Electronic Supplementary Information

Facile One-Pot Synthesis of Diarylacetylenes from Arylaldehydes via Addition-Double Elimination Process

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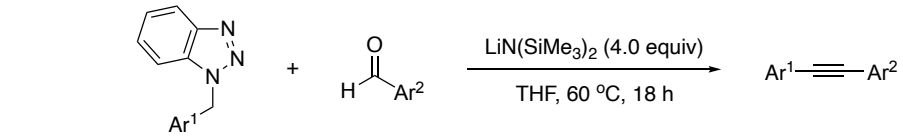
Table of Contents

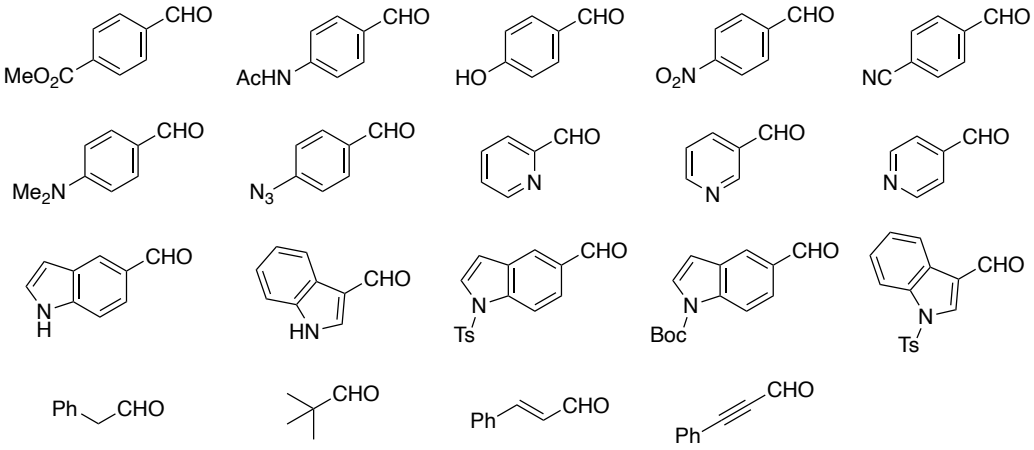
1. General Information

All reactions were carried out under nitrogen atmosphere unless otherwise noted. Anhydrous THF were purchased from Adamas. All reagents and solvents were obtained from commercial suppliers (Macklin, Bidepharm, Adamas, and Energy), and were used as received. ^{1}H and ^{13}C NMR were recorded on a Bruker 400 spectrometer using $CDCl_3$ as the solvent with tetramethylsilane (TMS) as the internal standard at room temperature. Chemical shifts (δ) are given in ppm relative to TMS, and the coupling constants (J) are given in Hz. The following abbreviations were used to explain multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet. All HRMS measurements were conducted on a Thermo QExactive.

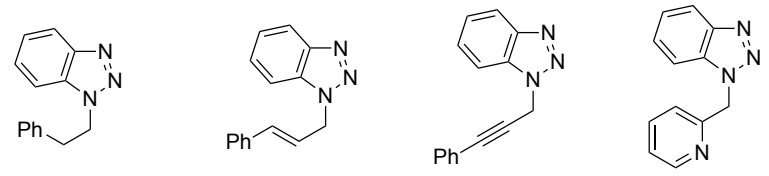
2. Failed aldehydes and benzotriazoles derivatives



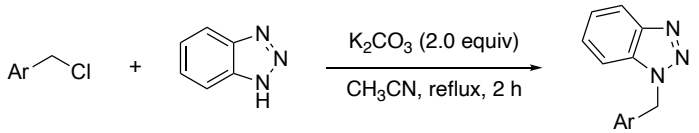
Failed aldehydes



Failed benzotriazole derivatives

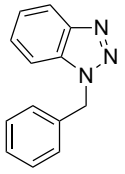


3. General Procedure for the Synthesis of 1-Arylmethylbenzotriazoles



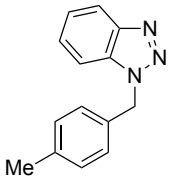
1.0 equiv 1.0 equiv **1a-1k**

1-(Arylmethyl)benzotriazole derivatives was prepared following the reported procedure:[1] To a 100 mL dry flask was added benzotriazole (10.0 mmol, 1.0 equiv), acetonitrile (30 mL), potassium carbonate (20.0 mmol, 2.0 equiv), and arylmethyl chloride (11.0 mmol, 1.1 equiv) successively. The mixture was then heated under reflux for 2 hours. After cooling down to room temperature, precipitates were removed through a celite pad, and the filtrate was concentrated under vacuum. The crude product was purified by flash column chromatography (silica gel, hexane-ethyl acetate: 20:1, then 3:1), affording the pure 1-(arylmethyl)benzotriazoles.



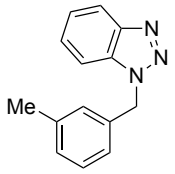
1a

1-Benzylbenzotriazole (**1a**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, J = 8.1 Hz, 1H), 7.44-7.24 (m, 8H), 5.84 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 134.7, 132.8, 129.0, 128.4, 127.5, 127.4, 123.9, 120.0, 109.7, 52.2 ppm. The spectra data were consistent with those reported in the literature.[2]



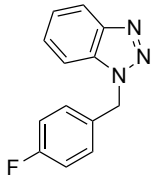
1b

1-(4-Methylbenzyl)benzotriazole (**1b**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.04 (d, J = 8.2 Hz, 1H), 7.42-7.28 (m, 3H), 7.17 (d, J = 7.9 Hz, 2H), 7.12 (d, J = 7.8 Hz, 2H), 5.78 (s, 2H), 2.30 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.2, 138.2, 132.7, 131.6, 129.5, 127.5, 127.2, 123.8, 119.9, 109,7, 52.0, 21.0` ppm. The spectra data were consistent with those reported in the literature.[2]



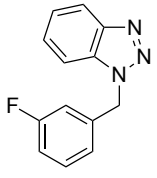
1c

1-(3-Methylbenzyl)benzotriazole (**1c**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.05 (d, J = 8.2 Hz, 1H), 7.42-7.30 (m, 3H), 7.21 (t, J = 7.5 Hz, 1H), 7.13-7.04 (m, 3H), 5.79 (s, 2H), 2.29 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 138.8, 134.6, 132.7, 129.2, 128.8, 128.2, 127.3, 124.6, 123.8, 119.9, 109.7, 52.2, 21.3 ppm. The spectra data were consistent with those reported in the literature.[2]



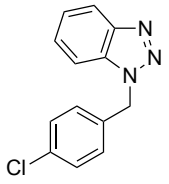
1d

1-(4-Fluorobenzyl)benzotriazole (**1d**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, J = 8.8 Hz, 1H), 7.45-7.39 (m, 1H), 7.38-7.33 (m, 2H), 7.31-7.24 (m, 2H), 7.02 (t, J = 8.5 Hz, 2H), 5.81 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.6 (d, J_{CF} = 246.0 Hz), 146.3, 132.6, 130.5 (d, J_{CF} = 3.3 Hz), 129.4 (d, J_{CF} = 8.3 Hz), 127.5, 124.0, 120.1, 116.0 (d, J_{CF} = 21.6 Hz), 109.5, 51.4 ppm. The spectra data were consistent with those reported in the literature.[3]



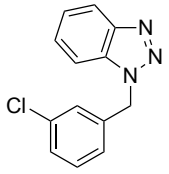
1e

1-(3-Fluorobenzyl)benzotriazole (**1e**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.08 (d, J = 8.4 Hz, 1H), 7.46-7.26 (m, 4H), 7.07-6.92 (m, 3H), 5.83 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.9 (d, J_{CF} = 249.1 Hz), 146.2, 137.1 (d, J_{CF} = 7.3 Hz), 132.7, 130.6 (d, J_{CF} = 8.3 Hz), 127.6, 124.0, 123.0 (d, J_{CF} = 3.0 Hz), 120.1, 115.4 (d, J_{CF} = 20.8 Hz), 114.5 (d, J_{CF} = 22.1 Hz), 109.4, 51.5 (d, J_{CF} = 1.8 Hz) ppm; HRMS (ESI) *m/z* calcd for $C_{13}H_{11}FN_3$ $[M+H]^+$: 228.0937, found: 228.0928.



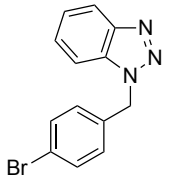
1f

1-(4-Chlorobenzyl)benzotriazole (**1f**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, J = 8.5 Hz, 1H), 7.42 (t, J = 7.5 Hz, 1H), 7.35 (t, J = 7.0 Hz, 2H), 7.30 (d, J = 8.4 Hz, 2H), 7.20 (d, J = 8.3 Hz, 2H), 5.81 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 134.4, 133.2, 132.6, 129.2, 128.9, 127.5, 124.0, 120.1, 109.4, 51.4 ppm. The spectra data were consistent with those reported in the literature.[2,3]



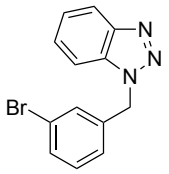
1g

1-(3-Chlorobenzyl)benzotriazole (**1g**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, J = 8.2 Hz, 1H), 7.46-7.32 (m, 3H), 7.30-7.21 (m, 3H), 7.13 (d, J = 7.0 Hz, 1H), 5.80 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.2, 136.7, 134.8, 132.6, 130.2, 128.6, 127.6, 127.5, 125.6, 124.0, 120.0, 109.4, 51.3 ppm. The spectra data were consistent with those reported in the literature.[4]



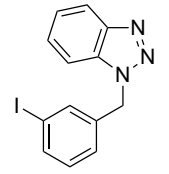
1h

1-(4-Bromobenzyl)benzotriazole (**1h**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.06 (d, J = 8.7 Hz, 1H), 7.45 (d, J = 8.3 Hz, 2H), 7.41 (d, J = 8.0 Hz, 1H), 7.35 (t, J = 7.0 Hz, 2H), 7.14 (d, J = 8.2 Hz, 2H), 5.79 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.2, 133.7, 132.6, 132.1, 129.1, 127.5, 124.0, 122.5, 120.1, 109.4, 51.4 ppm. The spectra data were consistent with those reported in the literature.[3]



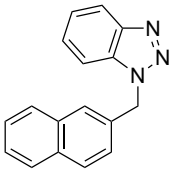
1i

1-(3-Bromobenzyl)benzotriazole (**1i**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.0 (d, J = 8.5 Hz, 1H), 7.56-7.41 (m, 3H), 7.40-7.33 (m, 2H), 7.23-7.15 (m, 2H), 5.81 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 136.9, 132.7, 131.6, 130.54, 130.52, 127.7, 126.1, 124.1, 123.0, 120.2, 109.4, 51.4 ppm; HRMS (ESI) *m/z* calcd for $C_{13}H_{11}BrN_3$ $[M+H]^+$: 288.0136, found: 288.0129.



1j

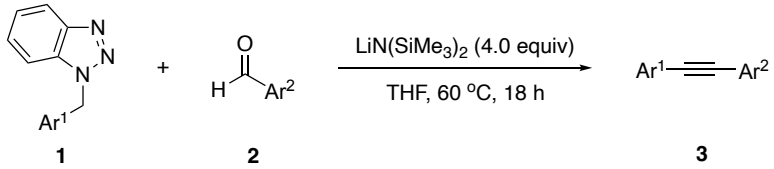
1-(3-Iodobenzyl)benzotriazole (**1j**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.08 (d, J = 8.7 Hz, 1H), 7.70-7.62 (m, 2H), 7.49-7.42 (m, 1H), 7.40-7.34 (m, 2H), 7.20 (d, J = 7.7 Hz, 1H), 7.06 (t, J = 7.7 Hz, 1H), 5.78 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 137.6, 136.9, 136.4, 132.7, 130.7, 127.7, 126.7, 124.1, 120.2, 109.4, 94.7, 51.2 ppm; HRMS (ESI) *m/z* calcd for $C_{13}H_{11}IN_3$ $[M+H]^+$: 335.9998, found: 335.9991.



1k

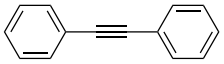
1-(Naphthalen-2-ylmethyl)benzotriazole (**1k**): Colorless solids; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.07 (d, J = 7.7 Hz ,1H), 7.82-7.71 (m, 4H), 7.51-7.43 (m, 2H), 7.41-7.28 (m, 4H), 5.98 (s, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 146.3, 133.1, 133.0, 132.8, 132.1, 129.0, 127.8, 127.7, 127.4, 126.63, 126.57, 126.5, 124.9, 123.9, 120.0, 109.7, 52.4 ppm. The spectra data were consistent with those reported in the literature.[5]

4. General Procedure for the Synthesis of Diarylacetylenes



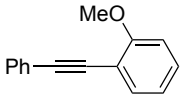
1 **2** **3**

General procedure: A 10 mL reaction tube was dried with a heat gun for 3 min under vacuum (< 5 mmHg at ca. 600 °C). After the displacement with N_2 gas, 1-arylmethylbenzotriazole **1** (0.44 mmol, 1.1 equiv), anhydrous THF (3.0 mL), arylaldehyde **2** (0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv). The resulting mixture was then stirred at 60 °C for 18 h under N_2 atmosphere. Seven drops water was added to quench the reaction. The reaction mixture was passed through a short pad of silica, washed with an additional 16 mL of ethyl acetate (4×10 mL), and the combined solutions were concentrated under reduced pressure. The crude product was purified by flash column chromatography (silica gel, hexane only) to give diarylacetylene **3**.



3aa

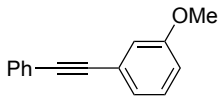
1,2-Diphenylethyne (**3aa**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), benzaldehyde **2a** (40.7 μL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3aa** (64.4 mg, 0.361 mmol, 90% yield) as colorless solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.62-7.49 (m, 4H), 7.43-7.28 (m, 6H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 131.6, 128.3, 128.2, 123.3, 89.4 ppm. The spectra data were consistent with those reported in the literature.[6]



3ab

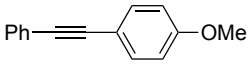
1-Methoxy-2-(phenylethynyl)benzene (**3ab**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-methoxybenzaldehyde **2b** (54.5 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ab** (81.2 mg, 0.390 mmol, 98% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.59-7.54 (m, 2H), 7.50 (d, J =

7.6 Hz, 1H), 7.38-7.27 (m, 4H), 6.97-6.88 (m, 2H), 3.92 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 159.9, 133.5, 131.6, 129.7, 128.2, 128.1, 123.5, 120.4, 112.4, 110.7, 93.4, 85.7, 55.8 ppm. The spectra data were consistent with those reported in the literature.[6]



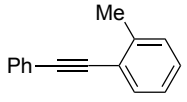
3ac

1-Methoxy-3-(phenylethynyl)benzene (**3ac**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-methoxybenzaldehyde **2c** (48.7 μL, *d* = 1.117 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ac** (61.7 mg, 0.296 mmol, 74% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.50 (m, 2H), 7.39-7.30 (m, 3H), 7.28-7.21 (m, 1H), 7.13 (d, *J* = 7.6 Hz, 1H), 7.06 (s, 1H), 6.89 (dd, *J* = 8.3, 1.7 Hz, 1H), 3.81 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 159.3, 131.6, 129.4, 128.32, 128.28, 124.23, 124.16, 123.2, 116.3, 114.9, 89.3, 89.2, 55.3 ppm. The spectra data were consistent with those reported in the literature.[6]



3ad

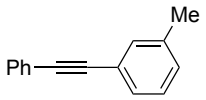
1-Methoxy-4-(phenylethynyl)benzene (**3ad**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), *p*-anisaldehyde **2d** (48.7 μL, *d* = 1.119 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ad** (39.8 mg, 0.191 mmol, 48% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.55-7.49 (m, 2H), 7.47 (d, *J* = 8.6 Hz, 2H), 7.37-7.27 (m, 3H), 6.87 (d, *J* = 8.6 Hz, 2H), 3.82 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 159.6, 133.0, 131.4, 128.3, 127.9, 123.6, 115.4, 114.0, 89.4, 88.1, 55.3 ppm. The spectra data were consistent with those reported in the literature.[6]



3ae

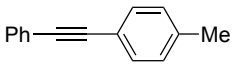
1-Methyl-2-(phenylethynyl)benzene (**3ae**): According to the general procedure, a mixture of 1-

benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-methylbenzaldehyde **2e** (46.3 μL, d = 1.039 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ae** (62.9 mg, 0.327 mmol, 82% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.53 (dd, J = 7.2, 1.5 Hz, 2H), 7.49 (d, J = 7.5 Hz, 1H), 7.38-7.29 (m, 3H), 7.25-7.20 (m, 2H), 7.19-7.13 (m, 1H), 2.51 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 140.2, 131.8, 131.5, 129.4, 128.32, 128.28, 128.1, 125.6, 123.5, 123.0, 93.3, 88.3, 20.7 ppm. The spectra data were consistent with those reported in the literature.[6]



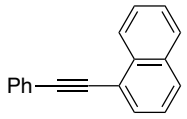
3af

1-Methyl-3-(phenylethynyl)benzene (**3af**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-methylbenzaldehyde **2f** (47.2 μL, d = 1.019 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3af** (63.3 mg, 0.329 mmol, 82% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.47 (m, 2H), 7.39-7.26 (m, 5H), 7.25-7.18 (m, 1H), 7.13 (d, J = 7.2 Hz, 1H), 2.34 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.0, 132.2, 131.6, 129.1, 128.7, 128.3, 128.2, 128.1, 123.4, 123.0, 89.6, 89.0, 21.2 ppm. The spectra data were consistent with those reported in the literature.[6]



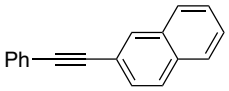
3ag

1-Methyl-4-(phenylethynyl)benzene (**3ag**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-methylbenzaldehyde **2g** (47.2 μL, d = 1.019 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ag** (56.6 mg, 0.294 mmol, 74% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.55-7.49 (m, 2H), 7.42 (d, J = 8.0 Hz, 2H), 7.36-7.27 (m, 3H), 7.14 (d, J = 7.9 Hz, 2H), 2.35 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.4, 131.52, 131.47, 129.1, 128.3, 128.0, 123.5, 120.2, 89.5, 88.7, 21.5 ppm. The spectra data were consistent with those reported in the literature.[6]



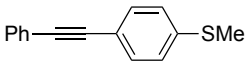
3ah

1-(Phenylethynyl)naphthalene (**3ah**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 1-naphthaldehyde **2h** (54.3 μL, d = 1.15 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ah** (77.6 mg, 0.340 mmol, 85% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.45 (d, J = 8.3 Hz, 1H), 7.82 (t, J = 9.4 Hz, 2H), 7.75 (d, J = 7.1 Hz, 1H), 7.64 (dd, J = 7.3, 0.9 Hz, 2H), 7.58 (t, J = 7.5 Hz, 1H), 7.50 (t, J = 8.0 Hz, 1H), 7.43 (t, J = 7.7 Hz, 1H), 7.40-7.29 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 133.24, 133.18, 131.6, 130.3, 128.7, 128.40, 128.35, 128.28, 126.7, 126.4, 126.2, 125.2, 123.4, 120.9, 94.3, 87.5 ppm. The spectra data were consistent with those reported in the literature.[6]



3ai

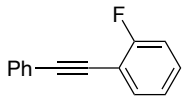
2-(Phenylethynyl)naphthalene (**3ai)**: According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-naphthaldehyde **2i** (62.5 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ai** (79.9 mg, 0.350 mmol, 88% yield) as colorless solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.04 (s, 1H), 7.84-7.75 (m, 3H), 7.62-7.53 (m, 3H), 7.51-7.42 (m, 2H), 7.39-7.29 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 133.0, 132.8, 131.6, 131.4, 128.39, 128.36, 128.3, 128.0, 127.75, 127.74, 126.6, 126.5, 123.3, 120.6, 89.8, 89.7 ppm. The spectra data were consistent with those reported in the literature.[7]



3aj

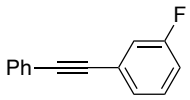
Methyl(4-(phenylethynyl)phenyl)sulfane (**3aj**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-(methylthio)benzaldehyde **2j** (53.2 μL, d = 1.144 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3aj**

(78.1 mg, 0.348 mmol, 87% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.55-7.48 (m, 2H), 7.43 (d, J = 8.4 Hz, 2H), 7.37-7.28 (m, 3H), 7.19 (d, J = 8.2 Hz, 2H), 2.48 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 139.3, 131.8, 131.5, 128.3, 128.2, 125.8, 123.3, 119.5, 89.4, 89.2, 15.3 ppm. The spectra data were consistent with those reported in the literature.[7]



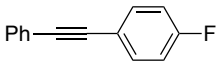
3ak

1-Fluoro-2-(phenylethynyl)benzene (**3ak**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-fluorobenzaldehyde **2k** (42.1 μL, d = 1.178 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ak** (72.8 mg, 0.371 mmol, 93% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.59-7.47 (m, 3H), 7.39-7.25 (m, 4H), 7.15-7.04 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.6 (d, J_{CF} = 250.0 Hz), 133.4 (d, J_{CF} = 1.4 Hz), 131.7, 129.9 (d, J_{CF} = 7.9 Hz), 128.6, 128.3, 123.9 (d, J_{CF} = 3.8 Hz), 122.9, 115.5 (d, J_{CF} = 83.1 Hz), 111.9 (d, J_{CF} = 15.6 Hz), 94.4 (d, J_{CF} = 3.2 Hz), 82.7 ppm. The spectra data were consistent with those reported in the literature.[7]



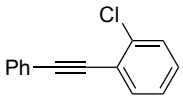
3al

1-Fluoro-3-(phenylethynyl)benzene (**3al**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-fluorobenzaldehyde **2l** (42.4 μL, d = 1.17 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3al** (72.5 mg, 0.369 mmol, 92% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.48 (m, 2H), 7.39-7.27 (m, 5H), 7.25-7.18 (m, 1H), 7.07-6.98 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.4 (d, J_{CF} = 244.9 Hz), 131.7, 129.9 (d, J_{CF} = 8.7 Hz), 128.6, 128.4, 127.5 (d, J_{CF} = 3.0 Hz), 125.1 (d, J_{CF} = 9.5 Hz), 122.8, 118.3 (d, J_{CF} = 22.6 Hz), 115.5 (d, J_{CF} = 21.1 Hz), 90.2, 88.1 (d, J_{CF} = 3.4 Hz) ppm. The spectra data were consistent with those reported in the literature.[8]



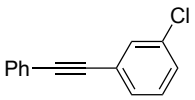
3am

1-Fluoro-4-(phenylethynyl)benzene (**3am**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-fluorobenzaldehyde **2m** (42.9 μL, d = 1.157 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3am** (68.2 mg, 0.348 mmol, 87% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.56-7.44 (m, 4H), 7.39-7.29 (m, 3H), 7.07-6.98 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.5 (d, J_{CF} = 248.0 Hz), 133.5 (d, J_{CF} = 8.3 Hz), 131.5, 128.4, 128.3, 123.1, 119.4 (d, J_{CF} = 3.4 Hz), 115.6 (d, J_{CF} = 21.9 Hz), 89.0 (d, J_{CF} = 1.5 Hz), 88.3 ppm. The spectra data were consistent with those reported in the literature.[7]



3an

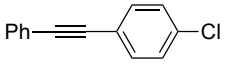
1-Chloro-2-(phenylethynyl)benzene (**3an**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-chlorobenzaldehyde **2n** (45.1 μL, d = 1.248 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3an** (80.2 mg, 0.377 mmol, 94% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.52-7.43 (m, 3H), 7.36-7.31 (m, 1H), 7.30-7.22 (m, 3H), 7.19-7.10 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 135.9, 133.2, 131.7, 129.3, 129.2, 128.6, 128.3, 126.4, 123.2, 122.9, 94.5, 86.2 ppm. The spectra data were consistent with those reported in the literature.[6]



3ao

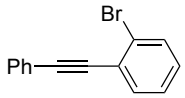
1-Chloro-3-(phenylethynyl)benzene (**3ao**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-chlorobenzaldehyde **2o** (45.3 μL, d = 1.241 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ao** (74.0

mg, 0.348 mmol, 87% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.47 (m, 3H), 7.43-7.22 (6H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 134.1, 131.6, 131.4, 129.7, 129.5, 128.6, 128.5, 128.4, 125.0, 122.7, 90.5, 87.9 ppm. The spectra data were consistent with those reported in the literature.[6]



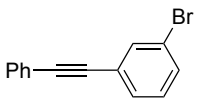
3ap

1-Chloro-4-(phenylethynyl)benzene (**3ap**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^{o}C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ap** (78.4 mg, 0.369 mmol, 92% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.56-7.48 (m, 2H), 7.45 (d, J = 8.3 Hz, 2H), 7.40-7.28 (m, 5H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 134.2, 132.8, 131.6, 128.7, 128.5, 128.4, 122.9, 121.8, 90.3, 88.2 ppm. The spectra data were consistent with those reported in the literature.[6]



3aq

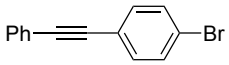
1-Bromo-2-(phenylethynyl)benzene (**3aq**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-bromobenzaldehyde **2q** (74.0 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^{o}C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3aq** (86.9 mg, 0.338 mmol, 85% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.63-7.50 (m, 4H), 7.39-7.30 (m, 3H), 7.26 (t, J = 7.6 Hz, 1H), 7.15 (t, J = 7.7 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 133.2, 132.4, 131.7, 129.3, 128.6, 128.3, 127.0, 125.6, 125.4, 122.9, 93.9, 88.0 ppm. The spectra data were consistent with those reported in the literature.[6]



3ar

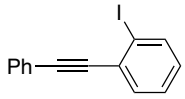
1-Bromo-3-(phenylethynyl)benzene (**3ar**): According to the general procedure, a mixture of 1-

benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-bromobenzaldehyde **2r** (74.0 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ar** (84.6 mg, 0.329 mmol, 82% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.59 (s, 1H), 7.48-7.40 (m, 2H), 7.36 (d, J = 7.8 Hz, 2H), 7.31-7.21 (m, 3H), 7.16-7.07 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 134.3, 131.6, 131.3, 130.1, 129.7, 128.6, 128.4, 125.3, 122.7, 122.1, 90.7, 87.8 ppm. The spectra data were consistent with those reported in the literature.[6]



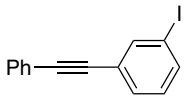
3as

1-Bromo-4-(phenylethynyl)benzene (**3as**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-bromobenzaldehyde **2s** (74.0 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3as** (88.0 mg, 0.342 mmol, 86% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.49 (m, 2H), 7.47 (d, J = 8.3 Hz, 2H), 7.38 (d, J = 8.2 Hz, 2H), 7.36-7.28 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 133.0, 131.58, 131.56, 128.5, 128.4, 122.9, 122.4, 122.2, 90.5, 88.3 ppm. The spectra data were consistent with those reported in the literature.[6]



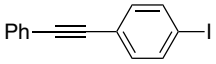
3at

1-Iodo-2-(phenylethynyl)benzene (**3at**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-iodobenzaldehyde **2t** (92.8 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3at** (99.7 mg, 0.328 mmol, 82% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.87 (d, J = 8.0 Hz, 3H), 7.60 (dd, J = 6.7, 3.0 Hz, 2H), 7.53 (dd, J = 8.3, 1.7 Hz, 1H), 7.41-7.28 (m, 4H), 7.01(td, J = 7.7, 1.7 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.7, 132.4, 131.6, 129.8, 129.3, 128.6, 128.4, 127.8, 122.9, 101.2, 93.4, 91.6 ppm. The spectra data were consistent with those reported in the literature.[9]



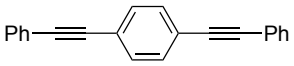
3au

1-Iodo-3-(phenylethynyl)benzene (**3au**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 3-iodobenzaldehyde **2u** (92.8 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3au** (104.3 mg, 0.343 mmol, 86% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.89 (s, 1H), 7.66 (d, J = 8.0 Hz, 1H), 7.57-7.45 (m, 3H), 7.39-7.30 (m, 3H), 7.07 (t, J = 7.8 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 140.1, 137.2, 131.6, 130.7, 129.8, 128.6, 128.4, 125.3, 122.7, 93.7, 90.7, 87.6 ppm. The spectra data were consistent with those reported in the literature.[10]



3av

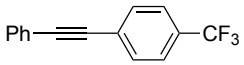
1-Iodo-4-(phenylethynyl)benzene (**3av**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-iodobenzaldehyde **2v** (92.8 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3av** (102.5 mg, 0.337 mmol, 84% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.68 (d, J = 8.4 Hz, 2H), 7.57-7.48 (m, 2H), 7.40-7.31 (m, 3H), 7.28-7.22 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.5, 133.1, 131.6, 128.5, 128.4, 122.9, 122.8, 94.1, 90.8, 88.4 ppm. The spectra data were consistent with those reported in the literature.[7]



3aw

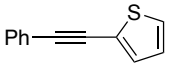
1,4-Bis(phenylethynyl)benzene (**3aw**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (184.1 mg, 0.88 mmol, 2.2 equiv), *p*-phthaldehyde **2w** (53.7 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (3.2 mL, 3.20 mmol, 8.0 equiv) in anhydrous THF (6.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3aw** (75.3 mg, 0.271 mmol, 68% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.58-7.46 (m, 8H), 7.39-7.30 (m, 6H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 131.6, 131.5, 128.44, 128.37, 123.08, 123.02, 91.2, 89.1

ppm. The spectra data were consistent with those reported in the literature.[11]



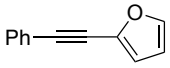
3ax

1-(Phenylethynyl)-4-(trifluoromethyl)benzene (**3ax**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 4-(trifluoromethyl)benzaldehyde **2x** (54.6 μL, d = 1.275 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ax** (83.0 mg, 0.337 mmol, 84% yield) as colorless solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.65-7.51 (m, 6H), 7.40-7.33 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 131.8, 131.7, 129.9 (q, J_{CF} = 24.5 Hz), 128.8, 128.4, 127.1 (q, J_{CF} = 1.0 Hz), 125.3 (q, J_{CF} = 2.8 Hz), 122.59, 122.56, 91.8, 88.0 ppm. The spectra data were consistent with those reported in the literature.[12]



3ay

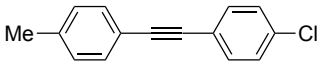
2-(Phenylethynyl)thiophene (**3ay**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-thiophenecarboxaldehyde **2y** (37.4 μL, d = 1.2 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ay** (59.4 mg, 0.322 mmol, 81% yield) as brown solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.57-7.47 (m, 2H), 7.41-7.22 (m, 5H), 7.05-6.97 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 131.9, 131.4, 128.4, 128.3, 127.2, 127.1, 123.3, 122.9, 93.0, 82.6 ppm. The spectra data were consistent with those reported in the literature.[13]



3az

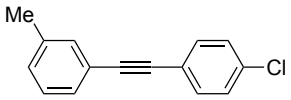
2-(Phenylethynyl)furan (**3az**): According to the general procedure, a mixture of 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3az** (60.6 mg, 0.360

mmol, 90% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.58-7.48 (m, 2H), 7.44-7.40 (m, 1H), 7.39-7.30 (m, 3H), 6.65 (d, J = 3.4 Hz, 1H), 6.48-6.39 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.6, 137.1, 131.4, 128.7, 128.4, 122.3, 115.2, 111.0, 93.2, 79.4 ppm. The spectra data were consistent with those reported in the literature.[14]



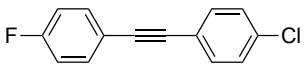
3bp

1-Chloro-4-(*p*-tolylethynyl)benzene (**3bp**): According to the general procedure, a mixture of 1-(4-methylbenzyl)benzotriazole **1b** (98.2 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^{o}C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3bp** (89.7 mg, 0.396 mmol, 99% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48-7.38 (m, 4H), 7.31 (d, J = 8.3 Hz, 2H), 7.16 (d, J = 7.8 Hz, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.7, 134.0, 132.7, 131.5, 129.2, 128.6, 122.0, 119.8, 90.5, 87.6, 21.5 ppm. The spectra data were consistent with those reported in the literature.[15]



3cp

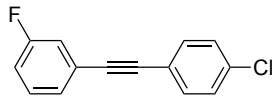
1-((4-Chlorophenyl)ethynyl)-3-methylbenzene (**3cp**): According to the general procedure, a mixture of 1-(3-methylbenzyl)benzotriazole **1c** (98.2 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^{o}C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3cp** (88.9 mg, 0.392 mmol, 98% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.44 (d, J = 8.4 Hz, 2H), 7.37-7.28 (m, 4H), 7.27-7.20 (m, 1H), 7.15 (d, J = 7.5 Hz, 1H), 2.35 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.1, 134.1, 132.8, 132.2, 129.4, 128.7, 128.3, 122.7, 121.9, 90.5, 87.9, 21.2 ppm (One carbon was missing probably because of overlapping). The spectra data were consistent with those reported in the literature.[16]



3dp

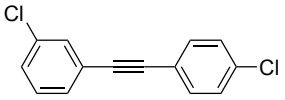
1-Chloro-4-((4-fluorophenyl)ethynyl)benzene (**3dp**): According to the general procedure, a

mixture of 1-(4-fluorobenzyl)benzotriazole **1d** (100.0 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3dp** (86.0 mg, 0.373 mmol, 93% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.54-7.47 (m, 2H), 7.44 (d, J = 8.4 Hz, 2H), 7.32 (d, J = 8.4 Hz, 2H), 7.05 (t, J = 8.6 Hz, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.6 (d, J_{CF} = 248.5 Hz), 134.3, 133.5 (d, J_{CF} = 8.4 Hz), 132.7, 128.7, 121.6, 119.0 (d, J_{CF} = 3.4 Hz), 115.7 (d, J_{CF} = 22.1 Hz), 89.2, 87.9 (d, J_{CF} = 1.7 Hz) ppm. The spectra data were consistent with those reported in the literature.[17]



3ep

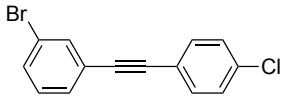
1-((4-Chlorophenyl)ethynyl)-3-fluorobenzene (**3ep**): According to the general procedure, a mixture of 1-(3-fluorobenzyl)benzotriazole **1e** (100.0 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ep** (78.3 mg, 0.339 mmol, 85% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.45 (d, J = 8.3 Hz, 2H), 7.38-7.27 (m, 4H), 7.21 (d, J = 9.8 Hz, 1H), 7.10-7.00 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.4 (d, J_{CF} = 245.1 Hz), 134.6, 132.9, 130.0 (d, J_{CF} = 8.6 Hz), 128.8, 127.5 (d, J_{CF} = 3.0 Hz), 124.8 (d, J_{CF} = 9.5 Hz), 121.3, 118.3 (d, J_{CF} = 22.7 Hz), 115.8 (d, J_{CF} = 21.1 Hz), 89.1, 89.0 (d, J_{CF} = 3.4 Hz) ppm. The spectra data were consistent with those reported in the literature.[15]



3gp

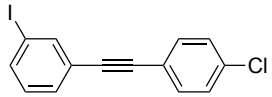
1-Chloro-3-((4-chlorophenyl)ethynyl)benzene (**3gp**): According to the general procedure, a mixture of 1-(3-chlorobenzyl)benzotriazole **1g** (107.2 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3gp** (82.9 mg, 0.335 mmol, 84% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.51 (s, 1H), 7.45 (d, J = 8.4 Hz, 2H), 7.39 (d, J = 7.2 Hz, 1H), 7.36-7.27 (m, 4H) ppm; ^{13}C

NMR (100 MHz, $CDCl_3$): δ = 134.7, 134.2, 132.9, 131.4, 129.7, 129.6, 128.8, 128.7, 124.6, 121.2, 89.4, 88.8 ppm; HRMS (ESI) *m/z* calcd for $C_{14}H_9Cl_2$ $[M+H]^+$: 247.0081, found: 247.1312.



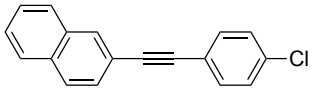
3ip

1-Bromo-3-((4-chlorophenyl)ethynyl)benzene (**3ip**): According to the general procedure, a mixture of **1i** (126.8 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^oC for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ip** (85.4 mg, 0.293 mmol, 73% yield) as brown solids. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.67 (s, 1H), 7.50-7.41 (m, 4H), 7,33 (d, *J* = 8.2 Hz, 2H), 7.22 (t, *J* = 7.9 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 134.7, 134.3, 132.8, 131.6, 130.1, 129.8, 128.8, 124.9, 122.2, 121.2, 89.5, 88.7 ppm. The spectra data were consistent with those reported in the literature.[18]



3jp

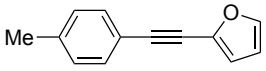
1-((4-Chlorophenyl)ethynyl)-3-iodobenzene (**3jp**): According to the general procedure, a mixture of 1-(3-iodobenzyl)benzotriazole **1j** (147.5 mg, 0.44 mmol, 1.1 equiv), 4-chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 ^oC for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3jp** (99.7 mg, 0.294 mmol, 74% yield) as brown solids. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.88 (s, 1H), 7.67 (d, *J* = 7.9 Hz, 1H), 7.47 (d, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 8.3 Hz, 2H), 7.33 (d, *J* = 8.3 Hz, 2H), 7.08 (t, *J* = 7.8 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 140.1, 137.4, 134.6, 132.8, 130.6, 129.9, 128.8, 125.0, 121.2, 93.7, 89.5, 88.5 ppm; HRMS (ESI) *m/z* calcd for $C_{14}H_9ClI$ $[M+H]^+$: 338.9437, found: 338.9416.



3kp

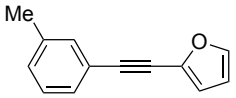
2-((4-Chlorophenyl)ethynyl)naphthalene (**3kp**): According to the general procedure, a mixture of 1-(naphthalen-2-ylmethyl)benzotriazole **1k** (114.1 mg, 0.44 mmol, 1.1 equiv), 4-

chlorobenzaldehyde **2p** (56.2 mg, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3kp** (97.1 mg, 0.369 mmol, 92% yield) as colorless solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.04 (s, 1H), 7.88-7.76 (m, 3H), 7.56 (d, J = 8.5 Hz, 1H), 7.49 (d, J = 8.7 Hz, 4H), 7.33 (d, J = 8.4 Hz, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 134.3, 133.0, 132.9, 132.8, 131.5, 128.7, 128.3, 128.1, 127.79, 127.77, 126.8, 126.6, 121.8, 120.2, 90.7, 88.6 ppm. The spectra data were consistent with those reported in the literature.[19]



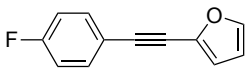
3bz

2-(*p*-Tolylethynyl)furan (**3bz**): According to the general procedure, a mixture of 1-(4-methylbenzyl)benzotriazole **1b** (98.2 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3bz** (58.5 mg, 0.321 mmol, 80% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.45-7.38 (m, 3H), 7.15 (d, J = 7.8 Hz, 2H), 6.63 (d, J = 3.4 Hz, 1H), 6.44-6.38 (m, 1H), 2.36 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.4, 138.9, 137.3, 131.3, 129.1, 119.2, 114.9, 111.0, 93.4, 78.7, 21.5 ppm. The spectra data were consistent with those reported in the literature.[20]



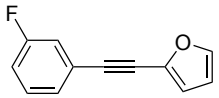
3cz

2-(*m*-Tolylethynyl)furan (**3cz**): According to the general procedure, a mixture of 1-(3-methylbenzyl)benzotriazole **1c** (98.2 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3cz** (63.8 mg, 0.350 mmol, 88% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.44-7.39 (m, 1H), 7.37-7.29 (m, 2H), 7.23 (t, J = 7.6 Hz, 1H), 7.15 (d, J = 7.6 Hz, 1H), 6.63 (d, J = 3.4 Hz, 1H), 6.44-6.39 (m, 1H), 2.34 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.5, 138.1, 137.2, 131.9, 129.6, 128.5, 128.3, 122.1, 115.1, 111.0, 93.4, 79.0, 21.2 ppm; HRMS (ESI) *m/z* calcd for $C_{13}H_{11}O$ $[M+H]^+$: 183.0810, found: 183.0808.



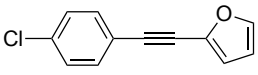
3dz

2-((4-Fluorophenyl)ethynyl)furan (**3dz**): According to the general procedure, a mixture of 1-(4-fluorobenzyl)benzotriazole **1d** (100.0 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, *d* = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3dz** (60.1 mg, 0.323 mmol, 81% yield) as yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.54-7.46 (m, 2H), 7.42 (s, 1H), 7.04 (t, *J* = 8.6 Hz, 2H), 8.65 (d, *J* = 3.3 Hz, 1H), 6.45-6.39 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.7 (d, J_{CF} = 248.7 Hz), 143.7, 137.0, 133.4 (d, J_{CF} = 8.4 Hz), 118.4 (d, J_{CF} = 3.6 Hz), 115.7 (d, J_{CF} = 22.1 Hz), 115.3, 111.0, 92.1, 79.1 (d, J_{CF} = 1.6 Hz) ppm; HRMS (ESI) *m/z* calcd for $C_{12}H_8FO$ $[M+H]^+$: 187.0559, found: 187.0558.



3ez

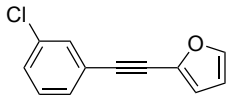
2-((3-Fluorophenyl)ethynyl)furan (**3ez**): According to the general procedure, a mixture of 1-(3-fluorobenzyl)benzotriazole **1e** (100.0 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, *d* = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3ez** (41.7 mg, 0.224 mmol, 56% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.44 (s, 1H), 7.35-7.27 (m, 2H), 7.21 (dd, *J* = 9.7, 2.1 Hz, 1H), 7.10-7.01 (m, 1H), 6.68 (d, *J* = 3.4 Hz, 1H), 6.46-6.41 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.3 (d, J_{CF} = 245.2 Hz), 144.0, 136.7, 130.0 (d, J_{CF} = 8.6 Hz), 127.3 (d, J_{CF} = 3.0 Hz), 124.1 (d, J_{CF} = 9.5 Hz), 118.1 (d, J_{CF} = 22.9 Hz), 116.0 (d, J_{CF} = 21.1 Hz), 115.8, 111.1, 92.0 (d, J_{CF} = 3.4 Hz), 80.3 ppm. HRMS (ESI) *m/z* calcd for $C_{12}H_8FO$ $[M+H]^+$: 187.0559, found: 187.0553.



3fz

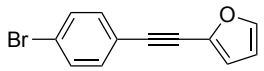
2-((4-Chlorophenyl)ethynyl)furan (**3fz**): According to the general procedure, a mixture of 1-(4-chlorobenzyl)benzotriazole **1f** (107.2 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, *d* = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product

was purified by flash column chromatography (silica gel, hexane only) to give **3fz** (55.4 mg, 0.273 mmol, 68% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48-7.41 (m, 3H), 7.32 (d, J = 8.5 Hz, 2H), 6.67 (d, J = 3.4 Hz, 1H), 6.46-6.41 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.8, 136.9, 134.8, 132.6, 128.8, 120.8, 115.6, 111.1, 92.1, 80.3 ppm; HRMS (ESI) *m/z* calcd for $C_{12}H_8ClO$ $[M+H]^+$: 203.0264, found: 203.0260.



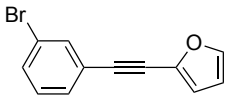
3gz

2-((3-Chlorophenyl)ethynyl)furan (**3gz**): According to the general procedure, a mixture of 1-(3-chlorobenzyl)benzotriazole **1g** (107.2 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3gz** (36.3 mg, 0.179 mmol, 45% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50 (s, 1H), 7.46-7.42 (m, 1H), 7.39 (d, J = 7.4 Hz, 1H), 7.34-7.23 (m, 2H), 6.68 (d, J = 3.4 Hz, 1H), 6.46-6.40 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.0, 136.7, 134.2, 131.1, 129.6, 129.5, 128.9, 124.0, 115.8, 111.1, 91.8, 80.5 ppm. The spectra data were consistent with those reported in the literature.[21]



3hz

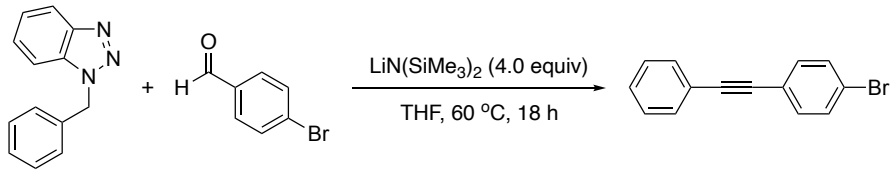
2-((4-Bromophenyl)ethynyl)furan (**3hz**): According to the general procedure, a mixture of 1-(4-bromobenzyl)benzotriazole **1h** (126.8 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3hz** (69.8 mg, 0.282 mmol, 71% yield) as yellow solids. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.48 (d, J = 8.4 Hz, 1H), 7.44 (s, 1H), 7.38 (d, J = 8.4 Hz, 2H), 6.67 (d, J = 3.4 Hz, 1H), 6.46-6.49 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 143.9, 136.9, 132.8, 131.7, 123.0, 121.3, 115.6, 111.1, 92.2, 80.5 ppm; HRMS (ESI) *m/z* calcd for $C_{12}H_8BrO$ $[M+H]^+$: 246.9759, found: 246.9672.



3iz

2-((3-Bromophenyl)ethynyl)furan (**3iz**): According to the general procedure, a mixture of 1-(3-bromobenzyl)benzotriazole **1i** (126.8 mg, 0.44 mmol, 1.1 equiv), 2-furaldehyde **2z** (33.1 μL, d = 1.16 g/mL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (1.6 mL, 1.60 mmol, 4.0 equiv) in anhydrous THF (3.0 mL) was stirred at 60 °C for 18 h under N_2 atmosphere. The crude product was purified by flash column chromatography (silica gel, hexane only) to give **3iz** (44.3 mg, 0.179 mmol, 45% yield) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.67 (s, 1H), 7.51-7.40 (m, 3H), 7.21 (t, J = 7.9 Hz, 1H), 6.68 (d, J = 3.4 Hz, 1H), 6.46-6.41 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.0, 136.7, 134.0, 131.8, 129.9, 129.8, 124.3, 122.2, 115.9, 111.1, 91.7, 80.7 ppm; HRMS (ESI) *m/z* calcd for $C_{12}H_8BrO$ $[M+H]^+$: 246.9759, found: 246.9570.

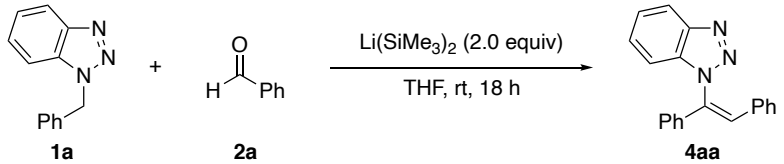
5. Gram-Scale Synthesis of 1-Bromo-4-(phenylethynyl)benzene 3as



1a (6.6 mmol) + **2s** (6.0 mmol) → **3as** (1.37, 89% yield)

A 250 mL dry flask was dried with a heat gun for 3 min under vacuum (< 5 mmHg at ca. 600 °C). After the displacement with N_2 gas, 1-benzylbenzotriazole **1a** (1.38 g, 6.60 mmol, 1.1 equiv), 4-bromobenzaldehyde **2s** (1.11 g, 6.00 mmol, 1.0 equiv), anhydrous THF (45.0 mL), and $LiN(SiMe_3)_2$ (1.0 M in THF) (24.0 mL, 24.00 mmol, 4.0 equiv). The resulting mixture was then stirred at 60 °C for 18 h under N_2 atmosphere. Water (60 mL) was added to quench the reaction, followed by extraction with ethyl acetate (3×60 mL). The organic layers were combined, washed with brine, dried over anhydrous Na_2SO_4, and concentrated under vacuum. The crude product was purified by flash column chromatography (silica gel, hexane only) to give 1-bromo-4-(phenylethynyl)benzene **3as** (1.37 g, 5.32 mmol) in 89% yield as yellow solids.

6. Mechanistic Study

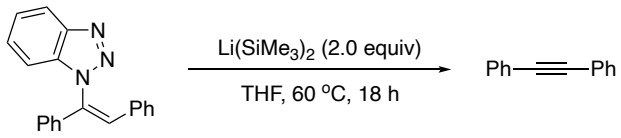


1a (1.1 equiv) + **2a** (1.0 equiv) → **4aa** 74% yield

A 10 mL reaction tube was dried with a heat gun for 3 min under vacuum (< 5 mmHg at ca. 600

°C). After the displacement with N_2 gas, 1-benzylbenzotriazole **1a** (92.1 mg, 0.44 mmol, 1.1 equiv), anhydrous THF (3.0 mL), benzaldehyde **2a** (40.7 μL, 0.40 mmol, 1.0 equiv), and $LiN(SiMe_3)_2$ (1.0 M in THF) (0.8 mL, 0.80 mmol, 2.0 equiv). The resulting mixture was then stirred at room temperature for 18 h under N_2 atmosphere. Seven drops water was added to quench the reaction. The reaction mixture was passed through a short pad of silica, washed with an additional 16 mL of ethyl acetate (4×10 mL), and the combined solutions were concentrated under reduced pressure. The crude product was purified by flash column chromatography (silica gel, hexane-ethyl acetate, 25:1) to give (*Z*)-1-(1,2-diphenylvinyl)-1*H*-benzo[*d*][1,2,3]triazole **4aa** (87.4 mg, 0.294 mmol, 74% yield) as colorless solids.

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.13 (d, J = 7.9 Hz, 1H), 7.41-7.29 (m, 6H), 7.23-7.16 (m, 2H), 7.15-7.03 (m, 4H), 6.74 (d, J = 7.4 Hz, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.8, 136.64, 133.58, 133.5, 133.1, 129.3, 128.9, 128.58, 128.55, 128.0, 127.6, 125.9, 124.2, 120.0, 110.5 ppm; HRMS (ESI) *m/z* calcd for $C_{20}H_{16}N_3$ $[M+H]^+$: 298.1344, found: 298.1338. The spectra data were consistent with those reported in the literature.[22]



4aa
(1.0 equiv)

3aa
96% yield

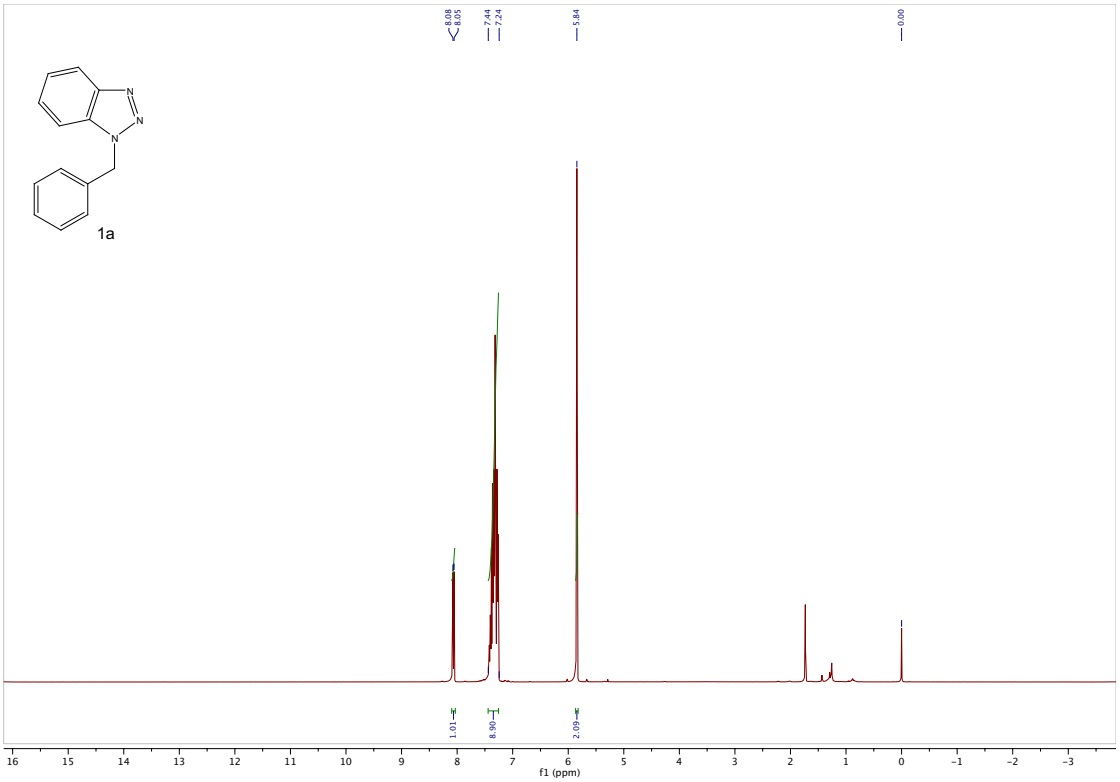
A 10 mL reaction tube was dried with a heat gun for 3 min under vacuum (< 5 mmHg at ca. 600 °C). After the displacement with N_2 gas, **4aa** (118.9 mg, 0.40 mmol, 1.0 equiv), anhydrous THF (3.0 mL), and $LiN(SiMe_3)_2$ (1.0 M in THF) (0.8 mL, 0.80 mmol, 2.0 equiv). The resulting mixture was then stirred at 60 °C for 18 h under N_2 atmosphere. Seven drops water was added to quench the reaction. The reaction mixture was passed through a short pad of silica, washed with an additional 16 mL of ethyl acetate (4×10 mL), and the combined solutions were concentrated under reduced pressure. The crude product was purified by flash column chromatography (silica gel, hexane only) to give 1,2-diphenylethyne **3aa** (68.4 mg, 0.384 mmol, 96% yield) as colorless solids.

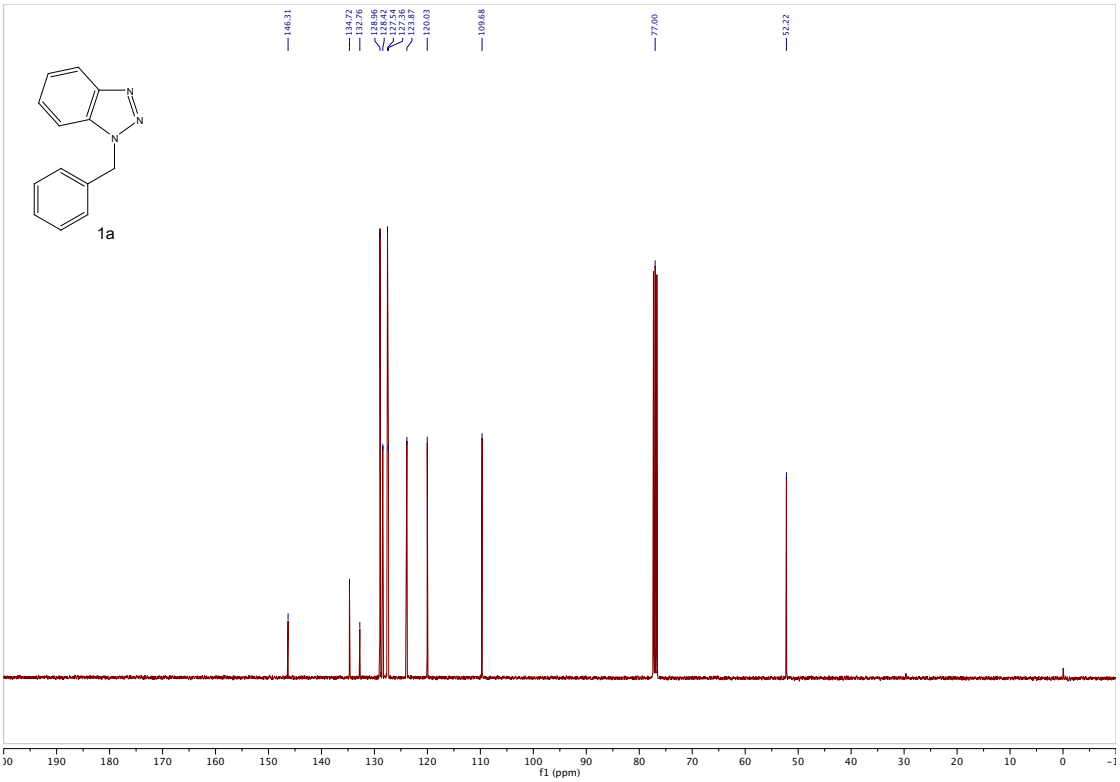
7. Reference

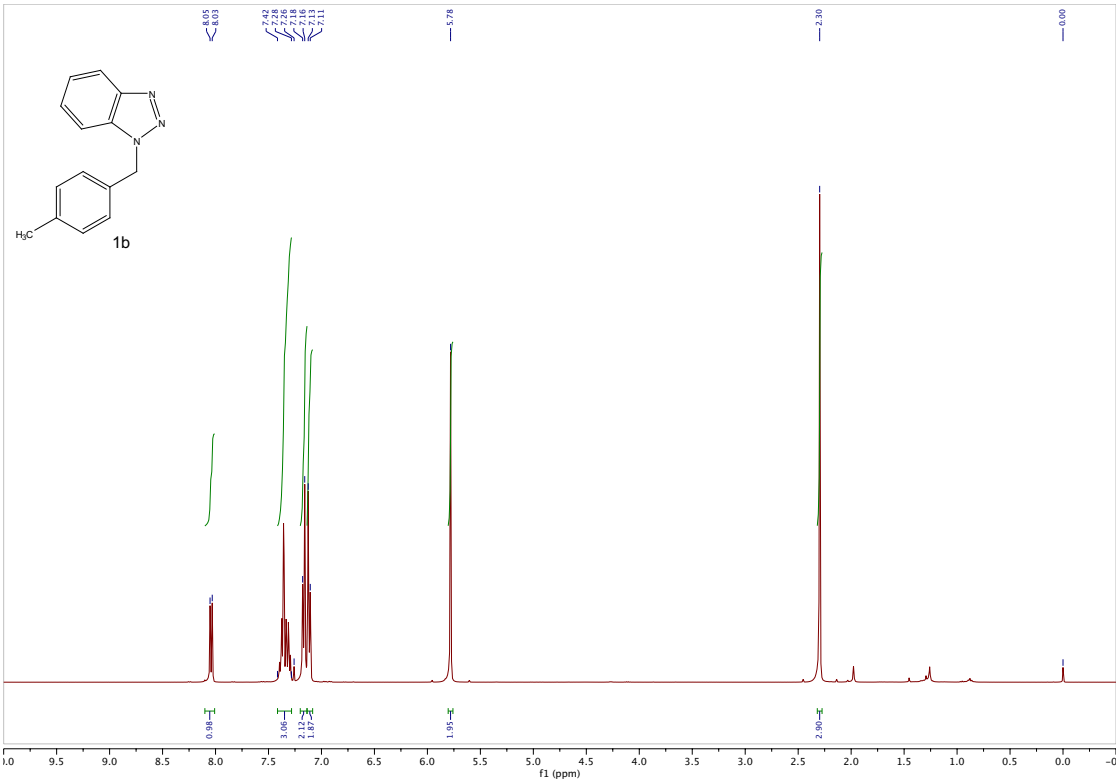
1. Paventi, M.; Elce, E.; Jackman, R. J.; Hay, A. S. *Tetrahedron Lett.* **1992**, *33*, 6405.
2. Xue, Q.; Xie, J.; Li, H.; Cheng, Y.; Zhu, C. *Chem. Commun.* **2013**, *49*, 3700.
3. Zhong, Z.; Hong, R.; Wang, X. *Tetrahedron Lett.* **2010**, *51*, 6763.
4. Liu, W.; Liu, C.; Zhang, Y.; Sun, Y.; Abdukadera, A.; Wang, B.; Li, H.; Ma, X.; Zhang, Z. *Org. Biomol. Chem.* **2015**, *13*, 7154.
5. Katritzky, A. R.; Zhang, G.; Xie, L. *J. Org. Chem.* **1997**, *62*, 721.

6. Hamasaka, G.; Roy, D.; Tazawa, A.; Uozumi, Y. *ACS Catal.* **2019**, *9*, 11640.
7. Wang, S.; Wang, M.; Wang, L.; Wang, B.; Li, P.; Yang, J. *Tetrahedron* **2011**, *67*, 4800.
8. Truong, T.; Daugulis, O. *Org. Lett.* **2011**, *13*, 4172.
9. Cao, W.; Liu, S.-L.; Shuai, L.; Xiao, Q. *Chem. Commun.* **2020**, *56*, 972.
10. Orita, A.; Taniguchi, H.; Otera, J. *Chem. Asian. J.* **2006**, *1*, 430.
11. Rao, M. L. N.; Jadhav, D. N.; Dasgupta, P. *Org. Lett.* **2010**, *12*, 2048.
12. Baralle, A.; Yorimitsu, H.; Osuka, A. *Chem. Eur. J.* **2016**, *22*, 10768.
13. Yang, Y.; Lim, Y. H.; Robins, E. G.; Johannes, C. *RSC Adv.* **2016**, *6*, 72810.
14. Fuji, K.; Morimoto, T.; Tsutsumi, K.; Kakiuchi, K. *Chem. Commun.* **2005**, 3295.
15. Gholap, A. R.; Venkatesan, K.; Pasricha, R.; Daniel, T.; Lahoti, R. J.; Srinivasan, K. V. *J. Org. Chem.* **2005**, *70*, 4869.
16. Hung, T.-T.; Huang, C.-M.; Tsai, F.-Y. *ChemCatChem* **2012**, *4*, 540.
17. Wang, H.; Li, L.; Bai, X.-F.; Deng, W.-H.; Zheng, Z.-J.; Yang, K.-F.; Xu, L.-W. *Green Chem.* **2013**, *15*, 2349.
18. Mio, M. J.; Kopel, L. C.; Braun, J. B.; Gadzikwa, T. L.; Hull, K. L.; Brisbois, R. G.; Markworth, C. J.; Grieco, P. A. *Org. Lett.* **2002**, *4*, 3199.
19. Katritzky, A. R.; Abdel-Fattah, A. A. A.; Wang, M. *J. Org. Chem.* **2002**, *67*, 7526.
20. Yan, H.; Lu, L.; Sun, P.; Zhu, Y.; Yang, H.; Liu, D.; Rong, G.; Mao, J. *RSC Adv.* **2013**, *3*, 377.
21. Sapegin, A.; Krasavin, M. *J. Org. Chem.* **2019**, *84*, 8788.
22. Duan, H.; Yan, W.; Sengupta, S.; Shi, X. *Bioorg. Med. Chem. Lett.* **2009**, 19, 3899.

8. NMR Spectra



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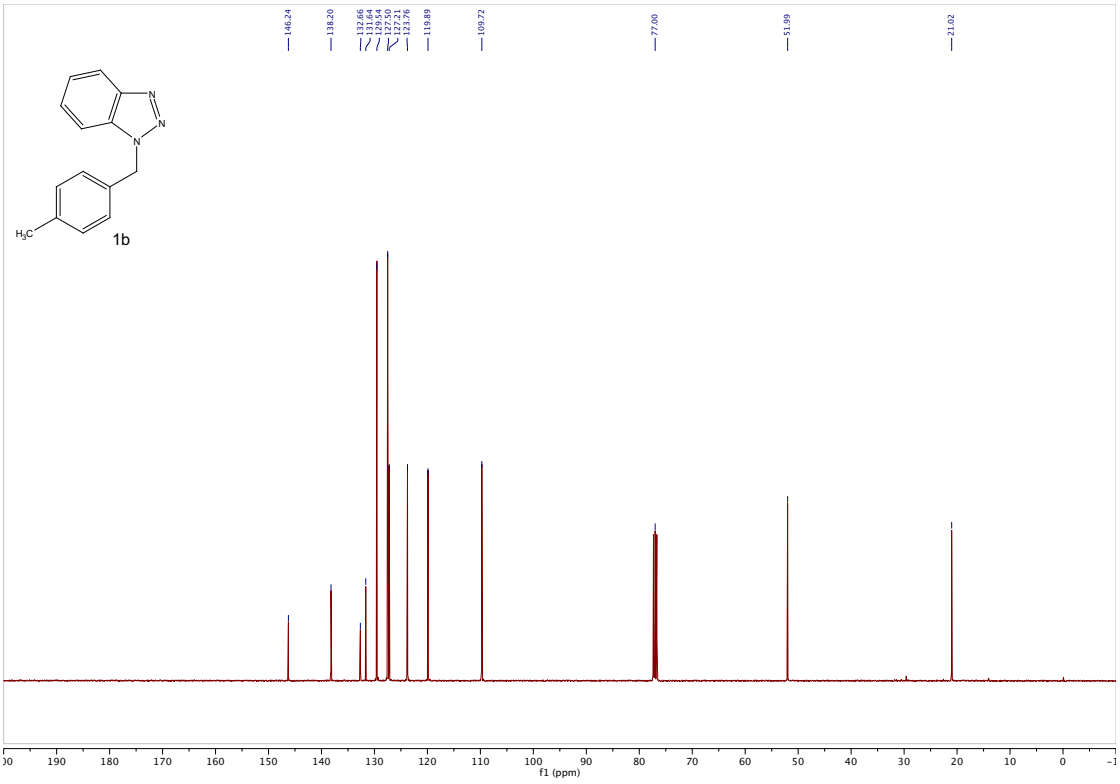
2.90
f1 (ppm)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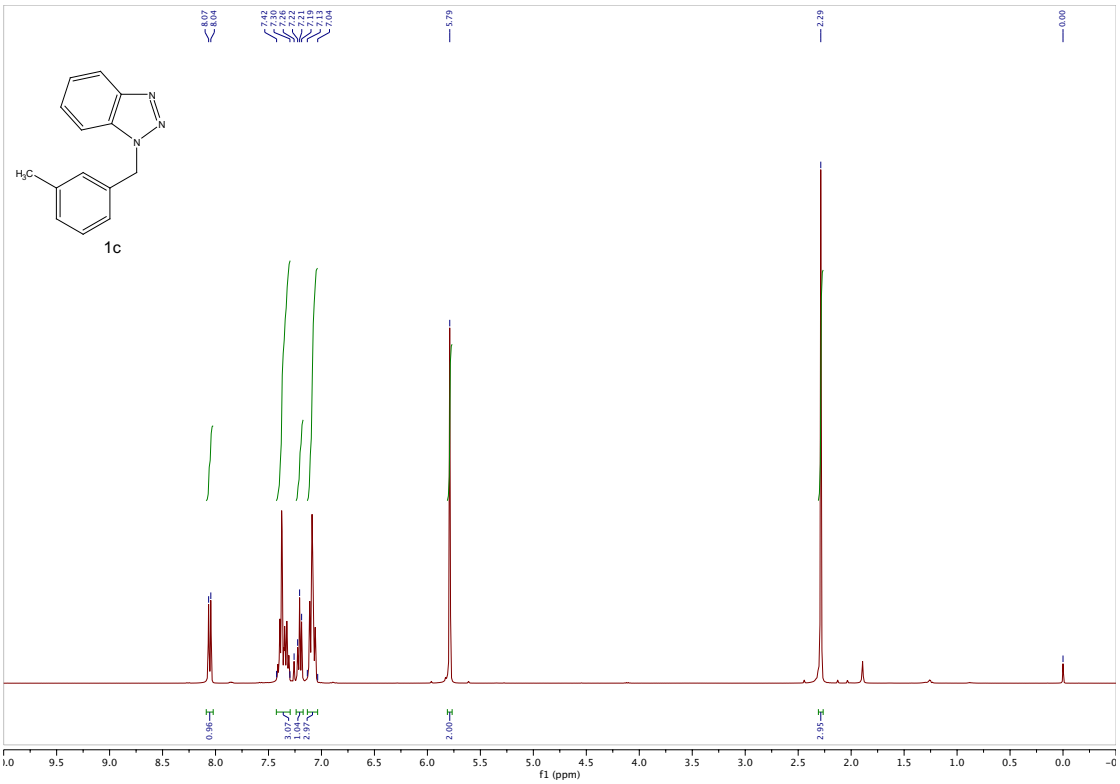
1b
f1 (ppm)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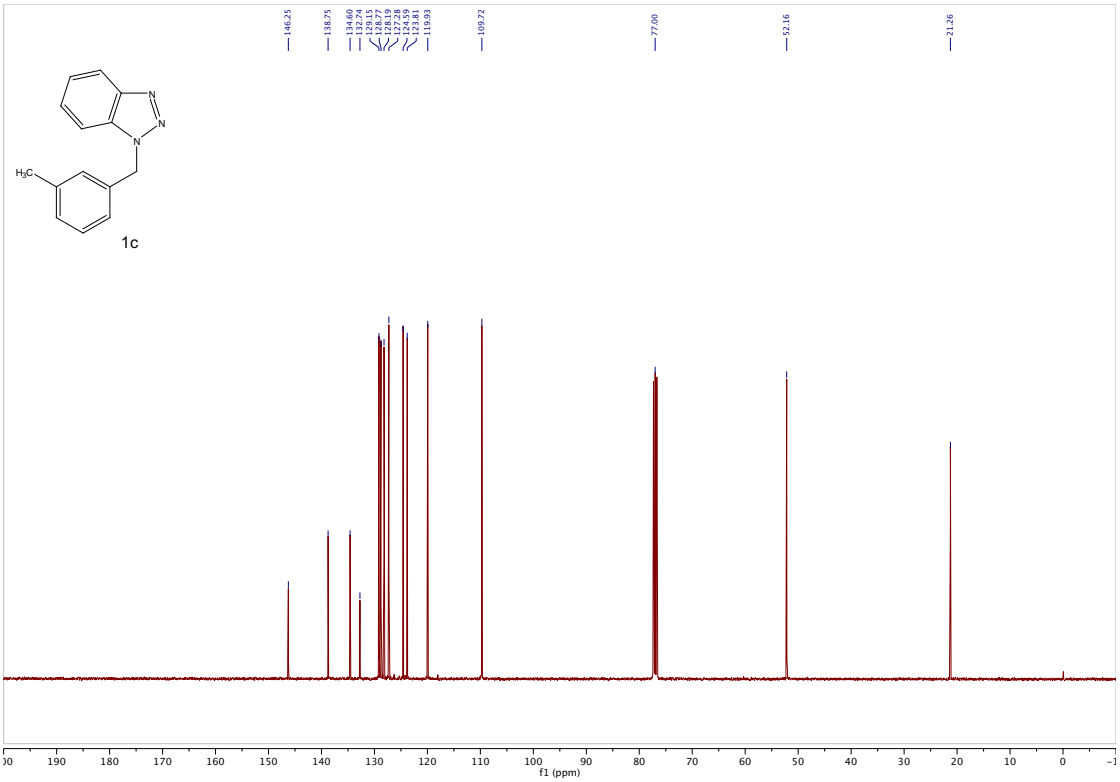
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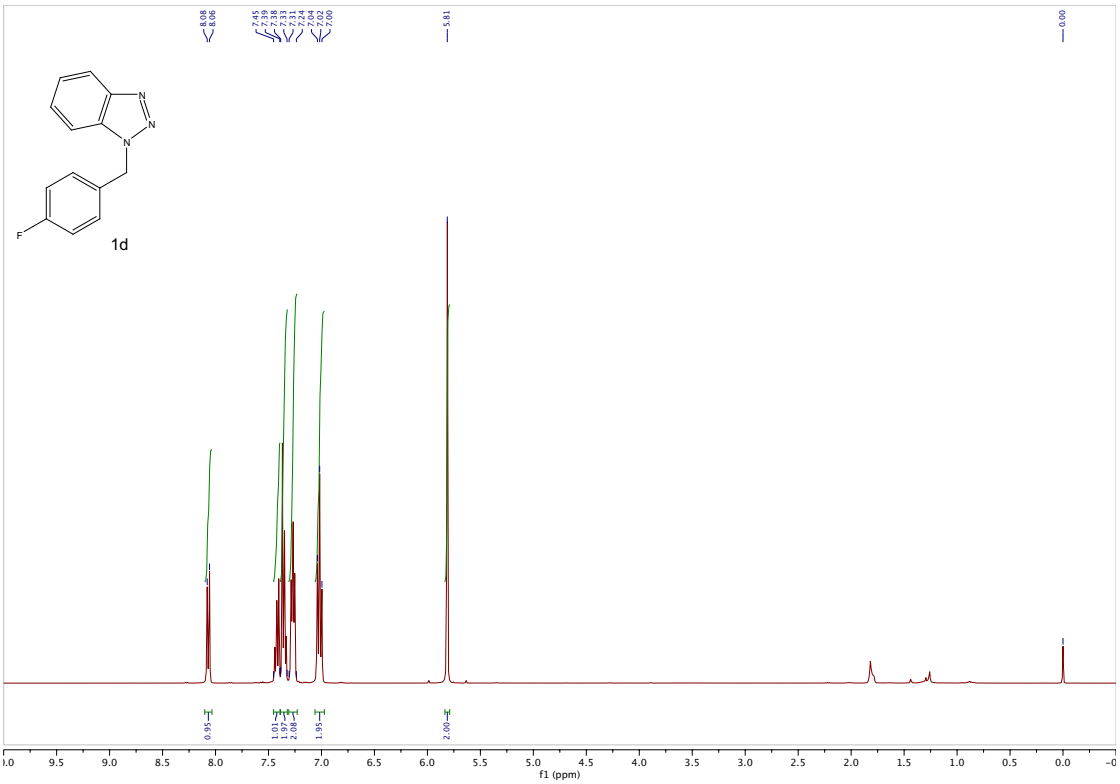
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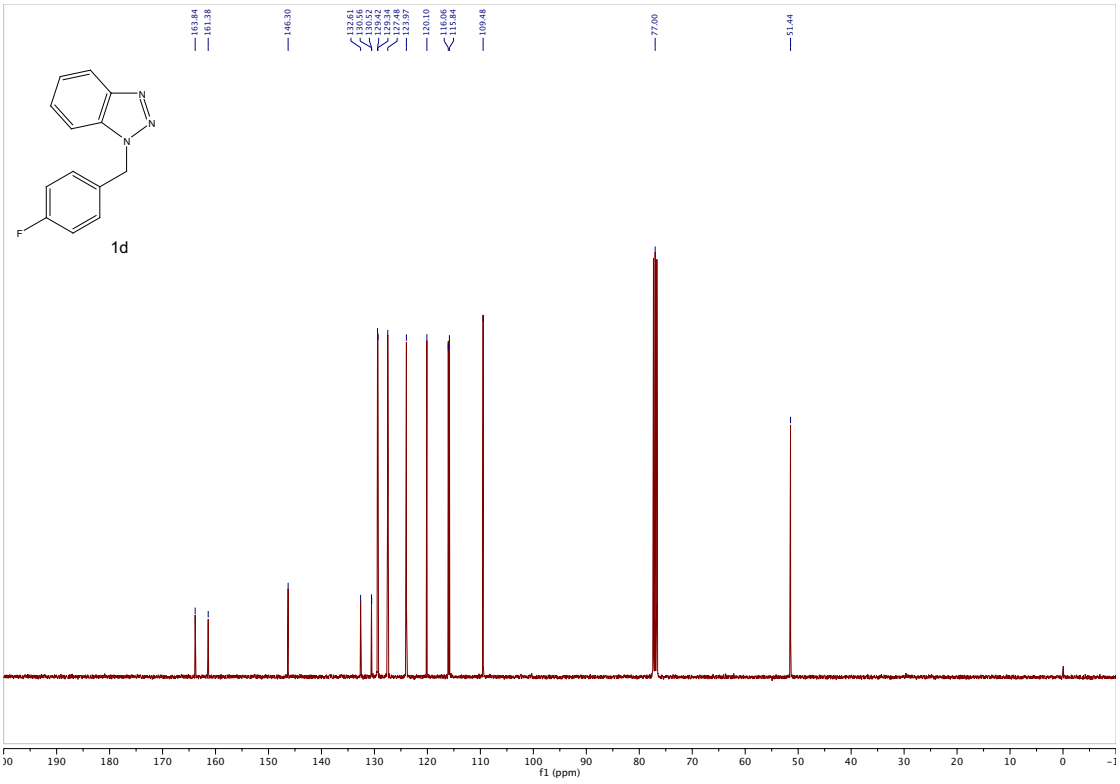
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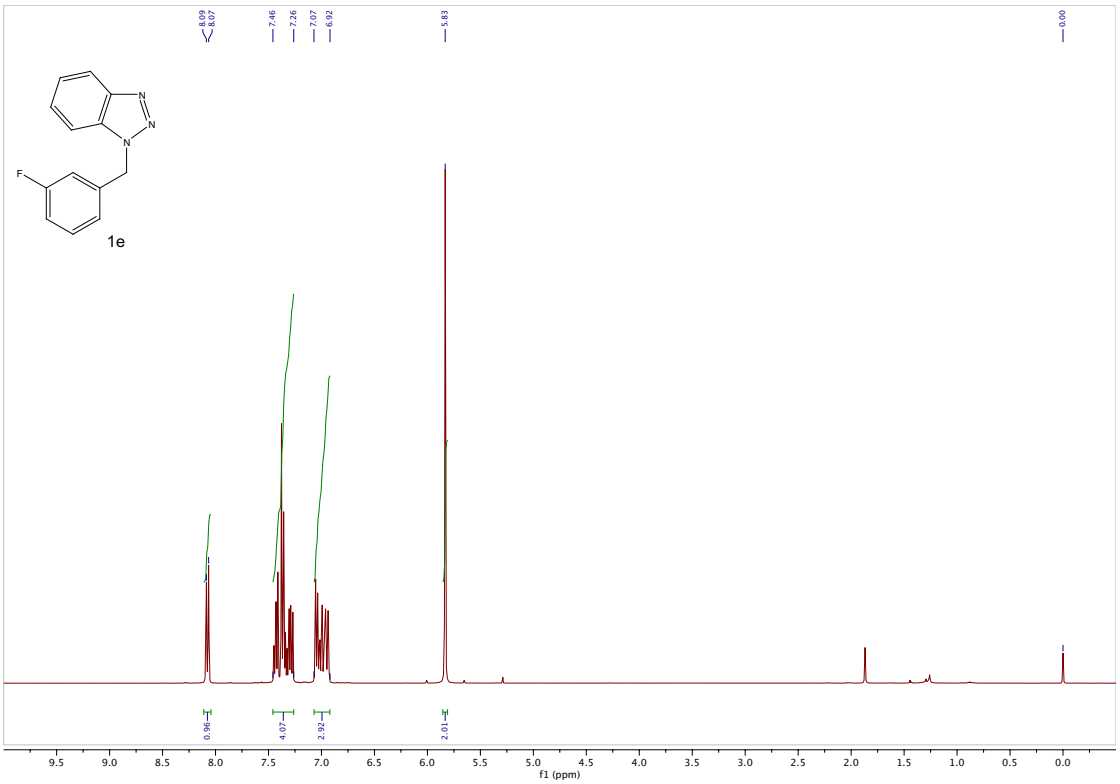
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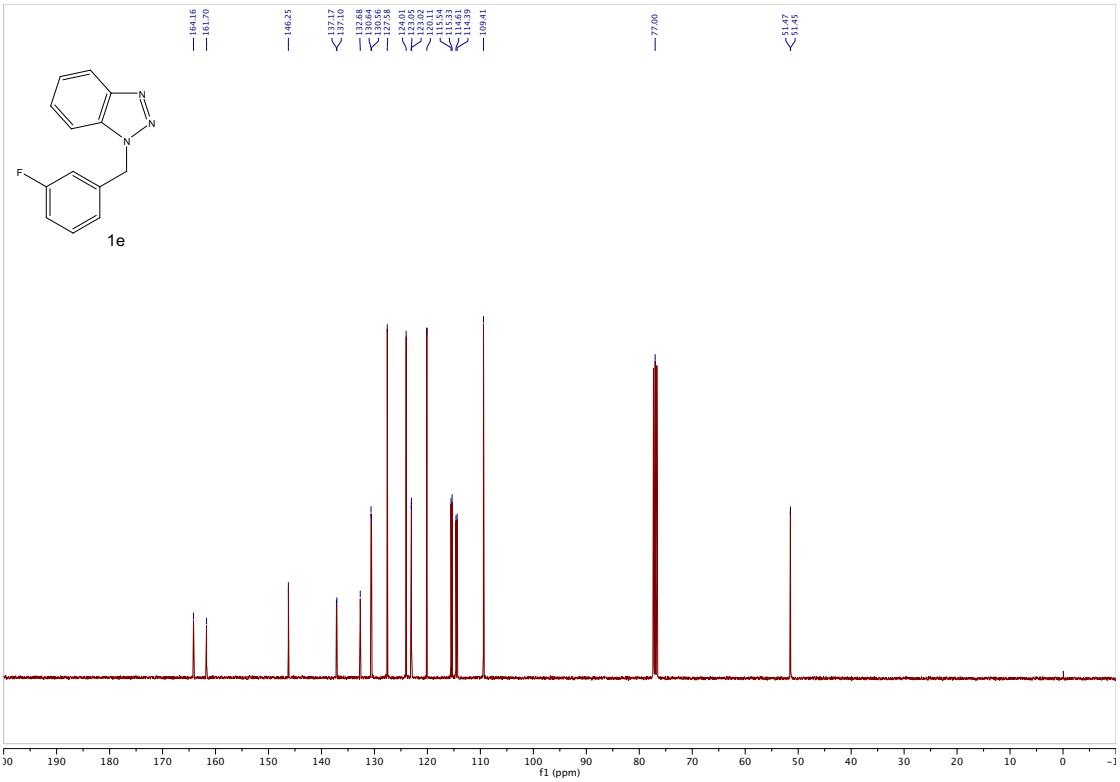
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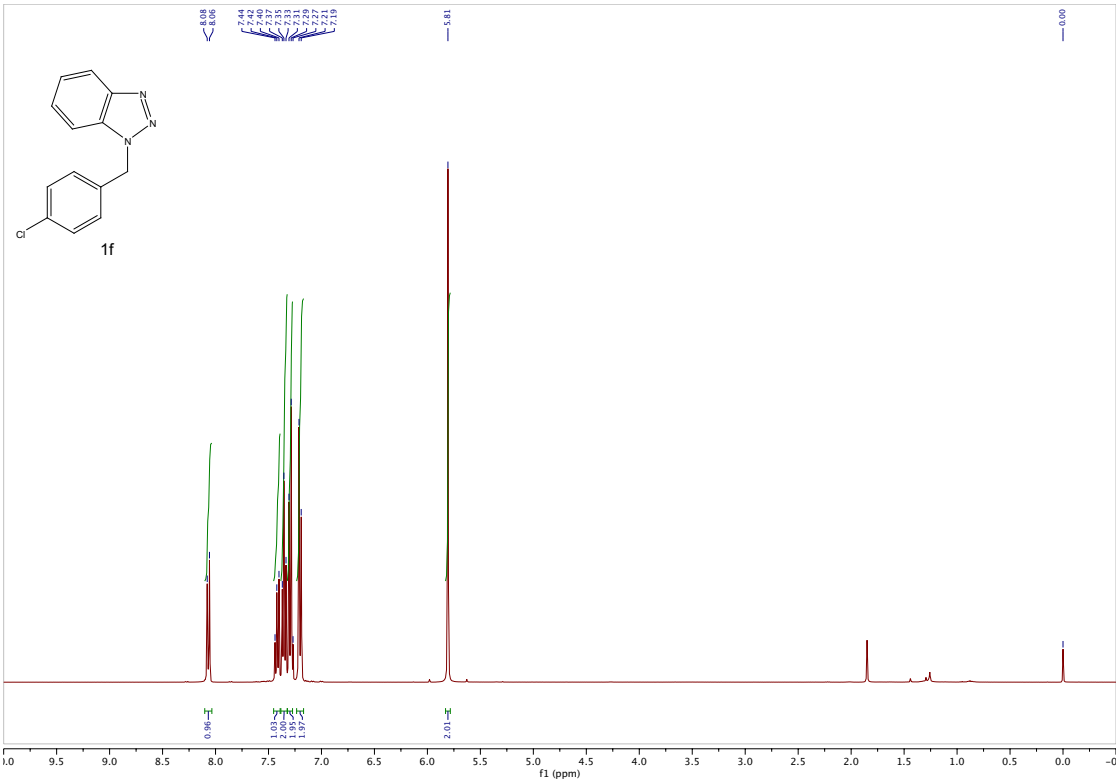
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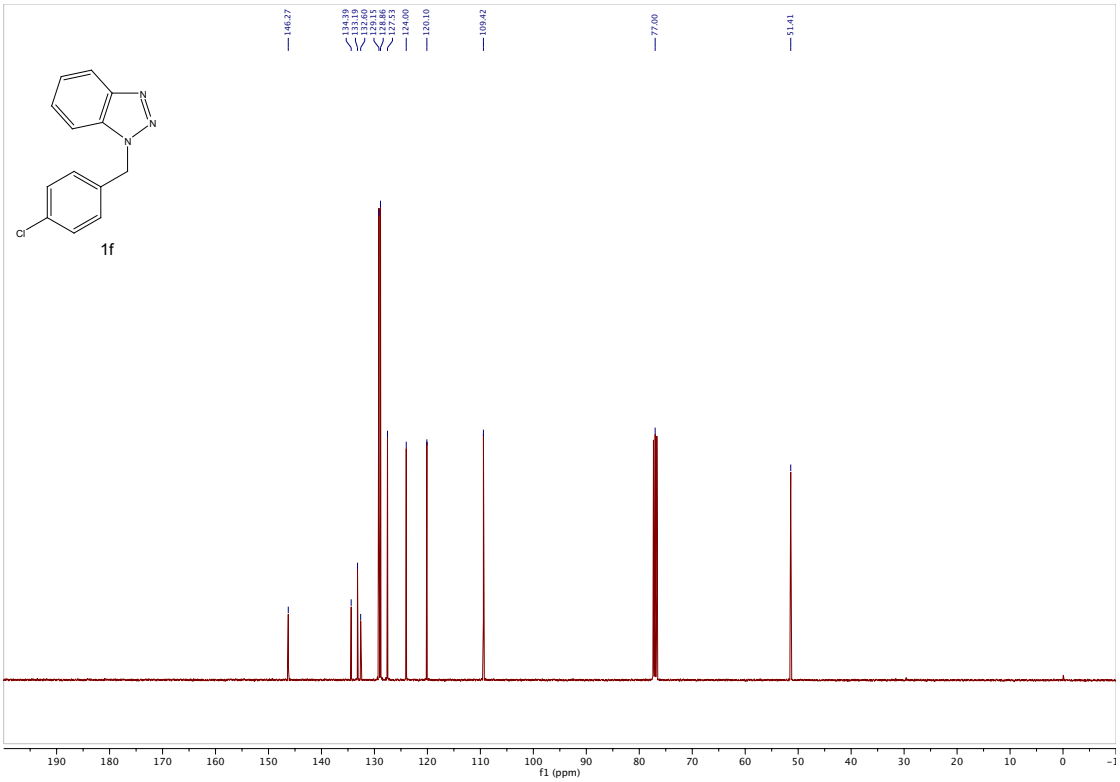
1.92
2.01
f1 (ppm)


146.27
134.39
133.19
132.60
130.15
128.86
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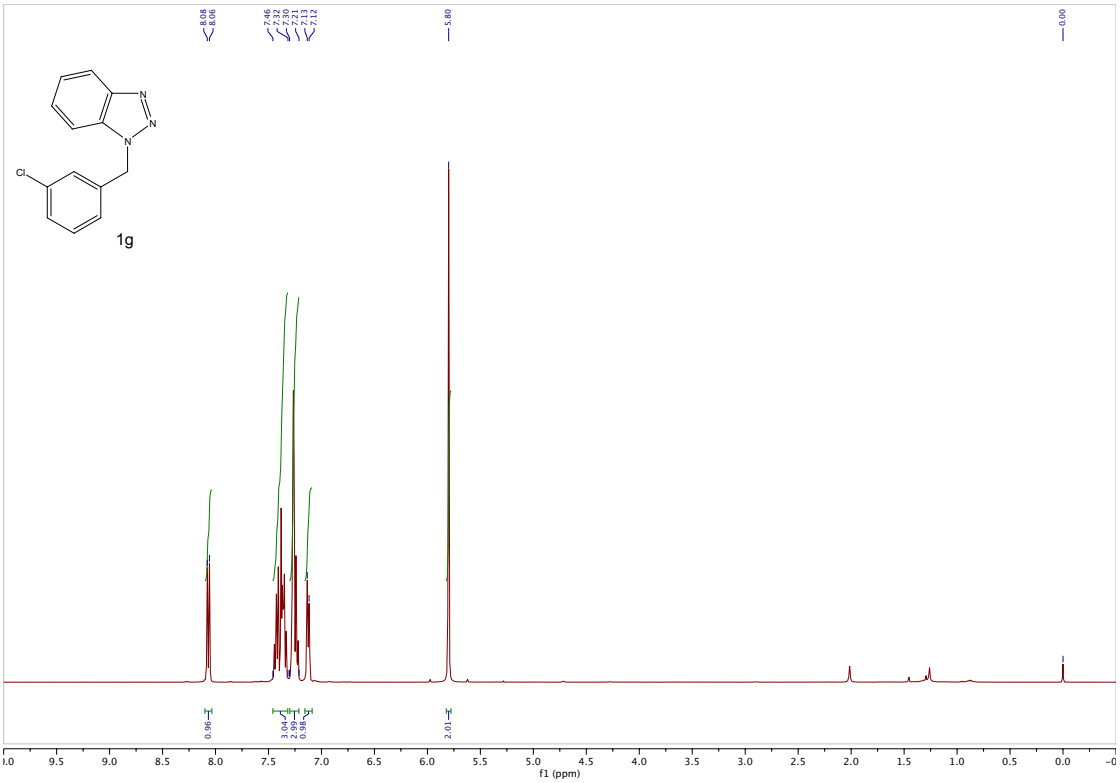
124.00
120.10
109.42
77.00
51.41
N
N
N
Cl
1f
f1 (ppm)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8.06
7.46
7.33
7.30
7.21
7.13
7.12
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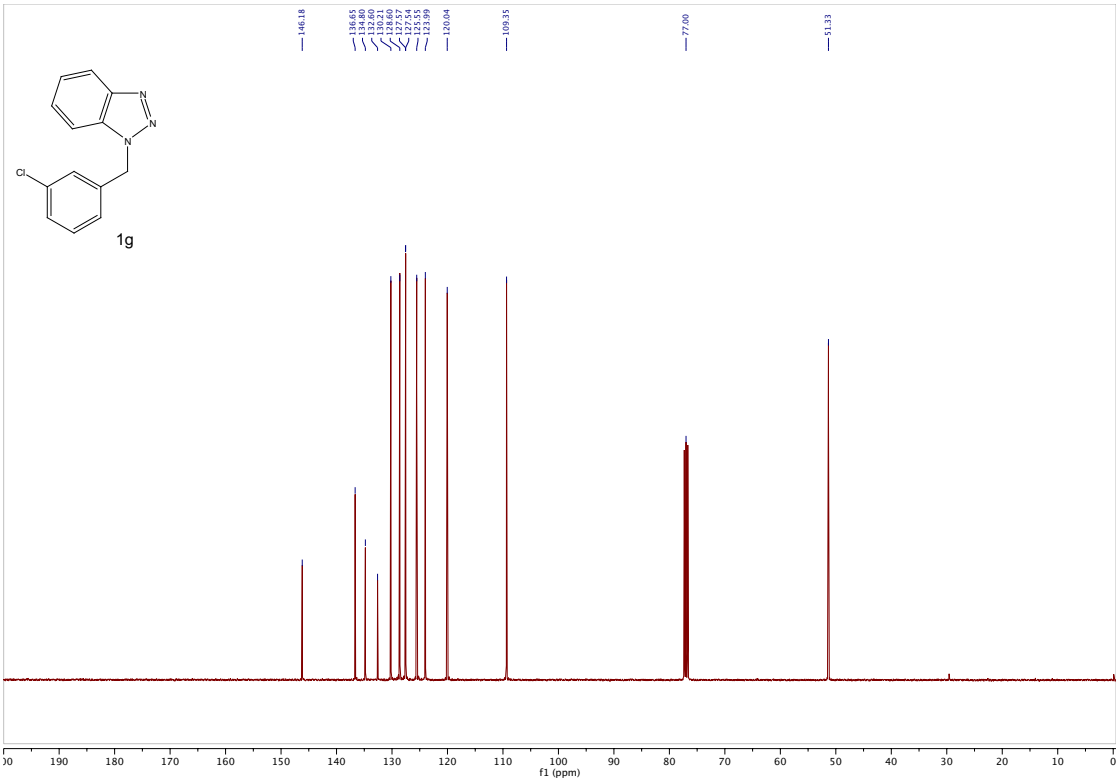
N
N
Cl
1g
0.96
3.04
2.99
0.98
2.01
f1 (ppm)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134.80
132.60
130.21
128.60
127.77
127.54
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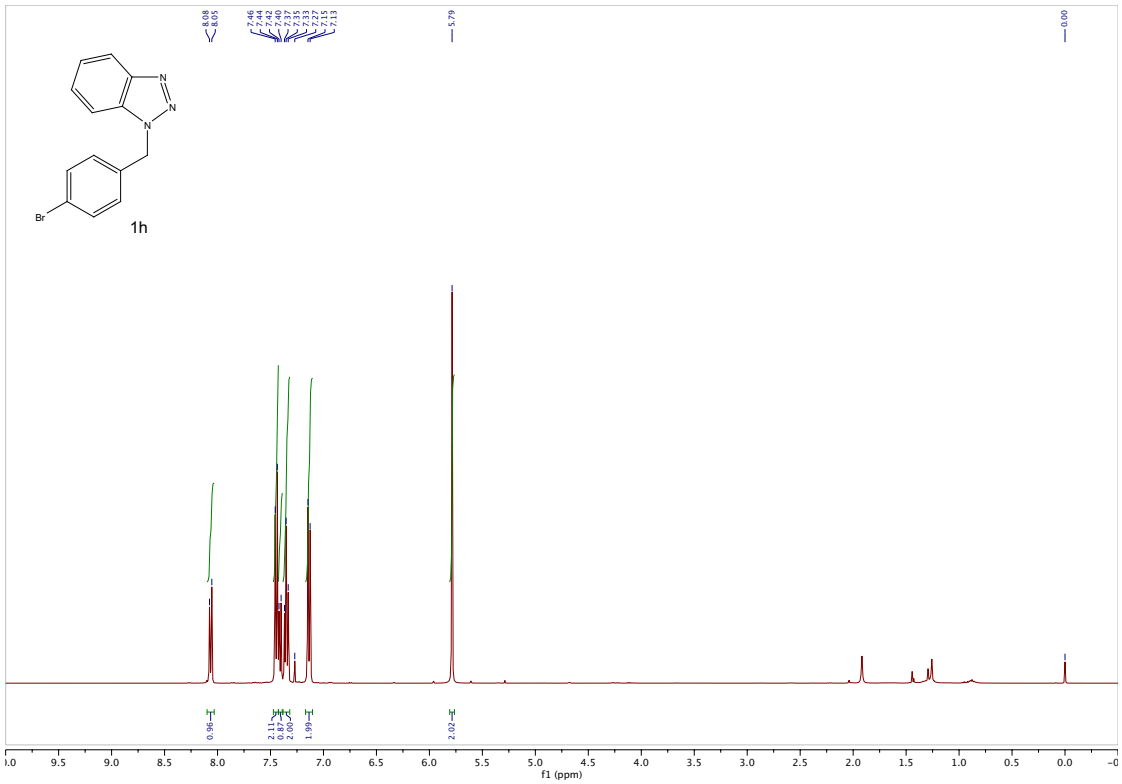
123.99
120.04
109.35
77.00
51.33
N
N
N
Cl
1g
f1 (ppm)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8.05
7.46
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7.42
7.40
7.37
7.35
7.33
7.27
7.15
7.13
5.79
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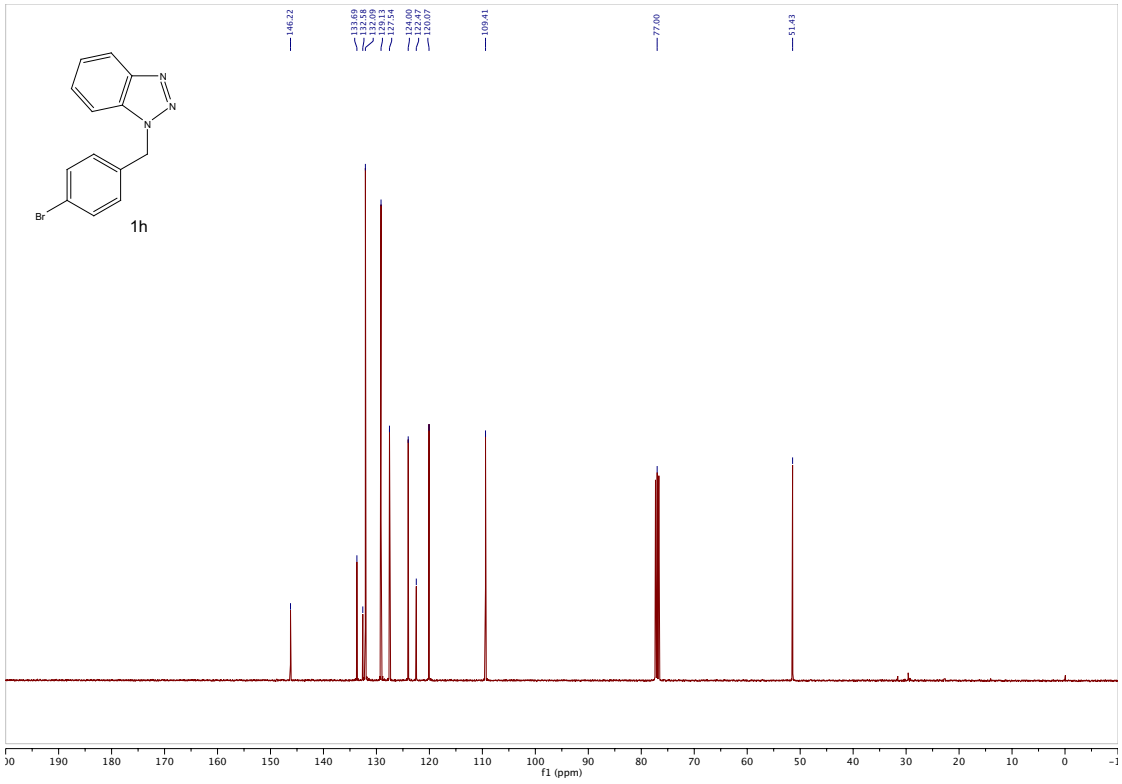
N
N
Br
1h
0.96
2.11
0.87
2.00
1.99
2.02
f1 (ppm)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133.58
132.08
129.13
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122.77
120.07
109.41
77.00
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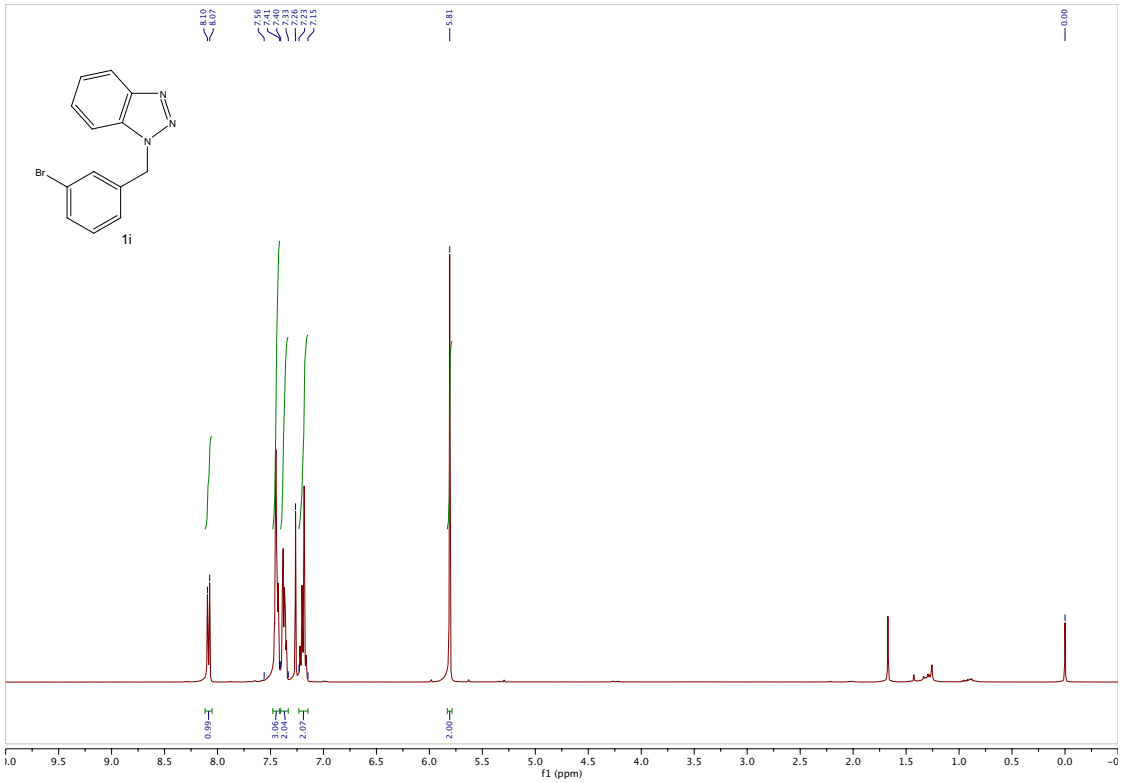
N
N
Br
1h
f1 (ppm)


8.10
8.07
7.56
7.41
7.40
7.33
7.26
7.23
7.15
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0.00
Br
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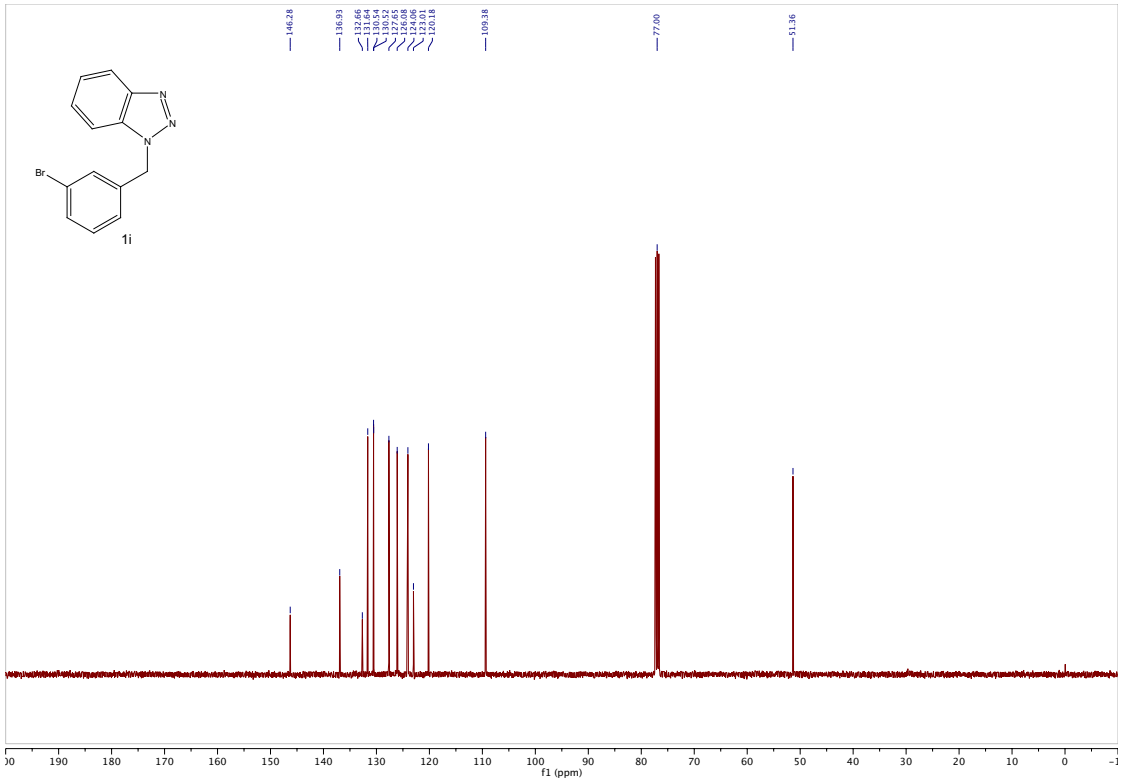
0.99
3.06
2.04
2.07
2.00
f1 (ppm)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136.93
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130.54
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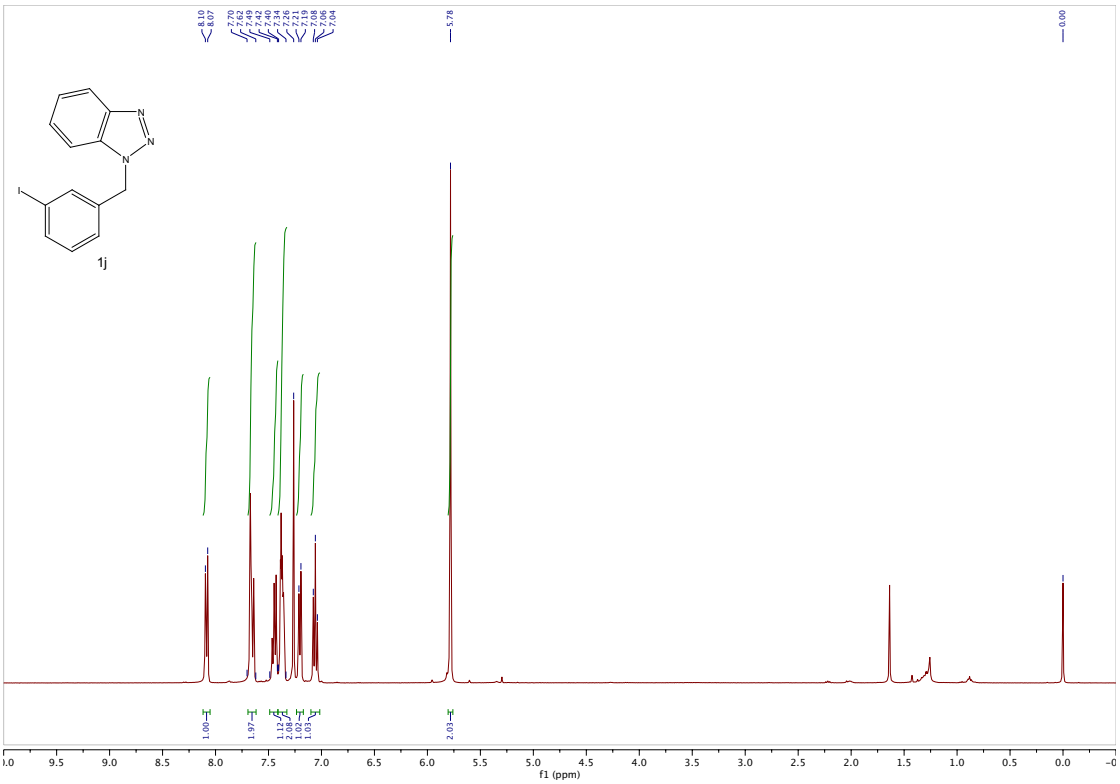
126.88
124.06
123.01
120.18
109.38
77.00
51.36
Br
1i
f1 (ppm)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8.07
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7.62
7.49
7.42
7.40
7.34
7.26
7.21
7.19
7.08
7.06
7.04
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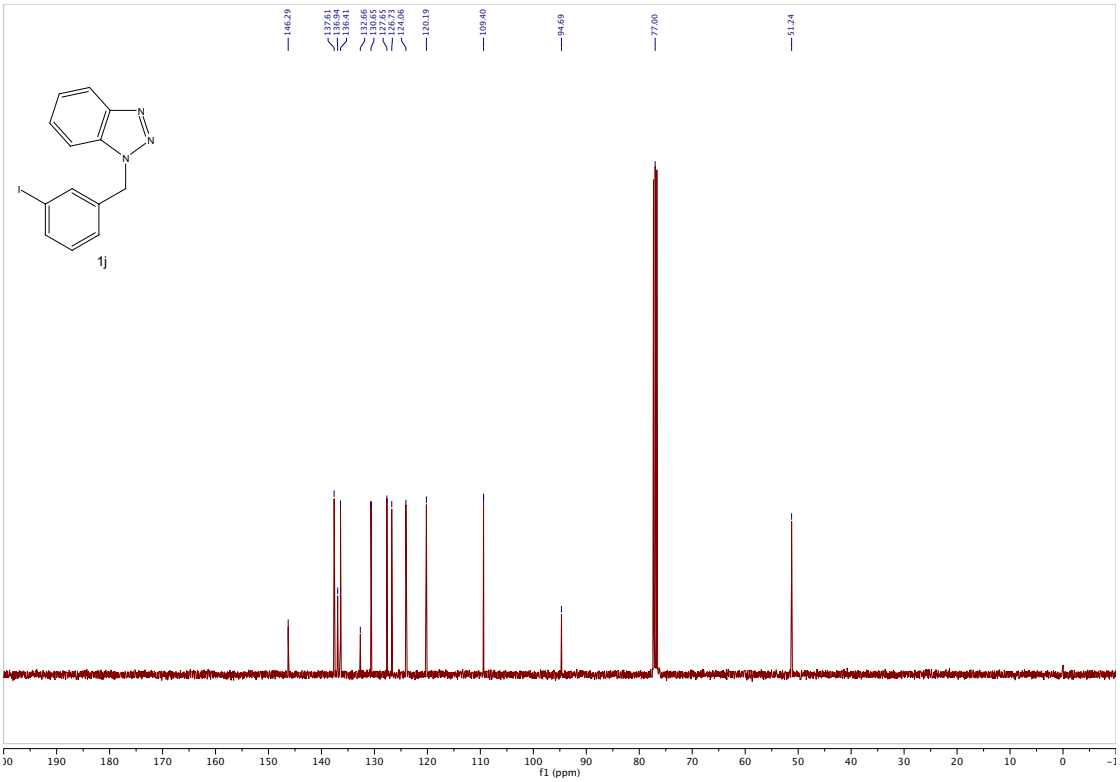
1.00
1.97
1.12
2.08
1.02
1.03
2.03
f1 (ppm)
1j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136.41
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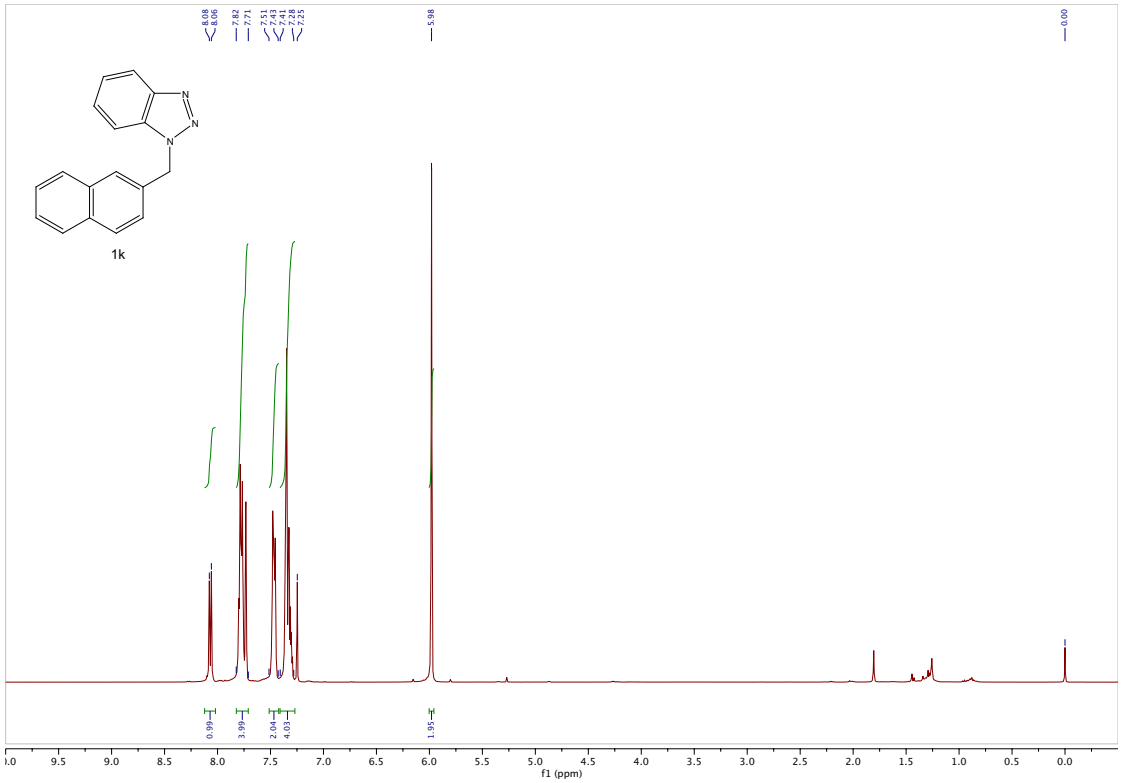
109.40
94.69
77.00
51.24
f1 (ppm)
1j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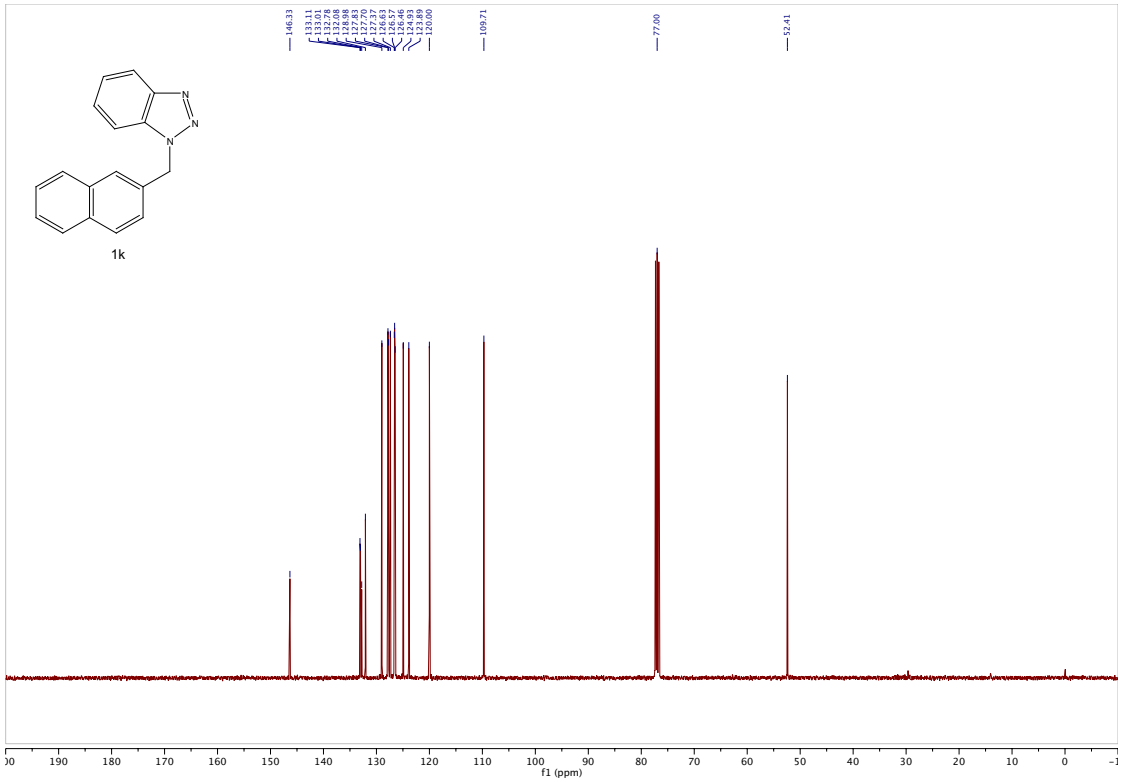
8.06
7.82
7.71
7.51
7.43
7.41
7.38
7.25
5.98
0.00
1k
0.99
3.99
2.04
4.03
1.95
f1 (ppm)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133.11
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132.08
130.86
127.83
127.70
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126.46
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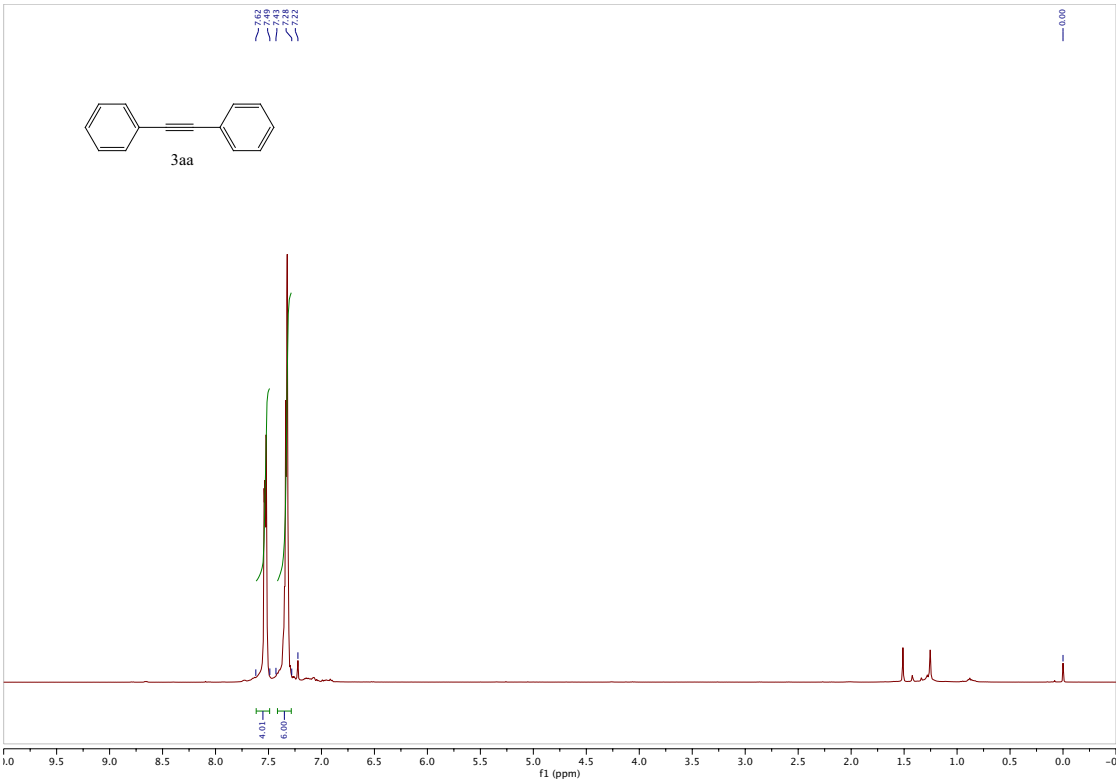
109.71
77.00
52.41
1k
f1 (ppm)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7.28
7.22
0.00
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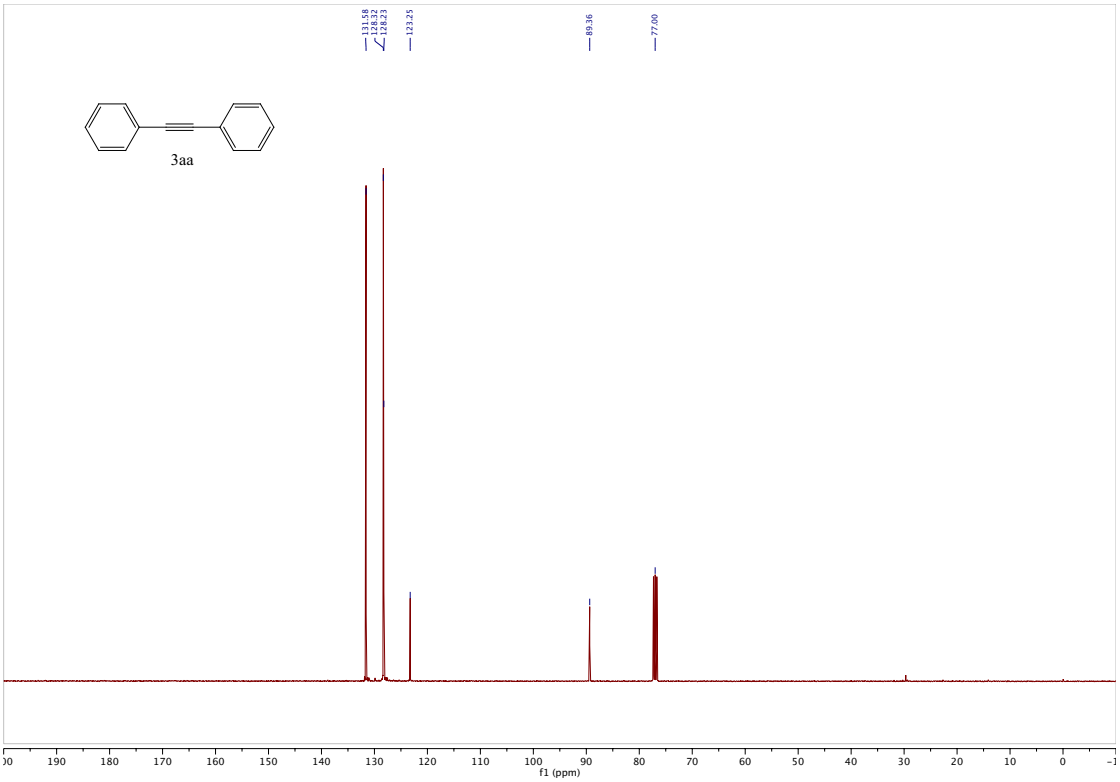
4.01
6.00
f1 (ppm)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128.72
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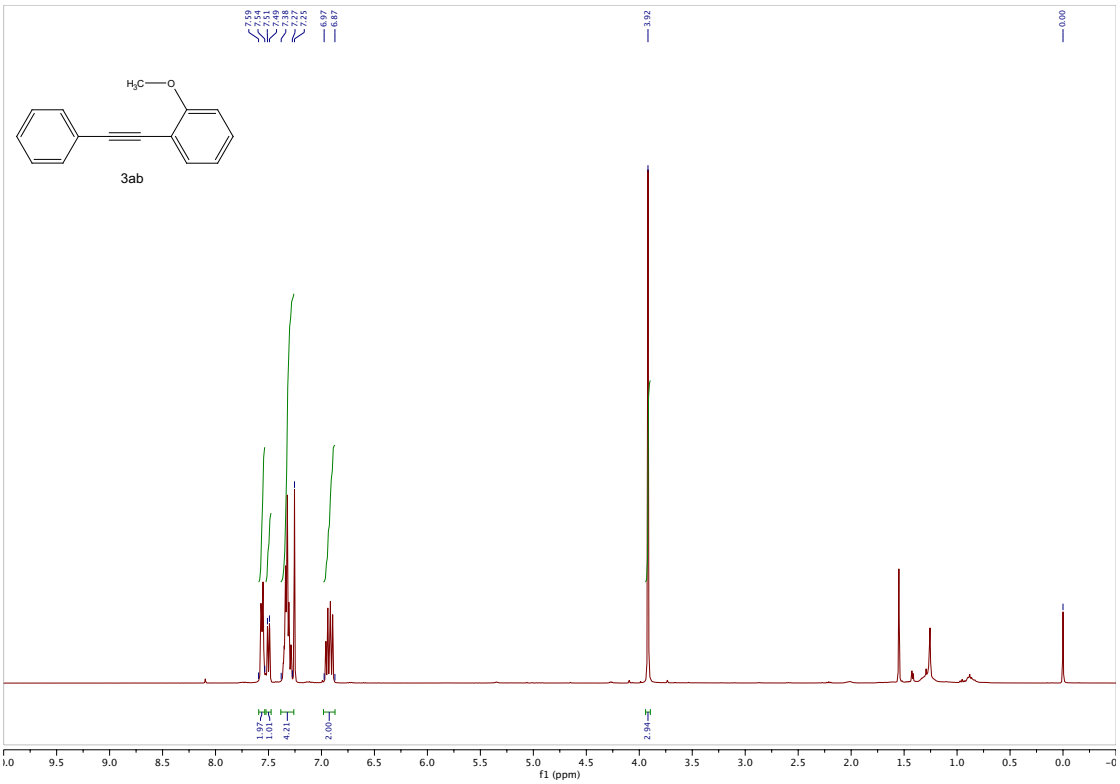
3aa
f1 (ppm)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7.54
7.51
7.49
7.38
7.27
7.25
6.97
6.87
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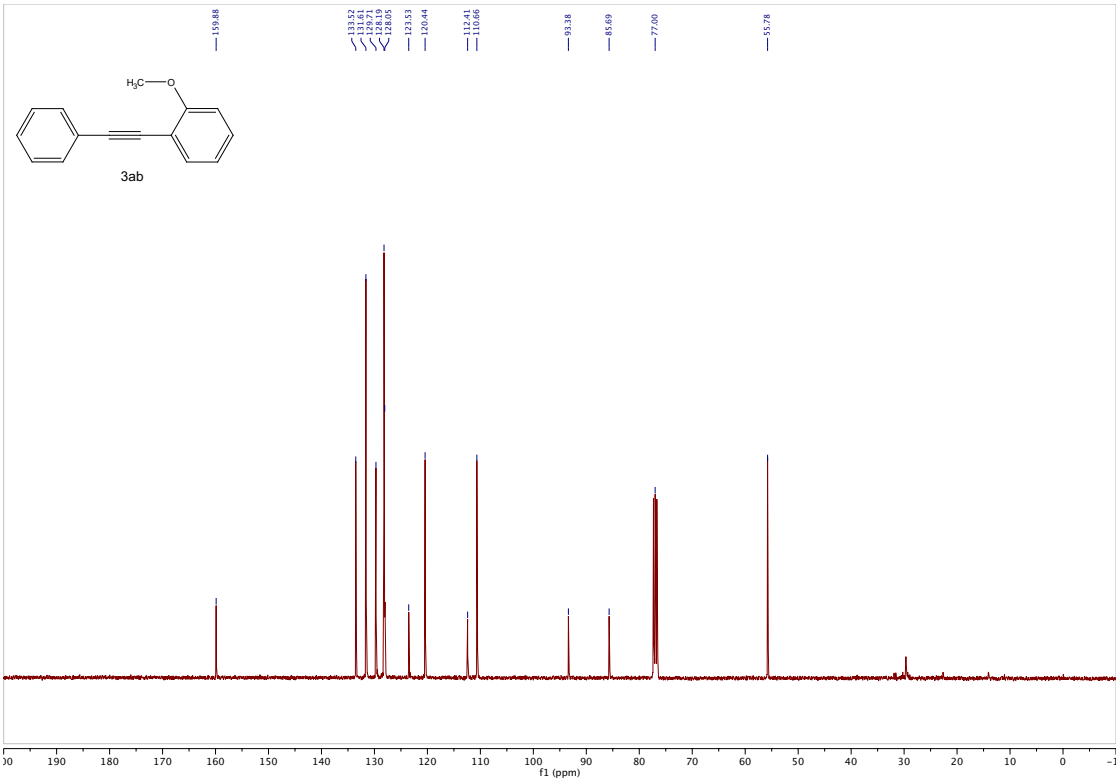
H3C—O
3ab
1.97
1.01
4.21
2.00
2.94
f1 (ppm)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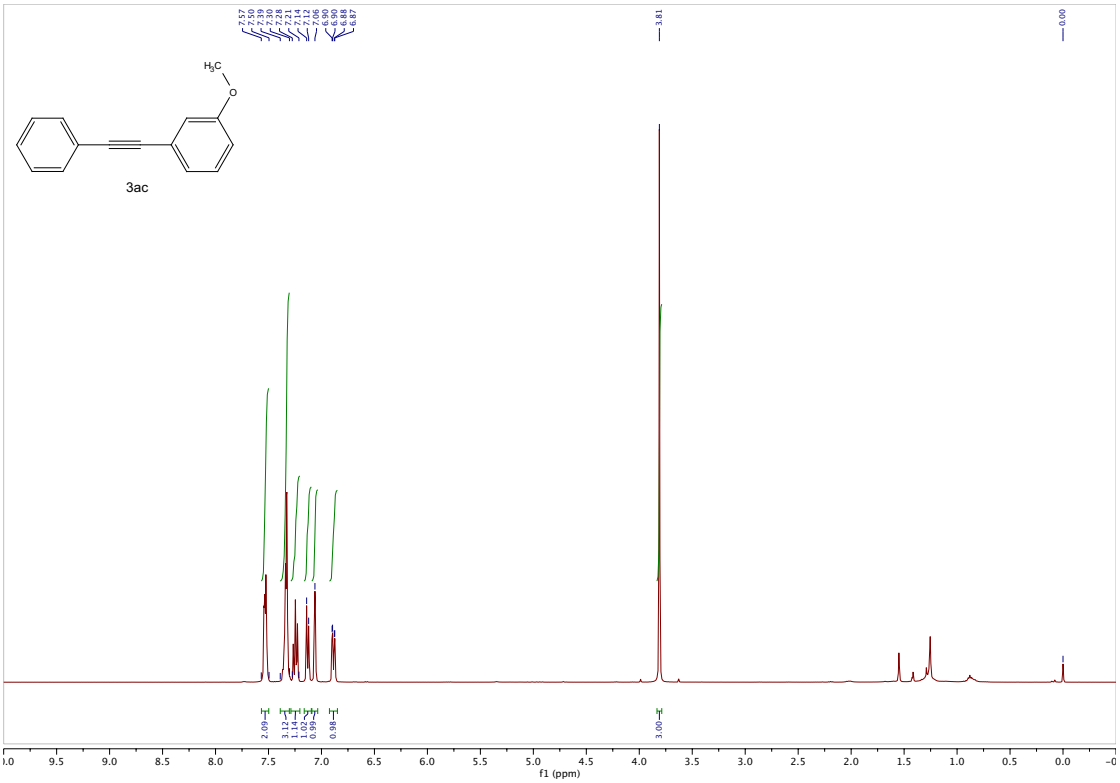
55.78
H3C—O
3ab
f1 (ppm)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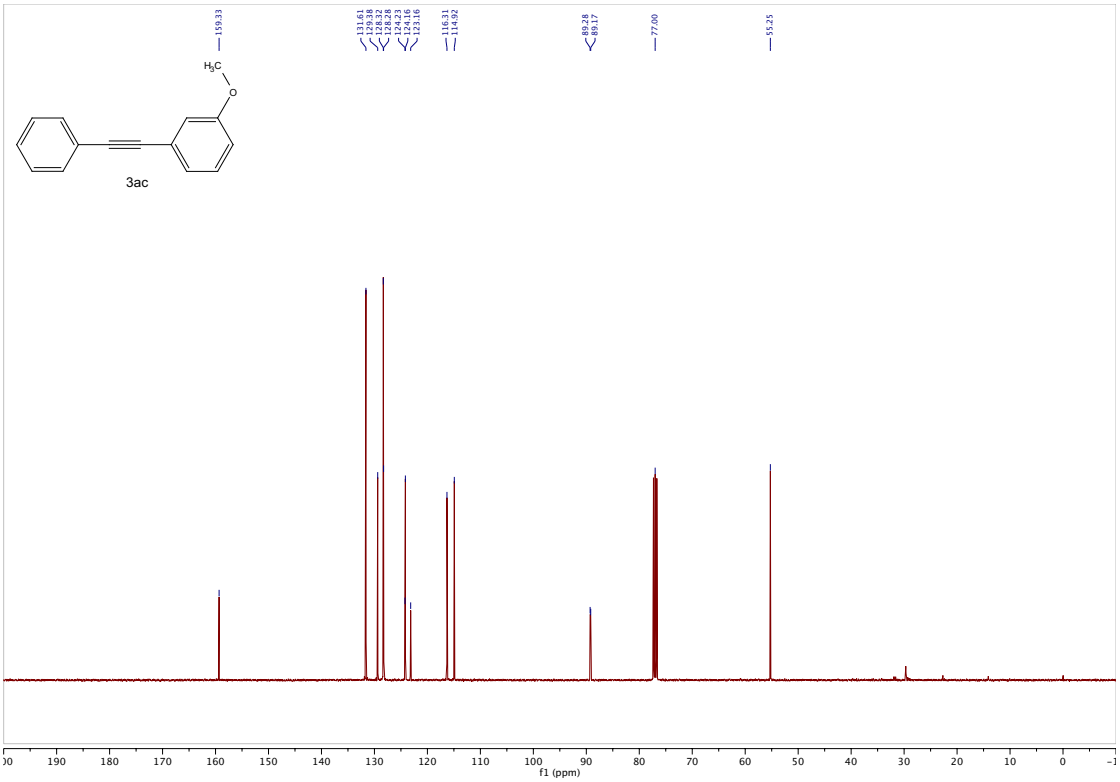
7.28
7.21
7.14
7.12
7.06
6.90
6.89
6.88
6.87
3.81
0.00
H3C
O
3ac
2.09
3.12
1.14
1.02
0.99
0.98
3.00
f1 (ppm)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128.32
128.08
124.23
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123.16
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114.92
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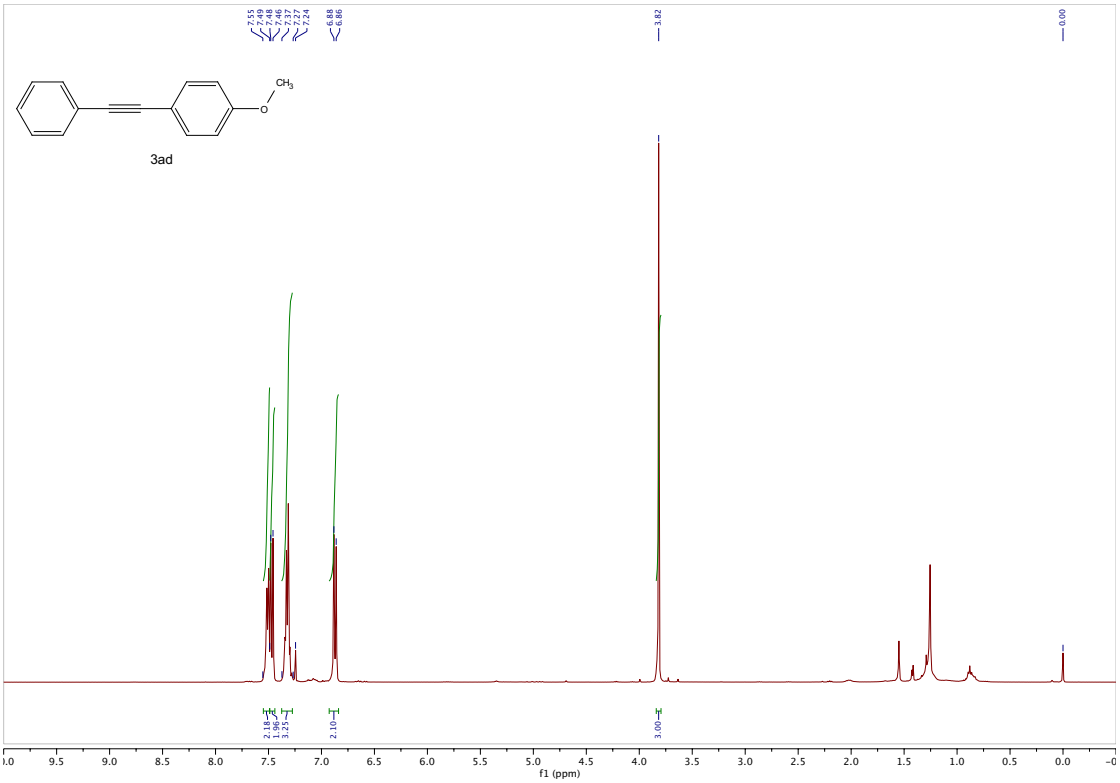
89.17
77.00
55.25
H3C
O
3ac
f1 (ppm)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7.46
7.27
7.27
7.24
6.88
6.86
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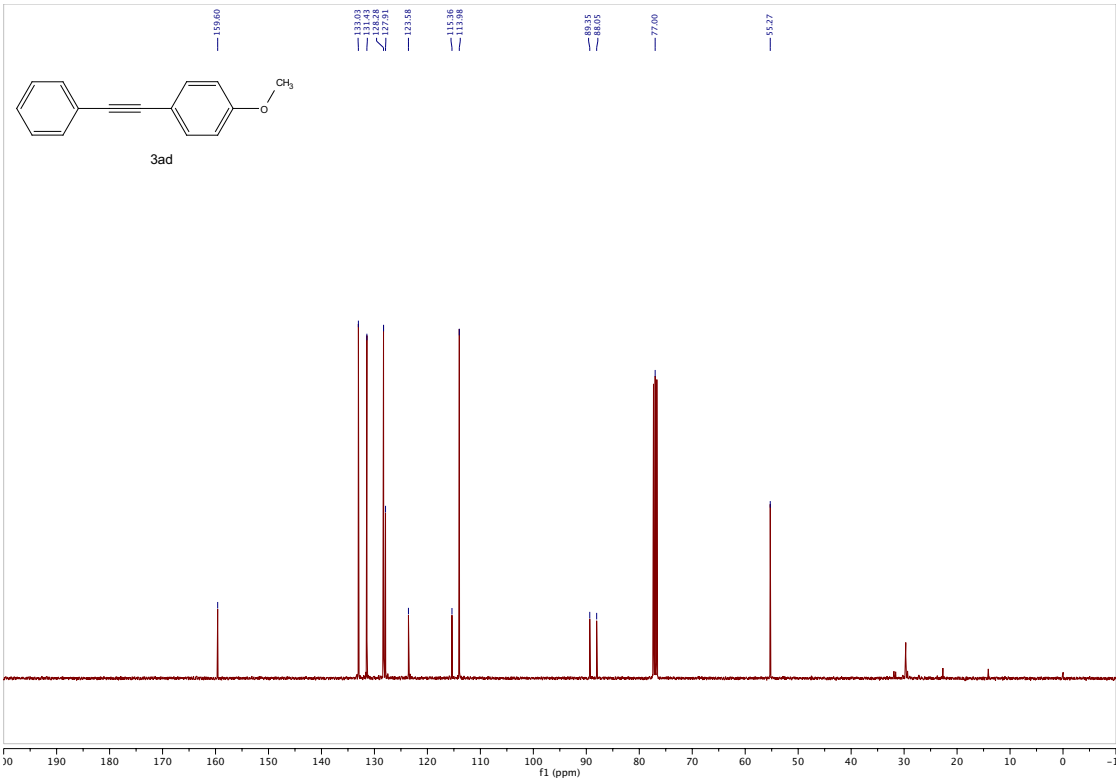
CH3
O
3ad
2.18
1.96
3.25
2.10
3.00
f1 (ppm)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113.98
89.35
88.05
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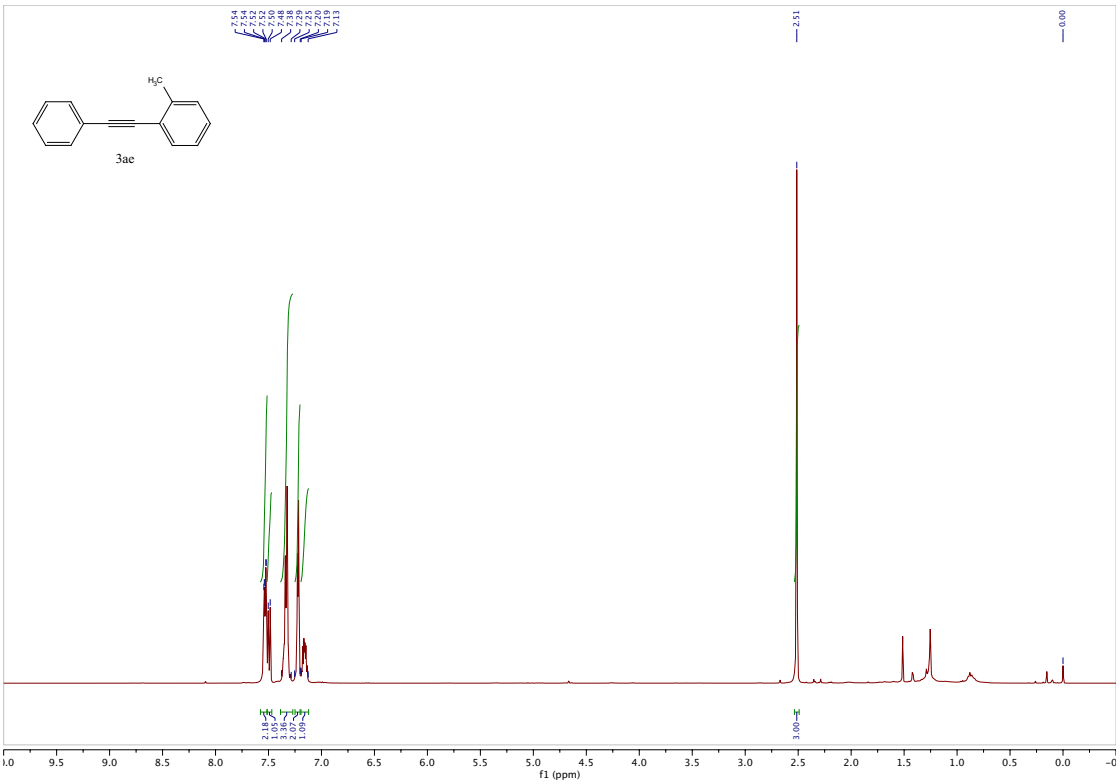
55.27
CH3
O
3ad
f1 (ppm)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7.54
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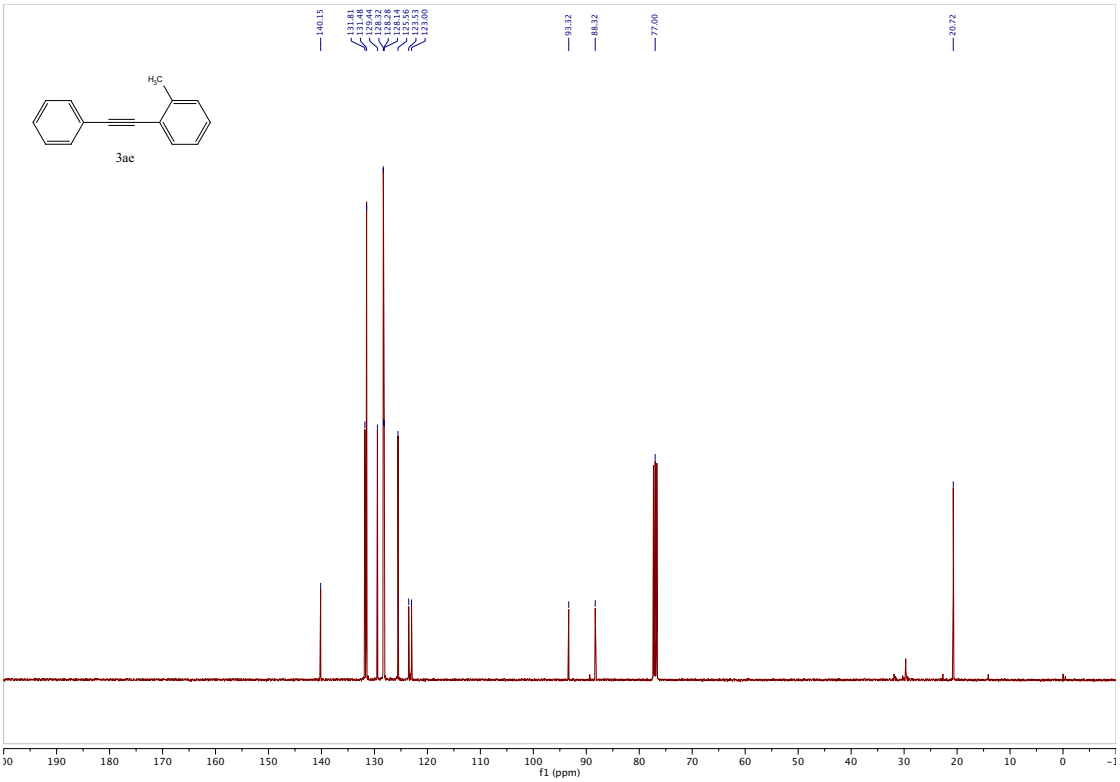
7.50
7.48
7.48
7.29
7.25
7.20
7.19
7.13
2.51
0.00
H3C
3ae
2.18
1.05
3.36
2.07
1.09
3.00
f1 (ppm)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129.44
128.32
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125.56
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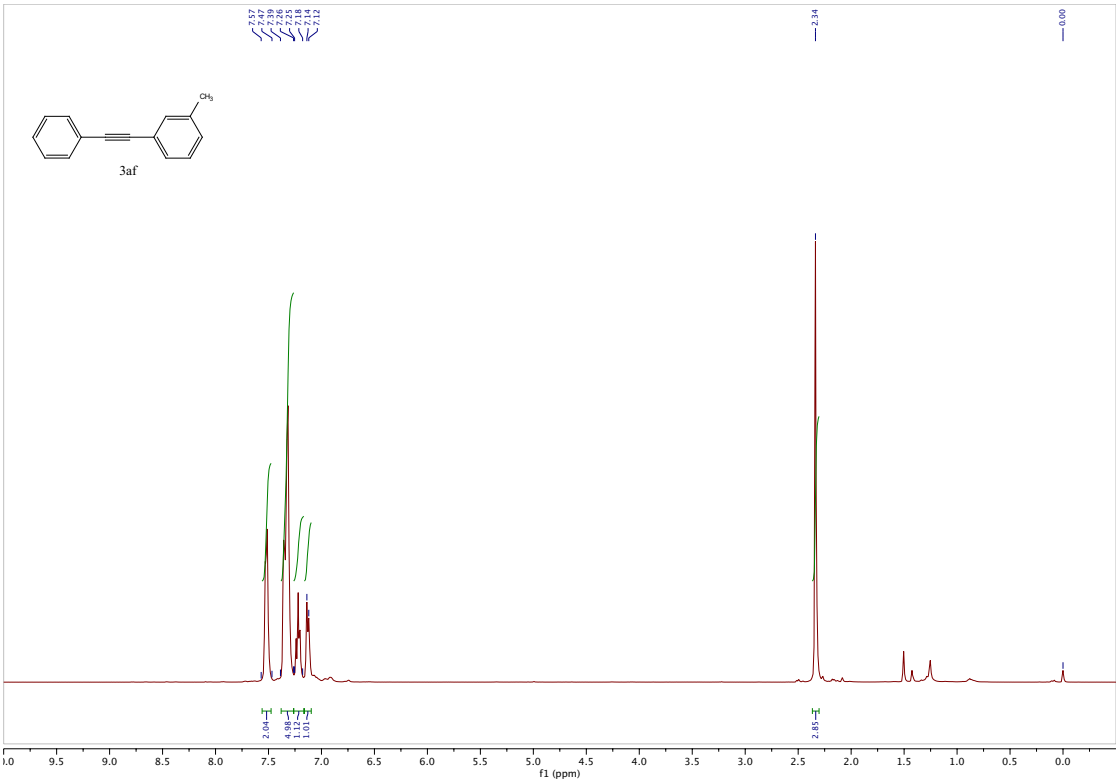
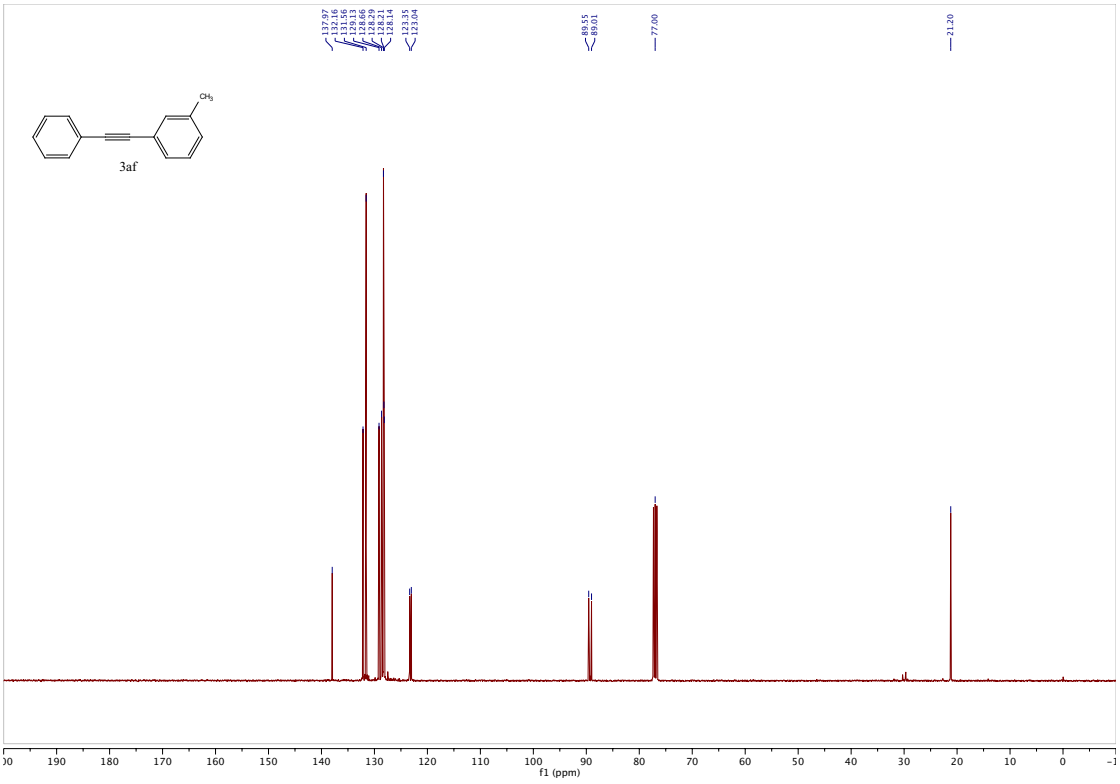
123.00
93.32
88.32
77.00
20.72
H3C
3ae
f1 (ppm)


7.57
7.37
7.39
7.26
7.25
7.18
7.14
7.12
2.34
0.00
CH3
3af
2.04
4.98
1.12
1.01
2.85
f1 (ppm)


137.97
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129.13
128.66
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128.14
123.35
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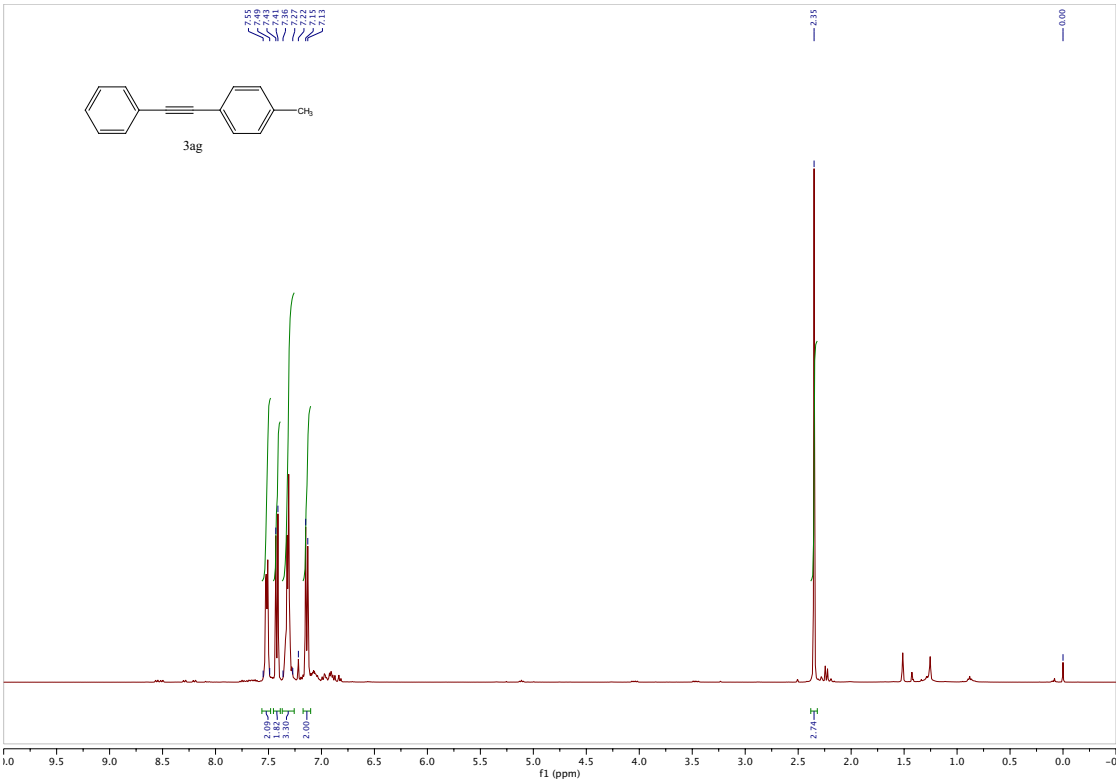
89.55
89.01
77.00
21.20
CH3
3af
f1 (ppm)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7.49
7.43
7.41
7.36
7.27
7.22
7.15
7.13
2.35
0.00
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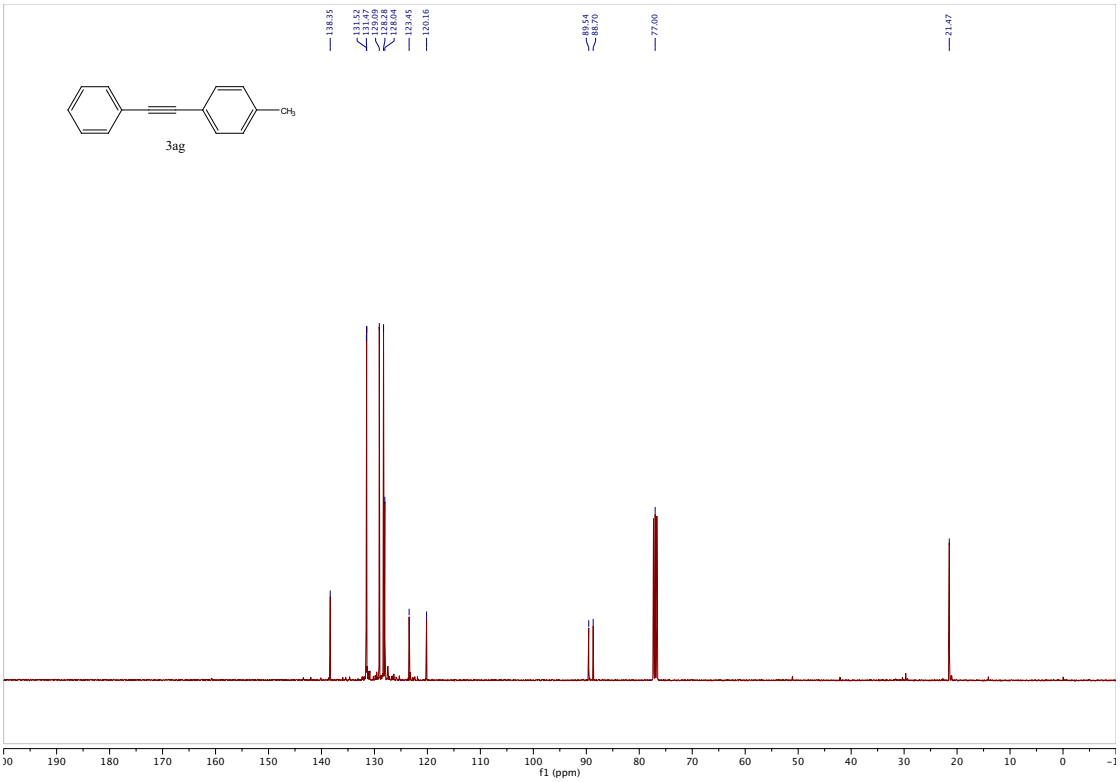
3ag
2.09
1.91
3.30
2.00
2.74
f1 (ppm)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131.47
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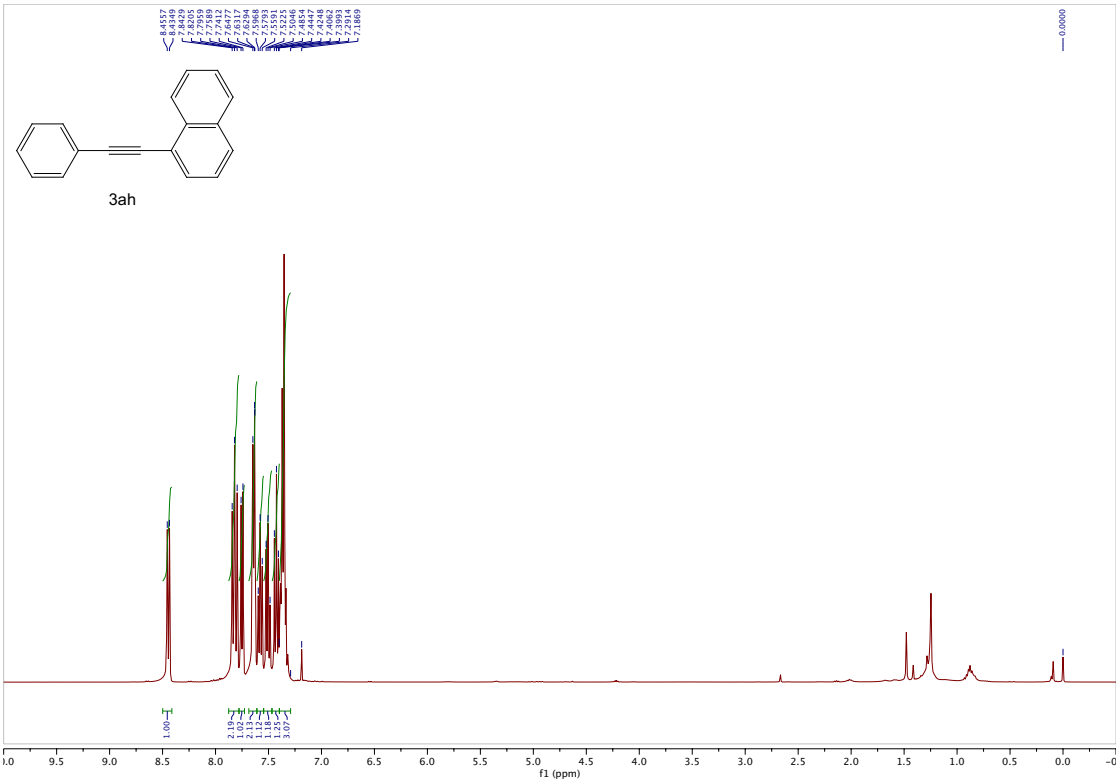
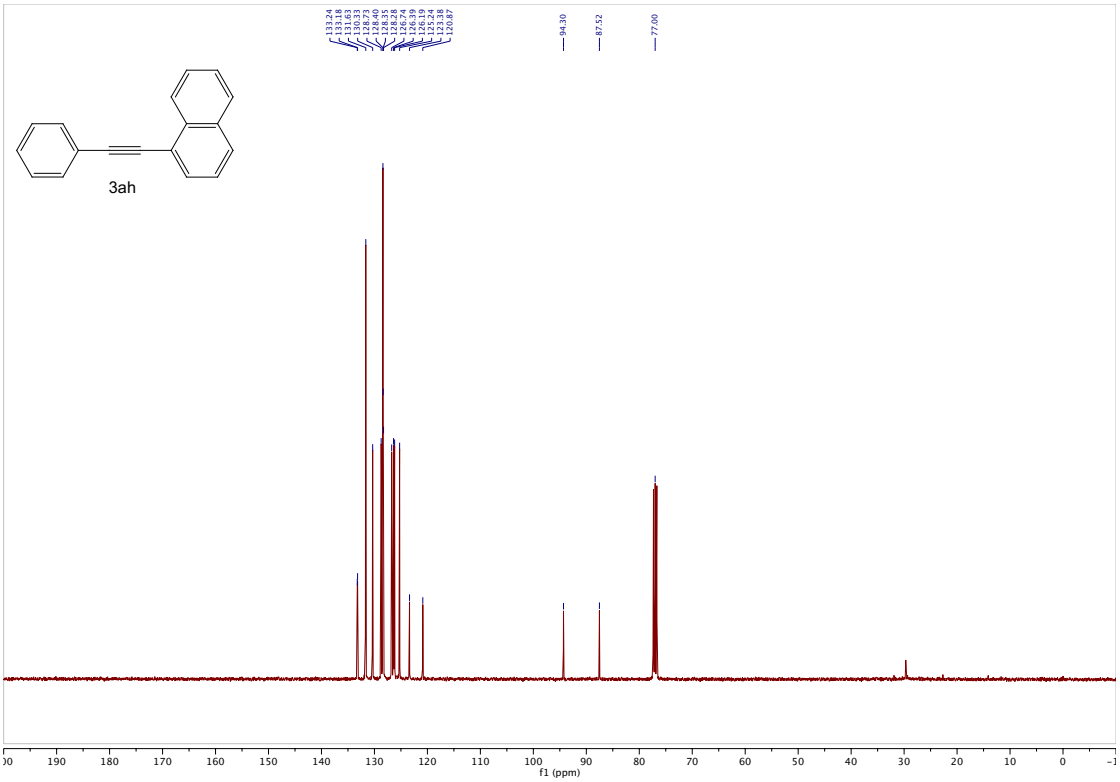
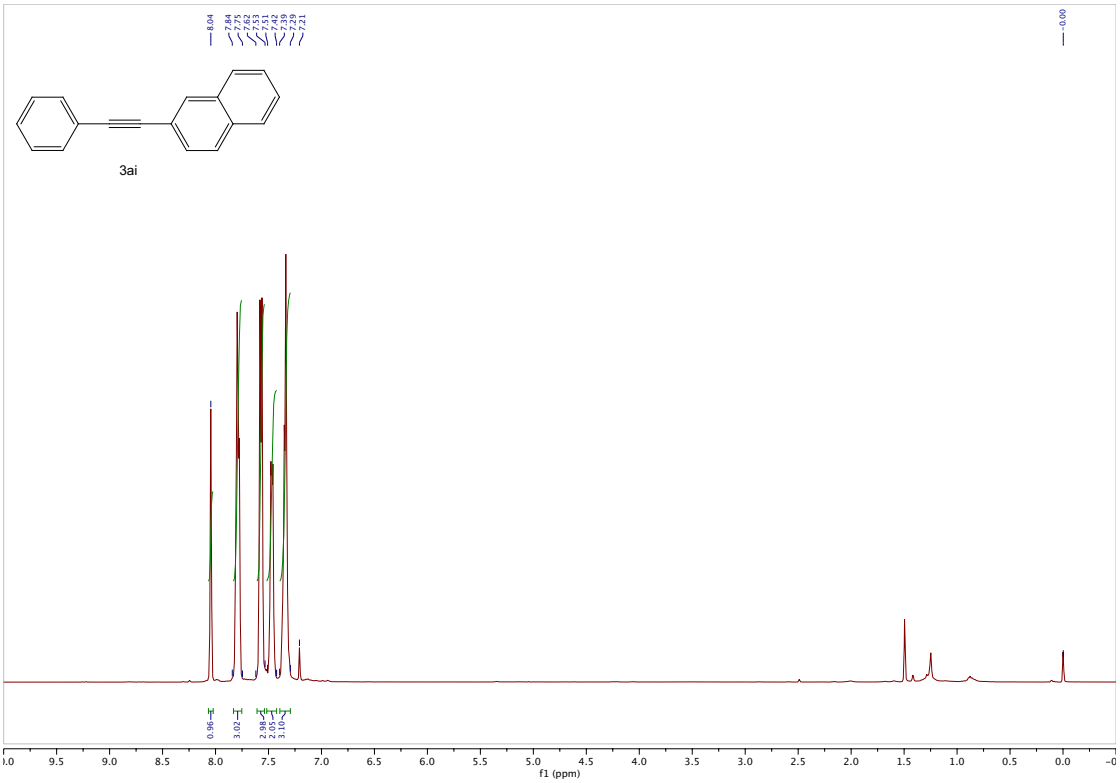
128.28
128.04
123.45
120.16
89.54
89.20
77.00
21.47
CH3
3ag
f1 (ppm)


3ah
f1 (ppm)


3ah
f1 (ppm)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7.51
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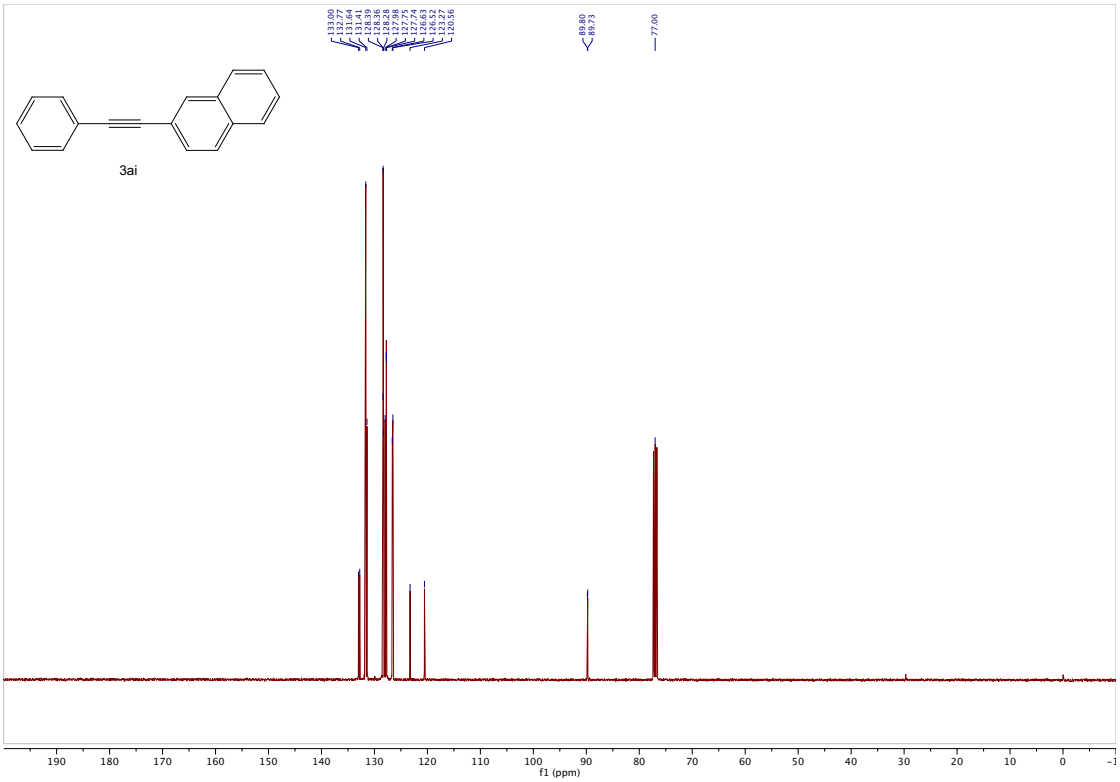
7.29
7.21
0.00
3ai
0.96
3.02
2.08
2.05
3.10
f1 (ppm)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128.36
128.30
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126.52
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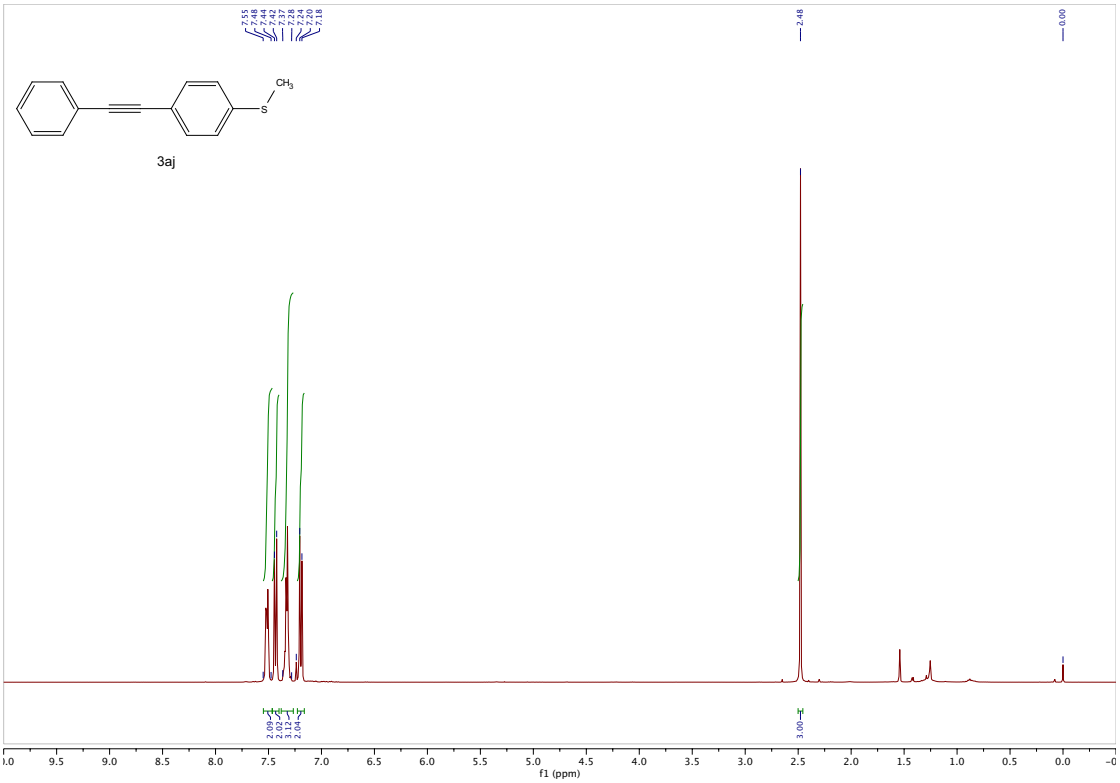
89.80
89.73
77.00
3ai
f1 (ppm)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7.37
7.28
7.24
7.20
7.18
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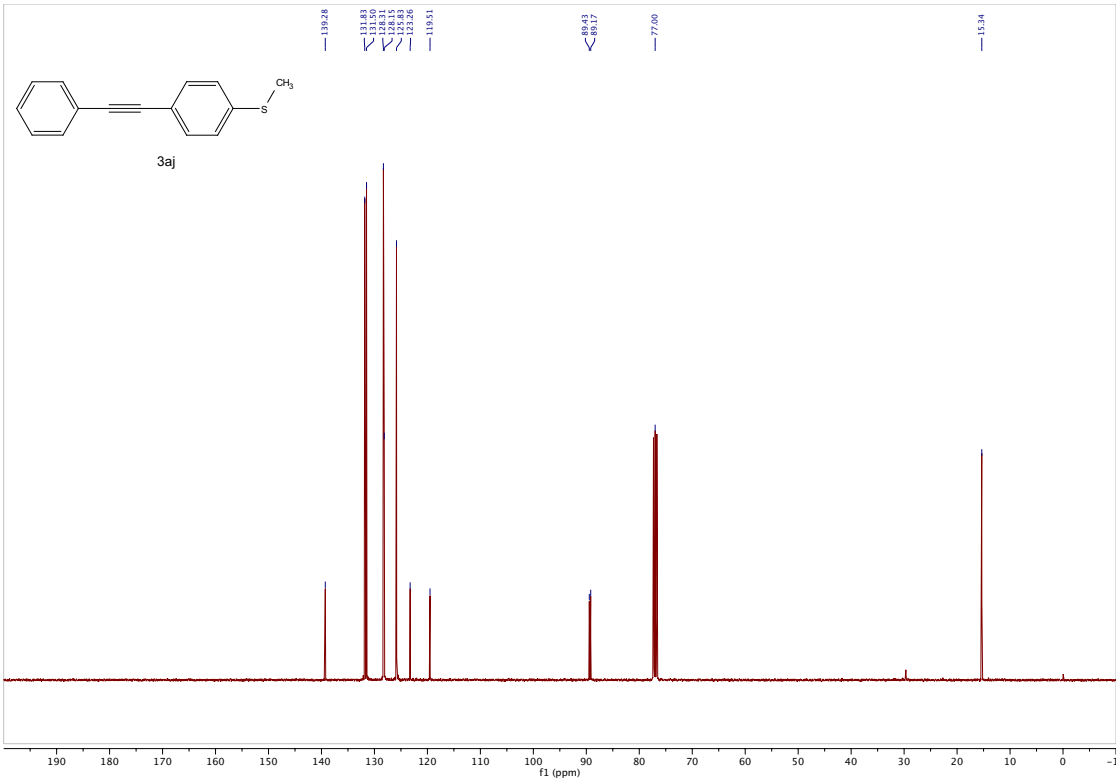
CH3
S
3aj
2.09
2.02
2.22
2.04
3.00
f1 (ppm)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89.17
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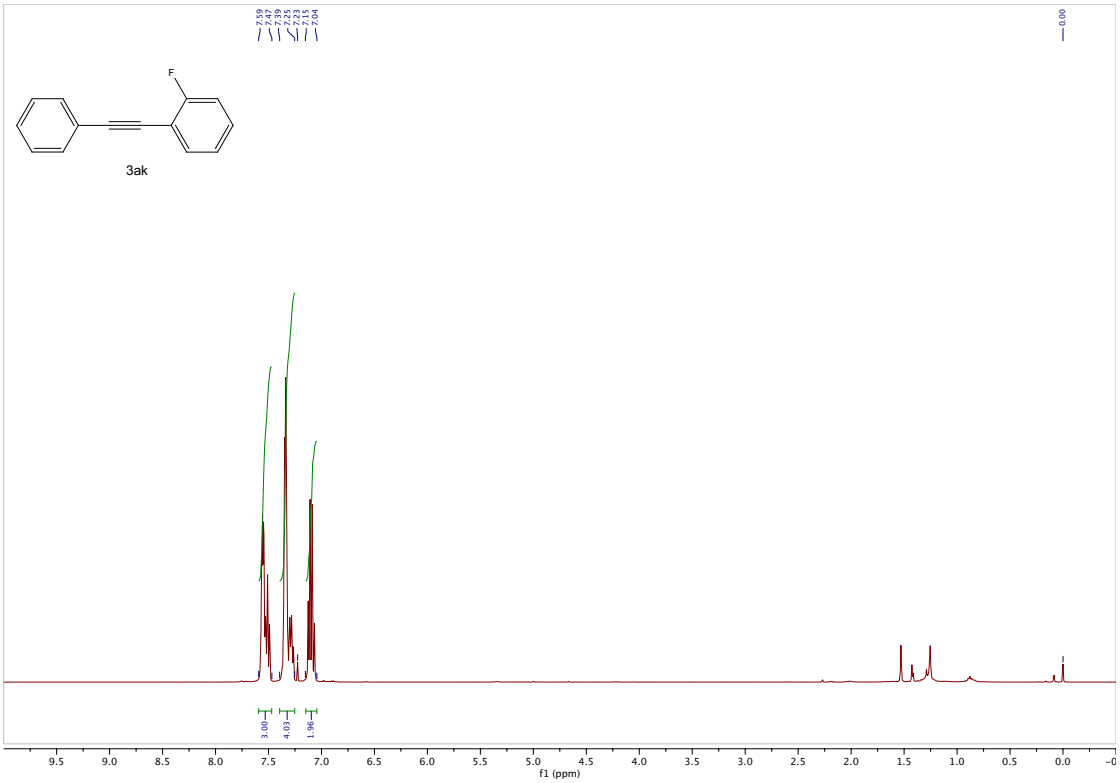
15.34
CH3
S
3aj
f1 (ppm)


7.59
7.47
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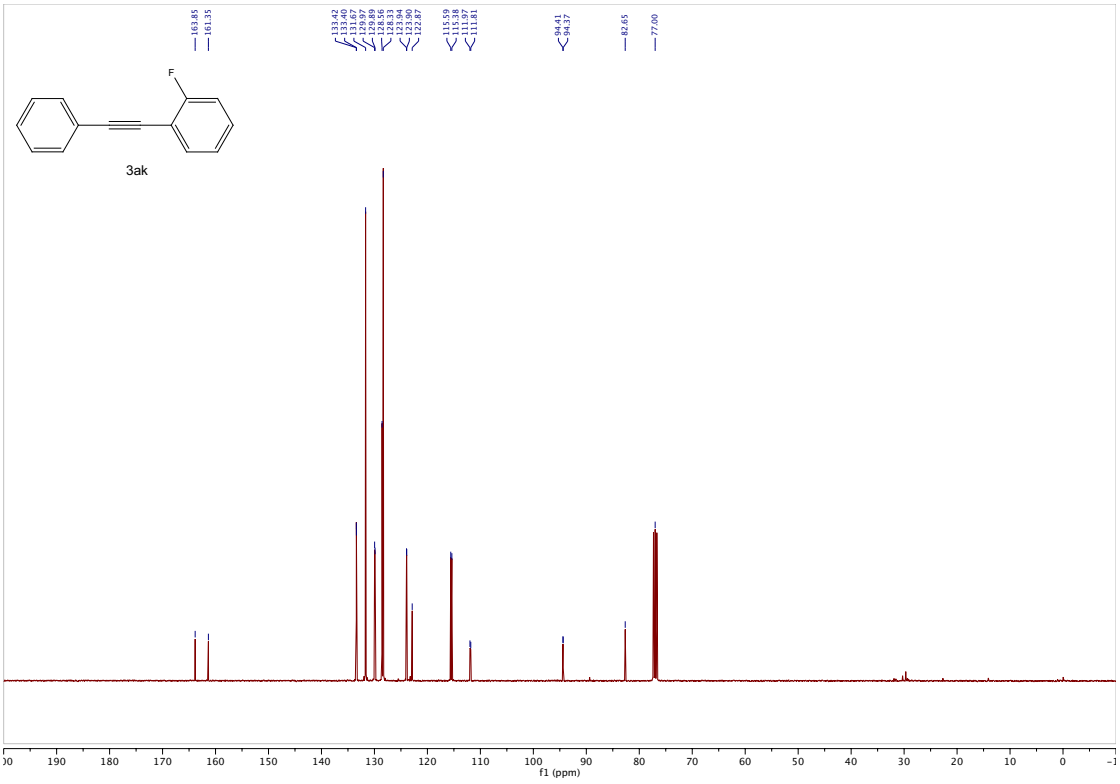
7.23
7.15
7.04
0.00
F
3ak
3.00
4.03
1.96
f1 (ppm)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128.33
124.34
123.90
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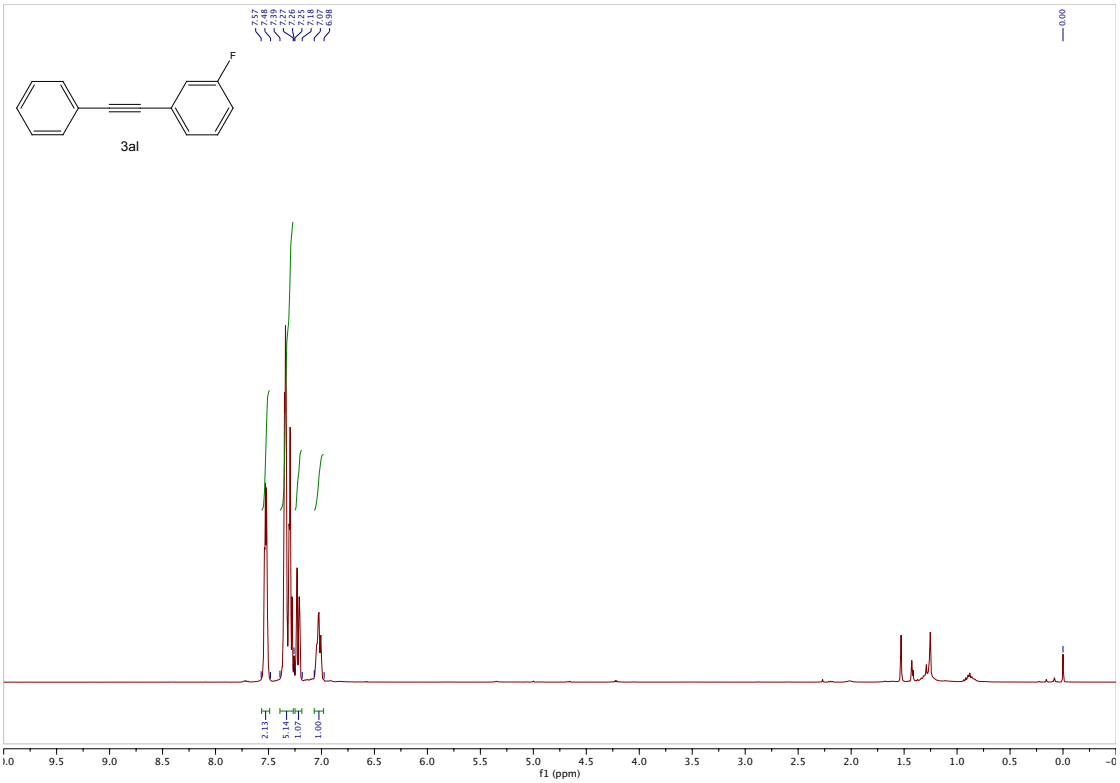
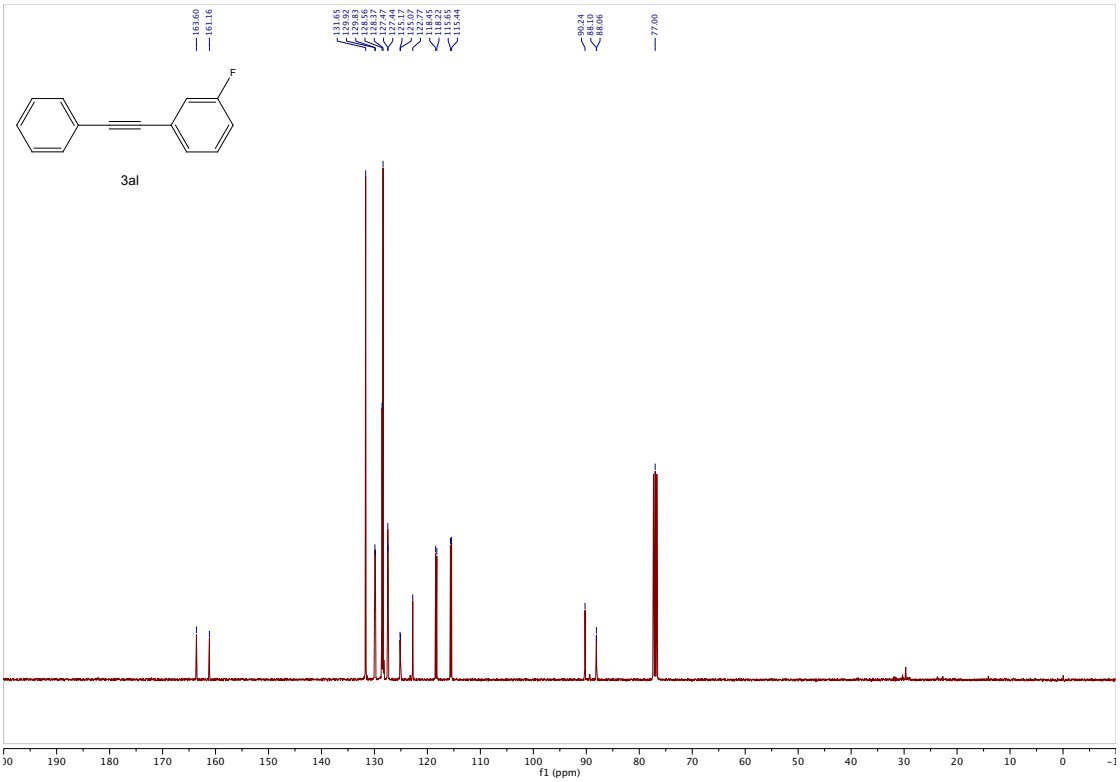
115.38
111.97
111.81
84.41
84.37
82.65
77.00
F
3ak
f1 (ppm)


7.57
7.48
7.39
7.27
7.26
7.25
7.18
7.07
6.98
0.00
F
3al
2.13
5.14
1.07
1.00
f1 (ppm)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130.23
129.83
128.56
128.27
127.47
127.44
125.17
125.07
122.77
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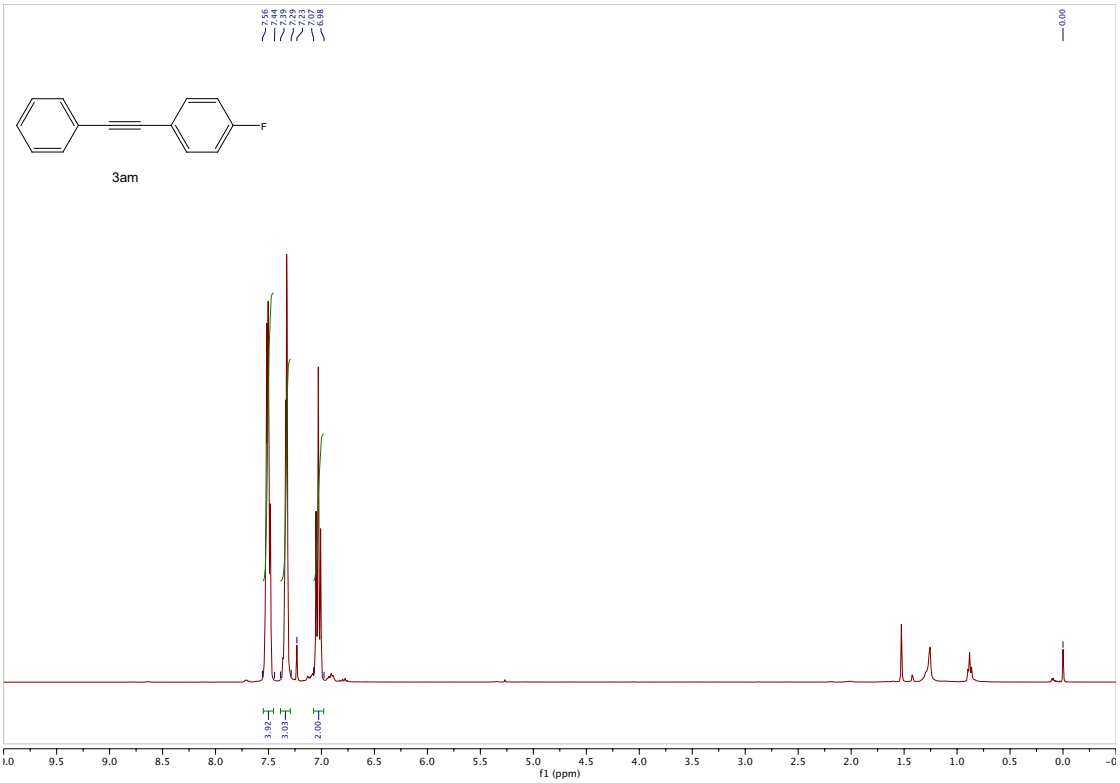
88.10
88.06
77.00
F
3al
f1 (ppm)


7.56
7.44
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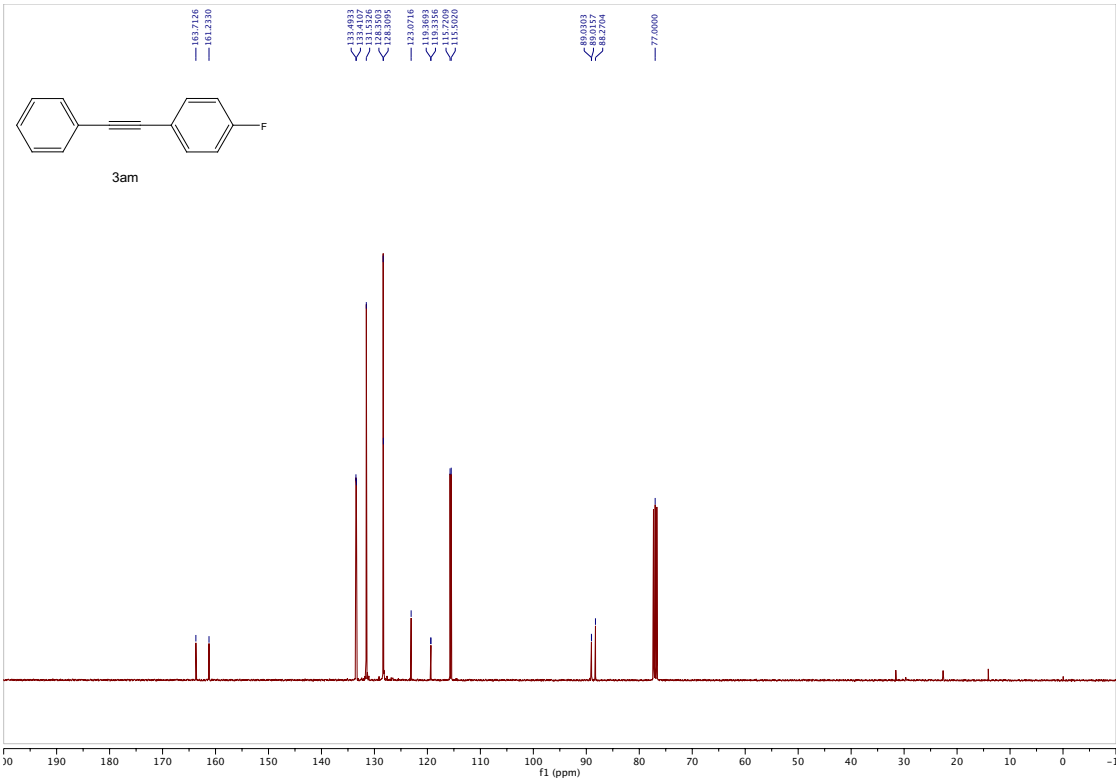
7.23
7.07
6.98
0.00
F
3am
3.92
3.03
2.00
f1 (ppm)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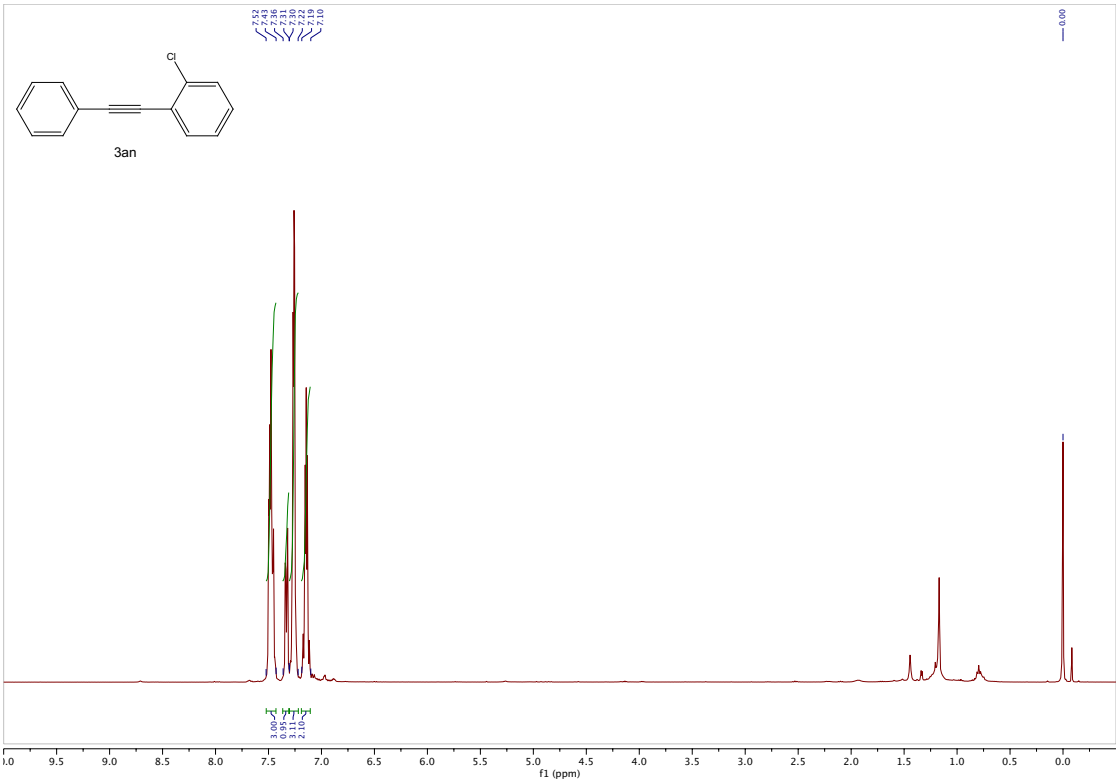
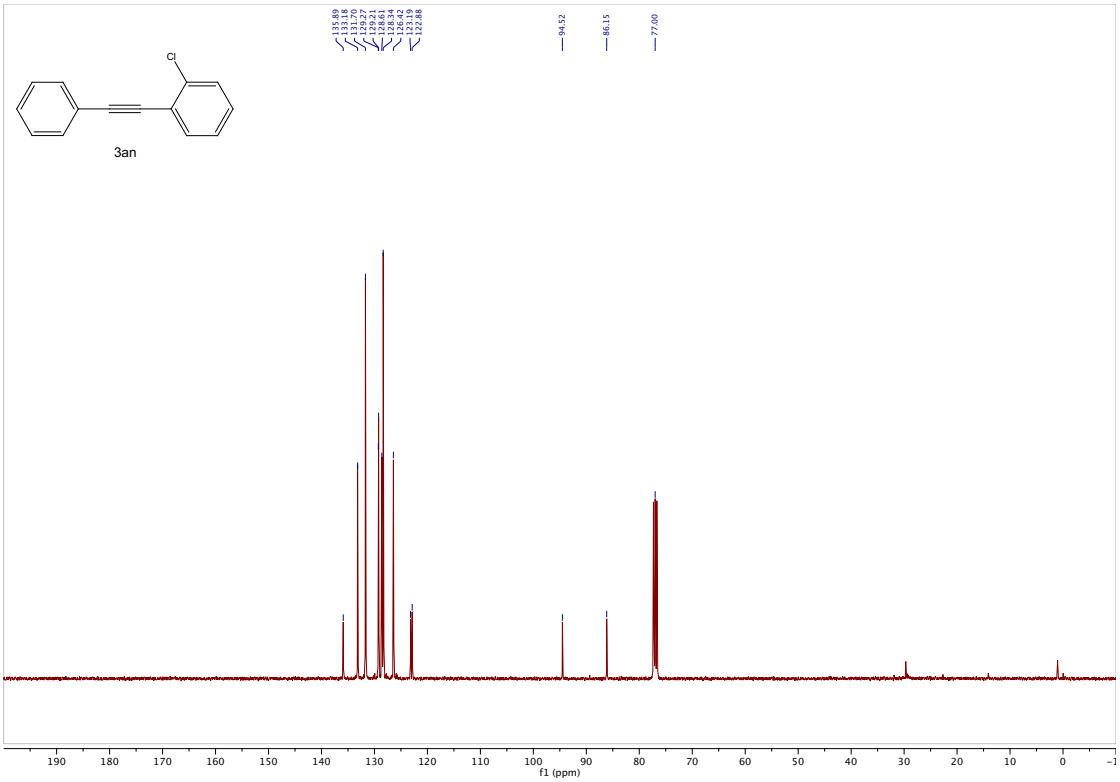
89.0303
89.0157
88.2704
77.0000
F
3am
f1 (ppm)


Cl
3an
7.52
7.43
7.36
7.31
7.30
7.22
7.19
7.10
0.00
3.00
0.95
3.11
2.16
f1 (ppm)


Cl
3an
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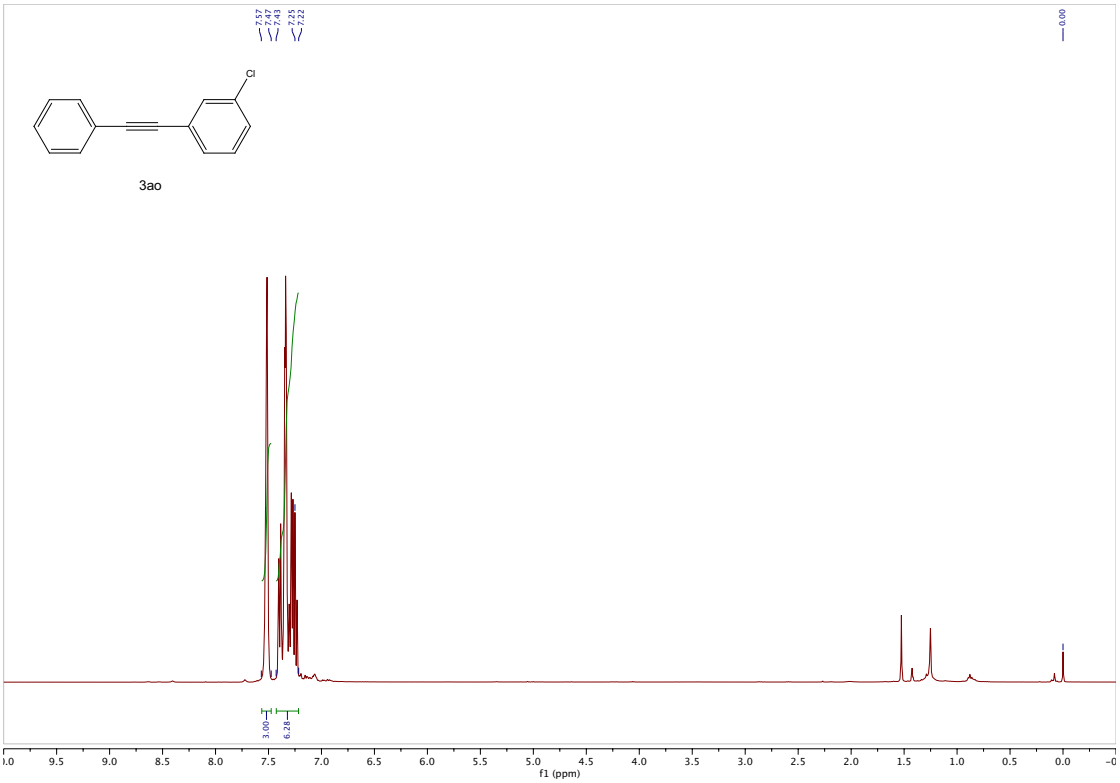
133.38
131.70
129.27
129.21
128.61
128.34
126.42
123.19
122.88
94.52
86.15
77.00
f1 (ppm)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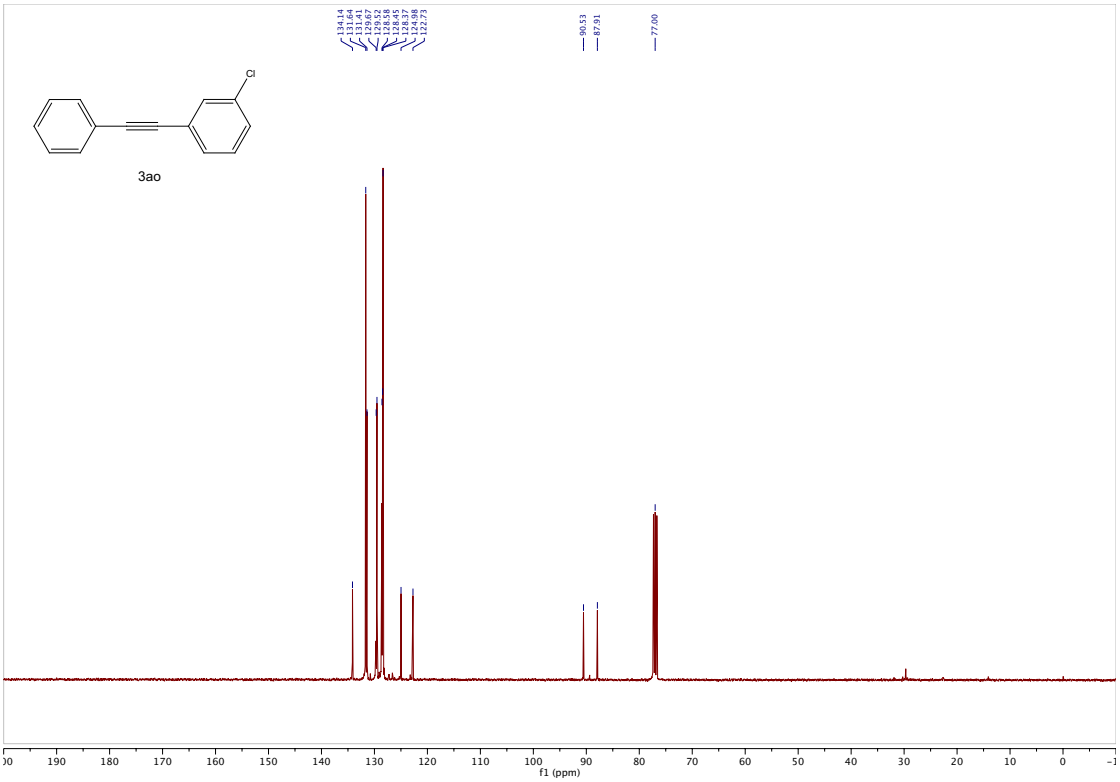
7.47
7.43
7.25
7.22
0.00
Cl
3ao
3.00
6.28
f1 (ppm)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131.64
131.41
129.67
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128.37
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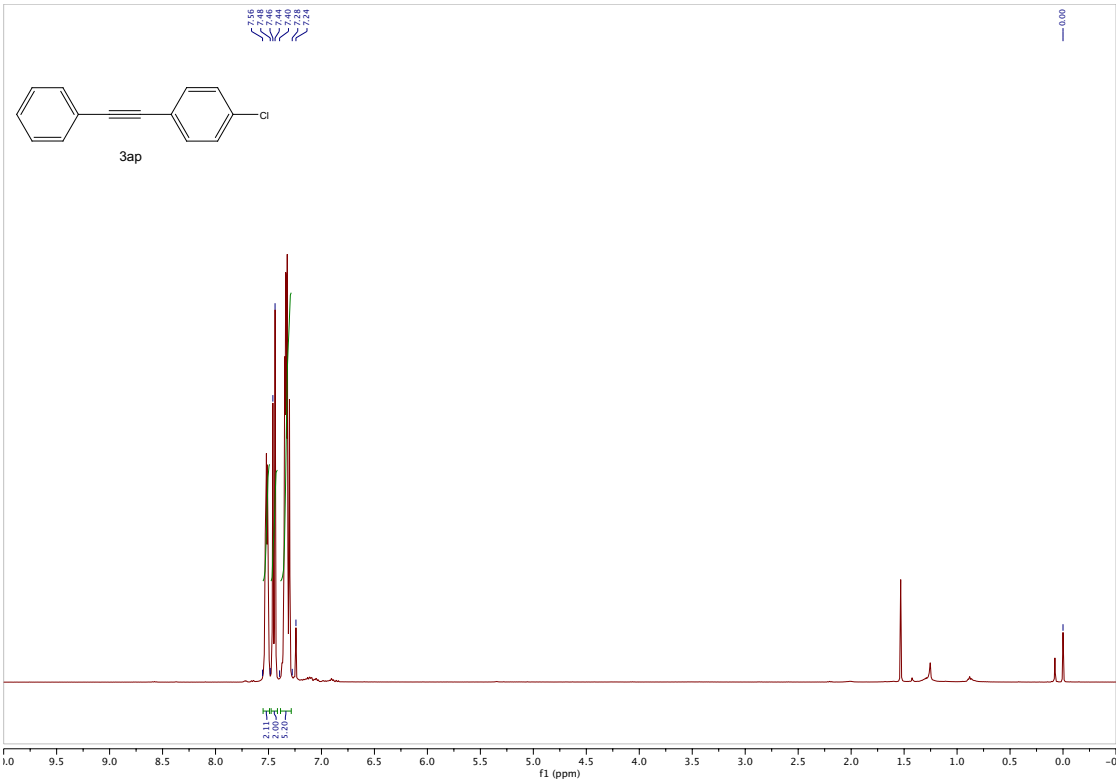
122.73
90.53
87.91
77.00
Cl
3ao
f1 (ppm)


7.56
7.48
7.46
7.44
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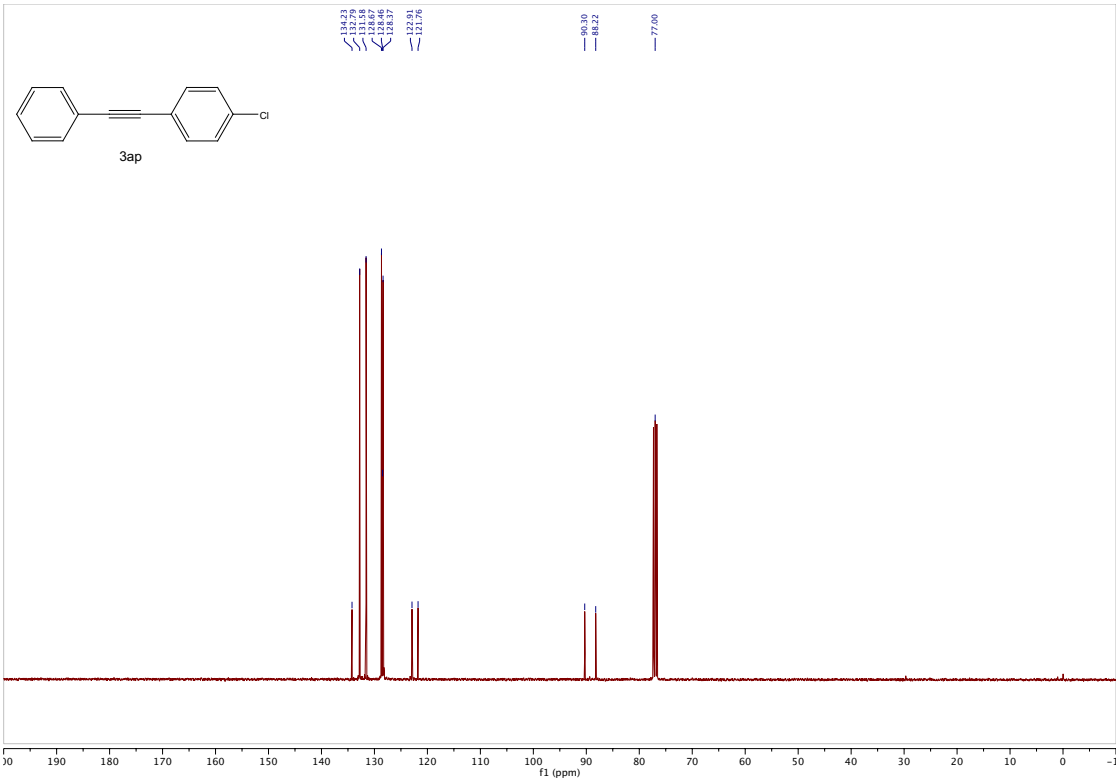
7.28
7.24
0.00
Cl
3ap
2.11
2.00
2.07
5.20
f1 (ppm)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132.79
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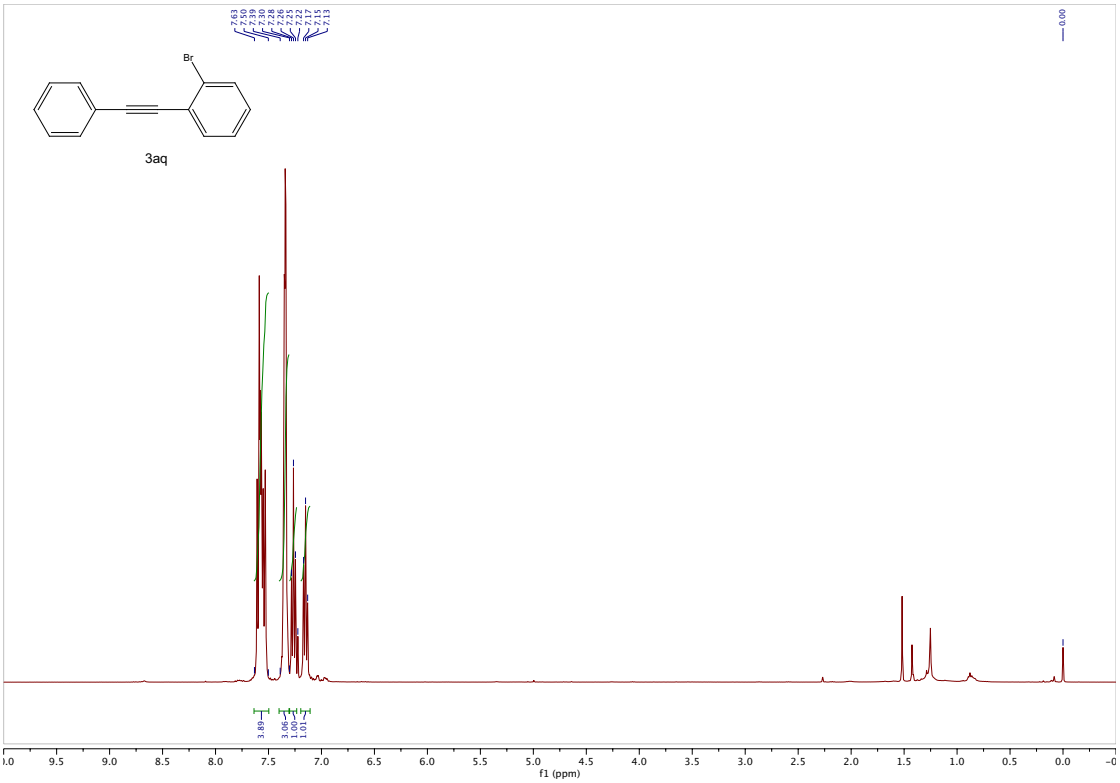
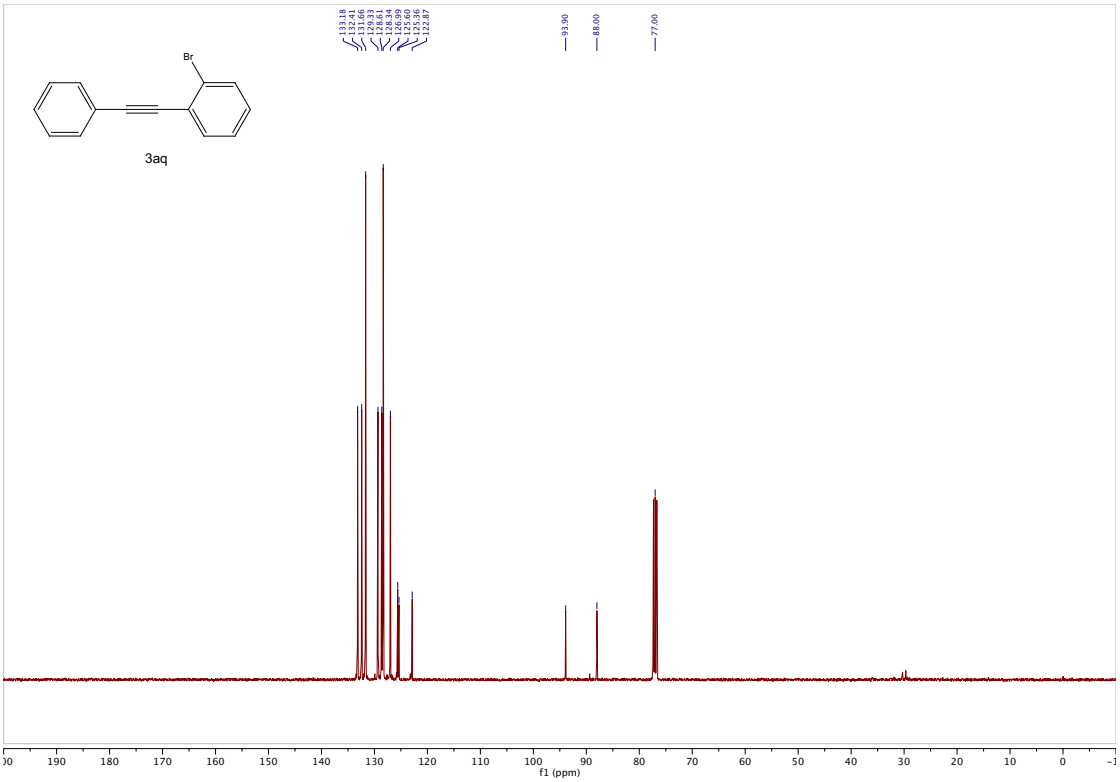
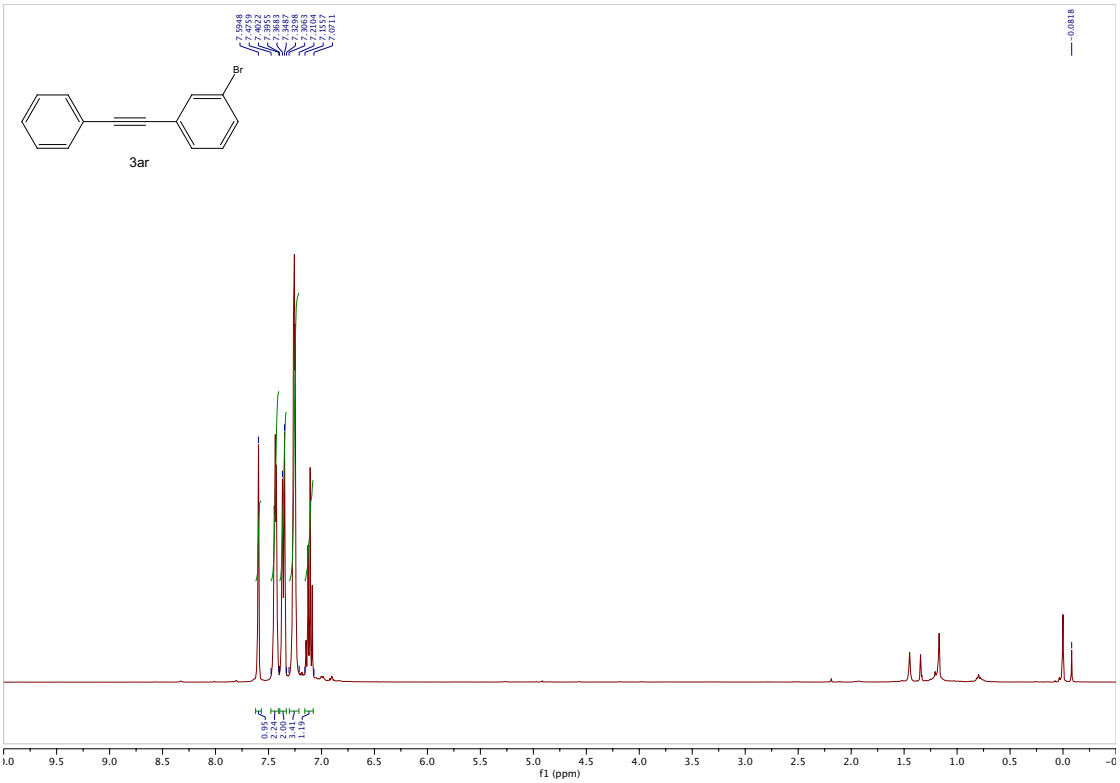
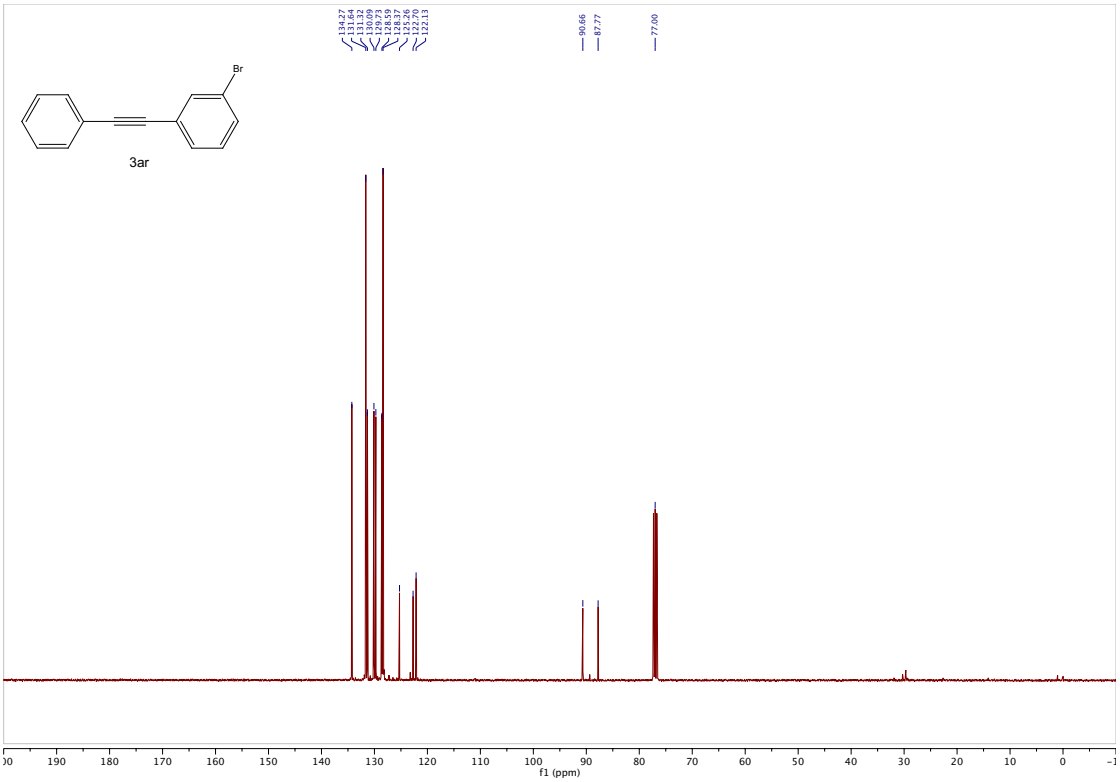
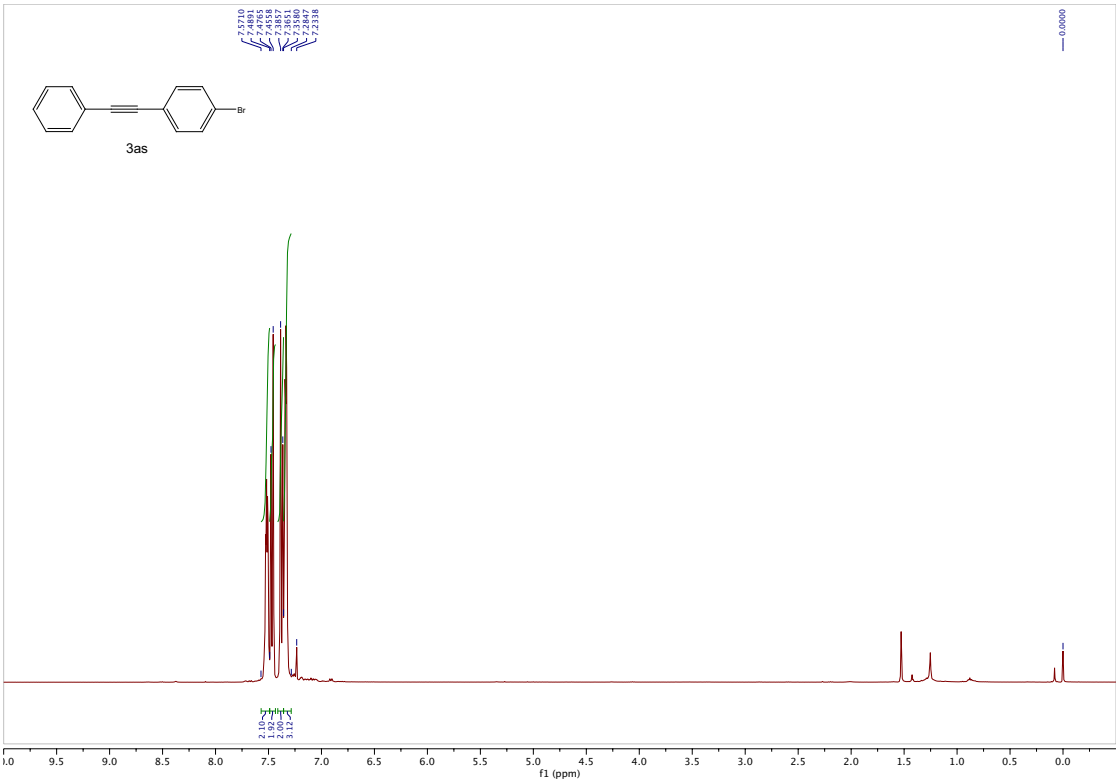
128.46
128.37
122.91
121.76
90.30
88.22
77.00
Cl
3ap
f1 (ppm)

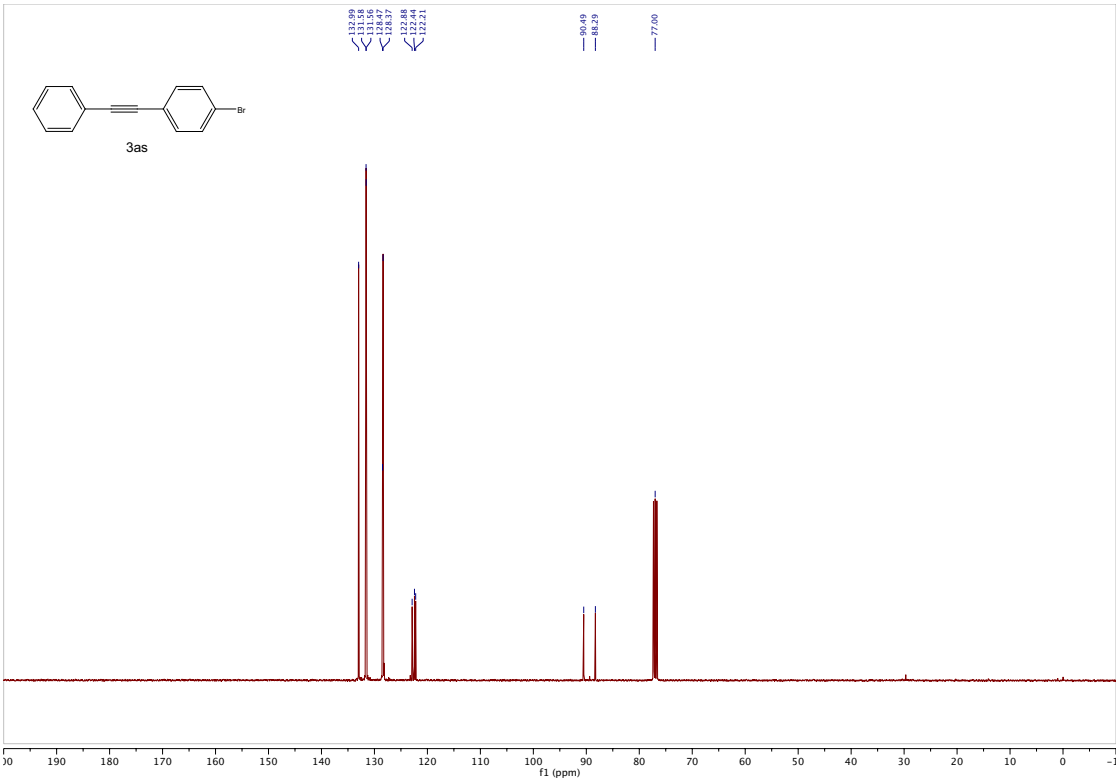

Br
3aq
f1 (ppm)

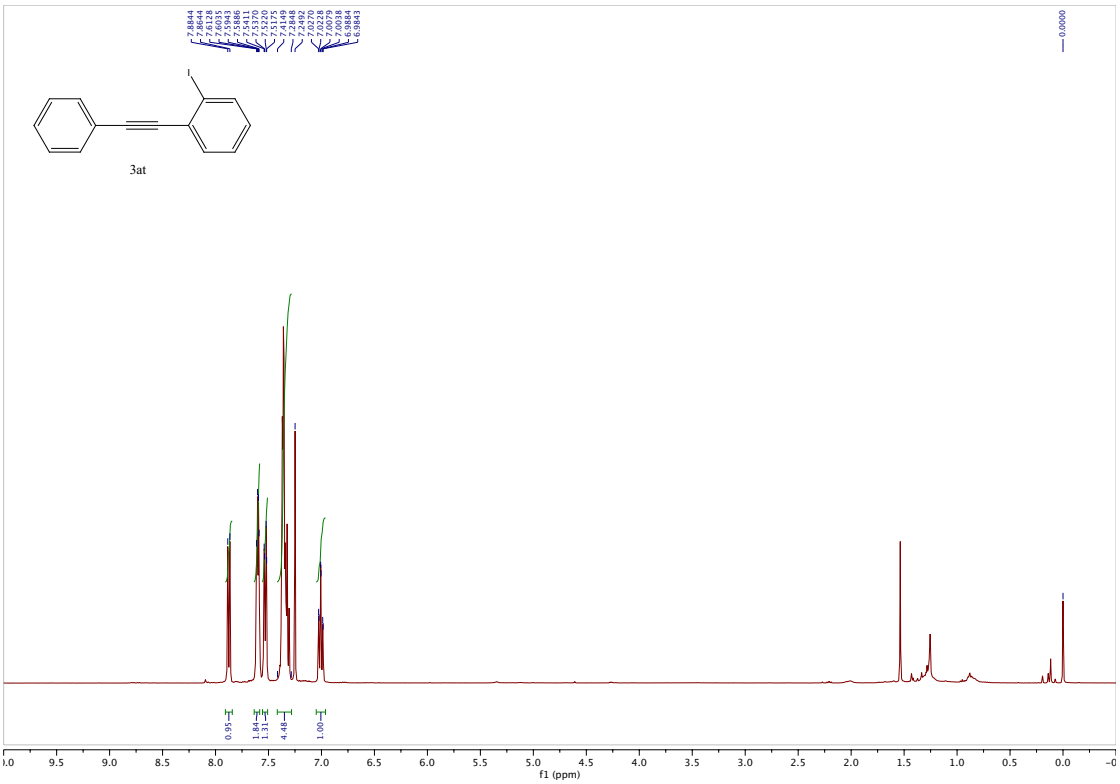

Br
3aq
f1 (ppm)


7.5948
7.4759
7.4622
7.3955
7.3683
7.3487
7.3298
7.2966
7.2104
7.1557
7.0911
-0.0818
Br
3ar
0.95
2.00
2.00
3.41
1.16
f1 (ppm)


134.27
131.64
131.32
130.09
129.73
128.59
128.37
125.26
123.20
122.13
90.66
87.77
77.00
Br
3ar
f1 (ppm)


7.5710
7.4891
7.4705
7.4558
7.3857
7.3681
7.3580
7.2837
7.2838
0.0000
Br
3as
2.10
1.92
2.00
3.12
f1 (ppm)


132.99
131.56
131.56
128.47
128.37
122.88
122.44
122.21
90.49
88.29
77.00
Br
3as
f1 (ppm)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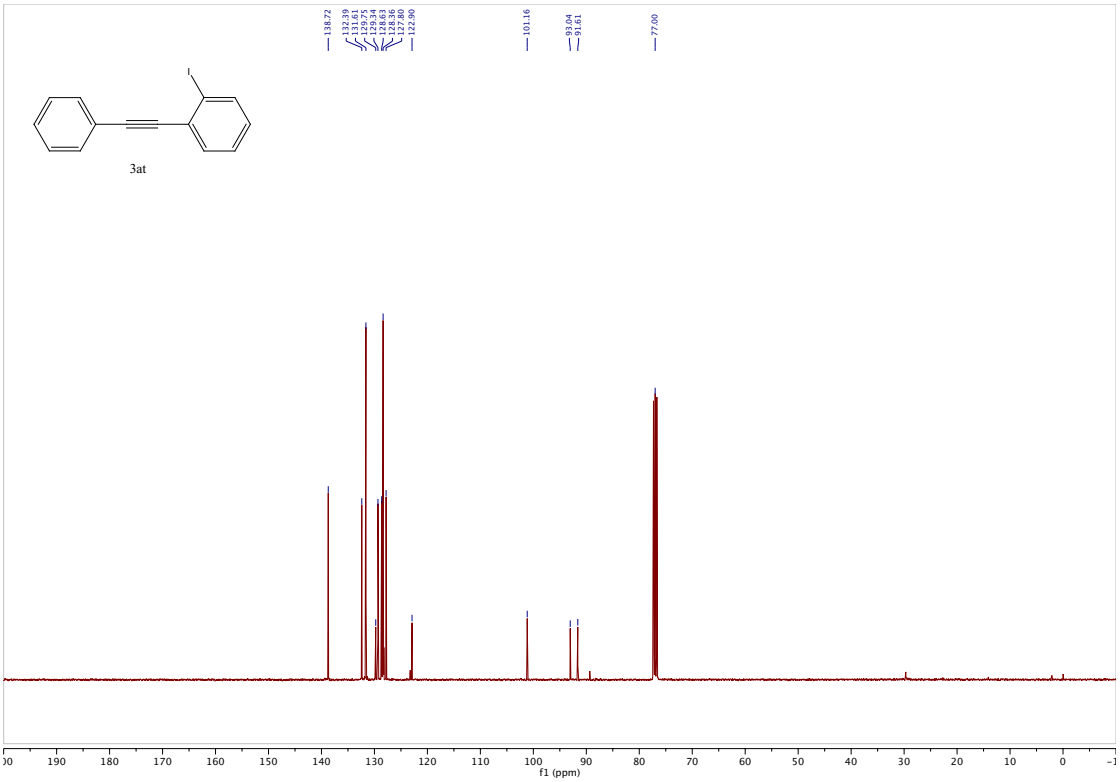
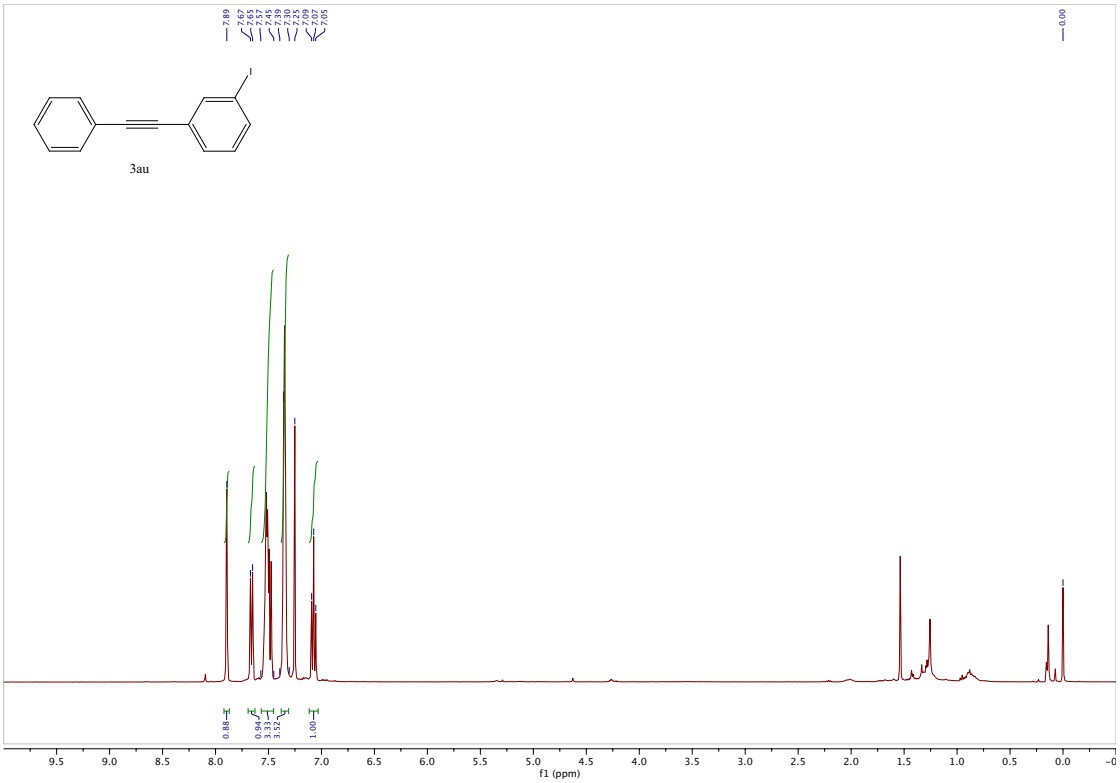
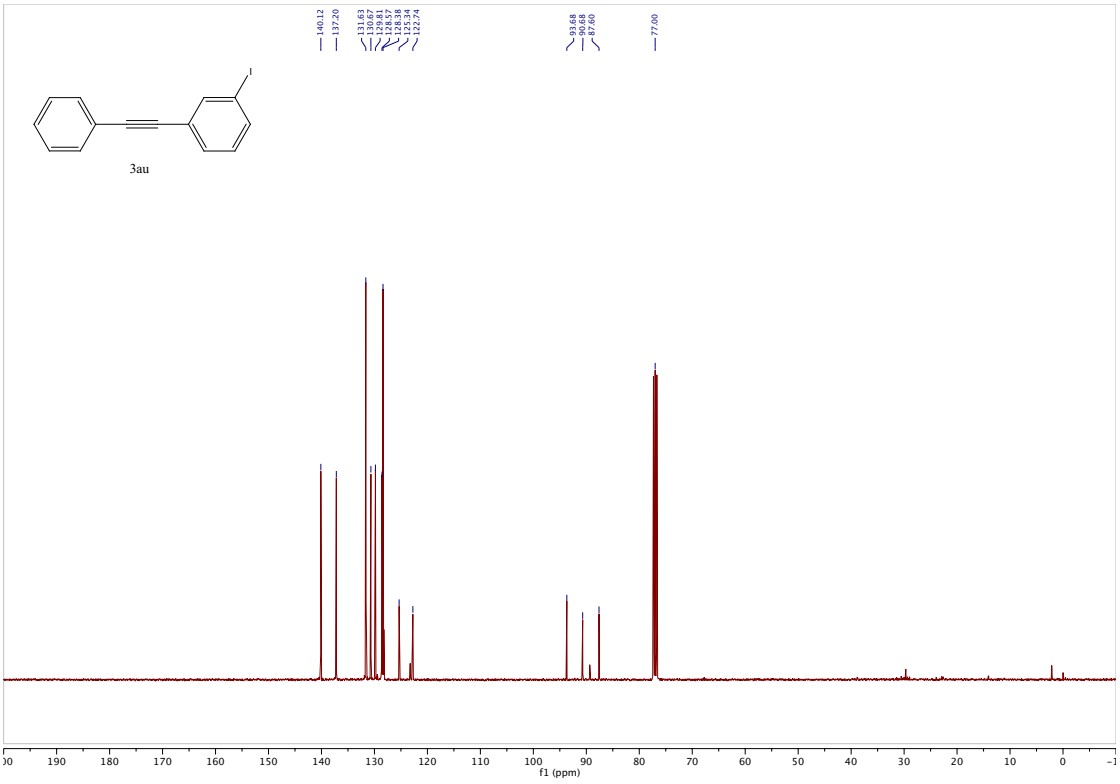
7.8644
7.6128
7.6035
7.5943
7.5886
7.5641
7.5370
7.5120
7.5125
7.4149
7.2848
7.2492
7.0270
7.0228
7.0059
7.0038
6.9884
6.9843
0.0000
I
3at
0.95
1.84
1.31
4.48
1.00
f1 (ppm)


138.72
132.39
131.61
129.75
129.34
128.63
128.36
127.80
122.90
101.16
93.04
91.61
77.00
I
3at
f1 (ppm)


7.89
7.67
7.65
7.52
7.45
7.39
7.30
7.25
7.09
7.07
7.05
0.00
I
3au
0.88
0.94
3.33
3.52
1.00
f1 (ppm)


140.12
137.20
131.63
130.67
129.81
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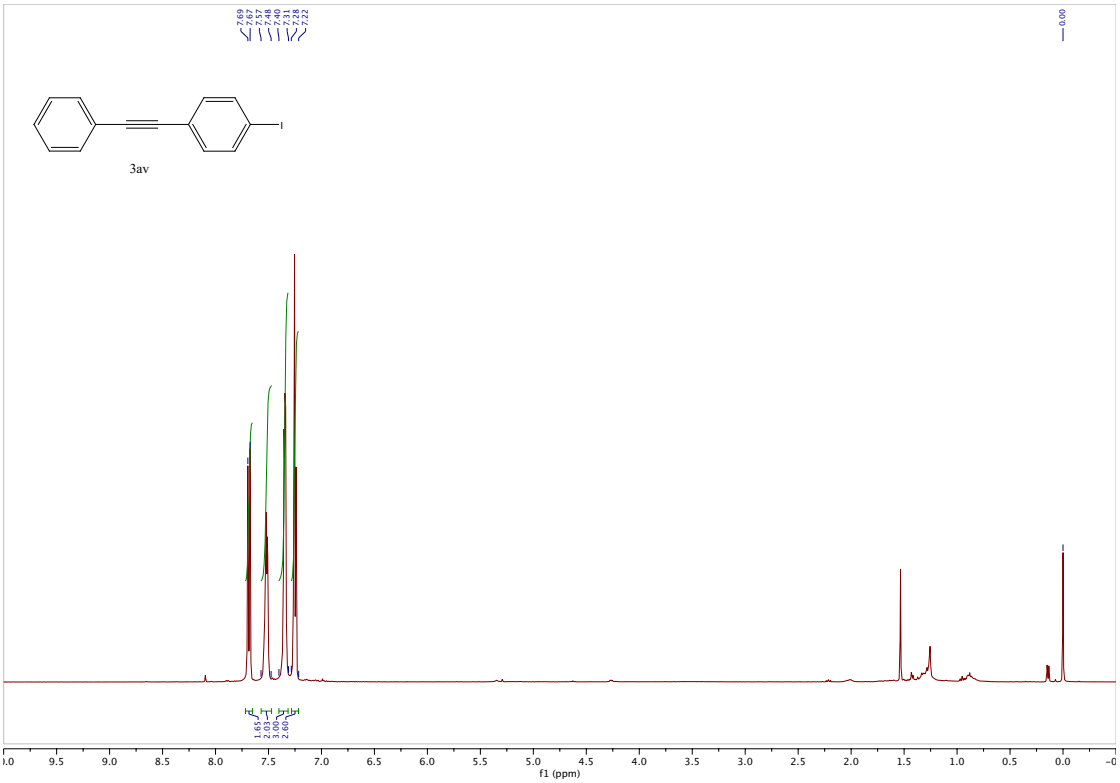
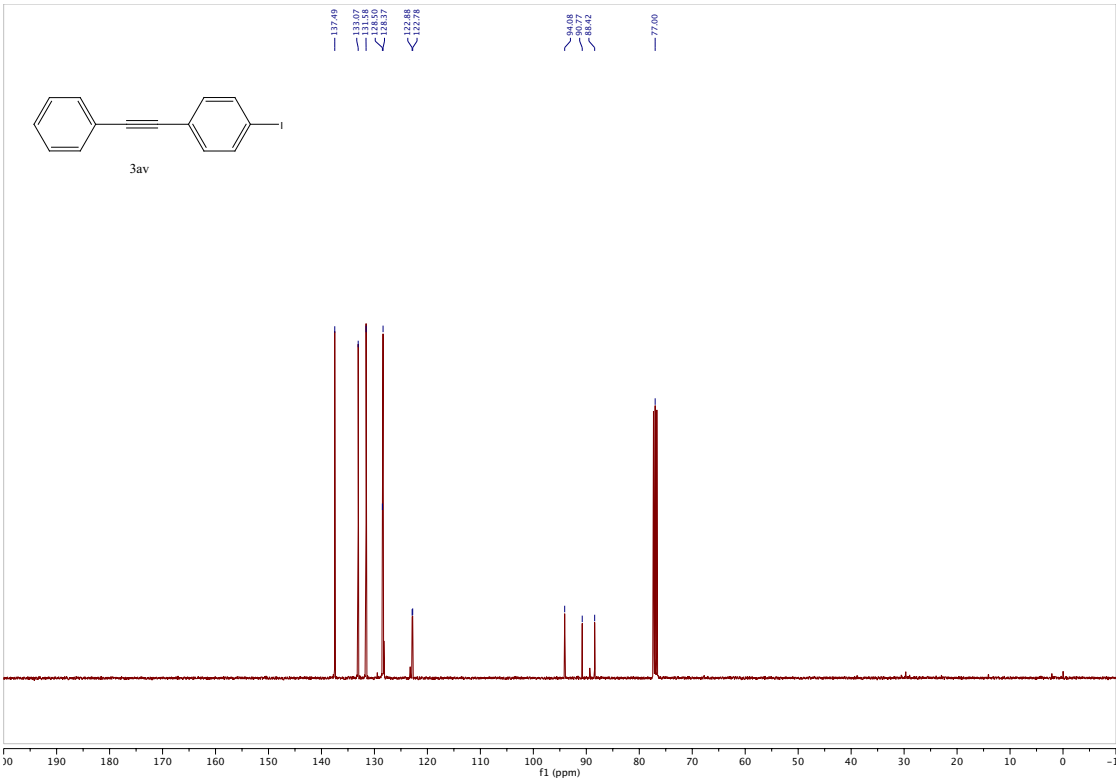
128.38
125.34
122.74
93.68
80.66
87.60
77.00
I
3au
f1 (ppm)


7.69
7.67
7.57
7.48
7.40
7.31
7.28
7.22
0.00
I
3av
1.65
2.03
3.00
2.60
f1 (ppm)


137.49
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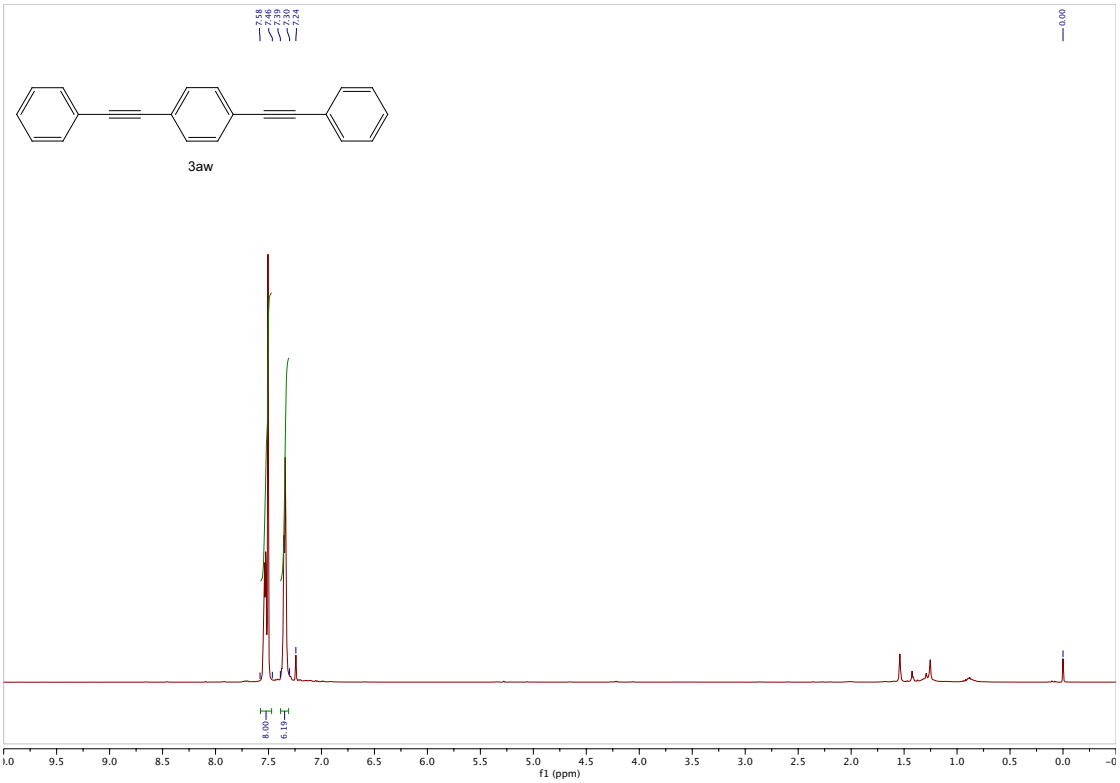
128.37
122.88
122.78
94.08
90.77
88.42
77.00
I
3av
f1 (ppm)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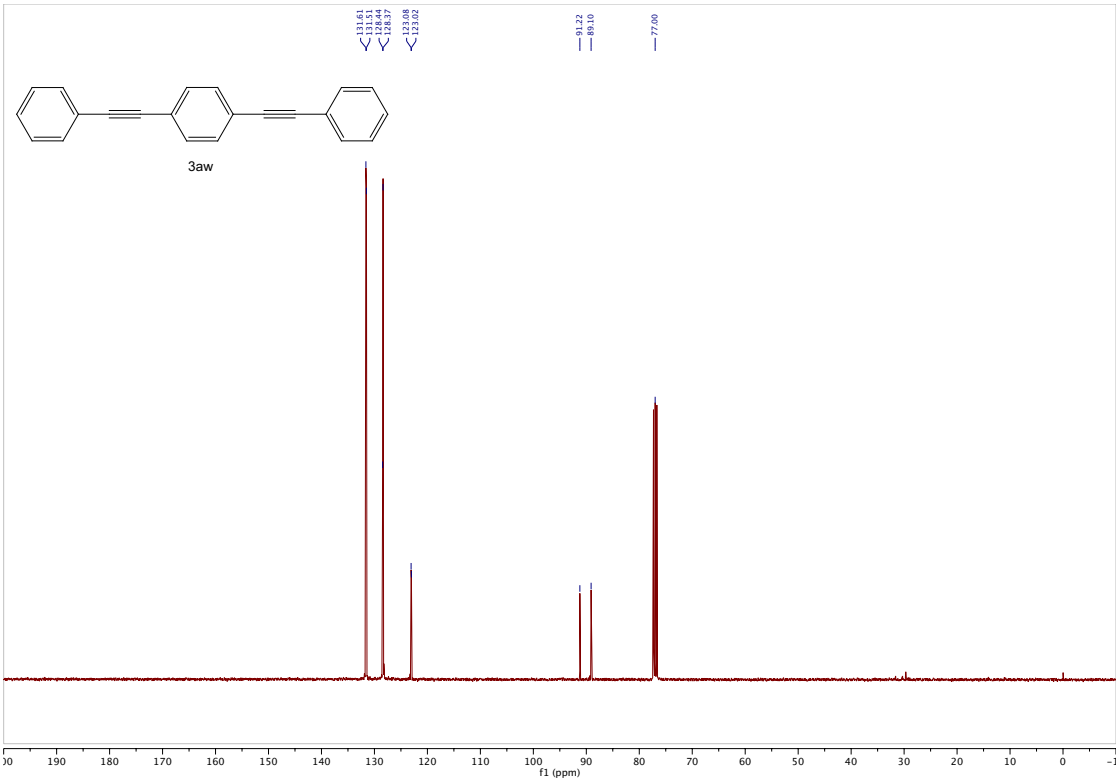
7.39
7.30
7.24
0.00
3aw
8.00
6.19
f1 (ppm)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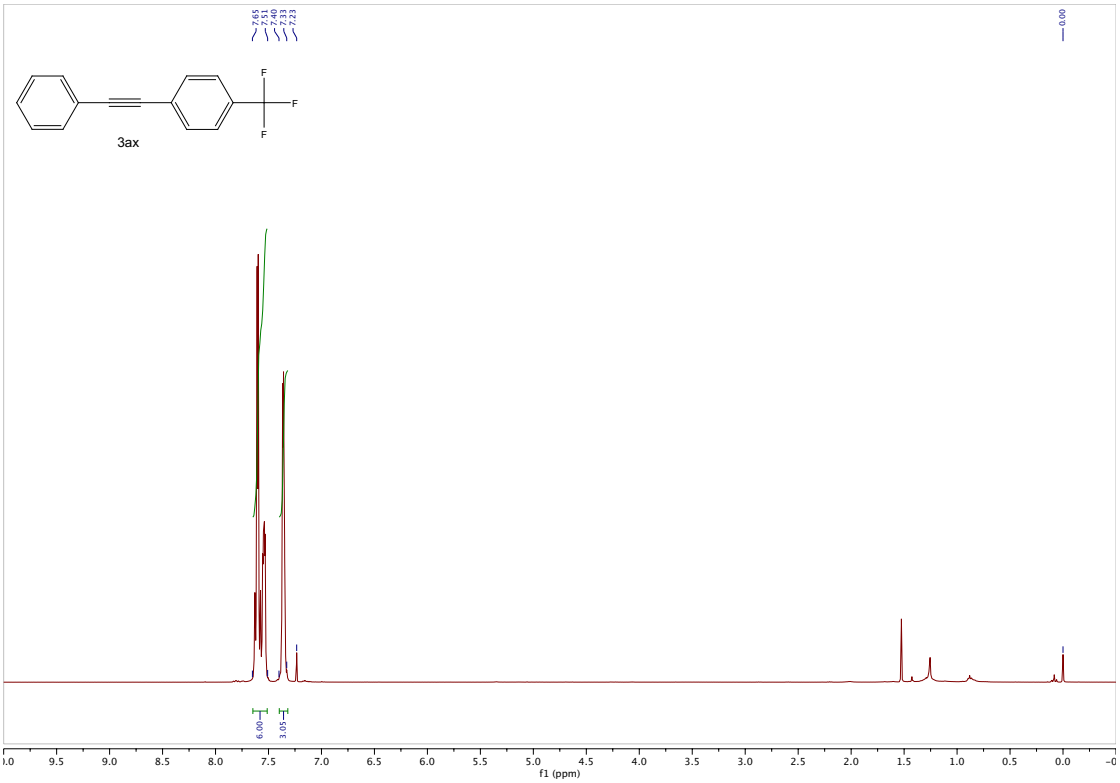
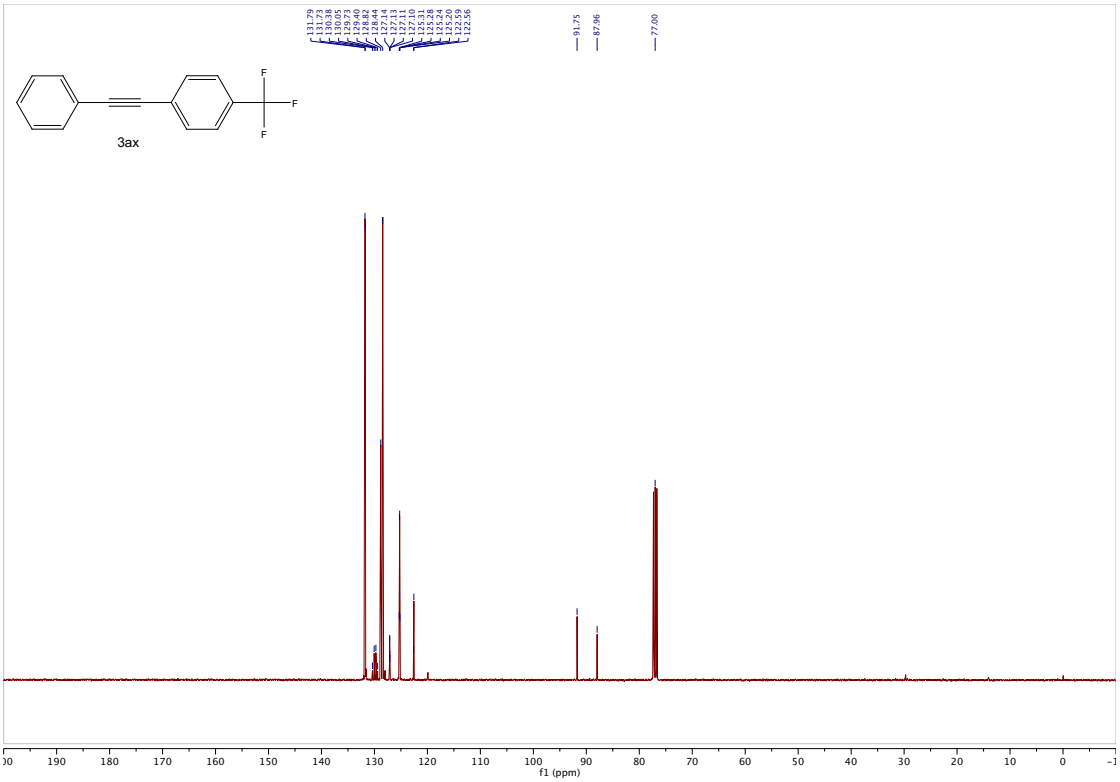
131.51
128.44
128.37
123.08
123.02
91.22
89.10
77.00
3aw
f1 (ppm)


7.65
7.41
7.40
7.33
7.23
0.00
F
F
F
3ax
6.00
3.05
f1 (ppm)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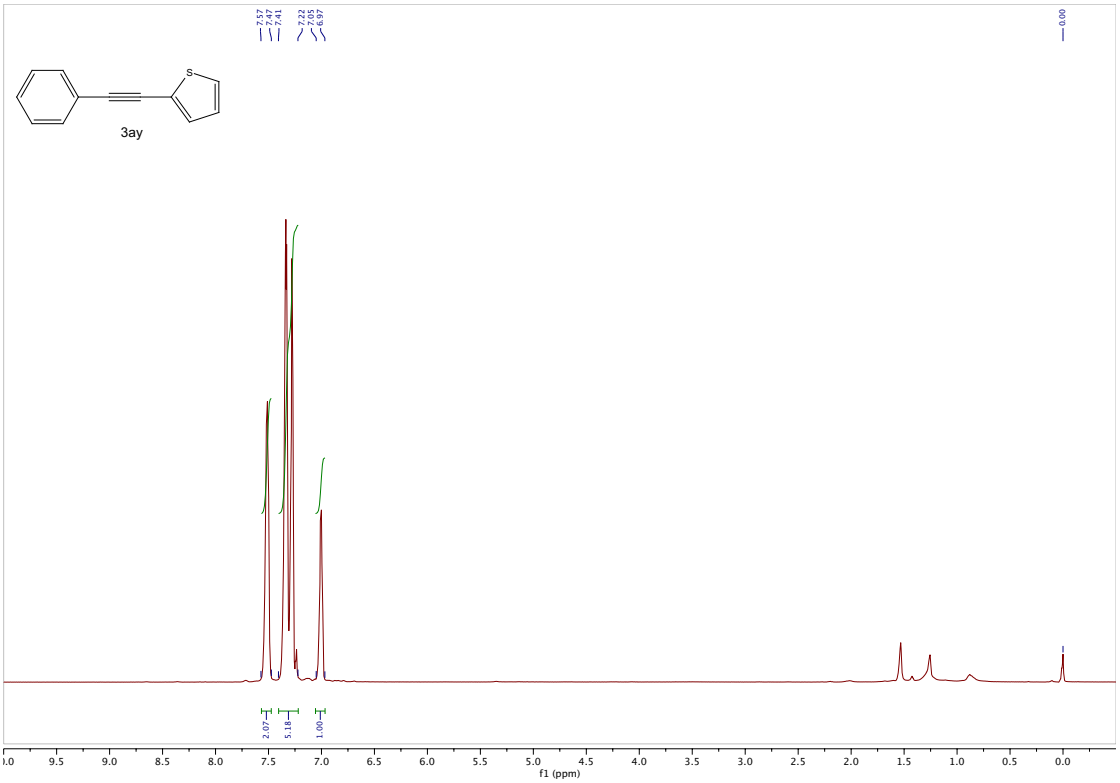
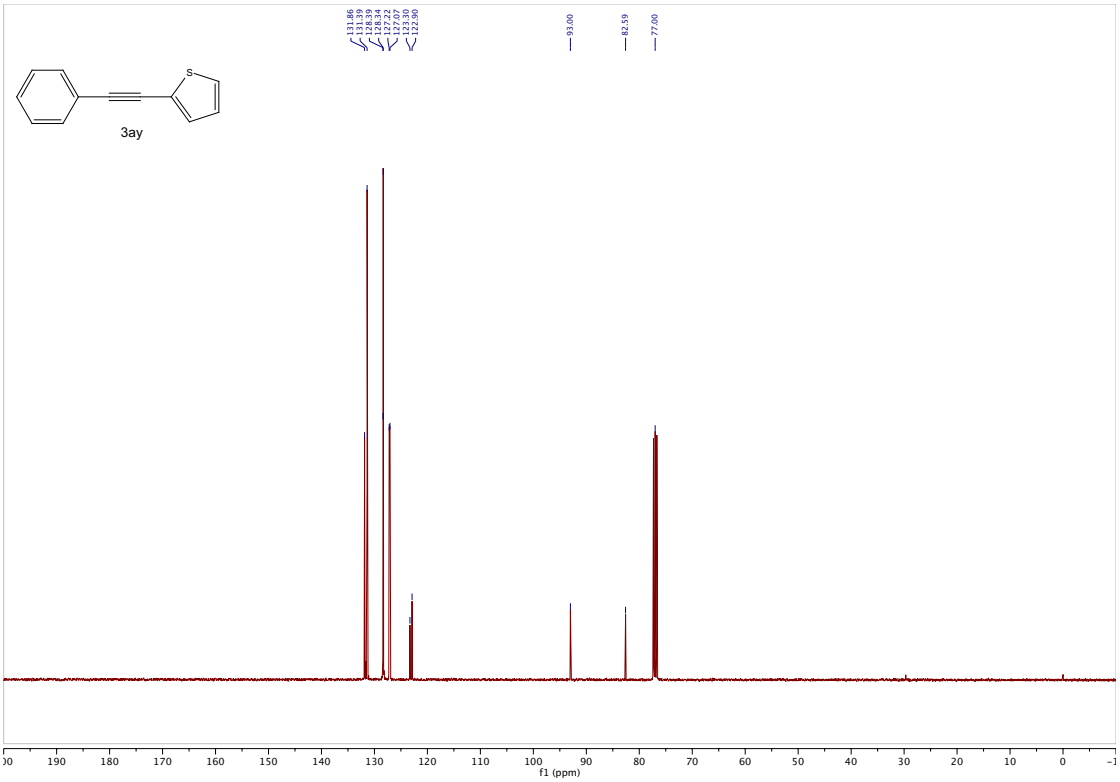
130.05
129.73
129.40
128.82
128.44
127.14
127.13
127.11
127.10
125.31
125.28
125.24
125.20
123.89
122.56
91.75
87.96
77.00
F
F
F
3ax
f1 (ppm)


7.57
7.47
7.41
7.22
7.05
6.97
0.00
S
3ay
2.07
5.18
1.00
f1 (ppm)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131.39
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127.07
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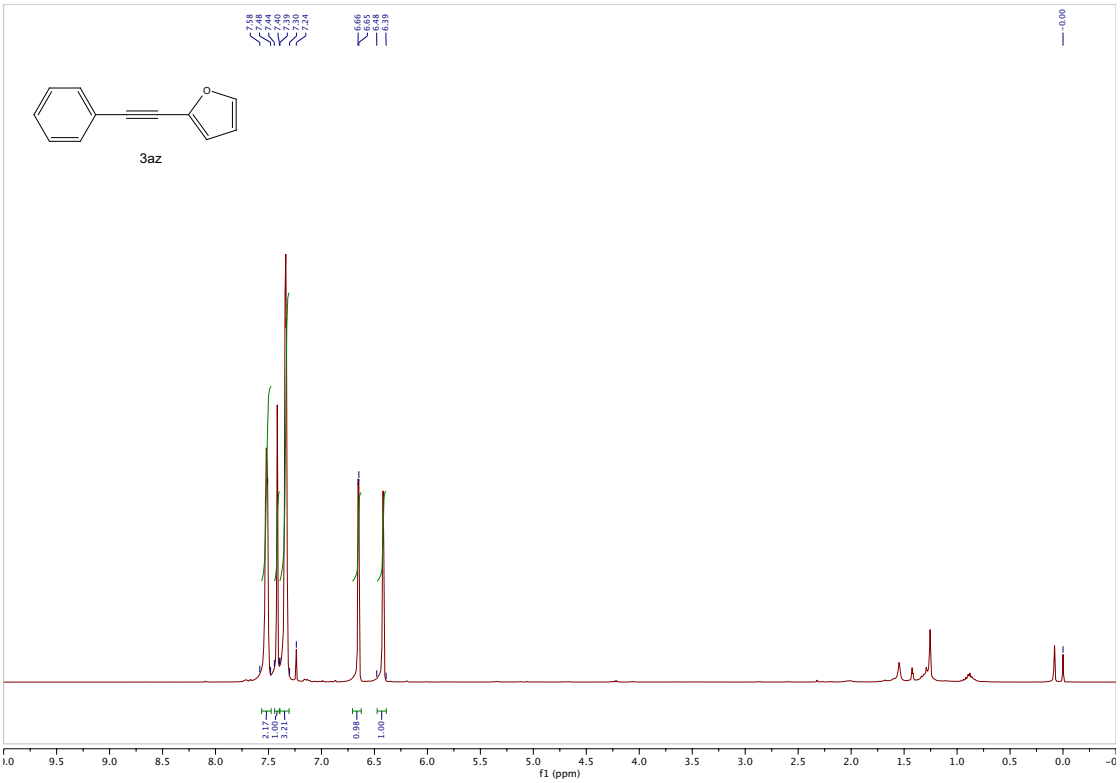
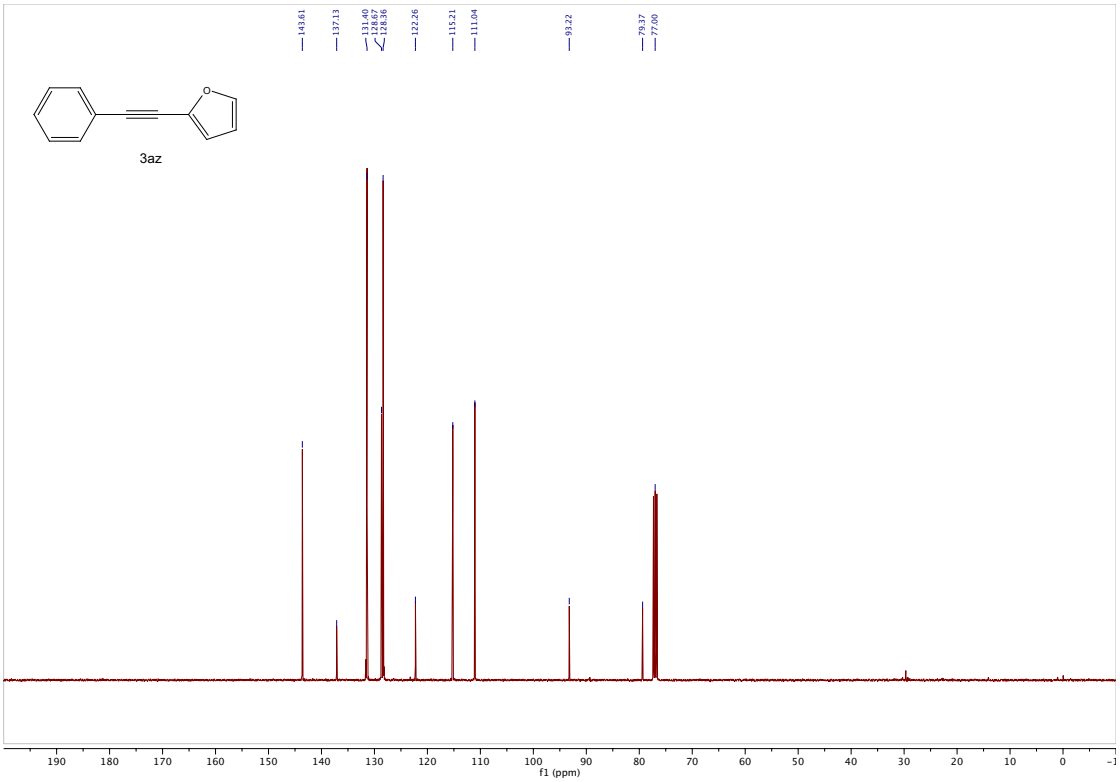
122.90
93.00
82.59
77.00
S
3ay
f1 (ppm)


7.58
7.48
7.44
7.40
7.39
7.30
7.24
6.66
6.65
6.48
6.39
0.00
O
3az
2.17
1.00
3.21
0.98
1.00
f1 (ppm)


143.61
137.13
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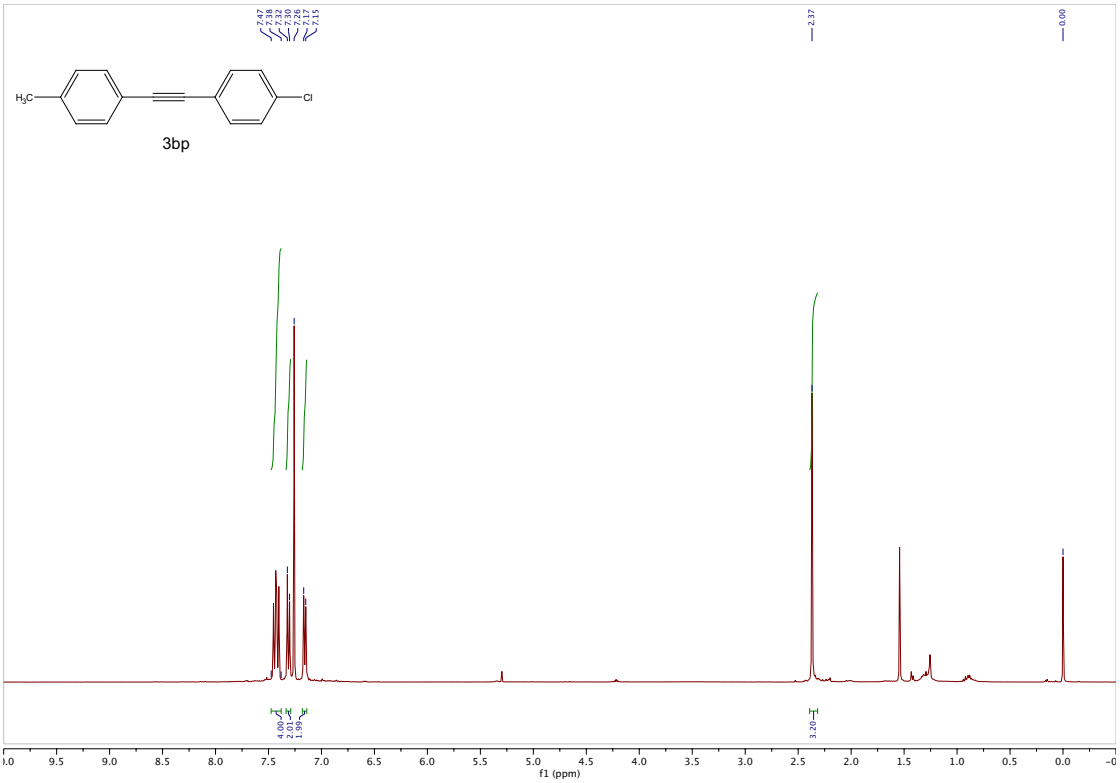
128.27
128.36
122.26
115.21
111.04
93.22
79.37
77.00
O
3az
f1 (ppm)


7.47
7.38
7.32
7.30
7.26
7.17
7.15
2.37
0.00
H3C
Cl
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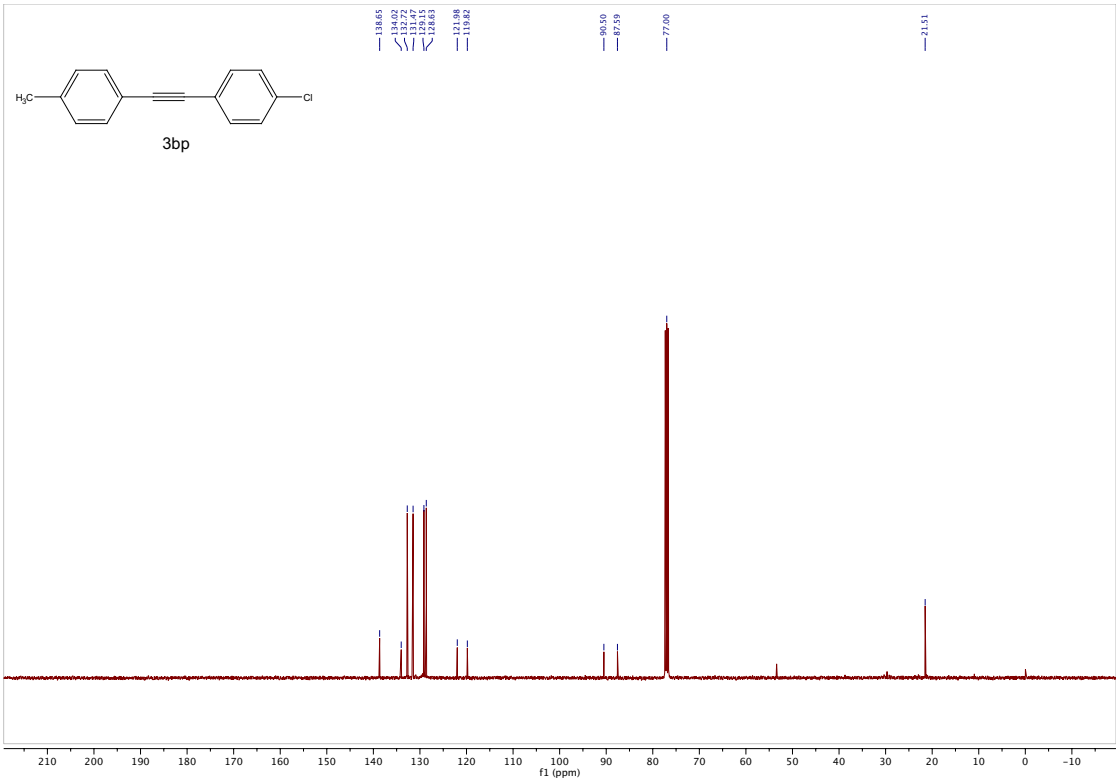
4.00
2.04
1.99
3.20
f1 (ppm)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131.47
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119.82
90.50
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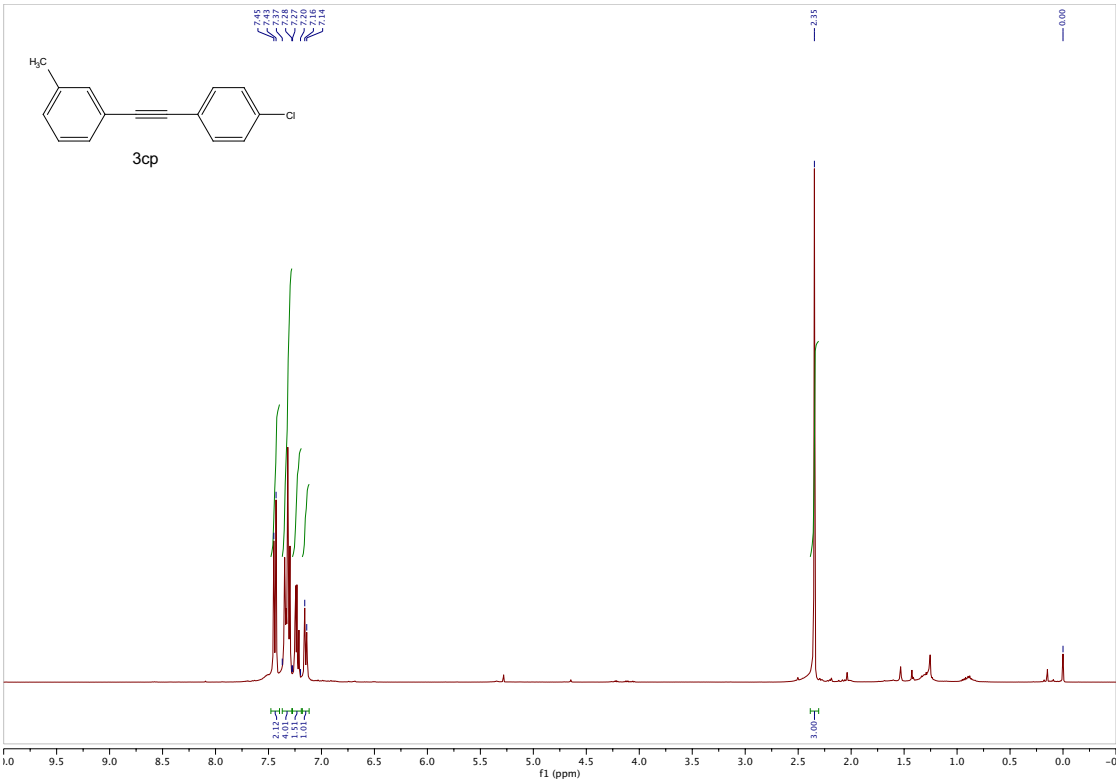
77.00
21.51
H3C
Cl
3bp
f1 (ppm)


7.45
7.43
7.27
7.28
7.27
7.09
7.16
7.14
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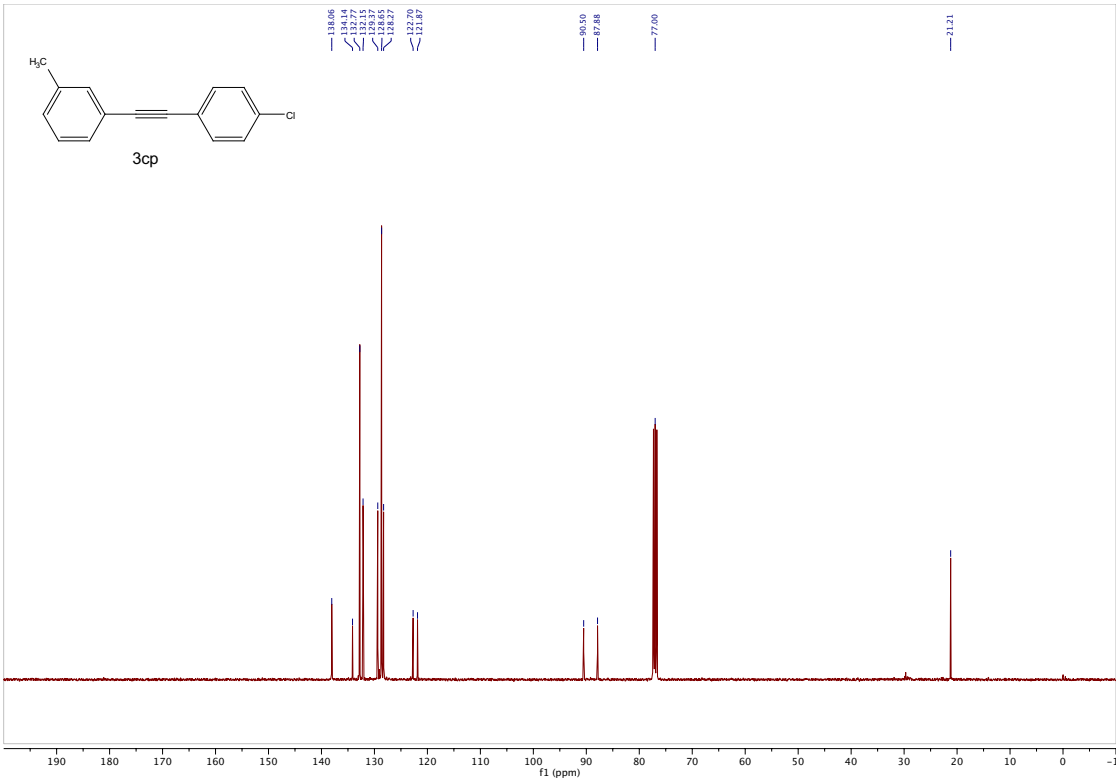
Cl
3cp
2.12
4.01
1.51
1.01
3.00
f1 (ppm)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132.15
130.32
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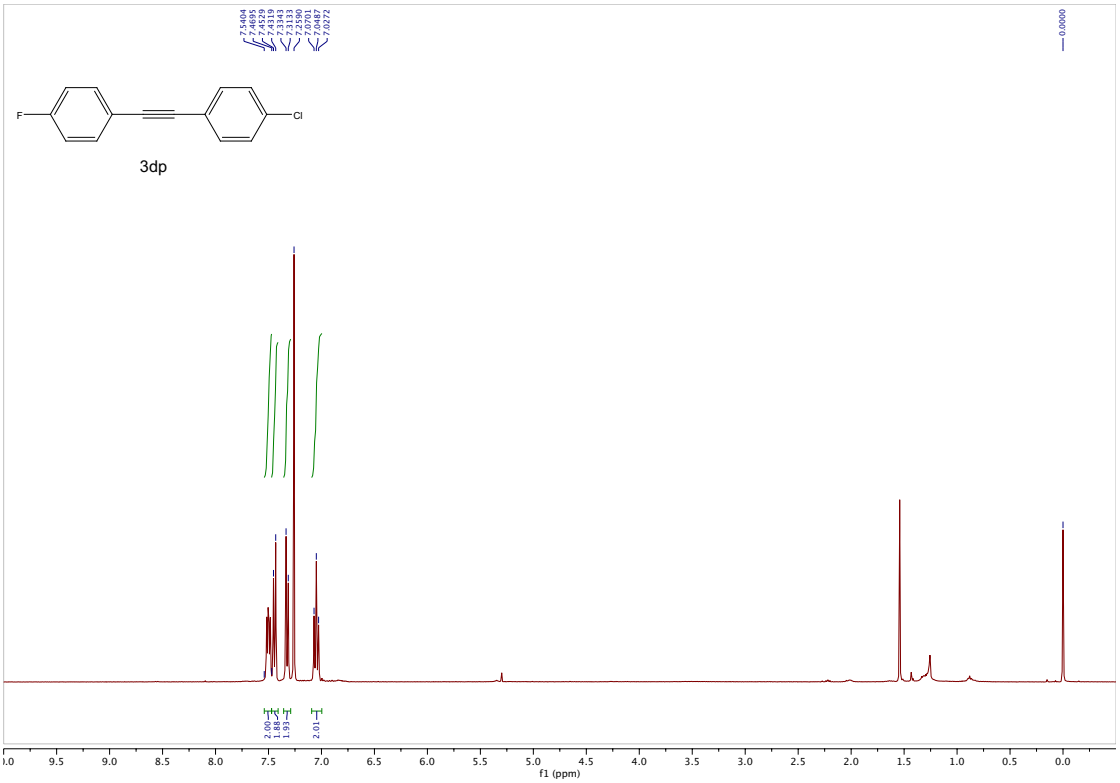
121.87
90.50
87.88
77.00
21.21
H3C
Cl
3cp
f1 (ppm)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7.4695
7.4659
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7.3343
7.3133
7.2590
7.0701
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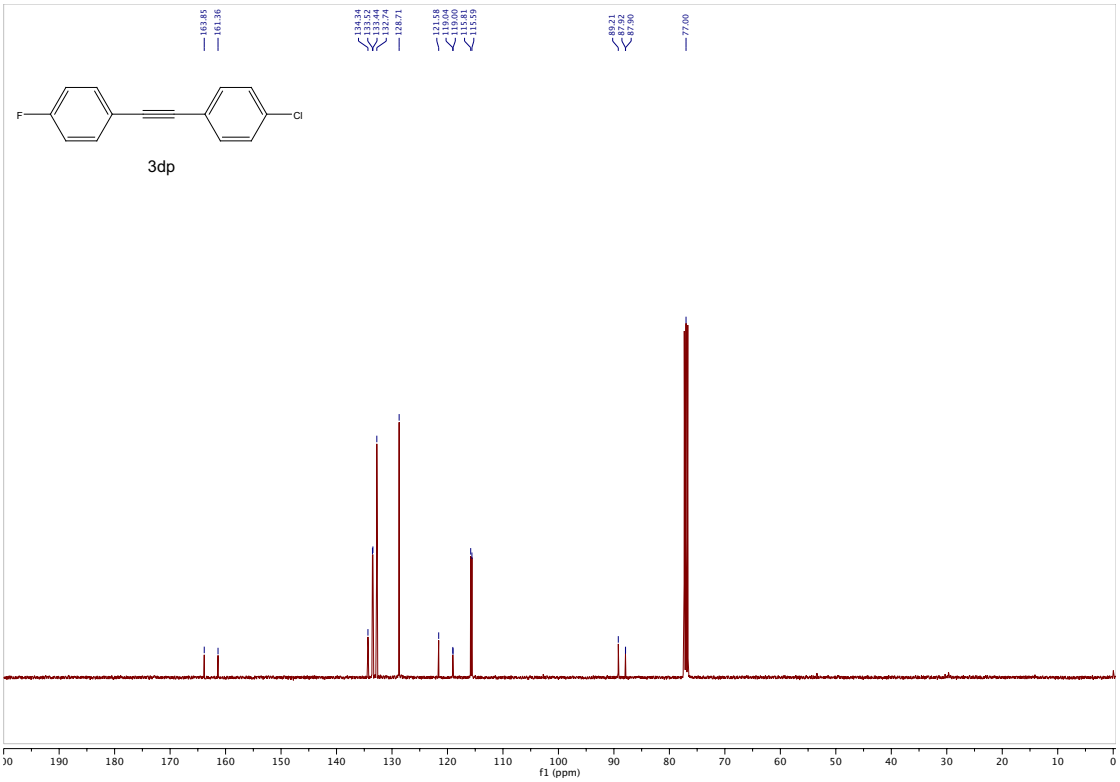
7.0272
0.0000
F
Cl
3dp
2.00
1.94
1.93
2.01
f1 (ppm)


163.85
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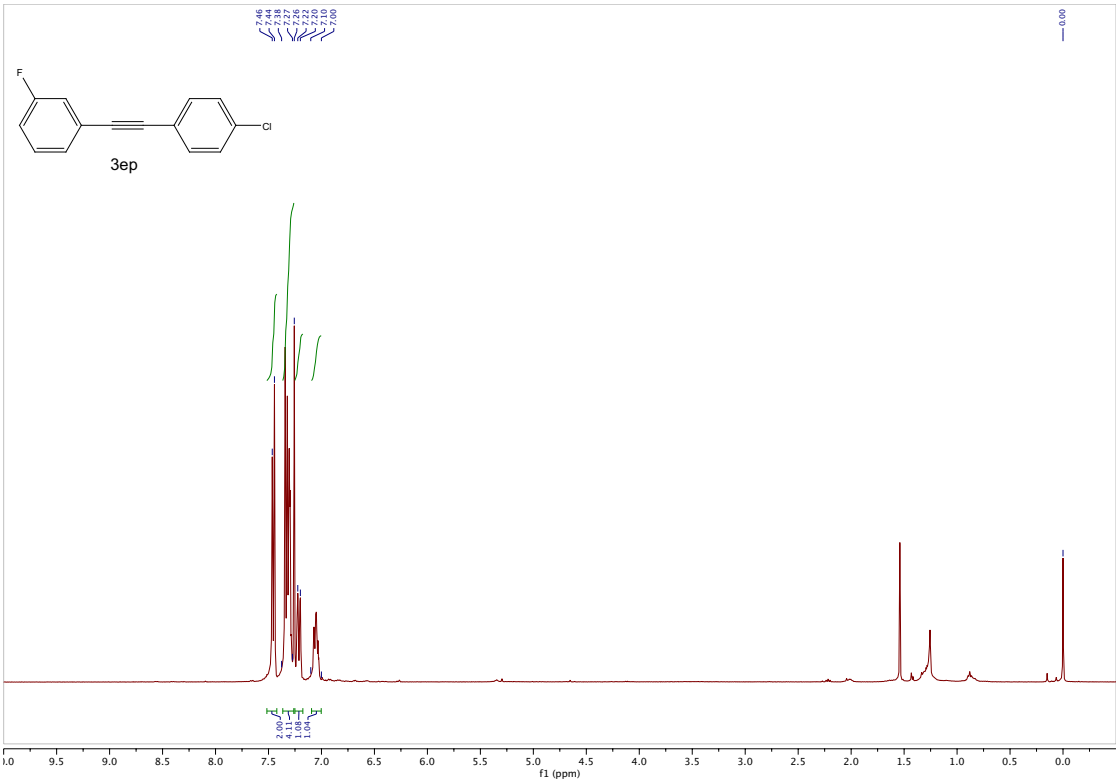
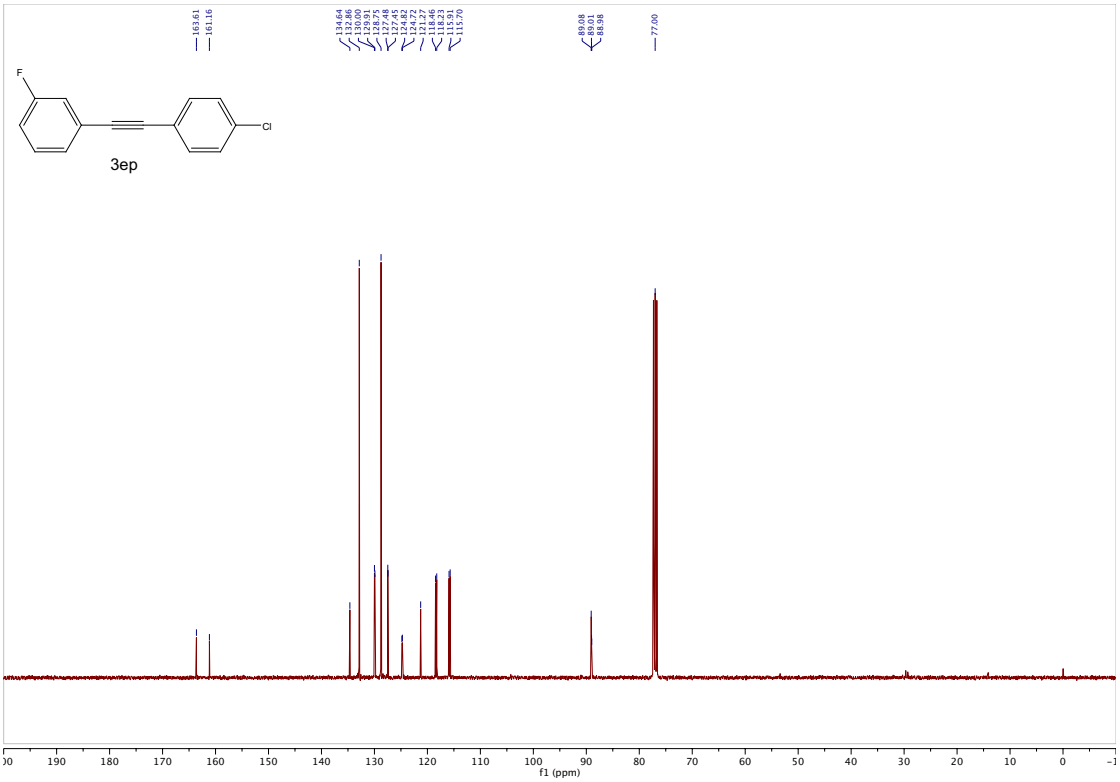
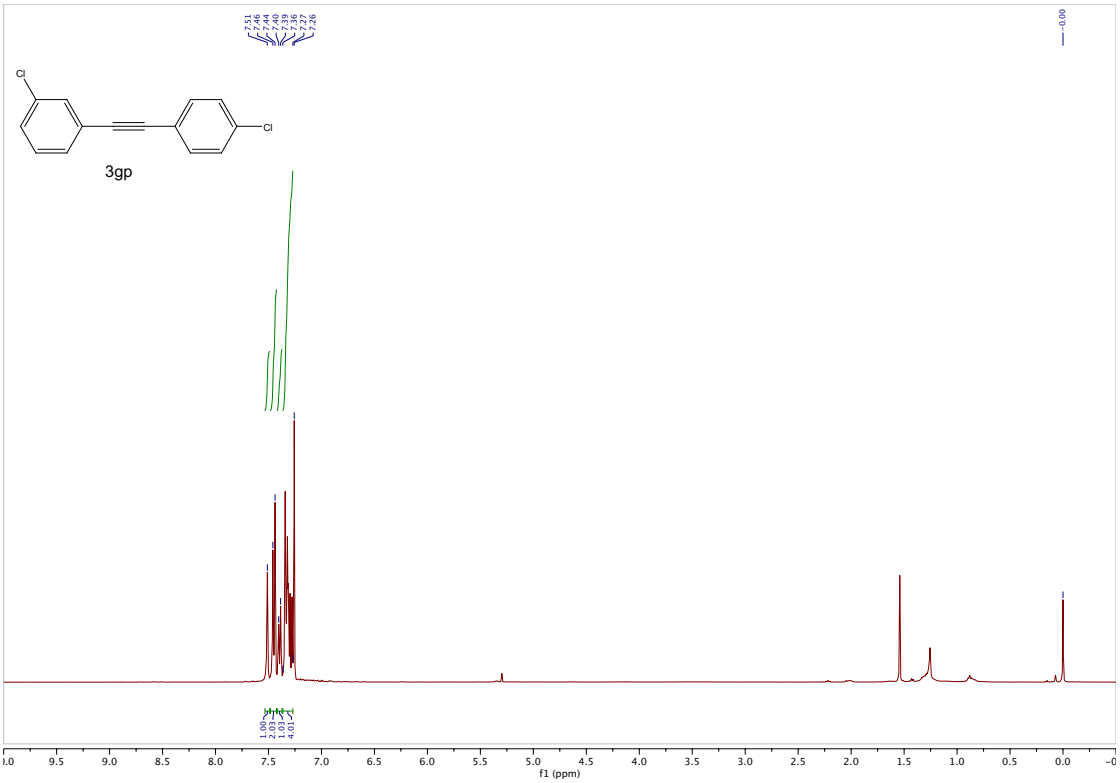
133.52
133.44
132.24
128.71
121.58
119.04
119.00
115.81
115.59
89.21
87.92
87.90
77.00
F
Cl
3dp
f1 (ppm)


F
Cl
3ep
f1 (ppm)


F
Cl
3ep
f1 (ppm)


7.51
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7.44
7.40
7.39
7.36
7.27
7.26
0.00
Cl
Cl
3gp
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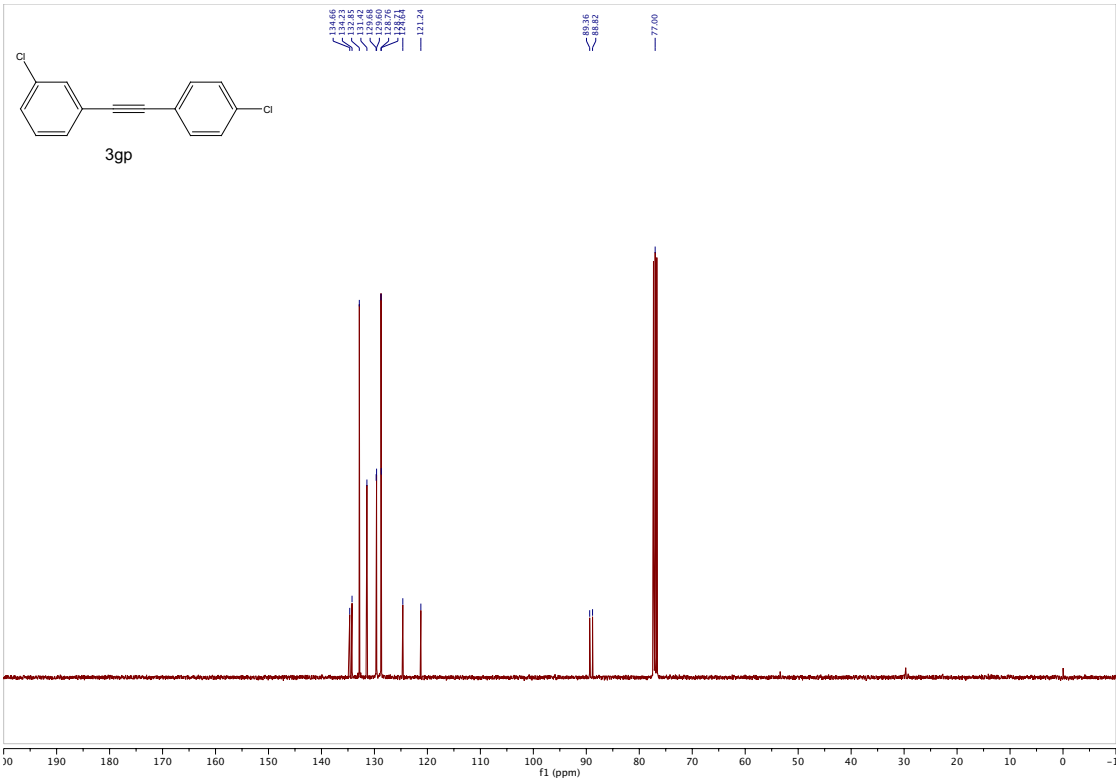
2.03
1.03
4.01
f1 (ppm)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134.23
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131.23
129.68
129.60
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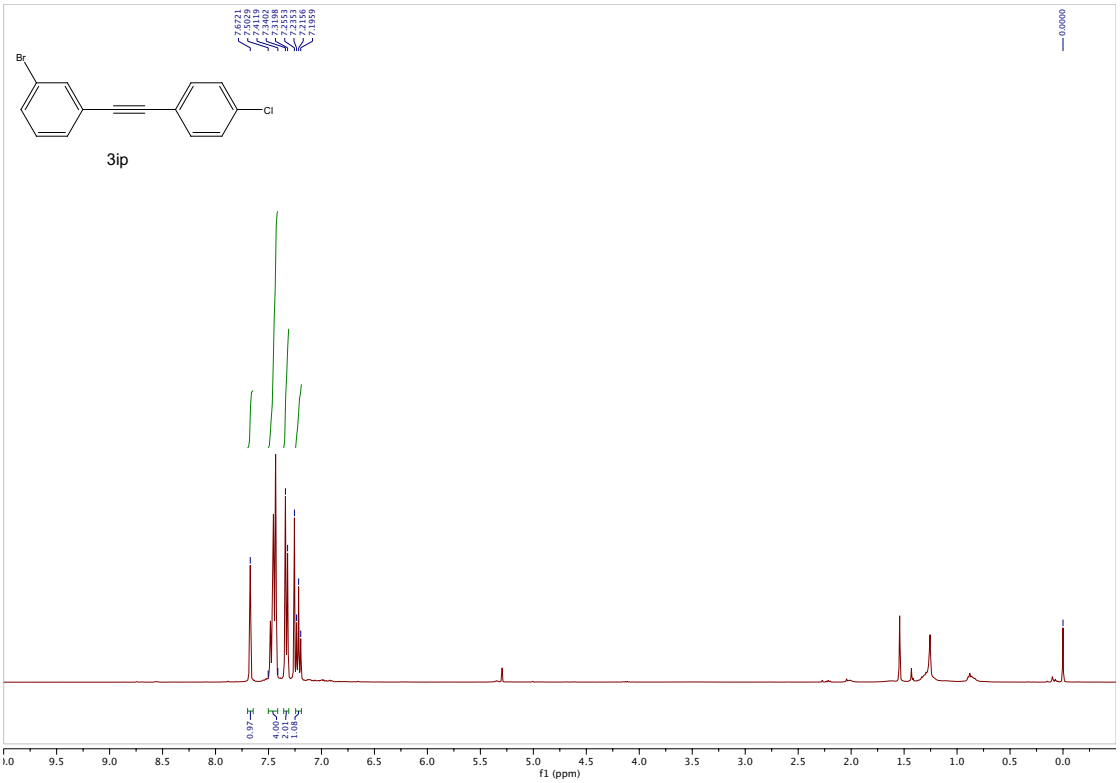
124.71
124.04
121.24
89.36
88.82
77.00
Cl
Cl
3gp
f1 (ppm)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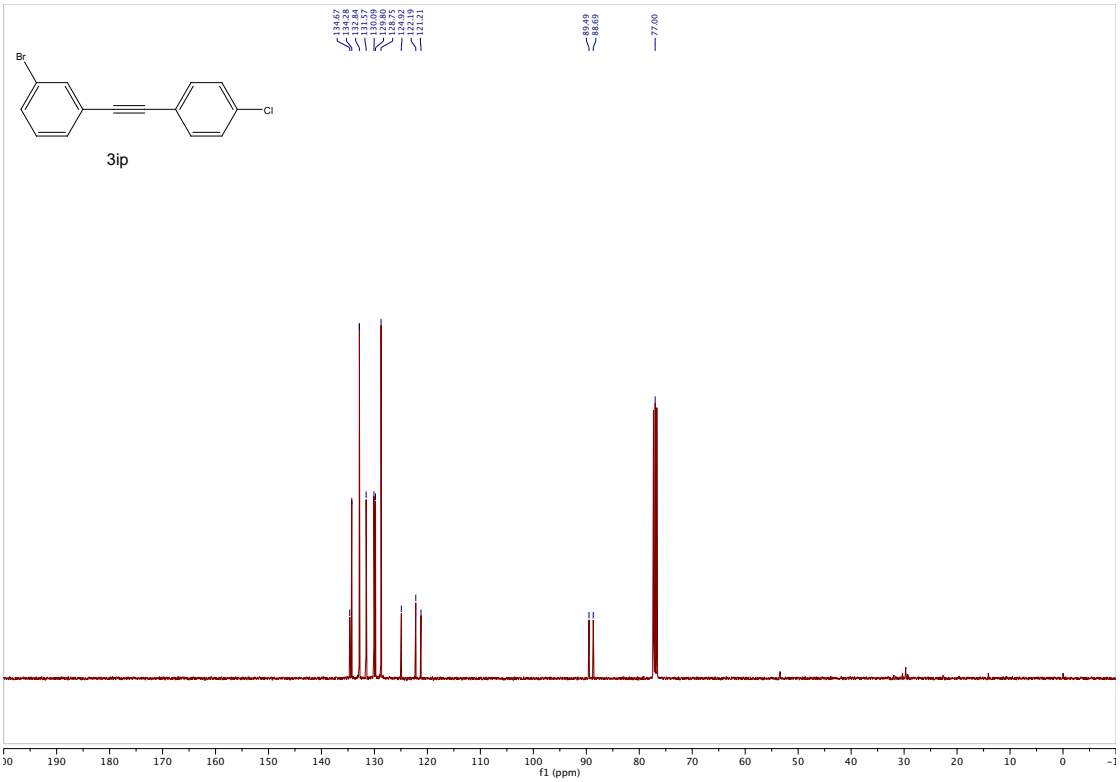
7.4119
7.3402
7.3198
7.2553
7.2353
7.2156
7.1959
0.0000
Br
Cl
3ip
0.97
4.00
2.01
1.08
f1 (ppm)


134.67
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131.57
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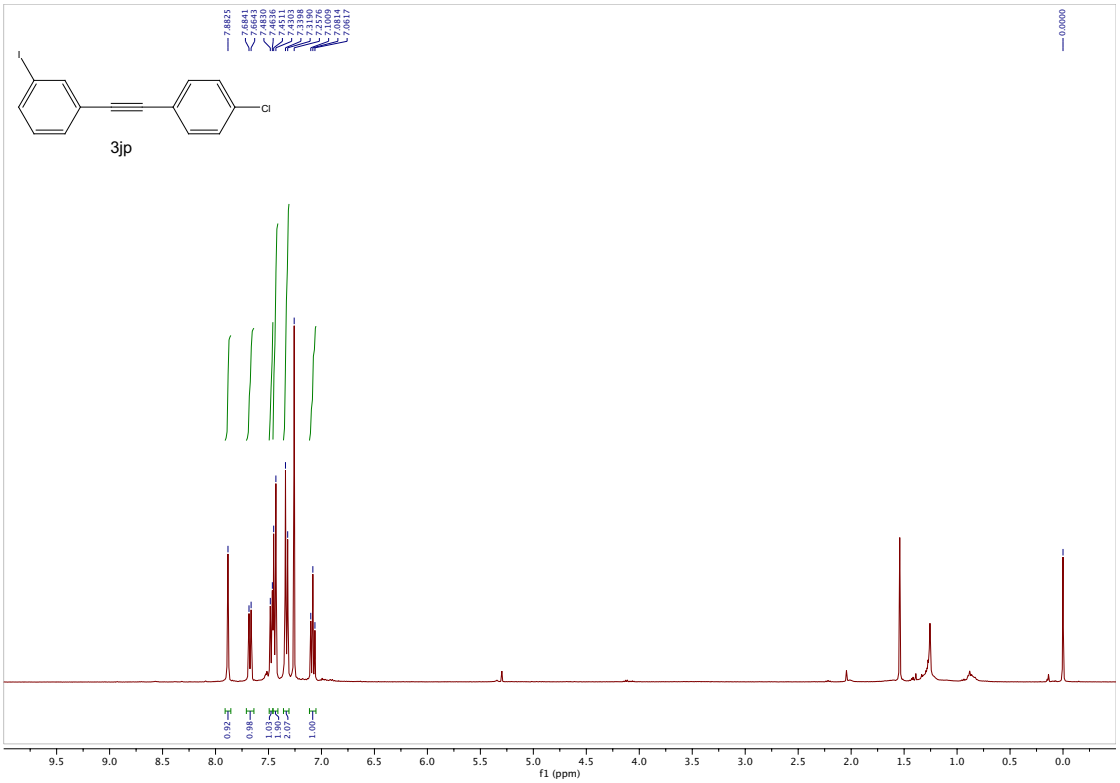
124.32
122.19
121.21
89.69
89.49
77.00
Br
Cl
3ip
f1 (ppm)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7.4511
7.3703
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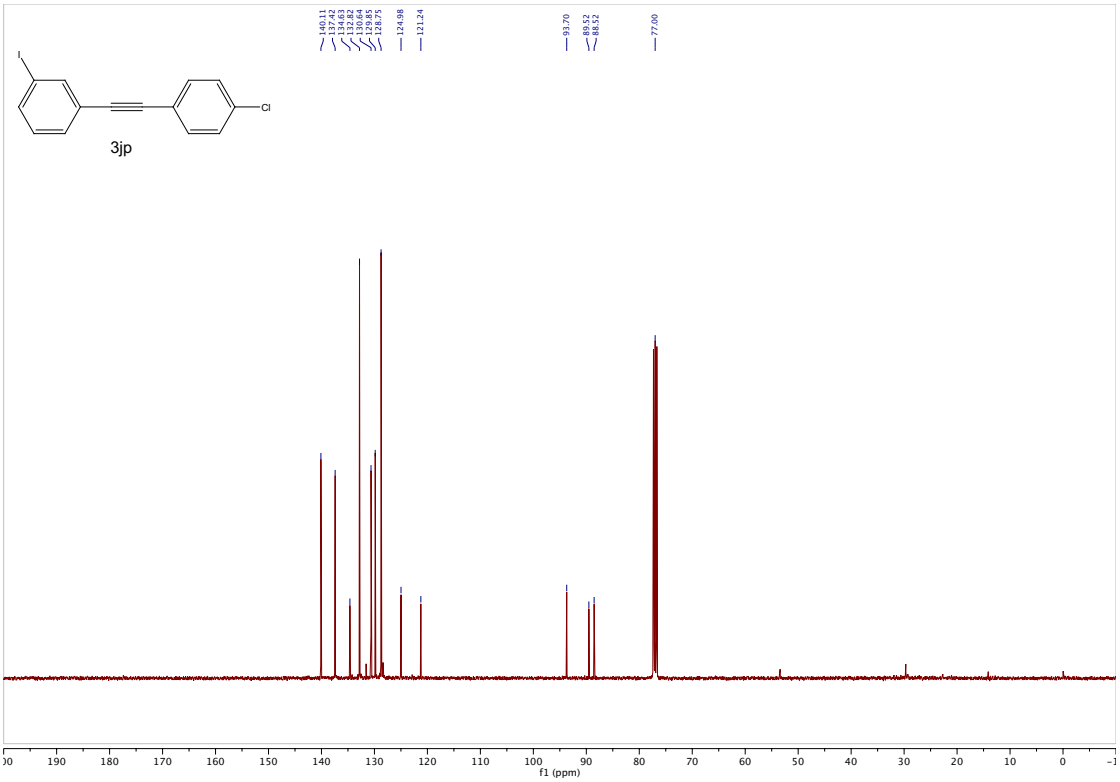
7.3190
7.1575
7.1009
7.0814
7.0617
0.0000
I
Cl
3jp
0.92
0.98
1.03
1.90
2.07
1.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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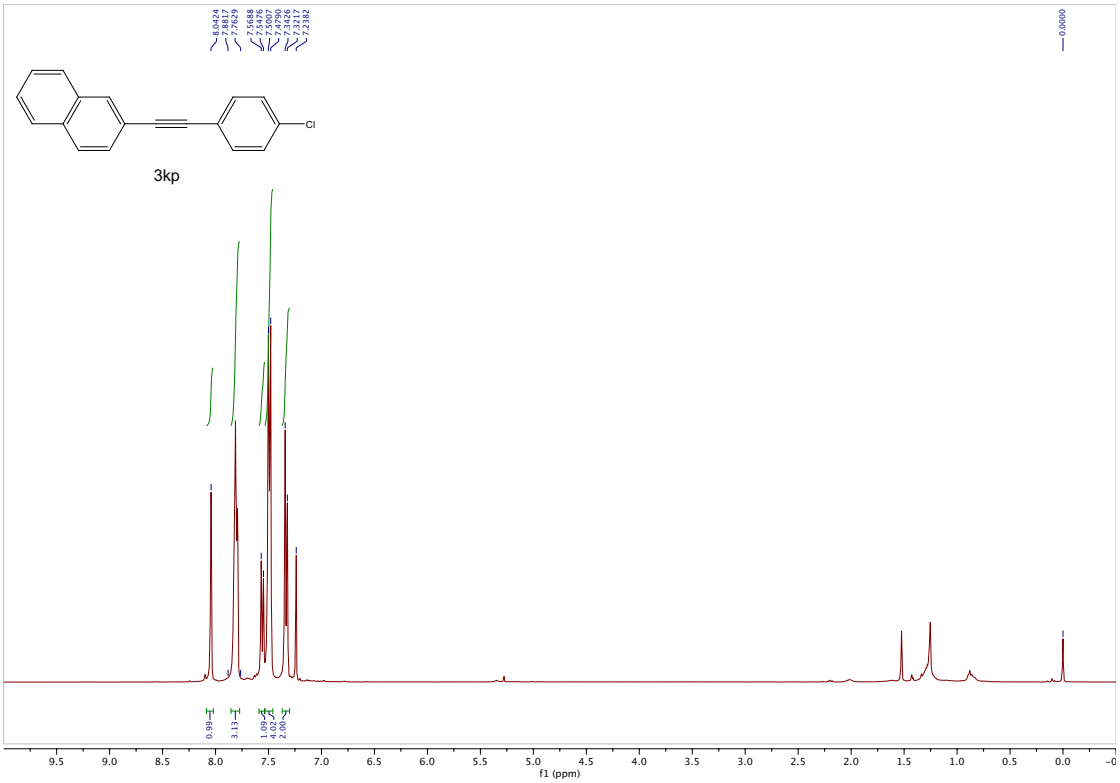
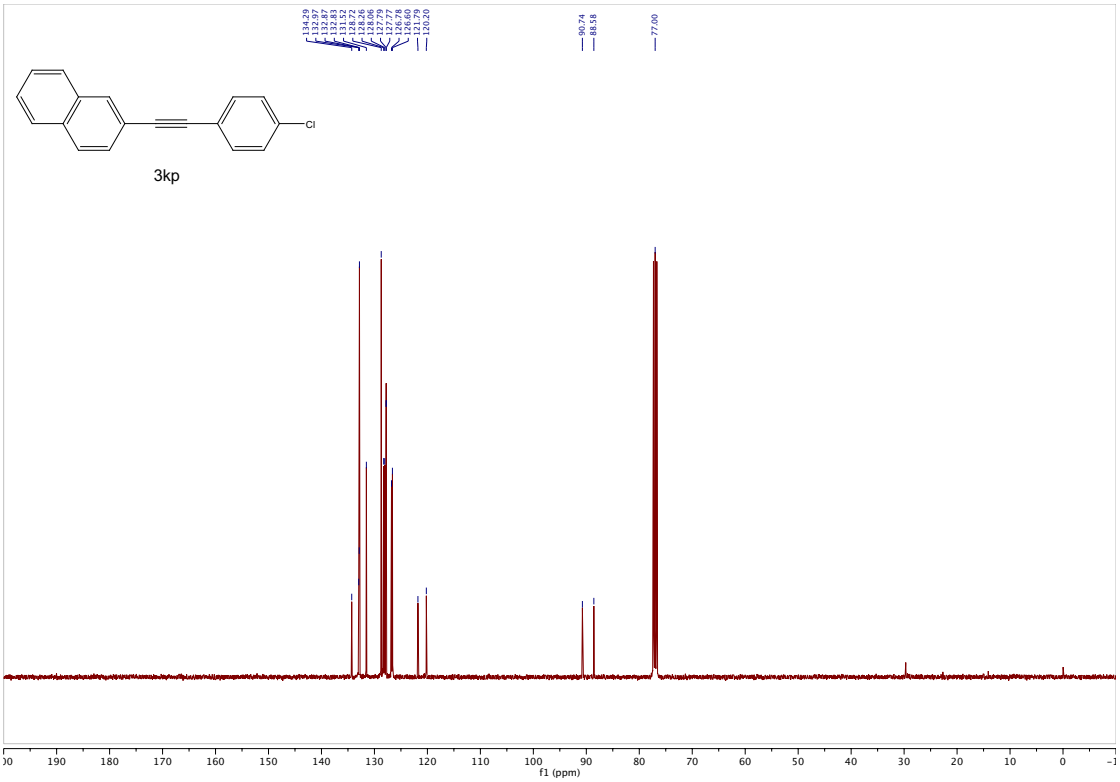
137.22
134.63
132.82
130.44
129.85
128.75
124.98
121.24
93.70
89.52
88.52
77.00
I
Cl
3jp
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.0424
7.8817
7.7629
7.5698
7.5496
7.5007
7.4790
7.4596
7.3217
7.2382
0.0000
Cl
3kp
0.99
3.13
1.09
4.02
2.00
f1 (ppm)


134.59
132.97
132.87
132.63
132.52
128.72
128.66
128.06
127.79
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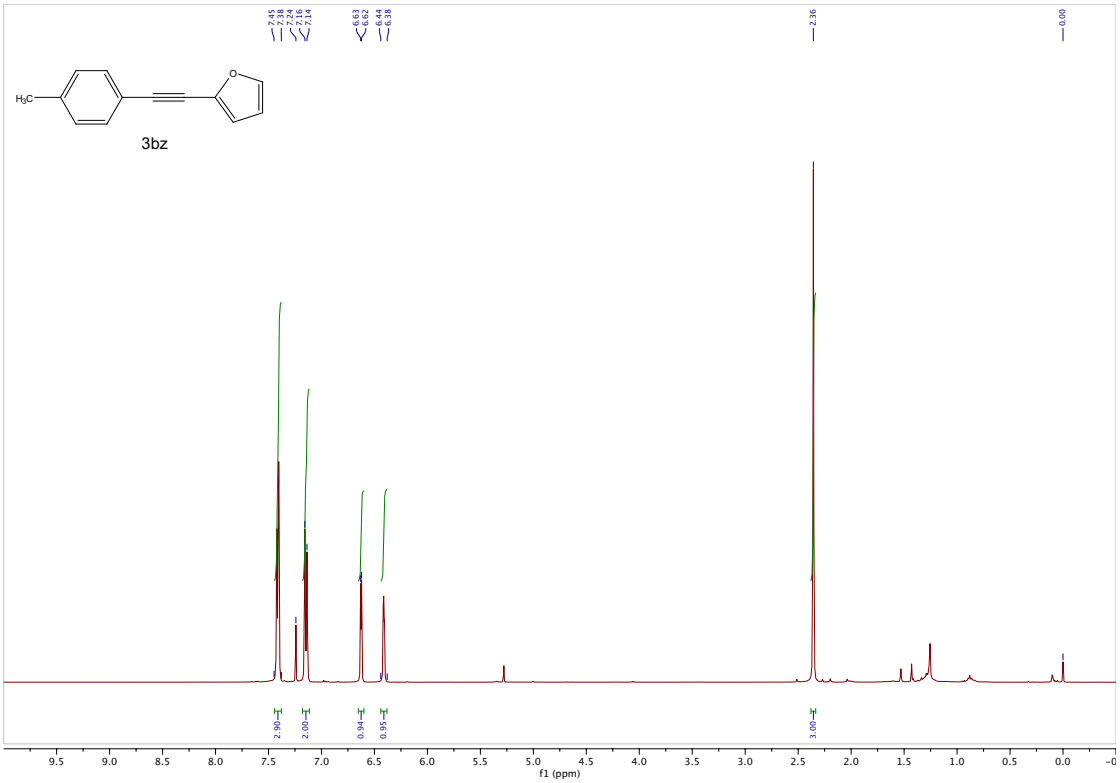
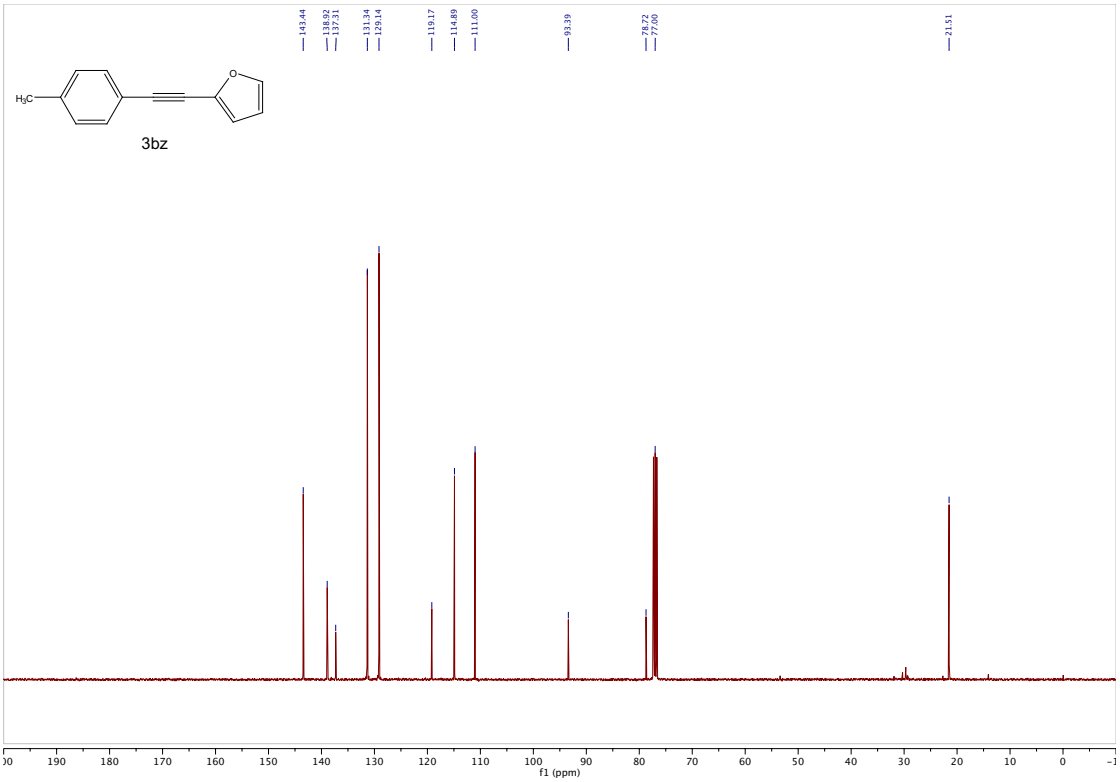
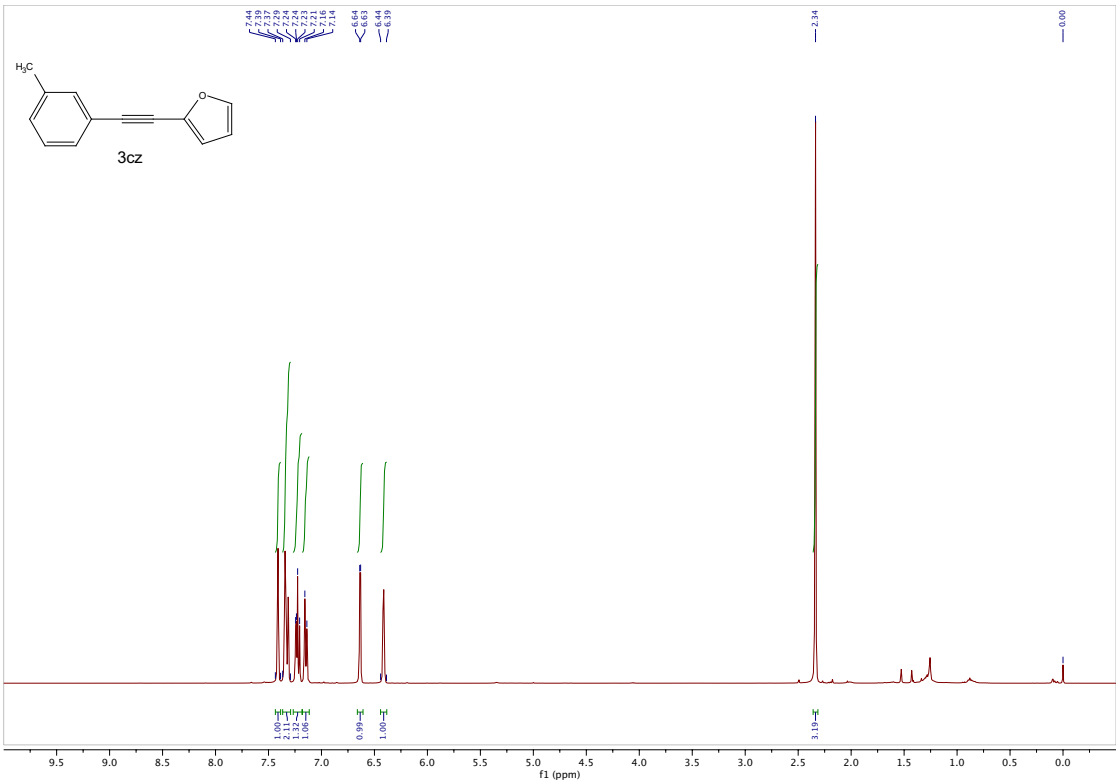
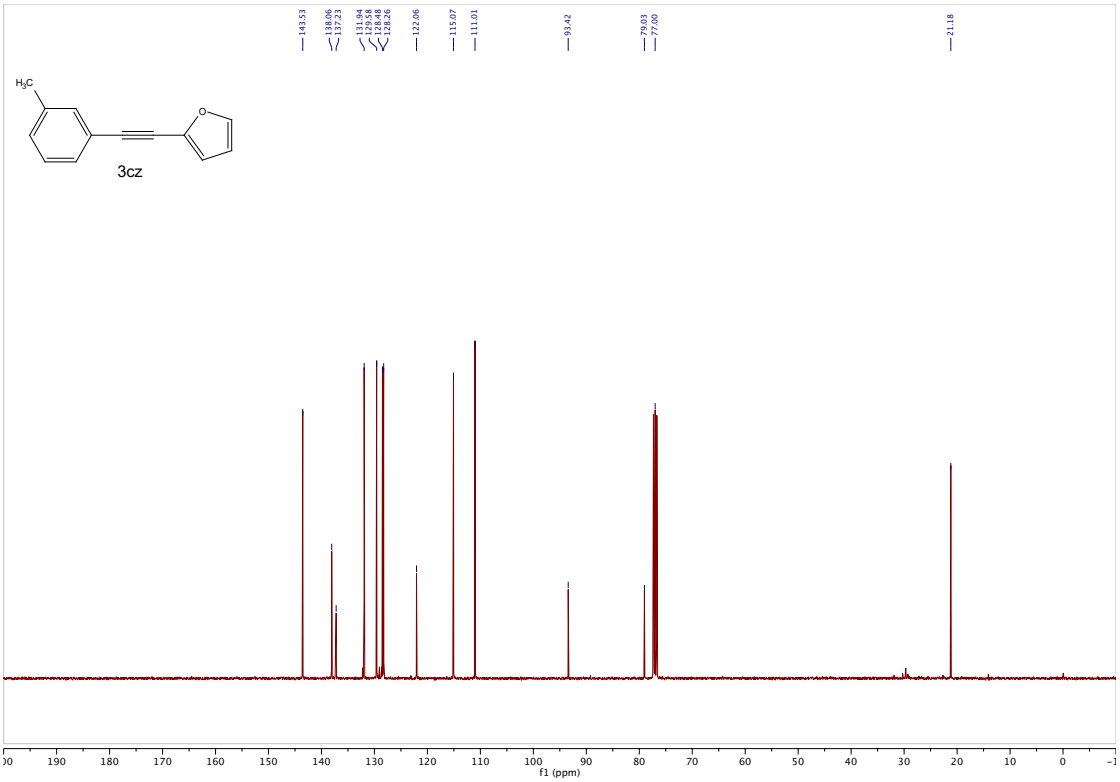
126.78
126.60
121.79
120.20
90.74
88.58
77.00
Cl
3kp
f1 (ppm)


7.45
7.38
7.34
7.16
7.14
6.63
6.62
6.44
6.38
2.36
0.00
H3C
O
3bz
2.90
2.00
0.94
0.95
3.00
f1 (ppm)


143.44
138.92
137.31
131.34
129.14
119.17
114.89
111.00
93.39
79.72
77.00
21.51
H3C
O
3bz
f1 (ppm)


7.44
7.39
7.37
7.36
7.24
7.23
7.21
7.16
7.14
6.64
6.63
6.44
6.39
2.34
0.00
H3C
O
3cz
1.00
2.11
1.32
1.06
0.99
1.00
3.19
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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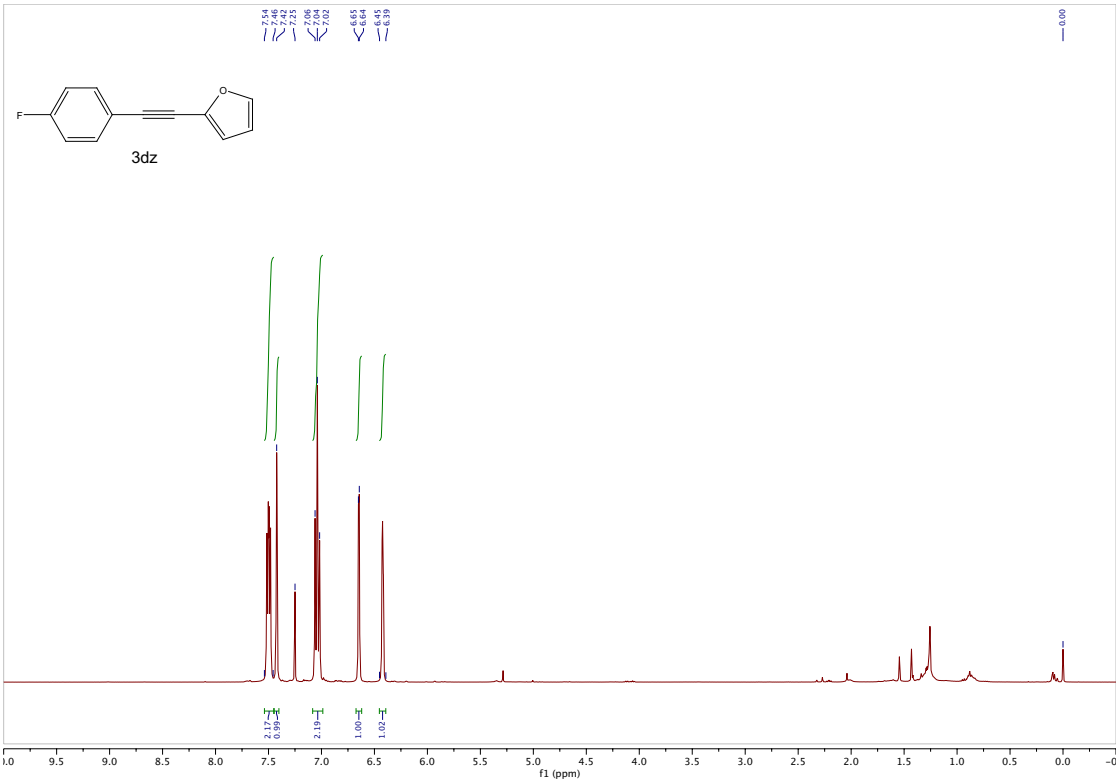
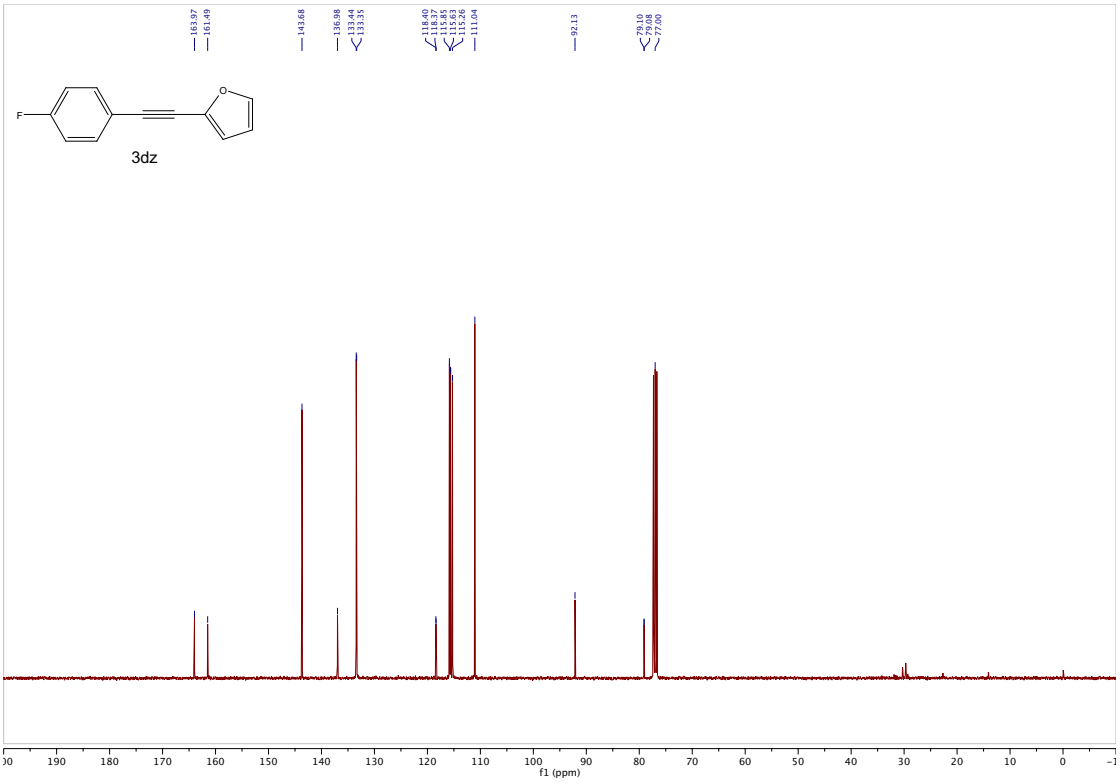
138.06
137.23
131.94
129.58
128.48
128.26
122.06
115.07
111.01
93.42
79.03
77.00
21.18
H3C
O
3cz
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.54
7.46
7.42
7.25
7.06
7.04
7.02
6.65
6.64
6.45
6.39
0.00
F
O
3dz
2.17
0.99
2.19
1.00
1.02
f1 (ppm)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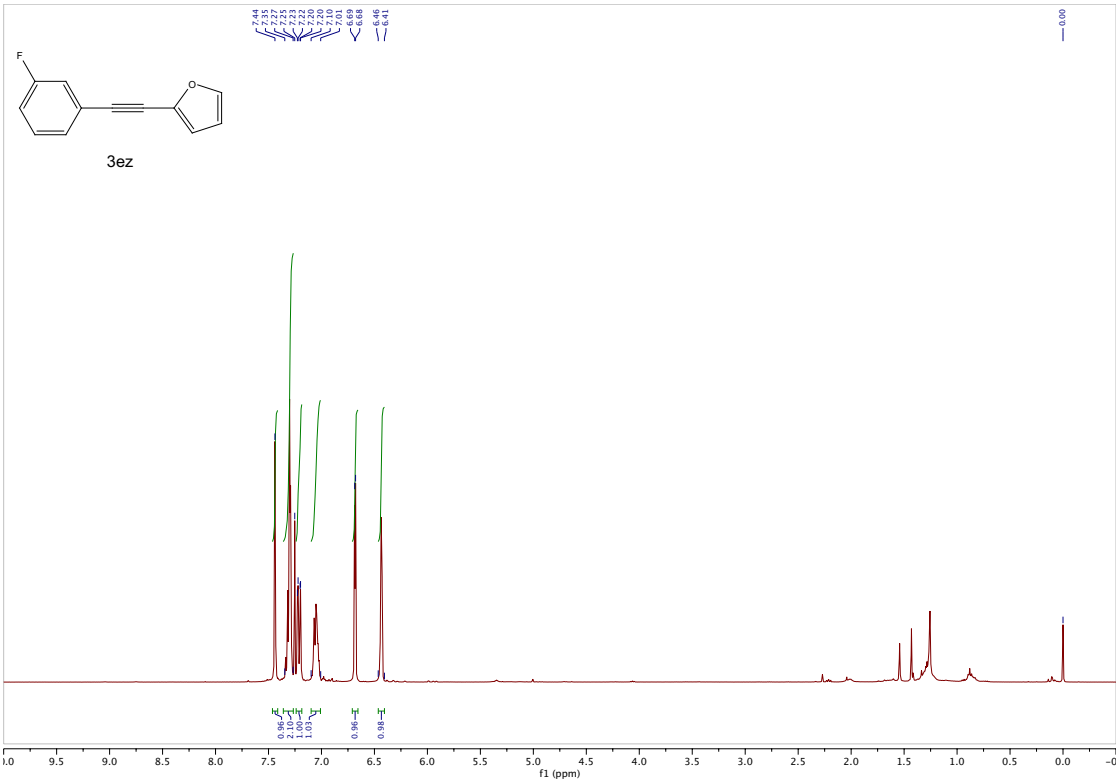
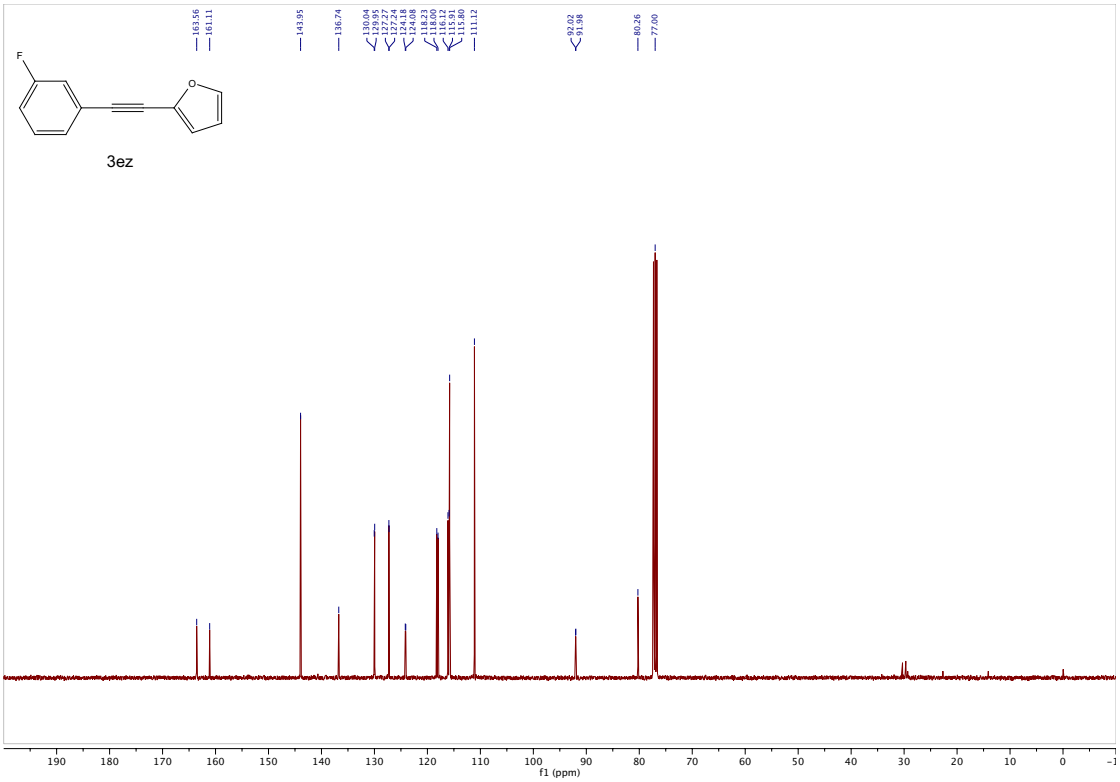
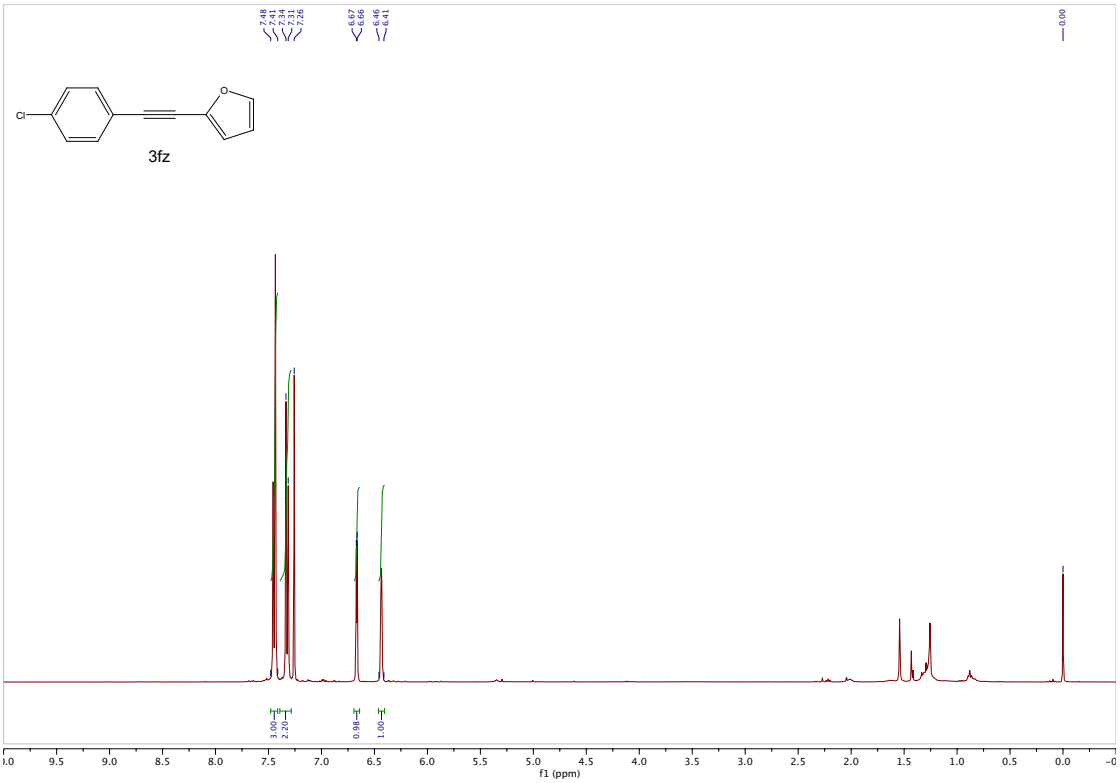
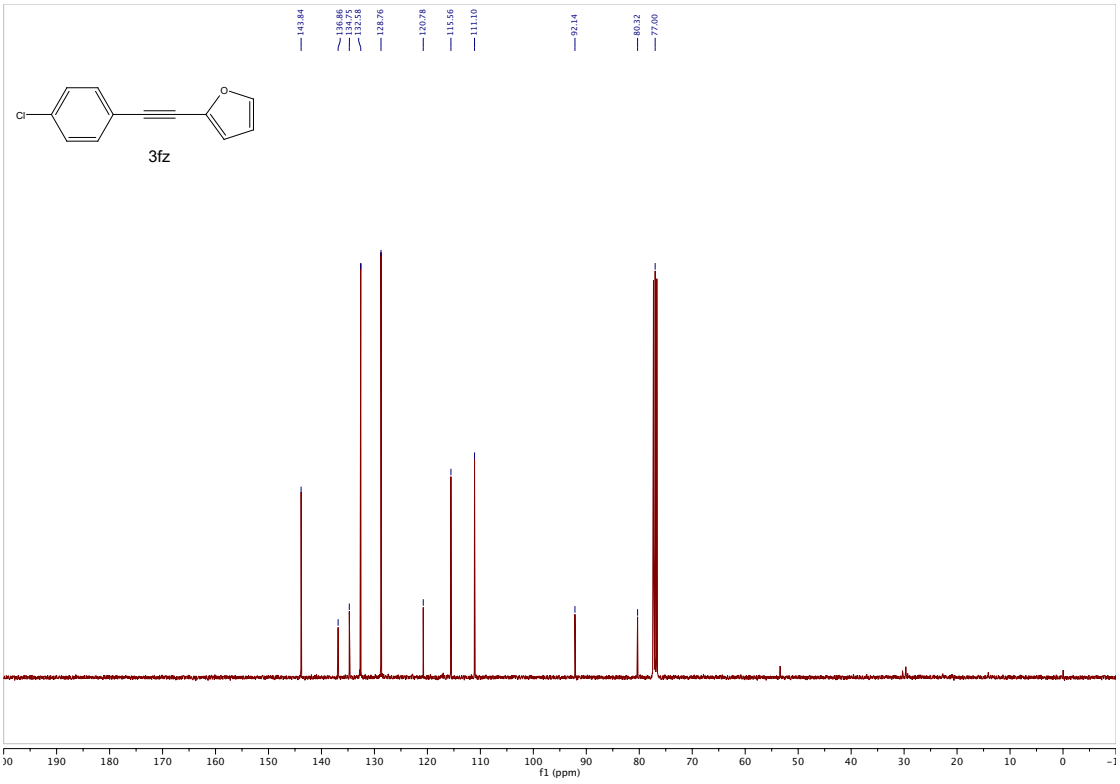
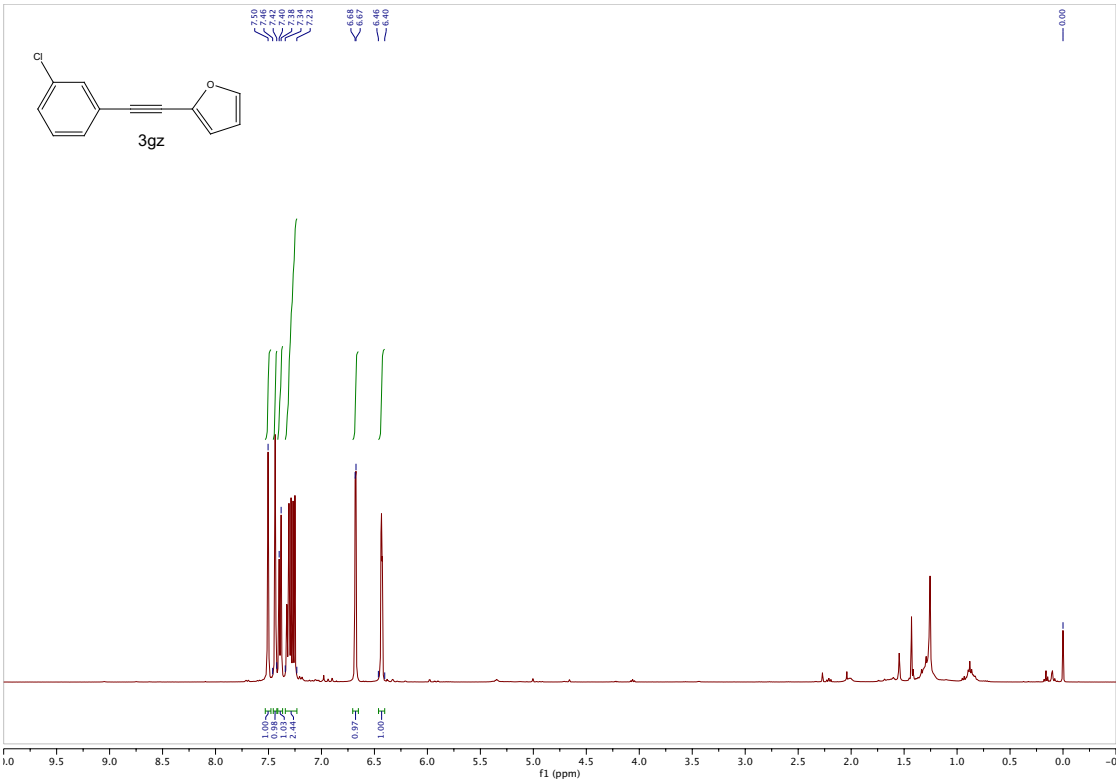
161.49
143.68
136.98
133.44
133.35
118.40
118.37
115.85
115.63
115.26
111.04
92.13
79.10
79.08
77.00
F
O
3dz
f1 (ppm)

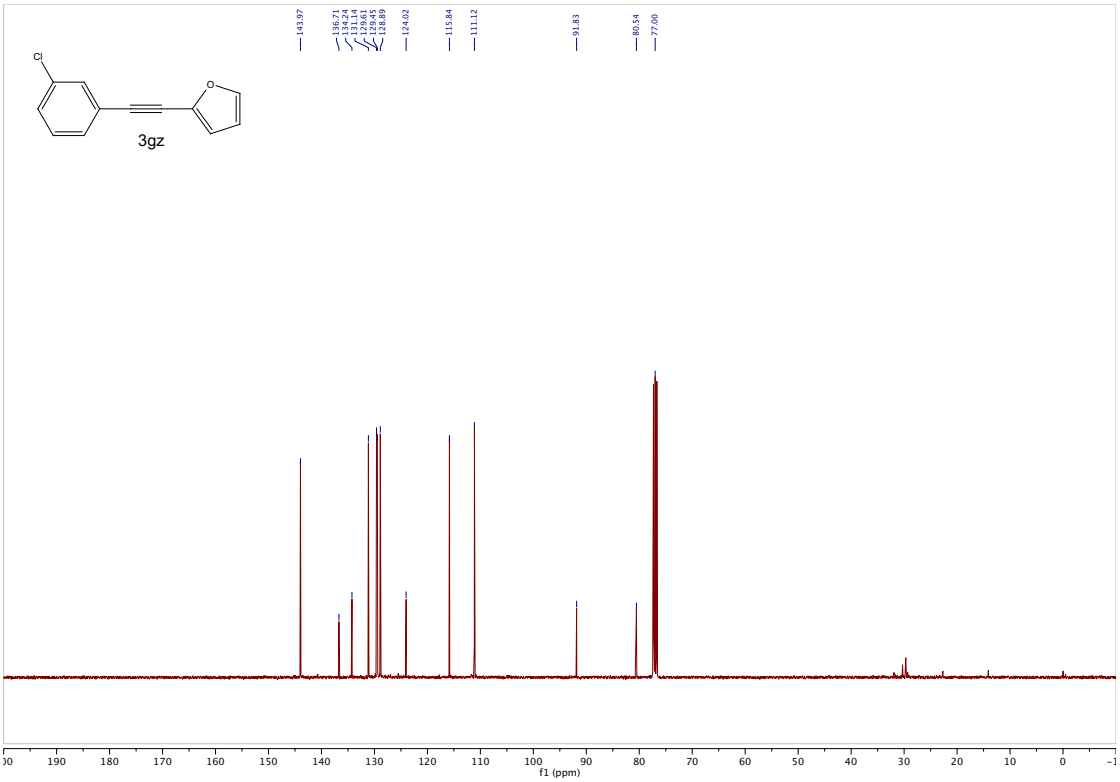

F
O
3ez
7.44
7.35
7.27
7.25
7.23
7.22
7.20
7.10
7.01
6.69
6.68
6.46
6.41
0.00
0.96
0.96
1.00
1.03
0.96
0.98
f1 (ppm)


F
O
3ez
163.56
161.11
143.95
136.74
130.04
129.95
127.32
127.24
124.18
124.08
118.23
118.00
116.12
115.91
115.80
111.12
92.02
91.98
80.26
77.00
f1 (ppm)


7.48
7.41
7.34
7.31
7.26
6.67
6.66
6.46
6.41
0.00
Cl
O
3fz
3.00
2.20
0.98
1.00
f1 (ppm)


143.84
136.86
134.75
132.58
128.76
120.78
115.56
111.10
92.14
80.32
77.00
Cl
O
3fz
f1 (ppm)


7.50
7.46
7.42
7.40
7.38
7.34
7.23
6.68
6.67
6.46
6.40
0.00
Cl
O
3gz
1.00
0.98
1.03
2.44
0.97
1.00
f1 (ppm)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136.71
134.24
131.14
129.61
129.45
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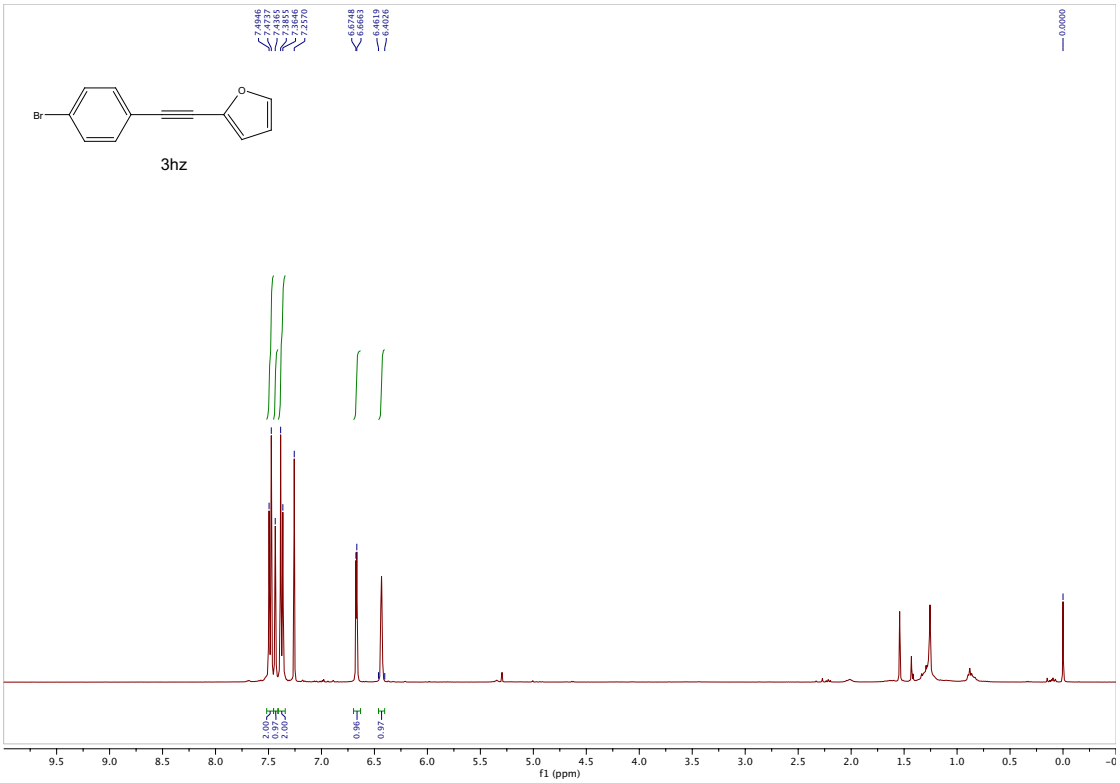
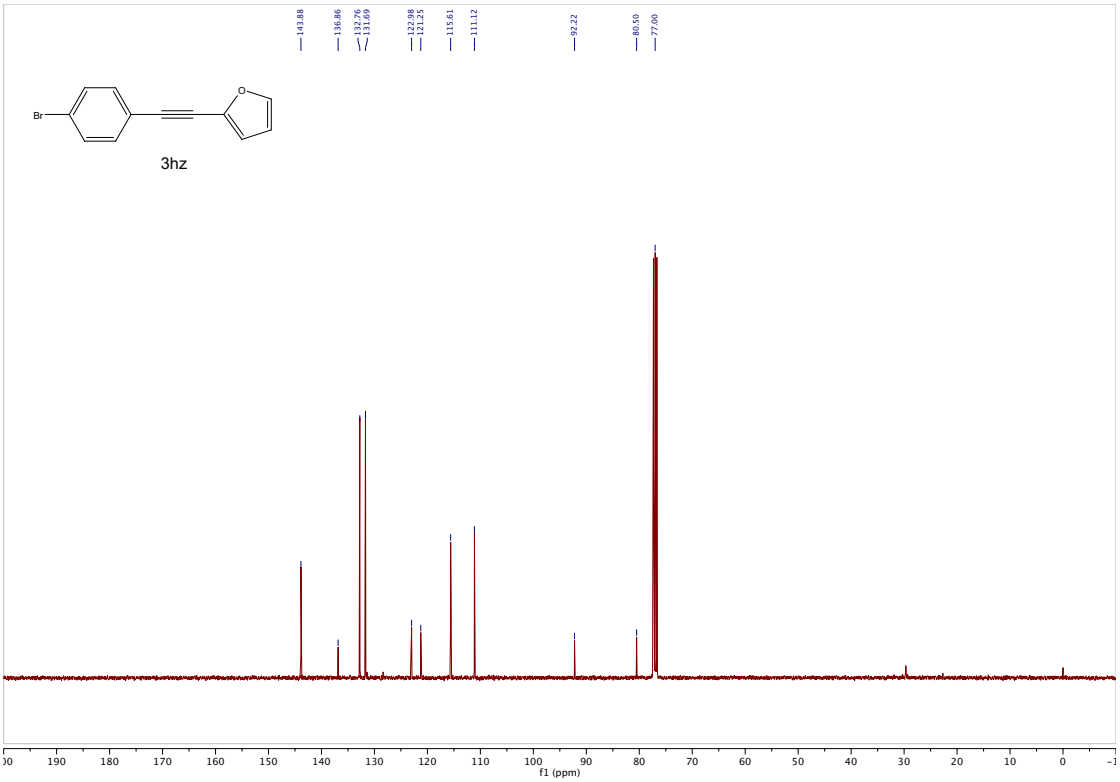
124.02
115.84
111.12
91.83
80.54
77.00
Cl
O
3gz
f1 (ppm)


7.4946
7.4737
7.3855
7.3646
7.2570
6.6748
6.6663
6.4619
6.4606
0.0000
Br
O
3hz
2.00
0.96
0.97
f1 (ppm)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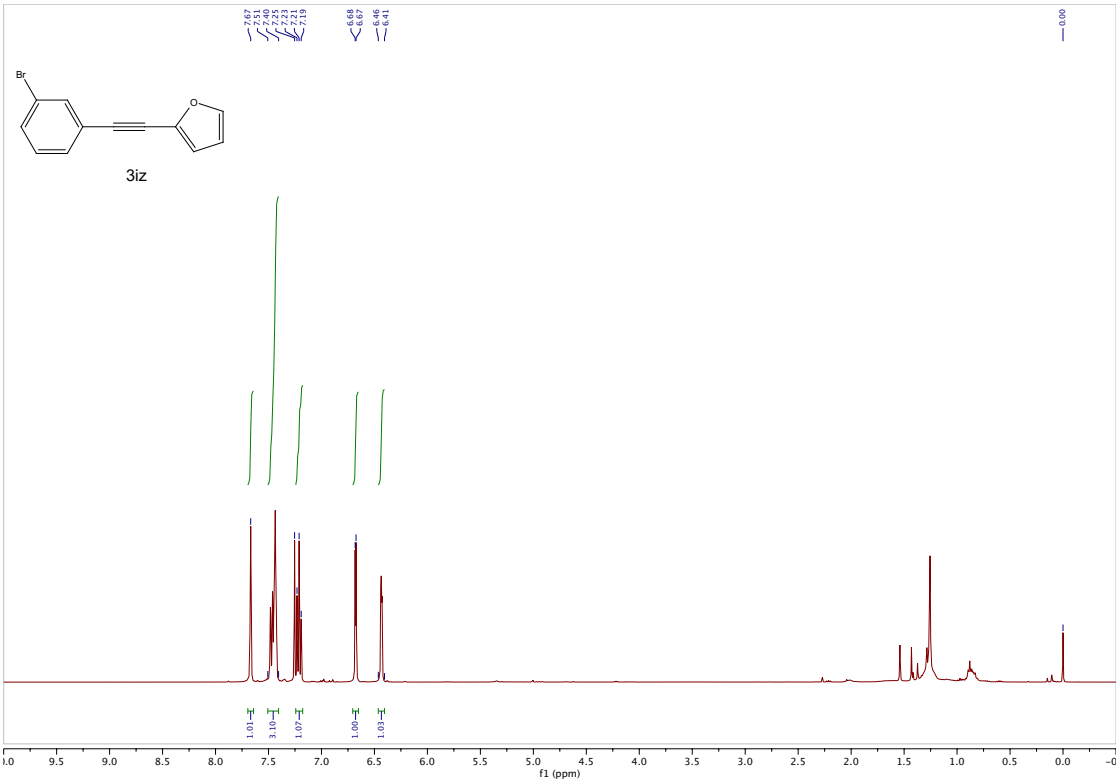
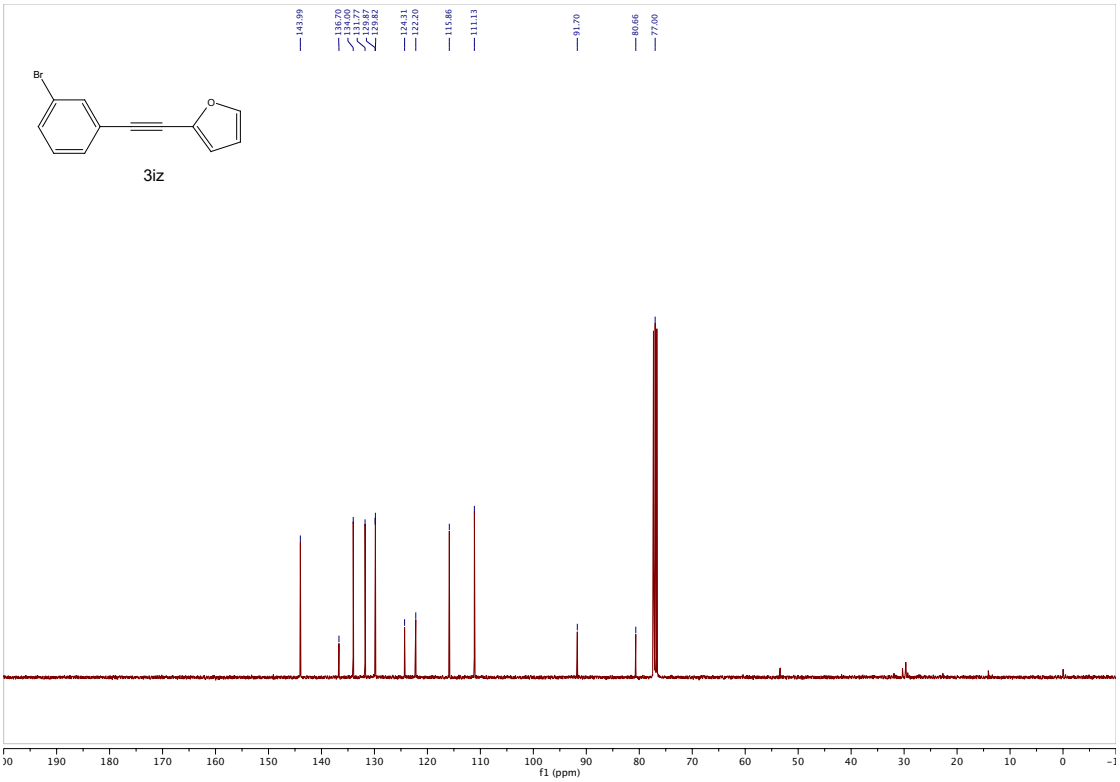
122.98
121.25
115.61
111.12
92.22
80.50
77.00
Br
O
3hz
f1 (ppm)


7.67
7.51
7.40
7.35
7.23
7.21
7.19
6.68
6.67
6.46
6.41
0.00
Br
O
3iz
1.01
3.10
1.07
1.00
1.03
f1 (ppm)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134.09
131.77
129.87
129.82
124.31
122.20
115.86
111.13
91.70
80.66
77.00
Br
O
3iz
f1 (ppm)