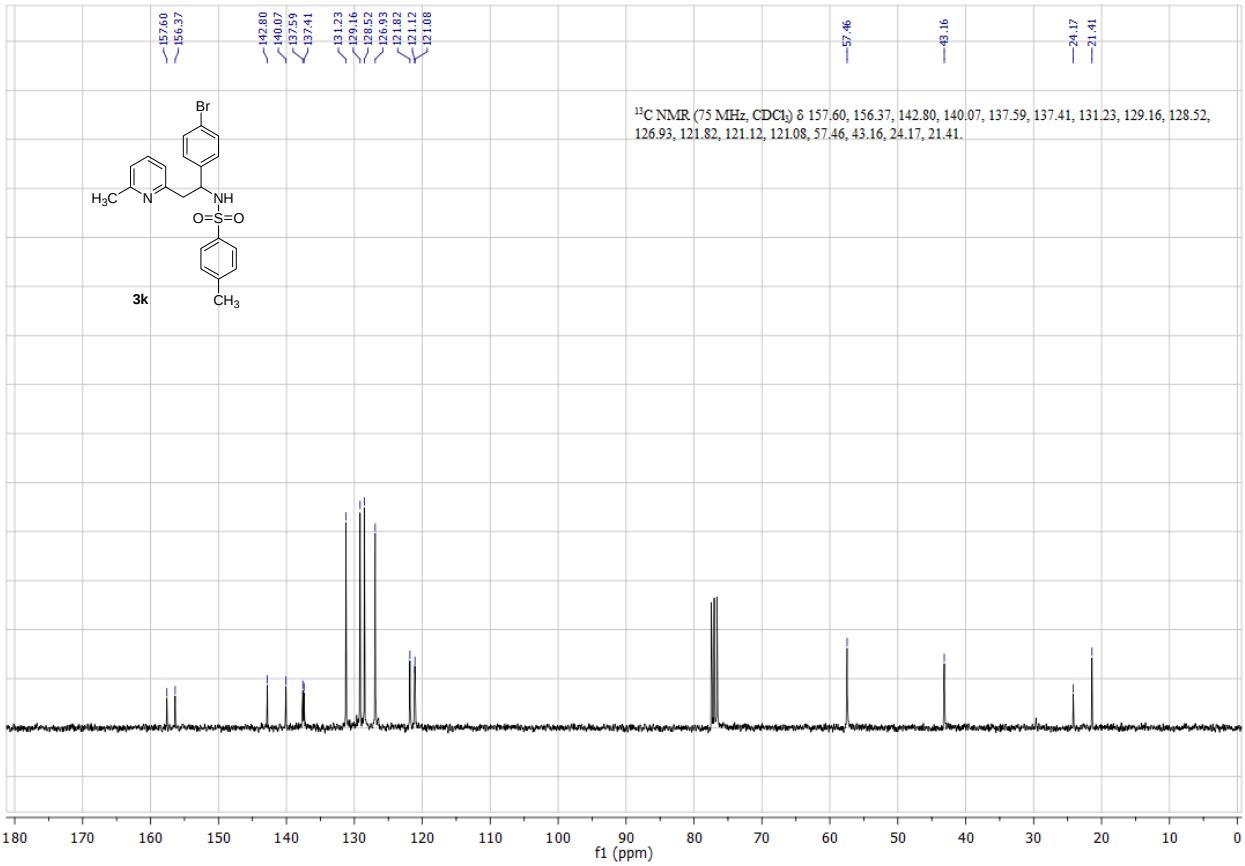

7.49
7.48
7.46
7.43
7.42
7.41
7.40
7.40
7.38
7.36
7.17
7.15
7.15
7.13
7.12
7.07
7.04
7.01
6.99
6.76
6.73
4.88
4.85
3.03
3.02
2.98
2.97
2.87
2.84
2.83
2.80
2.59
2.32
Br
H3C
N
NH
O=S=O
CH3
3i
0.77
2.84
1.22
0.79
1.01
2.76
1.23
1.05
1.00
1.01
1.02
3.06
3.12
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

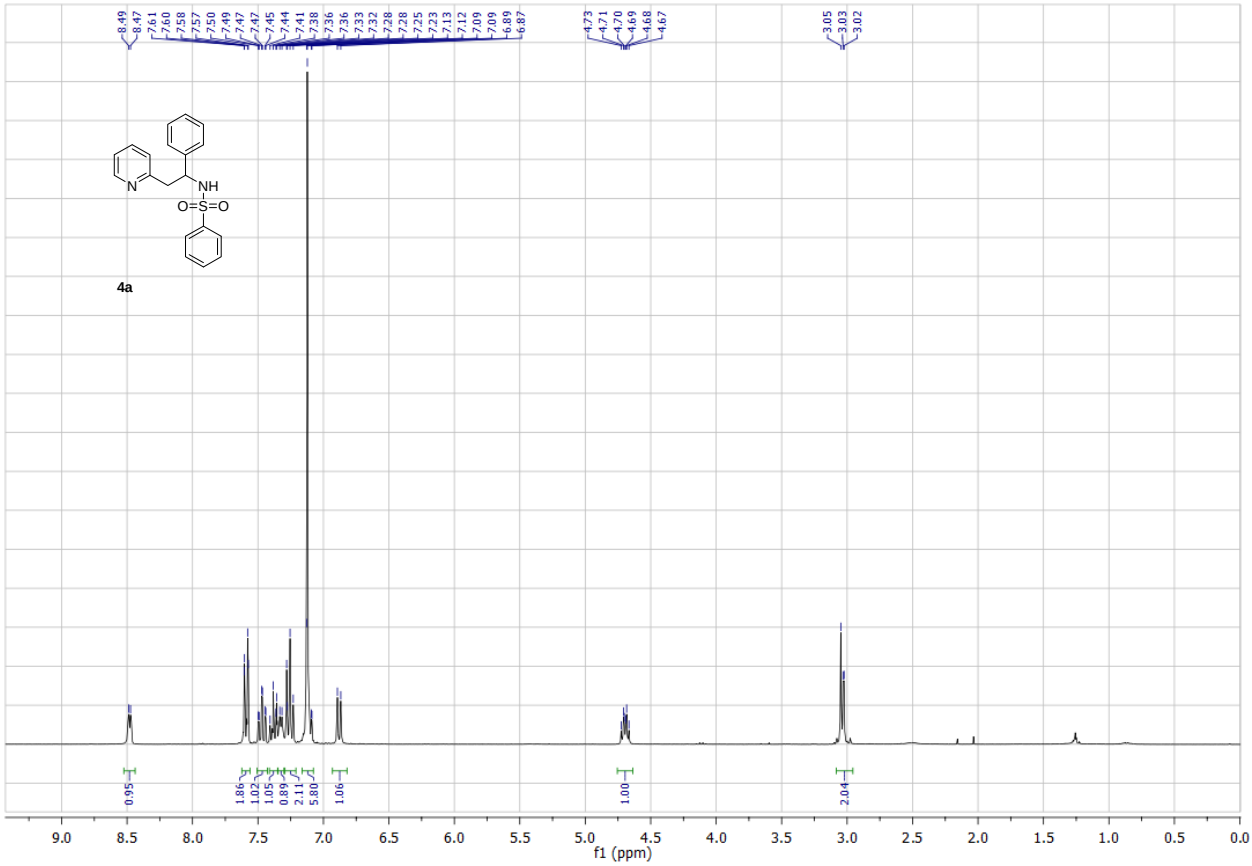

157.42
156.43
142.74
140.18
137.58
136.60
132.50
129.16
128.93
128.68
127.48
127.00
121.91
121.75
120.83
57.29
41.66
24.20
21.41
13C NMR (75 MHz, CDCl3) δ 157.42, 156.43, 142.74, 140.18, 137.58, 136.60, 132.50, 129.16, 128.93, 128.68, 127.48, 127.00, 121.91, 121.75, 120.83, 57.29, 41.66, 24.20, 21.41.
Br
H3C
N
NH
O=S=O
CH3
3i
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

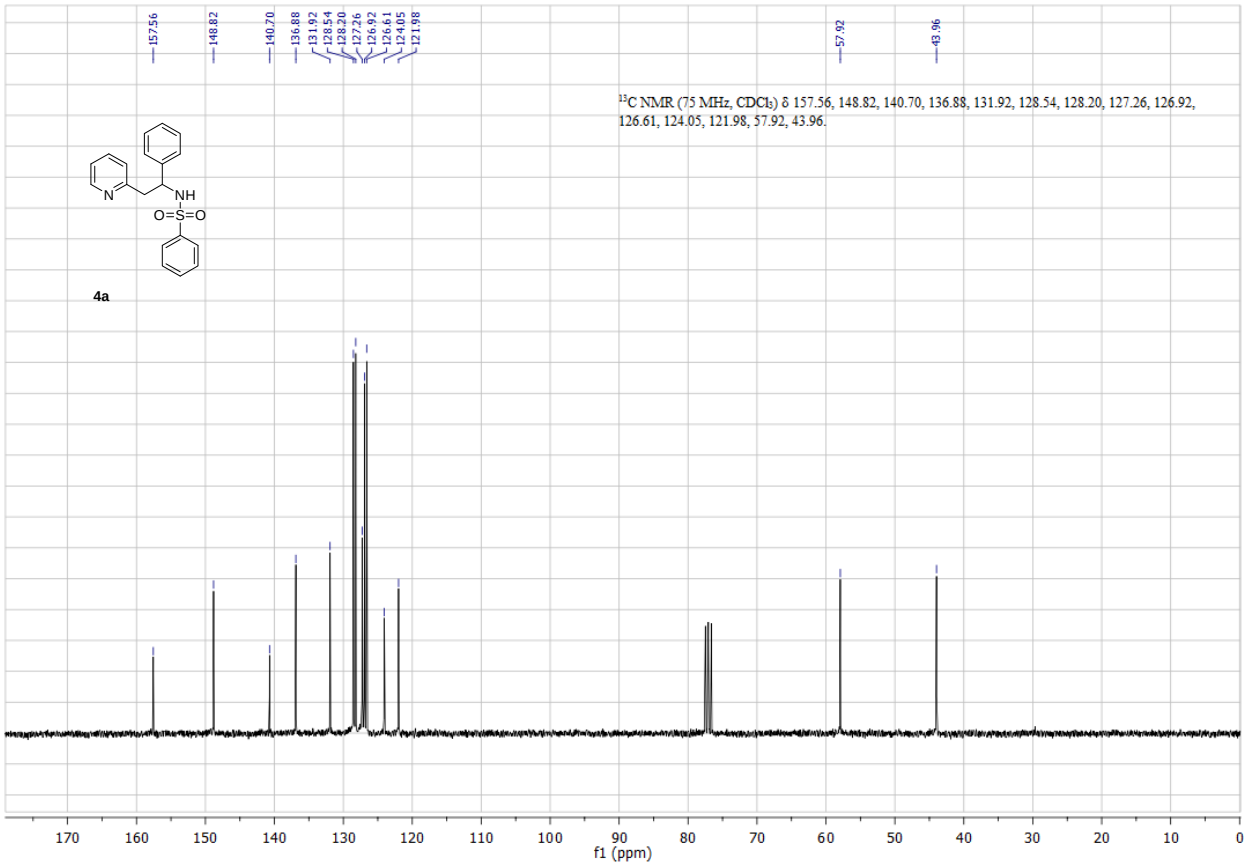

8.40
7.84
7.46
7.44
7.41
7.39
7.37
7.08
7.06
7.00
6.93
6.71
4.62
2.97
2.95
2.54
2.31
3j
1.57
0.65
0.87
1.98
1.03
2.84
1.00
0.92
0.77
1.89
3.06
3.16
f1 (ppm)

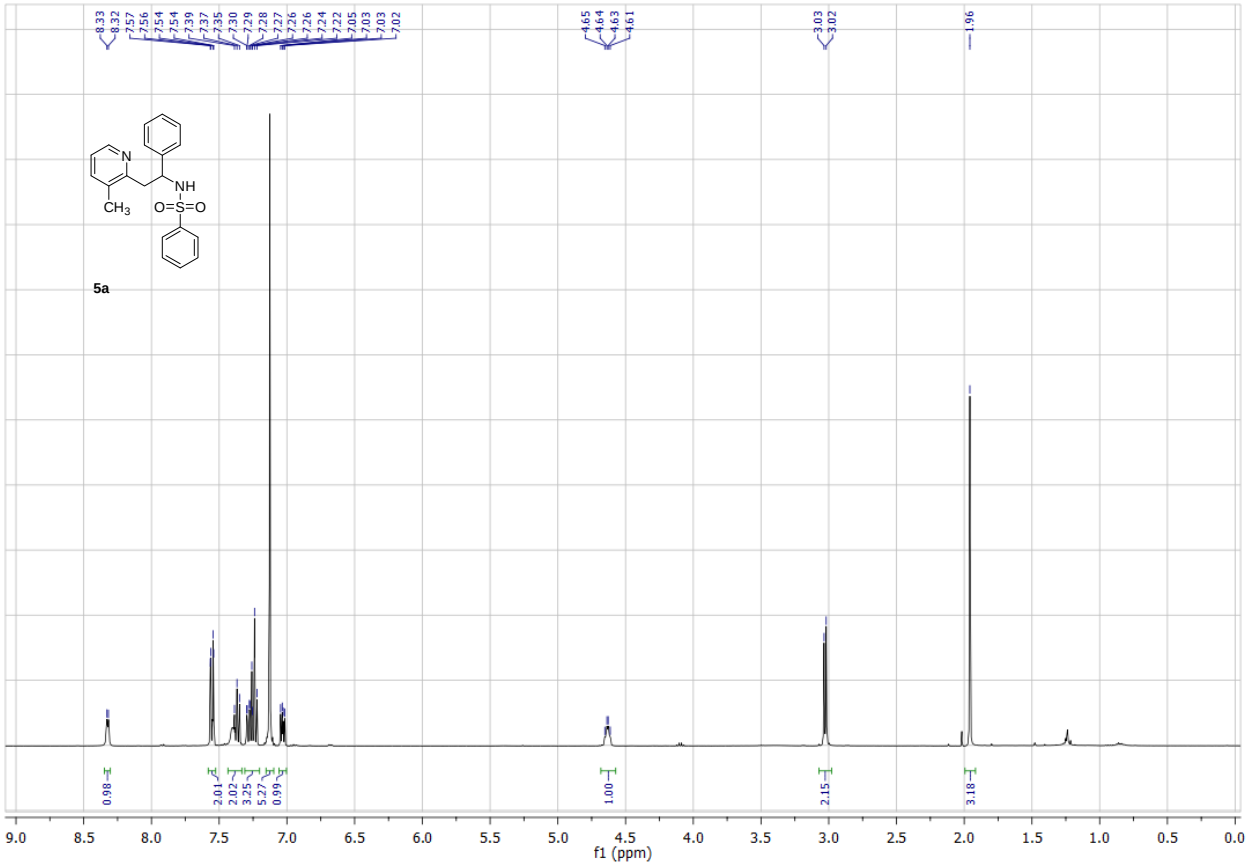

157.62
156.07
148.41
148.16
142.88
137.43
137.10
136.81
134.46
129.26
126.85
123.15
121.80
121.04
55.75
43.20
24.39
21.53
13C NMR (101 MHz, CDCl3) δ 157.62, 156.07, 148.41, 148.16, 142.88, 137.43, 137.10, 136.81, 134.46, 129.26, 126.85, 123.15, 121.80, 121.04, 55.75, 43.20, 24.39, 21.53.
3j
f1 (ppm)

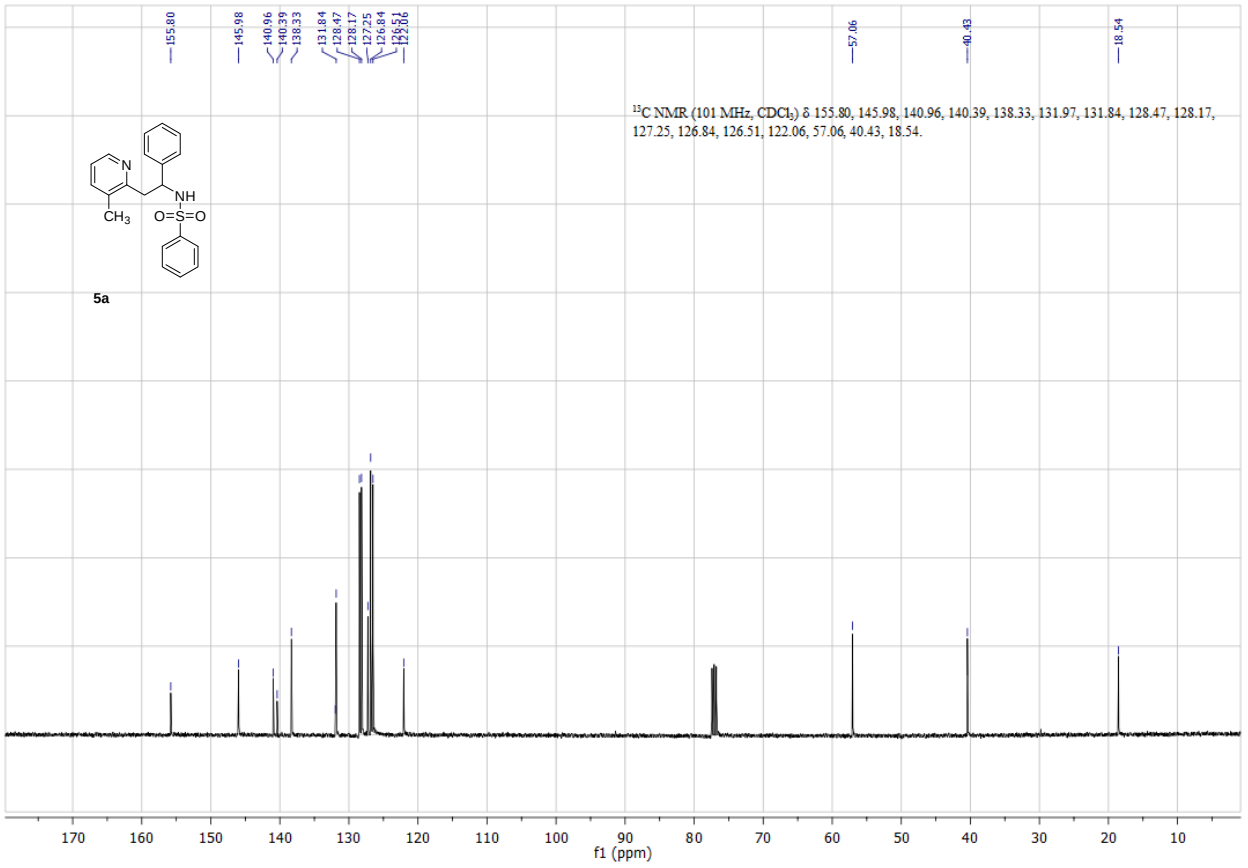

7.57
7.38
7.37
7.35
7.35
7.34
7.33
7.21
7.20
7.19
7.19
7.18
7.01
6.98
6.97
6.95
6.93
6.68
6.66
4.50
4.48
4.46
2.89
2.87
2.50
2.28
Br
H3C
N
NH
O=S=O
CH3
3k
0.89
2.87
2.23
5.06
1.02
1.00
1.91
3.07
3.21
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

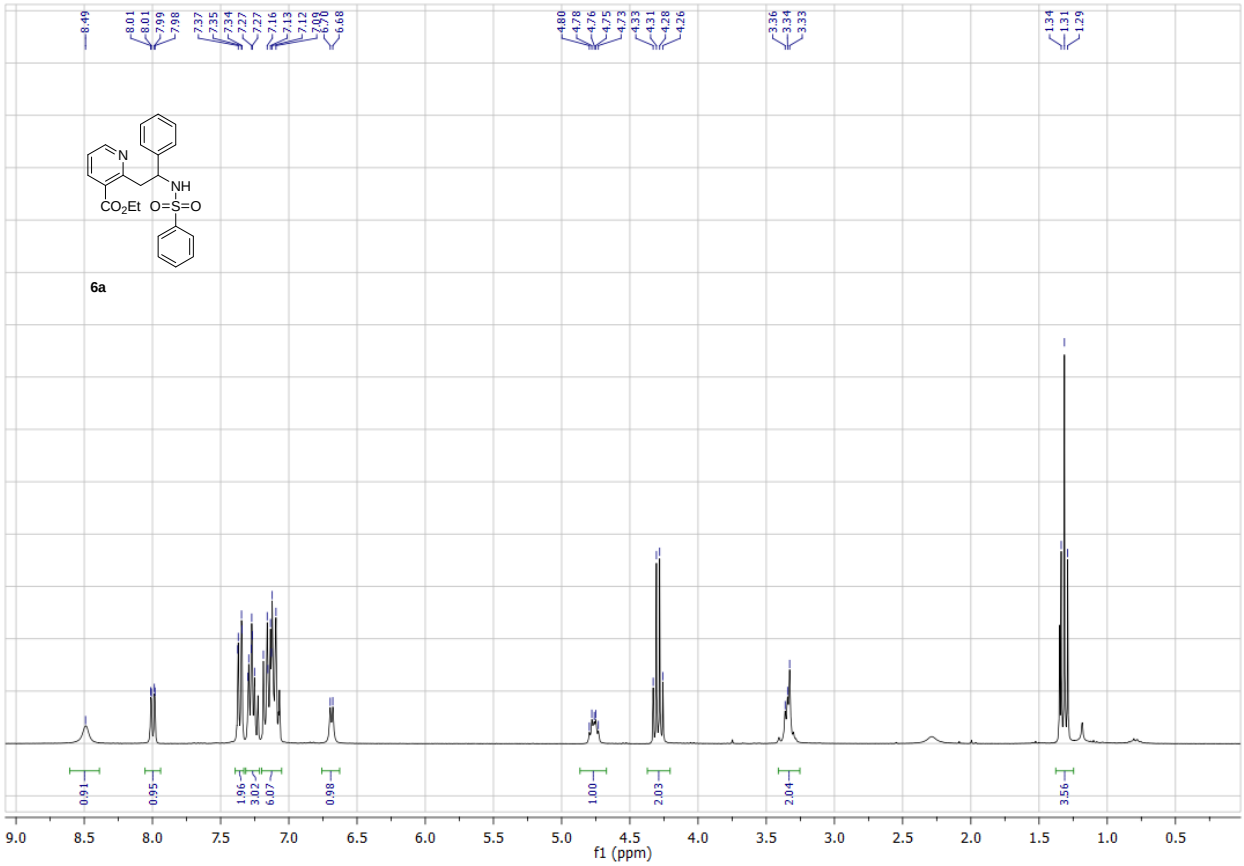

157.60
156.37
142.80
140.07
137.59
137.41
131.23
129.16
128.52
126.93
121.82
121.12
121.08
57.46
43.16
24.17
21.41
Br
H3C
N
NH
O=S=O
CH3
3k
13C NMR (75 MHz, CDCl3) δ 157.60, 156.37, 142.80, 140.07, 137.59, 137.41, 131.23, 129.16, 128.52, 126.93, 121.82, 121.12, 121.08, 57.46, 43.16, 24.17, 21.41.
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

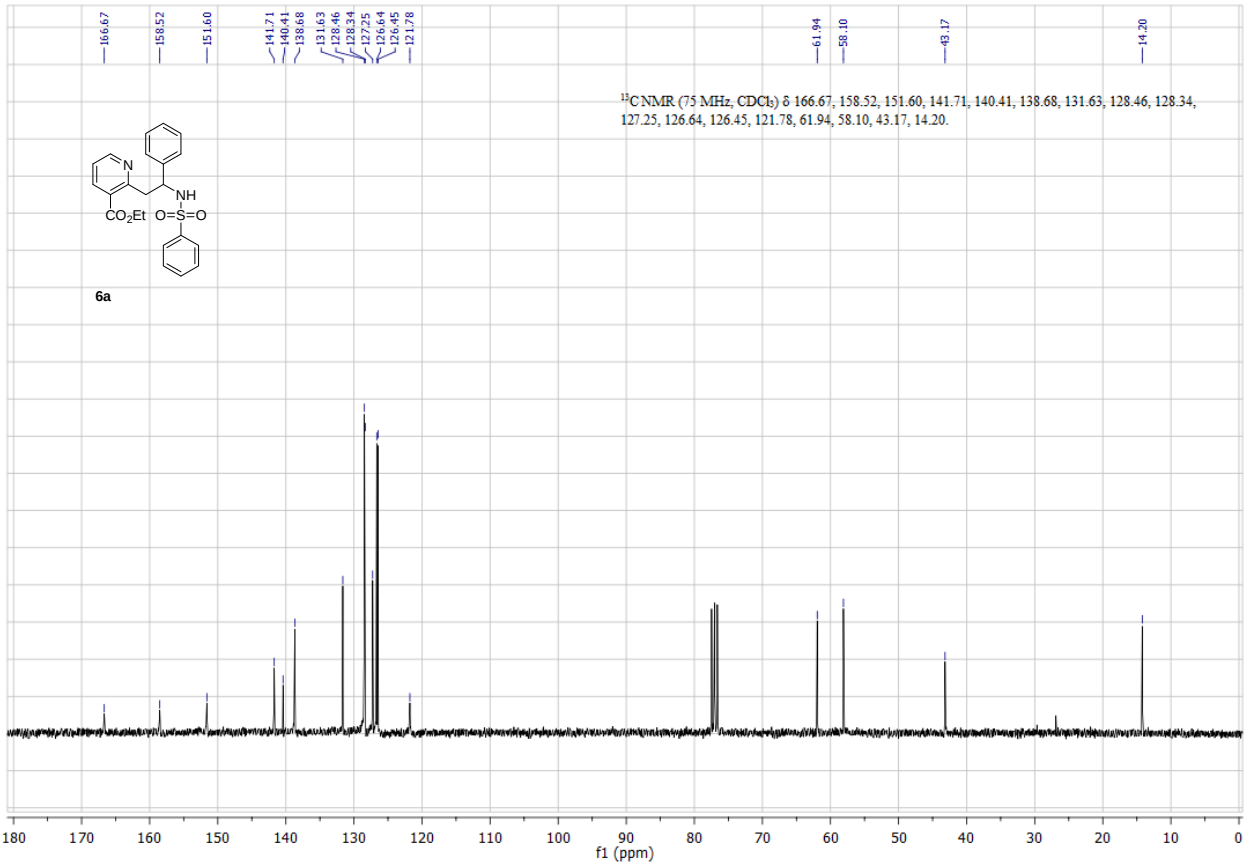

8.49
8.47
7.61
7.60
7.58
7.57
7.50
7.49
7.47
7.47
7.45
7.44
7.41
7.38
7.36
7.36
7.33
7.32
7.28
7.28
7.25
7.23
7.13
7.12
7.09
7.09
6.89
6.87
4.73
4.71
4.70
4.69
4.68
4.67
3.05
3.03
3.02
N
NH
O=S=O
4a
0.95
1.86
1.02
1.05
0.89
2.11
5.80
1.06
1.00
2.04
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

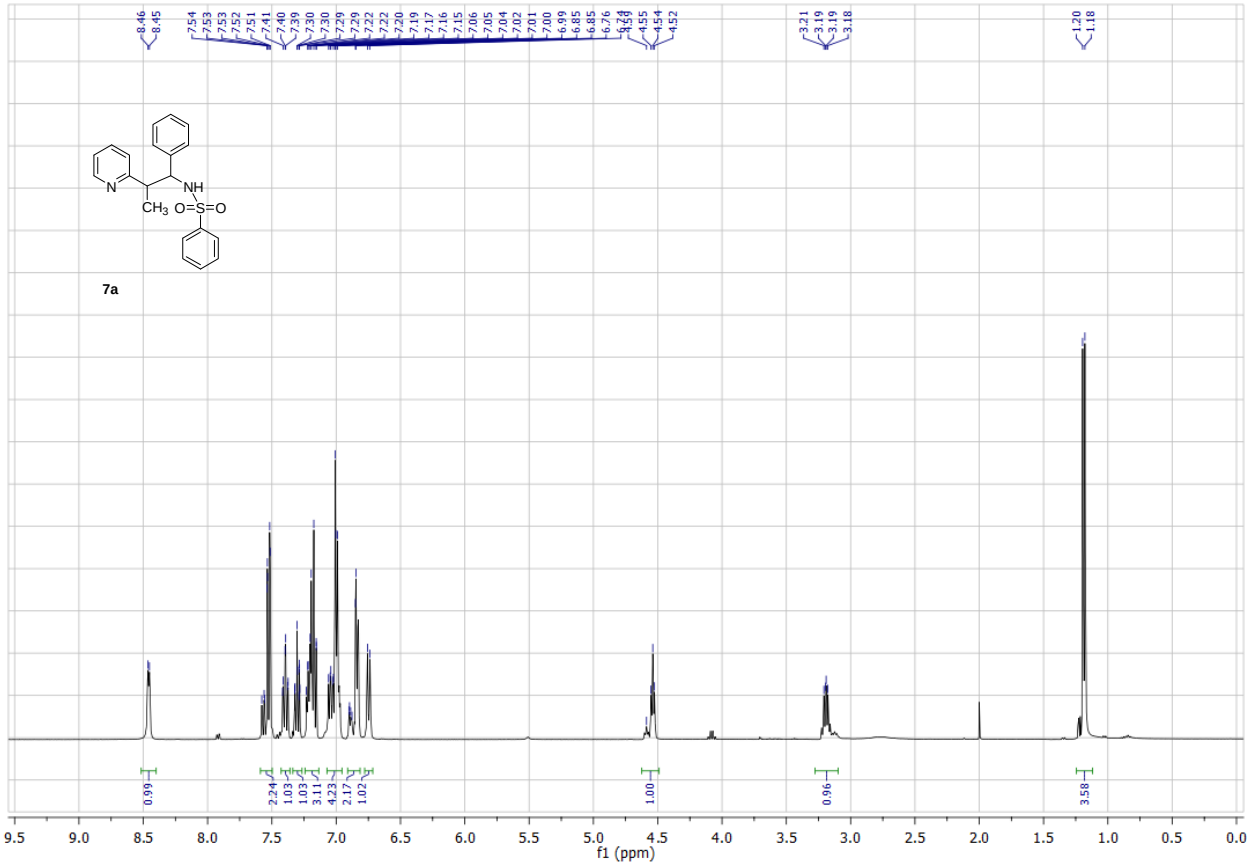

157.56
148.82
140.70
136.88
131.92
128.54
128.20
127.26
126.92
126.61
124.05
121.98
57.92
43.96
13C NMR (75 MHz, CDCl3) δ 157.56, 148.82, 140.70, 136.88, 131.92, 128.54, 128.20, 127.26, 126.92, 126.61, 124.05, 121.98, 57.92, 43.96.
N
NH
O=S=O
4a
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

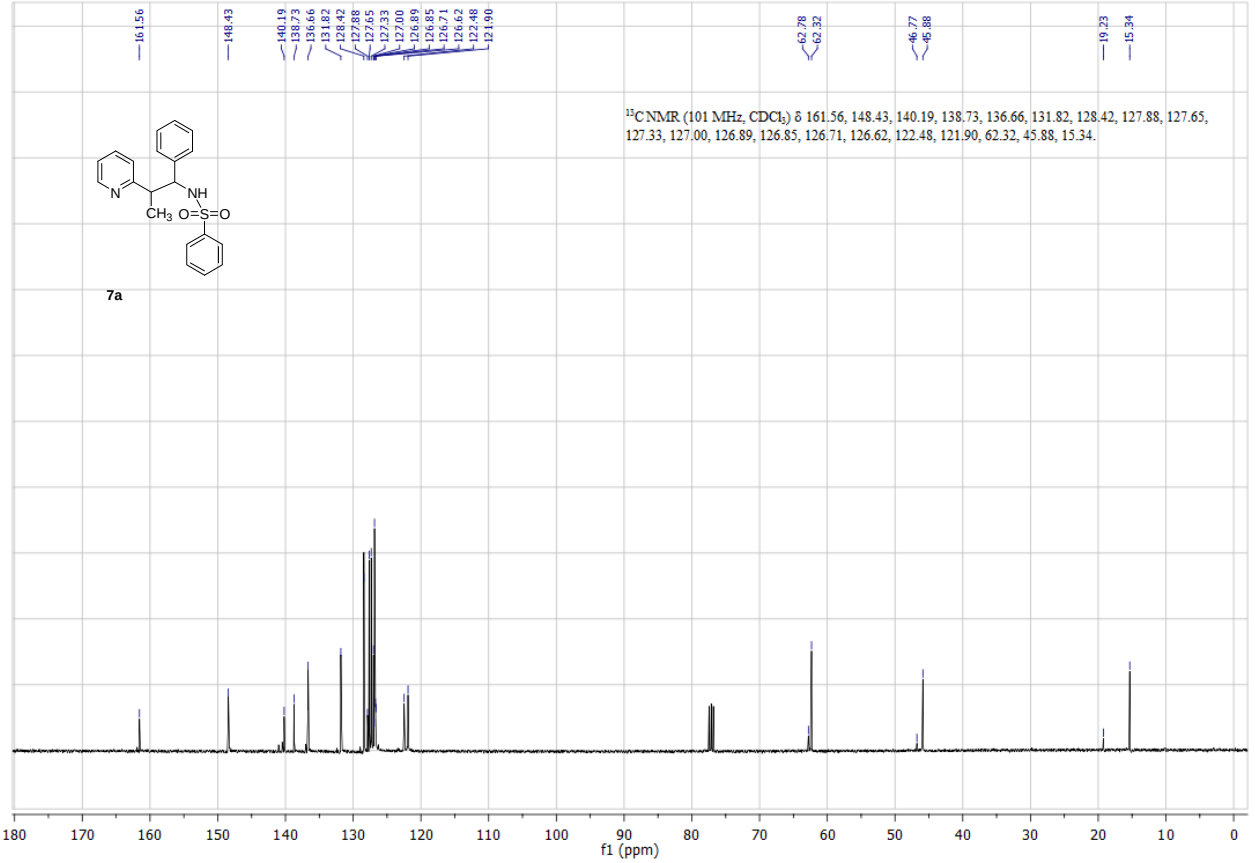

8.33
8.32
7.57
7.56
7.54
7.54
7.39
7.37
7.35
7.30
7.29
7.28
7.27
7.26
7.26
7.24
7.22
7.05
7.03
7.03
7.02
4.65
4.64
4.63
4.61
3.03
3.02
1.96
N
NH
CH3
O=S=O
5a
0.98
2.01
2.02
3.25
5.27
0.99
1.00
2.15
3.18
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

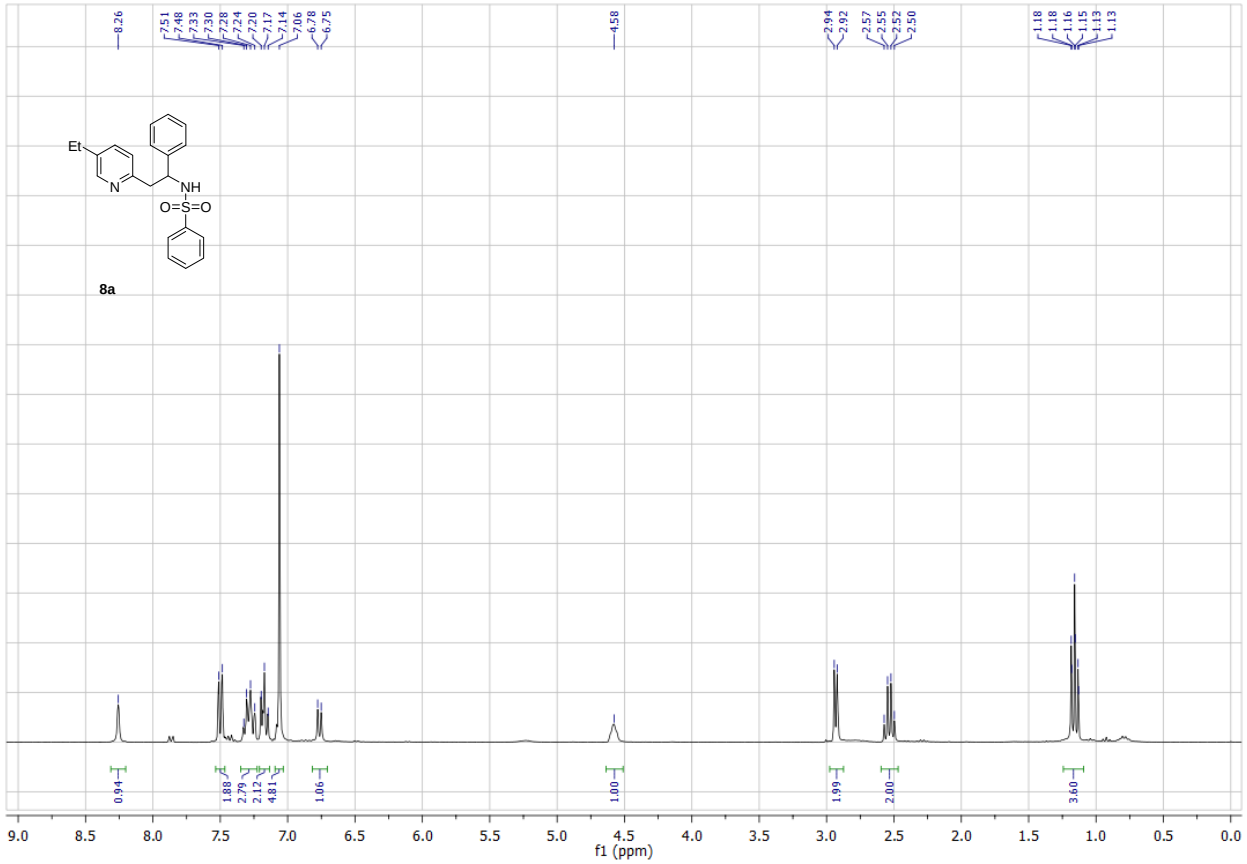

155.80
145.98
140.96
140.39
138.33
131.84
128.47
128.17
127.25
126.84
126.51
122.06
57.06
40.43
18.54
13C NMR (101 MHz, CDCl3) δ 155.80, 145.98, 140.96, 140.39, 138.33, 131.97, 131.84, 128.47, 128.17, 127.25, 126.84, 126.51, 122.06, 57.06, 40.43, 18.54.
N
NH
CH3
O=S=O
5a
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

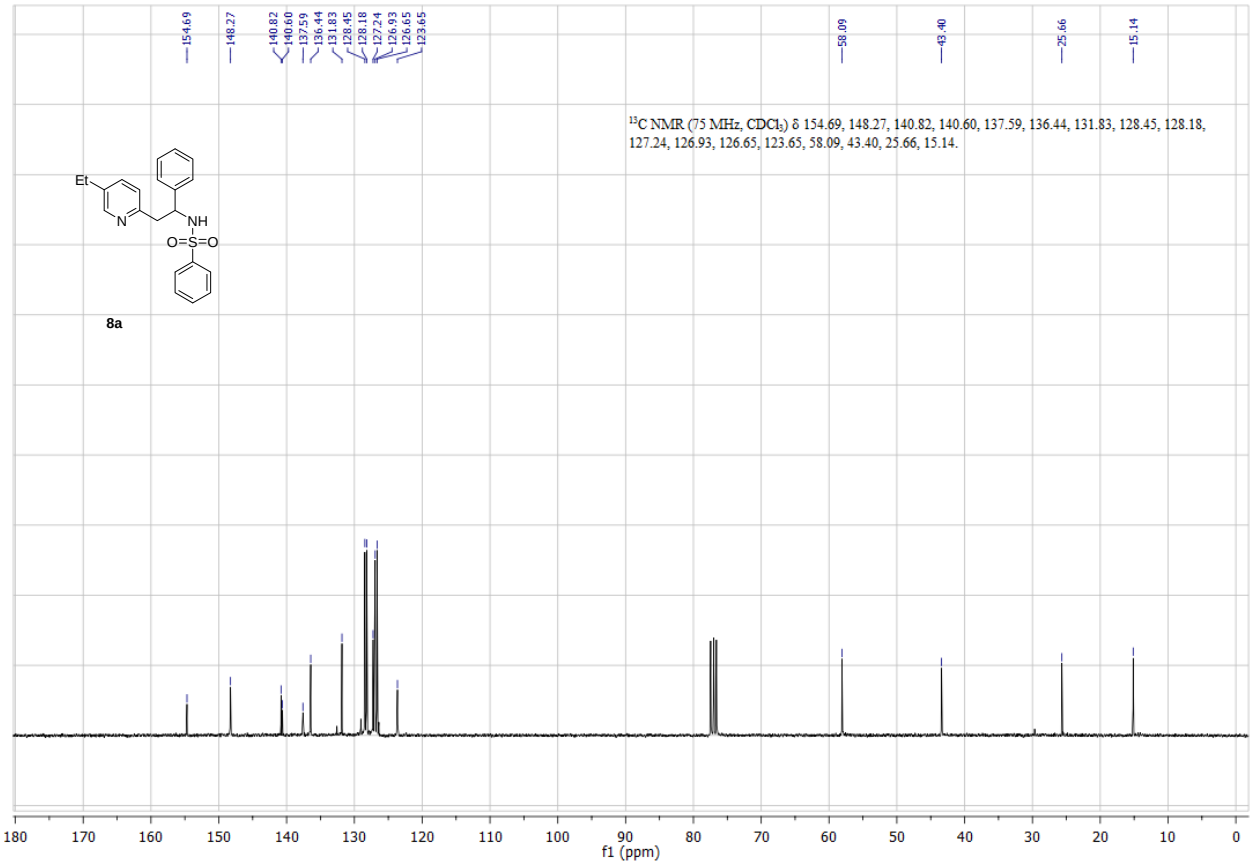

8.49
8.01
8.01
7.99
7.98
7.37
7.35
7.34
7.27
7.27
7.16
7.13
7.12
7.00
6.70
6.68
4.80
4.78
4.76
4.75
4.73
4.33
4.31
4.28
4.26
3.36
3.34
3.33
1.34
1.31
1.29
N
NH
CO2Et O=S=O
6a
0.91
0.95
1.96
3.02
6.07
0.98
1.00
2.03
2.04
3.56
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

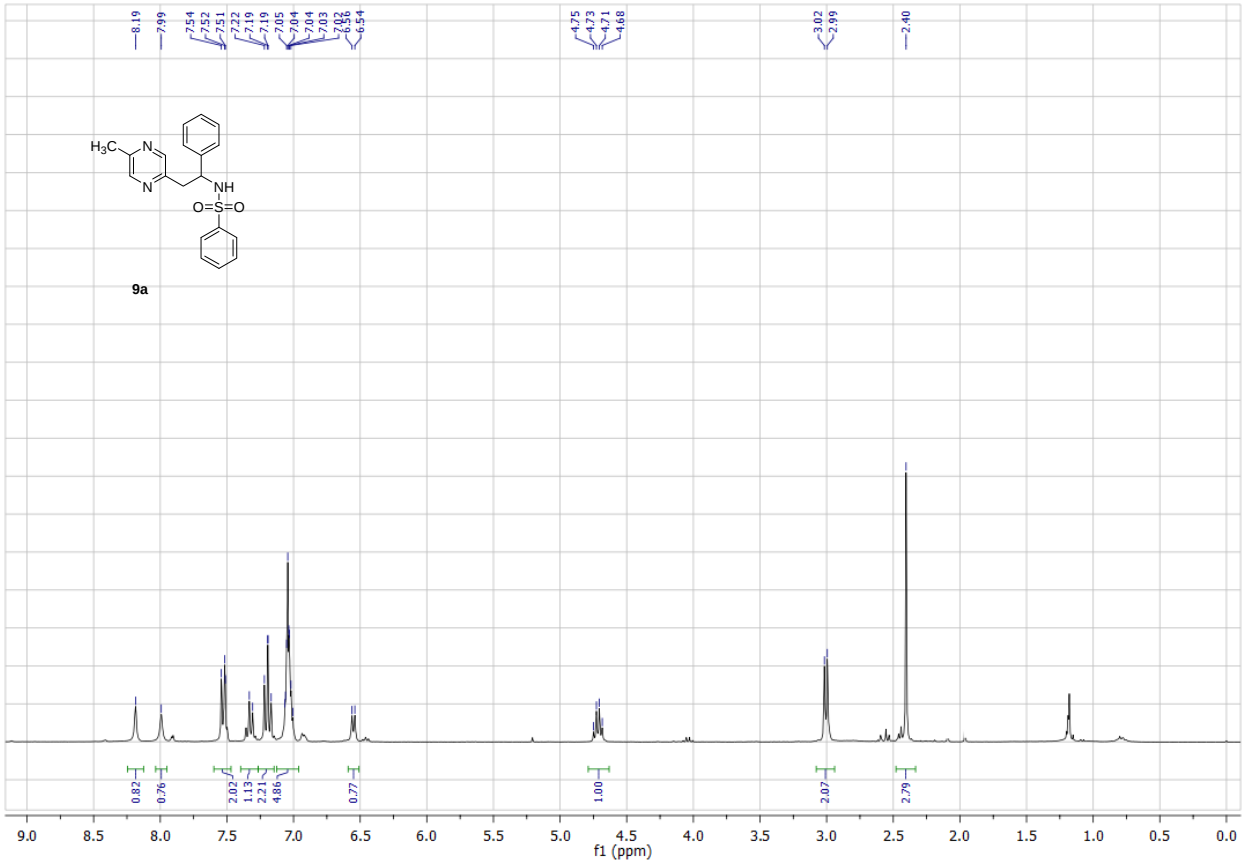

166.67
158.52
151.60
141.71
140.41
138.68
131.63
128.46
128.34
127.25
126.64
126.45
121.78
61.94
58.10
43.17
14.20
13C NMR (75 MHz, CDCl3) δ 166.67, 158.52, 151.60, 141.71, 140.41, 138.68, 131.63, 128.46, 128.34, 127.25, 126.64, 126.45, 121.78, 61.94, 58.10, 43.17, 14.20.
N
NH
CO2Et O=S=O
6a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

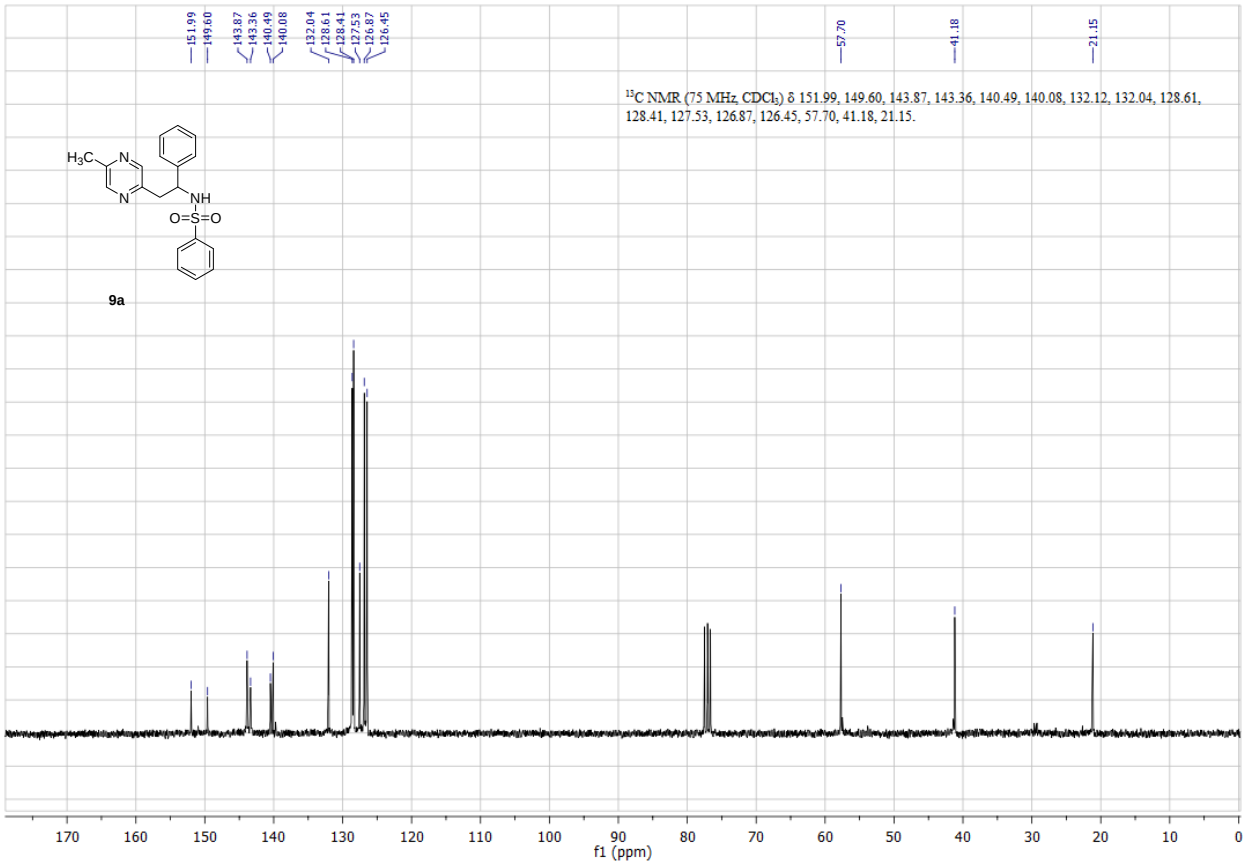

8.46
8.45
7.54
7.53
7.53
7.52
7.51
7.41
7.40
7.39
7.30
7.30
7.29
7.29
7.22
7.20
7.19
7.17
7.16
7.15
7.06
7.05
7.04
7.02
7.01
7.00
6.99
6.85
6.85
6.76
4.55
4.54
4.52
3.21
3.19
3.19
3.18
1.20
1.18
NH
CH3 O=S=O
7a
0.99
2.24
1.03
1.03
3.11
4.23
2.17
1.02
1.00
0.96
3.58
f1 (ppm)

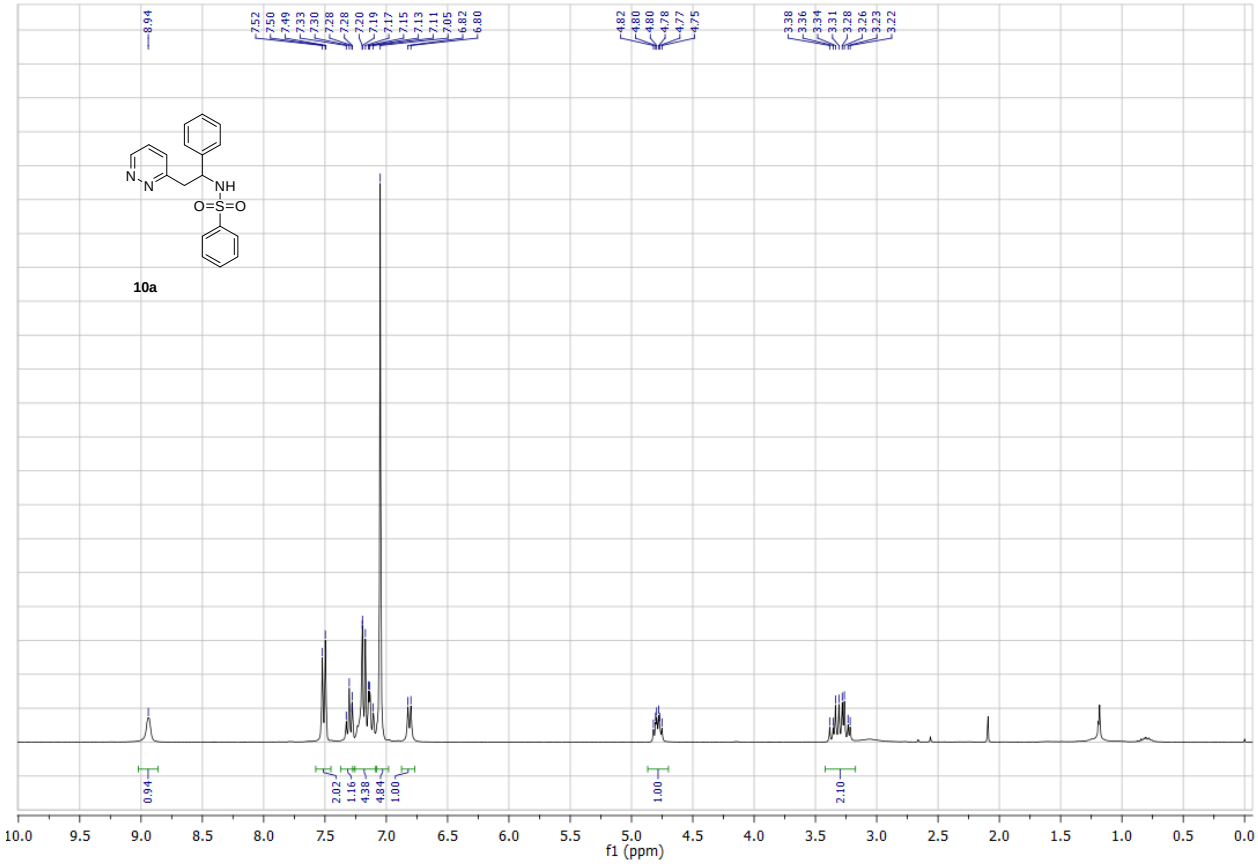

161.56
148.43
140.19
138.73
136.66
131.82
128.42
127.88
127.65
127.33
127.00
126.89
126.85
126.71
126.62
122.48
121.90
62.78
62.32
46.77
45.88
19.23
15.34
13C NMR (101 MHz, CDCl3) δ 161.56, 148.43, 140.19, 138.73, 136.66, 131.82, 128.42, 127.88, 127.65, 127.33, 127.00, 126.89, 126.85, 126.71, 126.62, 122.48, 121.90, 62.32, 45.88, 15.34.
NH
CH3 O=S=O
7a
f1 (ppm)

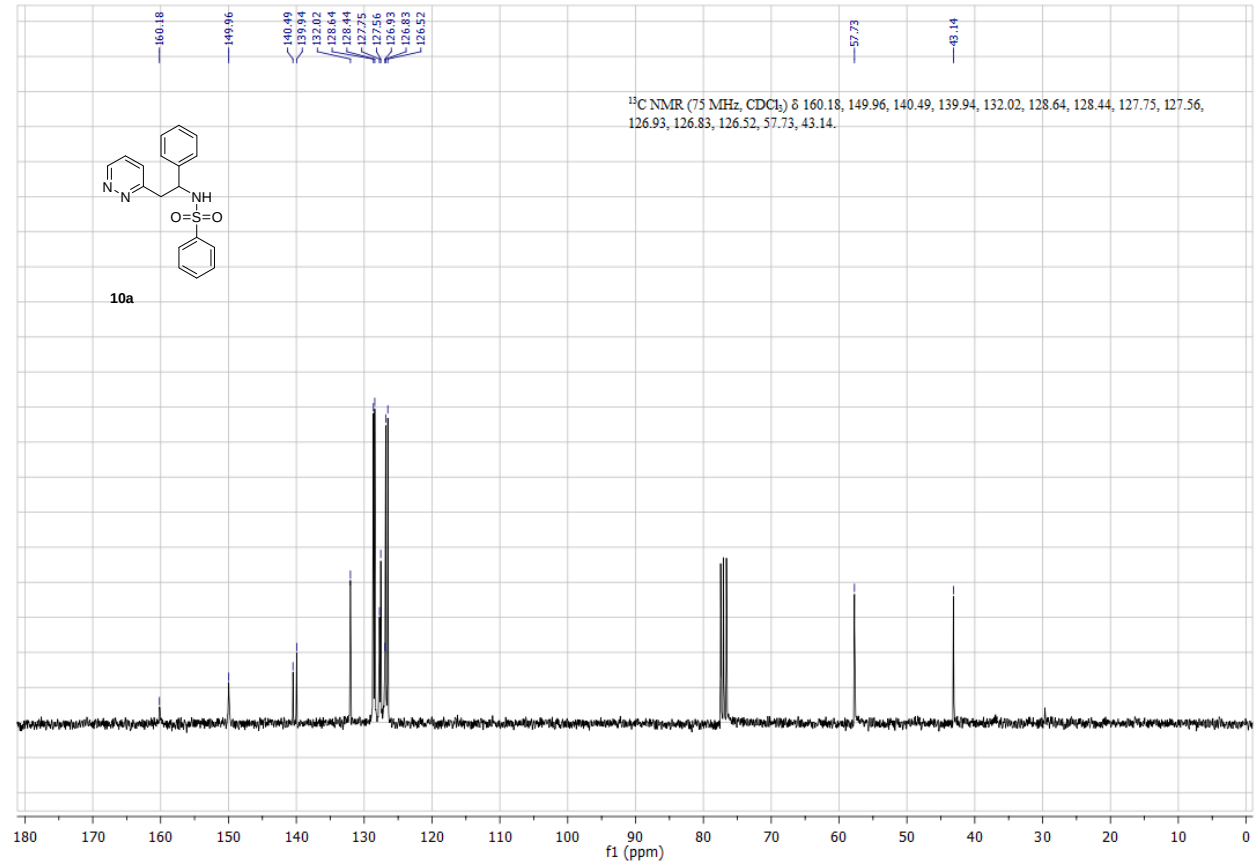

8.26
7.51
7.48
7.33
7.30
7.28
7.24
7.20
7.17
7.14
7.06
6.78
6.75
4.58
2.94
2.92
2.57
2.55
2.52
2.50
1.18
1.18
1.16
1.15
1.13
1.13
Et
N
NH
O=S=O
8a
0.94
1.88
2.79
2.12
4.81
1.06
1.00
1.99
2.00
3.60
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

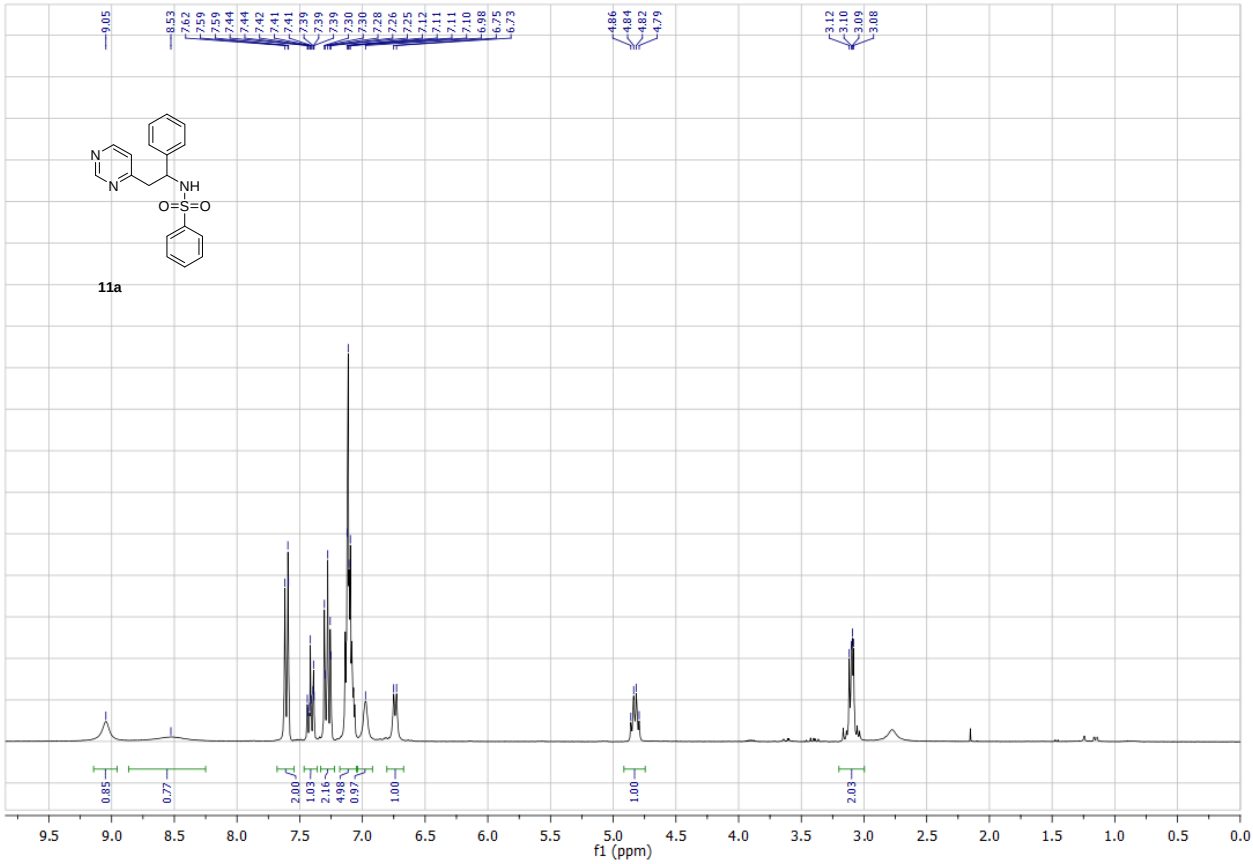

154.69
148.27
140.82
140.60
137.59
136.44
131.83
128.45
128.18
127.24
126.93
126.65
123.65
58.09
43.40
25.66
15.14
^{13}C NMR (75 MHz, $CDCl_3$) δ 154.69, 148.27, 140.82, 140.60, 137.59, 136.44, 131.83, 128.45, 128.18, 127.24, 126.93, 126.65, 123.65, 58.09, 43.40, 25.66, 15.14.
Et
N
NH
O=S=O
8a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

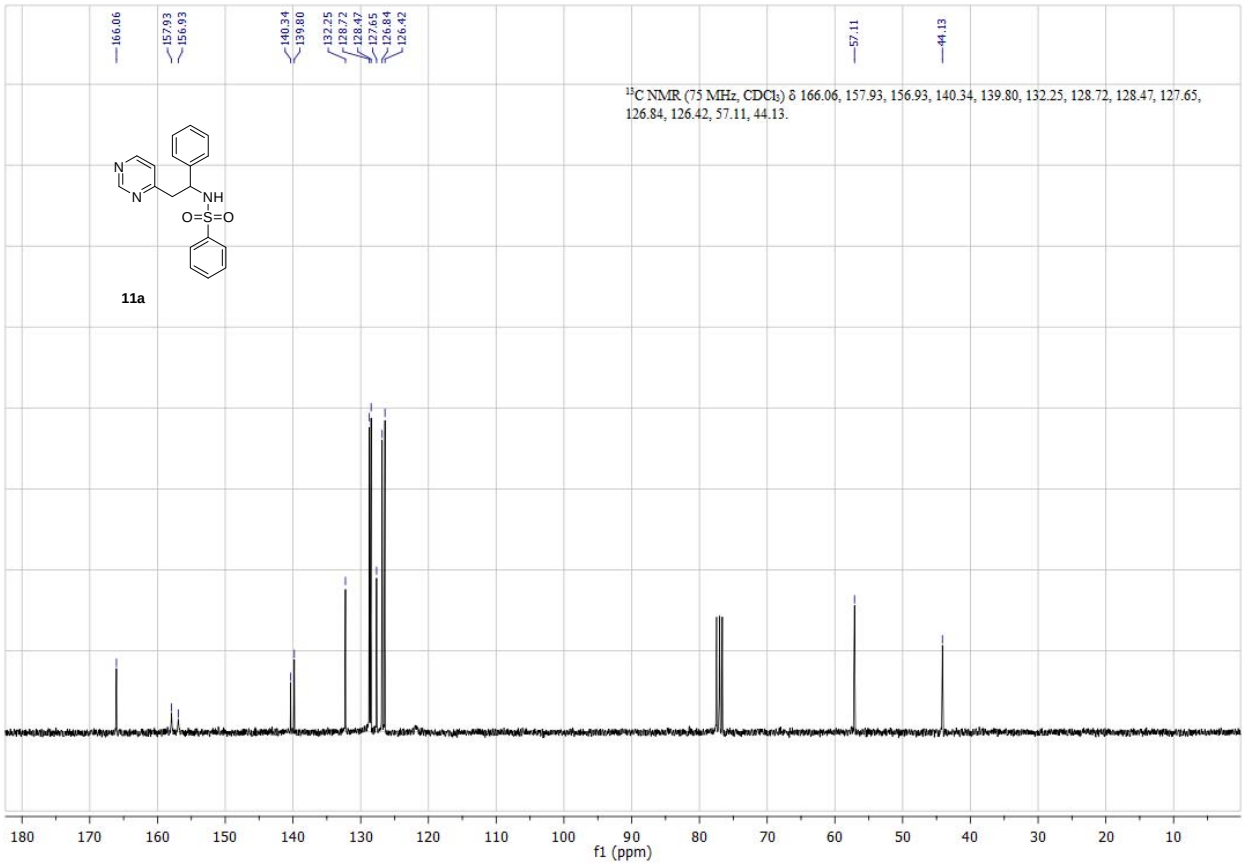

8.19
7.99
7.54
7.52
7.51
7.22
7.19
7.19
7.05
7.04
7.04
7.03
7.02
6.55
6.54
4.75
4.73
4.71
4.68
3.02
2.99
2.40
9a
0.82
0.76
2.02
1.13
2.21
4.86
0.77
1.00
2.07
2.79
f1 (ppm)

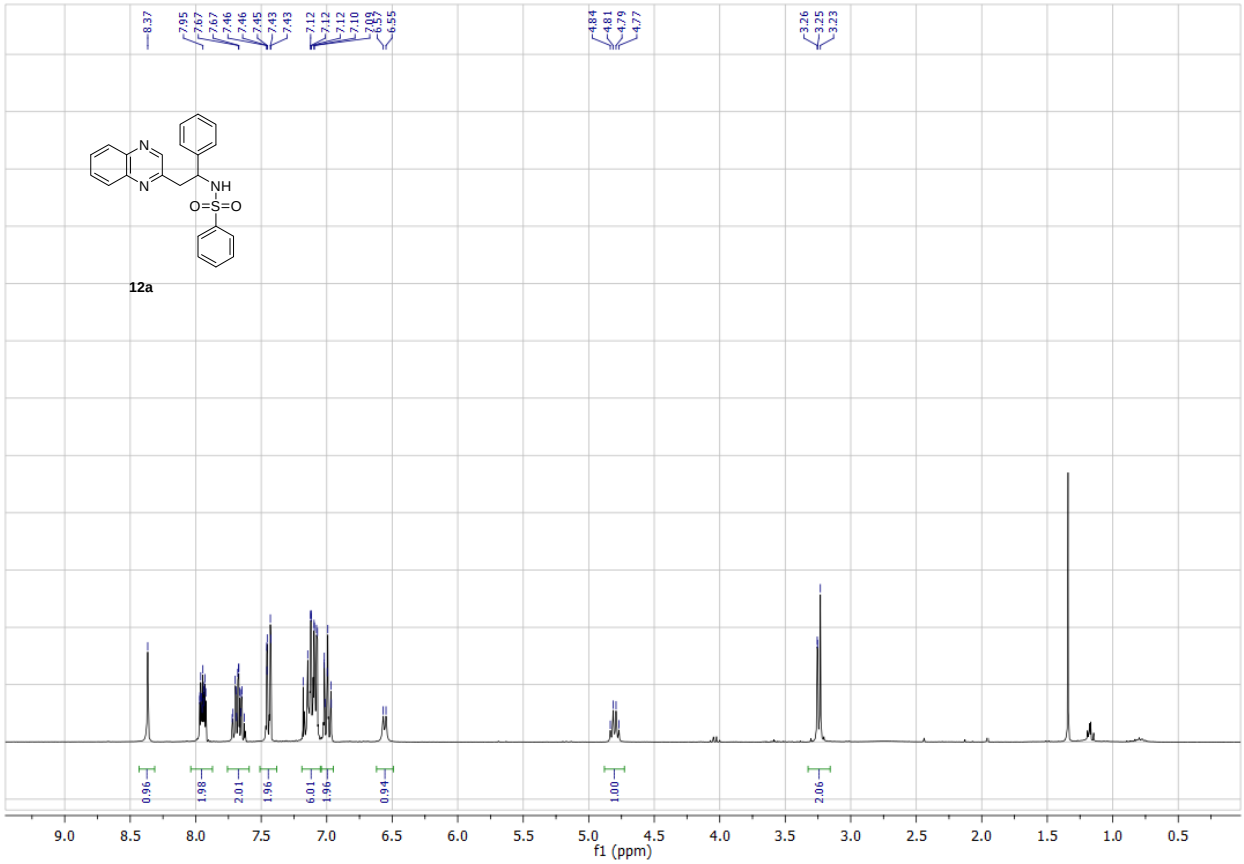

151.99
149.60
143.87
143.36
140.49
140.08
132.04
128.61
128.41
127.53
126.87
126.45
57.70
41.18
21.15
13C NMR (75 MHz, CDCl3) δ 151.99, 149.60, 143.87, 143.36, 140.49, 140.08, 132.12, 132.04, 128.61, 128.41, 127.53, 126.87, 126.45, 57.70, 41.18, 21.15.
9a
f1 (ppm)

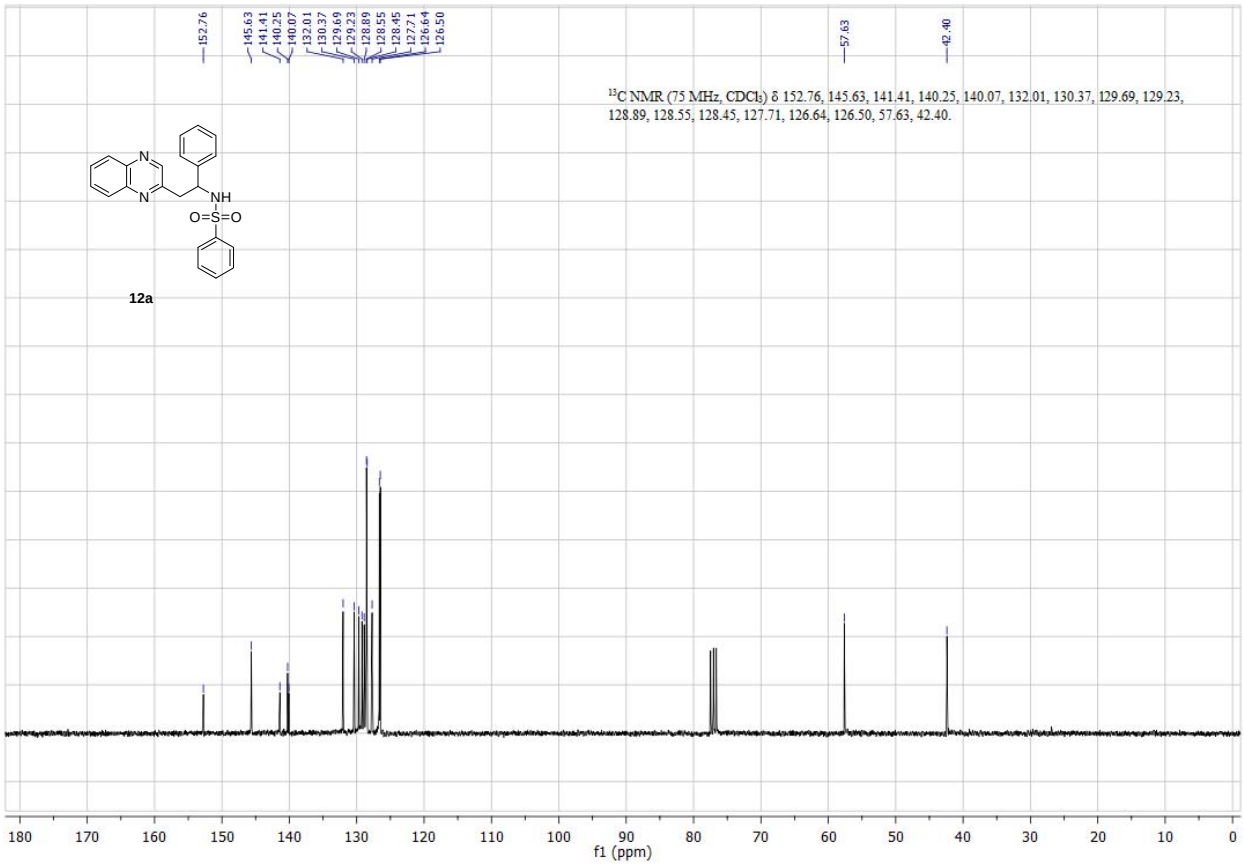

8.94
7.52
7.50
7.49
7.33
7.30
7.28
7.28
7.20
7.19
7.17
7.15
7.13
7.11
7.05
6.82
6.80
4.82
4.80
4.80
4.78
4.77
4.75
3.38
3.36
3.34
3.31
3.28
3.26
3.23
3.22
NH
O=S=O
10a
0.94
2.02
1.16
4.38
4.84
1.00
1.00
2.10
f1 (ppm)

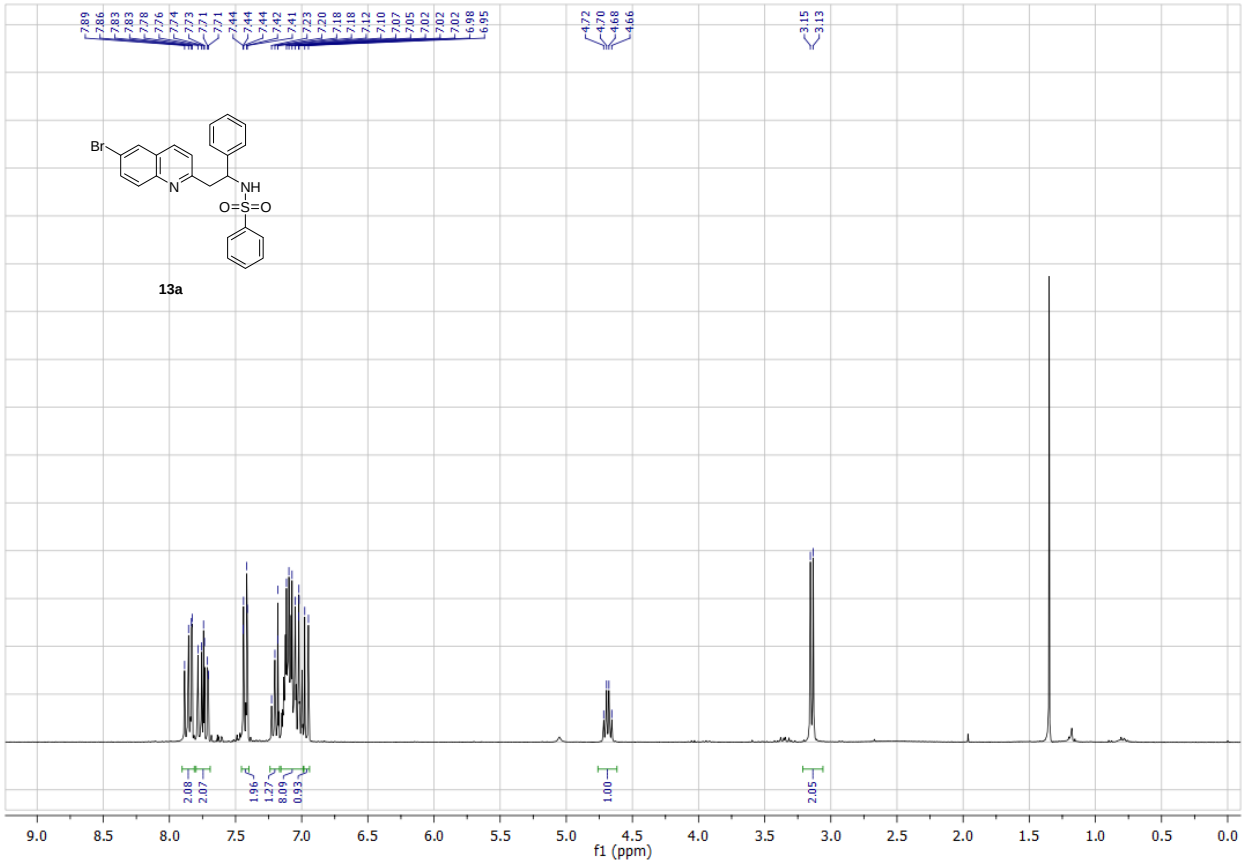

160.18
149.96
140.49
139.94
132.02
128.64
128.44
127.75
127.56
126.93
126.83
126.52
57.73
43.14
13C NMR (75 MHz, CDCl3) δ 160.18, 149.96, 140.49, 139.94, 132.02, 128.64, 128.44, 127.75, 127.56, 126.93, 126.83, 126.52, 57.73, 43.14.
NH
O=S=O
10a
f1 (ppm)

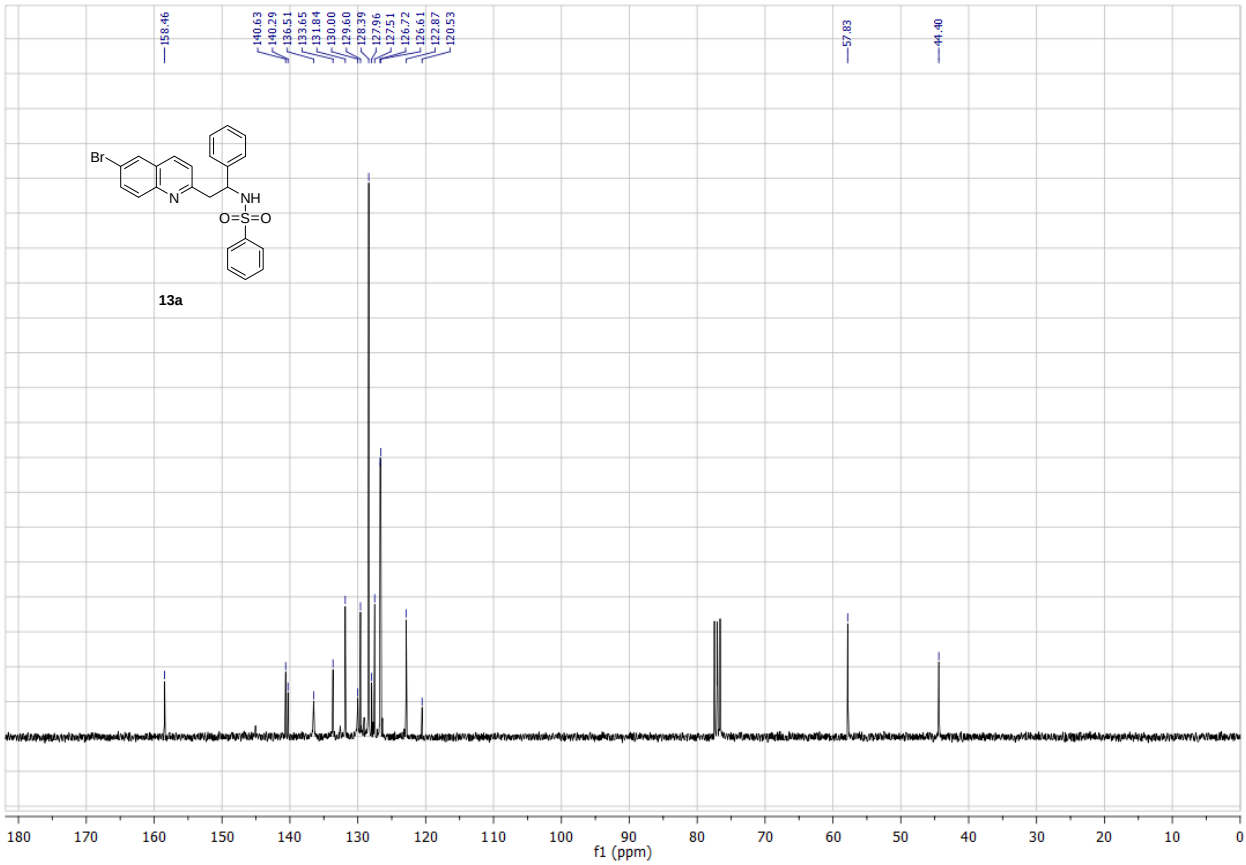

9.05
8.53
7.62
7.59
7.59
7.44
7.44
7.42
7.41
7.41
7.39
7.39
7.39
7.30
7.30
7.28
7.26
7.25
7.12
7.11
7.11
7.10
6.98
6.75
6.73
4.86
4.84
4.82
4.79
3.12
3.10
3.09
3.08
N
N
NH
O=S=O
11a
0.85
0.77
2.00
1.03
2.16
4.98
0.97
1.00
1.00
2.03
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

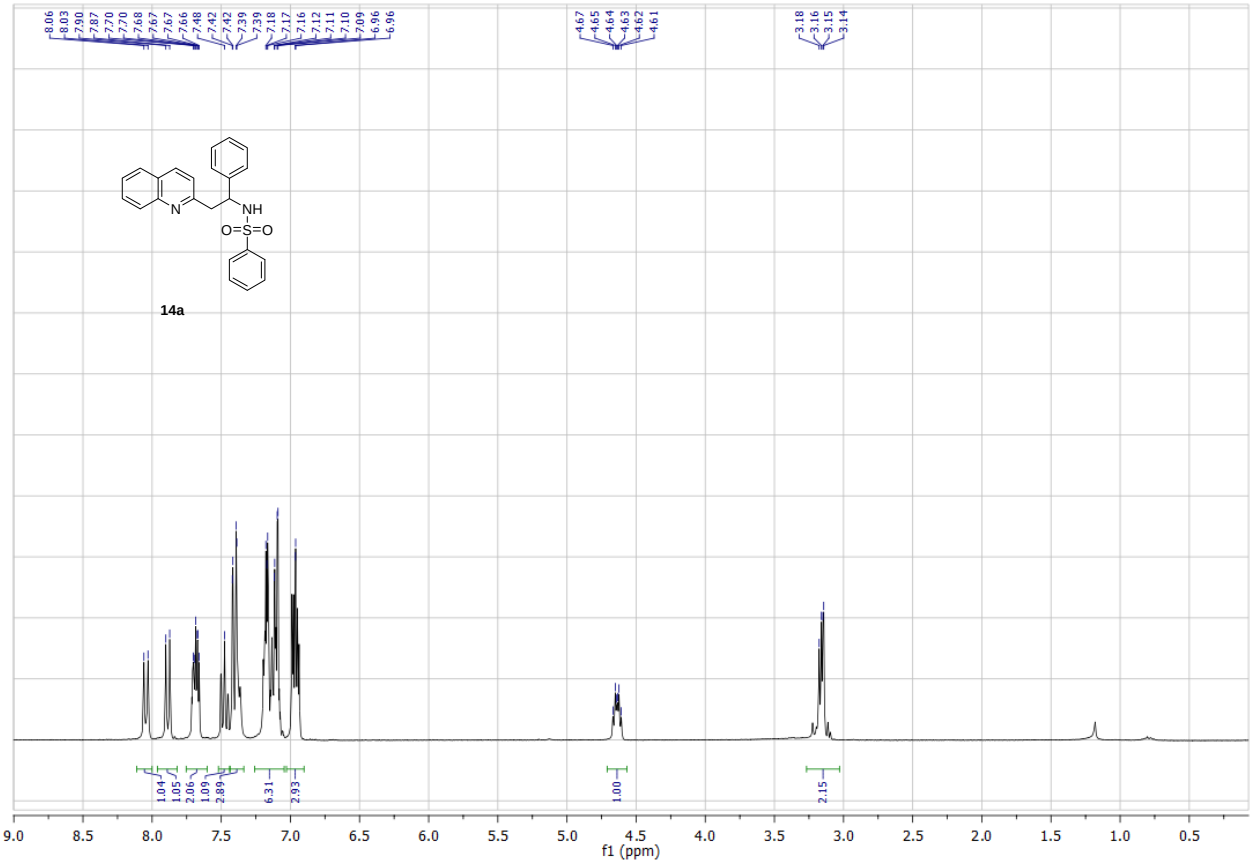

166.06
157.93
156.93
140.34
139.80
132.25
128.72
128.47
127.65
126.84
126.42
57.11
44.13
^{13}C NMR (75 MHz, CDCl$_3$) δ 166.06, 157.93, 156.93, 140.34, 139.80, 132.25, 128.72, 128.47, 127.65, 126.84, 126.42, 57.11, 44.13.
N
N
NH
O=S=O
11a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

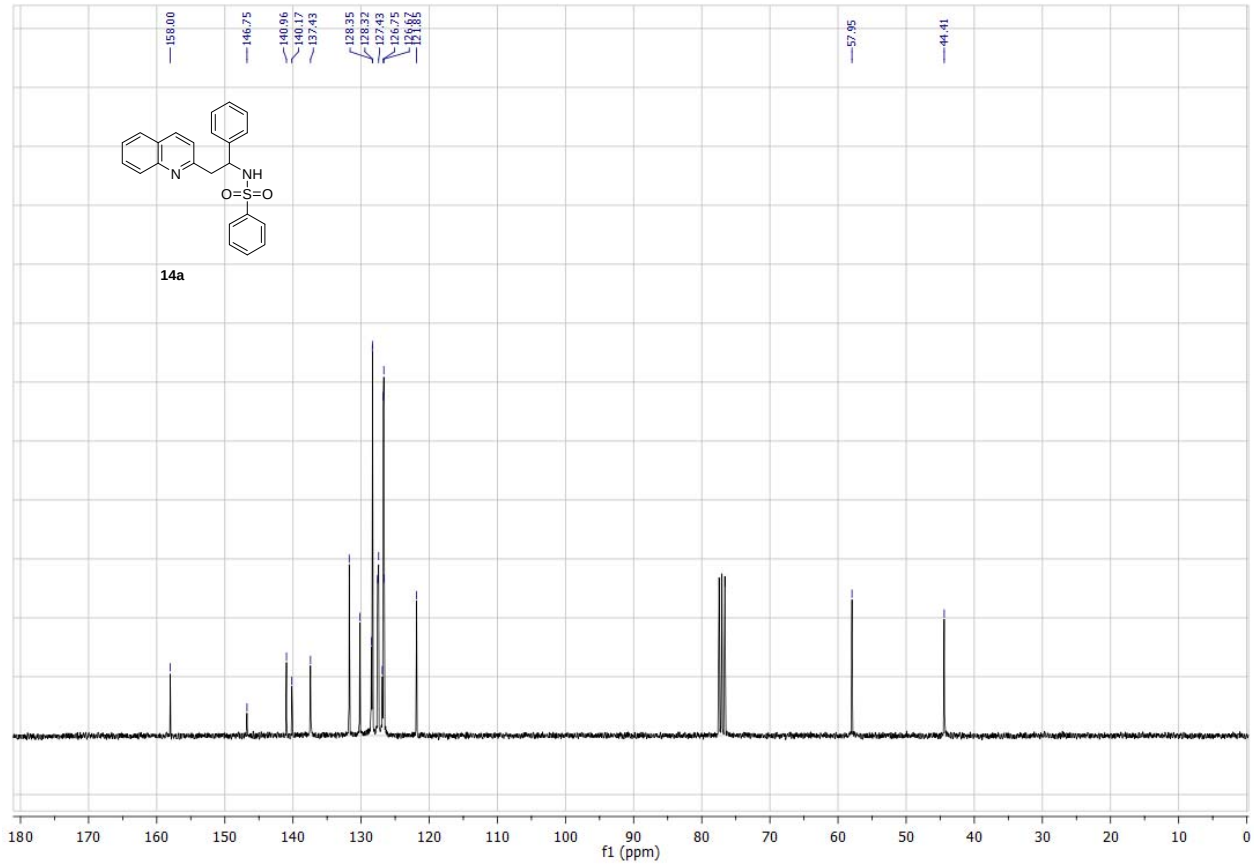

8.37
7.95
7.67
7.67
7.46
7.46
7.45
7.43
7.43
7.12
7.12
7.10
7.09
6.57
6.55
4.84
4.81
4.79
4.77
3.26
3.25
3.23
NH
O=S=O
12a
0.96
1.98
2.01
1.96
6.01
1.96
0.94
1.00
2.06
f1 (ppm)

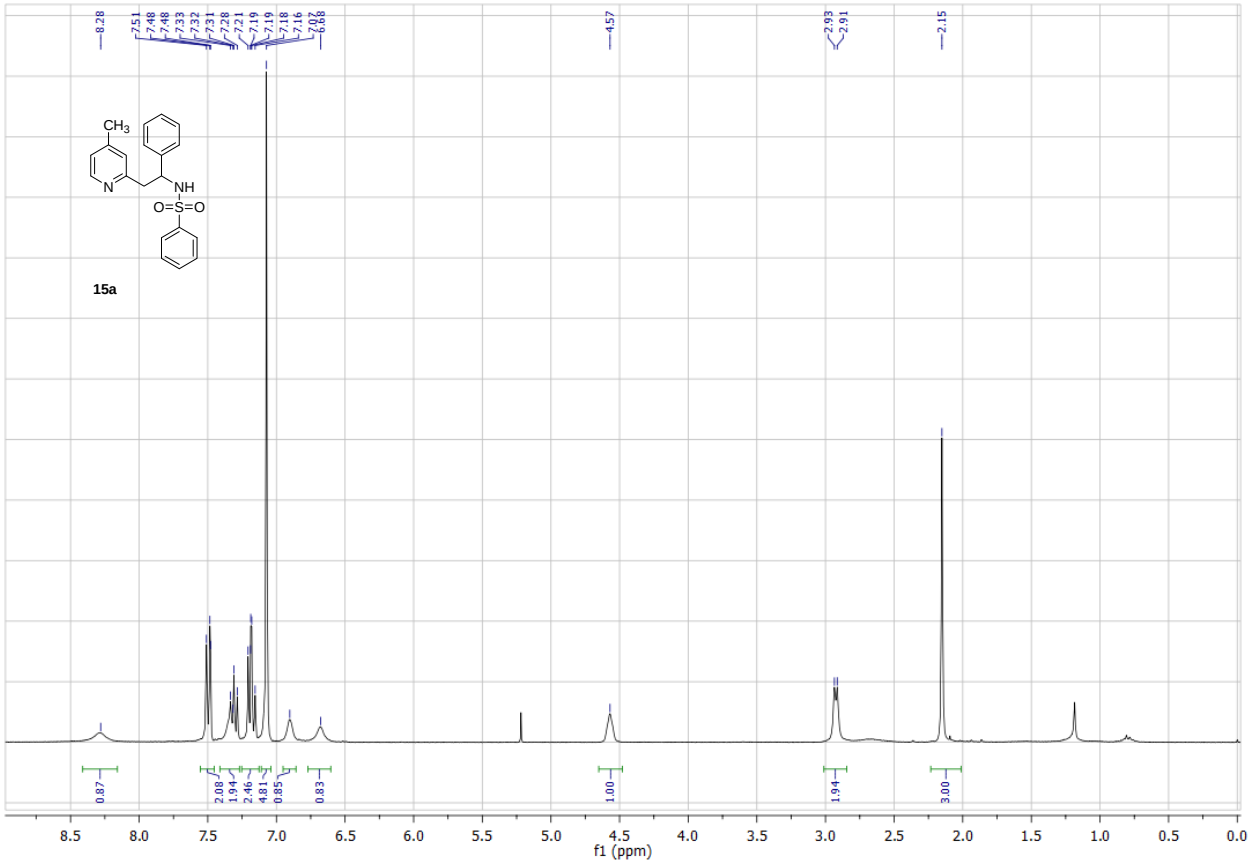

152.76
145.63
141.41
140.25
140.07
132.01
130.37
129.69
129.23
128.89
128.55
128.45
127.71
126.64
126.50
57.63
42.40
^{13}C NMR (75 MHz, CDCl$_3$) δ 152.76, 145.63, 141.41, 140.25, 140.07, 132.01, 130.37, 129.69, 129.23, 128.89, 128.55, 128.45, 127.71, 126.64, 126.50, 57.63, 42.40.
NH
O=S=O
12a
f1 (ppm)

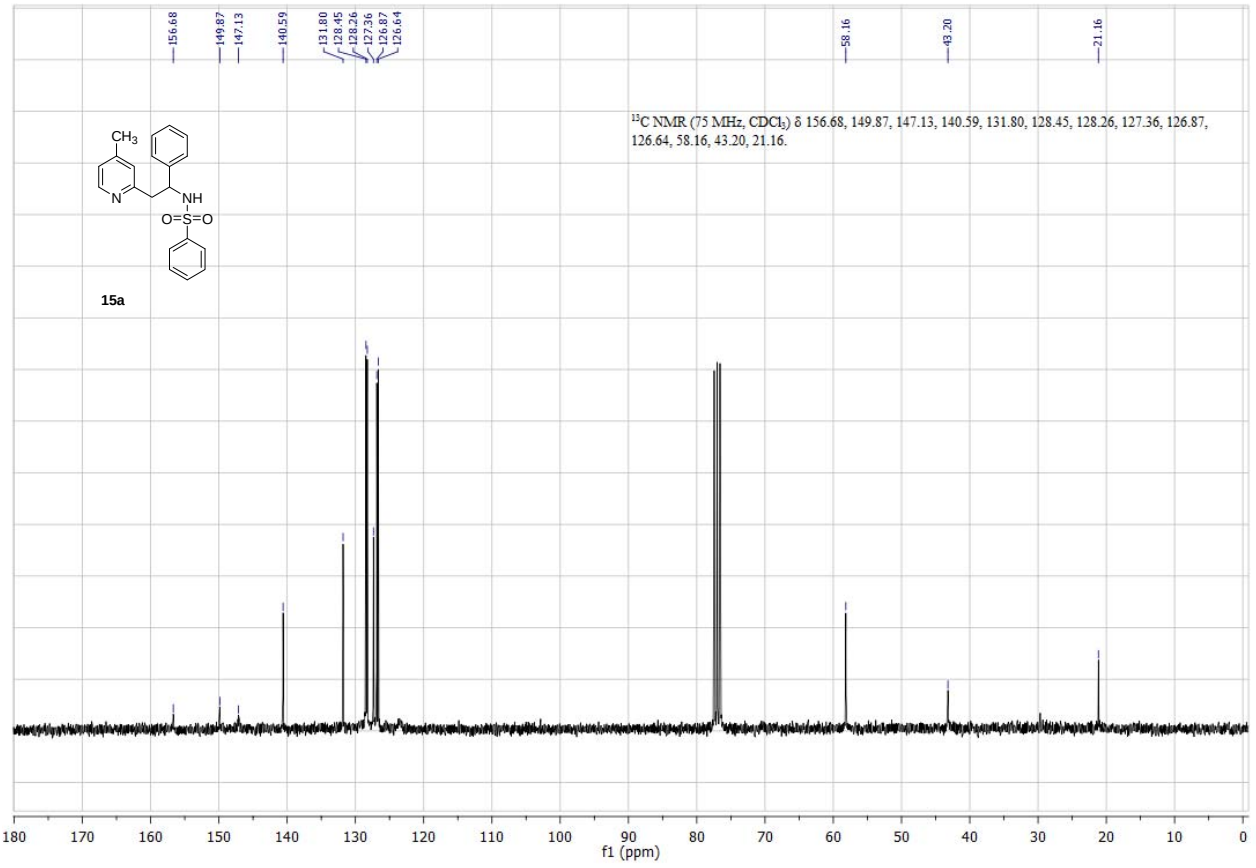

7.89
7.86
7.83
7.83
7.78
7.76
7.74
7.73
7.71
7.71
7.44
7.44
7.44
7.42
7.41
7.23
7.20
7.18
7.18
7.12
7.10
7.07
7.05
7.02
7.02
7.02
6.98
6.95
4.72
4.70
4.68
4.66
3.15
3.13
Br
N
NH
O=S=O
13a
2.08
2.07
1.96
1.27
8.09
0.93
1.00
2.05
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

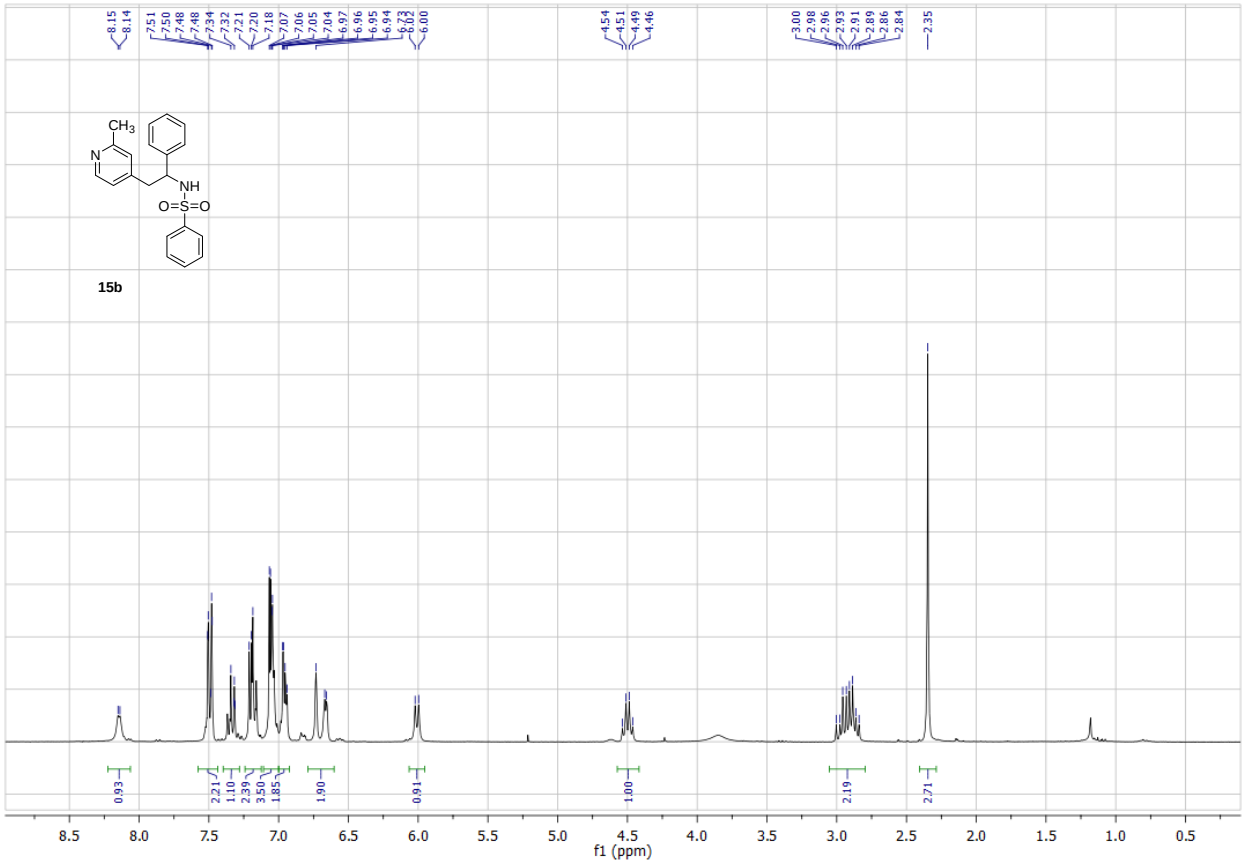

158.46
140.63
140.29
136.51
133.65
131.84
130.00
129.60
128.39
127.96
127.51
126.72
126.61
122.87
120.53
57.83
44.40
Br
N
NH
O=S=O
13a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

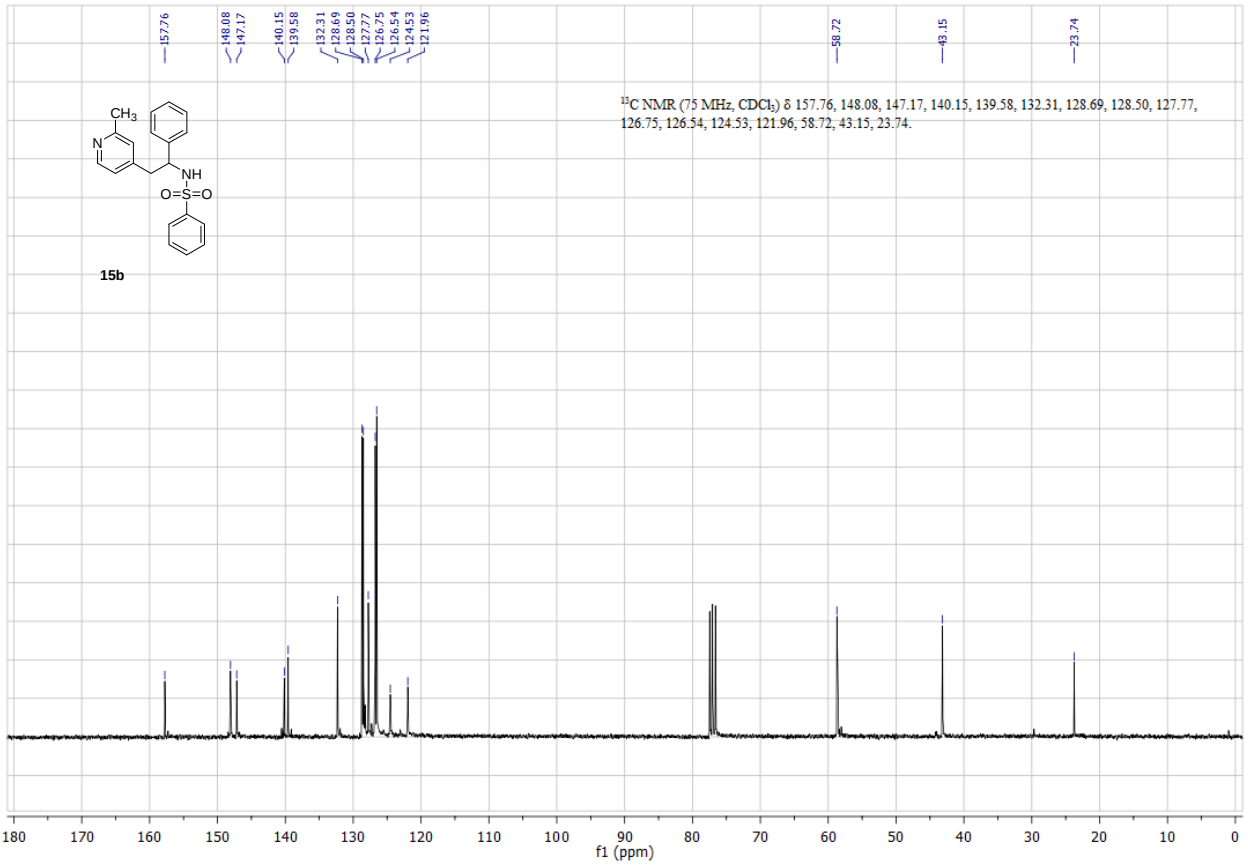

8.06
8.03
7.90
7.87
7.70
7.70
7.68
7.67
7.67
7.66
7.48
7.42
7.42
7.39
7.39
7.18
7.17
7.16
7.12
7.11
7.10
7.09
6.96
6.96
4.67
4.65
4.64
4.63
4.62
4.61
3.18
3.16
3.15
3.14
N
NH
O=S=O
14a
1.04
1.05
2.06
1.09
2.89
6.31
2.93
1.00
2.15
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

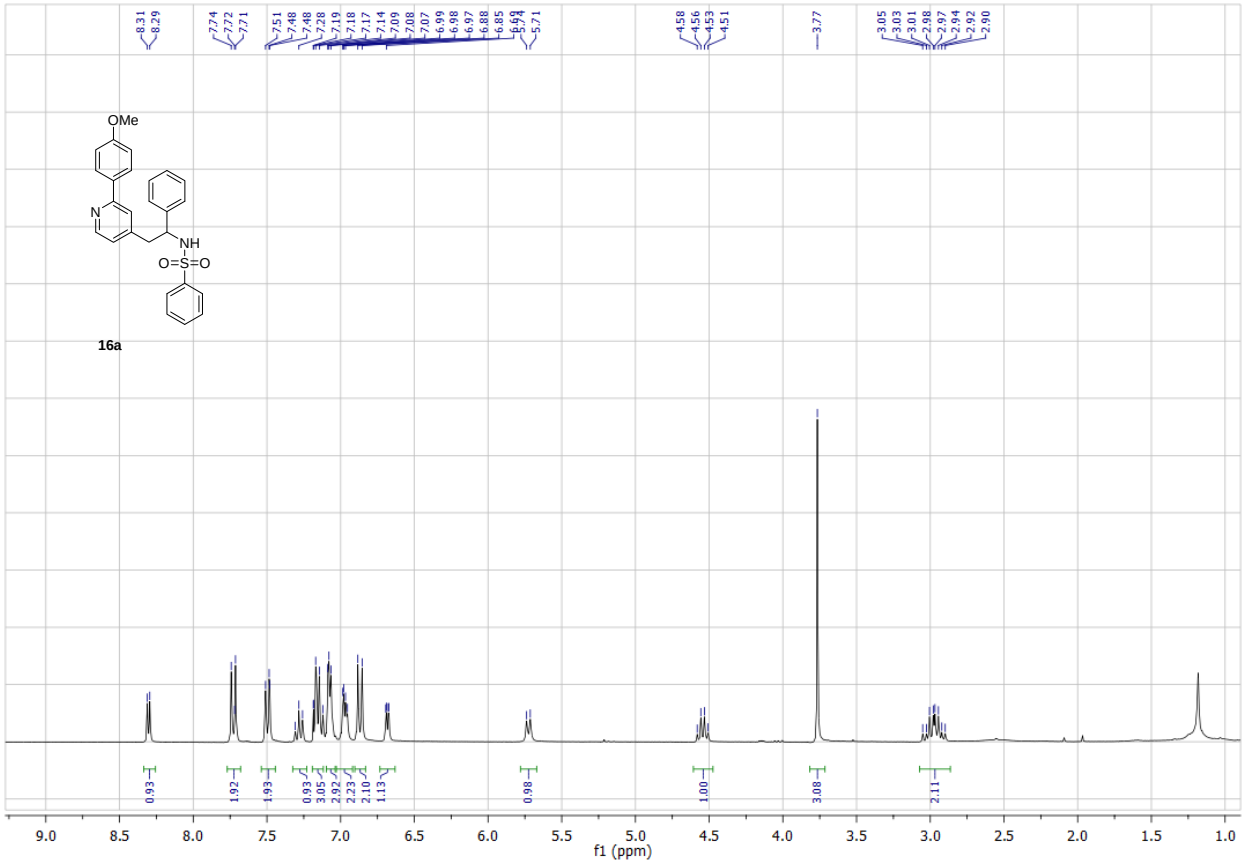

158.00
146.75
140.96
140.17
137.43
128.35
128.32
127.43
126.75
126.67
121.85
57.95
44.41
N
NH
O=S=O
14a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

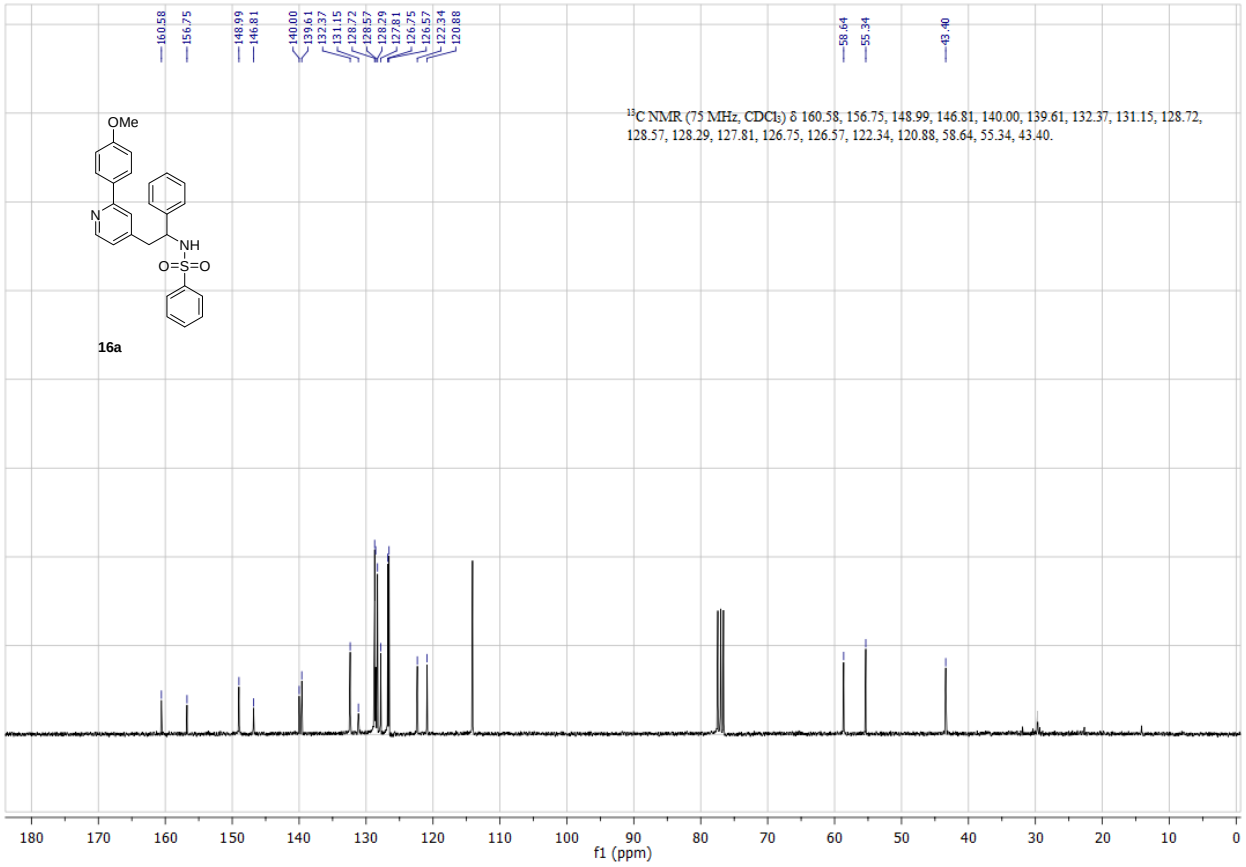

8.28
7.51
7.48
7.48
7.33
7.32
7.31
7.28
7.21
7.19
7.19
7.18
7.16
7.07
6.88
4.57
2.93
2.91
2.15
CH3
N
NH
O=S=O
15a
0.87
2.08
1.94
2.46
4.81
0.95
0.83
1.00
1.94
3.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


156.68
149.87
147.13
140.59
131.80
128.45
128.26
127.36
126.87
126.64
58.16
43.20
21.16
13C NMR (75 MHz, CDCl3) δ 156.68, 149.87, 147.13, 140.59, 131.80, 128.45, 128.26, 127.36, 126.87, 126.64, 58.16, 43.20, 21.16.
CH3
N
NH
O=S=O
15a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.15
8.14
7.51
7.50
7.48
7.48
7.34
7.32
7.21
7.20
7.18
7.07
7.06
7.05
7.04
6.97
6.96
6.95
6.94
6.03
6.00
4.54
4.51
4.49
4.46
3.00
2.98
2.96
2.93
2.91
2.89
2.86
2.84
2.35
CH3
N
NH
O=S=O
15b
0.93
2.21
1.10
2.39
3.50
1.85
1.90
0.91
1.00
2.19
2.71
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
f1 (ppm)


157.76
148.08
147.17
140.15
139.58
132.31
128.69
128.50
127.77
126.75
126.54
124.53
121.96
58.72
43.15
23.74
^{13}C NMR (75 MHz, $CDCl_3$) δ 157.76, 148.08, 147.17, 140.15, 139.58, 132.31, 128.69, 128.50, 127.77, 126.75, 126.54, 124.53, 121.96, 58.72, 43.15, 23.74.
CH3
N
NH
O=S=O
15b
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


OMe
N
NH
O=S=O
16a
f1 (ppm)


OMe
N
NH
O=S=O
16a
^{13}C NMR (75 MHz, CDCl$_3$) δ 160.58, 156.75, 148.99, 146.81, 140.00, 139.61, 132.37, 131.15, 128.72, 128.57, 128.29, 127.81, 126.75, 126.57, 122.34, 120.88, 58.64, 55.34, 43.40.
f1 (ppm)