Ligand and Base Free Copper(II)-Catalyzed C-N Bond Formation: Cross-coupling Reactions of Organoboron Compounds with Aliphatic Amines and Anilines

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General Synthetic Methods

CH_2Cl_2 was distilled from CaH_2 under argon. All other commercial solvents and reagents were used as received from the Aldrich Chemical Company, Fischer Scientific Ltd., EMD Chemicals Inc., Strem or BDH. The 4Å molecular sieves were purchased through the Aldrich Chemical Company in powdered form, activated and stored in a oven at 210 °C until their use. All glassware was oven dried at 210 °C and allowed to cool under a stream of dry oxygen. The oxygen gas (UHP/zero grade) was purchased from Air Products and was dried through a tube of Drierite (anhydrous $CaSO_4$) prior to connection to a manifold for delivery into the reaction flask.

Silica gel (60Å, 230-400 mesh) used in flash column chromatography was obtained from Silicycle and was used as received. Analytical thin-layer chromatography (TLC) was performed on pre-coated silica gel plates (Ultra Pure Silica Gel Plates purchased from Silicycle), visualized with a Spectroline UV_{254} lamp, and stained with a 20% phosphomolybdic acid in ethanol solution. Solvent systems associated with R_f values and flash column chromatography are reported as v/v ratios.

Melting points were obtained using a Fisher-Johns melting point apparatus and are uncorrected. Specific optical rotations were determined on a Perkin-Elmer 243B Polarimeter under the conditions indicated using the sodium D line (589 nm). Sample concentrations are reported as grams per 100 mL solvent. Analytical chiral HPLC (of **3f**, **3n** and **3s**) was performed on a Chiralcel OD column (4.6 x 250 mm) obtained from Daicel Chemical Industries, Ltd. ^1H and ^{13}C NMR were recorded at 300 MHz and 75 MHz respectively on a Varian Gemini 300 or Mercury 300 spectrometer. Proton chemical shifts were internally referenced to the residual proton resonance in $CDCl_3$ (δ 7.26 ppm). Carbon chemical shifts were internally referenced to the deuterated solvent signals in $CDCl_3$ (δ 77.20 ppm). FT-IR spectra were recorded on a Perkin-Elmer Spectrum 1000 spectrometer with samples loaded as neat films on NaCl plates. Low and high resolution mass spectra were recorded on a Bell and Howell 21-490 spectrometer and an AEI MS3074 spectrometer respectively.

References following compound names indicate literature articles where ^1H and ^{13}C NMR data have previously been reported.

Synthetic Methods and Characterization Data

Representative Procedure for the Cross-Coupling of $PhBF_3^-K^+$ with Aliphatic Amines

A suspension of $PhBF_3^-K^+$ (0.368 g, 2.00 mmol), $Cu(OAc)_2 \cdot H_2O$ (20.0 mg, 0.100 mmol), and powdered 4Å molecular sieves (0.750 g) in CH_2Cl_2 (8.00 mL) was stirred for 5 minutes at room temperature. To this stirring suspension was added *n*-butylamine (0.072 g, 99.0 µL, 1.00 mmol). The reaction mixture was then sealed with a rubber septa (heated if necessary), and stirred under an atmosphere of O_2. Following a period of 24 h, the crude reaction mixture was filtered through a plug of celite to remove the molecular sieves and any insoluble byproducts and then concentrated *in vacuo* to afford the crude product mixture. The product (**3a**) was isolated by silica gel column chromatography (eluting with hexanes:EtOAc 9:1 ~ 3:1 gradient) as a pale yellow oil in 89% yield (0.133 g, 0.89 mmol).

Representative Procedure for the Cross-Coupling of $PhB(OH)_2$ with Aliphatic Amines

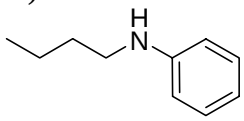
The above procedure was followed with substitution of $PhB(OH)_2$ (0.244 g, 2.00 mmol) in place of the potassium organotrifluoroborate salt. The product (**3a**) was isolated as a pale yellow oil in 92% yield (0.137 g, 0.89 mmol).

Representative Procedure for the Activation of Amine Hydrohalide Salts and Subsequent Cross-Coupling with $PhB(OH)_2$

To a stirring solution of 3-bromopropylamine hydrobromide (0.219 g, 1.00 mL) in acetonitrile (10.0 mL) was added Amberlyst A-21 resin (0.750 g). The suspension was stirred at room temperature for 30 min, then filtered and washed with CH_2Cl_2 to remove the resin. The filtrant was collected and concentrated *in vacuo*. The residue was then redissolved in acetonitrile (1.00 mL) and added to a prestirring suspension of $PhB(OH)_2$ (0.244 g, 2.00 mmol), $Cu(OAc)_2 \cdot H_2O$ (20.0 mg, 0.100 mmol), and powdered 4Å molecular sieves (0.750 g) in CH_2Cl_2 (8.00 mL). The reaction mixture was then sealed with a rubber septa, heated to 40 °C, and stirred under an atmosphere of O_2. Following a period of 24 h, the crude reaction mixture was filtered through a plug of celite to remove the molecular sieves and any insoluble byproducts, and then concentrated *in vacuo* to afford the crude product mixture. The product (**3l**) was isolated by silica gel column chromatography (eluting with hexanes:EtOAc 9:1 ~ 3:1 gradient) as a clear oil in 86% yield (0.184 g, 0.860 mmol).

Products of Experiments Summarized in Table 1

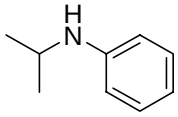
***n*-Butylphenylamine** (Alberti, A.; Cane, F.; Dembech, P.; Lazzari, D.; Ricci, A.; Seconi, G. *J. Org. Chem.* **1996**, *61*, 1677-1681.)



3a

Reactions were performed at room temperature. Product was isolated as a pale yellow oil in 89% yield from $PhBF_3^-K^+$ and in 92% yield from $PhB(OH)_2$: R_f = 0.80 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.22 (2H, ddd, *J* = 8.5, 7.5, 1.0 Hz), 6.74 (1H, tt, *J* = 7.5, 1.0 Hz), 6.65 (2H, dd, *J* = 8.5, 1.0 Hz), 3.62 (1H, br s), 3.15 (2H, tt, *J* = 7.0 Hz), 1.65 (2H, quintet, *J* = 7.0 Hz), 1.48 (2H, sextet, *J* = 7.0 Hz), 1.01 (3H, t, *J* = 7.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.70, 129.35, 117.19, 112.81, 43.80, 31.83, 20.48, 14.06.

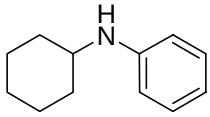
Isopropylphenylamine (Shaffer, C. L.; Morton, M. D.; Hanzlik, R. P. *J. Am. Chem. Soc.* **2001**, *123*, 8502-8508.



3b

Reactions were performed at room temperature. Product was isolated as a clear oil in 98% yield from both $PhBF_3^-K^+$ and $PhB(OH)_2$: R_f = 0.70 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.25 (2H, ddd, *J* = 8.0, 7.5, 1.0 Hz), 6.75 (1H, tt, *J* = 7.5, 1.0 Hz), 6.66 (2H, dd, *J* = 8.0, 1.0 Hz), 3.71 (1H, septet, *J* = 6.5 Hz), 3.50 (1H, br s), 1.28 (6H, d, *J* = 6.5 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.64, 129.40, 117.05, 113.34, 44.28, 23.14.

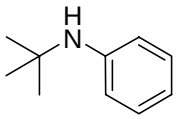
Cyclohexylphenylamine (Kawakami, T.; Sugimoto, T.; Shibata, I.; Baba, A.; Matsuda, H.; Sonoda, N. *J. Org. Chem.* **1995**, *60*, 2677-2682.)



3c

Product was isolated as a clear oil in 79% yield from $PhBF_3^-K^+$ at room temperature; and in 85% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.60 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.17 (2H, ddd, *J* = 8.5, 7.5, 2.0 Hz), 6.67 (1H, tt, *J* = 7.5, 1.0 Hz), 6.61 (2H, ddd, *J* = 8.5, 2.0, 1.0 Hz), 3.53 (1H, br s), 3.27 (1H, dddd, *J* = 14.0, 7.5, 6.5, 4.0 Hz), 2.14 - 2.02 (2H, m), 1.84 - 1.62 (3H, m), 1.48 - 1.10 (5H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.59, 129.43, 116.99, 113.30, 51.86, 33.68, 26.13, 25.21.

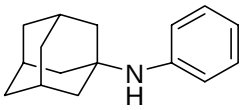
***t*-Butylphenylamine** (Arnauld, T.; Barton, D. H. R.; Doris, E. *Tetrahedron* **1997**, *53*, 4137-4144.)



3d

Product was isolated as a light beige oil in 26% yield from $PhBF_3^-K^+$ at room temperature; and in 39% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.40 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.16 (2H, t, *J* = 7.5 Hz), 6.8 - 6.72 (3H, m), 3.34 (1H, br s), 1.34 (9H, s); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.06, 129.08, 118.49, 117.68, 51.66, 30.28.

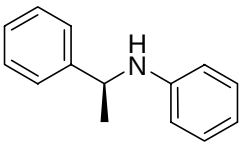
Adamantan-1-ylphenylamine (Olifirov, D. I.; Koshchii, V. A.; Kozlikovskii, Y. B. *J. Org. Chem. USSR (Engl. Transl.)*, **1992**, *28*, 152-157.)



3e

Reactions were performed at 40 °C. Product was isolated as a pale beige solid in 57% yield from $PhBF_3^-K^+$ and in 67% yield from $PhB(OH)_2$: R_f = 0.60 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19 - 7.13 (2H, m), 6.83 - 6.77 (3H, m), 3.31 (1H, br s), 2.12 (3H, m), 1.88 (6H, d, *J* = 3.0 Hz), 1.77 - 1.71 (6H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.21, 128.89, 119.25, 119.19, 52.35, 43.62, 36.63, 29.87; LRMS (EI): *m/z* (rel. intensity) = 229 (9), 227 (51), 171 (15), 170 (100), 135 (41), 133 (9), 107 (5), 94 (5), 93 (21), 92 (11), 91 (7), 79 (14), 77 (12), 67 (6); HRMS (EI): *m/z* calcd. for (M^+) = 227.1674, found = 227.1673.

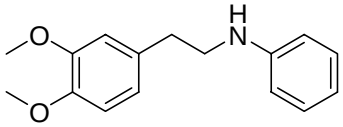
S-(-)-*N*-(1-Phenylethyl)aniline (Landor, S. R.; Sonola, O. O.; Tatchell, A. R. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 1658-1661.)



3f

Product was isolated as a clear oil in 91% yield from $PhBF_3^-K^+$ at room temperature: R_f = 0.44 (9:1 hexanes:EtOAc); $[\alpha]_D^{22}$ = -5.15 ° (c = 10, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37 - 7.15 (5H, m), 7.07 (2H, t, *J* = 7.5 Hz), 6.63 (1H, t, *J* = 7.5 Hz), 6.49 (2H, d, *J* = 7.5 Hz), 4.46 (1H, q, *J* = 7.0 Hz), 3.98 (1H, br s), 1.48 (3H, d, *J* = 7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.42, 145.37, 129.24, 128.77, 127.00, 125.98, 117.36, 113.43, 53.57, 25.16.

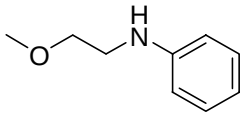
[2-(3,4-Dimethoxyphenyl)ethyl]phenylamine



3g

Product was isolated as a clear oil in 90% yield from $PhBF_3^-K^+$ at room temperature; and in 95% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.70 (1:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20 (2H, ddd, *J* = 8.0, 7.5, 1.0 Hz), 6.86 - 6.70 (4H, m), 6.63 (2H, dd, *J* = 7.5, 1.0 Hz), 3.88 (3H, s), 3.87 (3H, s), 3.68 (1H, br s), 3.40 (2H, t, *J* = 7.0 Hz), 2.88 (2H, t, *J* = 7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 149.13, 148.15, 147.78, 131.94, 129.39, 120.80, 117.59, 113.16, 112.17, 111.53, 56.06, 55.96, 45.23, 35.13; IR (film) ν 3394, 2932, 2360, 1603, 1513, 1465, 1419, 1319, 1261, 1235, 1156, 1140, 1027, 809, 750, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 257 (12), 152 (23), 151 (8), 107 (12), 106 (100), 86 (7), 84 (11), 79 (5), 77 (15); HRMS (EI): *m/z* calcd. for (M^+) = 257.1416, found = 257.1418.

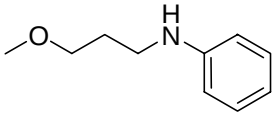
(2-Methoxyethyl)phenylamine



3h

Product was isolated as a clear oil in 32% yield from $PhBF_3^-K^+$ at room temperature; and in 79% yield from $PhBF_3^-K^+$ and 94% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.40 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19 (2H, t, *J* = 7.5 Hz), 6.70 (1H, t, *J* = 7.5 Hz), 6.61 (2H, d, *J* = 7.5 Hz), 4.02 (1H, br s), 3.57 (2H, t, *J* = 5.0 Hz), 3.37 (3H, s), 3.26 (2H, t, *J* = 5.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.31, 129.31, 117.67, 113.17, 71.09, 58.81, 43.53; IR (film) ν 3051, 2925, 2891, 1603, 1506, 1472, 1319, 1259, 1193, 1117, 1071, 1025, 871, 750, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 152 (9), 151 (48), 107 (14), 106 (100), 94 (7), 79 (12), 78 (5), 77 (24), 65 (7), 51 (11); HRMS (EI): *m/z* calcd. for (M^+) = 151.0997, found = 151.0991.

(3-Methoxypropyl)phenylamine

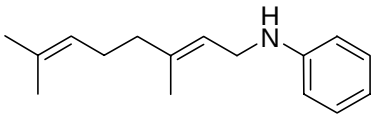


3i

Product was isolated as a clear oil in 78% yield from $PhBF_3^-K^+$ at room temperature; and in 85% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.50 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.19 (2H, ddd, *J* = 7.5, 3.0, 1.0 Hz), 6.70 (1H, tt, *J* = 7.5, 1.0 Hz), 6.63 (2H, dd, *J* = 7.5, 1.0 Hz), 3.94 (1H, br s), 3.53 (2H, t, *J* = 6.0 Hz), 3.37 (3H, s), 3.24 (2H, t, *J* = 6.0 Hz), 1.90 (2H, quintet, *J* = 6.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.66, 129.37, 117.27, 112.87, 71.37, 58.88, 41.92, 29.54; IR (film) ν 3394, 3051, 3021, 2924, 2871, 1604, 1508, 1478, 1433, 1389, 1321,

1262, 1180, 1117, 749, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 166 (6), 165 (37), 107 (13), 106 (100), 104 (6), 93 (11), 79 (10), 77 (18), 65 (6), 51 (7); HRMS (EI): *m/z* calcd. for (M^+) = 165.1154, found = 165.1150.

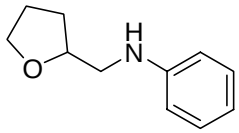
(3,7-Dimethylocta-2,6-dienyl)phenylamine (Ranu, B. C.; Majee, A.; Sarkar, A. *J. Org. Chem.* **1998**, *63*, 370-373.)



3j

Reactions were performed at 40 °C. Product was isolated as a yellow oil in 80% yield from $PhBF_3^-K^+$ and in 89% yield from $PhB(OH)_2$: R_f = 0.75 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.29 (2H, ddd, *J* = 8.5, 7.5, 2.0 Hz), 6.82 (1H, tt, *J* = 7.5, 1.0 Hz), 6.72 (2H, ddd, *J* = 8.5, 2.0, 1.0 Hz), 5.49 - 5.41 (1H, m), 5.25 - 5.18 (1H, m), 3.81 (2H, d, *J* = 6.5 Hz), 3.67 (1H, br s), 2.28 - 2.14 (4H, m), 1.82 (3H, s), 1.81 (3H, s), 1.73 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.58, 139.10, 131.81, 129.33, 124.10, 121.70, 117.40, 113.02, 42.10, 39.67, 26.59, 25.86, 17.86, 16.51.

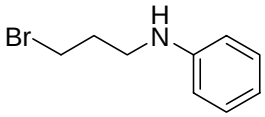
Phenyl(tetrahydrofuran-2-ylmethyl)amine



3k

Reactions were performed at 40 °C. Product was isolated as a pale yellow oil in 83% yield from $PhBF_3^-K^+$ and in 91% yield from $PhB(OH)_2$: R_f = 0.33 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20 (2H, ddd, *J* = 8.5, 7.5, 2.0 Hz), 6.74 (1H, tt, *J* = 7.5, 1.0 Hz), 6.66 (2H, ddd, *J* = 8.5, 2.0, 1.0 Hz), 4.15 (1H, dddd, *J* = 7.0, 7.0, 7.0, 4.0 Hz), 4.05 (1H, br s), 3.92 (1H, ddd, *J* = 8.0, 7.0, 7.0 Hz), 3.81 (1H, ddd, *J* = 8.0, 7.0, 7.0 Hz), 3.28 (1H, dd, *J* = 12.5, 4.0 Hz), 3.10 (1H, dd, *J* = 12.5, 7.5 Hz), 2.11 - 1.90 (3H, m), 1.74 - 1.62 (1H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.50, 129.28, 117.53, 113.10, 77.64, 68.12, 48.24, 29.19, 25.89; IR (film) ν 3390, 3051, 3021, 2971, 2869, 1603, 1506, 1459, 1433, 1378, 1360, 1320, 1256, 1180, 1070, 749, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 178 (7), 177 (27), 107 (17), 106 (100), 79 (7), 77 (16), 71 (9), 50 (6); HRMS (EI): *m/z* calcd. for (M^+) = 177.1154, found = 177.1156.

(3-Bromopropyl)phenyl amine

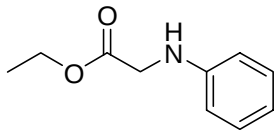


3l

The amine hydrobromide salt was pretreated with Amberlyst A-21 resin. Reaction was performed at 40 °C. Product was isolated as a clear oil in 86% yield from $PhB(OH)_2$ over both

steps: R_f = 0.30 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.29 (2H, ddd, *J* = 7.5, 2.0, 1.5 Hz), 6.83 (1H, tt, *J* = 7.5, 1.5 Hz), 6.73 (2H, dd, *J* = 7.5, 2.0 Hz), 3.95 (1H, br s), 3.60 (2H, t, *J* = 6.5 Hz), 3.42 (2H, t, *J* = 6.5 Hz), 2.24 (2H, quintet, *J* = 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.82, 129.46, 117.77, 113.01, 42.14, 32.07, 31.37; IR (film) ν 3410, 3051, 3021, 2961, 1603, 1507, 1431, 1322, 1255, 1180, 1100, 991, 870, 751, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 215 (19), 213 (18), 107 (15), 106 (100), 104 (7), 79 (11), 78 (7), 77 (27), 65 (8); HRMS (EI): *m/z* calcd. for (M^+) = 213.0153, found = 213.0151.

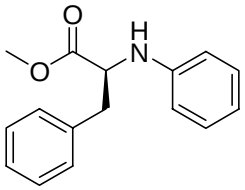
***N*-Phenyl-glycine ethyl ester** (Anderson, W. K.; Bhattacharjee, D.; Houston, D. M.; *J. Med. Chem.* **1989**, *32*, 119-127.)



3m

The amine hydrochloride salt was pretreated with Amberlyst A-21 resin. Reaction was performed at 40 °C. Product was isolated as a clear crystalline solid in 84% yield from $PhB(OH)_2$ over both steps: R_f = 0.50 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.21 (2H, t, *J* = 7.5 Hz), 6.76 (1H, dt, *J* = 7.5, 1.0 Hz), 6.62 (2H, dd, *J* = 7.5, 1.0 Hz), 4.28 (1H, br s), 4.25 (2H, q, *J* = 7.0 Hz), 3.91 (2H, s), 1.31 (3H, t, *J* = 7.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.33, 147.20, 129.48, 118.37, 113.19, 61.49, 46.05, 14.36.

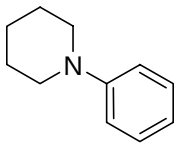
S-*N*-Phenyl-phenylalanine methyl ester (Tunge, J. A.; Gately, D. A.; Norton, J. R. *J. Amer. Chem. Soc.* **1999**, *121*, 4520-4521.)



3n

The amine hydrochloride salt was pretreated with Amberlyst A-21 resin. Reaction was performed at 40 °C. Product was isolated as a light beige oil in 90% yield from $PhB(OH)_2$ over both steps: R_f = 0.40 (3:1 hexanes:EtOAc); $[\alpha]_D^{22}$ = +25.88 ° (c = 10, CH_2Cl_2) for >99% ee (Chiralcel OD, 10% ethanol/hexanes, 1.0 mL/min, retention times for R and S enantiomers are 7.16 and 9.78 min respectively) with determination of the absolute stereochemistry by comparison of the specific rotation with the literature value; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48 - 7.28 (7H, m), 6.90 (1H, t, *J* = 7.5 Hz), 6.75 (2H, d, *J* = 7.5 Hz), 4.53 (1H, t, *J* = 6.5 Hz), 4.36 (1H, br s), 3.79 (3H, s), 3.28 (2H, ddd, *J* = 20.0, 13.5, 6.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.62, 146.39, 136.38, 129.39, 129.28, 128.55, 127.03, 118.41, 113.56, 57.70, 52.03, 38.62.

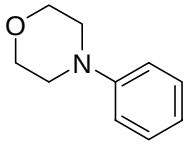
***N*-Phenylpiperidine** (Brenner, E.; Schneider, R.; Fort, Y.; *Tetrahedron*, **1999**, *55*, 12829-12842.)



3o

Product was isolated as a clear oil in 78% yield from $PhBF_3^-K^+$ at room temperature; and in 86% yield from $PhB(OH)_2$ at 40 °C: R_f = 0.40 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.25 (2H, dt, *J* = 7.5, 1.0 Hz), 6.94 (2H, dd, *J* = 7.5, 1.0 Hz), 6.82 (1H, dt, *J* = 7.5, 1.0 Hz), 3.16 (4H, t, *J* = 5.5 Hz), 1.76 - 1.66 (4H, m), 1.62 - 1.53 (2H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 152.47, 129.19, 119.36, 116.72, 50.87, 26.07, 24.52.

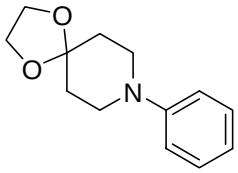
4-Phenyl-morpholine (Ishikawa, T.; Uedo, E.; Tani, R.; Saito, S. *J. Org. Chem.* **2001**, *66*, 186-191.)



3p

Reactions were performed at 40 °C. Product was isolated as a pale light beige, crystalline solid in 81% yield from $PhBF_3^-K^+$ and in 90% yield from $PhB(OH)_2$: R_f = 0.45 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.31 (2H, ddd, *J* = 9.0, 7.5, 1.5 Hz), 6.96 - 6.88 (3H, m), 3.91 - 3.85 (4H, m), 3.20 - 3.15 (4H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.41, 129.33, 120.17, 115.83, 67.08, 49.48.

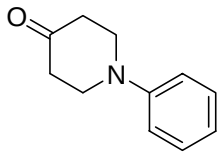
8-Phenyl-1,4-dioxa-8-azaspiro[4.5]decane



3q

Reactions were performed at 40 °C. Product was isolated as a clear oil in 87% yield from $PhBF_3^-K^+$ and in 86% yield from $PhB(OH)_2$: R_f = 0.40 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.34 (2H, ddd, *J* = 7.5, 2.0, 1.5 Hz), 7.04 (2H, dd, *J* = 7.5, 2.0 Hz), 6.93 (1H, dt, *J* = 7.5, 1.5 Hz), 4.07 (4H, s), 3.42 (4H, dd, *J* = 6.0, 6.0 Hz), 1.94 (4H, dd, *J* = 6.0, 6.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.08, 129.19, 119.49, 116.70, 107.27, 64.41, 47.83, 34.64; IR (film) ν 2956, 2882, 2828, 1599, 1497, 1466, 1365, 1228, 1143, 1105, 1037, 962, 946, 929, 896, 757, 693, 529 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 220 (18), 219 (100), 218 (10), 174 (28), 158 (20), 133 (18), 132 (55), 106 (11), 105 (73), 104 (25), 77 (21); HRMS (EI): *m/z* calcd. for (M^+) = 219.1259, found = 219.1265.

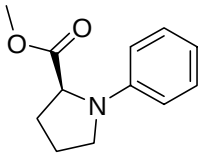
1-Phenyl-piperidin-4-one (Hermant, R. M.; Bakker, N. A. C.; Scherer, T.; Krijnen, B.; Verhoeven, J. W. *J. Amer. Chem. Soc.* **1990**, *112*, 1214-1221.)



3r

The amine hydrochloride salt was pretreated with Amberlyst A-21 resin. Reaction was performed at 40 °C. Product was isolated as a light beige solid in 83% yield from $PhB(OH)_2$ over both steps: R_f = 0.33 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.29 (2H, ddd, *J* = 7.5, 2.0, 1.5 Hz), 6.97 (2H, dd, *J* = 7.5, 2.0 Hz), 6.91 (1H, dt, *J* = 7.5, 1.5 Hz), 3.60 (4H, t, *J* = 6.0 Hz), 2.54 (4H, t, *J* = 6.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 208.35, 149.25, 129.58, 119.96, 116.01, 48.96, 40.86.

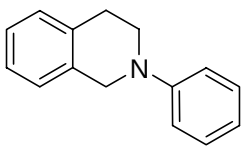
***N*-Phenyl-L-proline methyl ester** (Ishikawa, T.; Uedo, E.; Tani, R.; Saito, S. *J. Org. Chem.* **2001**, *66*, 186-191.)



3s

The amine hydrochloride salt was pretreated with Amberlyst A-21 resin. Reaction was performed at 40 °C. Product was isolated as a pale yellow oil in 74% yield from $PhB(OH)_2$ over both steps: R_f = 0.50 (3:1 hexanes:EtOAc); $[\alpha]_D^{22}$ = -13.81 ° (c = 1.0, $CHCl_3$) for >99% ee (Chiralcel OD, 10% ethanol/hexanes, 1.0 mL/min, retention times for R and S enantiomers are 6.19 and 8.77 min respectively) with determination of the absolute stereochemistry by comparison of the specific rotation with the literature value; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32 (2H, ddd, *J* = 7.5, 2.0, 1.5 Hz), 6.81 (1H, dt, *J* = 7.5, 1.5 Hz), 6.64 (2H, dd, *J* = 7.5, 2.0 Hz), 4.34 (1H, dd, *J* = 8.0, 2.0 Hz), 3.80 (3H, s), 3.70 - 3.66 (1H, m), 3.49 - 3.40 (1H, m), 2.45 - 2.07 (4H, m); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.10, 146.79, 129.35, 116.77, 112.04, 52.20, 48.37, 31.02, 23.99.

2-Phenyl-1,2,3,4-tetrahydroisoquinoline (Almena, J.; Foubelo, F.; Yus, M. *Tetrahedron* **1996**, *52*, 8545-8564.)

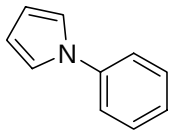


3t

Reactions were performed at room temperature. Product was isolated as a clear oil in 72% yield from both $PhBF_3^-K^+$ and $PhB(OH)_2$: R_f = 0.50 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz,

$CDCl_3$) δ 7.36 - 7.13 (6H, m), 7.02 (2H, d, *J* = 7.5 Hz), 6.87 (1H, t, *J* = 7.5 Hz), 4.45 (2H, s), 3.60 (2H, t, *J* = 6.0 Hz), 3.03 (2H, t, *J* = 6.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 150.44, 134.41, 129.16, 128.98, 128.48, 126.51, 126.30, 126.00, 118.66, 115.16.

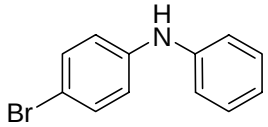
1-Phenyl-pyrrole (Lee, C. K.; Jun, J. H.; Yu, J. S. *J. Heterocycl. Chem.* **2000**, *37*, 15-24.)



3u

Reactions were performed at 40 °C. Product was isolated as a clear, crystalline solid in 80% yield from $PhBF_3^-K^+$ and in 89% yield from $PhB(OH)_2$: R_f = 0.60 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.56 - 7.48 (4H, m), 7.38 - 7.31 (1H, m), 7.20 (2H, t, *J* = 2.0 Hz), 6.46 (2H, t, *J* = 2.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.89, 129.69, 125.75, 120.66, 119.46, 110.55.

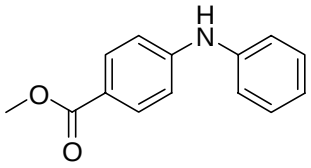
4-Bromodiphenylamine (Barchiesi, E.; Bradamante, S.; Pagani, G. A. *J. Chem. Soc. Perkin Trans. 2* **1987**, 1091-1096.)



3v

Reactions were performed at 40 °C. Product was isolated as a clear, crystalline solid in 30% yield from $PhBF_3^-K^+$ and in 53% yield from $PhB(OH)_2$: R_f = 0.40 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 - 7.22 (4H, m), 7.06 - 6.88 (5H, m), 5.63 (1H, br s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.56, 142.53, 132.31, 129.90, 121.79, 119.17, 118.43, 112.74.

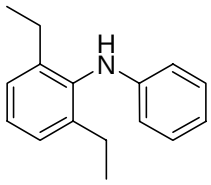
4-Anilinobenzoic acid methyl ester



3w

Reactions were performed at room temperature. Product was isolated as a beige, crystalline solid in 35% yield from $PhBF_3^-K^+$ and in 40% yield from $PhB(OH)_2$: R_f = 0.60 (1:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.92 (2H, d, *J* = 8.5 Hz), 7.34 (2H, t, *J* = 8.0 Hz), 7.17 (2H, d, *J* = 8.0 Hz), 7.07 (1H, t, *J* = 8.0 Hz), 6.99 (2H, d, *J* = 8.5 Hz), 6.07 (1H, br s), 3.88 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.16, 148.27, 141.03, 131.65, 129.67, 123.28, 121.26, 120.62, 114.75, 51.89; IR (film) ν 3343, 1695, 1591, 1521, 1496, 1434, 1328, 1282, 1172, 1109, 850, 769, 747, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 228 (24), 227 (100), 197 (21), 196 (95), 168 (23), 167 (56), 166 (14), 98 (11), 84 (20), 77 (15), 51 (11); HRMS (EI): *m/z* calcd. for (M^+) = 227.0946, found = 227.0919.

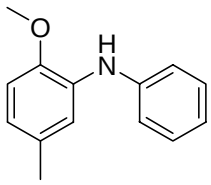
(2,6-Diethylphenyl)phenylamine



3x

Reactions were performed at room temperature. Product was isolated as an amber oil in 34% yield from $PhBF_3^-K^+$ and in 49% yield from $PhB(OH)_2$: R_f = 0.70 (3:1 hexanes:EtOAc); ^1H NMR (300 MHz, $CDCl_3$) δ 7.23 - 7.06 (5H, m), 6.71 (1H, tt, *J* = 7.5, 1.0 Hz), 6.47 (2H, dd, *J* = 8.5, 1.0 Hz), 5.13 (1H, br s), 2.58 (4H, q, *J* = 7.5 Hz), 1.14 (6H, t, *J* = 7.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.45, 142.52, 129.91, 129.36, 126.84, 126.69, 118.10, 113.41, 24.86, 14.86; IR (film) ν 3396, 3044, 2965, 2872, 1603, 1497, 1454, 1412, 1374, 1306, 1237, 1175, 1106, 1077, 1026, 994, 866, 798, 747, 693 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 226 (29), 225 (100), 211 (24), 210 (92), 208 (20), 196 (18), 194 (14), 193 (13), 182 (15), 181 (32), 180 (53), 170 (15), 168 (11), 167 (13), 148 (12), 134 (13), 91 (12), 77 (19), 51 (12); HRMS (EI): *m/z* calcd. for (M^+) = 225.1518, found = 225.1519.

(2-Methoxy-5-methylphenyl)phenylamine

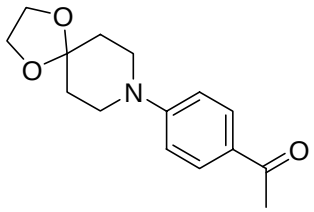


3y

Reactions were performed at room temperature. Product was isolated as an orange oil in 51% yield from $PhBF_3^-K^+$ and in 66% yield from $PhB(OH)_2$: R_f = 0.60 (3:1 hexanes:EtOAc); ^1H NMR (300 MHz, $CDCl_3$) δ 7.31 (2H, t, *J* = 7.5 Hz), 7.17 (3H, d, *J* = 7.5 Hz), 6.97 (1H, tt, *J* = 7.5, 1.0 Hz), 6.80 (1H, d, *J* = 8.0 Hz), 6.67 (1H, dd, *J* = 8.0, 1.0 Hz), 6.13 (1H, br s), 3.88 (3H, s), 2.29 (3H, s); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.45, 142.97, 132.90, 130.41, 129.42, 121.23, 120.26, 118.82, 115.64, 110.70, 55.94, 21.16; IR (film) ν 3410, 3047, 2935, 2860, 2833, 1594, 1526, 1496, 1463, 1413, 1311, 1293, 1244, 1221, 1176, 1156, 1079, 1033, 956, 865, 795, 748, 725, 708, 694, 620 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 214 (19), 213 (100), 199 (15), 198 (89), 197 (17), 183 (33), 170 (26), 155 (11), 154 (11), 77 (12); HRMS (EI): *m/z* calcd. for (M^+) = 213.1154, found = 213.1160.

Products of Experiments Summarized in Table 3

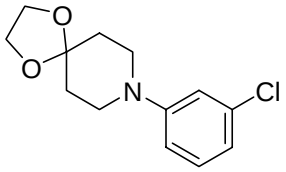
8-(4-Acetylphenyl)-1,4-dioxa-8-azaspiro[4.5]decane (Ogawa, K.; Kaji, M.; Kagawa, H.; Sagawa, M.; Kakuta, A. *Acta Crystallogr. Sect. C: Cryst. Struct. Commun.* **1994**, *50*, 95-97.)



4a

Reaction was performed at 40 °C. Product was isolated as a clear, crystalline solid in 93% yield from $PhB(OH)_2$: R_f = 0.10 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.84 (2H, ddd, *J* = 10.0, 5.0, 3.0 Hz), 6.85 (2H, ddd, *J* = 10.0, 5.0, 3.0 Hz), 3.98 (4H, s), 3.50 (4H, dd, *J* = 6.0, 6.0 Hz), 2.50 (3H, s), 1.78 (4H, dd, *J* = 6.0, 6.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.54, 153.58, 130.63, 127.21, 113.60, 107.14, 64.55, 45.95, 34.38, 26.22.

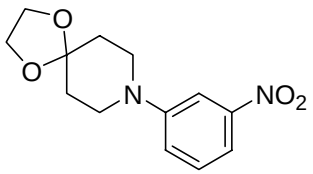
8-(3-Chlorophenyl)-1,4-dioxa-8-azaspiro[4.5]decane



4b

Reaction was performed at 40 °C. Product was isolated as a clear oil in 85% yield from $PhB(OH)_2$: R_f = 0.30 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.14 (1H, t, *J* = 8.0 Hz), 6.89 (1H, t, *J* = 2.0 Hz), 6.82 - 6.75 (2H, m), 3.98 (4H, s), 3.33 (4H, dd, *J* = 6.0, 6.0 Hz), 1.81 (4H, dd, *J* = 6.0, 6.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.00, 135.03, 130.18, 119.01, 116.27, 114.42, 107.15, 64.50, 47.35, 34.47; IR (film) ν 2958, 2883, 1595, 1563, 1487, 1466, 1365, 1231, 1144, 1097, 1037, 945, 768, 683 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 255 (37), 254 (21), 253 (100), 210 (10), 208 (30), 194 (11), 192 (21), 168 (16), 167 (18), 166 (42), 141 (26), 140 (15), 139 (74), 138 (20), 111 (13), 86 (11); HRMS (EI): *m/z* calcd. for (M^+) = 253.0869, found = 253.0870.

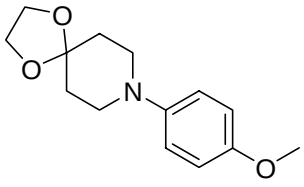
8-(3-Nitrophenyl)-1,4-dioxa-8-azaspiro[4.5]decane



4c

Reaction was performed at 40 °C. Product was isolated as a bright yellow oil in 84% yield from $PhB(OH)_2$: R_f = 0.25 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 (1H, t, *J* = 2.0 Hz), 7.57 (1H, ddd, *J* = 8.0, 2.0, 1.0 Hz), 7.32 (1H, t, *J* = 8.0 Hz), 7.16 (1H, ddd, *J* = 8.0, 2.0, 1.0 Hz), 3.97 (4H, s), 3.40 (4H, dd, *J* = 6.0, 6.0 Hz), 1.78 (4H, dd, *J* = 6.0, 6.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.34, 149.35, 129.79, 121.52, 113.27, 109.96, 106.86, 64.51, 46.98, 34.27; IR (film) ν 2960, 2886, 1616, 1526, 1349, 1234, 1144, 1112, 1036, 946, 856, 737, 674 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 265 (19), 264 (93), 219 (46), 204 (12), 203 (35), 178 (24), 177 (48), 151 (13), 150 (100), 149 (10), 132 (12), 105 (15), 104 (15), 99 (17), 86 (14), 77 (15); HRMS (EI): *m/z* calcd. for (M^+) = 264.1110, found = 264.1109.

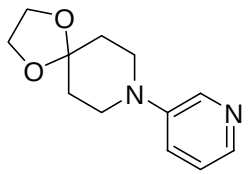
8-(4-Methoxyphenyl)-1,4-dioxa-8-azaspiro[4.5]decane



4d

Reaction was performed at 40 °C. Product was isolated as a clear, crystalline solid in 95% yield from $PhB(OH)_2$: mp = 60 - 61 ^{o}C (hexanes); R_f = 0.20 (3:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.92 (2H, ddd, *J* = 10.0, 6.0, 3.5 Hz), 6.82 (2H, ddd, *J* = 10.0, 6.0, 3.5 Hz), 3.98 (4H, s), 3.76 (3H, s), 3.18 (4H, dd, *J* = 5.5, 5.5 Hz), 1.86 (4H, dd, *J* = 5.5, 5.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.82, 145.74, 119.05, 114.44, 107.16, 64.41, 55.62, 49.47, 34.95; IR (film) ν 2956, 2821, 1512, 1466, 1442, 1417, 1368, 1288, 1249, 1224, 1180, 1115, 1036, 949, 896, 832, 704 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 250 (26), 249 (100), 235 (11), 234 (51), 204 (12), 188 (10), 163 (13), 162 (42), 136 (12), 135 (63), 133 (18), 121 (11), 120 (41), 99 (11), 92 (10), 86 (11), 84 (16), 55 (12), 51 (12); HRMS (EI): *m/z* calcd. for (M^+) = 249.1365, found = 249.1361.

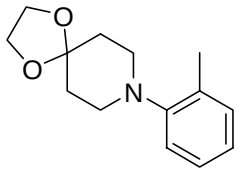
8-(Pyridin-3-yl)-1,4-dioxa-8-azaspiro[4.5]decane



4e

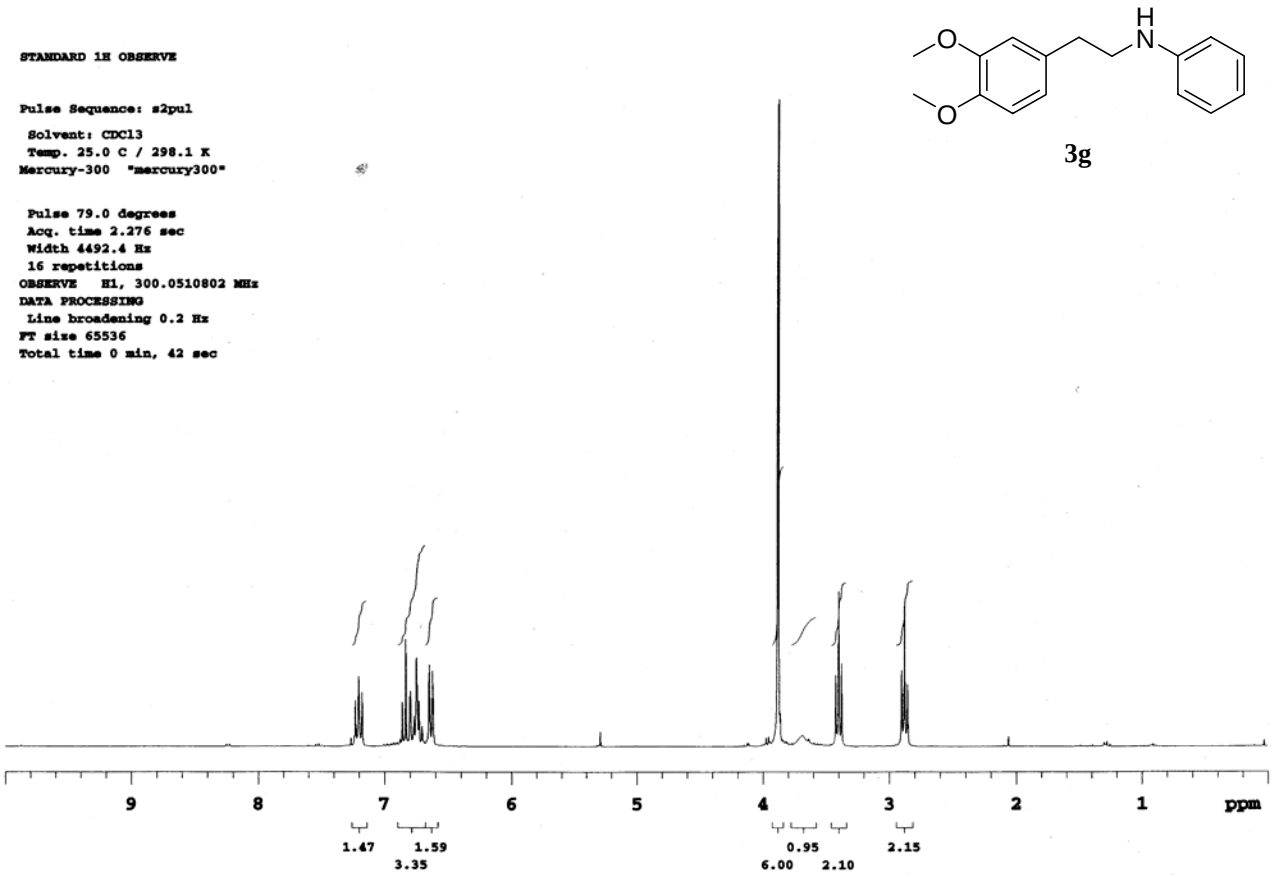
Reaction was performed at 40 °C. Product was isolated as light orange oil in 55% yield from $PhB(OH)_2$: R_f = 0.10 (1:1 CH2Cl2:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.31 (1H, s), 8.05 (1H, d, *J* = 3.5 Hz), 7.18 (1H, ddd, *J* = 8.5, 3.5, 1.5 Hz), 7.11 (1H, dd, *J* = 8.5, 3.5 Hz), 3.98 (4H, s), 3.34 (4H, dd, *J* = 5.5, 5.5 Hz), 1.82 (4H, dd, *J* = 5.5, 5.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.77, 140.50, 139.20, 123.60, 122.90, 106.98, 64.53, 47.24, 34.46; IR (film) ν 2958, 2884, 1672, 1582, 1488, 1426, 1365, 1235, 1144, 1102, 1052, 1035, 946, 930, 799, 708, 670, 614 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 221 (14), 220 (82), 175 (32), 159 (26), 134 (17), 133 (55), 107 (15), 106 (100), 105 (29), 99 (20), 86 (20), 78 (21), 55 (11), 51 (10); HRMS (EI): *m/z* calcd. for (M^+) = 220.1212, found = 220.1217.

8-*o*-Tolyl-1,4-dioxa-8-azaspiro[4.5]decane

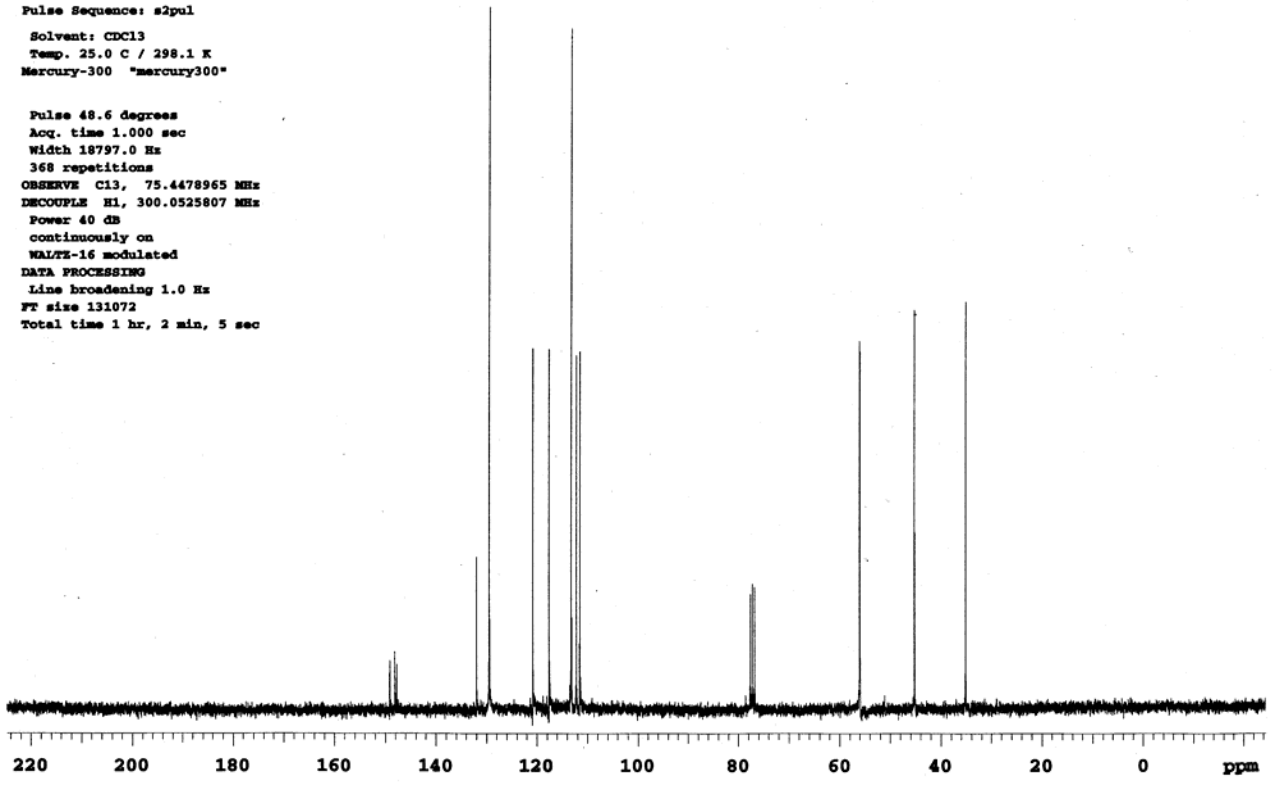


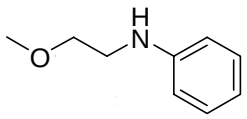
4f

Reaction was performed at 40 °C. Product was isolated as a pale yellow oil in 61% yield from $PhB(OH)_2$: R_f = 0.33 (9:1 hexanes:EtOAc); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.24 - 7.18 (2H, m), 7.07 (1H, dd, *J* = 7.5, 1.0 Hz), 6.99 (1H, dt, *J* = 7.5, 1.0 Hz), 4.02 (4H, s), 3.01 (4H, dd, *J* = 5.5, 5.5 Hz), 2.34 (3H, s), 1.91 (4H, dd, *J* = 5.5, 5.5 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.95, 132.76, 131.05, 126.60, 123.14, 119.38, 107.30, 64.41, 50.27, 35.79, 17.90; IR (film) ν 2955, 2880, 2823, 1599, 1493, 1470, 1363, 1328, 1217, 1142, 1101, 1038, 931, 899, 762, 724, 666 cm^{-1}; LRMS (EI): *m/z* (rel. intensity) = 234 (22), 233 (100), 232 (16), 188 (41), 172 (19), 147 (15), 146 (55), 132 (17), 119 (42), 118 (44), 91 (18); HRMS (EI): *m/z* calcd. for (M^+) = 233.1416, found = 233.1411.

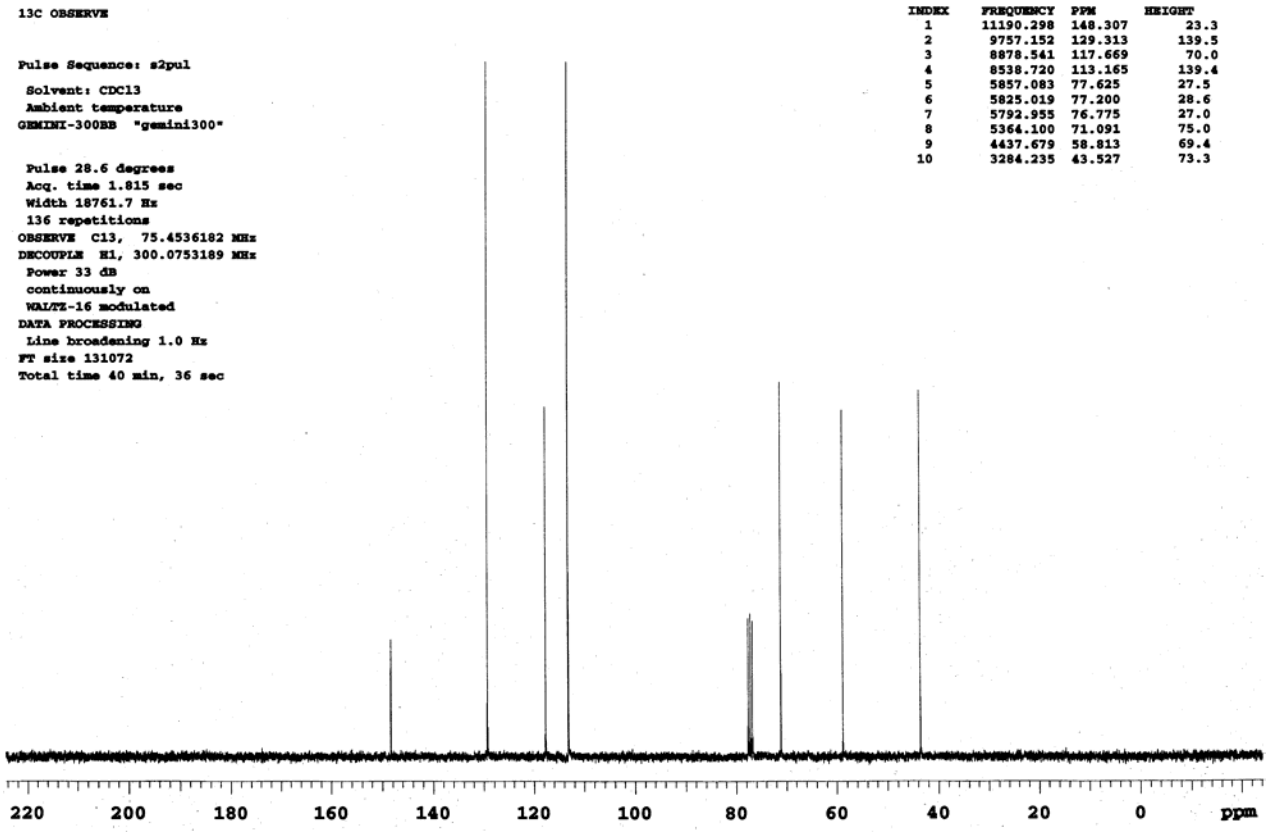

STANDARD 1H OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 79.0 degrees
Acq. time 2.276 sec
Width 4492.4 Hz
16 repetitions
OBSERVE H1, 300.0510802 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min, 42 sec
9
8
7
6
5
4
3
2
1
ppm
1.47
1.59
3.35
0.95
6.00
2.10
2.15

3g

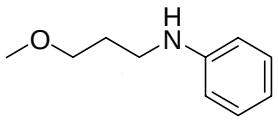

13C OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 48.6 degrees
Acq. time 1.000 sec
Width 18797.0 Hz
368 repetitions
OBSERVE C13, 75.4478965 MHz
DECOUPLE H1, 300.0525807 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 1 hr, 2 min, 5 sec
220
200
180
160
140
120
100
80
60
40
20
0
ppm



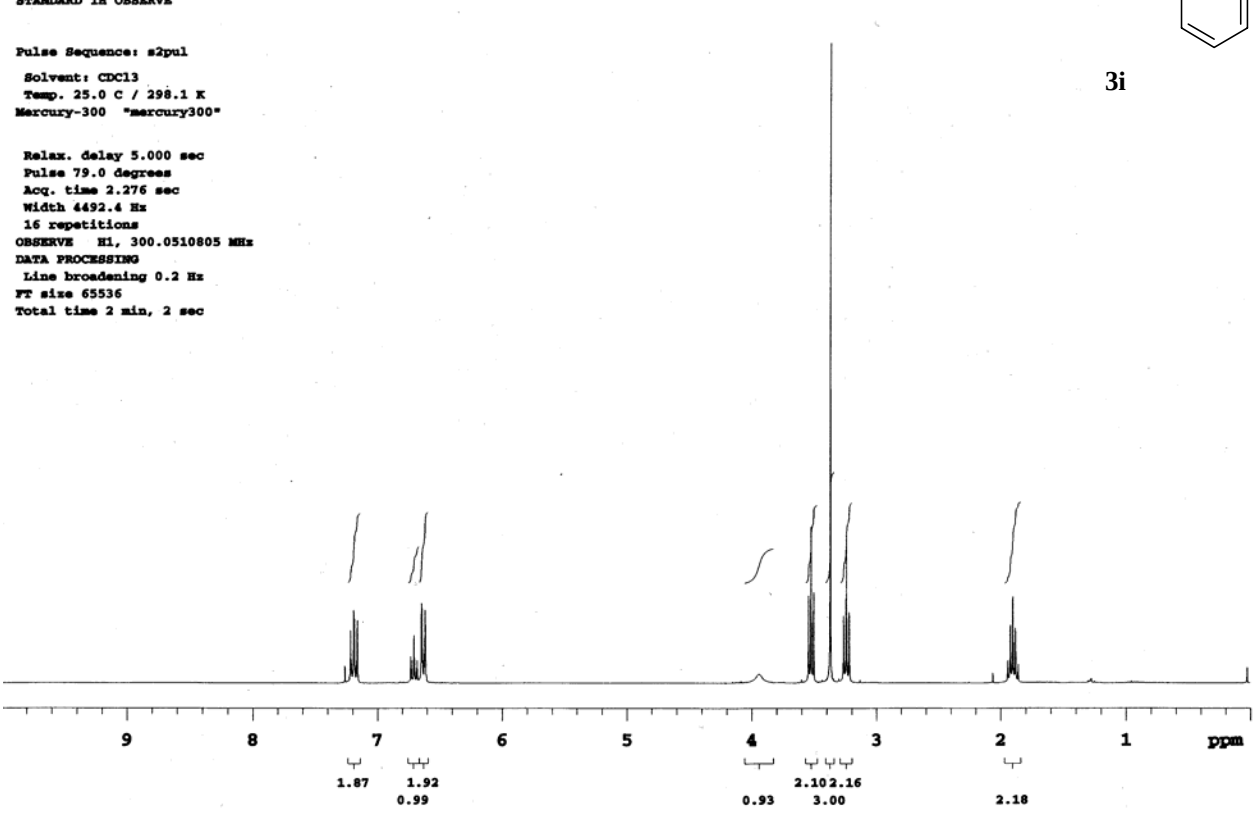
3h

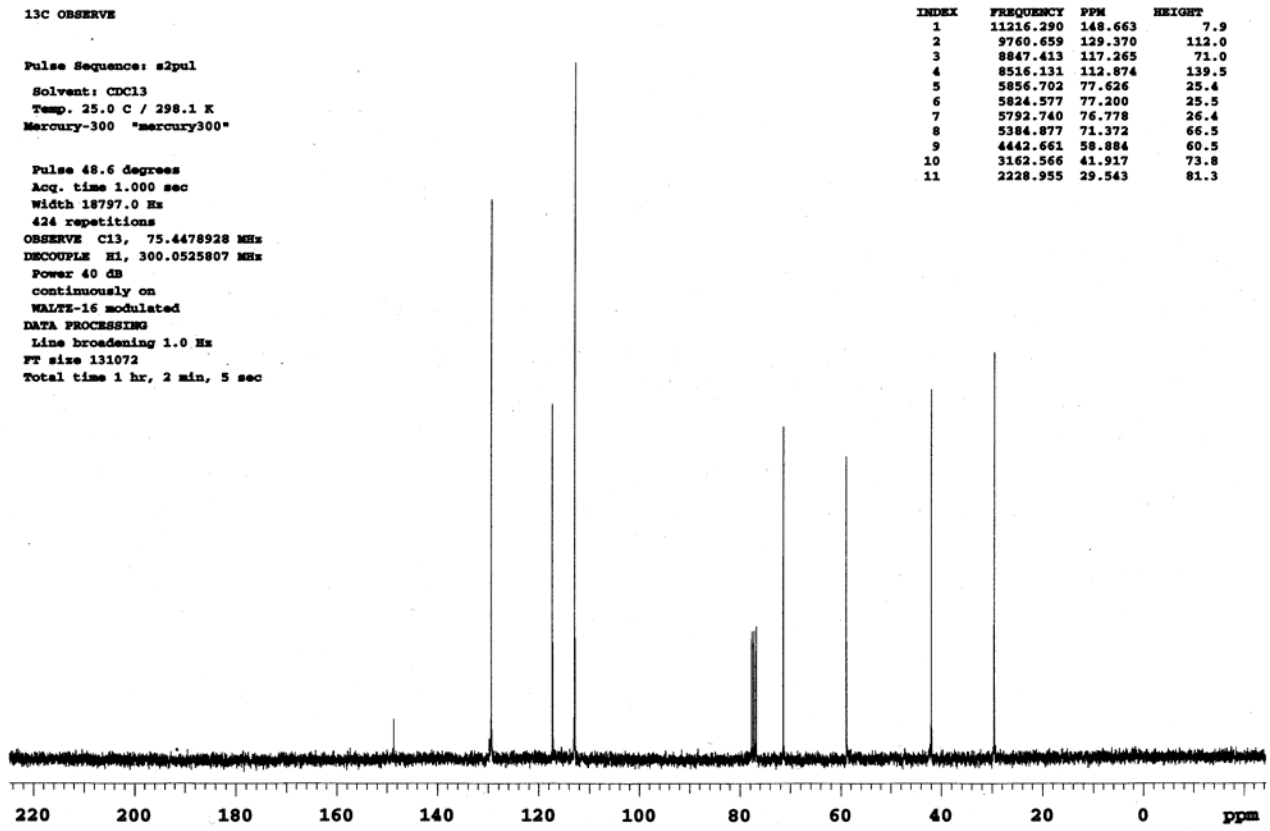


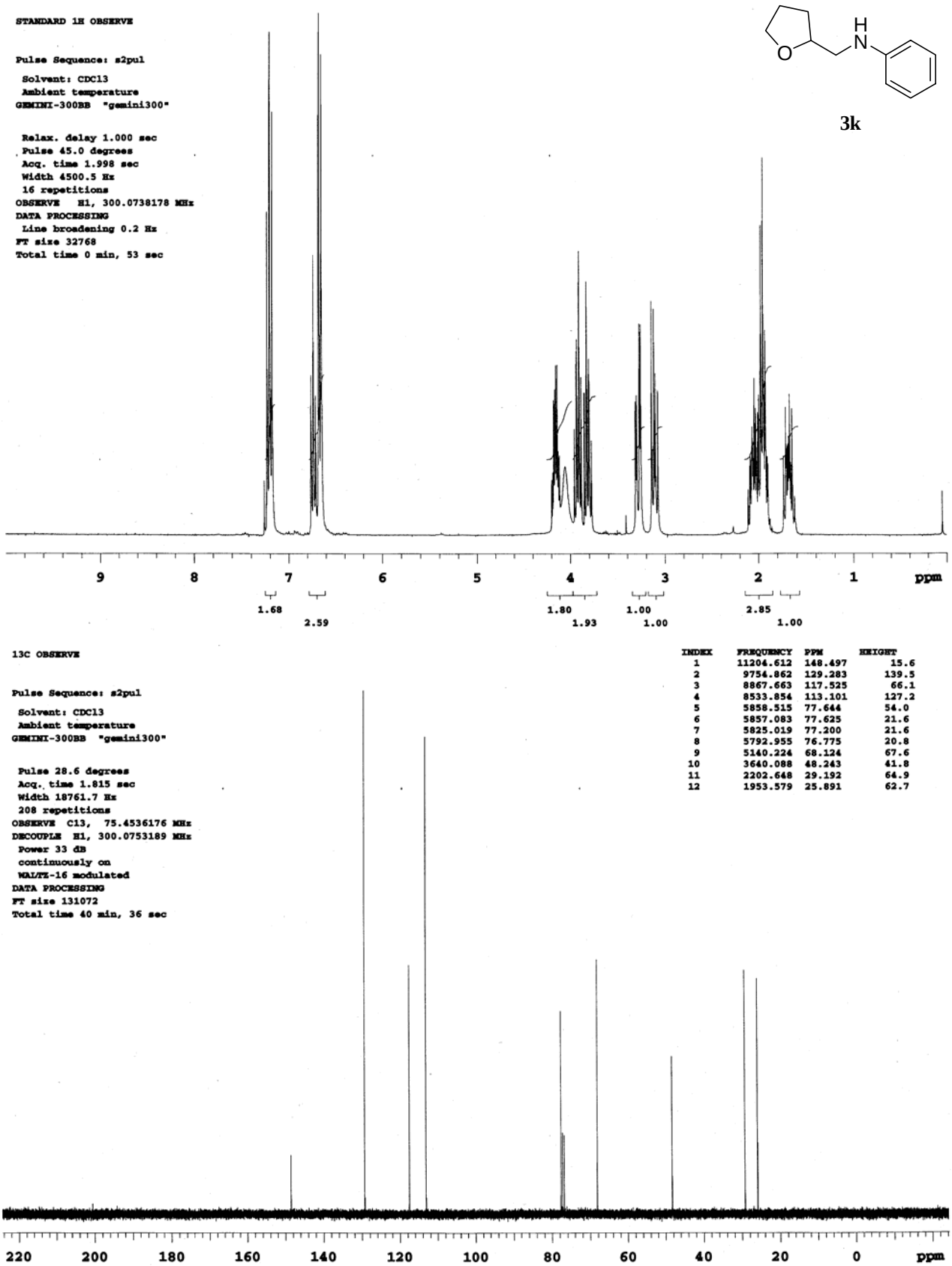
INDEX	FREQUENCY	PPM	HEIGHT
1	11190.298	148.307	23.3
2	9757.152	129.313	139.5
3	8878.541	117.669	70.0
4	8538.720	113.165	139.4
5	5857.083	77.625	27.5
6	5825.019	77.200	28.6
7	5792.955	76.775	27.0
8	5364.100	71.091	75.0
9	4437.679	58.813	69.4
10	3284.235	43.527	73.3



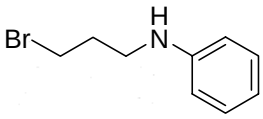
3i


STANDARD 1H OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Relax. delay 5.000 sec
Pulse 79.0 degrees
Acq. time 2.276 sec
Width 4492.4 Hz
16 repetitions
OBSERVE H1, 300.0510805 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 2 min, 2 sec
9
8
7
6
5
4
3
2
1
ppm
1.87
1.92
0.99
0.93
2.10
2.16
3.00
2.18


13C OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 48.6 degrees
Acq. time 1.000 sec
Width 18797.0 Hz
424 repetitions
OBSERVE C13, 75.4478928 MHz
DECOUPLE H1, 300.0525807 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 1 hr, 2 min, 5 sec
INDEX FREQUENCY PPM HEIGHT
1 11216.290 148.663 7.9
2 9760.659 129.370 112.0
3 8847.413 117.265 71.0
4 8516.131 112.874 139.5
5 5856.702 77.626 25.4
6 5824.577 77.200 25.5
7 5792.740 76.778 26.4
8 5384.877 71.372 66.5
9 4442.661 58.884 60.5
10 3162.566 41.917 73.8
11 2228.955 29.543 81.3
220
200
180
160
140
120
100
80
60
40
20
0
ppm



INDEX	FREQUENCY	PPM	HEIGHT
1	11204.612	148.497	15.6
2	9754.862	129.283	139.5
3	8867.663	117.525	66.1
4	8533.854	113.101	127.2
5	5858.515	77.644	54.0
6	5857.083	77.625	21.6
7	5825.019	77.200	21.6
8	5792.955	76.775	20.8
9	5140.224	68.124	67.6
10	3640.088	48.243	41.8
11	2202.648	29.192	64.9
12	1953.579	25.891	62.7



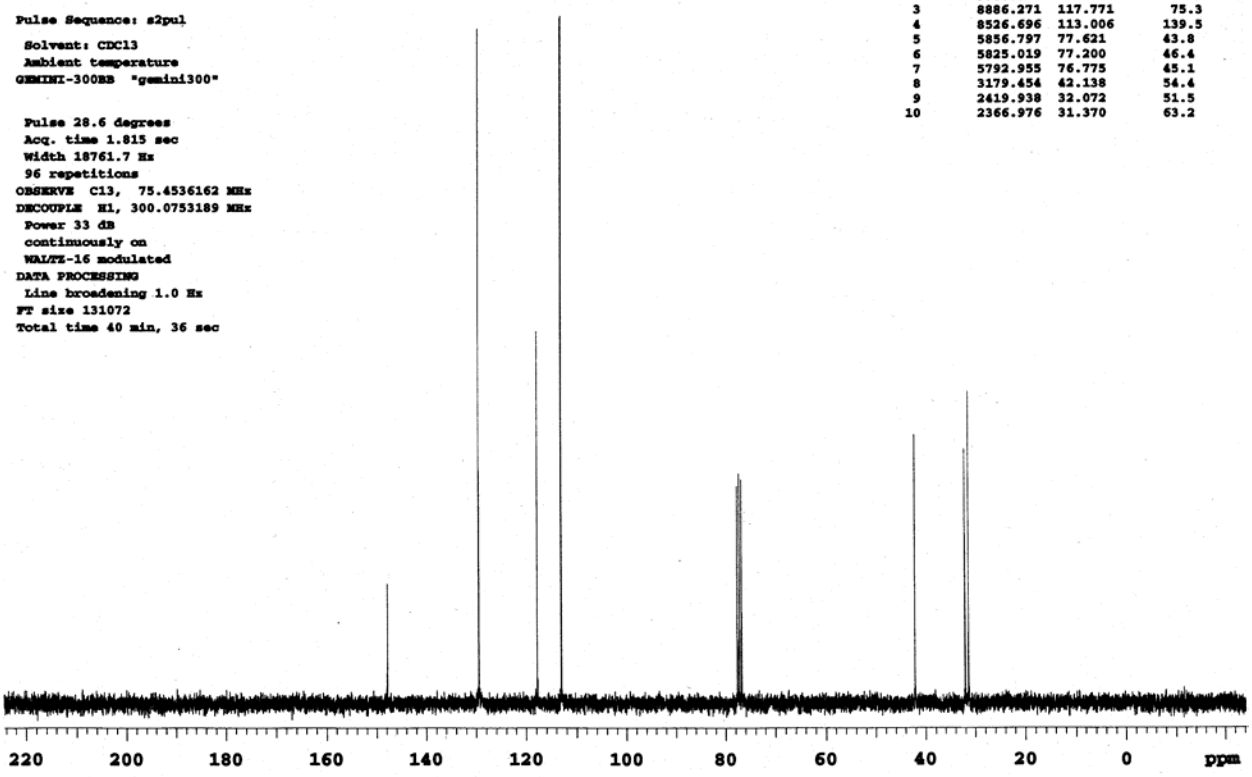
3l

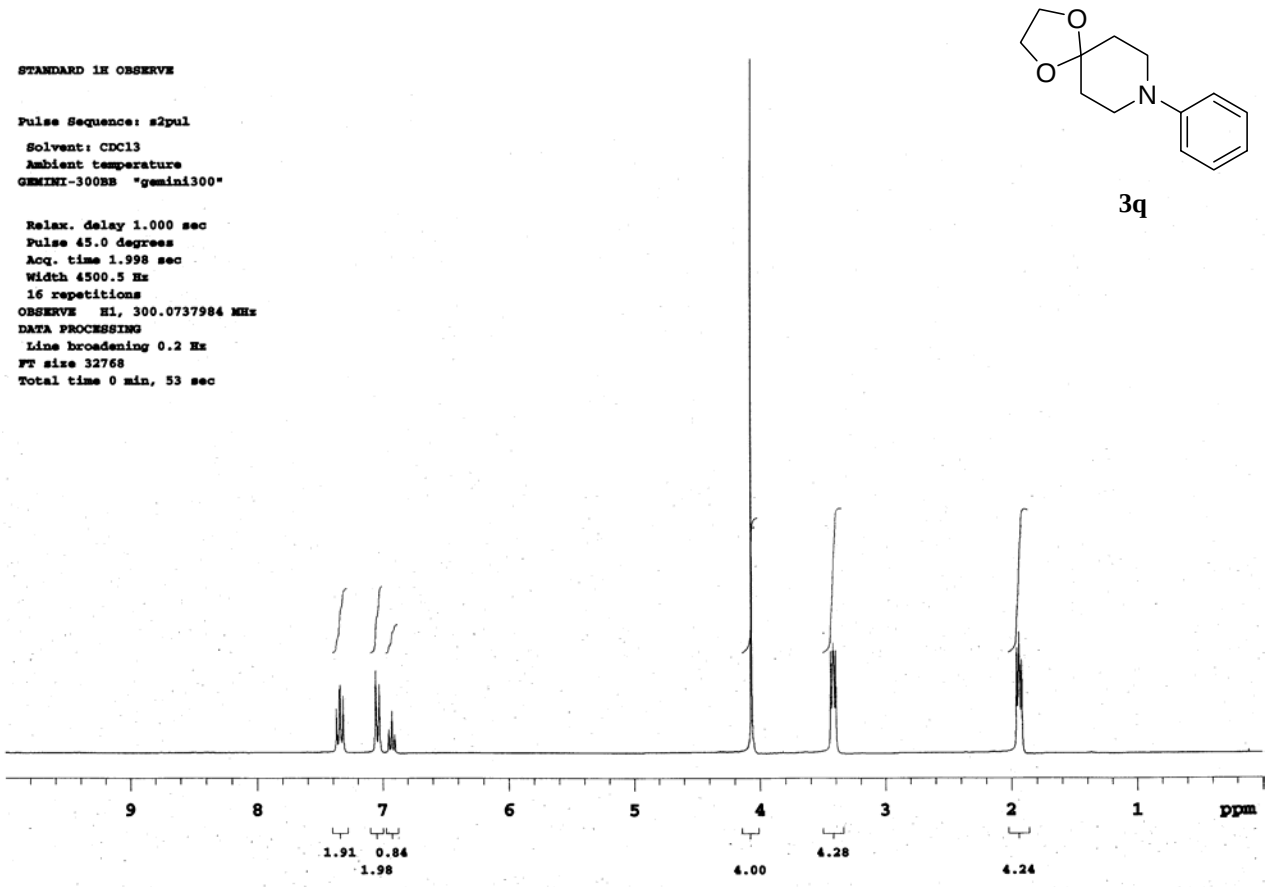
```
STANDARD 1H OBSERVE

Pulse Sequence: s2pul
 Solvent: CDCl3
 Ambient temperature
GEMINI-300BB  "gemini300"

 Relax. delay 1.000 sec
 Pulse 45.0 degrees
 Acq. time 1.998 sec
 Width 4500.5 Hz
 16 repetitions
OBSERVE    H1, 300.0737984 MHz
DATA PROCESSING
 Line broadening 0.2 Hz
FT size 32768
Total time 0 min, 53 sec
```



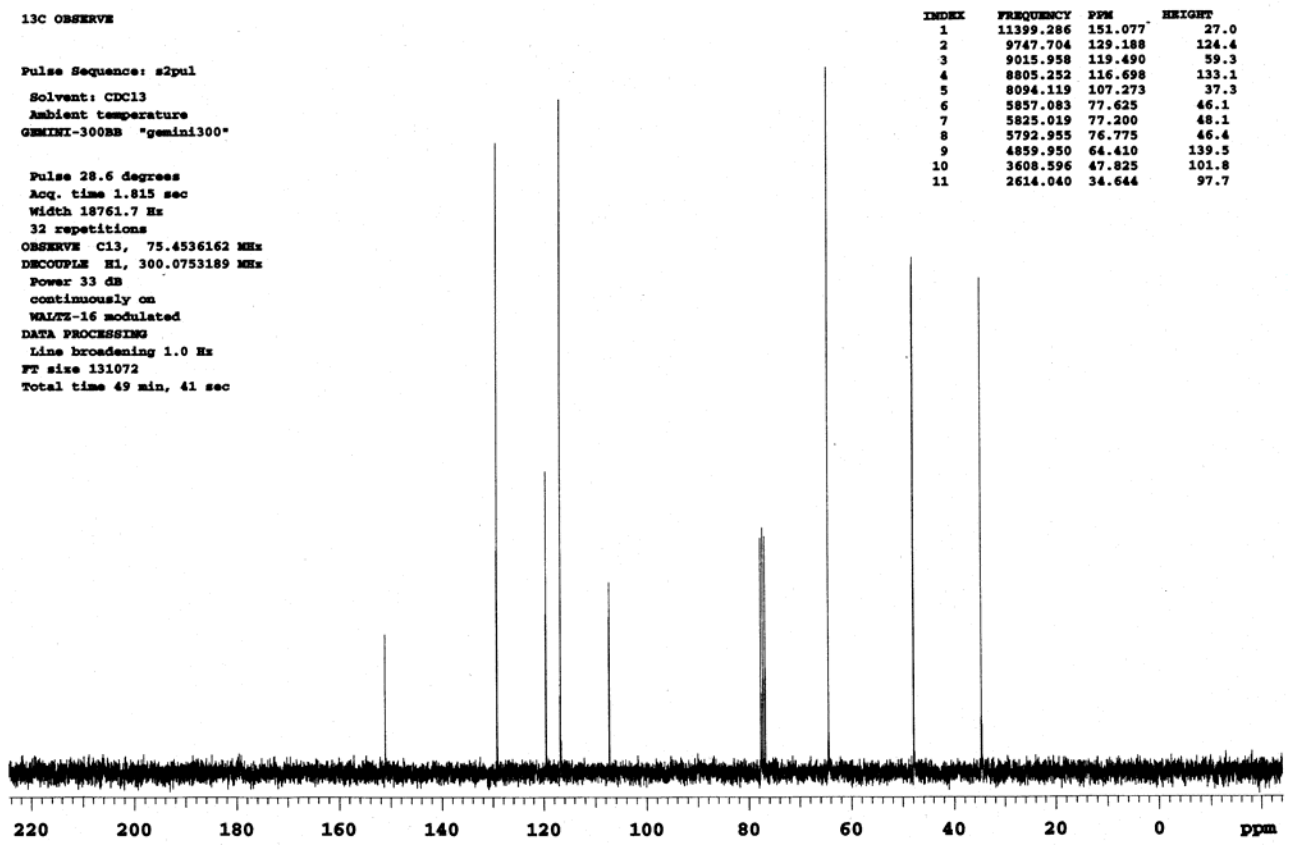
```
13C OBSERVE

Pulse Sequence: s2pul
 Solvent: CDCl3
 Ambient temperature
GEMINI-300BB  "gemini300"

 Pulse 28.6 degrees
 Acq. time 1.815 sec
 Width 18761.7 Hz
 96 repetitions
OBSERVE  C13,  75.4536162 MHz
DECOUPLE  H1, 300.0753189 MHz
 Power 33 dB
 continuously on
 WALTZ-16 modulated
DATA PROCESSING
 Line broadening 1.0 Hz
FT size 131072
Total time 40 min, 36 sec
```

INDEX	FREQUENCY	PPM	HEIGHT
1	11153.367	147.818	24.1
2	9768.317	129.461	136.9
3	8886.271	117.771	75.3
4	8526.696	113.006	139.5
5	5856.797	77.621	43.8
6	5825.019	77.200	46.4
7	5792.955	76.775	45.1
8	3179.454	42.138	54.4
9	2419.938	32.072	51.5
10	2366.976	31.370	63.2

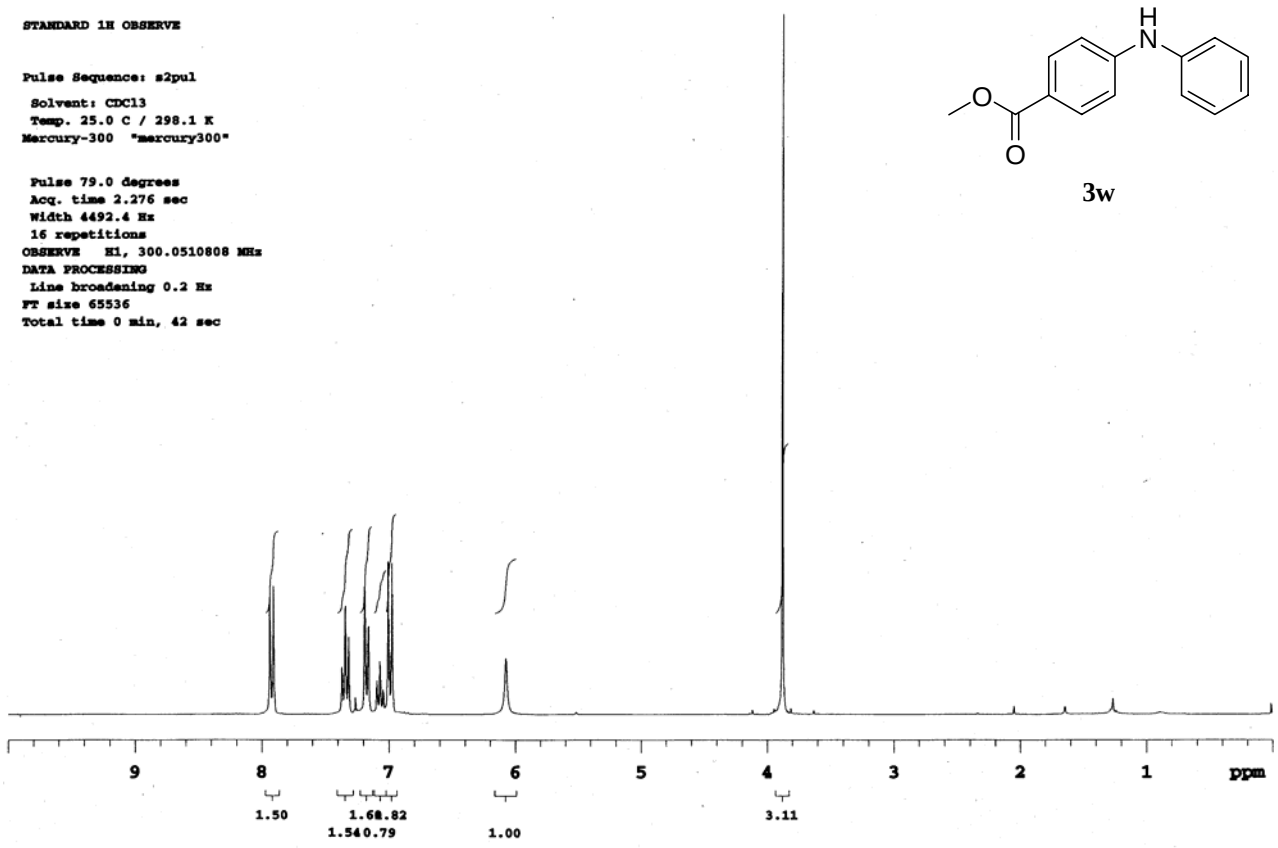


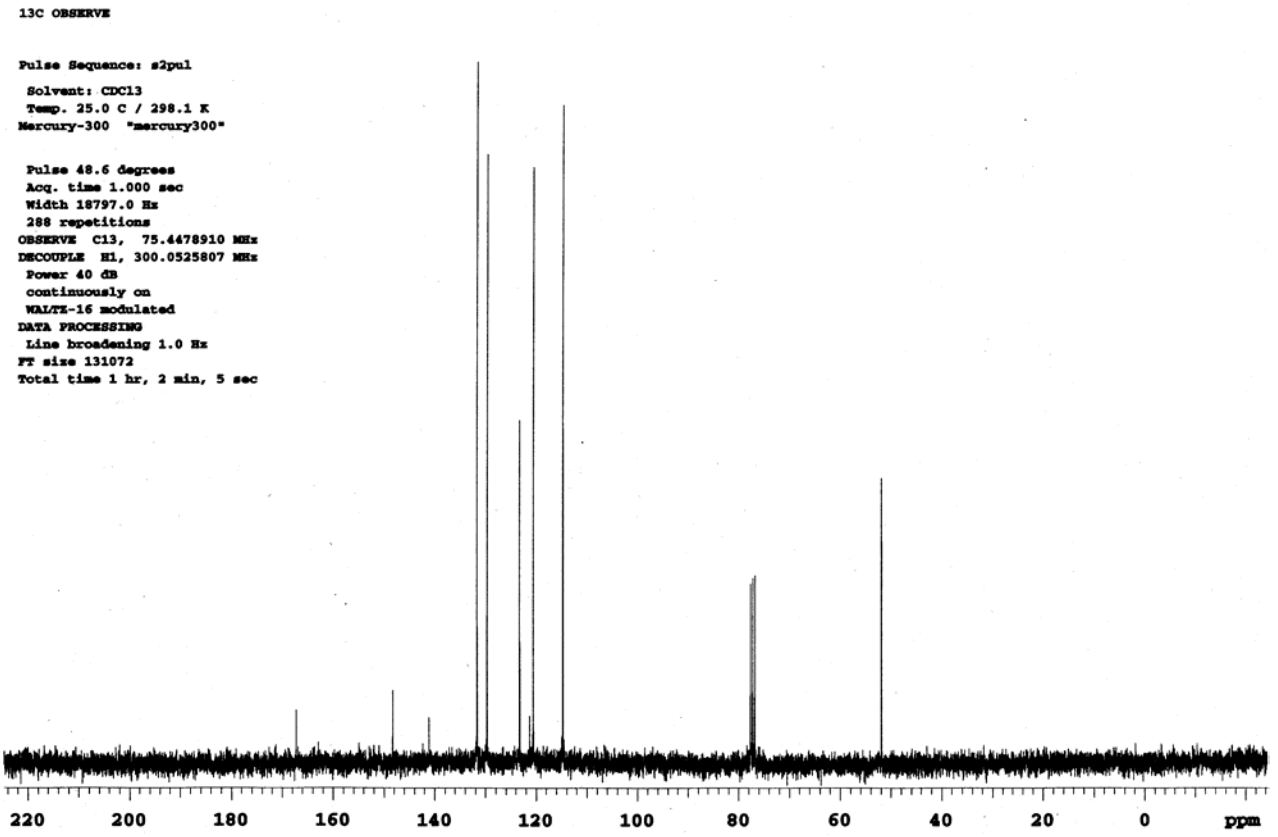


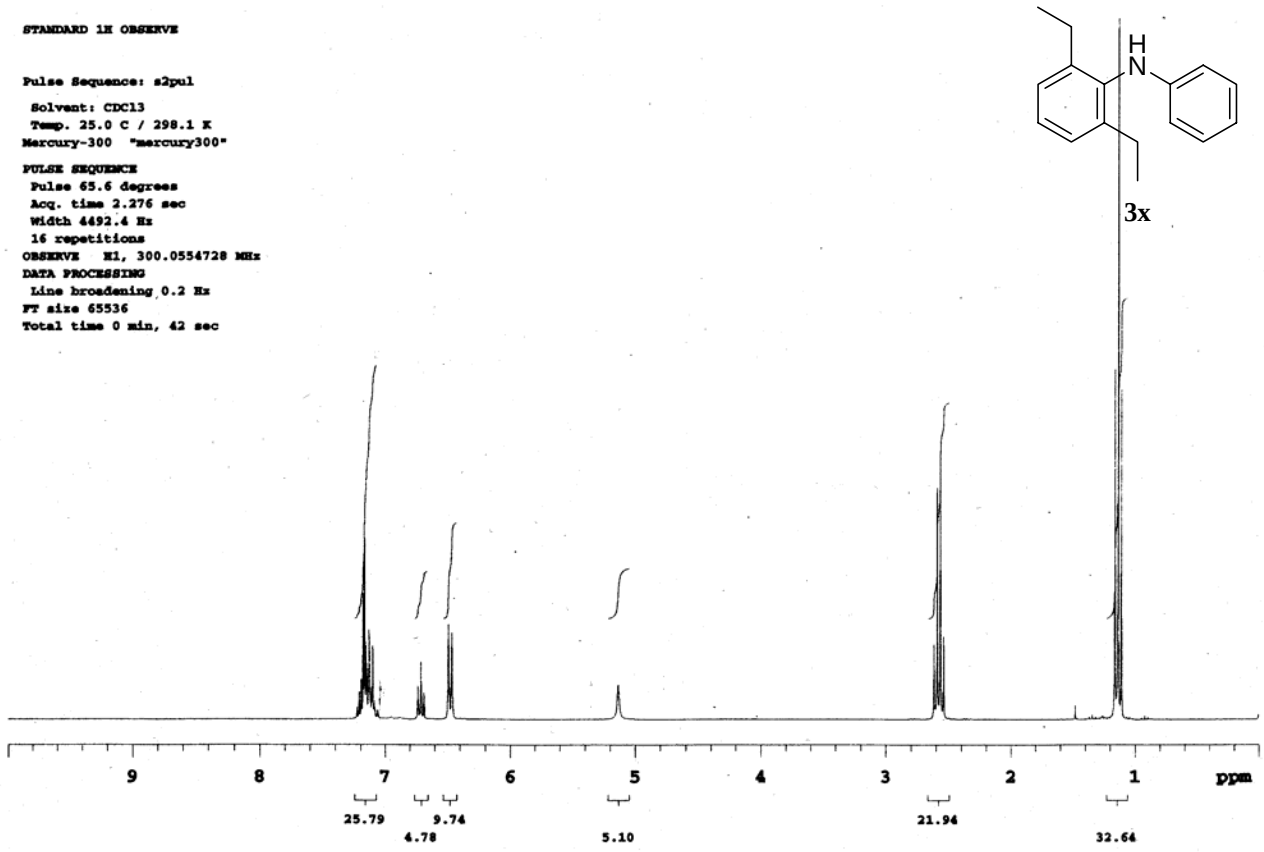
3q

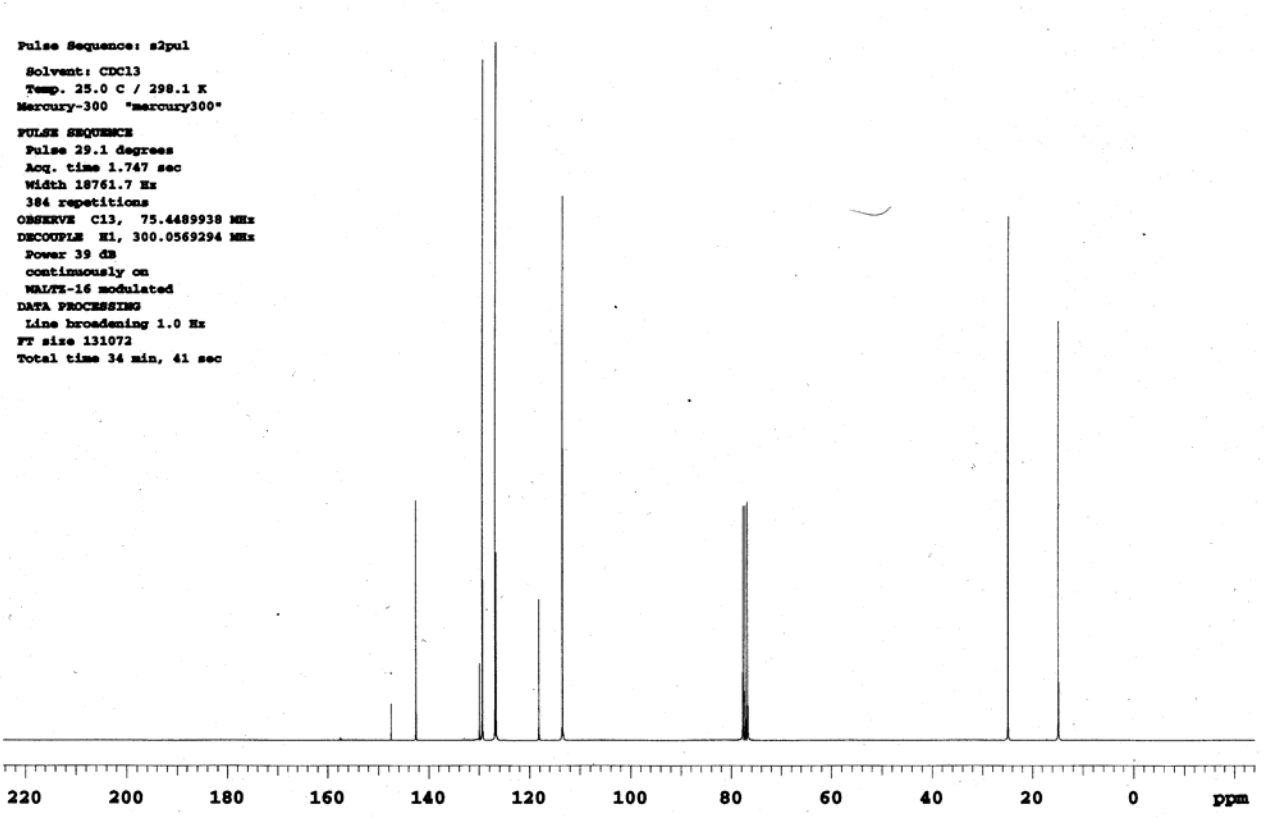


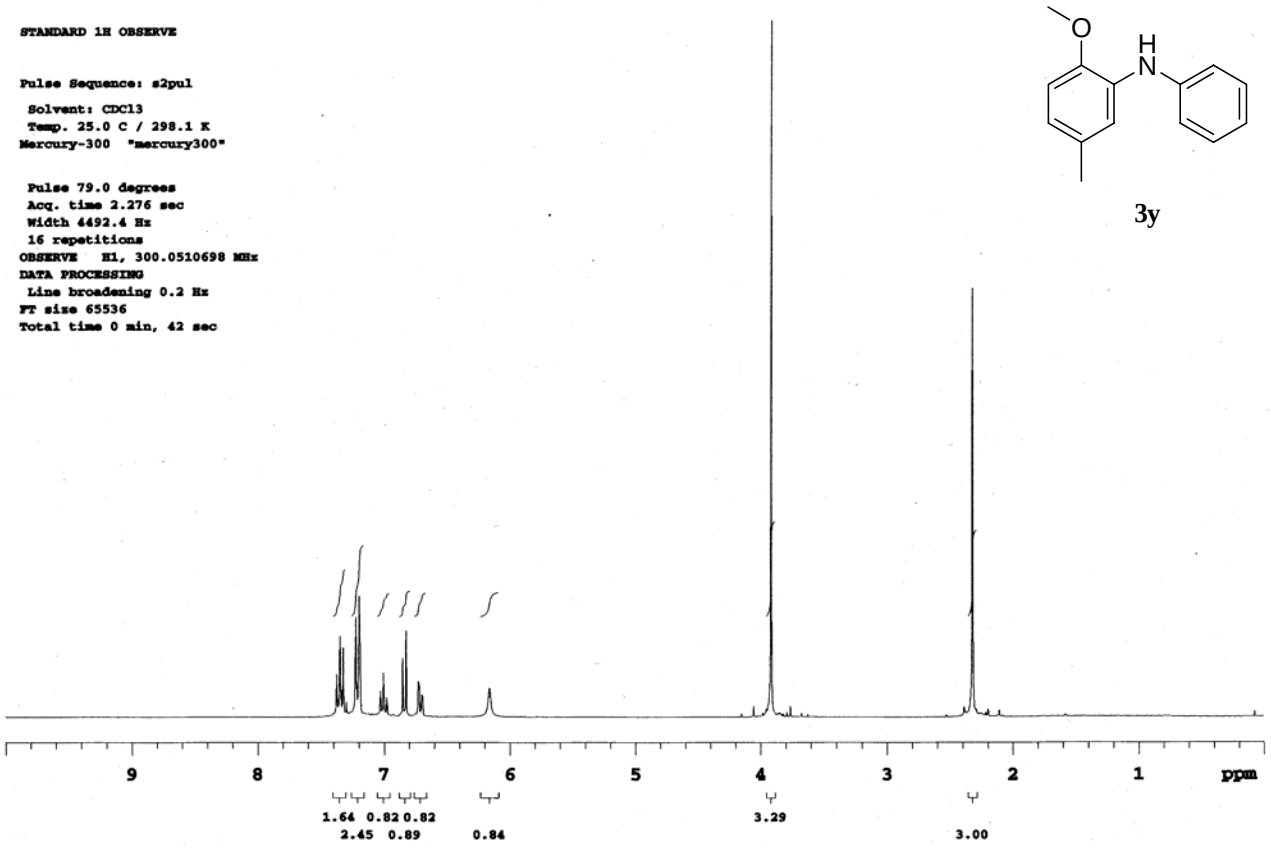
INDEX	FREQUENCY	PPM	HEIGHT
1	11399.286	151.077	27.0
2	9747.704	129.188	124.4
3	9015.958	119.490	59.3
4	8805.252	116.698	133.1
5	8094.119	107.273	37.3
6	5857.083	77.625	46.1
7	5825.019	77.200	48.1
8	5792.955	76.775	46.4
9	4859.950	64.410	139.5
10	3608.596	47.825	101.8
11	2614.040	34.644	97.7

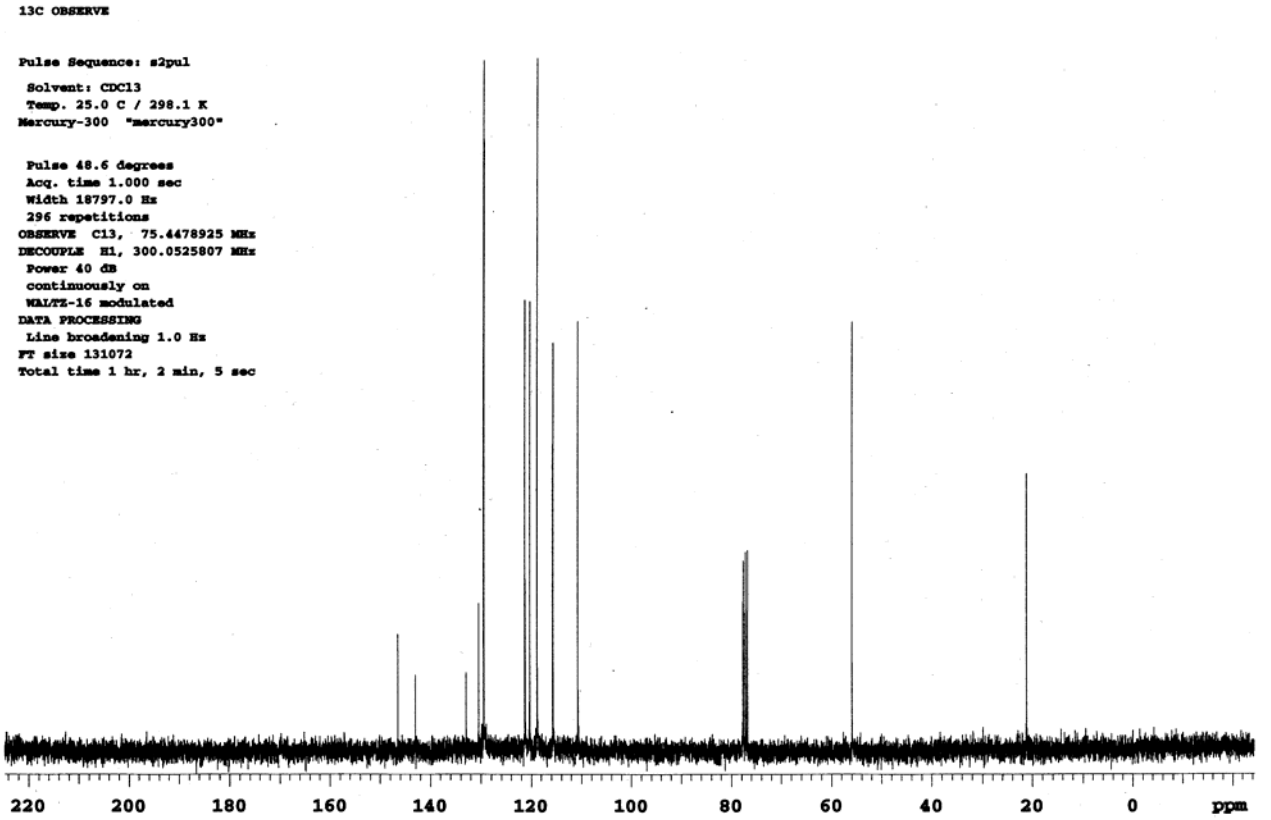

STANDARD 1H OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 79.0 degrees
Acq. time 2.276 sec
Width 4492.4 Hz
16 repetitions
OBSERVE H1, 300.0510808 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min, 42 sec
H
N
O
O
3w
9
8
7
6
5
4
3
2
1
ppm
1.50
1.54
0.79
1.68
.82
1.00
3.11

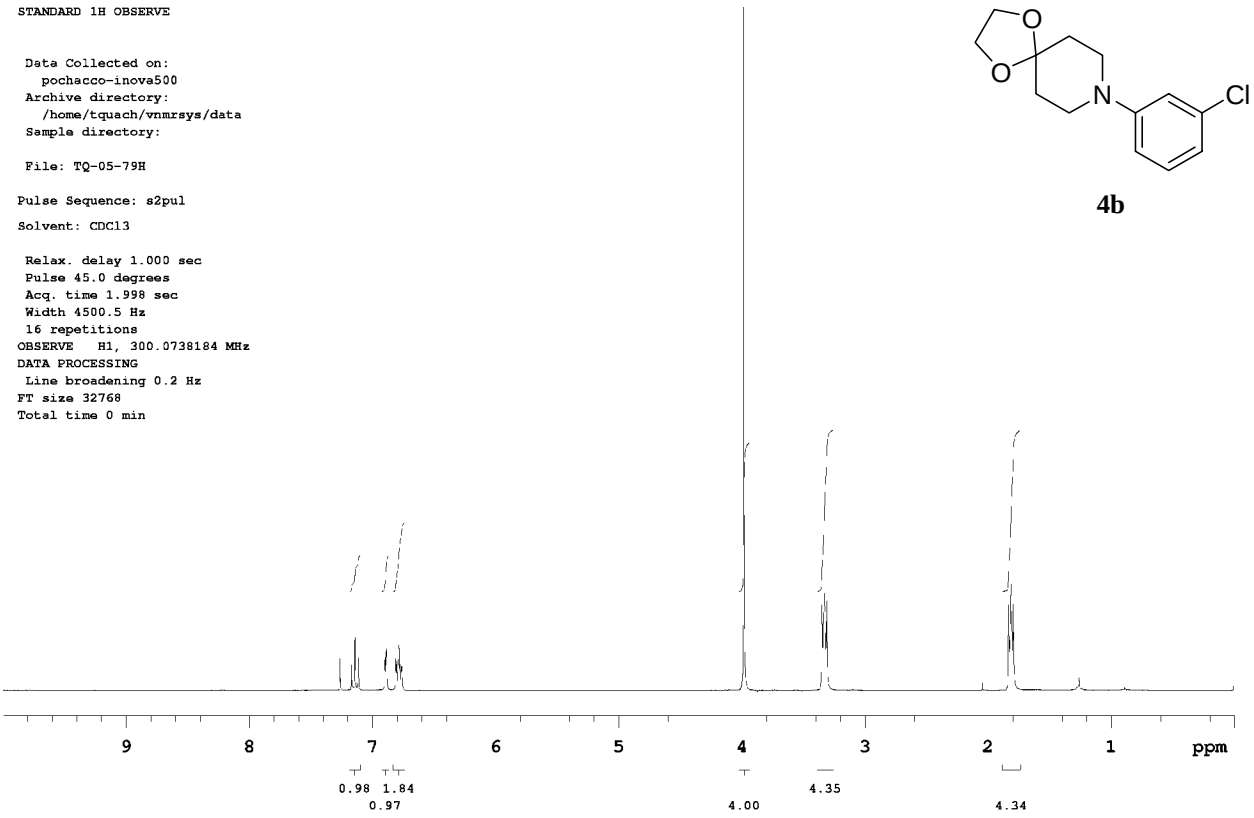

13C OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 48.6 degrees
Acq. time 1.000 sec
Width 18797.0 Hz
288 repetitions
OBSERVE C13, 75.4678910 MHz
DECOUPLE H1, 300.0525807 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 1 hr, 2 min, 5 sec
220
200
180
160
140
120
100
80
60
40
20
0
ppm

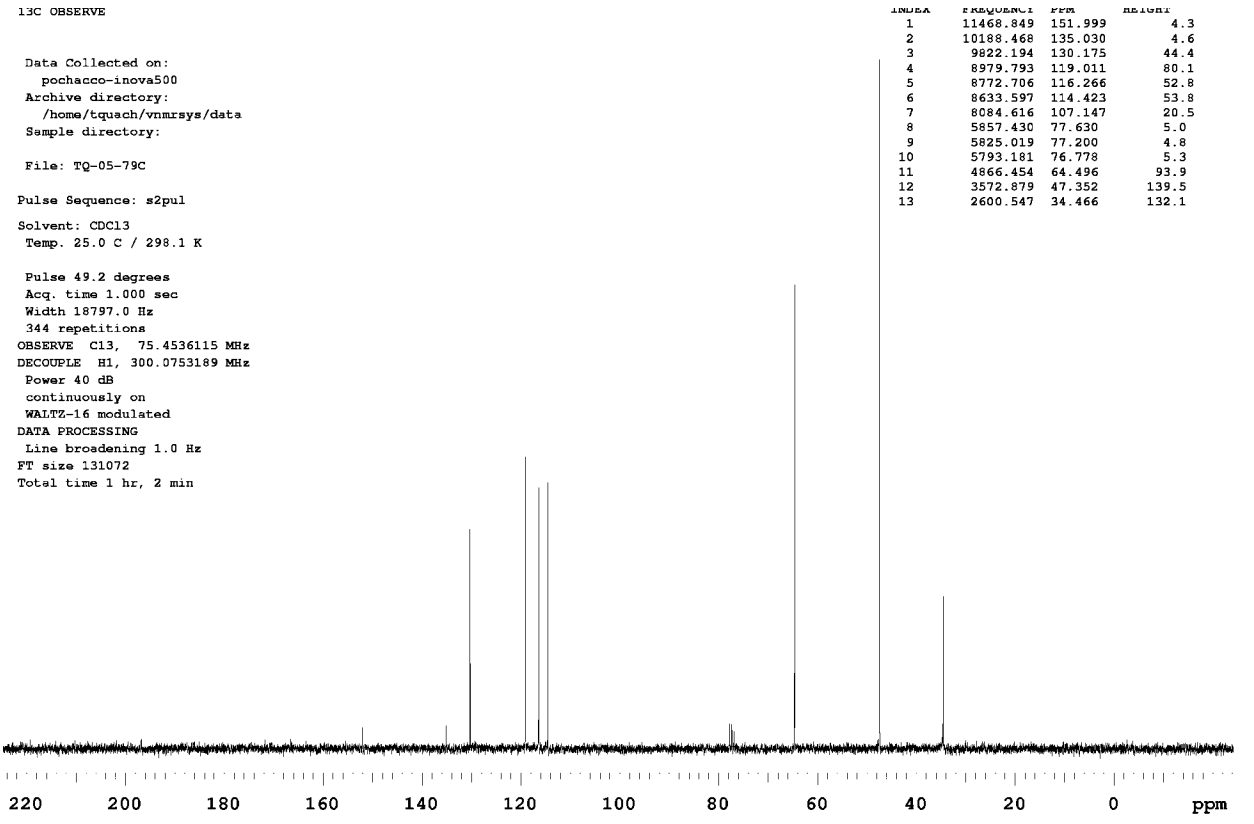

STANDARD 1H OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
PULSE SEQUENCE
Pulse 65.6 degrees
Acq. time 2.276 sec
Width 4492.4 Hz
16 repetitions
OBSERVE H1, 300.0554728 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min, 42 sec
H
N
3x
9
8
7
6
5
4
3
2
1
ppm
25.79
4.78
9.74
5.10
21.94
32.64

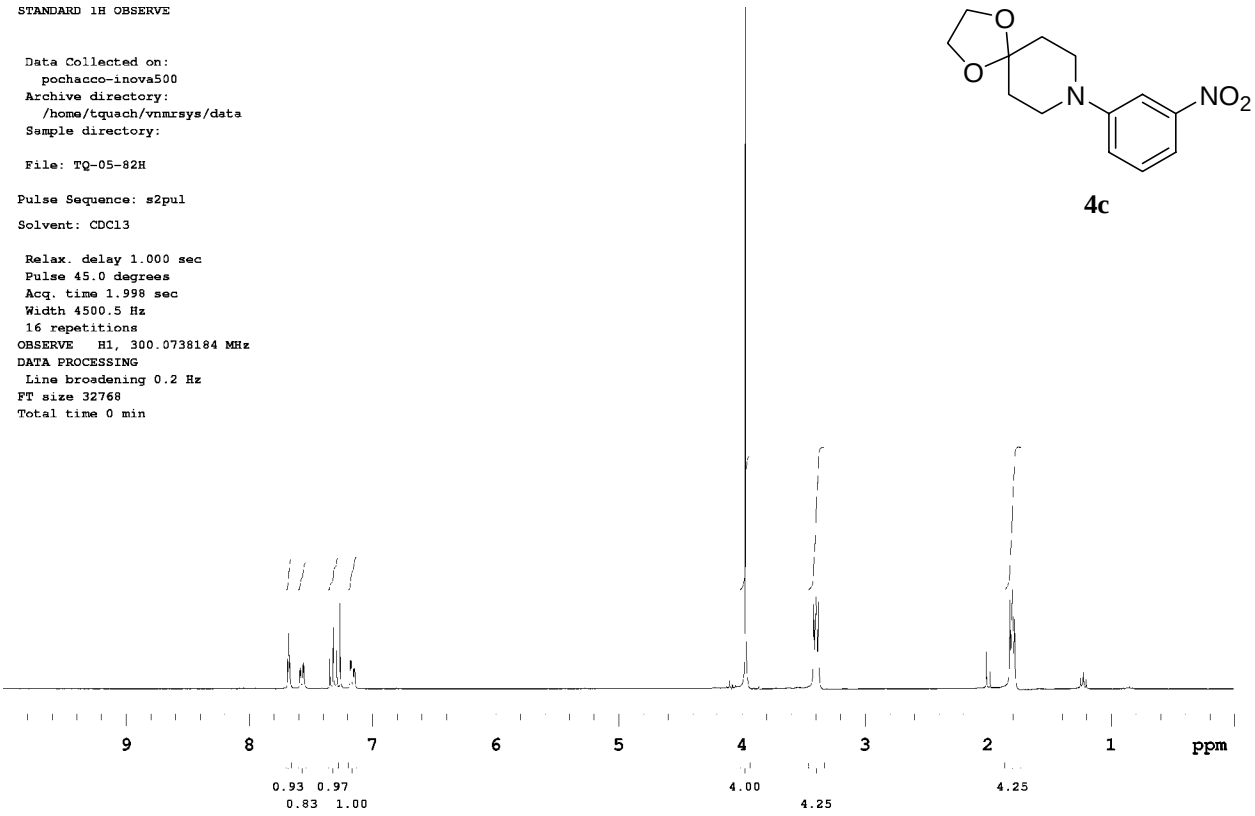

13C OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
PULSE SEQUENCE
Pulse 29.1 degrees
Acq. time 1.747 sec
Width 18761.7 Hz
384 repetitions
OBSERVE C13, 75.4489938 MHz
DECOUPLE H1, 300.0569294 MHz
Power 39 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 34 min, 41 sec
220
200
180
160
140
120
100
80
60
40
20
0
ppm

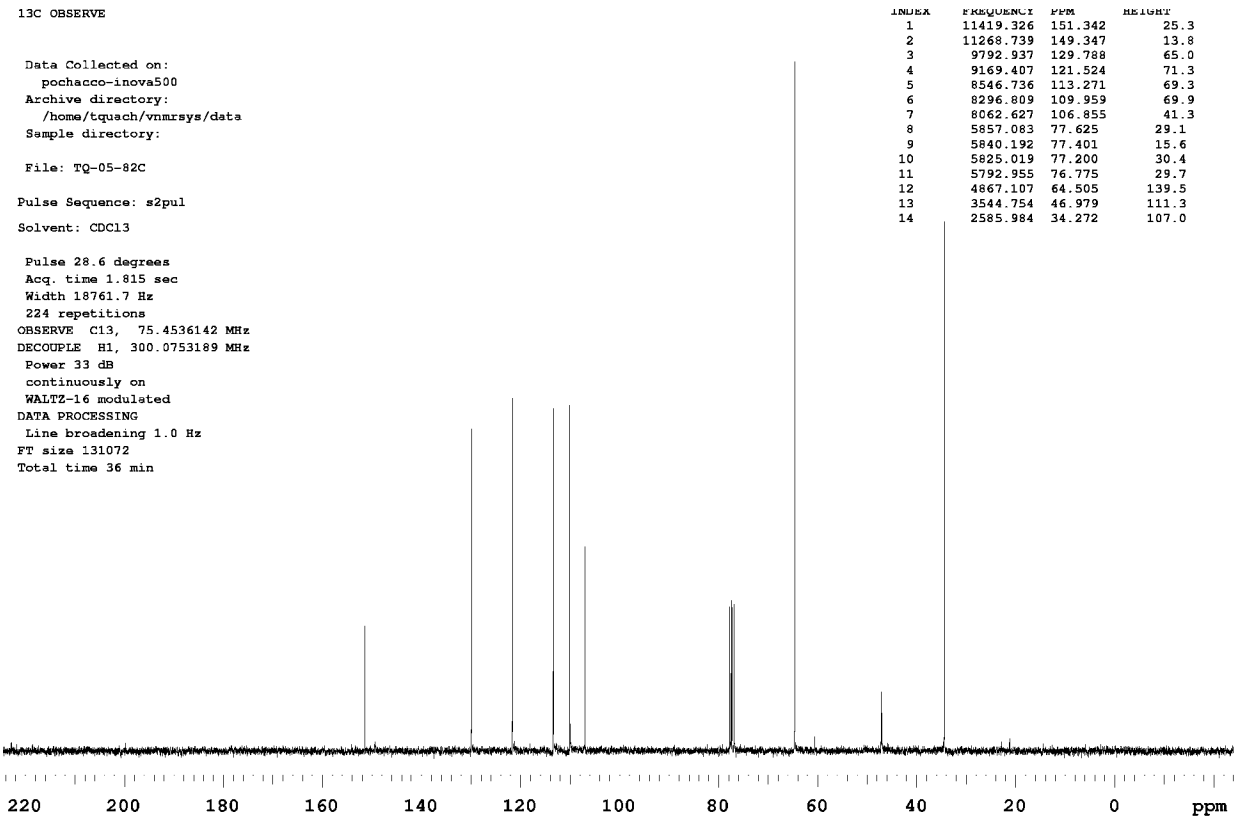

STANDARD 1H OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 79.0 degrees
Acq. time 2.276 sec
Width 4492.4 Hz
16 repetitions
OBSERVE H1, 300.0510698 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 65536
Total time 0 min, 42 sec
O
H
N
3y
9
8
7
6
5
4
3
2
1
ppm
1.64 0.82 0.82
2.45 0.89
0.84
3.29
3.00

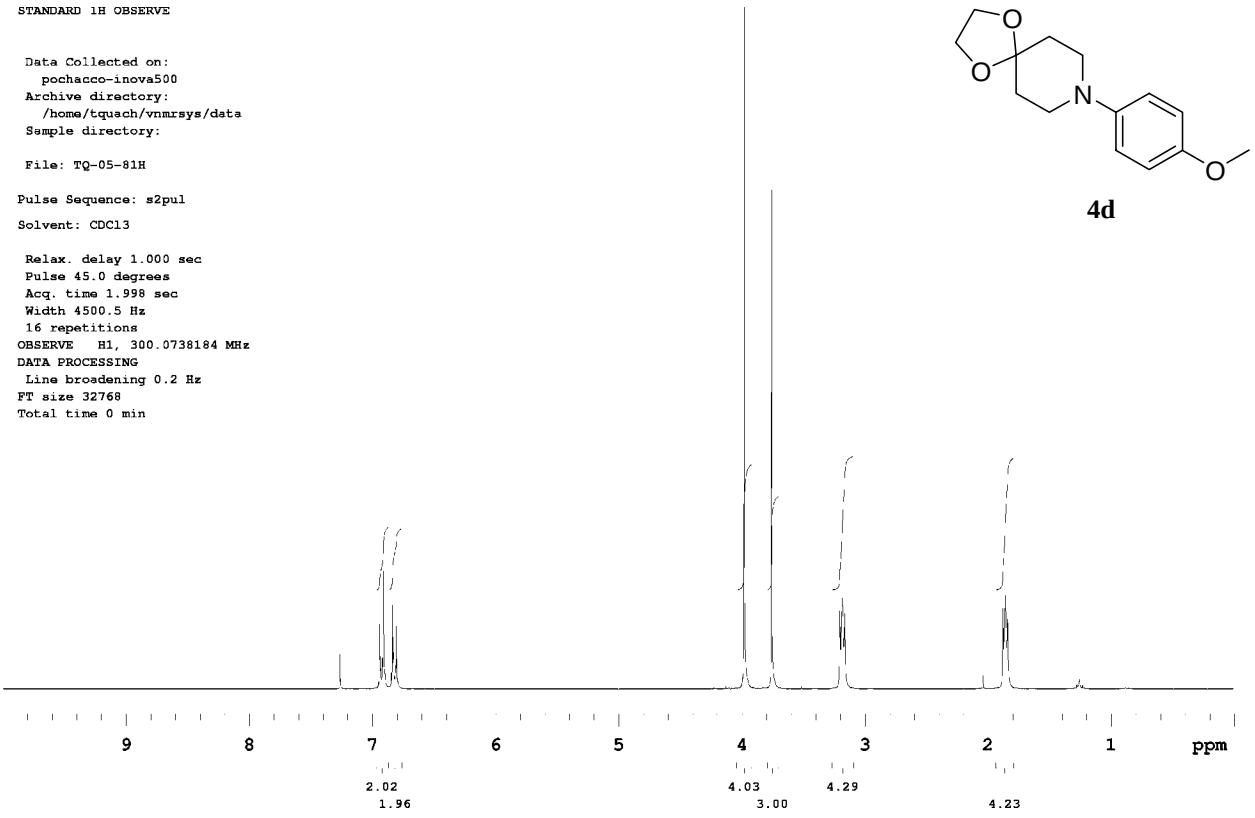

13C OBSERVE
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Mercury-300 "mercury300"
Pulse 48.6 degrees
Acq. time 1.000 sec
Width 18797.0 Hz
296 repetitions
OBSERVE C13, 75.4478925 MHz
DECOUPLE H1, 300.0525807 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 1 hr, 2 min, 5 sec
220
200
180
160
140
120
100
80
60
40
20
0
ppm

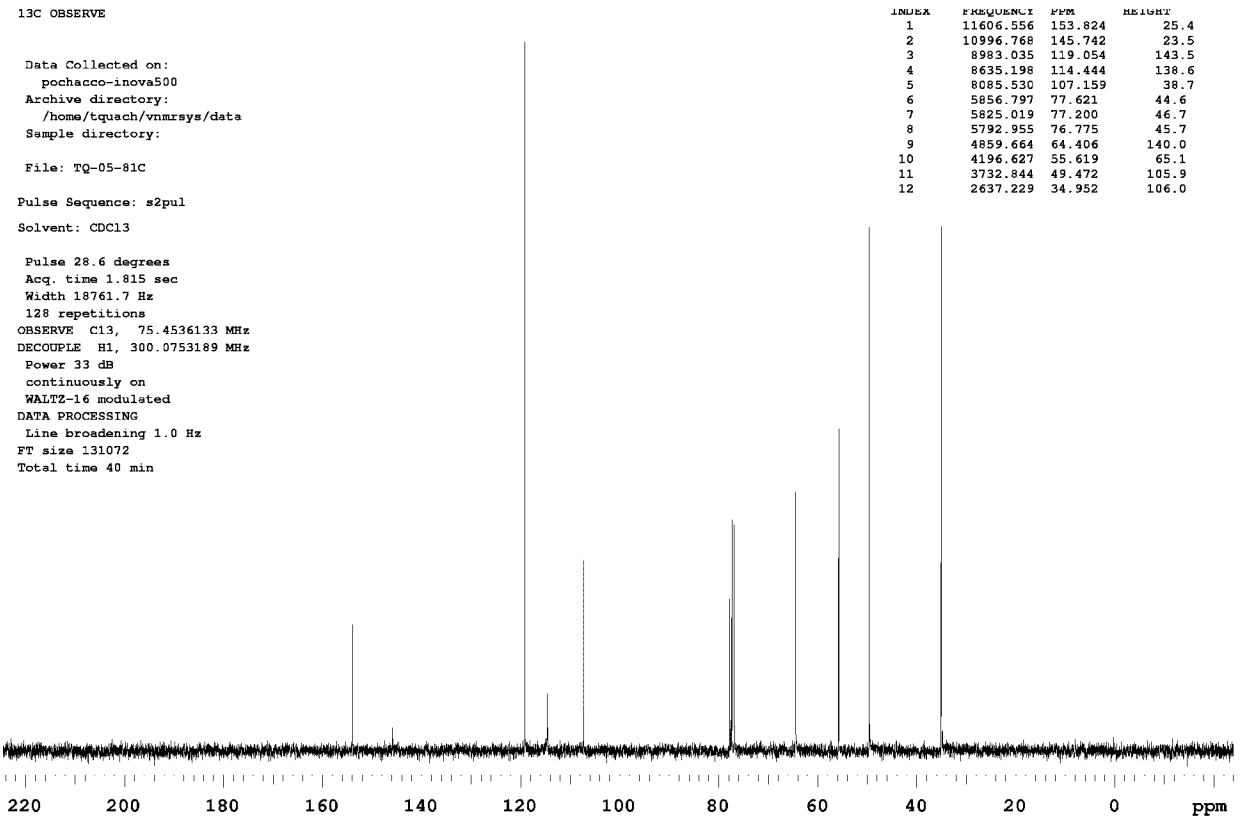

STANDARD 1H OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-79H
Pulse Sequence: s2pul
Solvent: CDCl3
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.998 sec
Width 4500.5 Hz
16 repetitions
OBSERVE H1, 300.0738184 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 32768
Total time 0 min
O
O
N
Cl
4b
9
8
7
6
5
4
3
2
1
ppm
0.98
1.84
0.97
4.00
4.35
4.34

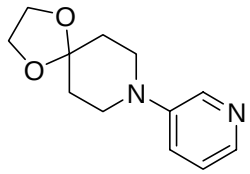

13C OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-79C
Pulse Sequence: s2pul
Solvent: CDCl3
Temp. 25.0 C / 298.1 K
Pulse 49.2 degrees
Acq. time 1.000 sec
Width 18797.0 Hz
344 repetitions
OBSERVE C13, 75.4536115 MHz
DECOUPLE H1, 300.0753189 MHz
Power 40 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 1 hr, 2 min
INDEX FREQUENCY PPM HEIGHT
1 11468.849 151.999 4.3
2 10188.468 135.030 4.6
3 9822.194 130.175 44.4
4 8979.793 119.011 80.1
5 8772.706 116.266 52.8
6 8633.597 114.423 53.8
7 8084.616 107.147 20.5
8 5857.430 77.630 5.0
9 5825.019 77.200 4.8
10 5793.181 76.778 5.3
11 4866.454 64.496 93.9
12 3572.879 47.352 139.5
13 2600.547 34.466 132.1
220
200
180
160
140
120
100
80
60
40
20
0
ppm


STANDARD 1H OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-82H
Pulse Sequence: s2pul
Solvent: CDCl3
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.998 sec
Width 4500.5 Hz
16 repetitions
OBSERVE H1, 300.0738184 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 32768
Total time 0 min
O
O
N
NO2
4c
9
8
7
6
5
4
3
2
1
ppm
0.93 0.97
0.83 1.00
4.00
4.25
4.25


13C OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-82C
Pulse Sequence: s2pul
Solvent: CDCl3
Pulse 28.6 degrees
Acq. time 1.815 sec
Width 18761.7 Hz
224 repetitions
OBSERVE C13, 75.4536142 MHz
DECOUPLE H1, 300.0753189 MHz
Power 33 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 36 min
INDEX FREQUENCY PPM HEIGHT
1 11419.326 151.342 25.3
2 11268.739 149.347 13.8
3 9792.937 129.788 65.0
4 9169.407 121.524 71.3
5 8546.736 113.271 69.3
6 8296.809 109.959 69.9
7 8062.627 106.855 41.3
8 5857.083 77.625 29.1
9 5840.192 77.401 15.6
10 5825.019 77.200 30.4
11 5792.955 76.775 29.7
12 4867.107 64.505 139.5
13 3544.754 46.979 111.3
14 2585.984 34.272 107.0
220
200
180
160
140
120
100
80
60
40
20
0
ppm

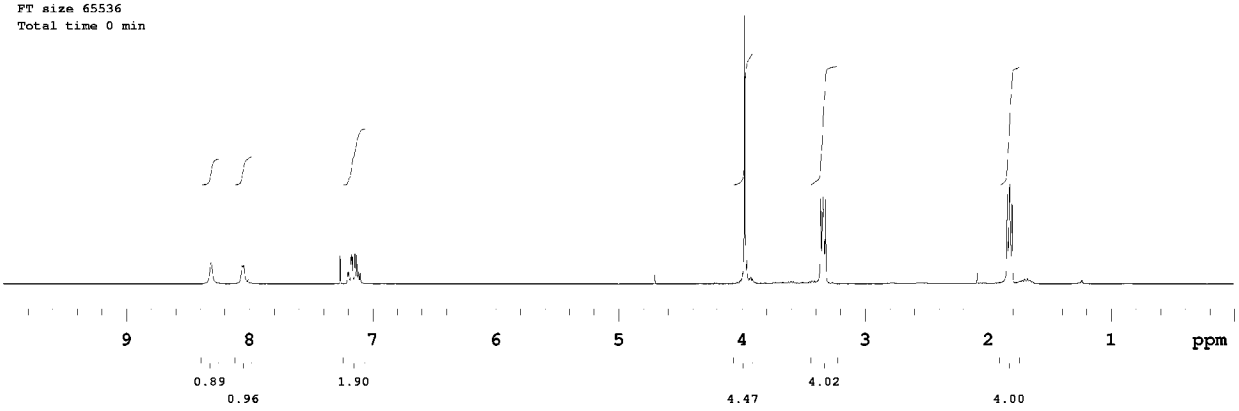

STANDARD 1H OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-81H
Pulse Sequence: s2pul
Solvent: CDCl3
Relax. delay 1.000 sec
Pulse 45.0 degrees
Acq. time 1.998 sec
Width 4500.5 Hz
16 repetitions
OBSERVE H1, 300.0738184 MHz
DATA PROCESSING
Line broadening 0.2 Hz
FT size 32768
Total time 0 min
O
O
N
O
4d
9
8
7
6
5
4
3
2
1
ppm
2.02
1.96
4.03
3.00
4.29
4.23


13C OBSERVE
Data Collected on:
pochacco-inova500
Archive directory:
/home/tquach/vnmrsys/data
Sample directory:
File: TQ-05-81C
Pulse Sequence: s2pul
Solvent: CDCl3
Pulse 28.6 degrees
Acq. time 1.815 sec
Width 18761.7 Hz
128 repetitions
OBSERVE C13, 75.4536133 MHz
DECOUPLE H1, 300.0753189 MHz
Power 33 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 131072
Total time 40 min
INDEX FREQUENCY PPM HEIGHT
1 11606.556 153.824 25.4
2 10996.768 145.742 23.5
3 8983.035 119.054 143.5
4 8635.198 114.444 138.6
5 8085.530 107.159 38.7
6 5856.797 77.621 44.6
7 5825.019 77.200 46.7
8 5792.955 76.775 45.7
9 4859.664 64.406 140.0
10 4196.627 55.619 65.1
11 3732.844 49.472 105.9
12 2637.229 34.952 106.0
220
200
180
160
140
120
100
80
60
40
20
0
ppm



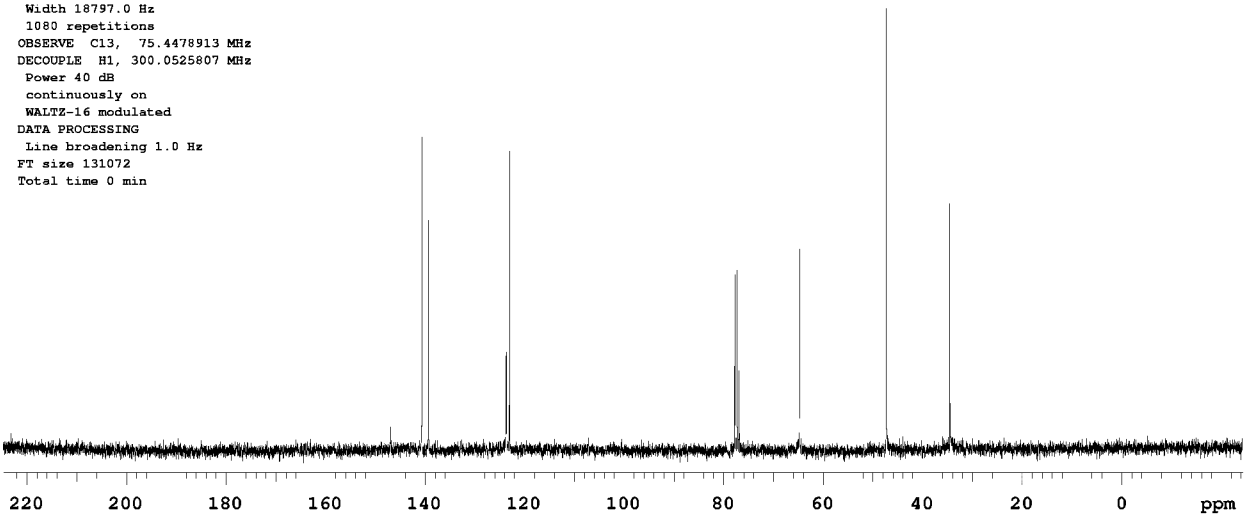
4e

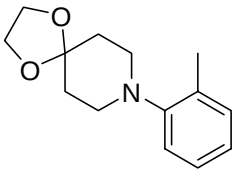
```
STANDARD 1H OBSERVE

 Data Collected on:
   pochacco-inova500
 Archive directory:
   /home/tquach/vnmrsys/data
 Sample directory:

 File: TQ-05-83H

Pulse Sequence: s2pul
Solvent: CDCl3
 Temp. 25.0 C / 298.1 K

 Relax. delay 1.000 sec
 Pulse 45.0 degrees
 Acq. time 2.276 sec
 Width 4492.4 Hz
 16 repetitions
OBSERVE   H1, 300.0510802 MHz
DATA PROCESSING
 Line broadening 0.2 Hz
FT size 65536
Total time 0 min
```




```
13C OBSERVE

 Data Collected on:
   pochacco-inova500
 Archive directory:
   /home/tquach/vnmrsys/data
 Sample directory:

 File: TQ-05-83C

Pulse Sequence: s2pul
Solvent: CDCl3
 Temp. 25.0 C / 298.1 K

 Pulse 49.2 degrees
 Acq. time 1.000 sec
 Width 18797.0 Hz
 1080 repetitions
OBSERVE  C13,  75.4478913 MHz
DECOUPLE  H1, 300.0525807 MHz
 Power 40 dB
 continuously on
 WALTZ-16 modulated
DATA PROCESSING
 Line broadening 1.0 Hz
FT size 131072
Total time 0 min
```

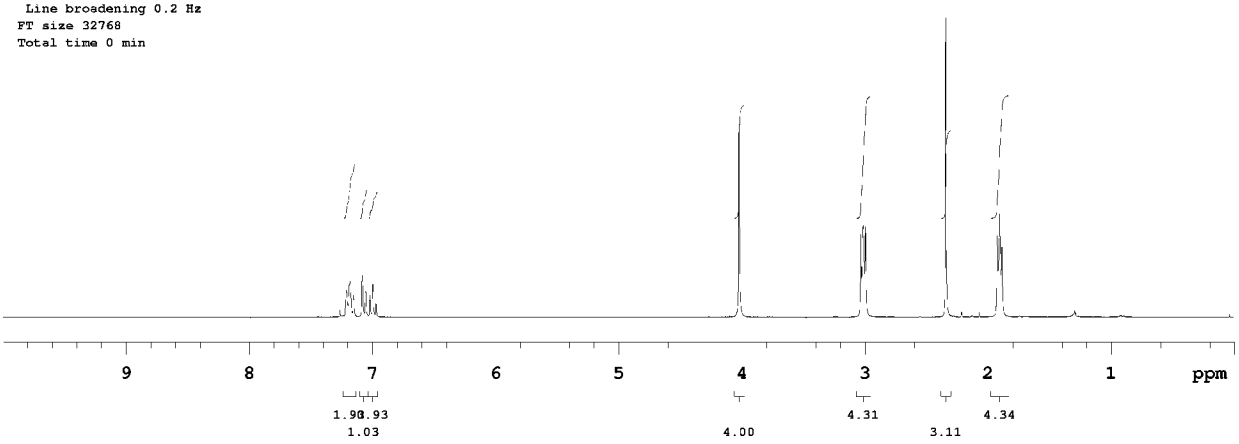
INDEX	FREQUENCY	PPM	HEIGHT
1	11074.025	146.777	4.1
2	10600.479	140.501	64.1
3	10502.385	139.201	45.8
4	9325.548	123.602	19.3
5	9272.772	122.903	59.8
6	8071.554	106.982	18.1
7	5856.701	77.626	34.9
8	5824.864	77.204	35.9
9	5792.740	76.778	36.0
10	4868.881	64.533	139.5
11	3564.406	47.243	131.6
12	2599.818	34.458	128.7





4f

```
STANDARD 1H OBSERVE

 Data Collected on:
   pochacco-inova500
 Archive directory:
   /home/tquach/vnmrsys/data
 Sample directory:

 File: TQ-05-84H

Pulse Sequence: s2pul
Solvent: CDCl3

 Relax. delay 1.000 sec
 Pulse 45.0 degrees
 Acq. time 1.998 sec
 Width 4500.5 Hz
 16 repetitions
OBSERVE   H1, 300.0738181 MHz
DATA PROCESSING
 Line broadening 0.2 Hz
FT size 32768
Total time 0 min
```




```
13C OBSERVE

 Data Collected on:
   pochacco-inova500
 Archive directory:
   /home/tquach/vnmrsys/data
 Sample directory:

 File: TQ-05-84C

Pulse Sequence: s2pul
Solvent: CDCl3

 Pulse 28.6 degrees
 Acq. time 1.815 sec
 Width 18761.7 Hz
 176 repetitions
OBSERVE  C13,  75.4536136 MHz
DECOUPLE  H1, 300.0753189 MHz
 Power 33 dB
 continuously on
 WALTZ-16 modulated
DATA PROCESSING
 Line broadening 1.0 Hz
FT size 131072
Total time 40 min
```

INDEX	FREQUENCY	PPM	HEIGHT
1	11465.131	151.949	30.6
2	10016.813	132.755	33.0
3	9887.984	131.047	68.4
4	9552.171	126.597	79.0
5	9291.651	123.144	68.8
6	9007.370	119.376	72.1
7	8096.123	107.299	38.7
8	5857.083	77.625	40.2
9	5825.019	77.200	40.2
10	5793.241	76.779	39.0
11	4859.950	64.410	139.5
12	3792.678	50.265	117.0
13	2700.498	35.790	113.6
14	1350.948	17.904	63.1