Facile Synthesis of Substituted 5-Amino- and 3-Amino-1,2,4-Thiadiazoles from a Common Precursor

Supplementary Material
(45 pages)

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General. All reagents were obtained commercially unless otherwise noted. Air- and moisture-sensitive liquids and solutions were transferred via syringe or stainless steel cannula. Organic solutions were concentrated under reduced pressure (ca. 15 Torr) by rotary evaporation. Anhydrous 1,4-dioxane and *n*-butanol were purchased from Aldrich and used as received. The LCMS method utilizes an Agilent 1100 Series HPLC LC/MSD system using a Capcell Pak C_{18} Column (4.6 x 50 mm, 3 μm particle size, Cat. No. 61526) with a water/0.1% formic acid and acetonitrile/0.1% formic acid gradient at 3.0 mL/min over a total run time of 3 min. Chromatographic purification of products was accomplished using forced-flow chromatography on a Teledyne ISCO CombiFlash system using preloaded RediSep Rf silica cartridges (35-70 μm). Thin layer chromatography was performed on Analtech silica gel HLF (w/organic binder w/UV254) plates (250 μm). Visualization of the developed chromatogram was accomplished by fluorescence quenching and by staining with ethanolic anisaldehyde, aqueous potassium permanganate, or aqueous ceric ammonium molybdate (CAM) solution.

NMR spectra were acquired on a Bruker 400 Ultrashield operating at 400 and 100 MHz or a Bruker 500 Ultrashield operating at 500 and 126 MHz for ^{1}H and ^{13}C, respectively, and are referenced internally according to residual solvent signals. Data for ^{1}H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s, singlet; d, doublet, t, triplet; q, quartet; m, multiplet), integration, coupling constant (Hz). Data for ^{13}C are reported in terms of chemical shift (δ, ppm). Infrared spectra were recorded as thin films using NaCl salt plates or as neat solids on a Thermo-Nicolet Avatar 370 DTGS spectrometer or a PerkinElmer Spectrometer One FT-IR spectrometer and are reported in frequency of absorption. HRMS data was collected on an Agilent Technologies 1200 Series HPLC with an Agilent Technologies LC/MSD TOF Detector.

Calculations were performed with Gaussian 03[1] and the bond dissociation energies of the carbon-halogen bonds were calculated using B3LYP/6-31G(d).

The results of the BDE calculations are as follows:

C-Cl BDE = 88.2 kcal/mol

C-Br BDE = 80.4 kcal/mol

Data associated with the calculations can be found at the end of the supporting information.

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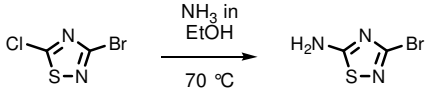
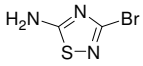
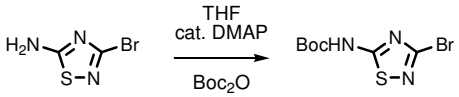
[1] Gaussian 03, Revision E.01, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery, Jr., T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui, A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez, and J. A. Pople, Gaussian, Inc., Wallingford CT, 2004.



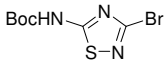
Synthesis of 3-bromo-5-amino-1,2,4-thiadiazole: To a sealed tube containing a solution of ammonia in EtOH (~2 M, 146 mL, 292 mmol, 2.00 equiv) was added 3-bromo-5-chloro-1,2,4-thiadiazole (30.6 g, 153 mmol, 1.05 equiv). The reaction mixture was heated to 70 °C over 4 h during which time a precipitate formed. The resulting suspension was left to cool to room temperature overnight (~14 h) and then filtered through a sintered glass filter. The filtered precipitate was rinsed sequentially with Et_2O (100 mL) and H_2O (3 x 50 mL). The resulting gummy white residue was dried for 24 h under high vacuum (~ 1mm Hg) in the presence of solid NaOH pellets to afford the desired product as an off-white powder (17.0 g, 64%). In some cases, NMR may show the presence of an errant peak due to contamination by ammonium chloride. Additional washings with water will remove this impurity.



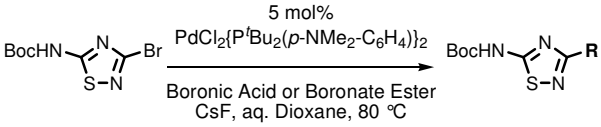
^{1}H NMR (400 MHz, DMSO-d_6) δ ppm 8.36 (br. s., 2 H). ^{13}C NMR (101 MHz, DMSO-d_6) δ ppm 183.94, 140.68. HRMS *m/z* calcd for $C_{12}H_{16}BrN_3O_2S$ (M^+ + H) 179.9231, found 179.9231. IR (neat) 3269, 3091, 1650, 1544, 1450, 1237, 1080, 775 cm^{-1}.



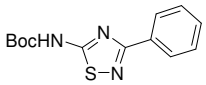
Synthesis of *tert*-butyl 3-bromo-1,2,4-thiadiazol-5-ylcarbamate: To a solution of DMAP (1.15 g, 9.44 mmol, 0.10 equiv) and 3-bromo-1,2,4-thiadiazol-5-amine (17.0 g, 94.4 mmol) in THF (200 ml) was added Boc_2O (28.9 g, 132 mmol, 1.40 equiv). The reaction mixture was stirred overnight (~14 h) at 65 °C. Volatiles were removed by concentration under reduced pressure. The residue was purified by chromatography on silica using 0 -> 25% EtOAc/Hexanes as eluant to afford the desired product as white solid (23.0 g, 87%).



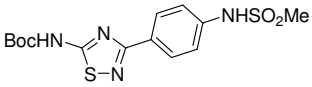
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 10.47 (br. s., 1H), 1.58 (s, 9H). ^{13}C NMR (101 MHz, $CDCL_3$) δ ppm 179.29, 152.64, 140.33, 85.19, 28.12. HRMS *m/z* calcd for $C_7H_{10}BrN_3O_2S$ (M^+ + H) 279.9755, found 223.9129 ($M^+ + H - C_4H_8$). IR (thin film) 3156, 3053, 2980, 1716, 1541, 1242, 1152, 930, 857 cm^{-1}.



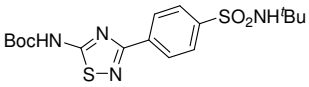
General procedure for Suzuki-Miyaura coupling of *tert*-butyl 3-bromo-1,2,4-thiadiazol-5-ylcarbamate: To a mixture of *tert*-butyl 3-bromo-1,2,4-thiadiazol-5-ylcarbamate (2.0 mmol), boronic acid or ester (2.6 mmol, 1.3 equiv.), cesium fluoride (4.2 mmol, 2.1 equiv.), and Pd catalyst ($PdCl_2\{P^tBu_2(p\text{-}NMe_2\text{-}C_6H_4)\}$, 70.8 mg, 0.10 mmol, 0.05 equiv.) was added 1,4-dioxane (6.0 mL) and water (0.60 mL). The reaction mixture was degassed by bubbling nitrogen through the solution for 5 min and the reaction was heated to 80 °C until the *tert*-butyl 3-bromo-1,2,4-thiadiazol-5-ylcarbamate was consumed (~6 h). The reaction mixture was diluted with EtOAc (100 mL), washed with water (1 x 20 mL), brine (1 x 20 mL), dried over $MgSO_4$, filtered, and concentrated. Purification by flash column chromatography on silica gel (EtOAc in hexanes) gave the desired product.



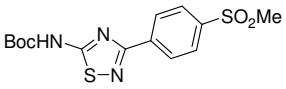
^{1}H NMR ((400 MHz, $CDCl_3$) δ ppm 11.14 (br. s., 1 H), 8.21 (dd, *J*=6.2, 2.8 Hz, 2 H), 7.36 - 7.56 (m, 3 H), 1.26 (s, 9 H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 178.35, 167.61, 152.83, 132.62, 130.18, 128.56, 128.02, 83.76, 27.58. HRMS *m/z* calcd for $C_{13}H_{15}N_3O_2S$ (M^+ + H) 278.0963, found 278.0960. IR (thin film) 3154, 3064, 2979, 1720, 1549, 1338, 1247, 1153, 865, 711 cm^{-1}.



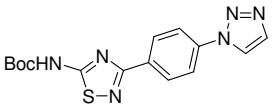
^{1}H NMR (400 MHz, DMSO-d_6) δ 12.43 (br. s., 1H), 10.07 (br. s., 1H), 8.07 (d, *J* = 8.7 Hz, 2H), 7.31 (d, *J* = 8.6 Hz, 2H), 3.06 (s, 3H), 1.51 (s, 9H). ^{13}C NMR (101 MHz, DMF-d_7) δ 178.0, 167.5, 154.1, 140.8, 128.9, 128.6, 119.2, 83.0, 39.1, 27.5. HRMS *m/z* calcd for $C_{14}H_{19}N_4O_4S_2$ (M^+ + H) 371.0847, found 371.0851. IR (neat) 1717, 1548, 1337, 1245, 973, 749 cm^{-1}.



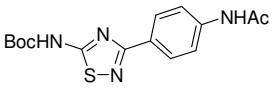
^{1}H NMR (400 MHz, DMSO-d_6) δ 12.57 (br. s., 1H), 8.28 (d, *J* = 8.6 Hz, 2H), 7.96 (d, *J* = 8.6 Hz, 2H), 7.65 (br. s., 1H), 1.53 (s, 9H), 1.12 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.1, 166.0, 153.8, 145.4, 135.3, 127.9, 127.0, 83.0, 53.4, 29.8, 27.8. HRMS *m/z* calcd for $C_{17}H_{25}N_4O_4S_2$ (M^+ + H) 413.1317, found 413.1314. IR (neat) 171727, 1368, 1287, 1248, 1151, 996, 730 cm^{-1}.



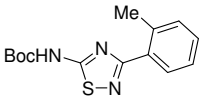
^{1}H NMR (400 MHz, DMSO-d_6) δ 12.57 (br. s., 1H), 8.34 (d, J = 8.4 Hz, 2H), 8.06 (d, J = 8.4 Hz, 2H), 3.26 (s, 3H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.2, 165.8, 153.7, 141.8, 136.7, 128.1, 127.7, 83.1, 43.5, 27.7. HRMS m/z calcd for $C_{14}H_{18}N_3O_4S_2$ (M^+ + H) 356.0738, found 356.0734. IR (neat) 1706, 1551, 1303, 1126, 781, 719 cm^{-1}.



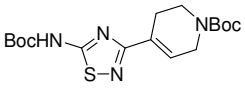
^{1}H NMR (400 MHz, DMSO-d_6) δ 12.54 (br. s., 1H), 8.92 (s, 1H), 8.32 (d, J = 8.8 Hz, 2H), 8.09 (d, J = 8.8 Hz, 2H), 8.02 (s, 1H), 1.54 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.0, 166.2, 153.7, 137.6, 134.6, 132.5, 128.8, 123.2, 120.3, 82.9, 27.8. HRMS m/z calcd for $C_{15}H_{17}N_6O_2S$ (M^+ + H) 345.1133, found 345.1142. IR (neat) 1702, 1548, 1236, 847 cm^{-1}.



8 mol% of the Pd catalyst was used and reaction was heated to 90 °C over 16 h. ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.41 (br. s., 1H), 10.14 (br. s., 1H), 8.05 (d, J = 8.4 Hz, 2H), 7.71 (d, J = 8.6 Hz, 2H), 2.08 (s, 3H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.5, 168.6, 167.1, 153.6, 141.0, 128.0, 127.3, 118.7, 82.8, 27.8, 24.1. HRMS m/z calcd for $C_{15}H_{19}N_4O_3S$ (M^+ + H) 335.1178, found 335.1182. IR (neat) 1710, 1599, 1447, 1327, 1286, 1150, 853, 770 cm^{-1}.

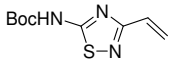


^{1}H NMR (400 MHz, $CDCl_3$) δ 10.34 (br. s., 1H), 7.91 (d, J = 1H), 7.35-7.24 (m, 3H), 2.64 (s, 3H), 1.33 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 177.2, 168.6, 152.8, 137.8, 132.4, 131.5, 130.6, 129.5, 125.8, 83.6, 27.7, 21.7. HRMS m/z calcd for $C_{14}H_{18}N_3O_2S$ (M^+ + H) 292.1119, found 292.1129. IR (neat) 1715, 1543, 1244, 769, 731 cm^{-1}.

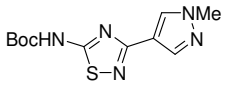


^{1}H NMR (400 MHz, DMSO-d_6) δ 12.32 (br. s., 1H), 6.81 (m, 1H), 4.05 (m, 2H), 3.50 (br. t., J = 5.7 Hz, 2H), 2.55 (m, 2H), 1.50 (s, 9H), 1.42 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 176.6, 167.8, 153.9, 153.6, 129.6, 128.6, 82.7, 78.9, 43.3, 43.0, 28.1, 27.7, 25.0. HRMS m/z calcd for

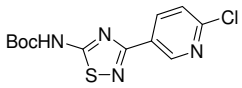
$C_{17}H_{27}N_4O_4S$ (M^+ + H) 383.1753, found 383.1759. IR (neat) 1717, 1674, 1546, 1424, 1366, 1319, 1152, 1122, 861, 712 cm^{-1}.



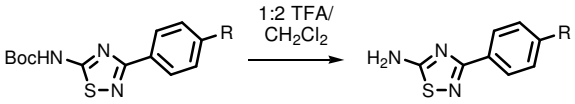
^1H NMR (400 MHz, DMSO-d_6) δ 12.34 (br. s., 1H), 6.70 (dd, J = 17.2, 10.5 Hz, 1H), 6.21 (dd, J = 17.5, 1.7 Hz, 1H), 5.69 (dd, J = 10.6, 1.9 Hz, 1H), 1.51 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.0, 167.2, 153.6, 130.0, 122.8, 82.8, 27.7. HRMS m/z calcd for $C_9H_{14}N_3O_2S$ (M^+ + H) 228.0806, found 228.0807. IR (neat) 1712, 1558, 1298, 1238, 1080, 993, 940, 827, 779 cm^{-1}.



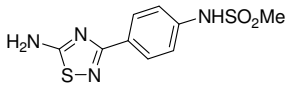
^1H NMR (400 MHz, DMSO-d_6) δ 12.36 (br. s., 1H), 8.19 (s, 1H), 7.86 (s, 1H), 3.90 (s, 3H), 1.51 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 177.2, 162.4, 153.5, 137.9, 130.8, 116.8, 82.7, 38.7, 27.8. HRMS m/z calcd for $C_{11}H_{16}N_5O_2S$ (M^+ + H) 282.1024, found 282.1017. IR (neat) 1707, 1550, 1240, 1152 cm^{-1}.



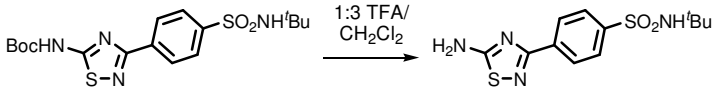
^1H NMR (400 MHz, DMSO-d_6) δ 12.60 (br. s., 1H), 9.06 (d, J = 2.0 Hz, 1H), 8.44 (dd, J = 8.4, 2.6 Hz, 1H), 7.67 (d, J = 8.4 Hz, 1H), 1.53 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 178.3, 164.0, 153.6, 151.4, 148.5, 138.1, 127.8, 124.7, 83.1, 27.7. HRMS m/z calcd for $C_{12}H_{14}ClN_4O_2S$ (M^+ + H) 313.0526, found 313.0521. IR (neat) 1699, 1542, 1364, 1275, 1246, 1023, 841, 744 cm^{-1}.



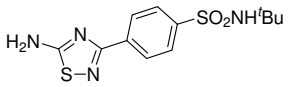
General procedure for Boc group removal: To a solution of the *tert*-butylcarbamate (5.0 mmol) in dichloromethane (20 mL) was added anisol (0.50 mL) and TFA (10 mL). The reaction mixture was stirred at room temperature until the *tert*-butylcarbamate was consumed. The solution was concentrated and the concentrate was suspended in saturated $NaHCO_3$ (50 mL). The mixture was stirred for 30 min. The solid was collected by filtration and washed with water followed by hexanes and dried under high vacuum to give the desired product.



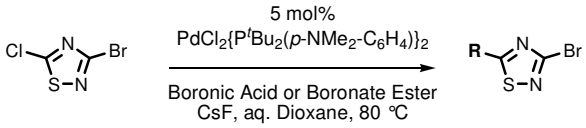
^{1}H NMR (400 MHz, DMSO-d_6) δ 10.02 (br. s., 3H), 8.01 (d, J = 8.6 Hz, 2H), 7.27 (d, J = 8.8 Hz, 2H), 3.06 (s, 3H). ^{13}C NMR (101 MHz, DMF-d_7) δ 184.3, 168.8, 140.5, 129.5, 129.0, 119.3, 39.2. HRMS *m/z* calcd for $C_9H_{11}N_4O_2S_2$ (M^+ + H) 271.0323, found 271.0327. IR (neat) 1620, 1515, 1461, 1309, 965, 744 cm^{-1}.



Procedure for Boc group removal from equation 6: To a solution of *tert*-butyl 3-(4-(*N-tert*-butylsulfamoyl)phenyl)-1,2,4-thiadiazol-5-ylcarbamate (1.90 g, 4.61 mmol) in dichloromethane (15 mL) at 0 °C was added anisol (0.50 mL) and TFA (5 mL). The reaction mixture was warmed to room temperature and stirred for 3 h and concentrated. The concentrate was suspended in a mixture of saturated $NaHCO_3$ (120 mL) and EtOAc (50 mL). The mixture was stirred for 15 min and the solid was collected by filtration, washed with water (50 mL) followed by hexanes (50 mL) and dried under high vacuum to give 4-(5-amino-1,2,4-thiadiazol-3-yl)-*N-tert*-butylbenzenesulfonamide (1.11 g, 77% yield) as a white solid.

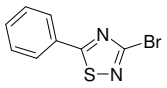


^{1}H NMR (400 MHz, DMSO-d_6) δ 8.19 (d, *J* = 8.4 Hz, 2H), 8.10 (br. s., 2H), 7.90 (d, *J* = 8.4 Hz, 2H), 7.58 (br. s., 1H), 1.10 (s, 9H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 183.8, 167.1, 144.9, 135.8, 127.8, 126.7, 53.4, 29.7. HRMS *m/z* calcd for $C_{12}H_{17}N_4O_2S_2$ (M^+ + H) 313.0793, found 313.0798. IR (neat) 1654, 1536, 1397, 1286, 1092, 1001, 846, 696 cm^{-1}.

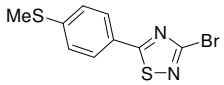


General procedure for cross-coupling of 3-bromo-5-chloro-1,2,4-thiadiazole: A solid mixture of reactants containing 3-bromo-5-chloro-1,2,4-thiadiazole (weighed by addition from syringe, 400 mg, 2.00 mmol), cesium fluoride (608 mg, 4.00 mmol, 2.0 equiv), boronic acid or boronate ester (2.400 mmol, 1.2 equiv), and Pd catalyst ($PdCl_2\{P^tBu_2(p\text{-}NMe_2\text{-}C_6H_4)\}$, 70.8 mg, 0.10 mmol, 0.05 equiv.) was suspended in 1,4-dioxane w/10% H_2O (10 mL). The suspension was degassed by bubbling nitrogen through the solution for 5 min and then heated to 80 °C for 16 h (in many cases reactions are complete after 6 h, however yields are reported for 16 h of reaction). Volatiles were removed by concentration under reduced pressure. The leftover residue was solubilized with 60 mL of a 1:1 mixture of Water and Ethyl Acetate. The organic phase was separated and the aqueous phase was extracted further with Ethyl Acetate (2 x 20 mL). The combined organic extracts were dried with $MgSO_4$, filtered, and concentrated.

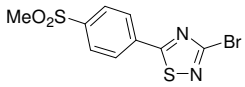
Purification by flash column chromatography on silica gel (Et_2O in hexanes) gave the desired product. **Note:** In the case of coupling using boronic acids or boronate esters without polar functionality, the use of 1.75 equiv of 3-bromo-5-chloro-1,2,4-thiadiazole minimizes the formation of bis-coupled product that can complicate purification.



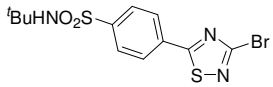
1.75 equiv of 3-bromo-5-chloro-1,2,4-thiadiazole was used. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.96 (d, *J*=7.3 Hz, 2H), 7.56 - 7.62 (m, 1H), 7.50 - 7.56 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 190.35, 145.93, 132.87, 129.45, 129.34, 127.31. HRMS *m/z* calcd for $C_8H_5BrN_2S$ (M^+ + H) 240.9435, found 240.9436. IR (thin film) 1595, 1462, 1369, 1200, 990, 891, 767 cm^{-1}.



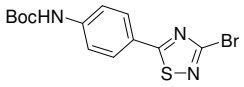
1.75 equiv of 3-bromo-5-chloro-1,2,4-thiadiazole was used. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.80 - 7.87 (m, 2 H), 7.28 - 7.35 (m, 2 H), 2.55 (s, 3 H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 189.70, 145.79, 145.77, 127.45, 125.77, 125.49, 14.84. HRMS *m/z* calcd for $C_9H_7BrN_2S_2$ (M^+ + H) 286.9312, found 286.9313. IR (thin film) 2919, 1592, 1451, 1371, 1205, 1095, 893, 815 cm^{-1}.



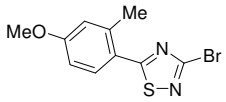
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 8.14 - 8.18 (m, 2H), 8.09 - 8.14 (m, 2H), 3.12 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 187.96, 146.66, 143.97, 133.70, 128.62, 128.20, 44.35. HRMS *m/z* calcd for $C_9H_7BrN_2O_2S_2$ (M^+ + H) 318.9211, found 318.9212. IR (thin film) 3003, 2918, 1454, 1296, 1207, 1149, 998, 897, 941, 774 cm^{-1}.



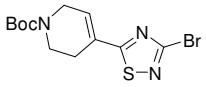
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.97 - 8.14 (m, 4 H) 5.27 (s, 1 H) 1.24 (s, 9 H). ^{13}C NMR (126 MHz, $CDCl_3$) δ ppm 188.35, 147.15, 146.37, 132.17, 127.95, 127.81, 55.05, 30.08. HRMS *m/z* calcd for $C_{12}H_{14}BrN_3O_2S_2$ (M^+ + H) 375.9789, found 375.9783. IR (thin film) 3277, 3093, 2975, 1452, 1324, 1202, 1153, 1094, 993, 895, 843 cm^{-1}.



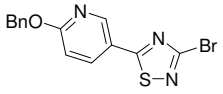
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.85 (d, *J*=8.6 Hz, 2H), 7.51 (d, *J*=8.6 Hz, 2H), 6.95 (br. s., 1H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 189.60, 152.09, 145.56, 142.77, 128.38, 123.62, 118.28, 81.40, 28.19. HRMS *m/z* calcd for $C_{13}H_{14}BrN_3O_2S$ (M^+ + H) 356.0068, found 356.0067. IR (thin film) 3326, 2978, 1710, 1607, 1533, 1369, 1232, 1155, 1054, 892, 743 cm^{-1}.



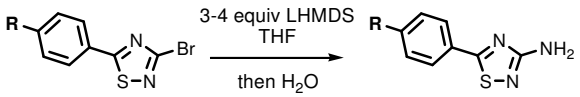
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 8.07 (d, *J*=8.1 Hz, 1H), 6.82 - 6.91 (m, 2H), 3.88 (s, 3H), 2.61 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 189.01, 162.34, 145.00, 139.59, 131.51, 121.93, 116.99, 112.18, 55.44, 22.37. HRMS *m/z* calcd for $C_{10}H_9BrN_2OS$ (M^+ + H) 284.9697, found 284.9698. IR (thin film) 2967, 1608, 1425, 1354, 1231, 1112, 990, 808 cm^{-1}.



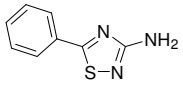
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 6.82 (m, 1 H), 4.16 (q, *J*=3.0 Hz, 2 H), 3.64 (t, *J*=5.8 Hz, 2 H), 2.55 - 2.65 (m, 2 H) 1.48 (s, 9 H). ^{13}C NMR (126 MHz, $CDCl_3$, 57 °C) δ ppm 190.15, 154.46, 145.54, 131.64, 128.08, 80.30, 43.61, 39.73, 28.39, 26.41. HRMS *m/z* calcd for $C_{12}H_{16}BrN_3O_2S$ (M^+ + H) 346.0147, found 289.9599 (M^+ + H – C_4H_8). IR (thin film) 2975, 1696, 1418, 1221, 1165, 943, 860 cm^{-1}.



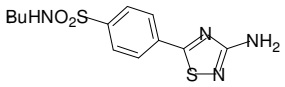
^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 8.77 (d, *J*=2.4 Hz, 1 H), 8.13 (dd, *J*=8.8, 2.4 Hz, 1 H), 7.48 (d, *J*=7.1 Hz, 2 H), 7.38 - 7.43 (m, 2 H), 7.33 - 7.38 (m, 1 H), 6.93 (d, *J*=8.8 Hz, 1 H), 5.48 (s, 2 H). ^{13}C NMR (126 MHz, $CDCl_3$) δ ppm 187.24, 166.14, 146.81, 145.93, 137.11, 136.34, 128.52, 128.15, 128.12, 119.74, 112.17, 68.52. HRMS *m/z* calcd for $C_{14}H_{10}BrN_3OS$ (M^+ + H) 347.9806, found 347.9803. IR (thin film) 3064, 3029, 1604, 1560, 1394, 1353, 1271, 1208, 1137, 980, 837 cm^{-1}.



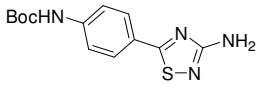
General procedure for amination of 3-bromo-5-substituted-1,2,4-thiadiazoles: To a solution of 3-bromo-5-substituted-1,2,4-thiadiazole (2.74 mmol) in THF (15 mL) was added 11 mL of a 1.0 M solution of LHMDS in THF (11 mmol, 4 equiv). After stirring for 1 h, 5 mL of water was added and the mixture stirred for 3h. Volatiles were removed by concentration under reduced pressure. The leftover residue was solubilized with 100 mL of a 1:1 mixture of Water and Ethyl Acetate. The organic phase was separated and the aqueous phase was extracted further with Ethyl Acetate (2 x 30 mL). The combined organic extracts were dried with $MgSO_4$, filtered, and concentrated. Purification by flash column chromatography on silica gel (EtOAc in hexanes) gave the desired product. **Note:** In the case of thiadiazoles lacking acidic protons, it is possible to use 3 equiv of LHMDS.



3 equiv of LHMDS was used. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm 7.81 - 7.95 (m, 2H), 7.41 - 7.55 (m, 3H), 5.23 (br. s., 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ ppm 187.76, 169.73, 131.75, 130.50, 129.13, 126.91. HRMS *m/z* calcd for $C_8H_7N_3S$ (M^+ + H) 178.0439, found 178.0440. IR (thin film) 3403, 3299, 3199, 1625, 1529, 1359, 1239, 1040, 916 cm^{-1}.



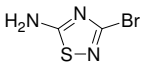
^{1}H NMR (500 MHz, DMSO-d_6) δ ppm 8.06 (d, *J*=8.6 Hz, 2 H), 7.97 (d, *J*=8.6 Hz, 2 H), 7.72 (s, 1 H), 6.92 (s, 2 H), 1.11 (s, 9 H). ^{13}C NMR (101 MHz, DMSO-d_6) δ ppm 184.17, 171.29, 146.77, 132.74, 127.38, 127.30, 53.51, 29.77. HRMS *m/z* calcd for $C_{12}H_{16}N_4O_2S_2$ (M^+ + H) 313.0793, found 313.0797. IR (thin film) 3375,3315, 3207, 2966, 1630, 1522, 1321, 1148, 991, 835 cm^{-1}.



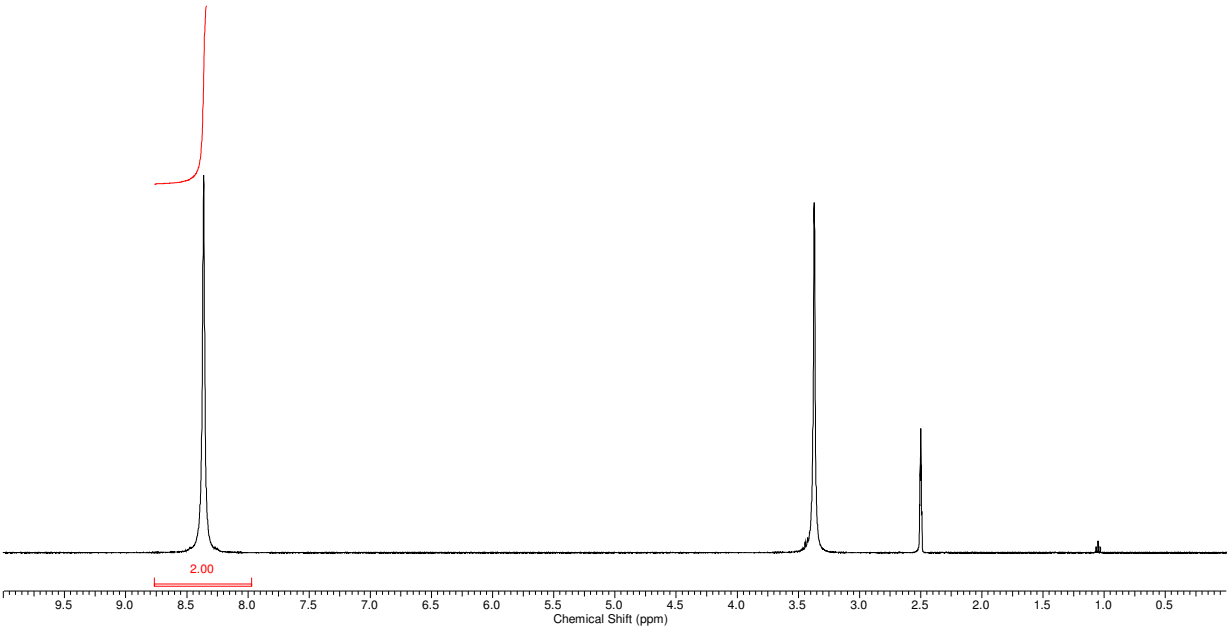
^{1}H NMR ((400 MHz, DMSO-d_6) δ ppm 9.75 (s, 1 H), 7.77 (d, *J*=8.8 Hz, 2 H), 7.61 (d, *J*=8.8 Hz, 2 H), 6.73 (s, 2 H), 1.49 (s, 9 H). ^{13}C NMR (101 MHz, DMSO-d_6) δ ppm 185.27, 170.84, 152.53, 142.86, 127.47, 123.89, 118.10, 79.69, 28.04. HRMS *m/z* calcd for $C_{13}H_{16}N_4O_2S$ (M^+ + H) 293.1072, found 293.1074. IR (thin film) 3363, 3320, 3198, 2979, 1702, 1630, 1504, 1232, 1165, 1036, 952, 840 cm^{-1}.

Recorded ^{1}H and ^{13}C NMR Spectral Data

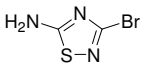
104908-42-1_010000fid.esp



400 MHz, DMSO

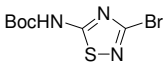


104908-42-1_011000fid.esp

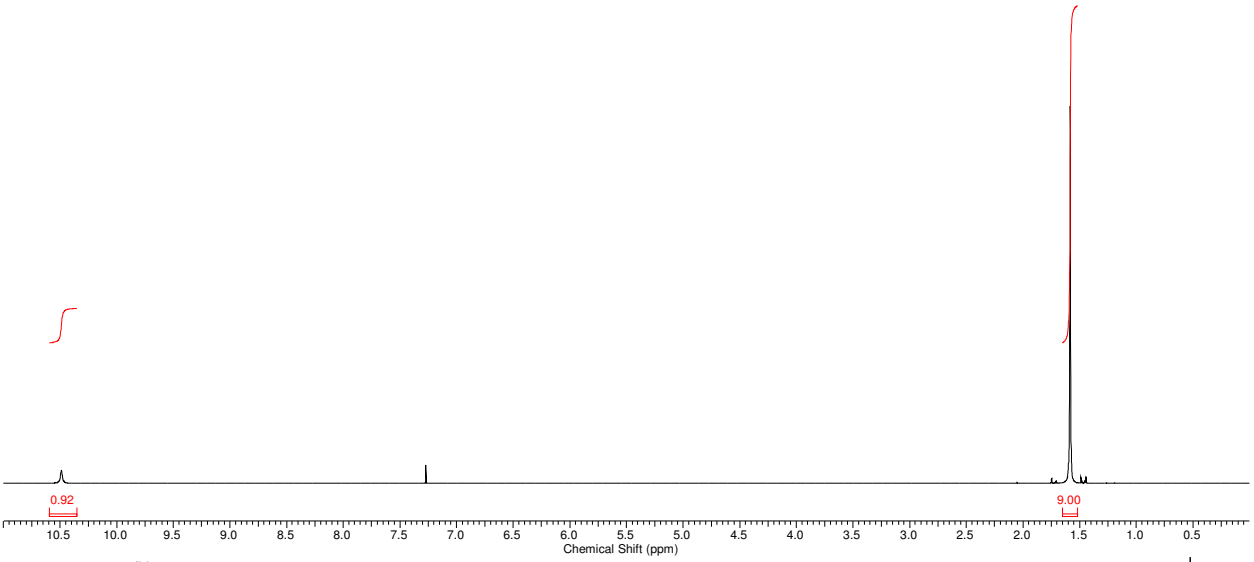


101 MHz, DMSO

104908-37-1_010000fid.esp



500 MHz, $CDCl_3$



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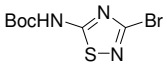

101 MHz, $CDCl_3$

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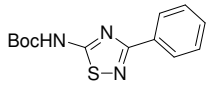
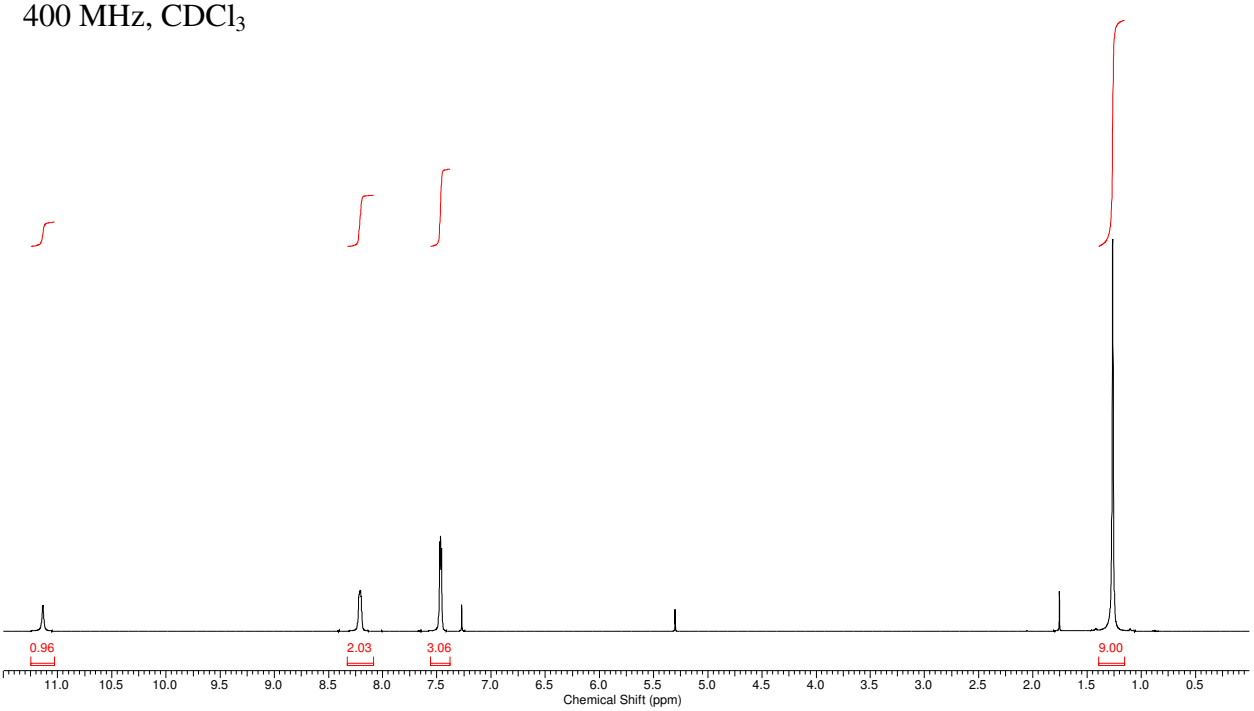


400 MHz, $CDCl_3$



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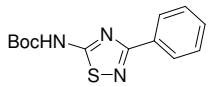
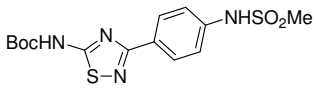
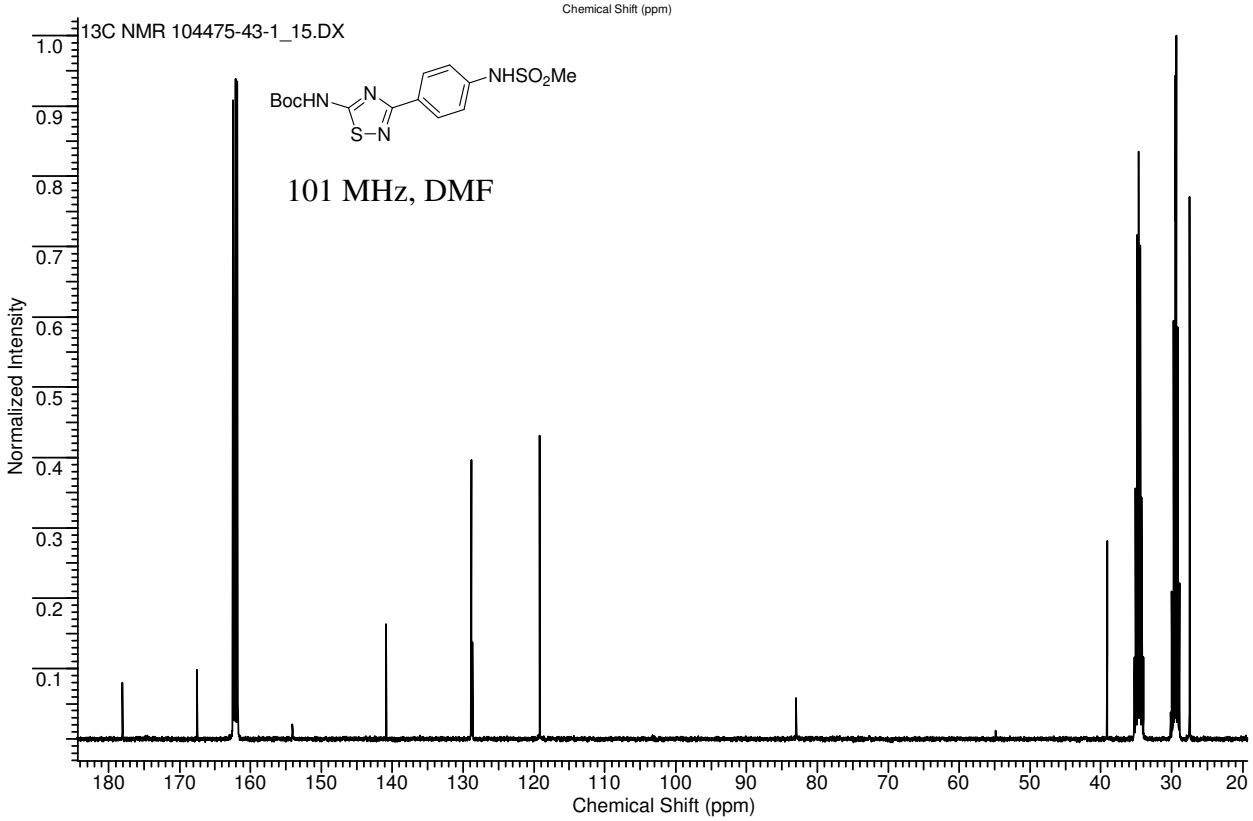


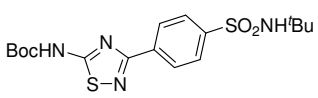
101 MHz, $CDCl_3$


BocHN
N
S–N
NHSO2Me

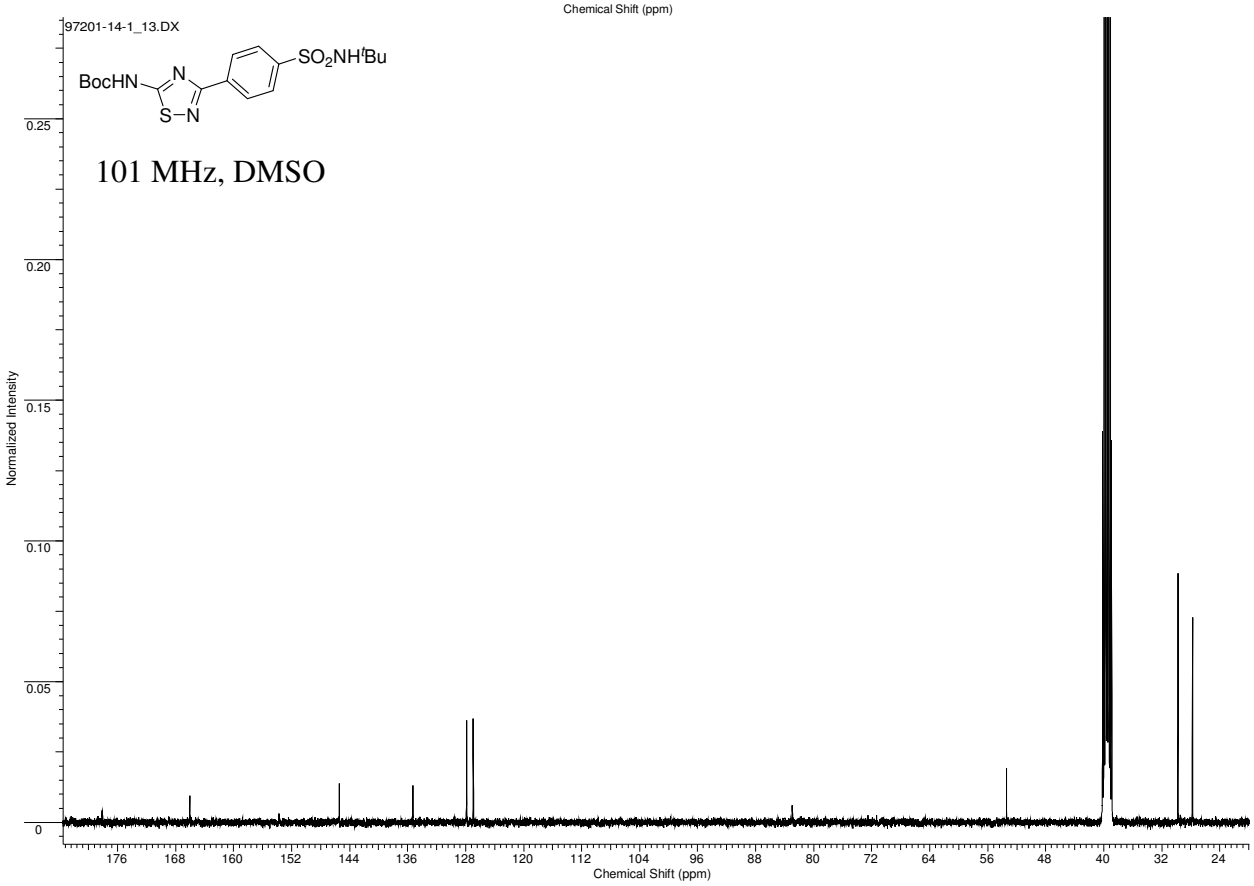
400 MHz, DMSO

0.96
0.98
1.98
1.99
3.01
9.00
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
Chemical Shift (ppm)

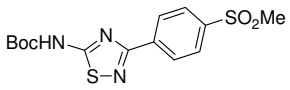

13C NMR 104475-43-1_15.DX
BocHN
N
S–N
NHSO2Me
101 MHz, DMF
Normalized Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
Chemical Shift (ppm)



400 MHz, DMSO

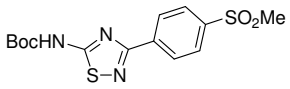


101 MHz, DMSO

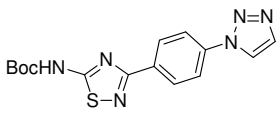


400 MHz, DMSO

13C NMR 104475-44-1_11.DX

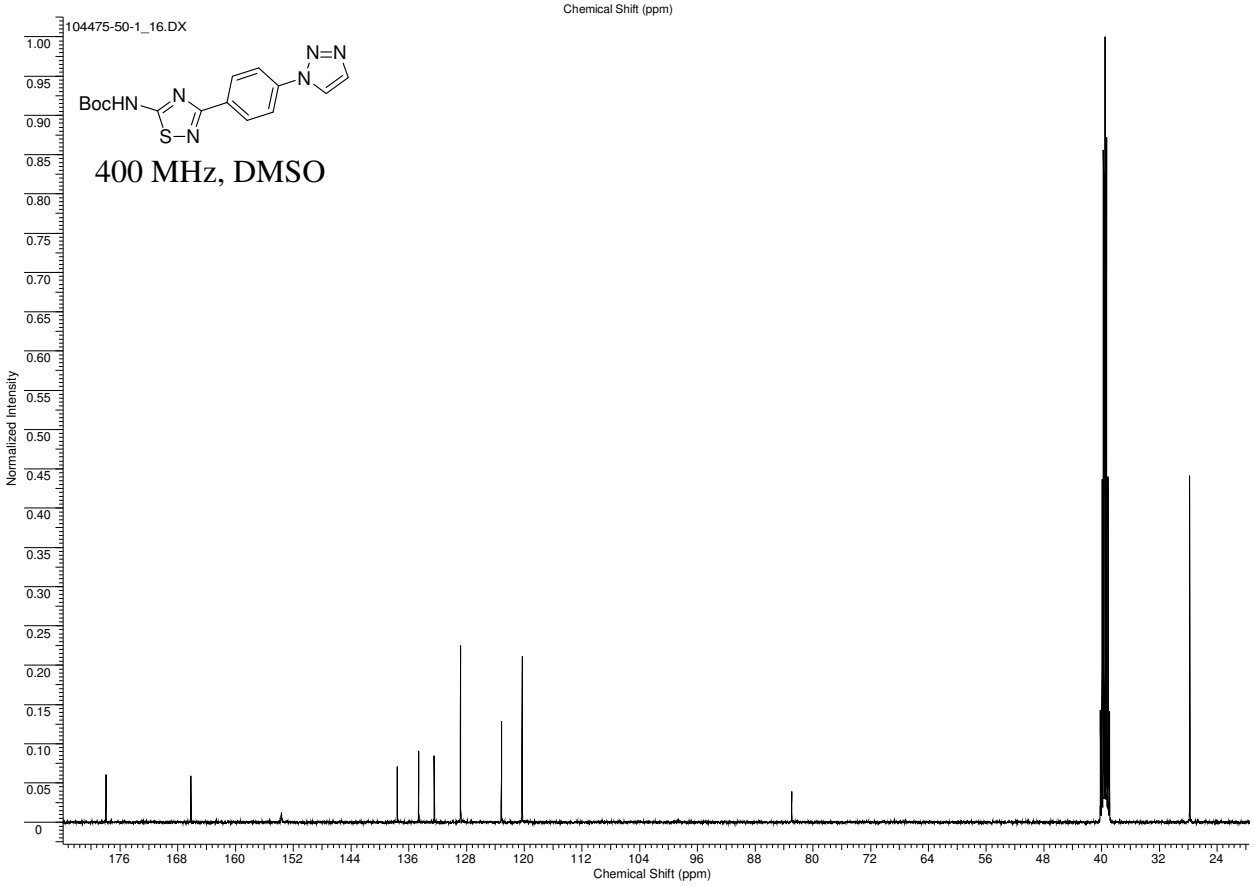


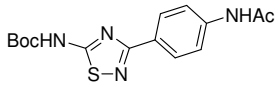
101 MHz, DMSO


BocHN
N
S–N
N=N
N

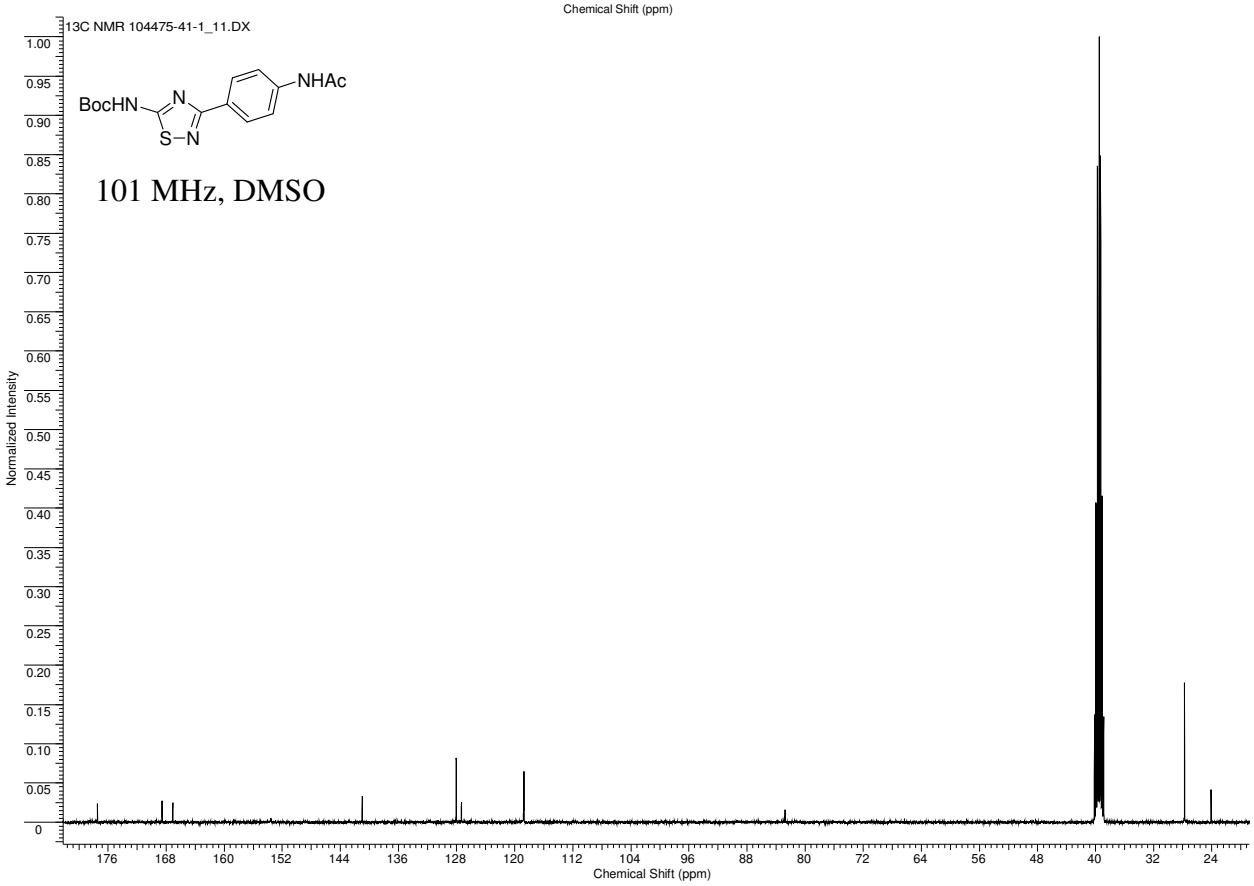
400 MHz, DMSO

0.92
1.01
3.01
9.00
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
Chemical Shift (ppm)

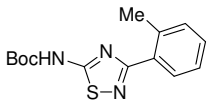

104475-50-1_16.DX
BocHN
N
S–N
N=N
N
400 MHz, DMSO
Normalized Intensity
1.00 0.95 0.90 0.85 0.80 0.75 0.70 0.65 0.60 0.55 0.50 0.45 0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05 0
176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24
Chemical Shift (ppm)



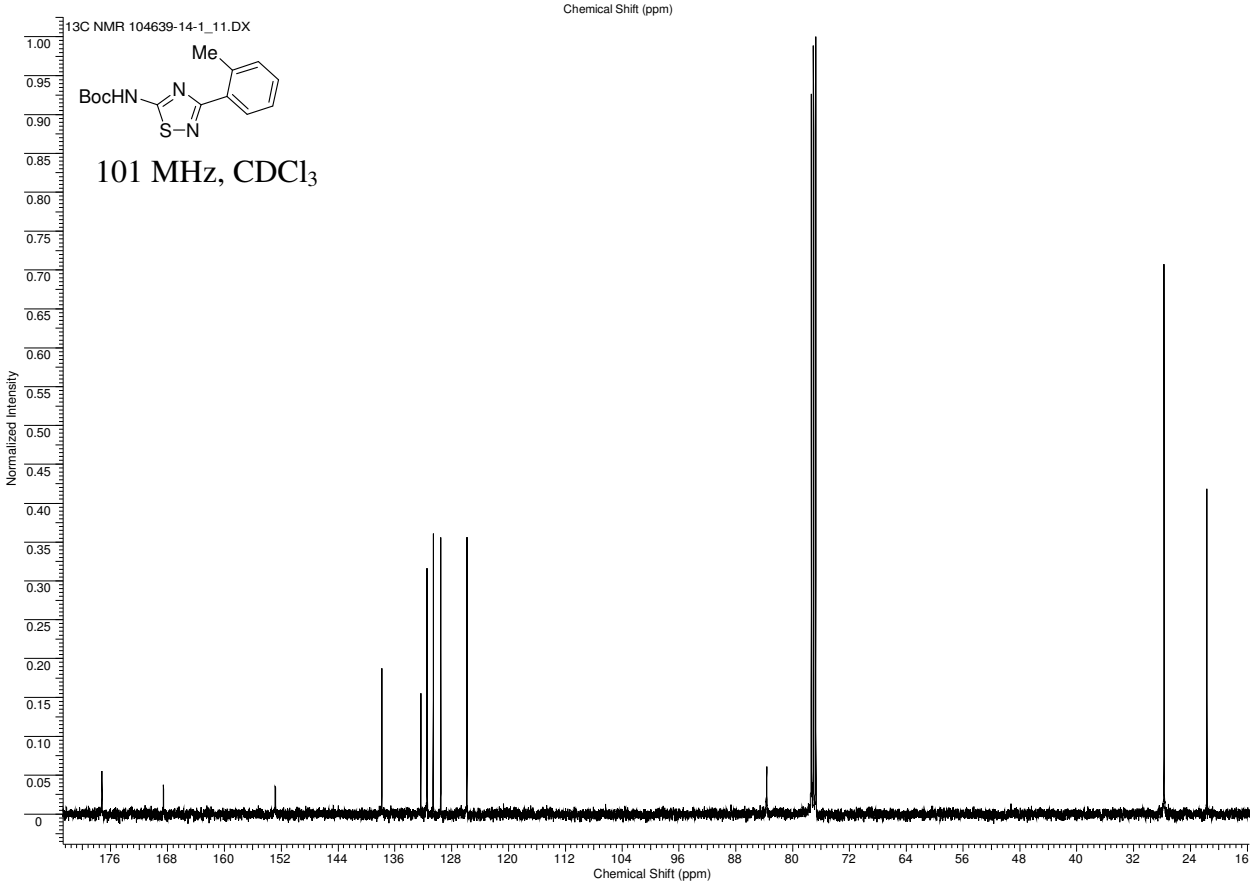
400 MHz, DMSO



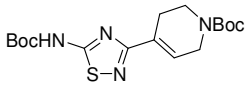
101 MHz, DMSO



400 MHz, $CDCl_3$

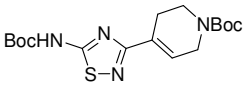


101 MHz, $CDCl_3$

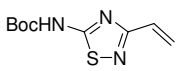


400 MHz, DMSO

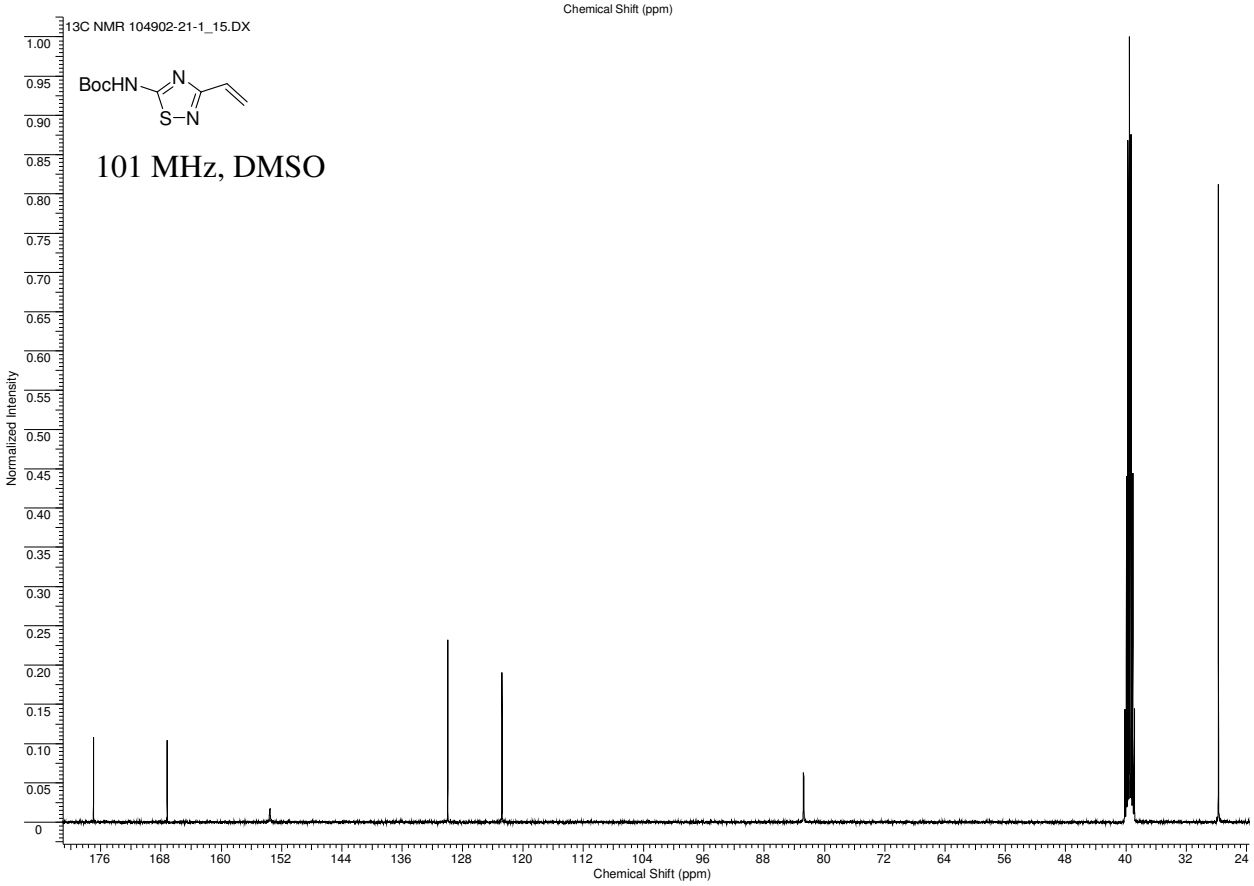
13C NMR 104902-19-1_15.DX



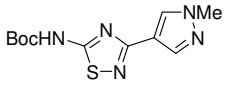
101 MHz, DMSO



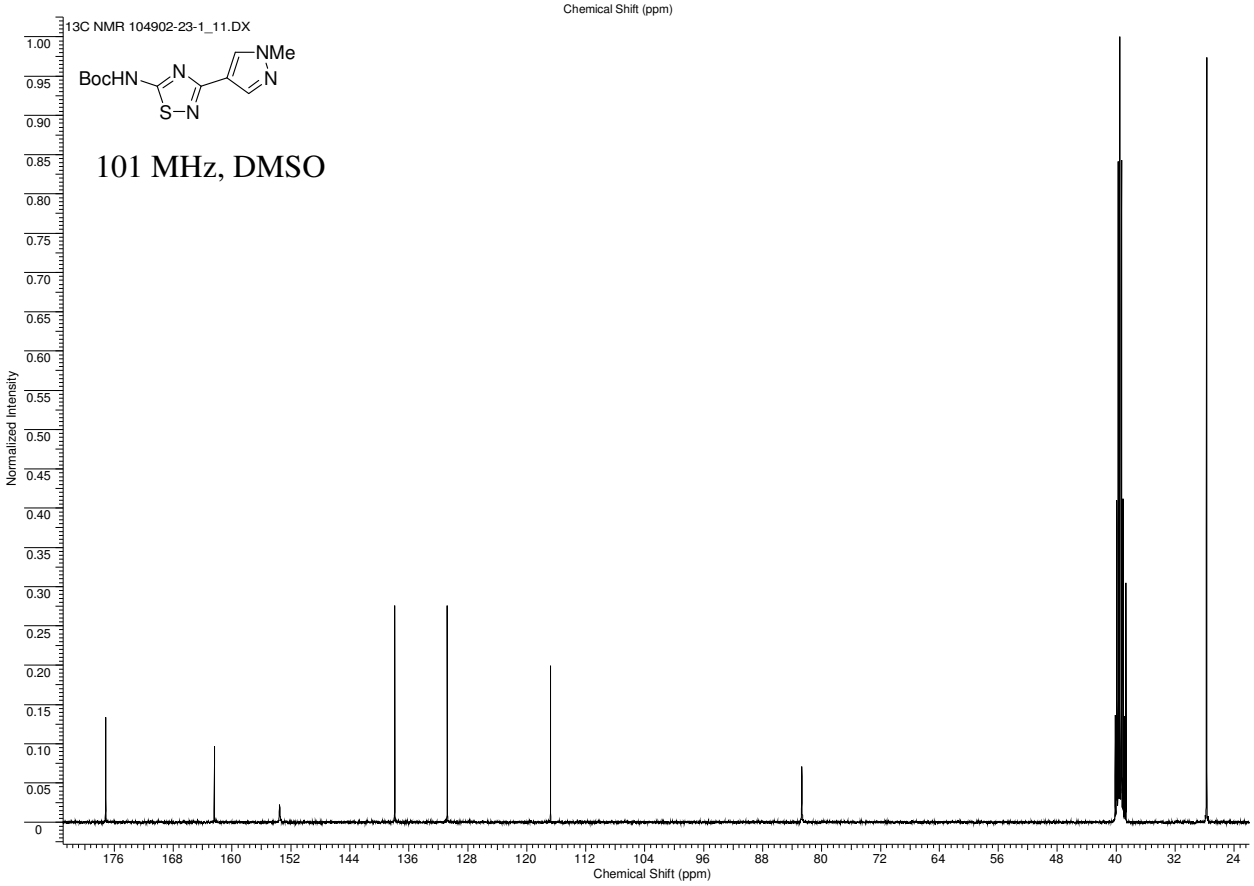
400 MHz, DMSO



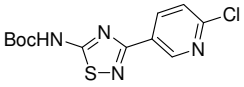
101 MHz, DMSO



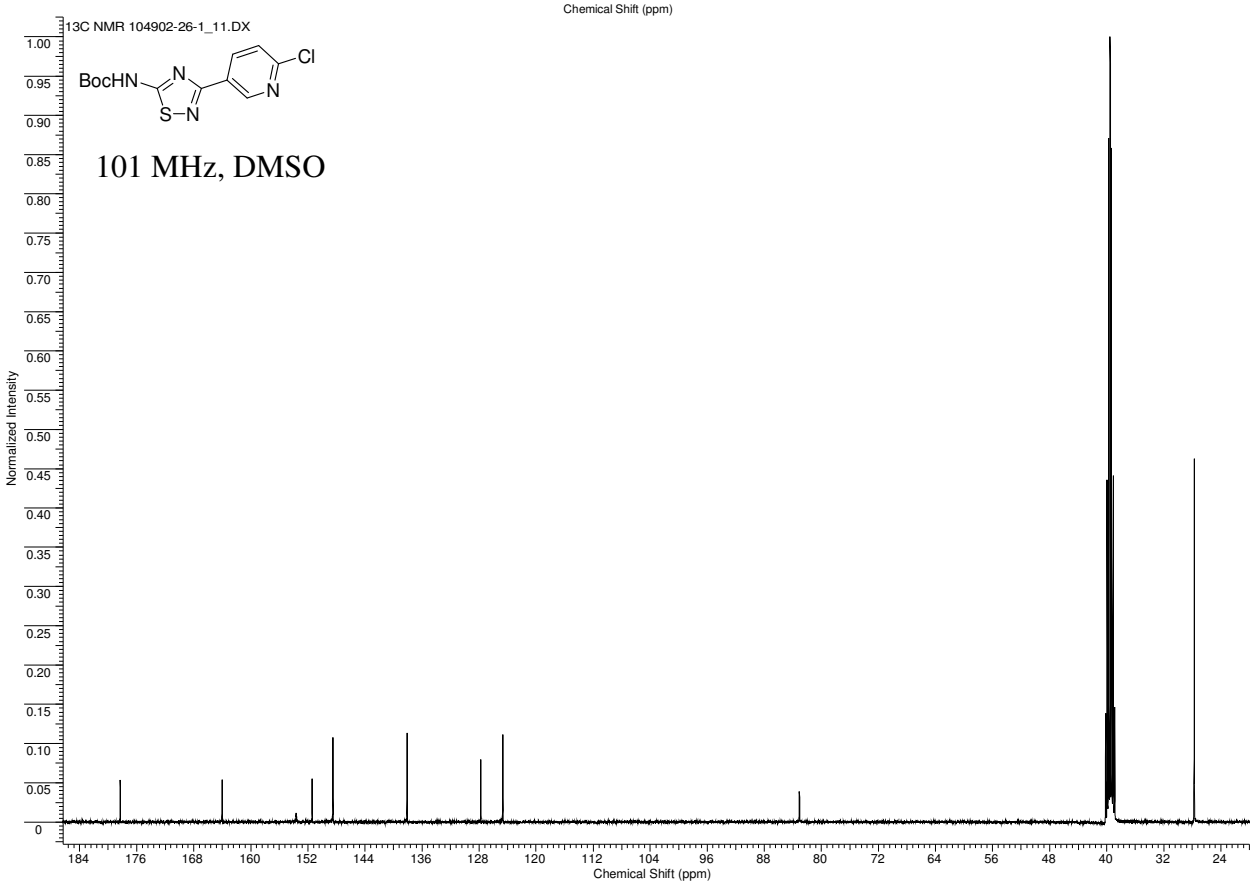
400 MHz, DMSO



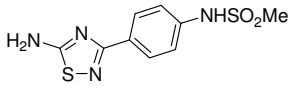
101 MHz, DMSO



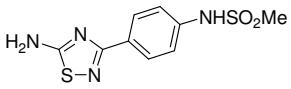
400 MHz, DMSO



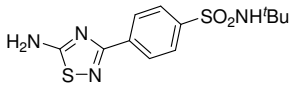
101 MHz, DMSO



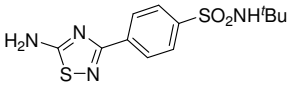
400 MHz, DMSO



101 MHz, DMF

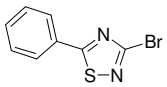


400 MHz, DMSO

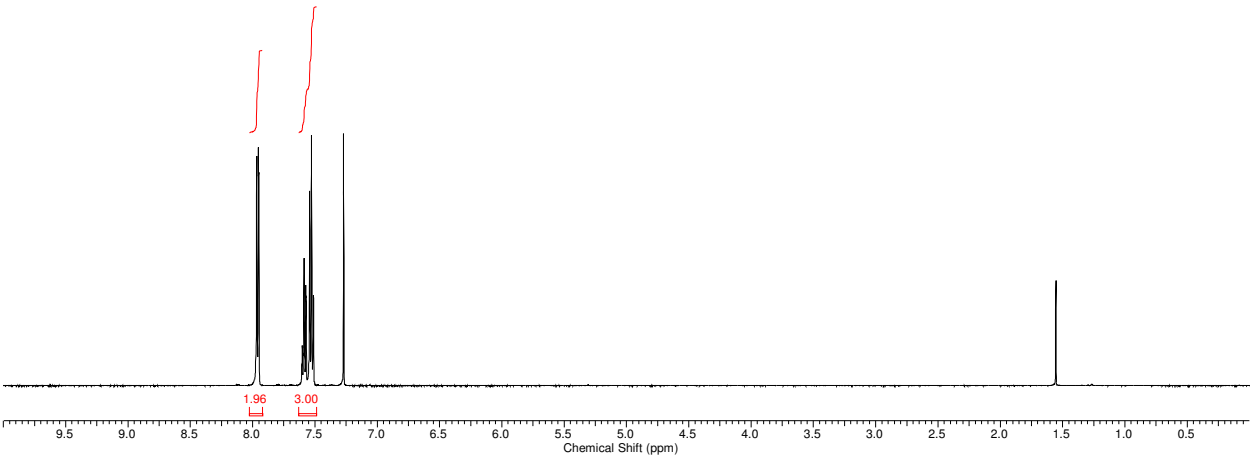


101 MHz, DMSO

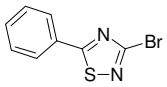
104908-22-1_010000fid.esp



500 MHz, $CDCl_3$

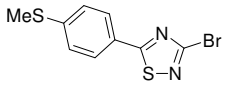


104908-22-1_012000fid.esp

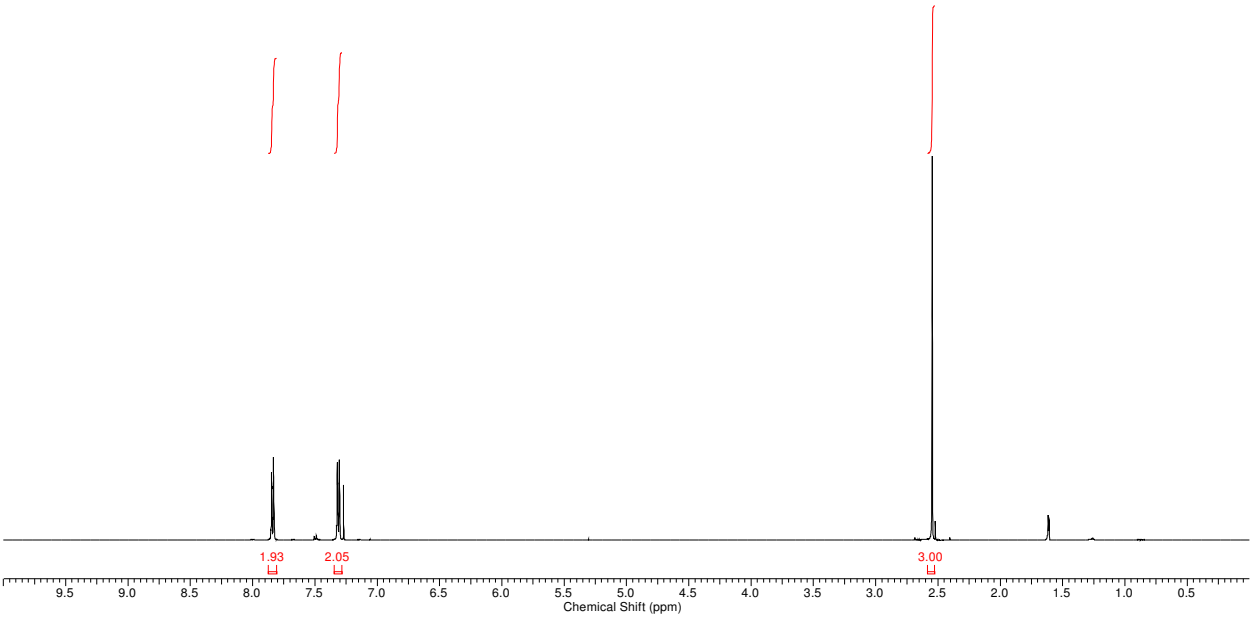


101 MHz, $CDCl_3$

104779-46-1_010000fid.esp



500 MHz, $CDCl_3$



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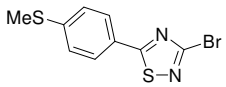
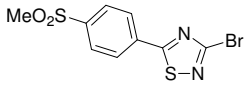
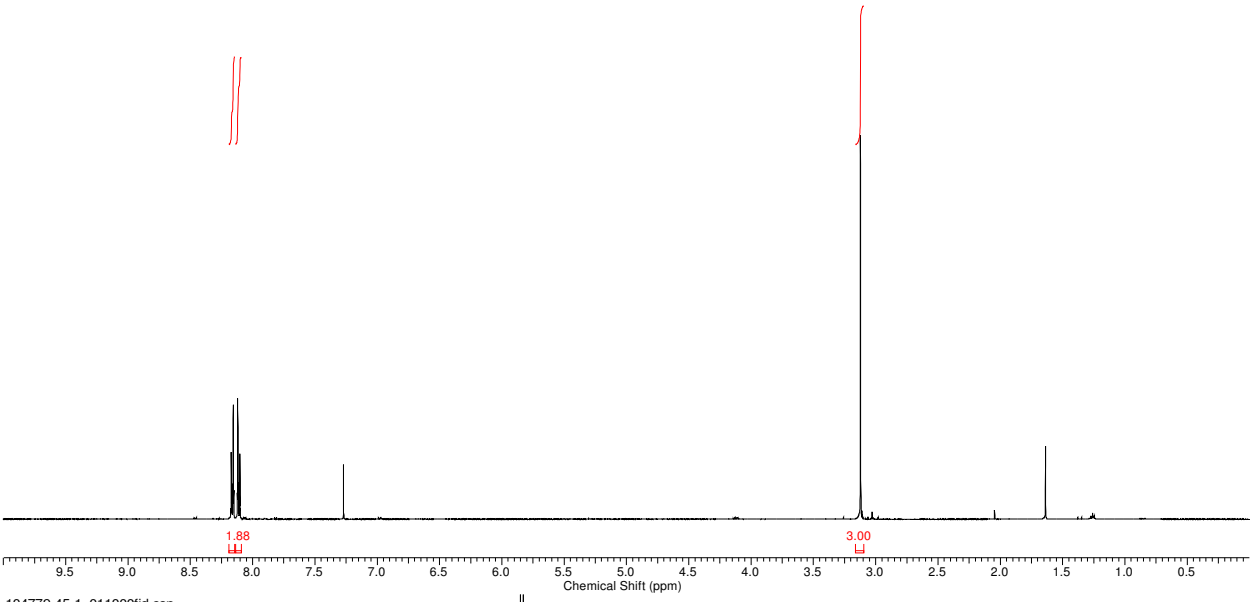


101 MHz, $CDCl_3$

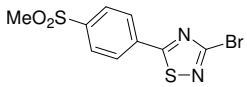
104779-45-1_010000fid.esp



500 MHz, $CDCl_3$

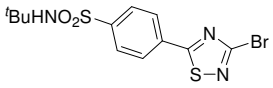


104779-45-1_011000fid.esp

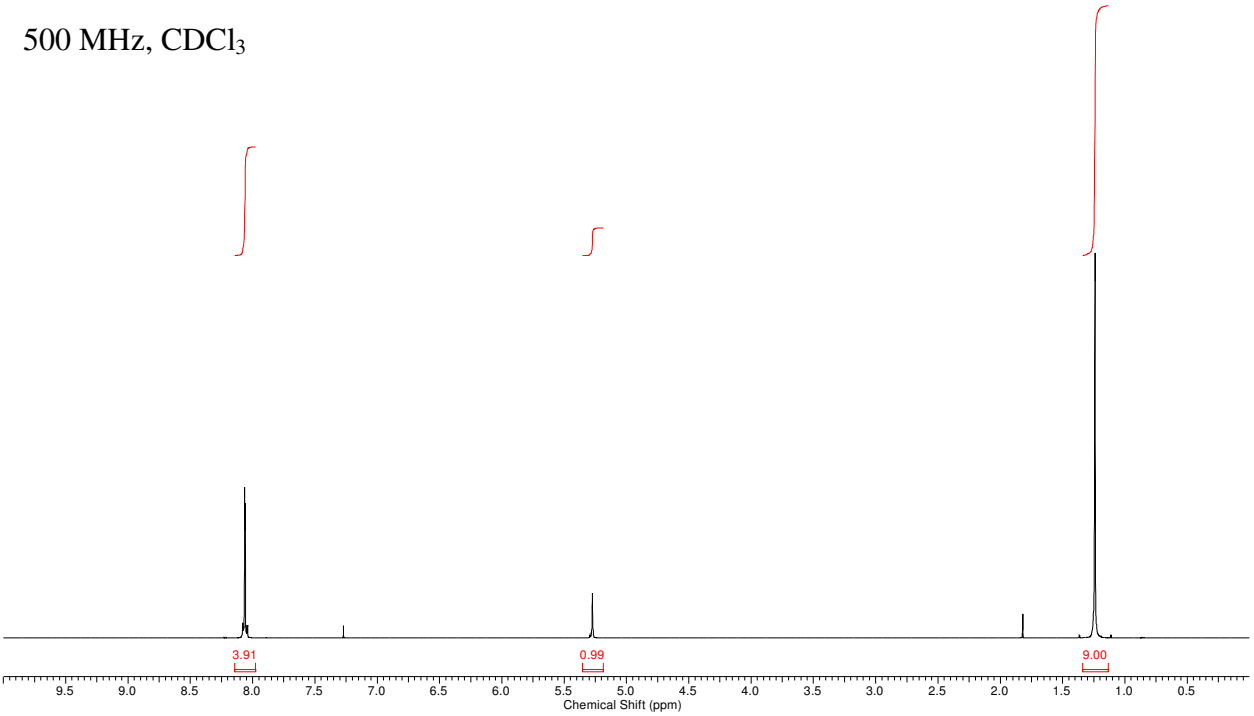


101 MHz, $CDCl_3$

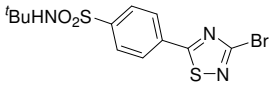
104779-39-1_010000fid.esp



500 MHz, $CDCl_3$

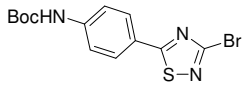


104779-39-1_011000fid.esp

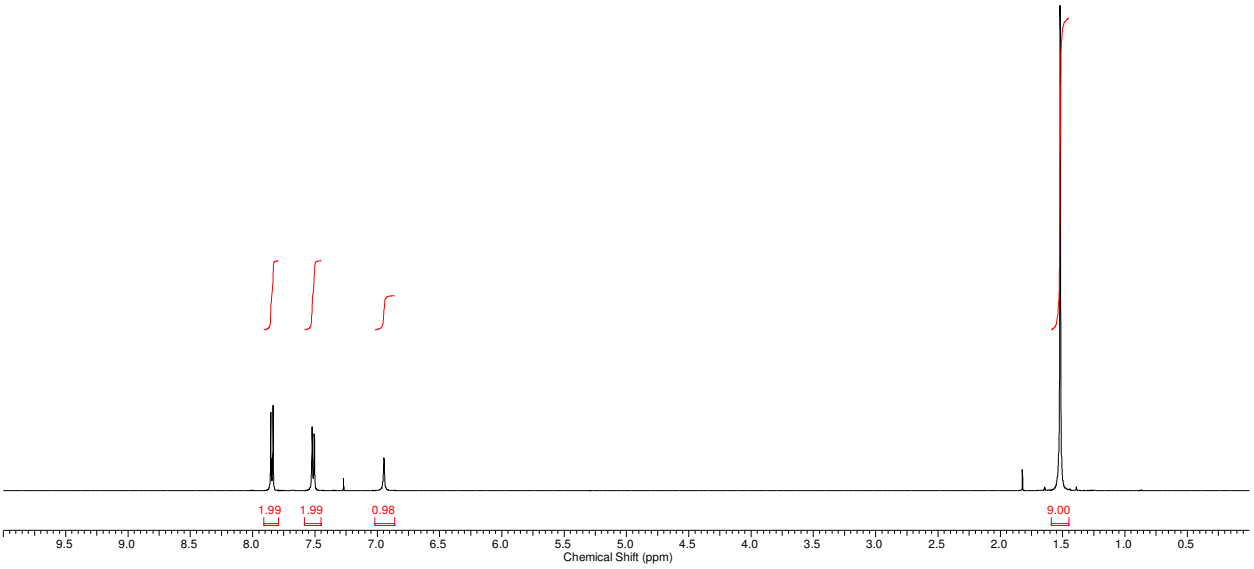


126 MHz, $CDCl_3$

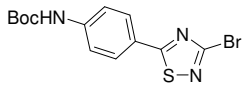
104908-31-1_010000fid.esp



500 MHz, $CDCl_3$

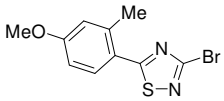


104908-31-1_011000fid.esp

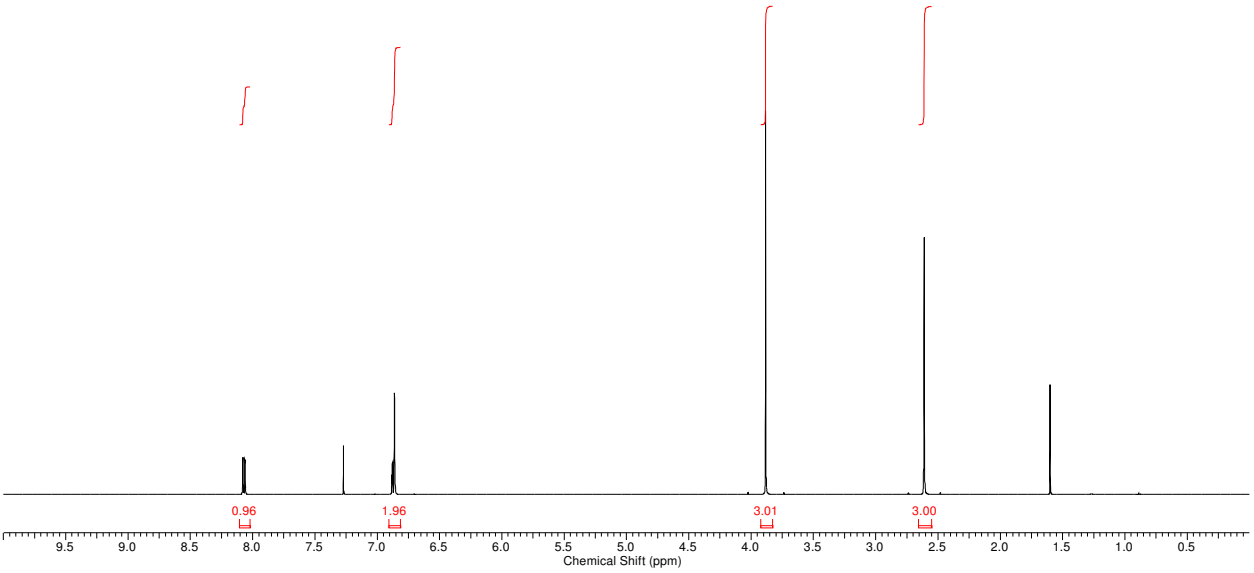


101 MHz, $CDCl_3$

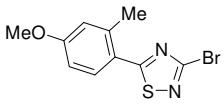
104908-2-1_010000fid.esp



500 MHz, $CDCl_3$

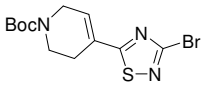


104908-2-1_012000fid.esp

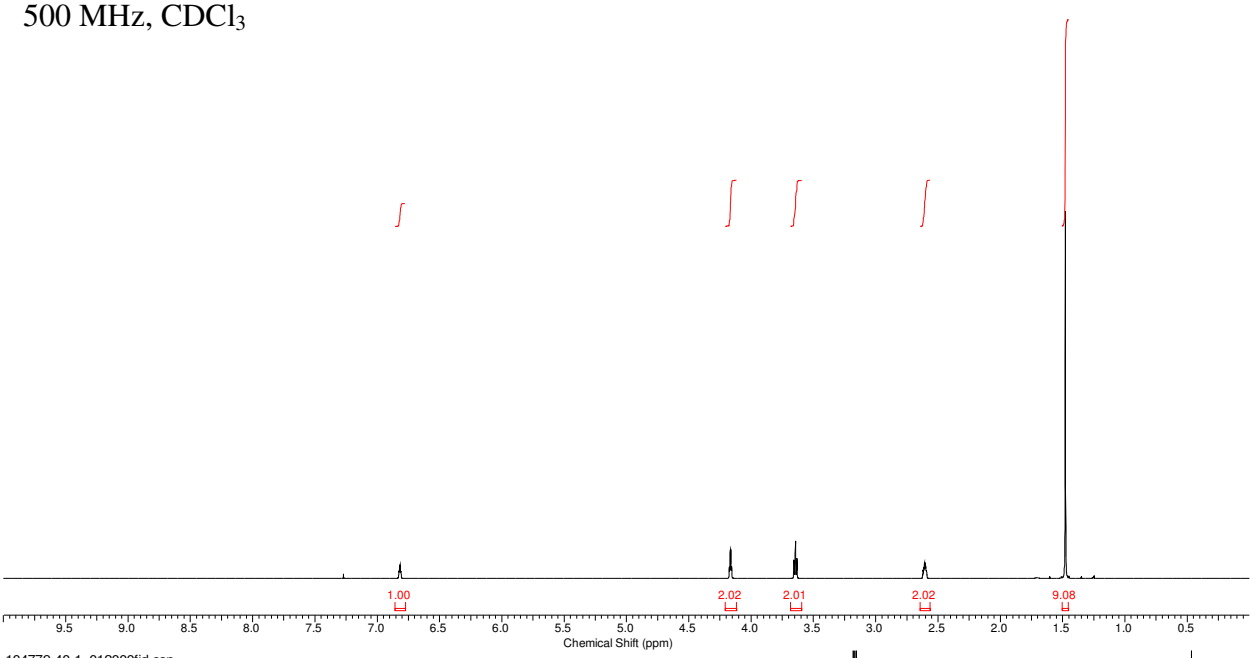


101 MHz, $CDCl_3$

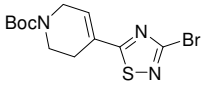
104779-40-1_010000fid.esp



500 MHz, $CDCl_3$

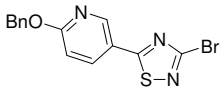


104779-40-1_012000fid.esp

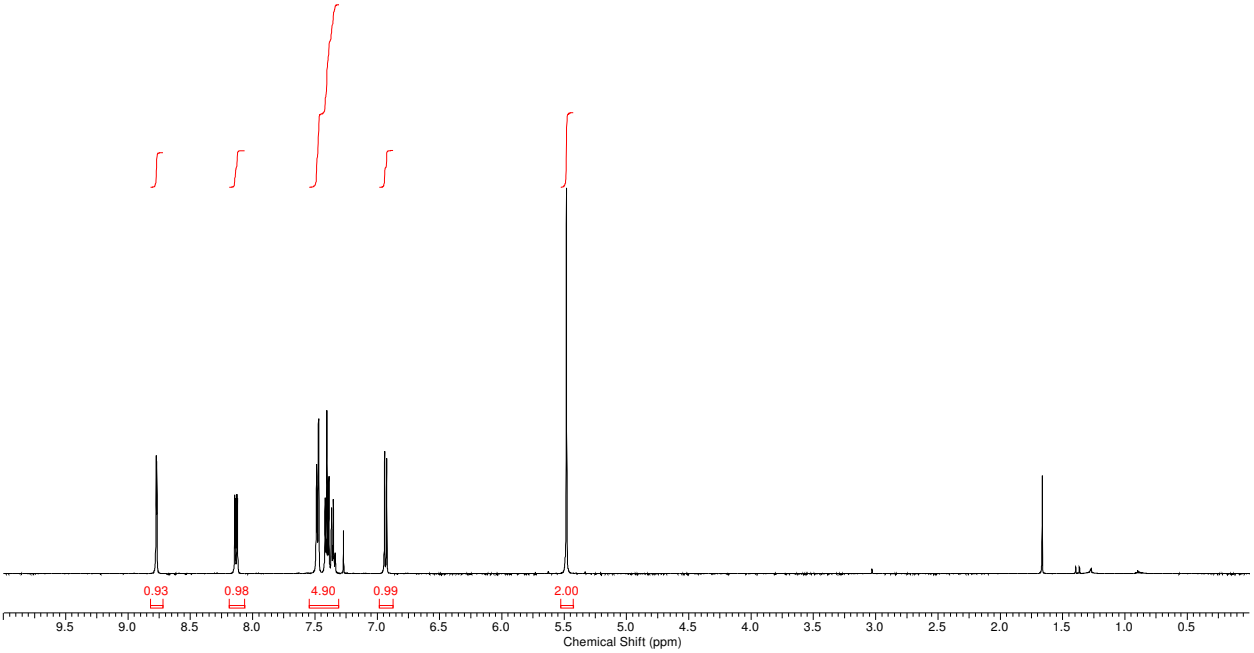


126 MHz, 57 °C, $CDCl_3$

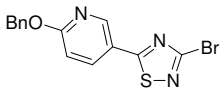
104779-36-1_010000fid.esp



500 MHz, $CDCl_3$

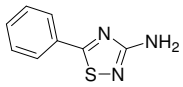


104779-36-1_011000fid.esp

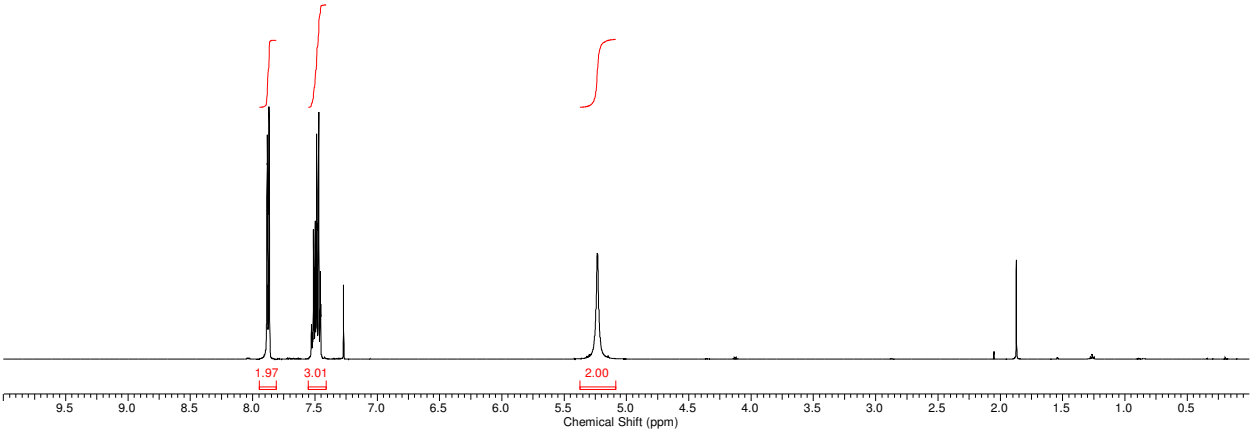


126 MHz, $CDCl_3$

104908-25-1_010000fid.esp



500 MHz, $CDCl_3$



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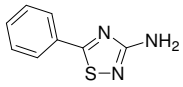
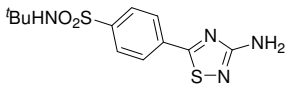


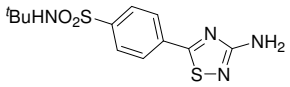
101 MHz, $CDCl_3$

104908-35-1_010000fid.esp



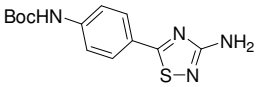
500 MHz, DMSO

104908-35-1_011000FID.ESP

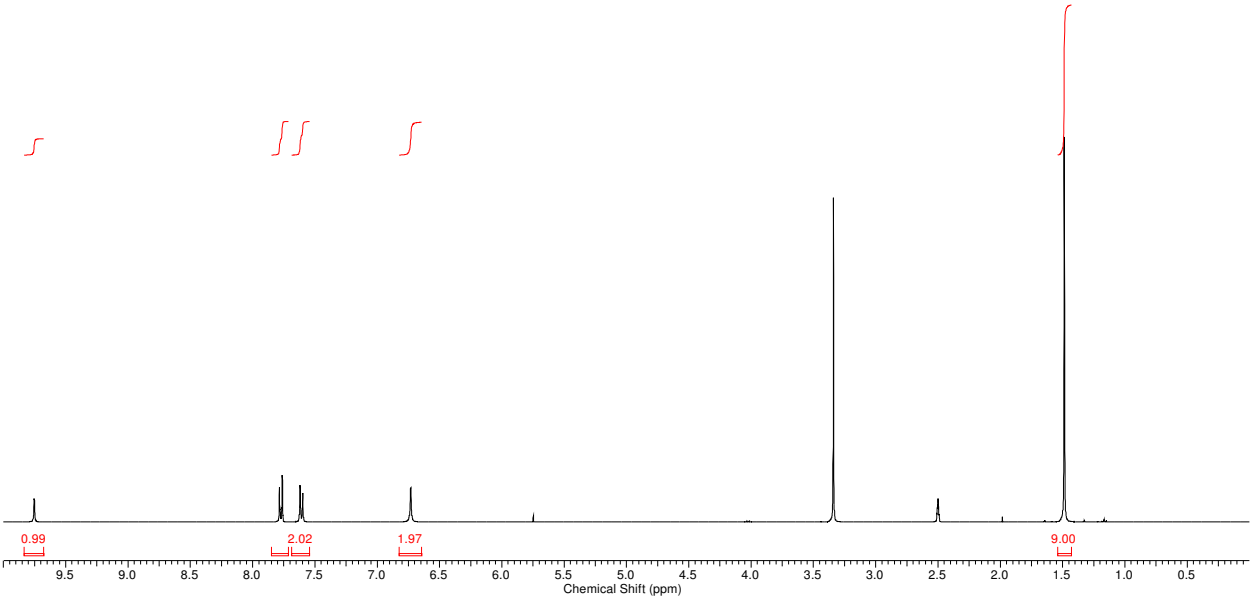


101 MHz, DMSO

104908-38-1_011000fid.esp



400 MHz, DMSO



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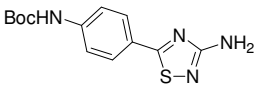
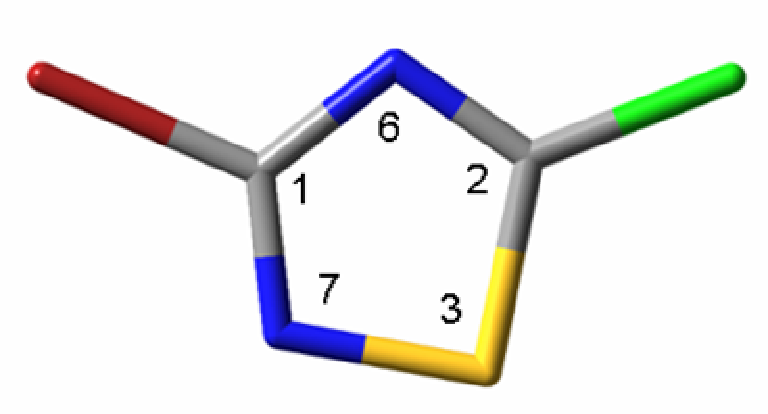


101 MHz, DMSO

Table S(1). LUMO molecular orbital coefficients



Atom	Number	2PZ	3PZ	4PZ
C	1	-0.22283	-0.20104	
C	2	0.44118	0.49058	
S	3	0.12317	-0.34821	-0.32596
N	6	-0.20858	-0.24808	
N	7	0.32088	0.34562	

```
*****************************************
 Gaussian 03:  IA32L-G03RevE.01 11-Sep-2007
               31-Jul-2009
 *****************************************

 ----------------------------------
 3-bromo-5-chloro-1,2,4=thiadiazole
 ----------------------------------

 -------------------
 - Thermochemistry -
 -------------------
 Temperature   298.150 Kelvin.  Pressure   1.00000 Atm.

 Zero-point correction=                           0.023907 (Hartree/Particle)
 Thermal correction to Energy=                    0.030132
 Thermal correction to Enthalpy=                  0.031076
 Thermal correction to Gibbs Free Energy=        -0.008767
 Sum of electronic and zero-point Energies=          -3615.752167
 Sum of electronic and thermal Energies=             -3615.745942
 Sum of electronic and thermal Enthalpies=           -3615.744998
 Sum of electronic and thermal Free Energies=        -3615.784841


 1\1\ \Freq\RB3LYP\6-31G(d)\C2Br1Cl1N2S1\ \31-Jul-
 2009\0\\#N Geom=AllCheck Guess=Read SCRF=Check GenChk RB3LYP/6-31G(d)
 Freq\\3-bromo-5-chloro-1,2,4=thiadiazole\\0,1\C,-0.614745065,-2.323414
 7984,0.0106747208\C,-0.9929143273,-0.2092965228,0.011531641\S,-2.58066
 80241,-0.9290099464,0.0113617291\Br,0.5044845705,-3.8406088407,0.00999
 59897\Cl,-0.743420102,1.4914222812,0.0121792821\N,-0.0305710408,-1.082
 5038572,0.0111217812\N,-1.9122286213,-2.4736170357,0.0107086561\\Versi
 on=IA32L-G03RevE.01\State=1-A\HF=-3615.7760742\RMSD=3.391e-09\RMSF=3.3
 59e-05\ZeroPoint=0.0239071\Thermal=0.0301318\Dipole=-0.3859061,0.56252
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 1001536,-0.0664972,-0.0000014,0.1632845,0.0310674,-0.0000955,0.0000883
 ,-0.0000785,0.2442382,-0.2019583,0.3221827,0.0001417,0.3093159,-0.3878
 746,-0.0001774,0.0001367,-0.0001785,0.0066894,-0.0648442,-0.198789,-0.
 0000727,-0.1266412,-0.848523,-0.0003271,-0.0000444,-0.0003215,0.009212
 ,-0.7396541,0.2505545,0.0001412,0.4009598,-1.1575622,-0.0004307,0.0002
 01,-0.0004201,-0.1332854,-0.4703074,0.2180305,0.0001,-0.2949208,-0.469
 302,-0.0000552,-0.0001009,-0.0000925,-0.2754898\Polar=78.3764831,-14.6
 647263,106.2443472,-0.0087476,0.0283659,36.6644096\PG=C01 [X(C2Br1Cl1N
 2S1)]\NImag=0\\0.63639635,-0.00949501,0.52318188,-0.00003921,0.0001512
 8,0.14041906,0.03518012,0.06460535,0.00002326,0.45703145,-0.00313162,-
 0.10476397,-0.00004309,-0.10912406,0.60855466,-0.00000338,-0.00004791,
 0.00559091,-0.00006771,0.00020585,0.10272990,-0.08376236,0.00809501,0.
 00000979,-0.11720225,-0.02812716,-0.00000568,0.31328249,0.04828444,-0.
 03938941,-0.00002276,-0.06052682,-0.03925782,0.00000519,-0.04200205,0.
 23483017,0.00002561,-0.00001994,0.00992444,-0.00001841,0.00000287,-0.0
 4149557,-0.00003567,0.00007859,0.04208422,-0.05939889,0.05571590,0.000
 02474,-0.00229335,-0.00217676,-0.00000052,-0.00240585,0.00436132,0.000
 00224,0.09104968,0.05022617,-0.09744115,-0.00003375,-0.00162542,-0.000
 81359,-0.00000112,0.00147168,-0.00038706,-0.00000214,-0.08522394,0.143
 37590,0.00002256,-0.00003415,-0.02102799,-0.00000031,-0.00000107,0.002
 30660,0.00000109,-0.00000233,0.00476654,-0.00003944,0.00005880,0.00977
```

916,-0.00521084,0.00008694,0.00000083,-0.04291671,-0.03631757,-0.00001
270,0.00152427,-0.01696139,-0.00000668,0.00068619,0.00024675,0.0000000
5,0.03725440,-0.00339754,0.00178100,-0.00000140,-0.03441490,-0.1812681
3,-0.00006011,-0.00626847,-0.01627952,-0.00000631,0.00093055,-0.001724
35,-0.00000075,0.03174255,0.25176589,-0.00000052,-0.00000166,0.0060189
5,-0.00001196,-0.00005997,-0.02138582,-0.00000250,-0.00000556,0.000987
77,0.00000031,-0.00000069,0.00000070,0.00001063,0.00009162,0.01187803,
-0.11144326,-0.06377917,-0.00002233,-0.28457143,0.16390147,0.00008012,
-0.06836238,-0.01610608,0.00000004,0.00333909,0.01767985,0.00000692,0.
00836940,0.00977229,0.00000319,0.49507059,-0.06331587,-0.20318594,-0.0
0004687,0.16821375,-0.23365428,-0.00008037,0.05908087,-0.01378685,-0.0
0001813,0.00127914,-0.03704408,-0.00001571,0.02521427,-0.04616251,-0.0
0001957,-0.09680176,0.55206332,-0.00002214,-0.00004681,-0.07284809,0.0
0008178,-0.00008010,-0.05859929,0.00002959,-0.00001284,0.02175251,0.00
000045,-0.00001689,0.00260325,0.00000924,-0.00001847,-0.00074825,-0.00
006687,0.00019064,0.08371624,-0.41176111,-0.05522902,0.00000293,-0.045
22783,0.01497571,0.00000988,-0.04307392,0.08295059,0.00003288,-0.03097
687,0.01722490,0.00000914,0.00029328,0.00163553,0.00000084,-0.04240201
,-0.09367040,-0.00003207,0.57314848,-0.01917057,-0.08018242,-0.0000034
1,-0.02712790,-0.04879687,-0.00002153,0.00775013,-0.12572950,-0.000034
94,0.02511380,-0.00596567,-0.00000479,-0.00401155,-0.00811237,-0.00000
417,-0.01466660,-0.01822966,-0.00001553,0.03211270,0.28701648,0.000017
09,-0.00000081,-0.06807727,-0.00000666,-0.00002448,0.01085327,0.000003
38,-0.00004029,-0.03801991,0.00001222,-0.00000421,0.00157175,-0.000001
36,-0.00000457,0.00324863,-0.00000108,-0.00001000,0.02412364,-0.000023
59,0.00008436,0.06629989\\-0.00000206,0.00002645,-0.00000016,-0.000085
53,-0.00004378,-0.00000005,0.00009104,0.00002047,-0.00000004,0.0000030
7,0.00002792,-0.00000005,-0.00002162,-0.00003328,-0.00000006,-0.000026
83,-0.00000887,0.00000023,0.00004194,0.00001110,0.00000014\\\@

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 ****************************************
 Gaussian 03:  IA32L-G03RevE.01 11-Sep-2007
               31-Jul-2009
 ****************************************

--------------------------------
 3-bromo-1,2,4-thiadiazole radical
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 - Thermochemistry -
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 Temperature   298.150 Kelvin.  Pressure   1.00000 Atm.

 Zero-point correction=                           0.020713 (Hartree/Particle)
 Thermal correction to Energy=                    0.025775
 Thermal correction to Enthalpy=                  0.026719
 Thermal correction to Gibbs Free Energy=        -0.010371
 Sum of electronic and zero-point Energies=          -3155.476553
 Sum of electronic and thermal Energies=             -3155.471492
 Sum of electronic and thermal Enthalpies=           -3155.470547
 Sum of electronic and thermal Free Energies=        -3155.507638


 1\1\ \Freq\UB3LYP\6-31G(d)\C2Br1N2S1(2)\ \31-Jul-
 2009\0\\#N Geom=AllCheck Guess=Read SCRF=Check GenChk UB3LYP/6-31G(d)
 Freq\\3-bromo-1,2,4-thiadiazole radical\\0,2\C,0.0463314289,-1.6708694
 351,0.2641787322\C,-0.2965701141,0.444357214,0.2647821023\S,-1.8956633
 252,-0.225060227,0.2648525217\Br,1.1432333812,-3.1995506235,0.26361609
 36\N,0.6353756604,-0.416815502,0.2644128491\N,-1.2523308412,-1.7996100
 164,0.2643432412\\Version=IA32L-G03RevE.01\State=2-A\HF=-3155.4972664\
 S2=0.756287\S2-1=0.\S2A=0.750023\RMSD=2.086e-09\RMSF=5.578e-05\ZeroPoi
 nt=0.0207132\Thermal=0.0257747\Dipole=-0.3155994,0.4199644,0.0001585\D
 ipoleDeriv=0.7233669,-0.5466879,-0.0002334,-0.6635365,1.3322726,0.0004
 146,-0.0002633,0.0003969,0.120865,0.8253278,-0.2115042,-0.0001884,-0.0
 116931,-0.06945,-0.0000054,-0.0001362,0.0000247,-0.0415969,-0.0078207,
 0.049783,0.000056,0.1629263,0.1085652,-0.0000674,0.0000857,-0.0000505,
 0.2742258,-0.2061623,0.3219165,0.0001174,0.3189128,-0.3489992,-0.00014
 34,0.0001168,-0.000144,0.0166866,-0.8840213,0.2578541,0.0001907,0.5243
 715,-0.7865286,-0.0002638,0.0002601,-0.0002224,-0.0784341,-0.4506903,0
 .1286384,0.0000576,-0.330981,-0.2358601,0.0000655,-0.000063,-0.0000046
 ,-0.2917465\Polar=73.0458547,-20.7373705,74.7068397,-0.0116261,0.01419
 99,32.2545661\PG=C01 [X(C2Br1N2S1)]\NImag=0\\0.62773956,-0.02341276,0.
 48312734,-0.00008197,0.00009512,0.13045572,0.03302877,0.08606068,0.000
 01911,0.41903312,-0.01289506,-0.10154175,-0.00002753,-0.23357981,0.503
 82916,-0.00000668,-0.00004266,0.01142419,-0.00011704,0.00015299,0.0559
 6319,-0.07574317,0.01847162,0.00001838,-0.11300415,-0.02725322,0.00000
 495,0.28679547,0.04512121,-0.03735386,-0.00002001,-0.05780535,-0.03586
 548,0.00000849,-0.04802840,0.19069622,0.00002532,-0.00001586,0.0127253
 0,-0.00000305,0.00000388,-0.03448182,-0.00005060,0.00004700,0.03851510
 ,-0.05926433,0.05636008,0.00002054,-0.00337608,-0.00029282,0.00000076,
 -0.00279027,0.00510263,0.00000249,0.08906907,0.05225745,-0.10069916,-0
 .00002880,0.00058429,-0.00311788,-0.00000143,0.00128450,-0.00095159,-0
 .00000171,-0.08543198,0.14609861,0.00001951,-0.00002945,-0.02013069,0.
 00000097,-0.00000129,0.00206032,0.00000152,-0.00000230,0.00489084,-0.0
 0003427,0.00004840,0.00938476,-0.10311521,-0.08910175,-0.00001735,-0.2
```

8551083,0.25979049,0.00010420,-0.05230075,-0.01497189,0.00000658,0.004
87961,0.01515732,0.00000355,0.46590095,-0.04128373,-0.15653441,-0.0000
1716,0.23832685,-0.30413231,-0.00010313,0.04655915,-0.01039063,-0.0000
1398,-0.00110833,-0.03498353,-0.00000953,-0.14688239,0.51480582,-0.000
00492,-0.00000978,-0.06554512,0.00009869,-0.00010639,-0.05049333,0.000
02252,-0.00000444,0.01564135,-0.00000065,-0.00001203,0.00251520,-0.000
09918,0.00013787,0.07274851,-0.42264563,-0.04837788,0.00004130,-0.0501
7083,0.01423041,0.00001382,-0.04295712,0.07058178,0.00001926,-0.028517
99,0.01614842,0.00000871,-0.02985377,-0.09561155,-0.00001645,0.5741453
3,-0.01978712,-0.08699816,-0.00000162,-0.03358667,-0.05917173,-0.00001
427,0.00896635,-0.10613466,-0.00001932,0.02537041,-0.00634645,-0.00000
582,-0.02399178,-0.00876494,-0.00000523,0.04302881,0.26741595,0.000048
74,0.00000264,-0.06892940,0.00000133,-0.00002166,0.01552745,0.00000324
,-0.00002873,-0.03729078,0.00001113,-0.00000444,0.00127956,0.00000221,
0.00000593,0.02513339,-0.00006664,0.00004626,0.06427978\\0.00006452,0.
00003378,0.00000025,-0.00010609,-0.00011687,0.00000020,0.00008396,-0.0
0003405,0.,0.00001490,0.00005031,0.00000006,-0.00007863,-0.00002118,-0
.00000033,0.00002134,0.00008800,-0.00000017\\\@

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Gaussian 03:  IA32L-G03RevE.01 11-Sep-2007
               31-Jul-2009
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5-chloro-1,2,4-thiadiazole radical
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- Thermochemistry -
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Temperature   298.150 Kelvin.  Pressure   1.00000 Atm.

Zero-point correction=                           0.021208 (Hartree/Particle)
Thermal correction to Energy=                    0.026070
Thermal correction to Enthalpy=                  0.027014
Thermal correction to Gibbs Free Energy=        -0.008812
Sum of electronic and zero-point Energies=          -1043.968110
Sum of electronic and thermal Energies=             -1043.963247
Sum of electronic and thermal Enthalpies=           -1043.962303
Sum of electronic and thermal Free Energies=        -1043.998130


1\1\ \Freq\UB3LYP\6-31G(d)\C2Cl1N2S1(2)\ \31-Jul-
2009\0\\#N Geom=AllCheck Guess=Read SCRF=Check GenChk UB3LYP/6-31G(d)
Freq\\5-chloro-1,2,4-thiadiazole radical\\0,2\C,0.8905962246,-3.316045
9324,0.5196413838\C,0.5210142714,-1.2338493356,0.5207091508\S,-1.07459
1507,-1.9497598108,0.5206869616\Cl,0.7572879618,0.4682423407,0.5214727
63\N,1.4951811936,-2.1057086871,0.5200987101\N,-0.3678683744,-3.529287
4247,0.5197919906\\Version=IA32L-G03RevE.01\State=2-A\HF=-1043.9893174
\S2=0.757625\S2-1=0.\S2A=0.750037\RMSD=4.633e-09\RMSF=1.077e-05\ZeroPo
int=0.0212078\Thermal=0.0260703\Dipole=-0.3703139,0.5988825,0.0003596\
DipoleDeriv=0.2624538,0.271752,0.0000972,0.2699296,0.3332366,0.0000575
,0.0000965,0.0000568,0.0997849,0.8615238,0.1500057,-0.0000975,0.240015
7,1.4415619,0.0006312,-0.0000549,0.0006492,0.0158167,-0.1308514,-0.137
426,0.0000052,0.146113,0.101912,-0.0000869,0.0001406,-0.0000299,0.2225
671,-0.0650702,-0.1931899,-0.0000763,-0.1981149,-0.7961202,-0.0003465,
-0.0000786,-0.0003473,0.0140169,-0.703292,0.0701563,0.0001531,0.011573
9,-0.7601479,-0.0003148,0.0001251,-0.0003265,-0.1043211,-0.224764,-0.1
61298,-0.0000818,-0.4695173,-0.3204425,0.0000594,-0.0002287,-0.0000022
,-0.2478645\Polar=57.9157806,3.3860741,73.2552023,-0.0046041,0.0214464
,26.8582861\PG=C01 [X(C2Cl1N2S1)]\NImag=0\\0.64747769,0.07533536,0.442
07196,-0.00007688,0.00015576,0.08424696,0.02675382,0.06872036,0.000028
89,0.44017152,-0.01770151,-0.11620473,-0.00005532,-0.10014532,0.586374
56,-0.00001240,-0.00007262,0.00712020,-0.00011548,0.00025120,0.1014841
5,-0.10824686,0.00690584,0.00002806,-0.11831809,-0.02775346,0.00000194
,0.29163051,0.08683753,-0.04650910,-0.00004703,-0.05467649,-0.03893531
,0.00001264,-0.01769687,0.17415114,0.00006625,-0.00003104,0.01559381,-
0.00001091,0.00000724,-0.04246481,-0.00005960,0.00006945,0.03600073,-0
.00367306,-0.00019698,0.00000182,-0.04248353,-0.03499649,-0.00001257,0
.00147564,-0.01730947,-0.00000829,0.03689095,-0.00217747,-0.00436649,-
0.00000445,-0.03527630,-0.18112496,-0.00006879,-0.00614289,-0.01453462
,-0.00000629,0.03061157,0.25169499,0.00000089,-0.00000484,0.00589544,-
0.00001270,-0.00006885,-0.02191516,-0.00000298,-0.00000407,0.00125900,
0.00000957,0.00010816,0.01183285,-0.09862802,-0.07265191,-0.00002656,-
```

0.26795206,0.16245153,0.00011981,-0.06096233,-0.02181549,0.00000630,0.
00699821,0.00912000,0.00000291,0.46864878,-0.07598161,-0.21490515,-0.0
0005978,0.15101033,-0.20665765,-0.00010197,0.05112820,-0.00144285,-0.0
0002169,0.02475905,-0.04435401,-0.00002599,-0.06229475,0.49624723,-0.0
0002817,-0.00006046,-0.05795123,0.00011432,-0.00010426,-0.05606310,0.0
0004114,-0.00000711,0.02260157,0.00001037,-0.00002286,-0.00021309,-0.0
0010841,0.00021363,0.07460487,-0.46368357,-0.07811266,0.00004467,-0.03
817166,0.01814525,0.00001869,-0.00557888,0.02466078,0.00000626,0.00079
179,0.00386509,0.00000230,-0.04810459,-0.08862122,-0.00002925,0.554746
90,-0.06631229,-0.06008649,0.00001083,-0.02963259,-0.04345190,-0.00002
047,-0.00644081,-0.07272926,-0.00001766,-0.00286768,-0.00731492,-0.000
00441,-0.01480938,-0.02888757,-0.00001893,0.12006276,0.21247014,0.0000
5031,0.00001321,-0.05490518,-0.00000413,-0.00003002,0.01183872,-0.0000
0857,-0.00002388,-0.03299030,-0.00000090,-0.00000576,0.00314097,0.0000
0596,-0.00000419,0.01702099,-0.00004267,0.00005064,0.05589481\\-0.0000
1595,-0.00000109,-0.00000013,0.00000953,-0.00000257,-0.00000001,0.0000
0206,0.00001329,0.,0.00002693,-0.00000670,-0.00000004,0.00000205,-0.00
001071,0.00000011,-0.00002462,0.00000778,0.00000007\\\@

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 ****************************************
 Gaussian 03:  IA32L-G03RevE.01 11-Sep-2007
               31-Jul-2009
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 br radical
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 - Thermochemistry -
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 Temperature   298.150 Kelvin.  Pressure   1.00000 Atm.

 Zero-point correction=                           0.000000 (Hartree/Particle)
 Thermal correction to Energy=                    0.001416
 Thermal correction to Enthalpy=                  0.002360
 Thermal correction to Gibbs Free Energy=        -0.016830
 Sum of electronic and zero-point Energies=          -2571.656918
 Sum of electronic and thermal Energies=             -2571.655502
 Sum of electronic and thermal Enthalpies=           -2571.654558
 Sum of electronic and thermal Free Energies=        -2571.673748


 1\1\ \Freq\UB3LYP\6-31G(d)\Br1(2)\ \31-Jul-2009\0
 \\#N Geom=AllCheck Guess=Read SCRF=Check GenChk UB3LYP/6-31G(d) Freq\\
 br radical\\0,2\Br,-0.17316527,0.12558891,0.00226685\\Version=IA32L-G0
 3RevE.01\HF=-2571.6569182\S2=0.751496\S2-1=0.\S2A=0.75\RMSD=1.337e-11\
 RMSF=0.000e+00\Thermal=0.0014163\Dipole=0.,0.,0.\DipoleDeriv=0.,0.,0.,
 0.,0.,0.,0.,0.,0.\Polar=11.1850568,0.,12.1705546,0.,0.,12.1705546\PG=O
 H [O(Br1)]\NImag=0\\0.,0.,0.,0.,0.,0.\\0.,0.,0.\\\@
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 ****************************************
 Gaussian 03:  IA32L-G03RevE.01 11-Sep-2007
               31-Jul-2009
 ****************************************

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 cl radical
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 - Thermochemistry -
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 Temperature   298.150 Kelvin.  Pressure   1.00000 Atm.

 Zero-point correction=                           0.000000 (Hartree/Particle)
 Thermal correction to Energy=                    0.001416
 Thermal correction to Enthalpy=                  0.002360
 Thermal correction to Gibbs Free Energy=        -0.015677
 Sum of electronic and zero-point Energies=           -460.136242
 Sum of electronic and thermal Energies=              -460.134826
 Sum of electronic and thermal Enthalpies=            -460.133882
 Sum of electronic and thermal Free Energies=         -460.151919


 1\1\ \Freq\UB3LYP\6-31G(d)\Cl1(2)\ \31-Jul-2009\0
 \\#N Geom=AllCheck Guess=Read SCRF=Check GenChk UB3LYP/6-31G(d) Freq\\
 cl radical\\0,2\Cl,-1.02263068,0.42685292,0.01338695\\Version=IA32L-G0
 3RevE.01\HF=-460.1362422\S2=0.751721\S2-1=0.\S2A=0.750001\RMSD=2.725e-
 10\RMSF=0.000e+00\Thermal=0.0014163\Dipole=0.,0.,0.\DipoleDeriv=0.,0.,
 0.,0.,0.,0.,0.,0.,0.\Polar=5.5423764,0.,5.7952054,0.,0.,5.5423764\PG=O
 H [O(Cl1)]\NImag=0\\0.,0.,0.,0.,0.\\0.,0.,0.\\\@
```