

Component-selective and Stereocontrolled One-step Three-Component Reaction among Aldehydes, Amines, and Allenyl Boronic Acids or Allenyl Pinacolboronates

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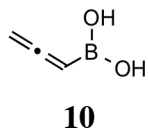
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Supporting Information

Experimental procedures and experimental data for compounds

General information. All reactions were performed at ambient temperature under nitrogen. The solvents were used without further purification and no dry conditions were necessary unless otherwise stated. The reactions were monitored by TLC on Silica Gel 60 precoated plates with F254 indicator. Visualization of the developed chromatograms was performed by staining with KMnO₄, ninhydrin, vanillin, or phosphomolybdic acid. The products were purified by flash column chromatography on Silica 60 Å 32-63 μm unless otherwise stated. ¹H and ¹³C NMR were recorded on a Bruker NMR (AMX500, AM360 or AC250) or a Varian Mercury 400 NMR. Chemical shifts of ¹H NMR are reported in parts per million on the δ scale from an internal standard of either residual chloroform (7.24 ppm), DMSO d₆ (2.49 ppm), acetone d₆ (2.04 ppm) or partly deuterated MeOH (3.3 ppm). Data are reported as follows: chemical shift, multiplicity (s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet and br=broad), coupling constants in Hz and integration. Chemical shifts of ¹³C NMR spectra are reported in ppm from the central peak of either CDCl₃ (77.0 ppm), DMSO d₆ (39.5 ppm) or partly deuterated MeOH (49.5 ppm). The mass spectra were recorded using FAB and EI ionization techniques.

Allenyl boronic acid (10): Prepared according to a literature procedure (Haruta, R.; Ishiguro,

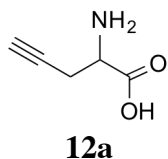


M.; Ikeda, N.; Yamamoto, H., *J. Am. Chem. Soc.* **1982**, *104*, 7667). To a

flamed-dried three-necked 100 ml round bottom flask equipped with a reflux condenser were added magnesium turnings (3.7 g, 150 mmol). The system was evacuated and filled with argon followed by the addition of anhydrous diethyl ether (50 ml). In a separate flask, propargyl bromide (80% in toluene, 16.9 ml, 22.6 g, 150 mmol) was diluted in anhydrous diethyl ether (30 ml) and a small amount of this solution (ca. 1ml) was directly added to the three-necked reaction flask to initiate the reaction (Note: To help the initiation of this process, a catalytic amount of HgCl₂ has been used, while a non-toxic mercury-free process using ZnBr₂ was reported in: Acharya, H. P.; Miyoshi, K.; Kobayashi, Y., *Org. Lett.* **2007**, *9*, 3535). As soon as the ether started to reflux the reaction was cooled at 0°C in an ice bath and the remainder of the propargyl bromide solution was added slowly. The resulting greenish solution was then stirred at room temperature for 45 minutes. Meanwhile, to a three-necked 250 ml flask equipped with a mechanical stirrer and two dropping funnels was added anhydrous diethyl ether (150 ml). The solution of the Grignard reagent was added to one of the dropping funnels, while the other dropping funnel was charged with a solution of methyl borate (16.8 ml, 150 mmol) in anhydrous diethyl ether (30 ml). The flask was then cooled to -78°C and under vigorous stirring the two solutions in the dropping funnels were alternatively added, resulting in the formation of a white precipitate. After the addition was completed the reaction mixture was stirred at -78°C for an additional hour and after it was warmed to 0°C it was treated with water (10ml) and then a solution of H₂SO₄ (75 ml of a solution prepared from 5.6 ml of conc. H₂SO₄ and 100 ml of water). After separation of the two layers, extraction of the aqueous layer with diethyl ether (2x30 ml), combination of the organic layers, drying with MgSO₄ and filtration, the solution was concentrated in a rotary evaporator. After most of the ether has been removed, the evaporator was charged with argon to prevent exposure of the allenyl boronic acid to air. The concentrated solution was then treated with hexane (70 ml) under argon resulting in the formation of white crystals of allenyl boronic acid (**10**) in about 40-60% yield. This product existed exclusively as the allenyl boronic acid without the presence of any propargyl boronic acid. The suspension of allenyl boronic acid in hexane could be stored at -40°C for several weeks without any decomposition. Prior to the next reaction the hexane was removed and the solid was dried without being exposed to the air as it is known to be a pyrophoric material. It

was always mixed with the solvent used in the next reaction and transferred to the reaction mixture either as a suspension (CH_2Cl_2) or as a solution (in EtOH or MeOH). $^1\text{H-NMR}$ (360 MHz, $\text{CDCl}_3\text{-d}_6\text{-Me}_2\text{SO}$): δ 4.74 (t, $J=7.2$ Hz, 1H), 4.42 (d, $J=6.6$ Hz, 2H); $^{13}\text{C-NMR}$ (90 MHz, $\text{CDCl}_3\text{-d}_6\text{-Me}_2\text{SO}$) δ 203.79 ($=\text{C}=\text{O}$), 67.48, 66.84.

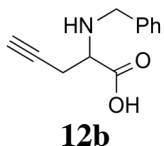
2-Amino-pent-4-ynoic acid (12a): To a suspension of preformed hydroxy glycine prepared



according to a published procedure (Hoefnagel, A. J.; Van Bekkum, H.; Peters, J. A., *J. Org. Chem.* **1992**, *57*, 391) (57 mg, 0.63 mmol) in MeOH (1 ml) was added 0.2 equivalents of Et_3N (18 μl) and the mixture was stirred at ambient temperature for 5 min. A solution of allenyl boronic acid **10** (63

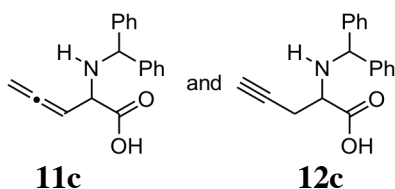
mg, 0.75 mmol) in MeOH (1.5 ml) was added in one portion to the above suspension and the mixture was stirred at rt for 12 hr. An additional amount of **10** (0.20mmol) was added and the mixture was stirred for another 3 hr. The white precipitate was filtered off and washed with cold MeOH (2 ml) to afford the α -propargyl amino acid **12a** (51 mg, 72% yield). $^1\text{H NMR}$ (250 MHz, MeOH d_4 , DCl) δ 4.20 (t, $J= 5.2$ Hz, 1H), 2.93 (dd, $J_1=5.0$ Hz, $J_2=2.8$ Hz, 2H), 2.65 (t, $J=2.8$ Hz, 1H, $\equiv\text{CH}$); $^{13}\text{C NMR}$ (62 MHz, MeOH d_4 , DCl) δ 170.55 ($\text{C}=\text{O}$), 77.55 ($\equiv\text{C}$), 75.58 ($\equiv\text{CH}$), 52.128 (CHN), 21.98 (CH_2).

2-Benzylamino-pent-4-ynoic acid (12b): To a 25-ml round bottomed flask equipped with a



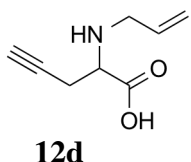
magnetic stirrer, was added CH_2Cl_2 (5 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (258 mg, 2.8 mmol), benzylamine (0.300 g, 2.8 mmol), and a suspension of allenyl boronic acid **10** (235 mg, 2.8

mmol) in CH_2Cl_2 (4 ml). The mixture was stirred under nitrogen for 24 hr, forming a white solid precipitate. The reaction mixture was filtered under vacuum and after washing with CH_2Cl_2 and cold MeOH, it was dried under high vacuum to form the α -propargyl amino acid **12b** (460 mg, 81% yield). $^1\text{H NMR}$ (500 MHz, MeOH d_4 , DCl) δ 7.6-7.5 (m, 2H), 7.5-7.4 (m, 3H), 4.35 (s, 2H), 4.19 (t, $J=5.3$ Hz, 1H), 3.04 (dd, $J_1=4.9$ Hz, $J_2=2.1$ Hz, 2H), 2.67 (t, $J=2.1$ Hz, 1H, $\equiv\text{CH}$); $^{13}\text{C NMR}$ (125 MHz, MeOH d_4 , DCl) δ 169.92 ($\text{C}=\text{O}$), 132.27, 131.98, 131.35, 130.76, 77.44 ($\equiv\text{C}$), 75.84 ($\equiv\text{CH}$), 59.06 (CHN), 52.05 (CH_2N), 20.93 (CH_2); IR cm^{-1} 3207 (br, OH), 2253 (s, $\text{C}\equiv\text{C}$), 1611 ($\text{C}=\text{O}$); FAB MS calc for $[\text{M}+1]$ ($\text{C}_{12}\text{H}_{14}\text{NO}_2$) 204.1025, found 204.19.

2-(Benzhydryl-amino)-penta-3,4-dienoic acid (11c) and 2-(Benzhydryl-amino)-pent-4-

ynoic acid (12c): To a 25-ml round bottomed flask equipped with a magnetic stirrer, was added MeOH (4 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (166 mg, 1.8 mmol), aminodiphenyl methane (330 mg, 1.8 mmol), and a solution

of allenyl boronic acid **10** (200 mg, 2.4 mmol) in MeOH (2 ml). The mixture was stirred under nitrogen for 24 hr, forming a white solid precipitate. The reaction mixture was filtered under vacuum and after washing with CH₂Cl₂ and cold MeOH, the solid product was dried under high vacuum. From the filtrate, another small amount of product was isolated after complete removal of the boric acid byproduct through continuous additions/ evaporations of MeOH (5x10 ml), and washing the residue with acetone. The combined solid was completely dried under vacuum to give a 32:68 mixture of the α -allenyl (**11c**) and α -propargyl (**12c**) amino acid (330 mg, 66% yield). ¹H NMR (500 MHz, MeOH d₄, DCI) δ 7.67-7.61 (m, 6.3H), 7.49-7.37 (m, 9.1H), 5.70 (s, 1H), 5.67 (s, 0.5H), 5.47 (m, 0.45H), 5.15-5.08 (m, 1.14H), 4.10 (d, J=9.7 Hz, 0.47H), 3.88 (t, J=5.5 Hz, 1H), 3.12-3.02 (m, 2H), 2.64 (t, J=2.4Hz, 1H); ¹³C NMR (125 MHz, MeOH d₄, DCI) δ 212.121, 169.75 (major) and 169.57 (minor), 137.06 (major) and 136.95 (minor), 136.40 (minor) and 136.17 (major), 131.14, 131.00, 130.93, 130.86, 129.86, 129.81, 129.71, 129.49, 84.00, 80.00, 77.49, 75.69, 67.73, 66.10, 59.92, 59.16, 21.27; IR (cm⁻¹): 3201 (br, OH), 2253 (s, C \equiv C), 1639 (C=O).

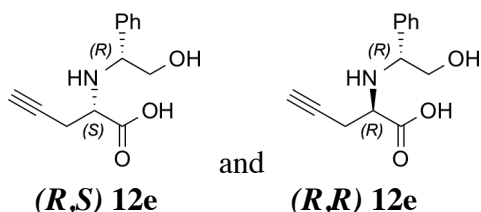
2-Allylamino-pent-4-ynoic acid (12d): To a 25-ml round bottomed flask equipped with a

magnetic stirrer, was added MeOH (2 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (166 mg, 1.8 mmol), allylamine (103 mg, 1.8 mmol), and a solution of allenyl boronic acid **10** (200 mg, 2.4 mmol) in MeOH (2 ml). The mixture was stirred under

nitrogen for 24 hr, forming a white solid precipitate. The reaction mixture was filtered under vacuum and after washing with CH₂Cl₂ and cold MeOH, the solid product it was dried under high vacuum. From the filtrate, another small amount of product was isolated after complete removal of the boric acid byproduct through continuous additions/evaporations of MeOH (5x10 ml) and washing the residue with acetone. The combined solid was completely dried under high

vacuum to afford the α -propargyl amino acid **12d** (0.175 g, 64% yield). ^1H NMR (500 MHz, MeOH d4) δ 5.95 (m, 1H), 5.50 (m, 2H), 3.73 (m, 2H), 3.63 (t, $J=4.8$ Hz, 1H), 2.87 (m, 2H), 2.58 (bt, $J=2.7$ Hz, 1H); ^{13}C NMR (125 MHz, MeOH d4) δ 171.97, 130.04, 124.68, 79.06, 74.83, 60.83, 50.62, 21.42; IR (cm^{-1}) 3215 (br, OH), 2261 (s, $\text{C}\equiv\text{C}$), 1619 (C=O).

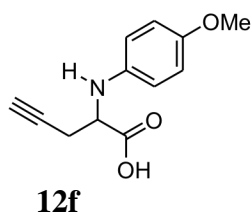
(S/R)-2-((R)-2-Hydroxy-1-phenylethylamino)pent-4-ynoic acid (12e): To a solution of



glyoxylic acid monohydrate (247 mg, 2.68mmol) and (R)-(-)-2-phenylglycinol (368 mg, 2.68 mmol) in MeOH (7 ml) was added a solution of allenyl boronic acid (**10**) (225 mg, 2.68 mmol) in MeOH (4 ml). The reaction mixture was stirred at rt for 24hr. The

reaction was then stopped and everything was solubilized by adding MeOH (5 ml). ^1H NMR spectrum of the crude homogeneous reaction mixture showed de=27% (from comparison of the integrals of the α H signals at 4.51 (0.58) and 4.37(1.00) ppm). Purification was performed by gradient flash chromatography (EtOAc/MeOH/ NH_4OH , 75/20/5 to 55/40/5). Both diastereomers were eluted together to afford the α -propargyl amino acid **12e** as a mixture of (R,S) and (R,R) diastereomers (105 mg, 34% yield). ^1H NMR (500 Mz, MeOH d4) δ 7.49-7.36 (m, 8H), 4.42 (t, $J=5.8$ Hz, 0.7H, minor) & 4.24 (dd, $J_1=7.6$ Hz, $J_2=5.5$ Hz 1H, major), 3.89 (m, 1.6H, minor) & 3.80 (m, 2H, major), 3.49 (dd, $J_1=5.6$ Hz, $J_2=3.6$ Hz, 0.6H, minor) & 3.29 (dd, $J_1=6.1$ Hz, $J_2=4.9$ Hz, 1H, major), 2.86 (ddd, $J_1=17.5$ Hz, $J_2=4.8$ Hz, $J_3=3.1$ Hz, 0.7H, minor) & 2.75 (ddd, $J_1=17.3$ Hz, $J_2=6.6$ Hz, $J_3=3.1$ Hz, 0.7H, minor) & 2.67 (ddd, $J_1=17.3$ Hz, $J_2=6.8$ Hz, $J_3=3.1$ Hz, 1H, major) & 2.59 (ddd, $J_1=17.4$ Hz, $J_2=5.4$ Hz, $J_3=3$ Hz, 1H, major), 2.56 (t, $J=2$ Hz, 0.45H, minor) & 2.44 (t, $J=2$ Hz, 0.6H, major); ^{13}C NMR (125 Mz, MeOH d4, dilute, some carbons not observed) δ 130.73, 130.65, 129.91, 129.85, 74.37 (minor) & 73.91 (major), 65.97 (major) & 65.81 (minor), 65.00 (major) & 64.80 (minor), 60.47 (major) & 59.95 (minor), 23.38 (major) & 21.83 (minor).

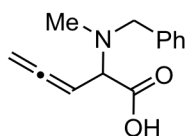
2-(4-Methoxyphenylamino)pent-4-ynoic acid (12f): Prepared in 56% yield using CH_2Cl_2 as



a solvent, similarly to the preparation of 2-allylamino-pent-4-ynoic acid **12d**. ^1H -NMR (360 MHz, d_4 -MeOH) δ 7.54 (d, $J=8.9$ Hz, 2H), 7.07 (d, $J=9.2$ Hz, 2H), 4.55 (t, $J=4.8$ Hz, 1H), 2.98 (dq, $J=17.9$ Hz and 4.2 Hz,

1H), 2.74 (t, J=3.2 Hz, 1H), 2.64 (dq, J=17.8 Hz and 2.8 Hz, 1H); ¹³C-NMR (90 MHz, d₄-MeOH): δ 169.37, 126.36, 116.39, 76.72, 75.89, 63.20, 56.31, 19.39; IR (cm⁻¹): 3207 (br, OH), 2261 (s, C≡C), 1615 (C=O)

2-(Benzyl-methyl-amino)-penta-3,4-dienoic acid (11g): To a 25-ml round bottomed flask

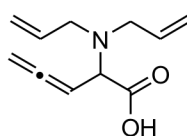


11g

equipped with a magnetic stirrer, was added EtOH (3.3 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (110 mg, 1.19 mmol), N-methyl benzylamine (0.15 ml, 1.19 mmol), and a suspension of allenyl boronic acid (**10**) (100 mg, 1.19 mmol) in CH₂Cl₂ (2.3 ml). The mixture was stirred under nitrogen for 24 hr. The crude mixture was then

purified with flash column chromatography (MeOH/EtOAc/NH₄OH, 10/85/5) to afford the α-allenyl amino acid **11g** (168 mg, 65% yield). ¹H NMR (500 MHz, MeOH d₄) δ 7.56 (m, 2H), 7.46 (m, 3H), 5.40 (m, 1H), 5.09 (m, 2H), 4.33 (d, J=12.5 Hz, 1H), 4.22 (d, J=12.7, 1H), 4.12 (d, J=9.9 Hz), 2.72 (s, 3H); ¹³C NMR (125 MHz, MeOH d₄) δ 214.36 (=C=), 171.20, 132.50, 132.13, 131.50, 130.77, 84.21, 78.04, 70.89, 59.65, 38.81; IR cm⁻¹ 3418 (br, OH), 1972 (s, C=C=C), 1624 (C=O); FAB MS calc for [M+1] (C₁₃H₁₆NO₂) 218.1181, found 218.21.

2-Diallylamino-penta-3, 4-dienoic acid (11h): To a 10-ml round bottomed flask equipped

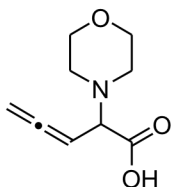


11h

with a magnetic stirrer, was added MeOH (2 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (166 mg, 1.8 mmol), diallylamine (175 mg, 1.8 mmol), and a solution of allenyl boronic acid **10** (200 mg, 2.4 mmol) in MeOH (2 ml). The mixture was then stirred under

nitrogen for 24 hr. Complete removal of the boric acid byproduct from the crude reaction mixture was performed through continuous additions/evaporations of MeOH (5x10 ml). The product was purified by gradient flash chromatography (EtOAc/MeOH/NH₄OH, 85/10/5 to 80/15/5) to afford the α-allenyl amino acid **11h** (230 mg, 66% yield). ¹H NMR (500 MHz, MeOH d₄) δ 5.96 (m, 2H), 5.51 (m, 4H), 5.35 (m, 1H), 5.03 (d, J=6.4 Hz, 2H), 4.17 (d, J=10 Hz, 1H), 3.81 (dd, J₁=13.8 Hz, J₂=6.8 Hz, 2H), 3.62 (dd, J₁=13.4, J₂=8 Hz, 2H); ¹³C NMR (125 MHz, MeOH d₄) δ 213.70 (=C=), 172.25, 130.02, 125.70, 84.78, 77.78, 67.57, 55.25; IR cm⁻¹ 3394 (br, OH), 1952 (s, C=C=C), 1631 (C=O).

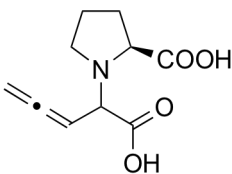
2-Morpholin-4-yl-penta-3,4-dienoic acid (11i): To a 10-ml round bottomed flask equipped

**11i**

with a magnetic stirrer, was added MeOH (2 ml) and while stirring it was followed by the addition of glyoxylic acid monohydrate (166 mg, 1.8 mmol), morpholine (157 mg, 1.8 mmol), and a solution of allenyl boronic acid **10** (0.200 g, 2.4 mmol) in MeOH (2 ml). The mixture was then stirred under nitrogen for 24 hr. Complete removal of the boric acid byproduct from the

crude reaction mixture was performed through continuous additions/evaporations of MeOH (5x10ml). The product precipitated by treatment of the residue with CH₂Cl₂ and hexanes, and the solid was filtered through suction filtration and washed with cold diethyl ether. Complete drying under high vacuum gave the α -allenyl amino acid **11i** (230 mg, 70% yield). ¹H NMR (500 MHz, MeOH d₄) δ 5.50 (m, 1H, =C=CH), 5.22 (m, 2H, =C=CH₂), 4.71 (d, J=9.3 Hz, 1H), 4.08 (t, J=11.3 Hz, 2H), 3.93 (m, 2H), 3.59 (dd, J₁=45.1 Hz, J₂=12.1 Hz, 2H), 3.42-3.27 (m, 2H); ¹³C NMR (125 MHz, MeOH d₄) δ 214.14 (=C=), 168.97 (C=O), 82.38, 79.70, 68.84, 65.31, 53.06, 51.34; IR (cm⁻¹): 3410 (br, OH), 1948 (s, C=C=C), 1624 (C=O).

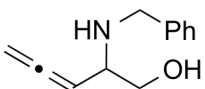
(S)-1-(1-Carboxybuta-2,3-dienyl)pyrrolidine-2-carboxylic acid (11j): To a solution of

**11j**

glyoxylic acid monohydrate (206 mg, 2.24 mmol) and L-proline (258 mg, 2.24 mmol) in MeOH (7 ml) was added a solution of allenyl boronic acid (**10**) (188 mg, 2.24 mmol) in MeOH (2 ml). The mixture was stirred at rt for 48hr. ¹H NMR spectrum was run from the crude homogeneous reaction mixture that showed de=44% (from comparison

of the integrals of the CH allenic signals). The reaction mixture was purified by gradient flash chromatography (EtOAc/MeOH/NH₄OH, 55/40/5 to 40/55/5 to final 35/60/5- both diastereomers were eluted together) to afford the α -allenyl amino acid **11j** (140 mg, 32% yield). ¹H NMR (500 MHz, MeOH d₄, DCl) δ 5.59-5.53 (m, 1.6H), 5.22-5.15 (m, 3.4H), 4.96 (d, J=9.7Hz, 1H-major) & 4.85 (d, J=9.8Hz, 0.6H-minor), 4.60 (dd, J₁=8.7 Hz, J₂=3.6 Hz, 1H-minor) & 4.49 (dd, J₁=8.7 Hz, J₂=5.3 Hz, 1H-major), 3.83 (m, 2.3H), 3.50 (m, 1.7H), 2.62-2.44 (m, 2H), 2.25-2.02 (m, 6H).

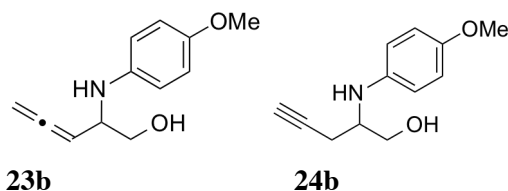
2-Benzylamino-penta-3,4-dien-1-ol (23a). In a 25-ml round bottomed flask equipped with a

**23a**

magnetic stirrer, 10 ml of MeOH were placed followed by glycolaldehyde dimer **25** (0.384 g, 3.2 mmol) and benzylamine (0.568 g,

579 μl , 5.3 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.538 g, 6.4 mmol) in 5.0 ml MeOH was added in one portion. The system was left under stirring at R.T. for 15 hr. Impurities and the residual starting materials were removed by gradient flash chromatography (MeOH/DCM, 2% to 5% to 10%) to afford the α -allenyl amino alcohol **23a**. Yield: 0.459g or 46%. ^1H NMR (400 MHz, CDCl_3) δ 7.31 (d, $J=4.5$ Hz, 4H), 7.27-7.22 (m, 1H), 5.09 (q, $J=6.7$ Hz, 1H), 4.85 (m, 2H), 3.92 (d, $J=13.0$ Hz, 1H), 3.71 (d, $J=12.12$ Hz, 1H), 3.62 (dd, $J_1=10.5$ Hz, $J_2=4.2$ Hz, 1H), 3.35 (dd, $J_1=10.6$ Hz, $J_2=8.1$ Hz, 1H), 3.29-3.24 (m, 1H). ^{13}C NMR (100 MHz, CDCl_3) δ 208.07, 139.91, 128.40, 128.22, 127.08, 90.04, 76.94, 64.81, 57.60, 51.10

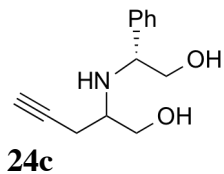
2-(4-Methoxy-phenylamino)-penta-3,4-dien-1-ol (23c) and 2-(4-Methoxy-phenylamino)-pent-4-yn-1-ol (24c): In a 25-ml round bottomed flask equipped with a magnetic stirrer, 6.0 ml



of DCM were placed followed by glycolaldehyde dimer **25** (0.226 g, 1.88 mmol) and p-anisidine (0.384 g, 3.12 mmol). To that mixture, a suspension of allenyl boronic acid **10** (0.262 g, 3.12 mmol) in 6.0 ml MeOH was added in one

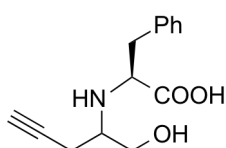
portion. The system was left under stirring at R.T. for 27 hr. A sample was withdrawn from the crude reaction mixture and the isomeric composition of the products was calculated by ^1H NMR. Both isomers **23b** and **24b** were obtained (propargyl/allenyl=50/50). Impurities and the residual starting materials were removed by gradient flash chromatography ($\text{Et}_2\text{O}/\text{DCM}$, 0% to 10% to 20%). Both isomers were eluted and no complete separation was feasible from this purification. Yield: 0.500g or 78%. ^1H NMR (250 MHz, CDCl_3) δ 6.86-6.58 (m, $J=8.9$ Hz, 5.6H), 5.17 (q, $J=6.3$ Hz, 0.3H), 4.82 (dt, $J_1=6.8$ Hz, $J_2=2.6$ Hz, 0.7H), 3.95 (m, 0.4H), 3.83-3.73 (s&m, 6.6H), 3.58 (m, 1.4H), 2.46 (m, 2H), 2.03 (t, $J=2.6$ Hz, 1H).

2-(2-Hydroxy-1-phenyl-ethylamino)-pent-4-yn-1-ol (24c): In a 25-ml round bottomed flask equipped with a magnetic stirrer, 4 ml of DCM were placed followed by glycolaldehyde dimer (0.133 g, 1.1 mmol) and (R)-(-)-2-phenylglycinol (0.303 g, 2.11 mmol). To that mixture, a suspension of allenyl boronic acid **10** (0.186 g, 2.21 mmol) in 3 ml DCM was added in one portion. The system was left under stirring at R.T. for 23 hr. ^1H NMR spectrum was run from the crude



homogeneous reaction mixture that showed de = 63% (from comparison of the integrals of the acetylenic signals). The reaction mixture was purified by gradient flash chromatography (MeOH/DCM, 2% to 5% to final 10%) to afford the α -propargyl amino alcohol **24c**. Yield: 0.147g or 61%. ^1H NMR (360 MHz, CDCl_3) δ 7.26-7.19 (m, 5H), 3.87 (m, 1H), 3.62 (dd, $J_1=11.0$ Hz, $J_2=4.3$ Hz, 1H), 3.50-3.43 (m, 3H), 2.90 (bs, 2H), 2.67 (m, 1H), 2.32-2.62 (m, 2H), 1.95 (bt, $J=2.6$ Hz, 1H). ^{13}C NMR (90 MHz, CDCl_3) δ 139.79, 128.54, 127.63, 127.31, 80.59, 70.90, 66.98, 63.85, 61.35, 53.90, 19.97.

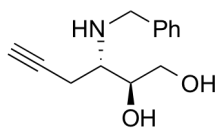
2-(1-Hydroxymethyl-but-3-ynylamino)-3-phenyl-propionic acid (24d): In a 10-ml round



24d

bottomed flask equipped with a magnetic stirrer, 3 ml of MeOH were placed followed by glycolaldehyde dimer (0.099 g, 0.82 mmol) and L-phenylalanine (0.272 g, 1.65 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.139 g, 1.65 mmol) in 2 ml MeOH was added in one portion. The system was left under stirring at R.T. for 24 hr. ^1H NMR spectrum was run from the crude homogeneous reaction mixture that showed de=67% (from comparison of the integrals of the acetylenic signals). 20% of the crude reaction mixture was purified by preparative TLC (MeOH/EtOAc/ NH_4OH , 55/40/5). After purification the major diastereomer of the α -propargyl product **24d** was only detected. Yield 0.055g or 68%. ^1H NMR (500 MHz, MeOH- d_4 , DCl) δ 7.33 (m, 5H), 4.55 (dd, $J_1=8.1$ Hz, $J_2=5.7$ Hz, 1H), 3.90 (d, $J=4.1$ Hz, 2H), 3.66 (s, 1H), 3.50-3.44 (m, 2H), 3.24 (dd, $J_1=14.2$ Hz, $J_2=7.9$ Hz, 1H), 2.72 (m, 2H), 2.58 (t, $J=2.8$ Hz, 1H). ^{13}C NMR (125 MHz, MeOH- d_4 , DCl) δ 171.13, 135.90, 130.94, 130.45, 129.28, 79.00, 74.44, 61.78, 60.31, 59.83, 37.65, 20.17. FAB MS $[\text{M}+1]$ ($\text{C}_{14}\text{H}_{18}\text{NO}_3$) 248.12, found 248.22.

3-Benzylamino-hex-5-yne-1,2-diol (24e): In a 25-ml round bottomed flask equipped with a

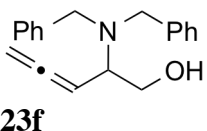


24e

magnetic stirrer, 10 ml of MeOH were placed followed by DL-glyceraldehyde dimer (0.184 g, 1.02 mmol) and benzylamine (0.219 g, 2.04 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.214 g, 2.55 mmol) in 3 ml MeOH was added in one portion. The system was left under stirring at R.T. for 24 hr. ^1H NMR spectrum was run from the crude homogeneous reaction mixture that showed de=28% (from comparison of the integrals of the acetylenic

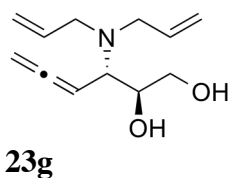
signals). The reaction mixture was purified by initial acid/base workup followed by flash chromatography. Two consecutive columns were needed to purify the products with 5% MeOH/DCM. Both diastereomers of the α -propargyl product **24e** were eluted together and their absolute configurations were not determined. Yield: 0.169g or 30%. ^1H NMR (360 MHz, CDCl_3) δ 7.33-7.26 (m, 8H), 3.94 (d, $J=12.8$, 1H-major) & 3.89 (d, $J=12.5$, 0.7H-minor), 3.79 (dd, $J_1=11.4$ Hz, $J_2=3.5$ Hz, 1H), 3.75-3.65 (m, 5H-overlapping signals), 3.63 (dd, $J_1=11.4$ Hz, $J_2=3.6$ Hz, 1H), 2.86 (m & bs, 6.4H), 2.64-2.40 (m, 3.7H), 2.02 (m, 1.2H-overlapping acetylenic signals). ^{13}C NMR (125 MHz, CDCl_3) δ 139.27(minor) & 139.20(major), 128.59(major) & 128.57(minor), 128.24, 127.41(major) & 127.35(minor), 80.35(minor) & 80.17(major), 71.25(major) & 71.20(minor), 71.01(major) & 70.63(minor), 65.24(minor) & 64.33(major), 58.72(minor) & 57.37(major), 51.40(minor) & 51.11(major), 19.67(major) & 19.42(minor).

2-Dibenzylamino-penta-3,4-dien-1-ol (23f): In a 25-ml round bottomed flask equipped with a



magnetic stirrer, 5.5 ml of DCM were placed followed by glycolaldehyde dimer **25** (0.120 gr, 1 mmol) and dibenzylamine (0.346 gr, 1.8 mmol). To that mixture, a suspension of allenyl boronic acid **10** (0.230 gr, 2.74 mmol) in 5.5 ml DCM was added in one portion. The system was left under stirring at R.T. for 24 hr. DCM was evaporated and 50 ml of EtOAc were added. The organic phase was extracted with aq. NaOH, 2N (3x20 ml), dried with MgSO_4 and the solvent was removed under reduced pressure. The product was dried under high vacuum to afford the α -allenyl amino alcohol **23f** (0.449 gr, 90%). ^1H NMR (500 MHz, CDCl_3) δ 7.3-7.1 (m, 5H), 5.07 (q, $J=6.6$ Hz, 1H), 4.74 (m, 2H), 3.78 (d, $J=13.1$ Hz, 2H), 3.55 (t, $J=12$ Hz, 1H), 3.42 (m, 2H), 3.36 (d, $J=13.3$, 2H), 2.86 (b, 1H). ^{13}C NMR (125 MHz, CDCl_3) δ 209.45, 138.82, 128.96, 128.46, 127.17, 83.74, 75.34, 60.96, 58.14, 53.62. FAB MS calc for $[\text{M}+1]$ ($\text{C}_{19}\text{H}_{22}\text{NO}$) 280.16, found 280.14.

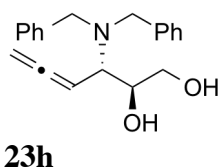
3-Diallylamino-hexa-4,5-diene-1,2-diol (23g): In a 50-ml round bottomed flask equipped



with a magnetic stirrer, 17 ml of MeOH were placed followed by DL-glyceraldehyde dimer (0.400 g, 2.2 mmol) and diallylamine (0.428 g, 4.4 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.745 g, 8.87 mmol) in 5 ml MeOH was added in one portion. The system

was left under stirring at R.T. for 24 hr. ^1H and ^{13}C NMR spectra were run from the crude homogeneous reaction mixture that showed the allenyl product **23g** with de>99% (only one diastereomer was observed, but its absolute configuration were not determined). The reaction mixture was purified by flash chromatography (5% MeOH/DCM). Yield: 0.647g or 70%. ^1H NMR (500 MHz, CDCl_3) δ 5.76 (m, 2H), 5.16 (m, 4H), 5.08 (m, 1H), 4.78 (m, 2H), 3.80-3.71 (overlapping multiplets, 2H), 3.66 (dd, $J_1=10.9$ Hz, $J_2=6.2$ Hz, 1H), 3.40 (t, $J=8.6$ Hz, 1H), 3.27 (m, 2H), 2.89 (dd, $J_1=14.4$ Hz, $J_2=8.7$ Hz, 1H). ^{13}C NMR (125 MHz, CDCl_3) δ 209.96, 135.16, 118.31, 83.92, 74.87, 70.08, 66.33, 63.65, 53.64.

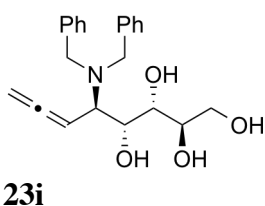
3-Dibenzylamino-hexa-4,5-diene-1,2-diol (23h): In a 25-ml round bottomed flask equipped



with a magnetic stirrer, 10 ml of MeOH were placed followed by DL-glyceraldehyde dimer (0.234 g, 1.3 mmol) and dibenzylamine (0.513 g, 2.6 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.273 g, 3.25 mmol) in 5 ml MeOH was added in one portion. The system was

left under stirring at R.T. for 24 hr. ^1H NMR spectrum was run from the crude homogeneous reaction mixture that showed the allenyl product **23h** with de>99% (only one diastereomer was observed in the ^1H and ^{13}C NMR spectra taken from the crude reaction mixture, but its absolute configuration were not determined). The reaction mixture was purified by gradient flash chromatography (EtOAc/Hexanes, 5% to 10% to 20% to 30% to final 40%). Yield: 0.522g or 65%. ^1H NMR (250 MHz, CDCl_3) δ 7.39-7.20 (m, 10H), 5.24 (m, 1H), 4.87 (m, 2H), 3.83 (m, 1H), 3.79 (d, $J=13.6$ Hz, 2H), 3.68 (bd, $J=4.6$ Hz, 2H), 3.38 (d, $J=13.4$ Hz, 2H), 3.26 (t, $J=9.0$ Hz, 1H). ^{13}C NMR (125 MHz, CDCl_3) δ 210.34, 138.68, 129.02, 128.49, 127.33, 83.81, 75.01, 71.17, 65.33, 61.67, 54.80

5-Dibenzylamino-oct-7-yne-1,2,3,4-tetraol (23i): In a 50-ml round bottomed flask equipped

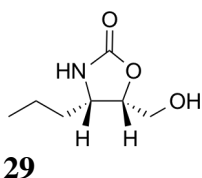


with a magnetic stirrer, 20 ml of MeOH were placed followed by D-arabinose (0.674 g, 4.49 mmol) and dibenzylamine (0.481 g, 4.49 mmol). To that mixture, a solution of allenyl boronic acid **10** (0.377 g, 4.49 mmol) in 3 ml MeOH was added in one portion. The system was left under stirring at R.T. for 48 hr. ^1H and ^{13}C NMR spectra were run

from the crude homogeneous reaction mixture that showed a single diastereomer of the allenyl

product **23i** (de>99%). The reaction mixture was purified by gradient flash chromatography (MeOH/DCM, 2% to 5% to final 10%). Yield: 0.344 g or 21%. ¹H NMR (500 MHz, MeOH d₄) δ 7.36 (bd, J=7.4 Hz, 4H), 7.28 (t, J=7.7 Hz, 4H), 7.20 (t, J=7.5 Hz, 2H), 5.25 (m, 1H), 4.85 (m, 1H), 4.77 (dd, J₁=10.4 Hz, J₂= 6.5 Hz, 1H), 4.04 (m, 2H), 3.77 (d, J=13.4 Hz, 2H), 3.73 (dd, J₁=11.6 Hz, J₂= 3.3 Hz, 1H), 3.63-3.53 (overlapping multiplets, 2H), 3.44 (t, J=9.7 Hz, 1H), 3.40 (d, J=13.4 Hz, 2H). ¹³C NMR (125 MHz, CDCl₃) δ 212.28, 141.17, 130.75, 129.78, 128.53, 86.20, 74.97, 73.53, 72.02, 65.50, 65.47, 61.84, 55.94.

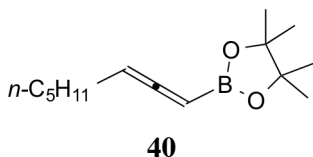
5-Hydroxymethyl-4-propyl-oxazolidin-2-one (29): In a 50-ml round bottomed flask



equipped with a magnetic stirrer, 10 ml of EtOH were placed followed by a solution of 3-dibenzylamino-hexa-4,5-diene-1,2-diol **23h** (0.500g, 1.62 mmol) in 10 ml EtOH and addition of 10% Pd/C (0.100 gr, 0.094 mmol).

The solution was degassed by high vacuum and set under nitrogen and consecutively under H₂ (1 atm). The system was left under stirring at R.T. for 48 hr but the reaction did not go to completion. At that point the H₂ was removed and replaced by N₂ and 0.100g of catalyst was added. The system was set under H₂ and let under stirring for an additional 24hr. At that time the system was set under N₂ and DCM was added. The catalyst was removed by filtration through Celite and the filtrate containing **28** was subjected to consecutive Boc protection. Thus, to that residue was added Boc₂O (0.354g, 1.62mmol) and Et₃N (1.62mmol) and the system was left under stirring for 10hr. The crude mixture was purified by gradient flash chromatography (EtOAc/Hexanes, 5% to 10%). Yield: 0.122g or 32%. The abovementioned product was dissolved in 8 ml dry THF and KOt-Bu (0.068g, 0.6 mmol) was added. The system was left under stirring at R.T. for 4 hr. THF was evaporated and 50 ml EtOAc was added. The organic phase was washed with sat. NH₄Cl and brine, it was dried with MgSO₄ and was purified with gradient flash chromatography (EtOAc/Hexanes, 20% to 40% to final 100% MeOH-essential for oxazolidinone elution) to afford the product **29**. Yield: 0.050 g, 60%. ¹H NMR (500 MHz, CDCl₃) δ 6.09 (bs, 1H), 4.66 (dt, J₁=8.0 Hz-cis oxazolidinone, J₂=4.0 Hz, 1H), 3.92 (dt, J₁=9.3 Hz, J₂=3.9 Hz, 1H), 3.86 (dd, J₁=12.3 Hz, J₂=6.9 Hz, 1H), 3.78 (dd, J₁=12.4 Hz, J₂=3.8 Hz, 1H), 1.63-1.09 (m, 4H), 0.94 (t, J=7.2 Hz, 3H). ¹³C NMR (125 MHz, CDCl₃) δ 158.96, 79.63, 60.76, 54.52, 31.69, 19.90, 13.80.

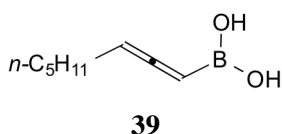
4,4,5,5-Tetramethyl-2-octa-1,2-dienyl-[1,3,2]dioxaborolane (40): In a flame dried 500-ml



round bottomed flask equipped with a magnetic stirrer, 140 ml of dry THF were placed followed by 1-bromo-2λ⁵-octa-1,2-diene (4.370 g, 23.1 mmol, contains 25% of 3-bromooct-1-yne). The system was degassed and cooled to -110°C with an external

Hexanes/liquid N₂ bath. The system was degassed once more at -110°C as well and n-BuLi (1.6 M in Hexanes, 17.5ml, 28mmol) was added through syringe (addition time: 1-2 min). It was left under stirring at that temperature for 5 min and subsequently 2-isopropoxy-4,4,5,5-tetramethyl-[1,3,2]dioxaborolane **40** (5.8 ml, 28mmol) was added in 2-3 min. The temperature was monitored by a Pt electrode and care was taken so that it was maintained at -110°C throughout both additions. After the end of the addition the bath was left on and the system was allowed to slowly warm up to ambient temperature for a total of 3.5hr. The mixture was then diluted with 150ml Et₂O and treated with aq. NH₄Cl (2x100ml), NaHCO₃ (1x100ml) and brine (1x100ml). It was dried with MgSO₄ and the volatiles were removed under reduced pressure. Further purification was essential so the crude residue was subjected to flash chromatography (gradient elution: Et₂O/Hex, 0% to 2% to final 5%). Yield: 1.635g or 30%. ¹H NMR (250 MHz, CDCl₃) δ 5.05 (q, J=6.8 Hz, 1H), 4.87 (m, 1H), 2.00 (m, 2H), 1.47-1.08 (s & s & m-overlapping peaks, 23H). ¹³C NMR (100 MHz, CDCl₃) δ 216.50, 85.98, 83.46, 31.14, 28.75, 27.19, 24.84, 24.55, 22.48, 14.06.

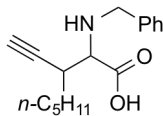
Octa-1,2-dienyl-boronic acid (39): Sodium periodate (0.815g, 3.81 mmol) was added to a



room temperature solution of 4,4,5,5-tetramethyl-2-octa-1,2-dienyl-[1,3,2]dioxaborolane (0.300g, 1.27 mmol) in THF/H₂O (8:2, 10 mL).

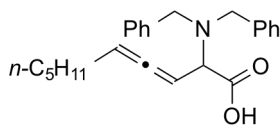
The mixture was stirred until homogeneous, and then 2N aq. HCl (0.4 mL) was added. After 1 hr, the reaction mixture was diluted with 50ml EtOAc, washed with H₂O and treated with aq. NH₄Cl (2x50ml), NaHCO₃ (1x50ml) and brine (1x50ml). It was dried with MgSO₄ and the volatiles were removed under reduced pressure. No further purification was performed since the boronic acid product **39** decomposes during flash chromatography. Crude yield: 0.184g or 94%. ¹H NMR (250 MHz, CDCl₃) δ 5.10 (s, 1H), 4.92 (s, 1H), 2.02 (m, 2H), 1.74 (m, 1H), 2.41-1.21 (m, 19H), 0.87 (t, J=6.7Hz, 9H)

2-Benzylamino-3-ethynyl-octanoic acid (42a): A 5-ml round bottomed flask equipped with a

**42a**

magnetic stirrer, was charged with 2 ml MeOH followed by glyoxylic acid monohydrate (0.028 g, 0.30 mmol) and benzylamine (0.032 g, 0.30 mmol). To that mixture, octa-1, 2-dienyl-boronic acid **39** (0.060 g, 0.39 mmol) was added in one portion. The system was left under stirring at R.T. Two additions were done (20mg at 24hr and 40mg at 48 hr) in order to obtain better conversion. The reaction was stopped at 72hr since no significant change was observed after the last addition of **39**. The crude residue showed two diastereomers of the propargyl product **42a** (de= 70%) while no allenyl product was observed. The diastereomers were purified and partly resolved by flash chromatography (gradient elution, EtOAc/MeOH/NH₄OH, 85/10/5 to final 80/15/5). The chemical shifts of the both diastereomers are mentioned below. Yield: 0.060 g or 28%. ¹H NMR (both diastereomers, 400 MHz, MeOH, d₄) δ 7.50-7.42 (m, 7H), 4.34 (d, J= 13.2Hz, 1H-major) & 4.32 (d, J=13.2Hz, 0.3H-minor), 4.22 (d, J=13.2 Hz, 1H-major) & 4.17 (d, J= 13.0Hz, 0.3H-minor), 3.52 (d, J=3.5 Hz, 1H-major) & 3.34 (d, J= 5.1Hz, 0.3H-minor), 3.03 (m, 1.3H-overlapping signals, H), 2.70 (d, J= 2.6Hz, 0.3H-minor) & 2.64 (d, J= 2.3Hz, 1H-major), 1.61-1.21 (m, overlapping signals, 12H), 0.90-0.86 (t, overlapping signals, 4.3H). ¹³C NMR (both diastereomers, 100 MHz, MeOH, d₄) δ 170.251(minor) & 169.258 (major), 130.985, 129.963, 129.210, 128.823, 81.471 (major) & 80.651 (minor), 74.074 (minor) & 73.428 (major), 63.330 (minor) & 63.278 (major), 50.950 (major) & 50.601 (minor), 33.389 (minor) & 32.944 (major), 31.640 (minor), 30.945, 29.575 (major), 26.945 (major) & 26.461 (minor), 22.085, 12.890.

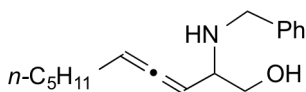
2-Dibenzylamino-deca-3, 4-dienoic acid (41b): A 5-ml round bottomed flask equipped with a

**41b**

magnetic stirrer, was charged with 3.4 ml MeOH followed by glyoxylic acid monohydrate (0.054 g, 0.59 mmol) and dibenzylamine (0.116 g, 0.59 mmol). To that mixture, octa-1,2-dienyl-boronic acid **39** (0.114 g, 0.74 mmol) was added in one portion. The system was left under stirring at R.T. for 88 hr. The crude residue was purified by flash chromatography (gradient elution, MeOH/DCM, 0% to 1% to 2% final 5%). It was dried under high vacuum. Yield: 0.060 g or 28%. Note: NMR data from the crude reaction mixture suggests that only the allenyl product **41b** is present with de= 59% (after flash, not feasible to determine de in the crude). The chemical shifts of the main

diastereomer are mentioned below. ^1H NMR (400 MHz, CDCl_3) δ 7.36-7.26 (m, 10H), 5.39-5.31 (m, 2H), 4.01 (dd, $J_1=8.2\text{Hz}$, $J_2=2.1\text{Hz}$, 1H), 3.83 (d, $J=13.3\text{Hz}$, 2H), 3.58 (d, $J_1=13.1\text{Hz}$, 2H), 2.07 (dq, $J_1=6.8\text{Hz}$, $J_2=2.9\text{Hz}$, 2H), 1.44-1.23 (overlapping signals, m, 6H), 0.86 (t, $J=7.1\text{Hz}$, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 207.571, 172.380, 136.697, 129.146, 128.761, 128.009, 92.463, 83.063, 62.198, 54.738, 31.260, 28.850, 28.411, 22.433, 14.018.

2-Benzylamino-deca-3,4-dien-1-ol (43c): A 5-ml round bottomed flask equipped with a

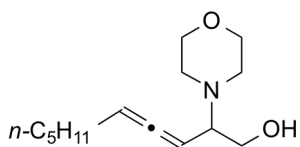


43c

magnetic stirrer, was charged with 1 ml MeOH followed by glycolaldehyde dimer (0.027 g, 0.22 mmol) and benzylamine (0.080 g, 0.75 mmol). To that mixture, 4,4,5,5-tetramethyl-2-octa-1,2-dienyl-[1,3,2]dioxaborolane **40** (0.130 g, 0.55 mmol) was added in

one portion. The system was left under stirring at R.T. for 20 hr. ^1H NMR was run from the crude residue that showed two diastereomers of the allenyl product **43c** only. The residue was finally purified by flash chromatography (gradient elution, MeOH/DCM, 1% to 2% final 3%). The presence of two diastereomers was observed in the ^{13}C NMR (double peaks) but de determination was not feasible since the ^1H signals were not resolved. Yield: 0.052 g 36%. ^1H NMR (400 MHz, CDCl_3 , both diastereomers) δ 7.25 (m, 4H), 7.18 (m, 1H), 5.21-5.18 (m, 1H), 5.00-4.96 (m, 1H), 3.87 (d, $J=12.6\text{Hz}$, 0.28H-minor), 3.86 (d, $J=12.9\text{Hz}$, 0.7H-major), 3.642 (d, $J=12.8\text{Hz}$, 0.7H-major), 3.636 (d, $J=12.9\text{Hz}$, 0.28H-minor), 3.55 (dd, $J_1=10.6\text{Hz}$, $J_2=4.1\text{Hz}$, 1H), 3.27 (m, 1H), 3.17 (m, 1H), 1.95 (m, 2H), 1.33 (m, 2H), 1.22 (m, 4H), 0.81 (t, $J=6.7\text{Hz}$, 3H). ^{13}C NMR (100 MHz, CDCl_3 , both diastereomers) δ 203.84 (minor) & 203.726 (major), 139.898, 128.471, 128.278, 127.163, 93.543 (major) & 93.415 (minor), 90.589, 64.986, 58.321 (minor) & 58.225 (major), 51.098, 31.306, 29.71 (minor), 28.856, 28.795 (major), 22.498, 14.076.

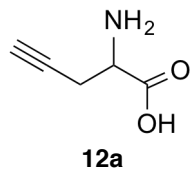
2-Morpholin-4-yl-deca-3,4-dien-1-ol (43d): A 5-ml round bottomed flask equipped with a



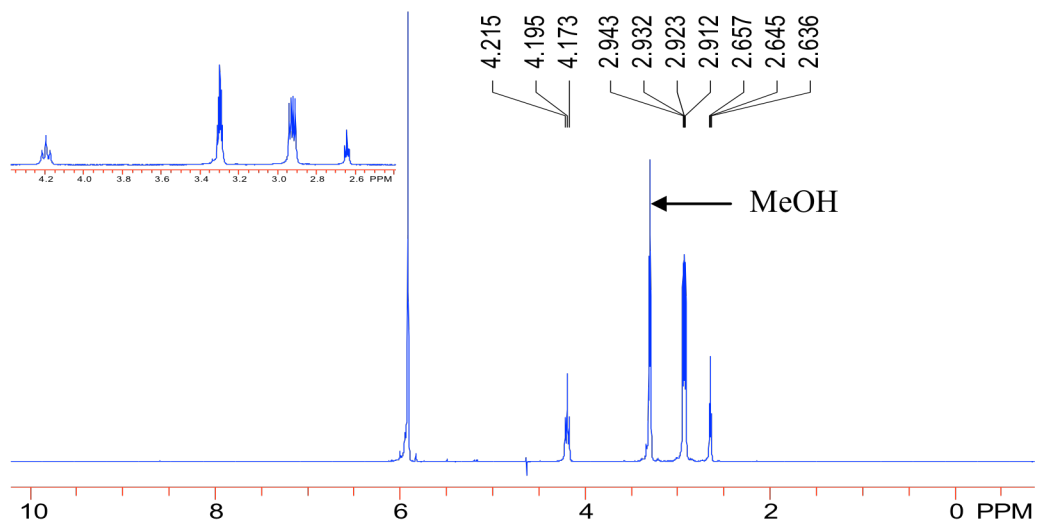
43d

magnetic stirrer, was charged with 0.5 ml DCM followed by glycolaldehyde dimer (0.036 g, 0.30 mmol) and morpholine (0.044 g, 0.50 mmol). To that mixture, 4,4,5,5-tetramethyl-2-octa-1,2-dienyl-[1,3,2]dioxaborolane **40** (0.065 g, 0.28 mmol) was added in one portion. The system was left under stirring at R.T. for 60 hr. ^1H

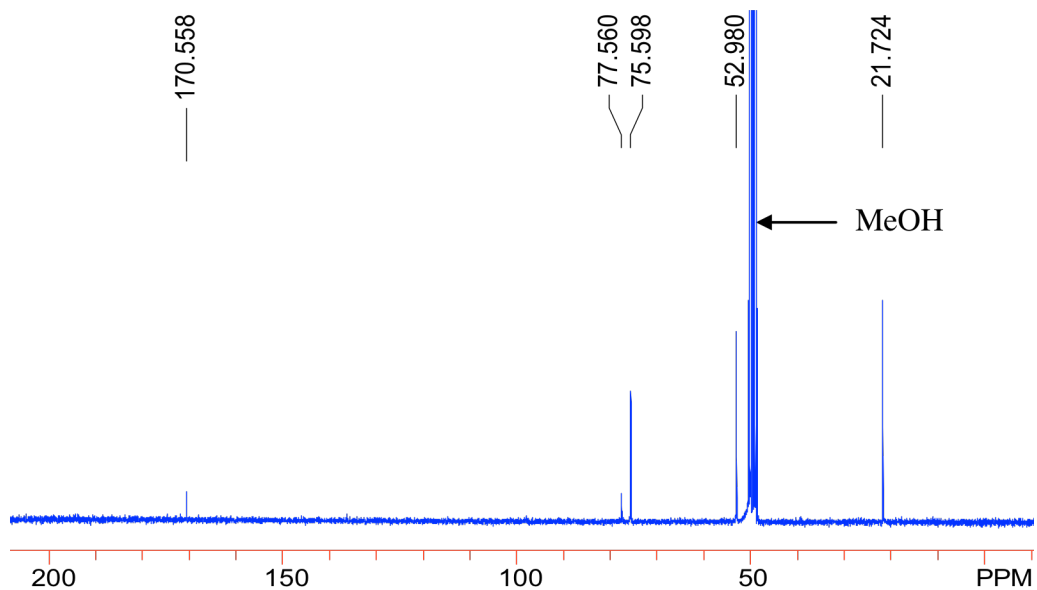
NMR was run from the crude residue that showed only the allenyl product **43d** only. The residue was diluted with Et₂O and washed with aq. NaOH 3N and finally purified by flash chromatography (gradient elution, MeOH/DCM, 1% to 2% final 5%). The presence of two diastereomers was observed in the ¹³C NMR (double peaks) but de determination was not feasible in that case since the ¹H signals are not resolved. Yield: 0.037 g 56.3%. ¹H NMR (400 MHz, CDCl₃, both diastereomers) δ 5.19-5.12 (m, 1H), 5.04-4.96 (m, 1H), 3.71 (m, 4H), 3.55-3.50 (m, 2H), 3.23-3.17 (m, 1H), 2.84 (bs, 1H), 2.68 (m, 2H), 2.48 (m, 2H), 2.01-1.93 (m, 2H), 1.36 (m, 2H), 1.31-1.22 (m, 4H), 0.88-0.84 (t, overlapping signals, 3H). ¹³C NMR (90 MHz, CDCl₃, both diastereomers) δ 205.163 (minor) & 205.073 (major), 91.970 (major) & 91.725 (minor), 84.385 (major) & 84.192 (minor), 67.145, 65.223, 64.919, 60.262, 48.720, 31.245, 28.827 (minor), 28.733, 28.537 (major), 22.443, 14.017.

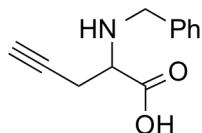
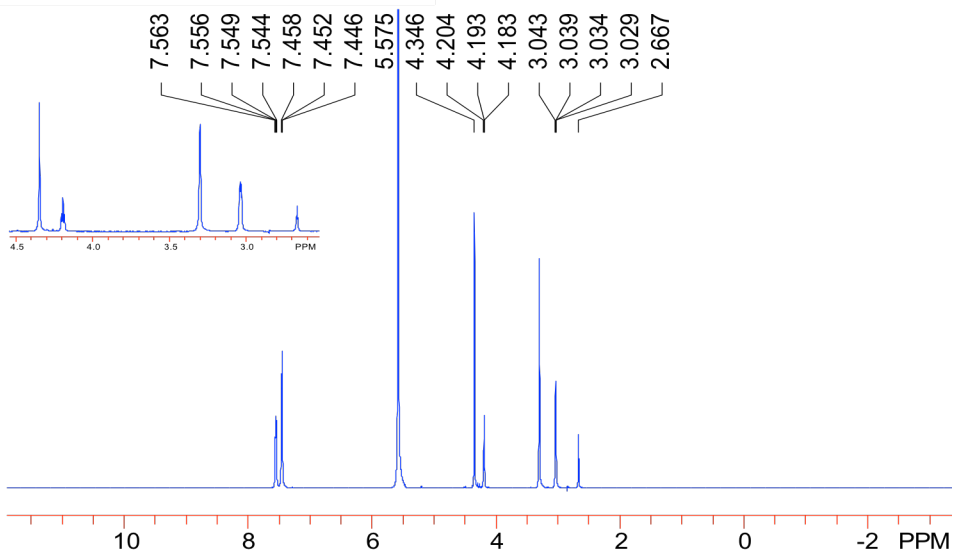
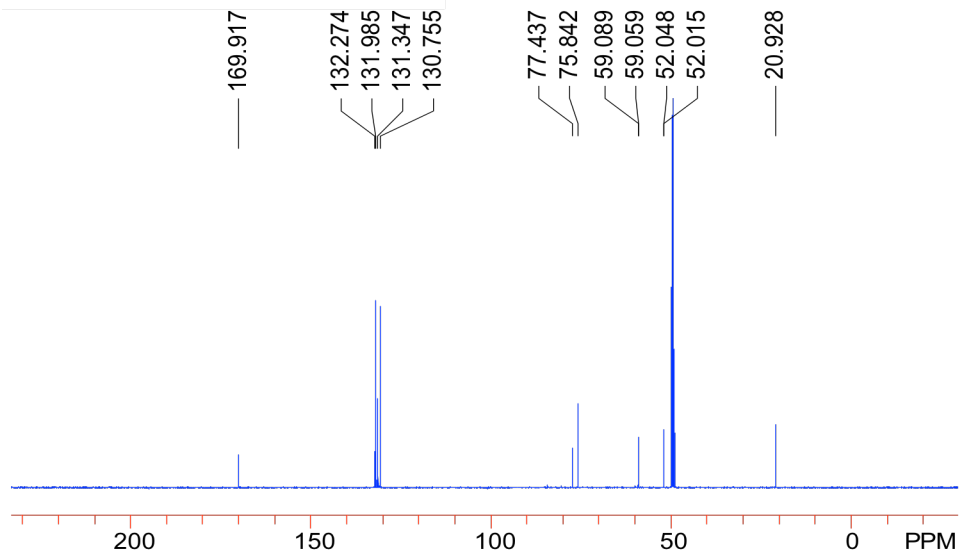


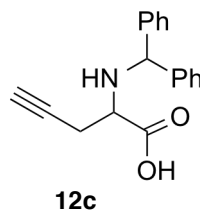
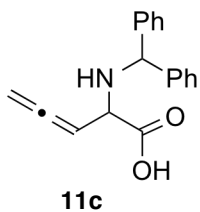
^1H NMR, 250 MHz, MeOH d_4



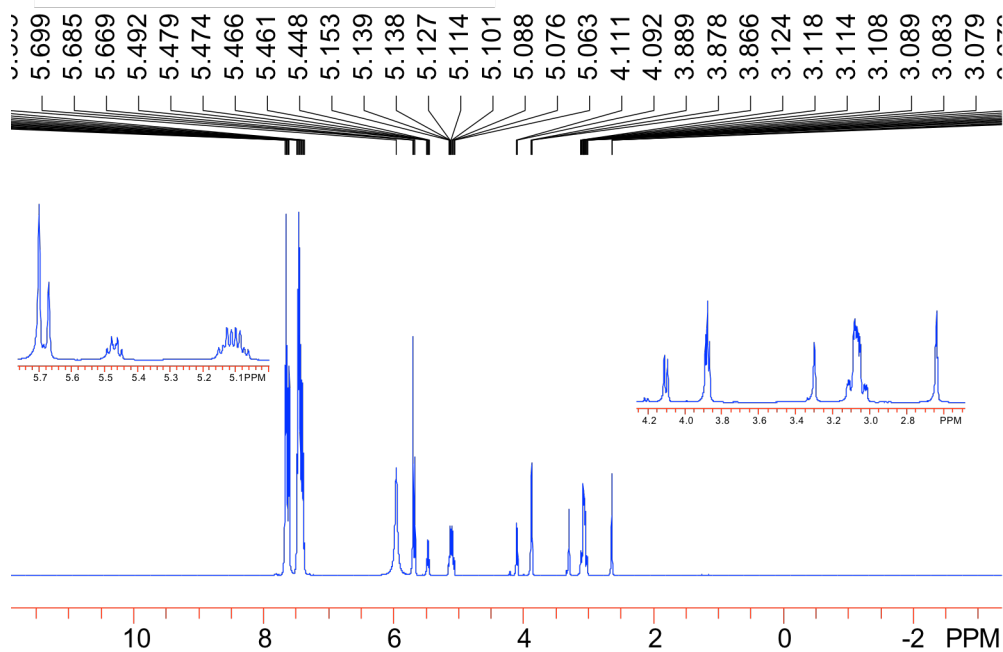
^{13}C NMR, 63 MHz, MeOH d_4



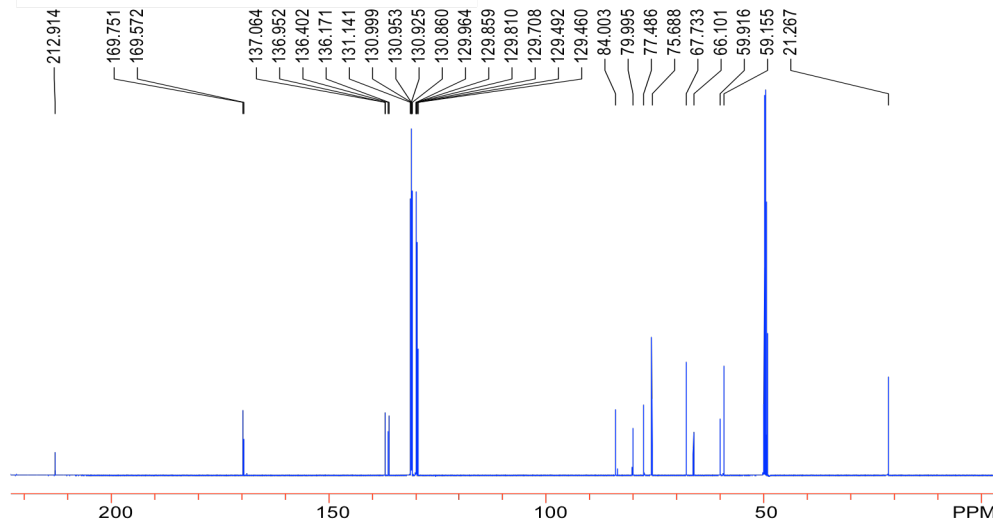
**12b**¹H NMR, 500 MHz, MeOH d₄¹³C NMR, 125 MHz, MeOH d₄

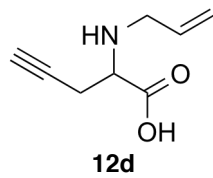


¹H NMR, 500 MHz, MeOH d₄

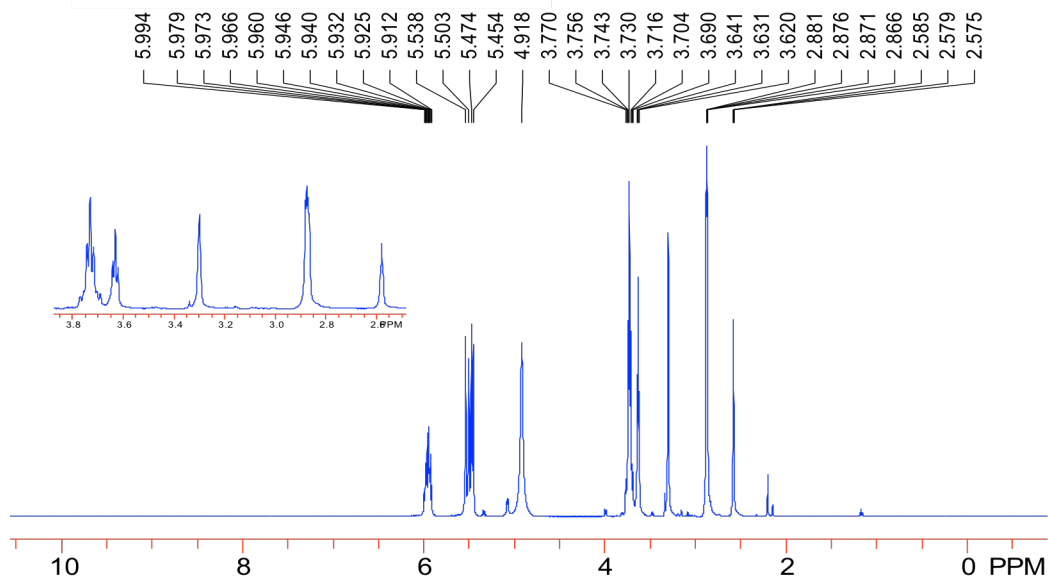


¹³C NMR, 125 MHz, MeOH

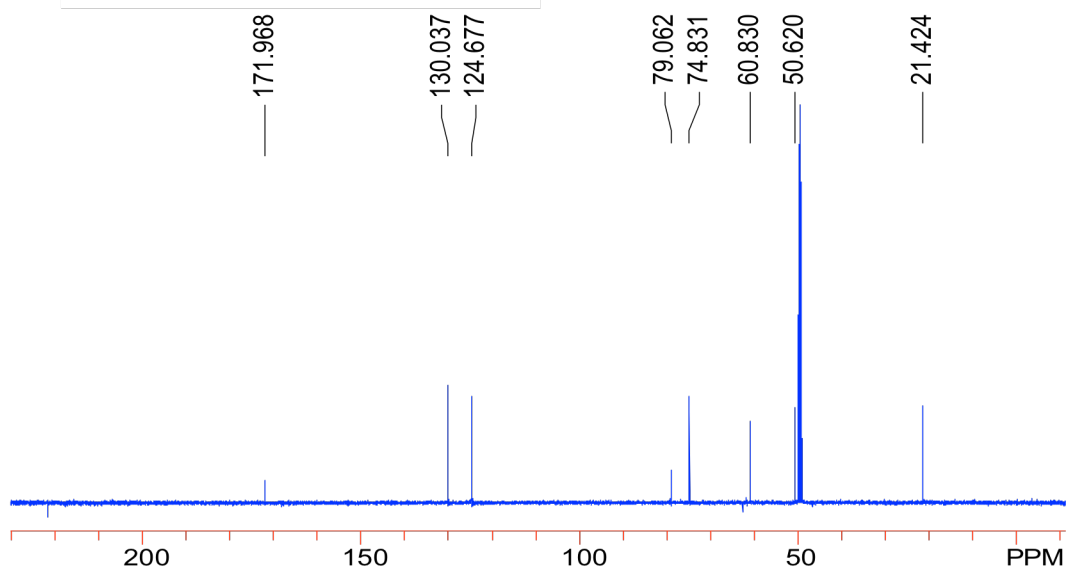


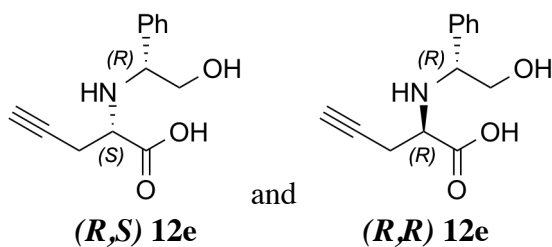


¹H NMR, 500 MHz, MeOH d₄

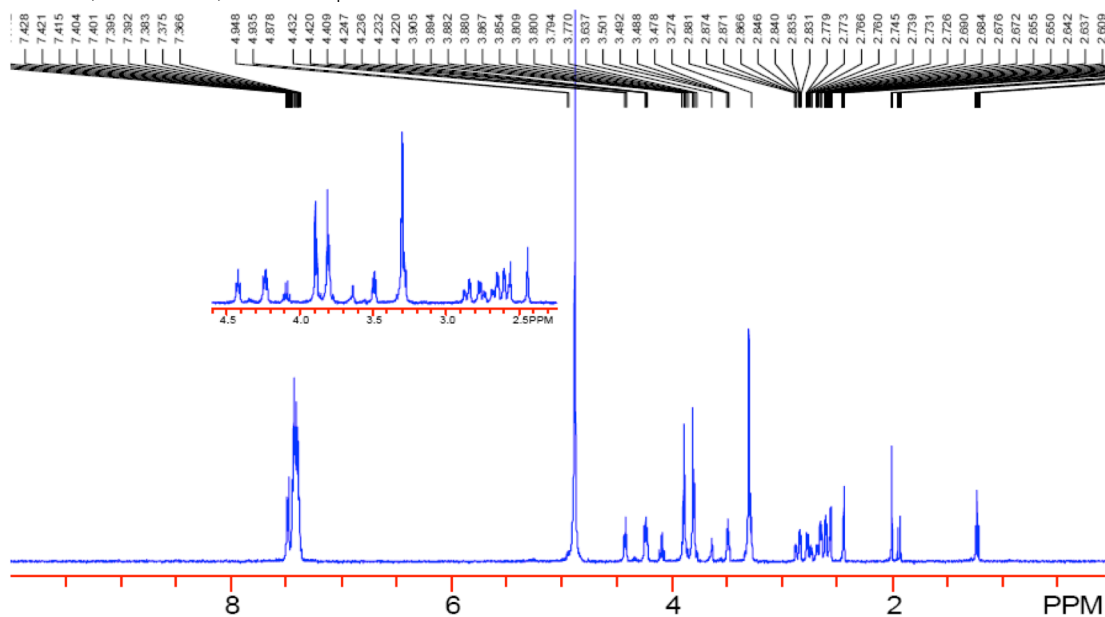


¹³C NMR, 125 MHz, MeOH d₄

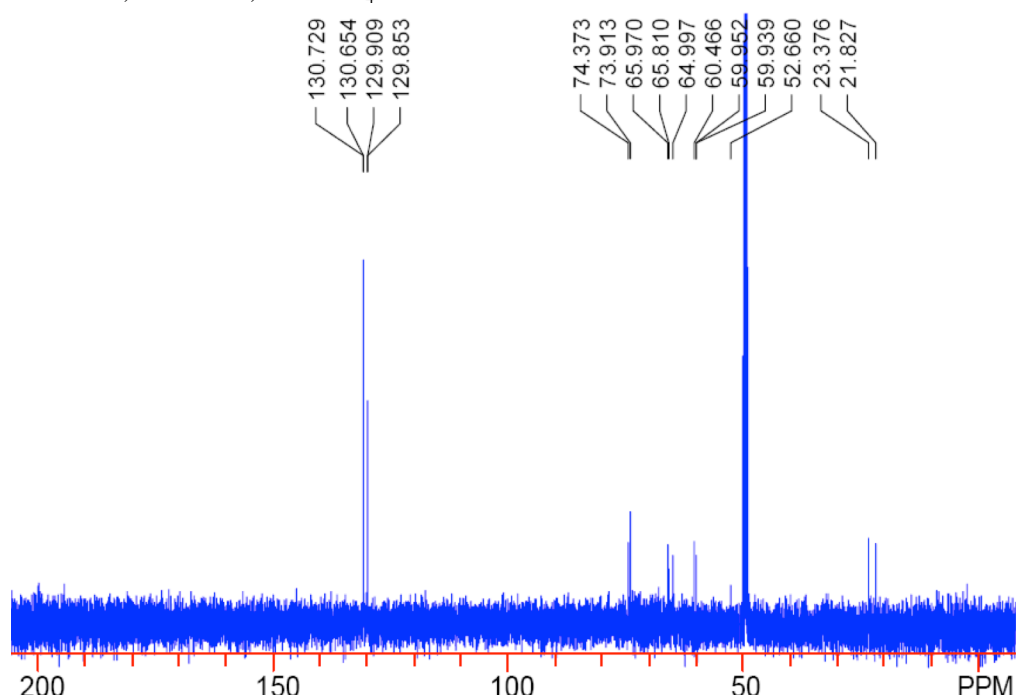


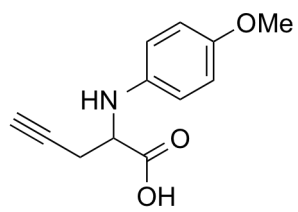
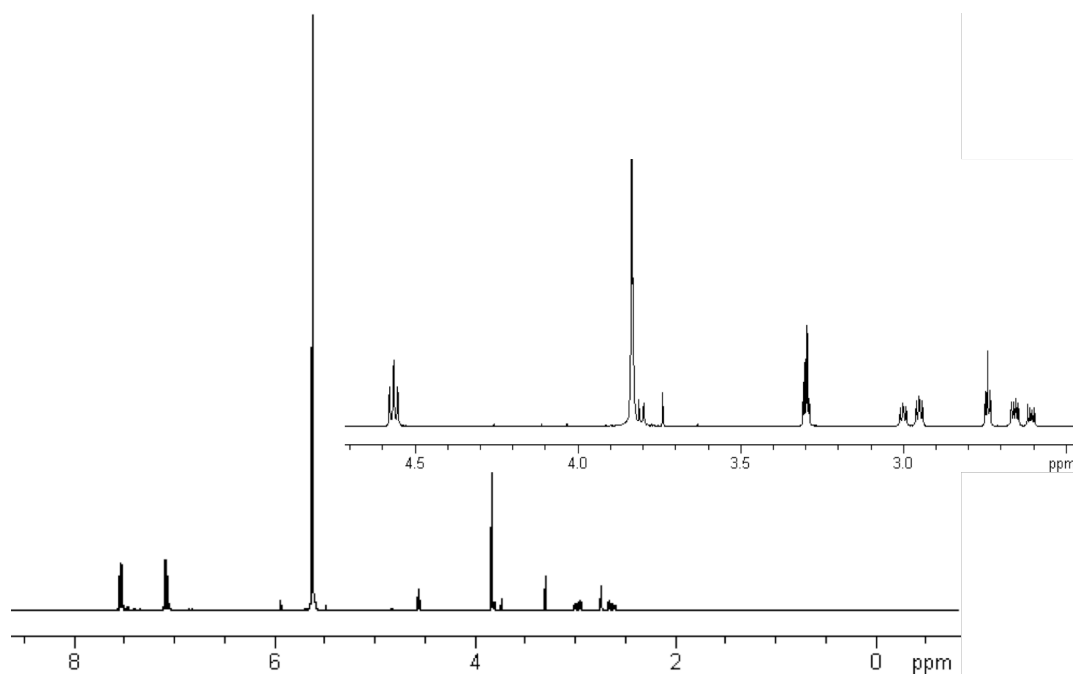
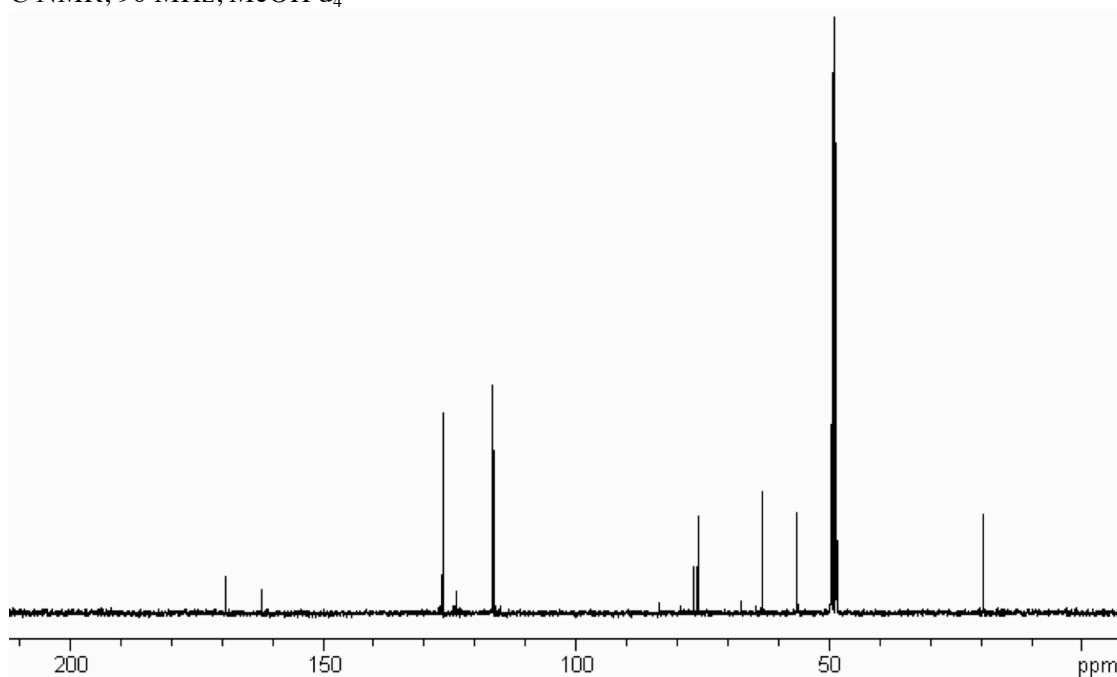


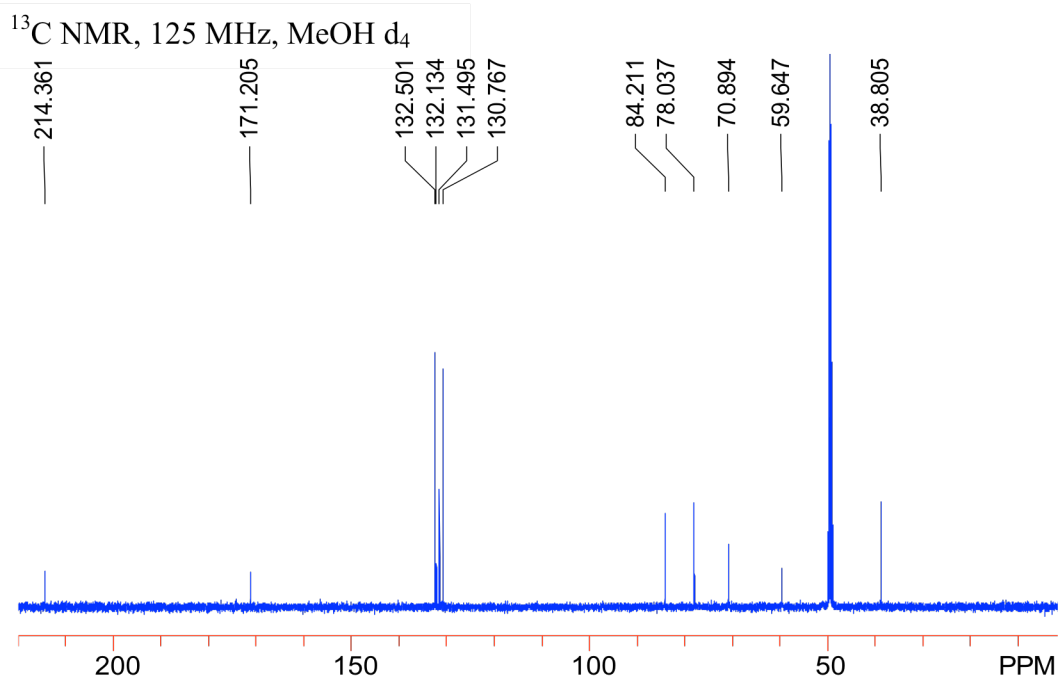
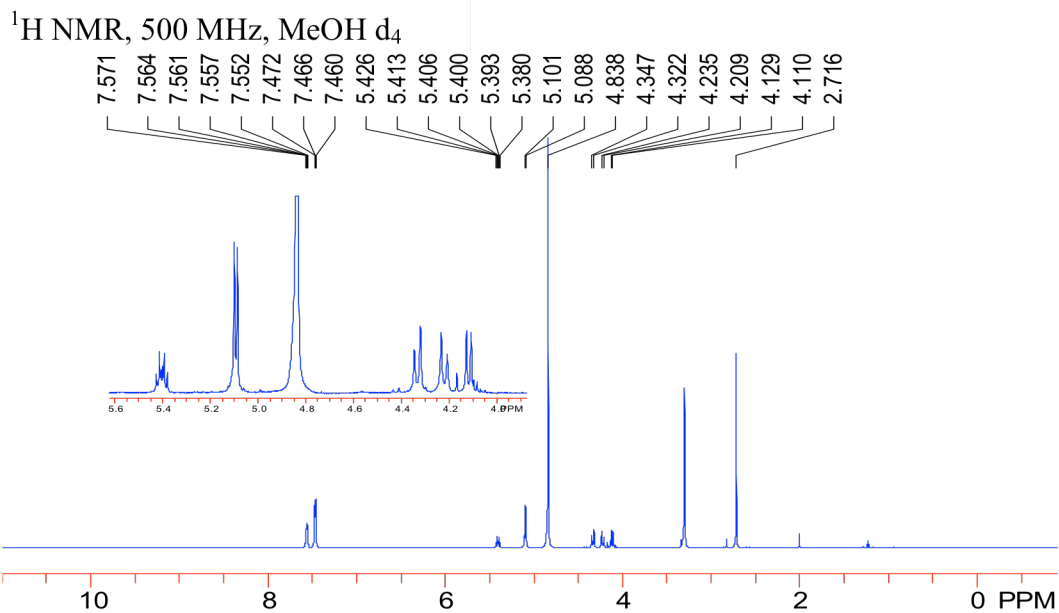
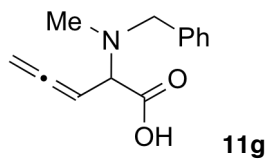
^1H NMR, 500 MHz, MeOH d_4

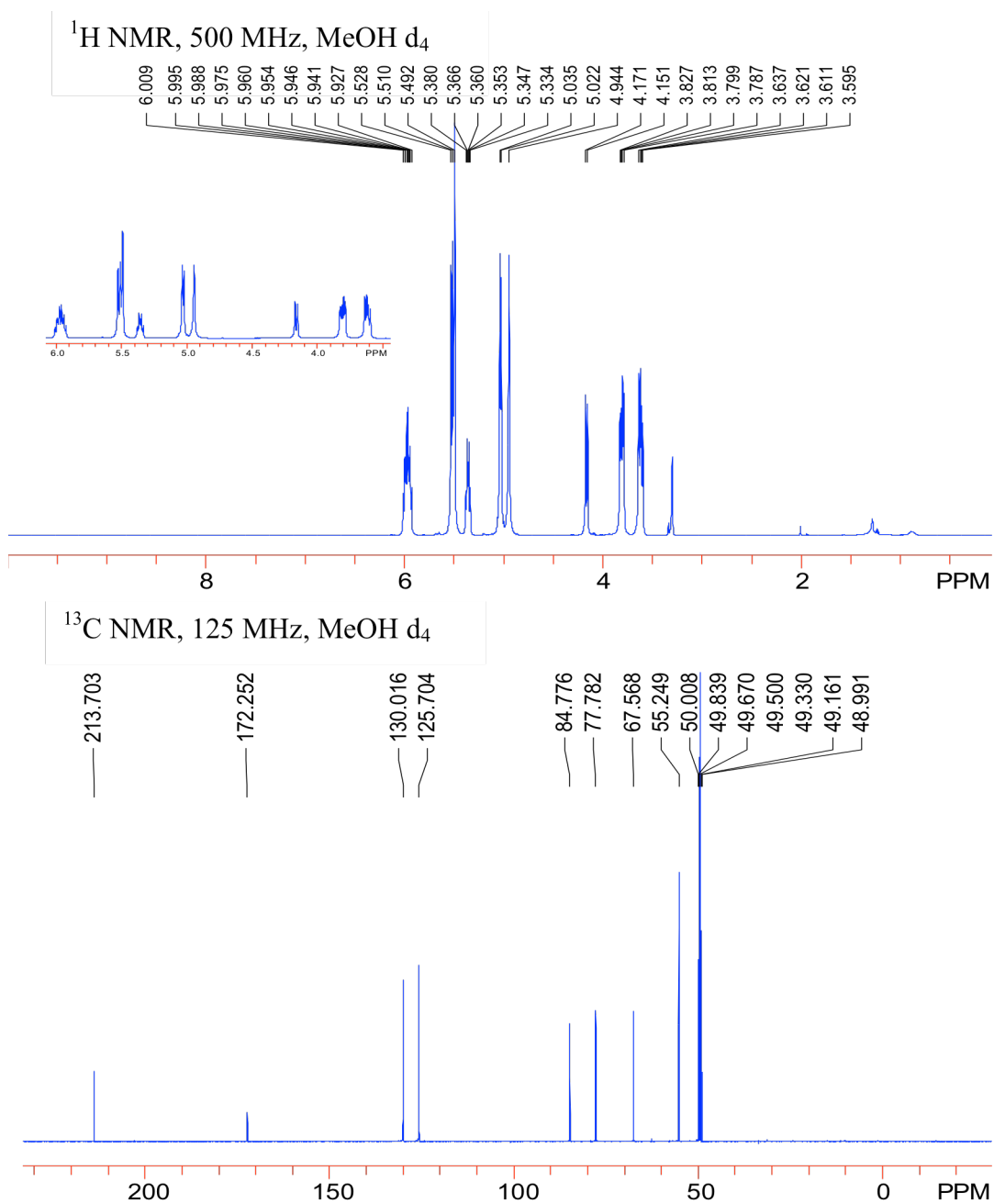
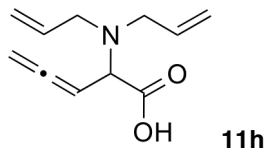


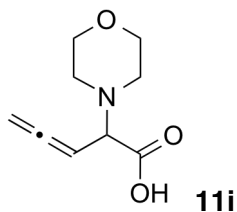
^{13}C NMR, 125 MHz, MeOH d_4



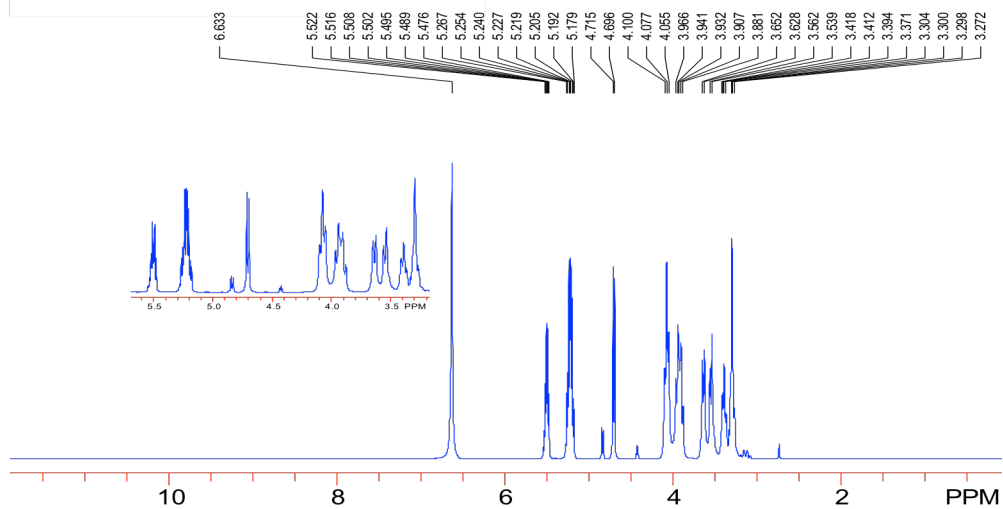
**12f**¹H NMR, 360 MHz, MeOH d₄¹³C NMR, 90 MHz, MeOH d₄



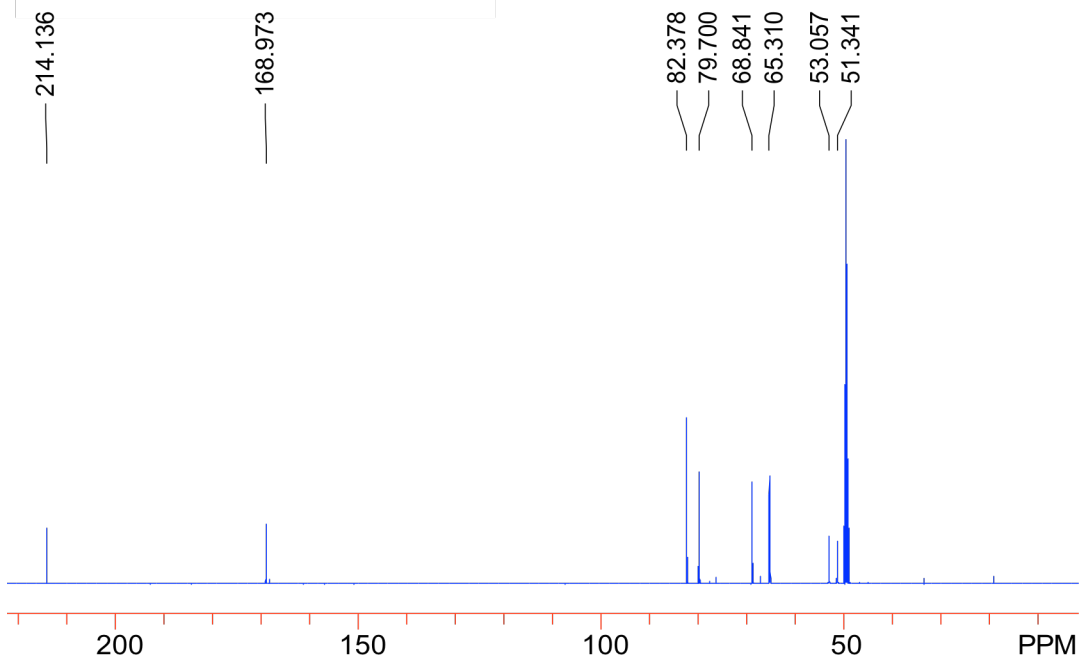


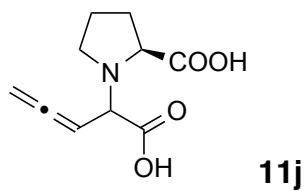


^1H NMR, 250 MHz, MeOH d_4

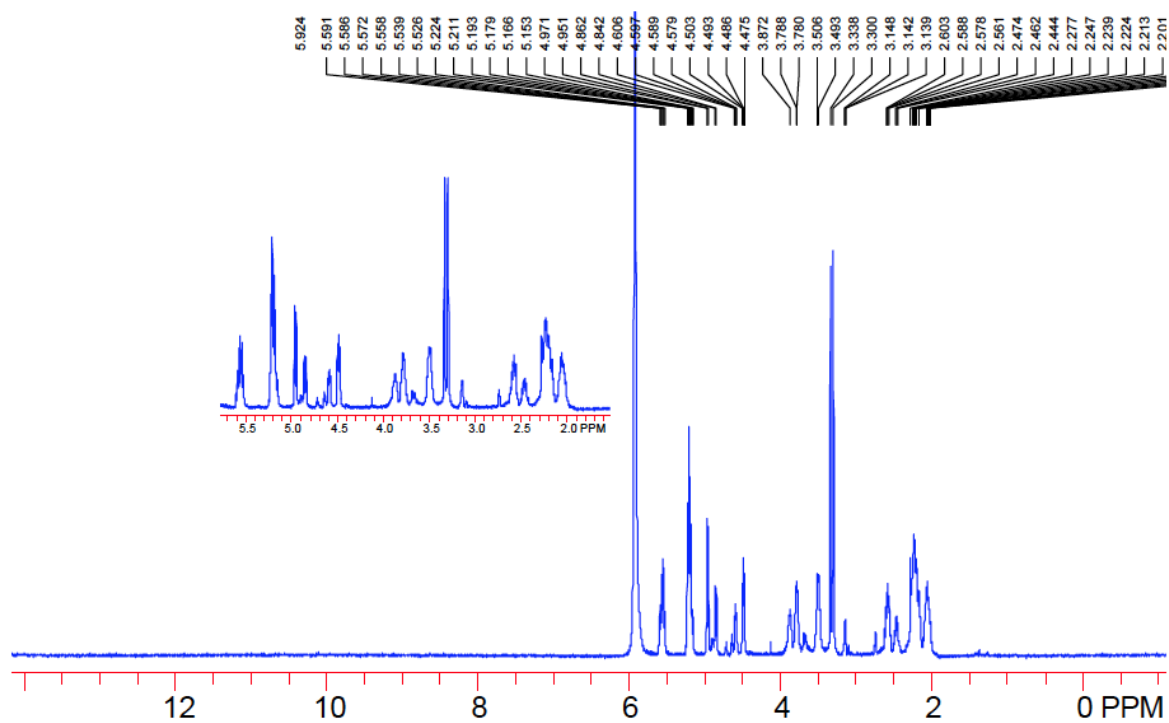


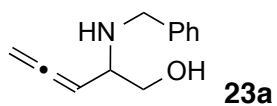
^{13}C NMR, 63 MHz, MeOH d_4



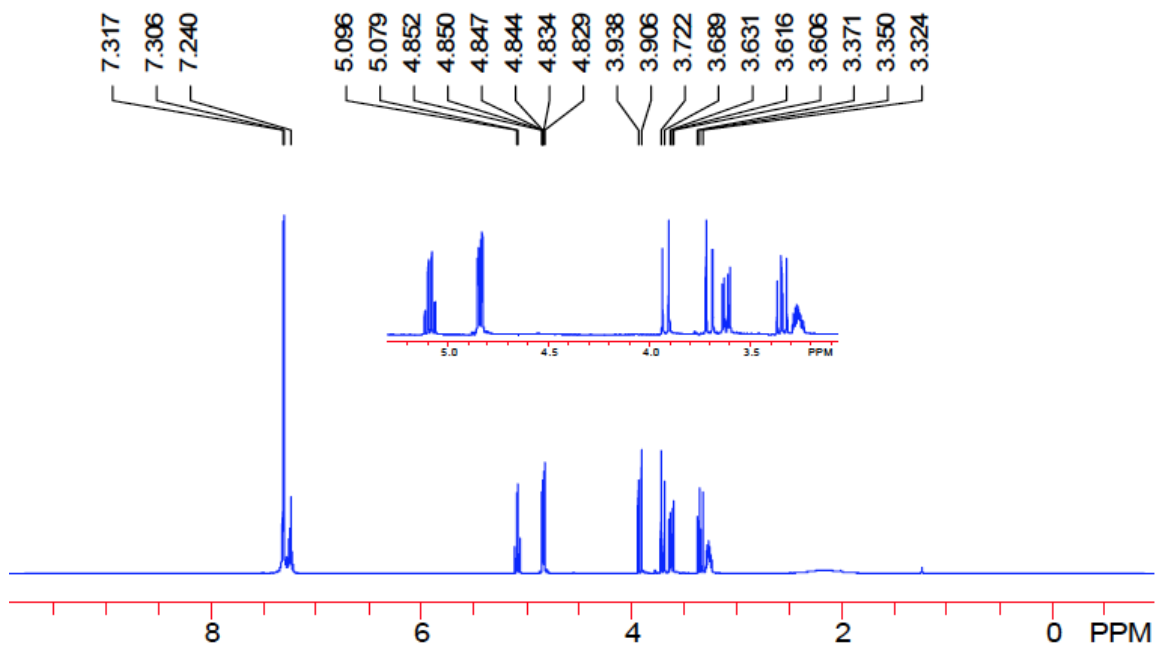


^1H NMR, 500 MHz, MeOH d_4 & DCl

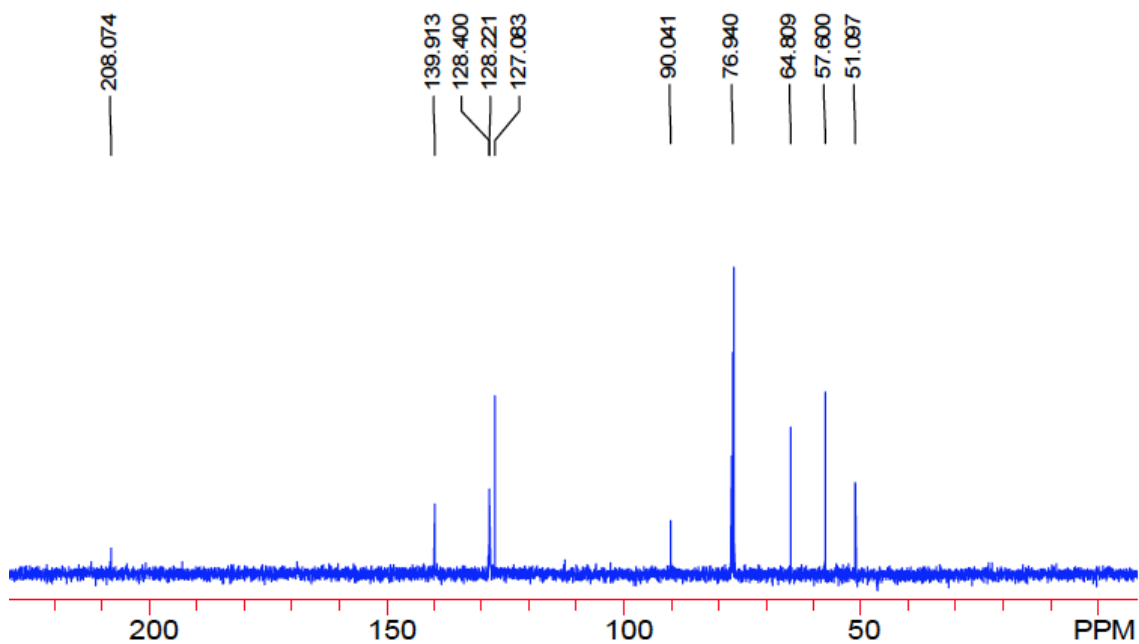


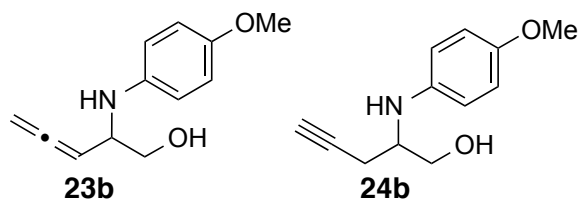


^1H NMR, 400 MHz, CDCl_3

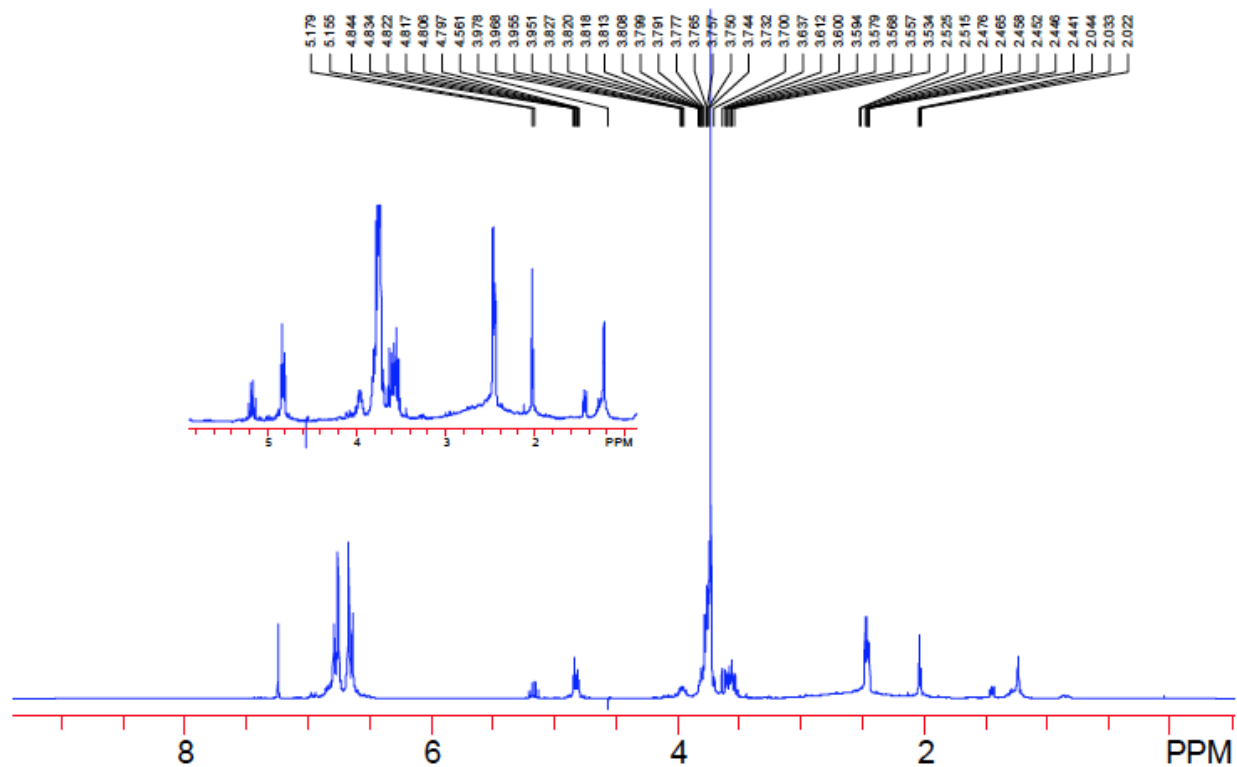


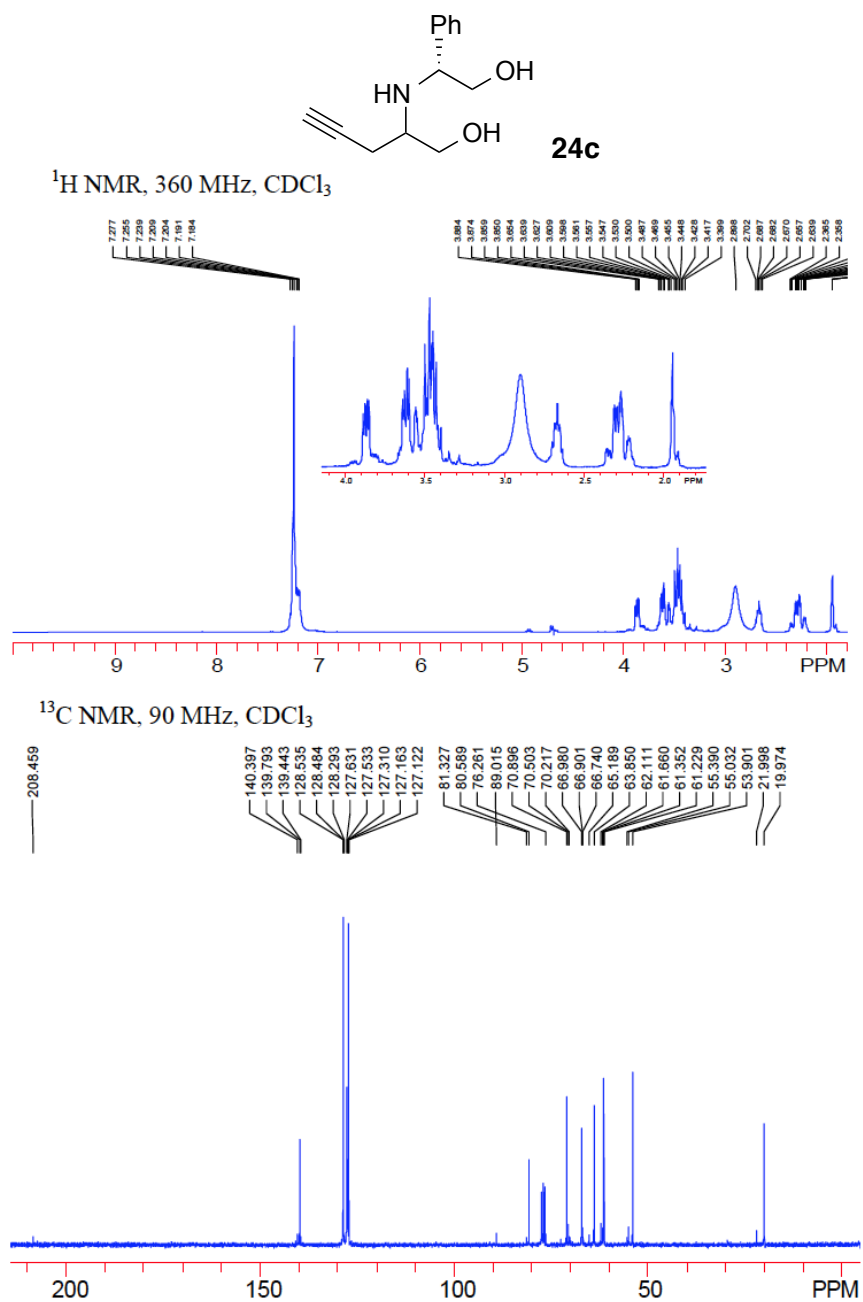
^{13}C NMR, 100 MHz, CDCl_3

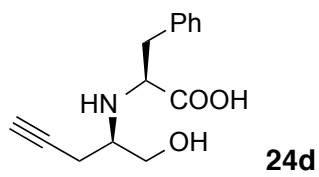




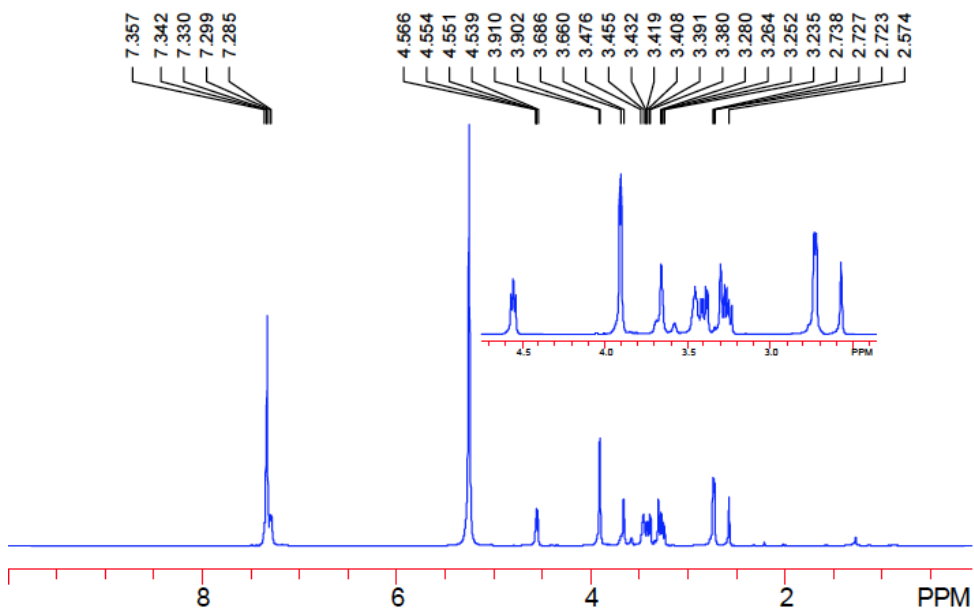
^1H NMR, 250 MHz, CDCl_3



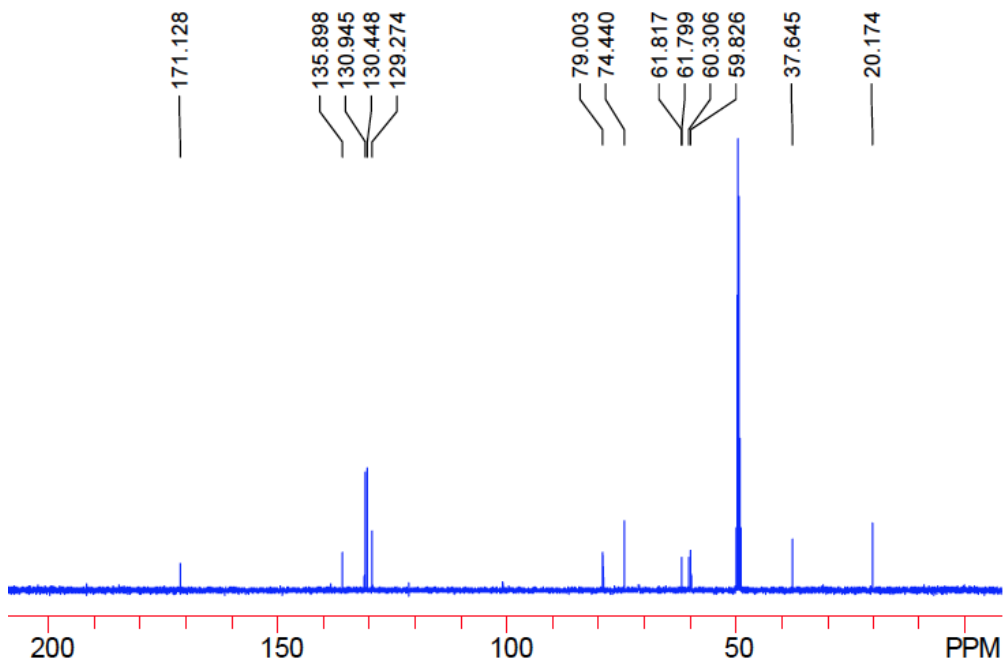


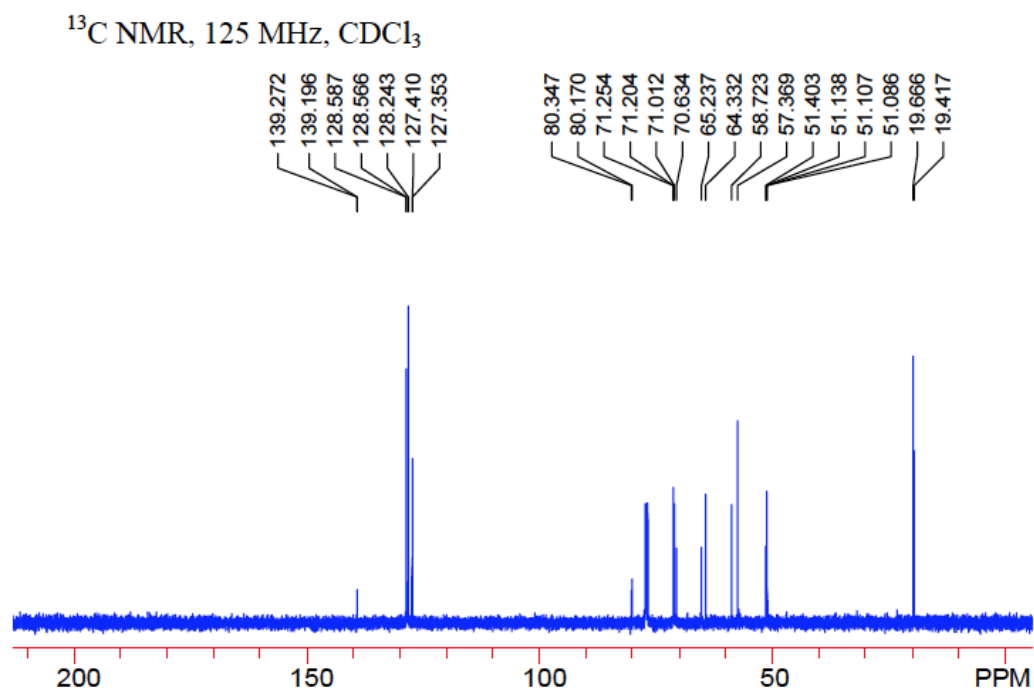
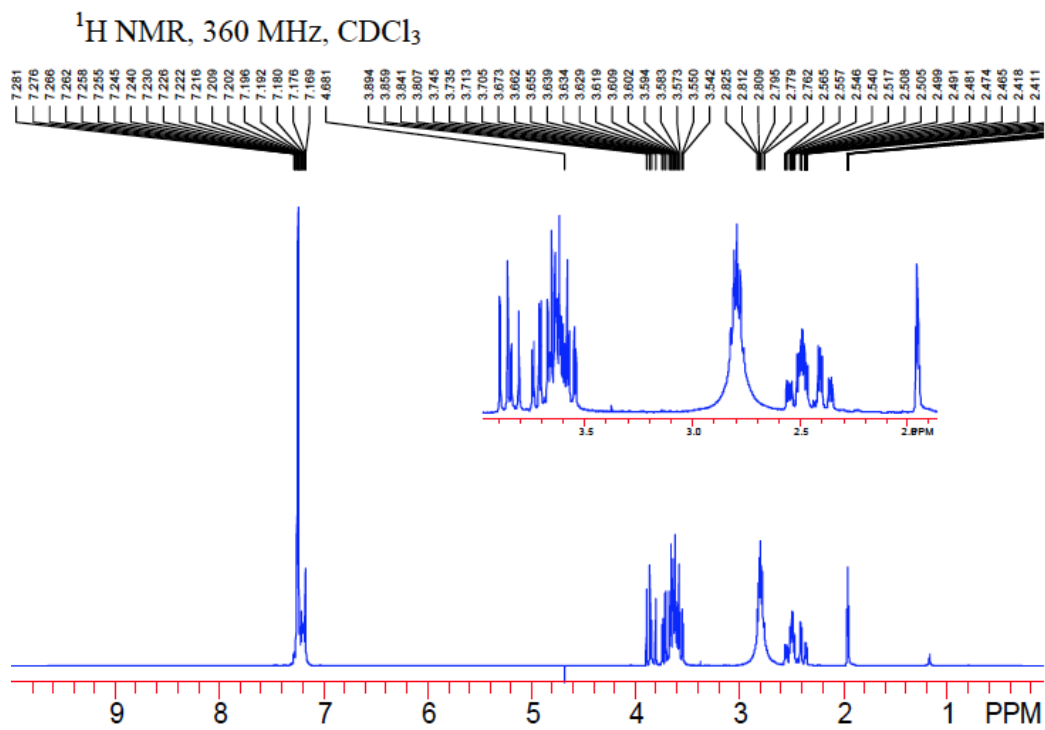
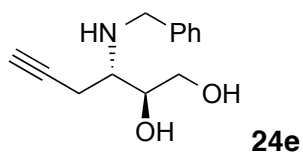


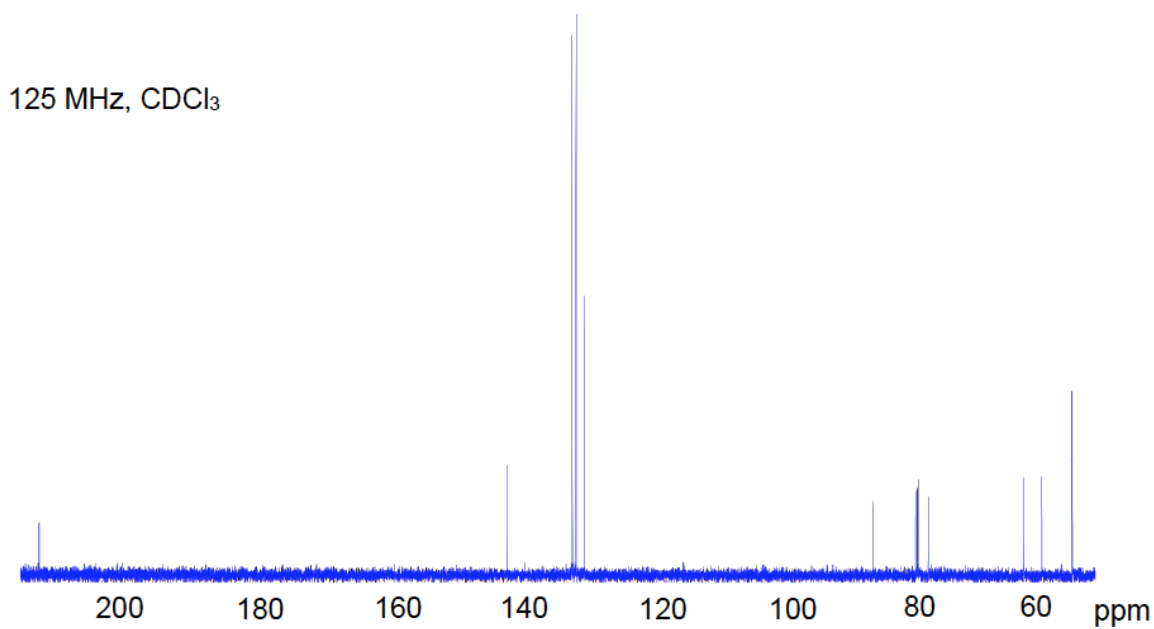
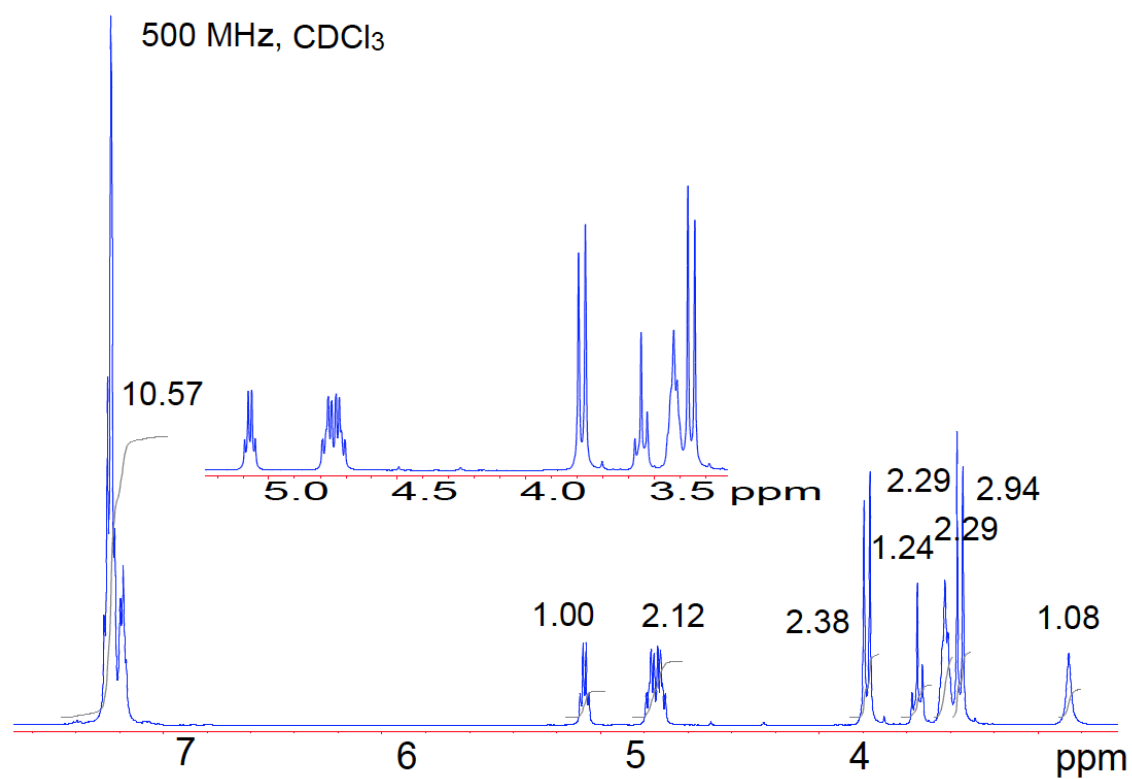
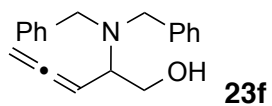
^1H NMR, 500 MHz, MeOH d_4

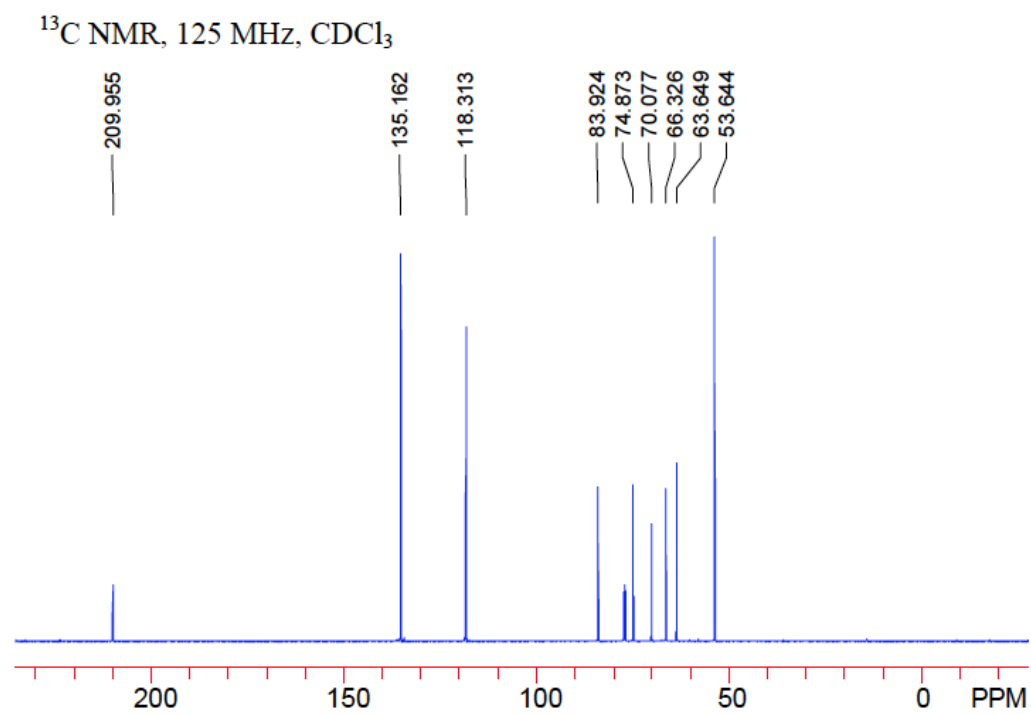
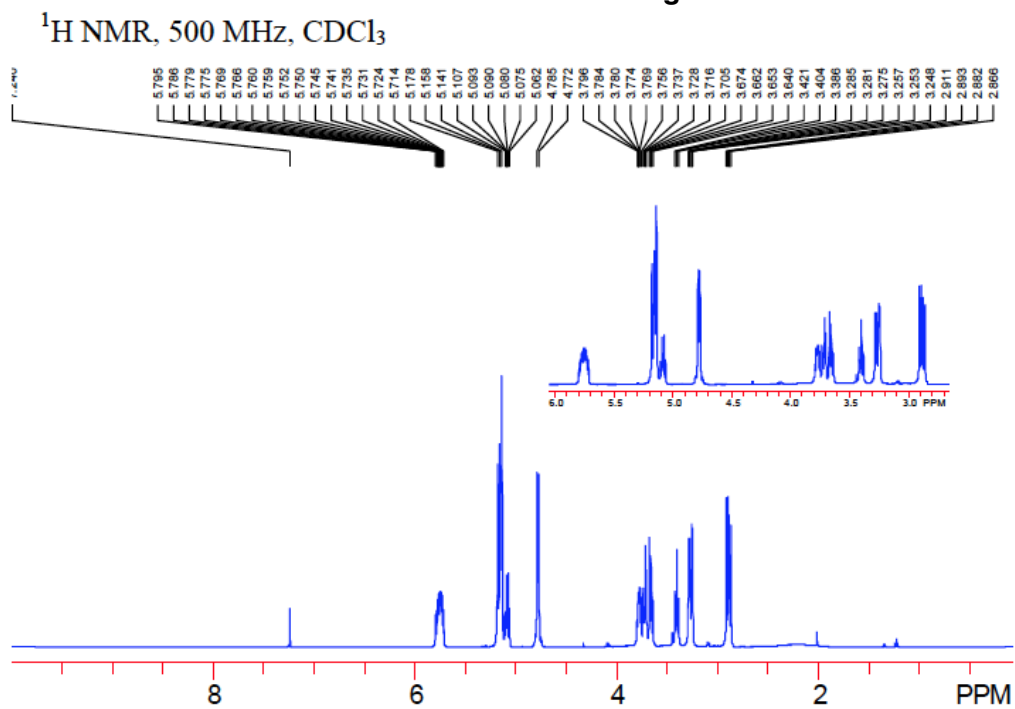
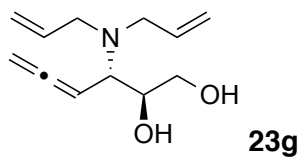


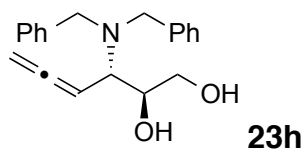
^{13}C NMR, 125 MHz, MeOH d_4



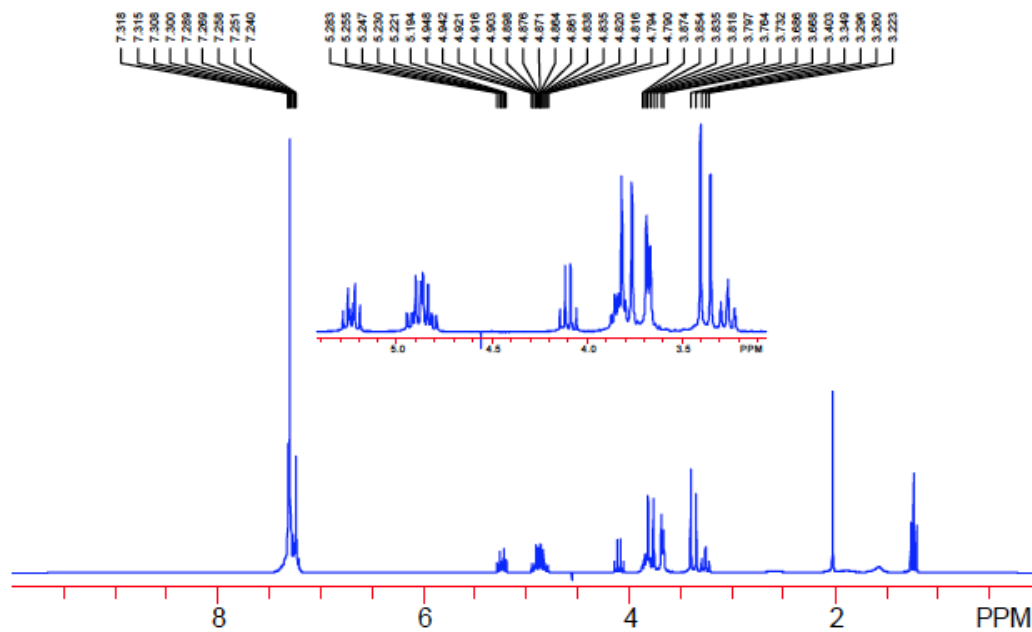




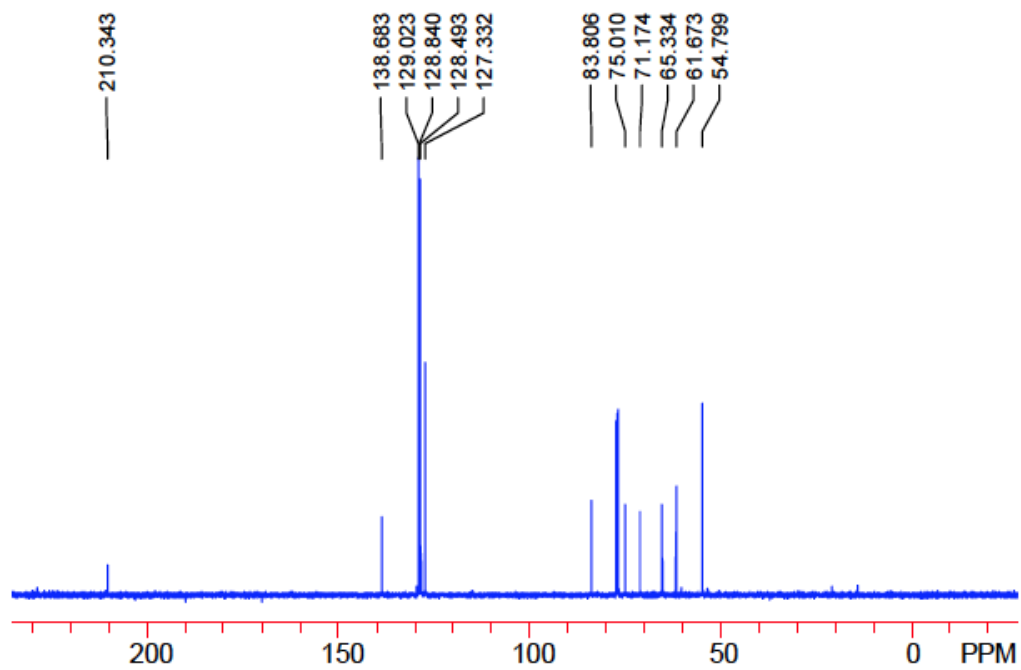


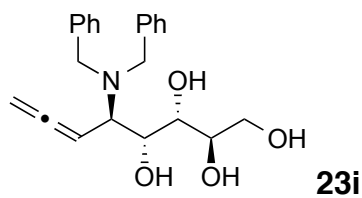


¹H NMR, 250 MHz, CDCl₃

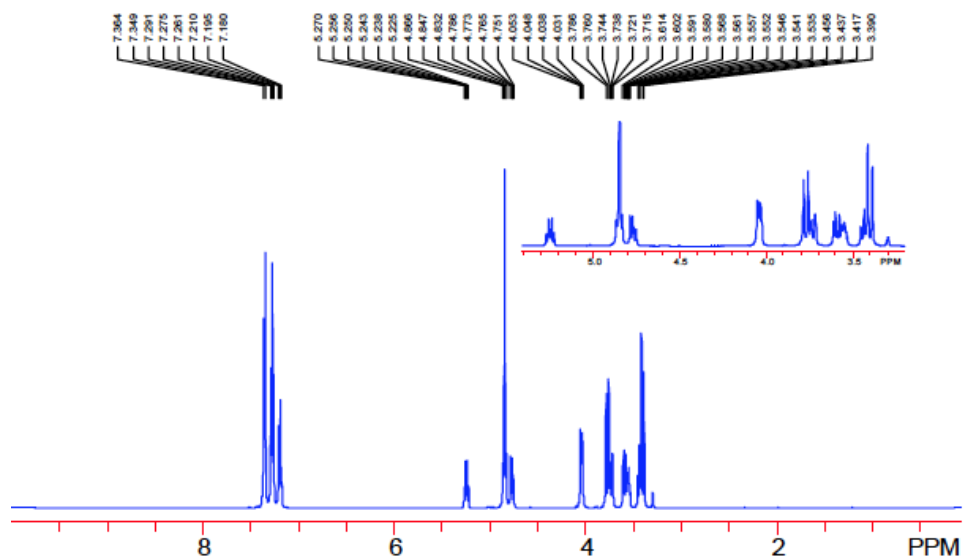


¹³C NMR, 125 MHz, CDCl₃

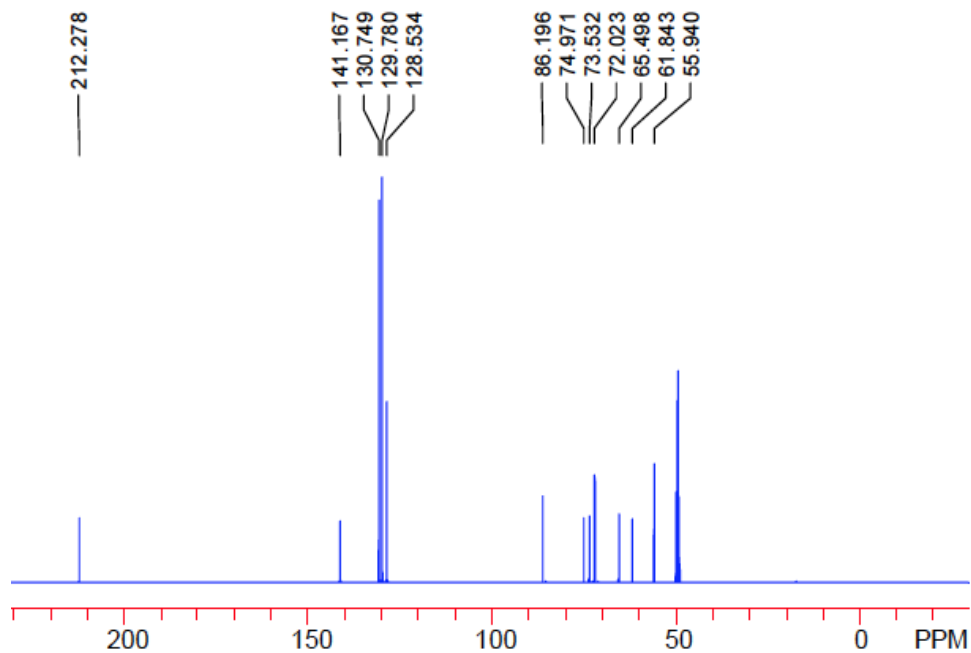


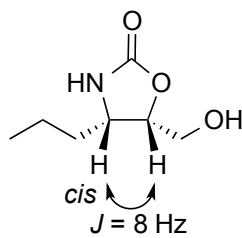


^1H NMR, 500 MHz, MeOH d_4

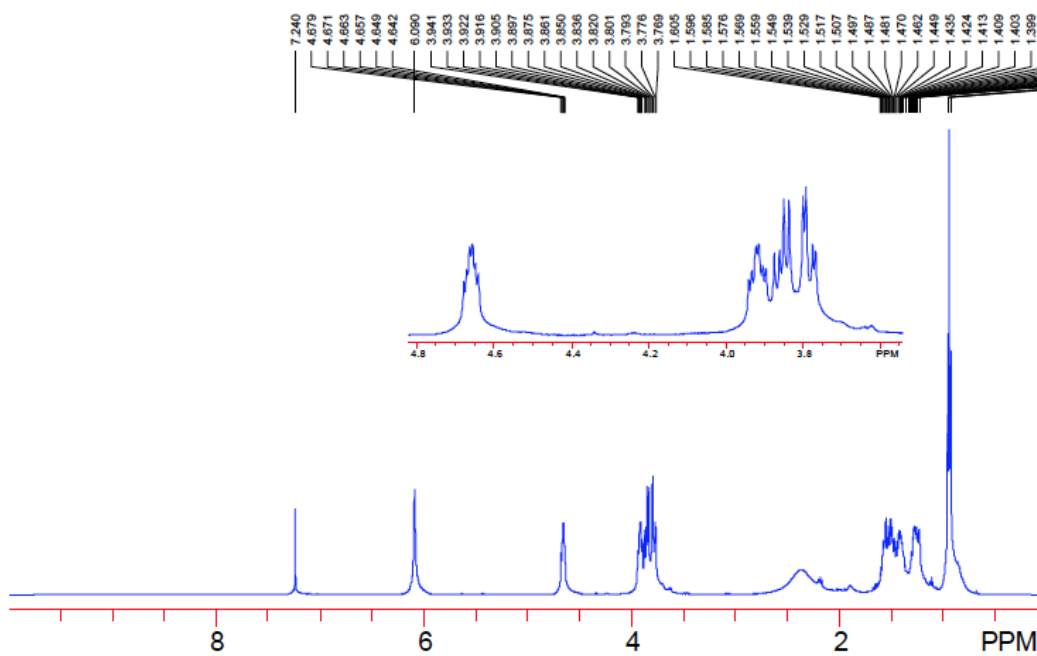


^{13}C NMR, 125 MHz, MeOH d_4

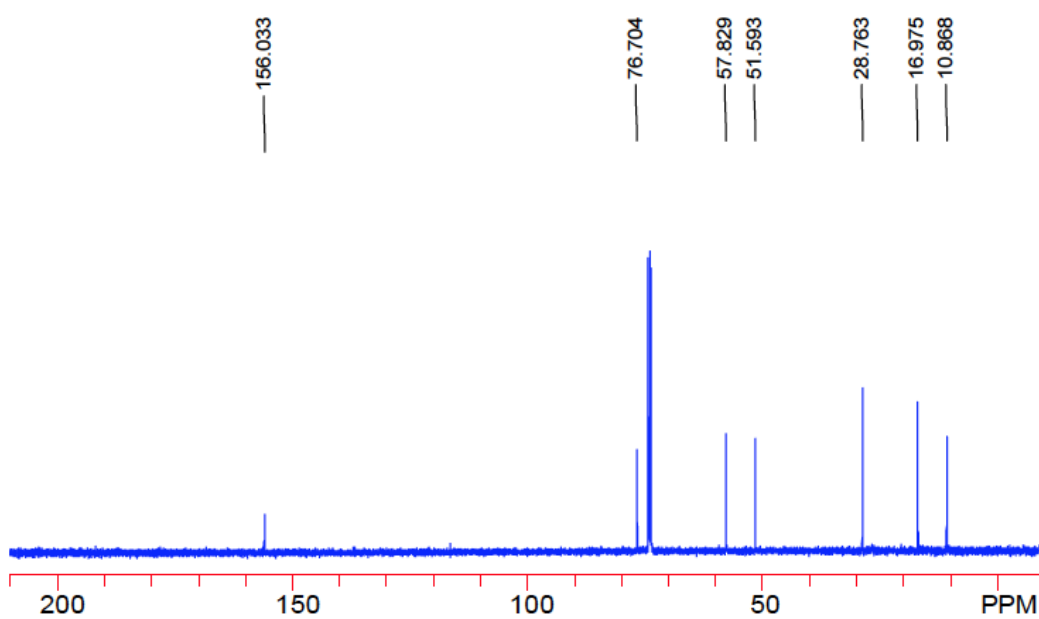


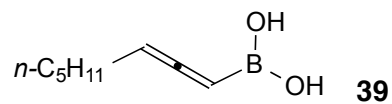


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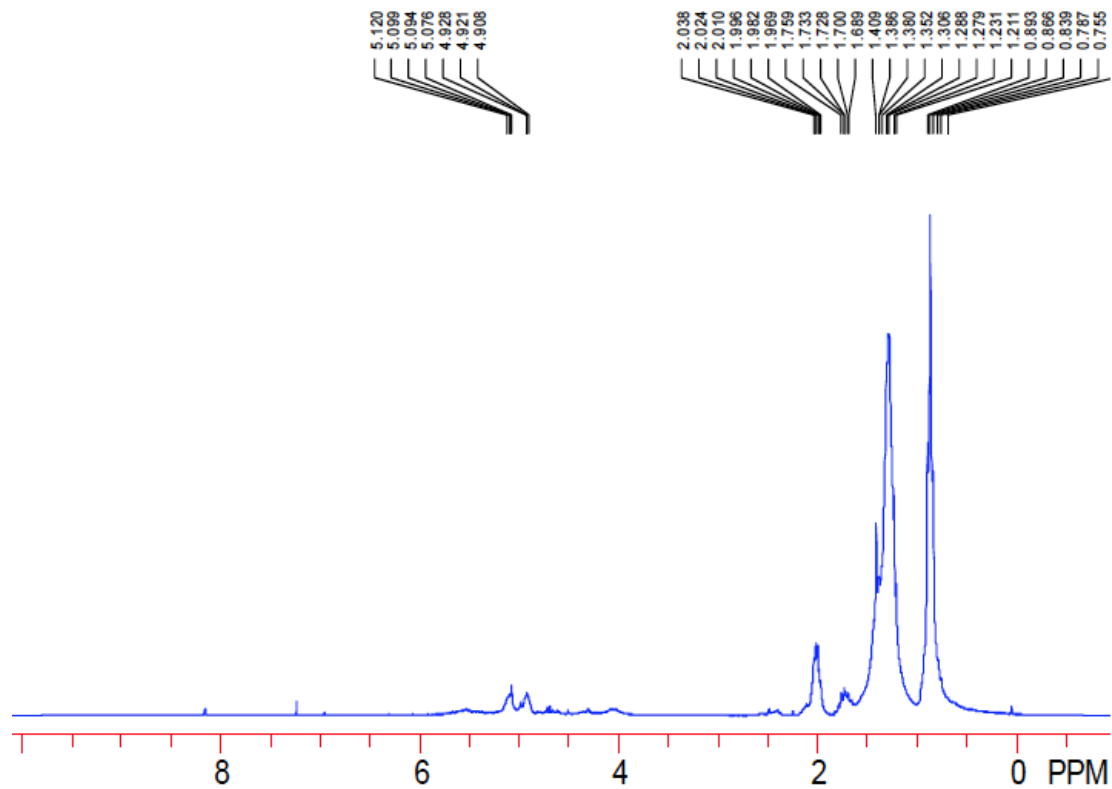


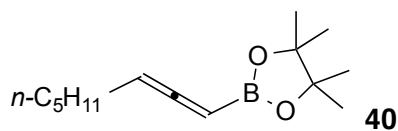
^{13}C NMR, 125 MHz, CDCl_3



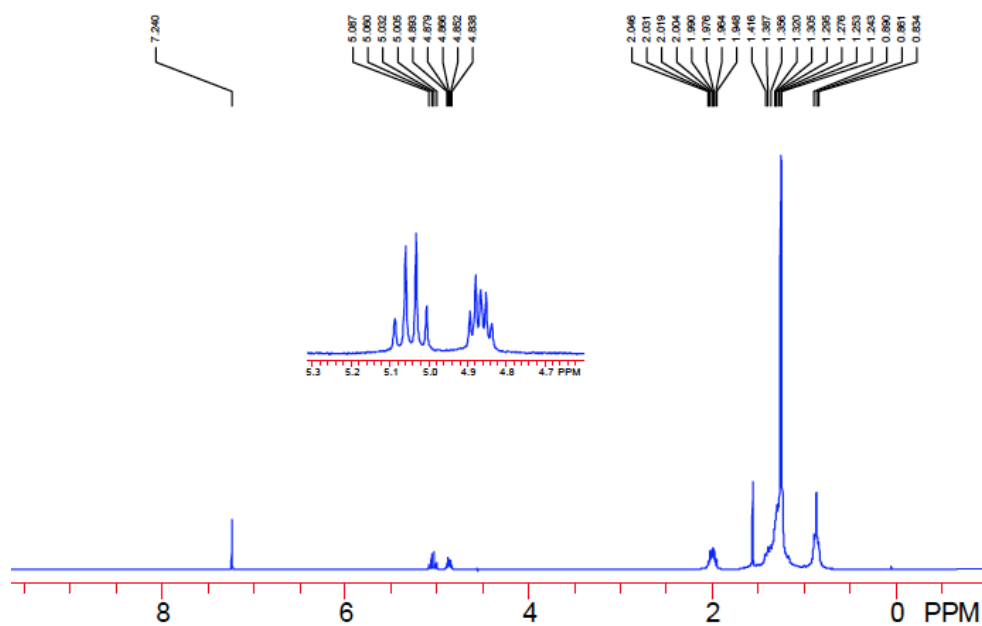


^1H NMR, 250 MHz, CDCl_3

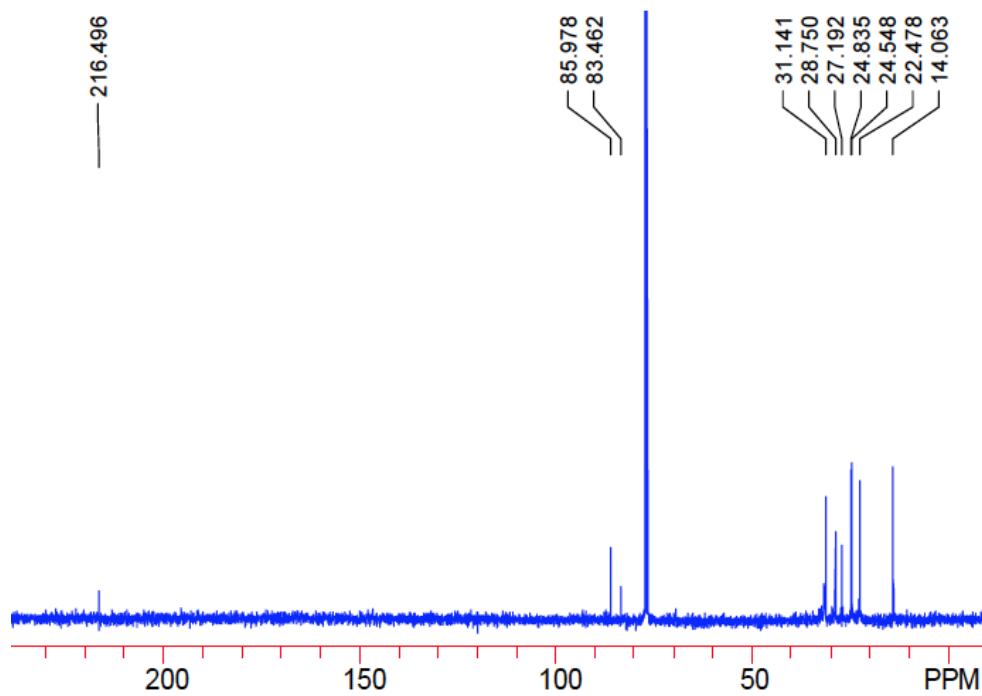


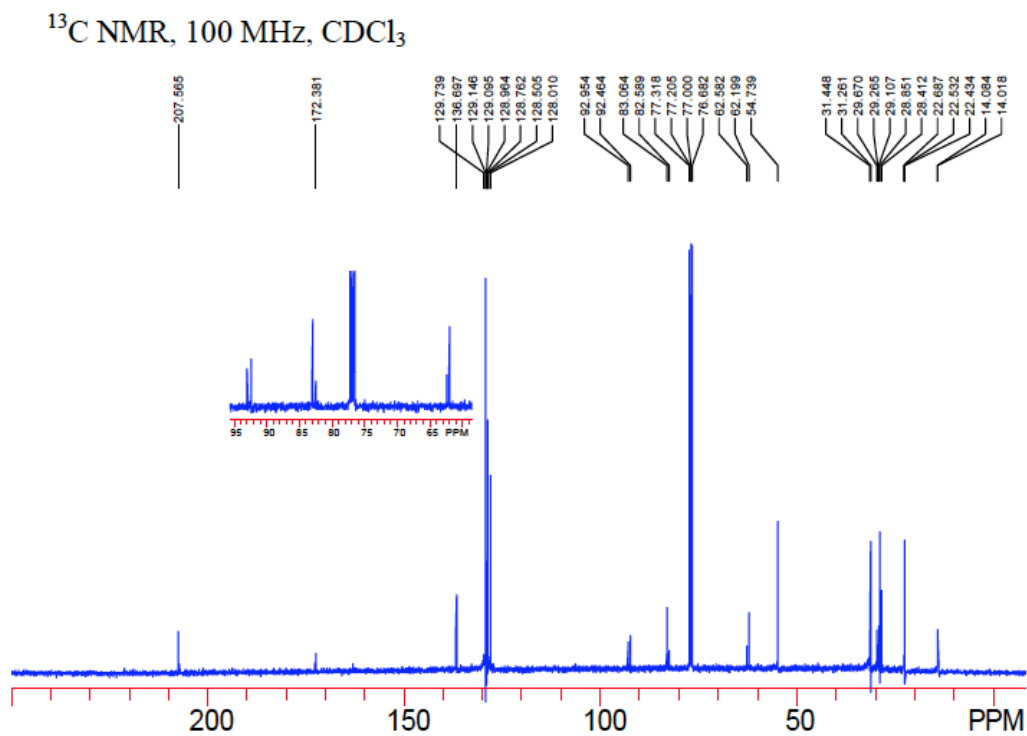
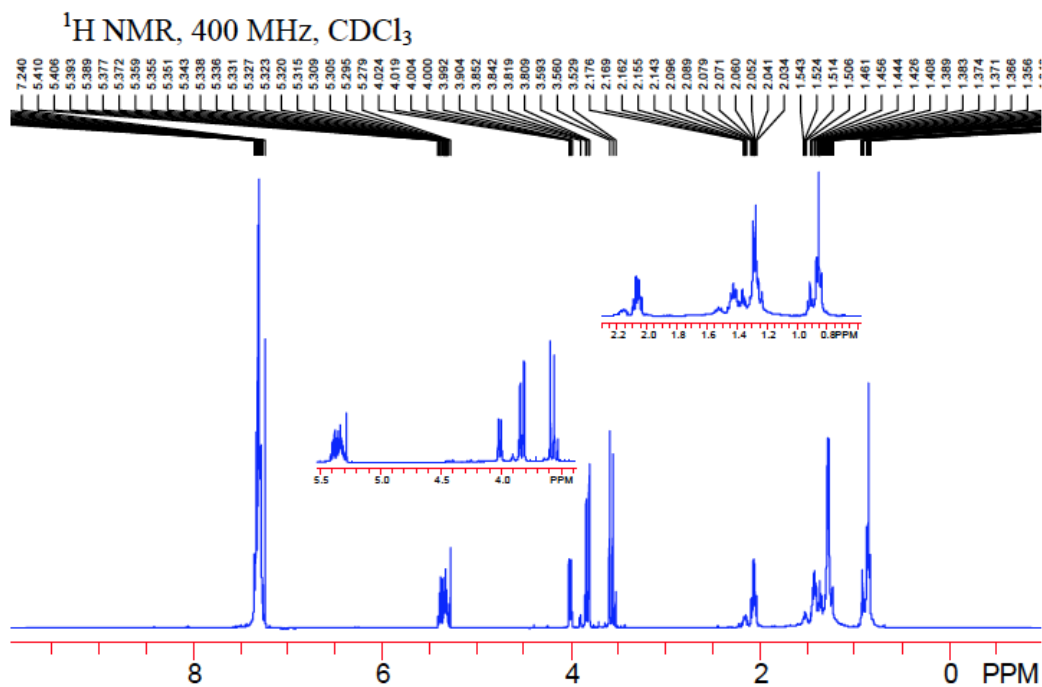
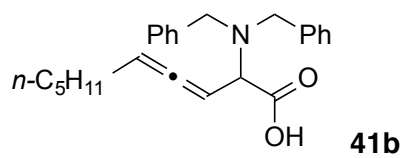


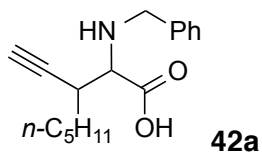
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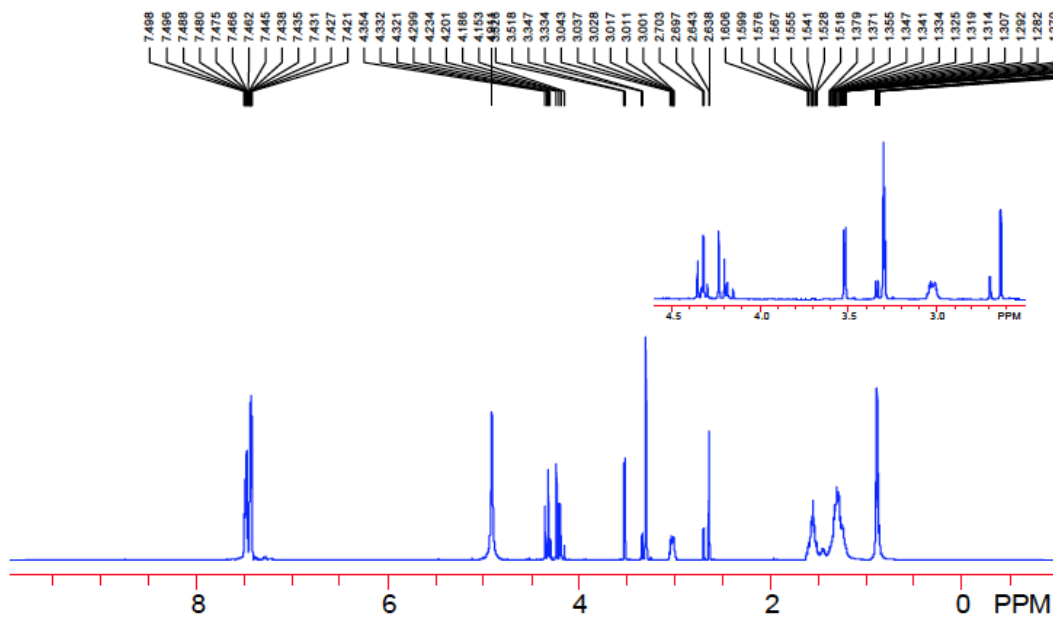
^{13}C NMR, 100 MHz, CDCl_3



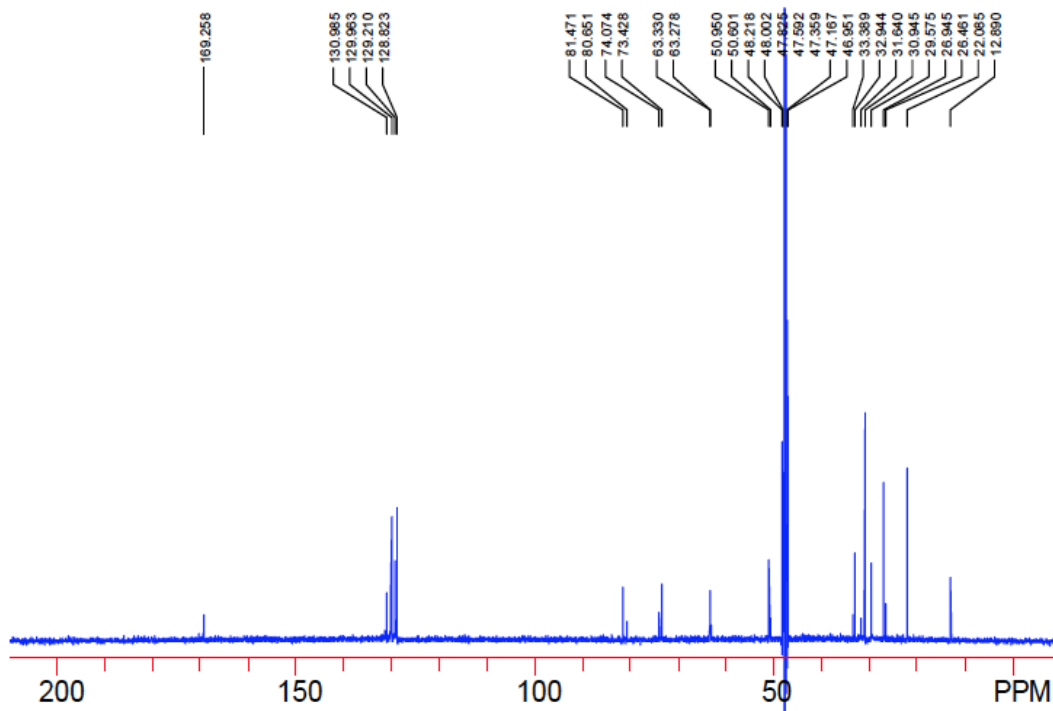


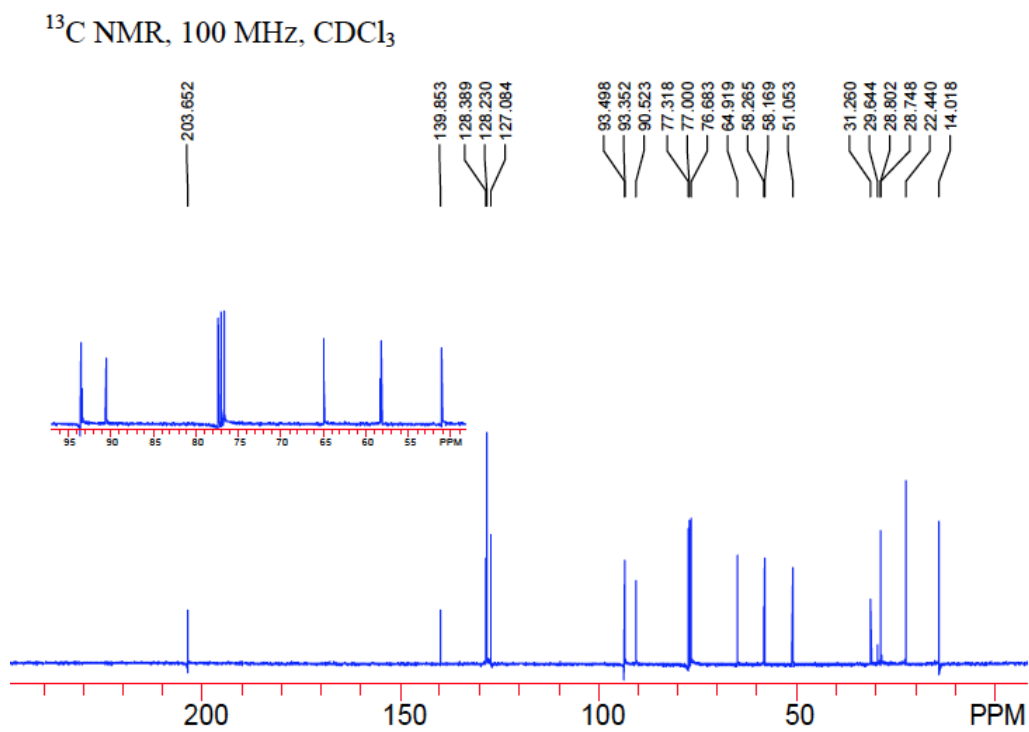
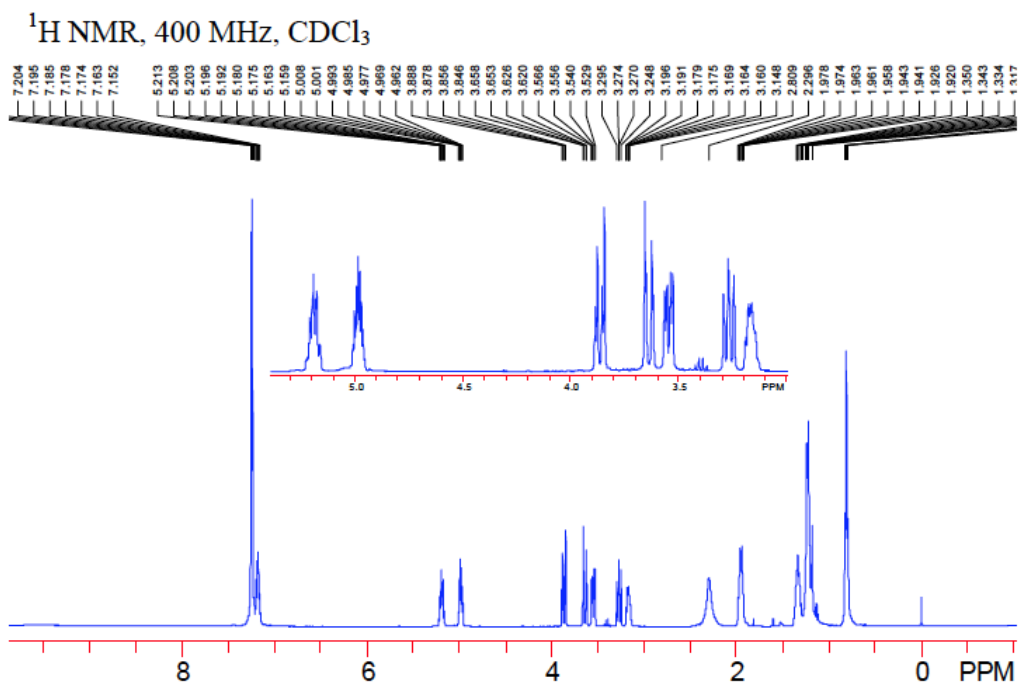
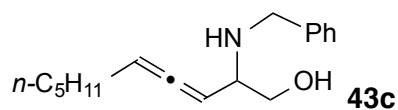


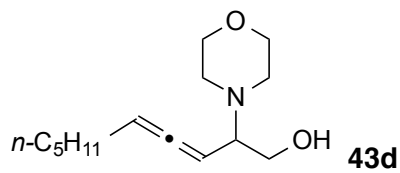
¹H NMR, 400 MHz, CDCl₃



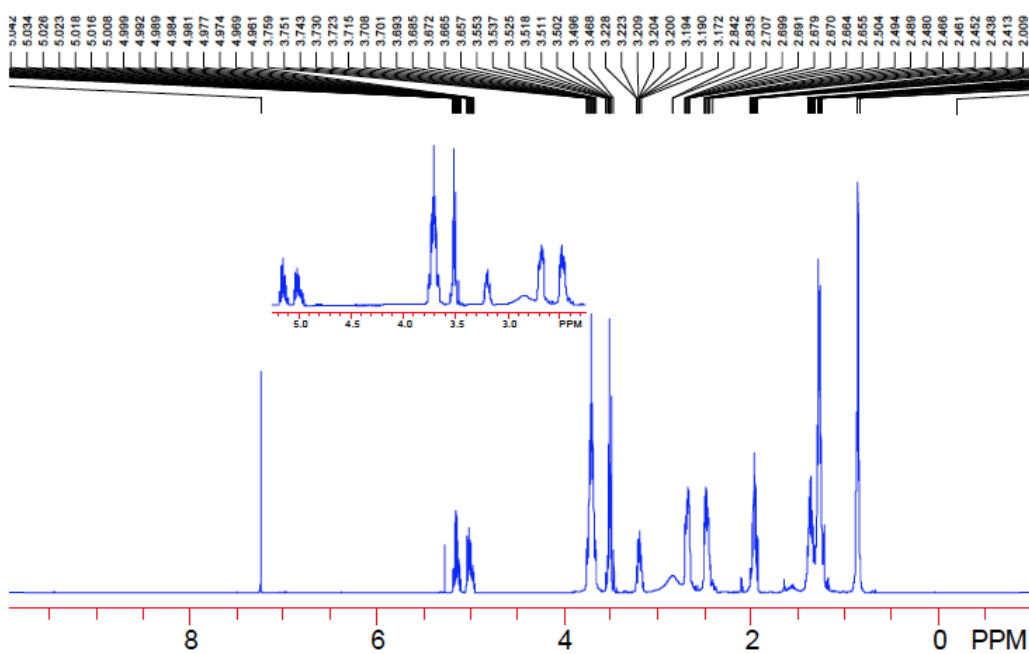
¹³C NMR, 100 MHz, CDCl₃







^1H NMR, 400 MHz, CDCl_3



^{13}C NMR, 90 MHz, CDCl_3

