Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information for:

Alkynyl-induced construction of stereodefined polysubstituted conjugated enynes via Pd-catalyzed allylic arylations

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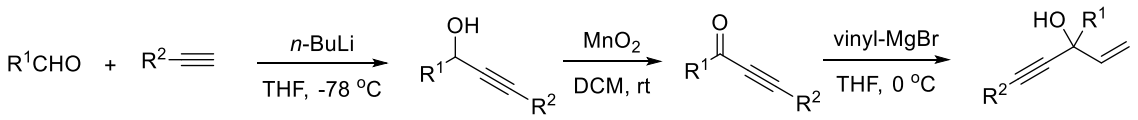
Contents:

General comments:

Commercially available arylboronic acids (derivatives) and solvents were purchased from Energy J&K, TCI and used without further purification. In the screening phase, the internal standard 2-methylnaphthalene was added after the reaction was finished. And then, an aliquot of the resulting mixture was taken and the yield was determined by means of ^{1}H NMR spectroscopy using $CDCl_3$ as solvent. ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra were recorded at room temperature on a Bruker AV-400 spectrometer and referenced to the residual deuterated solvent signals. All reported NMR values are given in parts per million (ppm). FT-IR measurements were carried out on a Thermo Fisher Nicolet 6700 FT-IR spectrometer or Bruker ALPHA II. High resolution mass spectra (HRMS) were obtained on a WATERS I-Class VION IMS Qtof Spectrometer. The X-ray analysis of **3an** was collected at 100 K on a Rigaku Oxford Diffraction Supernova Dual Source, Cu at Zero equipped with an AtlasS2 CCD using Cu Kα radiation.

Typical procedure for the preparation of alkynols

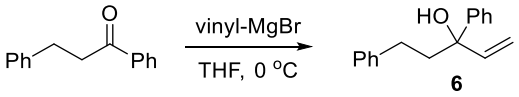


Step 1: To a solution of alkyne (20 mmol) in anhydrous THF (30 mL) was slowly added *n*-BuLi (12.5 mL, 20 mmol, 1.6 M in hexanes) at -78 ^{o}C under nitrogen atmosphere. The reaction mixture was stirred at 0 ^{o}C for 1 h. A solution of aldehyde (20 mmol) in anhydrous THF (20 mL) was then added dropwise. The reaction mixture was stirred at 0 ^{o}C for 4 h. After the completion of the reaction, the mixture was quenched with aqueous NH_4Cl. The aqueous layer was extracted with ethyl acetate (3 $\times$ 30 mL), and the combined organic layer was washed with water and brine. After filtration of $MgSO_4$, the filtrate was concentrated under reduced pressure. The crude propargylic alcohol could be directly used in the next step without purification.

Step 2: To a stirred solution of propargylic alcohol (10 mmol) in DCM (20 mL) was added activated manganese dioxide (6.1 g, 70 mmol, 7 equiv) at room temperature. After 24 h, the reaction mixture was filtered through a Celite pad with EtOAc. The filtrate was concentrated and purified by column chromatography on silica gel to yield the corresponding ketone.

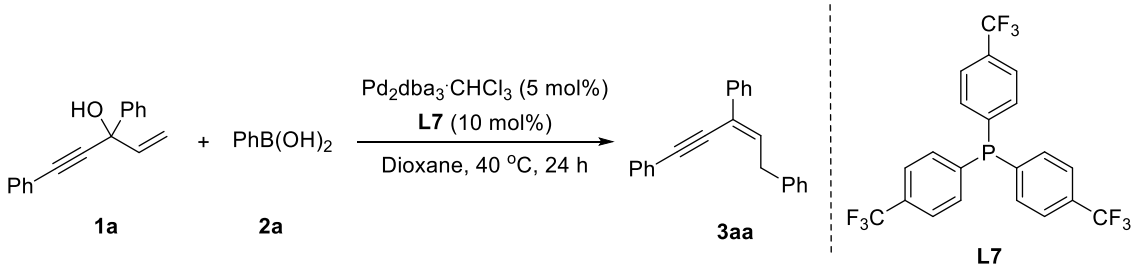
Step 3: To a solution of ketone (10 mmol) in anhydrous THF (30 mL) was slowly added vinyl Grignard reagent (15 mL, 15 mmol, 1.0 M in THF) at 0 ^{o}C under nitrogen atmosphere. The reaction mixture was stirred at 0 ^{o}C for 4 h. After the completion of the reaction, the mixture was quenched with aqueous NH_4Cl. The aqueous layer was extracted with ethyl acetate (3 $\times$ 30 mL), and the combined organic layer was washed with water and brine. After filtration of $MgSO_4$, the filtrate was concentrated under reduced pressure. Then, the residue was purified by column chromatography (hexane/EtOAc) to give the desired alkynol.

Procedure for the preparation of 6



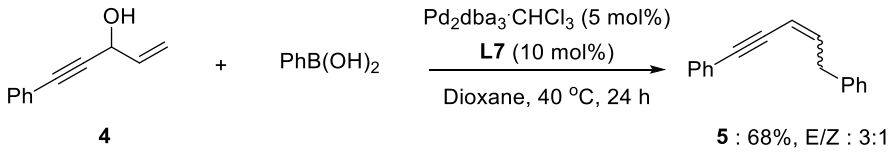
To a solution of 1,3-diphenylpropan-1-one (10 mmol) in anhydrous THF (30 mL) was slowly added vinyl Grignard reagent (15 mL, 15 mmol, 1.0 M in THF) at 0 °C under nitrogen atmosphere. The reaction mixture was stirred at 0 °C for 4 h. After the completion of the reaction, the mixture was quenched with aqueous NH_4Cl. The aqueous layer was extracted with ethyl acetate (3 × 30 mL), and the combined organic layer was washed with water and brine. After filtration of $MgSO_4$, the filtrate was concentrated under reduced pressure. Then, the residue was purified by column chromatography (hexane/EtOAc) to give the desired allylic alcohol **6**.

Typical procedure for the synthesis of 3aa

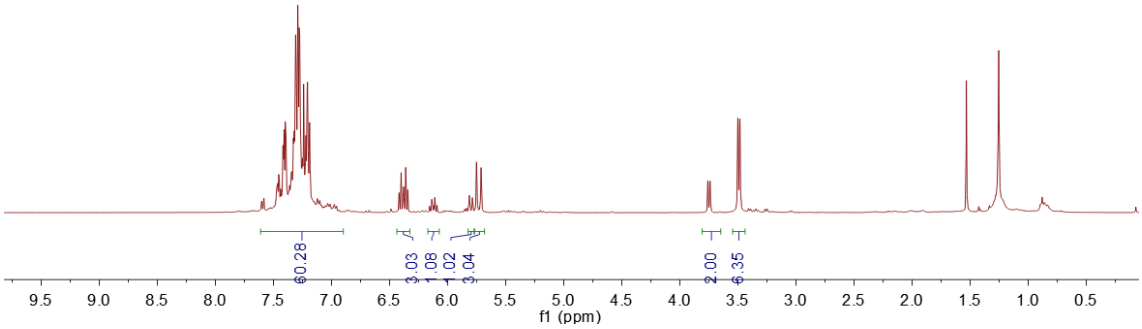


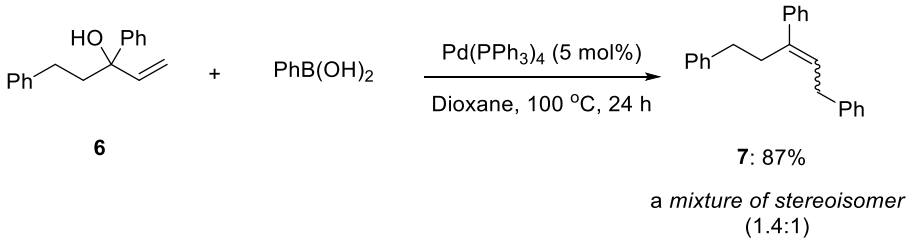
A 2 mL of screw-capped vial was charged with enynol **1a** (23.4 mg, 0.1 mmol, 1.0 equiv), phenylboronic acid **2a** (18.3 mg, 0.15 mmol, 1.5 equiv), $Pd_2(dba)_3 \cdot CHCl_3$ (5.2 mg, 0.005 mmol, 5 mol%), **L7** (4.7 mg, 0.01 mmol, 10 mol%) and 1,4-dioxane (1.0 mL). The reaction mixture was stirred at 40 °C for 24 h. Then, the pure product **3aa** was isolated (26.2 mg, 89%) from the reaction crude by flash chromatography (PE : EA = 100 : 1) as a yellow oil.

Control experiments



A 2 mL of screw-capped vial was charged with enynol **4** (15.8 mg, 0.1 mmol, 1.0 equiv), phenylboronic acid **2a** (18.3 mg, 0.15 mmol, 1.5 equiv), $Pd_2(dba)_3 \cdot CHCl_3$ (5.2 mg, 0.005 mmol, 5 mol%), **L7** (4.7 mg, 0.01 mmol, 10 mol%) and 1,4-dioxane (1.0 mL). The reaction mixture was stirred at 40 °C for 24 h. After that, the compound **5** was isolated from the reaction crude (14.8 mg, 68%) by flash chromatography (PE : EA = 100 : 1) as a yellow oil.



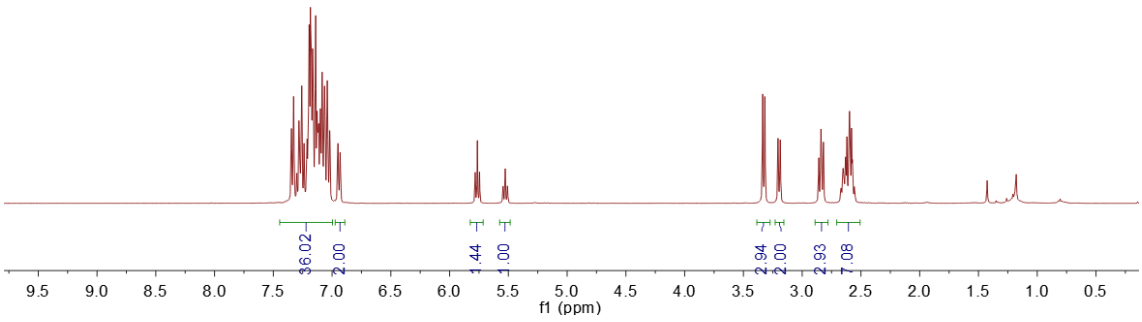


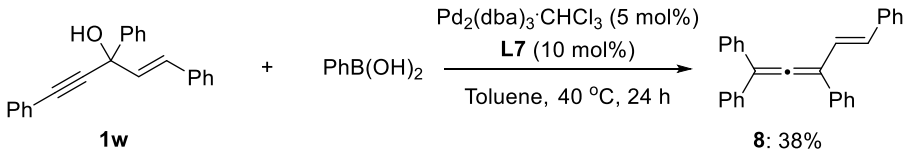
6

7: 87%

a *mixture of stereoisomer*
(1.4:1)

A 2 mL of screw-capped vial was charged with allylic alcohol **6** (23.8 mg, 0.1 mmol, 1.0 equiv), phenylboronic acid **2a** (18.3 mg, 0.15 mmol, 1.5 equiv), $Pd(PPh_3)_4$ (5.8 mg, 0.005 mmol, 5 mol%) and 1,4-dioxane (1.0 mL). The reaction mixture was stirred at 100 °C for 24 h, after which the compound **7** was isolated (25.9 mg, 87%) by flash chromatography (PE : EA = 100 : 1) as a yellow oil.





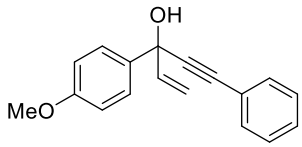
1w

8: 38%

A 2 mL of screw-capped vial was charged with alkynol **1w** (31.0 mg, 0.1 mmol, 1.0 equiv), phenylboronic acid **2a** (18.3 mg, 0.15 mmol, 1.5 equiv), $Pd_2(dba)_3 \cdot CHCl_3$ (5.2 mg, 0.005 mmol, 5 mol%), **L7** (4.7 mg, 0.01 mmol, 10 mol%) and toluene (1.0 mL). The reaction mixture was stirred at 40 °C for 24 h, after which the compound **8** was isolated (14.1 mg, 38%) by flash chromatography (PE : EA = 100 : 1) as a colorless oil.

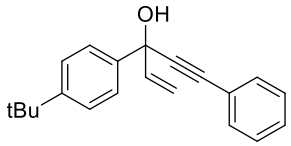
Characterization of synthesized compounds

1a, **1b**, **1e**, **1k**, **1n**, **1r**, **1s**, **1u**, **1v** and **1w** were prepared according to a reported procedure.[1]



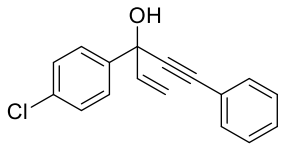
1c

3-(4-methoxyphenyl)-5-phenylpent-1-en-4-yn-3-ol (1c): Yellow oil, R_f = 0.21 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72-7.60 (m, 2H), 7.59-7.48 (m, 2H), 7.39-7.29 (m, 3H), 7.00-6.83 (m, 2H), 6.17 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.68 (d, *J* = 16.9 Hz, 1H), 5.25 (d, *J* = 10.2 Hz, 1H), 3.82 (s, 3H), 2.88 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 141.6, 135.4, 131.8, 128.7, 128.4, 127.2, 122.5, 113.7, 90.0, 87.3, 73.2, 55.4. IR (neat, cm^{-1}) 3441, 2836, 1606, 1508, 1303, 1246, 1172, 1031, 928, 832, 756, 691. HRMS (ESI): *m/z*: calcd for $C_{18}H_{15}O$ $[M\text{-}OH]^+$: 247.1123, found: 247.1125.



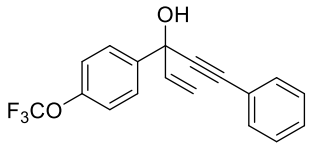
1d

3-(4-(*tert*-butyl)phenyl)-5-phenylpent-1-en-4-yn-3-ol (1d): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70-7.60 (m, 2H), 7.56-7.48 (m, 2H), 7.46-7.40 (m, 2H), 7.39-7.30 (m, 3H), 6.17 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.70 (d, *J* = 16.9 Hz, 1H), 5.25 (d, *J* = 10.2 Hz, 1H), 2.62 (s, 1H), 1.34 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.1, 141.5, 140.3, 131.9, 128.7, 128.4, 125.6, 125.5, 122.6, 113.9, 89.9, 87.4, 73.5, 34.7, 31.5. IR (neat, cm^{-1}) 3421, 2961, 2867, 1599, 1489, 1402, 1267, 1019, 928, 835, 756, 691. HRMS (ESI): *m/z*: calcd for $C_{21}H_{21}$ $[M\text{-}OH]^+$: 273.1643, found: 273.1646.



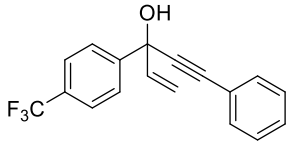
1f

3-(4-chlorophenyl)-5-phenylpent-1-en-4-yn-3-ol (1f): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70-7.60 (m, 2H), 7.55-7.47 (m, 2H), 7.40-7.31 (m, 5H), 6.12 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.70 (d, *J* = 16.9 Hz, 1H), 5.27 (d, *J* = 10.2 Hz, 1H), 2.98 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.7, 141.2, 133.8, 131.8, 128.9, 128.5, 128.5, 127.4, 122.1, 114.5, 89.3, 87.7, 73.2. IR (neat, cm^{-1}) 3405, 1595, 1487, 1402, 1091, 1014, 930, 830, 756, 690. HRMS (ESI): *m/z*: calcd for $C_{17}H_{12}Cl$ $[M\text{-}OH]^+$: 251.0628, found: 251.0627.



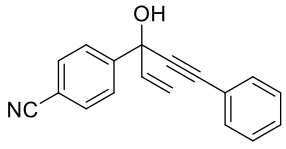
1g

5-phenyl-3-(4-(trifluoromethoxy)phenyl)pent-1-en-4-yn-3-ol (1g): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.64 (m, 2H), 7.54-7.42 (m, 2H), 7.38-7.28 (m, 3H), 7.24-7.13 (m, 2H), 6.10 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.68 (d, *J* = 16.9 Hz, 1H), 5.24 (d, *J* = 10.1 Hz, 1H), 2.88 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9 (q, *J* = 1.8 Hz), 141.9, 141.2, 131.9, 129.0, 128.5, 127.6, 122.1, 120.9, 120.6 (q, *J* = 257.2 Hz), 114.6, 89.2, 87.9, 73.2. ^{19}F NMR (376 MHz, $CDCl_3$) -57.8. IR (neat, cm^{-1}) 3363, 1598, 1503, 1253, 1209, 1155, 1018, 982, 929, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{18}H_{12}F_3O$ $[M\text{-}OH]^+$: 301.0840, found: 301.0838.



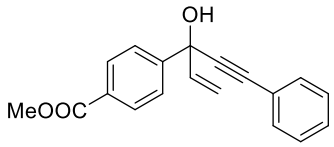
1h

5-phenyl-3-(4-(trifluoromethyl)phenyl)pent-1-en-4-yn-3-ol (1h): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (d, *J* = 8.2 Hz, 2H), 7.65 (d, *J* = 8.3 Hz, 2H), 7.56-7.47 (m, 2H), 7.44-7.31 (m, 3H), 6.13 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.74 (d, *J* = 16.9 Hz, 1H), 5.30 (d, *J* = 10.1 Hz, 1H), 3.01 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.1 (d, *J* = 1.5 Hz), 141.0, 131.9, 130.1 (q, *J* = 32.3 Hz), 129.1, 128.5, 126.4, 125.5 (q, *J* = 3.7 Hz), 124.2 (q, *J* = 272.1 Hz), 122.0, 115.0, 89.0, 88.1, 73.4. ^{19}F NMR (376 MHz, $CDCl_3$) -62.4. IR (neat, cm^{-1}) 3352, 1618, 1410, 1332, 1121, 1066, 1017, 842, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{18}H_{12}F_3$ $[M\text{-}OH]^+$: 285.0891, found: 285.0888.



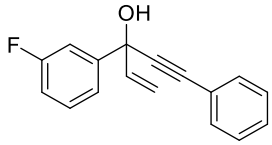
1i

4-(3-hydroxy-5-phenylpent-1-en-4-yn-3-yl)benzonitrile (1i): Yellow oil, R_f = 0.18 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (d, *J* = 8.2 Hz, 2H), 7.60 (d, *J* = 8.2 Hz, 2H), 7.51-7.43 (m, 2H), 7.39-7.28 (m, 3H), 6.08 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.72 (d, *J* = 16.9 Hz, 1H), 5.28 (d, *J* = 10.1 Hz, 1H), 3.61 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.4, 140.6, 132.1, 131.7, 128.9, 128.4, 126.6, 121.8, 118.7, 115.1, 111.3, 88.6, 88.0, 73.0. IR (neat, cm^{-1}) 3422, 2229, 1604, 1489, 1403, 1020, 930, 840, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{18}H_{12}N$ $[M\text{-}OH]^+$: 242.0970, found: 242.0969.



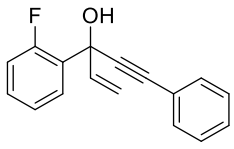
1j

methyl 4-(3-hydroxy-5-phenylpent-1-en-4-yn-3-yl)benzoate (1j): White solid, R_f = 0.18 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.12-7.97 (m, 2H), 7.83-7.67 (m, 2H), 7.60-7.44 (m, 2H), 7.43-7.27 (m, 3H), 6.12 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.70 (d, *J* = 16.9 Hz, 1H), 5.26 (d, *J* = 10.2 Hz, 1H), 3.91 (s, 3H), 2.99 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 148.1, 141.1, 131.9, 129.8, 129.7, 128.9, 128.5, 126.0, 122.2, 114.8, 89.2, 87.9, 73.4, 52.3. IR (neat, cm^{-1}) 3439, 2952, 1704, 1608, 1438, 1280, 1113, 1019, 932, 757, 691. HRMS (ESI): *m/z*: calcd for $C_{19}H_{15}O_2$ $[M\text{-}OH]^+$: 275.1072, found: 275.1080.



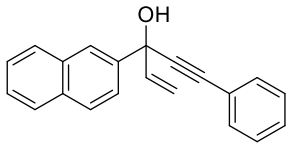
1l

3-(3-fluorophenyl)-5-phenylpent-1-en-4-yn-3-ol (1l): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54-7.37 (m, 4H), 7.36-7.26 (m, 4H), 6.98 (td, *J* = 8.3, 2.2 Hz, 1H), 6.09 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.68 (d, *J* = 16.9 Hz, 1H), 5.24 (d, *J* = 10.1 Hz, 1H), 2.83 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8 (d, *J* = 245.8 Hz), 145.8 (d, *J* = 6.9 Hz), 141.1, 131.9, 130.0 (d, *J* = 8.1 Hz), 128.9, 128.5, 122.1, 121.6 (d, *J* = 2.9 Hz), 114.9 (d, *J* = 21.2 Hz), 114.6, 113.2 (d, *J* = 23.2 Hz), 89.2, 87.7, 73.2 (d, *J* = 2.1 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) -112.5. IR (neat, cm^{-1}) 3381, 1612, 1590, 1484, 1441, 1233, 1028, 855, 781, 755, 690. HRMS (ESI): *m/z*: calcd for $C_{17}H_{12}F$ $[M\text{-}OH]^+$: 235.0923, found: 235.0925.



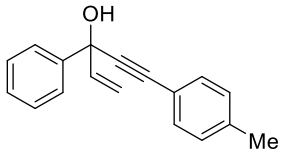
1m

3-(2-fluorophenyl)-5-phenylpent-1-en-4-yn-3-ol (1m): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (td, *J* = 7.9, 1.7 Hz, 1H), 7.58-7.47 (m, 2H), 7.39-7.29 (m, 4H), 7.21-7.04 (m, 2H), 6.30 (dd, *J* = 16.9, 10.2 Hz, 1H), 5.70 (d, *J* = 17.0 Hz, 1H), 5.32 (d, *J* = 10.2 Hz, 1H), 2.96 (d, *J* = 3.1 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.4 (d, *J* = 249.1 Hz), 139.5 (d, *J* = 1.4 Hz), 131.9, 130.1 (d, *J* = 10.3 Hz), 130.1 (d, *J* = 8.6 Hz), 128.8, 128.4, 127.5 (d, *J* = 3.0 Hz), 124.1 (d, *J* = 3.6 Hz), 122.4, 116.5 (d, *J* = 22.0 Hz), 115.3 (d, *J* = 1.3 Hz), 88.6, 87.2 (d, *J* = 1.8 Hz), 71.5. ^{19}F NMR (376 MHz, $CDCl_3$) -111.9. IR (neat, cm^{-1}) 3408, 1582, 1486, 1452, 1221, 1021, 932, 754, 690. HRMS (ESI): *m/z*: calcd for $C_{17}H_{12}F$ $[M\text{-}OH]^+$: 235.0923, found: 235.0926.



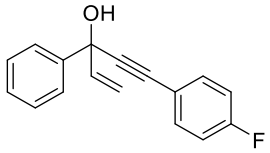
1o

3-(naphthalen-2-yl)-5-phenylpent-1-en-4-yn-3-ol (1o): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.27 (s, 1H), 7.99-7.76 (m, 4H), 7.65-7.51 (m, 4H), 7.44-7.32 (m, 3H), 6.30 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.83 (d, *J* = 16.6 Hz, 1H), 5.35 (d, *J* = 10.2 Hz, 1H), 3.07 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.3, 140.4, 133.1, 133.0, 131.9, 128.8, 128.5, 128.4, 128.3, 127.6, 126.3, 126.3, 124.4, 124.3, 122.4, 114.5, 89.8, 87.7, 73.7. IR (neat, cm^{-1}) 3382, 1598, 1488, 1354, 1268, 1119, 1019, 927, 747, 688. HRMS (ESI): *m/z*: calcd for $C_{21}H_{15}$ $[M\text{-}OH]^+$: 267.1174, found: 267.1175.



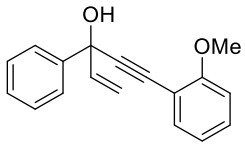
1p

3-phenyl-5-(*p*-tolyl)pent-1-en-4-yn-3-ol (1p): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): 7.80-7.67 (m, 2H), 7.47-7.37 (m, 4H), 7.35-7.30 (m, 1H), 7.15 (d, *J* = 7.9 Hz, 2H), 6.16 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.69 (d, *J* = 16.9 Hz, 1H), 5.24 (d, *J* = 10.2 Hz, 1H), 2.67 (s, 1H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 141.6, 139.0, 131.8, 129.2, 128.5, 128.1, 125.9, 119.4, 114.0, 89.1, 87.7, 73.7, 21.7. IR (neat, cm^{-1}) 3435, 3028, 1602, 1510, 1448, 1029, 930, 817, 767, 699. HRMS (ESI): *m/z*: calcd for $C_{18}H_{15}$ $[M\text{-}OH]^+$: 231.1174, found: 231.1172.



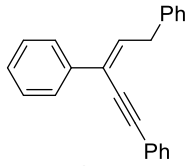
1q

5-(4-fluorophenyl)-3-phenylpent-1-en-4-yn-3-ol (1q): Yellow oil, R_f = 0.34 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): 7.77-7.68 (m, 2H), 7.55-7.32 (m, 5H), 7.11-6.97 (m, 2H), 6.18 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.70 (d, *J* = 16.9 Hz, 1H), 5.27 (d, *J* = 10.1 Hz, 1H), 2.89 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.8 (d, *J* = 249.9 Hz), 143.1, 141.5, 133.8 (d, *J* = 8.4 Hz), 128.5, 128.1, 125.9, 118.5 (d, *J* = 3.4 Hz), 115.7 (d, *J* = 22.0 Hz), 114.1, 89.6 (d, *J* = 1.4 Hz), 86.4, 73.6. ^{19}F NMR (376 MHz, $CDCl_3$) -110.2. IR (neat, cm^{-1}) 3408, 1600, 1505, 1448, 1221, 1155, 928, 834, 769, 697. HRMS (ESI): *m/z*: calcd for $C_{17}H_{12}F$ $[M\text{-}OH]^+$: 235.0923, found: 235.0922.



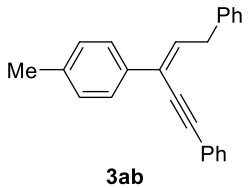
1t

5-(2-methoxyphenyl)-3-phenylpent-1-en-4-yn-3-ol (1t): Yellow oil, R_f = 0.21 (EA/PE = 1:5). ^{1}H NMR (400 MHz, $CDCl_3$): 7.83-7.71 (m, 2H), 7.49-7.28 (m, 5H), 6.97-6.86 (m, 2H), 6.16 (dd, *J* = 16.9, 10.1 Hz, 1H), 5.78 (d, *J* = 16.9 Hz, 1H), 5.24 (d, *J* = 10.2 Hz, 1H), 3.88 (s, 3H), 2.87 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.4, 143.4, 141.7, 133.6, 130.2, 128.4, 128.0, 126.1, 120.5, 114.1, 111.7, 110.7, 93.8, 84.0, 73.9, 55.9. IR (neat, cm^{-1}) 3436, 1597, 1491, 1452, 1262, 1022, 931, 752, 700. HRMS (ESI): *m/z*: calcd for $C_{18}H_{15}O$ $[M\text{-}OH]^+$: 247.1123, found: 247.1121.



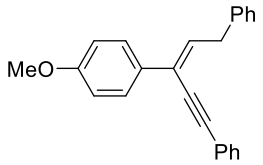
3aa

(*Z*)-pent-3-en-1-yne-1,3,5-triyltribenzene (3aa): Yellow oil (26.2 mg, 89% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, *J* = 7.6 Hz, 2H), 7.61-7.49 (m, 2H), 7.39-7.25 (m, 10H), 7.25-7.18 (m, 1H), 6.59 (t, *J* = 7.6 Hz, 1H), 3.93 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.1, 138.1, 136.5, 131.8, 128.8, 128.8, 128.5, 128.5, 127.9, 126.4, 126.3, 124.3, 123.5, 95.5, 86.9, 37.8. IR (neat, cm^{-1}) 3059, 3027, 1598, 1490, 1446, 1360, 1070, 1028, 754, 691. HRMS (ESI): *m/z*: calcd for $C_{23}H_{19}$ $[M+H]^+$: 295.1487, found: 295.1488.



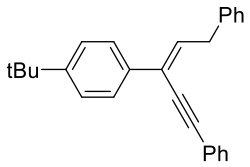
3ab

(*Z*)-(3-(p-tolyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ab): Yellow oil (24.9 mg, 81% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68-7.50 (m, 4H), 7.43-7.30 (m, 7H), 7.26-7.21 (m, 1H), 7.18 (d, *J* = 7.9 Hz, 2H), 6.57 (t, *J* = 7.6 Hz, 1H), 3.94 (d, *J* = 7.6 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.2, 137.7, 135.6, 135.3, 131.7, 129.2, 128.8, 128.7, 128.5, 128.4, 126.4, 126.2, 124.1, 123.6, 95.3, 87.1, 37.8, 21.3. IR (neat, cm^{-1}) 3060, 2923, 1730, 1667, 1511, 1491, 1452, 1268, 1178, 1026, 818, 756. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1642.



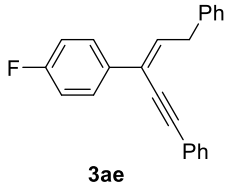
3ac

(*Z*)-(3-(4-methoxyphenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ac): Yellow oil (24.3 mg, 75% yield), R_f = 0.34 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69-7.61 (m, 2H), 7.60-7.54 (m, 2H), 7.44-7.30 (m, 7H), 7.26-7.21 (m, 1H), 6.91 (d, *J* = 8.9 Hz, 2H), 6.51 (t, *J* = 7.6 Hz, 1H), 3.94 (d, *J* = 7.6 Hz, 2H), 3.84 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.5, 140.3, 134.7, 131.7, 130.7, 128.8, 128.7, 128.5, 128.4, 127.4, 126.4, 123.7, 123.6, 113.9, 95.3, 87.1, 55.5, 37.8. IR (neat, cm^{-1}) 3028, 2836, 1605, 1509, 1490, 1293, 1248, 1177, 1032, 832, 755, 692. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}O$ $[M+H]^+$: 325.1592, found: 325.1594.



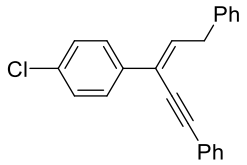
3ad

(*Z*)-(3-(4-(tert-butyl)phenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ad): Yellow oil (29.1 mg, 83% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (d, *J* = 8.4 Hz, 2H), 7.61-7.52 (m, 2H), 7.48-7.29 (m, 9H), 7.27-7.23 (m, 1H), 6.67-6.52 (m, 1H), 3.96 (d, *J* = 7.6 Hz, 2H), 1.36 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.0, 140.2, 135.8, 135.2, 131.8, 128.8, 128.7, 128.5, 128.4, 126.4, 126.0, 125.5, 124.1, 123.6, 95.3, 87.1, 37.8, 34.7, 31.5. IR (neat, cm^{-1}) 3028, 2961, 2903, 1601, 1490, 1453, 1362, 1268, 1111, 1027, 836, 753, 690. HRMS (ESI): *m/z*: calcd for $C_{27}H_{27}$ $[M+H]^+$: 351.2113, found: 351.2117.



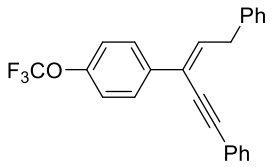
3ae

(*Z*)-(3-(4-fluorophenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ae): Yellow oil (20.9 mg, 67% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73-7.62 (m, 2H), 7.61-7.49 (m, 2H), 7.46-7.30 (m, 7H), 7.26-7.22 (m, 1H), 7.06 (t, *J* = 8.7 Hz, 2H), 6.54 (t, *J* = 7.6 Hz, 1H), 3.93 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6 (d, *J* = 247.1 Hz), 139.9, 136.3, 134.2, 134.1, 131.8, 128.8, 128.6, 128.6, 127.9 (d, *J* = 8.0 Hz), 126.5, 123.3 (d, *J* = 3.1Hz), 115.4 (d, *J* = 21.6 Hz), 95.6, 86.7, 37.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.7. IR (neat, cm^{-1}) 3061, 3029, 2924, 1600, 1506, 1491, 1453, 1228, 1158, 835, 754, 690. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1394.



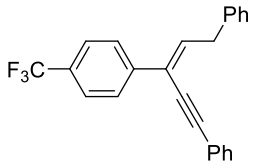
3af

(*Z*)-(3-(4-chlorophenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3af): Yellow oil (19.1 mg, 58% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65-7.58 (m, 2H), 7.56-7.51 (m, 2H), 7.39-7.28 (m, 9H), 7.26-7.20 (m, 1H), 6.56 (t, *J* = 7.6 Hz, 1H), 3.91 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.8, 136.9, 136.5, 133.6, 131.8, 128.8, 128.7, 128.6, 127.6, 126.5, 123.3, 123.2, 95.8, 86.4, 37.9. IR (neat, cm^{-1}) 3029, 2923, 1662, 1596, 1489, 1453, 1403, 1092, 1014, 831, 793, 698. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}Cl$ $[M+H]^+$: 329.1097, found: 329.1099.



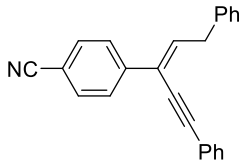
3ag

(*Z*)-(3-(4-(trifluoromethoxy)phenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ag): Yellow oil (21.2 mg, 56% yield), R_f = 0.50 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78-7.67 (m, 2H), 7.61-7.52 (m, 2H), 7.43-7.30 (m, 7H), 7.26-7.17 (m, 3H), 6.59 (t, *J* = 7.6 Hz, 1H), 3.95 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9 (d, *J* = 2.1 Hz), 139.7, 137.3, 136.8, 131.8, 128.8, 128.8, 128.7, 128.6, 127.6, 126.6, 123.2, 123.1, 121.0, 120.6 (q, *J* = 257.2 Hz), 95.9, 86.4, 37.9. IR (neat, cm^{-1}) 3030, 2925, 1599, 1507, 1491, 1252, 1207, 1161, 850, 754, 690. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}F_3O$ $[M+H]^+$: 379.1310, found: 379.1306.



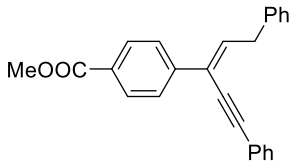
3ah

(*Z*)-(3-(4-(trifluoromethyl)phenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ah): Yellow oil (19.9 mg, 55% yield), R_f = 0.45 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (d, *J* = 8.0 Hz, 2H), 7.62 (d, *J* = 8.2 Hz, 2H), 7.60-7.52 (m, 2H), 7.45-7.30 (m, 7H), 7.26 (s, 1H), 6.68 (t, *J* = 7.6 Hz, 1H), 3.97 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.5, 139.5, 138.5, 131.8, 129.8 (q, *J* = 32.5 Hz), 128.9, 128.8, 128.8, 128.6, 126.6, 126.6, 125.5 (q, *J* = 3.7 Hz), 124.3 (q, *J* = 271.9 Hz), 123.4, 123.1, 96.1, 86.1, 37.9. IR (neat, cm^{-1}) 3030, 2925, 1618, 1491, 1322, 1165, 1121, 1067, 1017, 843, 754, 689. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}F_3$ $[M+H]^+$: 363.1361, found: 363.1361.



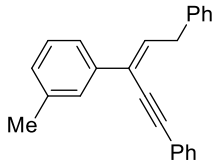
3ai

(*Z*)-4-(1,5-diphenylpent-3-en-1-yn-3-yl)benzonitrile (3ai): Yellow oil (17.2 mg, 54% yield), R_f = 0.21 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (d, *J* = 8.5 Hz, 2H), 7.65 (d, *J* = 8.5 Hz, 2H), 7.61-7.53 (m, 2H), 7.43-7.30 (m, 7H), 7.26 (s, 1H), 6.71 (t, *J* = 7.6 Hz, 1H), 3.96 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.4, 139.5, 139.2, 132.4, 131.8, 128.9, 128.9, 128.8, 128.6, 126.8, 126.7, 123.1, 122.9, 119.0, 111.2, 96.5, 85.5, 38.0. IR (neat, cm^{-1}) 3029, 2924, 2226, 1603, 1491, 1453, 1410, 1261, 1028, 841, 755, 691. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}N$ $[M+H]^+$: 320.1439, found: 320.1435.



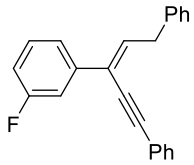
3aj

methyl (*Z*)-4-(1,5-diphenylpent-3-en-1-yn-3-yl)benzoate (3aj): Yellow oil (26.8 mg, 76% yield), R_f = 0.24 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (d, *J* = 8.5 Hz, 2H), 7.76 (d, *J* = 8.5 Hz, 2H), 7.66-7.52 (m, 2H), 7.47-7.30 (m, 7H), 7.26 (d, *J* = 1.8 Hz, 1H), 6.72 (t, *J* = 7.6 Hz, 1H), 3.97 (d, *J* = 7.6 Hz, 2H), 3.93 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 142.4, 139.6, 138.5, 131.8, 129.9, 129.4, 128.8, 128.8, 128.7, 128.6, 126.6, 126.2, 123.6, 123.2, 96.0, 86.2, 52.2, 37.9. IR (neat, cm^{-1}) 2950, 2924, 1717, 1605, 1490, 1434, 1274, 1184, 1108, 1018, 857, 754, 692. HRMS (ESI): *m/z*: calcd for $C_{25}H_{21}O_2$ $[M+H]^+$: 353.1542, found: 353.1545.



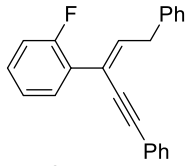
3ak

(*Z*)-(3-(m-tolyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3ak): Yellow oil (23.1 mg, 75% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61-7.55 (m, 2H), 7.54-7.49 (m, 2H), 7.42-7.31 (m, 7H), 7.28-7.22 (m, 2H), 7.13 (d, *J* = 7.6 Hz, 1H), 6.61 (t, *J* = 7.6 Hz, 1H), 3.96 (d, *J* = 7.6 Hz, 2H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.1, 138.1, 138.0, 136.4, 131.8, 128.8, 128.7, 128.6, 128.5, 128.4, 126.9, 126.4, 124.4, 123.6, 123.5, 95.3, 87.0, 37.8, 21.7. IR (neat, cm^{-1}) 3028, 2922, 1664, 1600, 1490, 1452, 1266, 1173, 1028, 783, 755, 692. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1638.



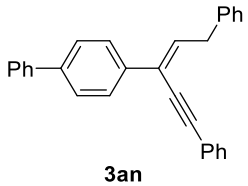
3al

(*Z*)-(3-(3-fluorophenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3al): Yellow oil (20.0 mg, 64% yield), R_f = 0.61 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57 (dd, *J* = 6.6, 3.0 Hz, 2H), 7.48 (d, *J* = 7.9 Hz, 1H), 7.43-7.28 (m, 9H), 7.28-7.22 (m, 1H), 6.99 (td, *J* = 8.3, 2.5 Hz, 1H), 6.62 (t, *J* = 7.6 Hz, 1H), 3.94 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.1 (d, *J* = 245.0 Hz), 140.3 (d, *J* = 7.7 Hz), 139.7, 137.5, 131.8, 129.9 (d, *J* = 8.3 Hz), 128.8, 128.8, 128.7, 128.6, 126.6, 123.3 (d, *J* = 2.6 Hz), 123.2, 121.8 (d, *J* = 2.8 Hz), 114.6 (d, *J* = 21.4 Hz), 113.3 (d, *J* = 22.8 Hz), 95.7, 86.3, 37.8. IR (neat, cm^{-1}) 2920, 2850, 1612, 1583, 1490, 1443, 1269, 1150, 875, 782, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1392.



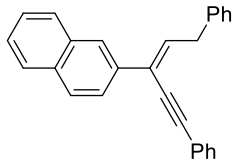
3am

(*E*)-(3-(2-fluorophenyl)pent-3-en-1-yne-1,5-diyl)dibenzene (3am): Yellow oil (11.5 mg, 37% yield), R_f = 0.61 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69-7.59 (m, 1H), 7.56-7.45 (m, 2H), 7.38-7.19 (m, 9H), 7.17-7.01 (m, 2H), 6.63 (t, *J* = 7.6 Hz, 1H), 3.95 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.1 (d, *J* = 249.8 Hz), 141.5 (d, *J* = 7.5 Hz), 139.8, 131.7, 130.5 (d, *J* = 3.1 Hz), 129.1 (d, *J* = 8.4 Hz), 128.8, 128.7, 128.5, 126.4 (d, *J* = 11.5 Hz), 126.4, 124.2 (d, *J* = 3.7 Hz), 123.4, 119.0 (d, *J* = 1.9 Hz), 116.2 (d, *J* = 22.8 Hz), 94.4, 86.9, 37.9. ^{19}F NMR (376 MHz, $CDCl_3$) δ -115.0. IR (neat, cm^{-1}) 3029, 2923, 1599, 1489, 1452, 1260, 1225, 1028, 755, 691. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1393.



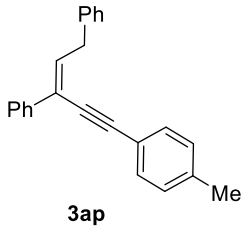
3an

(*Z*)-4-(1,5-diphenylpent-3-en-1-yn-3-yl)-1,1'-biphenyl (3an): White solid (30.3 mg, 82% yield), R_f = 0.53 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.62-7.50 (m, 6H), 7.39 (t, *J* = 7.5 Hz, 2H), 7.36-7.24 (m, 8H), 7.24-7.17 (m, 1H), 6.61 (t, *J* = 7.6 Hz, 1H), 3.93 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.7, 140.6, 140.0, 136.9, 136.4, 131.7, 128.9, 128.8, 128.7, 128.5, 128.5, 127.5, 127.2, 127.1, 126.7, 126.4, 123.9, 123.4, 95.6, 86.8, 37.8. IR (neat, cm^{-1}) 3059, 3028, 1599, 1487, 1452, 1406, 1359, 1070, 1007, 841, 755. 695. HRMS (ESI): *m/z*: calcd for $C_{29}H_{23}$ $[M+H]^+$: 371.1800, found: 371.1798.



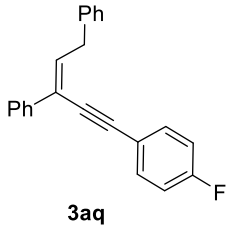
3ao

(*Z*)-2-(1,5-diphenylpent-3-en-1-yn-3-yl)naphthalene (3ao): Yellow oil (26.5 mg, 77% yield), R_f = 0.53 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.20 (s, 1H), 7.93-7.80 (m, 4H), 7.67-7.59 (m, 2H), 7.53-7.46 (m, 2H), 7.45-7.31 (m, 7H), 7.30-7.26 (m, 1H), 6.77 (t, *J* = 7.6 Hz, 1H), 4.02 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.1, 137.0, 135.3, 133.5, 133.1, 131.8, 128.9, 128.8, 128.6, 128.6, 128.4, 128.1, 127.7, 126.5, 126.4, 126.1, 125.7, 124.3, 123.9, 123.5, 95.7, 86.9, 38.0. IR (neat, cm^{-1}) 3026, 2923, 1664, 1597, 1490, 1270, 1069, 1028, 857, 816, 749, 690. HRMS (ESI): *m/z*: calcd for $C_{27}H_{21}$ $[M+H]^+$: 345.1643, found: 345.1645.



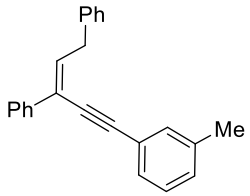
3ap

(*Z*)-(5-(p-tolyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3ap): Yellow oil (16.3 mg, 53% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, *J* = 7.6 Hz, 2H), 7.44 (d, *J* = 7.5 Hz, 2H), 7.39-7.20 (m, 8H), 7.16 (d, *J* = 7.7 Hz, 2H), 6.57 (t, *J* = 7.5 Hz, 1H), 3.93 (d, *J* = 7.5 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.1, 138.6, 138.1, 136.1, 131.6, 129.3, 128.8, 128.7, 128.5, 127.8, 126.4, 126.3, 124.4, 120.4, 95.6, 86.3, 37.8, 21.7. IR (neat, cm^{-1}) 2920, 2850, 1602, 1509, 1493, 1447, 1178, 815, 758, 696. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1645.



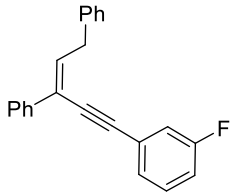
3aq

(*Z*)-(5-(4-fluorophenyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3aq): Yellow oil (22.2 mg, 71% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73-7.63 (m, 2H), 7.56-7.48 (m, 2H), 7.39-7.19 (m, 8H), 7.11-6.99 (m, 2H), 6.59 (t, *J* = 7.6 Hz, 1H), 3.91 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.7 (d, *J* = 249.8 Hz), 140.0, 138.0, 136.6, 133.6 (d, *J* = 8.4 Hz), 128.8, 128.8, 128.6, 127.9, 126.5, 126.3, 124.2, 119.6 (d, *J* = 3.5 Hz), 115.8 (d, *J* = 22.1 Hz), 94.3, 86.6, 37.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ -110.7. IR (neat, cm^{-1}) 3027, 2920, 1598, 1506, 1494, 1452, 1229, 1155, 1092, 834, 758, 696. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1396.



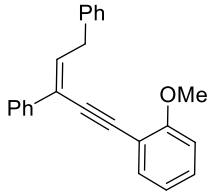
3ar

(*Z*)-(5-(m-tolyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3ar): Yellow oil (24.6 mg, 80% yield), R_f = 0.62 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75-7.64 (m, 2H), 7.41-7.21 (m, 11H), 7.17 (d, *J* = 7.8 Hz, 1H), 6.60 (t, *J* = 7.6 Hz, 1H), 3.95 (d, *J* = 7.6 Hz, 2H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.1, 138.2, 138.1, 136.4, 132.3, 129.4, 128.8, 128.8, 128.7, 128.5, 128.4, 127.8, 126.4, 126.3, 124.3, 123.3, 95.6, 86.5, 37.8, 21.4. IR (neat, cm^{-1}) 3028, 2920, 2850, 1662, 1494, 1450, 1262,1030, 784, 758, 696. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1639.



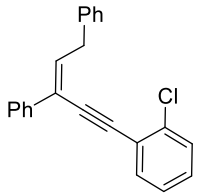
3as

(*Z*)-(5-(3-fluorophenyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3as): Yellow oil (16.8 mg, 54% yield), R_f = 0.62 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (d, *J* = 7.1 Hz, 2H), 7.41-7.26 (m, 9H), 7.26-7.20 (m, 2H), 7.10-6.98 (m, 1H), 6.62 (t, *J* = 7.6 Hz, 1H), 3.92 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6 (d, *J* = 246.8 Hz), 139.8, 137.8, 137.2, 130.1 (d, *J* = 8.7 Hz), 128.8, 128.6, 128.0, 127.6 (d, *J* = 3.1 Hz), 126.5, 126.2, 125.3 (d, *J* = 9.5 Hz), 124.0, 118.5 (d, *J* = 22.7 Hz), 115.8 (d, *J* = 21.2 Hz), 94.1 (d, *J* = 3.4 Hz), 87.8, 37.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ -112.9. IR (neat, cm^{-1}) 3028, 2923, 1608, 1579, 1494, 1486, 1436, 1263, 1148, 871, 759, 697. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1387.



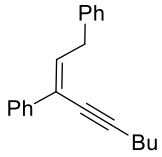
3at

(*Z*)-(5-(2-methoxyphenyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3at): Yellow oil (27.9 mg, 86% yield), R_f = 0.39 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 7.7 Hz, 2H), 7.50 (d, *J* = 7.6 Hz, 1H), 7.40-7.19 (m, 9H), 6.99-6.85 (m, 2H), 6.59 (t, *J* = 7.5 Hz, 1H), 3.98 (d, *J* = 7.6 Hz, 2H), 3.87 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.3, 140.3, 138.0, 136.0, 133.2, 129.9, 128.9, 128.7, 128.4, 127.7, 126.3, 124.5, 120.6, 112.9, 110.8, 91.9, 91.2, 55.9, 37.8. IR (neat, cm^{-1}) 3026, 2920, 1595, 1491, 1453, 1434, 1276, 1249, 1024, 750, 696. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}O$ $[M+H]^+$: 325.1592, found: 325.1591.



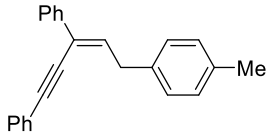
3au

(*Z*)-(5-(2-chlorophenyl)pent-2-en-4-yne-1,3-diyl)dibenzene (3au): Yellow oil (19.7 mg, 60% yield), R_f = 0.58 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, *J* = 7.7 Hz, 2H), 7.61-7.54 (m, 1H), 7.43 (d, *J* = 6.8 Hz, 1H), 7.39-7.19 (m, 10H), 6.64 (t, *J* = 7.5 Hz, 1H), 3.99 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.9, 137.7, 137.5, 136.0, 133.4, 129.5, 129.5, 128.8, 128.8, 128.6, 127.9, 126.6, 126.5, 126.3, 124.0, 123.5, 92.2, 92.1, 37.9. IR (neat, cm^{-1}) 3026, 2920, 2850, 1599, 1494, 1473, 1437, 1058, 1031, 752, 712, 695. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}Cl$ $[M+H]^+$: 329.1097, found: 329.1093.



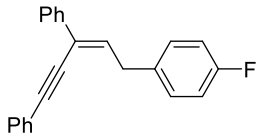
3av

(*Z*)-non-2-en-4-yne-1,3-diyldibenzene (3av): Yellow oil (17.5 mg, 64% yield), R_f = 0.37 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68-7.54 (m, 2H), 7.36-7.14 (m, 8H), 6.46 (t, *J* = 7.5 Hz, 1H), 3.82 (d, *J* = 7.5 Hz, 2H), 2.48 (t, *J* = 7.0 Hz, 2H), 1.71-1.56 (m, 2H), 1.55-1.44 (m, 2H), 0.95 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.4, 138.6, 135.0, 128.7, 128.6, 128.4, 127.6, 126.3, 126.2, 124.7, 96.7, 77.9, 37.6, 31.1, 22.2, 19.5, 13.8. IR (neat, cm^{-1}) 2957, 2930, 1600, 1494, 1452, 1265, 1030, 759, 670. HRMS (ESI): *m/z*: calcd for $C_{21}H_{23}$ $[M+H]^+$: 275.1800, found: 275.1798.



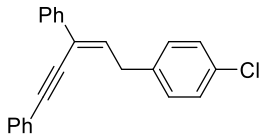
3ba

(*Z*)-(5-(p-tolyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ba): Yellow oil (12.3 mg, 40% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75-7.63 (m, 2H), 7.59-7.49 (m, 2H), 7.41-7.31 (m, 5H), 7.30-7.25 (m, 1H), 7.24-7.18 (m, 2H), 7.12 (d, *J* = 7.8 Hz, 2H), 6.58 (t, *J* = 7.6 Hz, 1H), 3.89 (d, *J* = 7.6 Hz, 2H), 2.32 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.1, 136.9, 136.9, 136.0, 131.8, 129.4, 128.7, 128.5, 128.5, 127.8, 126.3, 124.1, 123.5, 95.4, 87.0, 37.4, 21.2. IR (neat, cm^{-1}) 2920, 2850, 1596, 1513, 1488, 1446, 1070, 812, 754, 689. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1642.



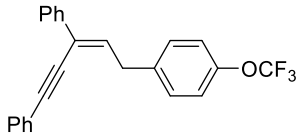
3ca

(*Z*)-(5-(4-fluorophenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ca): Yellow oil (27.1 mg, 87% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 7.4 Hz, 2H), 7.63-7.53 (m, 2H), 7.45-7.35 (m, 5H), 7.34-7.26 (m, 3H), 7.08-6.98 (m, 2H), 6.57 (t, *J* = 7.6 Hz, 1H), 3.91 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.7 (d, *J* = 244.1 Hz), 137.9, 136.2, 135.6 (d, *J* = 3.1 Hz), 131.7, 130.2 (d, *J* = 7.9 Hz), 128.6, 128.6, 128.0, 126.3, 124.5, 123.4, 115.5 (d, *J* = 21.2 Hz), 95.6, 86.7, 36.9. ^{19}F NMR (376 MHz, $CDCl_3$) δ -117.0. IR (neat, cm^{-1}) 3032, 2922, 1599, 1507,1489, 1445, 1219, 1156, 826, 753, 689. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1392.



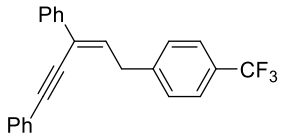
3da

(*Z*)-(5-(4-chlorophenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3da): Yellow oil (18.7 mg, 57% yield), R_f = 0.61 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78-7.65 (m, 2H), 7.62-7.53 (m, 2H), 7.42-7.35 (m, 5H), 7.34-7.22 (m, 5H), 6.55 (t, *J* = 7.6 Hz, 1H), 3.91 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.5, 137.8, 135.6, 132.2, 131.7, 130.1, 128.8, 128.6, 128.6, 128.6, 128.0, 126.3, 124.8, 123.3, 95.7, 86.7, 37.1. IR (neat, cm^{-1}) 2922, 2850, 1597, 1489, 1446, 1091, 1015, 820, 755, 690. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}Cl$ $[M+H]^+$: 329.1097, found: 329.1099.



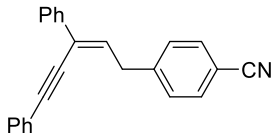
3ea

(*Z*)-(5-(4-(trifluoromethoxy)phenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ea): Yellow oil (30.6 mg, 81% yield), R_f = 0.53 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.64 (m, 2H), 7.59-7.50 (m, 2H), 7.39-7.30 (m, 7H), 7.25 (d, *J* = 1.5 Hz, 1H), 7.16 (d, *J* = 8.1 Hz, 2H), 6.55 (t, *J* = 7.6 Hz, 1H), 3.92 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.9 (d, *J* = 2.0 Hz), 138.8, 137.8, 135.5, 131.8, 130.0, 128.6, 128.6, 128.6, 128.1, 126.3, 124.9, 123.3, 121.3, 120.6 (q, *J* = 256.8 Hz), 95.7, 86.6, 37.0. ^{19}F NMR (376 MHz, $CDCl_3$) δ -57.9. IR (neat, cm^{-1}) 3032, 2925, 1596, 1507, 1446, 1253, 1220, 1158, 1020, 754, 690. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}F_3O$ $[M+H]^+$: 379.1310, found: 379.1305.



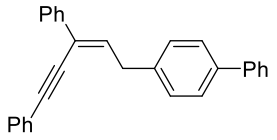
3fa

(*Z*)-(5-(4-(trifluoromethyl)phenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3fa): Yellow oil (15.2 mg, 42% yield), R_f = 0.61 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75-7.66 (m, 2H), 7.61-7.53 (m, 4H), 7.47-7.35 (m, 7H), 7.34-7.28 (m, 1H), 6.56 (t, *J* = 7.6 Hz, 1H), 3.99 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.2, 137.7, 134.9, 131.8, 129.1, 128.7, 128.6, 128.6, 128.1, 126.3, 124.4 (q, *J* = 270.1 Hz), 125.7 (q, *J* = 3.8 Hz), 125.3, 123.2, 95.9, 86.6, 37.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.3. IR (neat, cm^{-1}) 2920, 2850, 1619, 1489, 1323, 1163, 1122, 1066, 1019, 831, 755, 691. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}F_3$ $[M+H]^+$: 363.1361, found: 363.1358.



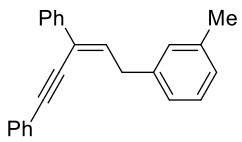
3ga

(*Z*)-4-(3,5-diphenylpent-2-en-4-yn-1-yl)benzonitrile (3ga): Yellow oil (21.7 mg, 68% yield), R_f = 0.16 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78-7.66 (m, 2H), 7.61 (d, *J* = 8.2 Hz, 2H), 7.58-7.51 (m, 2H), 7.45-7.35 (m, 7H), 7.35-7.30 (m, 1H), 6.53 (t, *J* = 7.6 Hz, 1H), 3.99 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.6, 137.5, 133.9, 132.5, 131.7, 129.5, 128.8, 128.6, 128.6, 128.2, 126.3, 125.8, 123.1, 119.1, 110.3, 96.1, 86.4, 37.7. IR (neat, cm^{-1}) 3032, 2924, 2227, 1605, 1489, 1445, 1415, 1176, 1021, 755, 690. HRMS (ESI): *m/z*: calcd for $C_{24}H_{18}N$ $[M+H]^+$: 320.1439, found: 320.1442.



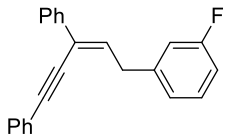
3ha

(*Z*)-4-(3,5-diphenylpent-2-en-4-yn-1-yl)-1,1'-biphenyl (3ha): Yellow oil (18.5 mg, 50% yield), R_f = 0.55 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.70 (m, 2H), 7.62-7.55 (m, 6H), 7.46-7.33 (m, 11H), 6.65 (t, *J* = 7.6 Hz, 1H), 4.00 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.1, 139.5, 139.1, 138.0, 136.3, 131.8, 129.2, 128.9, 128.6, 128.6, 128.5, 127.9, 127.5, 127.3, 127.2, 126.3, 124.5, 123.5, 95.6, 86.9, 37.5. IR (neat, cm^{-1}) 3027, 2963, 1598, 1487, 1446, 1261, 1073, 1026, 755, 691. HRMS (ESI): *m/z*: calcd for $C_{29}H_{23}$ $[M+H]^+$: 371.1800, found: 371.1797.



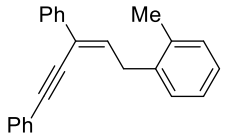
3ia

(*Z*)-(5-(m-tolyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ia): Yellow oil (12.0 mg, 39% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.66 (m, 2H), 7.61-7.52 (m, 2H), 7.42-7.27 (m, 6H), 7.25-7.19 (m, 1H), 7.14 (d, *J* = 7.1 Hz, 2H), 7.06 (d, *J* = 7.5 Hz, 1H), 6.61 (t, *J* = 7.6 Hz, 1H), 3.92 (d, *J* = 7.6 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.0, 138.4, 138.1, 136.7, 131.8, 129.6, 128.7, 128.5, 128.5, 127.8, 127.2, 126.3, 125.8, 124.2, 123.5, 95.4, 87.0, 37.8, 21.6. IR (neat, cm^{-1}) 2920, 2851, 1606, 1489, 1446, 1070, 1027, 755, 690. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1638.



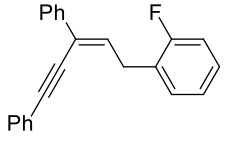
3ja

(*Z*)-(5-(3-fluorophenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ja): Yellow oil (22.5 mg, 72% yield), R_f = 0.62 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75-7.66 (m, 2H), 7.61-7.51 (m, 2H), 7.42-7.35 (m, 5H), 7.34-7.27 (m, 2H), 7.14-7.01 (m, 2H), 6.97-6.87 (m, 1H), 6.57 (t, *J* = 7.6 Hz, 1H), 3.94 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.1 (d, *J* = 245.8 Hz), 142.5 (d, *J* = 7.1 Hz), 137.8, 135.4, 131.8, 130.1 (d, *J* = 8.3 Hz), 128.6, 128.6, 128.6, 128.0, 126.3, 124.9, 124.4 (d, *J* = 2.7 Hz), 123.3, 115.7 (d, *J* = 21.2 Hz), 113.3 (d, *J* = 21.0 Hz), 95.7, 86.6, 37.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -113.3. IR (neat, cm^{-1}) 3032, 2924, 1589, 1487, 1446, 1247, 1136, 862, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1395.



3ka

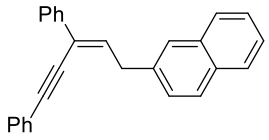
(*Z*)-(5-(*o*-tolyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3ka): Yellow oil (24.6 mg, 80% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79-7.67 (m, 2H), 7.66-7.56 (m, 2H), 7.46-7.28 (m, 7H), 7.25-7.14 (m, 3H), 6.55 (t, *J* = 7.5 Hz, 1H), 3.96 (d, *J* = 7.5 Hz, 2H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.3, 138.1, 136.7, 136.1, 131.7, 130.4, 129.4, 128.5, 128.5, 128.5, 127.8, 126.7, 126.3, 126.2, 124.2, 123.5, 95.8, 86.9, 35.8, 19.8. IR (neat, cm^{-1}) 3024, 2924, 1597, 1489, 1446, 1070, 1027, 755, 741, 690. HRMS (ESI): *m/z*: calcd for $C_{24}H_{21}$ $[M+H]^+$: 309.1643, found: 309.1644.



3la

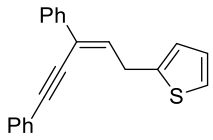
(Z)-(5-(2-fluorophenyl)pent-3-en-1-yne-1,3-diyl)dibenzene (3la): Yellow oil (13.4 mg, 43% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 7.6 Hz, 2H), 7.62-7.52 (m, 2H), 7.44-7.27 (m, 7H), 7.25-7.17 (m, 1H), 7.15-7.00 (m,

2H), 6.59 (t, *J* = 7.6 Hz, 1H), 3.97 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.1 (d, *J* = 245.4 Hz), 137.9, 134.8, 131.8, 130.9 (d, *J* = 4.7 Hz), 128.5, 128.1 (d, *J* = 8.0 Hz), 127.9, 126.9 (d, *J* = 16.0 Hz), 126.3, 124.9, 124.3 (d, *J* = 3.6 Hz), 123.5, 115.5 (d, *J* = 22.0 Hz), 95.9, 86.6, 30.8 (d, *J* = 3.0 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -118.0. IR (neat, cm^{-1}) 3060, 2920, 1584, 1489, 1446, 1229, 1070, 752, 689. HRMS (ESI): *m/z*: calcd for $C_{23}H_{18}F$ $[M+H]^+$: 313.1393, found: 313.1396.



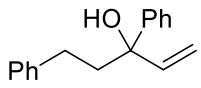
3ma

(*Z*)-2-(3,5-diphenylpent-2-en-4-yn-1-yl)naphthalene (3ma): Yellow oil (24.4 mg, 71% yield), R_f = 0.55 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88-7.80 (m, 3H), 7.79-7.70 (m, 3H), 7.64-7.58 (m, 2H), 7.52-7.45 (m, 3H), 7.43-7.35 (m, 5H), 7.35-7.30 (m, 1H), 6.70 (t, *J* = 7.6 Hz, 1H), 4.13 (d, *J* = 7.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.0, 137.5, 136.3, 133.8, 132.4, 131.8, 128.6, 128.6, 128.5, 128.4, 127.9, 127.8, 127.7, 127.5, 126.9, 126.3, 126.2, 125.5, 124.5, 123.5, 95.6, 86.9, 38.0. IR (neat, cm^{-1}) 3054, 2963, 1597, 1489, 1444, 1261, 1071, 1026, 817, 690. HRMS (ESI): *m/z*: calcd for $C_{27}H_{21}$ $[M+H]^+$: 345.1643, found: 345.1649.



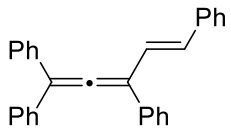
3na

(*Z*)-2-(3,5-diphenylpent-2-en-4-yn-1-yl)thiophene (3na): White solid (9.6 mg, 32% yield), R_f = 0.66 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76-7.64 (m, 2H), 7.61-7.52 (m, 2H), 7.44-7.28 (m, 6H), 7.18 (dd, *J* = 5.0, 1.3 Hz, 1H), 7.03-6.90 (m, 2H), 6.61 (t, *J* = 7.5 Hz, 1H), 4.12 (d, *J* = 7.4 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.4, 138.6, 135.0, 128.7, 128.6, 128.4, 127.6, 126.3, 126.2, 124.7, 96.7, 77.9, 37.6, 31.1, 22.2, 19.5, 13.8. IR (neat, cm^{-1}) 2921, 2850, 1489, 1446, 1070, 1033, 848, 824, 755, 689. HRMS (ESI): *m/z*: calcd for $C_{21}H_{17}S$ $[M+H]^+$: 301.1051, found: 301.1053.



6

3,5-diphenylpent-1-en-3-ol (6): colorless oil, R_f = 0.29 (EA/PE = 1:10). ^{1}H NMR (400 MHz, $CDCl_3$): 7.60-7.48 (m, 2H), 7.46-7.36 (m, 2H), 7.35-7.26 (m, 3H), 7.24-7.14 (m, 3H), 6.28 (dd, *J* = 17.3, 10.7 Hz, 1H), 5.39 (dd, *J* = 17.3, 1.1 Hz, 1H), 5.25 (dd, *J* = 10.7, 1.0 Hz, 1H), 2.87-2.65 (m, 1H), 2.63-2.48 (m, 1H), 2.36-2.16 (m, 2H), 2.02 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.4, 144.2, 142.4, 128.5, 128.5, 128.4, 127.1, 125.9, 125.4, 113.0, 77.1, 44.0, 30.2. IR (neat, cm^{-1}) 3450, 3026, 1602, 1494, 1447, 920, 699. HRMS (ESI): *m/z*: calcd for $C_{17}H_{17}$ $[M-OH]^+$: 221.1330, found: 221.1323.



8

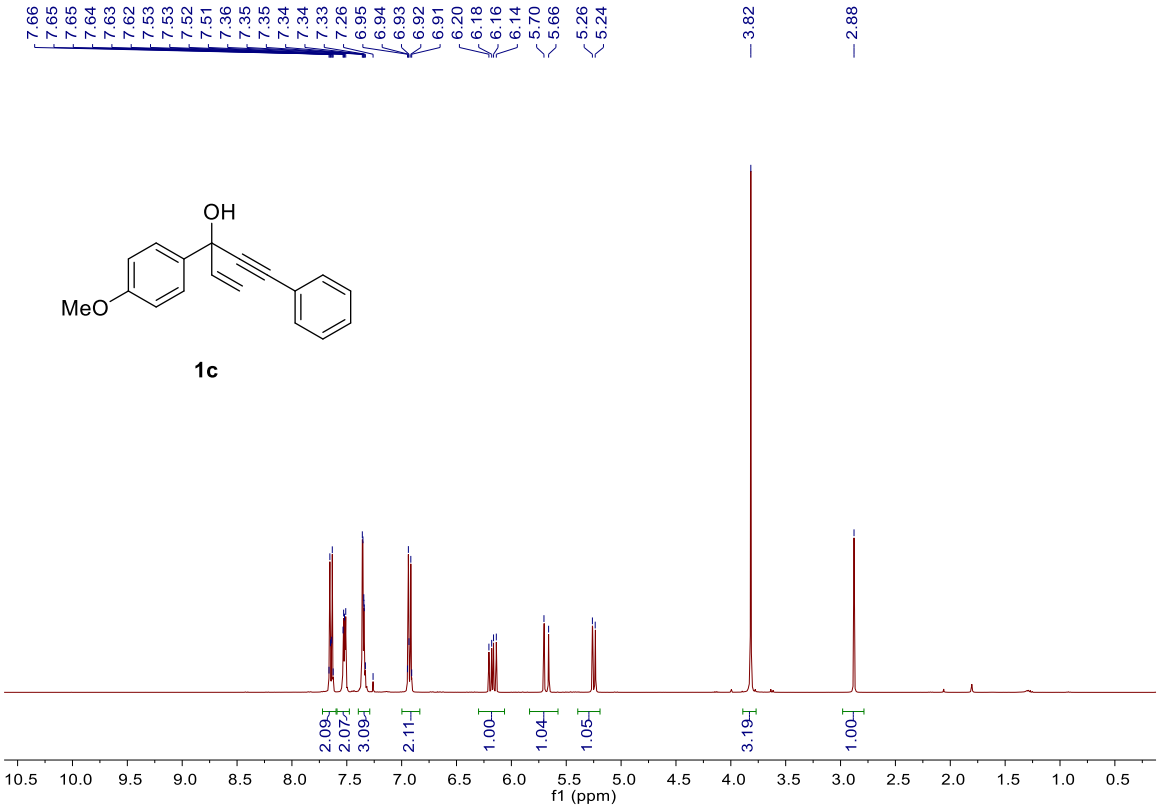
(*E*)-penta-1,2,4-triene-1,1,3,5-tetrayltetrabenzene (8): colorless oil (14.1 mg, 38% yield), R_f = 0.39 (EA/PE = 1:20). ^{1}H NMR (400 MHz, $CDCl_3$): 7.61-7.56 (m, 2H), 7.54-7.32 (m, 17H), 7.32-7.26 (m, 1H), 7.07 (d, *J* = 16.0 Hz, 1H), 6.82 (d, *J* = 16.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 210.5, 137.3, 136.4, 135.9, 132.1, 128.8, 128.7, 128.7, 128.7, 128.1, 127.8, 127.7, 127.7, 126.6, 124.3, 112.7, 111.1. IR (neat, cm^{-1}) 3056, 3025, 1596, 1491, 1444, 1264, 961, 735, 691. HRMS (ESI): *m/z*: calcd for $C_{29}H_{23}$ $[M+H]^+$: 371.1800, found: 371.1790.

Reference

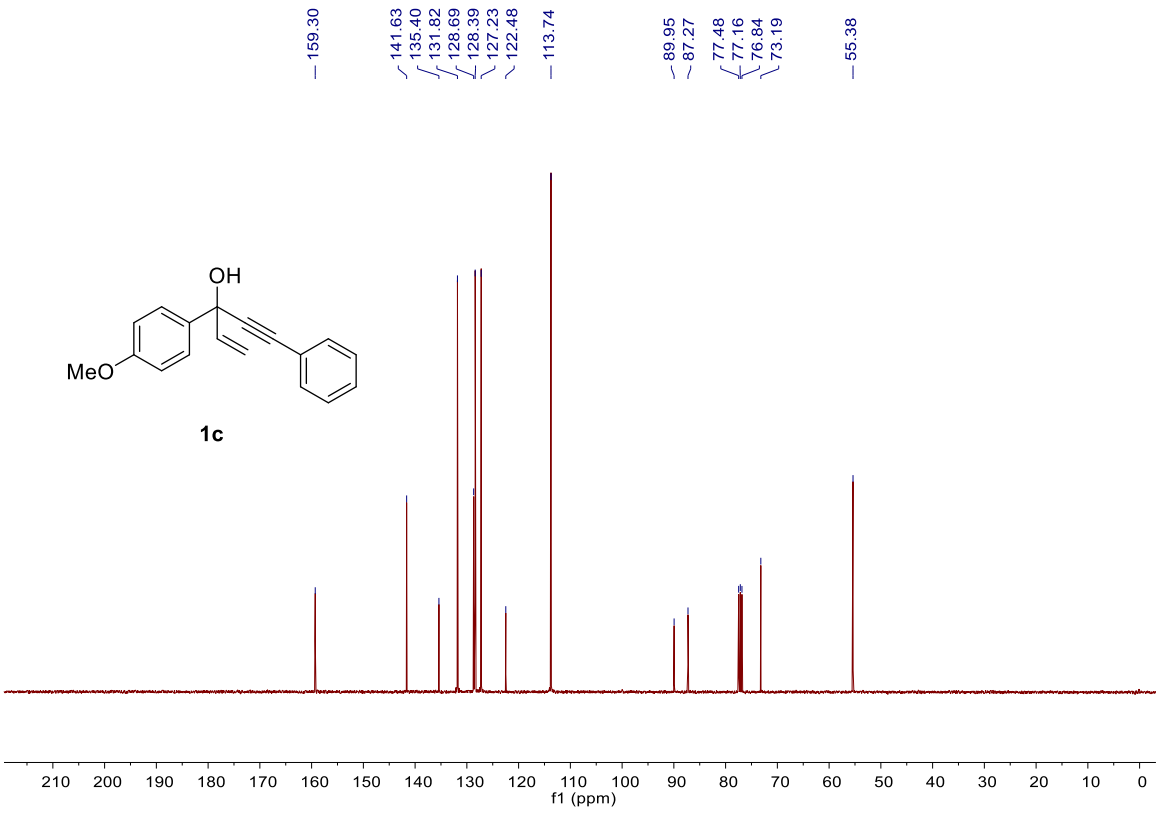
1. Y. Liu, T. Liu, B. Yan, K. Wei and W. Guo, *Adv. Synth. Catal*., 2022, **364**, 916-921.

NMR spectra

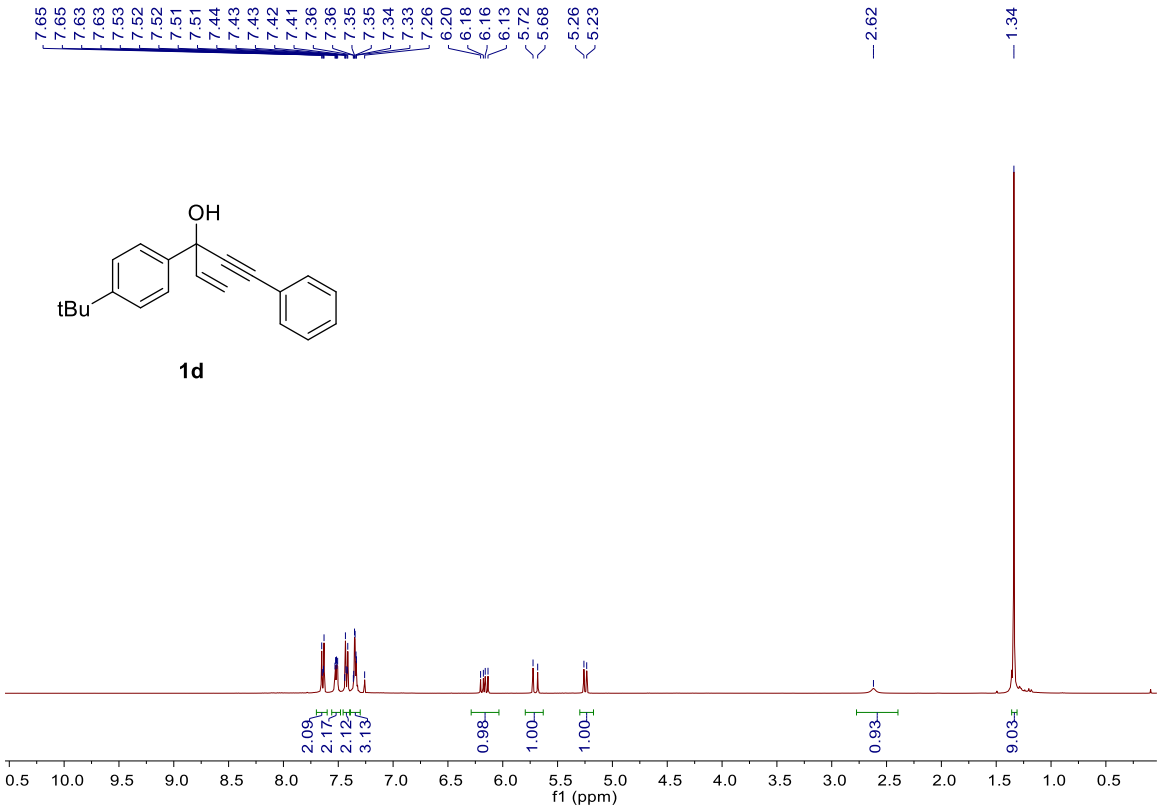
^{1}H NMR spectrum ($CDCl_3$)



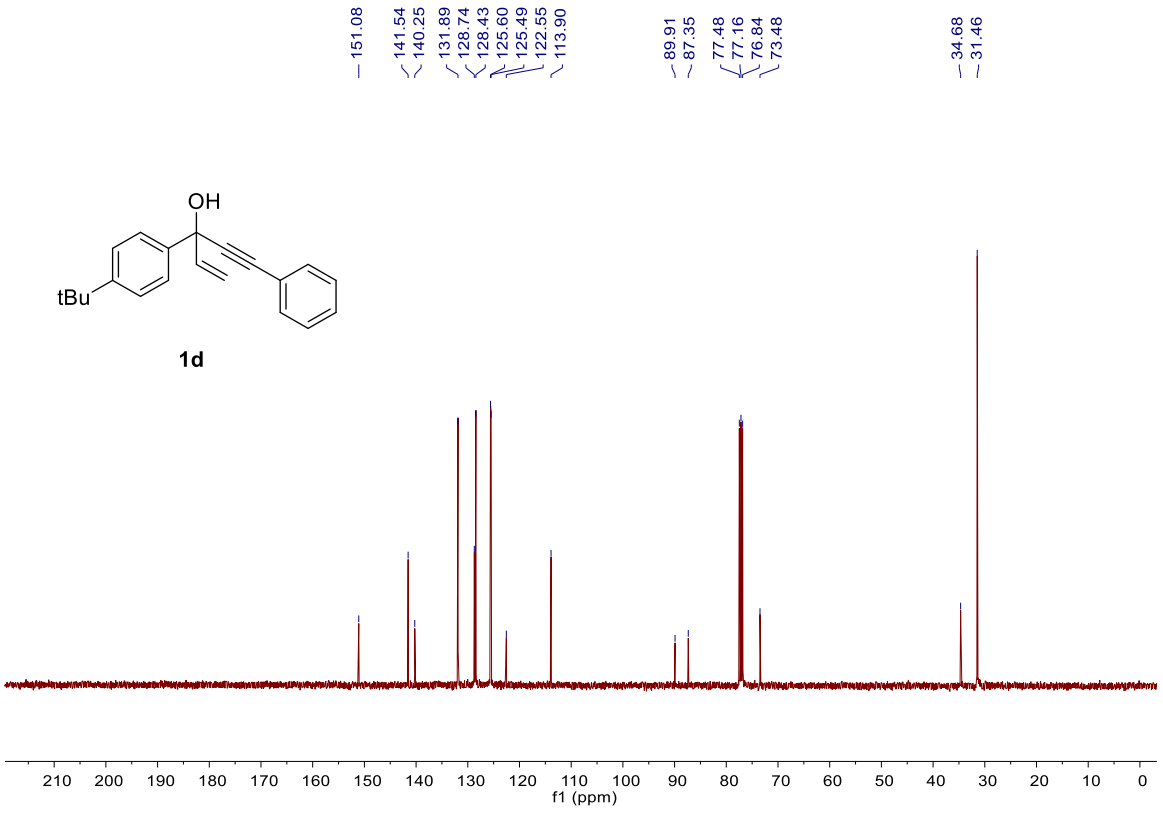
^{13}C NMR spectrum ($CDCl_3$)



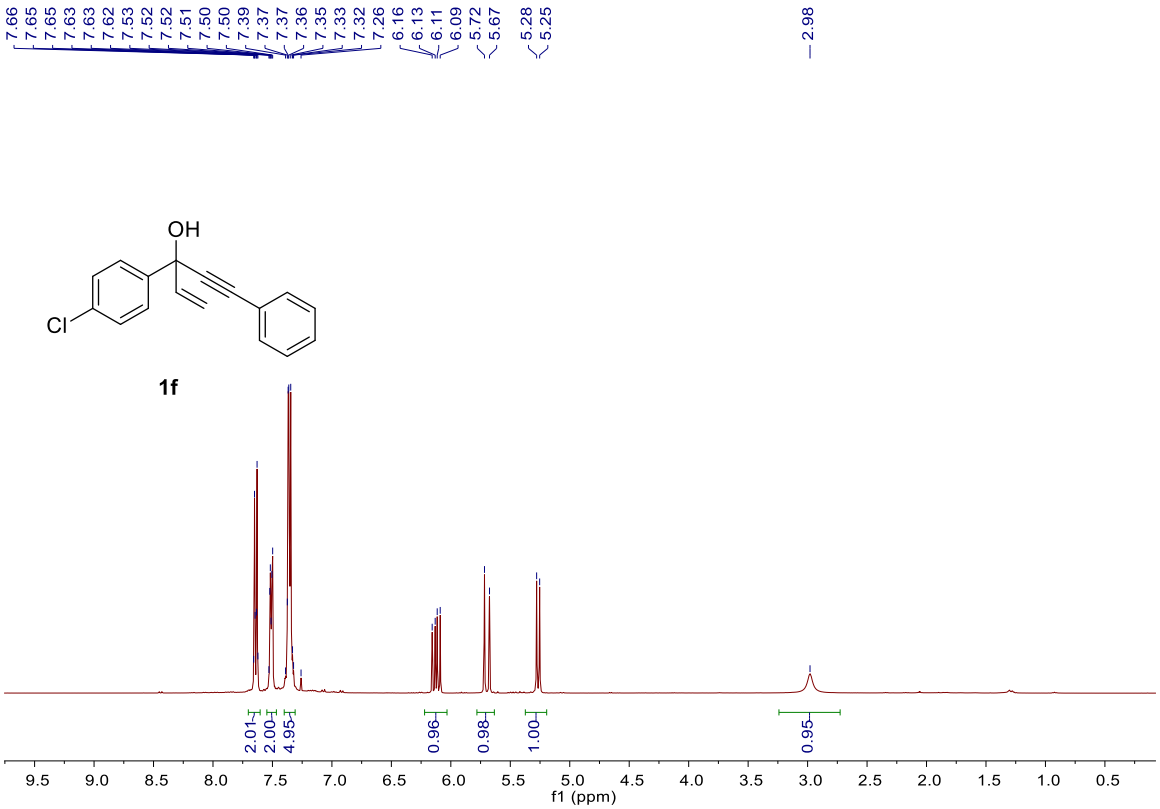
^{1}H NMR spectrum ($CDCl_3$)



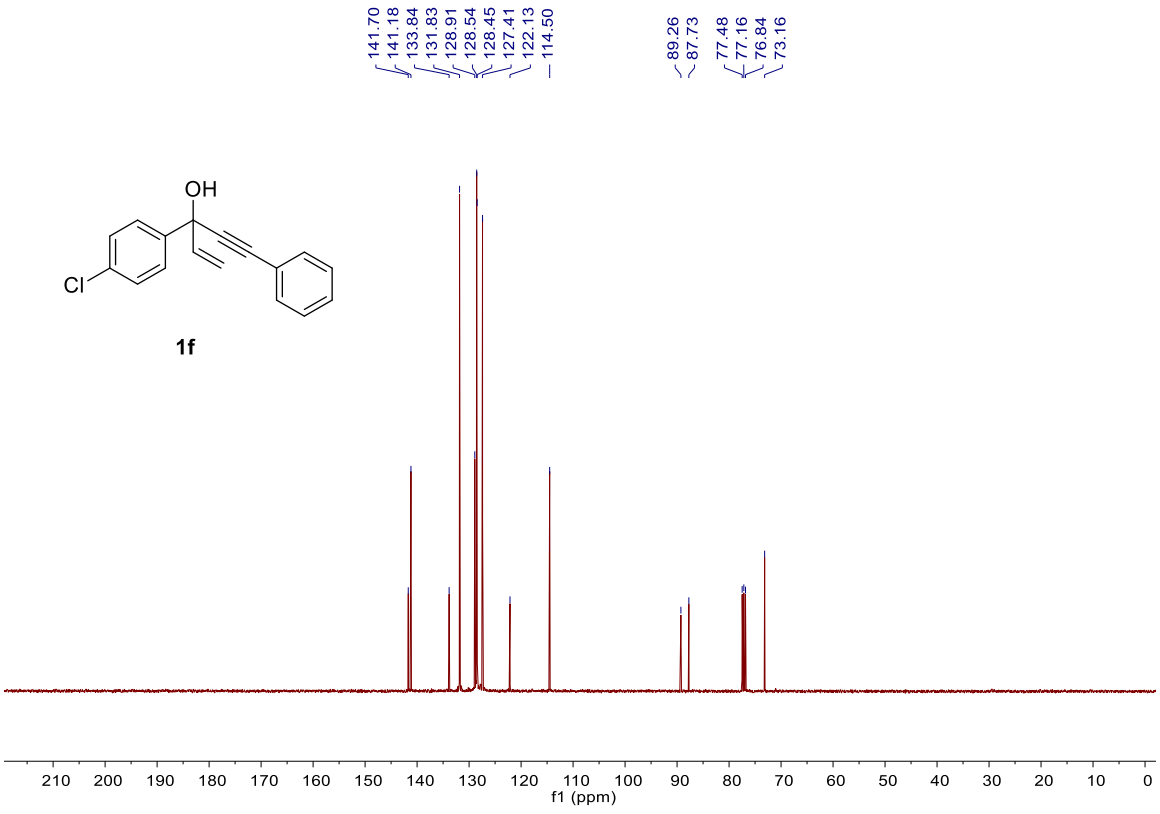
^{13}C NMR spectrum ($CDCl_3$)



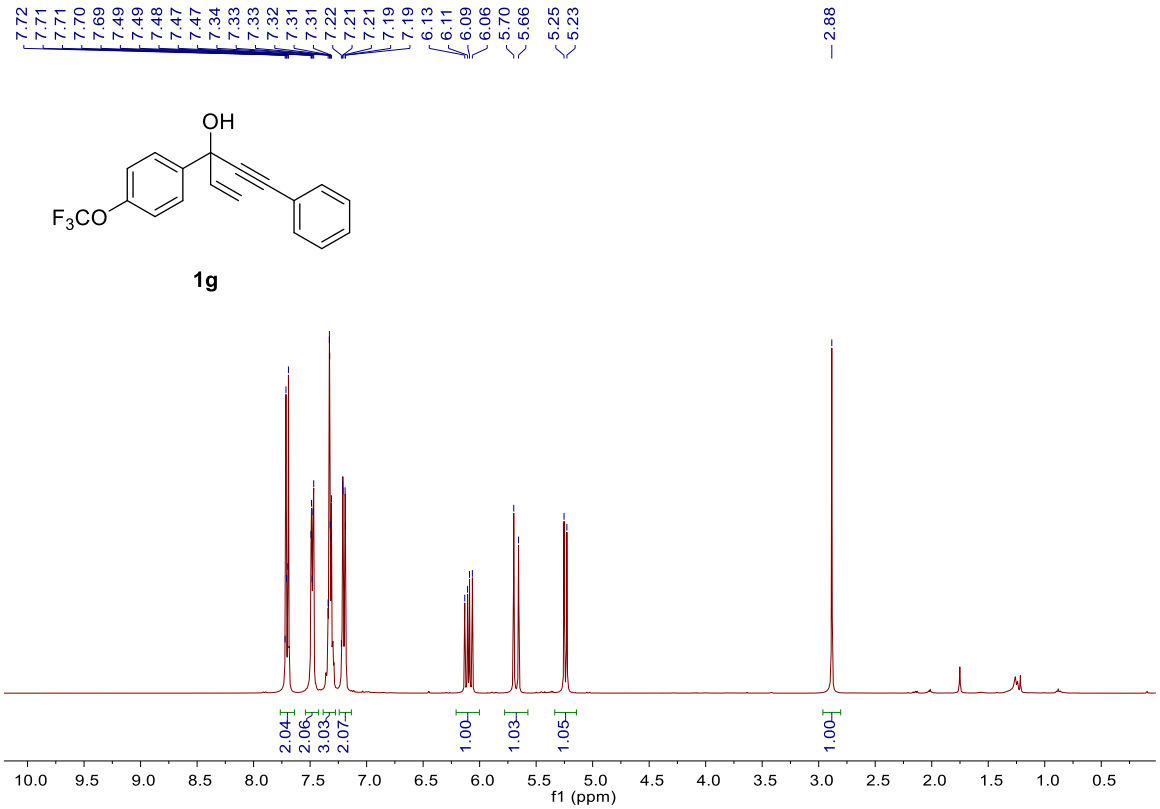
^{1}H NMR spectrum ($CDCl_3$)



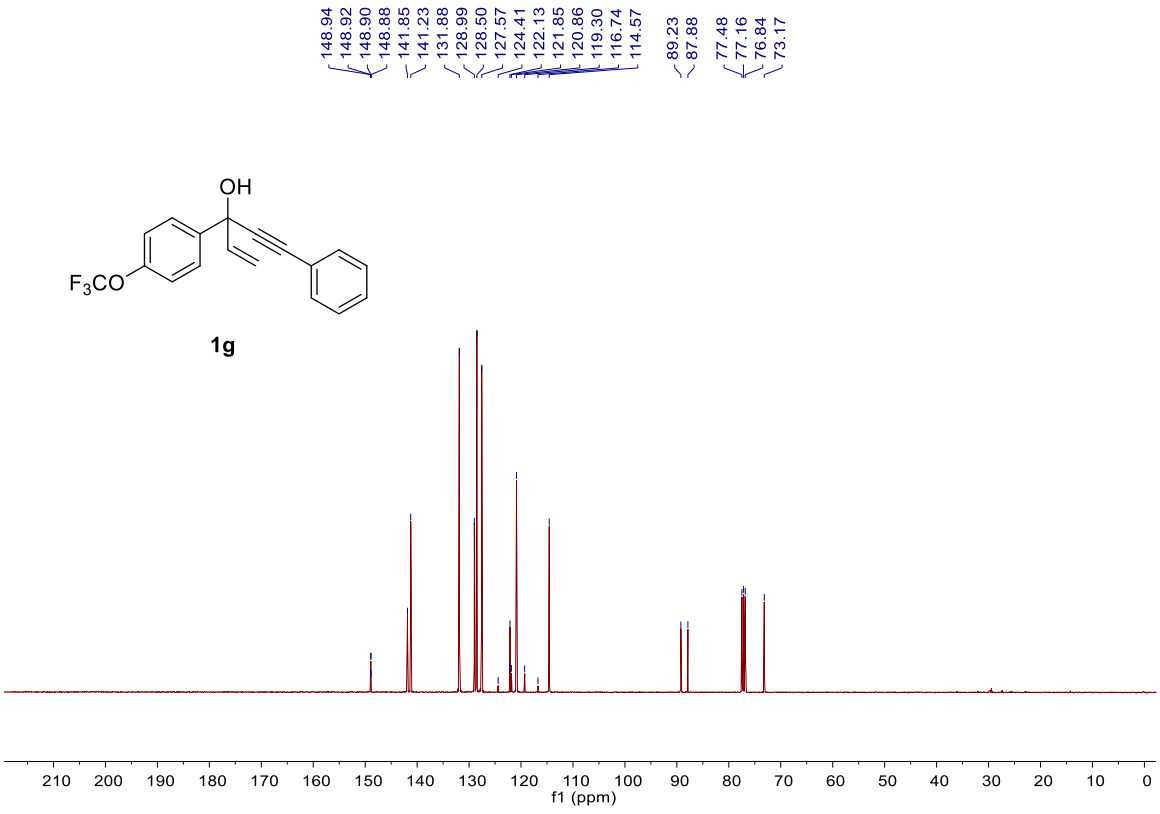
^{13}C NMR spectrum ($CDCl_3$)



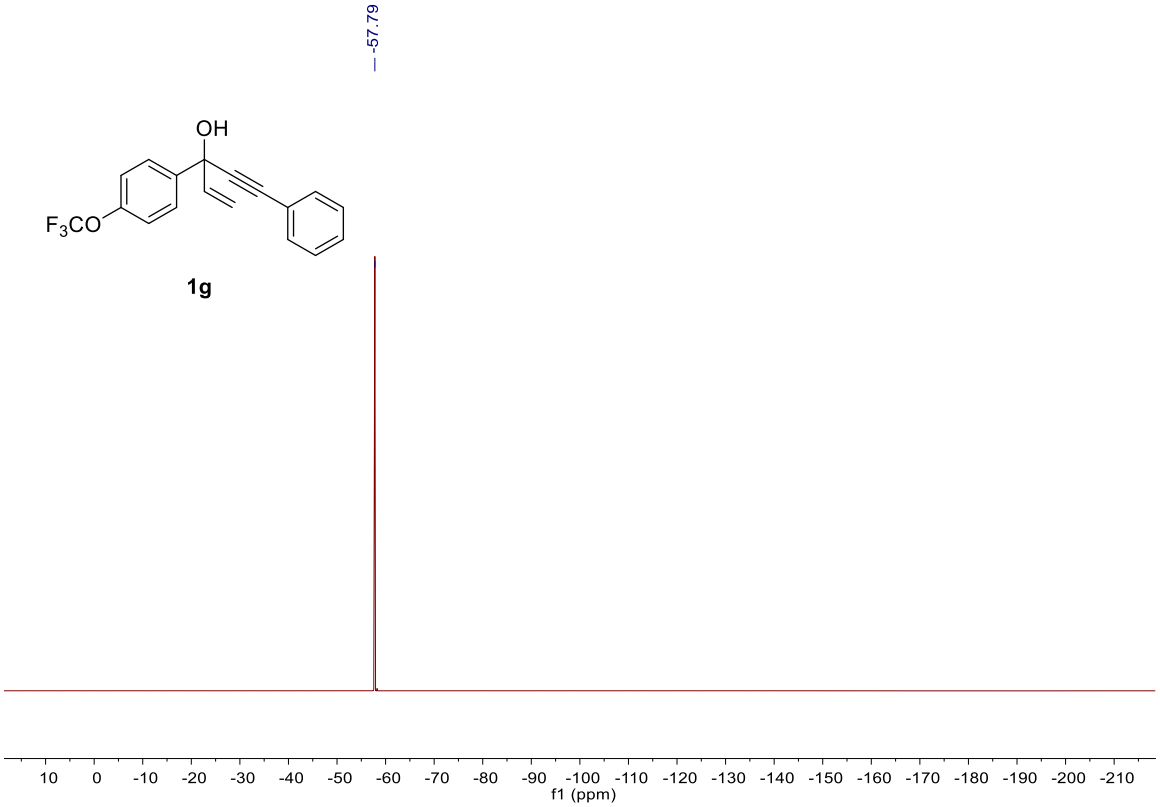
^{1}H NMR spectrum ($CDCl_3$)



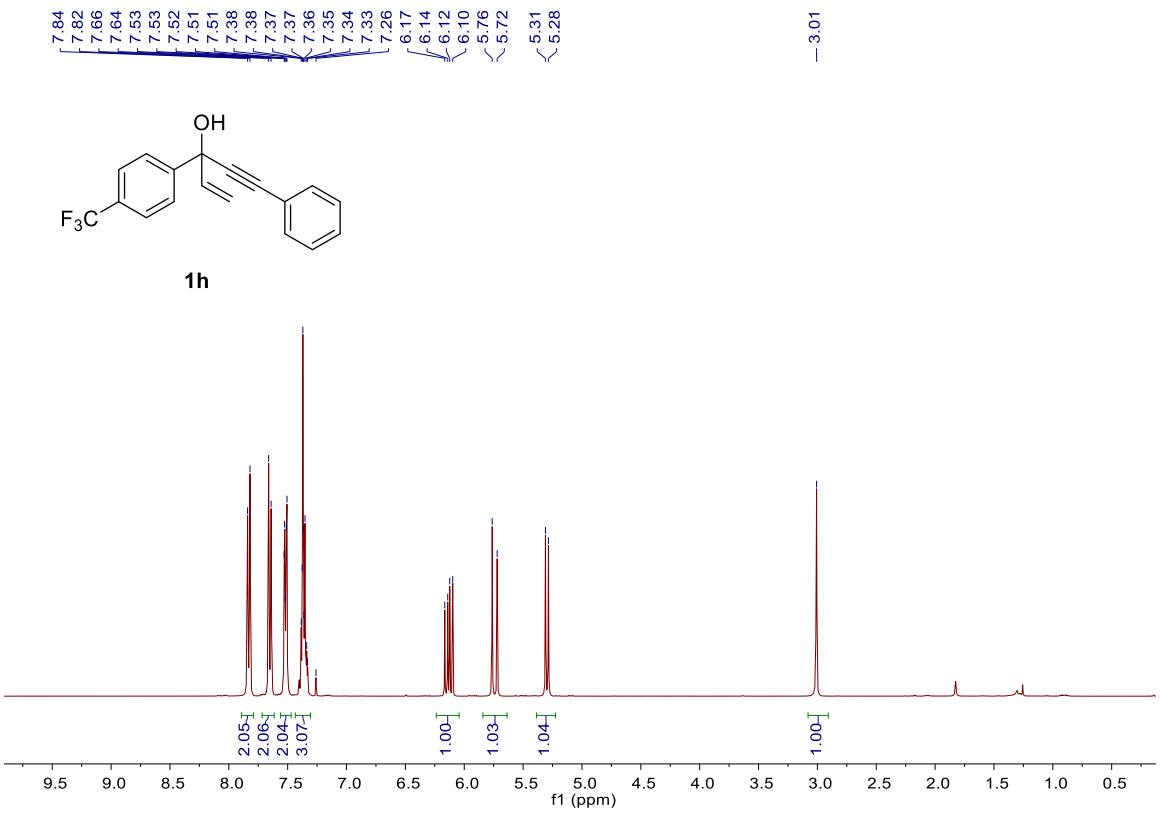
^{13}C NMR spectrum ($CDCl_3$)



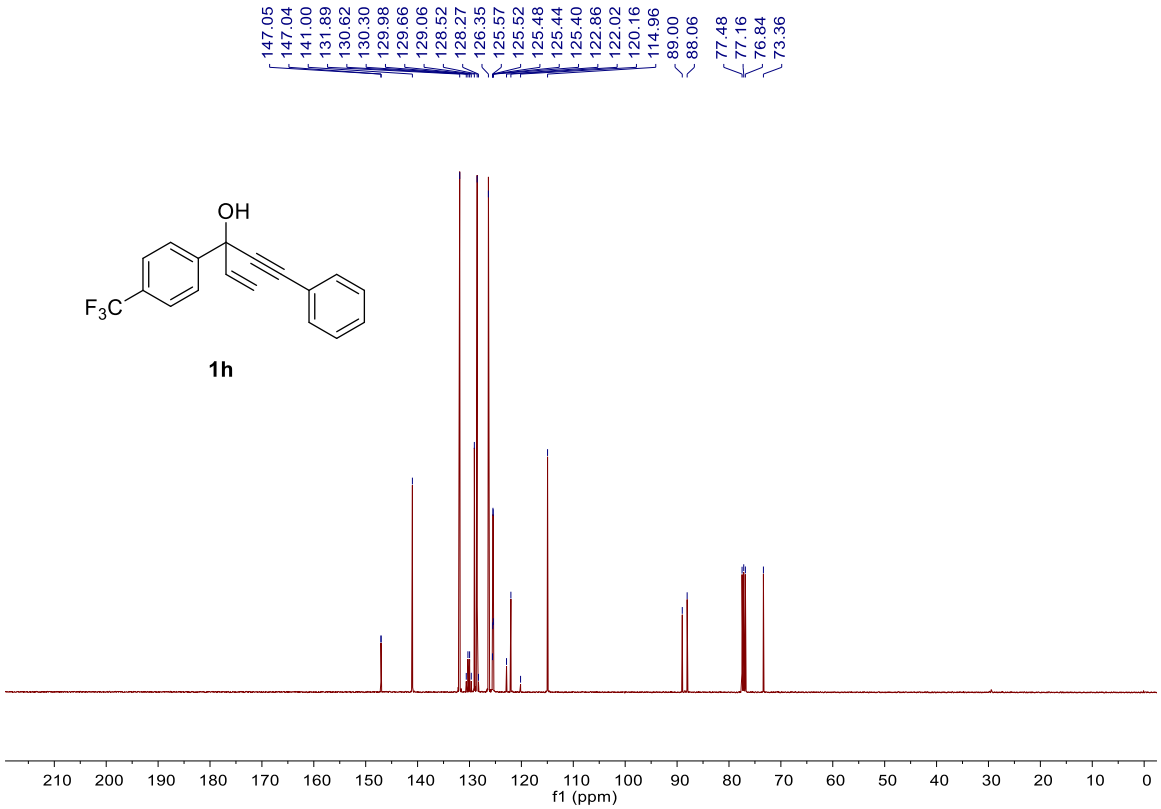
^{19}F NMR spectrum ($CDCl_3$)



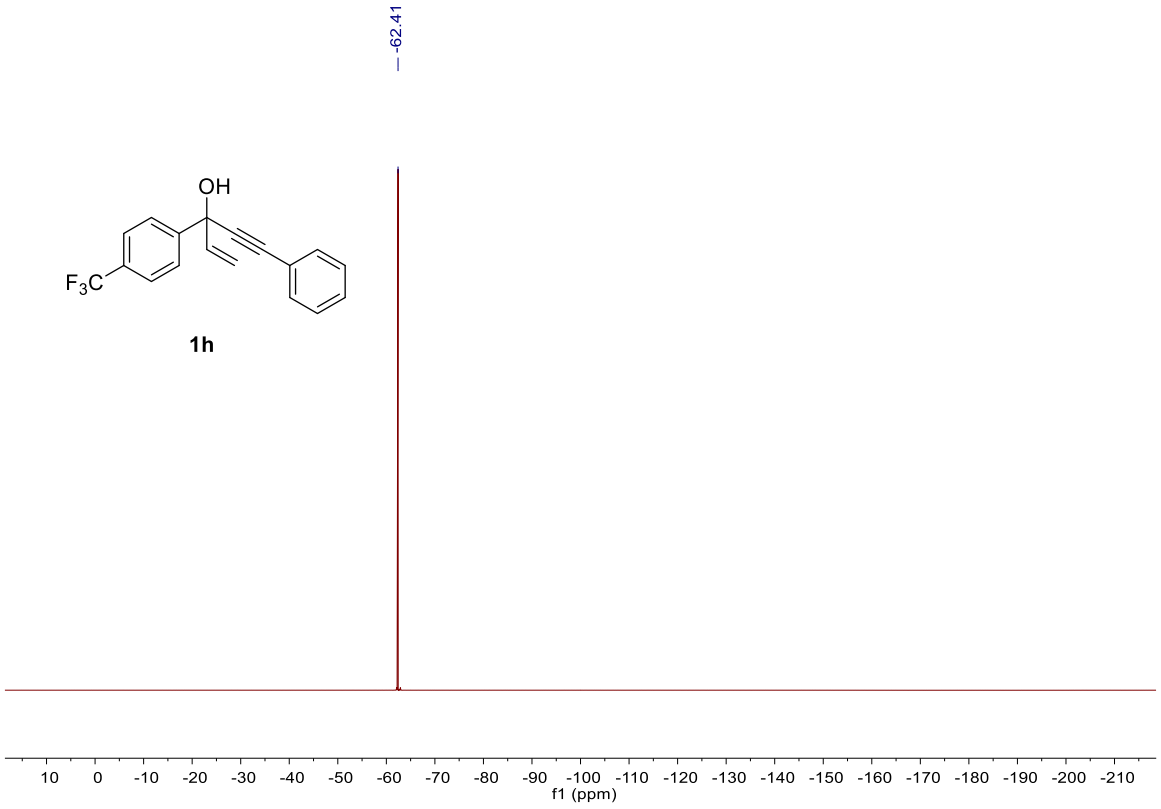
^{1}H NMR spectrum ($CDCl_3$)



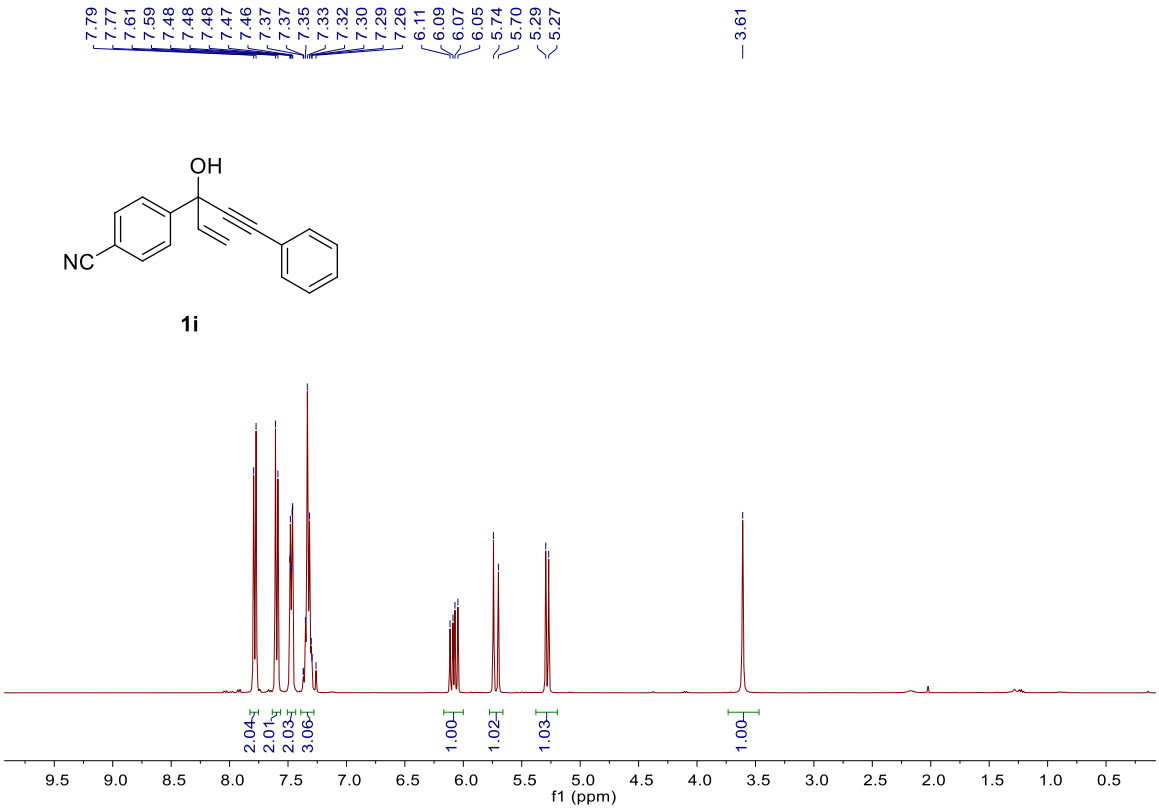
^{13}C NMR spectrum ($CDCl_3$)



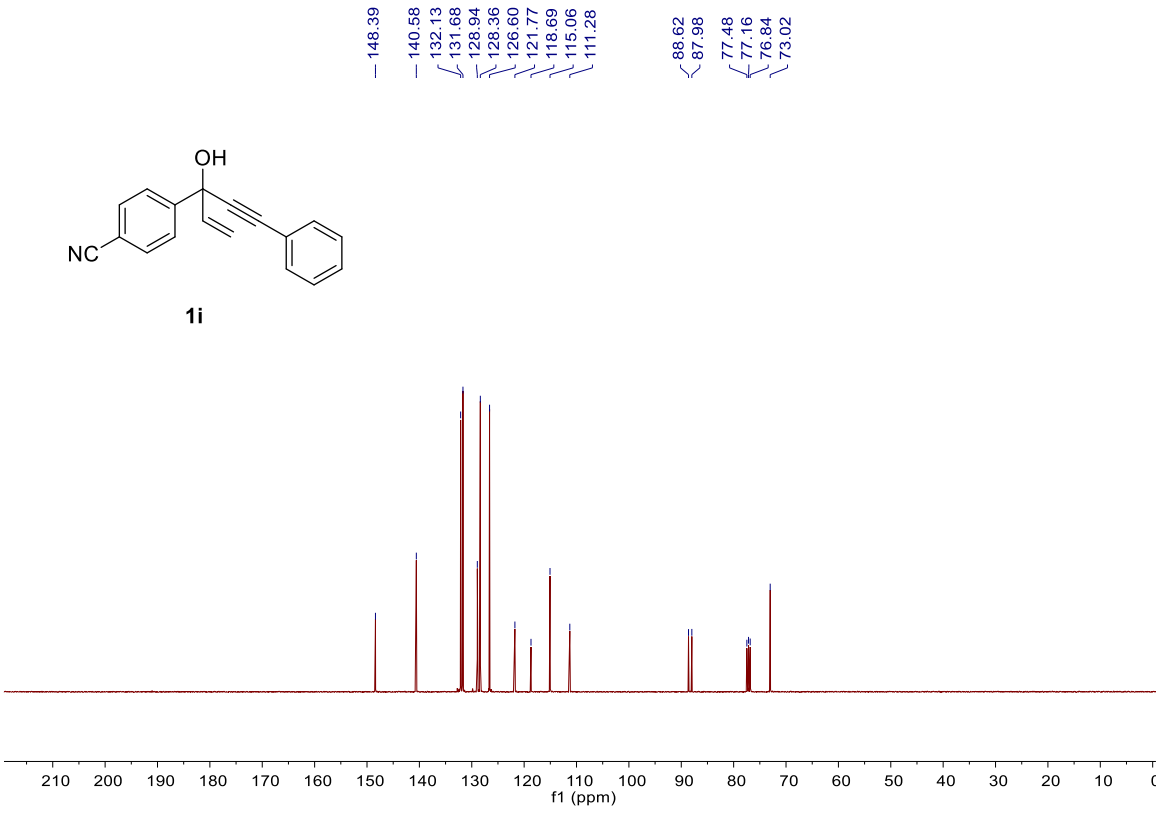
^{19}F NMR spectrum ($CDCl_3$)



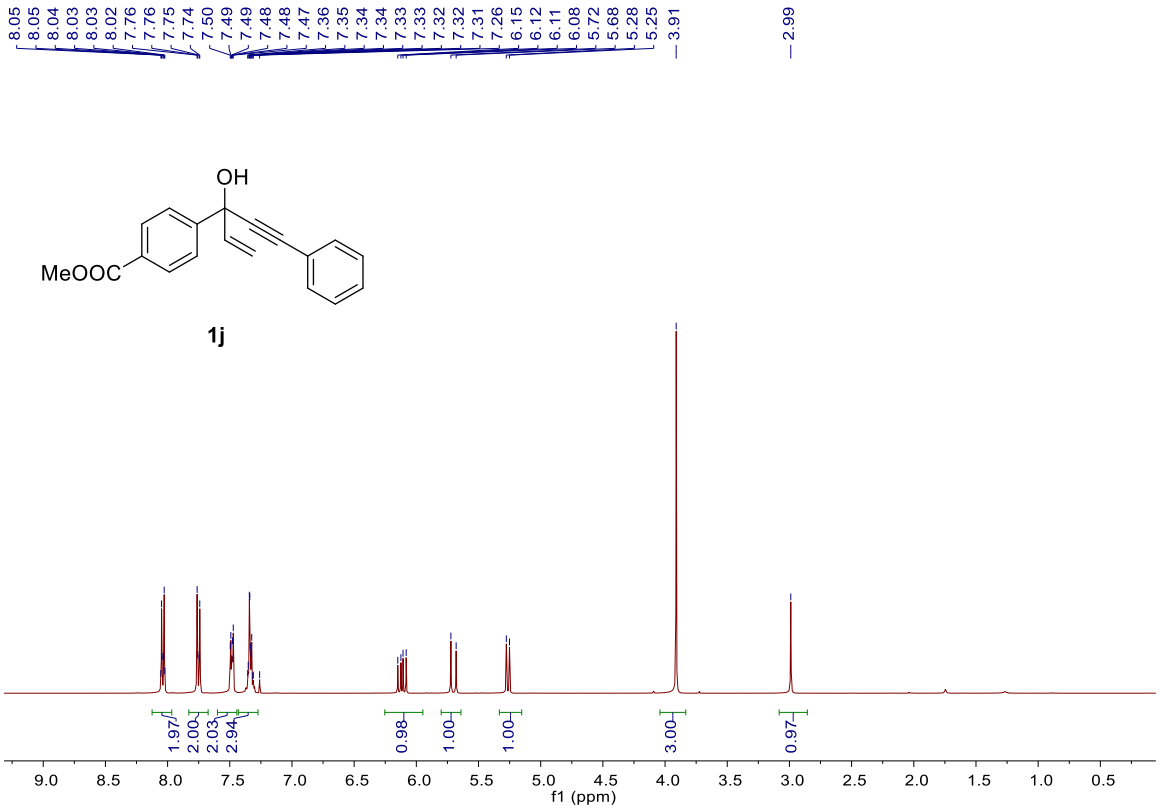
^{1}H NMR spectrum ($CDCl_3$)



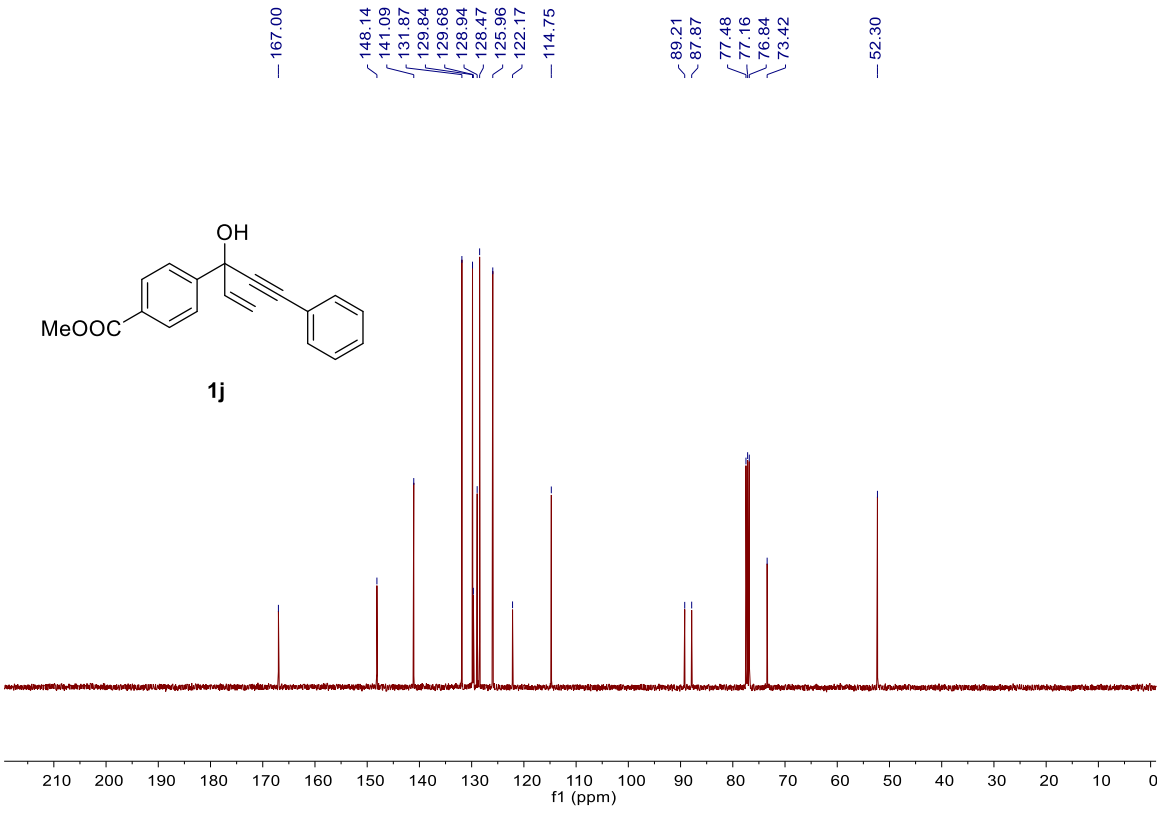
^{13}C NMR spectrum ($CDCl_3$)



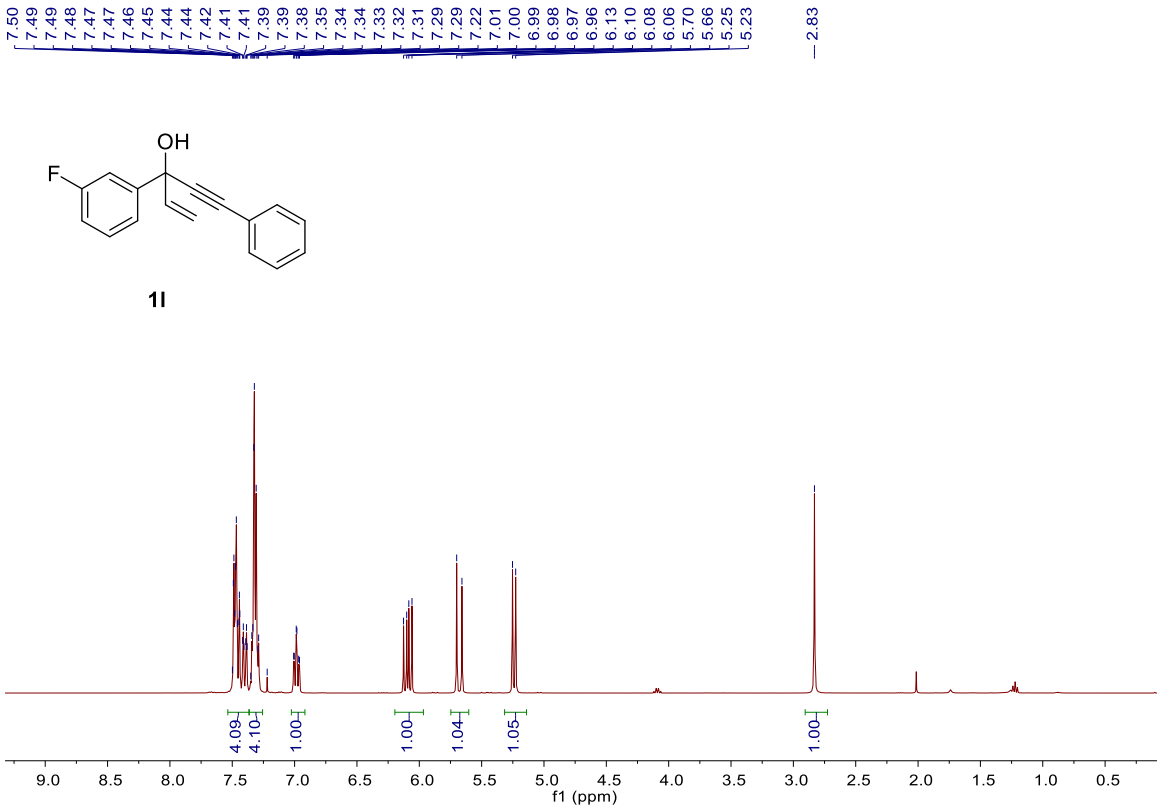
^{1}H NMR spectrum ($CDCl_3$)



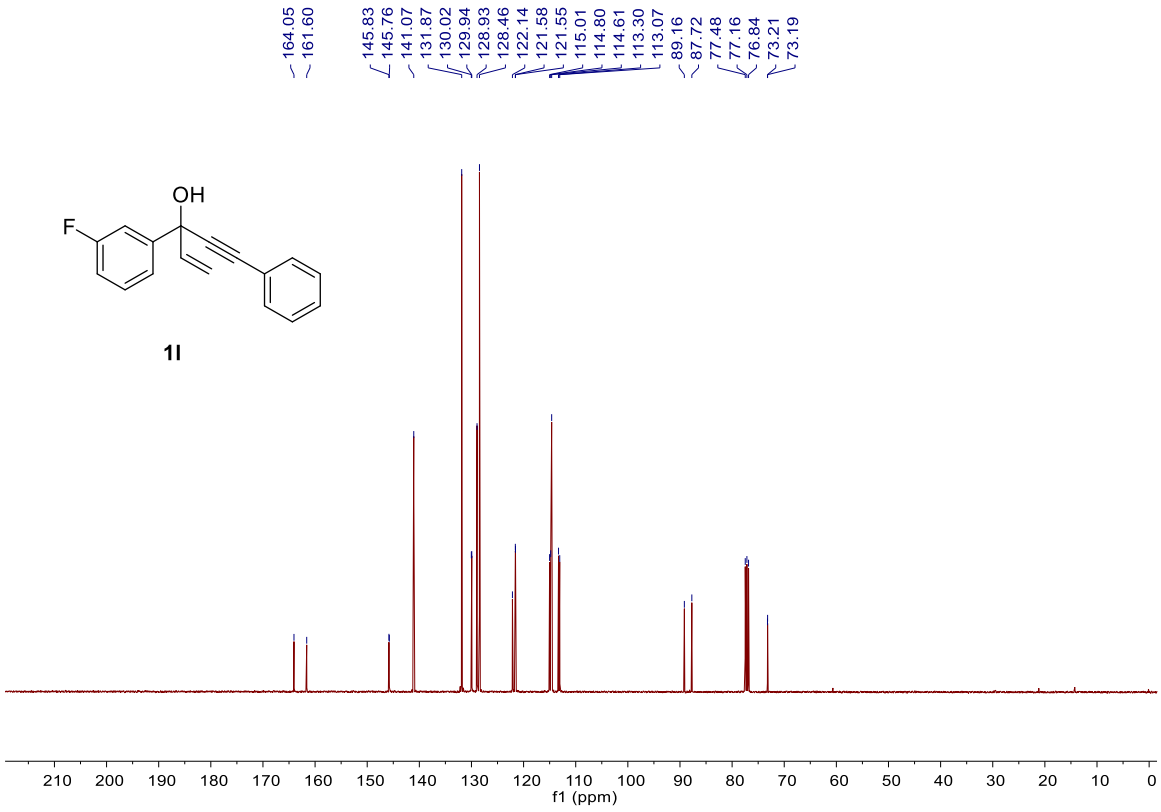
^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)

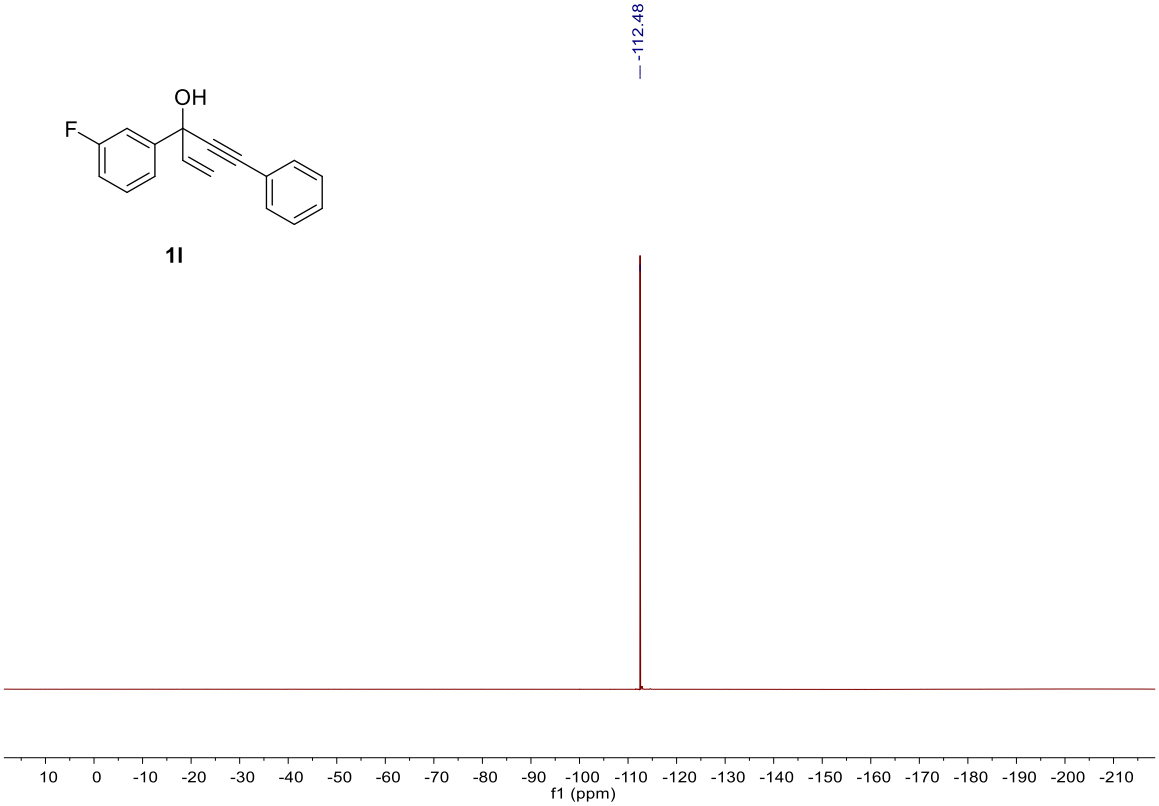


^{13}C NMR spectrum ($CDCl_3$)

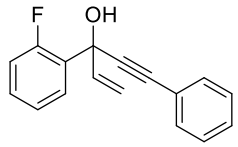


^{19}F NMR spectrum ($CDCl_3$)

1l



^{1}H NMR spectrum ($CDCl_3$)



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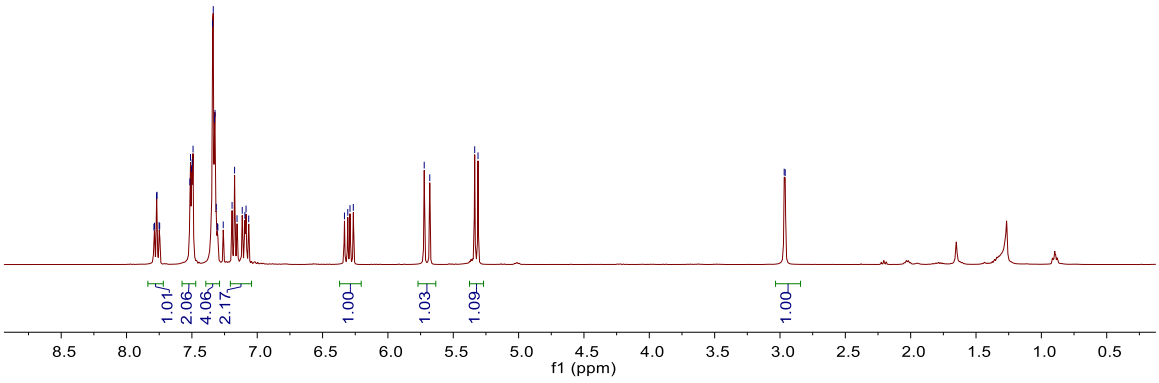
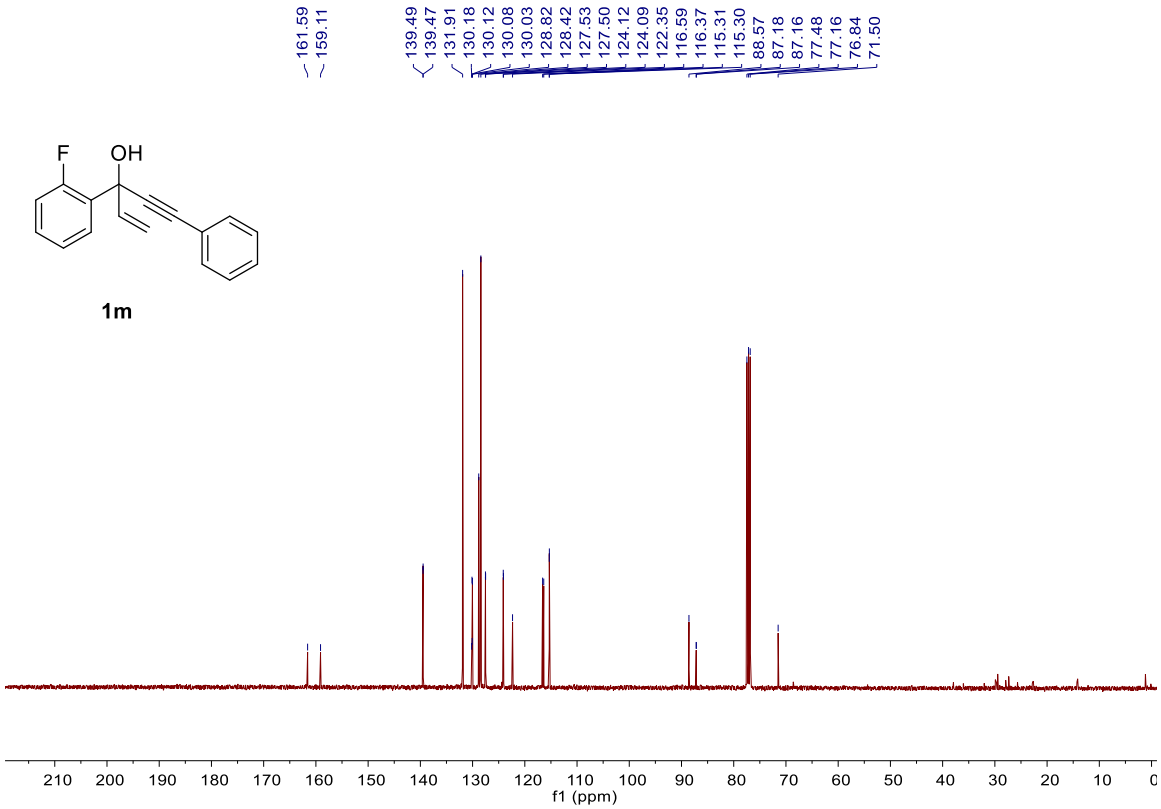
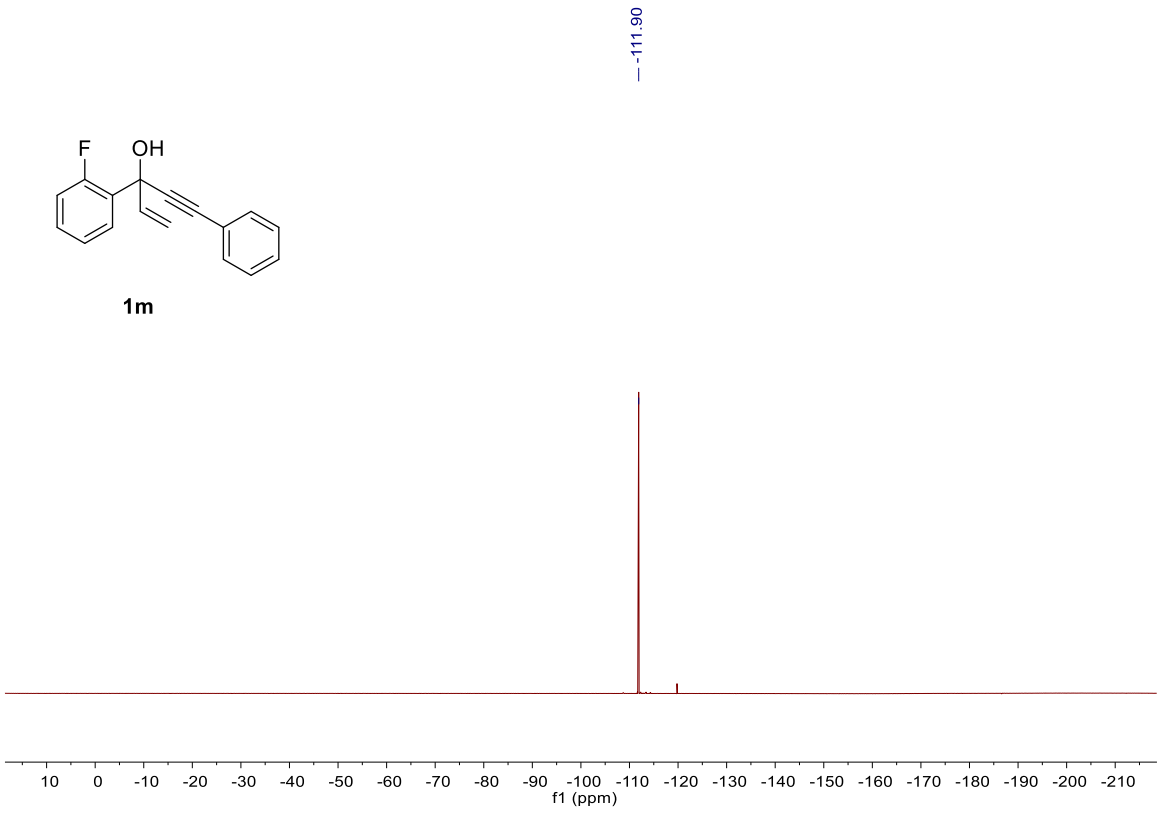


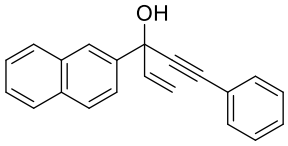
^{13}C NMR spectrum ($CDCl_3$)



^{19}F NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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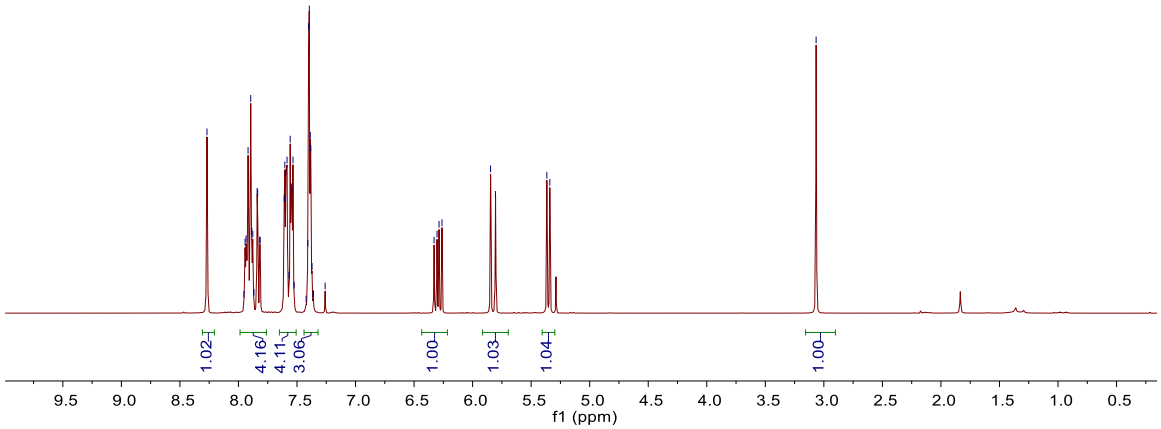
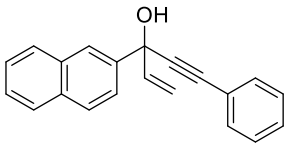


^{13}C NMR spectrum ($CDCl_3$)



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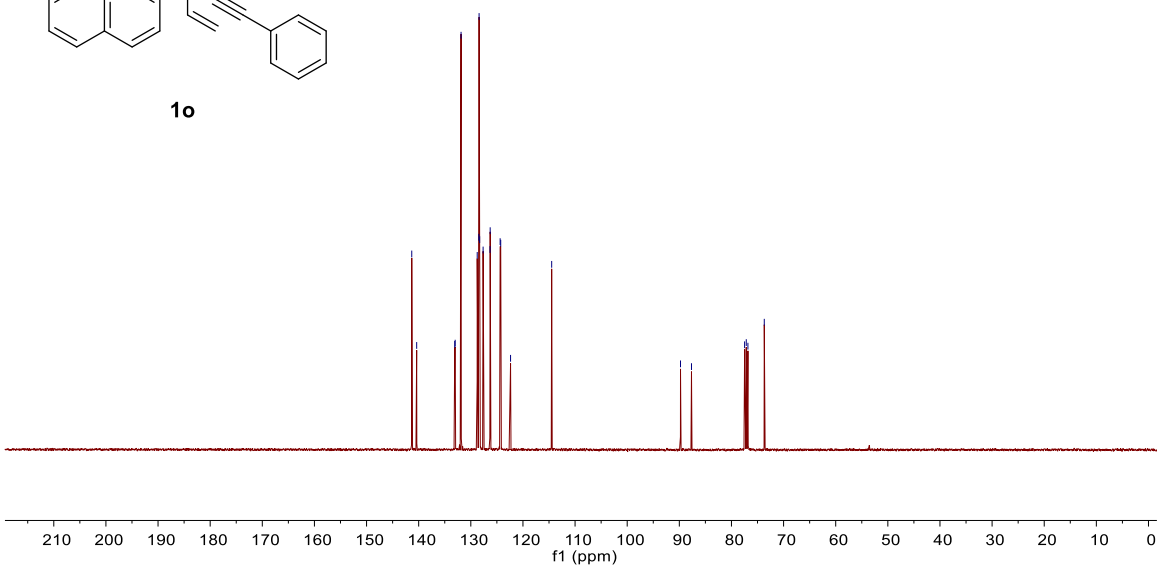
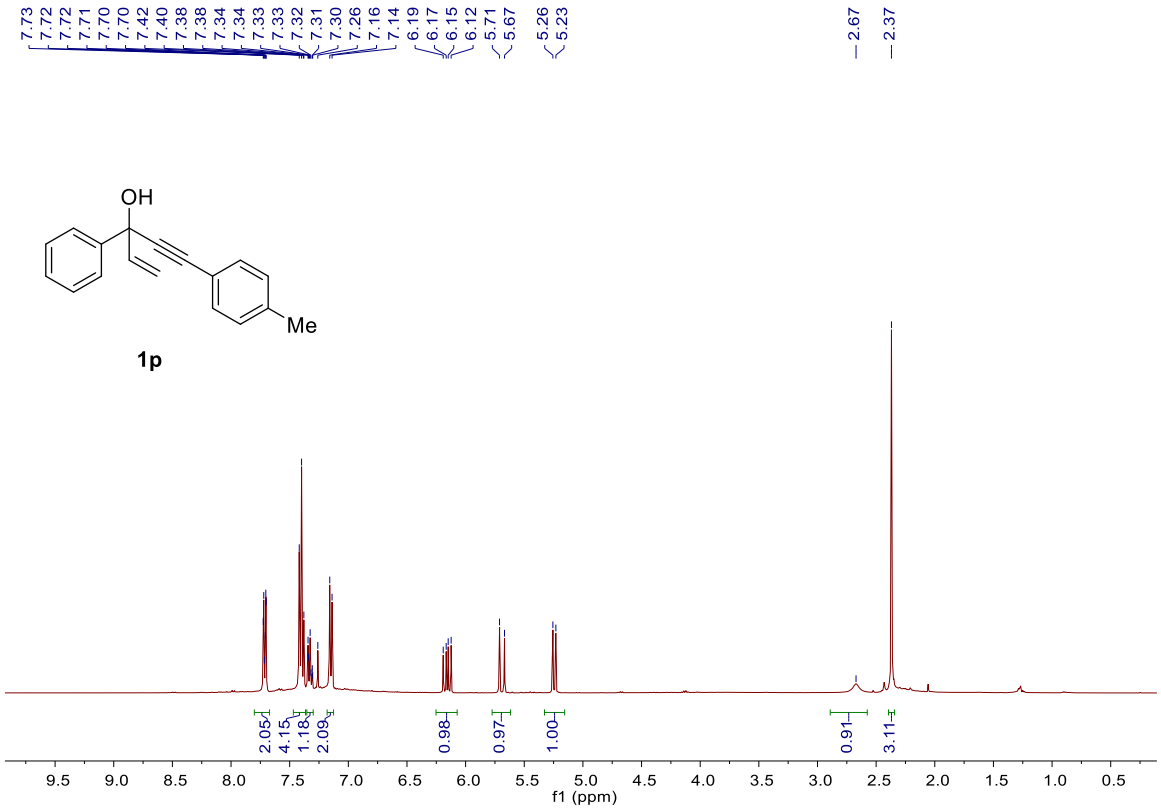


^{1}H NMR spectrum ($CDCl_3$)



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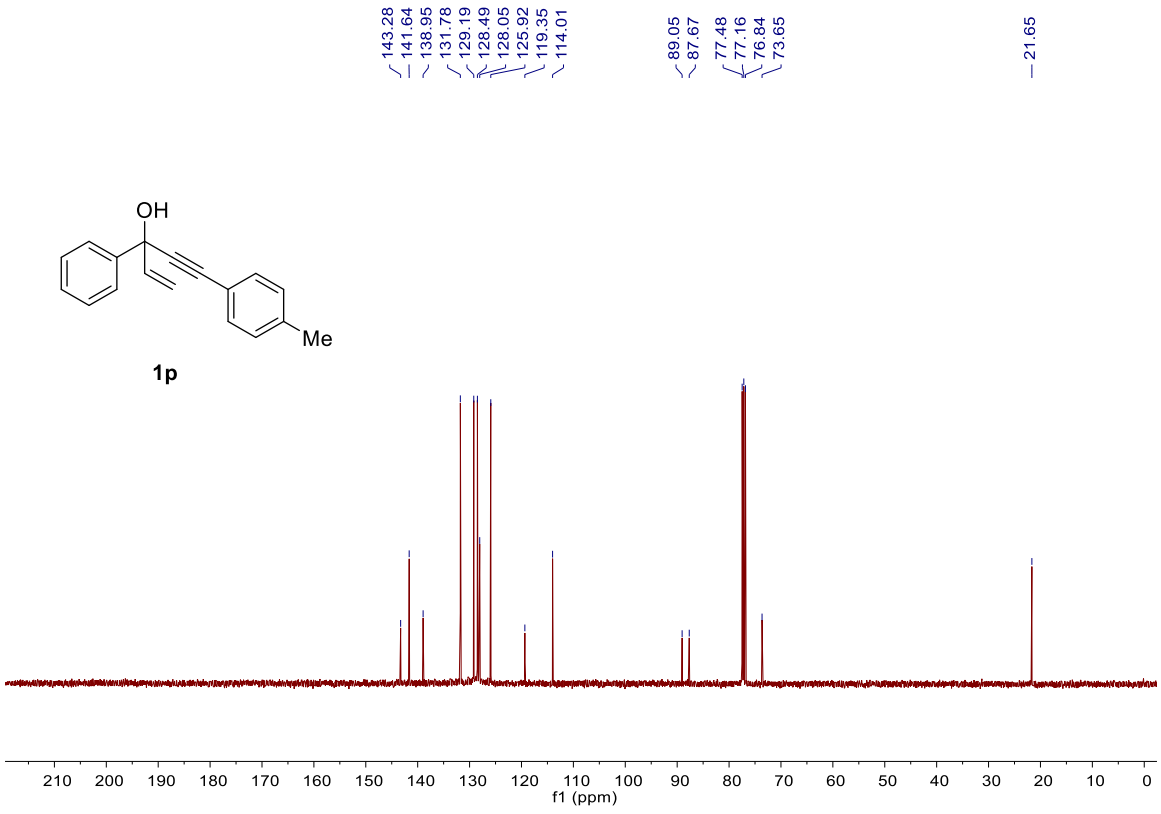
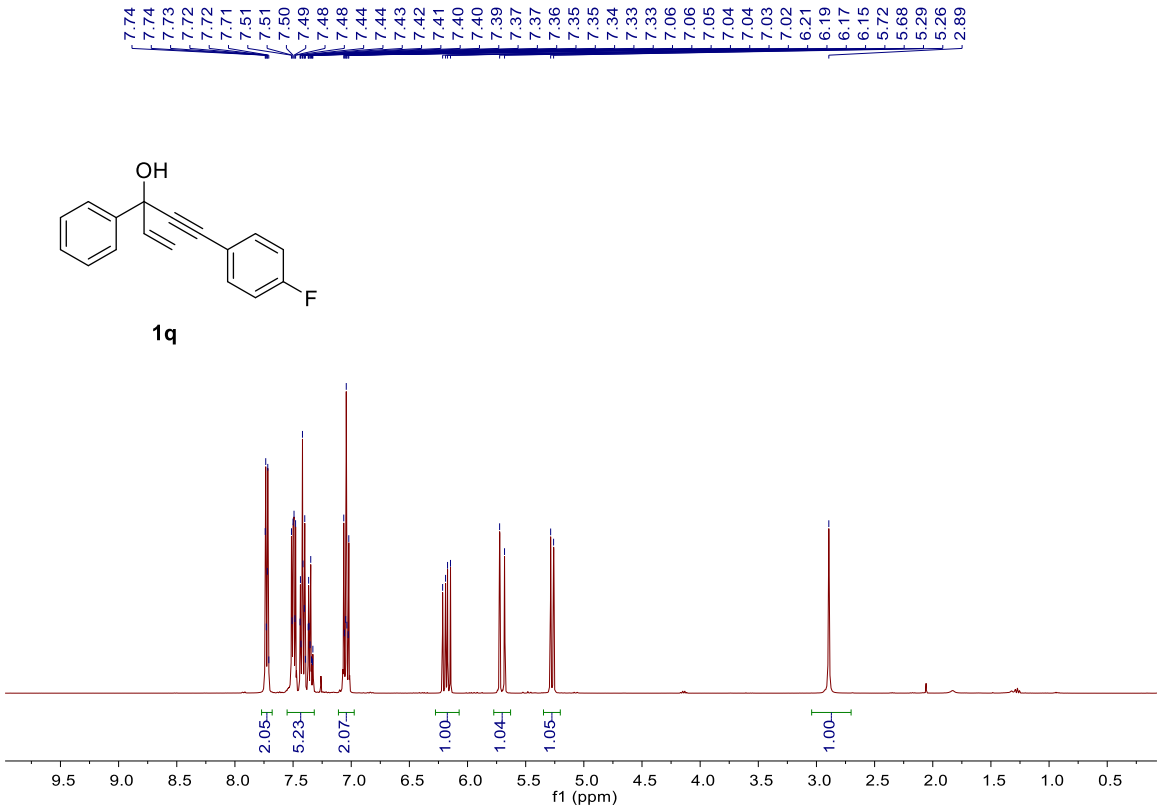
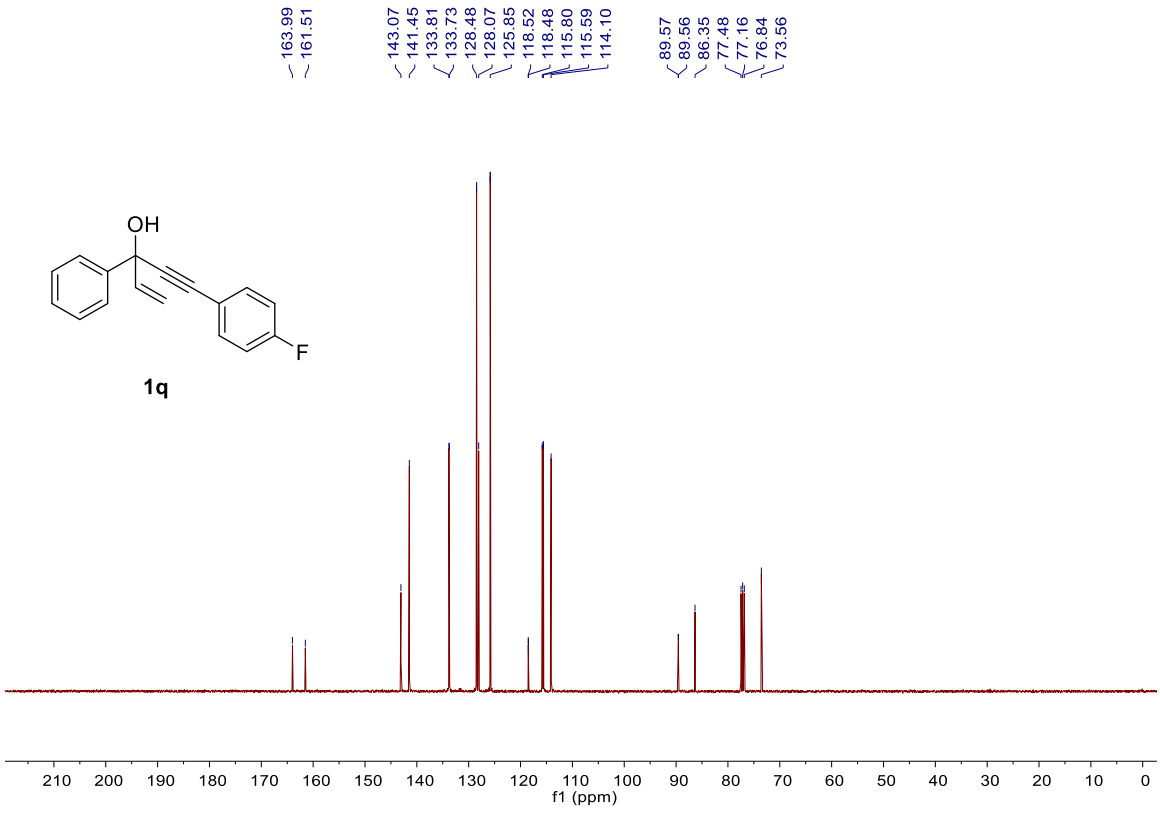


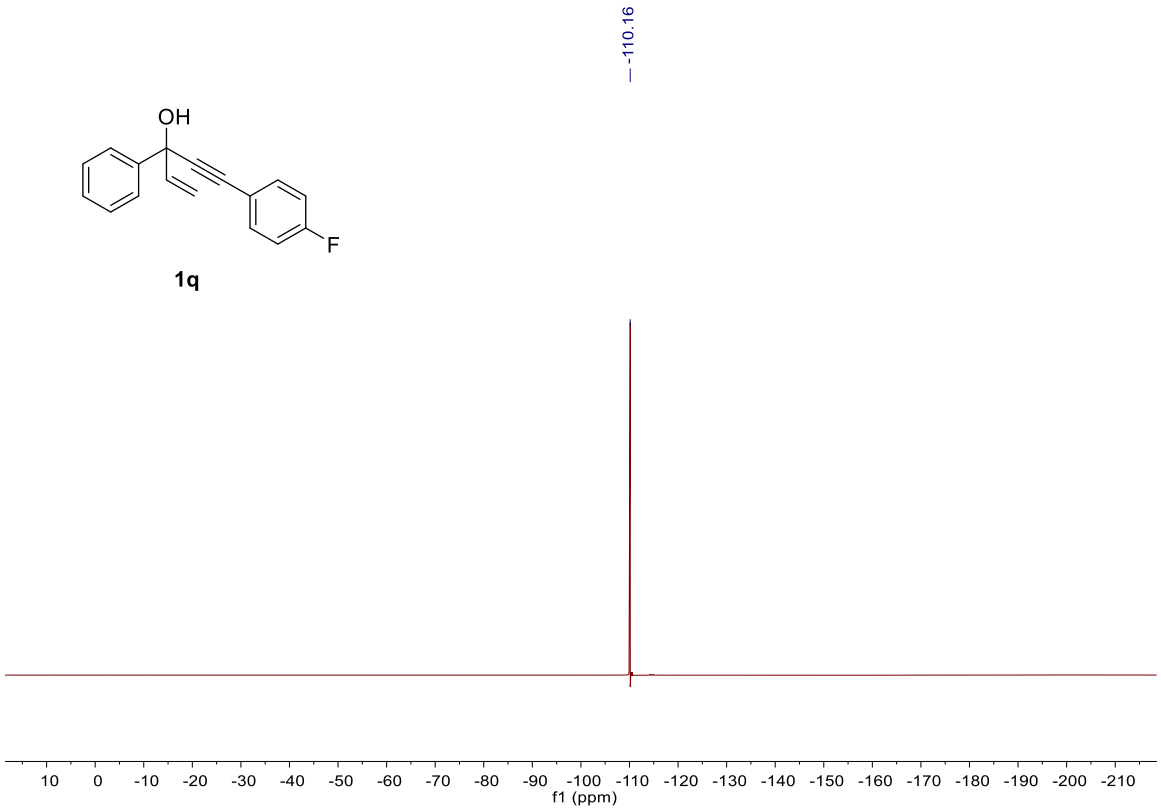
^{1}H NMR spectrum ($CDCl_3$)



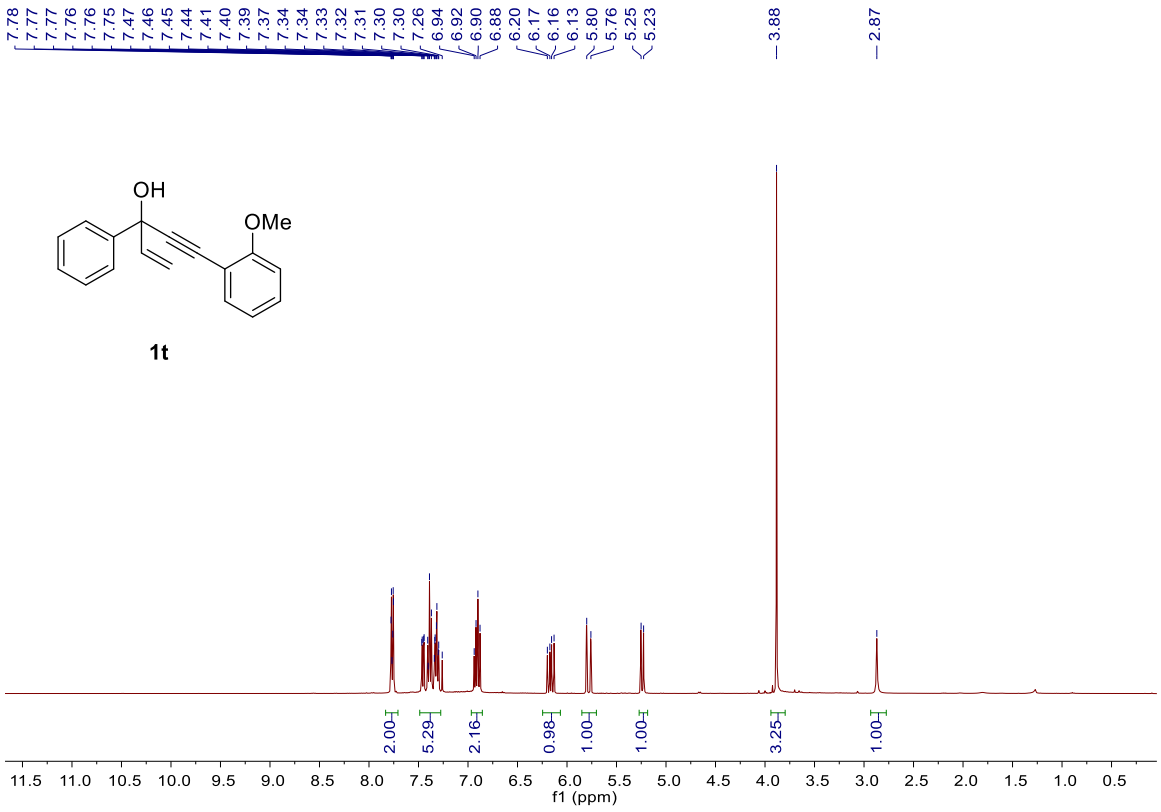
^{13}C NMR spectrum ($CDCl_3$)



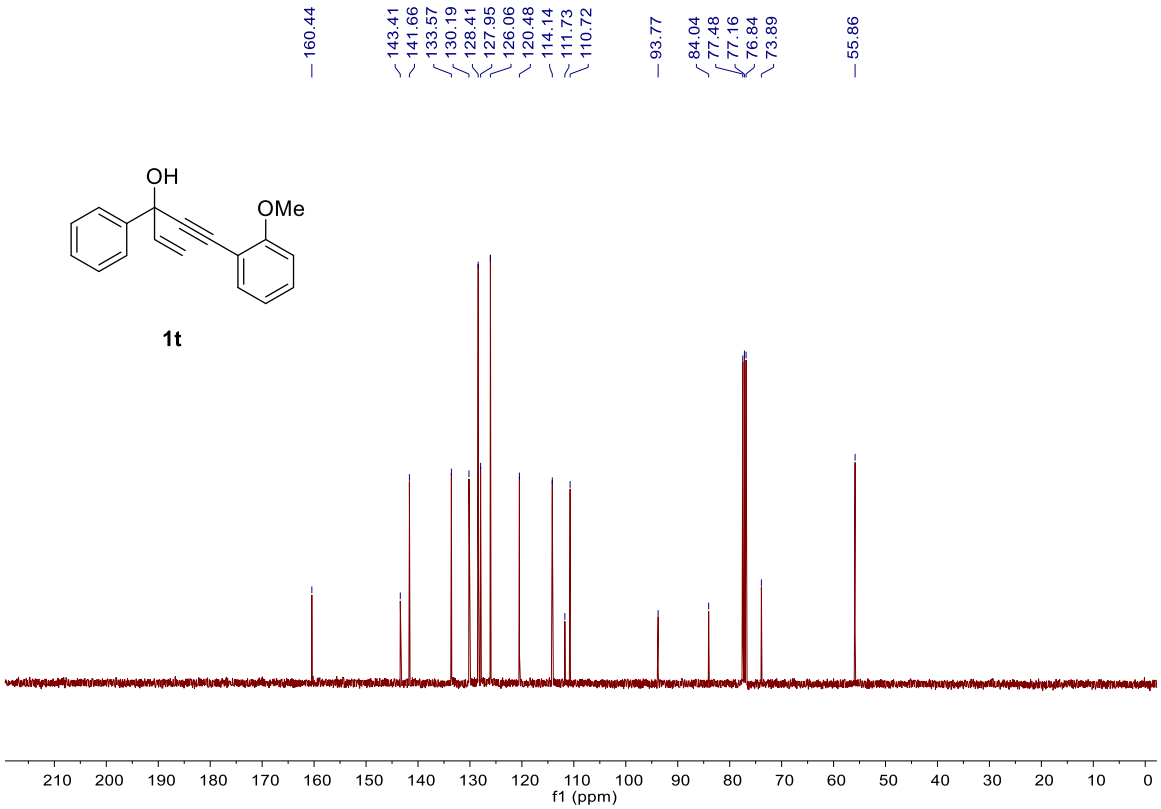
^{19}F NMR spectrum ($CDCl_3$)



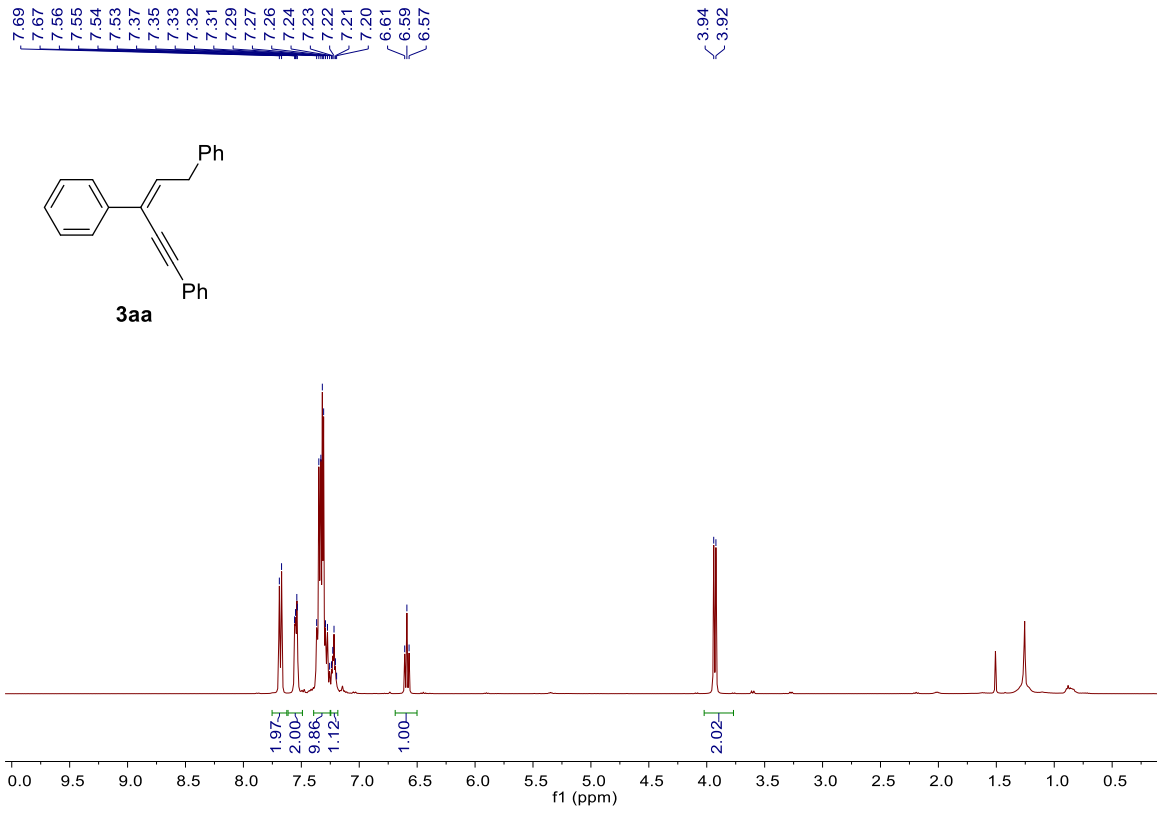
^{1}H NMR spectrum ($CDCl_3$)



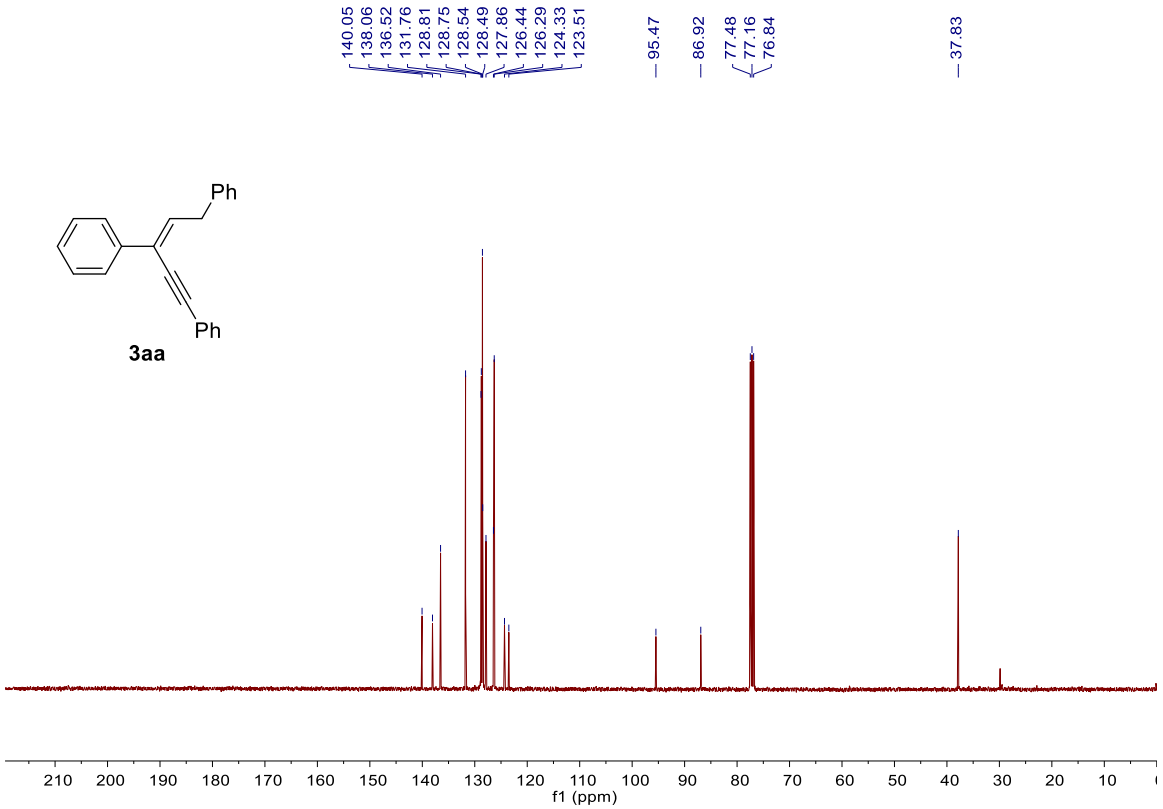
^{13}C NMR spectrum ($CDCl_3$)



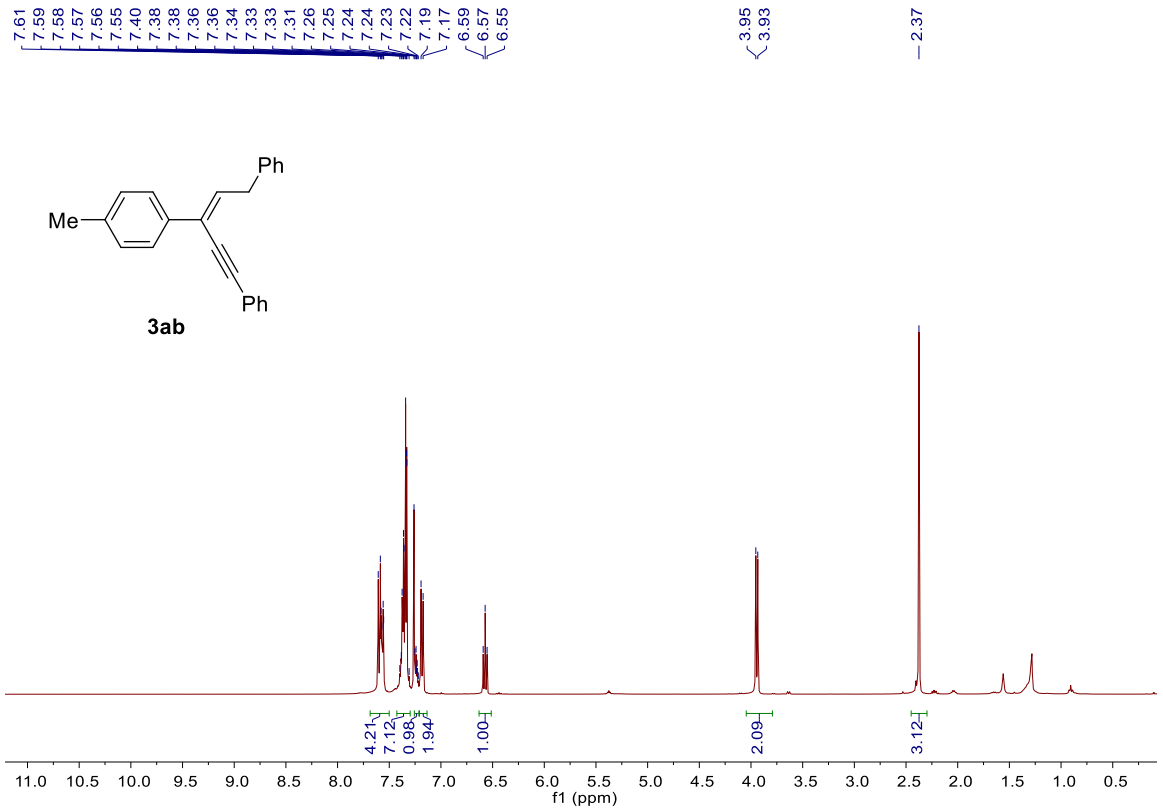
^{1}H NMR spectrum ($CDCl_3$)



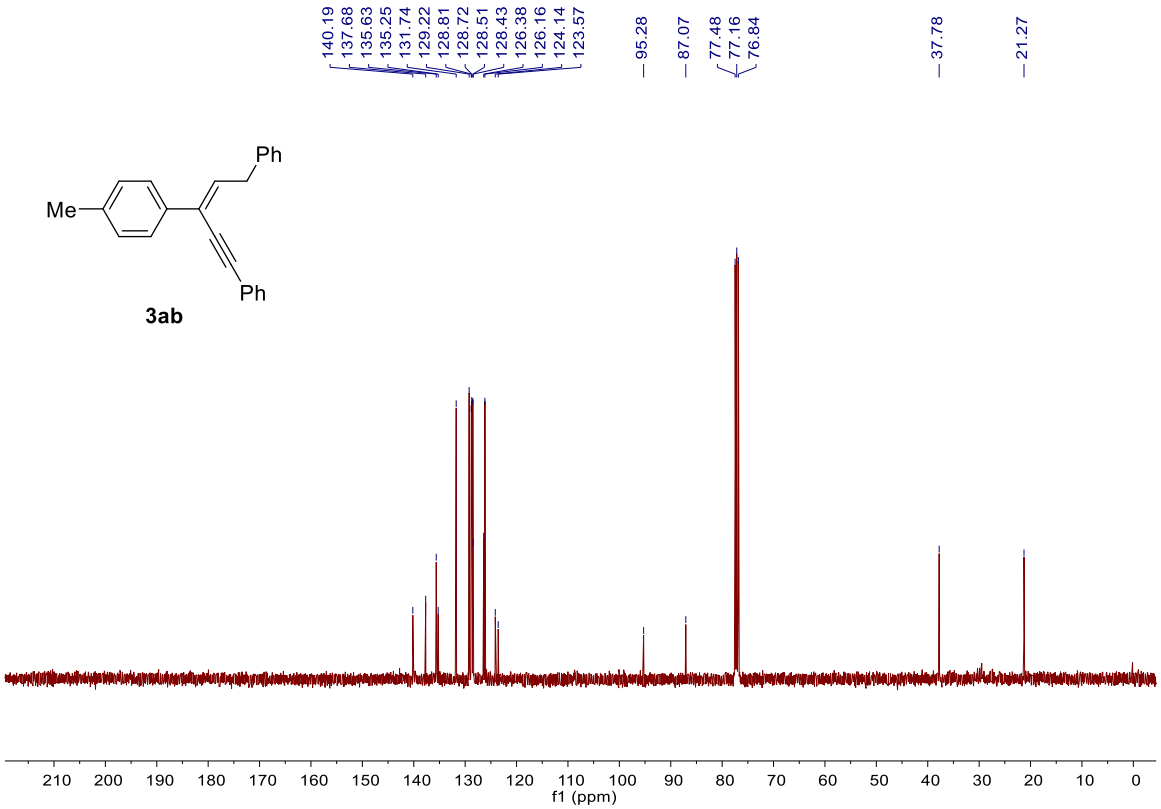
^{13}C NMR spectrum ($CDCl_3$)



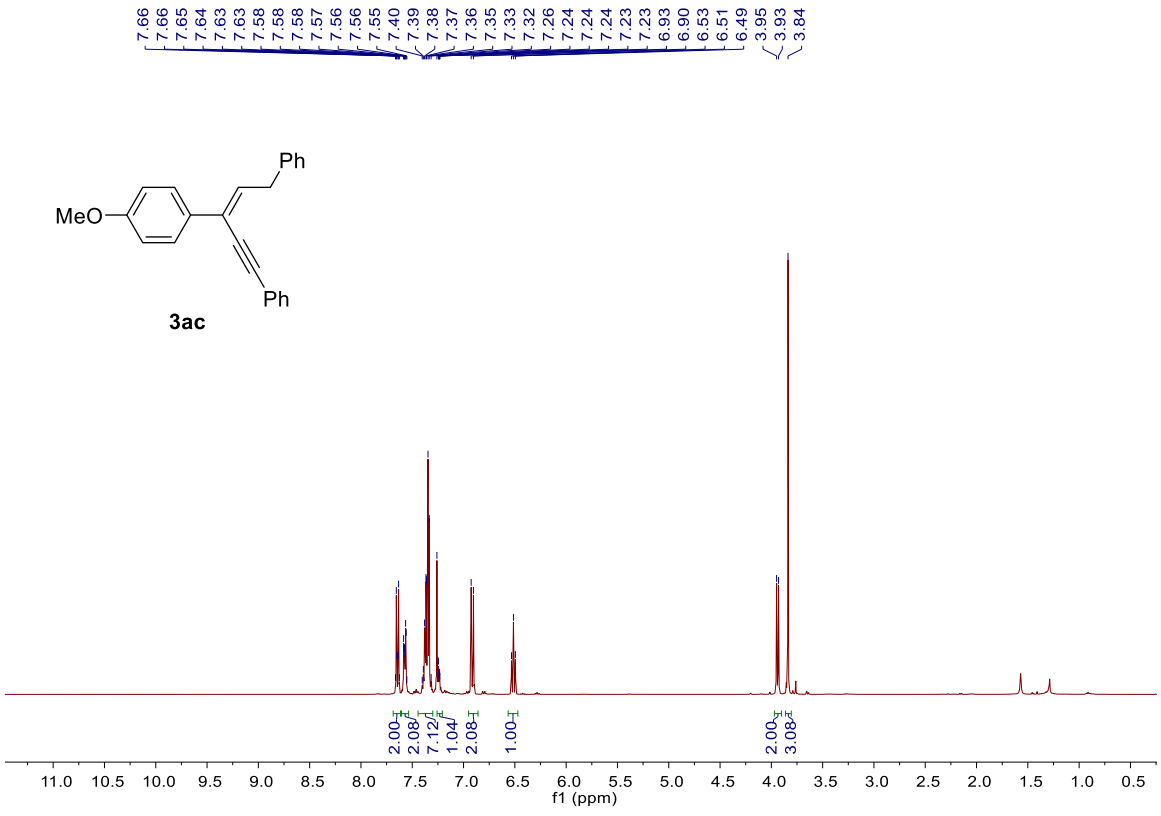
^{1}H NMR spectrum ($CDCl_3$)



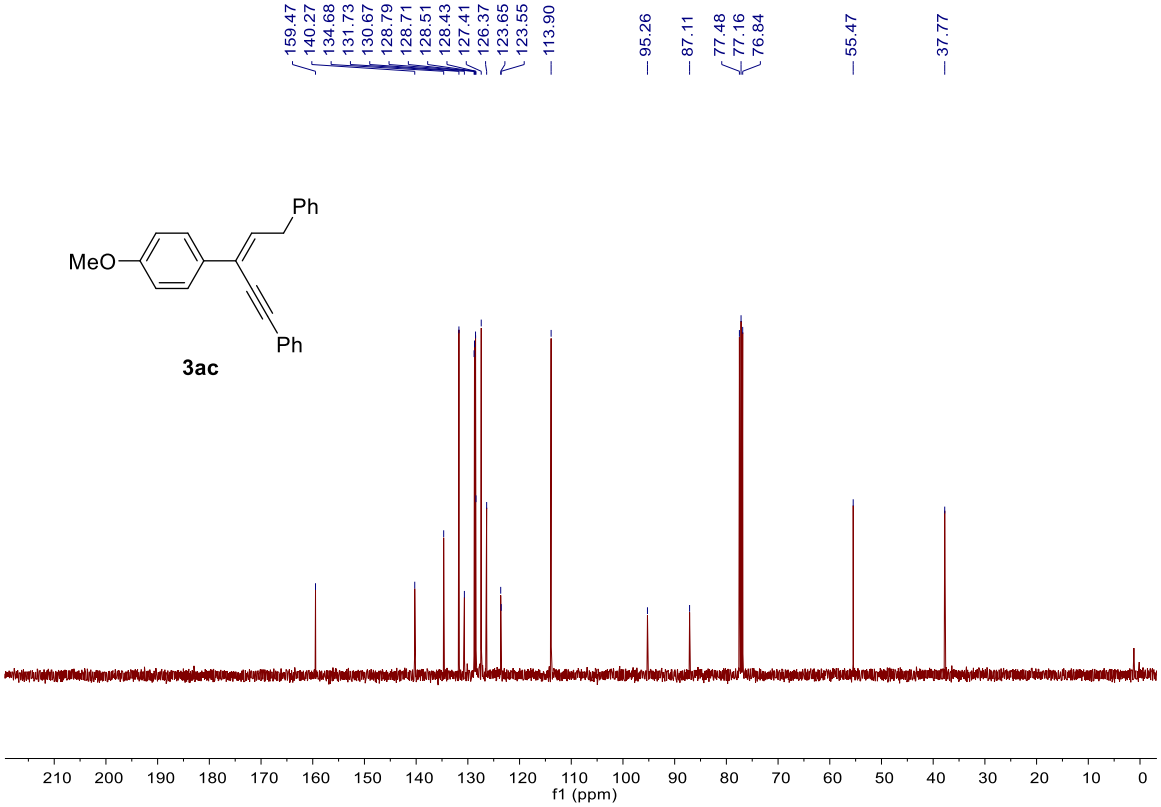
^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



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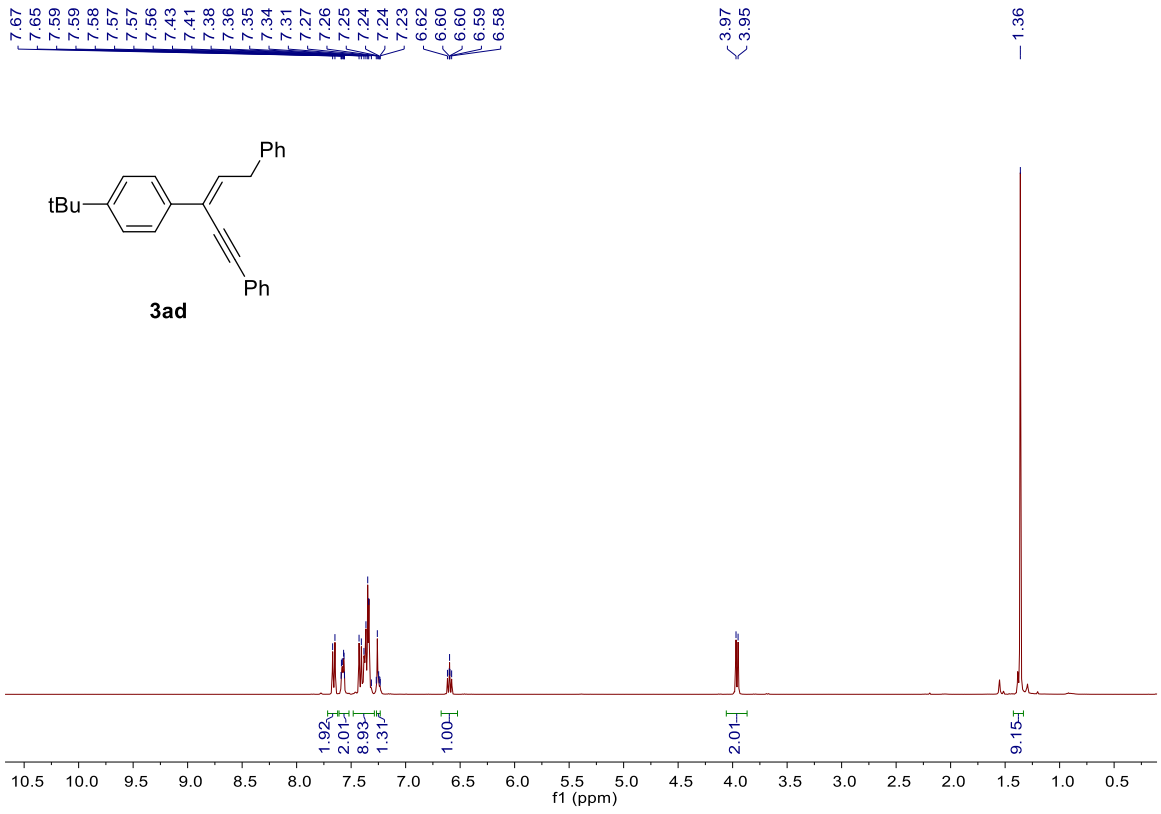

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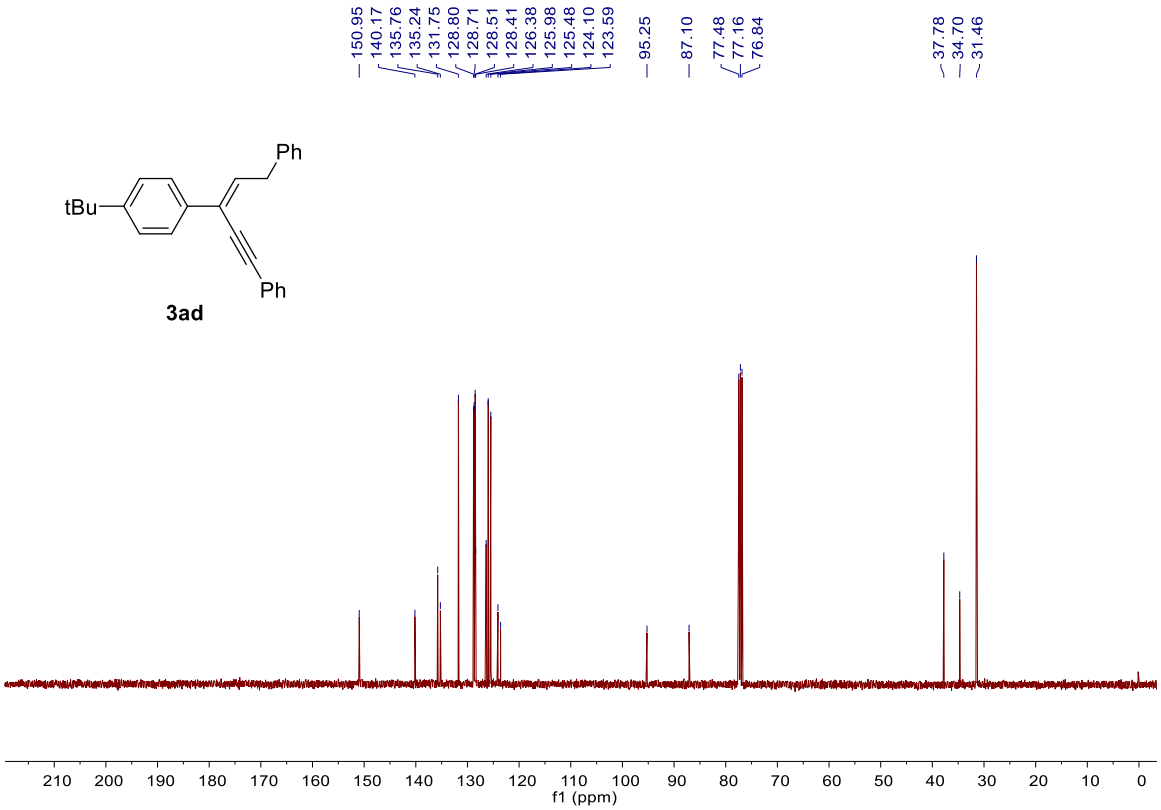
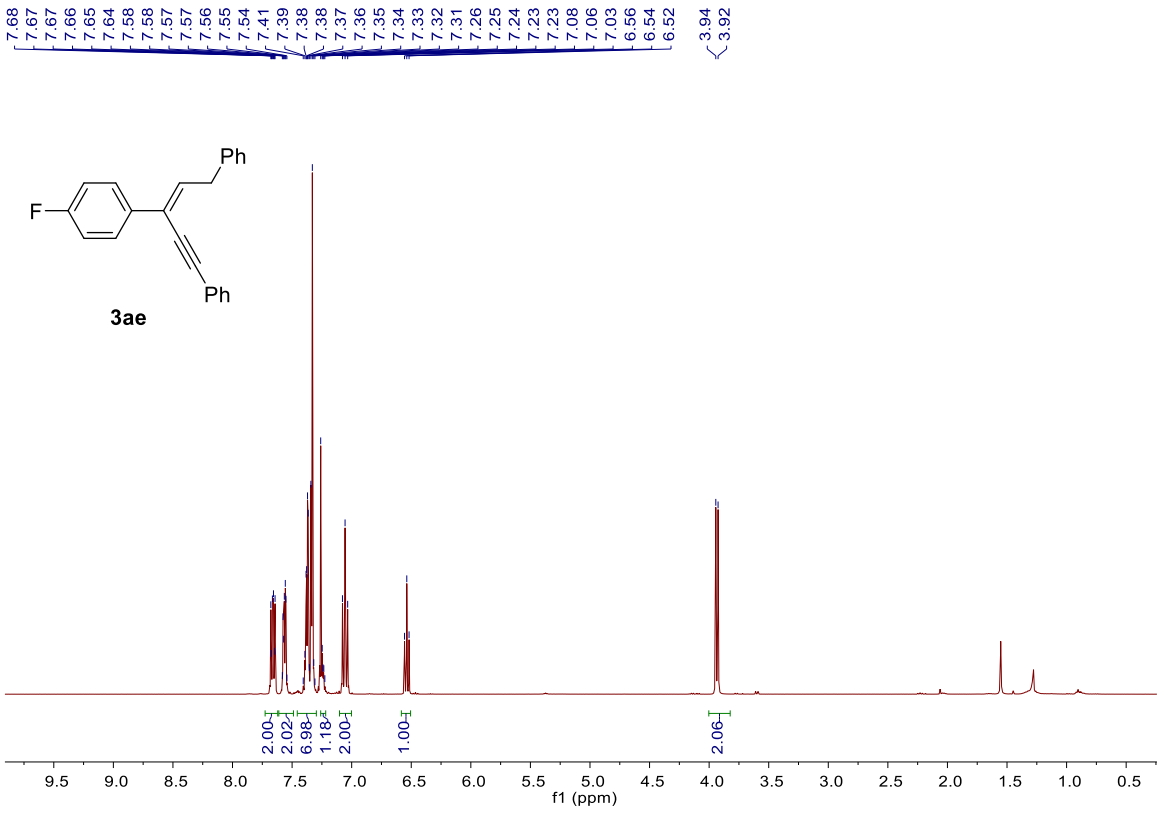


^{1}H NMR spectrum ($CDCl_3$)



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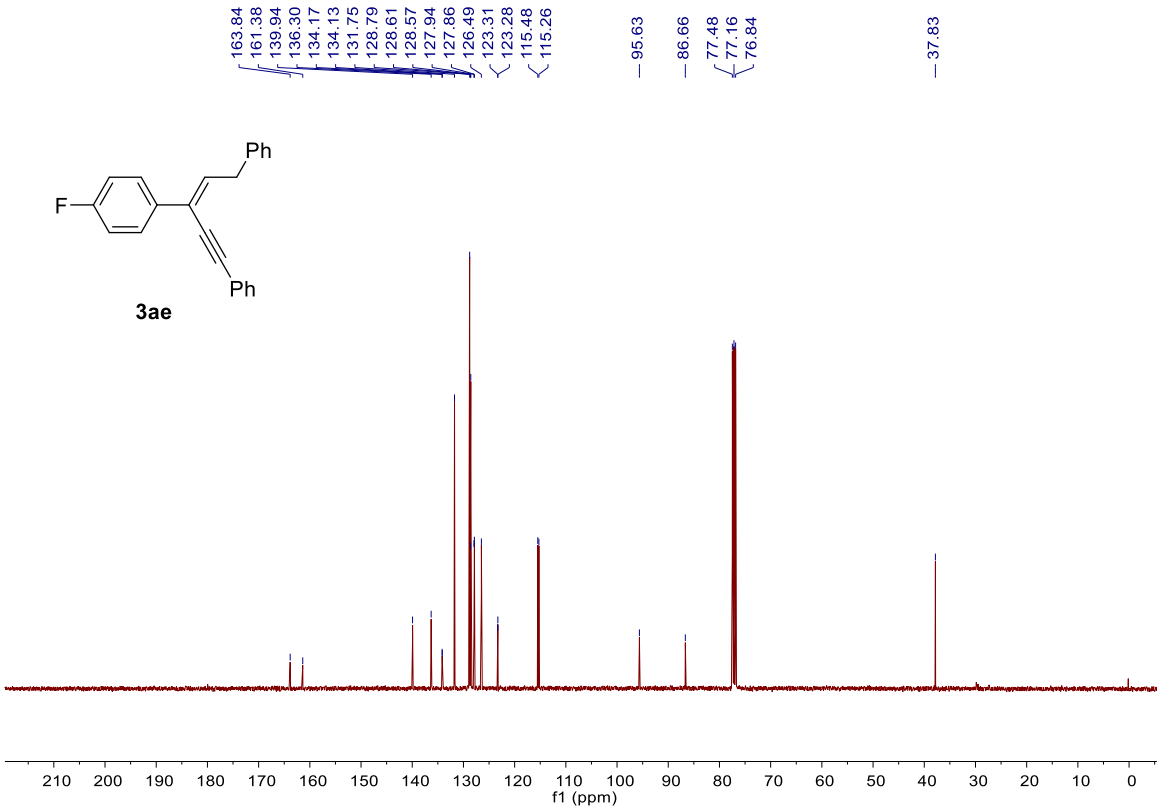

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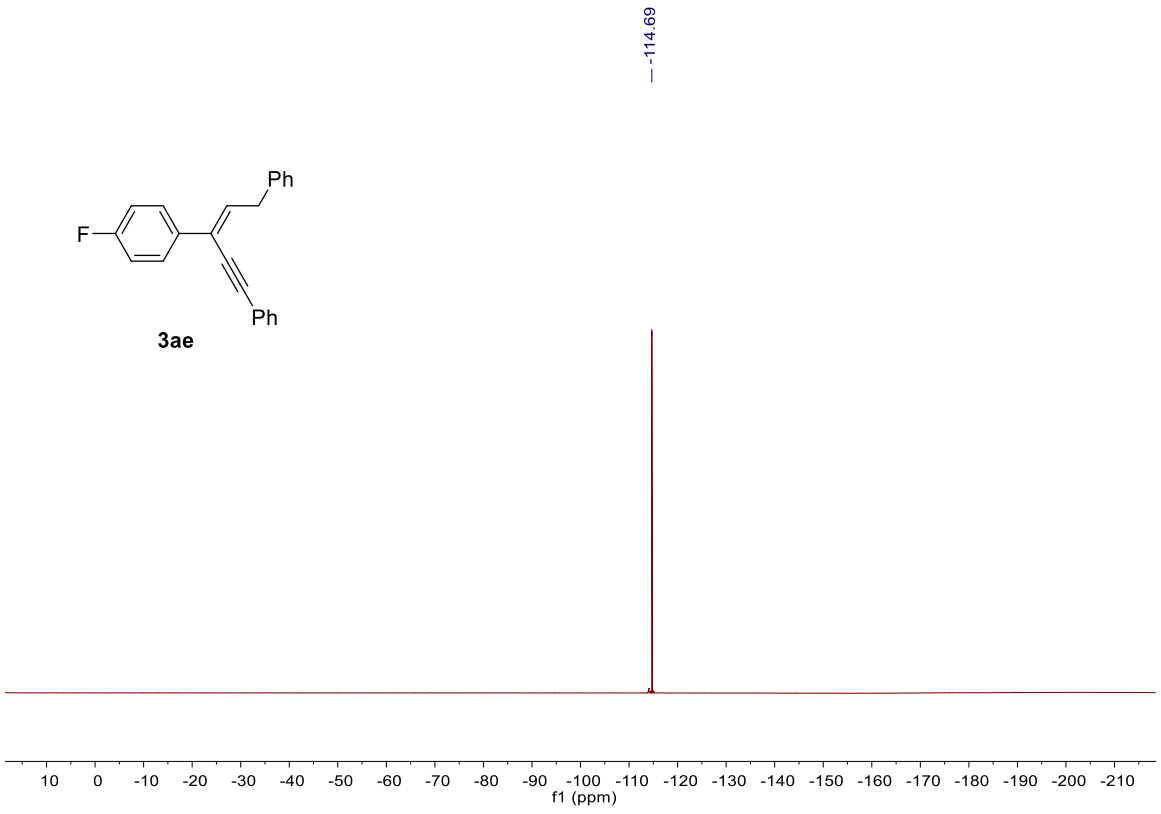
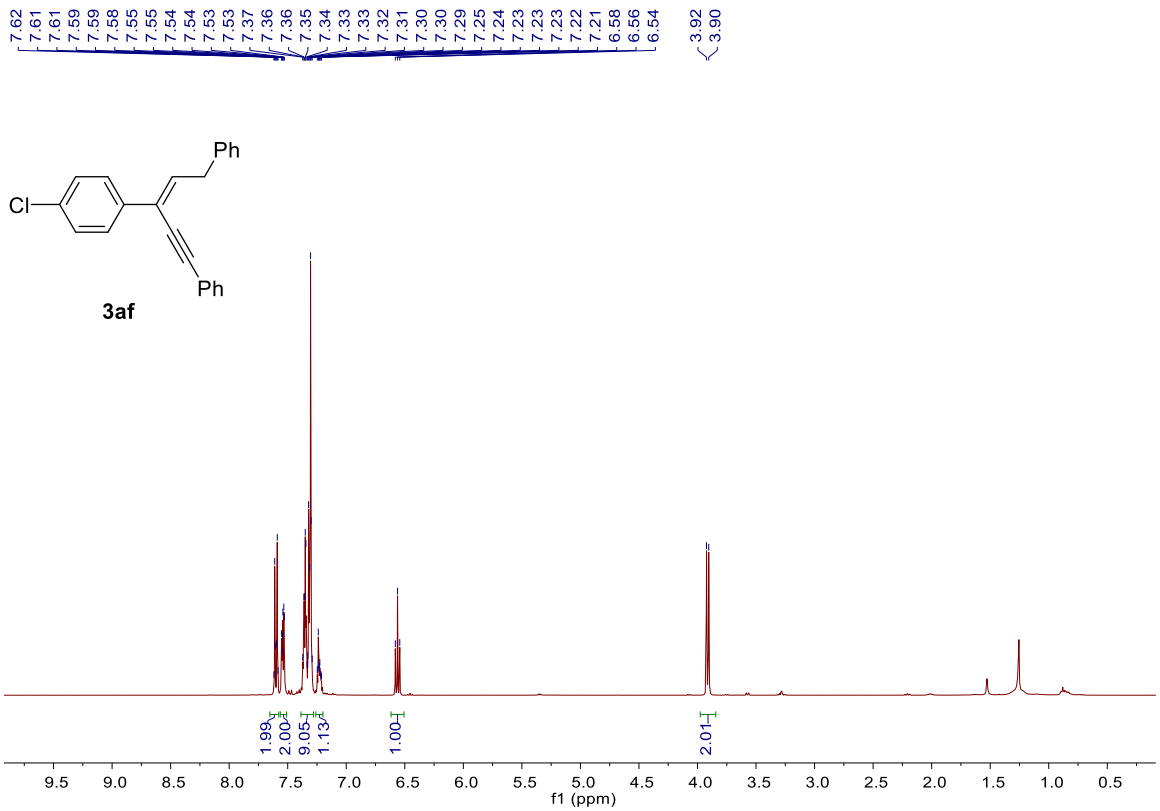
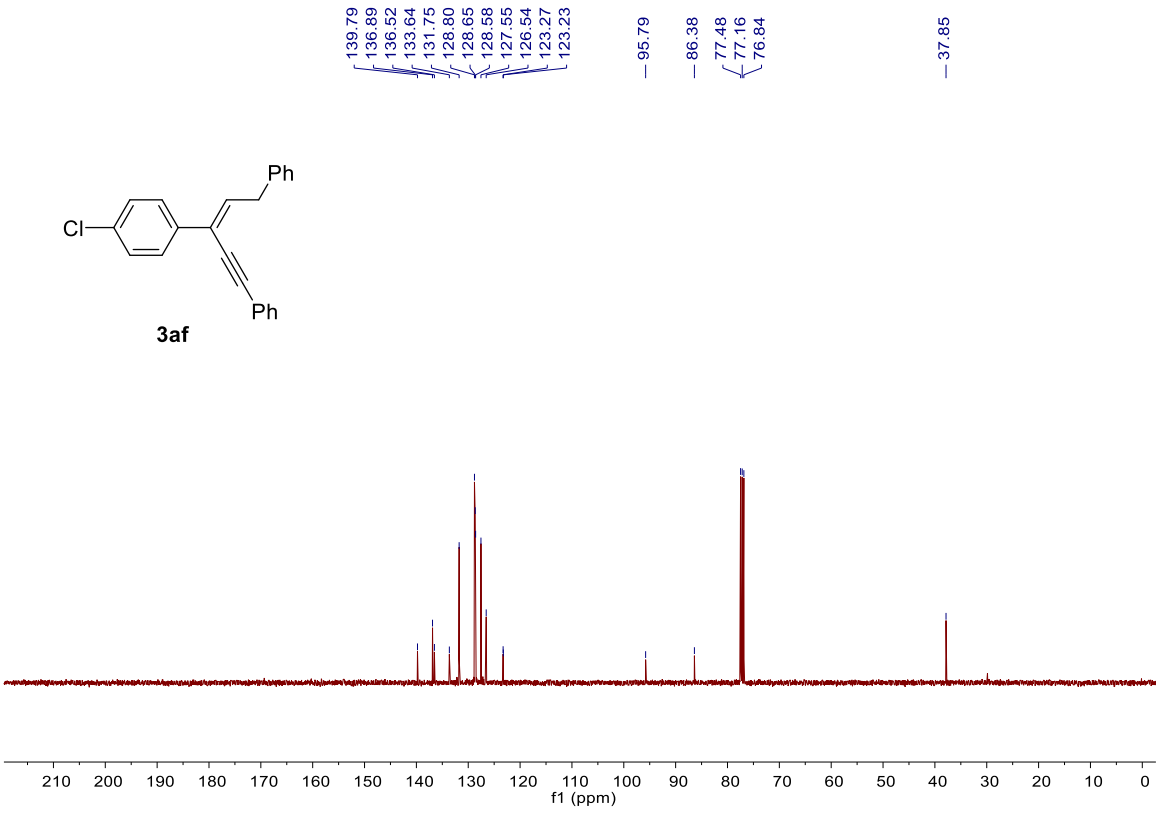


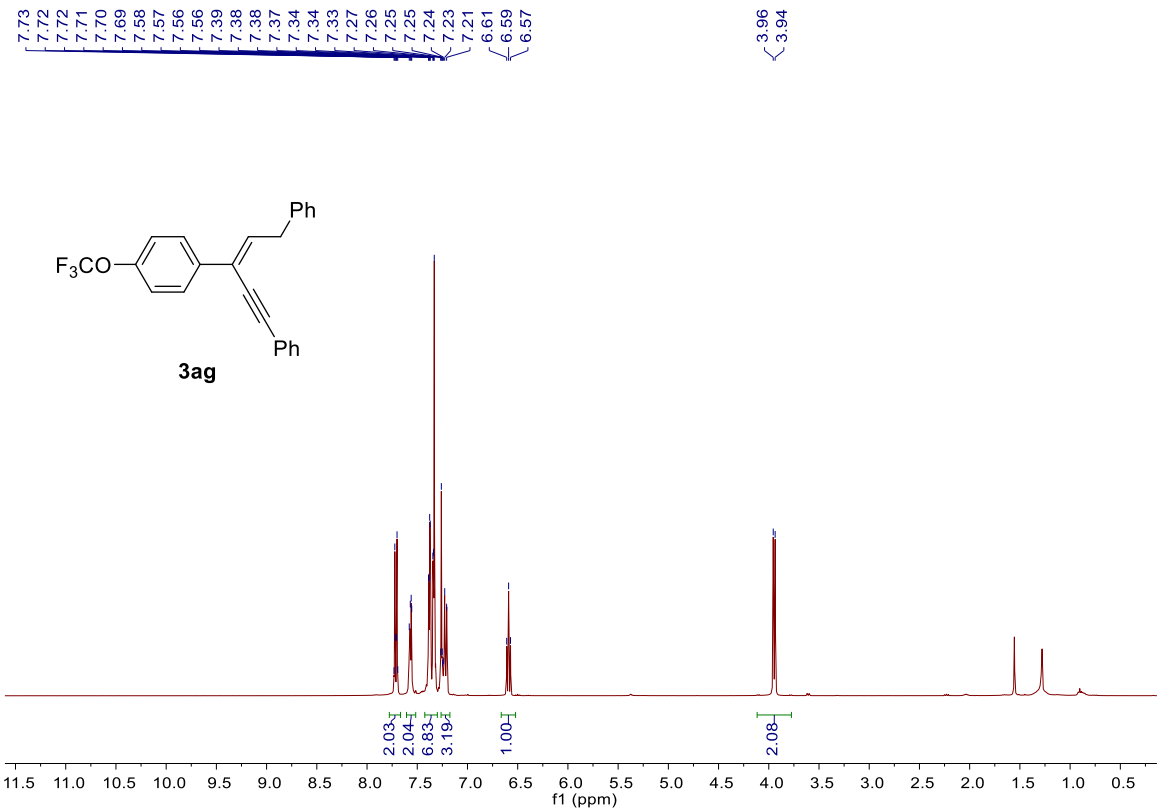
^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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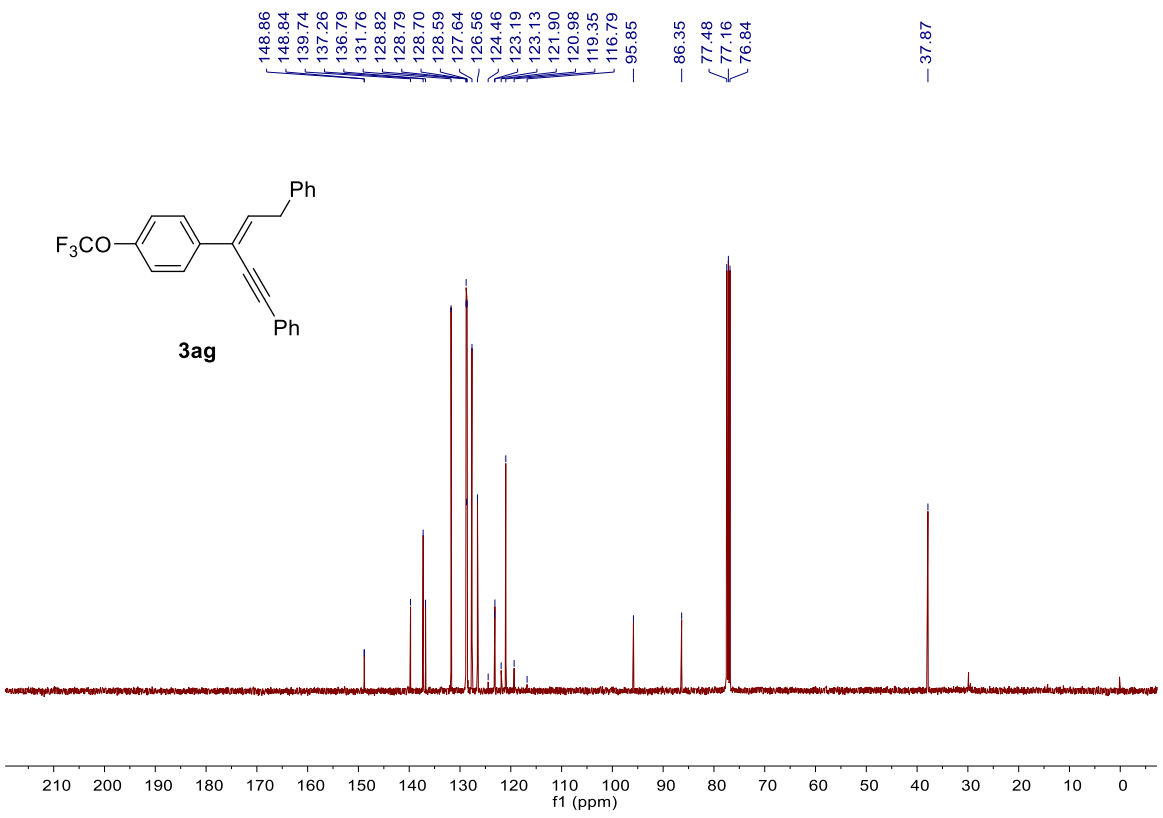
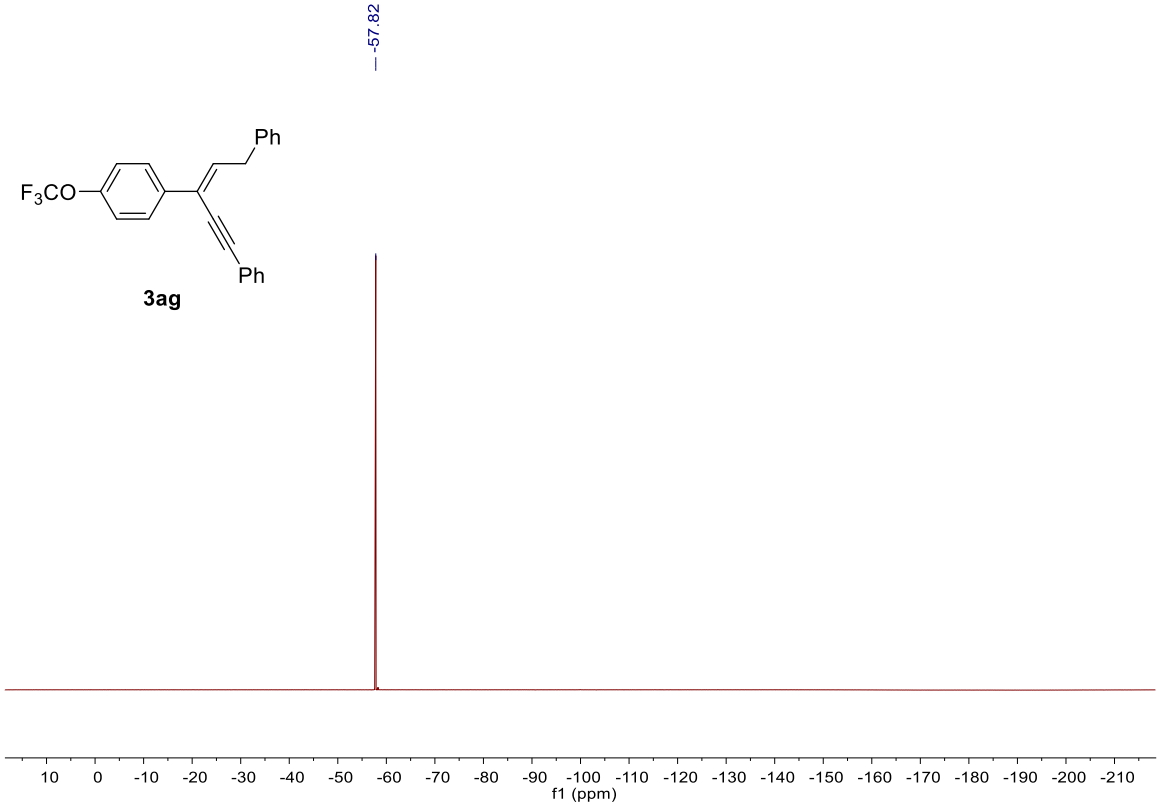
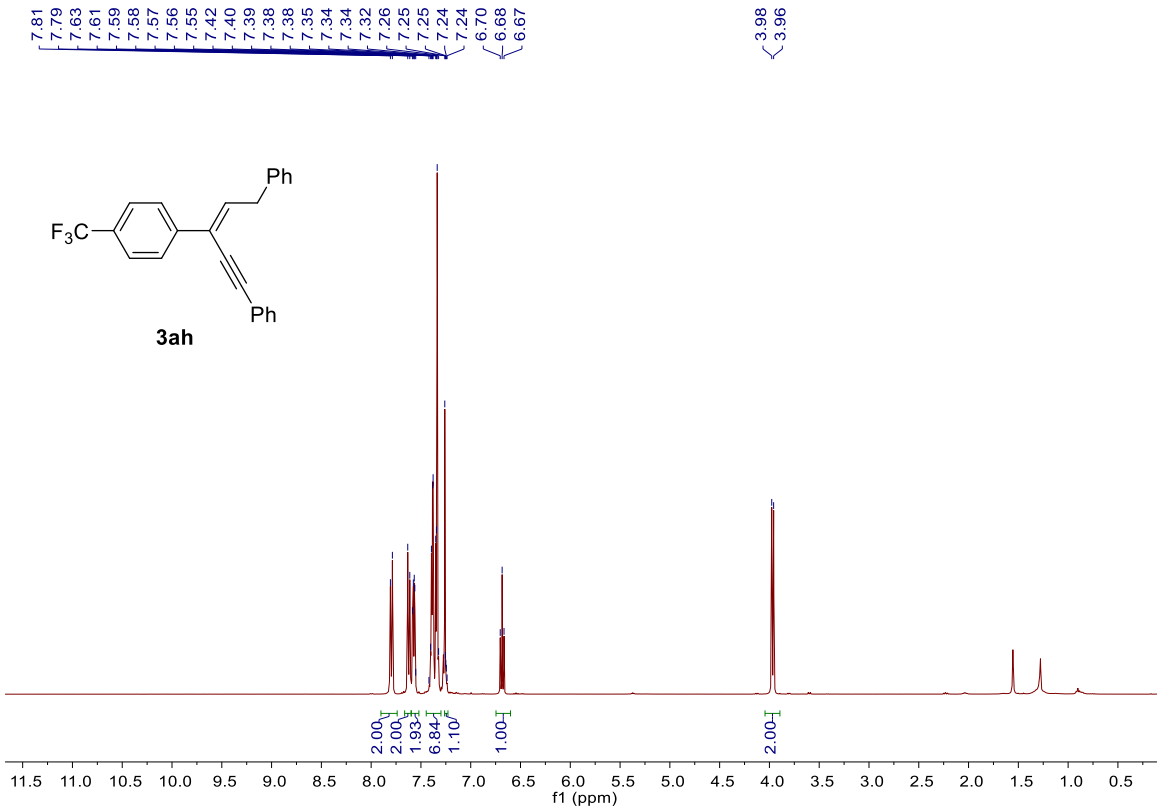


^{19}F NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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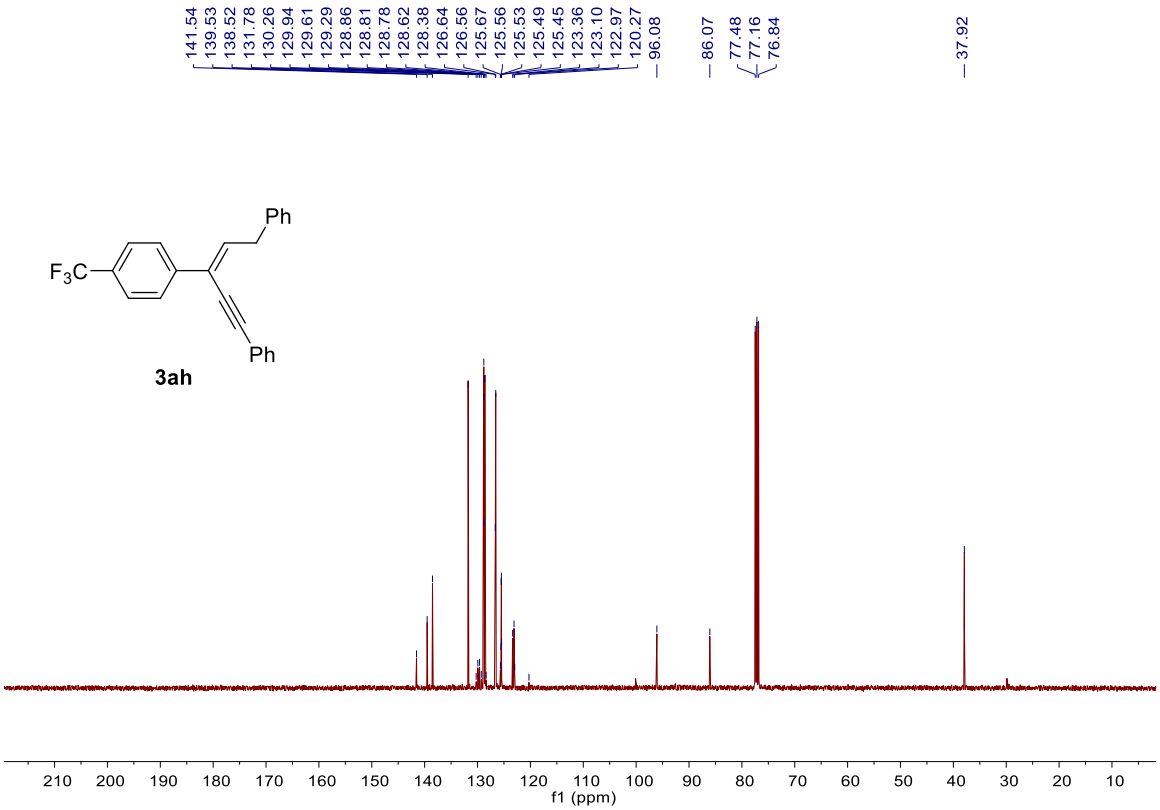
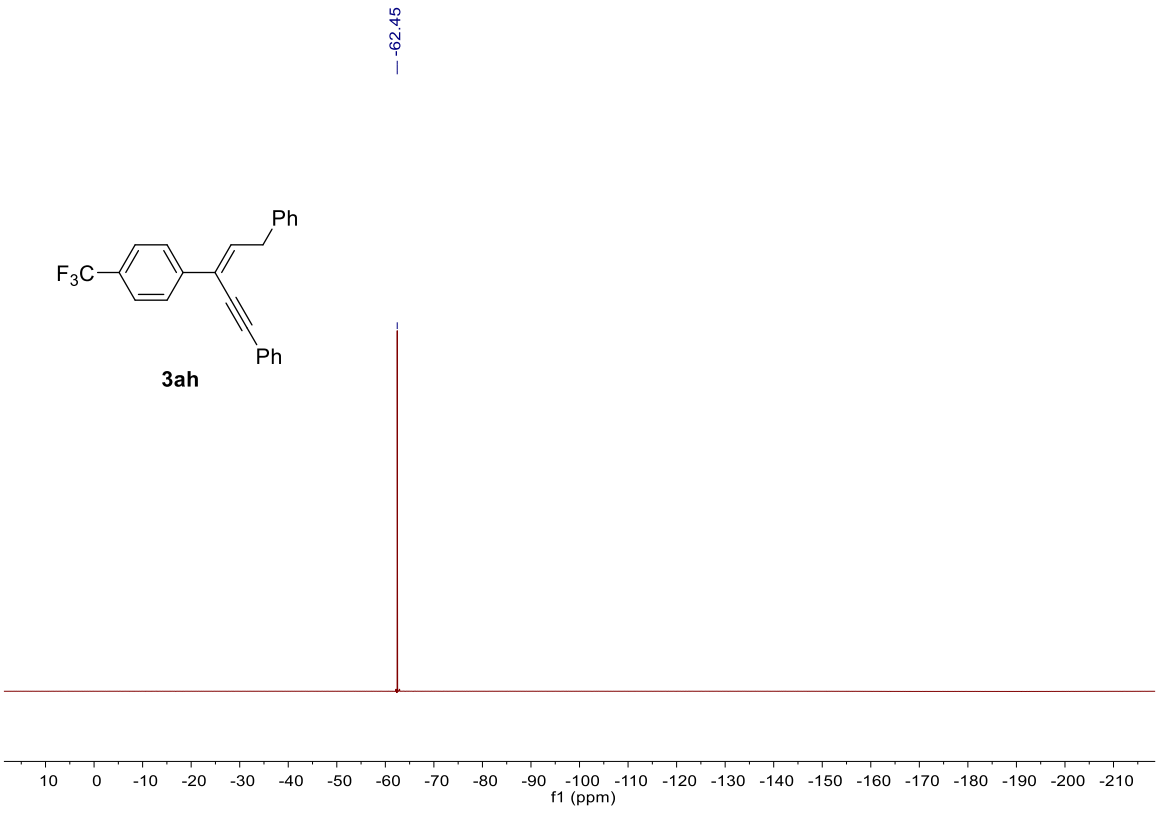
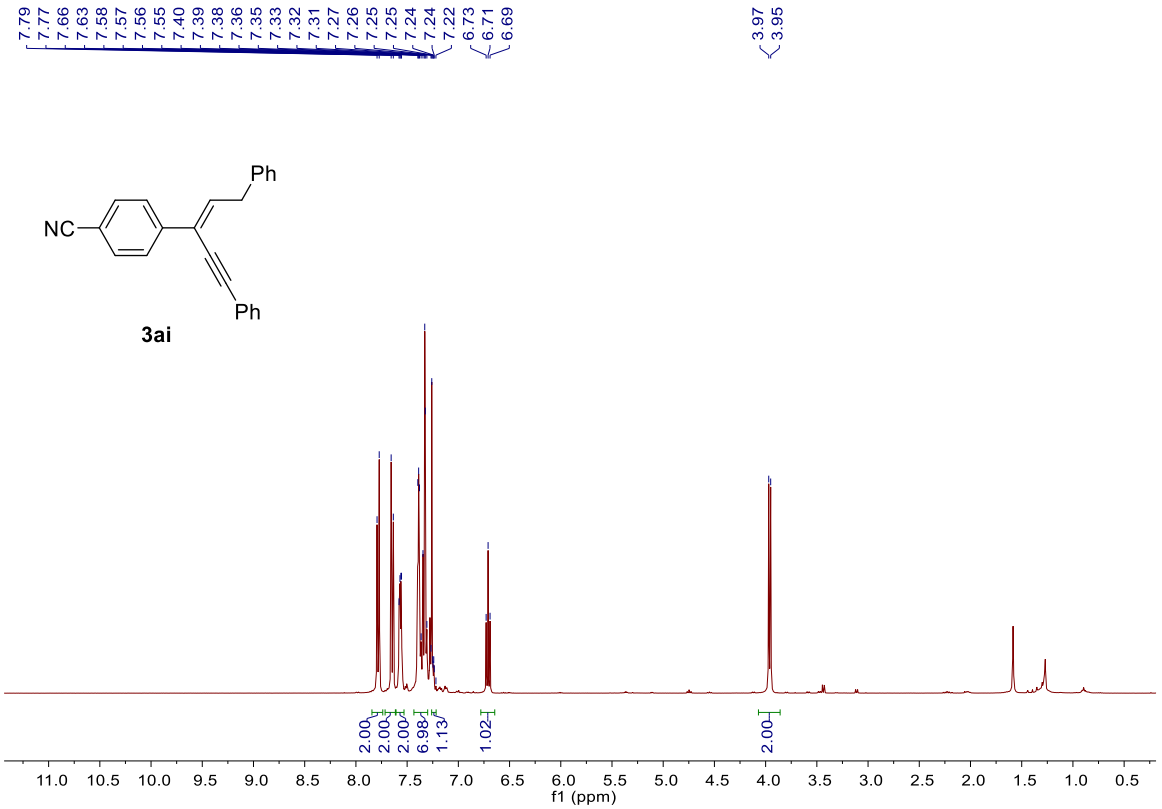


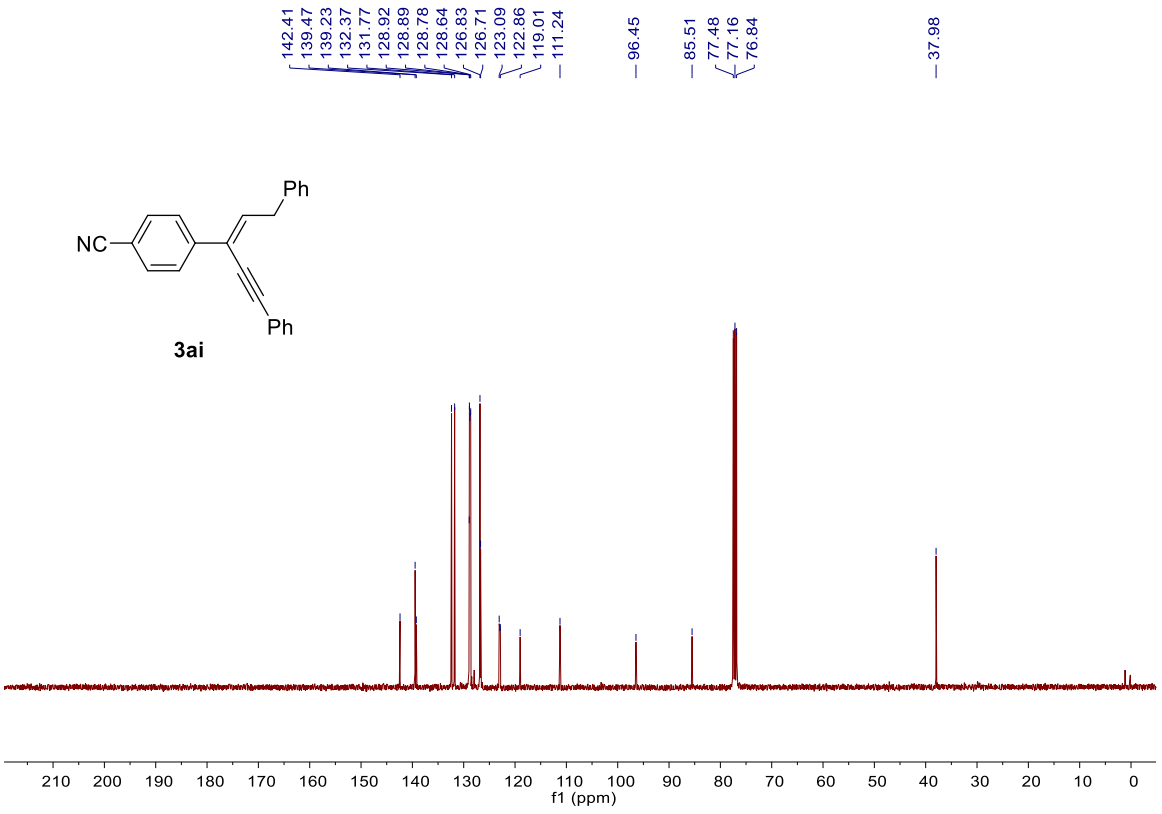
^{19}F NMR spectrum ($CDCl_3$)



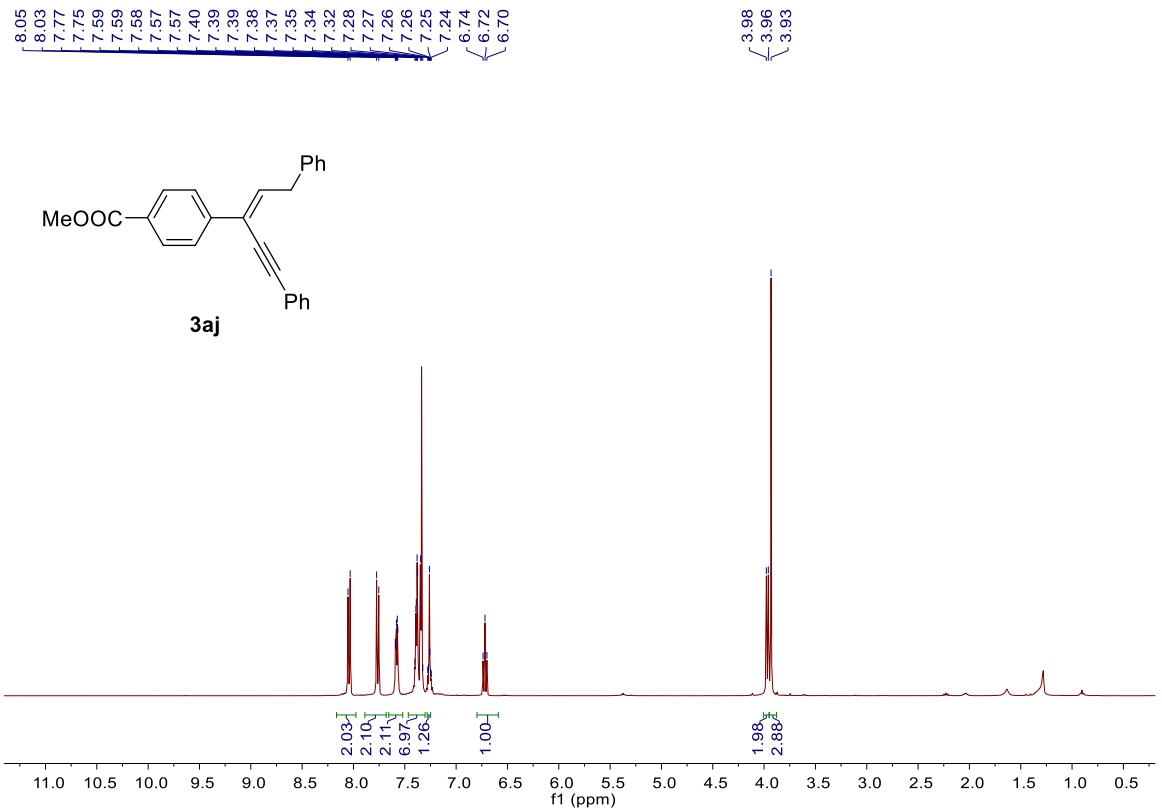
^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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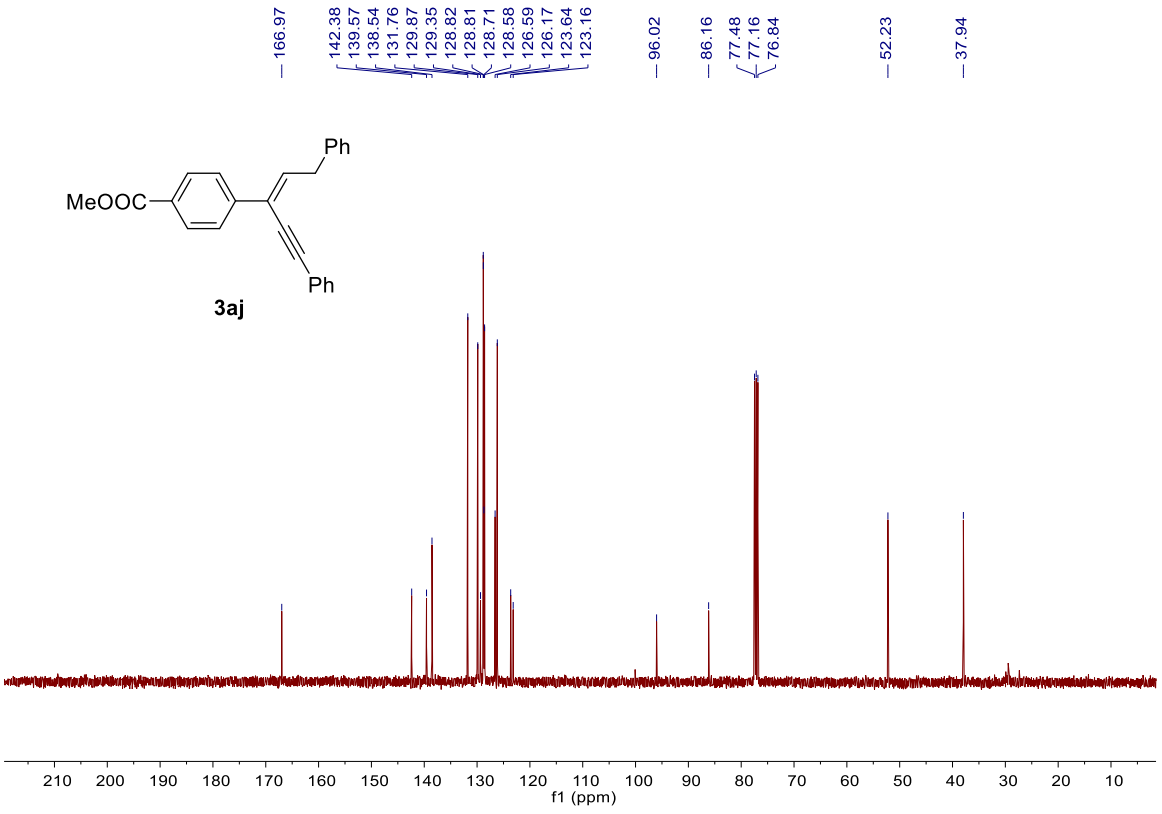
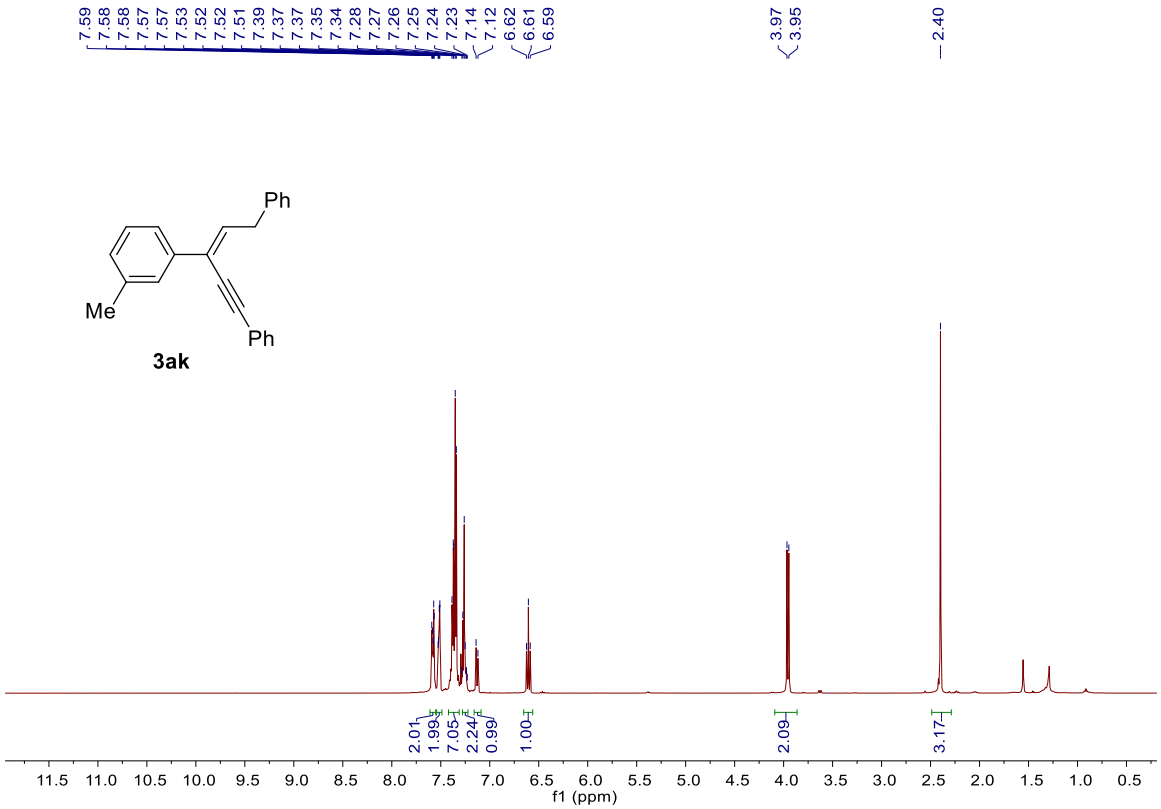
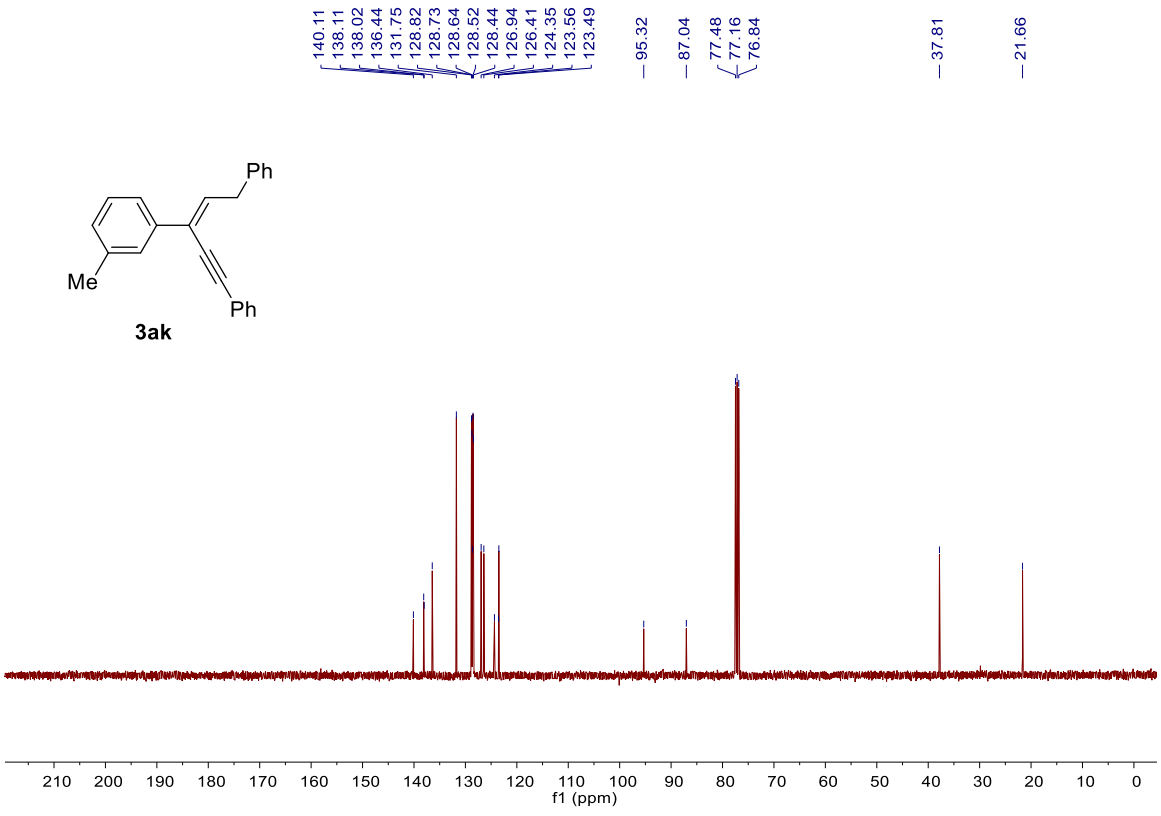


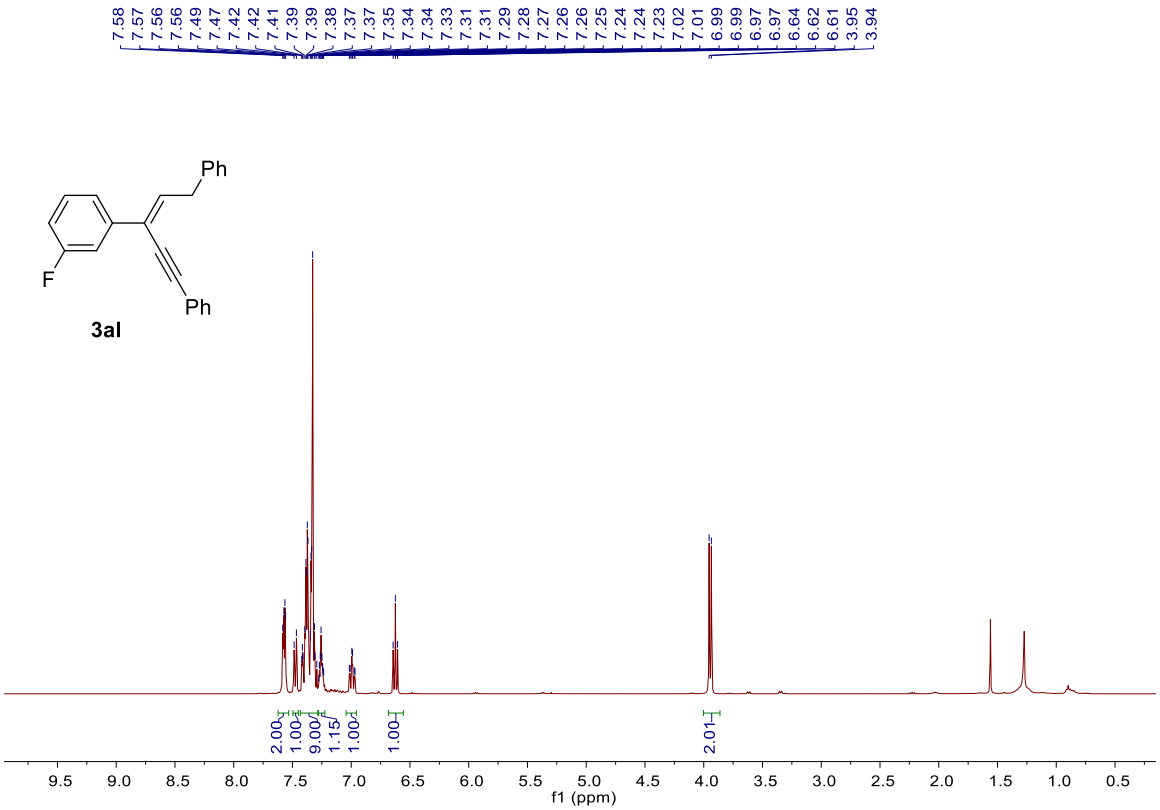
^{1}H NMR spectrum ($CDCl_3$)



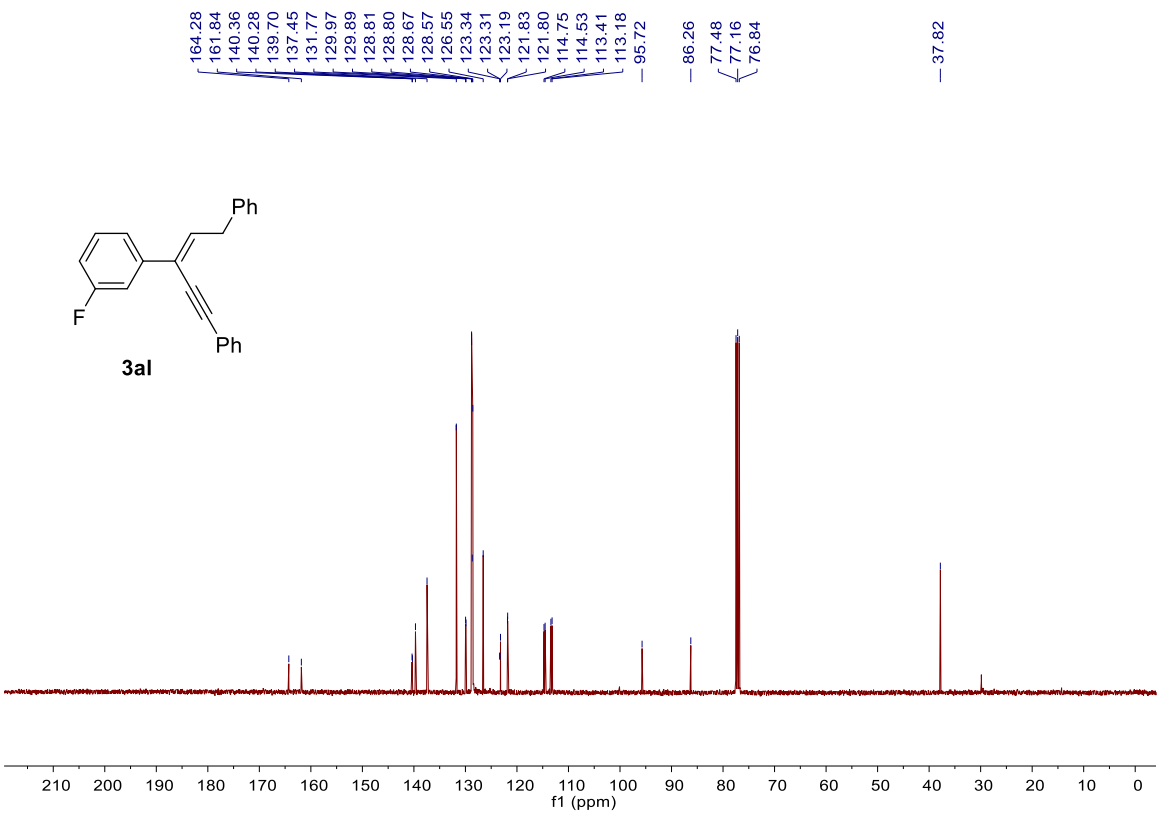
^{13}C NMR spectrum ($CDCl_3$)



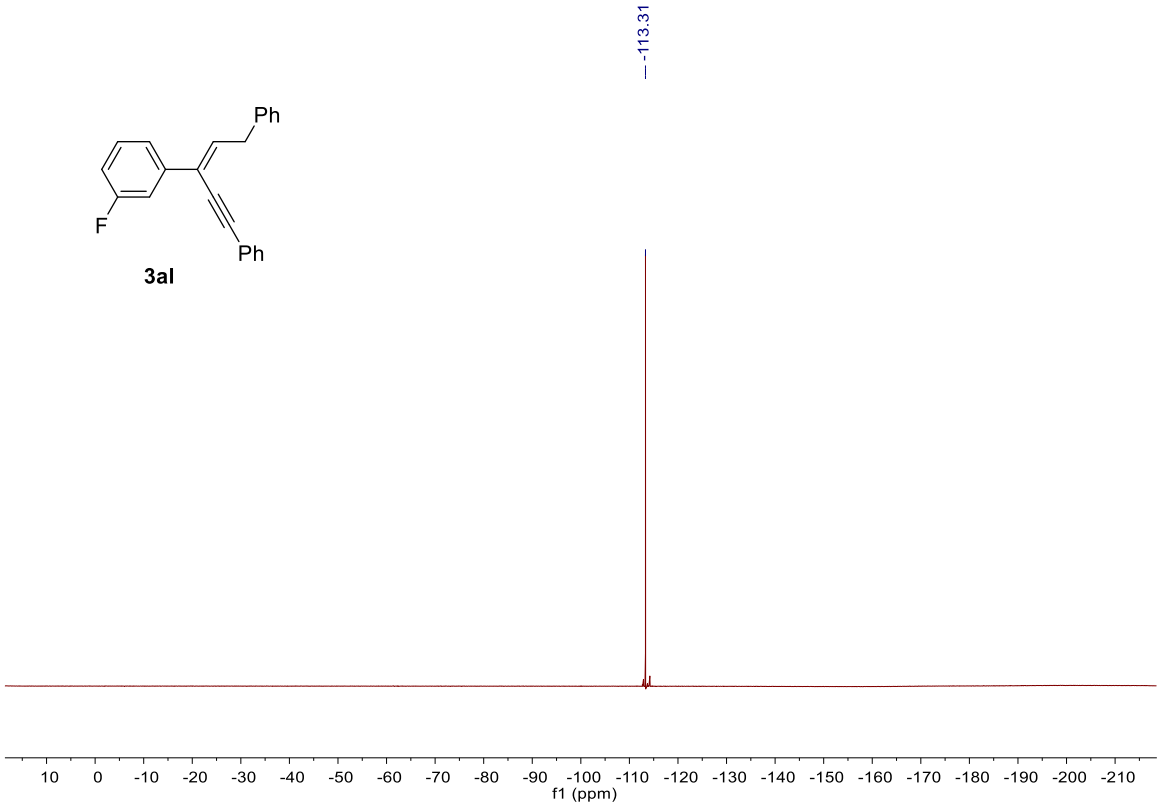
^{1}H NMR spectrum ($CDCl_3$)



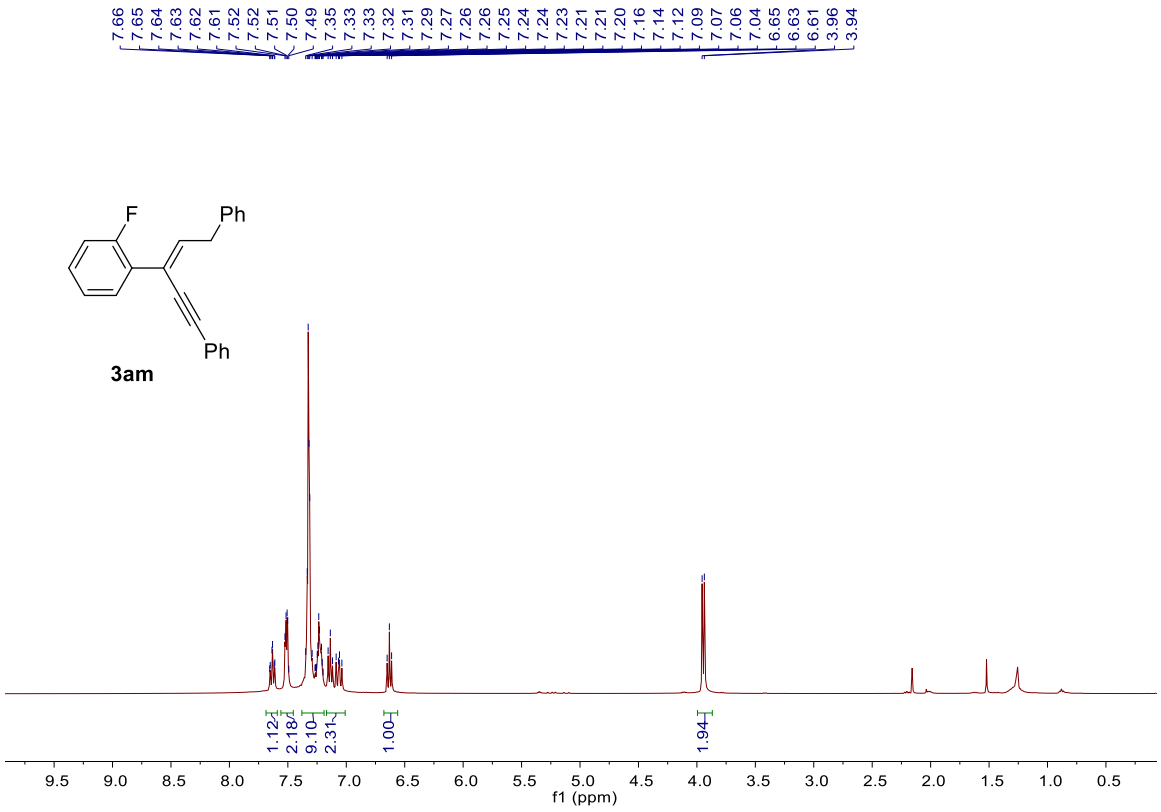
^{13}C NMR spectrum ($CDCl_3$)



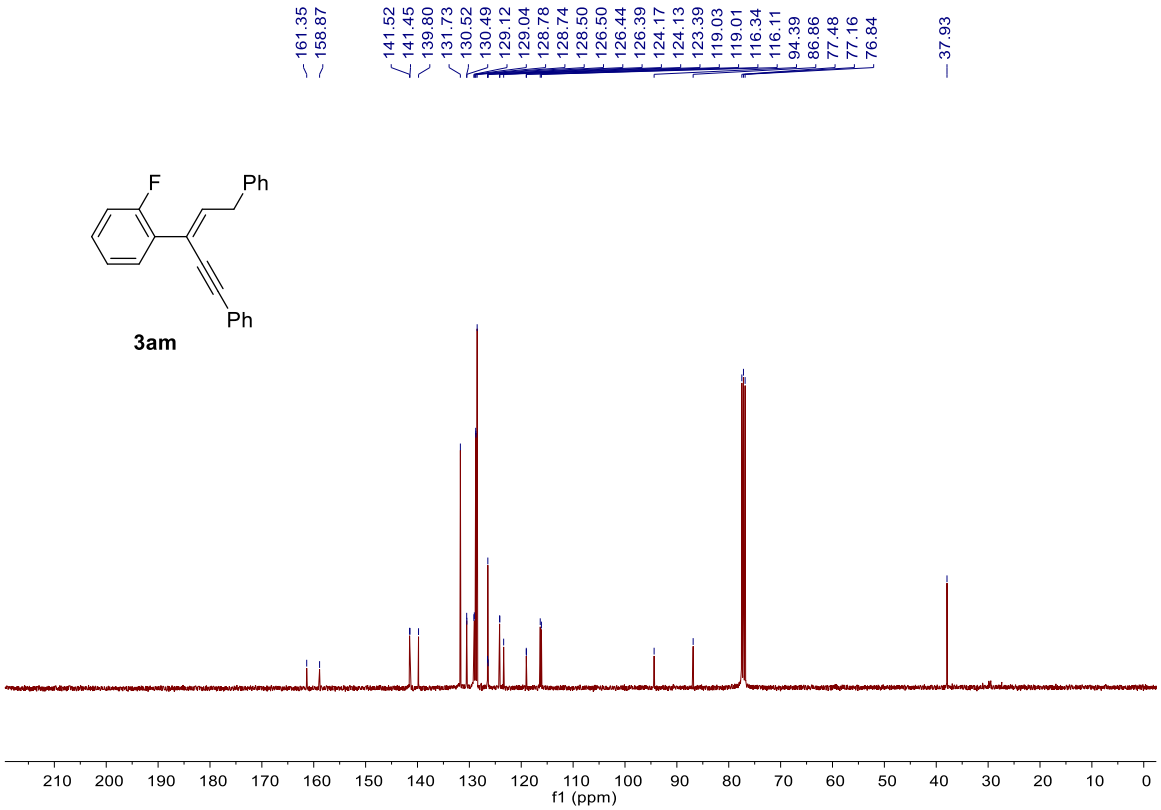
^{19}F NMR spectrum ($CDCl_3$)



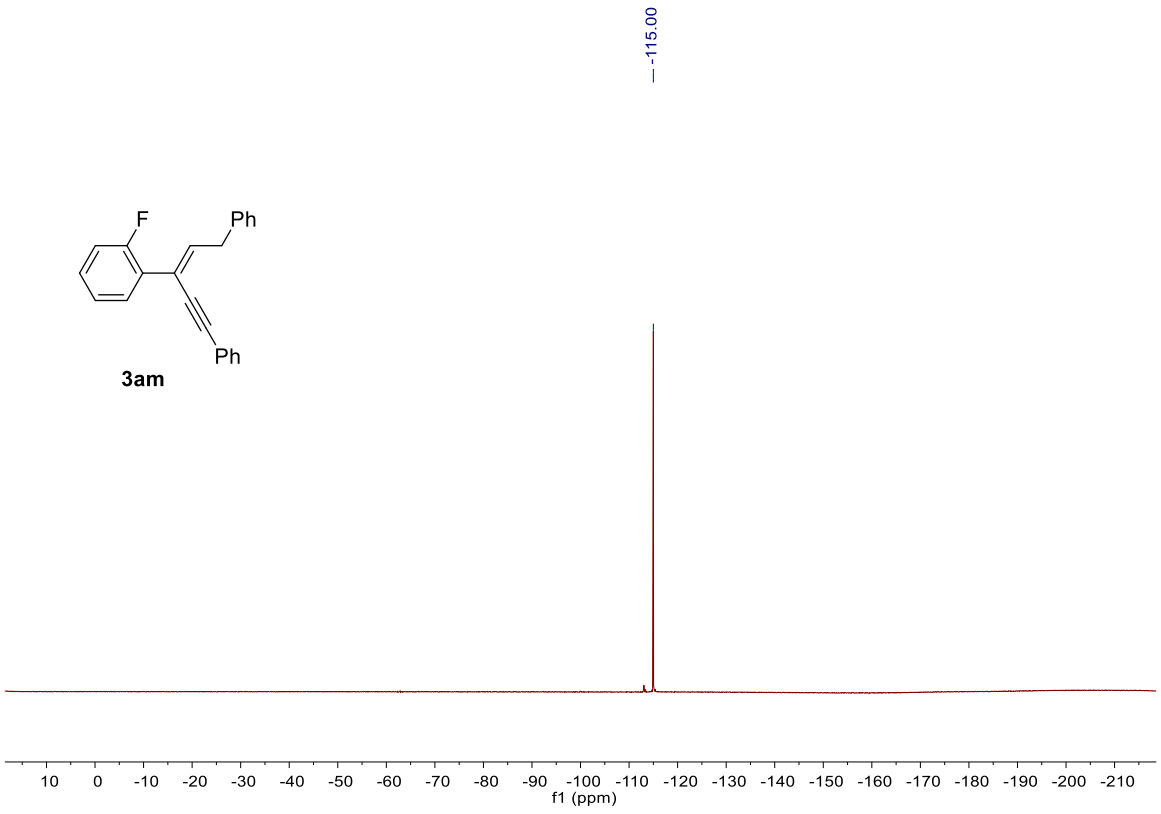
^{1}H NMR spectrum ($CDCl_3$)



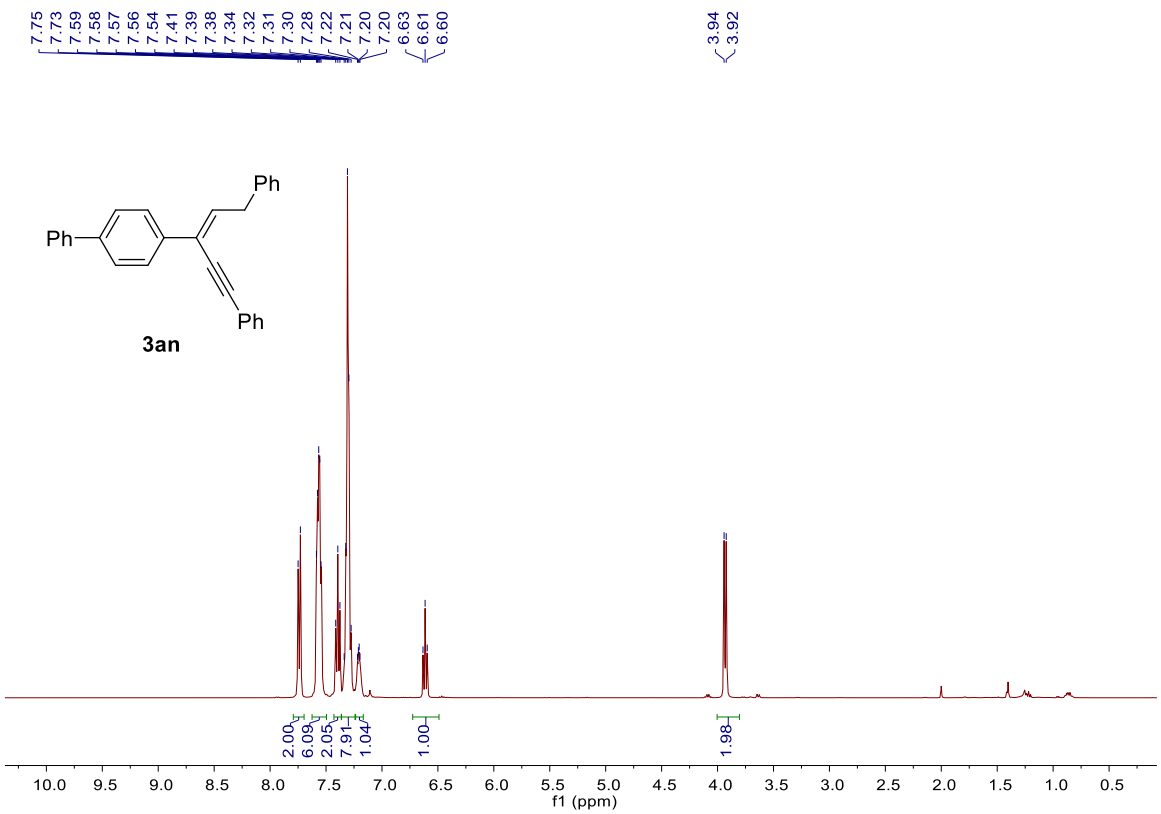
^{13}C NMR spectrum ($CDCl_3$)



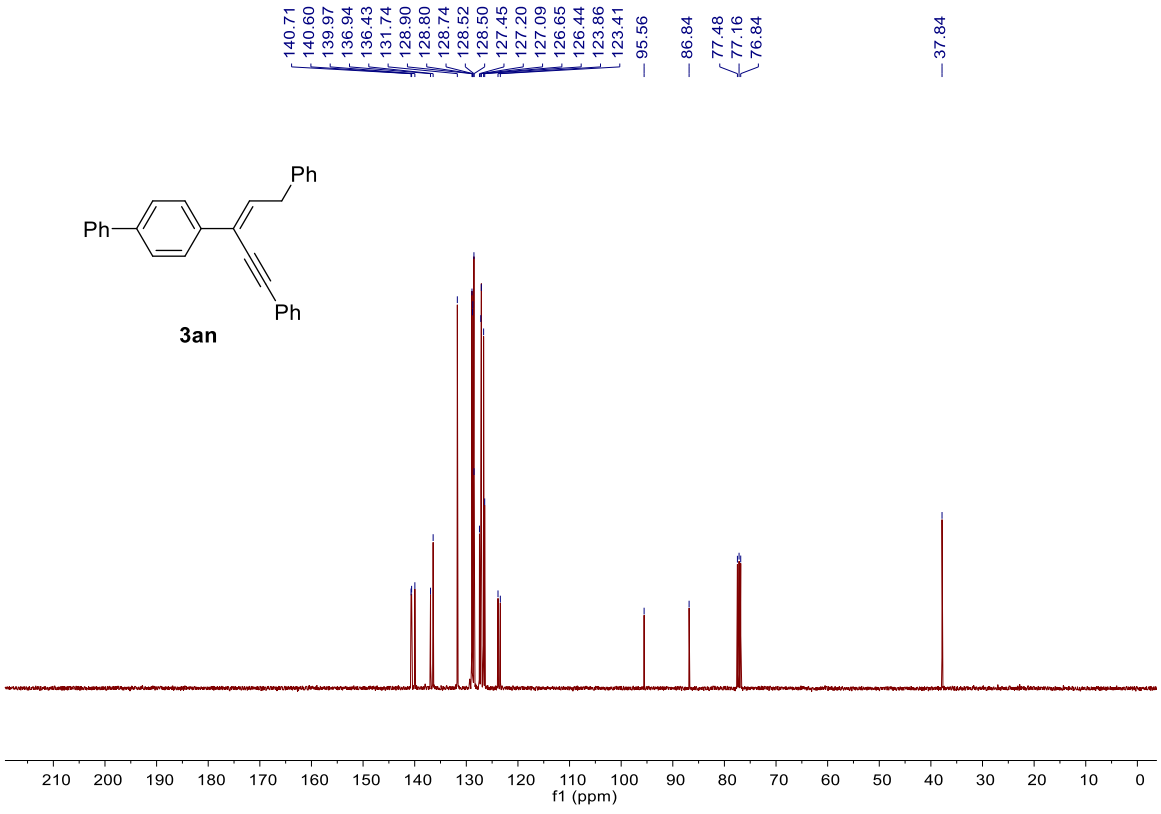
^{19}F NMR spectrum ($CDCl_3$)



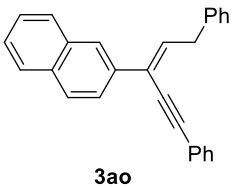
^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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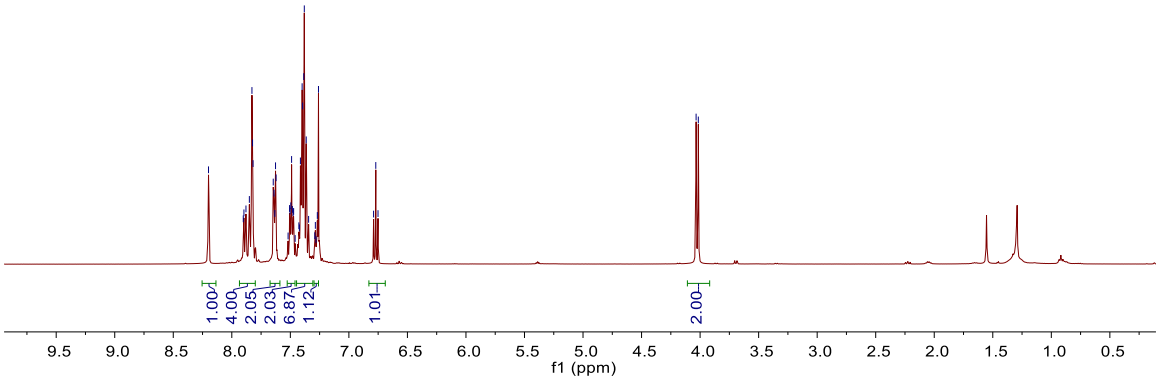
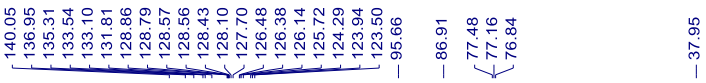
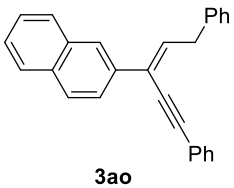


^{13}C NMR spectrum ($CDCl_3$)





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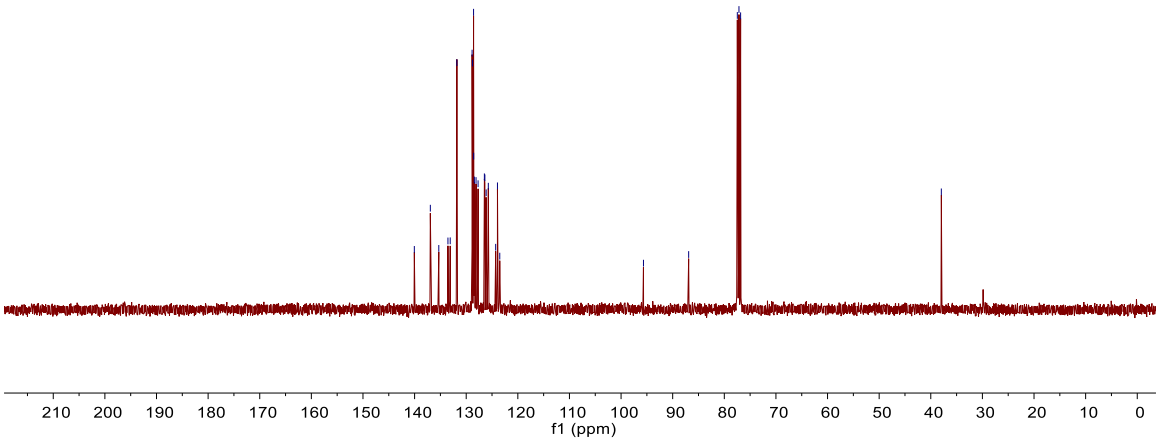
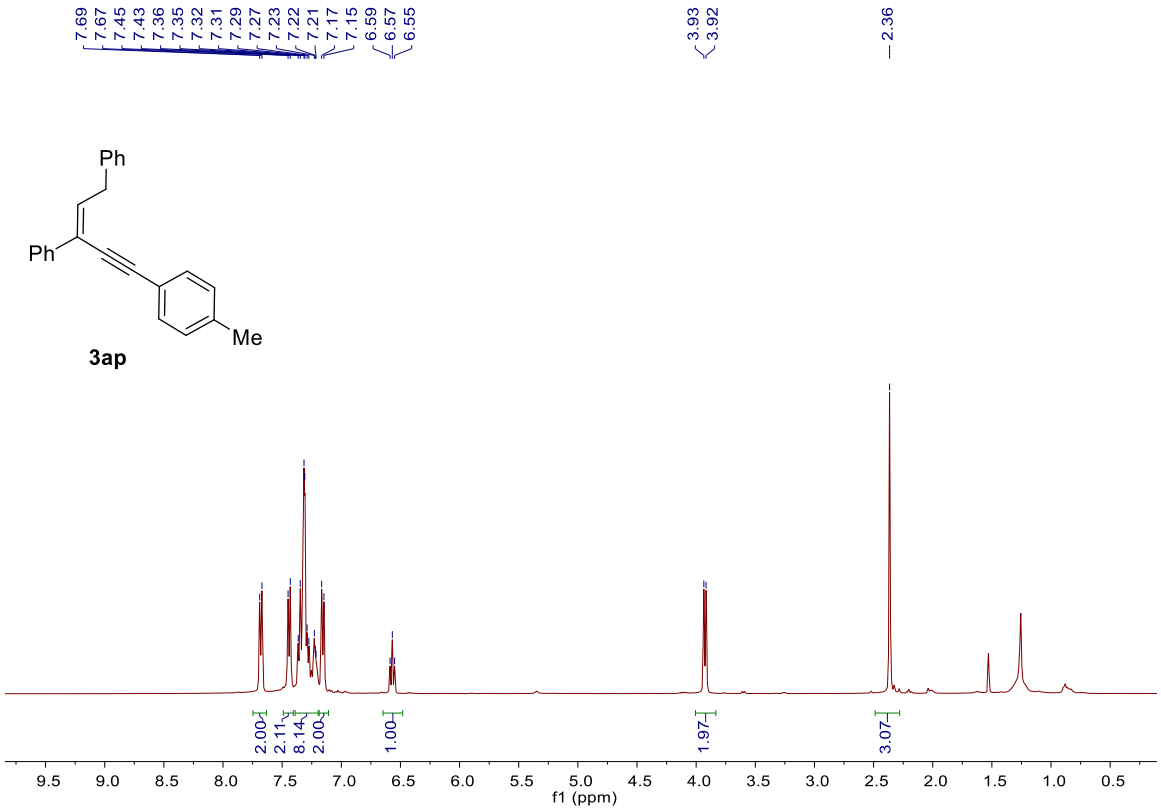
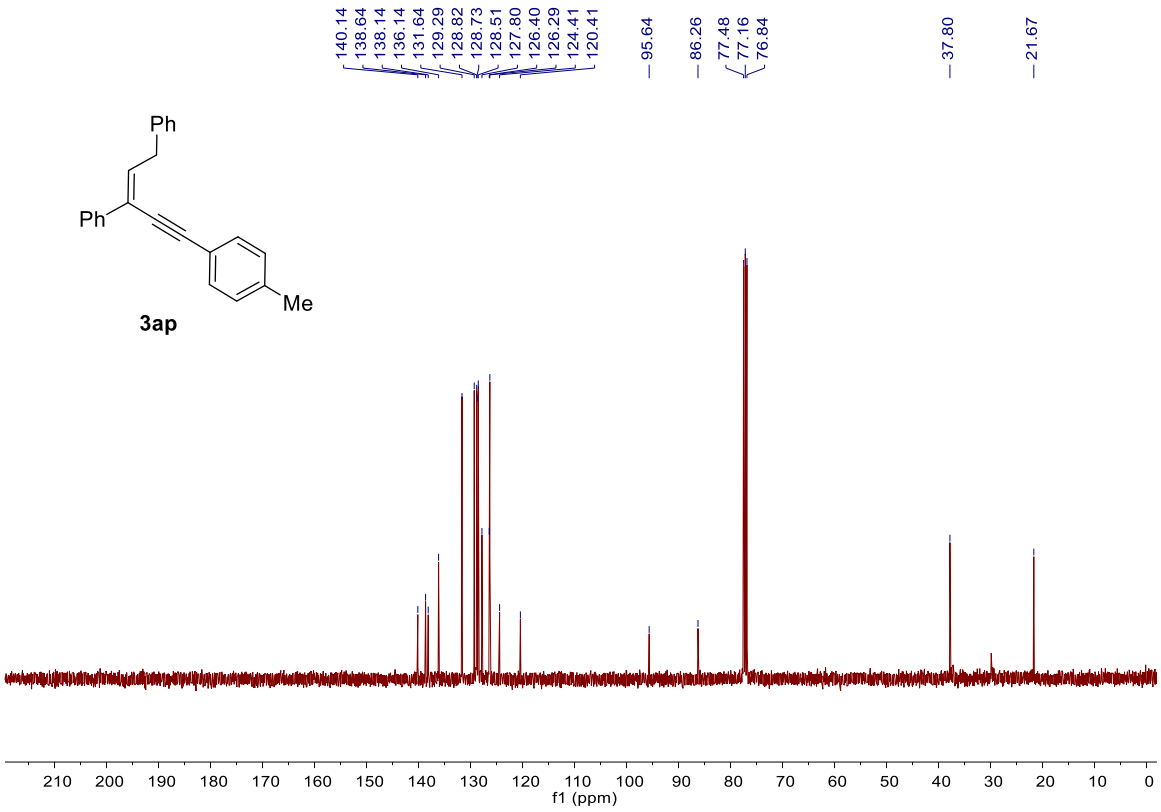


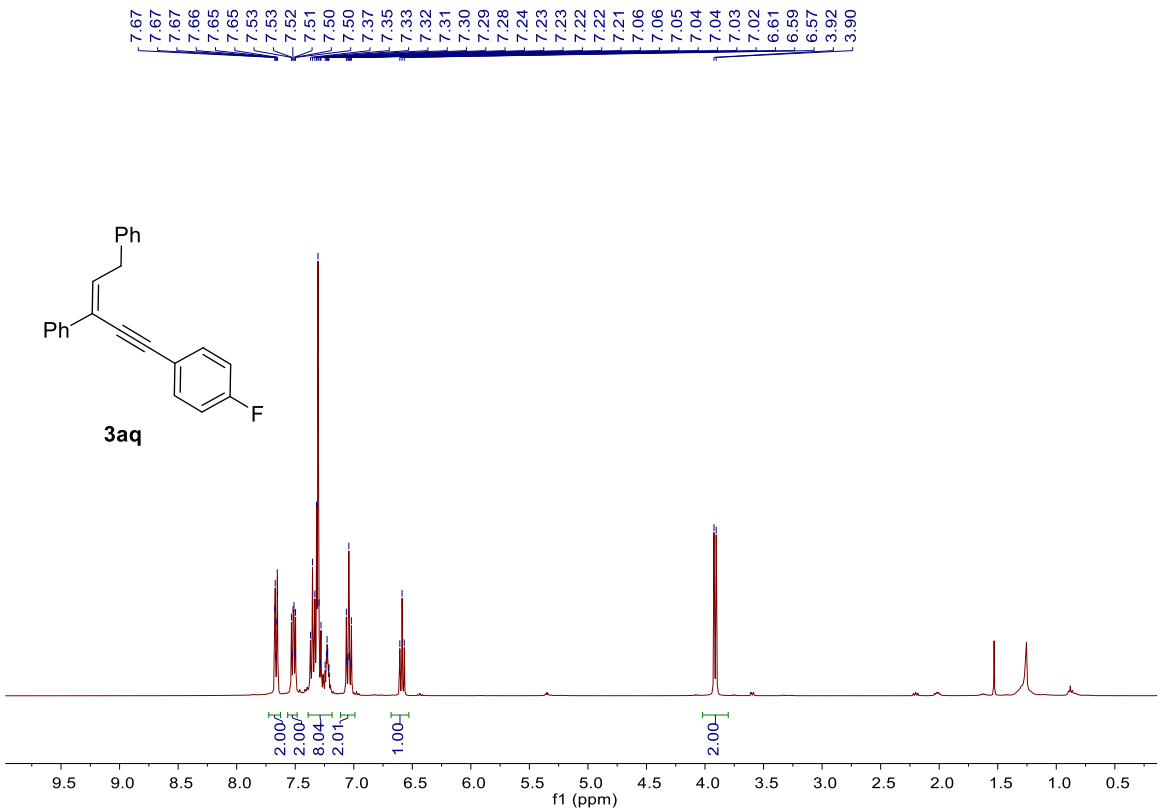
^{1}H NMR spectrum ($CDCl_3$)



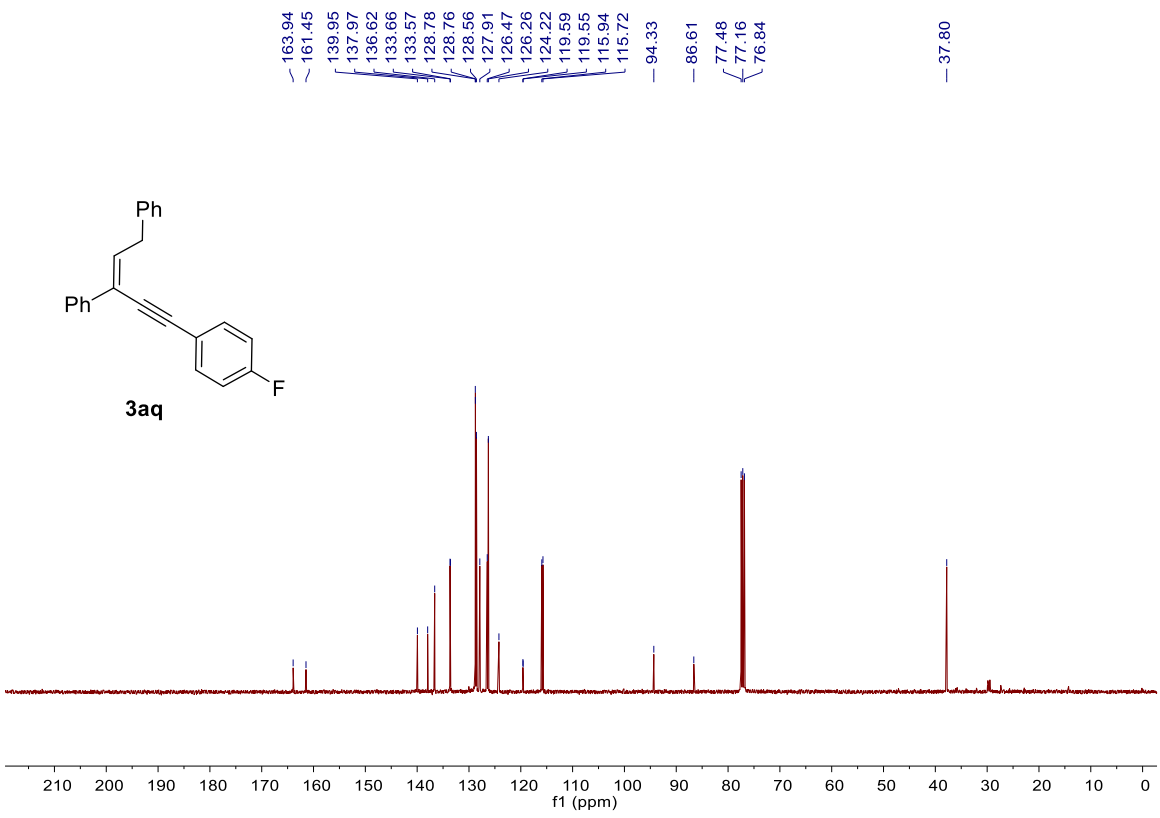
^{13}C NMR spectrum ($CDCl_3$)



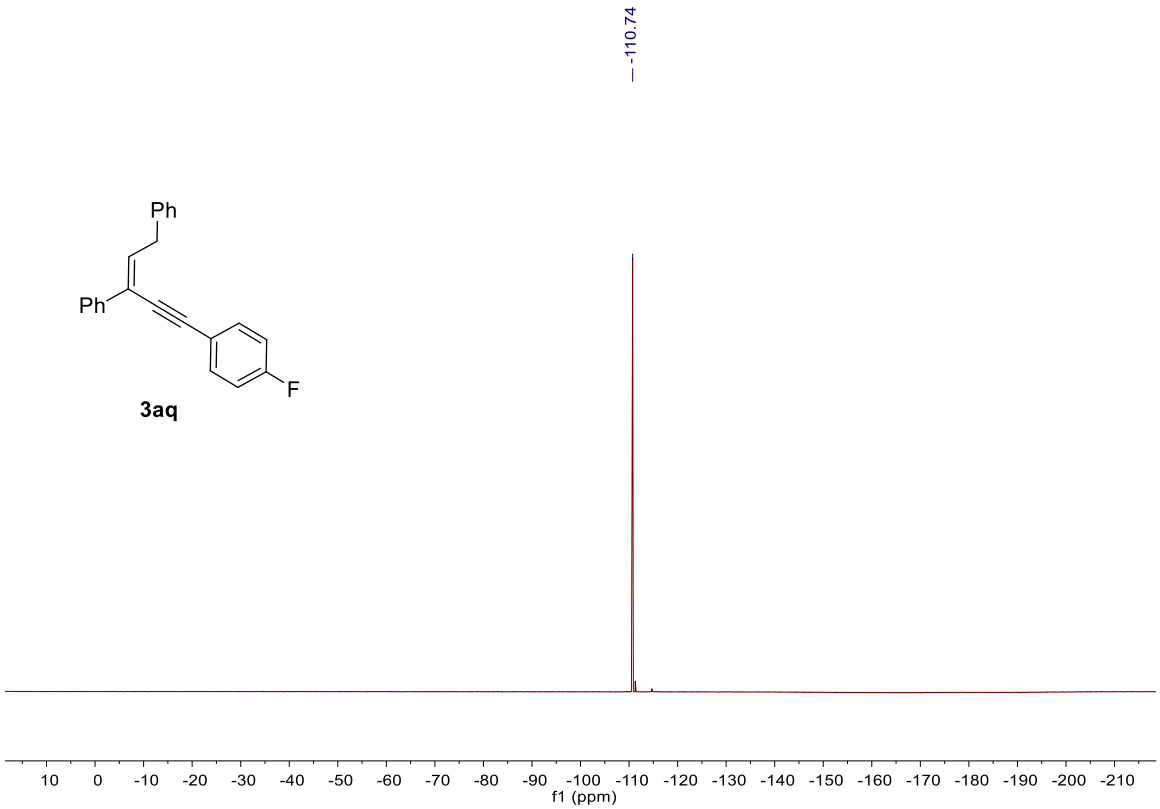
^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



^{19}F NMR spectrum ($CDCl_3$)



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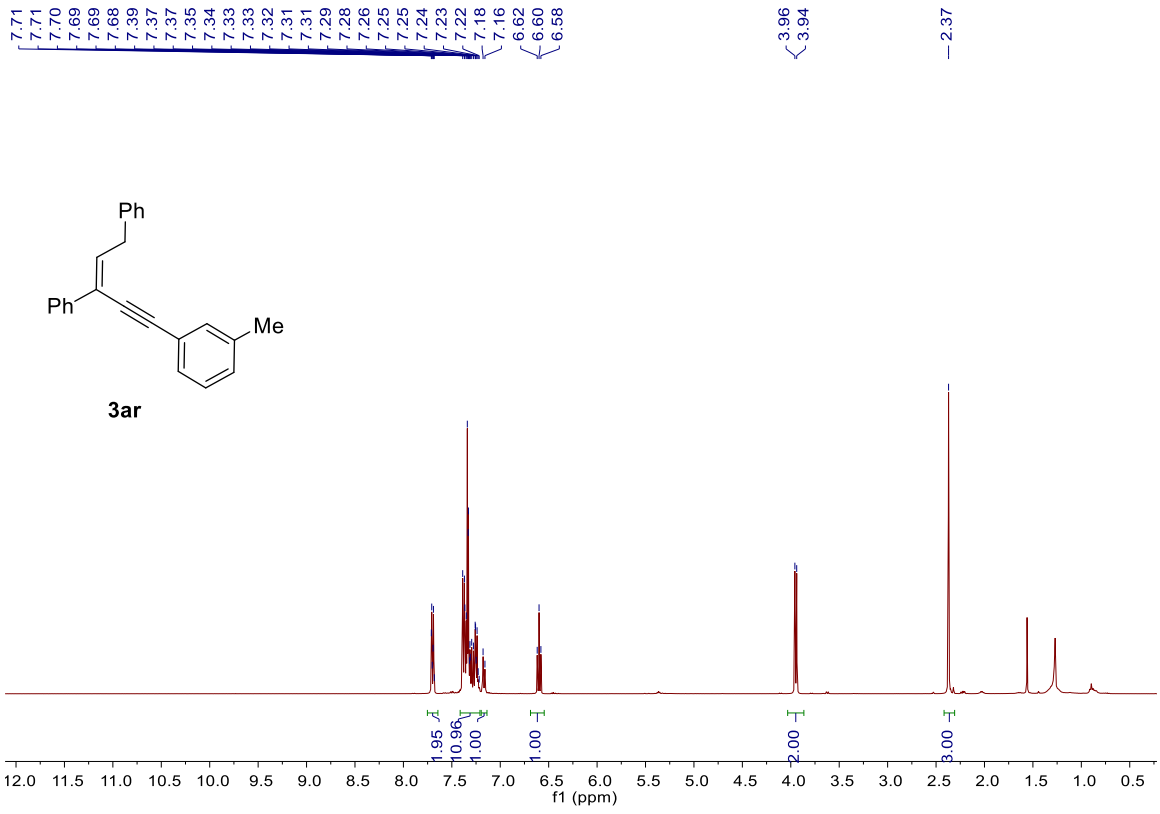
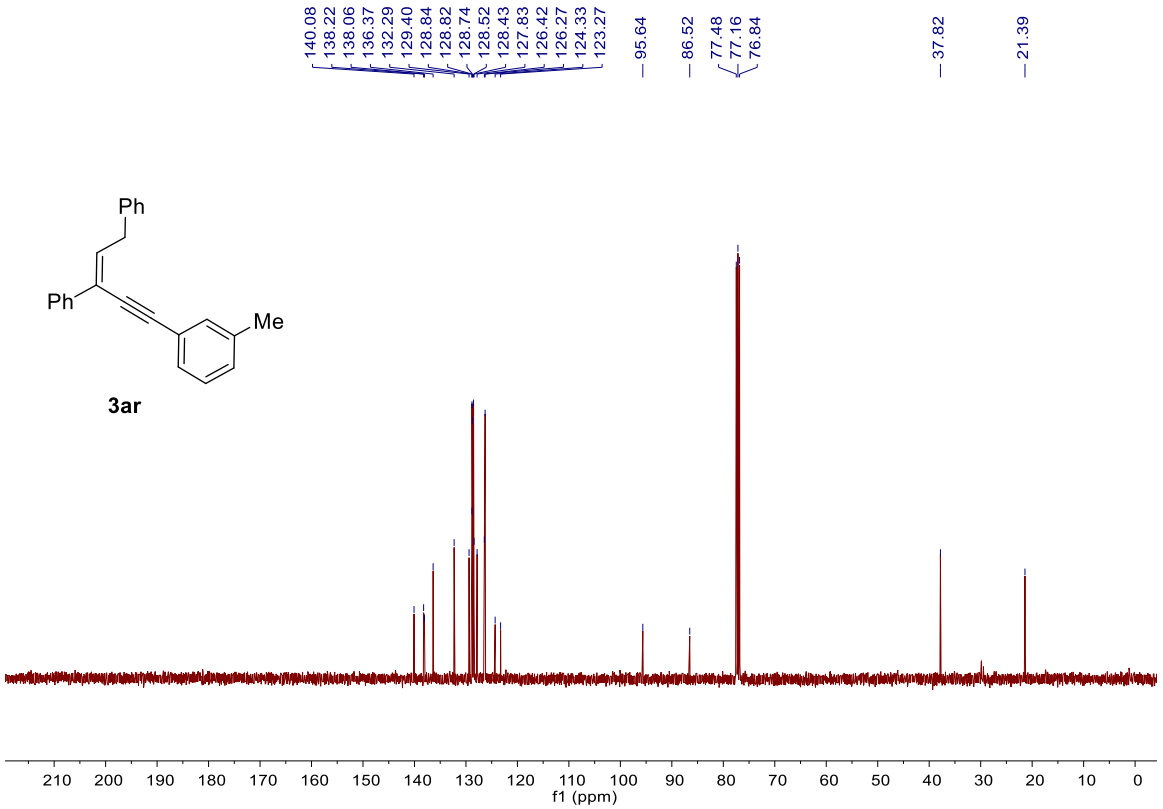
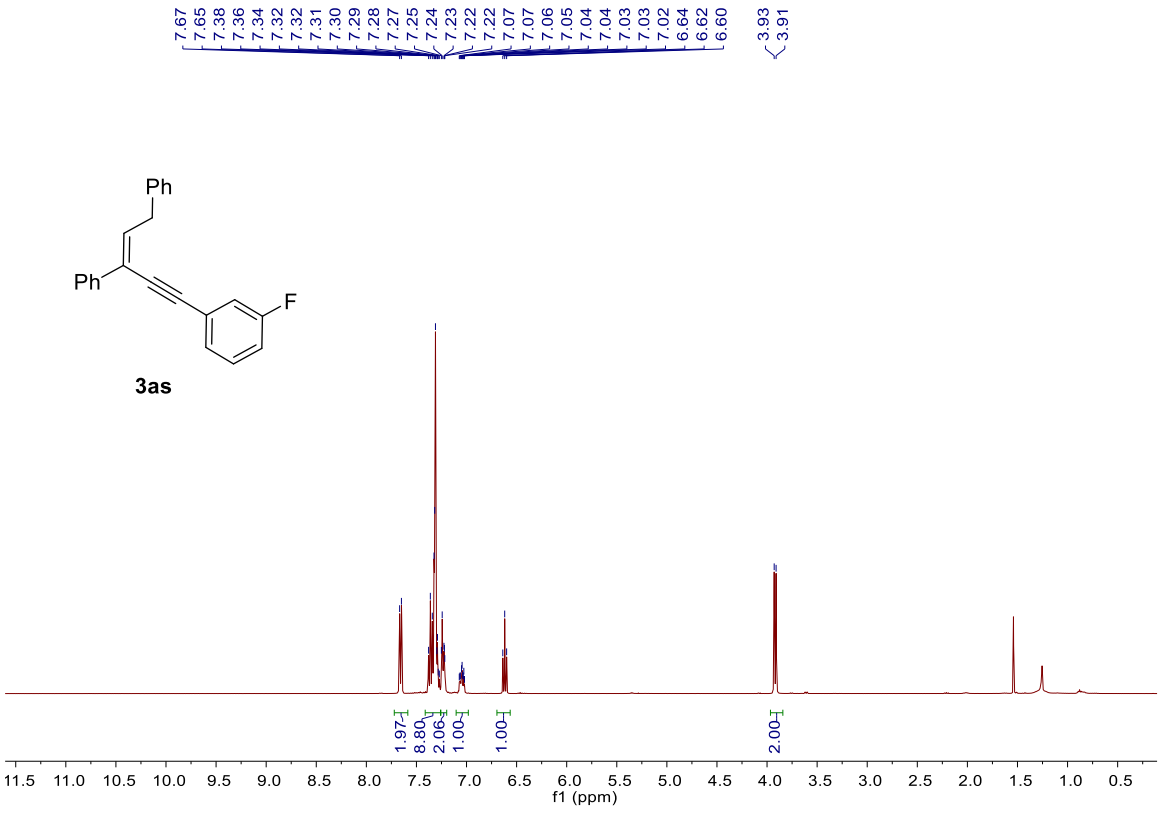


^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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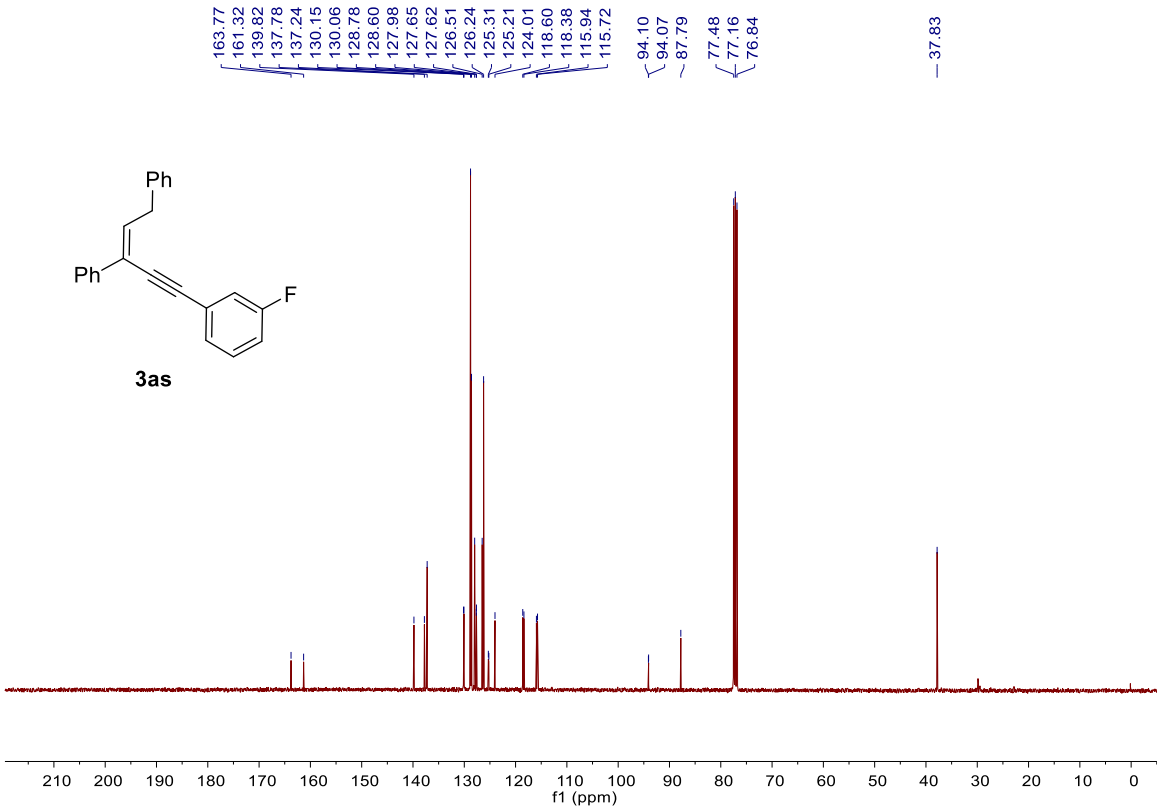

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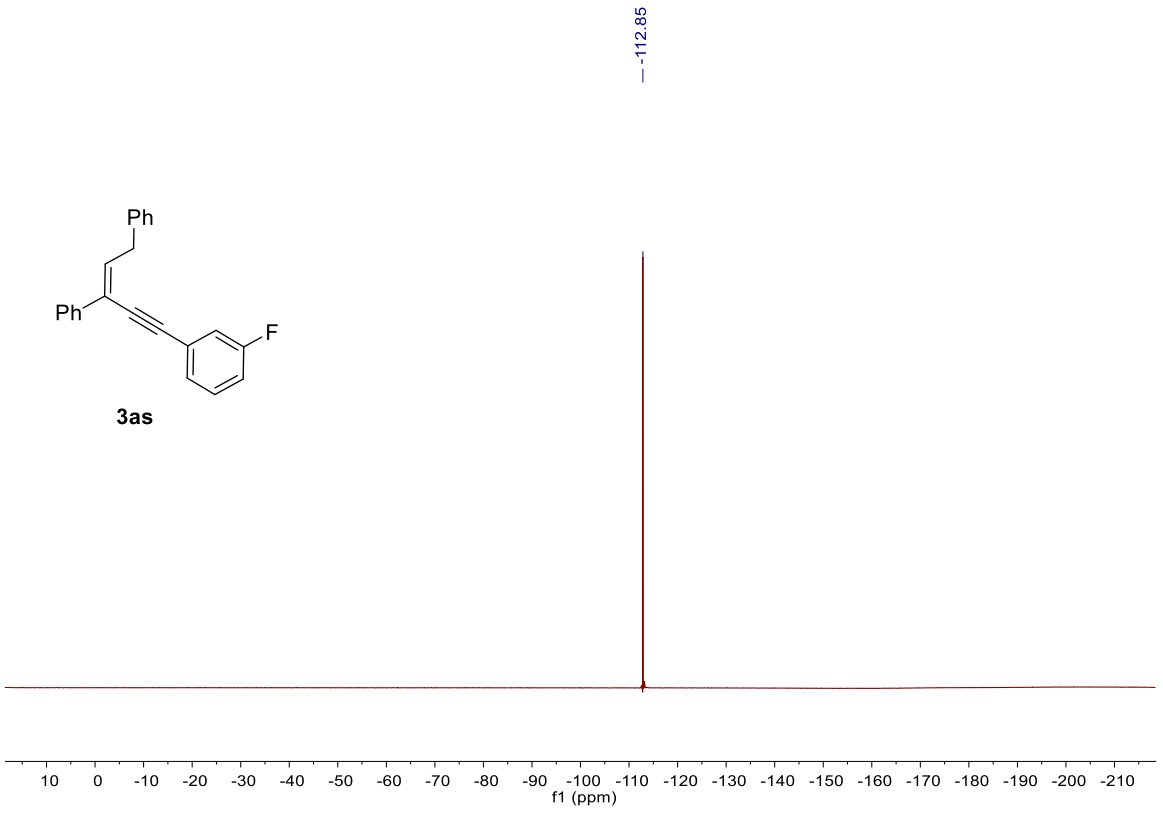

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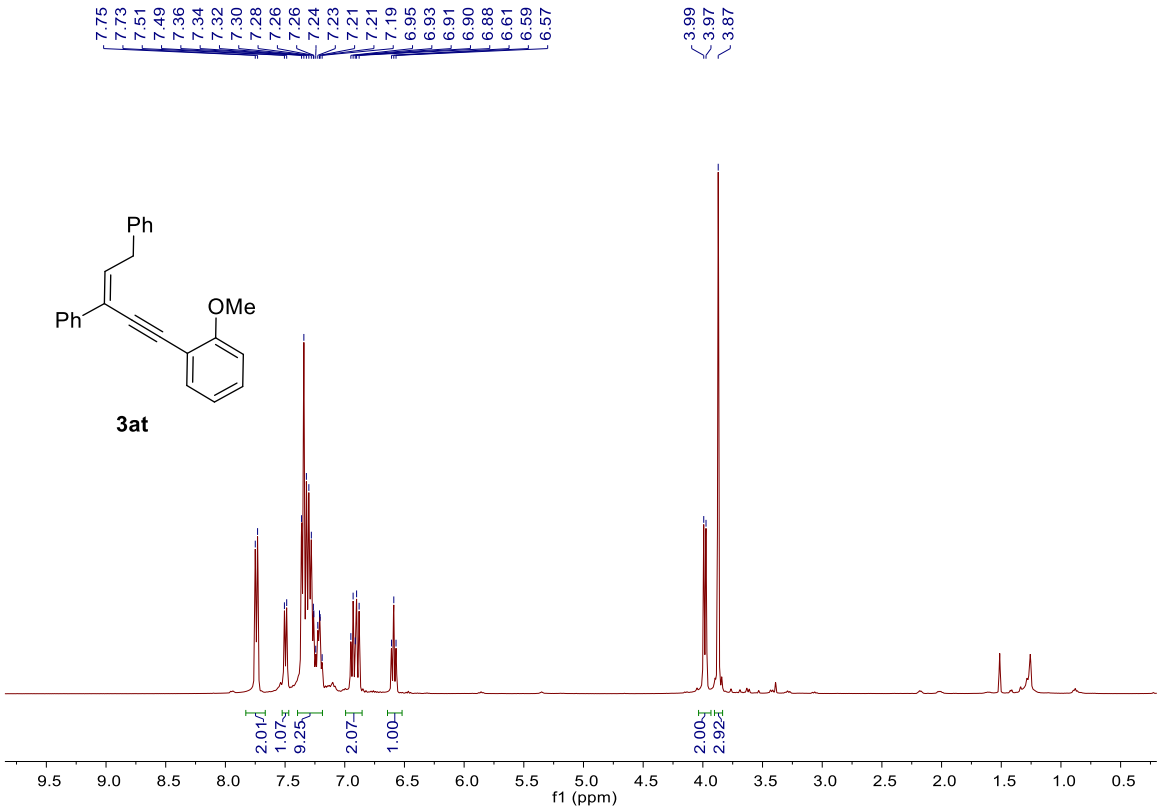

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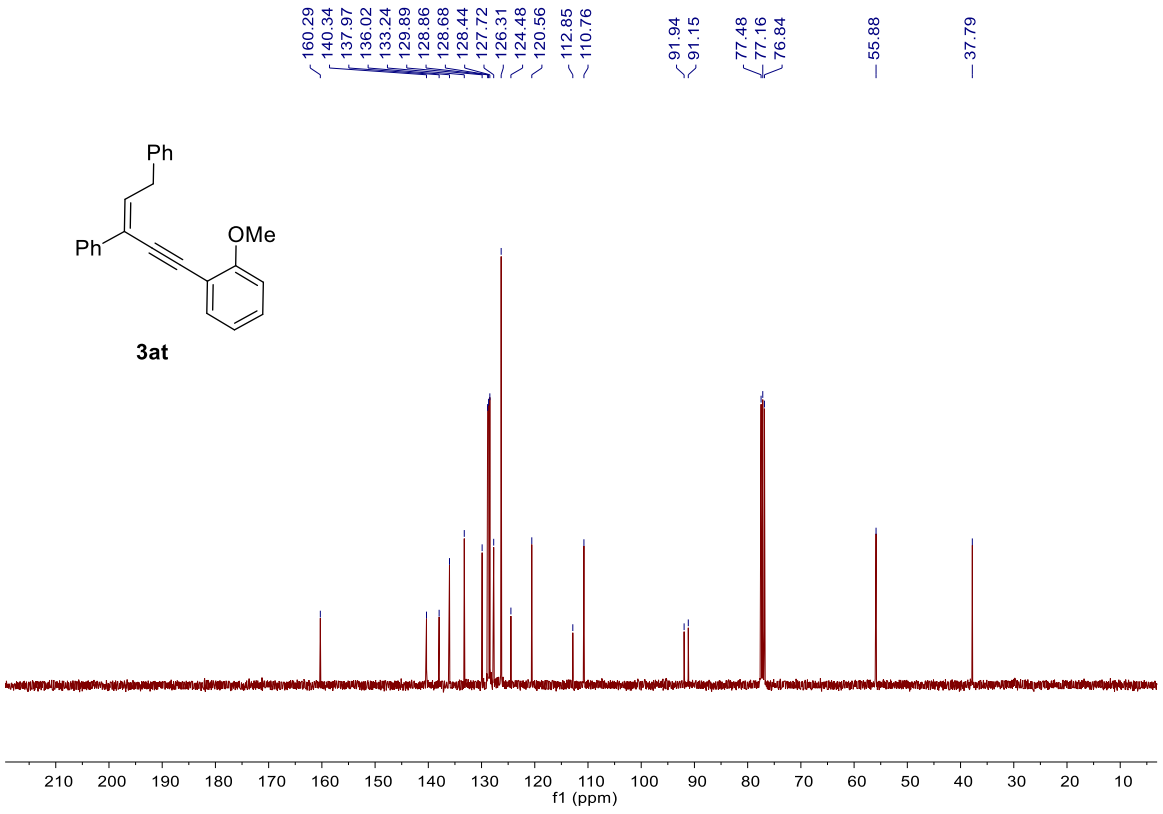

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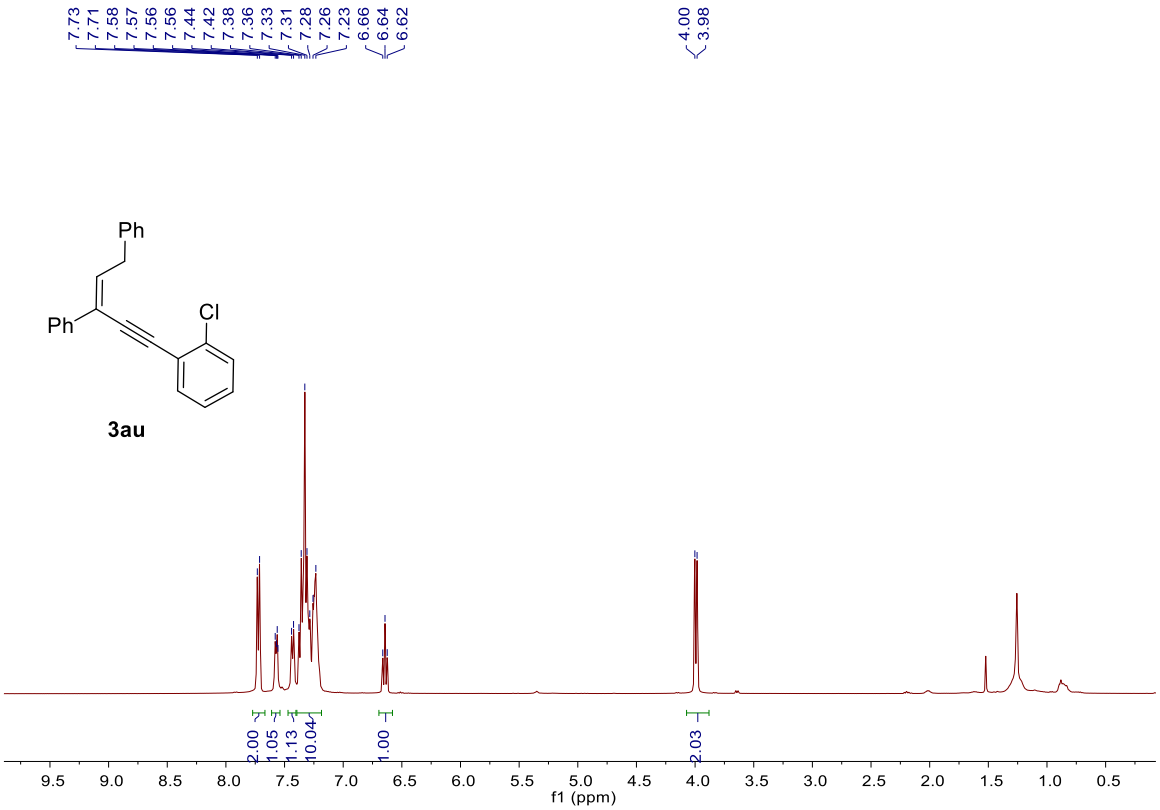
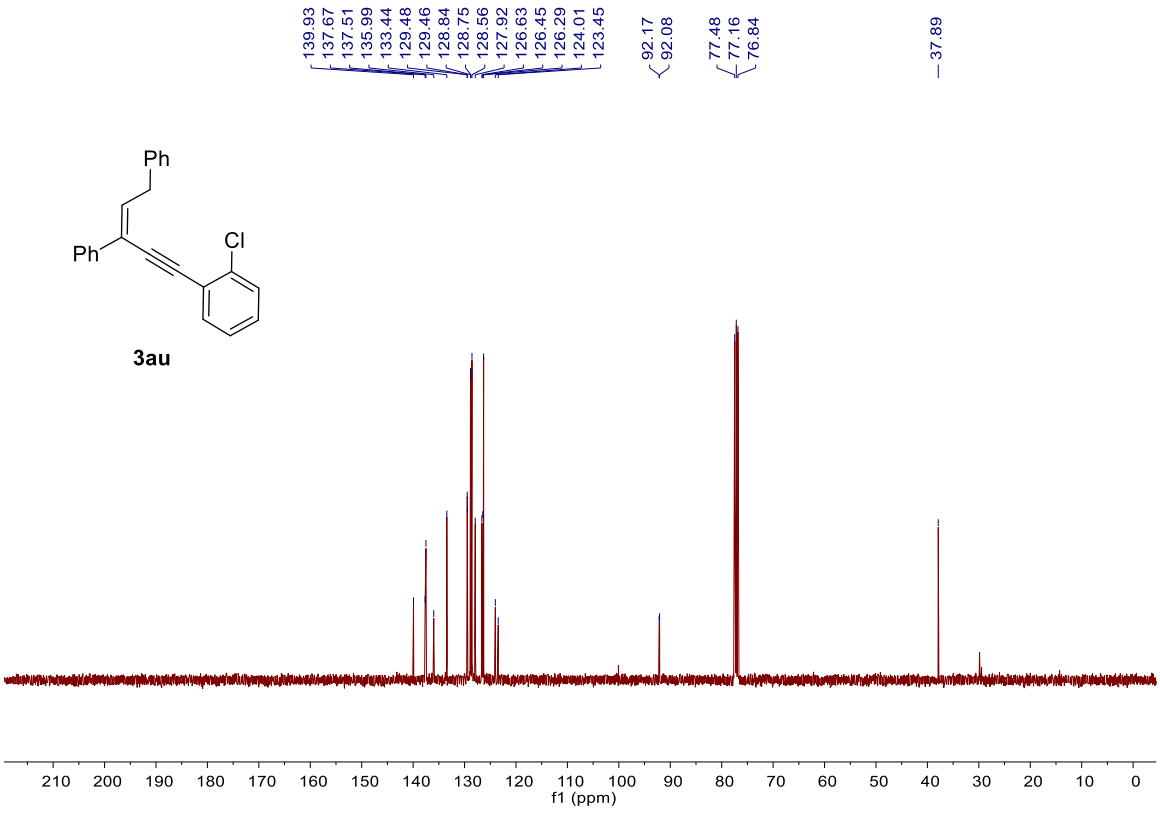


^{13}C NMR spectrum ($CDCl_3$)



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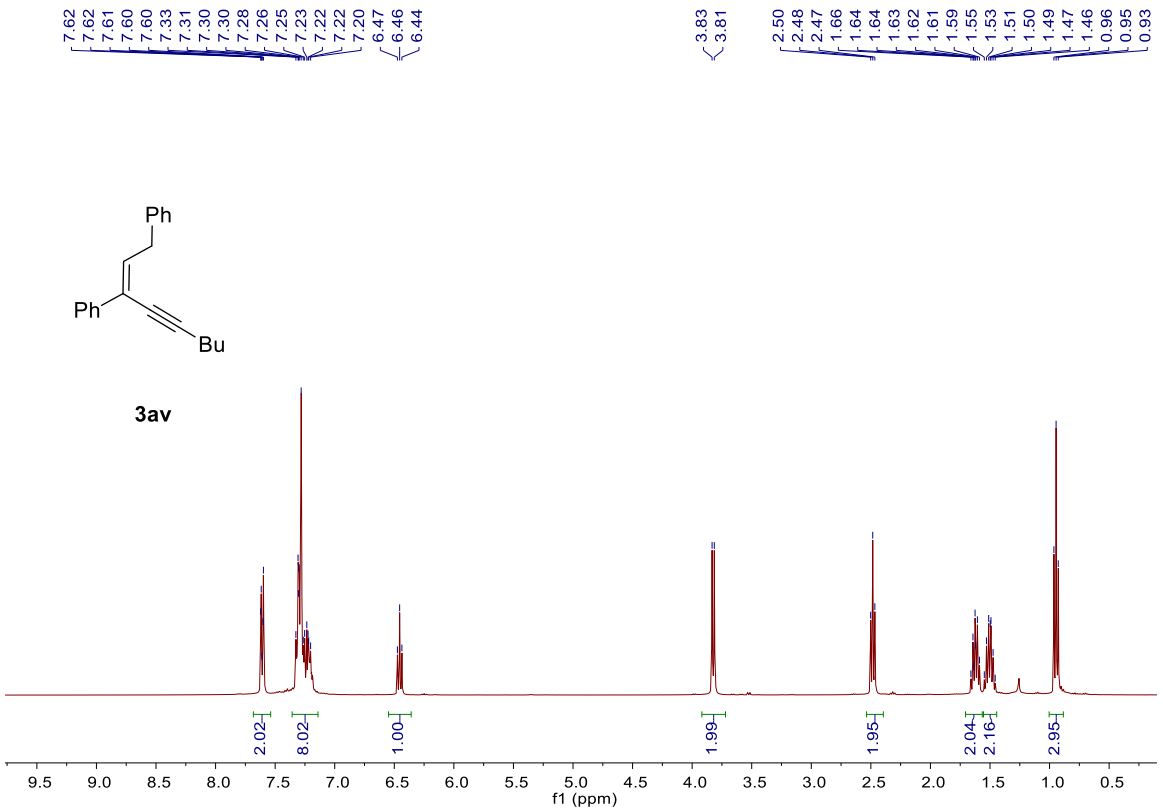
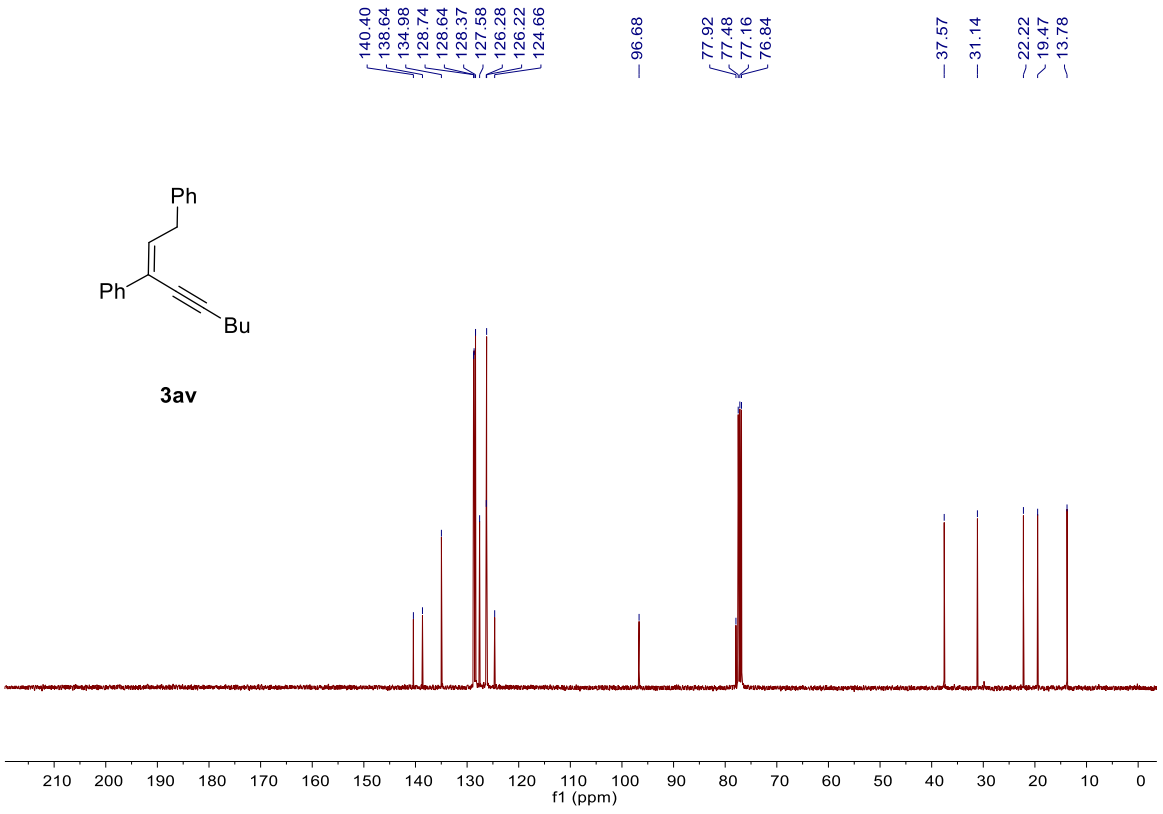


^{13}C NMR spectrum ($CDCl_3$)



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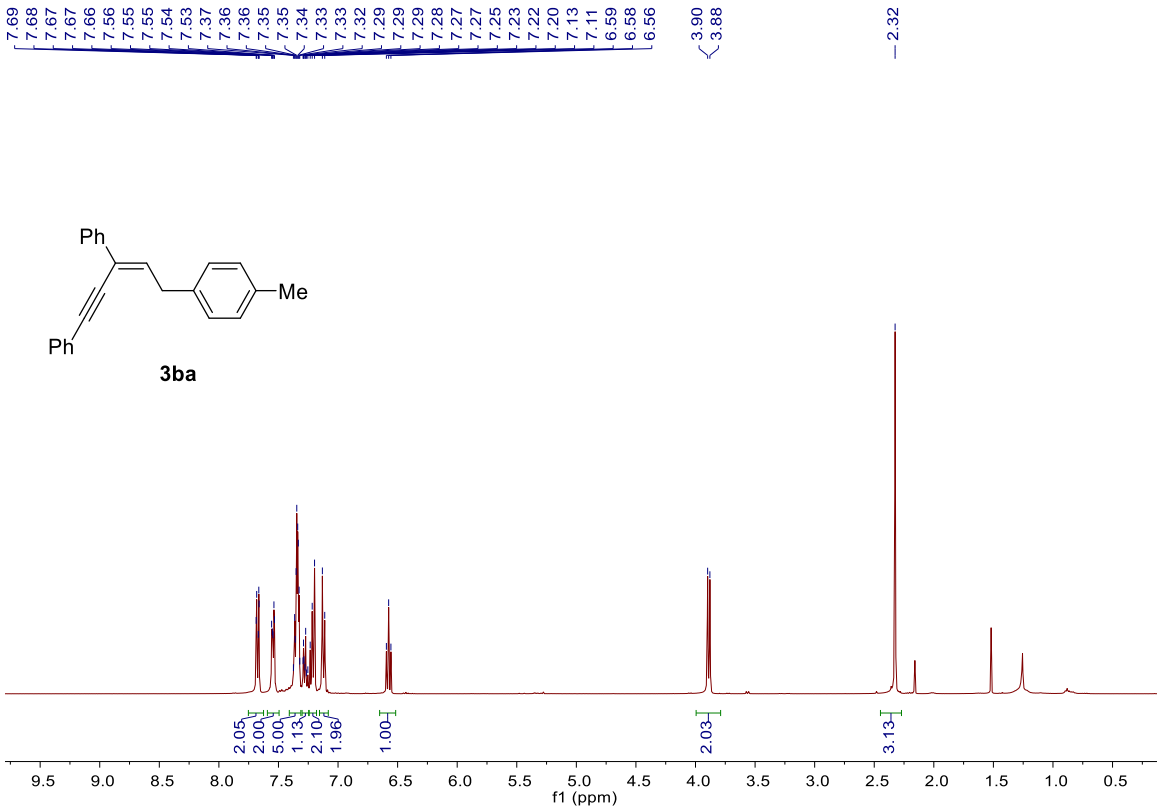
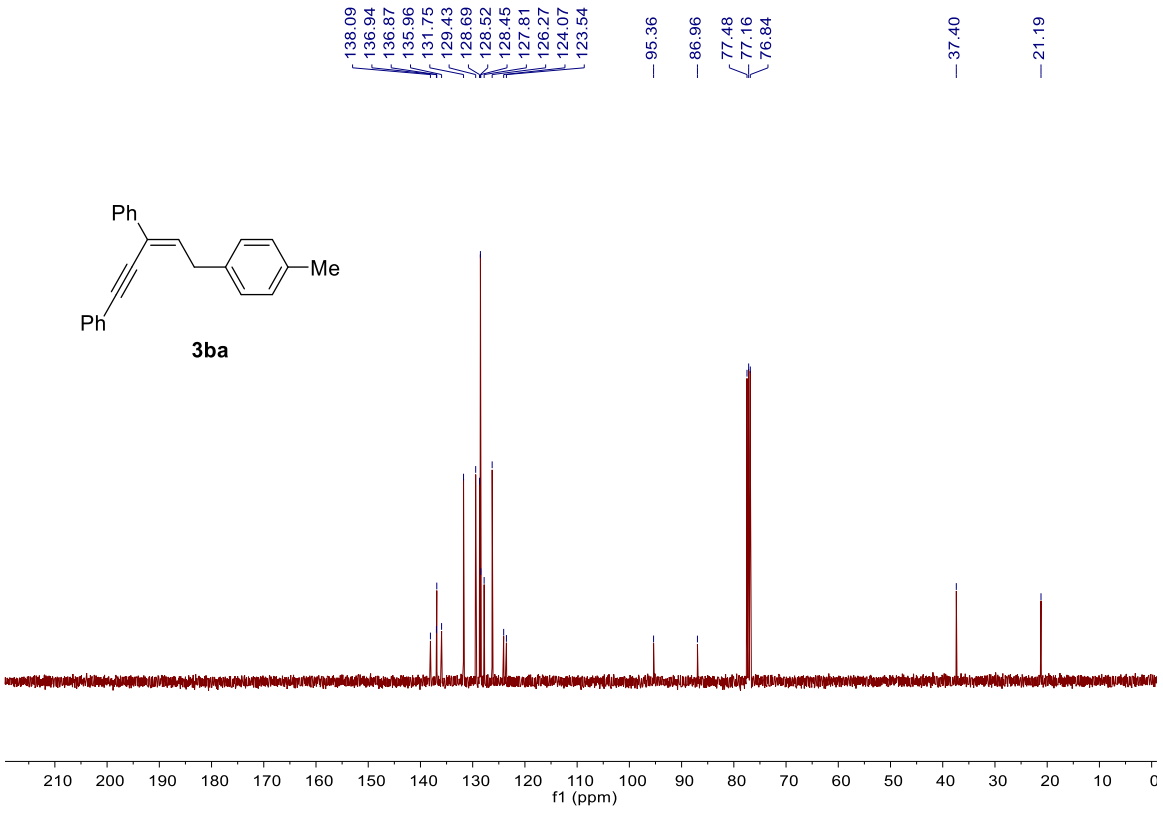
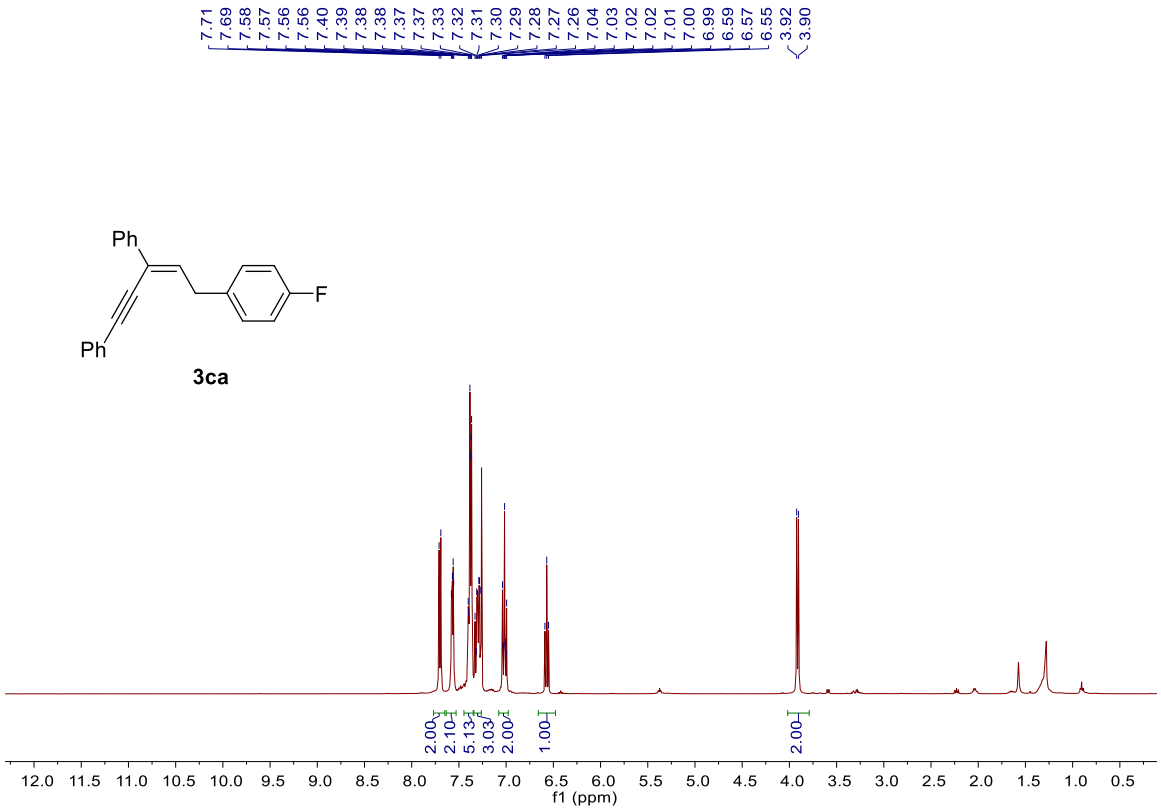


^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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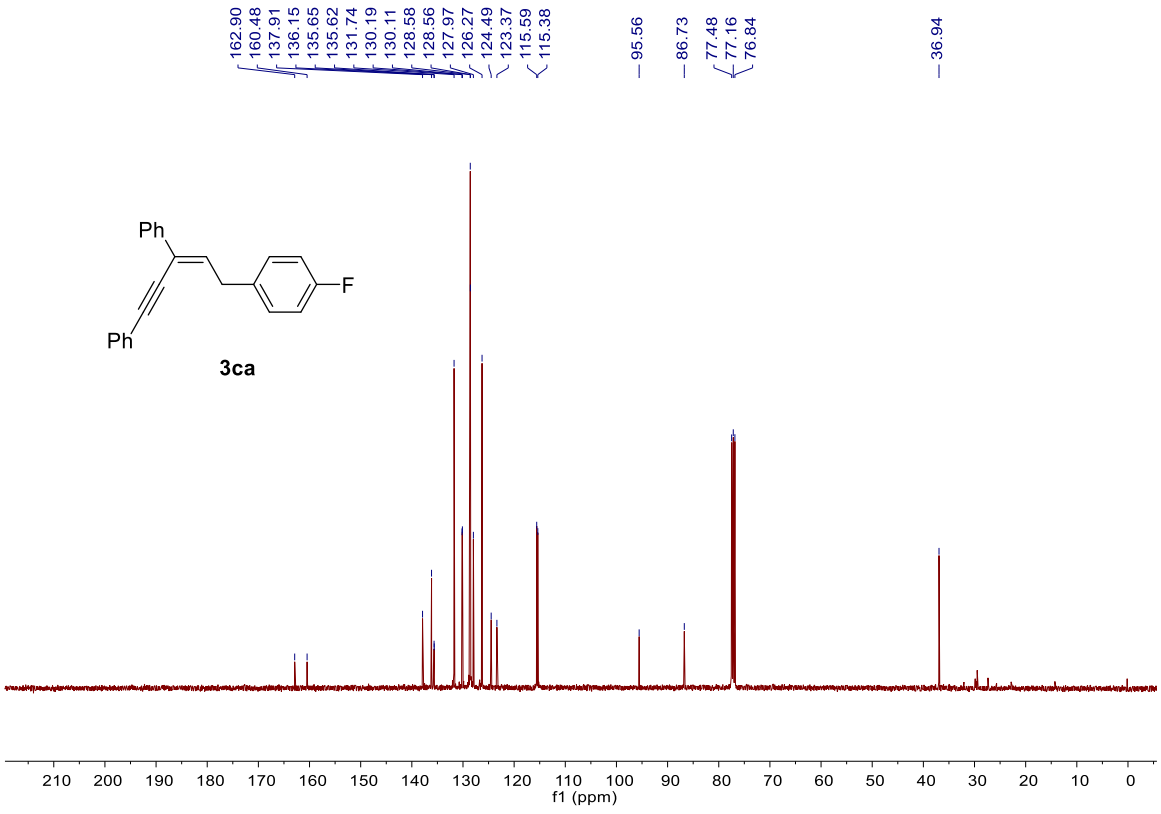
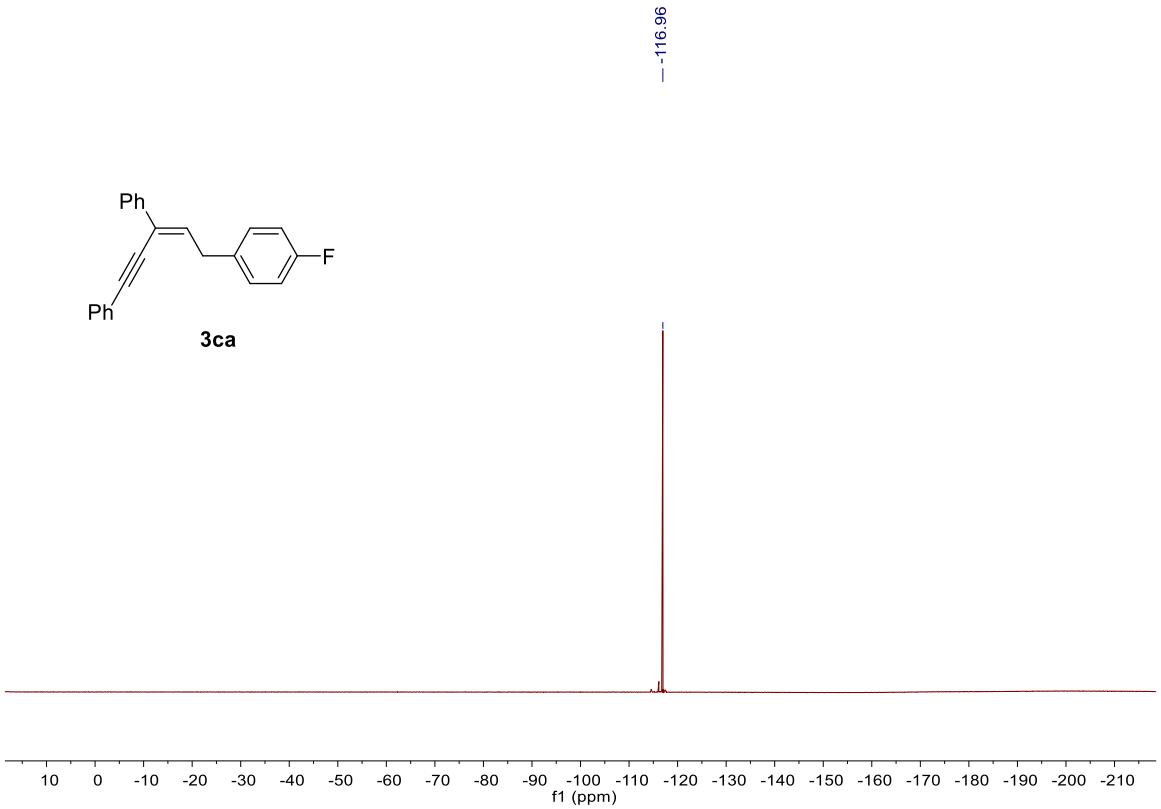


^{19}F NMR spectrum ($CDCl_3$)



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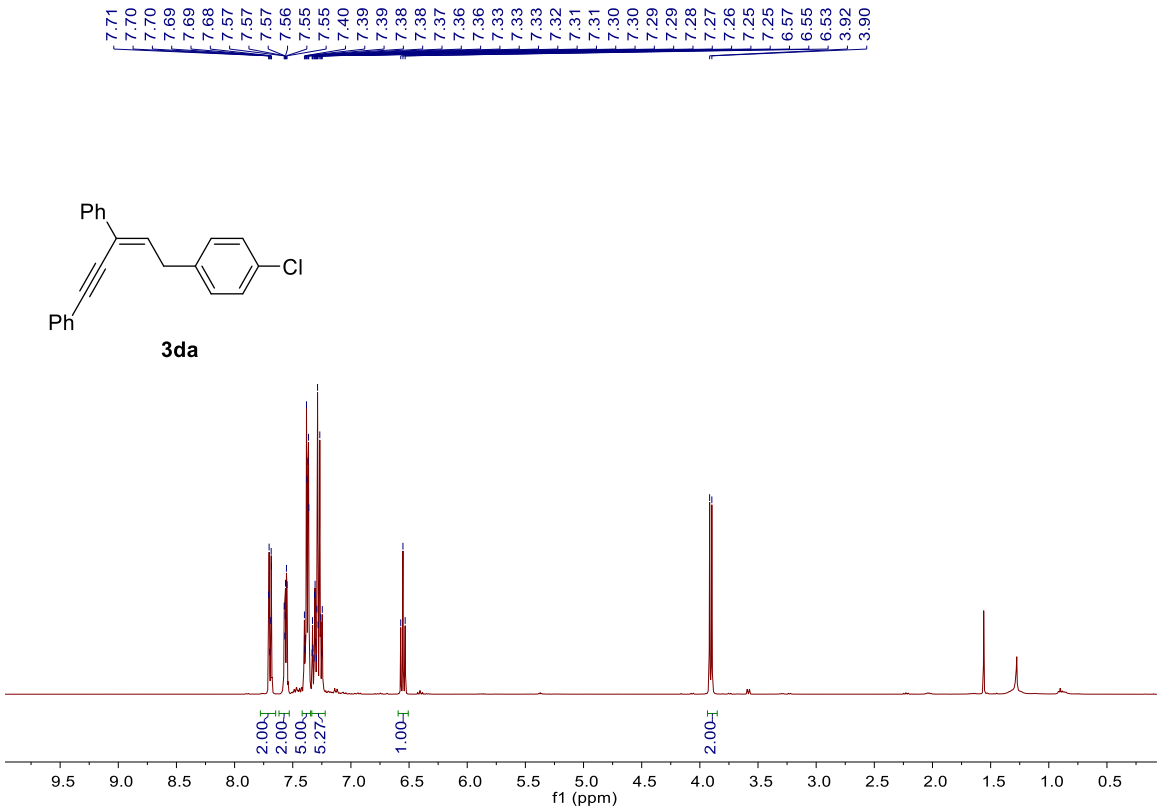

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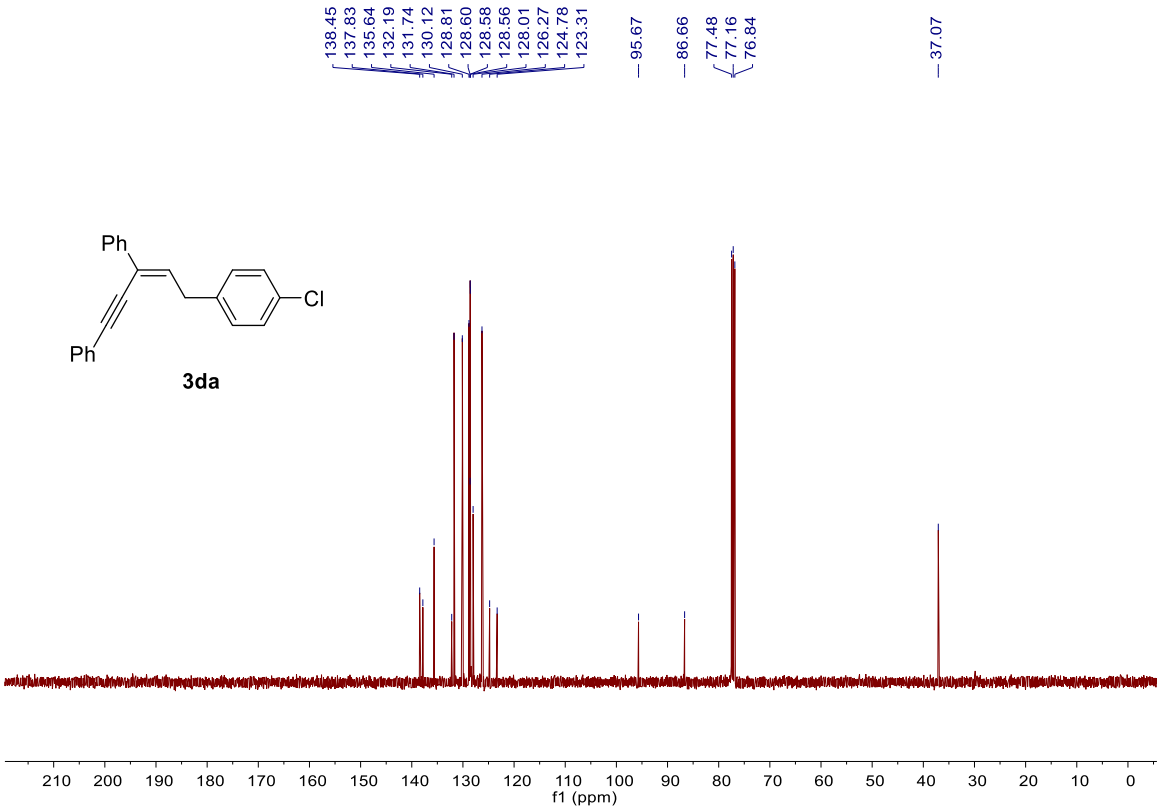

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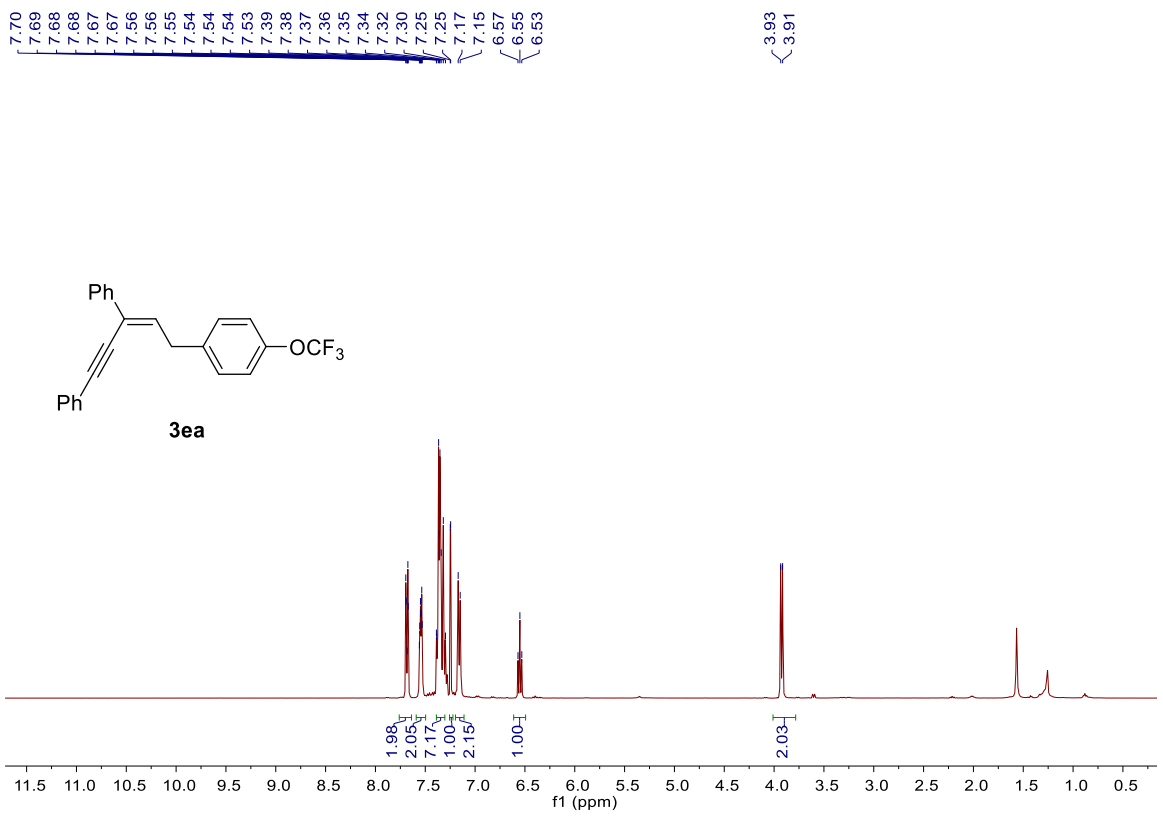
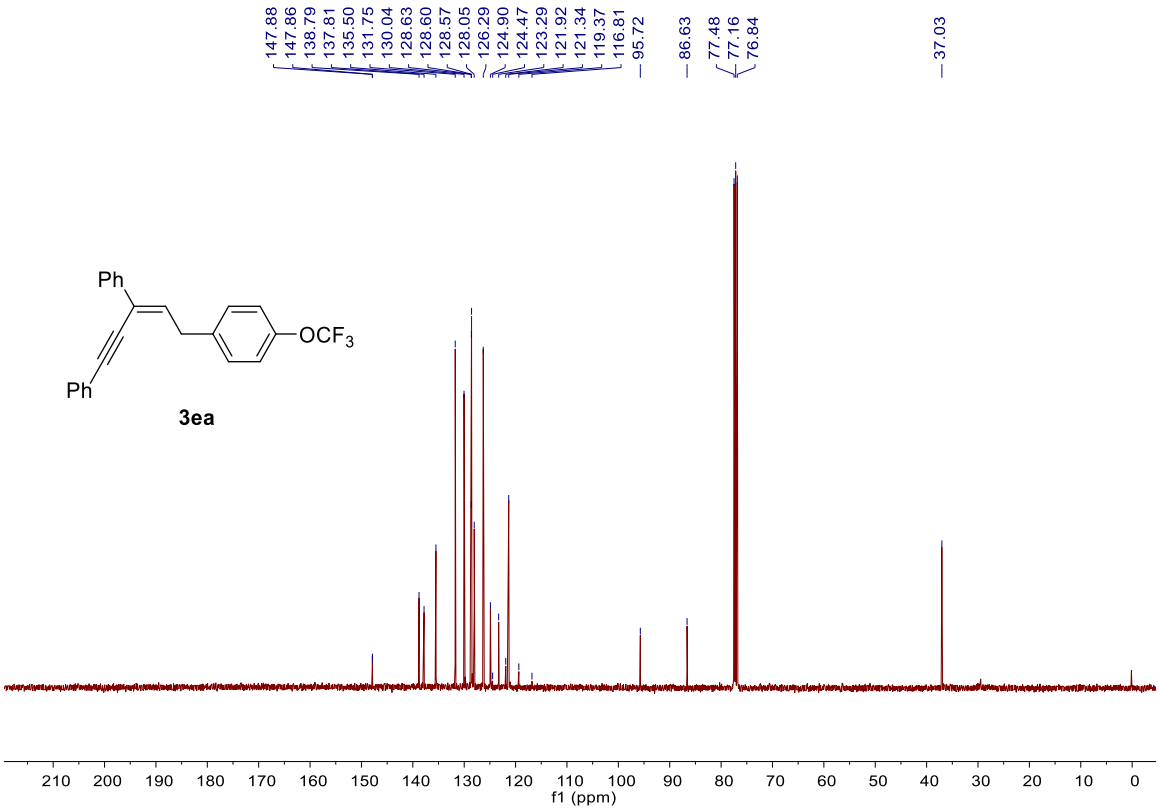
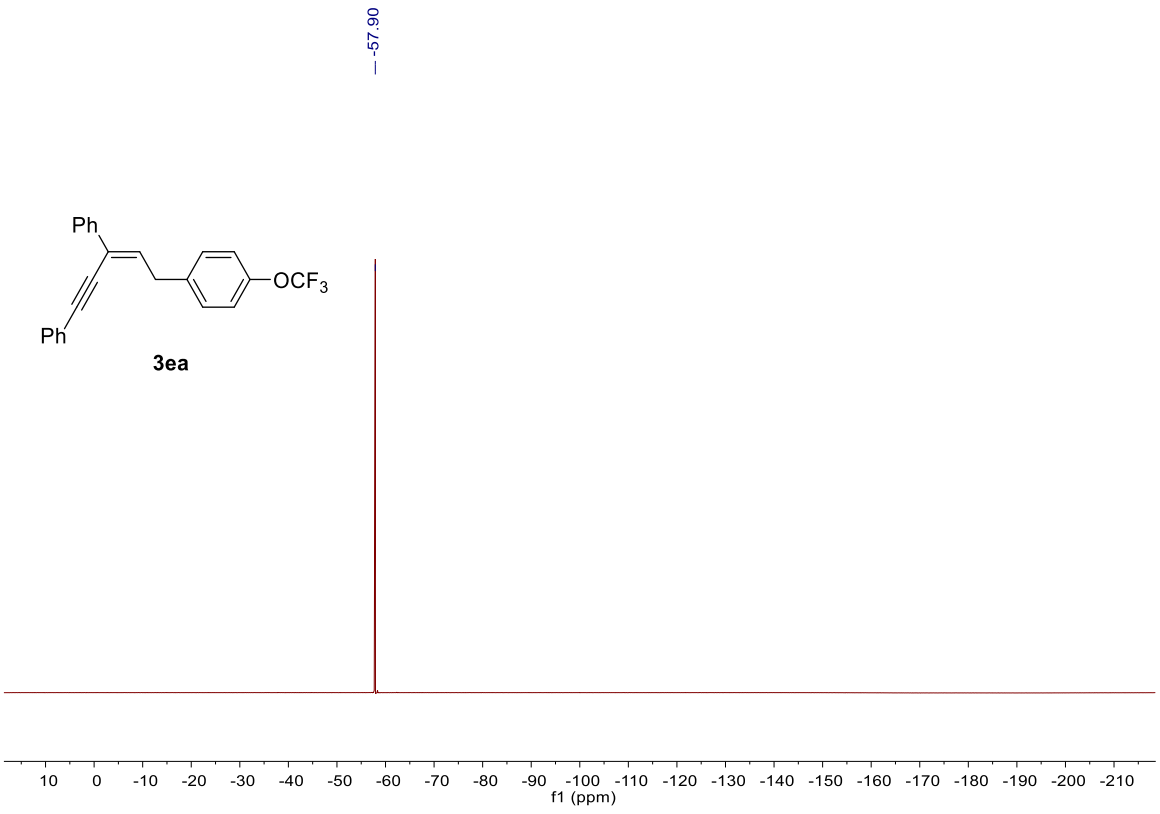


^{13}C NMR spectrum ($CDCl_3$)



^{19}F NMR spectrum ($CDCl_3$)



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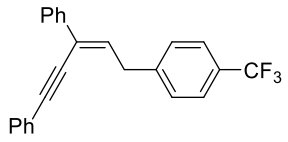

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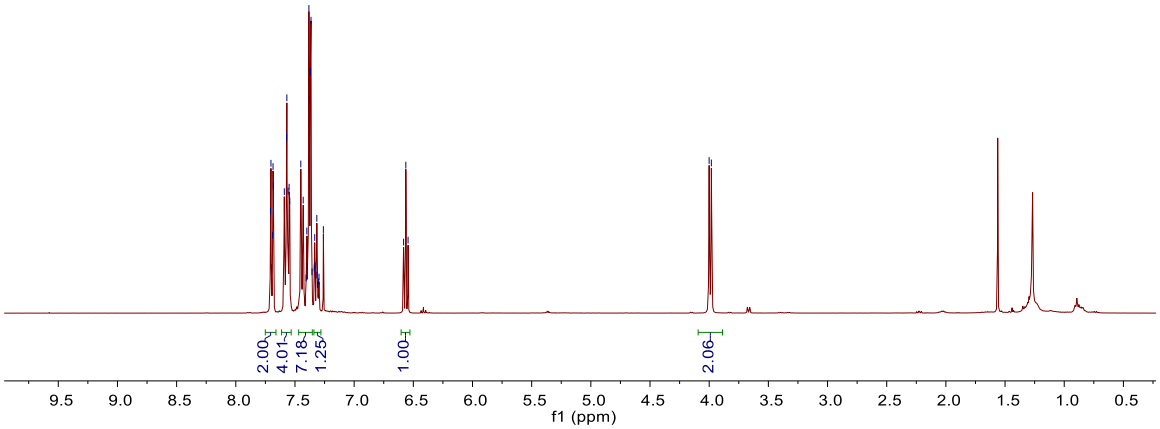

^{13}C NMR spectrum ($CDCl_3$)

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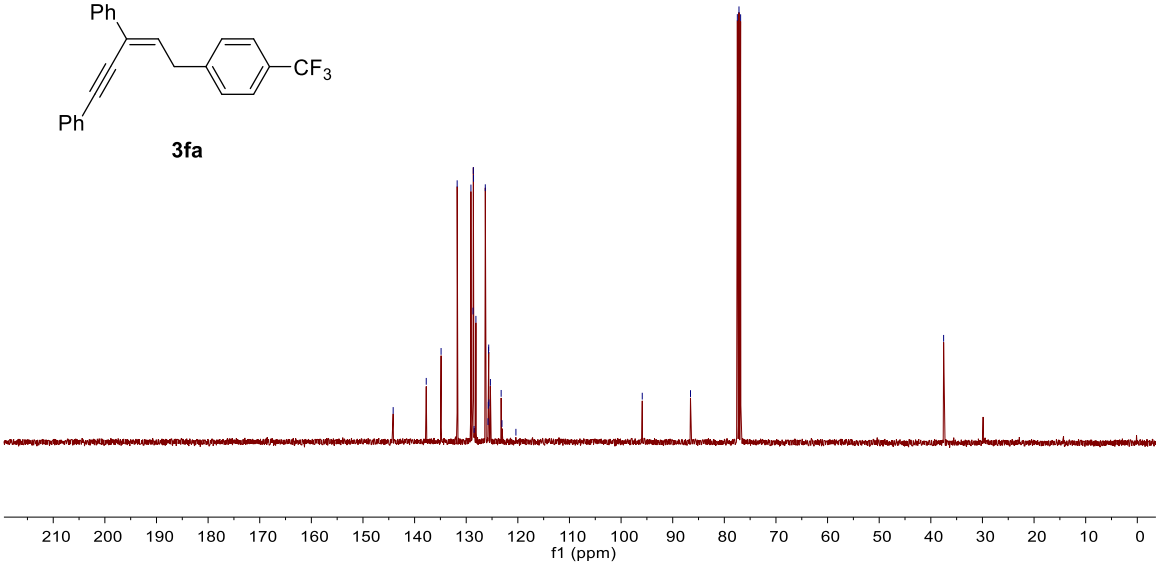
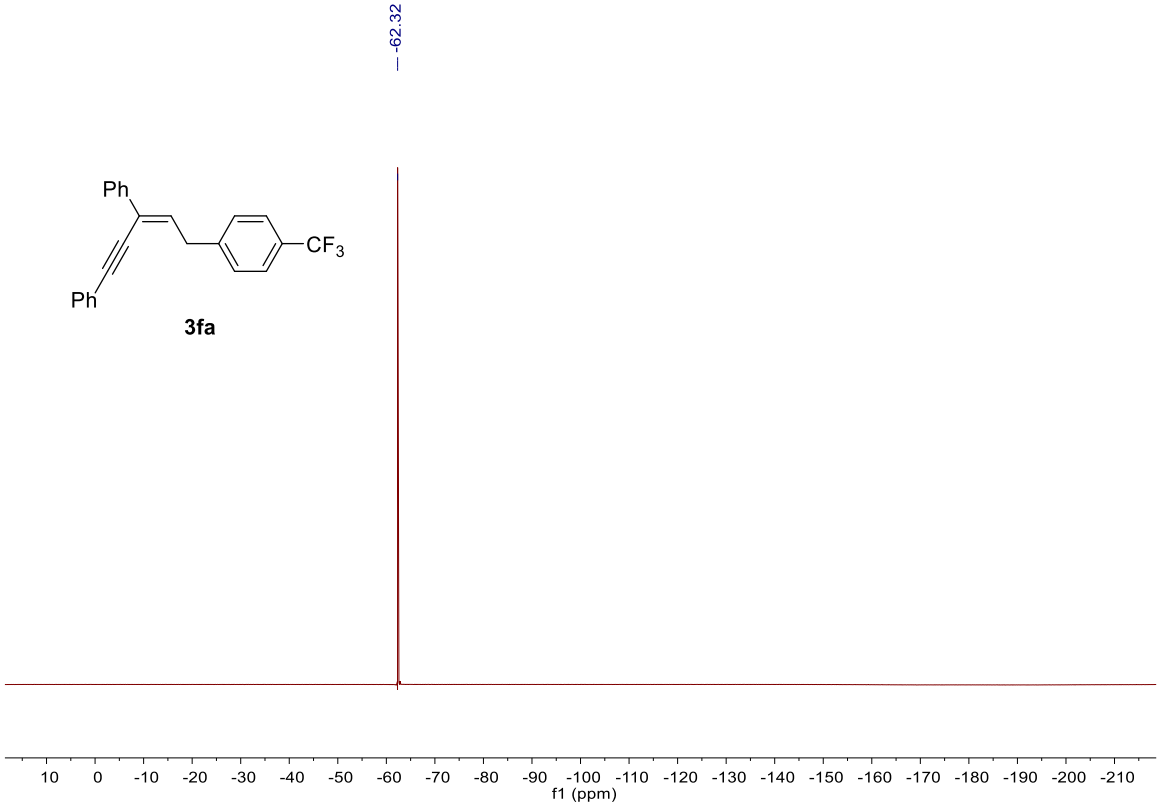
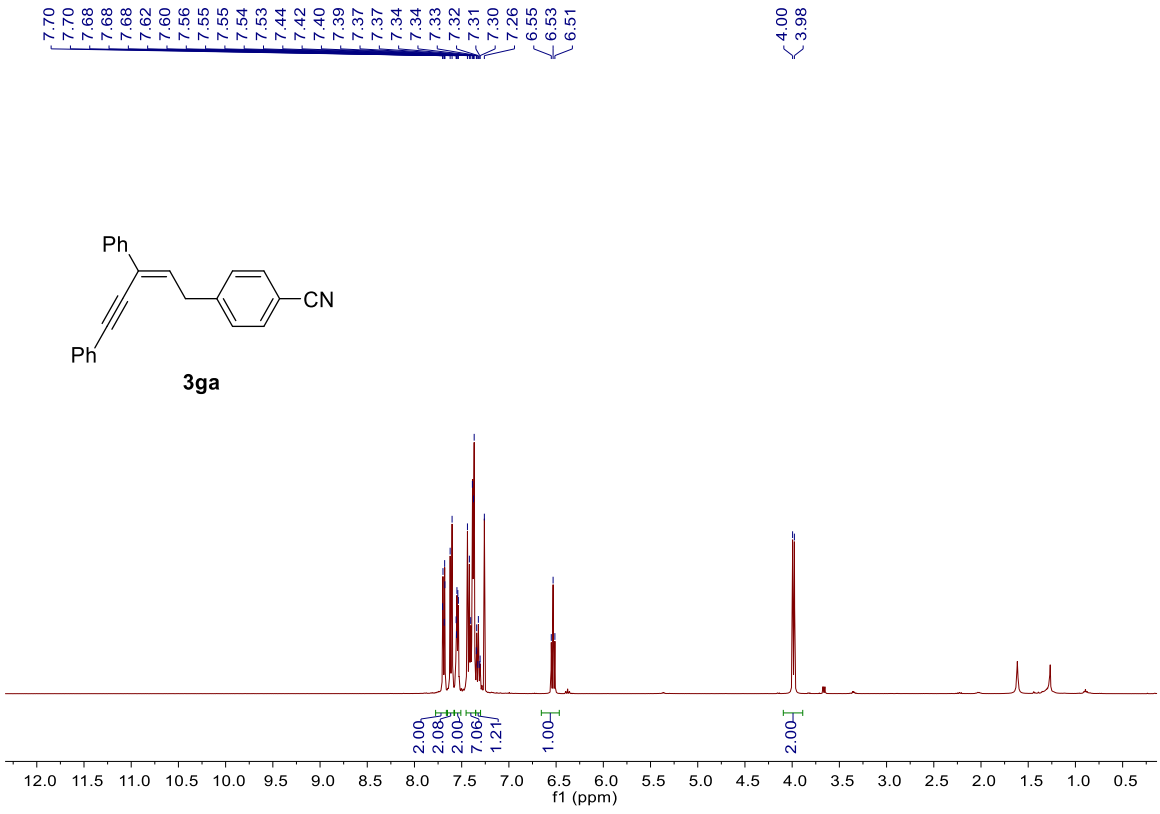


^{19}F NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



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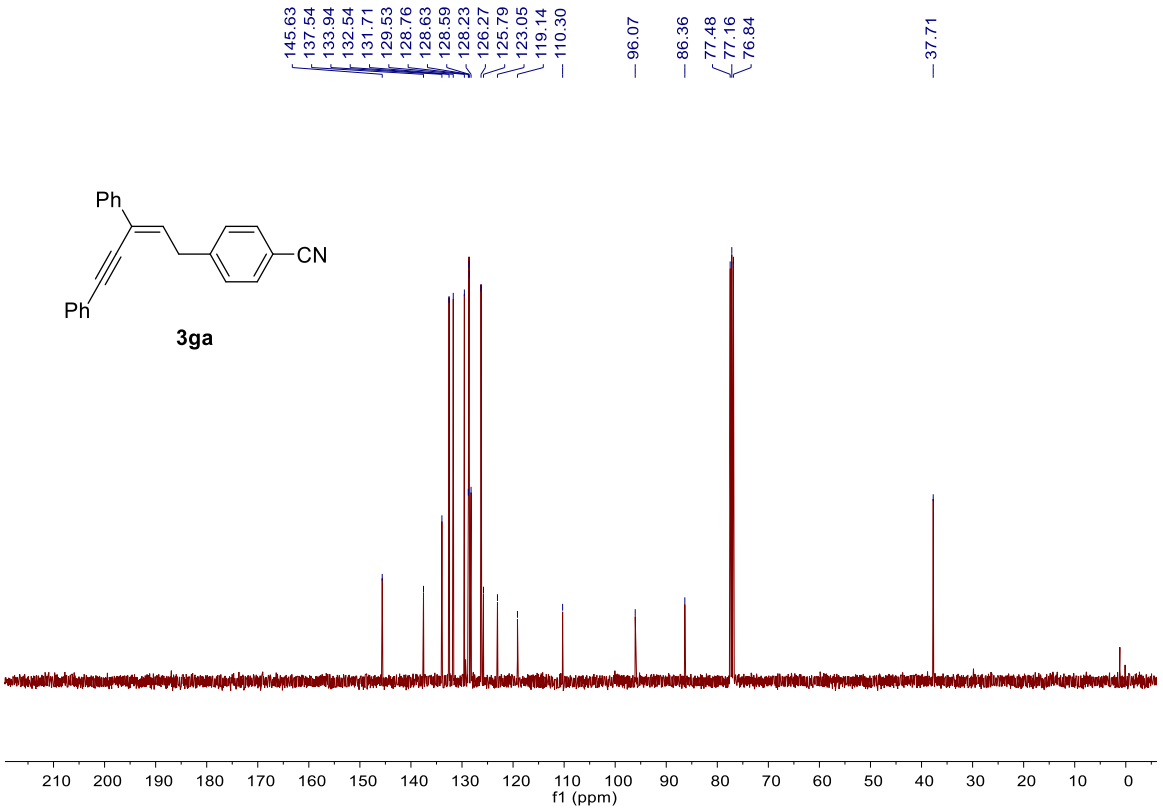
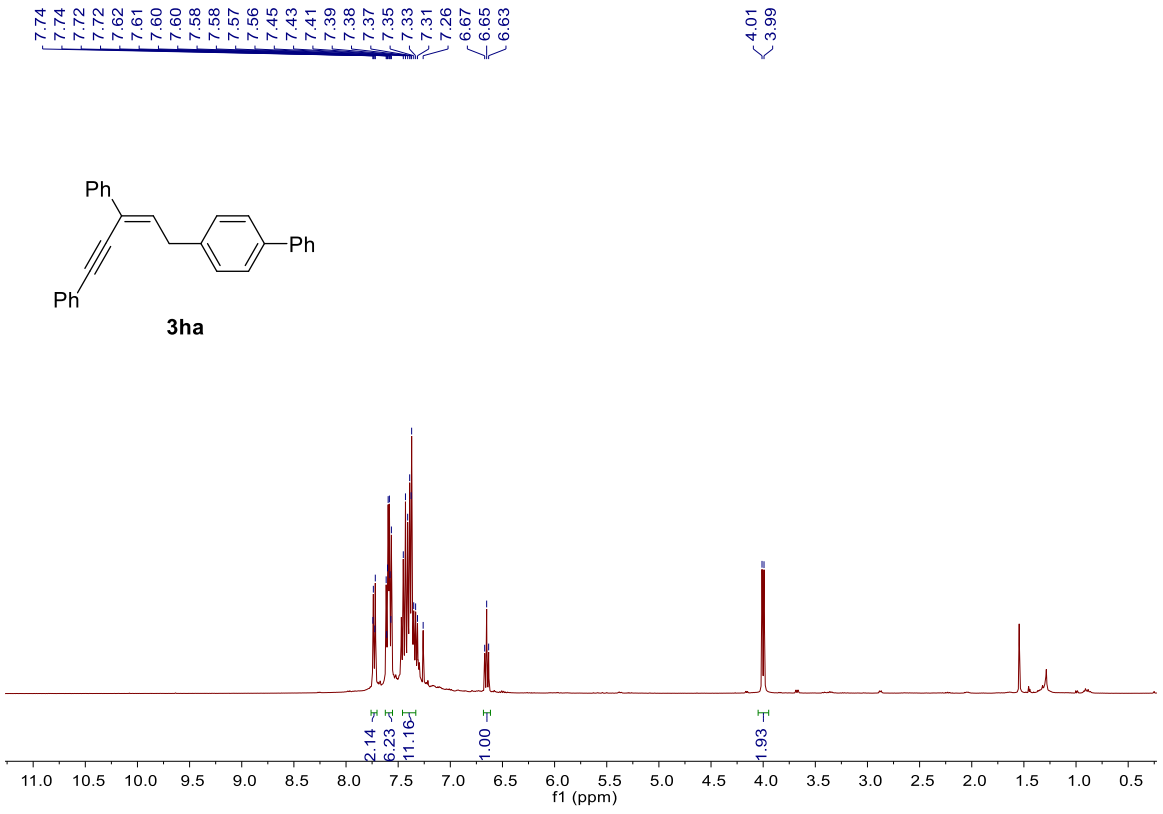
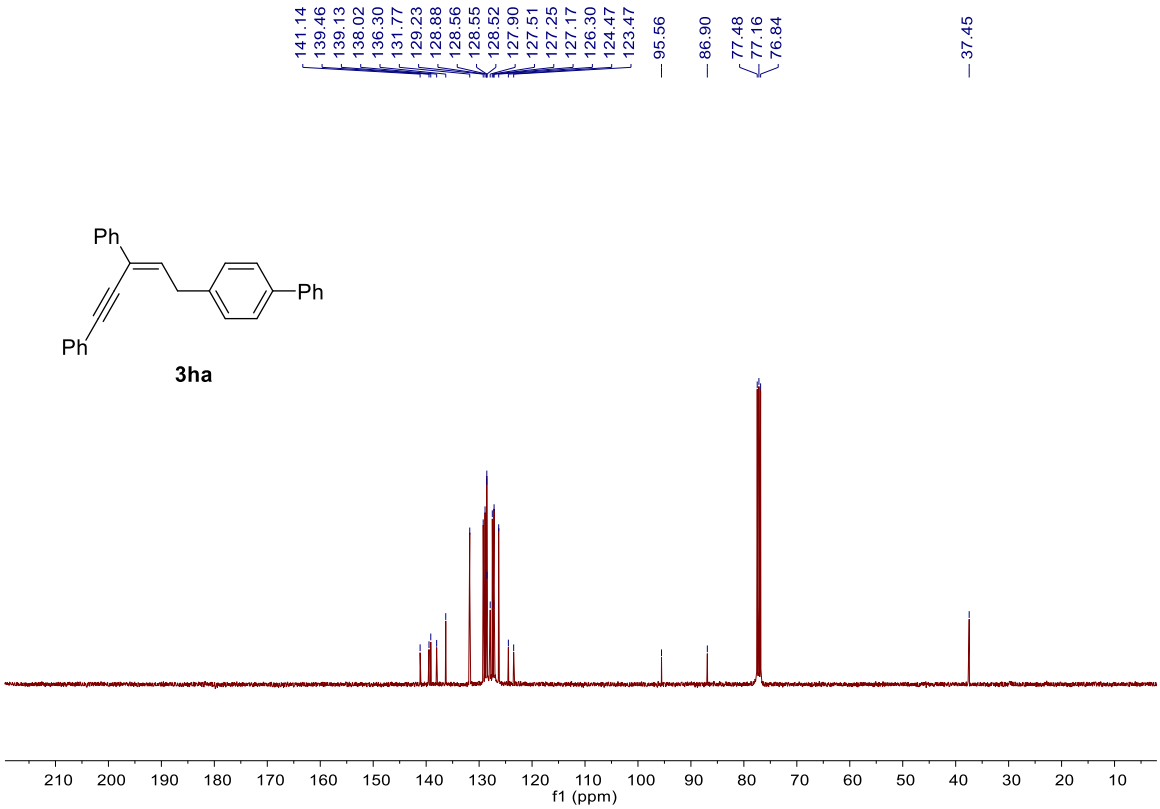


^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



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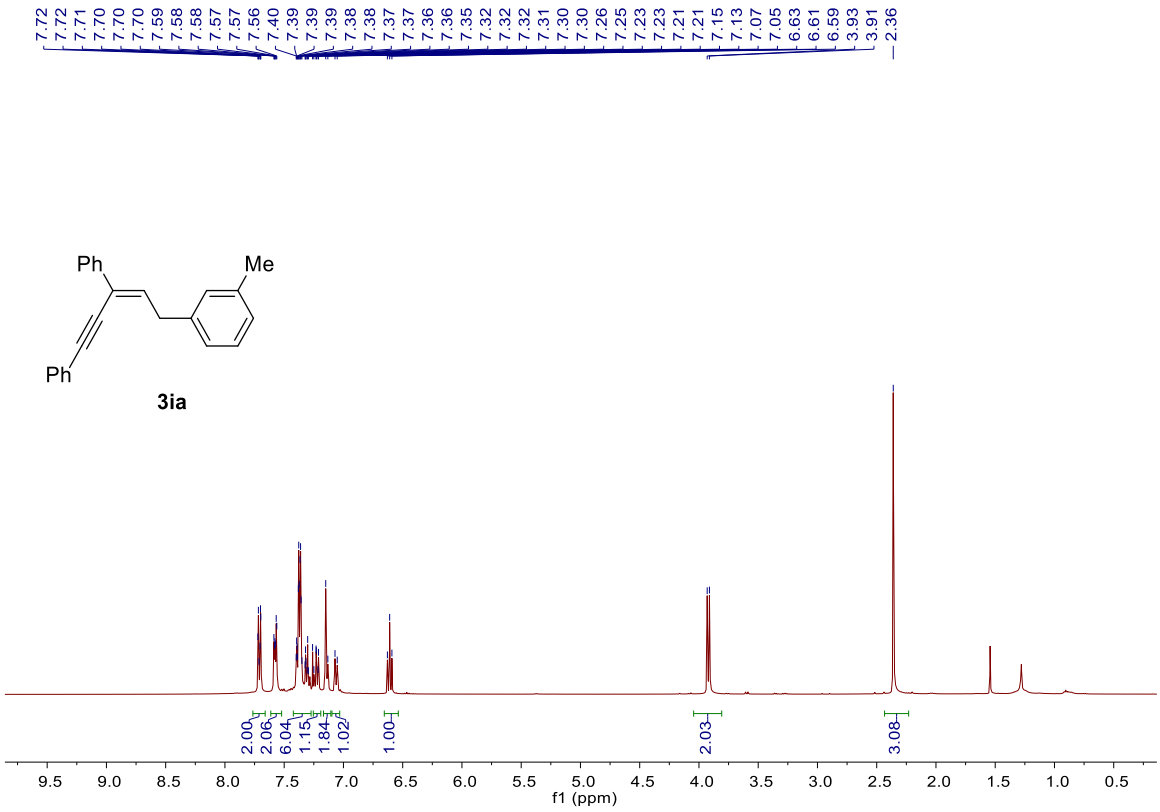

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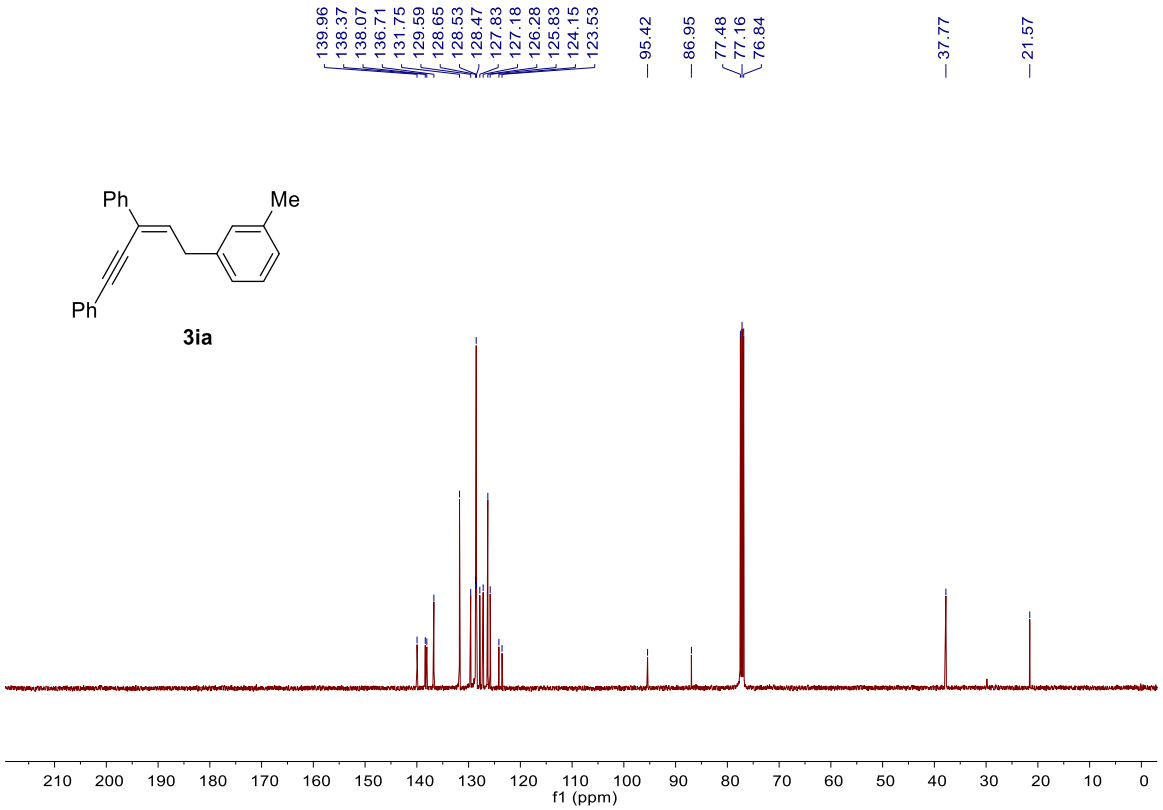
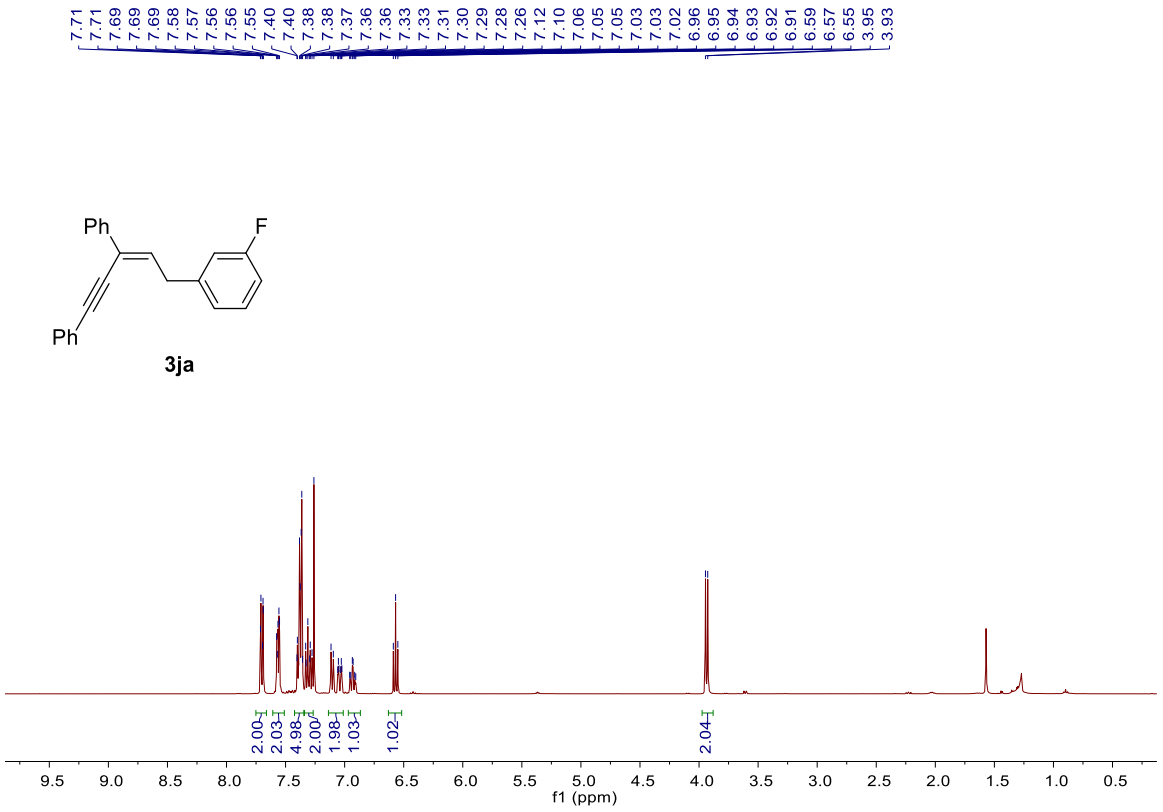


^{1}H NMR spectrum ($CDCl_3$)



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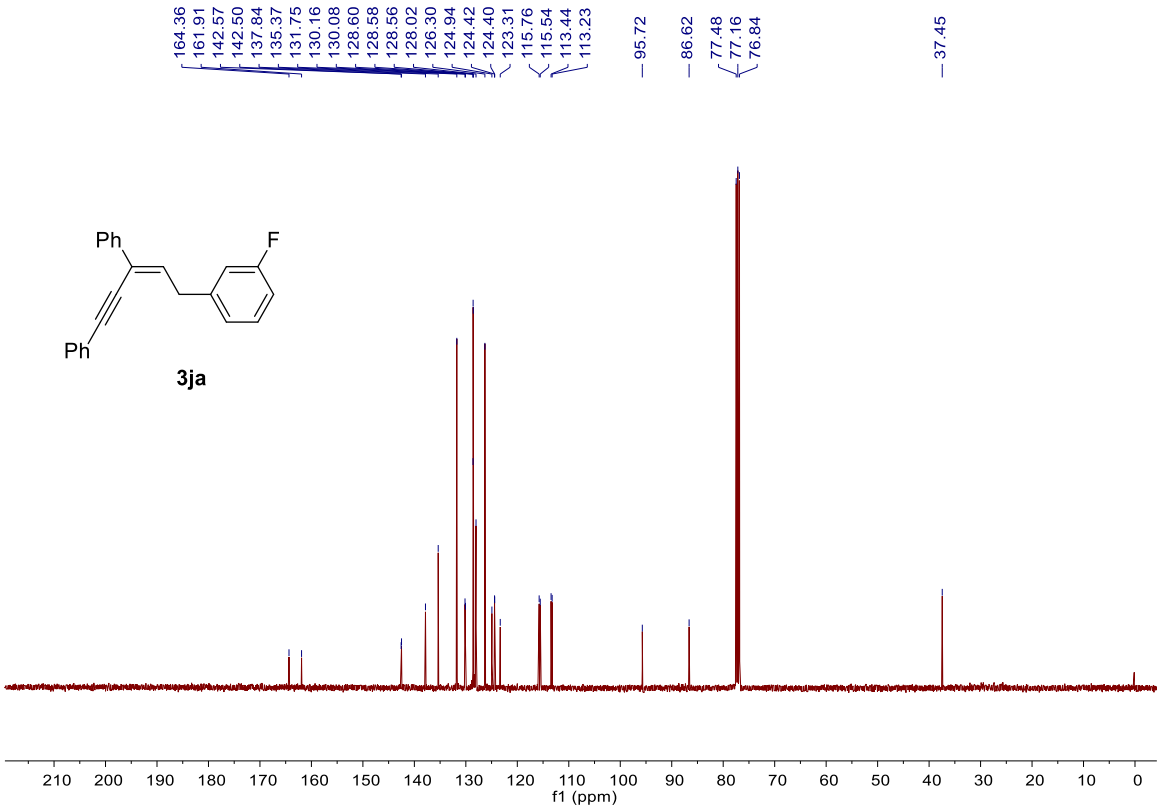
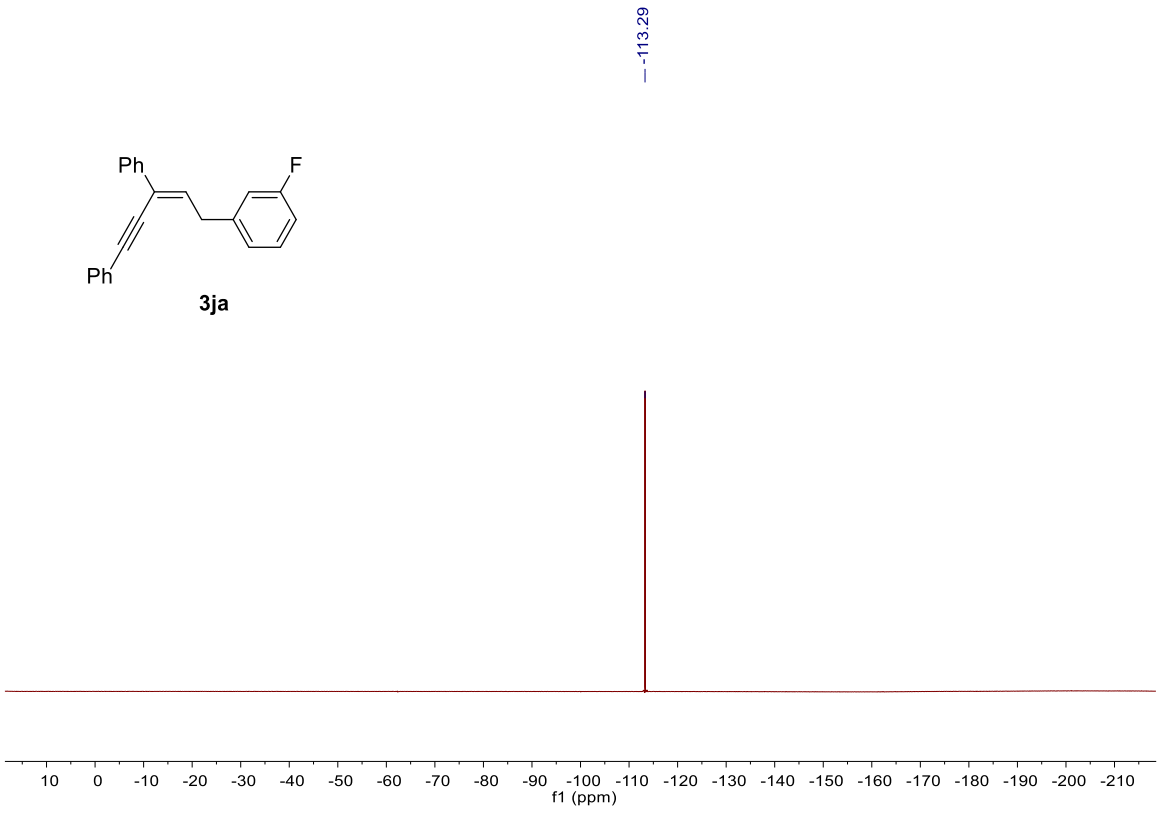
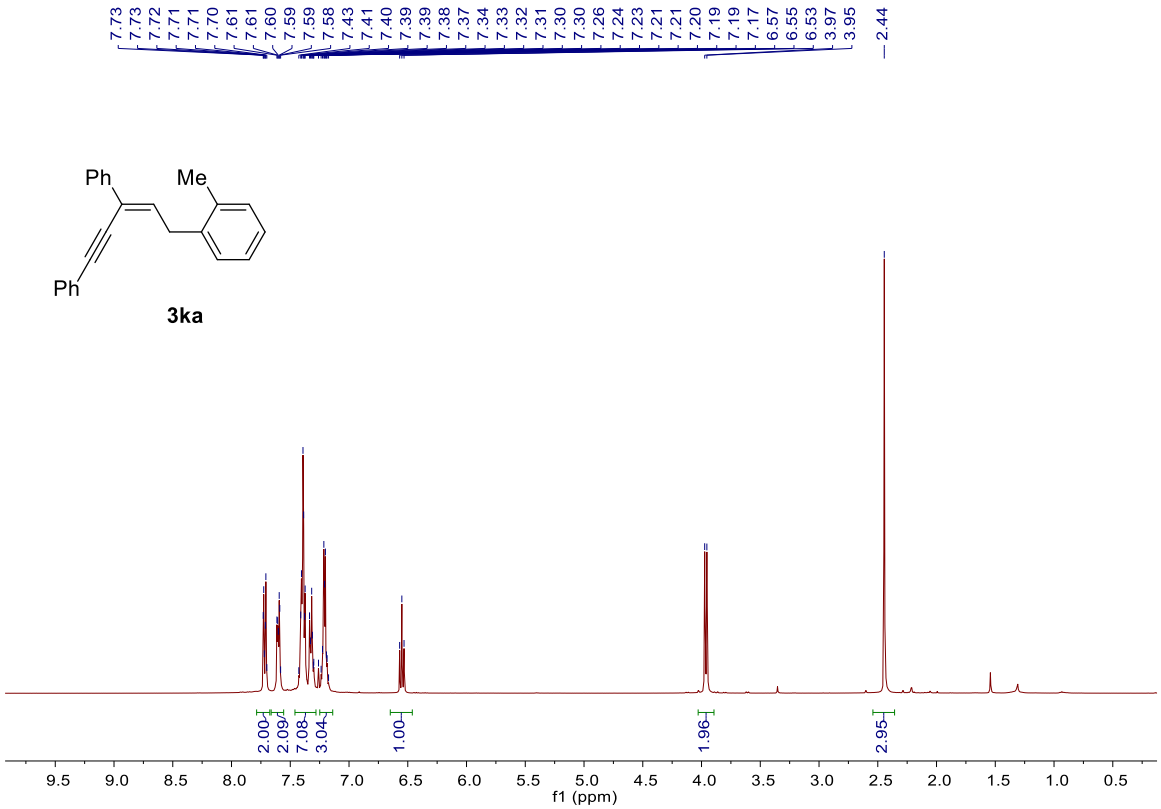


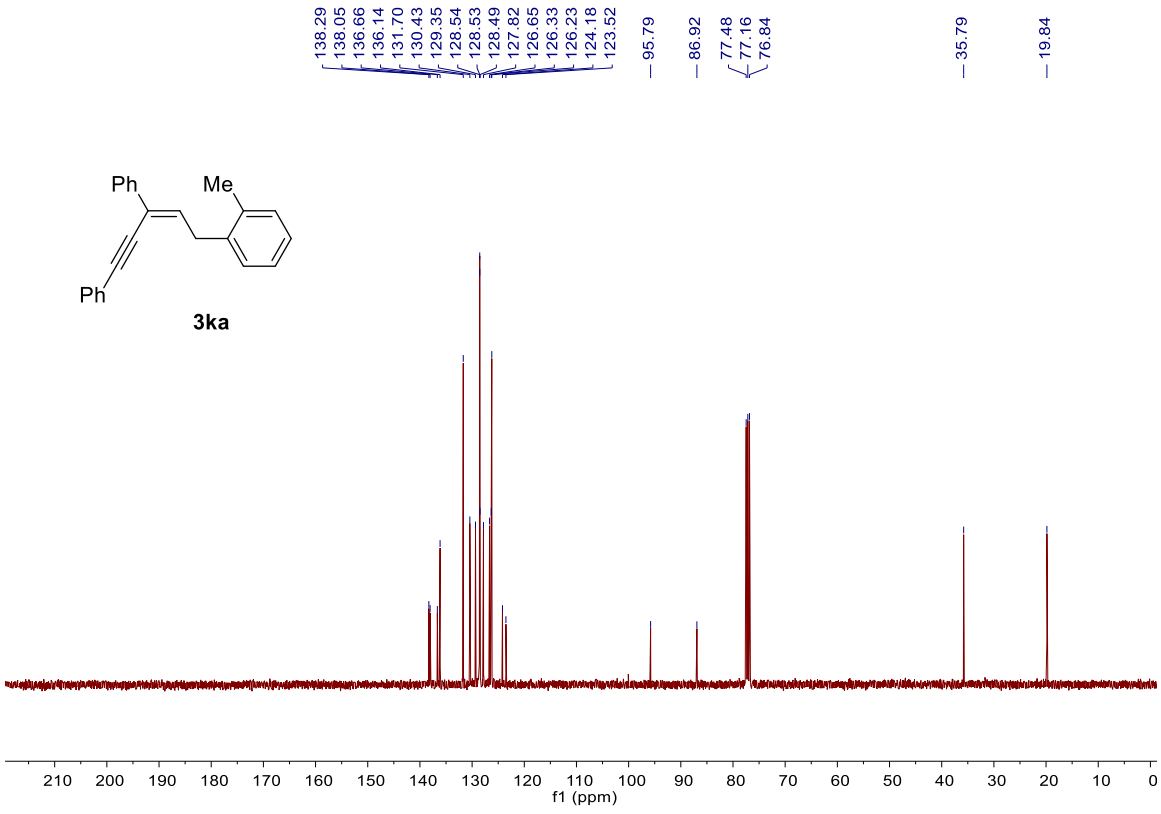
^{19}F NMR spectrum ($CDCl_3$)



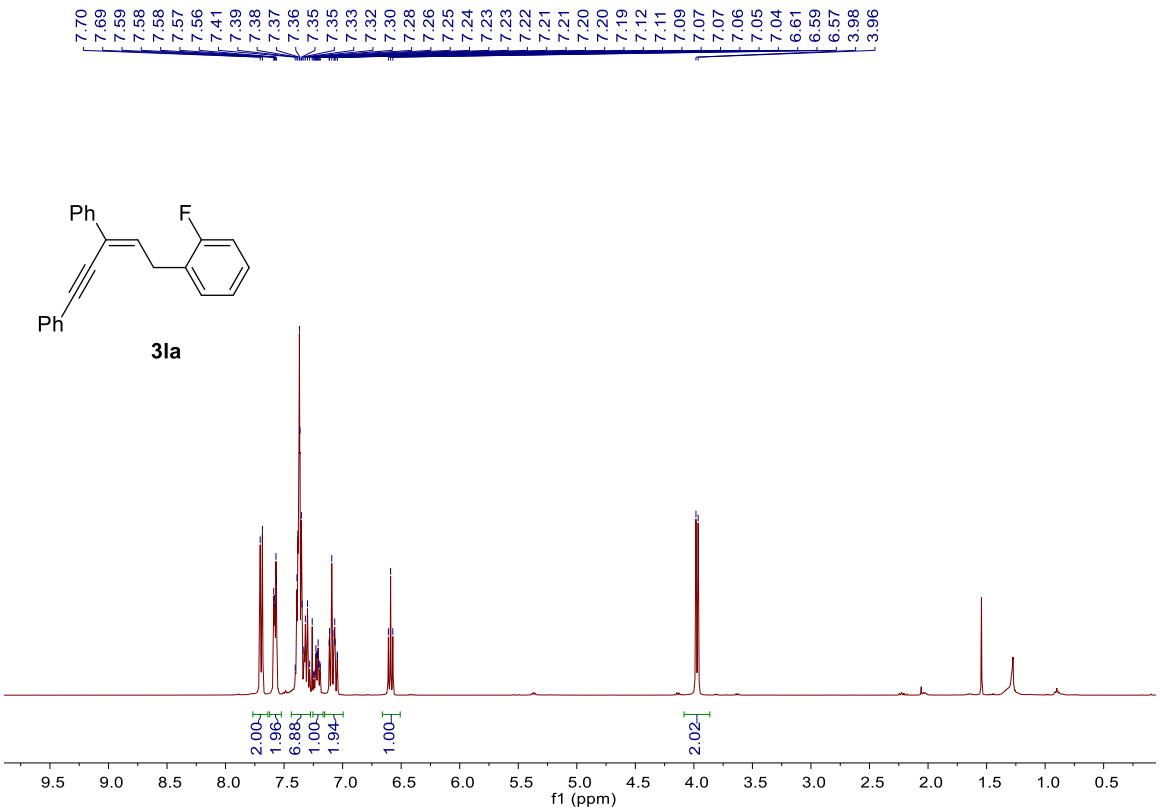
^{1}H NMR spectrum ($CDCl_3$)



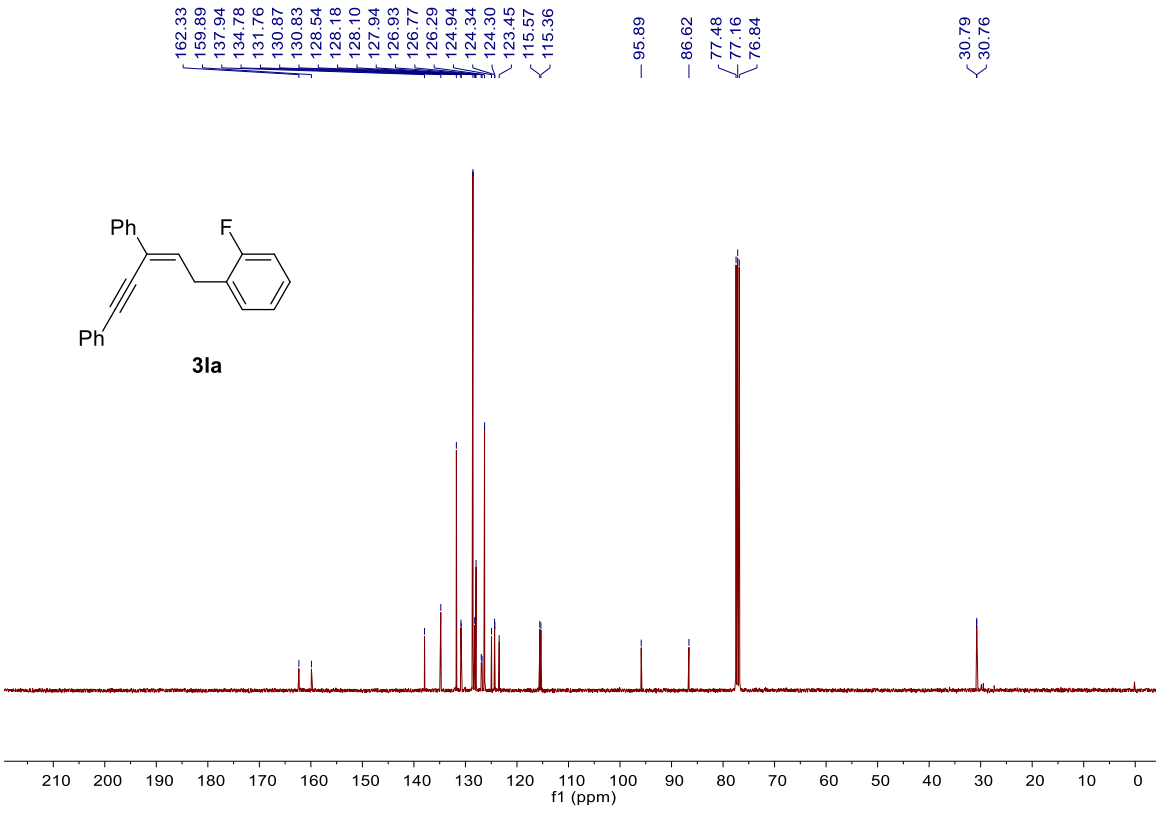
^{13}C NMR spectrum ($CDCl_3$)



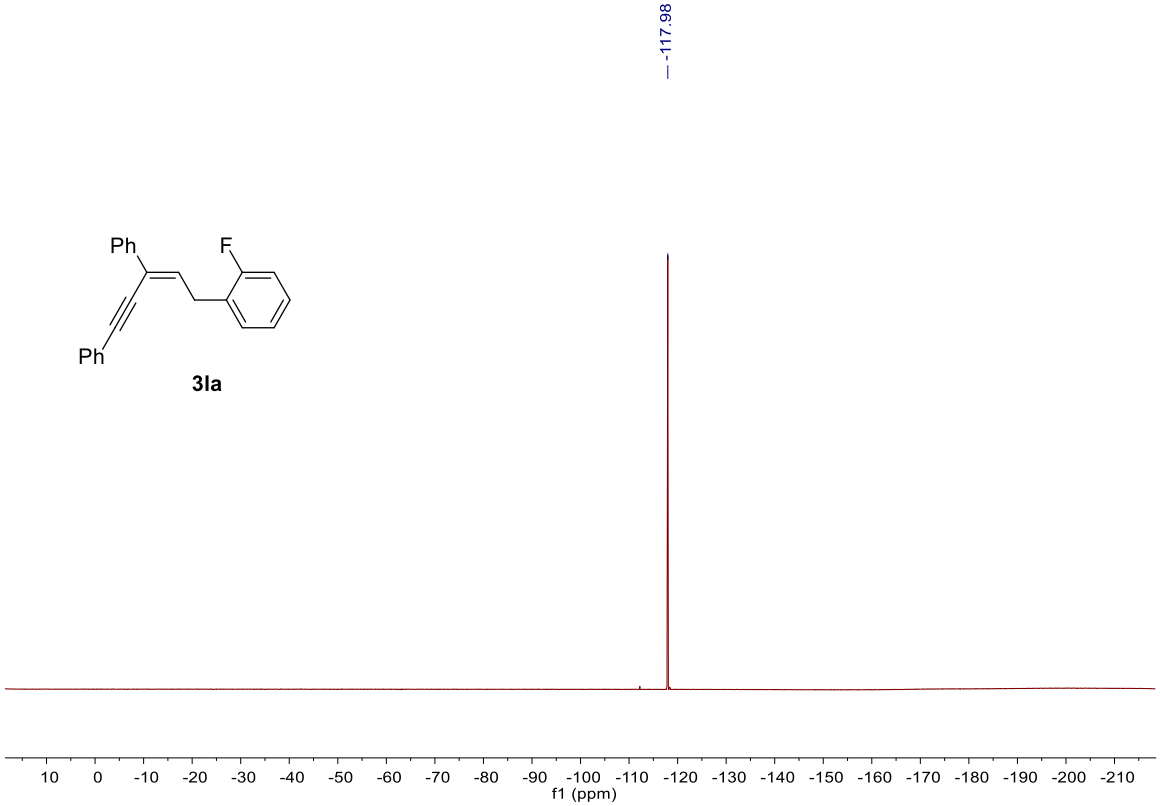
^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)

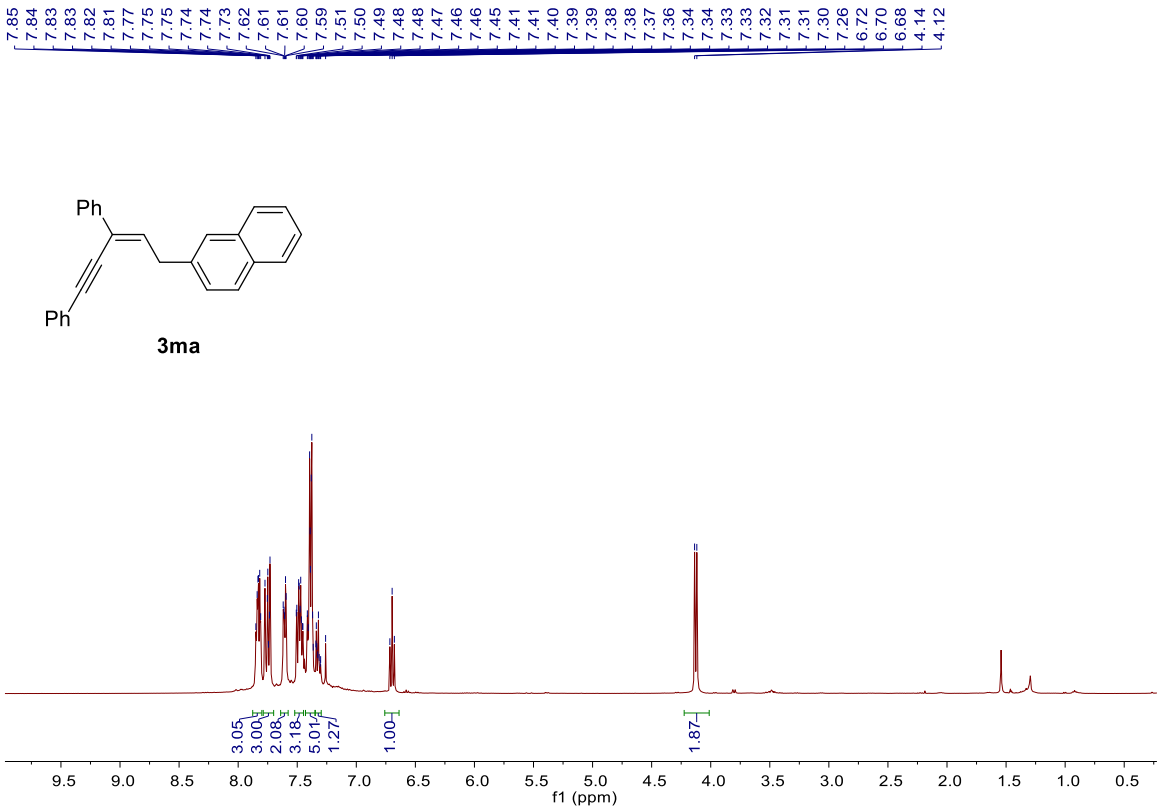


^{19}F NMR spectrum ($CDCl_3$)



3la

^{1}H NMR spectrum ($CDCl_3$)



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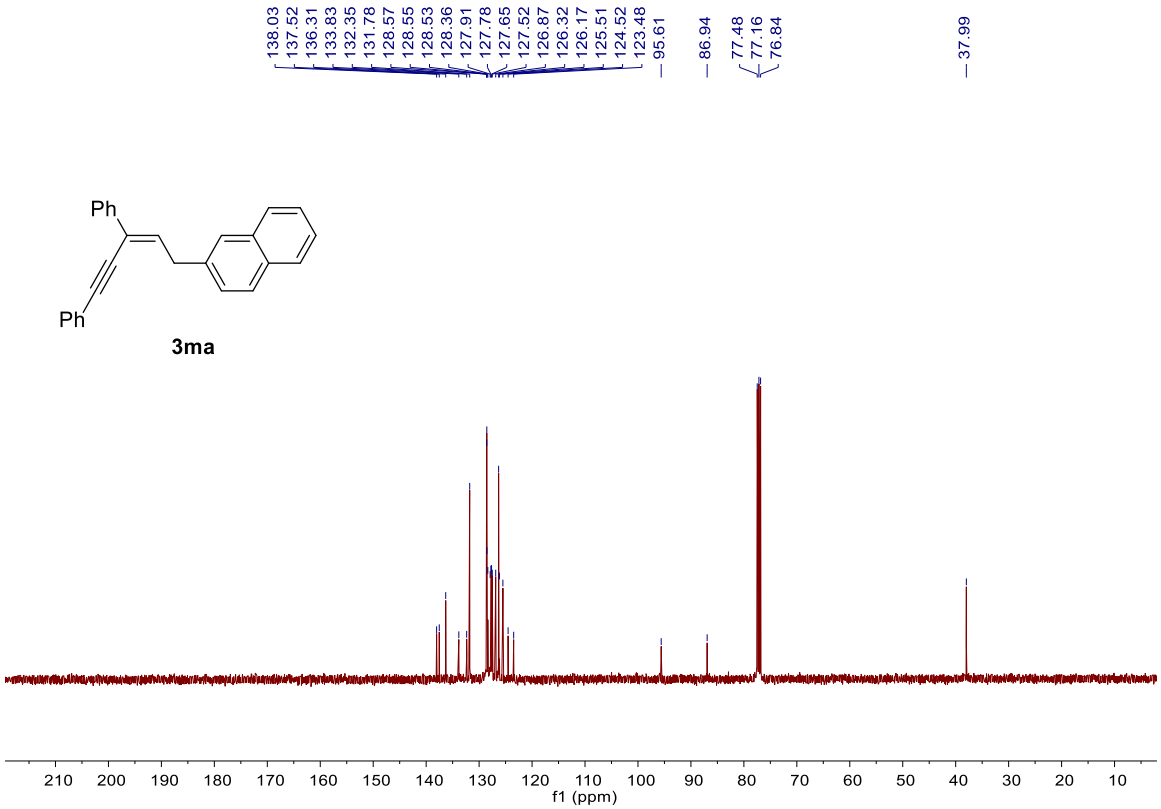
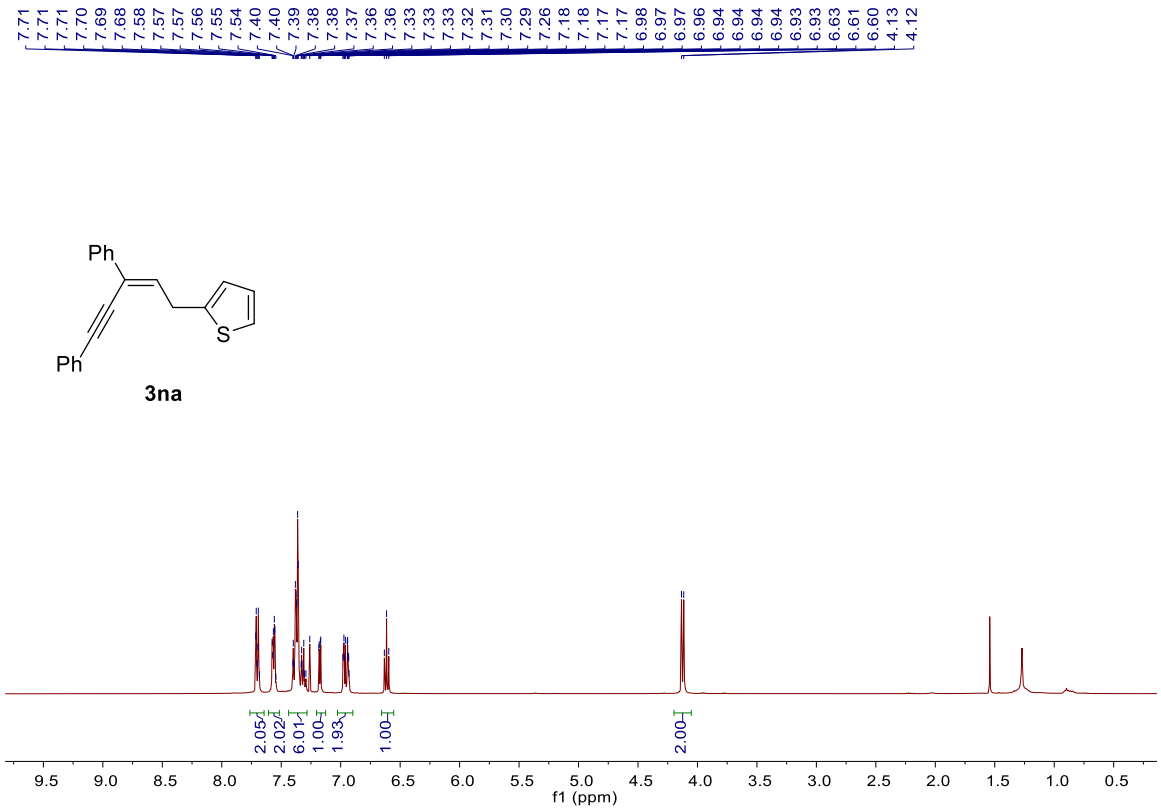
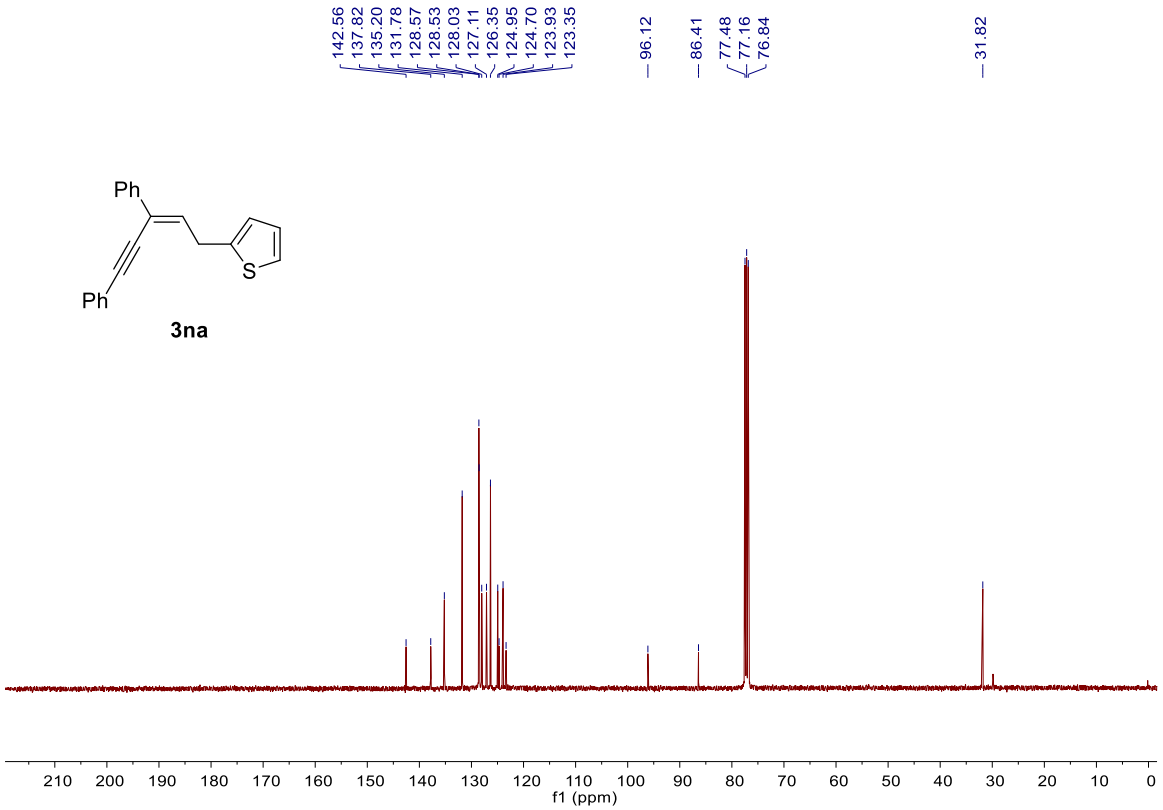


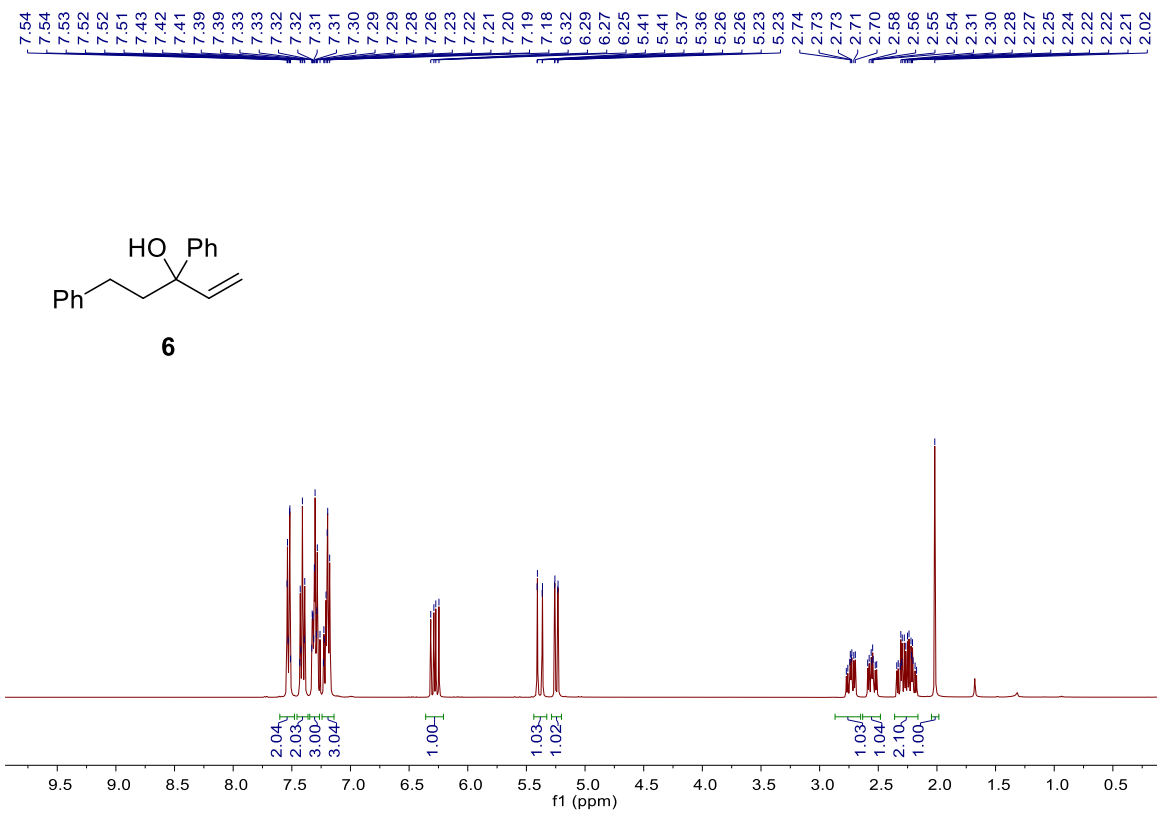
^{1}H NMR spectrum ($CDCl_3$)



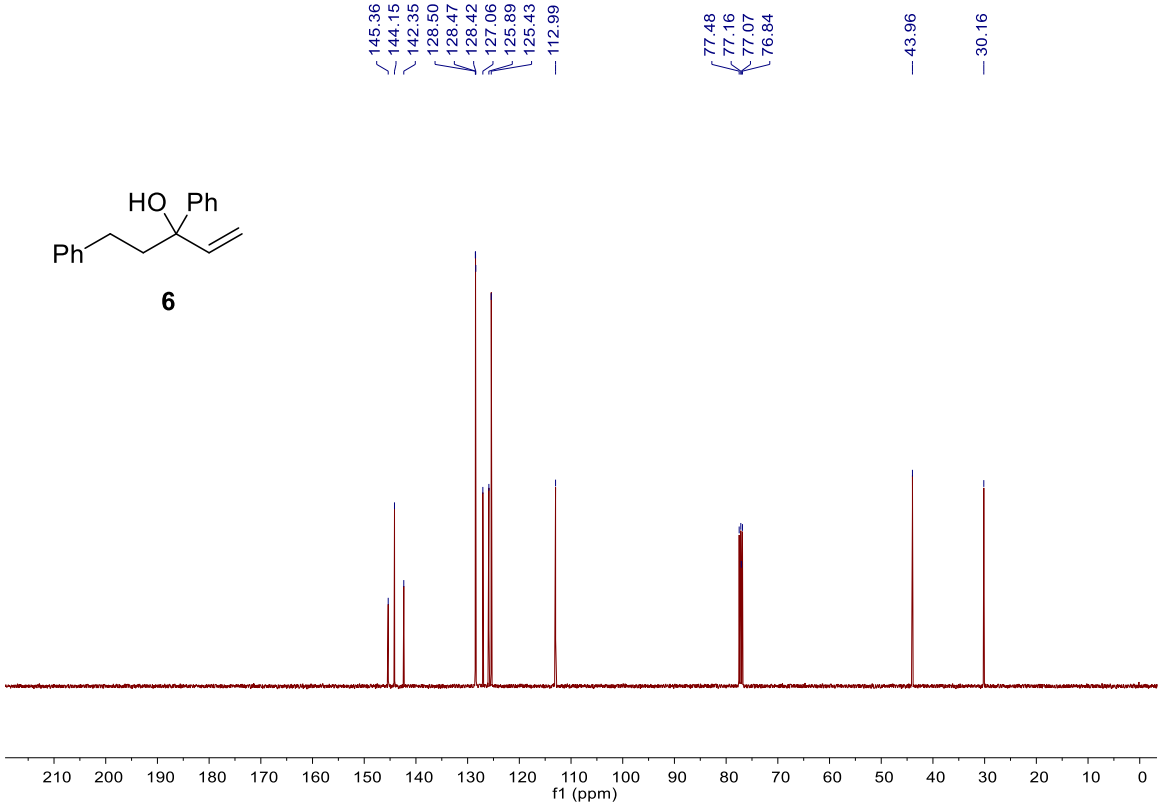
^{13}C NMR spectrum ($CDCl_3$)



^{1}H NMR spectrum ($CDCl_3$)



^{13}C NMR spectrum ($CDCl_3$)



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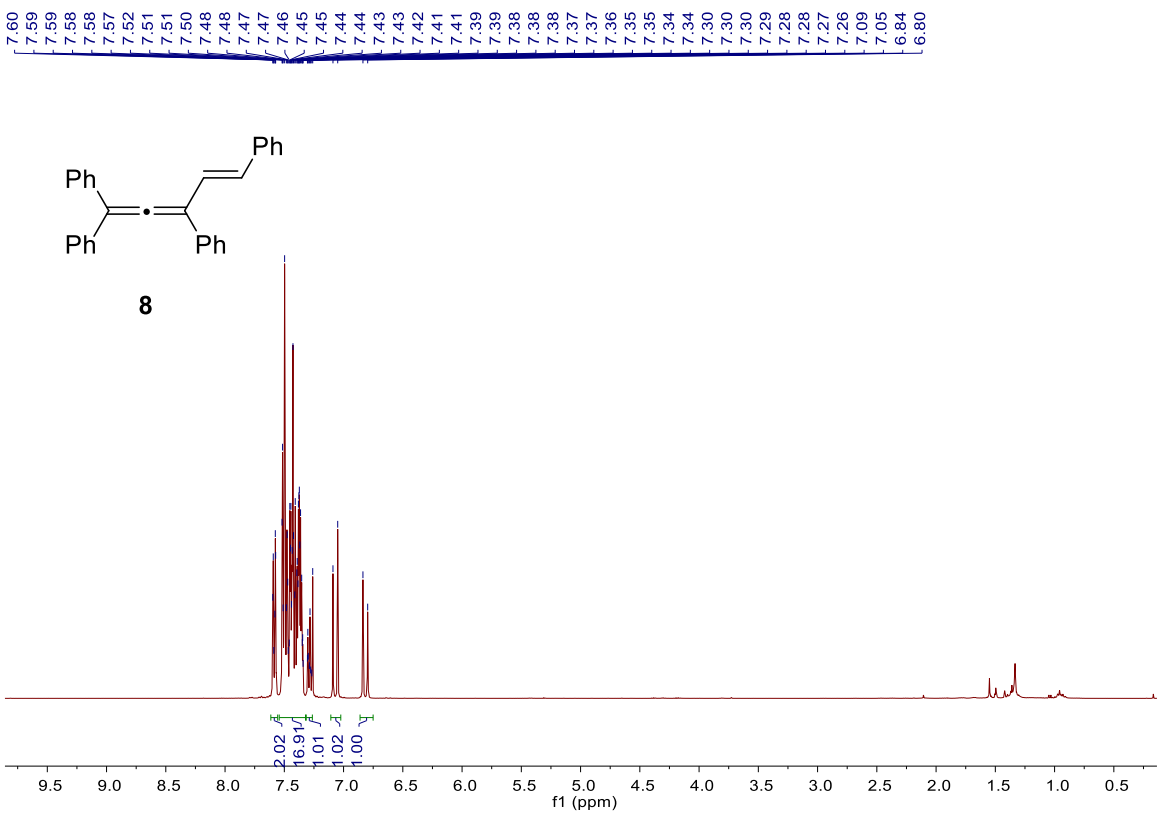
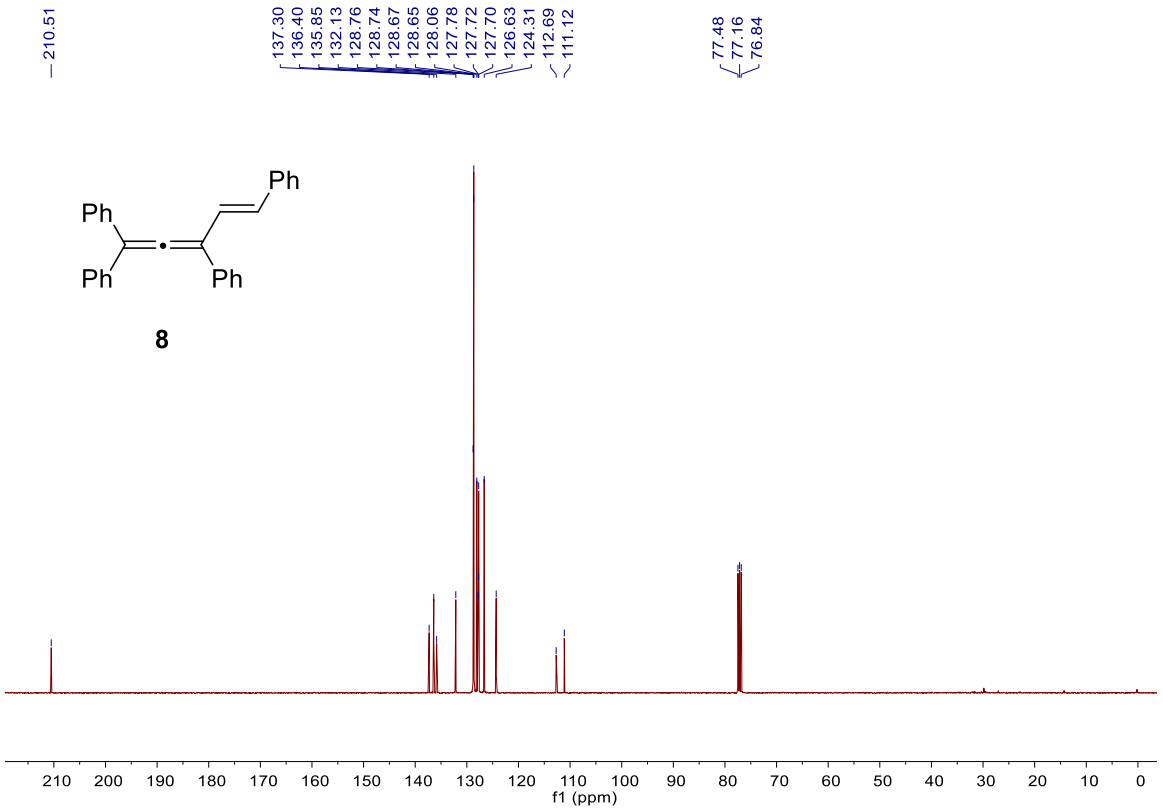
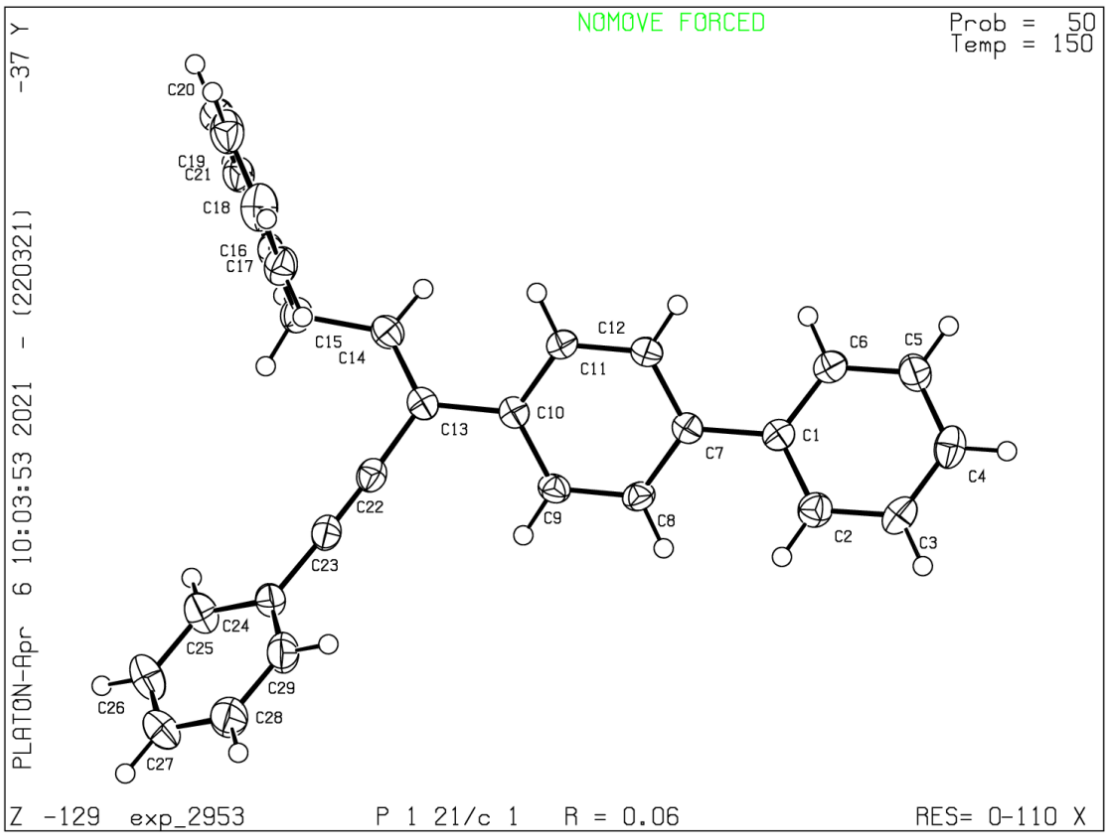


^{13}C NMR spectrum ($CDCl_3$)



X-ray molecular structure of 3an



X-ray molecular structure of **3an**