Supporting Information for:

Regioselective and Diastereoselective Aminoarylation of 1,3-Dienes

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Materials and Methods

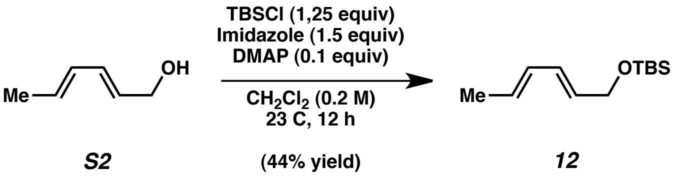
All reactions were carried out under an atmosphere of nitrogen in flame-dried glassware with magnetic stirring unless otherwise indicated. Commercially obtained reagents were used as received. Solvents were dried by passage through an activated alumina column under argon. Liquids and solutions were transferred via syringe. All reactions were monitored by thin-layer chromatography with E. Merck silica gel 60 F254 pre-coated plates (0.25 mm). All flash chromatography purifications were performed on a Teledyne Isco CombiFlash® Rf unless otherwise indicated. ^{1}H and ^{13}C NMR spectra were recorded on Varian Inova-400 or 500 spectrometers. Data for ^{1}H NMR spectra are reported relative to chloroform as an internal standard (7.26 ppm) and are reported as follows: chemical shift (δ ppm), multiplicity, coupling constant (Hz), and integration. Data for ^{13}C NMR spectra are reported relative to chloroform as an internal standard (77.23 ppm) and are reported in terms of chemical shift (δ ppm). Infrared spectra were recorded on a Perkin-Elmer 1000 series FTIR. HRMS data were obtained at The Scripps Center for Mass Spectrometry.

Grignard Reagents

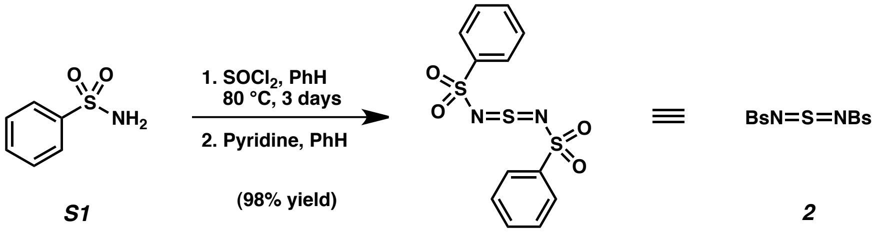
All Grignard Reagents were purchased from Sigma-Aldrich.

1,3-Dienes

All 1,3-dienes in Tables 2 and 3 were purchased from Sigma-Aldrich. Diene **12** was synthesized by the following procedure. Spectroscopic data for diene **12** was identical to the reported data in the literature.[1]



Synthesis of Benzenesulfonyl Sulfurdiimide 2



Our procedure was modified from a method reported in the literature for the synthesis of similar arylsulfonyl sufurdiimides[2]: A solution of benzenesulfonamide **S1** (50 g, 0.318 mol) and $SOCl_2$ (80 mL, 1.1 mol) in benzene (30 mL) was refluxed at 80 °C for 3 days (over the course of the reaction, the mixture became a clear solution). When the starting material was consumed by ^1H NMR analysis of an aliquot, the mixture was concentrated under vacuum to remove benzene and excess $SOCl_2$. Trace amounts of $SOCl_2$ were removed by redissolving the residue in toluene (50 mL), concentrating under reduced pressure, and storing under vacuum at 50 °C for 6 h. The residue was then treated with benzene (70 mL) and heated slightly to ensure all material dissolved in the solvent. Once the solution was cooled to 23 °C, pyridine (0.5 mL) was added, and the mixture was stirred. After 12 h, stirring was ceased, and a yellow precipitate crystallized slowly from the solution. The precipitate was separated by vacuum filtration and stored under vacuum at 50 °C for 8 h. Benzensulfonyl sulfurdiimide **2** was obtained as a yellow solid (53.5 g, 98% yield). *Since benzenesulfonyl sulfurdiimide **2** is sensitive to water, we store it in a dessicator inside a sealed flask that has been purged with N_2. Optimal results for the enantioselective allylic amination were obtained when benzenesulfonyl sulfurdiimide **2** was broken into a fine powder immediately before use.*

^1H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, J = 8.0 Hz, 2H), 7.67 (t, J = 8.0 Hz, 1H), 7.53 (t, J = 8.0 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 137.9, 135.0, 129.6, 128.3. IR (thin film): 3348, 3255, 1557, 1332, 1159 cm^{-1}.

*Although we continue to synthesize benzensulfonyl sulfurdiimide **2** in our lab, Sigma-Aldrich has decided to commercialize this reagent based on conversations with our group about its synthetic utility (Catalog # L511390, $25/gram).*

General Procedures for the Aminoarylation of Dienes

Table 1 – Two-pot procedure for the aminoarylation of 1,3-butadiene: A solution of benzenesulfonyl sulfurdiimide **2** (360 mg, 1.0 mmol, 1.0 equiv) in CH_2Cl_2 (5 mL, 0.2 M) was sparged with 1,3-butadiene for 10 min at 23 °C. The resulting solution was stirred at 23 °C in the absence of 1,3-butadiene for an additional 10 min. The mixture was concentrated under reduced pressure and purified by flash chromatography to yield [4+2] cycloadduct **6** (gradient eluent hexanes:ethyl acetate) as a white solid: ^1H NMR (400 MHz, $CDCl_3$), δ 7.96 (d, J = 8.0 Hz, 2H), 7.77 (d, J=8.0 Hz, 2H), 7.68 (t, J = 8.0 Hz, 1H), 7.58 (t, J = 7.6 Hz, 2H), 7.48 (t, J = 7.8 Hz, 1H),

7.40 (d, $J = 7.6$ Hz, 2H), 5.95-5.89 (m, 1H), 5.81-5.76 (m, 1H), 4.14-4.08 (m, 1H), 4.00-3.94 (m, 1H), 3.76-3.69 (m, 1H), 3.35-3.28 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.46, 136.86, 134.65, 131.94, 129.79, 128.88, 128.28, 126.32, 124.25, 115.31, 47.72, 39.08. LRMS (ESI) calcd for $[C_{16}H_{17}N_2O_4S_3]^+([M+H]^+)$: 396.03, found 397.0.

The [4+2] cycloadduct was dissolved in solvent (5 mL, 0.2 M) and treated with copper catalyst (2 mol%, 0.02 mmol). The solution was treated with Grignard reagent (3 mmol, 3 equiv) and stirred at 23 °C for 30–120 min. The reaction was quenched by the addition of saturated aqueous NH_4Cl (10 mL) and extracted with ethyl acetate (10 mL). The organic layer was dried over $MgSO_4$, concentrated under reduced pressure, and purified by flash chromatography (gradient eluent hexanes:ethyl acetate).

Table 2 – Procedure for the aminoarylation of 1,3-butadiene: A solution of benzenesulfonyl sulfurdiimide **2** (360 mg, 1.0 mmol, 1.0 equiv) in DME (5 mL, 0.2 M) was sparged with 1,3-butadiene for 10 min at 23 °C. The resulting solution was stirred at 23 °C in the absence of 1,3-butadiene for an additional 10 min. The mixture was treated with $CuBr{\bullet}SMe_2$ (2 mol%, 0.02 mmol) and cooled to –78 °C. The Grignard reagent (3 mmol, 3 equiv) was added at –78 °C, and the solution was stirred at 23 °C for 30 min. The reaction was quenched by the addition of saturated aqueous NH_4Cl (10 mL), and the mixture was extracted with ethyl acetate (10 mL). The organic layer was dried over $MgSO_4$, concentrated under reduced pressure, and purified by flash chromatography (gradient eluent hexanes:ethyl acetate).

Table 3 – Procedure for the aminoarylation of substituted 1,3-dienes: A solution of benzenesulfonyl sulfurdiimide **2** (360 mg, 1.0 mmol, 1.0 equiv) in DME (5 mL, 0.2 M) was treated with the 1,3-diene (1.5 mmol, 1.5 equiv) and stirred at 23 °C for 10 min. The mixture was treated with $CuBr{\bullet}SMe_2$ (2 mol%, 0.02 mmol) and cooled to –78 °C. The Grignard reagent (3 mmol, 3 equiv) was added at –78 °C, and the solution was stirred at 23 °C for 30 min. The reaction was quenched by the addition of saturated aqueous NH_4Cl (10 mL), and the mixture was extracted with ethyl acetate (10 mL). The organic layer was dried over $MgSO_4$, concentrated under reduced pressure, and purified by flash chromatography (gradient eluent hexanes:ethyl acetate).

Characterization Data for Products

NB: Linear to branched regioselectivity was determined by HNMR. Flash chromatography afforded an inseparable mixture of linear and branched products.

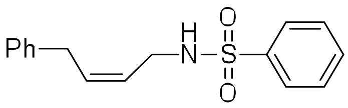


Table 2, entry 1: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (252 mg, 88% yield for two steps, 9:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$), δ 7.92 (d, $J = 8.0$ Hz, 2H), 7.61-7.58 (m, 1H), 7.52 (t, $J = 8.0$ Hz, 2H), 7.28 (t, $J = 7.5$ Hz, 2H), 7.20 (t, $J = 7.5$ Hz, 1H), 7.10 (d, $J = 7.5$ Hz, 2H), 5.72-5.67 (m, 1H), 5.47-5.42 (m, 1H), 5.05 (t, $J = 5.8$ Hz, 1H for NH), 3.74 (d, $J = 6.8$ Hz, $J = 5.8$Hz, 2H), 3.32 (d, $J = 7.6$ Hz, 2H). ^{13}C NMR (100 MHz,

$CDCl_3$) δ 138.95, 139.79, 132.84, 132.70, 129.26, 128.67, 128.35, 127.25, 126.31, 124.97, 40.24, 33.50. IR (thin film): 3282, 3062, 3026, 1585, 1601, 1480, 1495, 1447, 1325, 1161, 1094, 1071, 753, 689 cm^{-1}. HRMS (ESI) calcd for $[C_{16}H_{18}NO_2S]^+$($[M+H]^+$): 288.1053, found 288.1055.

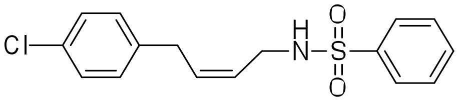


Table 2, entry 2: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (263 mg, 82 % yield for two steps, 9:1) as a clear oil: ^1H NMR (500 MHz, $CDCl_3$), δ 7.89 (d, J = 8.0 Hz, 2H), 7.61-7.58 (m, 1H), 7.52 (t, J = 8.0 Hz, 2H), 7.23 (d, J = 8.0 Hz, 2H), 7.01 (d, J = 8.0 Hz, 2H), 5.68-5.63 (m, 1H), 5.47-5.42 (m, 1H), 4.61 (br, 1H for NH), 3.72 (t, J = 6.4Hz, 2H), 3.28 (d, J = 7.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.78, 138.02, 132.78, 132.18, 132.00, 129.53, 129.15, 128.64, 127.09, 125.22, 40.06, 32.70. IR (thin film): 3279, 3026, 1586, 1476, 1324, 1160, 1092, 587cm^{-1}. HRMS (ESI) calcd for $[C_{16}H_{17}ClNO_2S]^+$ ($[M+H]^+$): 322.0663, found 322.0661.

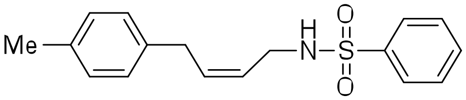


Table 2, entry 3: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (261 mg, 87 % yield for two steps, 7:1) as a clear oil: ^1H NMR (500 MHz, $CDCl_3$), δ 7.88 (d, J = 8.0 Hz, 2H), 7.61-7.58 (m, 1H), 7.53 (t, J = 8.0 Hz, 2H), 7.09 (d, J = 8.0 Hz, 2H), 6.97 (d, J = 8.0 Hz, 2H), 5.73-5.68(m, 1H), 5.44-5.40 (m, 1H), 4.42 (br, 1H for NH), 3.73 (t, J = 6.5Hz, 2H), 3.27 (d, J = 7.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.82, 136.50, 135.79, 133.17, 132.73, 129.26, 129.13, 128.04, 127.11, 124.48, 40.12, 32.93, 20.97 IR (thin film): 3278, 3021, 1585, 1447, 1326, 1162, 1092,863, 589, 1509, 1088 cm^{-1}. HRMS (ESI) calcd for $[C_{17}H_{20}NO_2S]^+$ ($[M+H]^+$): 302.1209, found 302.1207.

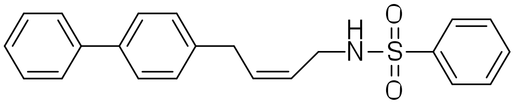


Table 2, entry 4: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (323 mg, 89 % yield for two steps, 5:1) as a clear oil: ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.87 (m, 2H), 7.55 (m, 7H), 7.44 (t, J = 7.6Hz, 2H), 7.34 (t, J = 7.0Hz, 1H), 7.16 (d, J = 7.9Hz, 2H), 5.77-5.71 (m, 1H), 5.52 – 5.41 (m, 1H), 4.61 (br, 1H), 3.76 (t, J = 6.1Hz, 2H), 3.35 (d, J = 7.6Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.81, 139.83, 139.26, 138.68, 132.77, 132.67, 129.16, 128.76, 128.62, 127.32, 127.18, 127.13, 126.99, 124.92, 40.16, 33.02. IR (thin film): 3282, 3027, 1600, 1487, 1447, 1325, 1161, 1094, 759, 584 cm^{-1}. HRMS (ESI) calcd for $[C_{22}H_{22}NO_2S]^+$ ($[M+H]^+$): 364.1366, found 364.1367.

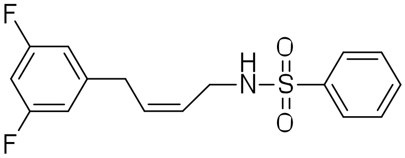


Table 2, entry 5: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (213 mg, 66 % yield for two steps, 5:1) as a clear oil: ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.99 – 7.83 (m, 2H), 7.65 – 7.38 (m, 3H), 6.68 – 6.50 (m, 3H), 5.69 – 5.52 (m, 1H), 5.52 – 5.36 (m, 1H), 5.15 (s, 1H), 3.67 (t, J = 6.0 Hz, 2H), 3.26 (d, J = 7.4 Hz, 2H). ^{13}C NMR (100 MHz, CDCl3) δ 163.15 (dd, J_1 = 249.4 Hz, J_3 = 12.9 Hz), 143.71 (t, J_3 = 9.0 Hz), 139.91, 132.96, 130.87, 129.32, 127.23, 126.34, 111.20 (dd, J_2 = 25.0 Hz, J_4 = 6.6 Hz), 101.81 (t, J_2 = 25.4 Hz), 40.12, 33.09 (t, J_4 = 1.9 Hz). IR (thin film): 3281, 3089, 3067, , 2924, 1625, 1594, 1460, 1447, 1322, 1161, 1117, 991, 848, 586 cm^{-1}. HRMS (ESI) calcd for $[C_{16}H_{16}F_2NO_2S]^+$ ([M+H]$^+$): 324.0864, found 324.0864.

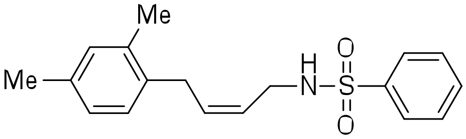


Table 2, entry 6: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (176 mg, 56 % yield for two steps, 10:1) as a clear oil: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.89 (d, J = 7.9Hz, 2H), 7.67 – 7.49 (m, 3H), 7.03 – 6.85 (m, 3H), 5.67-5.62(m, 1H), 5.44-5.40 (m, 1H), 4.46 (s, 1H), 3.73 (t, J = 6.4 Hz, 2H), 3.22 (d, J = 7.4Hz, 2H), 2.29 (s, 3H), 2.18 (s, 3H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 140.01, 136.19, 136.00, 134.99, 132.94, 132.82, 131.29, 129.34, 128.50, 127.33, 126.99, 124.76, 40.41, 30.99, 21.08, 19.58. IR (thin film): 3283, 3018, 2920, 1615, 1501, 1447, 1325, 1161, 1094, 1057, 792, 755 cm^{-1}. HRMS (ESI) calcd for $[C_{18}H_{22}NO_2S]^+$ ([M+H]$^+$): 316.1366, found 316.1367.

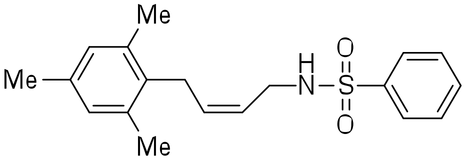


Table 2, entry 7: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (105 mg, 32 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (500 MHz, CDCl$_3$), δ 7.95 (d, J = 8.0 Hz, 2H), 7.63-7.60 (m, 1H), 7.56 (t, J = 8.0 Hz, 2H), 6.83 (s, 2H), 5.39-5.31 (m, 2H), 4.82 (br, 1H for NH), 3.78 (t, J = 8.0 Hz, 2H), 3.25 (d, J = 8.0 Hz, 2H), 2.25 (s, 3H), 2.18 (s, 6H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 139.80, 136.06, 135.65, 133.37, 132.76, 132.05, 129.16, 128.99, 128.96, 128.94, 127.16, 123.93, 40.38, 27.66, 20.80, 19.91. IR (thin film): 3284, 3064, 2919, 1613, 1581, 1446, 1326, 1162, 1094, 1060, 851, 586, cm^{-1}. HRMS (ESI) calcd for $[C_{19}H_{24}NO_2S]^+$ ([M+H]$^+$): 330.1522, found 330.1528.

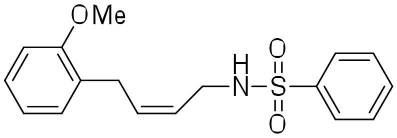


Table 2, entry 8: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (300 mg, 95 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$), δ 7.89-7.86 (m, 2H), 7.58-7.54 (m, 1H), 7.51-7.46 (m, 2H), 7.20-7.16 (m, 1H), 7.03-7.01 (m, 1H), 6.88-6.82 (m, 2H), 5.64-5.57 (m, 1H), 5.37-5.33 (m, 1H), 4.89 (br, 1H for NH), 3.80 (s, 3H), 3.71 (t, *J* = 6.5Hz, 2H), 3.23 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.20, 140.04, 133.04, 132.78, 129.79, 129.24, 127.94, 127.78, 127.25, 124.12, 120.87, 110.58, 55.45, 40.08, 28.52. IR (thin film): 3284, 3023, 1656, 1587, 1493, 1325, 1159, 722, cm^{-1}. HRMS (ESI) calcd for $[C_{17}H_{20}NO_3S]^+$ ($[M+H]^+$): 318.1158, found 318.1157.

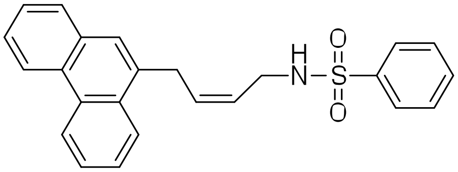


Table 2, entry 9: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (313 mg, 81 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.74 (d, *J* = 8.2 Hz, 1H), 8.66 (d, *J* = 8.1Hz, 1H), 7.94 (d, *J* = 8.1Hz, 1H), 7.87 (d, *J* = 7.7Hz, 2H), 7.81 (d, *J* = 8.0Hz, 1H), 7.72 – 7.57 (m, 5H), 7.53 (t, *J* = 7.1Hz, 1H), 7.45 (t, *J* = 7.7Hz, 2H), 5.91-5.86 (m, 1H), 5.59-5.54 (m, 1H), 4.65 (s, 1H), 3.82 (t, *J* = 5.6 Hz, 3H), 3.77 (d, *J* = 7.2, 2H). ^{13}C NMR (100 MHz, CDCl3) δ 139.86, 134.03, 132.79, 132.00, 131.80, 131.07, 130.76, 129.82, 129.21, 128.31, 127.18, 126.85, 126.79, 126.52, 126.40, 126.13, 125.83, 124.30, 123.33, 122.55, 40.39, 31.11. IR (thin film): 3280, 3063, 2922, 1602, 1495, 1447, 1325, 1161, 1093, 1069, 887, 750 cm^{-1}. HRMS (ESI) calcd for $[C_{24}H_{22}NO_2S]^+$ ($[M+H]^+$): 388.1366, found 388.1368.

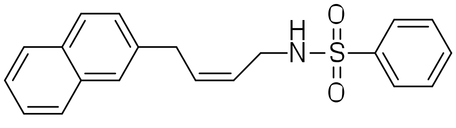


Table 2, entry 10: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (286 mg, 85 % yield for two steps, 7:1) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.86 (m, 2H), 7.83 – 7.78 (m, 1H), 7.76 (d, *J* = 8.0 Hz, 2H), 7.59 – 7.41 (m, 6H), 7.24 – 7.19 (m, 1H), 5.80-5.76 (m, 1H), 5.54 – 5.42 (m, 1H), 4.78 (s, 1H), 3.78 (t, *J* = 6.5 Hz, 2H), 3.47 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.98, 137.28, 133.72, 132.90, 132.68, 132.24, 129.31, 128.38, 127.79, 127.62, 127.28, 127.08, 126.45, 126.29, 125.62, 125.28, 40.36, 33.70. IR (thin film): 3282, 3056, 1631, 1599, 1508, 1447, 1324, 1161, 1093, 817 cm^{-1}HRMS (ESI) calcd for $[C_{20}H_{20}NO_2S]^+$ ($[M+H]^+$): 338.1209, found 338.1209.

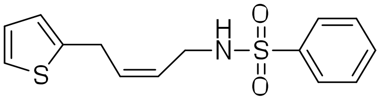


Table 2, entry 11: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (219 mg, 75 % yield for two steps, 12:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$), δ 7.87-7.85 (m, 2H), 7.87-7.85(m, 2H), 7.58-7.54 (m, 1H), 7.51-7.47 (m, 2H), 7.10-7.08 (m, 1H), 6.70-6.69 (m, 1H), 5.72-5.67 (m, 1H), 5.44-5.39 (m, 1H), 4.78 (br, 1H for NH), 3.68 (t, *J* = 6.5Hz, 2H), 3.46 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.47, 139.94, 132.92, 131.86, 129.32, 127.27, 127.12, 125.60, 124.65, 123.86, 40.17, 27.76. IR (thin film): 3281, 3026, 1585, 1447, 1324, 1160, 1093, 849 cm^{-1}. HRMS (ESI) calcd for $[C_{14}H_{16}NO_2S_2]^+$ ($[M+H]^+$): 294.0617, found 294.0617.

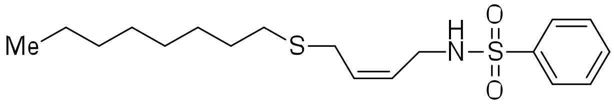


Table 2, entry 12: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the observed product (195 mg, 55 % yield for two steps) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.80 (m, 2H), 7.66 – 7.55 (m, 1H), 7.51 (dd, *J* = 8.2, 6.8 Hz, 2H), 5.58 (m, 1H), 5.42 (m, 1H), 4.89 (s, 1H), 3.62 (t, *J* = 6.6 Hz, 2H), 3.02 (d, *J* = 7.9 Hz, 2H), 2.50 – 2.22 (m, 2H), 1.53 – 1.44 (m, 2H), 1.37 – 1.20 (m, 10H), 0.87 (t, *J* = 6.9, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.96, 132.92, 130.48, 129.31, 127.27, 126.57, 39.97, 31.96, 31.75, 29.55, 29.35, 29.05, 28.20, 25.90, 22.81, 14.27. IR (thin film): 3281, 3066, 3027, 2925, 1586, 1447, 1327, 1161, 1094, 754, 689 cm^{-1}. HRMS (ESI) calcd for $[C_{18}H_{30}NO_2S_2]^+$ ($[M+H]^+$): 356.1712, found 356.1714.

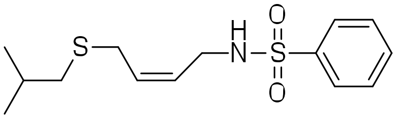


Table 2, entry 13: Following the general procedure for the aminoarylation of 1,3-butadiene (Table 2 procedure), purification by flash chromatography afforded the observed product (134 mg, 45 % yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.93 – 7.84 (m, 2H), 7.61 (dd, *J* = 8.4, 6.5 Hz, 1H), 7.54 (t, *J* = 7.6 Hz, 2H), 5.67 – 5.58 (m, 1H), 5.45 (m, 1H), 4.63 (s, 1H), 3.64 (t, *J* = 6.3Hz, 2H), 3.03 (d, *J* = 8.0Hz, 2H), 2.31 (d, *J* = 6.9 Hz, 2H), 1.73 (dp, *J* = 13.4, 6.7Hz, 1H), 0.96 (d, *J* = 6.7Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.01, 133.01, 130.76, 129.38, 127.33, 126.59, 41.00, 40.05, 28.72, 28.63, 22.25. IR (thin film): 3280, 3065, 3027, 2957, 1586, 1447, 1425, 1326, 1161, 1094, 900, 755, 720, 588 cm^{-1}. HRMS (ESI) calcd for $[C_{14}H_{22}NO_2S_2]^+$ ($[M+H]^+$): 300.1086, found 300.1089.

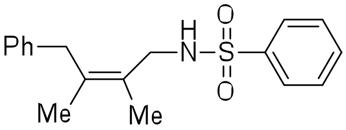


Table 3, entry 1: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-

aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (192 mg, 61 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (d, *J* = 7.8, 2H), 7.54 (t, *J* = 7.4, 1H), 7.47 (t, *J* = 7.7, 2H), 7.30 – 7.08 (m, 3H), 6.99 (d, *J* = 7.4, 2H), 4.82-4.78(m, 1H), 3.65 (d, *J* = 5.9, 2H), 3.28 (s, 2H), 1.64 (s, 3H), 1.55 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.96, 133.30, 132.69, 129.13, 128.58, 128.35, 127.18, 126.17, 125.03, 46.11, 39.73, 19.28, 17.20. IR (thin film): 3282, 3061, 3026, 2861, 1601, 1493, 1447, 1323, 1161, 1093, 1048, 830, 754, 727, 588 cm^{-1}. HRMS (ESI) calcd for $[C_{18}H_{22}NO_2S]^+$, ($[M+H]^+$): 316.1366, found 316.1363.

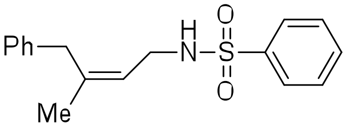


Table 3, entry 2: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (231 mg, 77 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89-7.85 (m, 2H), 7.59-7.55 (m, 1H), 7.54 – 7.46 (m, 2H), 7.29 – 7.22 (m, 2H), 7.22 – 7.14 (m, 1H), 7.08 – 6.98 (m, 2H), 5.24 (t, *J* = 7.2 Hz, 1H), 4.52 (s, 1H), 3.70 (t, *J* = 6.2 Hz, 2H), 3.27 (d, *J* = 8.1 Hz, 2H), 1.60 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.05, 139.03, 132.83, 129.27, 128.69, 128.53, 127.29, 126.41, 120.82, 77.55, 77.23, 76.91, 41.26, 37.95, 23.68. IR (thin film): 3282, 3061, 3026, 2970, 2916, 1668, 1600, 1494, 1447, 1326, 1161, 1094, 1045, 840, 755, 585 cm^{-1}. HRMS (ESI) calcd for $[C_{17}H_{20}NO_2S]^+$ ($[M+H]^+$): 302.1209 , found 302.1208.

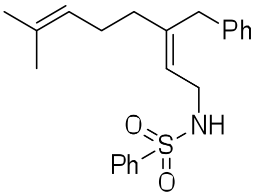


Table 3, entry 3: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (292 mg, 79 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86 (d, *J* = 8.0 Hz, 2H), 7.59 (t, *J* = 7.4Hz, 1H), 7.52 (t, *J* = 7.7Hz, 2H), 7.30 – 7.23 (m, 3H), 7.19 (t, *J* = 7.2Hz, 1H), 7.03 (d, *J* = 7.5Hz, 2H), 5.27 (t, *J* = 7.2Hz, 1H), 4.98 (t, *J* = 6.3, 1H), 4.30 (t, *J* = 5.5Hz, 1H), 3.71 (t, *J* = 6.5Hz, 2H), 3.30 (s, 2H), 2.03 – 1.87 (m, 4H), 1.67 (d, *J* = 15.5, 3H), 1.55 (d, *J* = 10.7, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.80, 140.14, 139.26, 132.88, 132.19, 129.36, 129.31, 128.99, 128.74, 128.52, 127.31, 126.44, 123.74, 120.51, 41.35, 36.84, 36.46, 26.45, 25.86, 17.89. IR (thin film): 3281, 3061, 3026, 2923, 1665, 1601, 1494, 1447, 1326, 1161, 1094, 1046, 754, 730 cm^{-1}. HRMS (ESI) calcd for $[C_{22}H_{28}NO_2S]^+$ ($[M+H]^+$): 370.1835, found 370.1833.

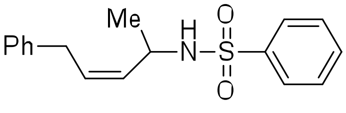


Table 3, entry 4: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-

aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (242 mg, 80 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.93 – 7.88 (m, 2H), 7.55 (t, J = 7.4 Hz, 1H), 7.47 (t, J = 7.7Hz, 2H), 7.28 (t, J = 7.4Hz, 2H), 7.21 (t, J = 7.4 Hz, 1H), 7.07 (d, J = 7.5Hz, 2H), 5.47-5.42 (m, 1H), 5.28-5.23 (m, 1H), 5.15 (br, 1H), 4.36-4.32 (m, 1H), 3.25-3.21 (m, 2H), 1.24 (d, J = 6.7 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.06, 139.98, 132.66, 131.49, 129.73, 129.09, 128.65, 128.41, 127.30, 126.27, 47.28, 33.59, 22.80. IR (thin film): 3274, 3062, 3026, 2976, 1658, 1601, 1495, 1447, 1326, 1162, 1092, 1070, 879, 744, 721, 593 cm^{-1}. HRMS (ESI) calcd for $[C_{17}H_{19}NO_2SNa]^+$ ($[M+Na]^+$): 324.1029, found 324.1024.

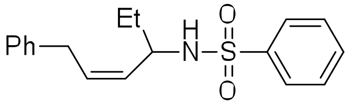


Table 3, entry 5: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (176 mg, 56 % yield for two steps, >20:1) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.73 (m, 2H), 7.51 (t, J = 7.4 Hz, 1H), 7.41 (t, J = 7.6 Hz, 2H), 7.25 (t, J = 7.3 Hz, 2H), 7.17 (t, J = 7.3 Hz, 1H), 7.04 (d, J = 7.3, 2H), 5.52 – 5.41 (m, 1H), 5.25 – 5.05 (m, 2H), 4.15 – 4.02 (m, 1H), 3.20-3.16 (m, 2H), 1.74 – 1.55 (m, 1H), 1.55 – 1.40 (m, 1H), 0.85 (t, J = 7.4, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.23, 140.07, 132.55, 130.73, 130.02, 129.00, 128.59, 128.43, 127.25, 126.21, 52.75, 33.77, 29.52, 10.08. IR (thin film): 3276,3062, 1601, 1447, 1326, 1161, 1093, 729, 563, 1509 cm^{-1}. HRMS (ESI) calcd for $[C_{18}H_{22}NO_2S]^+$ ($[M+H]^+$): 316.1366 , found 316.1368.

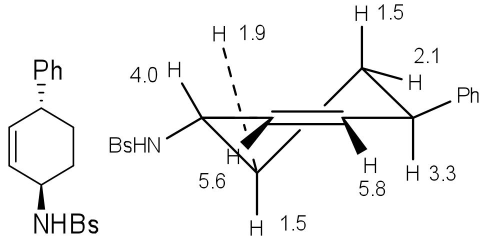
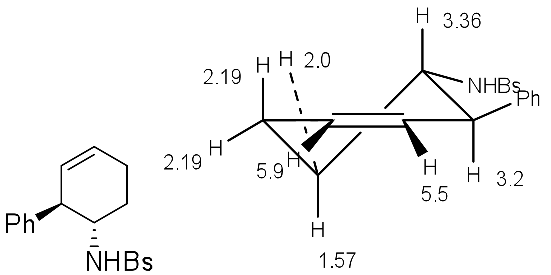


Table 3, entry 6: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product along with the 1,2-aminoarylation product as an inseparable mixture (226 mg, 72 % yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.09 – 7.96 (m, 2H), 7.70 – 7.49 (m, 3H), 7.41 – 7.26 (m, 2H), 7.21 (t, J = 7.3, 1H), 7.17 – 6.96 (m, 2H), 5.80-5.76 (m, 1H), 5.61-5.58 (m, 1H), 5.14 (d, J = 8.7, 1H), 4.07 – 3.94 (m, 1H), 3.41 – 3.22 (m, 1H), 2.13 – 1.92 (m, 2H), 1.65 – 1.41 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 144.93, 134.16, 132.77, 129.32, 128.75, 128.62, 127.63, 127.11, 126.55, 49.97, 41.48, 30.86, 30.07. IR (thin film): 3276, 3061, 3026, 1601, 1491, 1447, 1326, 1160, 1088, 897, 757 cm^{-1}. HRMS (ESI) calcd for [C18H19NO2SNa]$^+$ ($[M+Na]^+$): 336.1029, found 336.1026.



Purification by flash chromatography also afforded the 1,2-aminoarylation product (56 mg, 18 % yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.62 (t, *J* = 11.0 Hz, 2H), 7.50 (t, *J* = 7.5, 1H), 7.37 (t, *J* = 7.8 Hz, 2H), 7.21 – 7.14 (m, 3H), 6.97 (dd, *J* = 6.1, 3.3 Hz, 2H), 5.95 – 5.83 (m, 1H), 5.56-5.50 (m, 1H), 4.86 (d, *J* = 7.2, 1H), 3.34 (td, *J* = 9.6, 2.9 Hz, 1H), 3.22 (d, *J* = 2.9, 1H), 2.19 (s, 2H), 2.10 – 1.98 (m, 1H), 1.60 (dt, *J* = 21.5, 6.6, 1H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 141.84, 140.36, 132.42, 129.12, 128.73, 128.49, 128.43, 127.42, 127.11, 127.04, 55.91, 48.28, 26.86, 23.08. IR (thin film): 3281, 3061, 3026, 1650, 1601, 1479, 1447, `325, 1161, 1071, 906, 720, 688, 578 cm^{-1}. . HRMS (ESI) calcd for [C$_{18}$H$_{20}$NO$_2$S]$^+$ ([M+H]$^+$): 314.1209, found 314.1207.

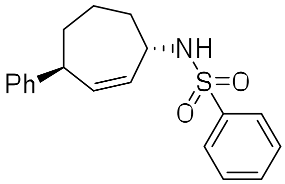
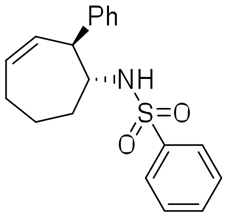
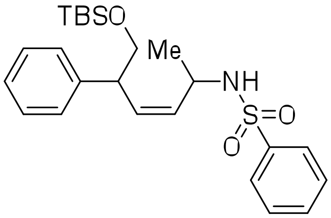


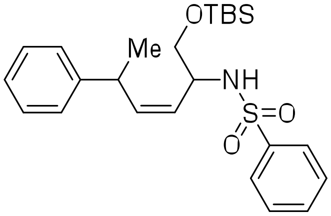
Table 3, entry 7: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product (229 mg, 70% yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, CDCl$_3$) δ 8.02 – 7.87 (m, 2H), 7.60-7.55 (m, 3H), 7.29 (t, *J* = 7.5 Hz, 2H), 7.20 (t, *J* = 7.3 Hz, 1H), 7.12 (d, *J* = 7.3 Hz, 2H), 5.76 – 5.62 (m, 1H), 5.41-5.48 (m, 1H), 5.12 (d, *J* = 8.1, 1H), 4.13-4.10 (m, 1H), 3.52 (s, 1H), 1.87-1.60 (m, 6H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 145.92, 141.12, 137.11, 132.79, 132.08, 129.30, 128.71, 127.39, 127.21, 126.35, 53.14, 45.83, 35.35, 34.22, 23.19. IR (thin film): 3279, 3061, 3025, 2929, 1650, 1600, 1447, 1327, 1160, 1093, 911, 755, 594 cm^{-1}. HRMS (ESI) calcd for [C$_{19}$H$_{22}$NO$_2$S]$^+$ ([M+H]$^+$): 328.1366, found 328.1366.



Purification by flash chromatography also afforded the 1,2-aminoarylation product (49 mg, 15 % yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.77 – 7.68 (m, 2H), 7.56 (t, *J* = 7.4Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.23 – 7.14 (m, 3H), 7.03 – 6.91 (m, 2H), 6.01 (dt, *J* = 11.7, 6.0Hz, 1H), 5.54 (dd, *J* = 11.6, 6.0Hz, 1H), 4.69 (d, *J* = 7.5Hz, 1H), 3.66 – 3.54 (m, 1H), 3.50 (t, *J* = 6.6Hz, 1H), 2.27-2.13 (m, 2H), 2.03 – 1.89 (m, 1H), 1.79 – 1.59 (m, 2H), 1.55-1.47 (m, 1H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 140.73, 140.64, 134.59, 132.55, 130.31, 129.17, 128.93, 128.24, 127.15, 126.95, 56.90, 51.61, 34.40, 28.88, 22.30. IR (thin film): 3286, 3061, 3025, 1650, 1600, 1493, 1447, 1326, 1161, 1094, 754, 689 cm^{-1}. HRMS (ESI) calcd for $[C_{19}H_{22}NO_2S]^+$ ($[M+H]^+$): 328.1366, found 328.1364.



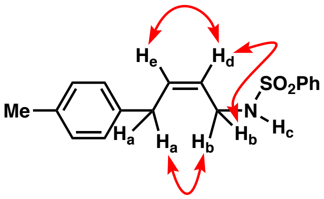
Scheme 3, Product 13: Following the general procedure for the aminoarylation of substituted 1,3-dienes (Table 3 procedure), purification by flash chromatography afforded the desired 1,4-aminoarylation product (148 mg, 33 % yield for two steps) as a clear oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (d, *J* = 7.3 Hz, 2H), 7.63 (t, *J* = 7.4Hz, 1H), 7.57 (t, *J* = 7.6Hz, 3H), 7.28-7.22 (m, 3H), 7.18 (t, *J* = 7.3 Hz, 1H), 6.97 (d, *J* = 7.1Hz, 2H), 5.68-5.62 (m, 1H), 5.46 – 5.31 (m, 2H), 4.04-3.97 (m, 1H), 3.65-3.58 (m, 2H), 3.31-3.25 (m, 1H), 1.12 (d, *J* = 6.5 Hz, 3H), 0.90 (s, 9H), 0.04 (d, *J* = 8.0 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.43, 140.71, 132.74, 132.67, 129.08, 128.48, 127.87, 127.54, 126.72, 67.62, 47.26, 46.26, 26.15, 21.97, 18.64, -5.26, -5.34. IR (thin film): 3270, 2928, 1447, 1327, 1163, 1094, 836 cm^{-1}. HRMS (ESI) calcd for $[C_{24}H_{36}NO_3SSi]^+$ ($[M+H]^+$): 446.2180, found 446.2184.



Scheme 3, Product 14: Purification by flash chromatography afforded the regioisomeric 1,4-aminoarylation product (36 mg, 8 % yield for two steps) as a clear oil: ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, *J* = 8.2 Hz, 2H), 7.59 (d, *J* = 7.0 Hz, 1H), 7.53 – 7.45 (m, 2H), 7.29 – 7.21 (m, 3H), 7.16 (d, *J* = 6.5Hz, 1H), 7.10 (d, *J* = 7.8Hz, 2H), 5.60 (t, *J* = 10.3 Hz, 1H), 5.21 (t, *J* = 10.0 Hz, 1H), 5.07 (d, *J* = 4.4 Hz, 1H), 4.10 (s, 1H), 3.55 (s, 1H), 3.36 – 3.28 (m, 1H), 3.28 – 3.17 (m, 1H), 1.26 (s, 3H), 0.83 – 0.77 (m, 9H), -0.11 (d, *J* = 6.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.28, 140.78, 138.25, 132.82, 129.15, 128.78, 127.50, 126.91, 126.36, 125.87, 77.55, 77.23, 76.91, 64.86, 53.15, 38.14, 29.91, 25.99, 22.87, 18.39, -5.33, -5.43. IR (thin film): 3274, 3026, 1147, 1160, 1094 cm^{-1}. HRMS (ESI) calcd for $[C_{24}H_{36}NO_3SSi]^+$ ($[M+H]^+$): 446.2180, found 446.2180.

Determination of *Z*-Olefin Geometry of Products

NOE studies of the product from Table 2, Entry 3 allowed the assignment of the *Z*-olefin geometry for the aminoarylation product. The *Z*-olefin geometry for all other products was assumed by analogy.



Detection of Sulfur By-Products

$BsNH_2$ was detected by HNMR. The $BsNH_2$ generated from the aminoarylation reaction was spectroscopically identical to commercial $BsNH_2$ purchased from Sigma-Aldrich.

Sulfur by-products **19** and **20** were detected by GCMS (Agilent 7820A/5935).
Column: HP-5ms, 0.25 micron (19091S-433)
Method: initial temperature 40 °C for 2 min, ramp 20 °C/min until 250 °C, hold at 250 °C for 4 min

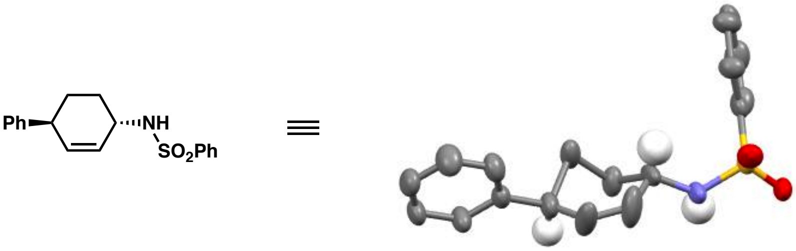
Retention time of commercial **19** = 10.0 min (MS: 186.1)
Retention time of **19** generated as by-product in aminoarylation = 10.1 min (MS: 186.1)

Retention time of commercial **20** = 11.4 min (MS: 218.1)
Retention time of **20** generated as by-product in aminoarylation = 11.5 min (MS: 218.1)

Determination of Relative Stereochemistry of Aminoarylation Products

We thank Dr. Vincent Lynch (Manager of the X-ray Diffraction Lab at UT Austin) for all the X-ray structural analysis.

A sample of the major product from Table 3, entry 6 was recrystallized from methylene chloride and hexanes (slow diffusion). The resulting crystals were suitable for X-ray diffraction and the structure was solved. This structure allowed the assignment of relative configuration as shown.



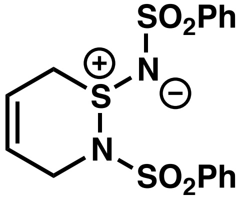
References

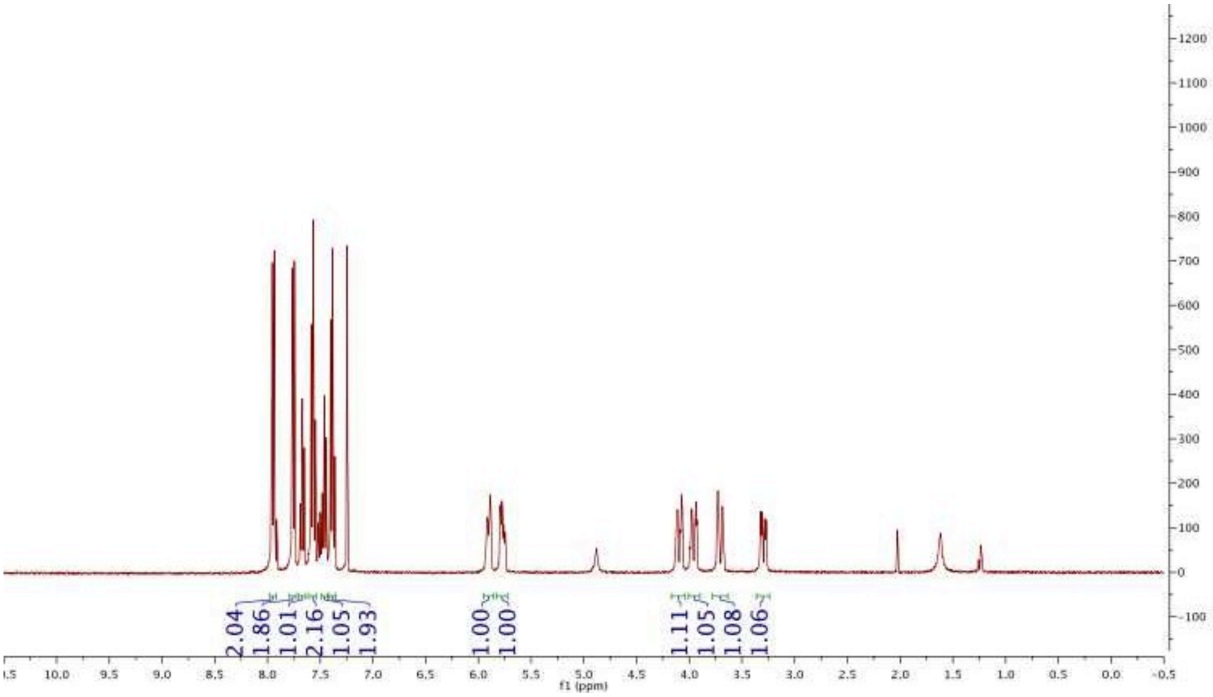
[1] Frohn, M.; Dalkiewicz, M.; Tu, Y.; Wang, Z.-X.; Shi, Y. *J. Org. Chem.* **1998**, *63*, 2948-2953.

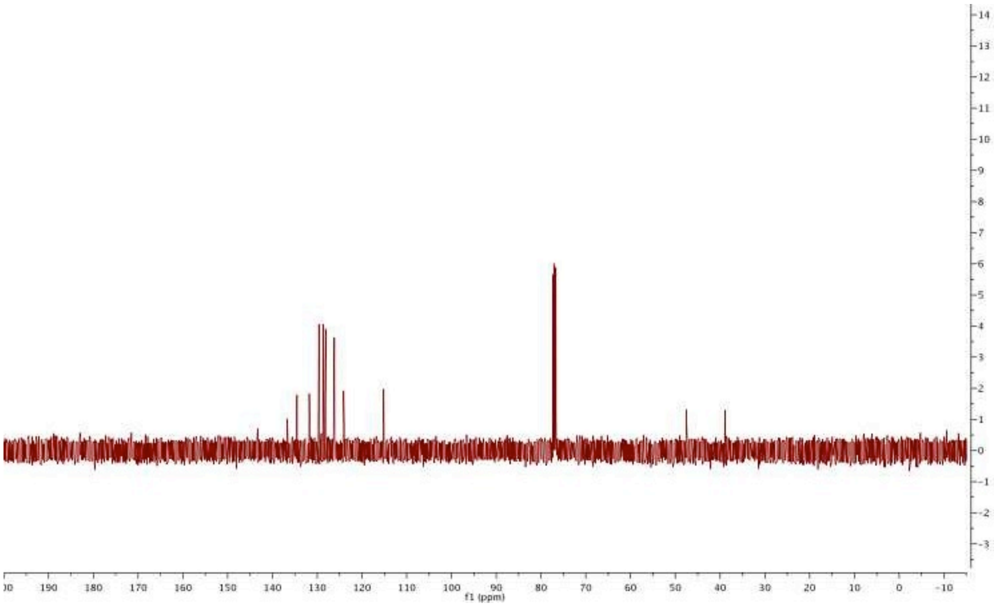
[2] Smyth, T. P.; O'Donnell, M. E.; O'Connor, M. J.; St. Ledger, J. O. *J. Org. Chem.* **1998**, *63*, 7600-7618.

NMR Spectra

*[4+2] Cycloadduct **6***







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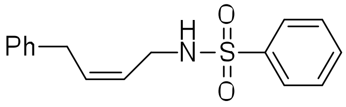

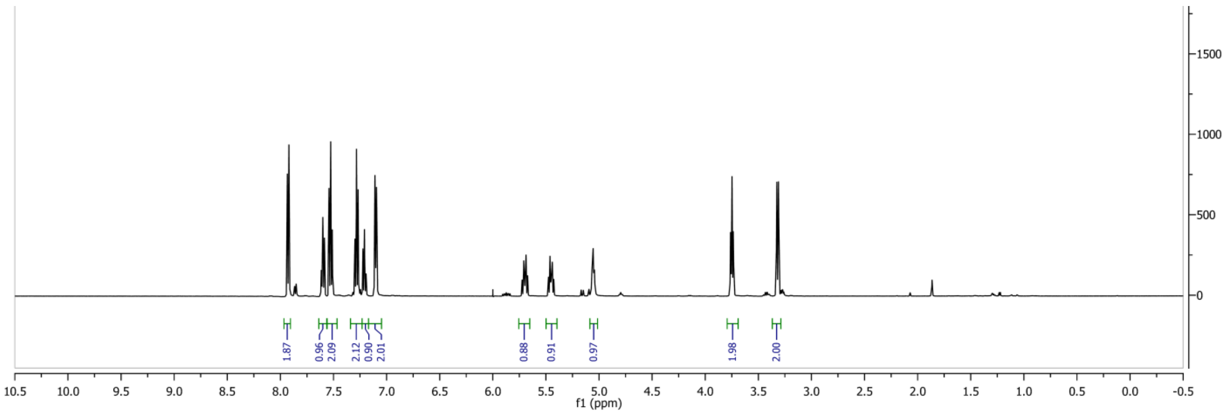

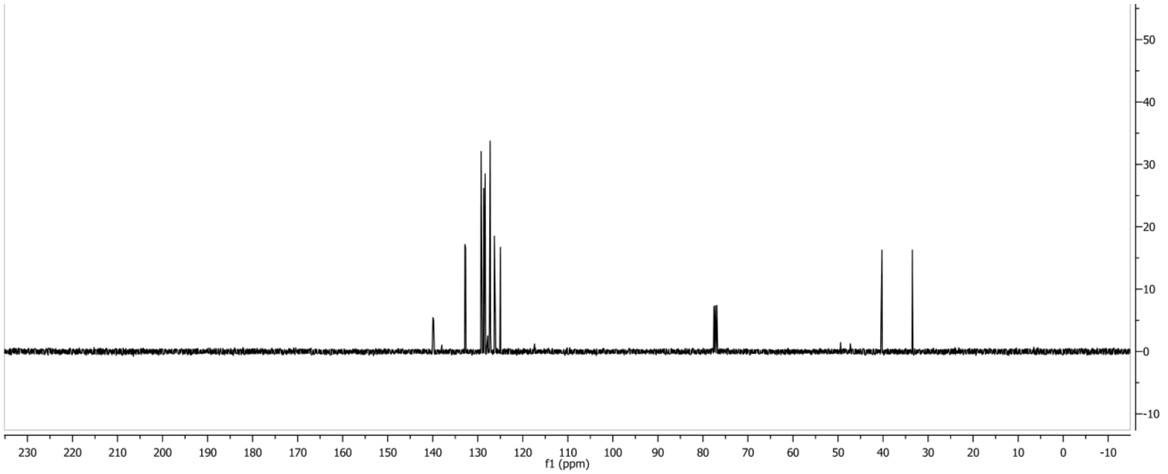

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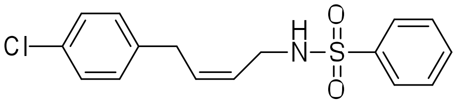

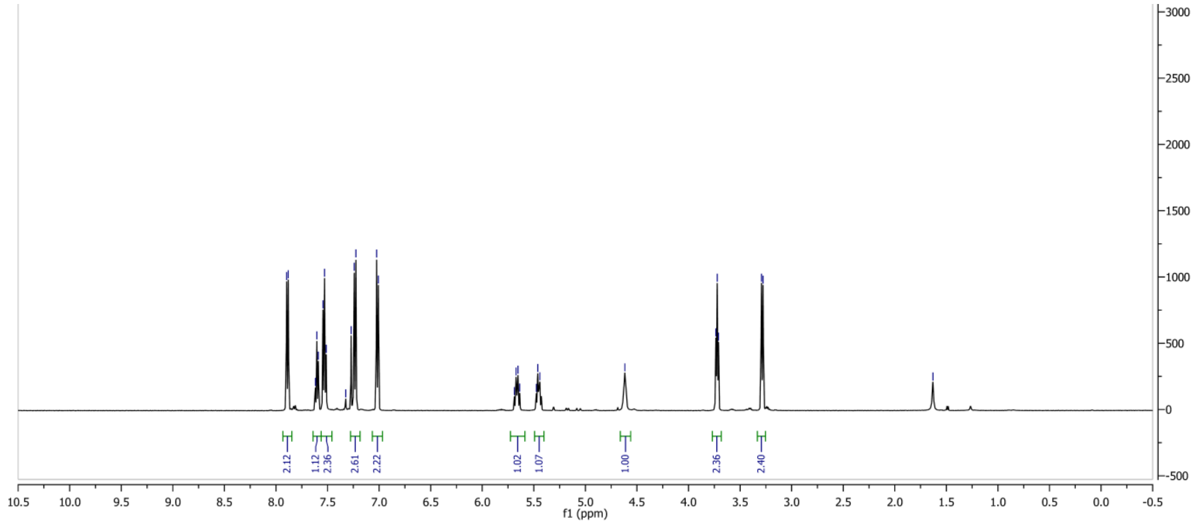

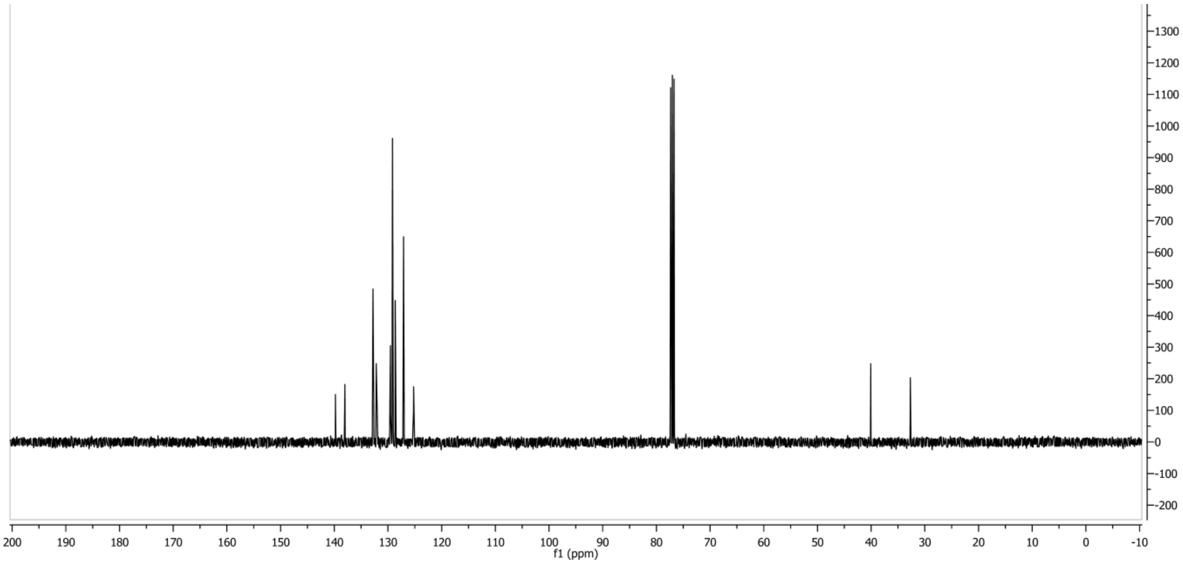

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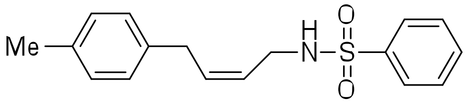

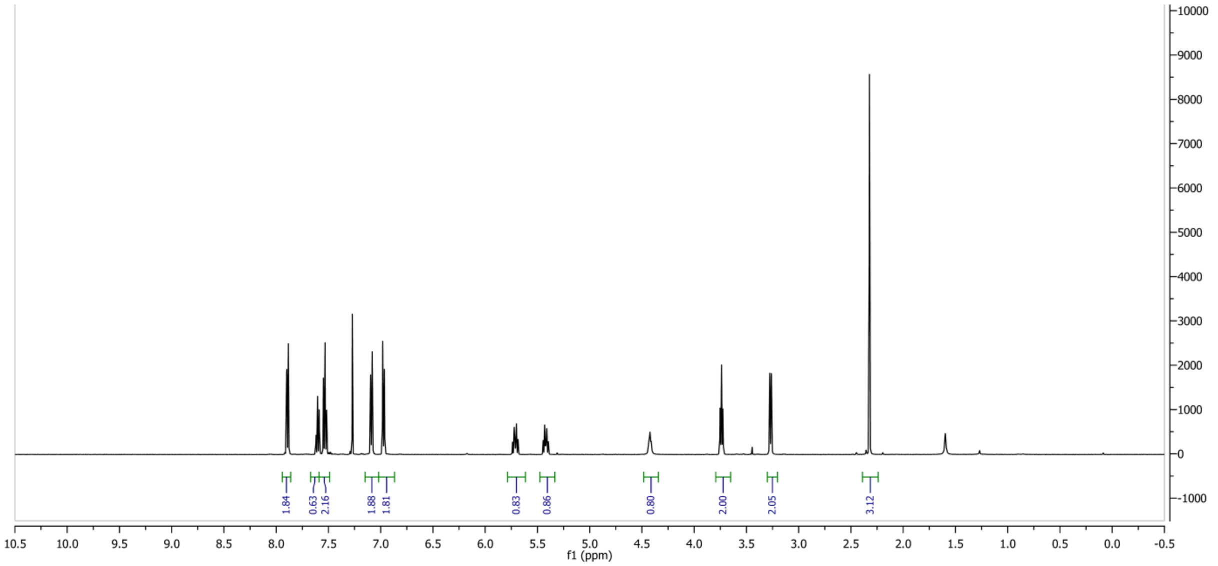

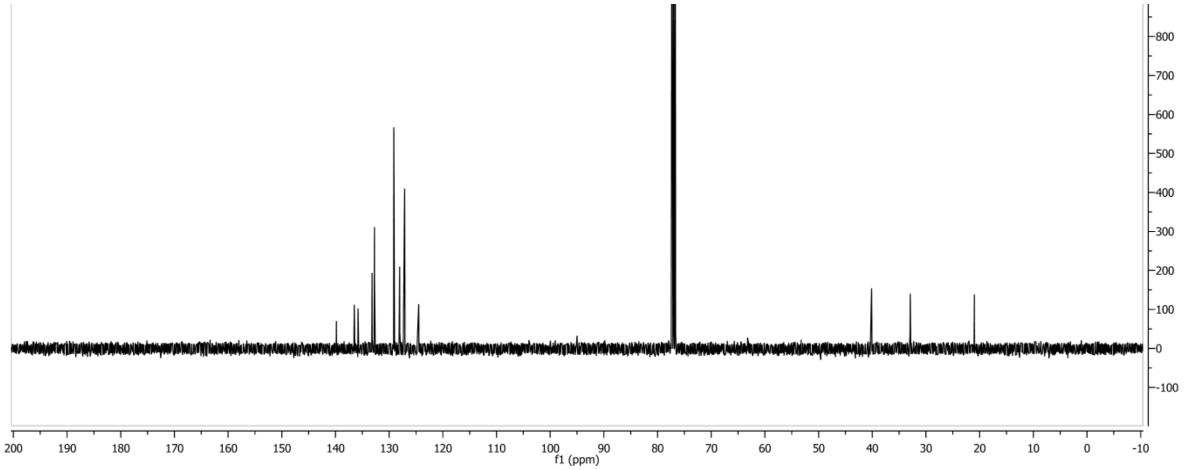

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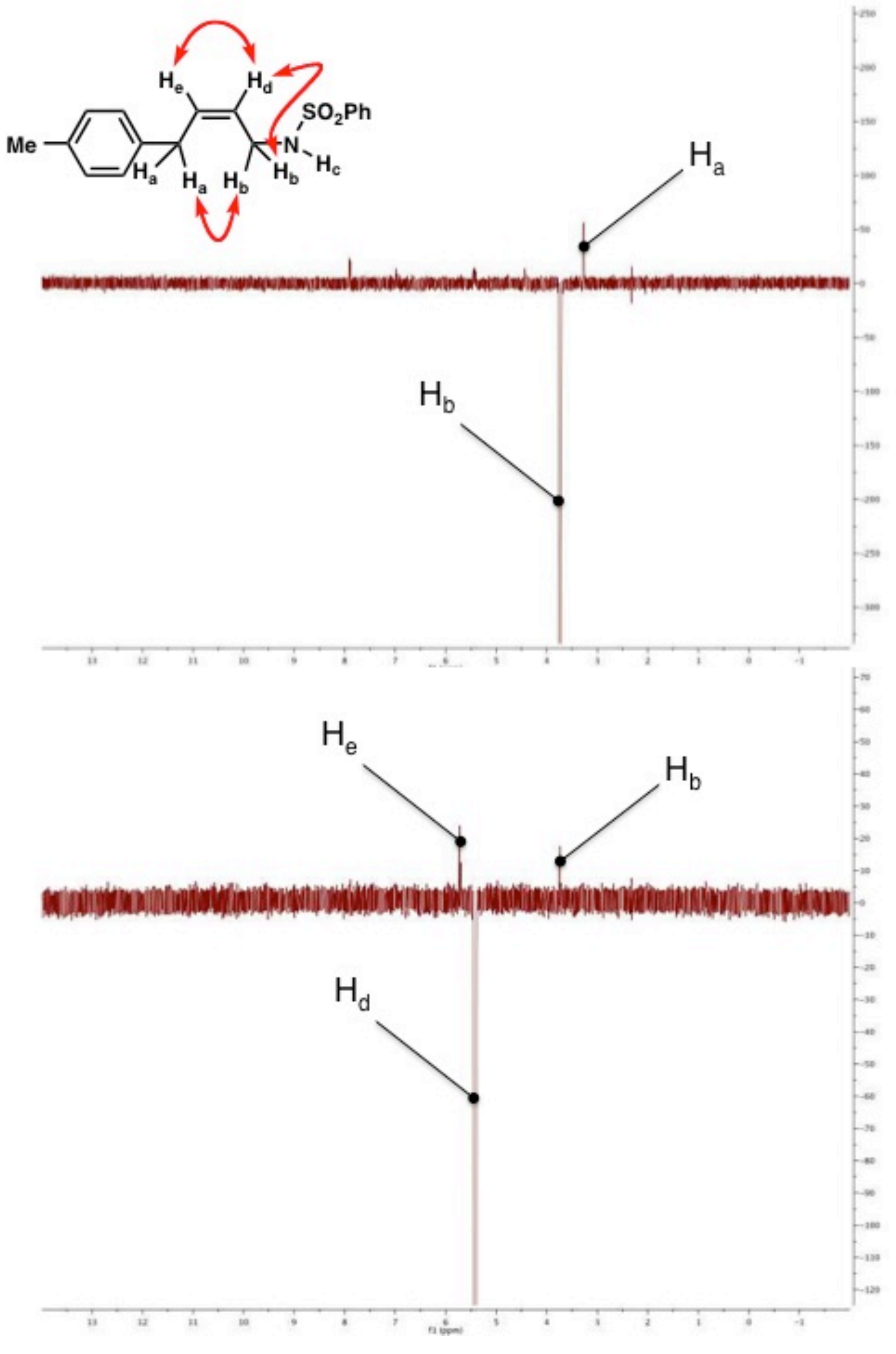

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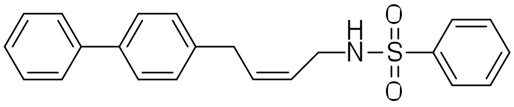

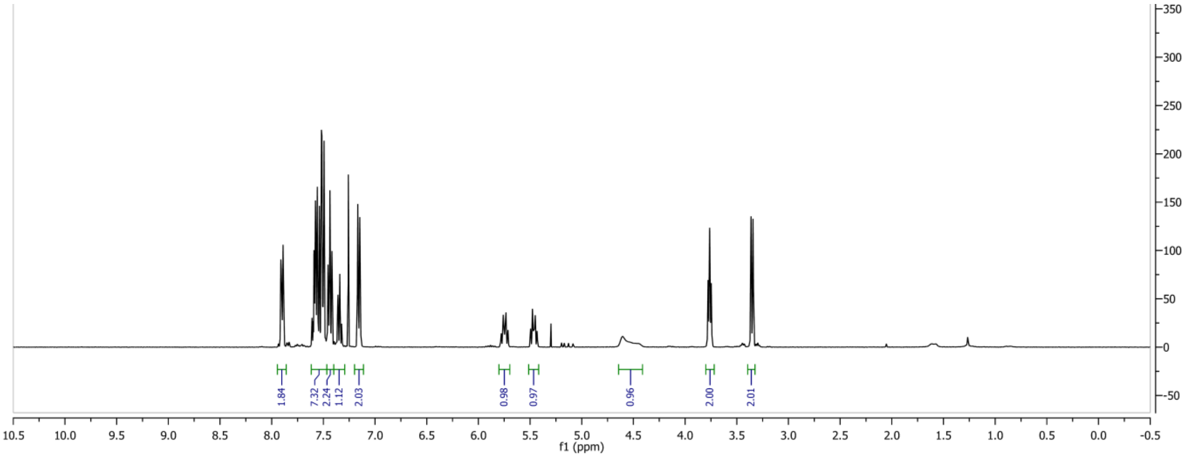

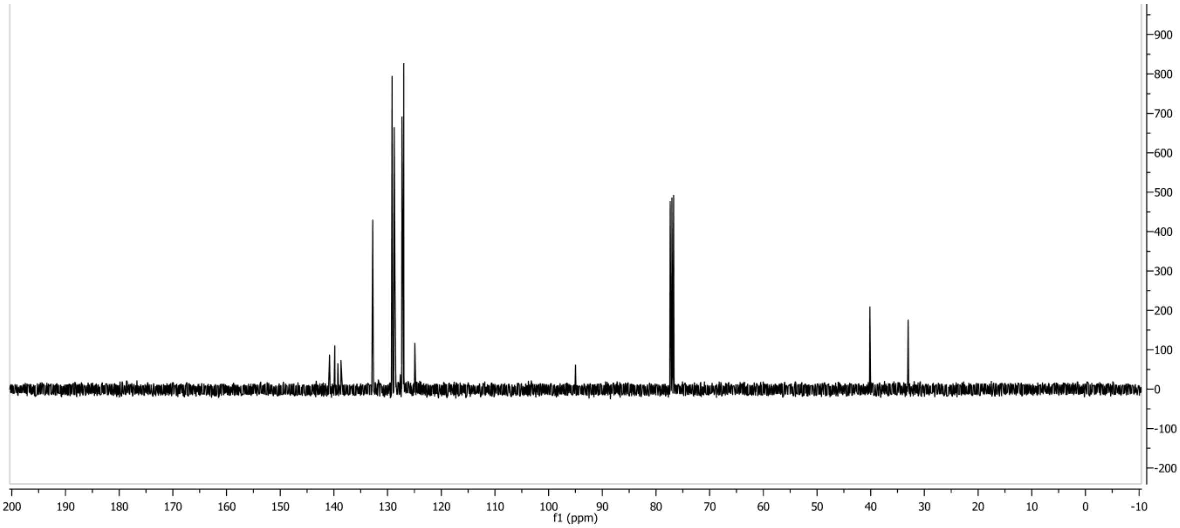

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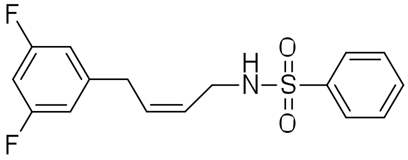

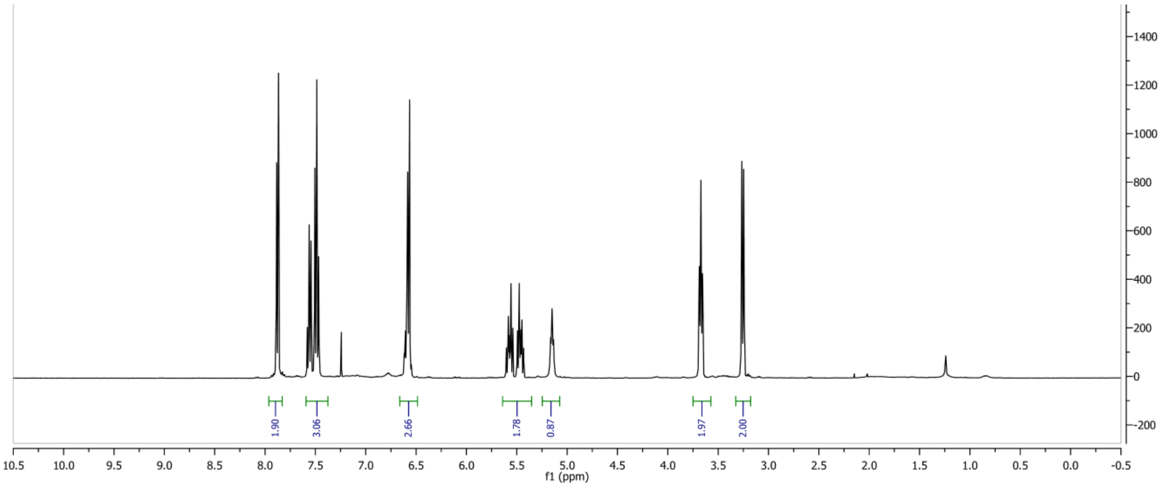

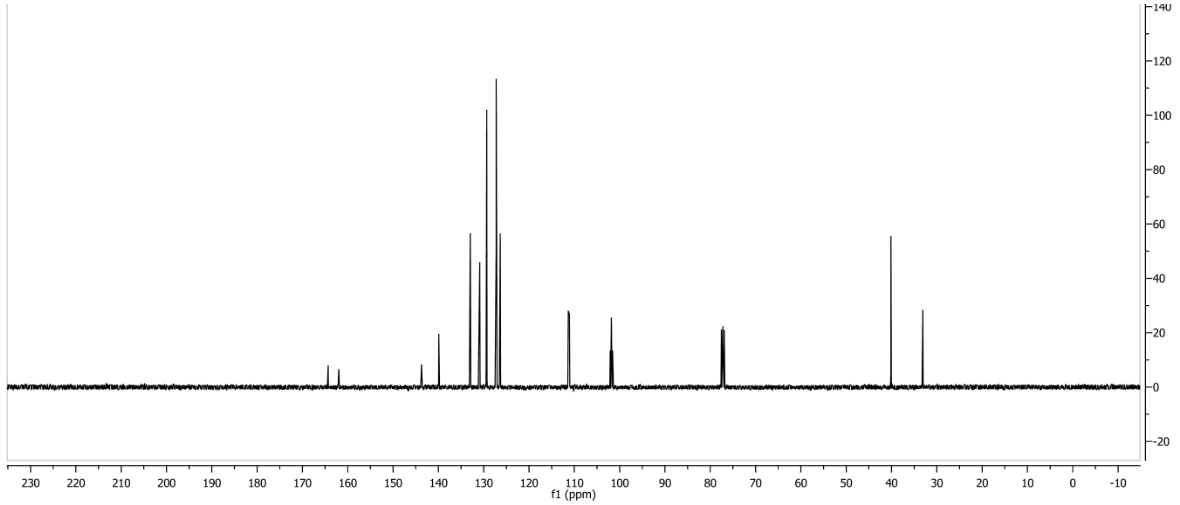

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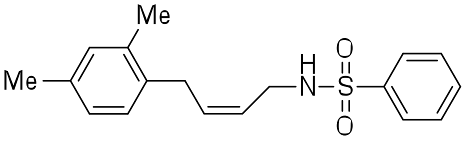

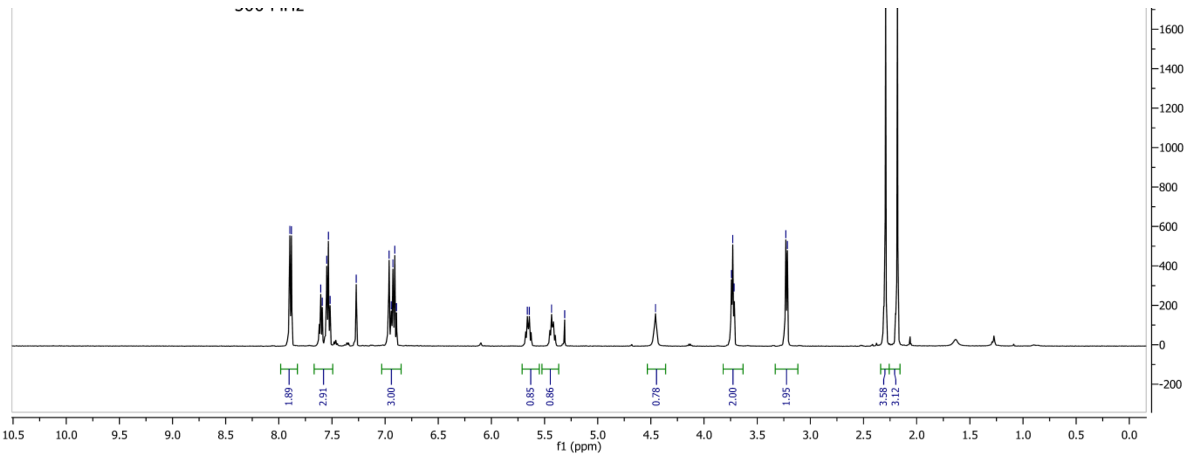

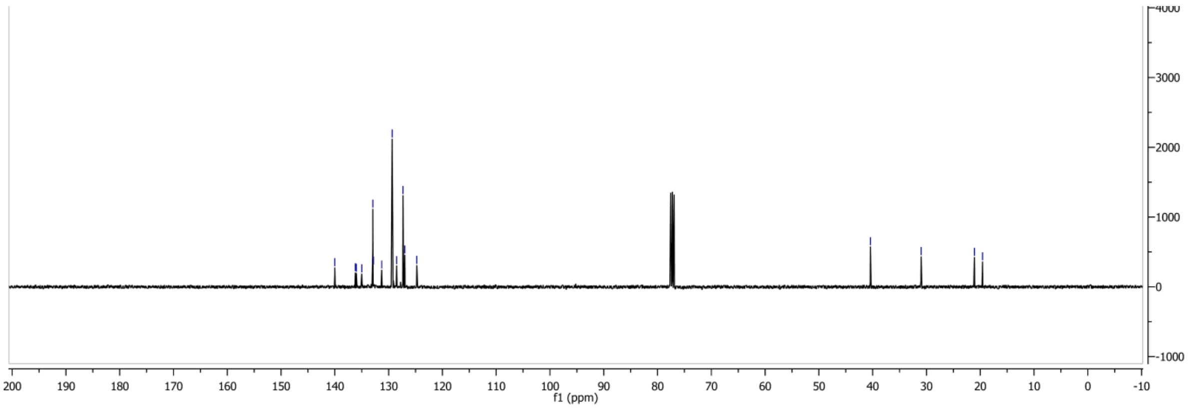

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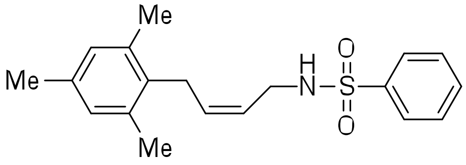

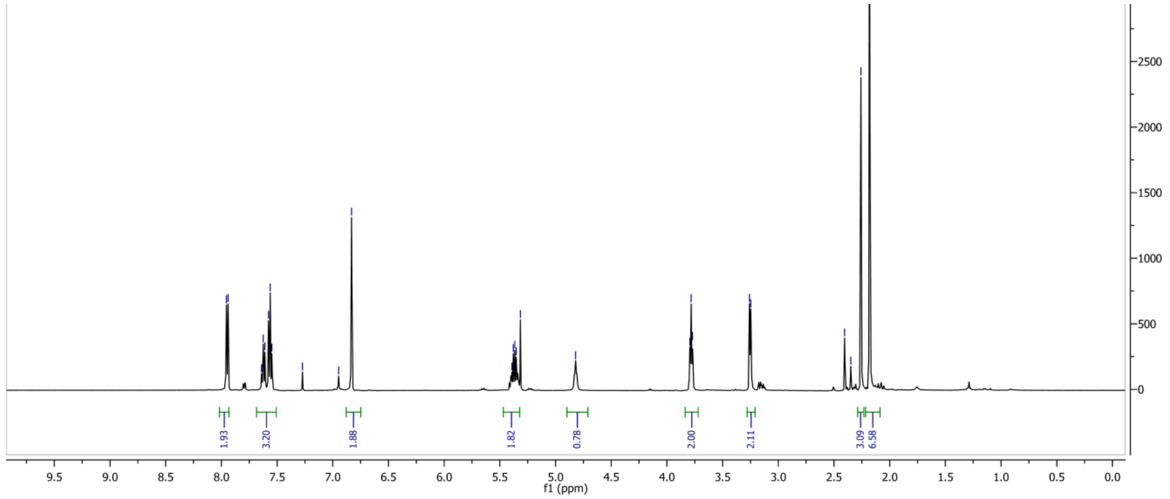

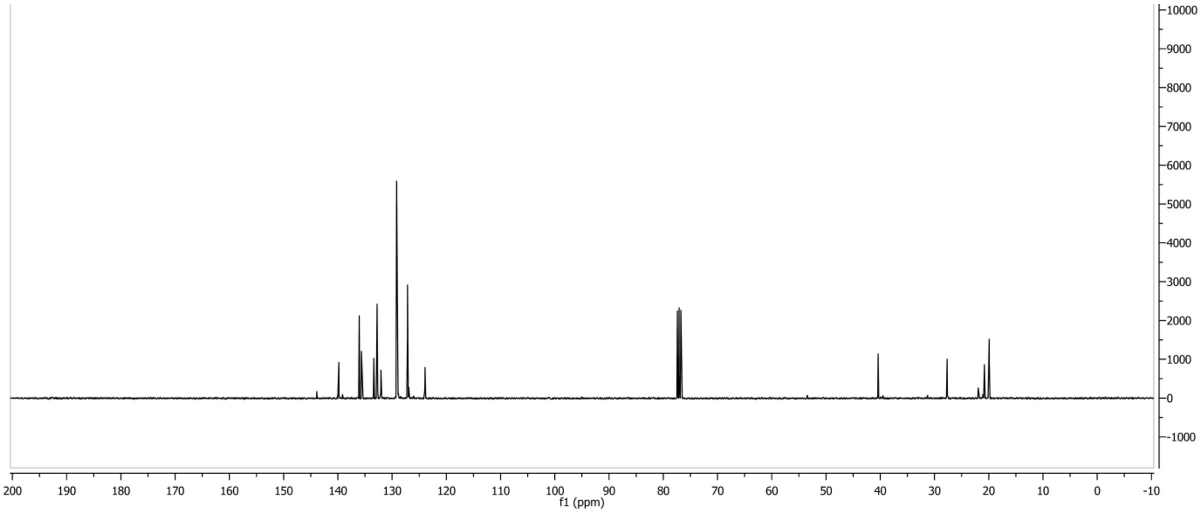

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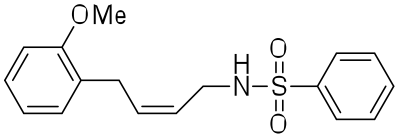

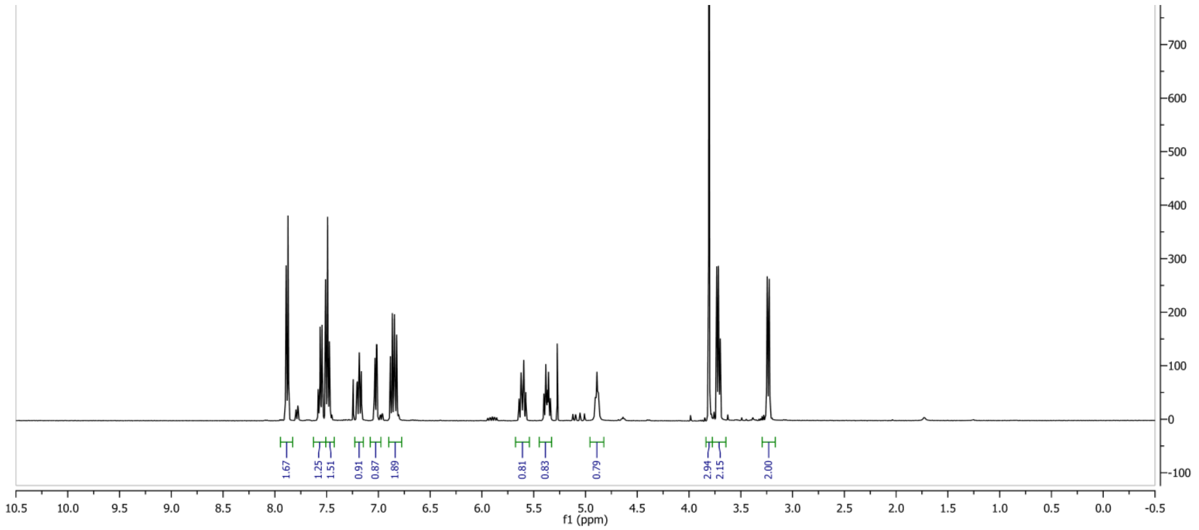

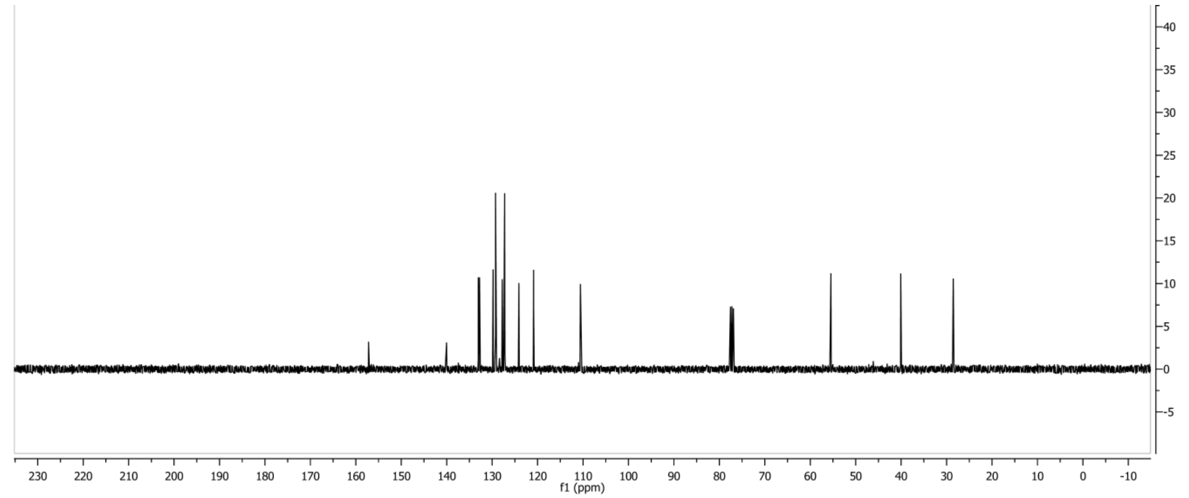

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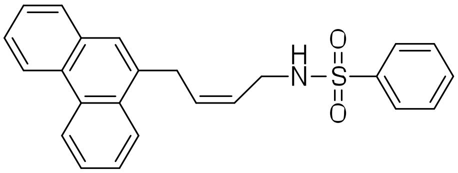

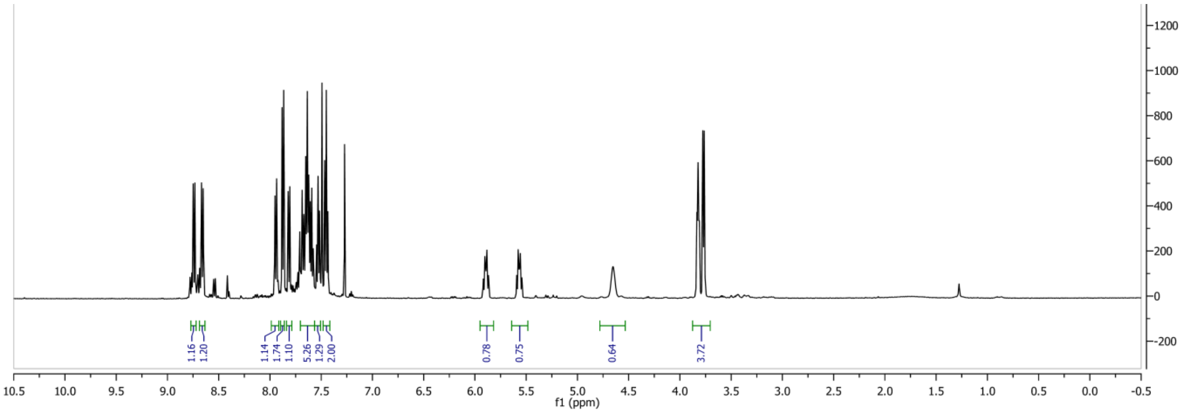

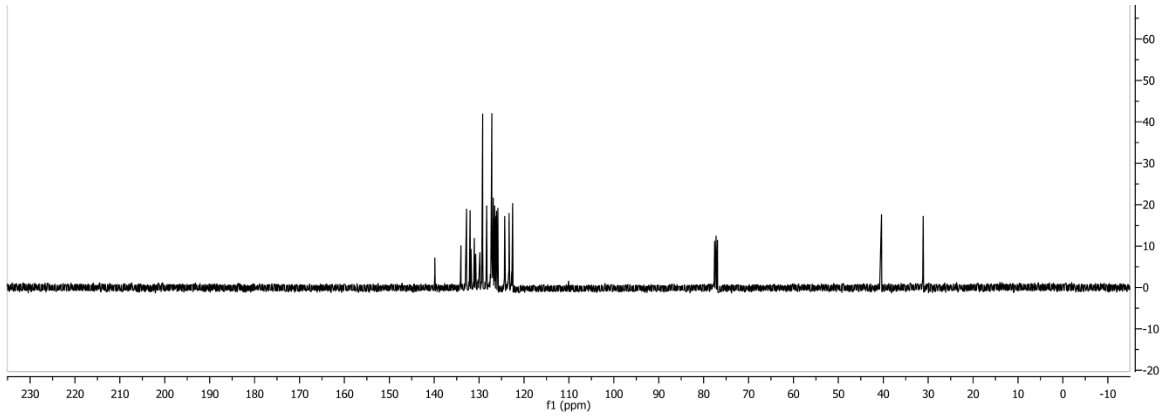

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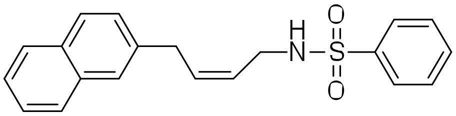

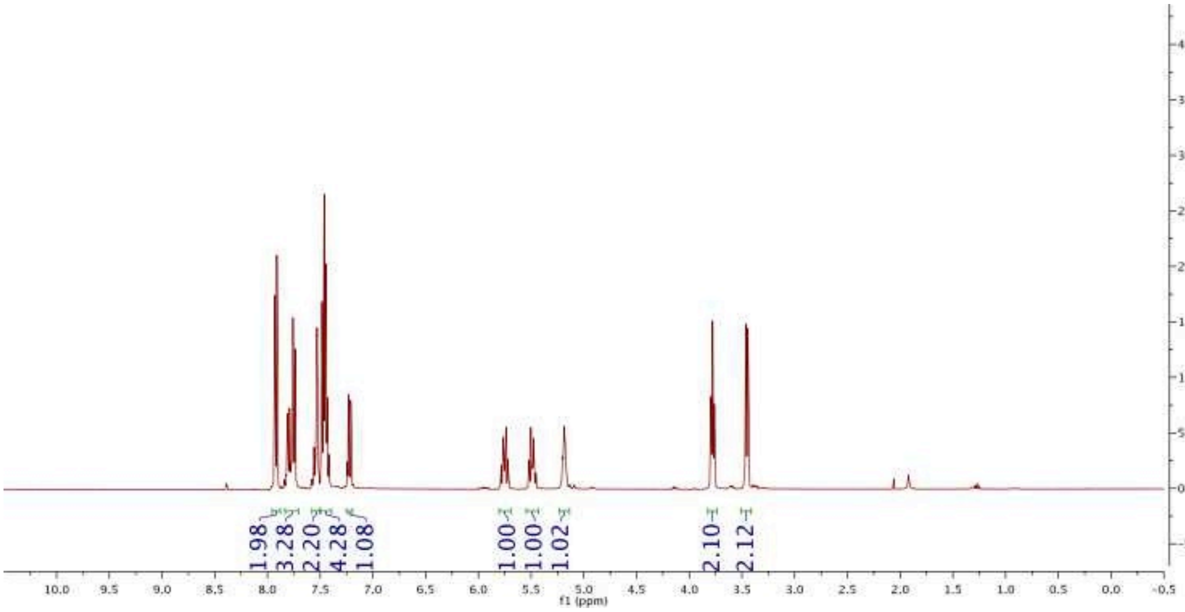

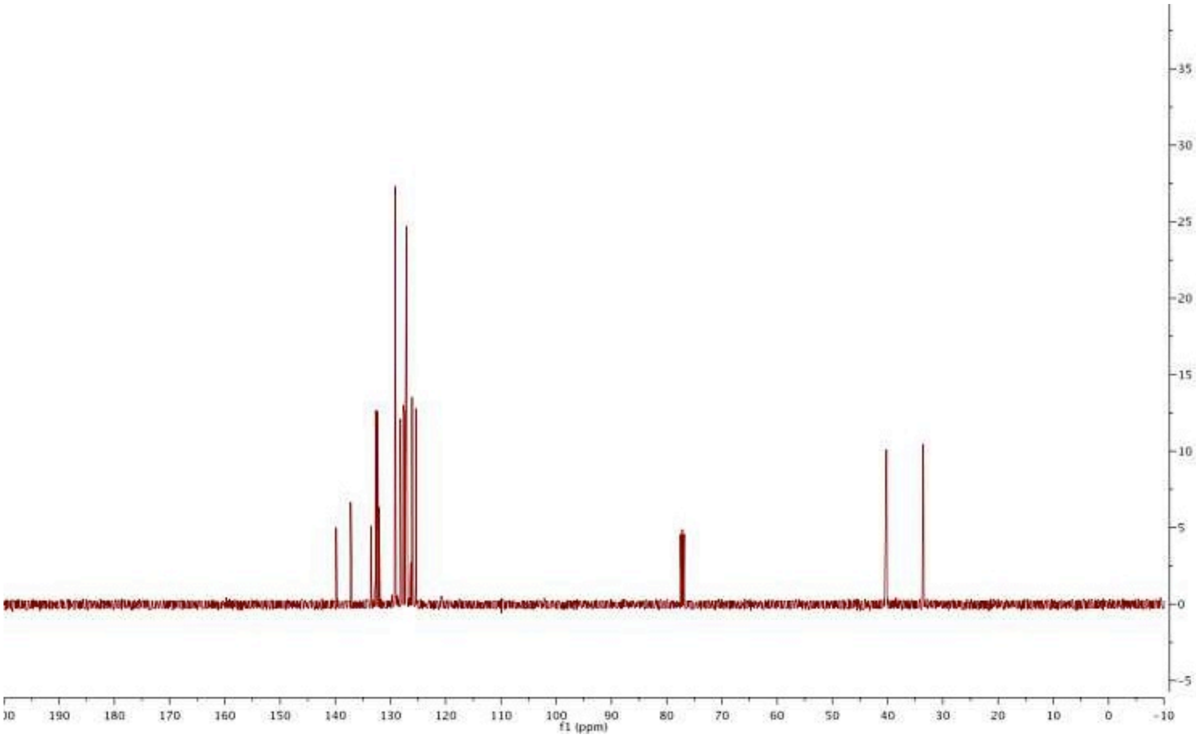

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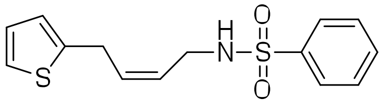

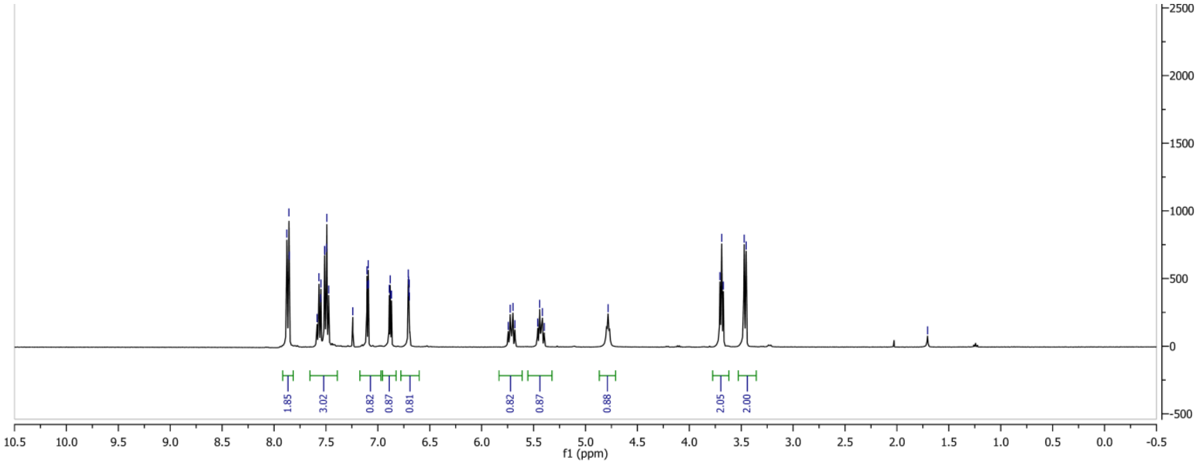

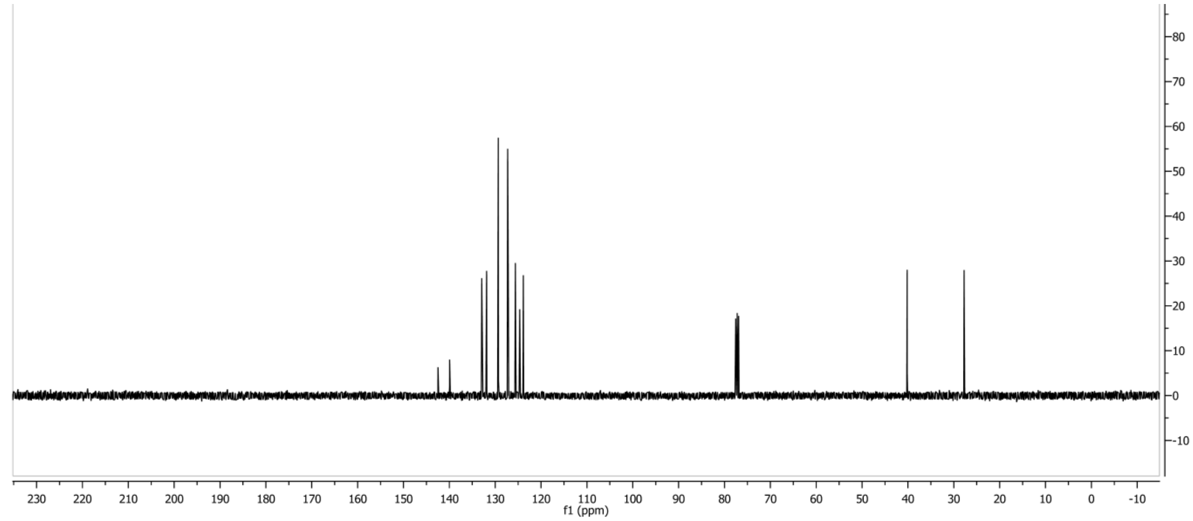

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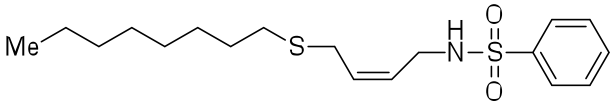

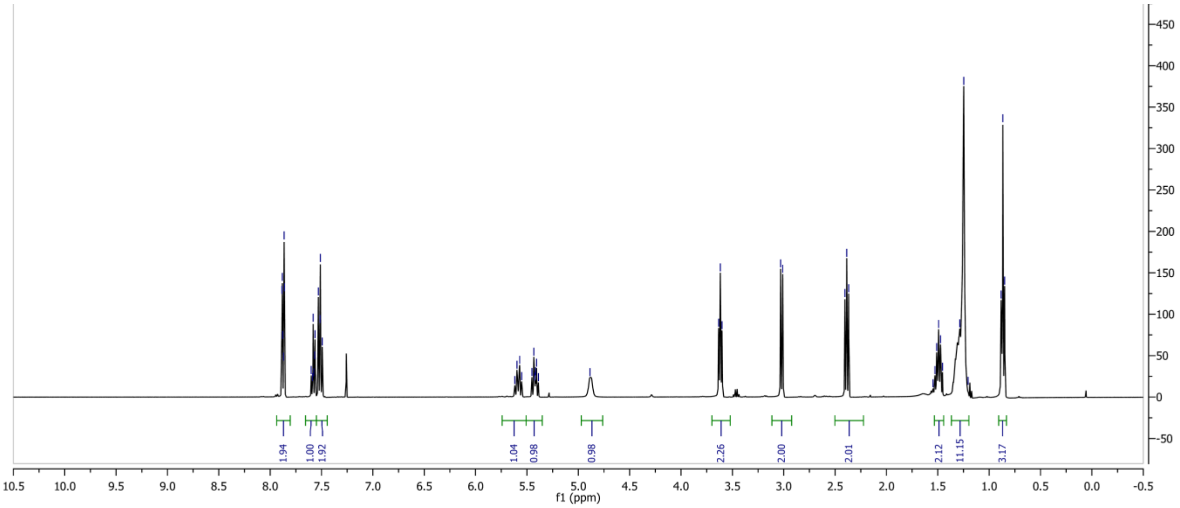

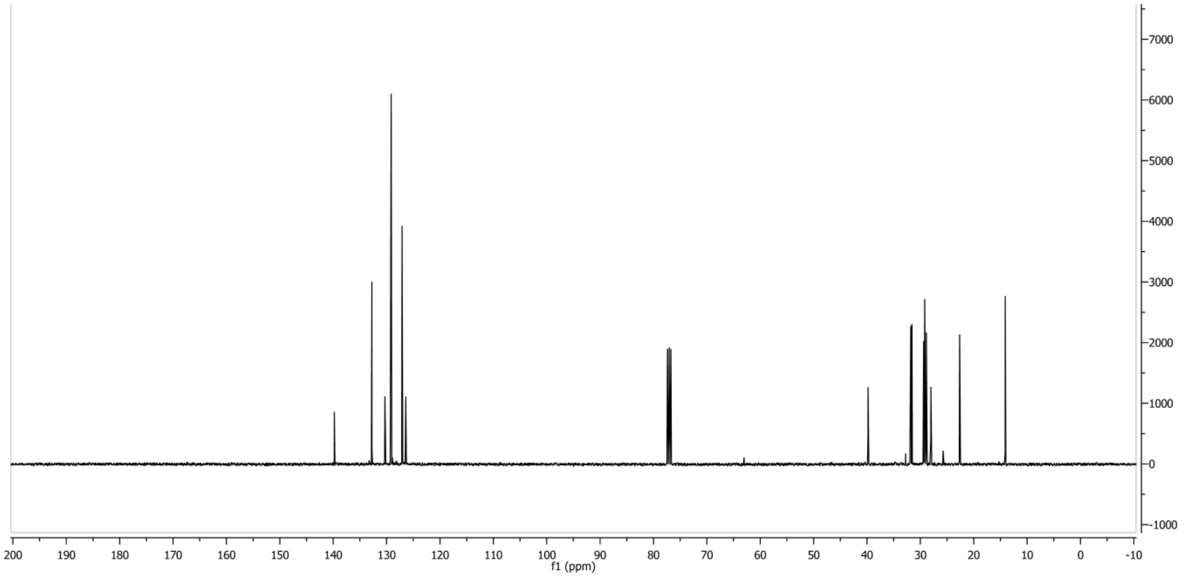

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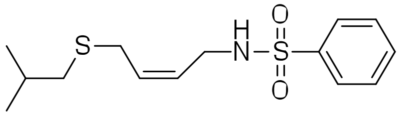

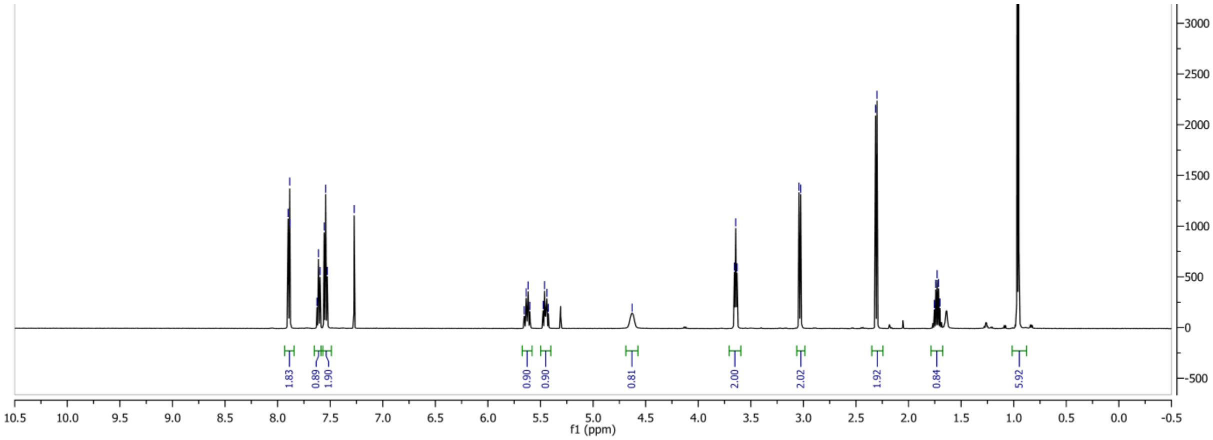

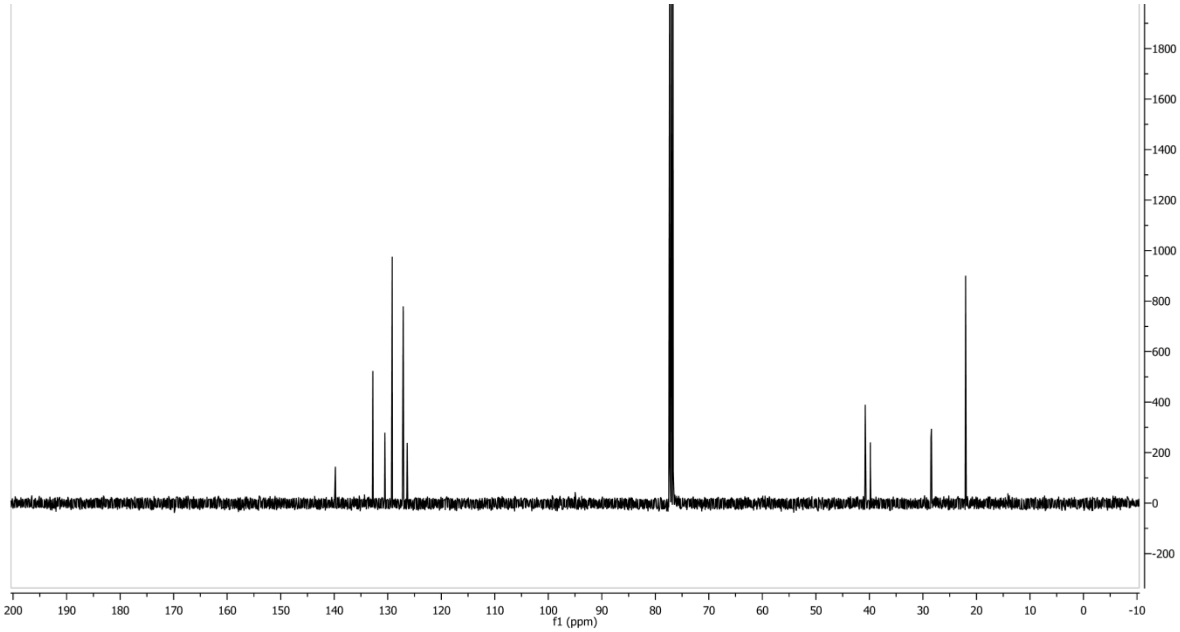

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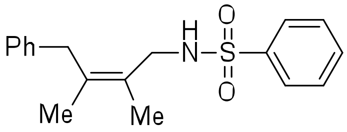

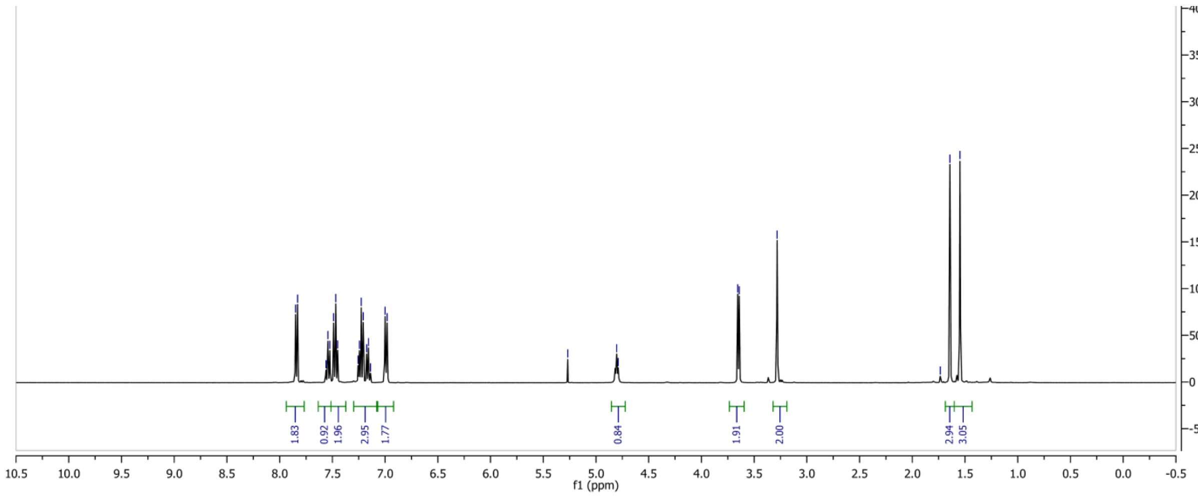

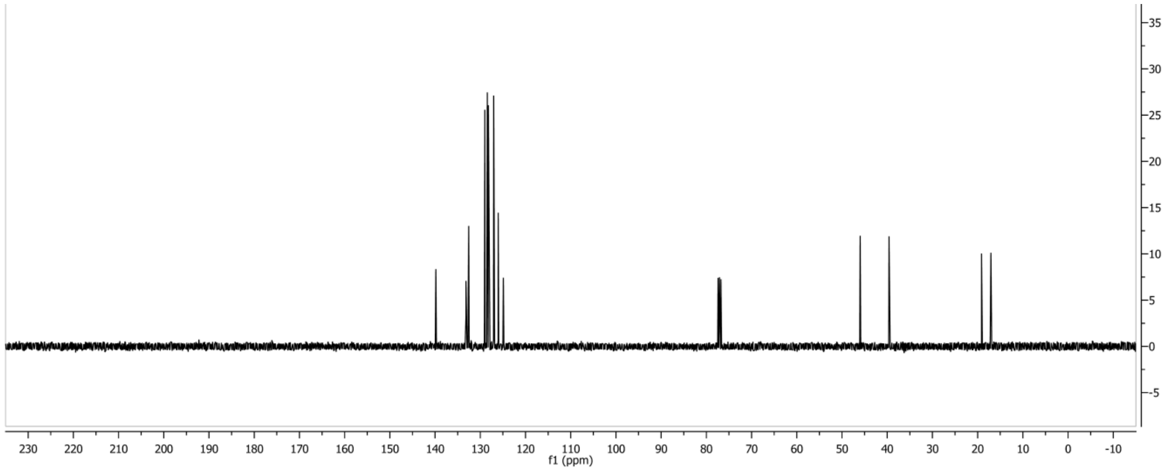

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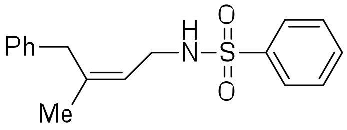

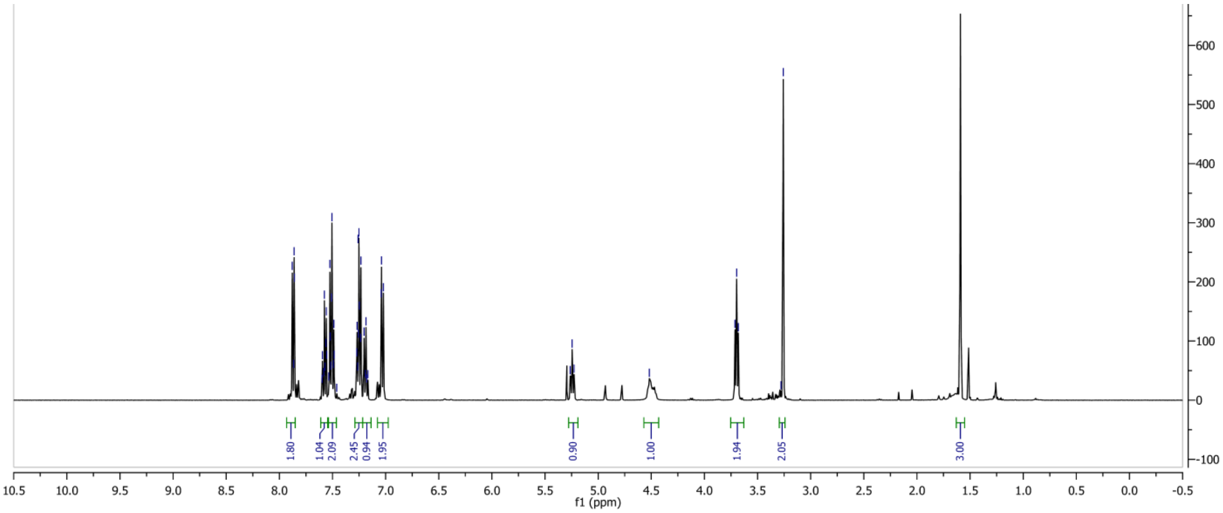

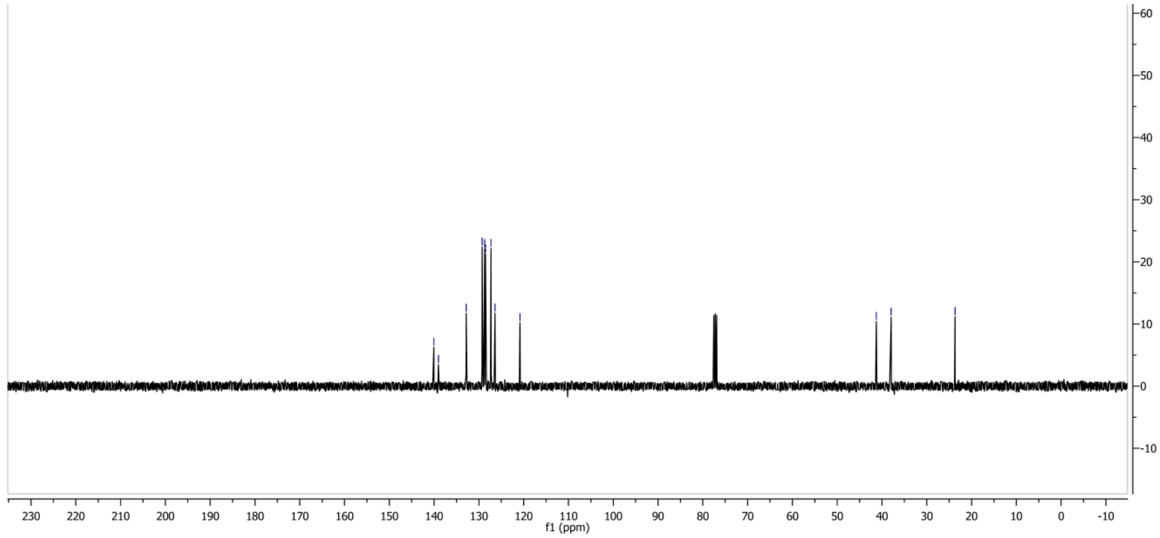

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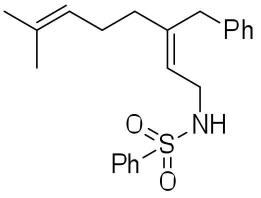

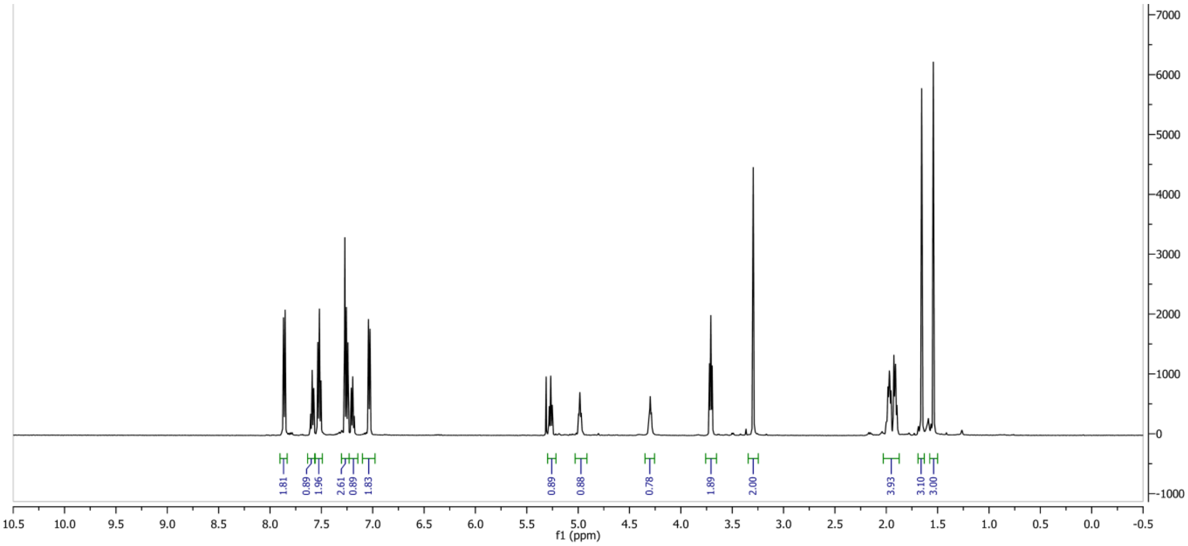

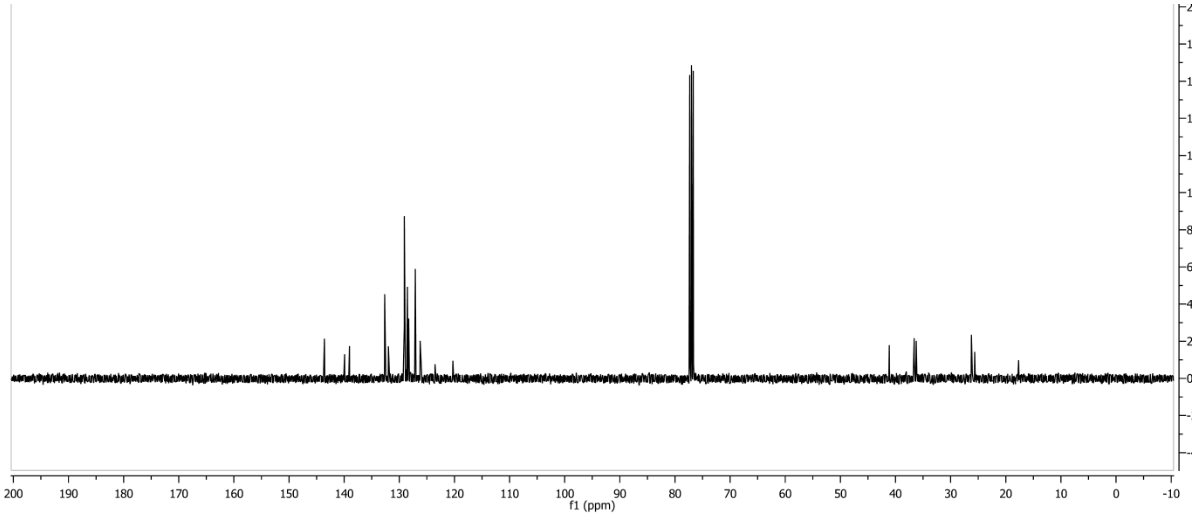

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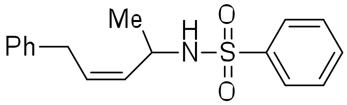

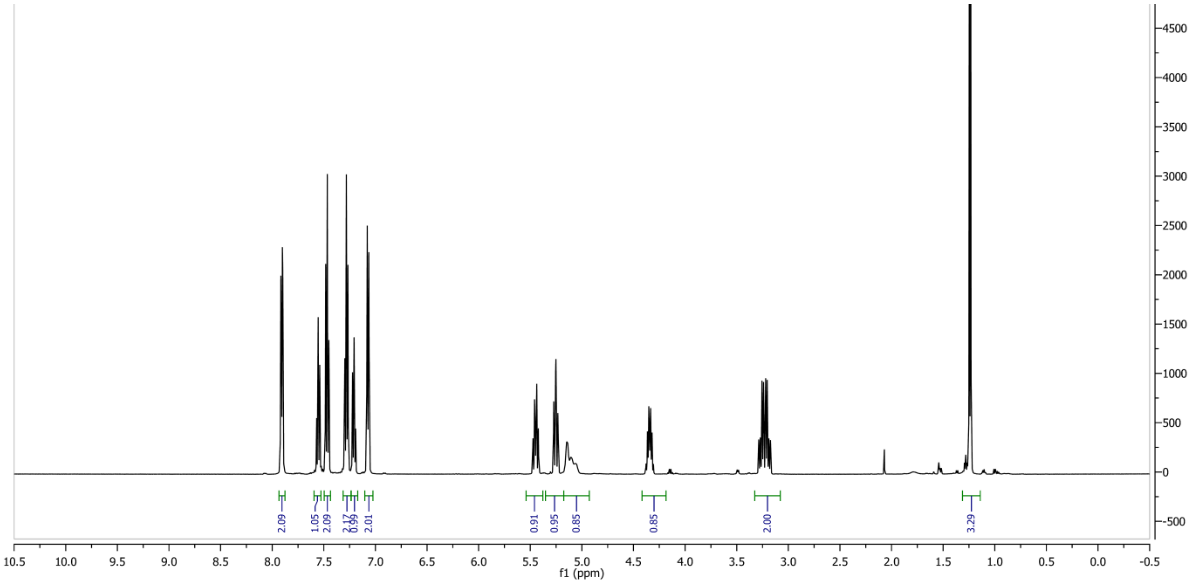

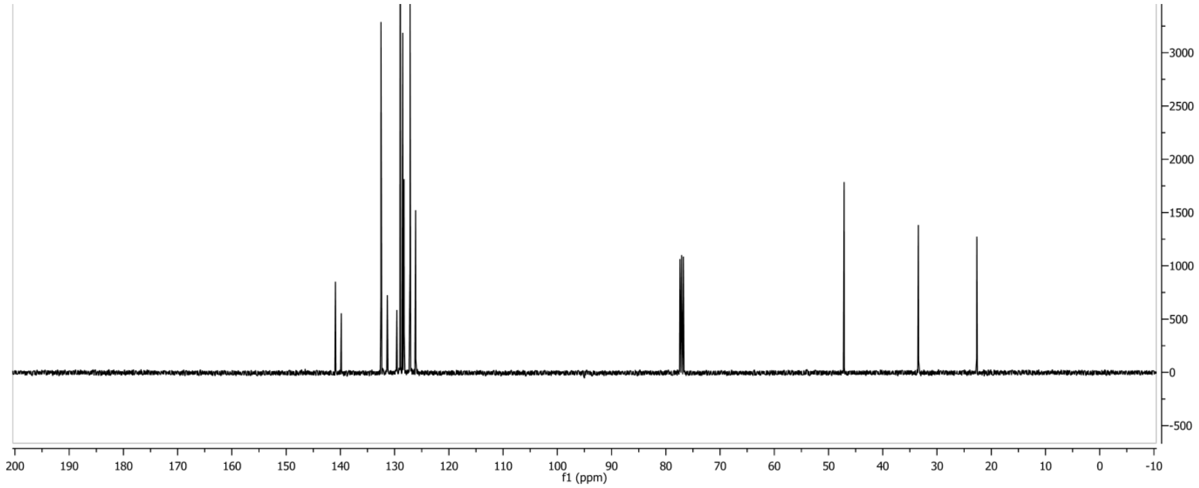

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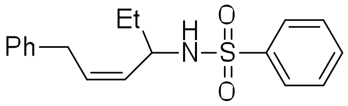
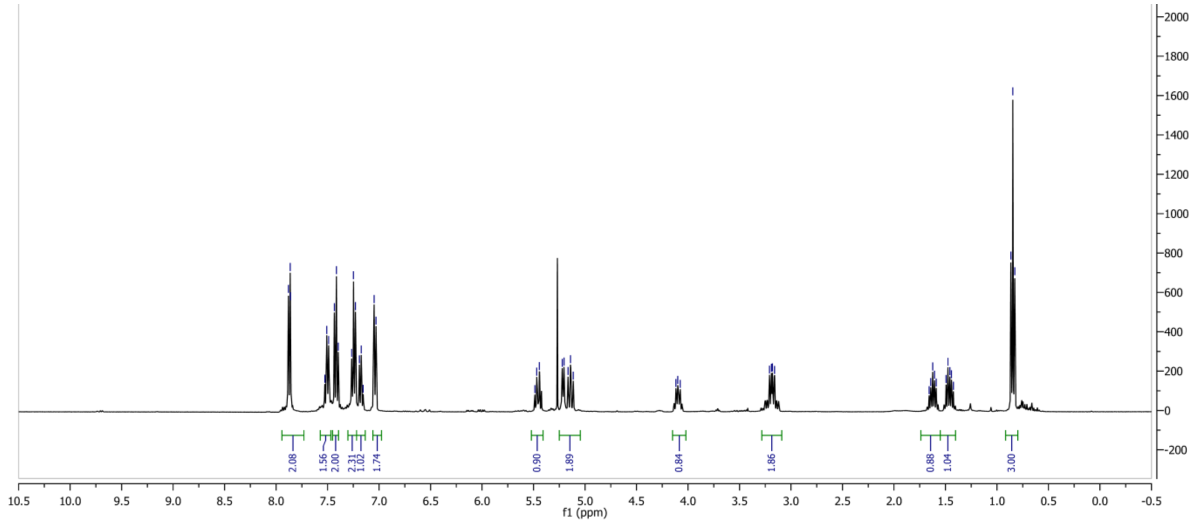




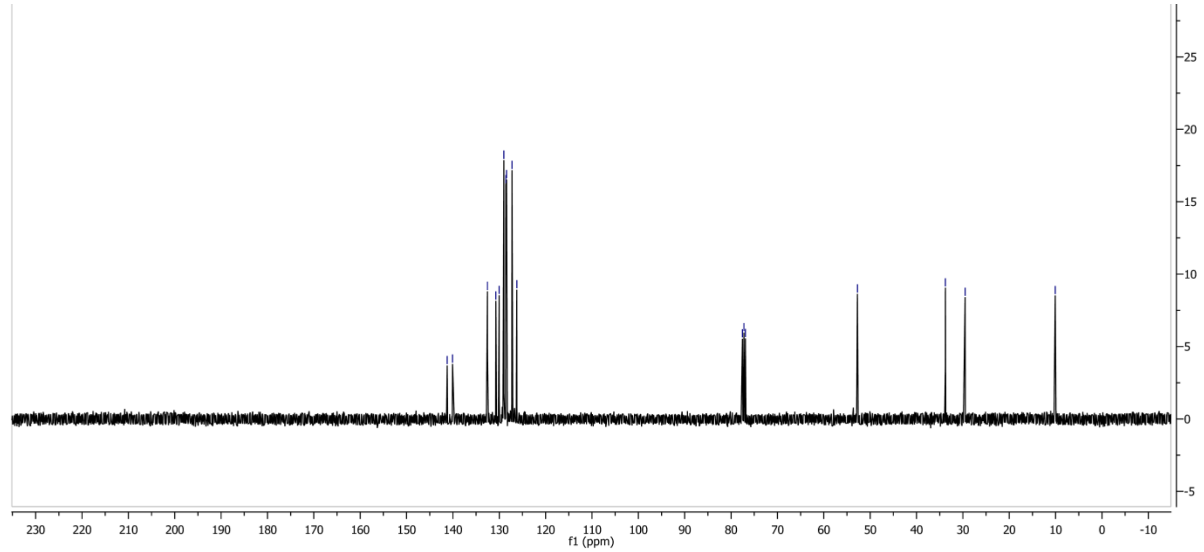
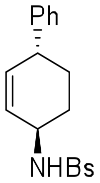
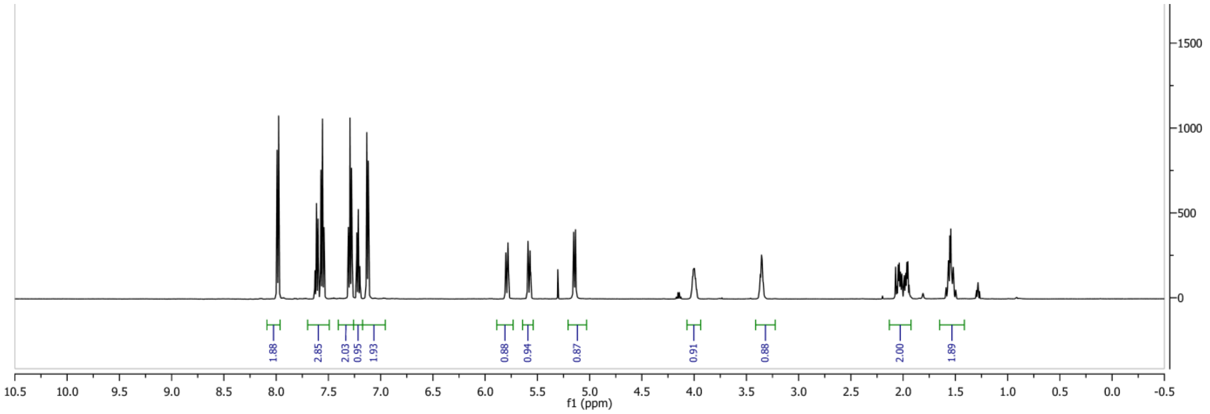


Table 3, Entry 6 – 1,4 Aminoarylation





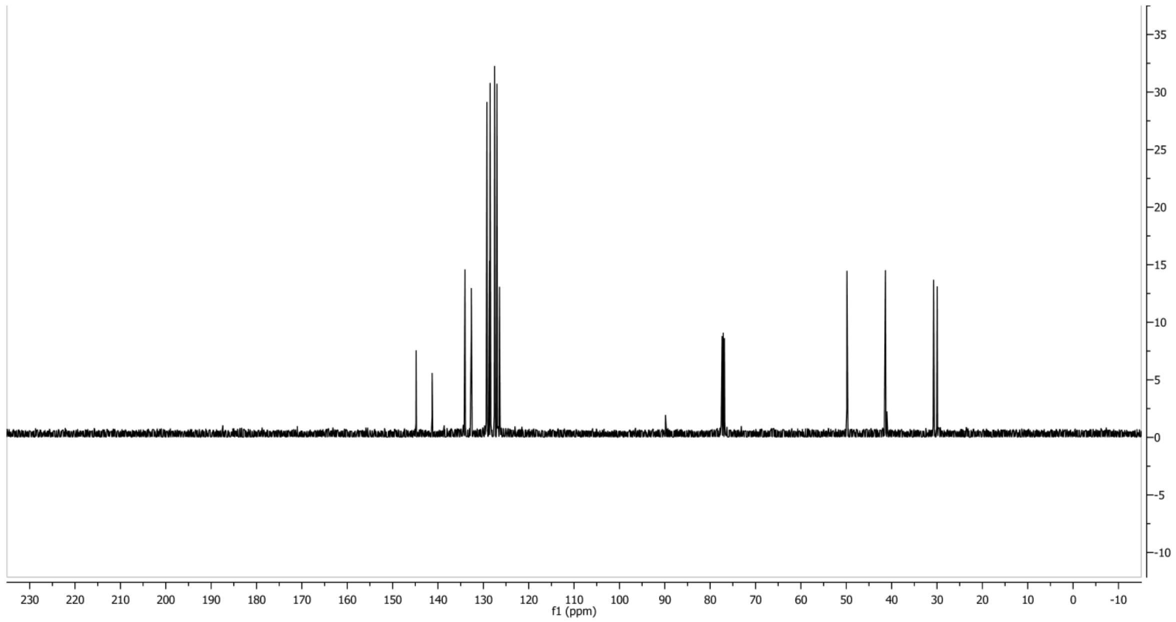
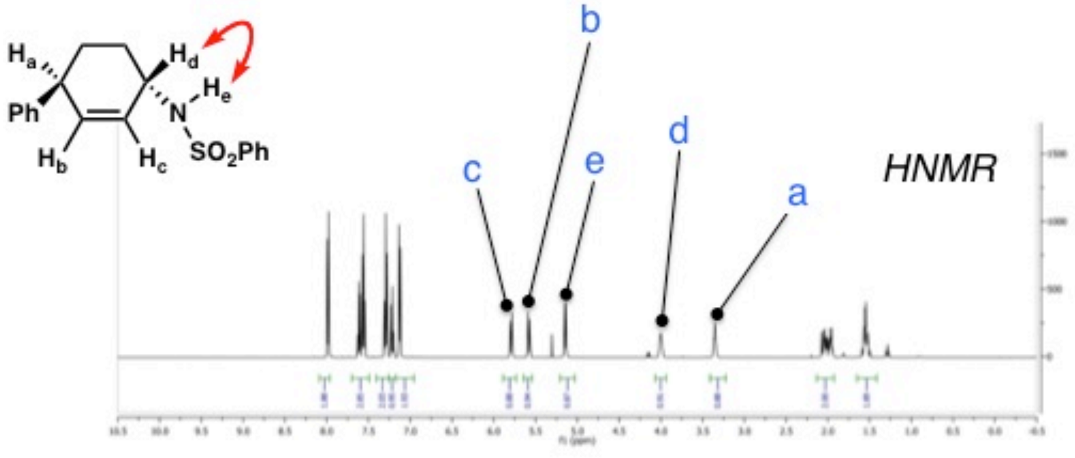


Table 3, Entry 6 – 1,4 Aminoarylation (continued)



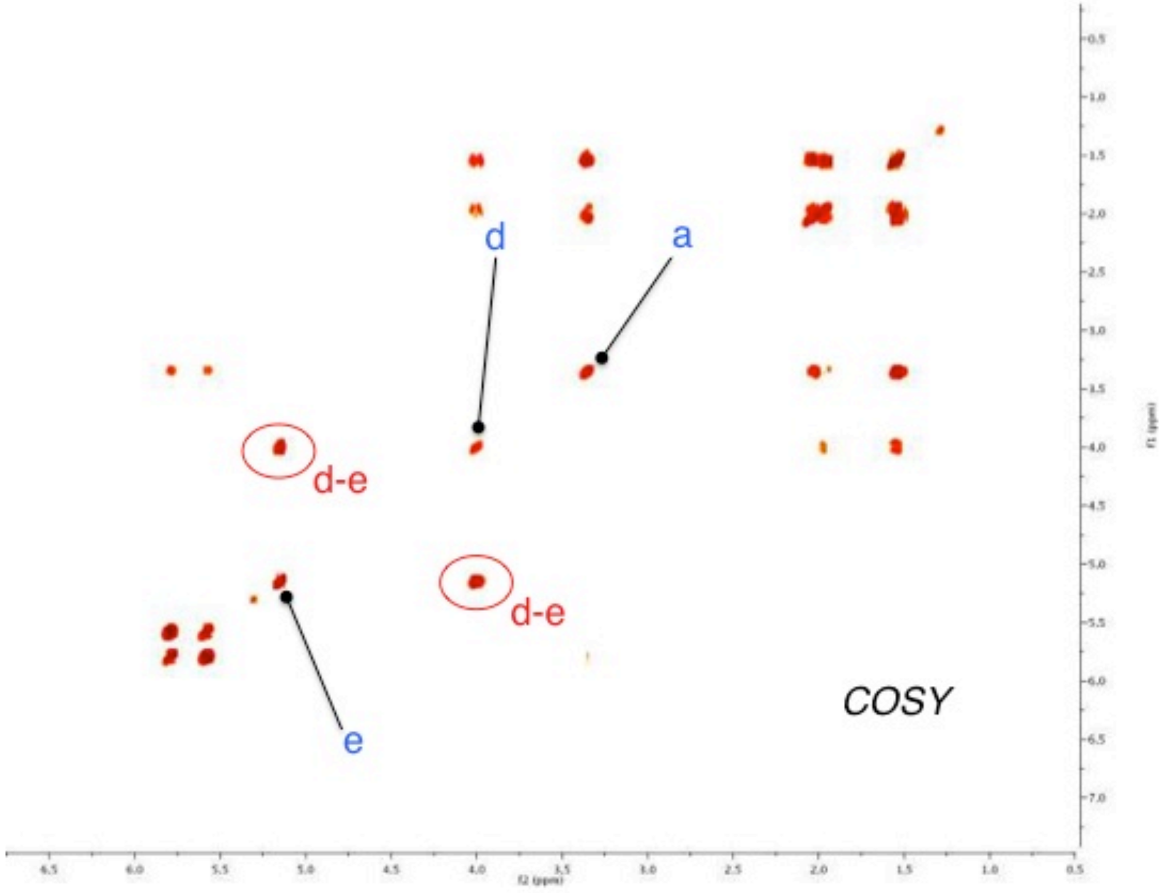
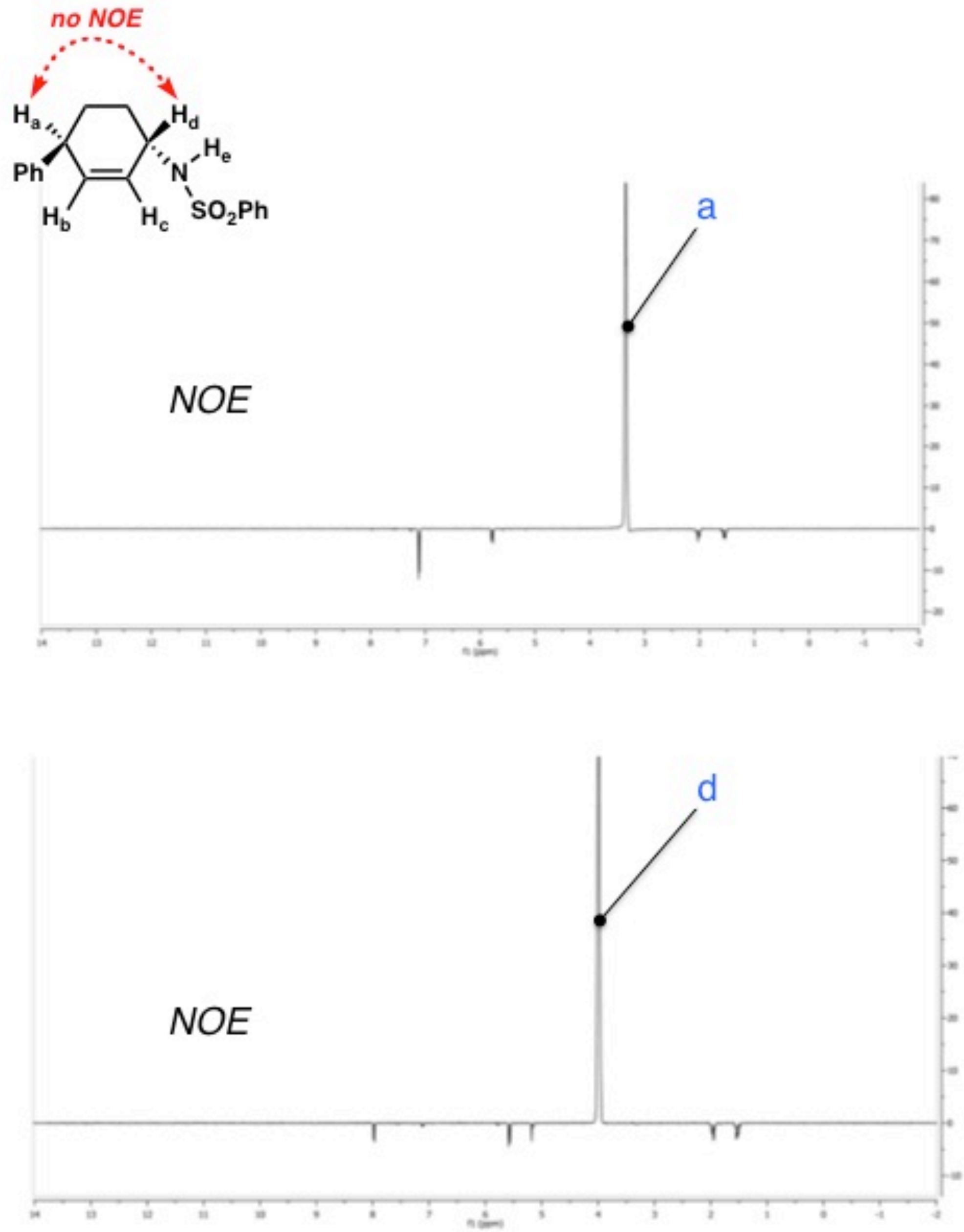
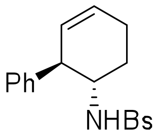


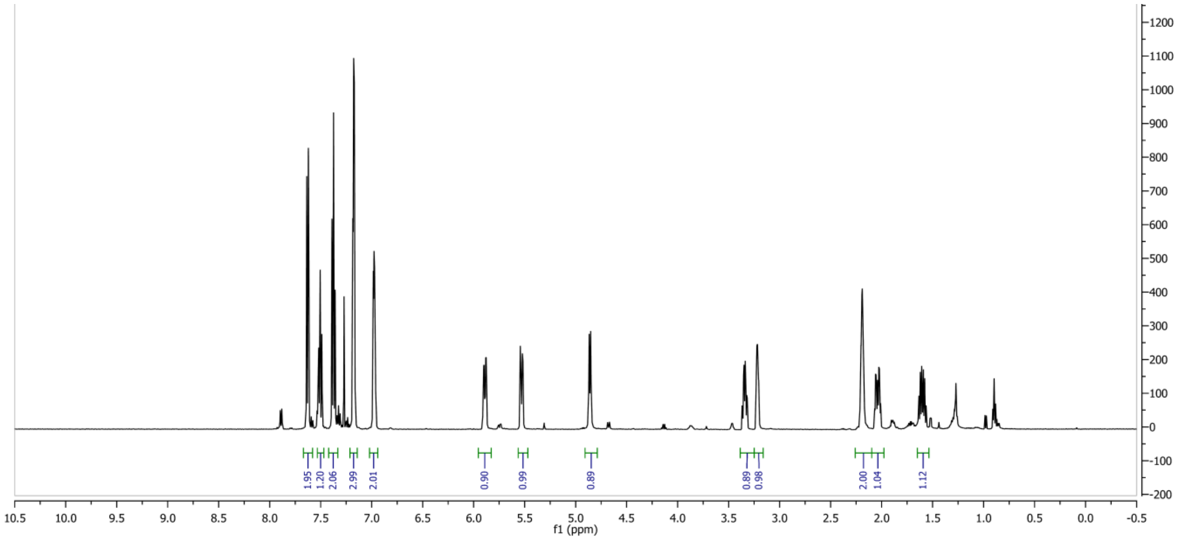
Table 3, Entry 6 – 1,4 Aminoarylation (continued)



NOE was not detected between H_a and H_d ⟶ anti relationship

Table 3, Entry 6 – 1,2 Aminoarylation





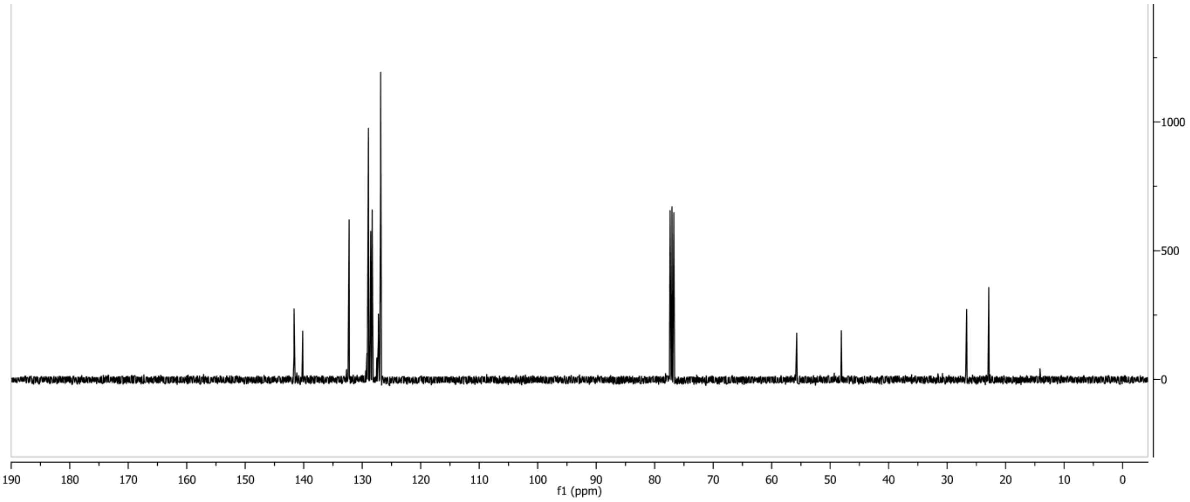
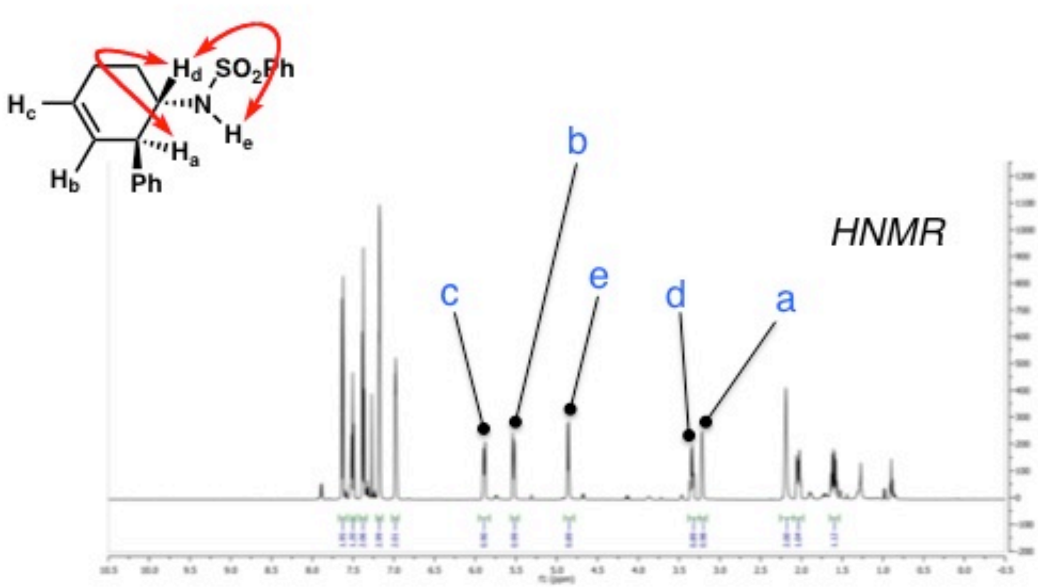


Table 3, Entry 6 – 1,2 Aminoarylation (continued)



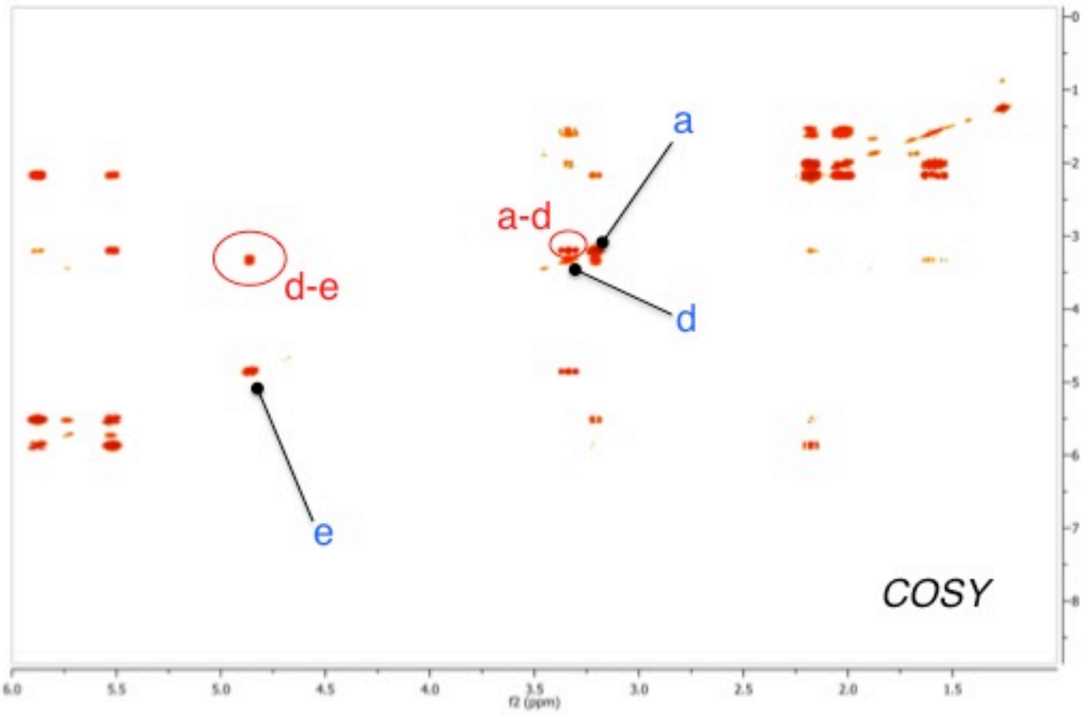
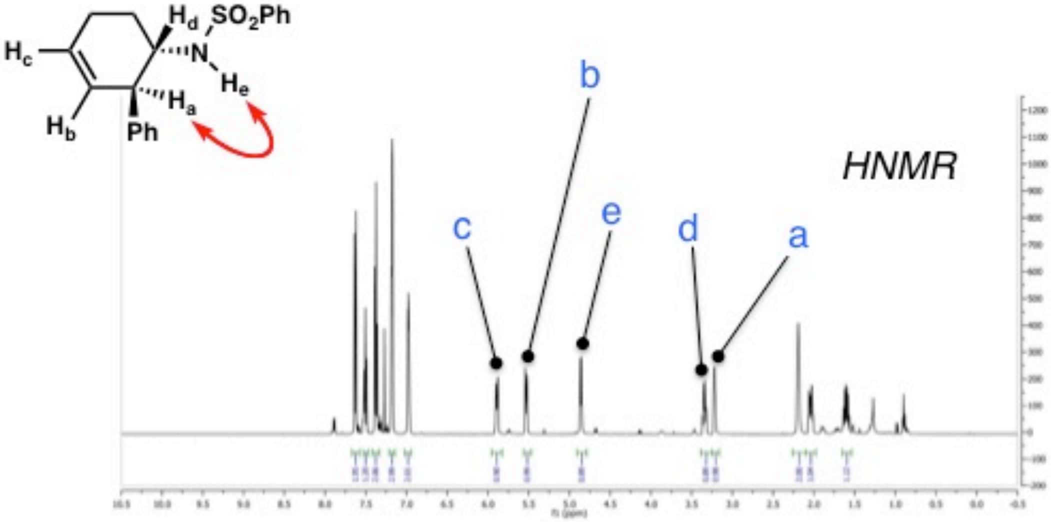


Table 3, Entry 6 – 1,2 Aminoarylation (continued)



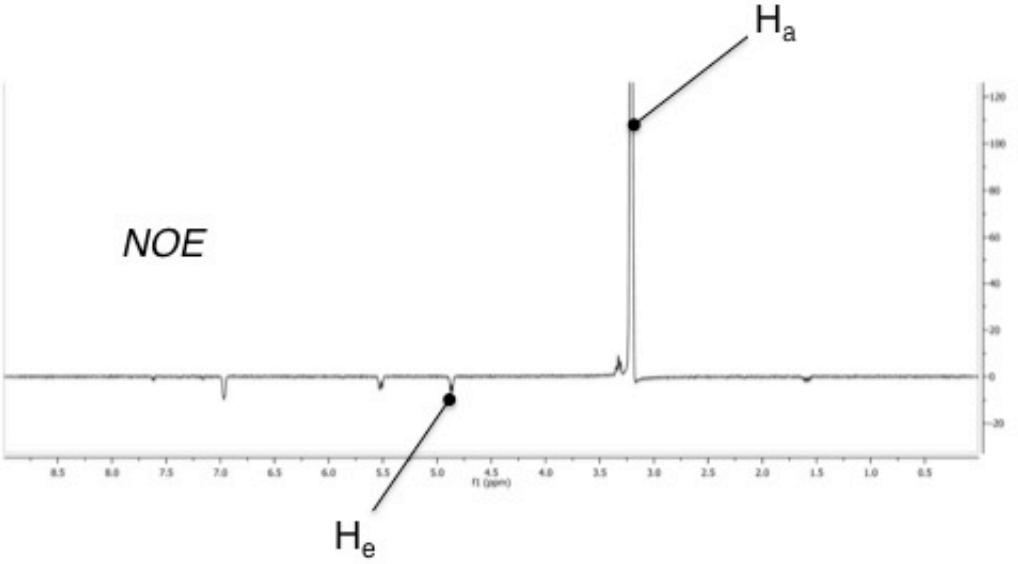
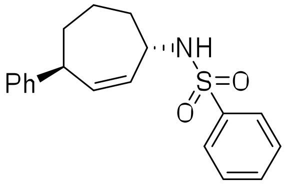
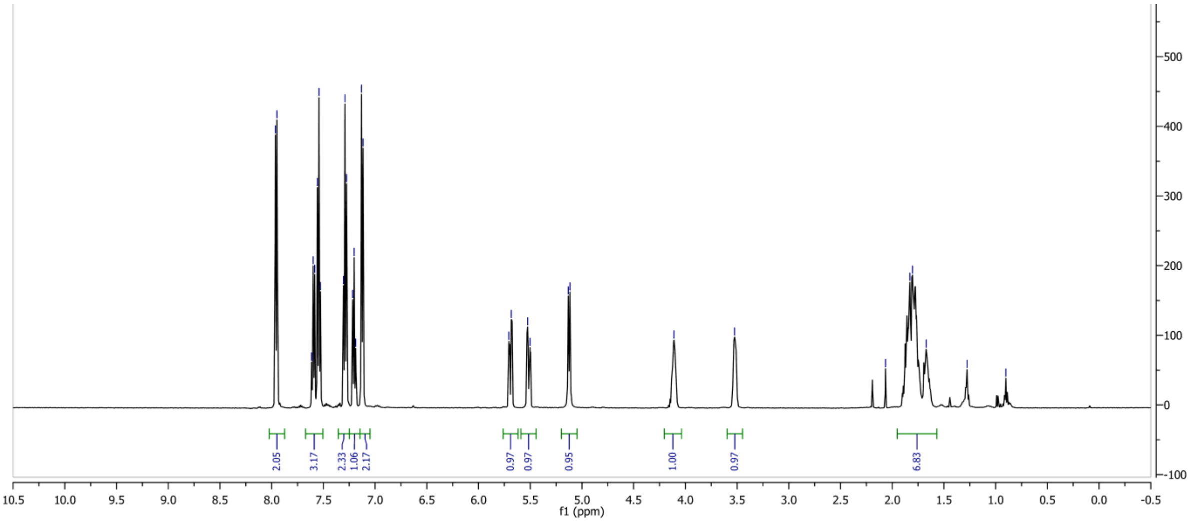


Table 3, Entry 7 – 1,4 Aminoarylation





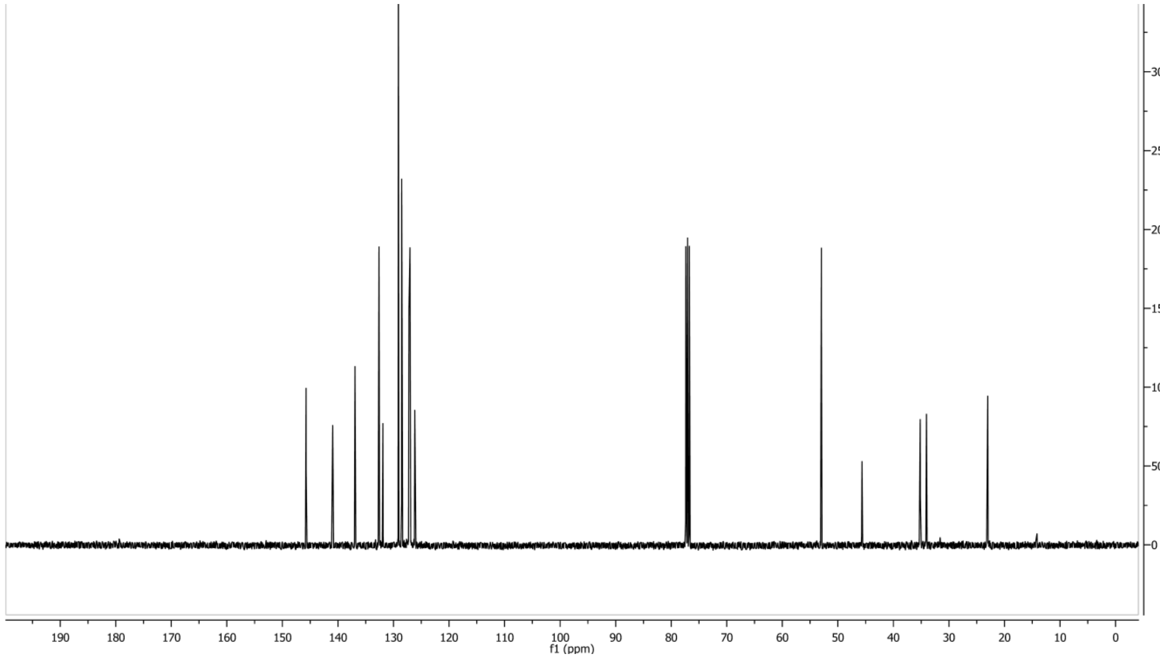
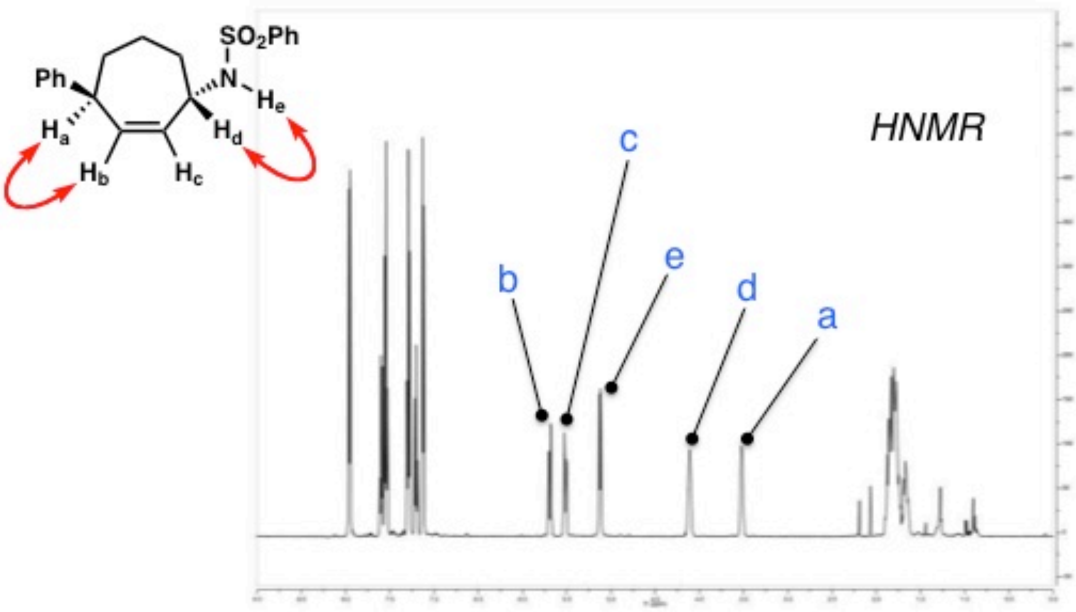


Table 3, Entry 7 – 1,4 Aminoarylation (continued)



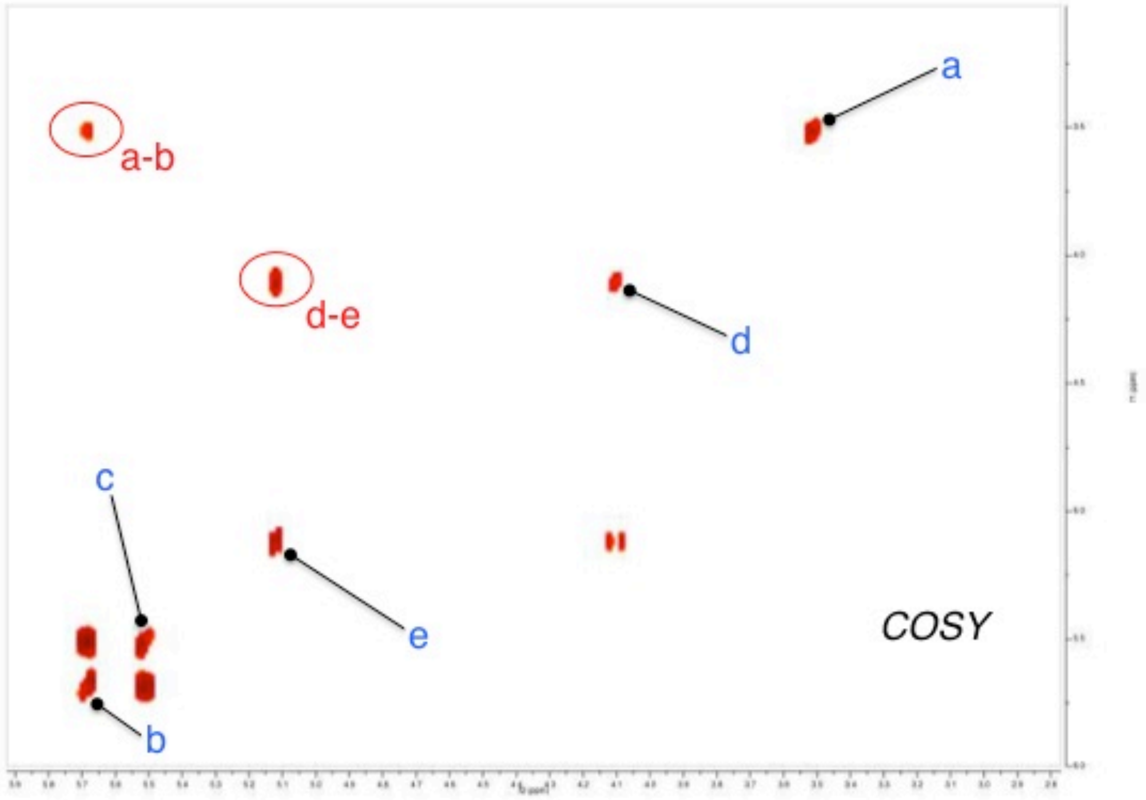
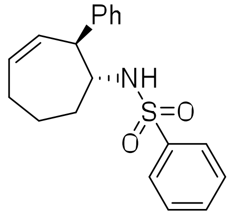
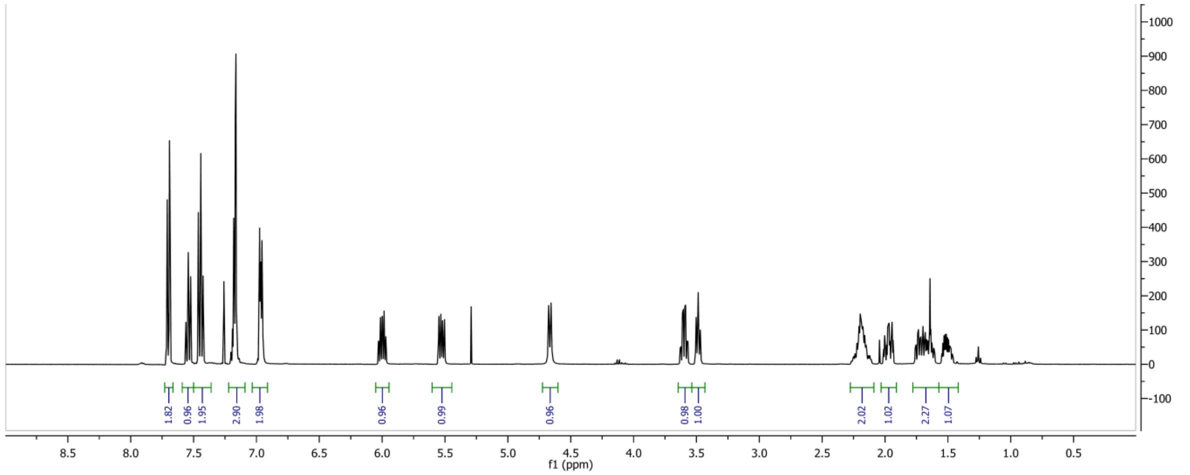


Table 3, Entry 7 – 1,2 Aminoarylation





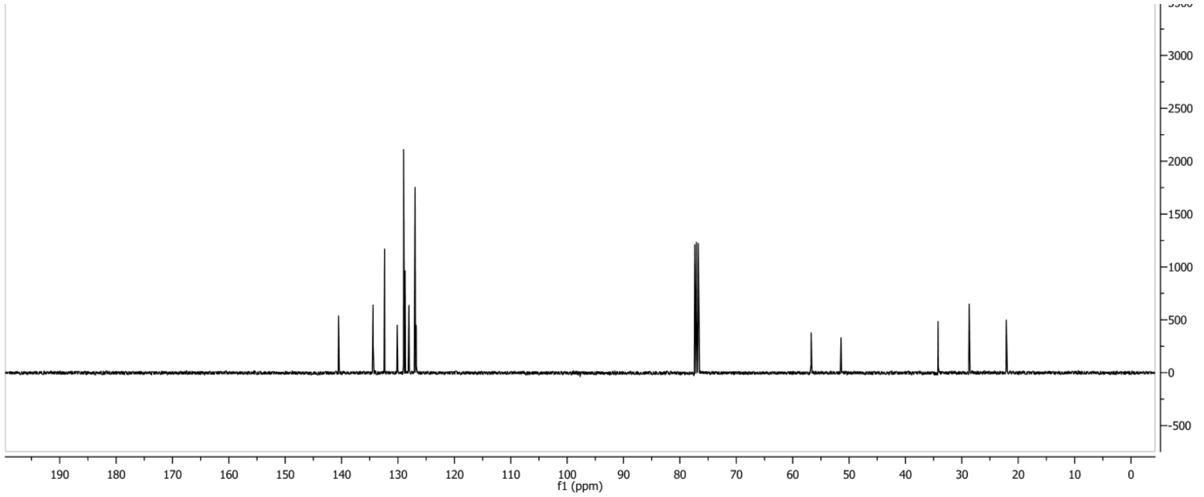
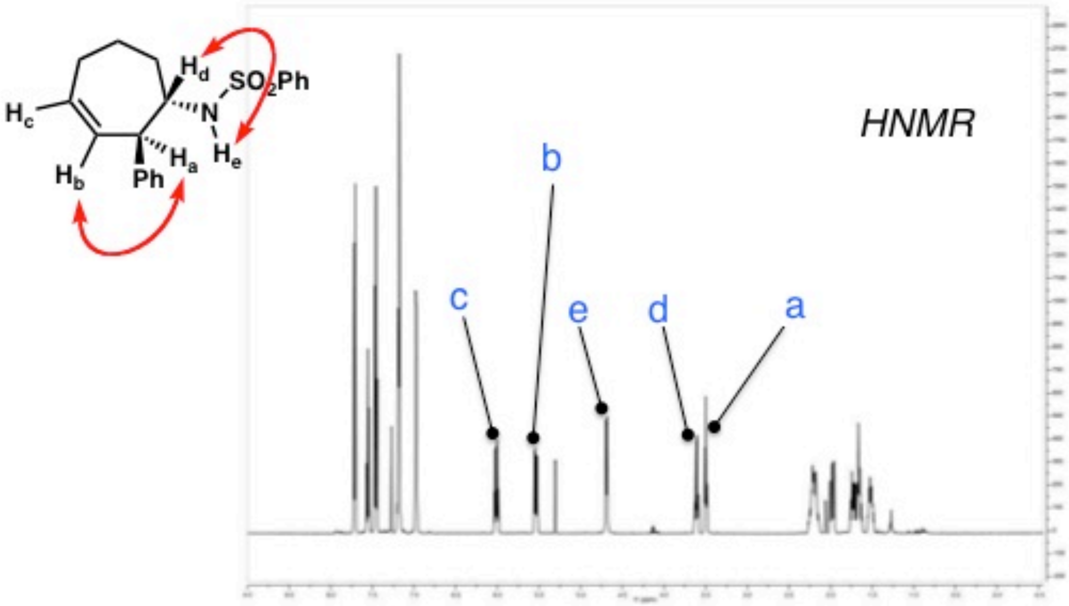
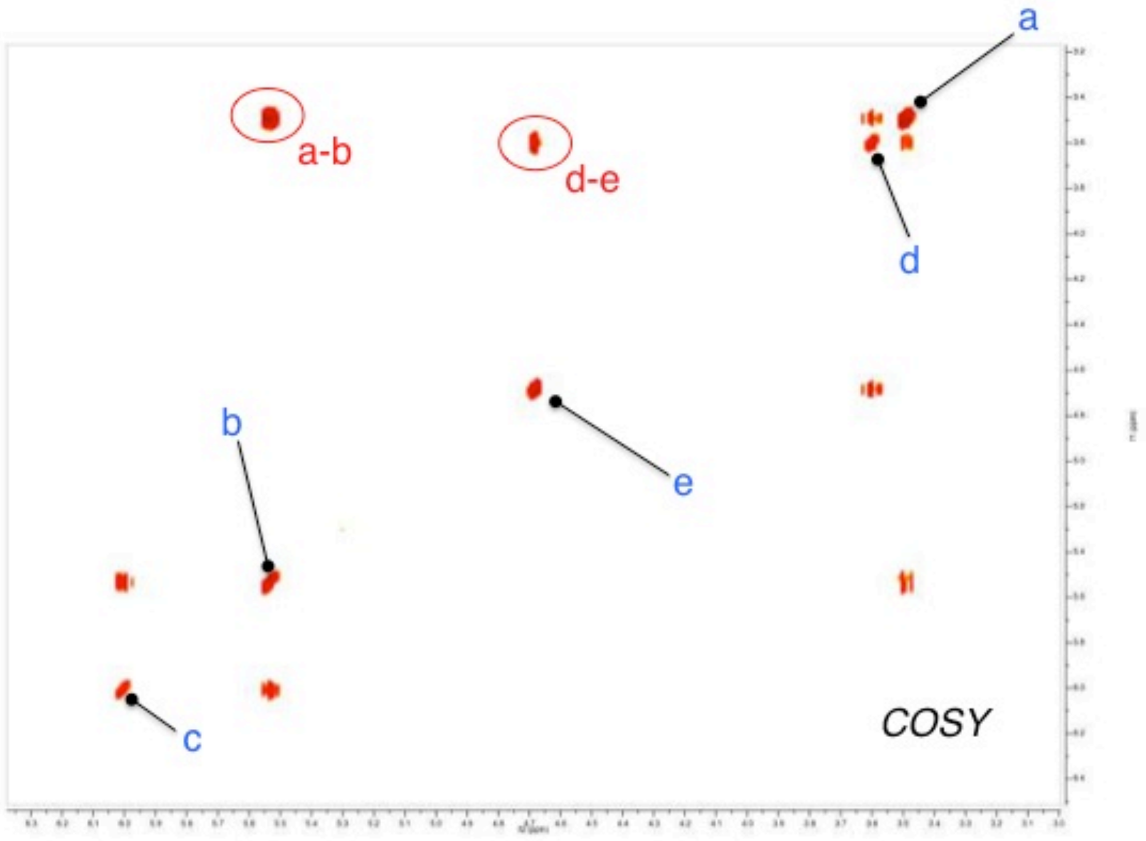
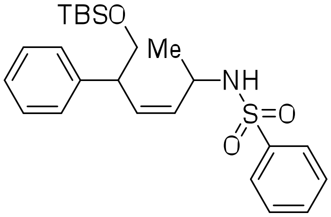


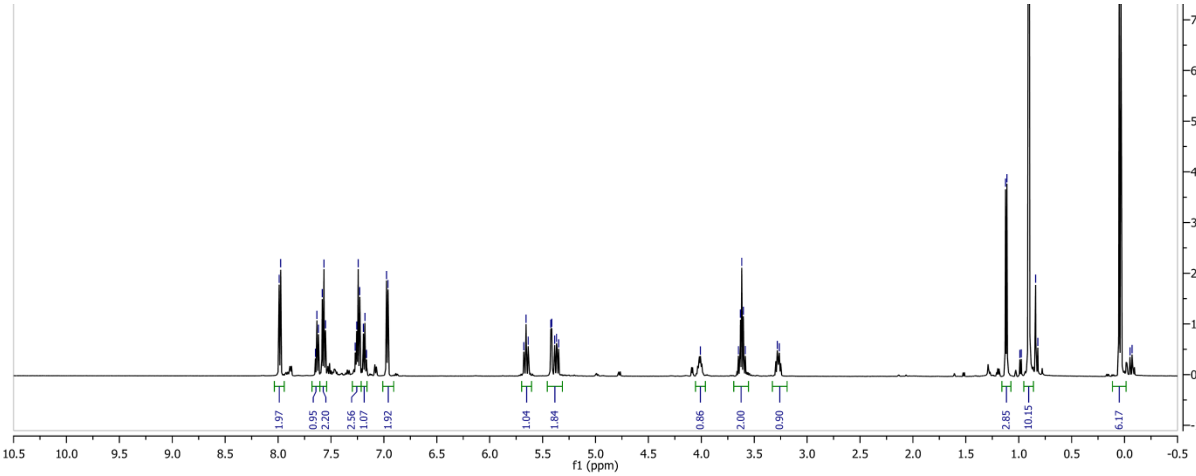
Table 3, Entry 7 – 1,2 Aminoarylation (continued)

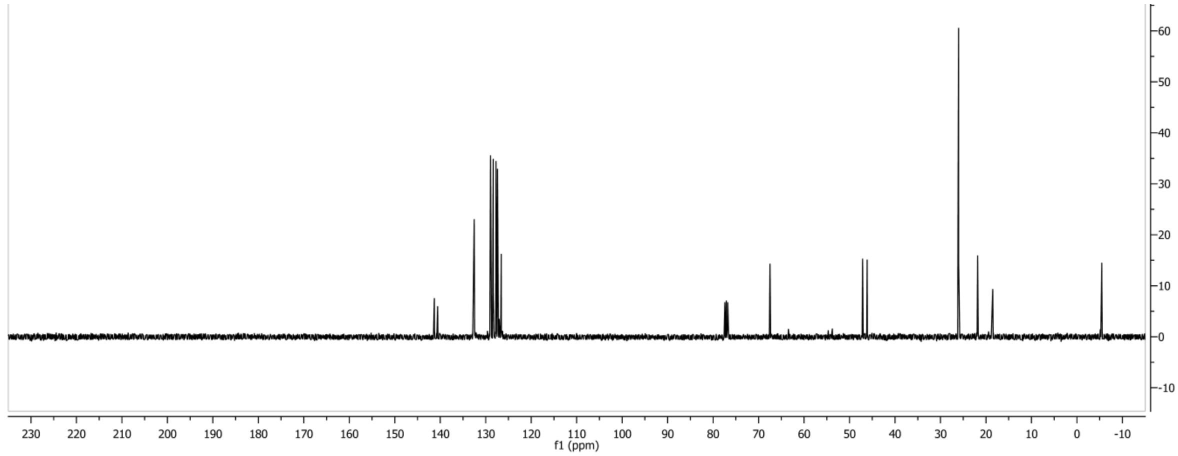




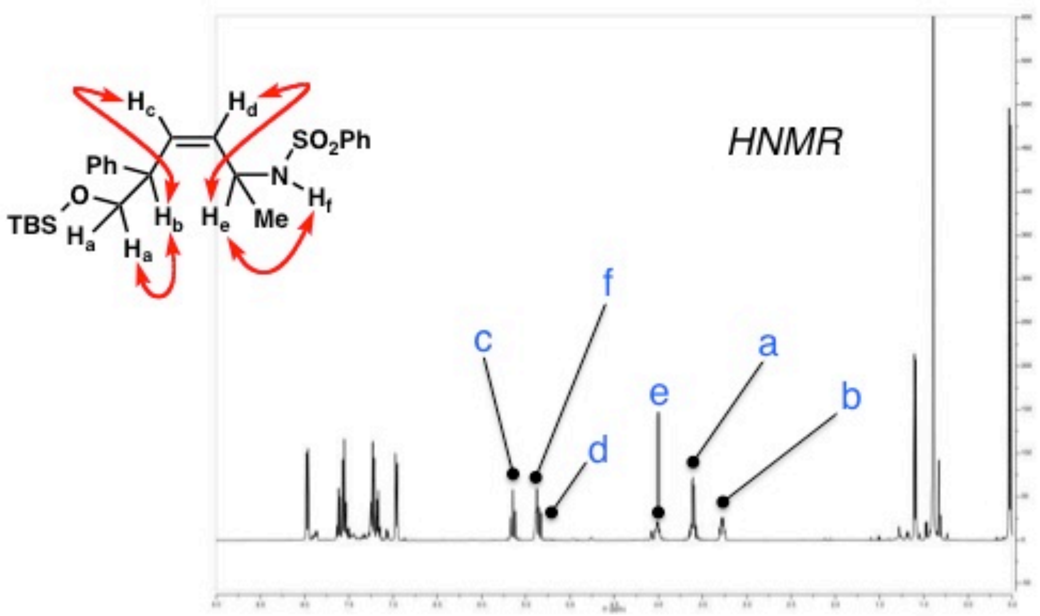
*Scheme 3, Product **13** (Major Product)*

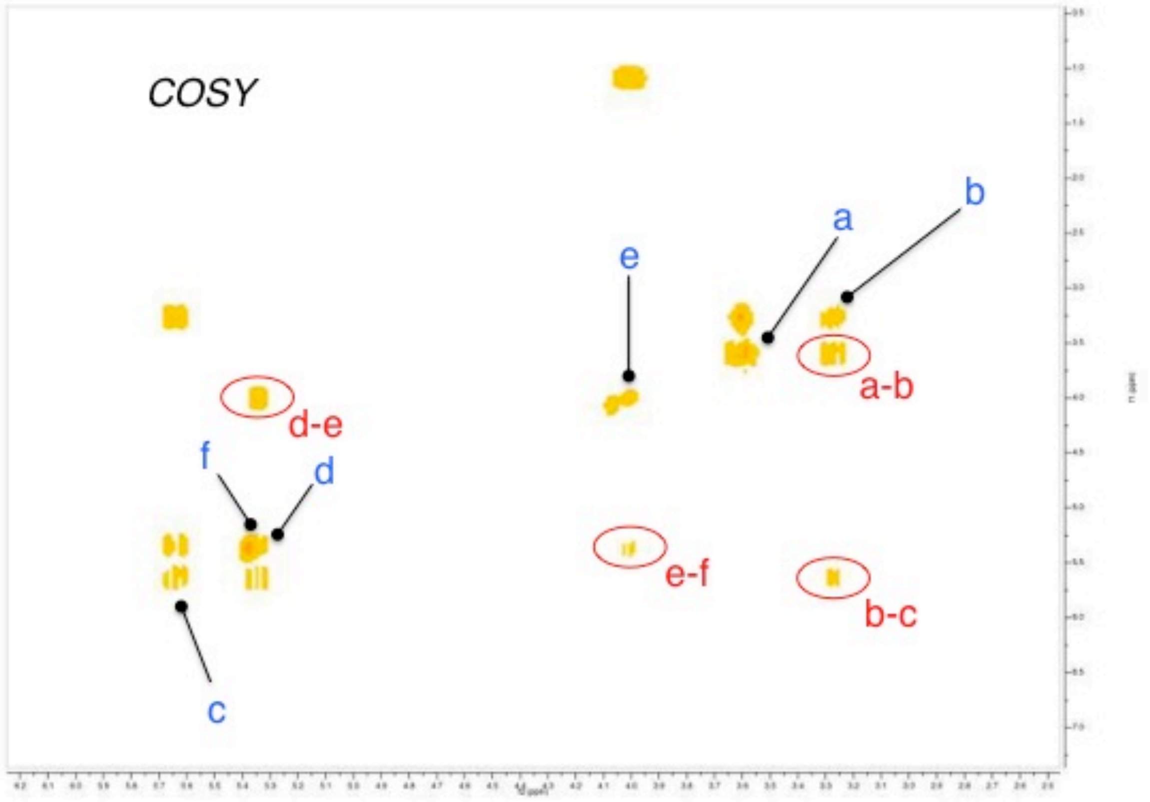




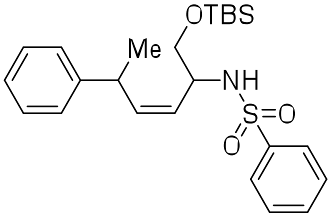


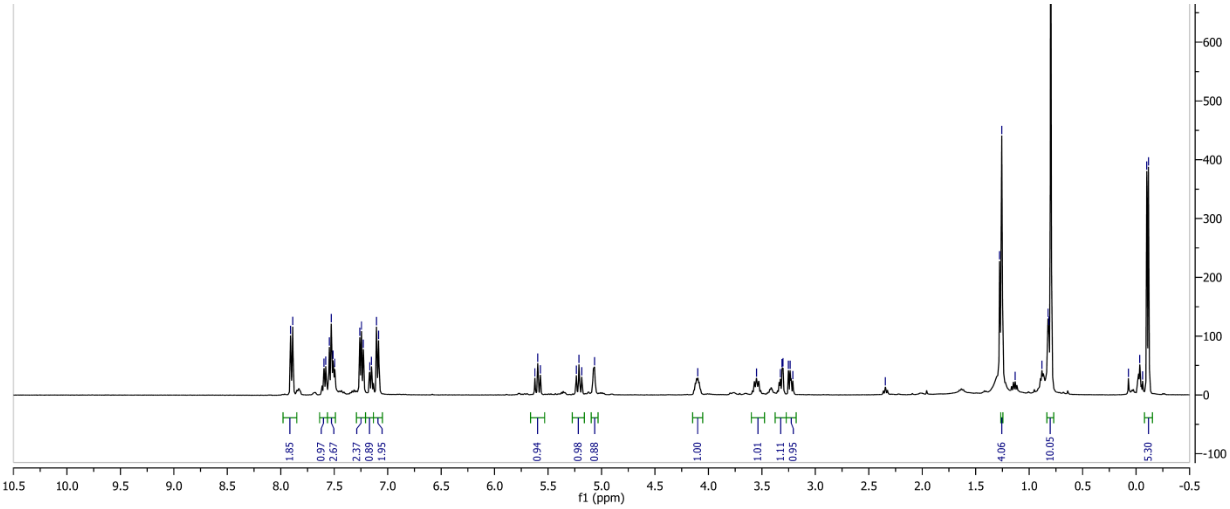
*Scheme 3, Product **13** (Major Product) – Continued*

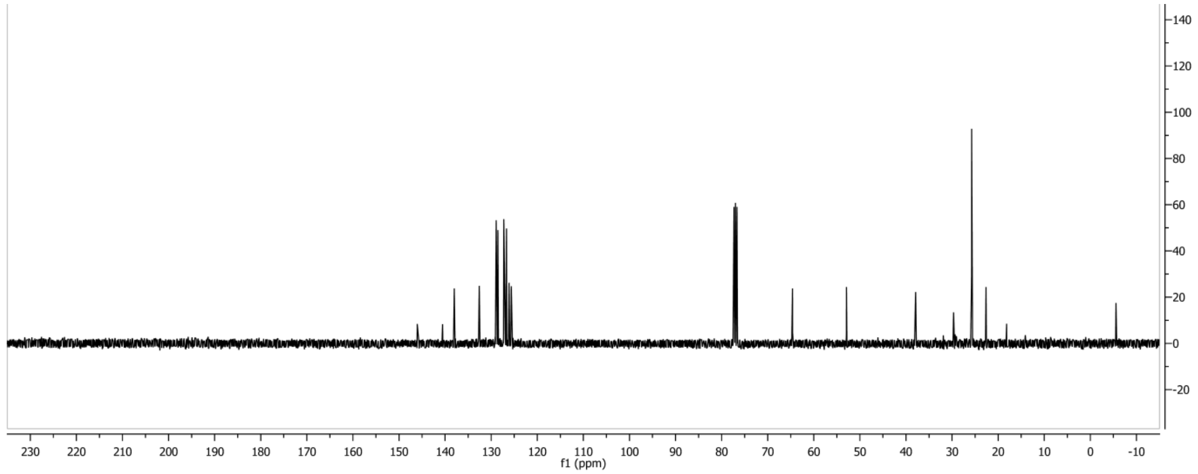




Scheme 3, Product ***14*** *(Minor Product)*







*Scheme 3, Product **14** (Minor Product) – Continued*