Electronic Supplementary Material (ESI) for Chemical Communications.

Supporting Information For:

Rapid Synthesis of Bicyclic Lactones via Palladium-Catalyzed Aminocarbonylative Lactonizations

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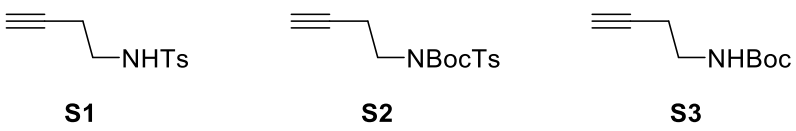
Part 1. Experimental Procedures and Spectra Data

I. General Methods

NMR spectra were recorded on Bruker spectrometers (^{1}H at 500 MHz and ^{13}C at 125 MHz). Chemical shifts (δ) were given in ppm with reference to solvent signals [^{1}H NMR: $CHCl_3$ (7.26); ^{13}C NMR: $CDCl_3$ (77.2)]. Column chromatography was performed on silica gel. All reactions sensitive to air or moisture were conducted under argon atmosphere in dry and freshly distilled solvents under anhydrous conditions, unless otherwise noted. Anhydrous THF was distilled over sodium benzophenone ketyl under Argon. Anhydrous CH_2Cl_2 was distilled over calcium hydride under Argon. Anhydrous MeCN was distilled over calcium hydride under Argon. All other solvents and reagents were used as obtained from commercial sources without further purification.

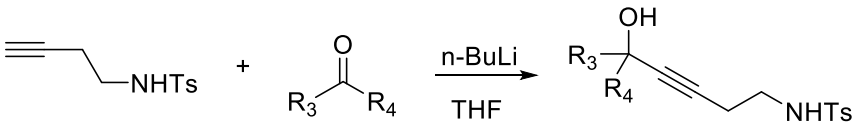
II. Synthesis of starting materials



S1 **S2** **S3**

Starting materials **S1**[1], **S2**[2], **S3**[3] are prepared according to the previously reported procedures.

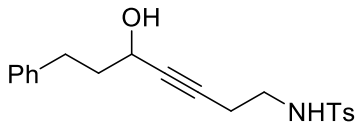
General procedure of preparation of 12a, b, d, f-j, i-t:



S1 **12a, b, d, f-j, i-t**

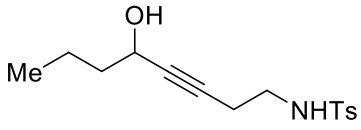
To a stirred solution of **S1** (112 mg, 0.50 mmol) in dry THF (5 mL), a 2.5 M solution of *n*-BuLi (0.39 mL, 0.98 mmol) in hexane was added dropwise at -78 ˚C over 10 min under argon atmosphere. The reaction mixture was allowed to react at the same temperature and stirred for 1 h. The corresponding aldehyde or ketone (1.5 mmol) dissolved in 5 mL THF was added at -78 ˚C over 10 min. The reaction mixture was allowed to warm up to room temperature and react for additional 1 h. The reaction was

quenched by saturated NH_4Cl solution (5 mL) and extracted with EtOAc for 3 times. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 3/2) to give **12a, b, d, f-j, i-t**.



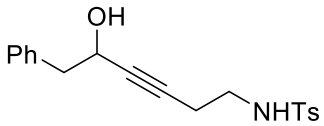
12a

114 mg, 64% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-d) δ 7.77 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.24 (m, 4H), 7.19 (m, 3H), 5.30 (t, *J* = 6.4 Hz, 1H), 4.31 (s, 1H), 3.09 (q, *J* = 6.4 Hz, 2H), 2.74 (t, *J* = 7.9 Hz, 2H), 2.41 (s, 3H), 2.38 (td, *J* = 6.4, 1.9 Hz, 2H), 2.06 – 1.84 (m, 2H); ^{13}C NMR (125 MHz, Chloroform-d) δ 143.77, 141.46, 137.10, 129.96, 128.63, 128.57, 127.22, 126.11, 83.86, 81.58, 61.87, 42.00, 39.44, 31.57, 21.68, 20.23; IR (neat): *v* = 3289,1599, 1496, 1454, 1324, 1157, 1093 cm^{-1}; HRMS (ESI), calcd for $C_{20}H_{23}NO_3SNa$ $[M+Na]^+$ 380.1297, found 380.1280 m/z.



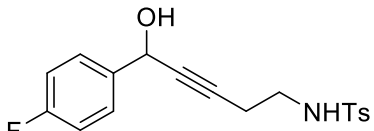
12b

108 mg, 73% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 4.94 (t, *J* = 6.4 Hz, 1H), 4.32 (s, 1H), 3.09 (q, *J* = 6.5 Hz, 2H), 2.43 (s, 3H), 2.38 (td, *J* = 6.5, 2.0 Hz, 2H), 1.95 (s, 1H), 1.70 – 1.54 (m, 3H), 1.48 – 1.36 (m, 2H), 0.93 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.79, 137.18, 129.97, 127.26, 84.19, 81.11, 62.46, 42.00, 40.19, 21.72, 20.25, 18.65, 13.92; IR (neat): *v* =3290, 1432, 1331, 1159, 1093 cm^{-1}; HRMS (ESI), calcd for $C_{15}H_{21}NO_3SNa$ $[M+Na]^+$ 318.1141, found 318.1094 m/z.



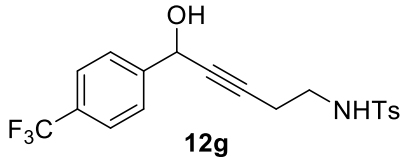
12d

50.2 mg, 29% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.20 (m, 7H), 5.10 (t, *J* = 6.4 Hz, 1H), 4.62 – 4.44 (m, 1H), 3.04 (q, *J* = 6.4 Hz, 2H), 2.94 (dd, *J* = 6.5, 2.0 Hz, 2H), 2.42 (s, 3H), 2.33 (td, *J* = 6.4, 2.0 Hz, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.72, 137.18, 136.88, 129.92, 129.83, 128.57, 127.19, 127.06, 83.20, 82.36, 63.39, 44.26, 41.91, 21.69, 20.23; IR (neat): *v* =3282, 1598, 1453, 1324, 1157, 1093 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{21}NO_3SNa$ $[M+Na]^+$ 352.0984, found 352.1004 m/z.



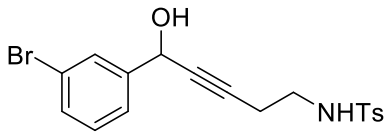
12f

119 mg, 69%yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.51 – 7.41 (m, 2H), 7.30 – 7.26 (m, 2H), 7.10 – 6.95 (m, 2H), 5.53 – 5.32 (m, 2H), 3.10 (q, *J* = 6.4 Hz, 2H), 2.52 – 2.32 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 163.72, 161.76, 143.83, 136.90 (d, *J* = 33.4 Hz), 129.96, 128.57 (d, *J* = 8.1 Hz), 127.20, 115.53 (d, *J* = 21.6 Hz), 83.45, 82.69, 63.95, 41.88, 21.70, 20.37; ^{19}F NMR (470 MHz, Chloroform-*d*) δ -114.98 (s); IR (neat): *v* =3290, 1603, 1507, 1420, 1323, 1223, 1157, 1094, 814, 552 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{18}FNO_3SNa$ $[M+Na]^+$ 370.0890, found 370.0929 m/z.



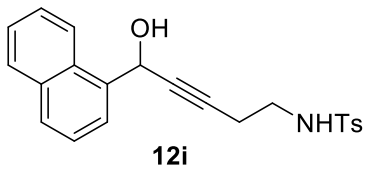
12g

141 mg, 71% yield, while solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.3 Hz 2H), 7.58 (s, 4H), 7.29 – 7.23 (m, 2H), 5.62 (t, *J* = 6.4 Hz, 1H), 5.54 – 5.36 (m, 1H), 3.37 (d, *J* = 5.5 Hz, 1H), 3.10 (q, *J* = 6.3 Hz, 2H), 2.50 – 2.35 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 144.74, 143.94, 136.92, 130.37 (q, *J* = 32.5 Hz), 129.98, 127.16, 126.98, 125.58 (q, *J* = 3.8 Hz), 83.81, 82.31, 63.88, 41.84, 21.65, 20.34.; ^{19}F NMR (470 MHz, Chloroform-*d*) δ -63.56 (m); IR (neat): *v* =3283, 1619, 1507, 1417, 1324, 1157, 1123, 1066, 814, 661, 551 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{18}F_3NO_3SNa$ $[M+Na]^+$ 420.0858, found 420.0786 m/z.



12h

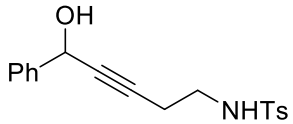
134 mg, 66% yield, light yellow oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.63 (t, *J* = 1.9 Hz, 1H), 7.48 – 7.38 (m, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 7.23 (t, *J* = 7.8 Hz, 1H), 5.38 (d, *J* = 5.9 Hz, 1H), 5.08 (t, *J* = 6.4 Hz, 1H), 3.12 (q, *J* = 6.4 Hz, 2H), 2.66 (d, *J* = 5.8 Hz, 1H), 2.48 – 2.32 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.88, 143.05, 137.06, 131.53, 130.36, 130.01, 129.75, 127.23, 125.31, 122.78, 83.76, 82.30, 63.96, 41.86, 21.74, 20.43; IR (neat): *v* =3286, 1595, 1427, 1322, 1157, 1093, 814, 662, 550 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{18}BrNO_3SNa$ $[M+Na]^+$ 430.0089, found 430.0099 m/z.



12i

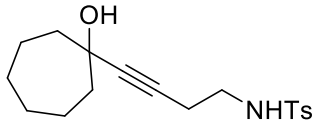
147 mg, 49% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 8.27 (d, *J* = 8.5 Hz, 1H), 7.92

– 7.82 (m, 2H), 7.76 (d, *J* = 7.0 Hz, 1H), 7.65 (d, *J* = 8.3 Hz, 2H), 7.59-7.51 (m, 2H), 7.47 (dd, *J* = 8.2, 7.1 Hz, 1H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.06 (m, 1H), 4.84 (t, *J* = 6.4 Hz, 1H), 3.11 (q, *J* = 6.4 Hz, 2H), 2.47 (d, *J* = 5.6 Hz, 1H), 2.43 (td, *J* = 6.4, 2.0 Hz, 2H), 2.39 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.73, 137.11, 135.91, 134.21, 130.54, 129.92, 129.52, 129.03, 127.19, 126.72, 126.16, 125.44, 124.54, 123.93, 83.86, 82.67, 63.13, 41.90, 21.69, 20.43; IR (neat): *v* =3285, 1597, 1412, 1326, 1157, 1093, 782, 661, 550 cm^{-1}; HRMS (ESI), calcd for $C_{22}H_2NO_3SNa$ $[M+Na]^+$ 402.1141, found 402.1066 m/z.



12j

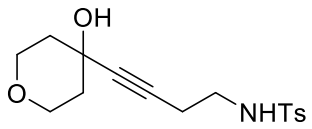
116 mg, 70% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.3 Hz, 2H), 7.51 – 7.46 (m, 2H), 7.40 – 7.30 (m, 3H), 7.28 (d, *J* = 8.0 Hz, 2H), 5.41 (s, 1H), 5.00 (t, *J* = 6.4 Hz, 1H), 3.12 (q, *J* = 6.5 Hz, 2H), 2.49 – 2.38 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.75, 140.84, 137.07, 129.93, 128.80, 128.54, 127.21, 126.64, 83.19, 82.83, 64.74, 41.87, 21.68, 20.36; IR (neat): *v* =3300, 1453, 1324, 1157, 817, 662, 550 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{19}NO_3SNa$ $[M+Na]^+$ 366.1141, found 366.1105 m/z.



12l

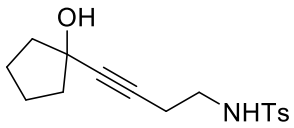
124 mg, 74% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.4 Hz, 2H), 5.51 (t, *J* = 6.3 Hz, 1H), 3.05 (q, *J* = 6.5 Hz, 2H), 2.63 (s, 1H), 2.40 (s, 3H), 2.33 (t,

J = 6.6 Hz, 2H), 1.97 – 1.82 (m, 2H), 1.78 – 1.72 (m, 2H), 1.65 – 1.31 (m, 8H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.59, 137.22, 129.86, 127.15, 87.70, 79.50, 71.81, 43.16, 42.09, 28.11, 22.27, 21.64, 20.13; IR (neat): *v* =3290, 1598, 1445, 1325, 1157, 1094, 1025, 814, 664, 551 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{25}NO_3SNa$ $[M+Na]^+$ 358.1454, found 358.1405 m/z.



12m

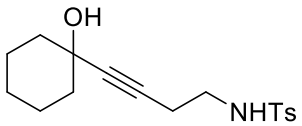
52.3 mg, 32% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 5.59 (t, *J* = 6.3 Hz, 1H), 3.83 (dt, *J* = 11.7, 4.2 Hz, 2H), 3.55 (ddd, *J* = 11.8, 9.0, 3.0 Hz, 2H), 3.14 (s, 1H), 3.08 (q, *J* = 6.3 Hz, 2H), 2.41 (s, 3H), 2.37 (t, *J* = 6.5 Hz, 2H), 1.85 -1.71 (m, 4H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.79, 137.09, 129.95, 127.14, 85.43, 81.23, 65.70, 64.91, 42.02, 40.00, 21.67, 20.17; IR (neat): *v* =3280, 1598, 1424, 1327, 1156, 1092, 815, 663, 550 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{21}NO_4SNa$ $[M+Na]^+$ 346.1090, found 346.1049 m/z.



12n

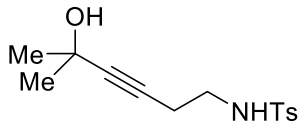
95 mg, 62% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.29 (d, *J* = 8.4 Hz, 2H), 5.52 (t, *J* = 6.3 Hz, 1H), 3.05 (q, *J* = 6.5 Hz, 2H), 2.58 (s, 1H), 2.40 (s, 3H), 2.32 (t, *J* = 6.5 Hz, 2H), 1.91 – 1.71 (m, 6H), 1.67 – 1.63 (m, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.61, 137.15, 129.86, 127.16, 86.74, 79.24, 74.42, 42.43, 42.01, 23.47, 21.64, 20.16; IR (neat): *v* =3281, 1598, 1436, 1324, 1157, 1093, 993, 814, 662, 550 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{21}NO_3SNa$

$[M+Na]^+$ 330.1141, found 330.1099 m/z.



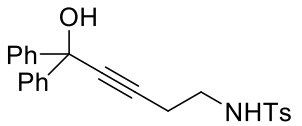
12o

37 mg, 31% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.1 Hz, 2H), 5.26 (t, *J* = 6.3 Hz, 1H), 3.08 (q, *J* = 6.5 Hz, 2H), 2.42 (s, 3H), 2.36 (t, *J* = 6.5 Hz, 2H), 1.83 – 1.78 (m, 2H), 1.69 – 1.58 (m, 2H), 1.57 – 1.37 (m, 5H), 1.25 – 1.20 (m, 1H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.69, 137.22, 129.92, 127.20, 86.71, 80.31, 68.76, 42.11, 40.08, 25.28, 23.45, 21.69, 20.15; IR (neat): *v* =3277, 1597, 1448, 1328, 1158, 1094, 963, 814, 662, 552 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{23}NO_3SNa$ $[M+Na]^+$ 344.1297, found 344.1228 m/z.



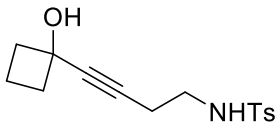
12p

48.4 mg, 59%, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.77 (d, *J* = 8.4 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 5.32 (t, *J* = 6.4 Hz, 1H), 3.07 (q, *J* = 6.4 Hz, 2H), 2.42 (s, 3H), 2.33 (t, *J* = 6.6 Hz, 2H), 1.45 (s, 6H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.72, 137.21, 129.93, 127.21, 87.79, 78.34, 65.23, 42.00, 31.63, 21.69, 20.09; IR (neat): *v* =3285, 1598, 1432, 1324, 1157, 1093, 815, 664, 551 cm^{-1}; HRMS (ESI), calcd for $C_{14}H_{19}NO_3SNa$ $[M+Na]^+$ 304.0984, found 304.0950 m/z.



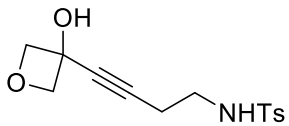
12q

125 mg, 62% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.68 (d, *J* = 8.3 Hz, 2H), 7.60 – 7.49 (m, 4H), 7.36 – 7.29 (m, 4H), 7.29 – 7.22 (m, 4H), 4.93 (t, *J* = 6.4 Hz, 1H), 3.13 (q, *J* = 6.5 Hz, 2H), 2.99 (s, 1H), 2.49 (t, *J* = 6.5 Hz, 2H), 2.41 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 145.15, 143.74, 137.08, 129.95, 128.45, 127.88, 127.21, 126.07, 85.93, 83.85, 74.49, 41.96, 21.71, 20.44; IR (neat): *v* =3284, 1597, 1449, 1324, 1157, 1093, 814, 754, 700, 662, 550 cm^{-1}; HRMS (ESI), calcd for $C_{24}H_{23}NO_3SNa$ $[M+Na]^+$ 428.1297, found 428.1320 m/z.



12r

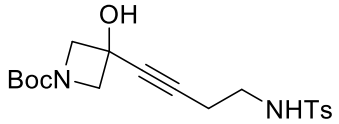
49.7 mg, 34% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 5.33 (t, *J* = 6.4 Hz, 1H), 3.08 (q, *J* = 6.4 Hz, 2H), 2.85 (s, 1H), 2.42 (s, 3H), 2.37 (t, *J* = 6.5 Hz, 2H), 2.34 – 2.27 (m, 2H), 2.20 (qd, *J* = 9.3, 2.8 Hz, 2H), 1.84 – 1.66 (m, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.72, 137.16, 129.93, 127.21, 86.52, 79.71, 67.93, 42.02, 38.65, 21.69, 20.27, 13.00; IR (neat): *v* =3282, 1770, 1598, 1423, 1325, 1157, 1093, 815, 661, 551 cm^{-1}; HRMS (ESI), calcd for $C_{15}H_{19}NO_3SNa$ $[M+Na]^+$ 316.0984, found 314.0950 m/z.



12s

82.4 mg, 56% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.77 (m, *J* = 8.3 Hz, 2H), 7.33 (m, *J* = 8.0 Hz, 2H), 5.16 (t, *J* = 6.4 Hz, 1H), 4.73 (d, *J* = 7.0 Hz, 2H), 4.66 (d, *J* = 7.0 Hz, 2H), 3.12 (q, *J* = 6.4 Hz, 2H), 3.04 (s, 1H), 2.54 – 2.33 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ

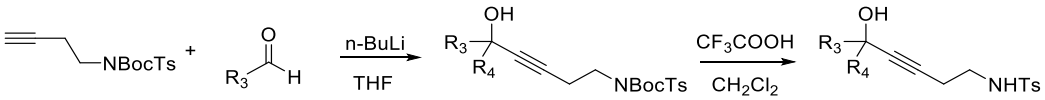
144.01, 137.01, 130.06, 127.23, 84.70, 83.13, 82.41, 67.18, 41.81, 21.75, 20.43; IR (neat): *v* =3283, 1597, 1422, 1323, 1154, 1092, 973, 815, 662, 550 cm^{-1}; HRMS (ESI), calcd for $C_{14}H_{17}NO_4SNa$ $[M+Na]^+$ 318.0777, found 318.0752 m/z.



12t

129 mg, 65% yield, white solid; ^1H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 7.9 Hz, 2H), 5.52 (s, 1H), 4.08 (d, *J* = 9.0, 2H), 3.97 (d, *J* = 9.0, 2H), 3.79 (s, 1H), 3.09 (q, *J* = 6.4 Hz, 2H), 2.43 (s, 3H), 2.40 (t, *J* = 6.3 Hz, 2H), 1.42 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 156.43, 143.92, 137.00, 130.03, 127.20, 83.16, 82.64, 80.19, 77.43, 62.09, 41.80, 28.53, 21.72, 20.37; IR (neat): *v* =3281, 1825, 1676, 1421, 1330, 1252, 1158, 1095, 815, 663, 551 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{23}N_2O_5SNa$ $[M+Na]^+$ 417.1461, found 417.1402 m/z.

General procedure of preparation of 12c, e, k：



S2 **S4c, e, k** **12c, e, k**

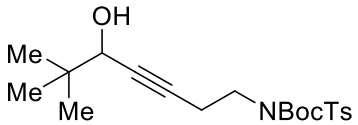
Step1:

To a stirred solution of **S2** (323 mg, 1.0 mmol) in dry THF (10 mL), a 2.5 M solution of *n*-BuLi (0.40 mL, 1.0 mmol) in hexane was added dropwise at -78 ˚C over 10 min under argon atmosphere. The reaction mixture was allowed to react at the same temperature and stirred for 1 h. The corresponding aldehyde (1.5 mmol) dissolved in 10 mL THF was added at -78 ˚C over 10 min. The mixture was allowed to warm up to room temperature and react for additional 1 h. The reaction was quenched by

saturated NH_4Cl solution (10 mL) and extracted with EtOAc for 3 times. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 5/1) to give **S4c, e, k**.

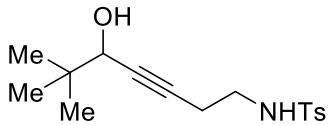
Step2:

To a stirred solution of **S4** (0.50 mmol) in dry CH_2Cl_2 (5 mL), 1.0 mL CF_3COOH was added dropwise at 0 ˚C over 10 min under argon atmosphere. The reaction mixture was allowed to warm up to room temperature and react for additional 3 h. The solvent was removed under reduced pressure and the residue was dissolved in EtOAc (5 mL). The organic layer was washed with saturated $NaHCO_3$ solution and brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 3/2) to give **12c, e, k**.



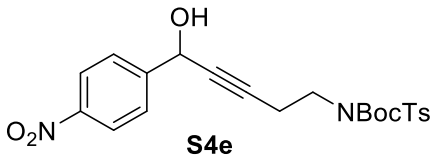
S4c

367 mg, 87% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.78 (d, *J* = 8.4 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 4.07 – 3.92 (m, 3H), 2.78 – 2.65 (m, 2H), 2.44 (s, 3H), 1.95 (d, *J* = 5.9 Hz, 1H), 1.33 (s, 9H), 0.97 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 150.95, 144.43, 137.50, 129.47, 127.98, 84.80, 82.43, 82.40, 71.68, 45.60, 35.91, 28.05, 25.48, 21.81, 20.29; IR (neat): *v* =3545, 1729, 1597, 1354, 1158, 1090, 674 cm^{-1}; HRMS (ESI), calcd for $C_{21}H_{32}NO_5S$ $[M+H]^+$ 410.2002, found 410.1994 m/z.



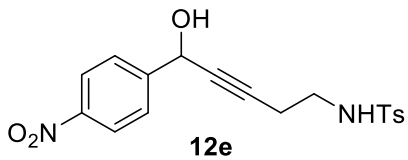
12c

28.6 mg, 18%, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.76 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 5.14 (t, *J* = 6.3 Hz, 1H), 3.94 (t, *J* = 2.0 Hz, 1H), 3.09 (q, *J* = 6.5 Hz, 2H), 2.42 (s, 3H), 2.37 (td, *J* = 6.6, 2.0 Hz, 2H), 2.04 (s, 1H), 0.93 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.75, 137.13, 129.95, 127.23, 82.60, 81.95, 71.52, 42.09, 35.88, 25.45, 21.69, 20.20; IR (neat): *v* =3280, 1598, 1324, 1158, 1094, 814, 662, 574 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{23}NO_3SNa$ $[M+Na]^+$ 332.1297, found 332.1272 m/z.



S4e

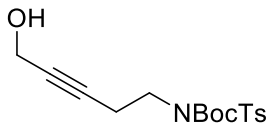
321 mg, 68%, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 8.21 (d, *J* = 8.8 Hz, 2H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.72 (d, *J* = 8.2 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 5.53 (s, 1H), 4.05 (t, *J* = 6.7 Hz, 2H), 3.02 (s, 1H), 2.74 (td, *J* = 6.7, 2.1 Hz, 2H), 2.44 (s, 3H), 1.31 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 150.87, 148.07, 147.79, 144.63, 137.35, 129.51, 127.93, 127.60, 123.86, 85.06, 84.95, 81.89, 63.77, 45.36, 28.02, 21.80, 20.22; IR (neat): *v* =3509, 1729, 1522, 1346, 1155, 672 cm^{-1}; HRMS (ESI), calcd for $C_{23}H_{27}N_2O_7S$ $[M+H]^+$ 475.1540, found 475.1536 m/z.



12e

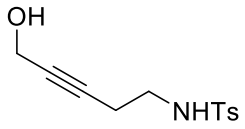
166 mg, 89% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 8.19 (d, *J* = 8.8 Hz, 2H), 7.74

(d, J = 8.3 Hz, 2H), 7.66 (d, J = 8.2 Hz, 2H), 7.30 (d, J = 7.8 Hz, 2H) 5.51 (d, J = 2.1 Hz, 1H), 5.22 (t, J = 6.5 Hz, 1H), 3.13 (q, J = 6.4 Hz, 2H), 2.50 – 2.35 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 147.73, 144.04, 136.97, 130.03, 128.88, 127.46, 127.20, 123.91, 84.38, 81.91, 63.65, 41.81, 21.73, 20.49; IR (neat): v =3280, 1591, 1519, 1345, 1157 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{18}N_2O_5SNa$ $[M+Na]^+$ 397.0835, found 397.0816 m/z.



S4k

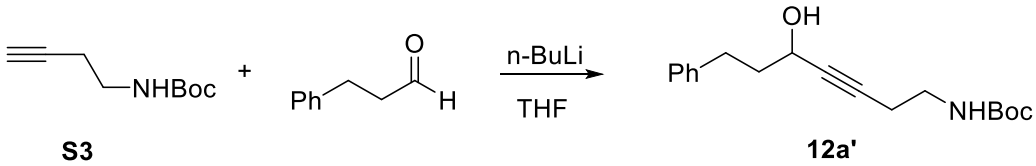
123 mg, 35%, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.79 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 7.7 Hz, 2H), 4.23 (t, J = 2.2 Hz, 2H), 4.00 (t, J = 7.1 Hz, 2H), 2.77 – 2.62 (m, 2H), 2.44 (s, 3H), 1.69 (br, 2H), 1.34 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 150.91, 144.47, 137.45, 129.47, 128.02, 84.79, 82.80, 81.05, 51.49, 45.52, 28.04, 21.81, 20.32; IR (neat): v =3529, 1727, 1351, 1291, 1155, 1090, 814, 673, 583 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{24}NO_5S$ $[M+H]^+$ 354.1376, found 354.1329 m/z.



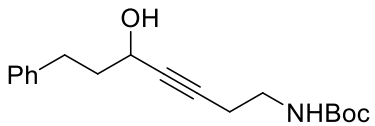
12k

41.1 mg, 33%, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.77 (d, J = 8.3 Hz, 2H), 7.31 (d, J = 7.7 Hz, 2H), 5.46 (br, 1H), 4.20 (t, J = 2.1 Hz, 2H), 3.08 (q, J = 6.2 Hz, 2H), 2.42 (s, 3H), 2.36 (tt, J = 6.4, 2.2 Hz, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.77, 137.07, 129.95, 127.21, 82.22, 81.18, 51.16, 41.92, 21.70, 20.27; IR (neat): v =3277, 1597, 1429, 1323, 1157, 1093, 816, 662, 549 cm^{-1}; HRMS (ESI), calcd for $C_{12}H_{15}NO_3SNa$ $[M+Na]^+$ 276.0668 found 276.0623 m/z.

Preparation of 12a'：

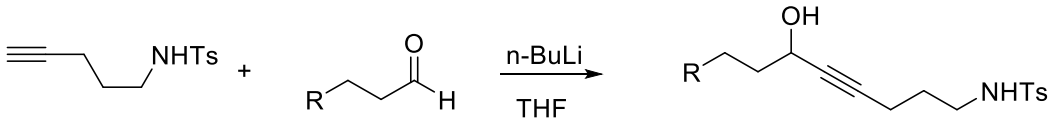


To a stirred solution of **S3** (85 mg, 0.50 mmol) in dry THF (5 mL), a 2.5 M solution of *n*-BuLi (0.39 mL, 0.98 mmol) in hexane was added dropwise at -78 ˚C over 10 min under argon atmosphere. The reaction mixture was allowed to react at the same temperature and stirred for 1 h. 3-Phenylpropanal (200 mg, 1.5 mmol) was added at -78 ˚C over 10 min. The mixture was allowed to warm up to room temperature and react for additional 1 h. The reaction was quenched with saturated NH_4Cl solution (5 mL) and extracted with EtOAc for 3 times. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 3/1) to give a clear, colorless oil.



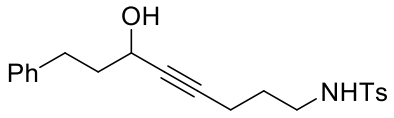
94 mg, 62% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.32 – 7.25 (m, 2H), 7.24 – 7.16 (m, 3H), 4.82 (s, 1H), 4.44 – 4.27 (m, 1H), 3.28 (q, *J* = 6.4 Hz, 2H), 2.78 (t, *J* = 7.8 Hz, 2H), 2.42 (td, *J* = 6.5, 2.0 Hz, 2H), 2.15 – 1.85 (m, 2H), 1.44 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 155.96, 141.49, 128.66, 128.61, 126.15, 83.12, 82.77, 79.72, 62.06, 39.65, 31.64, 28.58, 20.53; IR (neat): *v* =3355, 1690, 1514, 1251, 1169, 1060, 699 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{25}NO_3Na$ $[M+Na]^+$ 326.1732, found 326.1717 m/z.

Preparation of 15a, b:



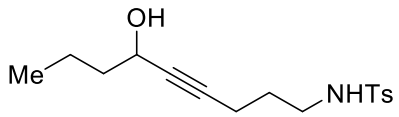
S5 **15a: R=Ph; 15b: R=Me.**

To a stirred solution of **S5**[1] (237 mg, 1.0 mmol) in dry THF (10 mL), a 2.5 M solution of *n*-BuLi (0.80 mL, 2.0 mmol) in hexane was added dropwise at -78 ˚C over 10 min under argon atmosphere. The reaction mixture was allowed to react at the same temperature and stirred for 1 h. The corresponding aldehyde (3.0 mmol) dissolved in 10 mL THF was added at -78 ˚C over 10 min. The mixture was allowed to warm up to room temperature and react for additional 1 h. The reaction was quenched with saturated NH_4Cl solution (10 mL) and extracted with EtOAc for 3 times. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 3/2) to give **15a, b.**



15a

332 mg, 89% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.25 (m, 4H), 7.21 – 7.16 (m, 3H), 5.14 (t, *J* = 6.3 Hz, 1H), 4.44 – 4.26 (m, 1H), 3.05 (q, *J* = 6.6 Hz, 2H), 2.74 (t, *J* = 7.9 Hz, 2H), 2.43 (d, *J* = 5.3 Hz, 1H), 2.39 (s, 3H), 2.26 (td, *J* = 6.8, 2.0 Hz, 2H), 2.05 – 1.88 (m, 2H), 1.67 (p, *J* = 6.7 Hz, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.57, 141.53, 136.98, 129.86, 128.61, 128.53, 127.19, 126.05, 84.21, 82.60, 61.93, 42.28, 39.59, 31.58, 28.29, 21.64, 16.14; IR (neat): *v* =3277, 1599, 1453, 1321, 1154, 1093, 814, 669, 661, 549 cm^{-1}; HRMS (ESI), calcd for $C_{21}H_{25}NO_3SNa$ $[M+Na]^+$ 394.1451, found 394.1378 m/z.



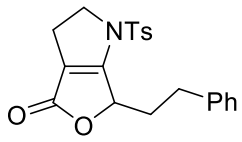
15b

296 mg, 76% yield, colorless oil;^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 5.29 (t, *J* = 6.3 Hz, 1H), 4.28 (tt, *J* = 6.7, 2.0 Hz, 1H), 3.02 (q, *J* = 6.6 Hz, 2H), 2.40 (s, 4H), 2.22 (td, *J* = 6.8, 2.0 Hz, 2H), 1.75 – 1.48 (m, 4H), 1.48 – 1.32 (m, 2H), 0.89 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 143.49, 137.00, 129.82, 127.18, 83.67, 82.86, 62.35, 42.24, 40.19, 28.28, 21.62, 18.58, 16.09, 13.86; IR (neat): *v* =3280, 1598, 1431, 1322, 1155, 1093, 1019, 814, 661, 550 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{23}NO_3SNa$ $[M+Na]^+$ 332.1297, found 332.1211 m/z.

III. Palladium-Catalyzed carbonylation

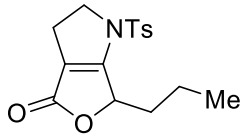
General procedure of preparation of 13a-t and 16a, b：

$Pd(MeCN)_2Cl_2$ (2.6 mg, 0.01 mmol), AgOTf (5.2 mg, 0.02 mmol) and ligand **G** (3.6 mg, 0.01 mmol) were dissolved in dry MeCN (2 mL) and allowed to react for 1 h under argon atmosphere. DDQ (34.1 mg, 0.15 mmol) and **12 a-t** or **15a, b** (0.1 mmol) were added and the reaction was filled by CO balloon. The mixture was allowed to react at room temperature. The reaction was monitored by TLC until no starting material left. The solvent was removed under reduced pressure and the residue was dissolved in $CHCl_3$ (1 mL). The crude product in $CHCl_3$ was purified by flash column chromatography ($CHCl_3$ then hexane/ethyl acetate = 5/1) to give **13a-t** or **16a,b**, respectively.



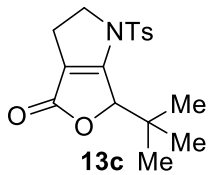
13a

38.3 mg, 90% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.59 (d, *J* = 8.3 Hz, 2H), 7.36 – 7.28 (m, 4H), 7.27 – 7.19 (m, 3H), 5.17 – 5.14 (m, 1H), 4.23 (td, *J* = 10.8, 6.5 Hz, 1H), 4.00 (td, *J* = 10.8, 8.0 Hz, 1H), 2.85 – 2.80 (m, 2H), 2.74 – 2.53 (m, 3H), 2.45 (s, 3H), 2.25 – 2.06 (m, 1H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.92, 167.24, 145.74, 140.28, 132.97, 130.55, 128.84, 128.62, 127.59, 126.37, 116.52, 77.01, 57.27, 34.17, 30.83, 22.85, 21.82; IR (neat): *v* =1755, 1651, 1405, 1363, 1167, 671, 576, 544 cm^{-1}; HRMS (ESI), calcd for $C_{21}H_{22}NO_4S$ $[M+H]^+$ 384.1270, found 384.1308 m/z.



13b

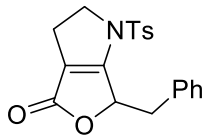
29.1 mg, 91% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 7.9 Hz, 2H), 5.31 – 5.09 (m, 1H), 4.30 (td, *J* = 10.9, 6.5 Hz, 1H), 4.03 (td, *J* = 10.8, 7.7 Hz, 1H), 2.77 – 2.55 (m, 2H), 2.47 (s, 3H), 2.30 – 2.14 (m, 1H), 1.87 – 1.67 (m, 1H), 1.53 – 1.43 (m, 2H), 0.98 (t, *J* = 7.4 Hz, 3H).^{13}C NMR (125 MHz, Chloroform-*d*) δ 172.19, 167.39, 145.77, 132.98, 130.56, 127.67, 116.51, 78.01, 57.16, 35.05, 22.91, 21.84, 18.02, 13.72; IR (neat): *v* =1755, 1848, 1407, 1362, 1168, 671, 575 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{20}NO_4S$ $[M+H]^+$ 322.1114, found 322/1165 m/z.



13c

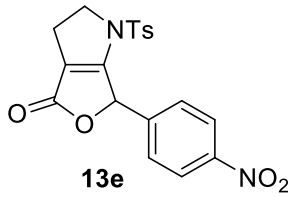
31.1 mg, 93% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 8.4 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 5.08 (dd, *J* = 2.5, 1.1 Hz, 1H), 4.27 (dt, *J* = 12.6, 10.4 Hz, 1H), 4.15 (ddd, *J* = 12.6, 9.4, 3.1 Hz, 1H), 2.46 (s, 3H), 2.36 (dddd, *J* = 15.6, 10.3, 3.1, 1.1 Hz, 1H), 2.07 (dddd, *J* = 15.6,

10.4, 9.4, 2.5 Hz, 1H), 1.09 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.78, 167.29, 145.76, 132.69, 130.49, 127.84, 124.65, 86.23, 58.23, 36.51, 26.06, 23.13, 21.86; IR (neat): *v* =1760, 1653, 1364, 1167, 979, 677, 576 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{22}NO_4S$ $[M+H]^+$ 336.1270, found 336.1257 m/z.



13d

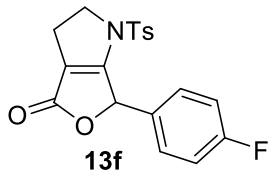
33.7 mg, 91% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.70 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.1 Hz, 2H), 7.33 – 7.23 (m, 5H), 7.23 (tt, *J* = 5.6, 1.9 Hz, 2H), 5.40 (dp, *J* = 5.5, 1.6 Hz, 1H), 4.20 (td, *J* = 10.9, 6.1 Hz, 1H), 3.90 (td, *J* = 10.7, 7.9 Hz, 1H), 3.52 (dd, *J* = 14.3, 3.4 Hz, 1H), 3.22 (dd, *J* = 14.3, 5.8 Hz, 1H), 2.50 – 2.32 (m, 5H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 170.66, 166.79, 145.84, 134.61, 132.74, 130.60, 129.97, 128.45, 127.70, 127.36, 117.78, 77.92, 56.94, 38.84, 22.76, 21.83; IR (neat): *v* =1758, 1653, 1362, 1166, 1031, 671, 577 cm^{-1}; HRMS (ESI), calcd for $C_{20}H_{20}NO_4S$ $[M+H]^+$ 370.1114, found 370.1098 m/z.



13e

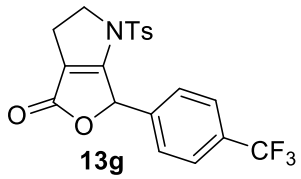
20.5 mg, 51% yield, light yellow solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 8.8 Hz, 2H), 7.58 (d, *J* = 8.8 Hz, 2H), 7.25 – 7.19 (m, 4H), 6.23 (s, 1H), 4.35 (td, *J* = 10.4, 7.7 Hz, 1H), 4.22 (td, *J* = 10.6, 8.0 Hz, 1H), 2.89 – 2.85 (m, 2H), 2.42 (s, 3H).; ^{13}C NMR (125 MHz, Chloroform-*d*) δ 170.85, 166.40, 148.84, 145.90, 140.54, 133.43, 130.38, 129.41, 127.28, 124.14, 115.61, 57.14, 23.29, 21.83;

IR (neat): *v* =1759, 1649, 1522, 1347, 1166, 1101, 975, 669, 577 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{17}N_2O_6S$ $[M+H]^+$ 401.0808, found 401.0790 m/z.



13f

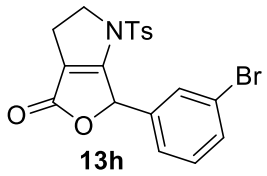
30.9 mg, 83% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.37 – 7.31 (m, 2H), 7.21 – 7.15 (m, 2H), 7.12 – 7.05 (m, 4H), 6.13 (S, 1H), 4.40 (td, *J* = 10.8, 6.8 Hz, 1H), 4.15 (ddd, *J* = 11.3, 10.4, 7.5 Hz, 1H), 2.99 – 2.75 (m, 2H), 2.40 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.21, 167.01, 164.63, 162.65, 145.37, 133.83, 130.40 (d, *J* = 8.5 Hz), 130.15, 127.25, 116.03 (d, *J* = 21.8 Hz), 114.66, 78.10, 56.94, 23.14, 21.76; ^{19}F NMR (470 MHz, Chloroform-*d*) δ -112.27 (s); IR (neat): *v* =1759, 1650, 1410, 1324, 1165, 1113, 1066, 975, 673, 577, 542 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{17}FNO_4S$ $[M+H]^+$ 374.0863, found 374.0913 m/z.



13g

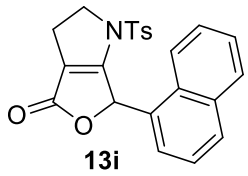
28.8 mg, 68% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 8.1 Hz, 2H), 7.49 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 8.5 Hz, 2H), 7.03 (d, *J* = 8.4 Hz, 2H), 6.19 (s, 1H), 4.42 (td, *J* = 10.8, 6.8 Hz, 1H), 4.17 (ddd, *J* = 11.3, 10.5, 7.6 Hz, 1H), 3.00 – 2.75 (m, 2H), 2.38 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.02, 166.80, 145.50, 137.50, 133.74, 132.04 (q, *J* = 32.7 Hz), 130.14, 128.96, 127.09, 125.96 (q, *J* = 4.3 Hz), 114.74, 77.83, 57.03, 29.86, 23.18, 21.73; ^{19}F NMR (470 MHz, Chloroform-*d*) δ -63.86 (m); IR (neat): *v* =1756, 1650, 1510, 1408, 1361, 1167, 1105, 971, 670, 574

cm^{-1}; HRMS (ESI), calcd for $C_{20}H_{17}F_3NO_4S$ $[M+H]^+$ 424.0831, found 424.0872 m/z.



13h

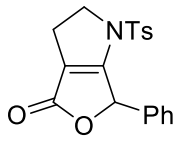
37.8 mg, 87% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.57 (ddd, *J* = 7.9, 2.0, 1.2 Hz, 1H), 7.41 – 7.33 (m, 2H), 7.29 (t, *J* = 7.8 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 8.4 Hz, 2H), 6.09 (s, 1H), 4.42 (td, *J* = 10.7, 6.9 Hz, 1H), 4.17 (ddd, *J* = 11.2, 10.4, 7.7 Hz, 1H), 2.97 – 2.75 (m, 2H), 2.40 (s, 4H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 170.83, 166.84, 145.39, 135.74, 133.72, 132.98, 130.86, 130.60, 130.22, 127.74, 127.18, 122.99, 114.75, 77.91, 56.99, 23.14, 21.77; IR (neat): *v* =1758, 1647, 1361, 1167, 1107, 974, 669, 576 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{17}BrNO_4S$ $[M+H]^+$ 424.0062, found 424.0040 m/z.



13i

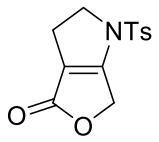
13.3 mg, 33% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 8.22 (d, *J* = 8.4 Hz, 1H), 7.94 – 7.91 (m, 2H), 7.62 (ddd, *J* = 8.5, 6.8, 1.5 Hz, 1H), 7.56 (ddd, *J* = 8.0, 6.8, 1.2 Hz, 1H), 7.36 (dd, *J* = 8.2, 7.1 Hz, 1H), 7.31 – 7.20 (m, 1H), 7.10 (s, 4H), 6.97 (t, *J* = 1.8 Hz, 1H), 4.51 (td, *J* = 10.7, 7.4 Hz, 1H), 4.34 (td, *J* = 10.8, 7.4 Hz, 1H), 3.12 – 2.78 (m, 2H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.11, 167.09, 145.22, 134.09, 133.90, 131.96, 130.67, 130.04, 129.77, 128.96, 127.41, 127.35, 126.51, 125.96, 125.16, 123.35, 116.06, 75.48, 57.15, 23.38, 21.77; IR (neat): *v* =1755, 1650, 1411, 1361, 1167, 1036, 958, 671, 576 cm^{-1}; HRMS (ESI), calcd for $C_{23}H_{20}NO_4S$ $[M+H]^+$

406.1114, found 406.1110 m/z.



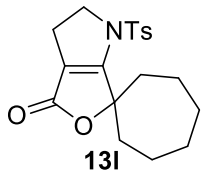
13j

18.7 mg, 53% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.50 –7.33 (m, 5H), 7.11 (d, *J* = 8.1 Hz, 2H), 6.99 (d, *J* = 8.4 Hz, 2H), 6.15 (s, 1H), 4.42 (td, *J* = 10.8, 6.6 Hz, 1H), 4.11 (ddd, *J* = 11.3, 10.4, 7.6 Hz, 1H), 3.02 – 2.75 (m, 2H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 171.25, 167.17, 144.95, 133.70, 133.35, 129.91, 129.72, 128.90, 128.38, 127.19, 114.16, 78.76, 56.67, 22.97, 21.58; IR (neat): *v* =1754, 1646, 1410, 1360, 1167, 1104, 969, 670, 576 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{18}NO_4S$ $[M+H]^+$ 356.0957, found 356.0963 m/z.



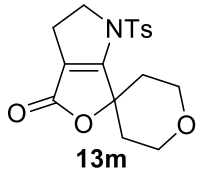
13k

13.7 mg, 49% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.70 (d, *J* = 8.4 Hz, 2H), 7.40 (d, *J* = 8.0 Hz, 2H), 5.01 (t, *J* = 2.0 Hz, 2H), 4.18 (dd, *J* = 9.5, 8.5 Hz, 2H), 2.85 – 2.69 (m, 2H), 2.47 (s, 3H). ^{13}C NMR (125 MHz, Chloroform-*d*) δ 170.04, 167.75, 145.89, 133.14, 130.67, 127.57, 114.26, 65.67, 56.67, 23.43, 21.88; IR (neat): *v* =1757, 1653, 1424, 1361, 1166, 1108, 986, 671, 576, 544 cm^{-1}; HRMS (ESI), calcd for $C_{13}H_{14}NO_4S$ $[M+H]^+$ 280.0641, found 280.0612 m/z.



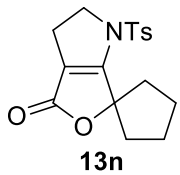
13l

33.8 mg, 94% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.0 Hz, 2H), 4.27 – 4.04 (m, 2H), 2.70 – 2.63 (m, 2H), 2.46 (s, 3H), 1.97 – 1.80 (m, 4H), 1.80 – 1.67 (m, 5H), 1.67 – 1.47 (m, 3H), 1.42 (q, *J* = 6.0, 5.6 Hz, 1H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 176.07, 166.89, 145.31, 133.86, 130.26, 127.64, 113.55, 87.77, 57.48, 36.83, 26.92, 22.64, 21.78, 21.68; IR (neat): *v* =1751, 1639, 1360, 1167, 670, 577, 544 cm^{-1}; HRMS (ESI), calcd for $C_{19}H_{24}NO_4S$ $[M+H]^+$ 362.1427, found 362.1399 m/z.



13m

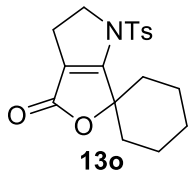
24.6 mg, 71% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 4.25 – 4.15 (m, 2H), 3.99 – 3.96 (m, 2H), 3.85 (td, *J* = 12.4, 2.0 Hz, 2H), 2.86 (td, *J* = 13.0, 5.5 Hz, 2H), 2.73 – 2.64 (m, 2H), 2.47 (s, 3H), 1.56 (d, *J* = 13.3 Hz, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 173.53, 166.10, 145.64, 133.80, 130.50, 127.69, 115.78, 82.27, 63.86, 57.70, 33.52, 22.06, 21.84; IR (neat): *v* =1751, 1637, 1395, 1359, 1165, 1055, 670, 581, 544 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{20}NO_5S$ $[M+H]^+$ 350.1063, found 350.1029 m/z.



13n

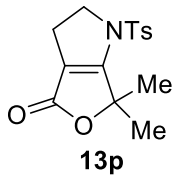
28.1 mg, 84% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.72 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 4.27 – 4.12 (m, 2H), 2.73 – 2.65 (m, 2H), 2.65 – 2.54 (m, 2H), 2.47 (s, 3H), 2.03 – 1.84 (m, 6H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 172.04, 166.61, 145.49, 134.00, 130.47, 127.63,

116.09, 92.55, 57.53, 37.15, 25.00, 22.24, 21.84; IR (neat): v =1751, 1639, 1398, 1360, 1168, 1067, 978, 669, 580, 544 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{20}NO_4S$ $[M+H]^+$ 334.1114, found 334.1082 m/z.



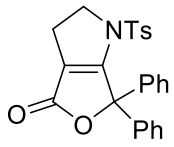
13o

30.3 mg, 87% yield, white solid; ^1H NMR (500 MHz, Chloroform-*d*) δ 7.78 – 7.67 (m, 2H), 7.45 – 7.34 (m, 2H), 4.22 – 4.06 (m, 2H), 2.65 (dd, J = 9.8, 8.7 Hz, 2H), 2.55 – 2.40 (m, 5H), 1.82 – 1.63 (m, 7H), 1.45 – 1.23 (m, 1H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 175.03, 166.83, 145.44, 133.88, 130.42, 127.70, 115.37, 85.24, 57.68, 33.41, 24.22, 22.07, 22.00, 21.82; IR (neat): v =1746, 1637, 1392, 1360, 1167, 1089, 1066, 670, 578, 544 cm^{-1}; HRMS (ESI), calcd for $C_{18}H_{22}NO_4S$ $[M+H]^+$ 348.1270, found 348.1230 m/z.



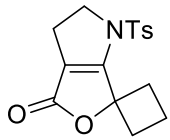
13p

30.0 mg, 98% yield or 1.44 g, 94%; white solid; ^1H NMR (500 MHz, Chloroform-*d*) δ 7.73 (d, J = 8.4 Hz, 2H), 7.39 (d, J = 8.0 Hz, 2H), 4.27 – 4.07 (m, 2H), 2.75 – 2.60 (m, 2H), 2.46 (s, 3H), 1.78 (s, 6H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 174.81, 166.42, 145.53, 133.78, 130.44, 127.74, 114.79, 83.14, 57.48, 25.36, 22.11, 21.82; IR (neat): v =1752, 1641, 1396, 1357, 1164, 1091, 671, 568, 544 cm^{-1}; HRMS (ESI), calcd for $C_{15}H_{18}NO_4S$ $[M+H]^+$ 308.0957, found 308.0969 m/z.



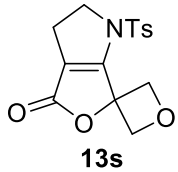
13q

16.4 mg, 38% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.53 – 7.48 (m, 4H), 7.48 – 7.38 (m, 6H), 7.03 (d, *J* = 8.0 Hz, 2H), 6.59 (d, *J* = 8.3 Hz, 2H), 4.39 – 4.19 (m, 2H), 2.83 (t, *J* = 9.3 Hz, 2H), 2.36 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 172.00, 166.59, 145.03, 136.96, 133.04, 129.90, 129.65, 129.18, 128.22, 127.90, 116.24, 89.91, 57.50, 22.16, 21.72; IR (neat): *v* =1757, 1636, 1391, 1365, 1092, 559, 578 cm^{-1}; HRMS (ESI), calcd for $C_{25}H_{22}NO_4S$ $[M+H]^+$ 432.1270, found 432.1238 m/z.



13r

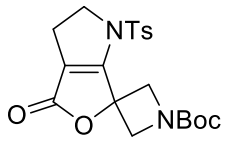
27.7 mg, 87% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.74 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 4.27 – 4.07 (m, 2H), 3.35 – 3.04 (m, 2H), 2.74 – 2.55 (m, 2H), 2.55 – 2.39 (m, 5H), 2.39 – 2.18 (m, 1H), 2.18 – 1.94 (m, 1H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 170.67, 166.36, 145.50, 133.94, 130.51, 127.57, 116.28, 85.60, 57.48, 32.29, 22.23, 21.83, 14.85; IR (neat): *v* =1751, 1634, 1400, 1359, 1258, 1163, 1089, 1053, 670, 579, 543 cm^{-1}; HRMS (ESI), calcd for $C_{16}H_{18}NO_4S$ $[M+H]^+$ 320.0957, found 320.0955 m/z.



13s

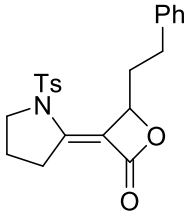
31.9 mg, 99% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.79 (d, *J* = 8.4 Hz, 2H), 7.41 (d,

J = 8.4 Hz, 2H), 5.37 (dd, *J* = 7.3, 1.1 Hz, 2H), 4.93 (dd, *J* = 7.3, 1.2 Hz, 2H), 4.37 – 4.19 (m, 2H), 2.80 – 2.65 (m, 2H), 2.47 (s, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 166.59, 164.96, 145.93, 133.90, 130.61, 127.68, 116.89, 82.06, 78.05, 57.58, 22.34, 21.86; IR (neat): *v* =1765, 1637, 1411, 1361, 1167, 1091, 671, 581 cm^{-1}; HRMS (ESI), calcd for $C_{15}H_{16}NO_5S$ $[M+H]^+$ 322.0750, found 322.0743 m/z.



13t

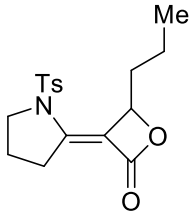
30.0 mg, 71% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.80 (d, *J* = 8.4 Hz, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 4.77 – 4.56 (m, 2H), 4.47 – 4.10 (m, 4H), 2.89 – 2.65 (m, 2H), 2.48 (s, 3H), 1.47 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 168.15, 165.25, 156.63, 145.90, 133.98, 130.66, 127.77, 116.08, 80.57, 59.40, 57.97, 57.42, 28.49, 22.46, 21.88; IR (neat): *v* =1769, 1704, 1416, 1366, 1166, 1053, 671 cm^{-1}; HRMS (ESI), calcd for $C_{20}H_{25}N_2O_6S$ $[M+H]^+$ 421.1434, found 431.1374 m/z.



16a

15.2 mg, 40% yield, white solid; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.65 (d, *J* = 8.2 Hz, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 7.30 – 7.17 (m, 5H), 5.34 (d, *J* = 7.9 Hz, 1H), 3.73 – 3.69 (m, 1H), 3.39 – 3.34 (m, 1H), 3.05 (ddd, *J* = 16.6, 7.2, 4.3 Hz, 1H), 2.99 – 2.72 (m, 2H), 2.68 – 3.61 (m, 1H), 2.59 – 2.48 (m, 1H), 2.45 (s, 3H), 2.24 – 2.07 (m, 1H), 1.88 – 1.70 (m, 2H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 166.13, 145.49, 143.82, 141.35, 133.96, 130.34, 128.70, 128.53, 127.34, 126.05, 112.94, 80.38, 51.97,

34.10, 32.33, 31.07, 21.85; IR (neat): ν =1784, 1692, 1363, 1205, 1165, 1086, 813, 671, 589, 544 cm^{-1}; HRMS (ESI), calcd for $C_{22}H_{24}NO_4S$ $[M+H]^+$ 398.1427, found 398.1356 m/z.

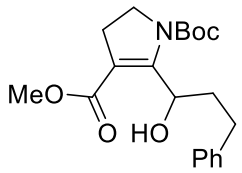


16b

6.0 mg, 18% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.36 (d, *J* = 7.8 Hz, 2H), 5.33 (d, *J* = 8.5 Hz, 1H), 3.85 – 3.69 (m, 1H), 3.37 (ddd, *J* = 9.9, 8.8, 6.8 Hz, 1H), 3.11 (ddd, *J* = 16.5, 7.3, 4.0 Hz, 1H), 2.59 – 2.37 (m, 5H), 2.37 – 2.22 (m, 1H), 1.97 – 1.63 (m, 4H), 1.60 – 1.47 (m, 3H), 0.98 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 166.33, 145.48, 143.46, 133.94, 130.35, 127.41, 113.79, 81.25, 51.93, 34.79, 32.28, 21.98, 21.86, 18.44, 13.99; IR (neat): ν =1713, 1327, 1159, 1094, 815, 664, 550 cm^{-1}; HRMS (ESI), calcd for $C_{17}H_{22}NO_4S$ $[M+H]^+$ 336.1270, found 336.1236 m/z.

Preparation of 14[4]***:***

$Pd(tfa)_2$ (3.3 mg, 0.01 mmol) and *p*-benzoquinone (16.2 mg, 0.15 mmol) were dissolved in dry MeOH (3 mL) and DMSO (0.33 mL) was added dropwise at 0 ^oC to react for 10 min under argon atmosphere. **12'** (30.3 mg, 0.10 mmol) was added and the reaction was filled by CO balloon. The mixture was allowed to react at room temperature. After 48 h, 5% NaOH (5 mL) was added to the mixture and was extracted by CH_2Cl_2 (5 mL for each) three times. The solvent was removed under vacuum and purified by flash column chromatography (hexane/ethyl acetate = 5/1) to give colorless oil.



14

8.6 mg, 24% yield, colorless oil; ^{1}H NMR (500 MHz, Chloroform-*d*) δ 7.26 (m, 2H), 7.23 – 7.11 (m, 3H), 5.77 (d, *J* = 12.1 Hz, 1H), 5.67 – 5.62 (m, 1H), 3.80 – 3.61 (m, 5H), 3.01 – 2.89 (m, 1H), 2.76 – 2.58 (m, 3H), 2.22 – 2.15 (m, 1H), 2.02 – 1.95 (m, 1H), 1.50 (s, 9H); ^{13}C NMR (125 MHz, Chloroform-*d*) δ 166.77, 157.54, 153.01, 142.34, 128.65, 128.38, 125.83, 110.85, 82.71, 66.08, 51.70, 48.23, 36.67, 32.42, 28.40, 27.51; IR (neat): *v* =1715, 1681, 1453, 1403, 1308, 1251, 1158 cm^{-1}; HRMS (ESI), calcd for $C_{20}H_{28}NO_5$ $[M+H]^+$ 475.1540, found 475.1536 m/z.

References

[1] Wang, X.; Yao, Z.; Dong, S.; Wei, F.; Wang, H.; Xu, Z. *Org. Lett.*, **2013**, *15*, 2234

[2] Teichert, J. F.; Zhang, S., Zijl, A. W.; Slaa, J. W.; Minnaard, A. J.; Feringa, B. L. *Org. Lett.*, **2010**, *12*, 4658.

[3]Tran, G.; Pardo, D. G.; Tsuchiya, T.; Hillebrand, S.; Vors, J-P.; Sossy, J. *Org. Lett.*, **2015**, *17* , 3414

[4] Shen, R.; Kusakabe, T.; Takahashi, K.; Kato, K. *Org. Biomol. Chem.,* **2014**, *12*, 4602.

Part 2. Biological Evaluations

Brief summary: The broth microdilution assay was utilized to determine the minimum inhibitory concentration (MIC) of the new compounds against important bacterial (Methicillin-resistant *Staphylococcus aureus* (MRSA), *Enterococcus faecium*, *Acinetobacter baumannii, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Clostridium difficile*) and fungal pathogens (*Candida albicans, Candida glabrata, Candida krusei, Cryptococcus gattii, Cryptococcus neoformans, Aspergillus fumigatus, Aspergillus niger,* and *Aspergillus brasiliensis*) following the guidelines of the Clinical and Laboratory Standards Institute.

Antibacterial:

Two compounds, **13h** and **13s**, exhibited activity against toxigenic strains of *C. difficile* (Table 1). Interestingly, these two compounds did not show side effect on beneficial intestinal microflora (Table 2).

We evaluated the toxicity of compounds **13h** and **13s** against Caco-2 cell line. None of the compounds showed toxicity up to 256 μM Figure 1.

Antifungal:

Four compounds (**13h**, **13k**, **13s**, and **16b**) showed activity against important yeast and mold pathogens (Table 3).

Table (1): MIC (μM) of active compounds against *C. difficile* strains

Strains	13h	13s	Vancomycin
C. difficile P 8	128	64	1
C. difficile BAA1870	128	>128	1
C. difficile P 20	128	128	1
C. difficile P 7	>128	128	1
C. difficile P 21	128	128	0.25

Table (2): MIC (μM) of active compounds against human normal microflora

Strain	13h	13s	Vancomycin
Bacteroides dorei HM-717	>256	>256	>8
Bifidobacterium longum HM-848	>256	>256	2
Lactobacillus casei ATCC-334	>256	>256	>8
Lactobacillus gasseri HM-400	>256	>256	>8
Bifidobacterium longum HM-845	>256	>256	0.5
Bacteroides fragilis HM-711	>256	>256	>8

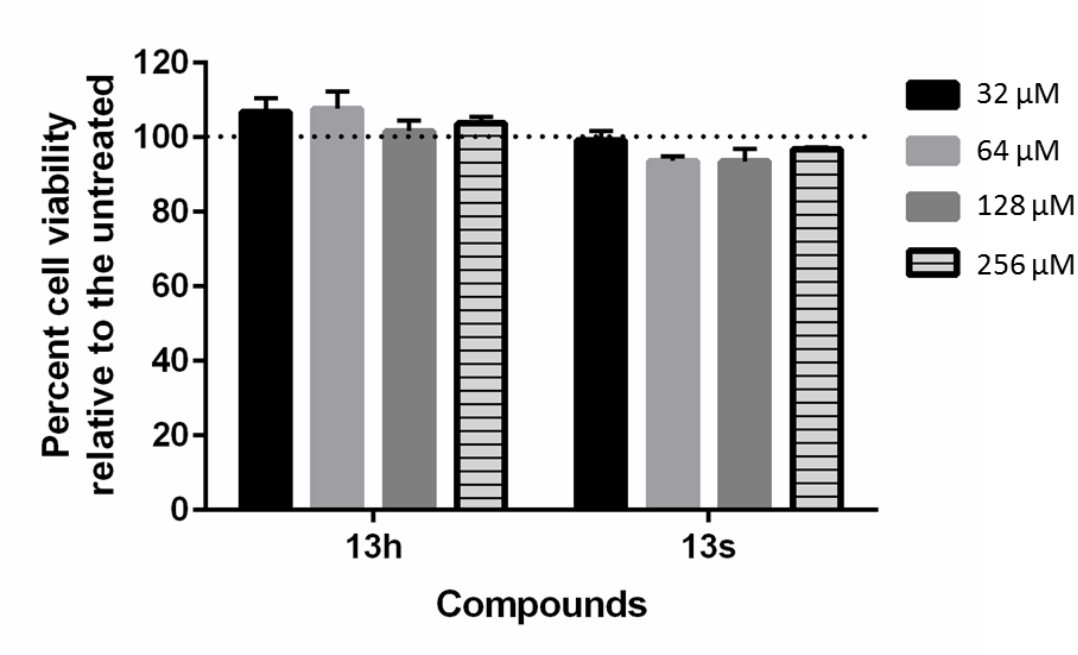


Figure (1): Toxicity of **13h** and **13s** against Caco-2 cell line
(*)= significantly difference ($P<0.05$)

Supplementary table 1: C. difficile strains used in this study

Strain	ID number	Source	Comments
C. difficile P 8	NR-32888	Fecal material of a human patient with a *C. difficile* infection in western Pennsylvania, USA in 2011	It was deposited as a toxigenic strain. The complete genome of *C. difficile*, strain P8 is available (GenBank: AVLR00000000).
C. difficile 1870	ATCC BAA1870	Human feces (adult with diarrhea) in Belgium.	Toxigenic, Binary Toxin gene cdtB was amplified by PCR. Presence of tcdA and tcdB genes confirmed by PCR. Toxinotype IIIb
C. difficile P 20	NR-32896	Fecal material of a human patient with a relapsing *C. difficile* infection in western Pennsylvania, USA in 2005.	It was deposited as a toxigenic strain. The complete genome of *C. difficile*, strain P20 is available (GenBank: AVLX00000000).
C. difficile P 7	NR-32887	Fecal material of a human patient with a *C. difficile* infection in western Pennsylvania, USA in 2001	It was deposited as a toxigenic strain. The complete genome of *C. difficile*, strain P7 is available (GenBank: AVLQ00000000).
C. difficile P 21	NR-32897	Fecal material of a human patient with a relapsing *C. difficile* infection in western Pennsylvania, USA in 2005	Strain P21 was deposited as a toxigenic strain The complete genome of *C. difficile*, strain P21 is available (GenBank: AVLY00000000).
Bacteroides dorei	HM-717 (CL02T00C 15)	Healthy adult human feces in Boston, Massachusetts, USA.	Reference genome for The Human Microbiome Project (HMP)
Bifidobacterium longum	HM-848 (2-2B)	Six-year-old human patient.	Reference genome for The Human Microbiome Project (HMP), It was sequenced at the J. Craig Venter Institute (GenBank: AJTJ00000000).
Lactobacillus casei	ATCC-334	Dairy products; emmental cheese	-----
Lactobacillus gasseri	HM-400 (EX336960 VC03)	-----	Reference genome for The Human Microbiome Project (HMP)
Bifidobacterium longum	HM-845	One-year-old human patient.	Reference genome for The Human Microbiome Project (HMP ID 1312).
Bacteroides fragilis	HM-711	Healthy adult feces in Boston, Massachusetts, USA.	Reference genome for The Human Microbiome Project (HMP ID 1079).

Table 3. Minimum inhibitory concentration (MIC, in µM) of compounds against important fungal pathogens.

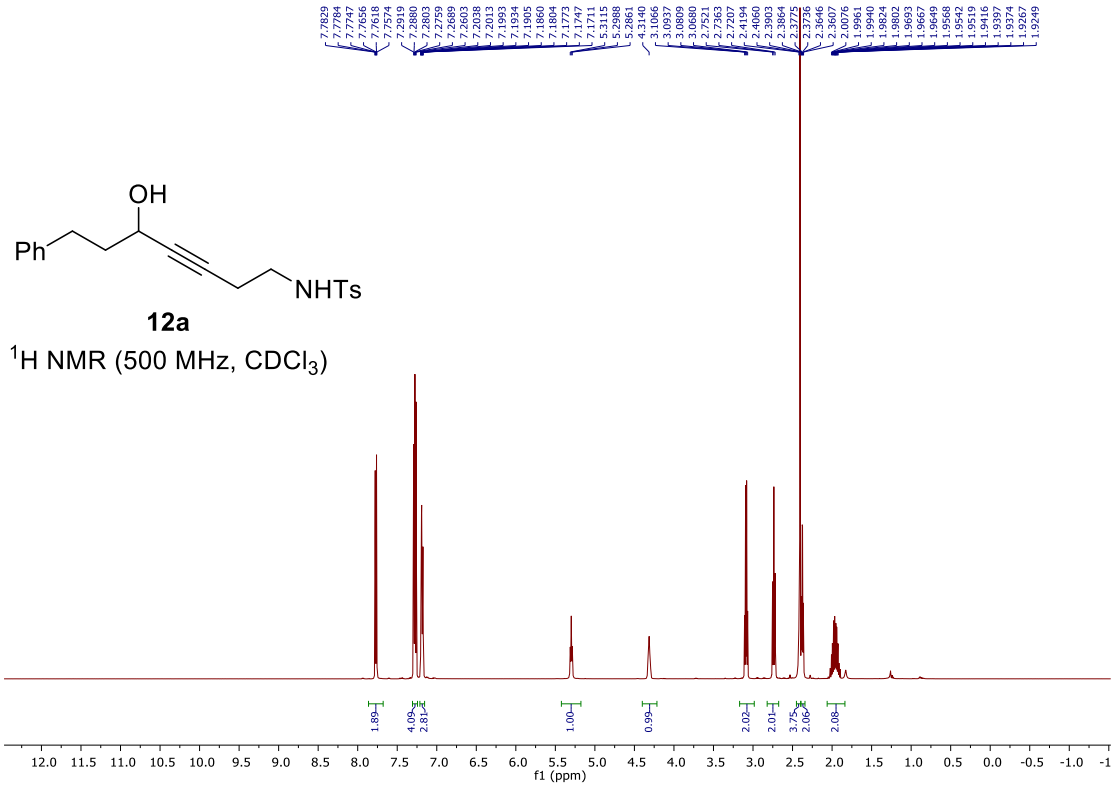
	Fungal Strain							
Compound Name/Antibiotic	***Candida albicans* ATCC 64124**	***Candida glabrata* ATCC 64677**	***Candida krusei* ATCC 34135**	***Cryptococcus gattii* NR-43208**	***Cryptococcus neoformans* NR-48767**	***Aspergillus fumigatus* NR-35302**	***Aspergillus niger* ATCC 16888**	***Aspergillus brasiliensis* ATCC 16404**
13h	128	64	128	64	64	64	> 128	> 128
13k	128	128	128	128	128	> 128	> 128	> 128
13s	> 128	128	> 128	128	128	> 128	> 128	> 128
16b	128	64	64	64	64	> 128	64	128
Fluconazole	>128	4	32	4	2	>128	>128	>128

Supplementary Table 2: description of the fungal strains used in the study:

Strain	**ID**	**Designation**	**comment**
Candida albicans	**ATCC 64124**	Darlington	Clinical isolate (mouth swab), Resistant to fluconazole and amphotericin
Candida glabrata	**ATCC 64677**	*LRA 85.10.75*	Fluconazole resistant
Candida krusei	**ATCC 34135**	*ST-112*	Fluconazole resistant
Cryptococcus gattii	**NR 43208**	R256	Isolated from a human on Vancouver Island, Canada during the outbreak that began in the late 1990's.
Cryptococcus neoformans	**NR 48767**	H99O	Isolated from the cerebrospinal fluid of a human male who had been treated for Hodgkin's disease in North Carolina, USA.
Aspergillus fumigatus	**NR 35302**	B5854	Isolated from human peritoneal fluid in California, USA. Intrinsically resistance to fluconazole

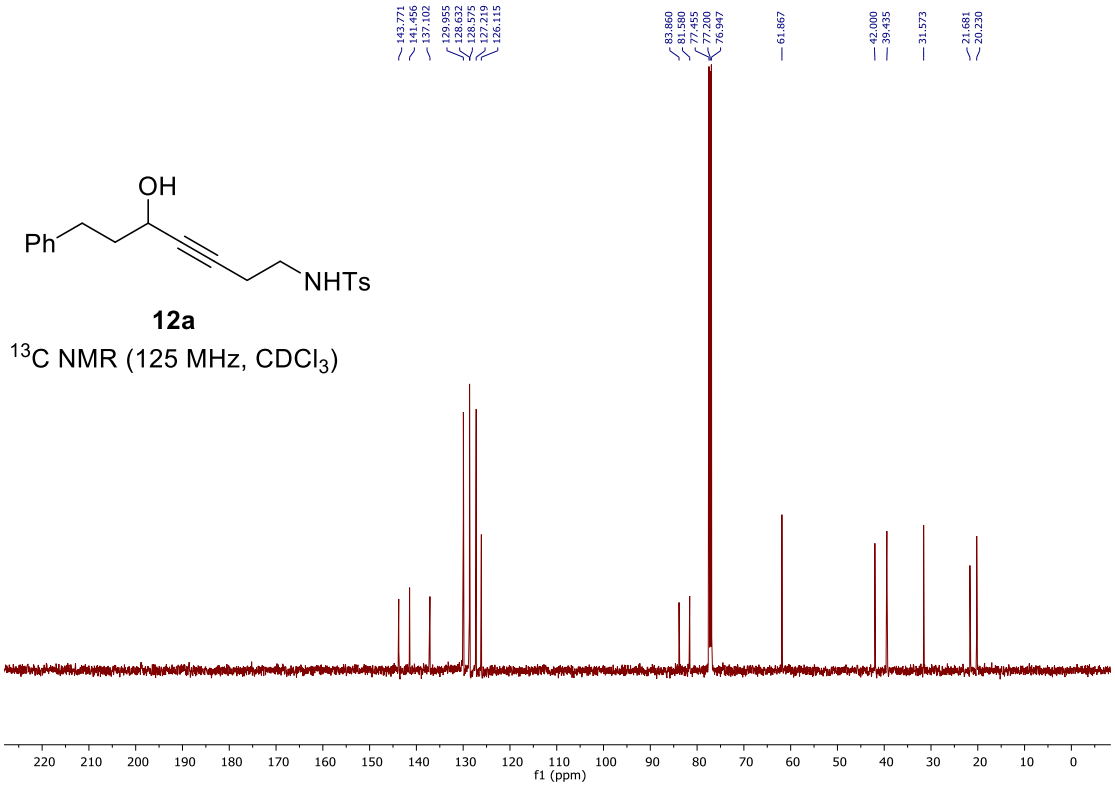
Aspergillus niger	**ATCC 16888**	*WB 326 [CBS 554.65, IMI 50566, NRRL 326; 2766]*	Intrinsically resistance to fluconazole
Aspergillus brasiliensis	**ATCC 16404**	*WLRI 034(120) [CBS 733.88, DSM 1387, DSM 1988, IFO 9455, IMI 149007, NCPF 2275]*	Intrinsically resistance to fluconazole

Part 2. ^{1}H and ^{13}C NMR Spectra for New Compounds



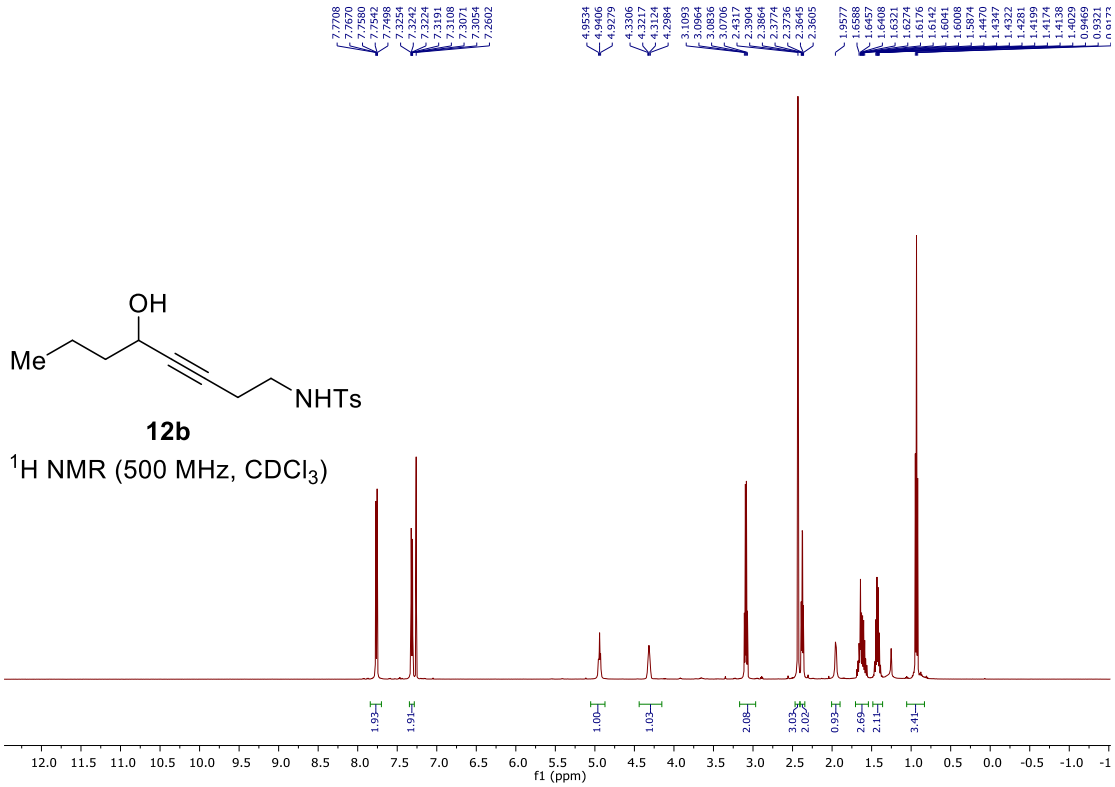
12a

^{1}H NMR (500 MHz, $CDCl_3$)



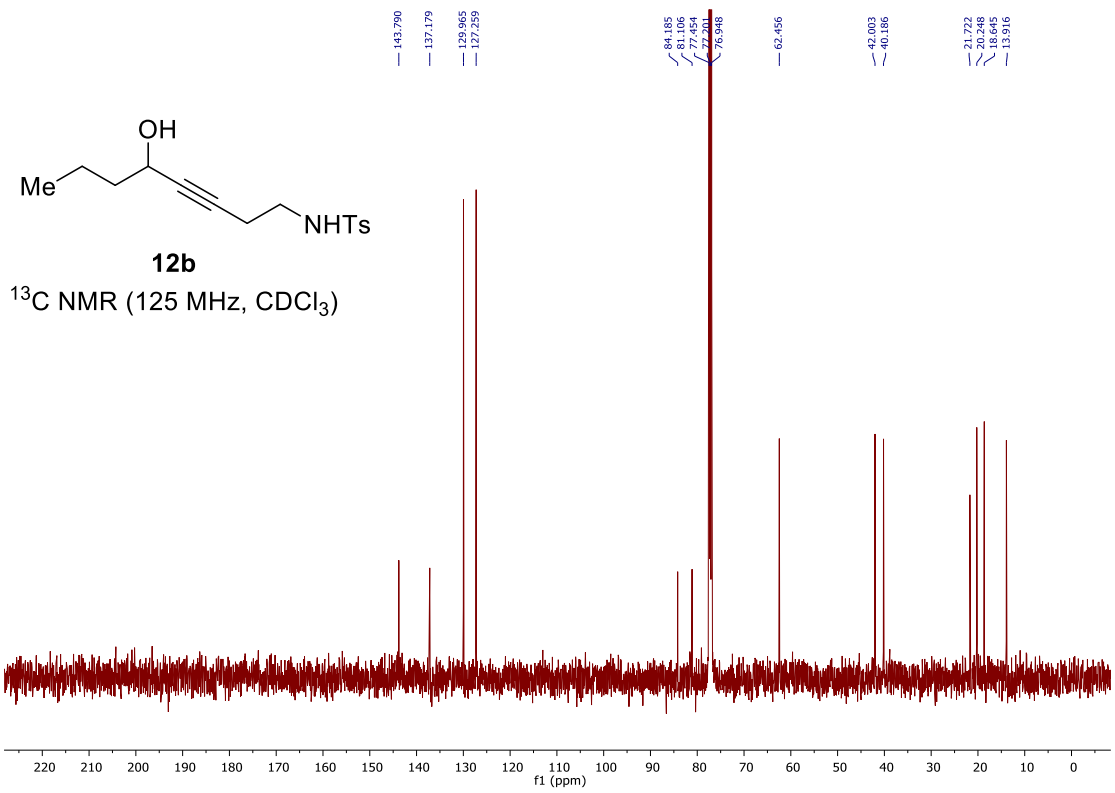
12a

^{13}C NMR (125 MHz, $CDCl_3$)



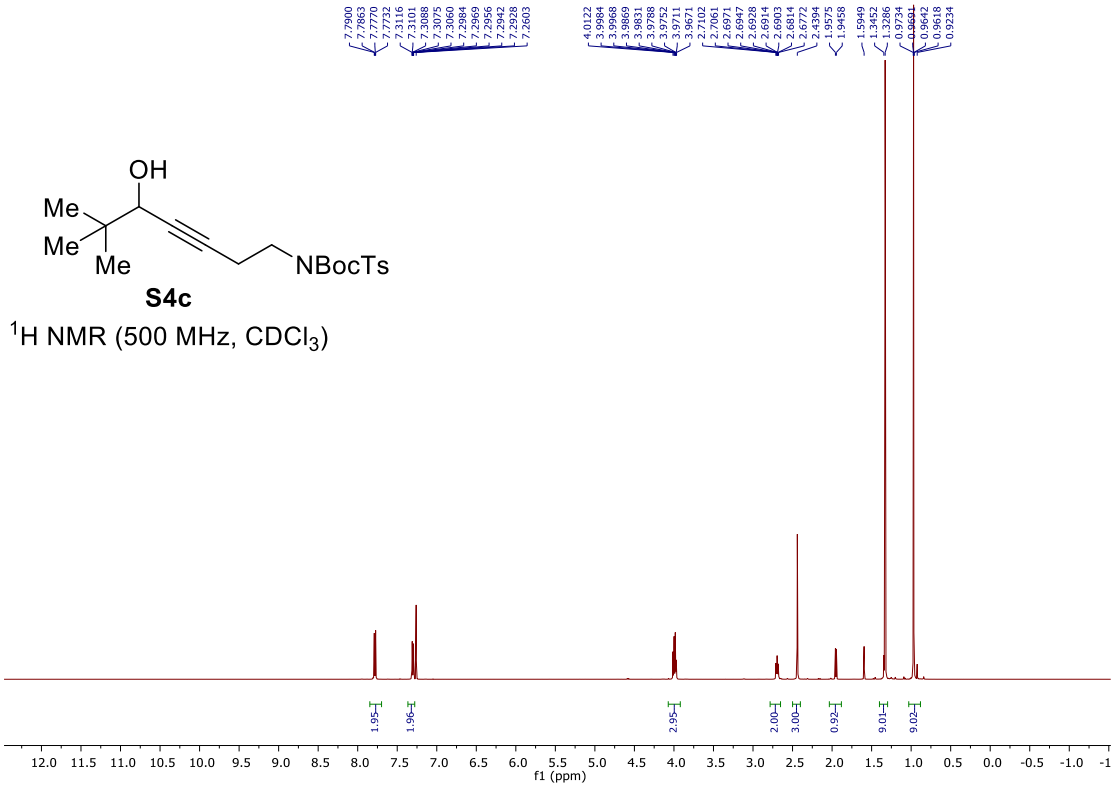
12b

^{1}H NMR (500 MHz, $CDCl_3$)



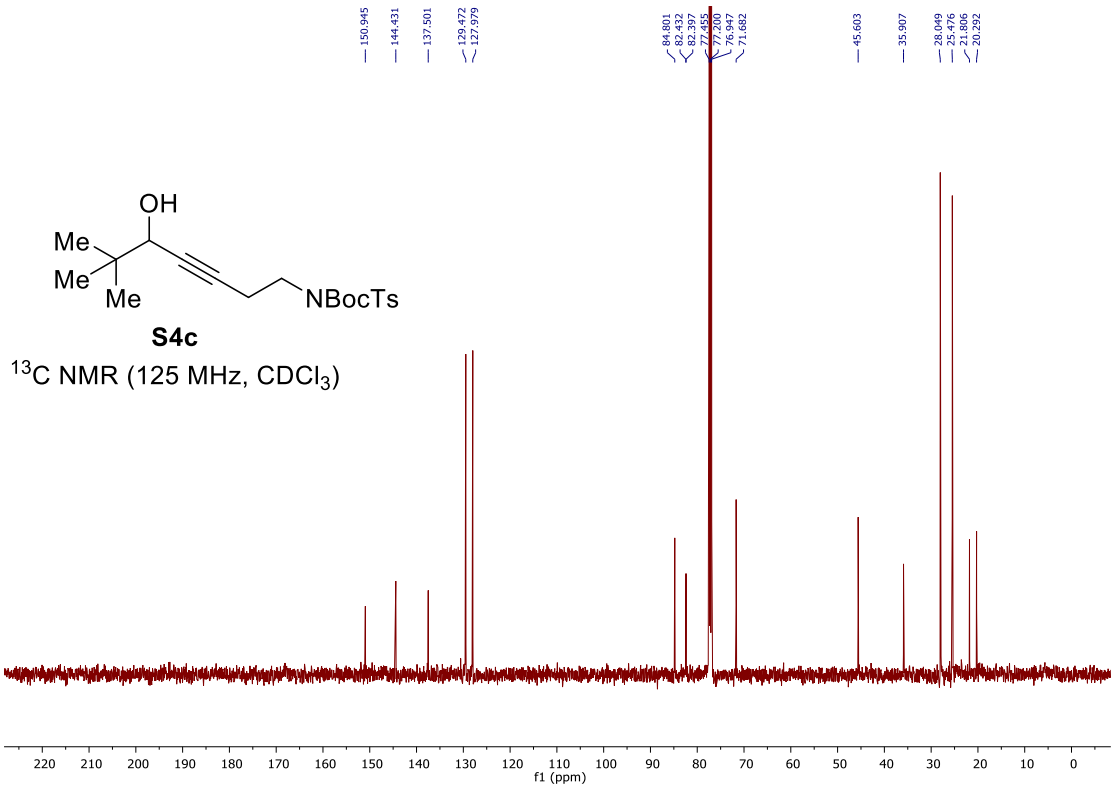
12b

^{13}C NMR (125 MHz, $CDCl_3$)



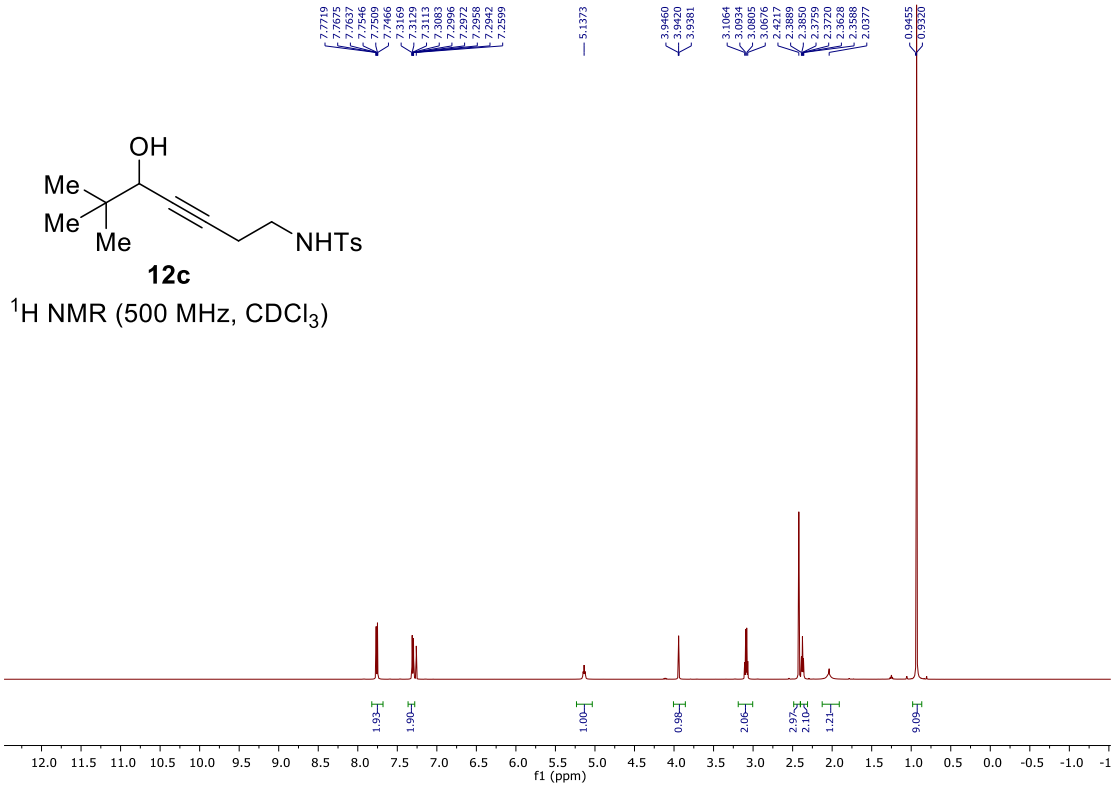
S4c

^{1}H NMR (500 MHz, $CDCl_3$)



S4c

^{13}C NMR (125 MHz, $CDCl_3$)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Me
Me
Me
NHTs
12c
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7.7509
7.7466
7.3169
7.3129
7.3113
7.3083
7.2996
7.2972
7.2958
7.2942
7.2599
5.1373
3.9460
3.9420
3.9381
3.1064
3.0934
3.0805
3.0676
2.4217
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2.3850
2.3759
2.3720
2.3628
2.3588
2.0377
0.9455
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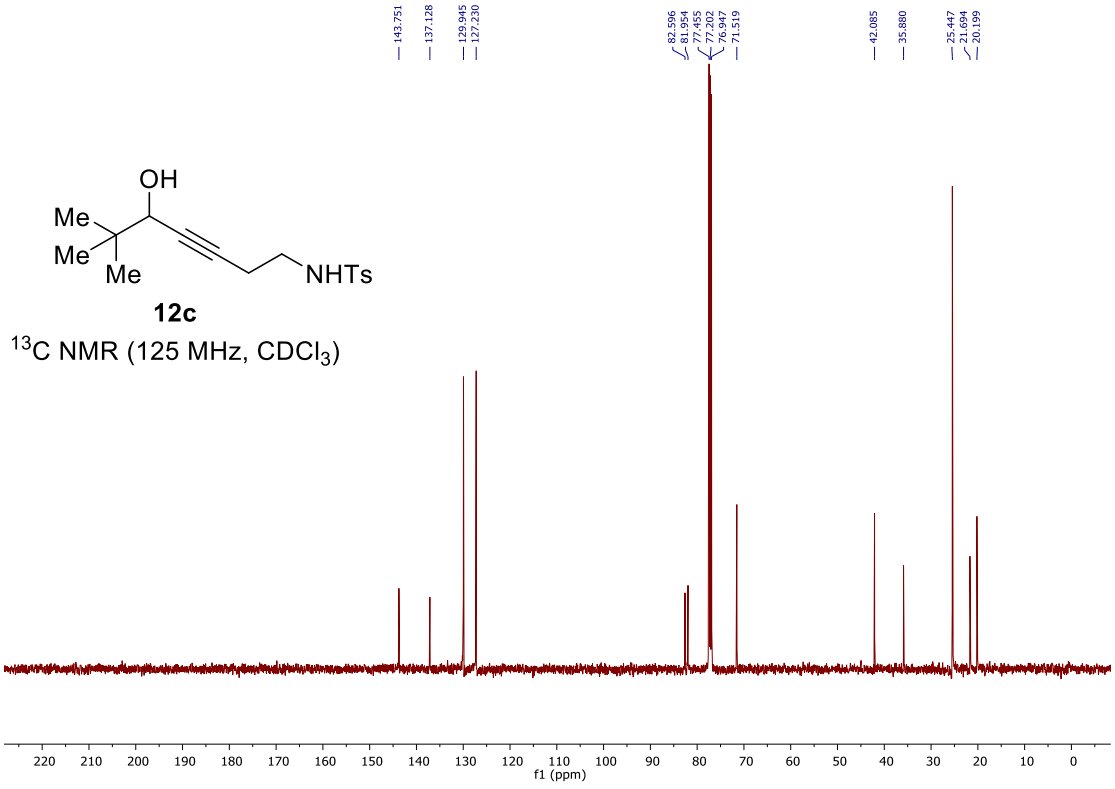
f1 (ppm)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Me
Me
Me
NHTs
12c
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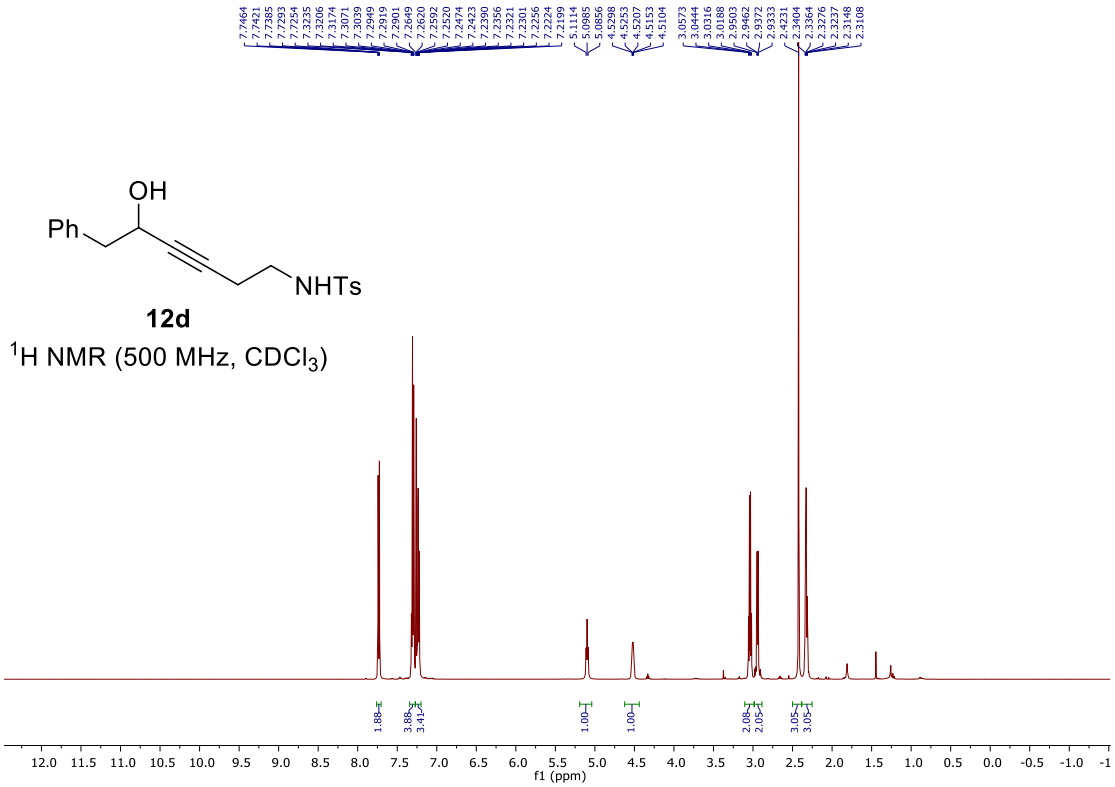
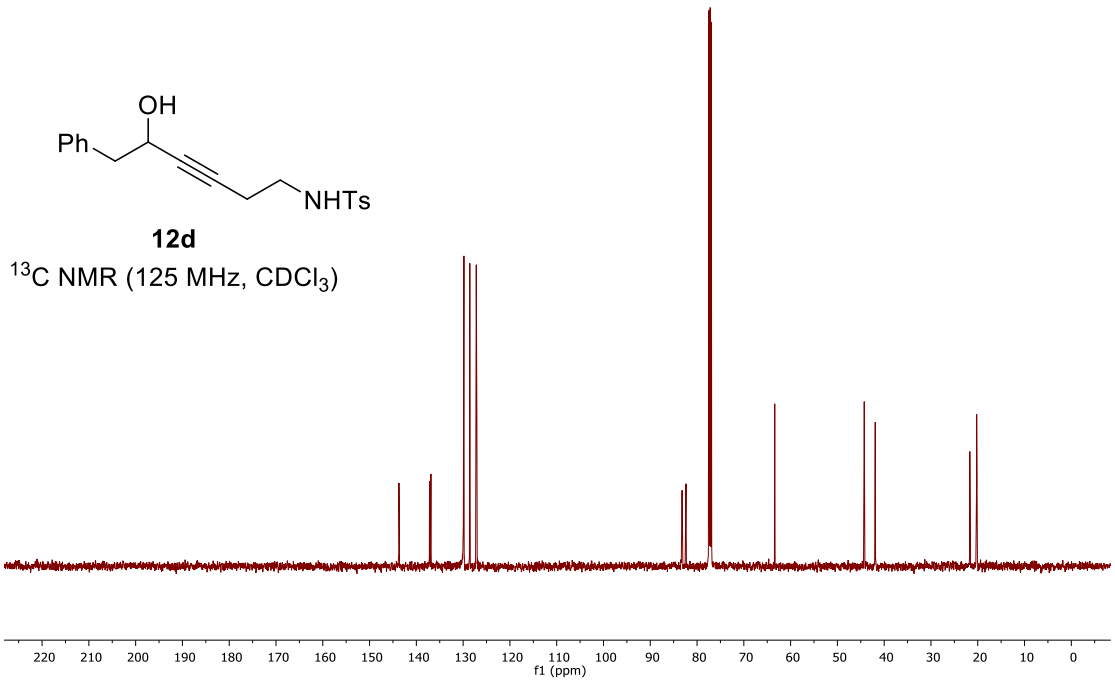
f1 (ppm)



12d

^{1}H NMR (500 MHz, $CDCl_3$)



12d

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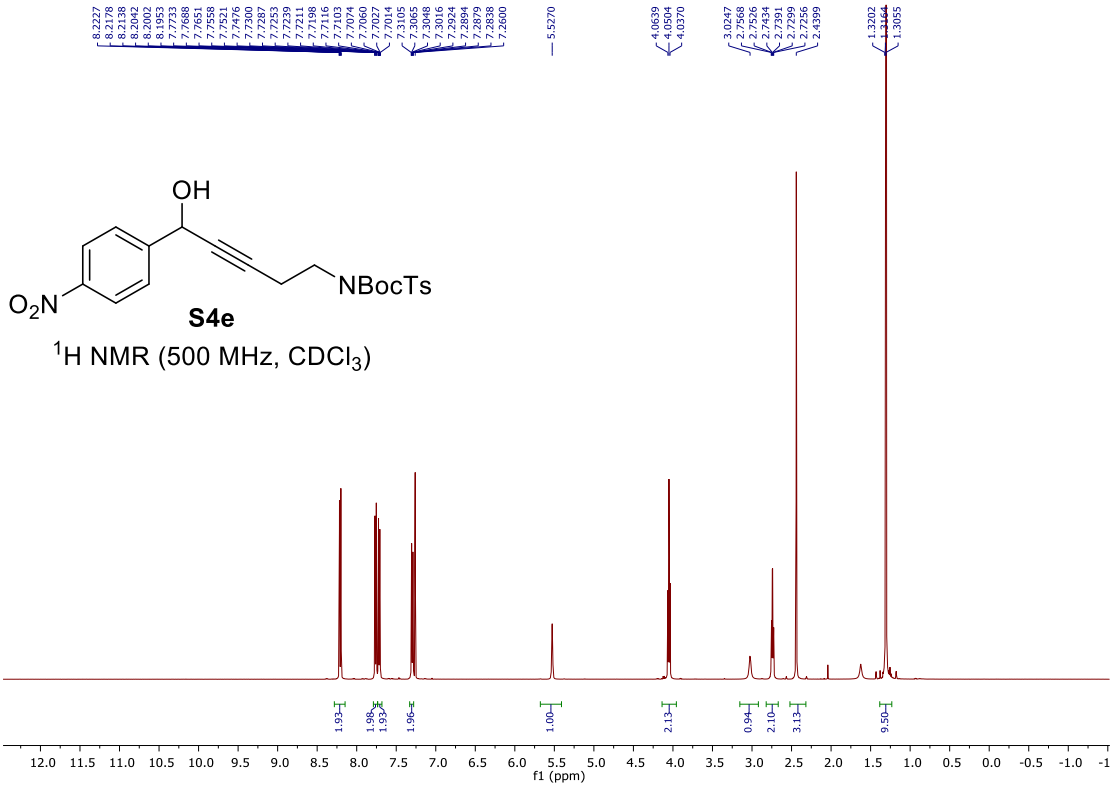
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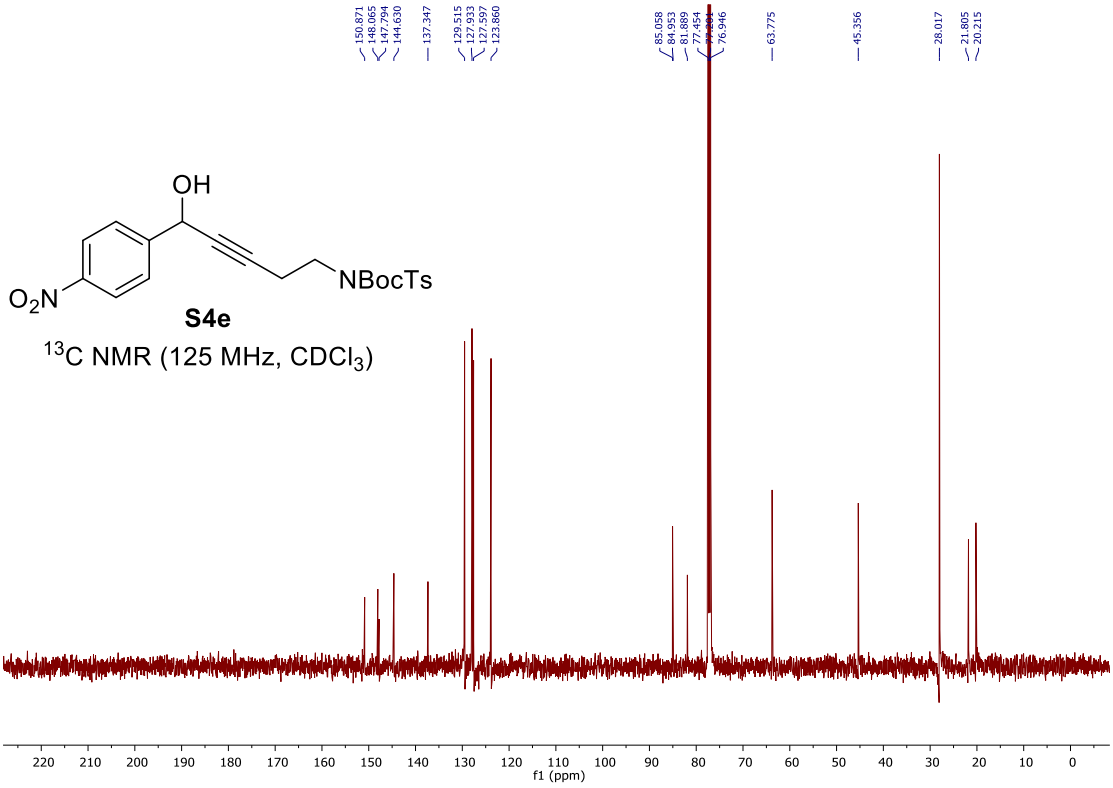
O2N
S4e
1H NMR (500 MHz, CDCl3)
f1 (ppm)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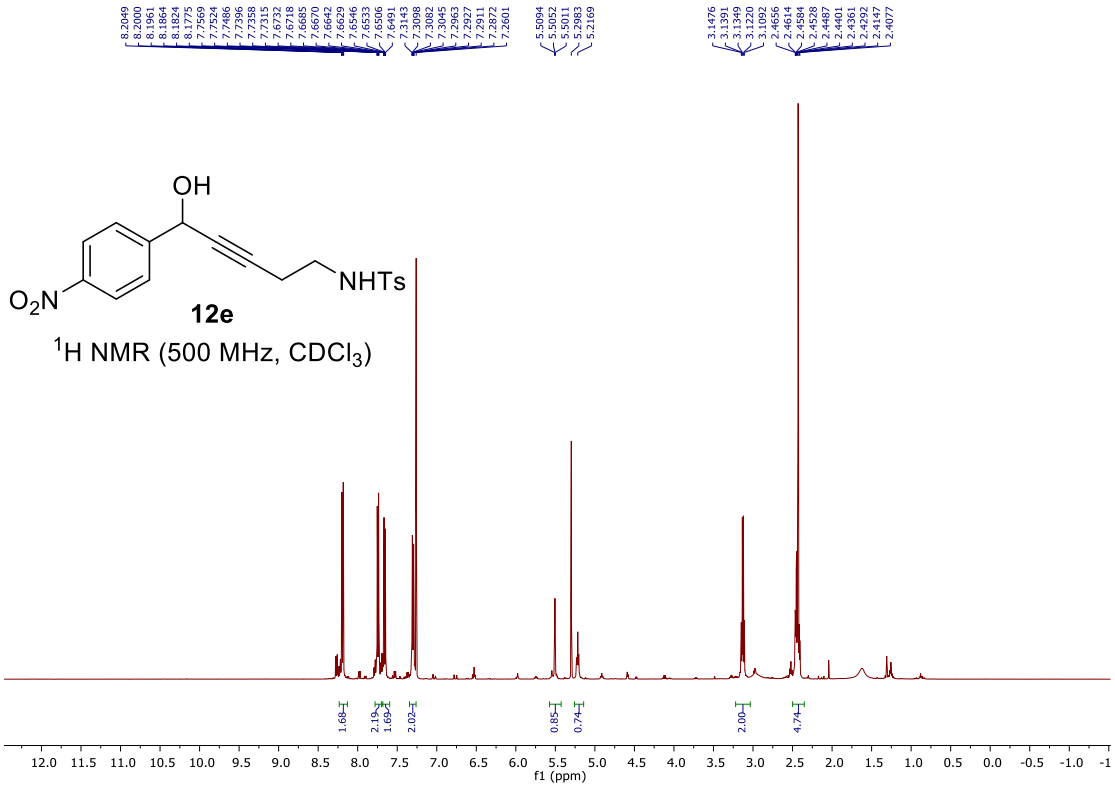
f1 (ppm)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NHTs
O2N
12e
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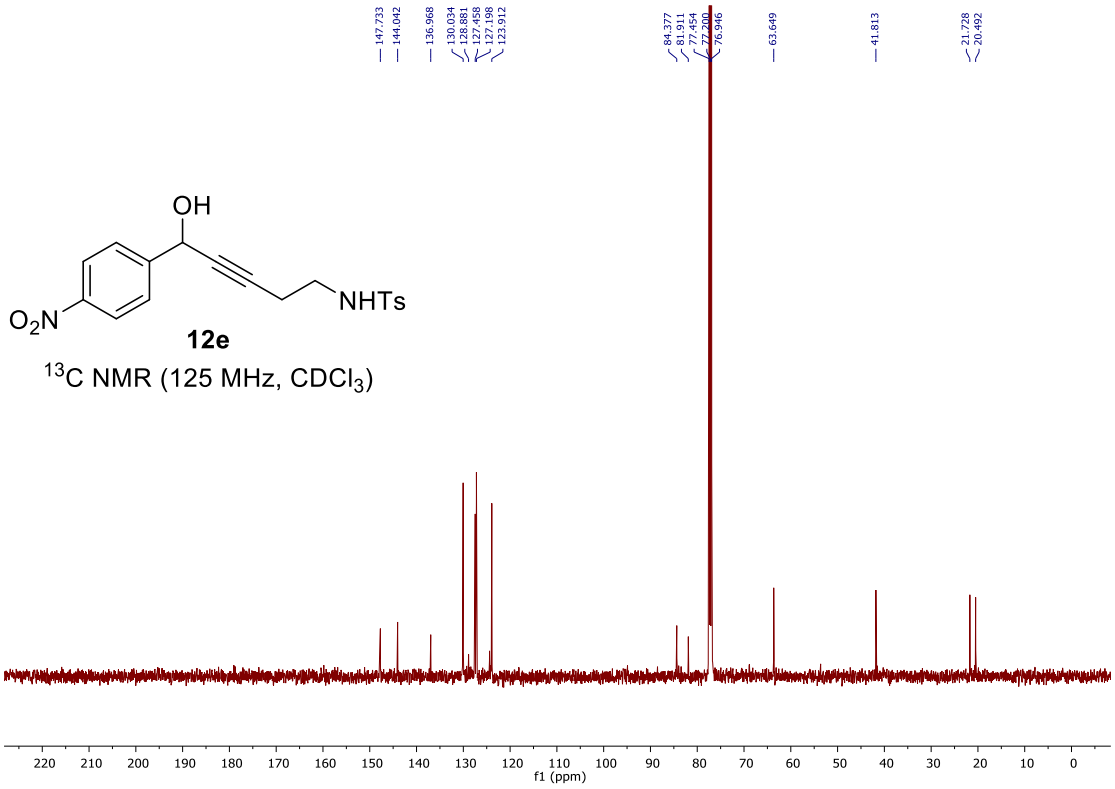
f1 (ppm)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NHTs
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12e
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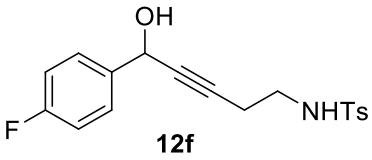
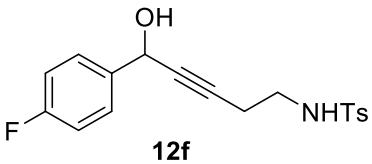
f1 (ppm)



12f

^{1}H NMR (500 MHz, $CDCl_3$)



12f

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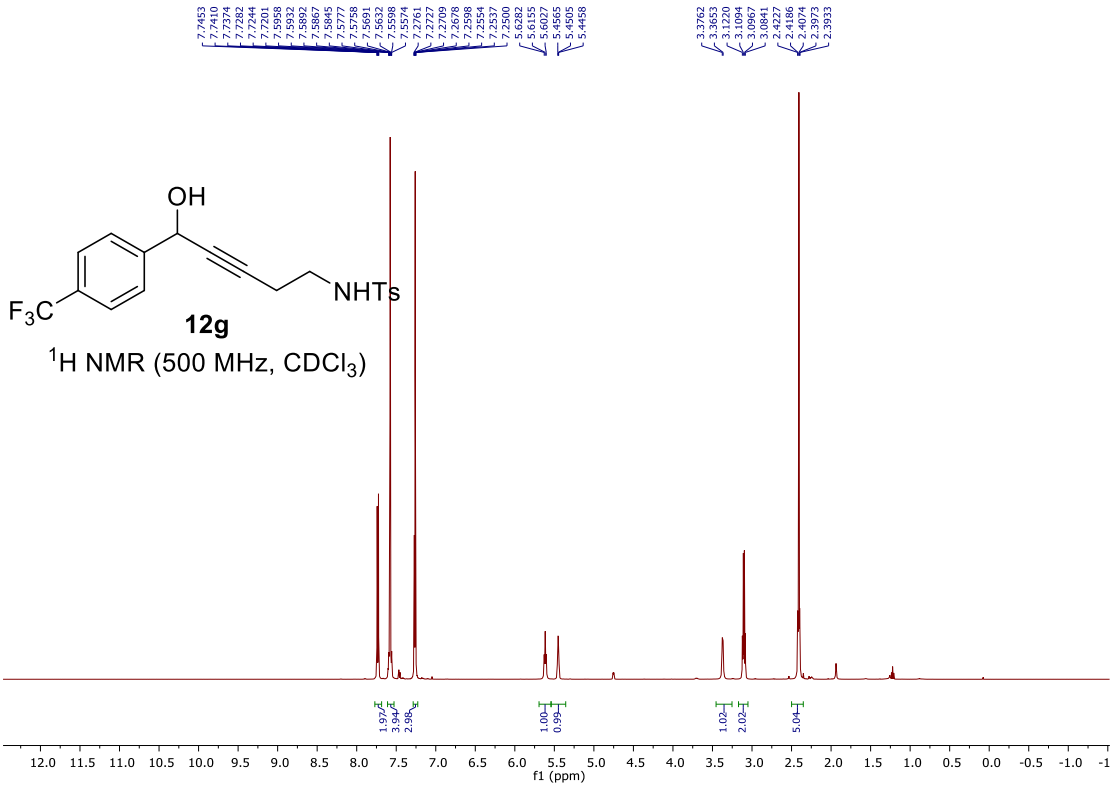
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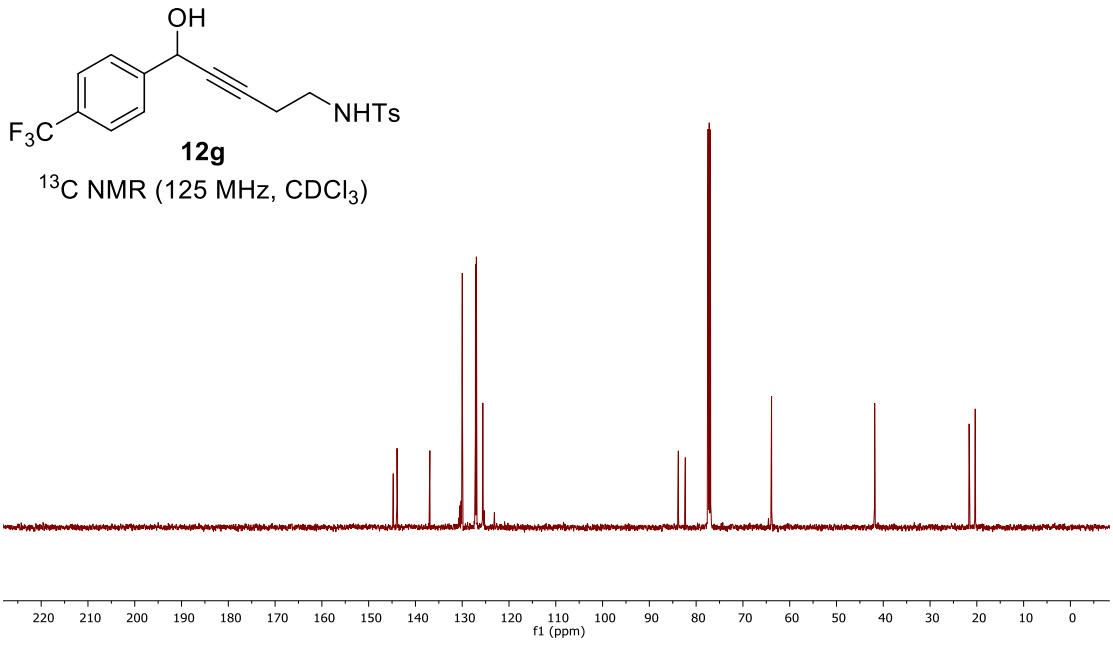
12g
1H NMR (500 MHz, CDCl3)
f1 (ppm)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NHTs
F3C
12g
13C NMR (125 MHz, CDCl3)
f1 (ppm)


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7.6354
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7.4528
7.4506
7.4410
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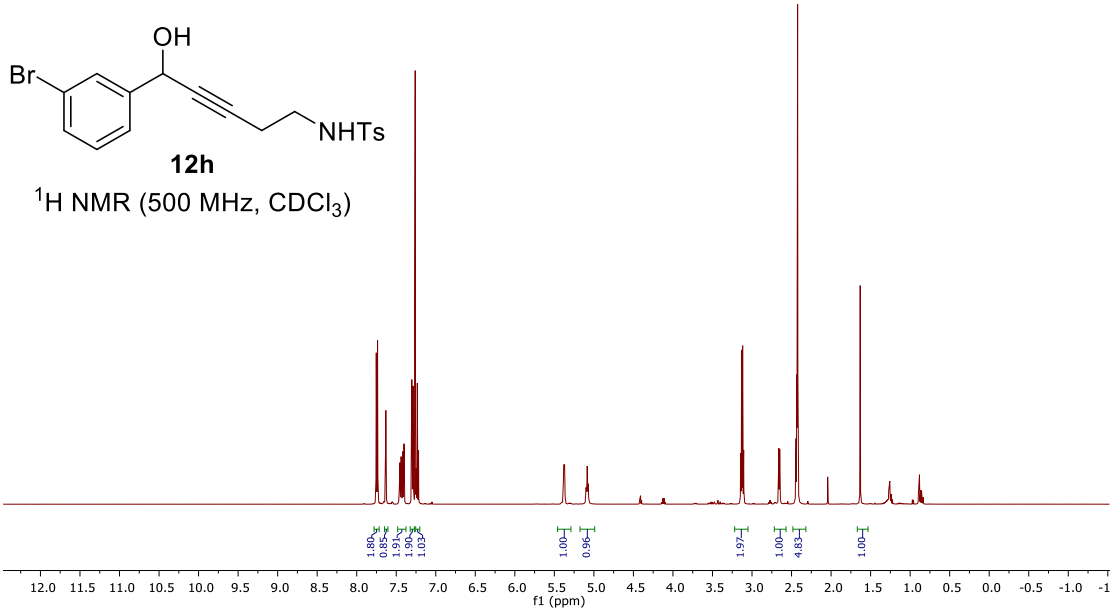
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Br
NHTs
12h
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0.85
1.91
1.96
1.03
1.00
0.96
1.97
1.00
4.83
1.00
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1
f1 (ppm)


143.876
143.055
137.065
131.527
130.355
130.009
129.753
127.328
125.309
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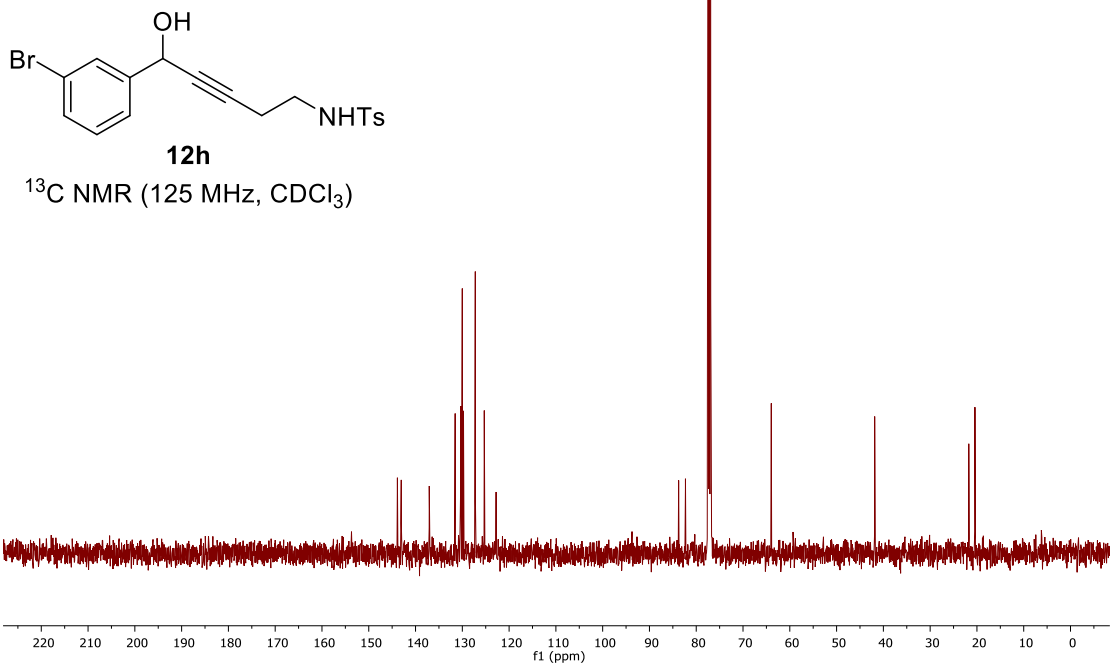
76.946
63.955
41.859
21.740
20.428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Br
NHTs
12h
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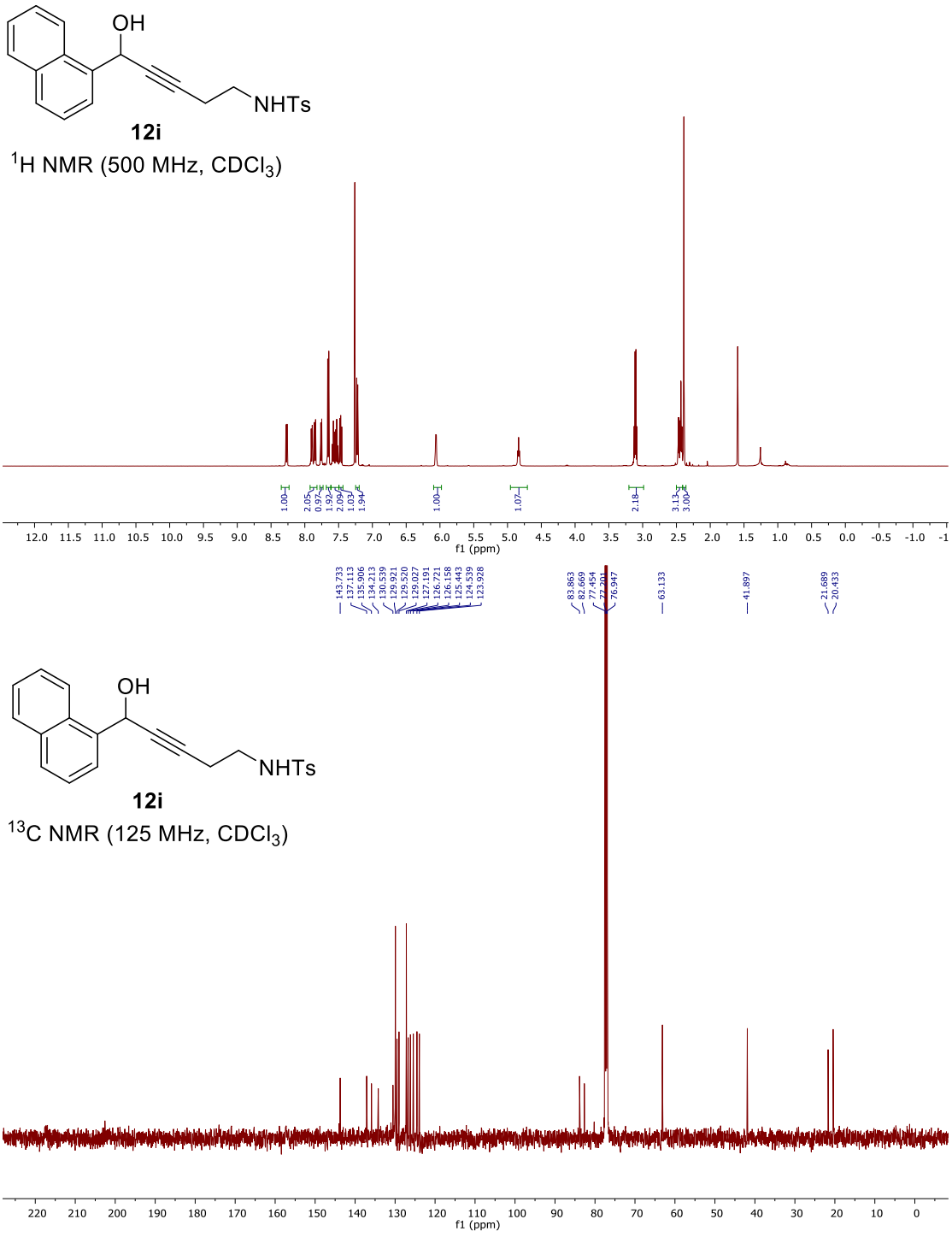
f1 (ppm)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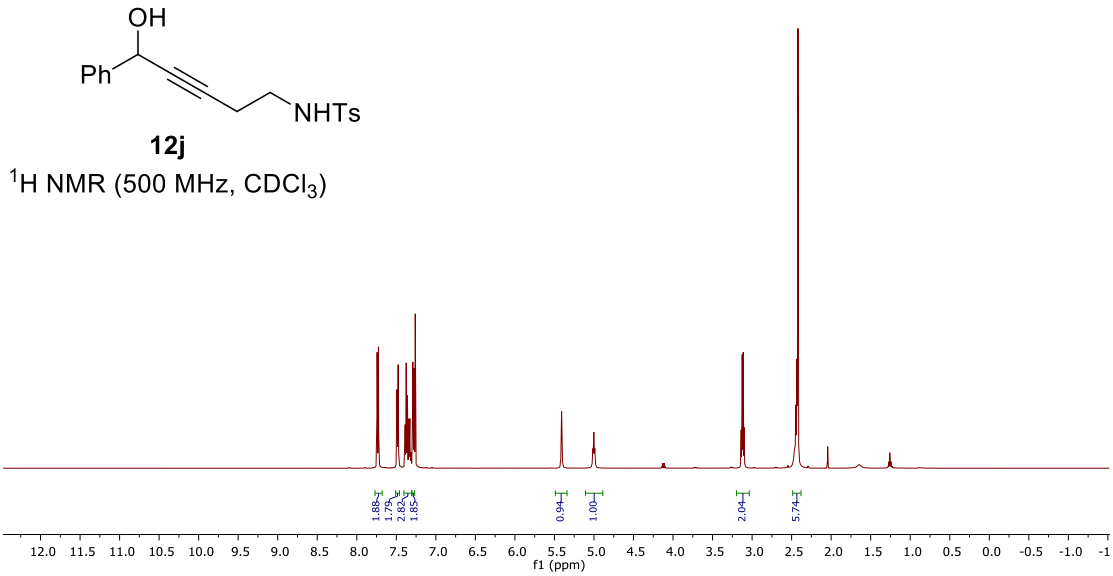
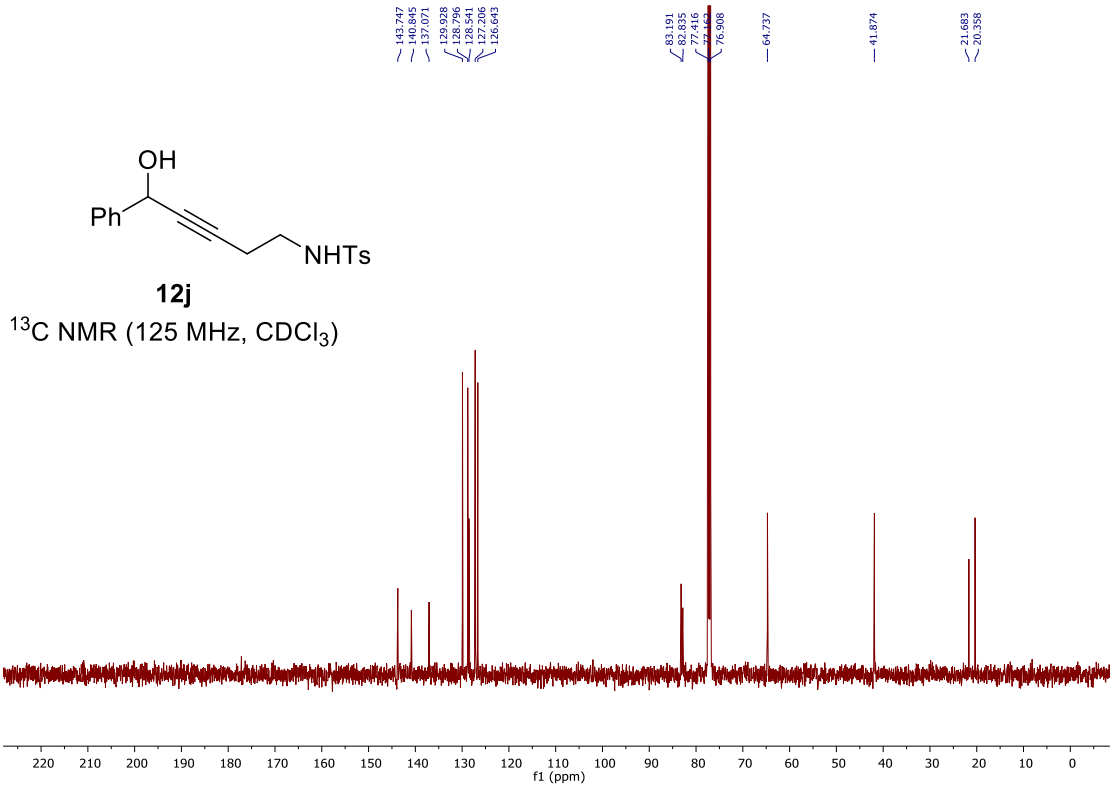
NHTs
12i
1H NMR (500 MHz, CDCl3)
f1 (ppm)
OH
NHTs
12i
13C NMR (125 MHz, CDCl3)
f1 (ppm)



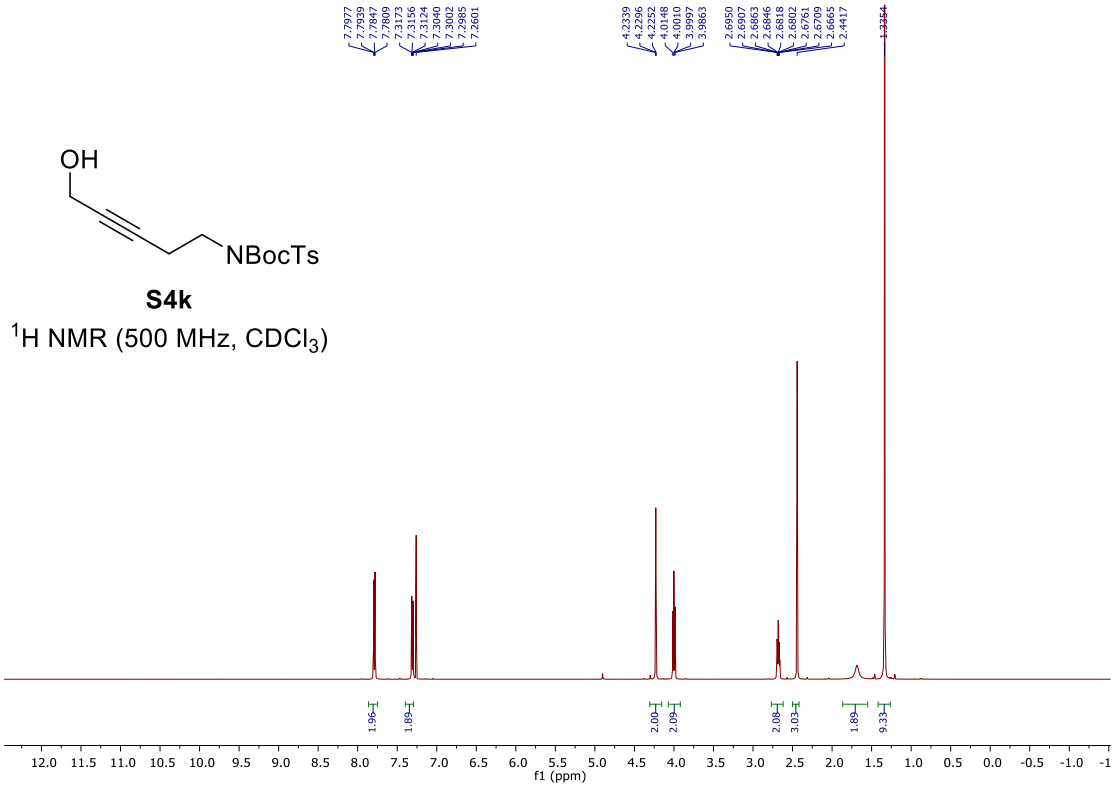
12j

^{1}H NMR (500 MHz, $CDCl_3$)



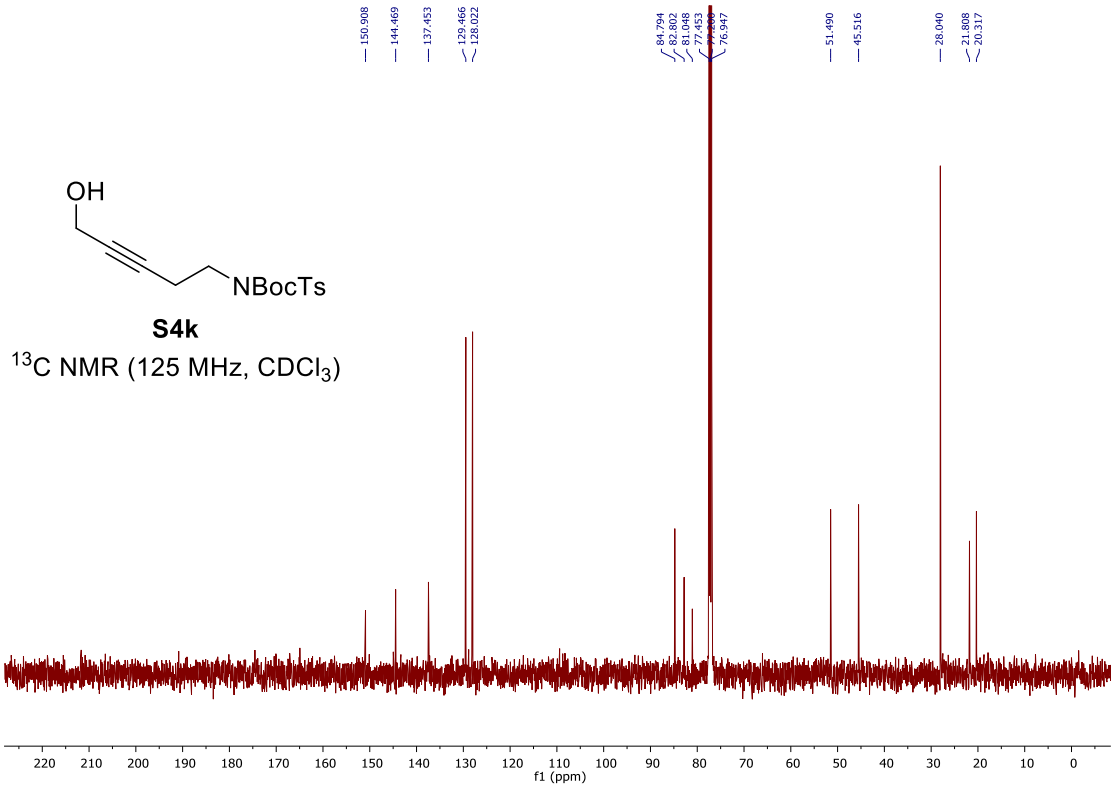
12j

^{13}C NMR (125 MHz, $CDCl_3$)



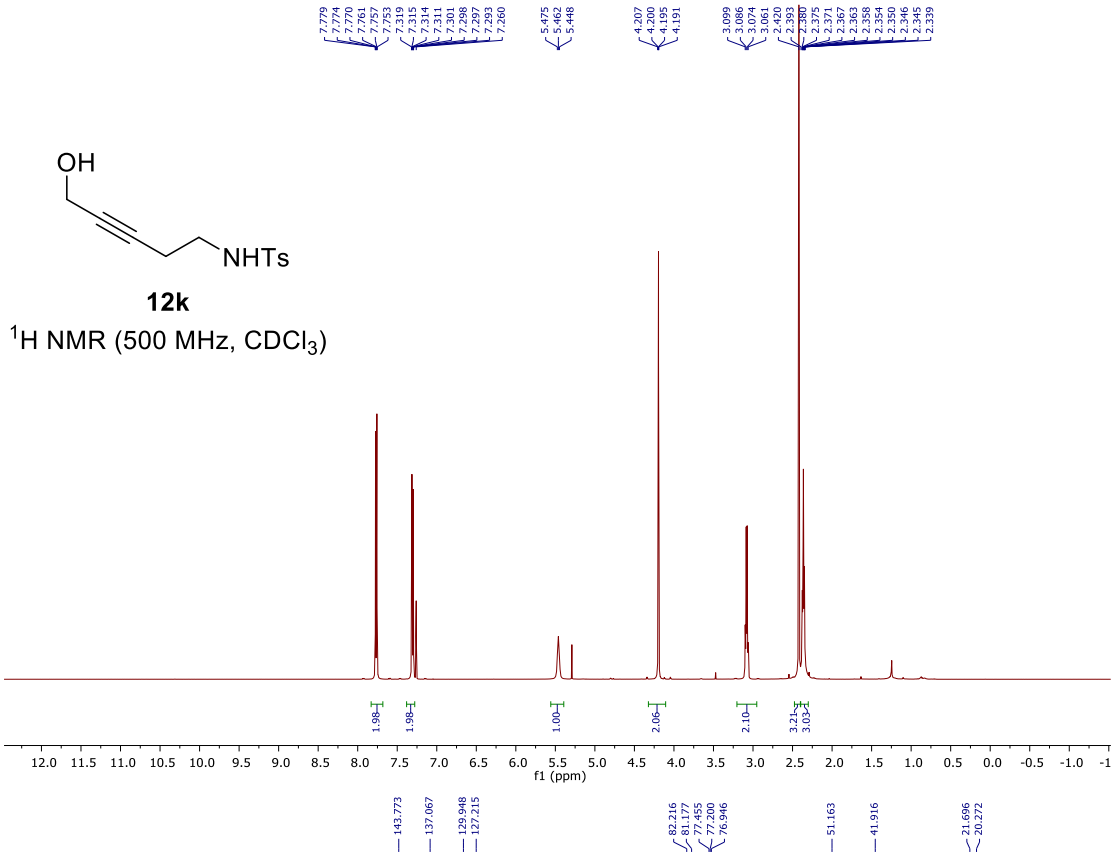
S4k

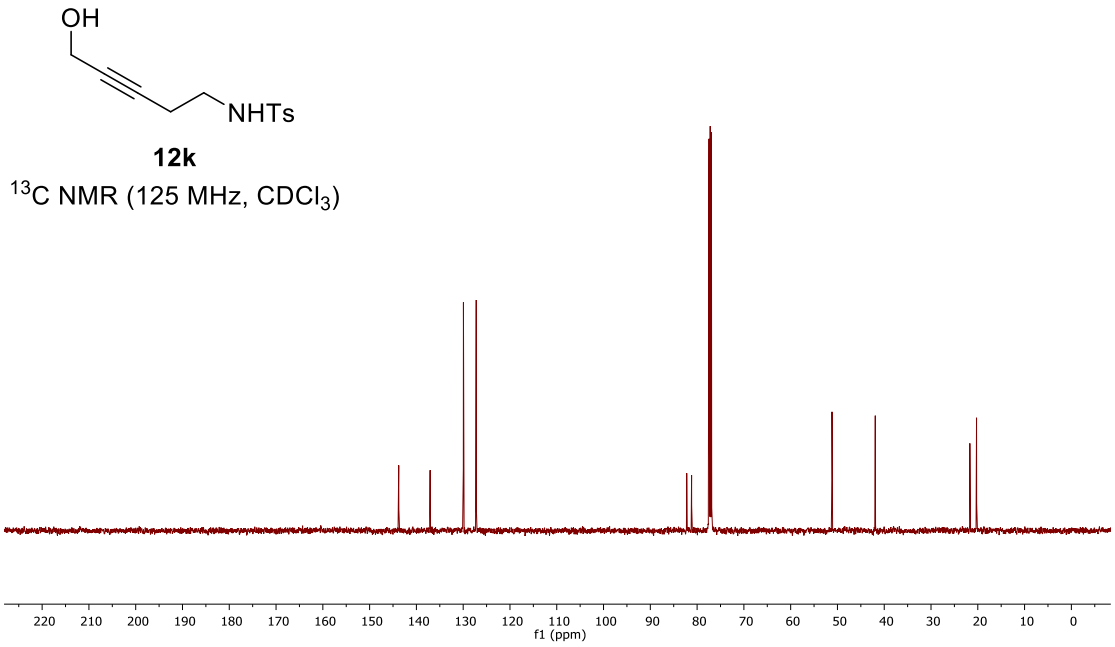
^{1}H NMR (500 MHz, $CDCl_3$)

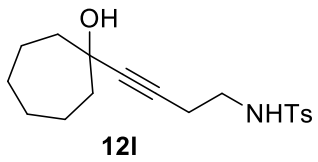


S4k

^{13}C NMR (125 MHz, $CDCl_3$)

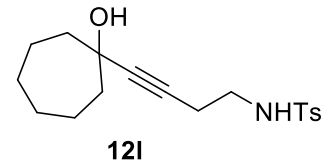

OH
NHTs
12k
1H NMR (500 MHz, CDCl3)
7.779
7.774
7.770
7.761
7.757
7.753
7.319
7.315
7.314
7.311
7.301
7.298
7.297
7.293
7.260
5.475
5.462
5.448
4.207
4.200
4.195
4.191
3.099
3.086
3.074
3.061
2.420
2.393
2.380
2.375
2.371
2.367
2.363
2.358
2.354
2.350
2.346
2.345
2.339
1.98
1.98
1.00
2.06
2.10
3.21
3.03
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1
f1 (ppm)


OH
NHTs
12k
13C NMR (125 MHz, CDCl3)
143.773
137.067
129.948
127.215
82.216
81.177
77.455
77.200
76.946
51.163
41.916
21.696
20.272
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



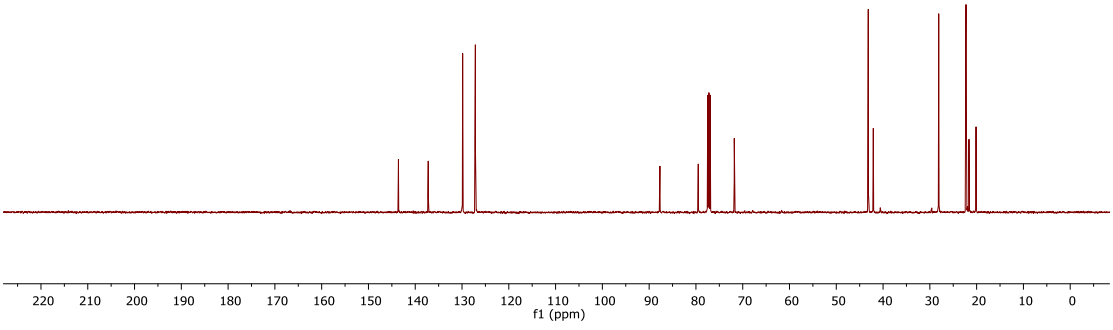
12l

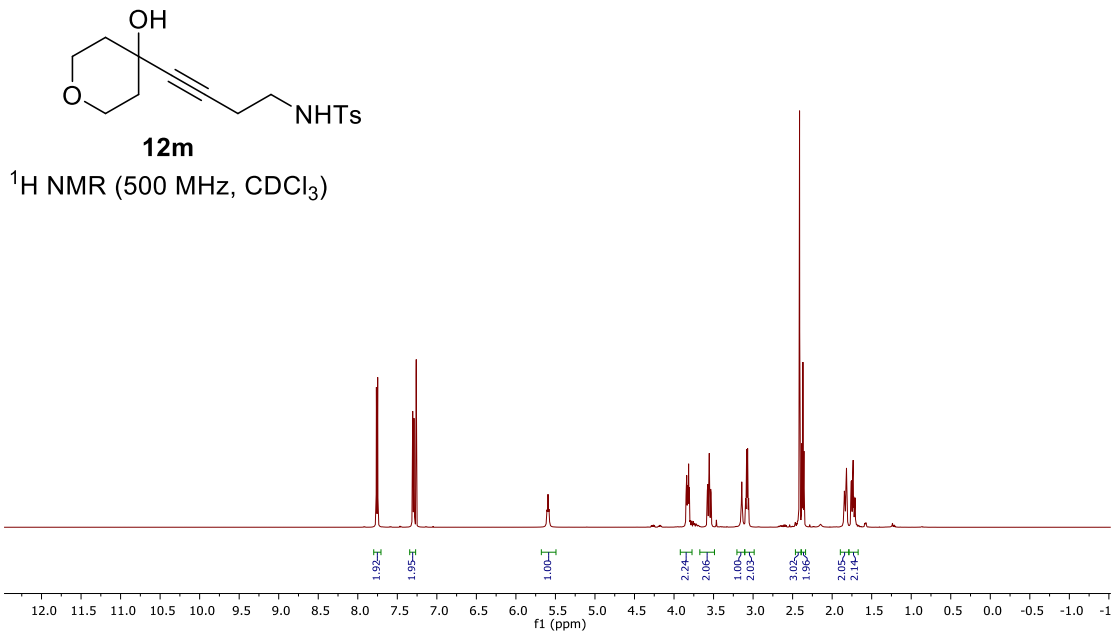
^{1}H NMR (500 MHz, $CDCl_3$)



12l

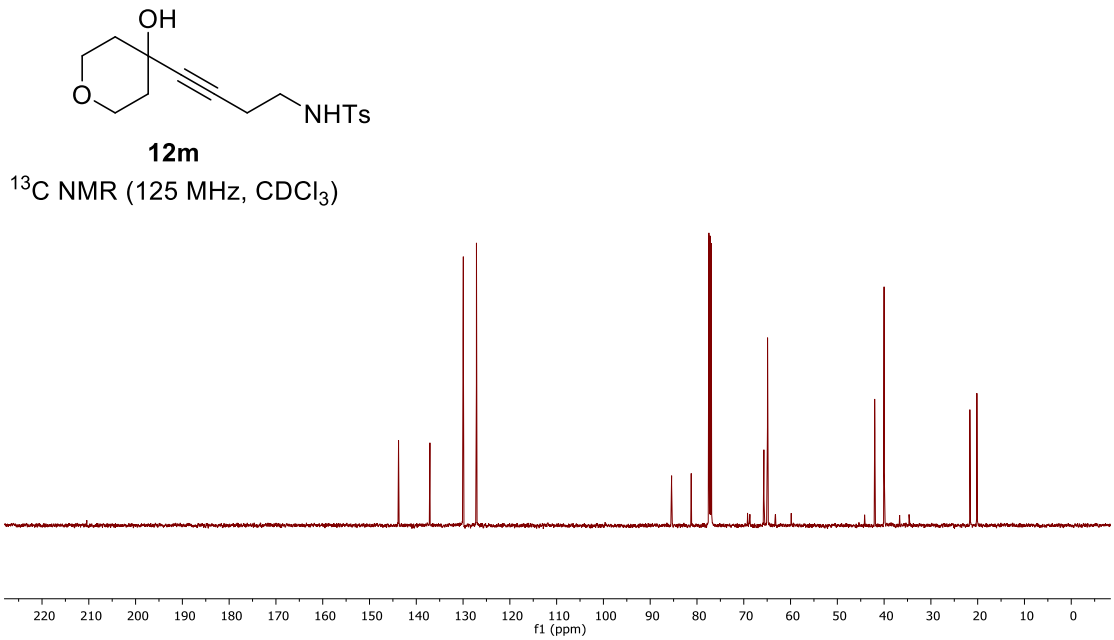
^{13}C NMR (125 MHz, $CDCl_3$)





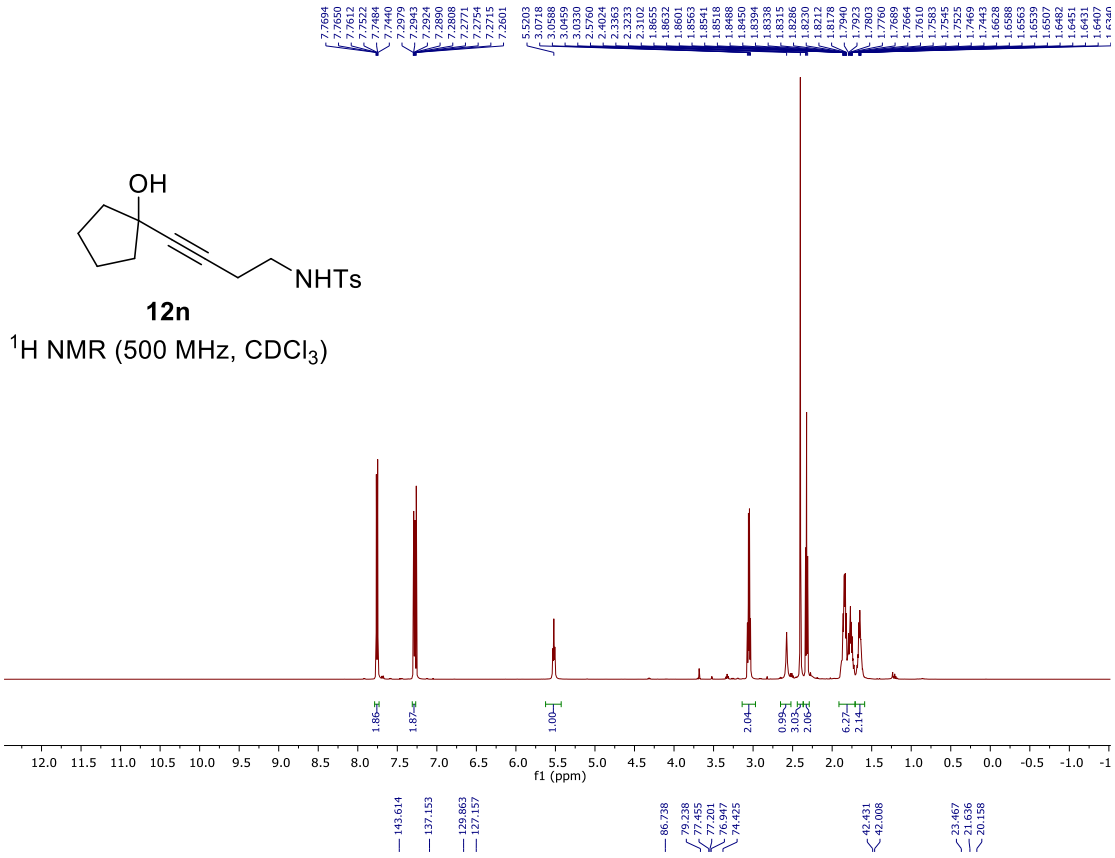
12m

^{1}H NMR (500 MHz, $CDCl_3$)



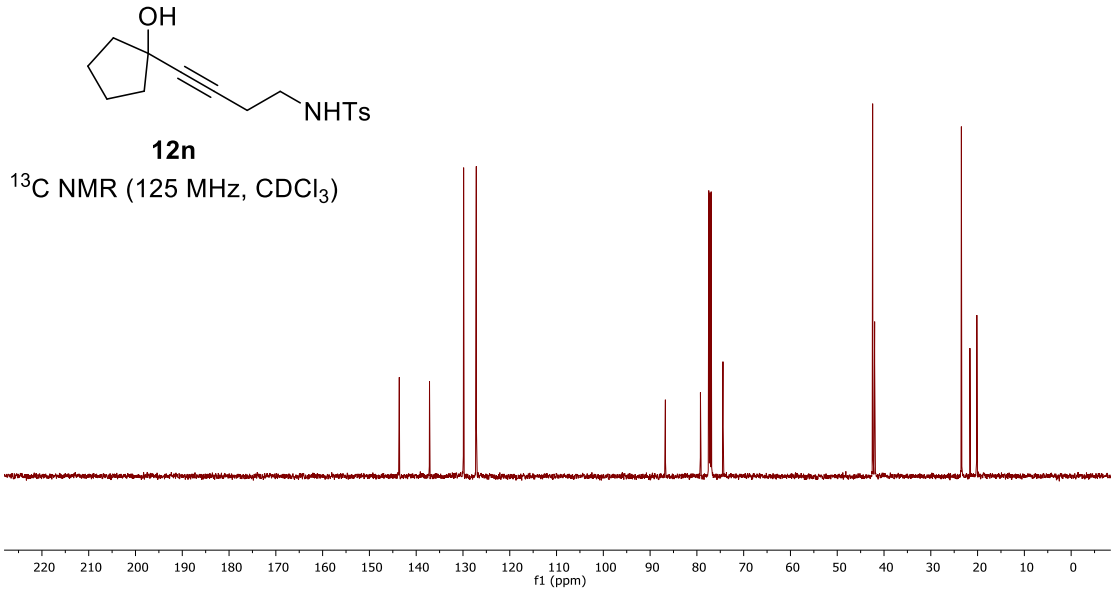
12m

^{13}C NMR (125 MHz, $CDCl_3$)



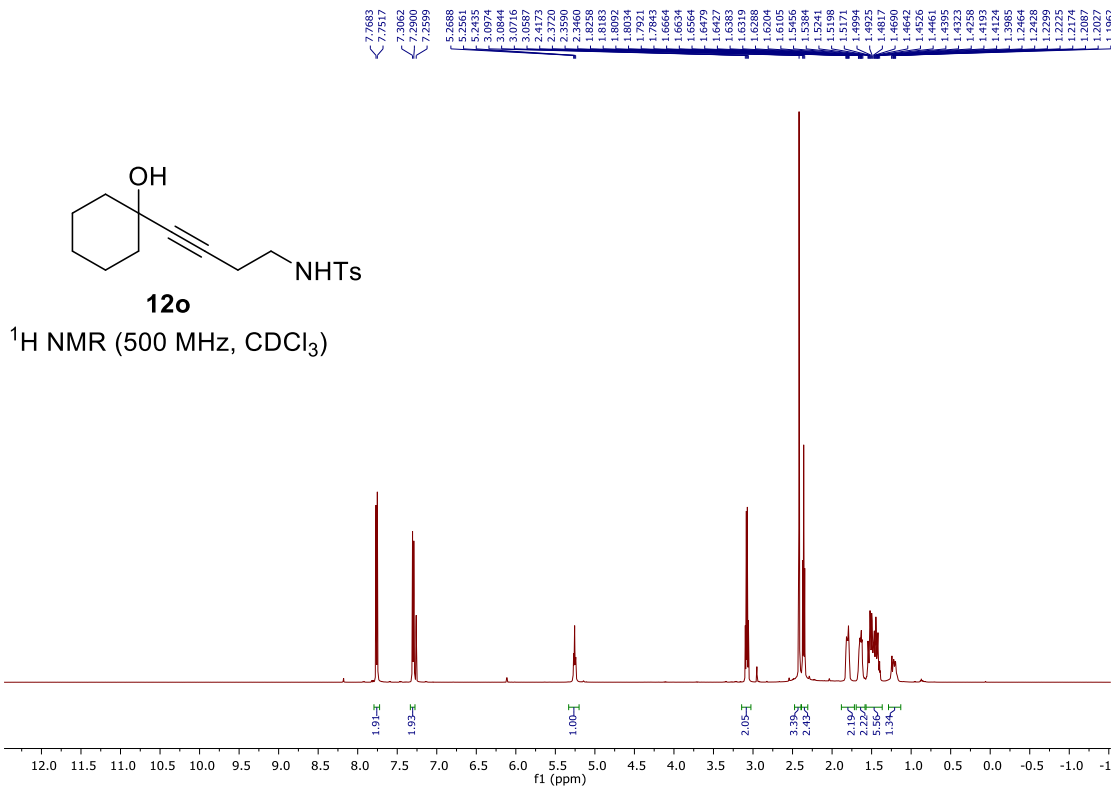
12n

^{1}H NMR (500 MHz, $CDCl_3$)



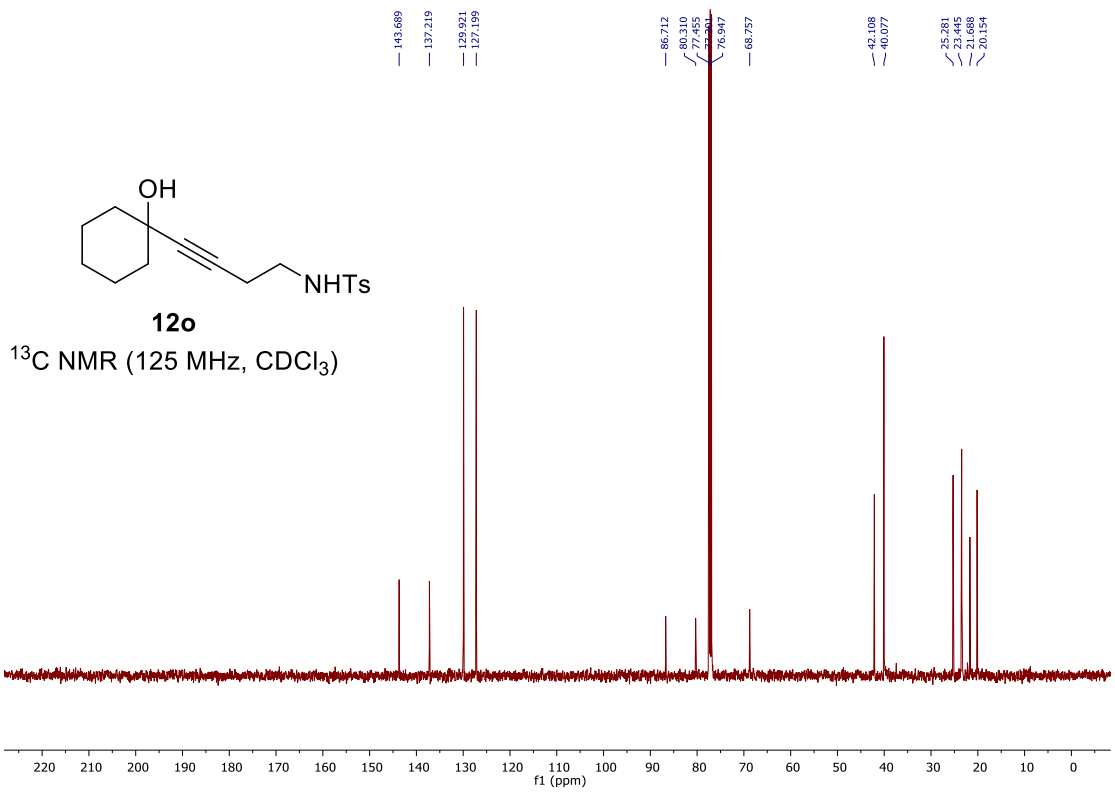
12n

^{13}C NMR (125 MHz, $CDCl_3$)



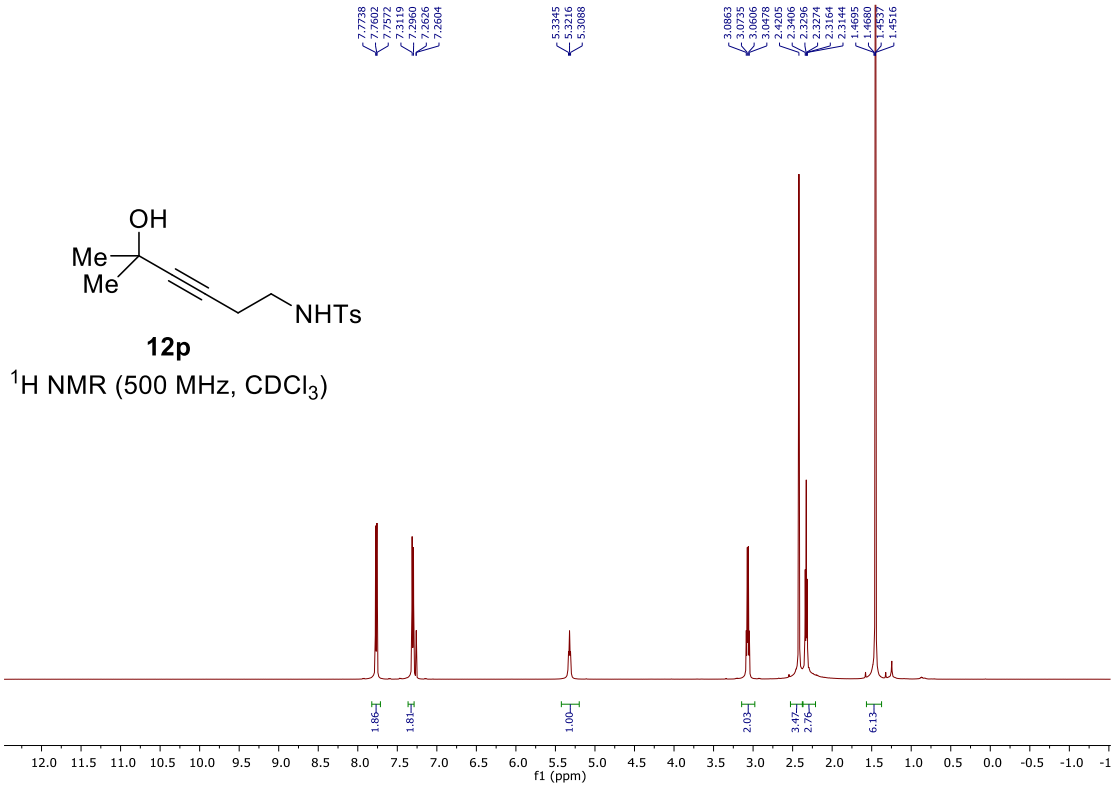
12o

^{1}H NMR (500 MHz, $CDCl_3$)



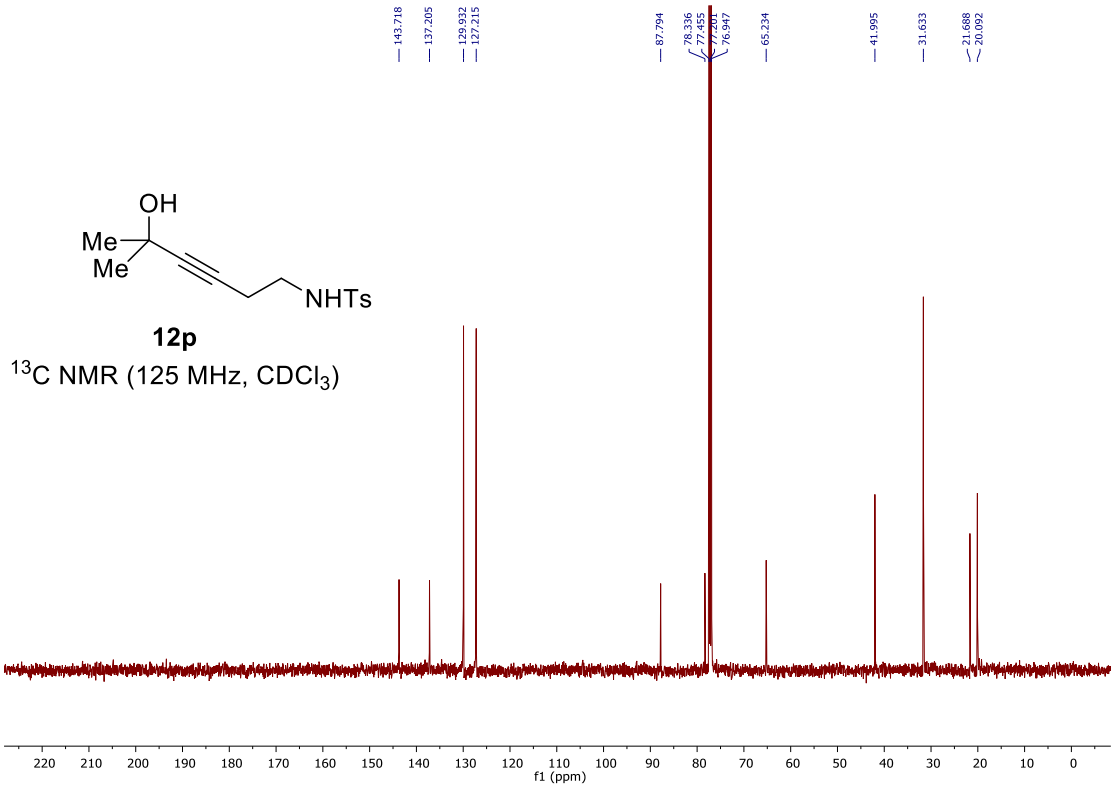
12o

^{13}C NMR (125 MHz, $CDCl_3$)



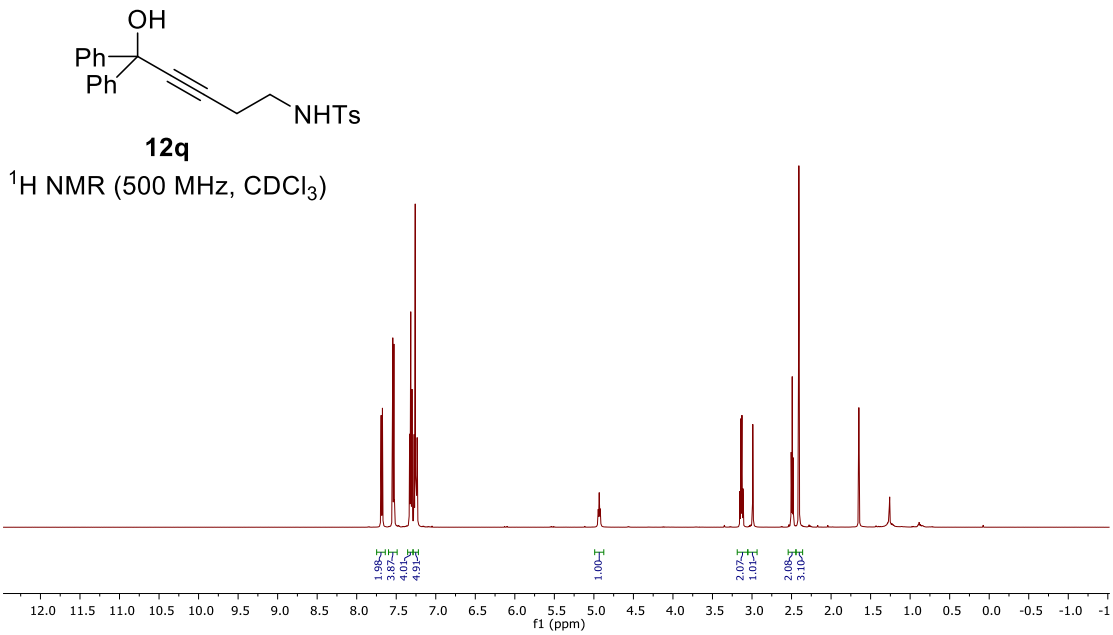
12p

^{1}H NMR (500 MHz, $CDCl_3$)



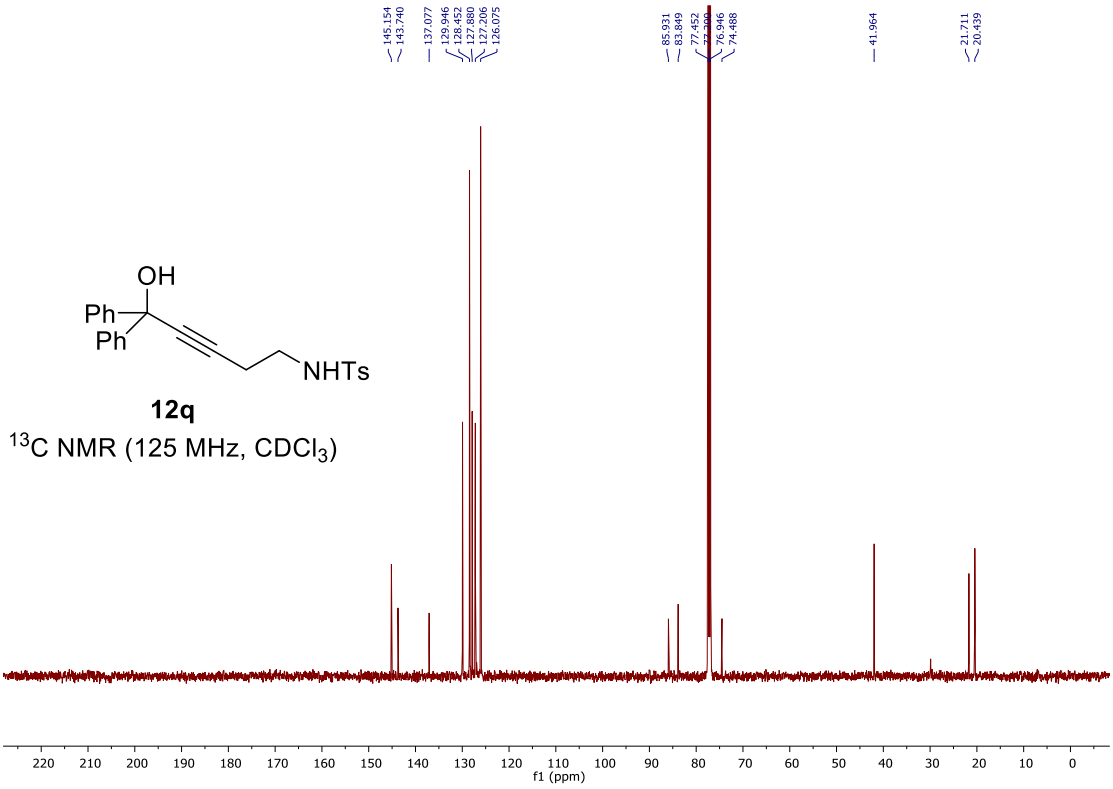
12p

^{13}C NMR (125 MHz, $CDCl_3$)



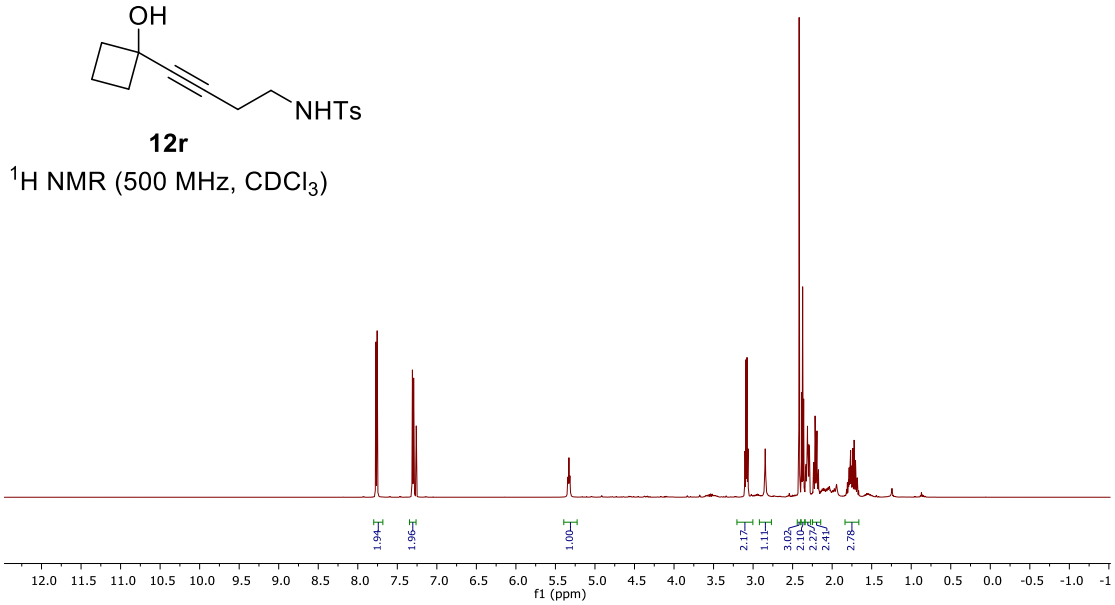
12q

^{1}H NMR (500 MHz, $CDCl_3$)



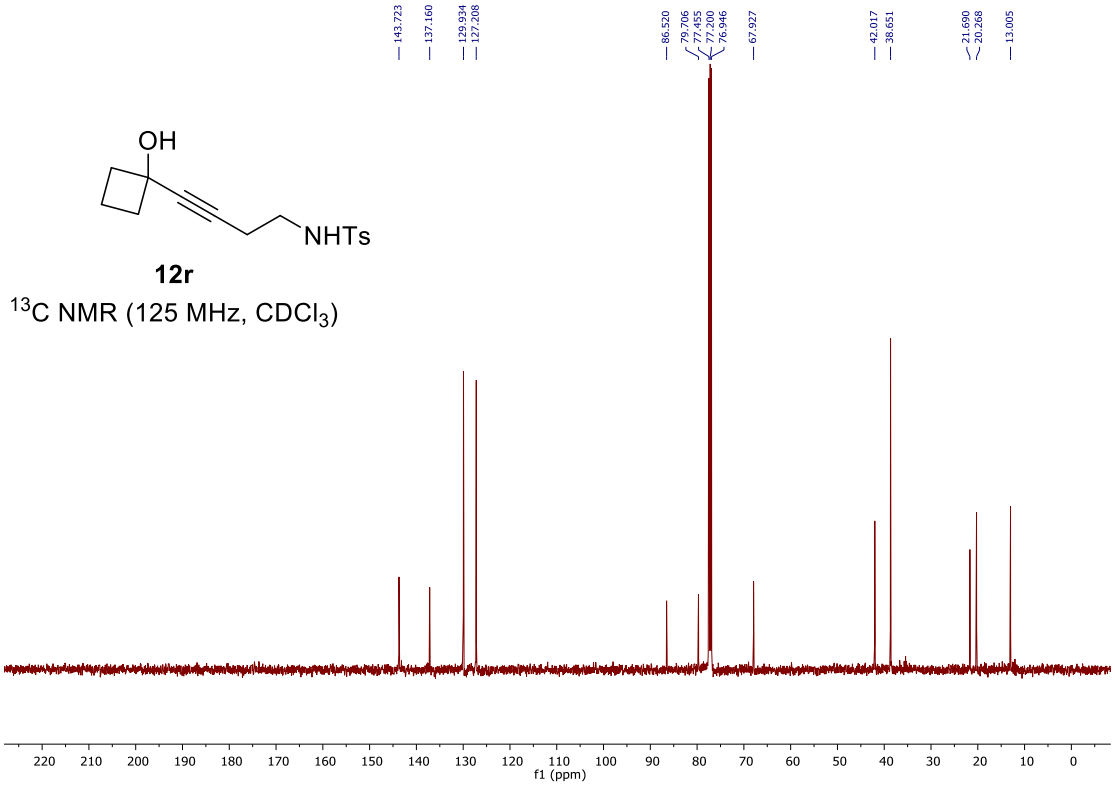
12q

^{13}C NMR (125 MHz, $CDCl_3$)



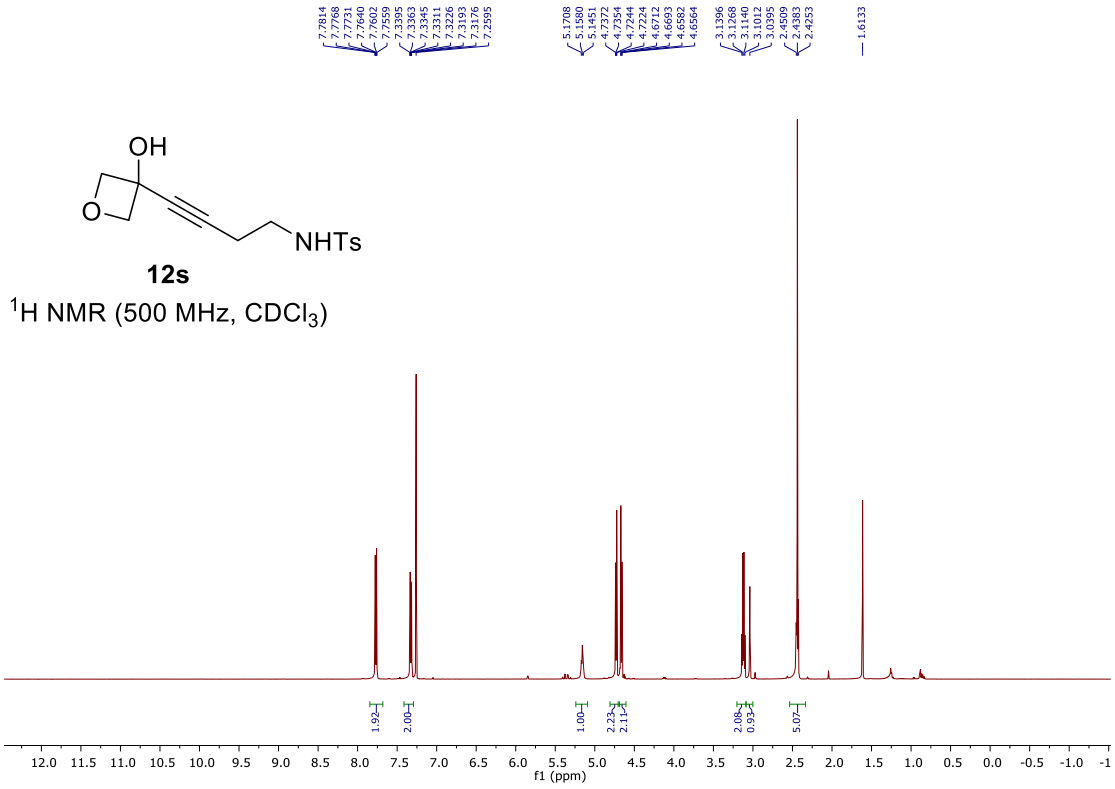
12r

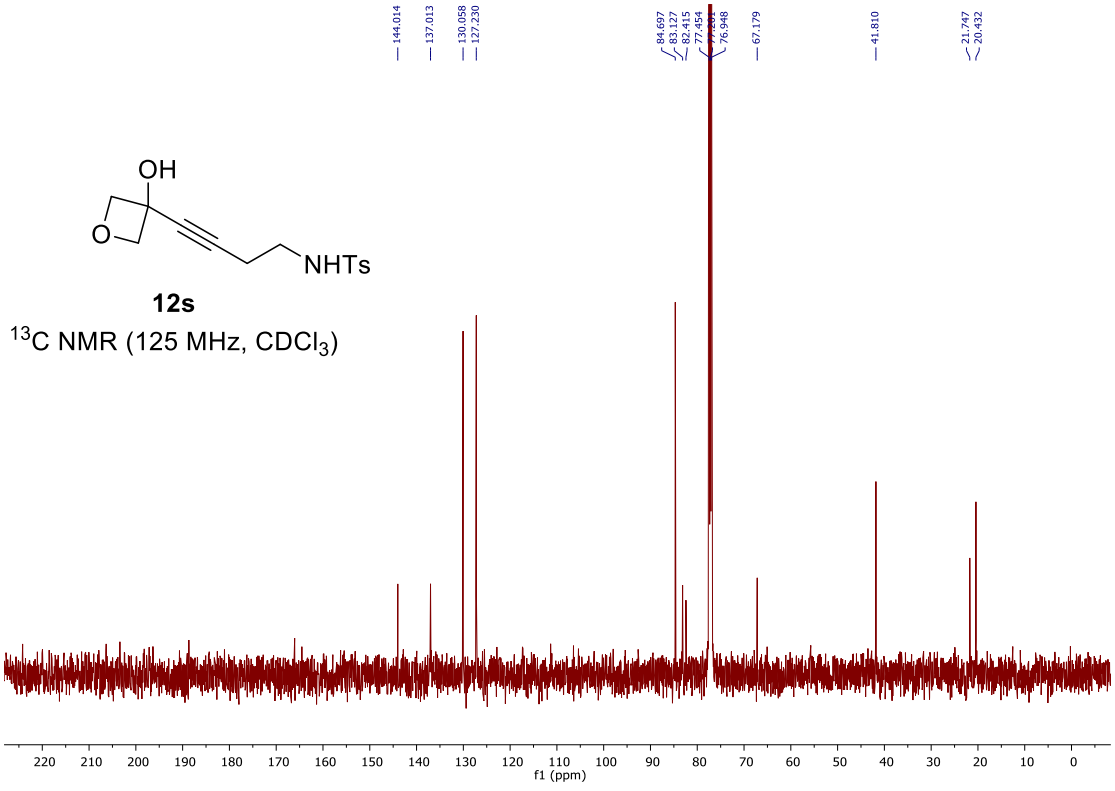
^{1}H NMR (500 MHz, $CDCl_3$)

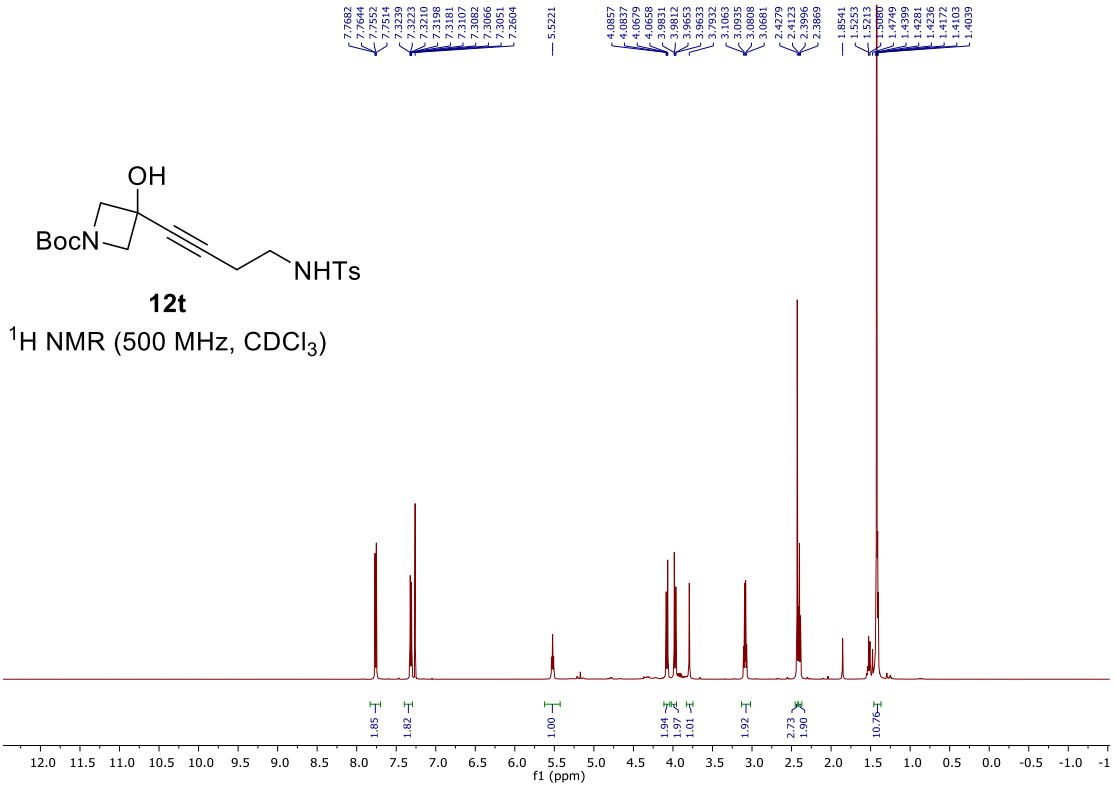


12r

^{13}C NMR (125 MHz, $CDCl_3$)

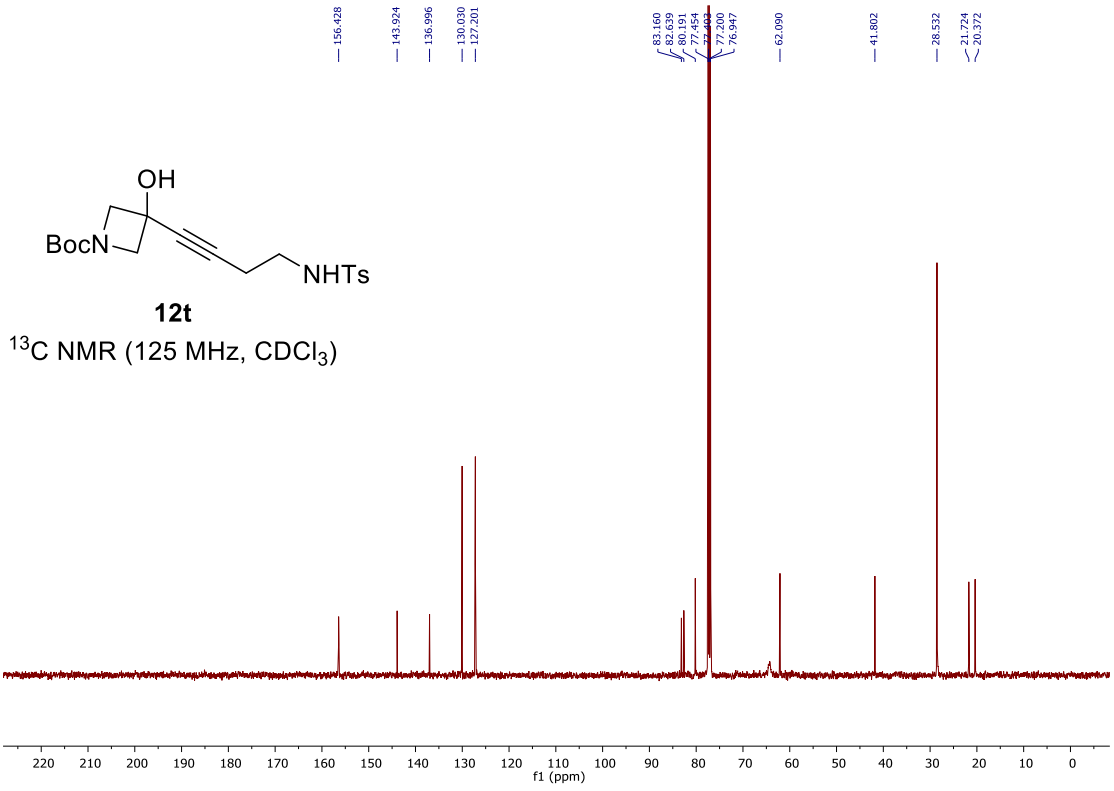

OH
O
NHTs
12s
1H NMR (500 MHz, CDCl3)
f1 (ppm)


OH
O
NHTs
12s
13C NMR (125 MHz, CDCl3)
f1 (ppm)



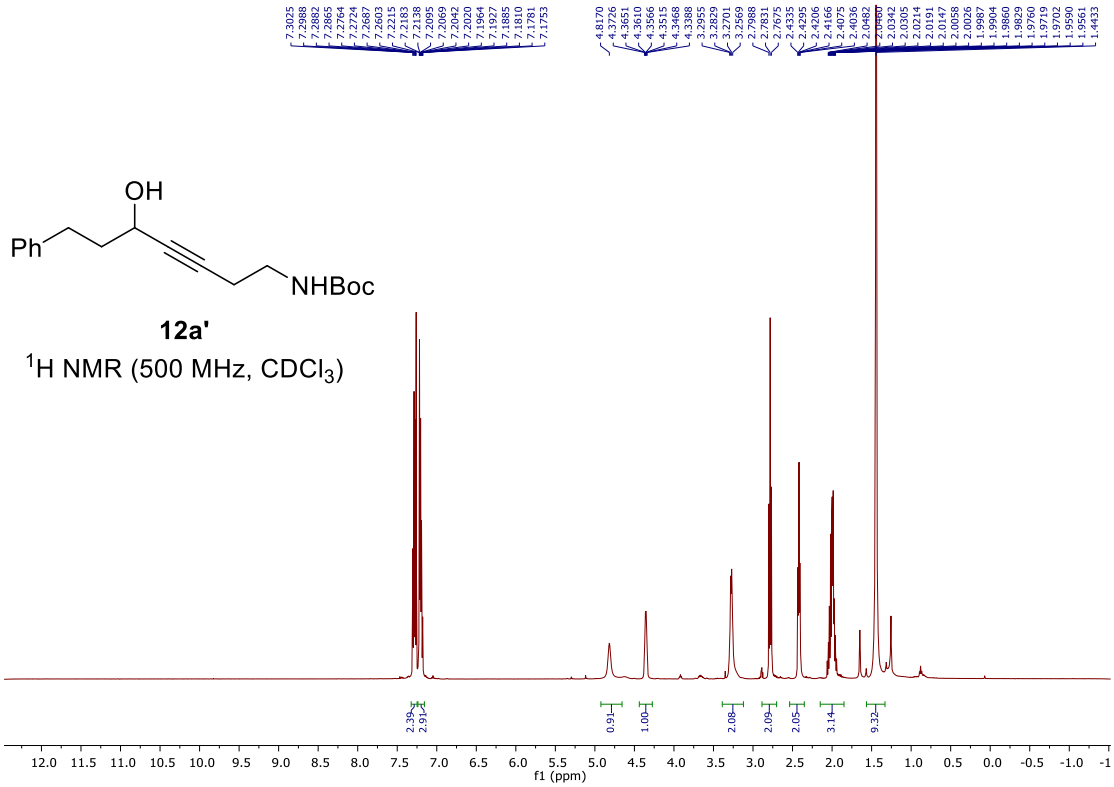
12t

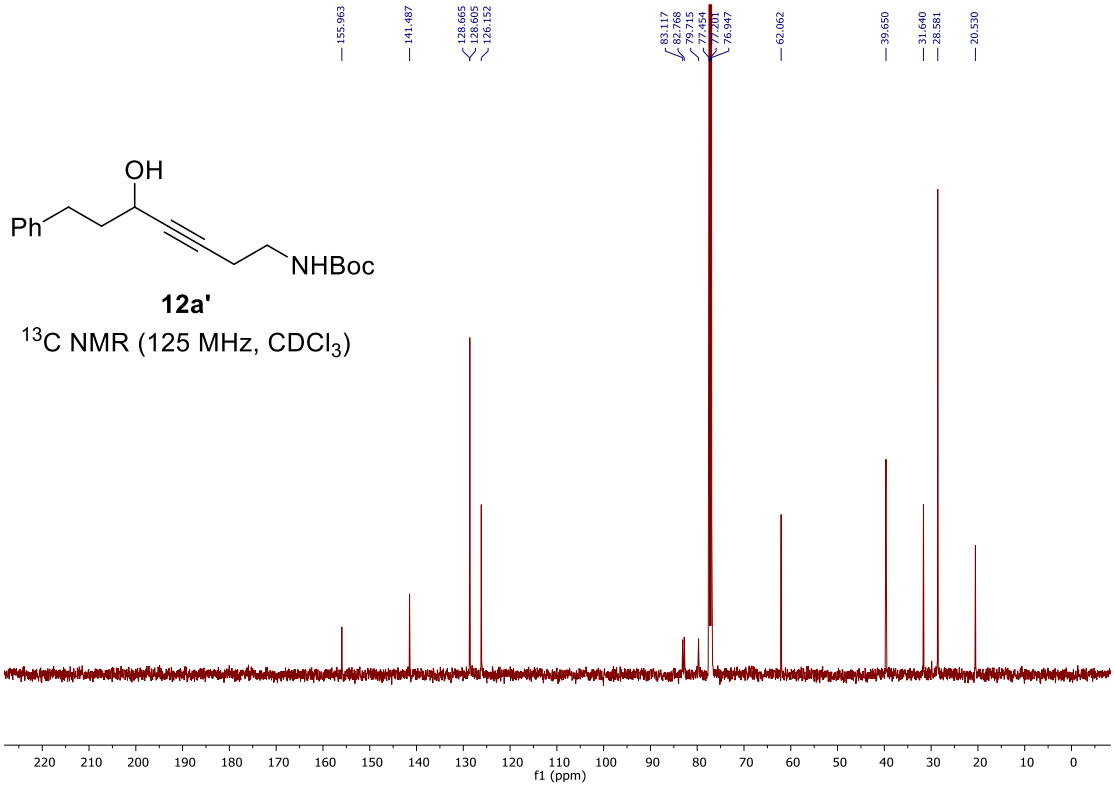
^{1}H NMR (500 MHz, $CDCl_3$)

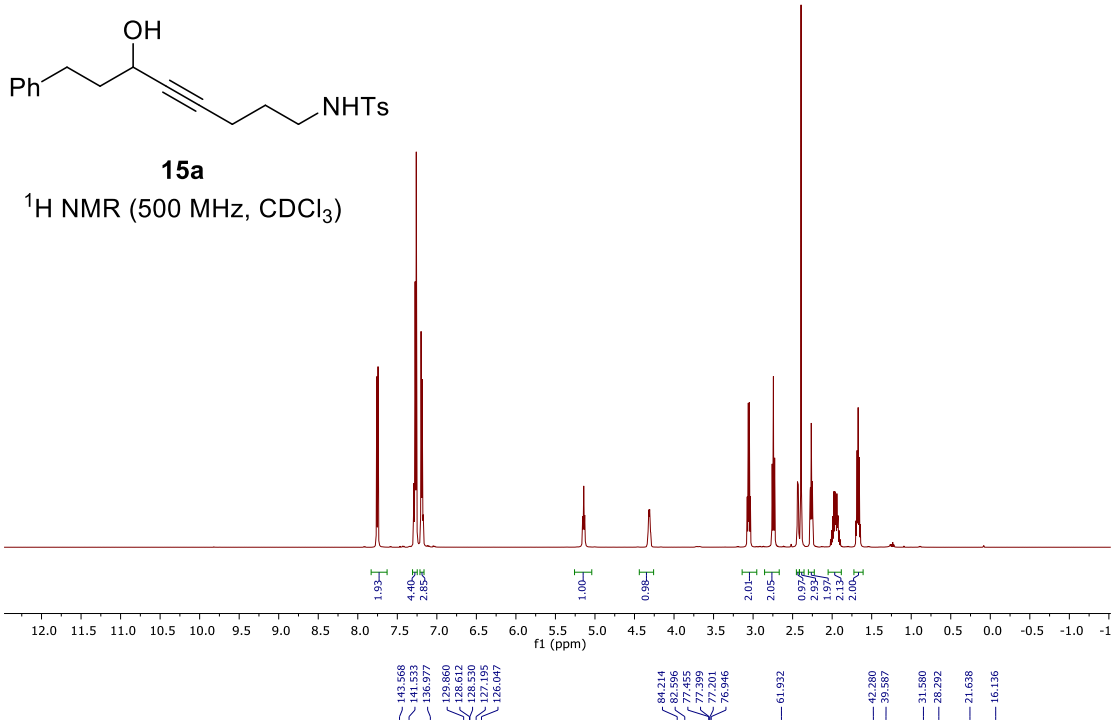


12t

^{13}C NMR (125 MHz, $CDCl_3$)

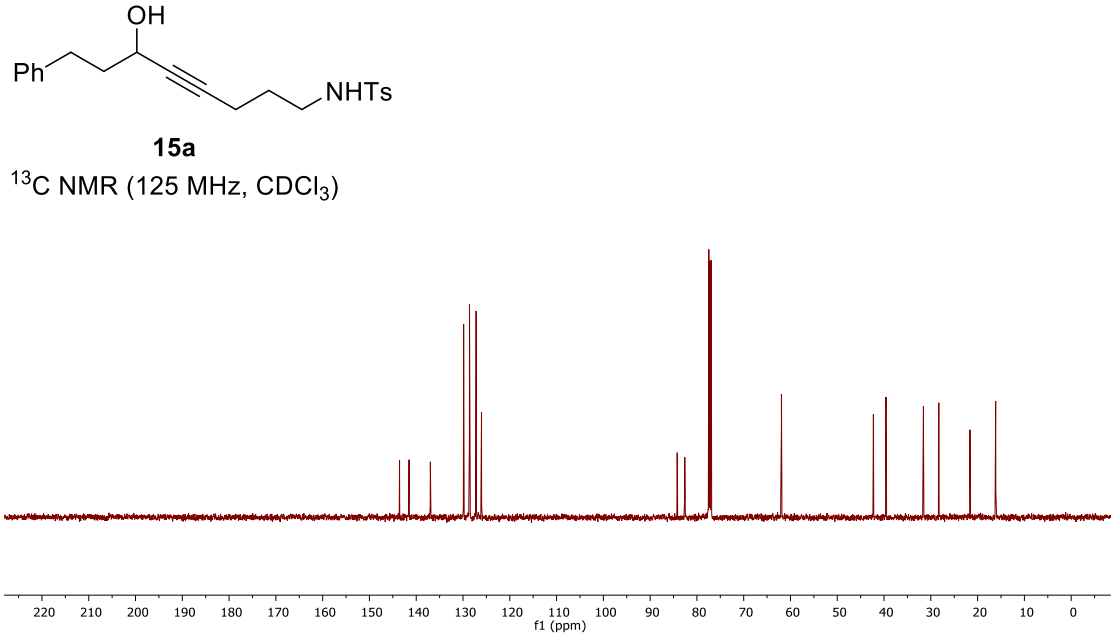

OH
Ph
NHBoc
12a'
1H NMR (500 MHz, CDCl3)
f1 (ppm)


OH
Ph
NHBoc
12a'
13C NMR (125 MHz, CDCl3)
f1 (ppm)



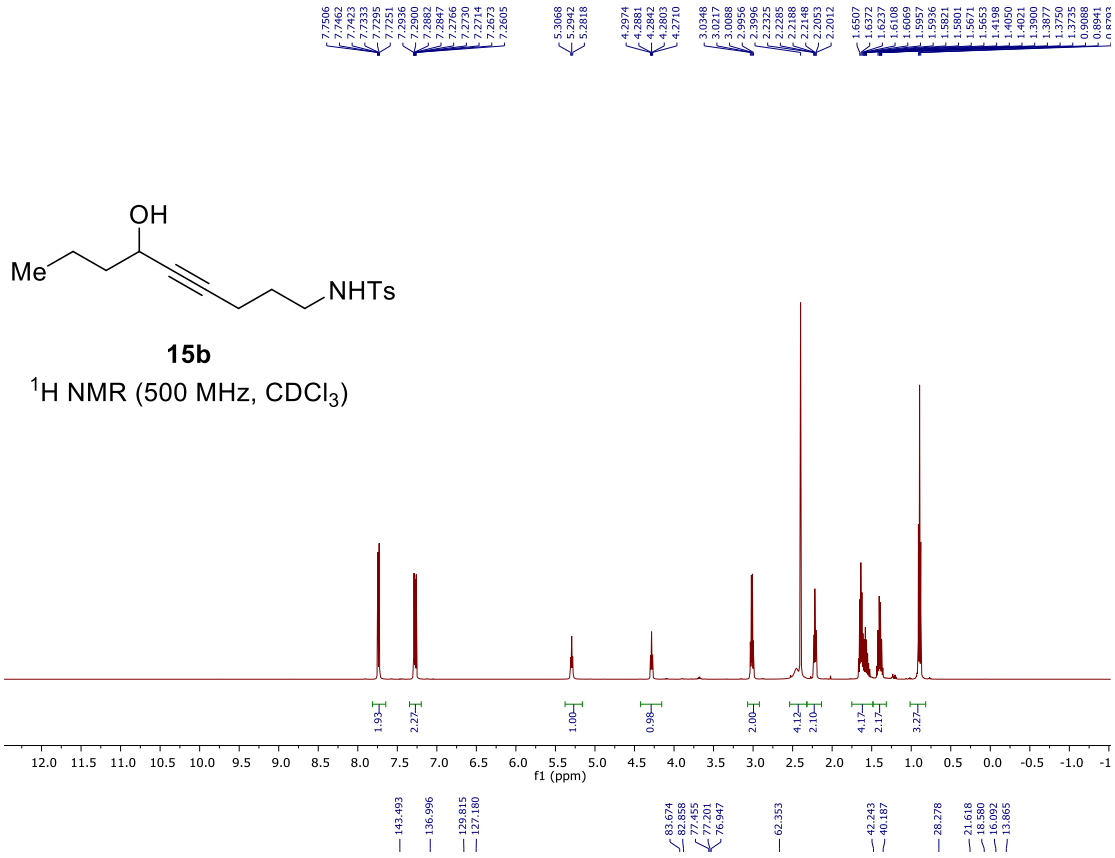
15a

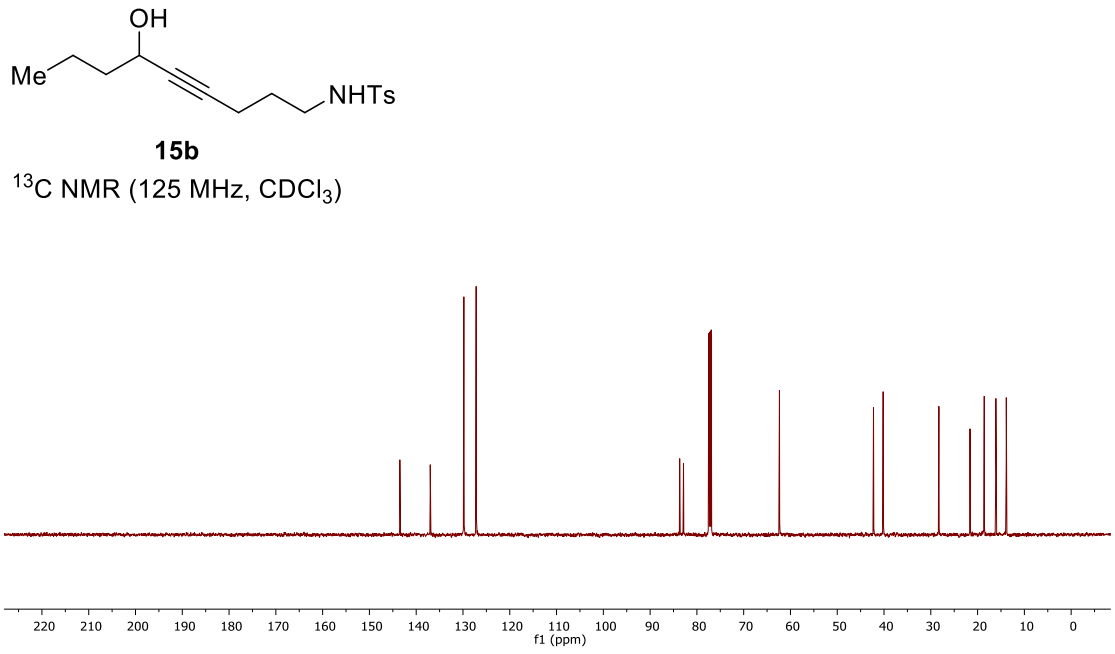
^{1}H NMR (500 MHz, $CDCl_3$)

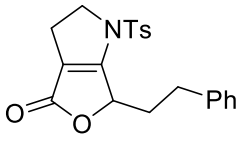


15a

^{13}C NMR (125 MHz, $CDCl_3$)

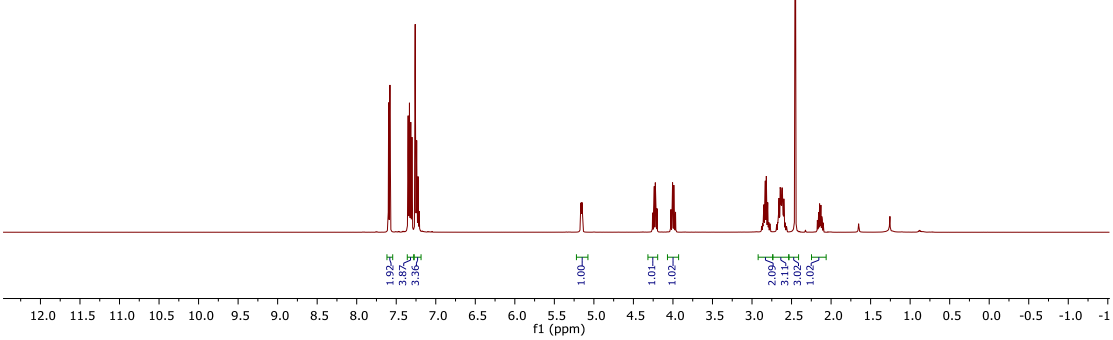

OH
Me
NHTs
15b
1H NMR (500 MHz, CDCl3)
7.7506
7.7462
7.7423
7.7333
7.7295
7.7251
7.2936
7.2900
7.2882
7.2847
7.2766
7.2730
7.2714
7.2673
7.2605
5.3068
5.2942
5.2818
4.2974
4.2881
4.2842
4.2803
4.2710
3.0348
3.0217
3.0088
2.9956
2.3996
2.2325
2.2285
2.2188
2.2148
2.2053
2.2012
1.6507
1.6372
1.6237
1.6108
1.6069
1.5957
1.5936
1.5821
1.5801
1.5671
1.5653
1.5498
1.4450
1.4021
1.3900
1.3877
1.3750
1.3735
0.9088
0.8941
1.93
2.27
1.00
0.98
2.00
4.12
2.10
4.17
2.17
3.27
f1 (ppm)
143.493
136.996
129.815
127.180
83.674
82.858
77.455
77.201
76.947
62.353
42.243
40.187
28.278
21.618
18.580
16.092
13.865

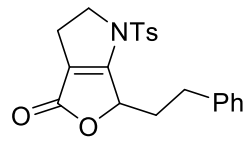

OH
Me
NHTs
15b
13C NMR (125 MHz, CDCl3)
f1 (ppm)



13a

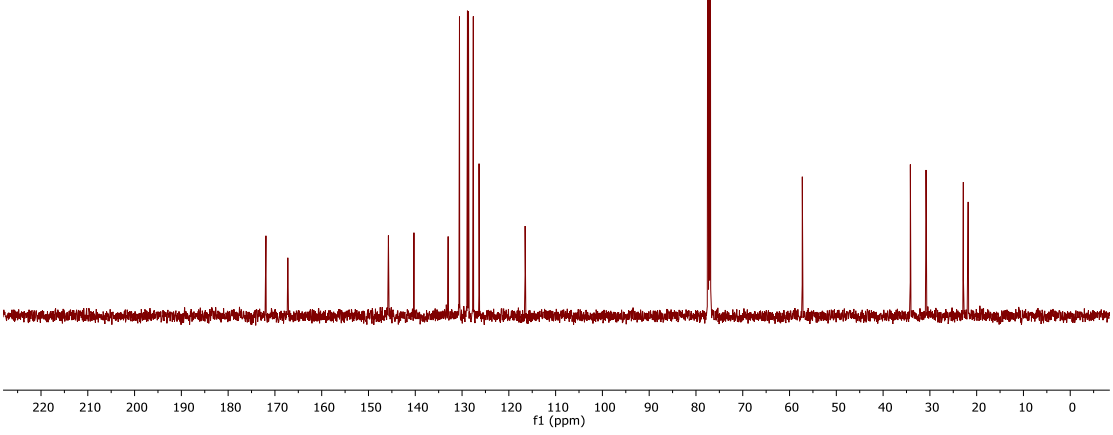
^{1}H NMR (500 MHz, $CDCl_3$)

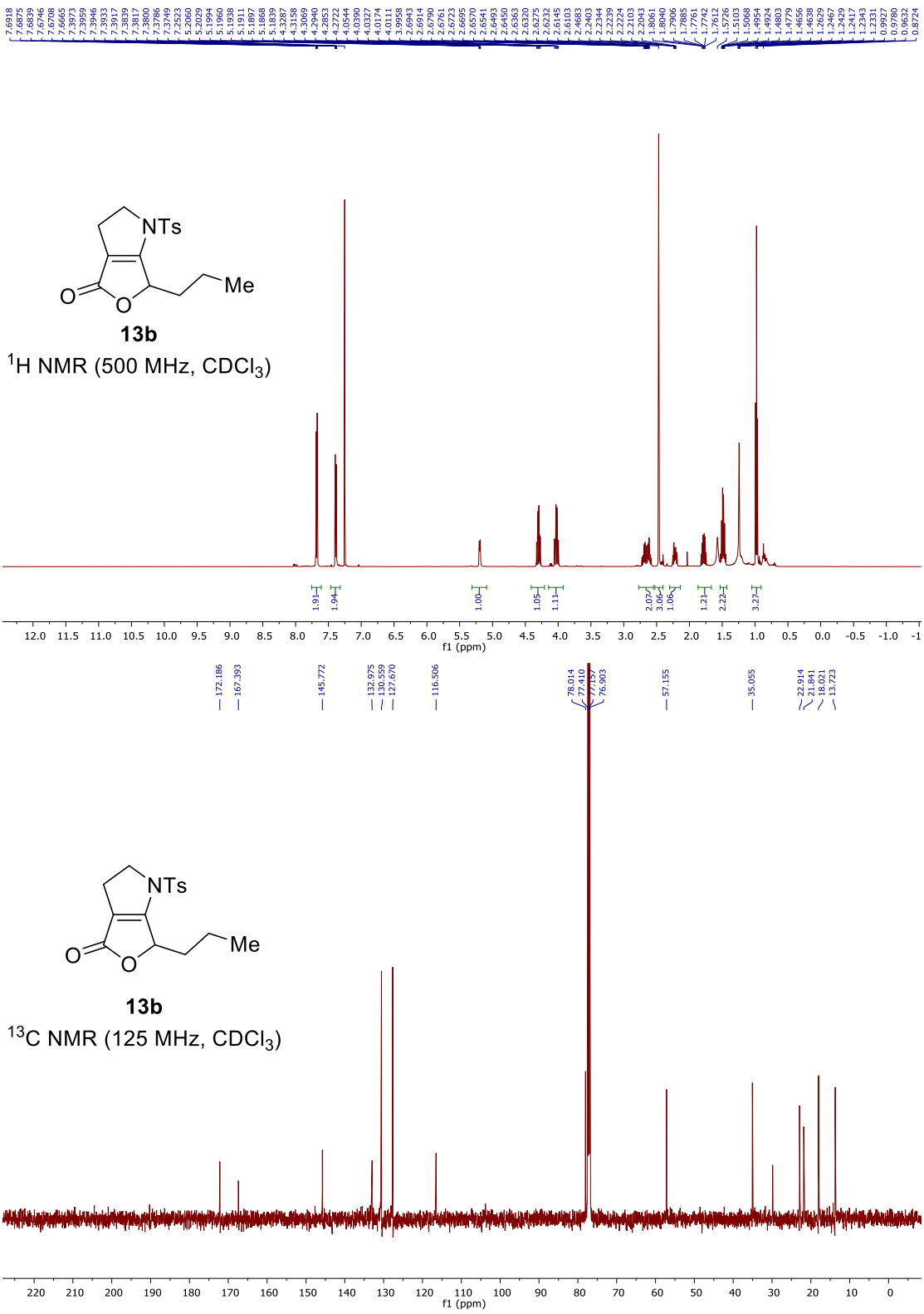


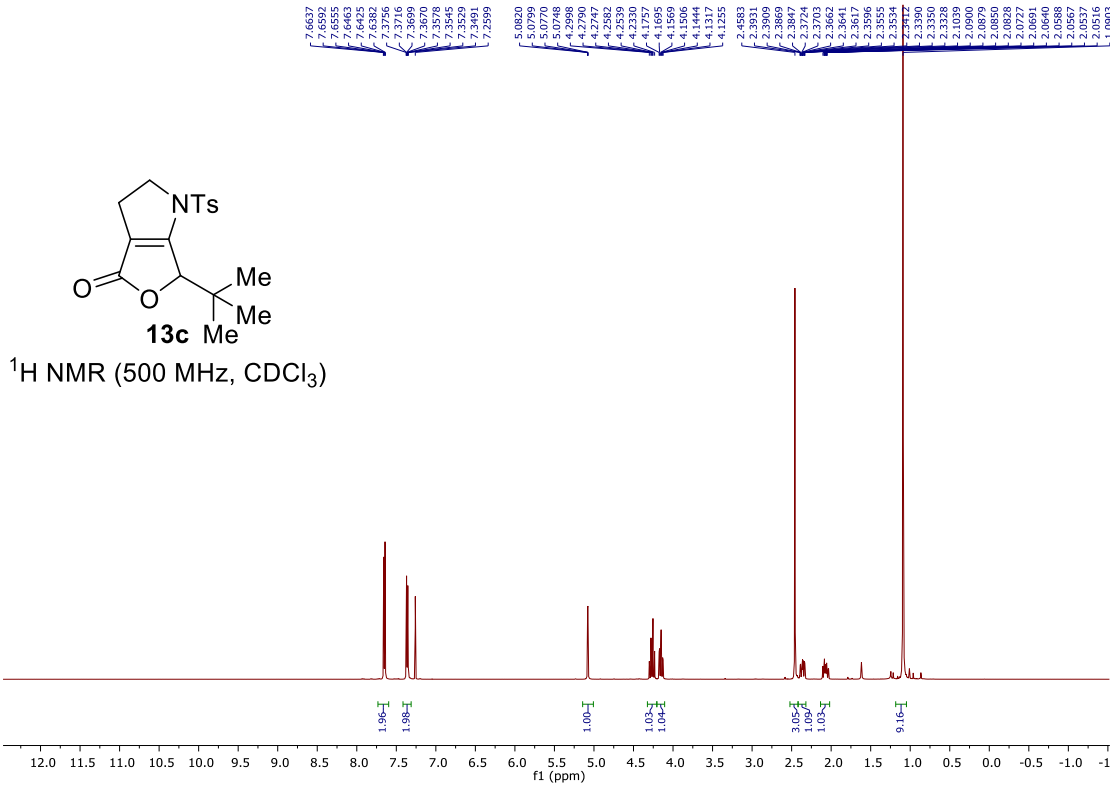


13a

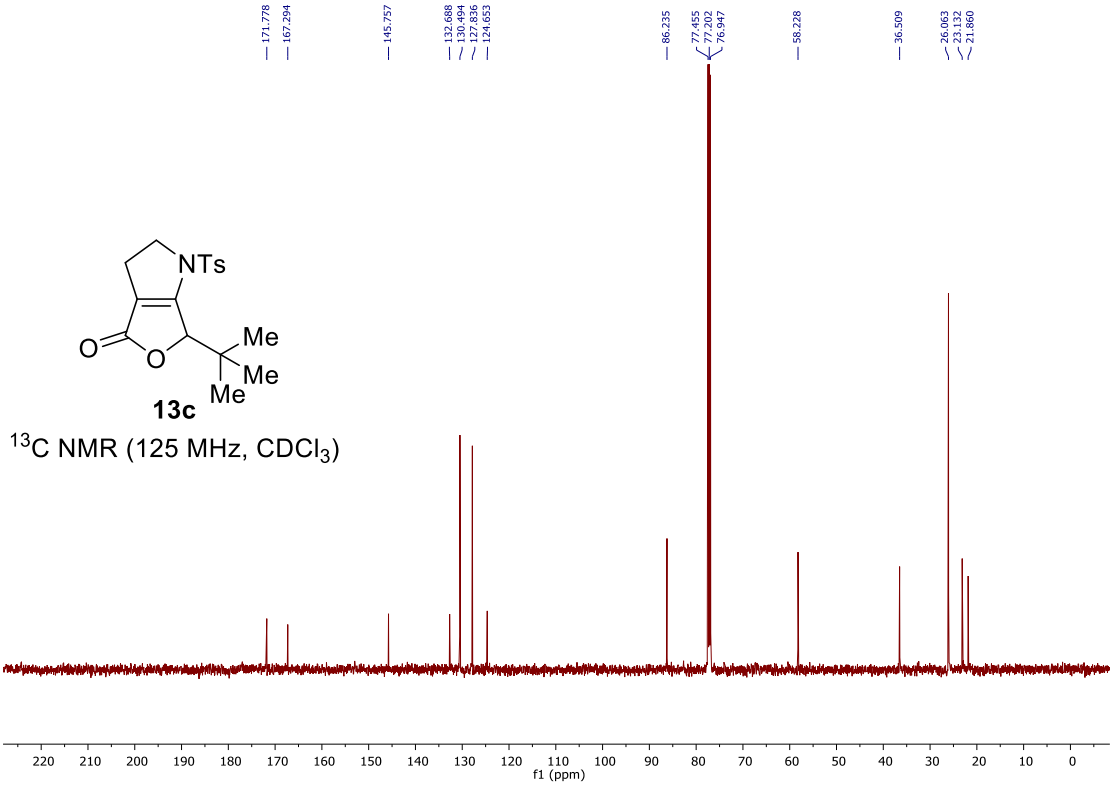
^{13}C NMR (125 MHz, $CDCl_3$)



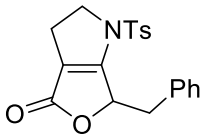

NTs
Me
O
O
13b
1H NMR (500 MHz, CDCl3)
f1 (ppm)
NTs
Me
O
O
13b
13C NMR (125 MHz, CDCl3)
f1 (ppm)



^{1}H NMR (500 MHz, $CDCl_3$)

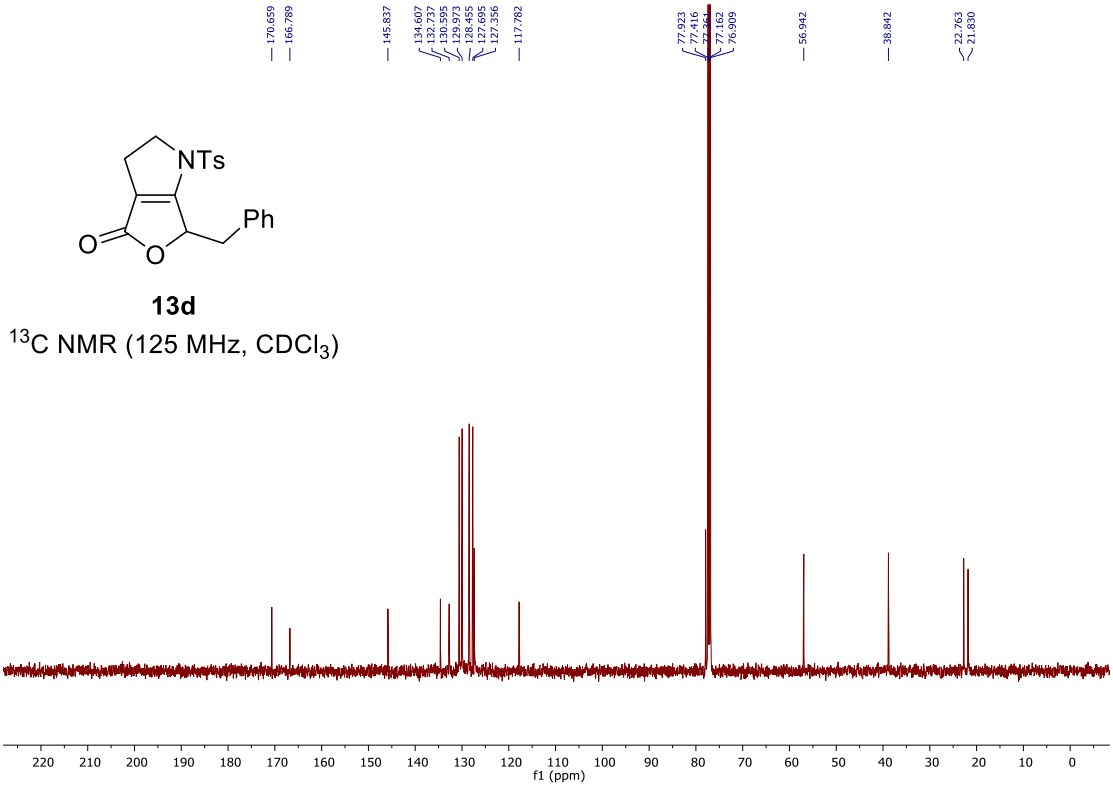


^{13}C NMR (125 MHz, $CDCl_3$)



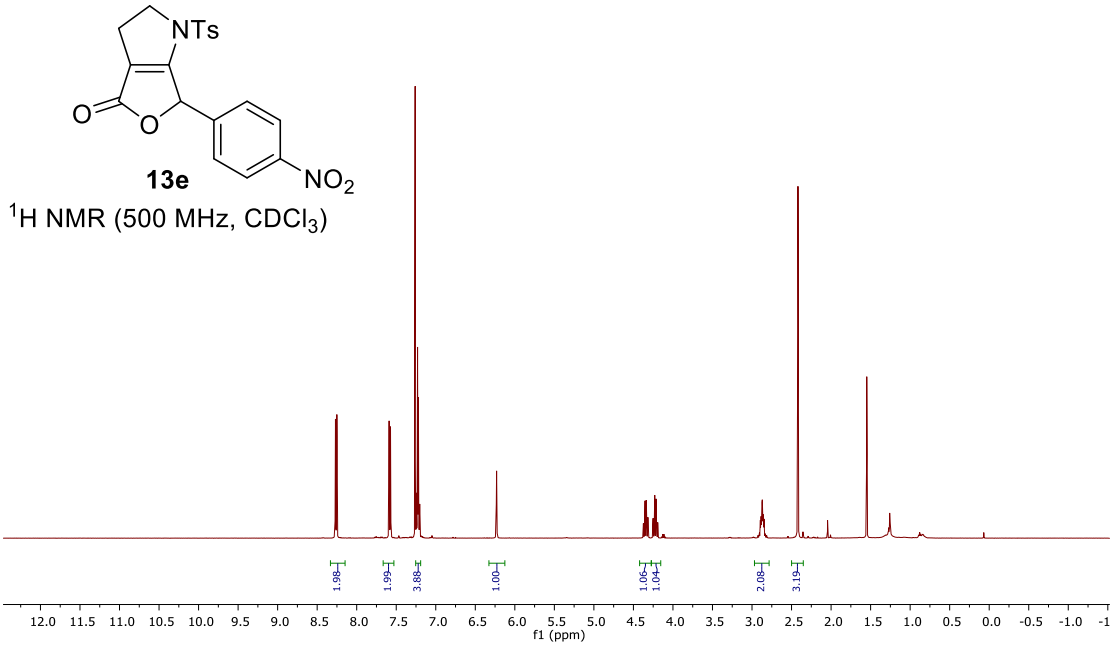
13d

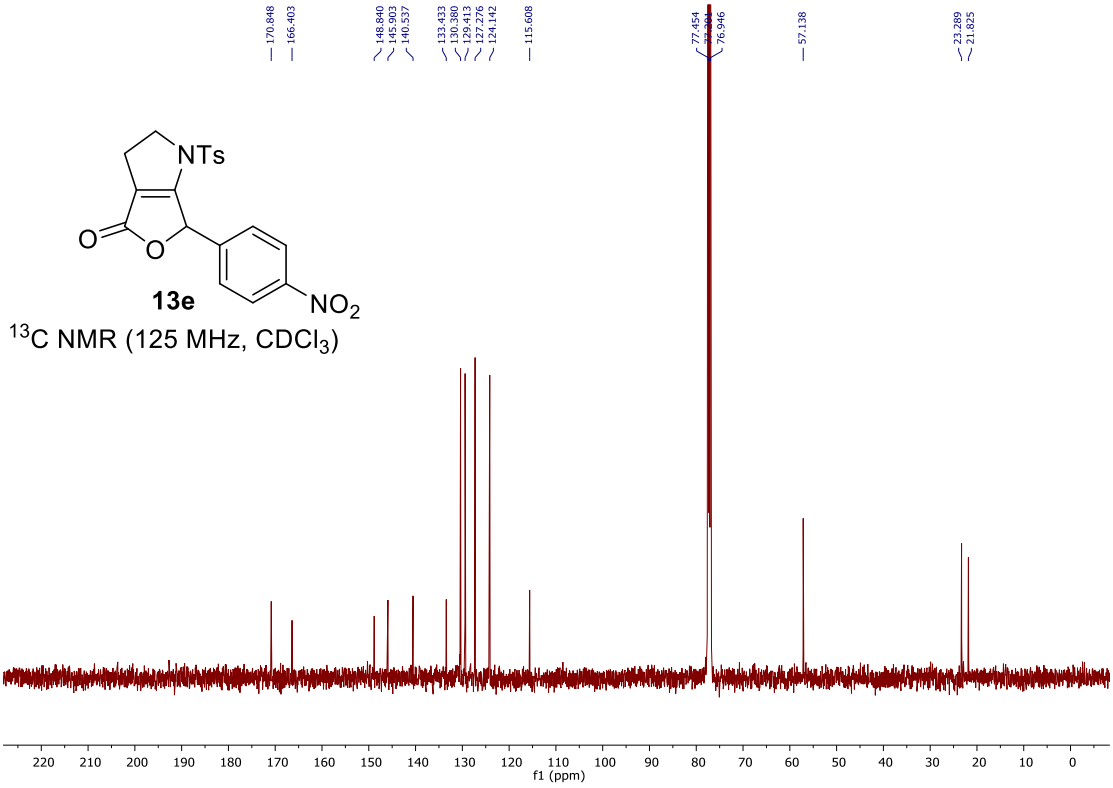
^{1}H NMR (500 MHz, $CDCl_3$)

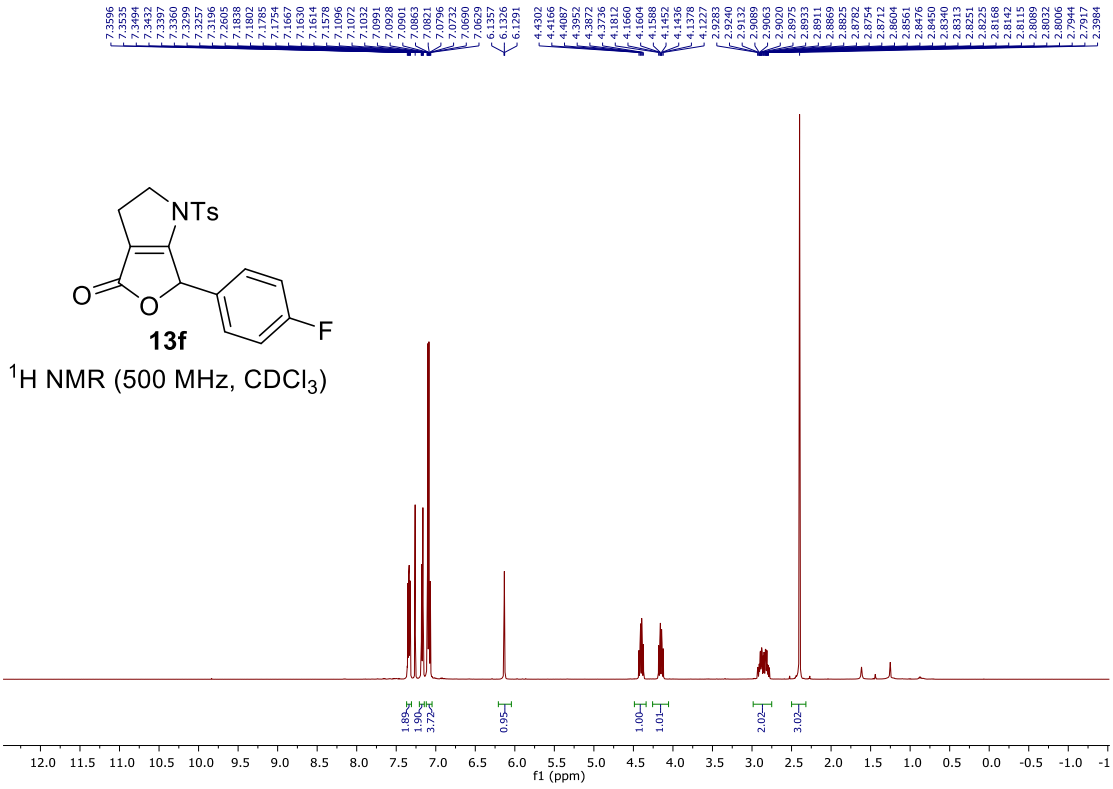


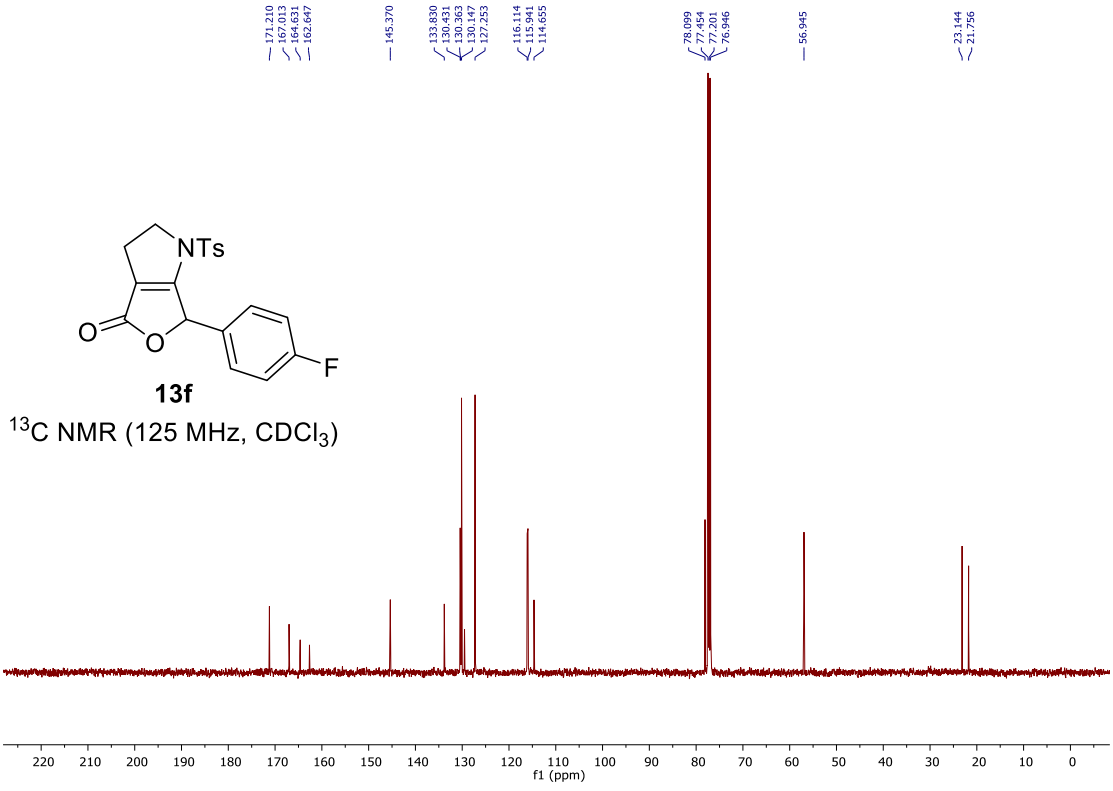
13d

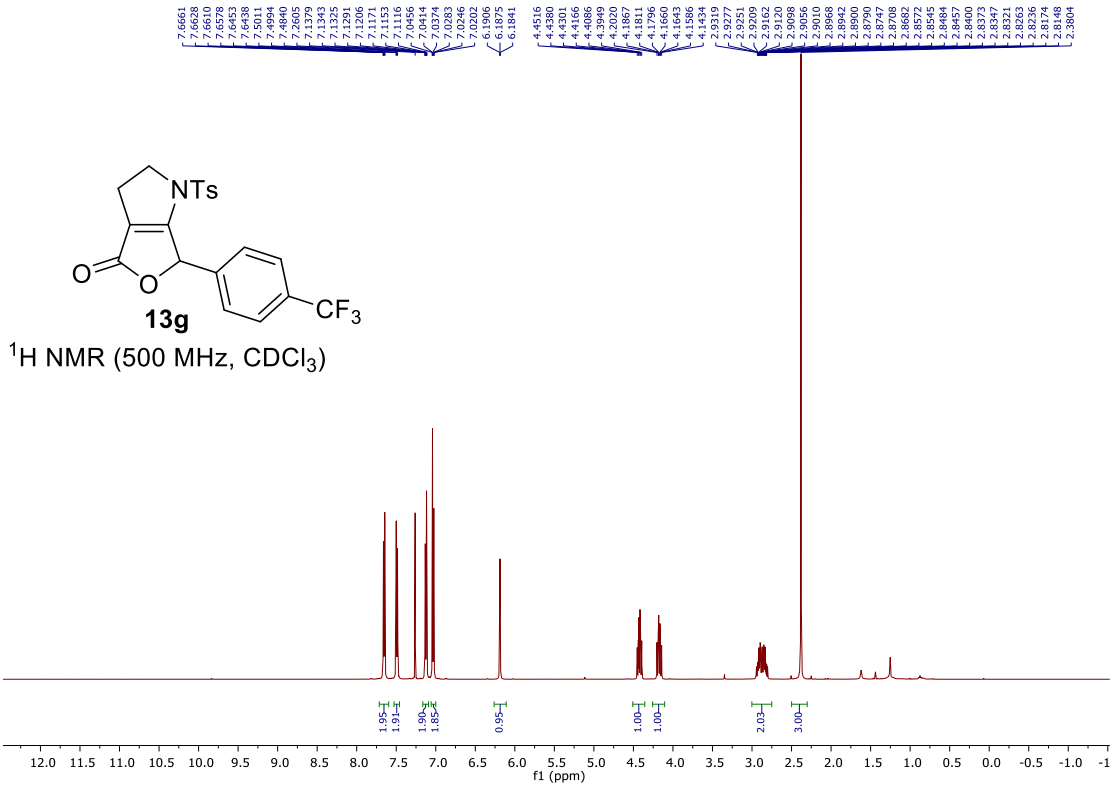
^{13}C NMR (125 MHz, $CDCl_3$)


NTs
O
O
NO2
13e
1H NMR (500 MHz, CDCl3)
f1 (ppm)


NTs
O
O
NO2
13e
13C NMR (125 MHz, CDCl3)
f1 (ppm)

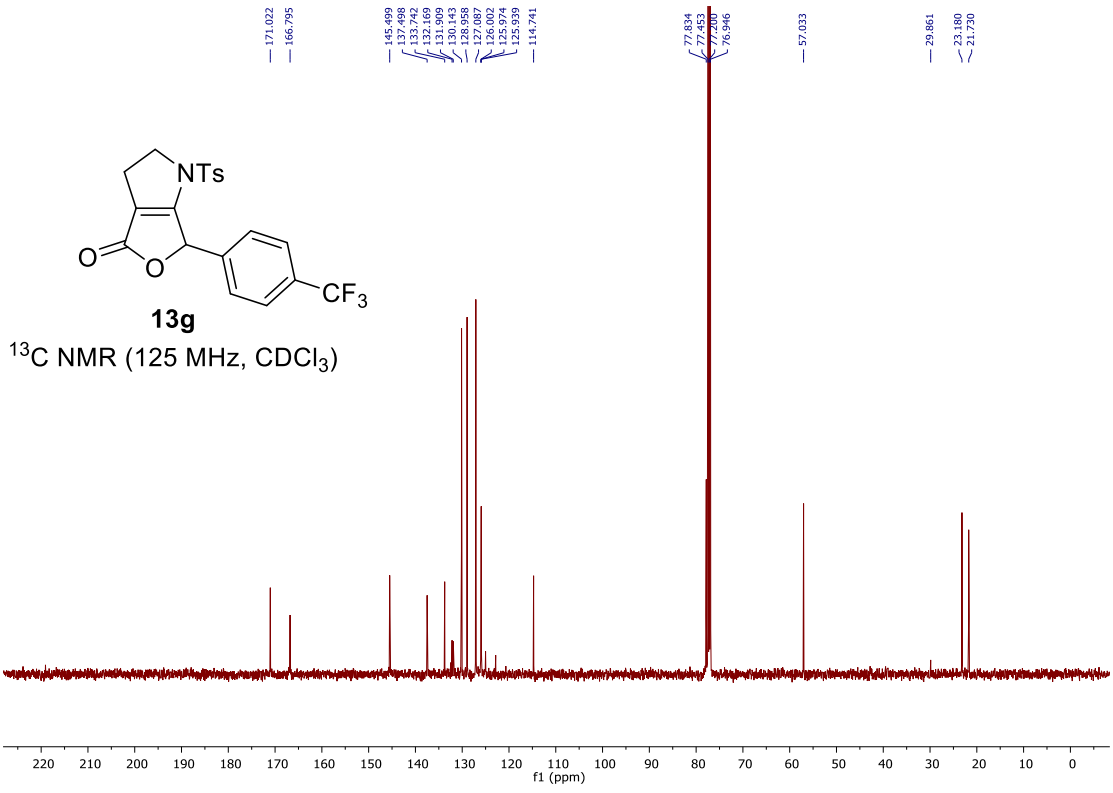

NTs
O
O
F
13f
1H NMR (500 MHz, CDCl3)
f1 (ppm)


NTs
O
O
F
13f
13C NMR (125 MHz, CDCl3)
f1 (ppm)



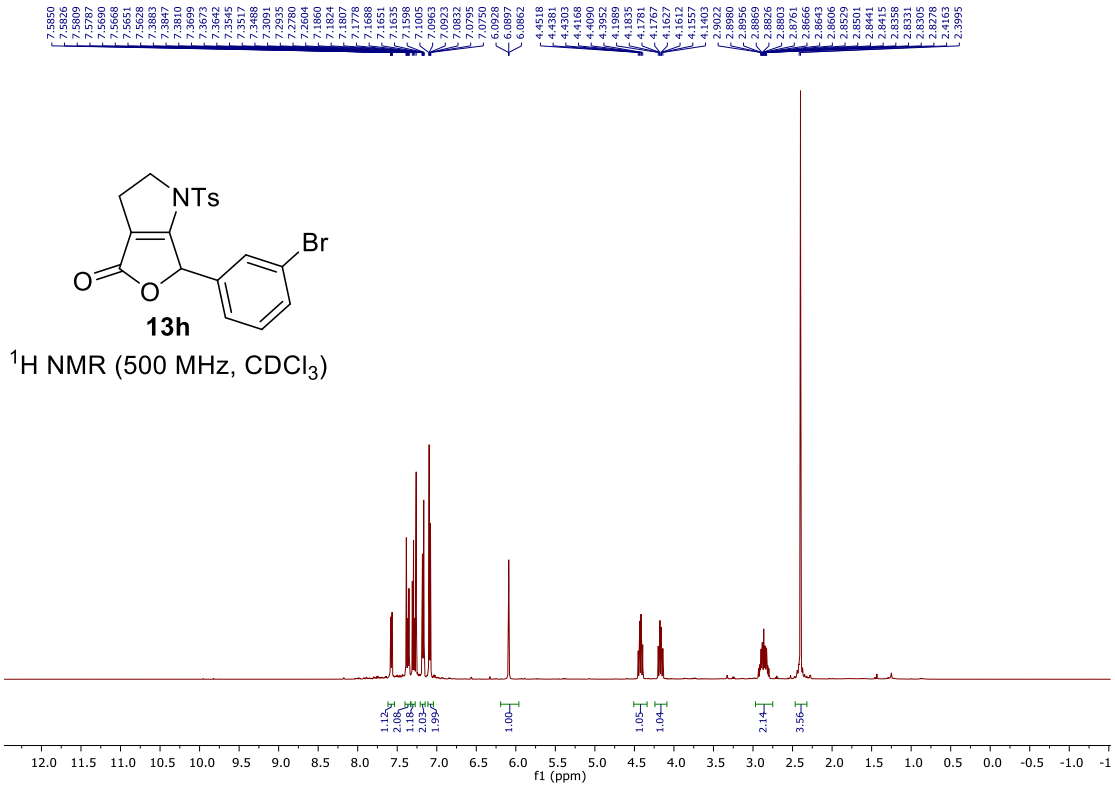
13g

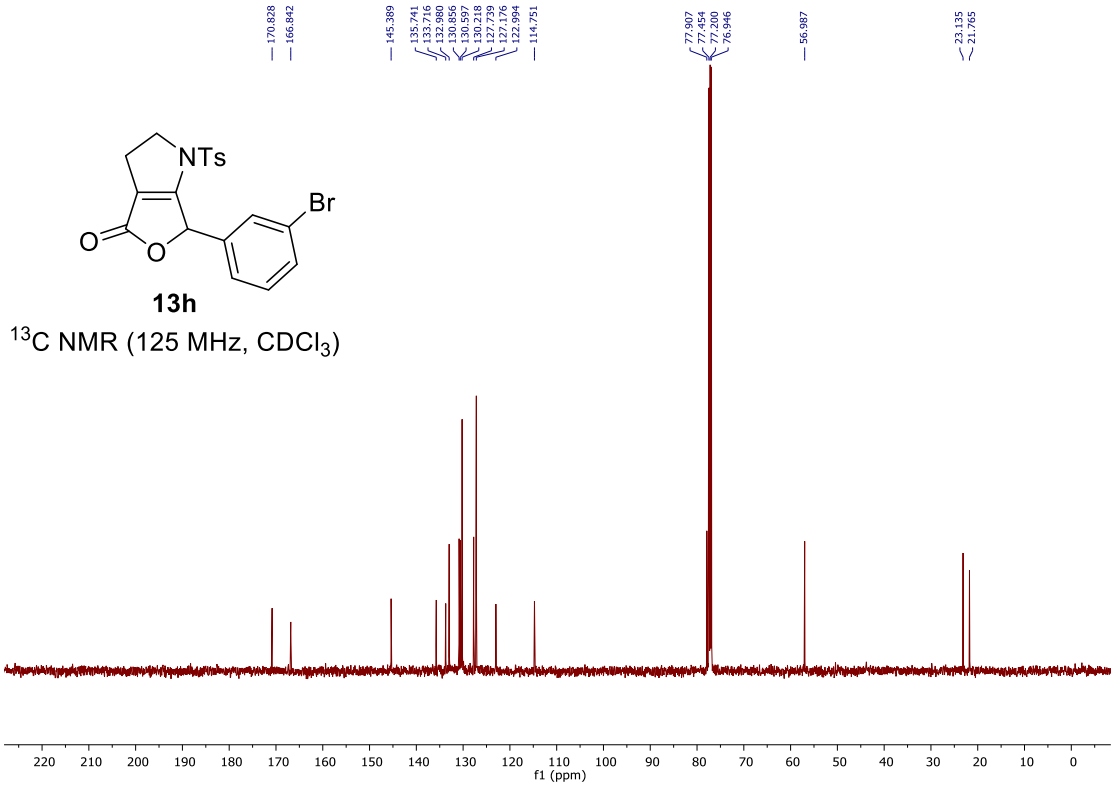
^{1}H NMR (500 MHz, $CDCl_3$)

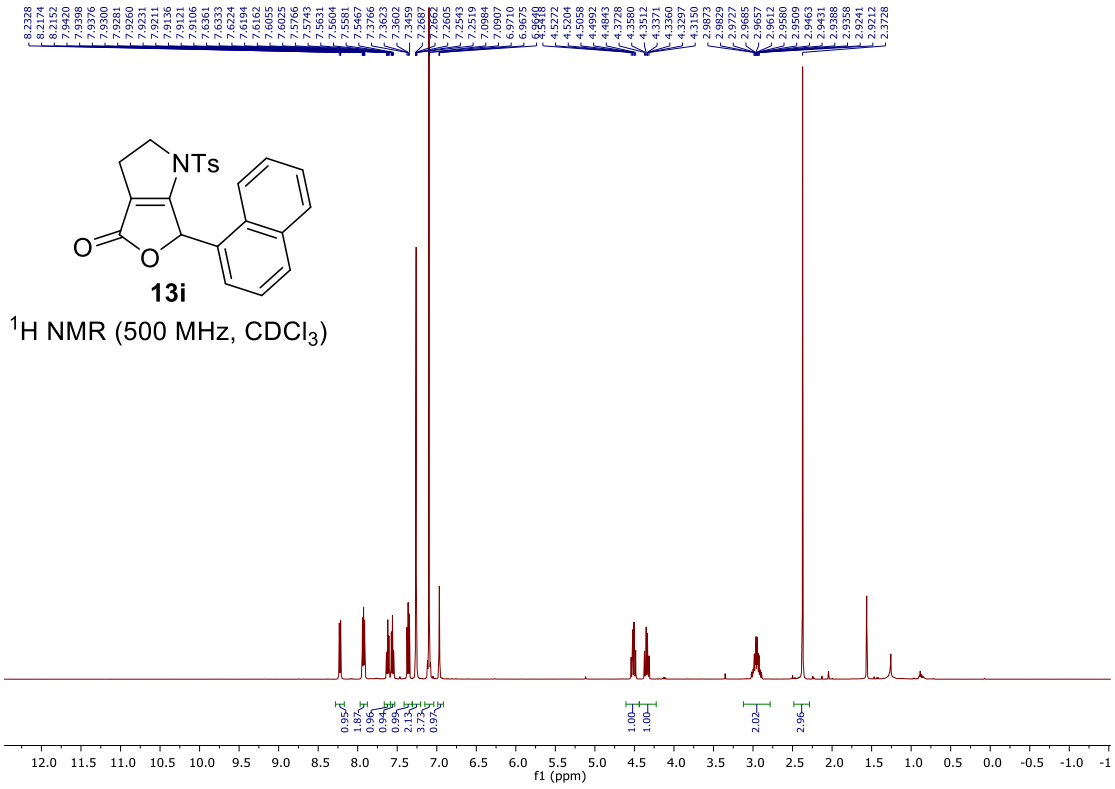


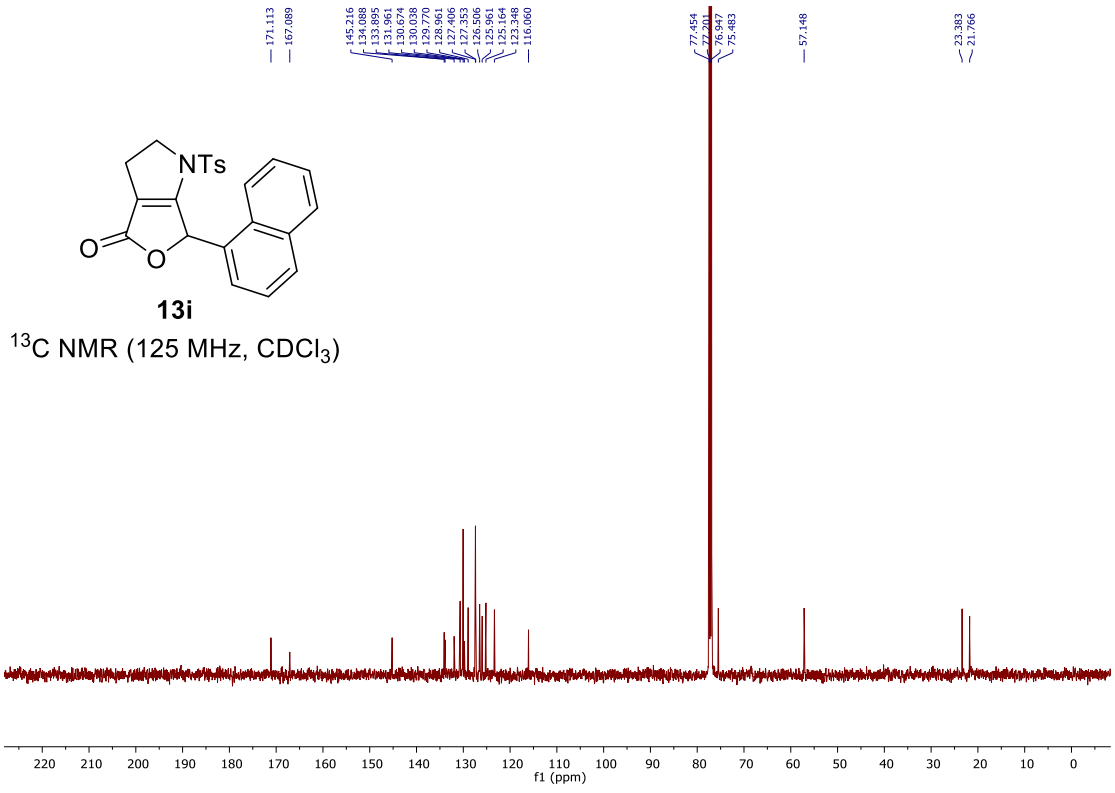
13g

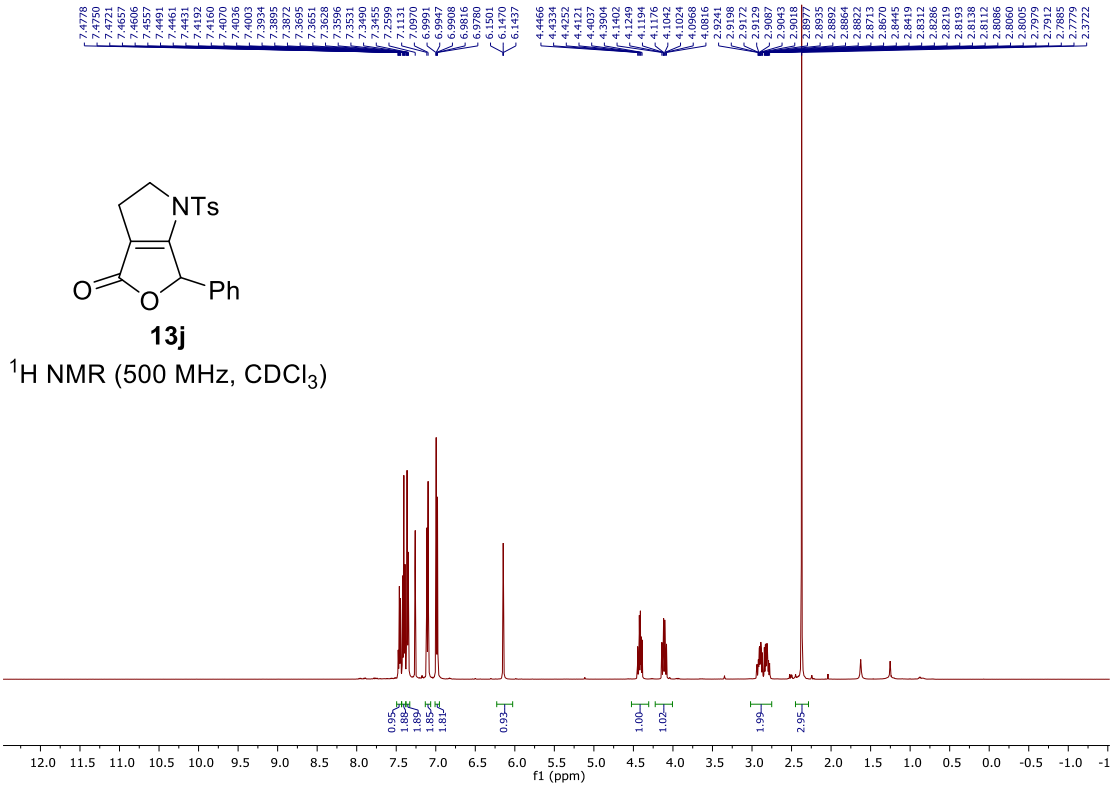
^{13}C NMR (125 MHz, $CDCl_3$)


NTs
Br
O
O
13h
1H NMR (500 MHz, CDCl3)
f1 (ppm)


NTs
Br
O
O
13h
13C NMR (125 MHz, CDCl3)
f1 (ppm)

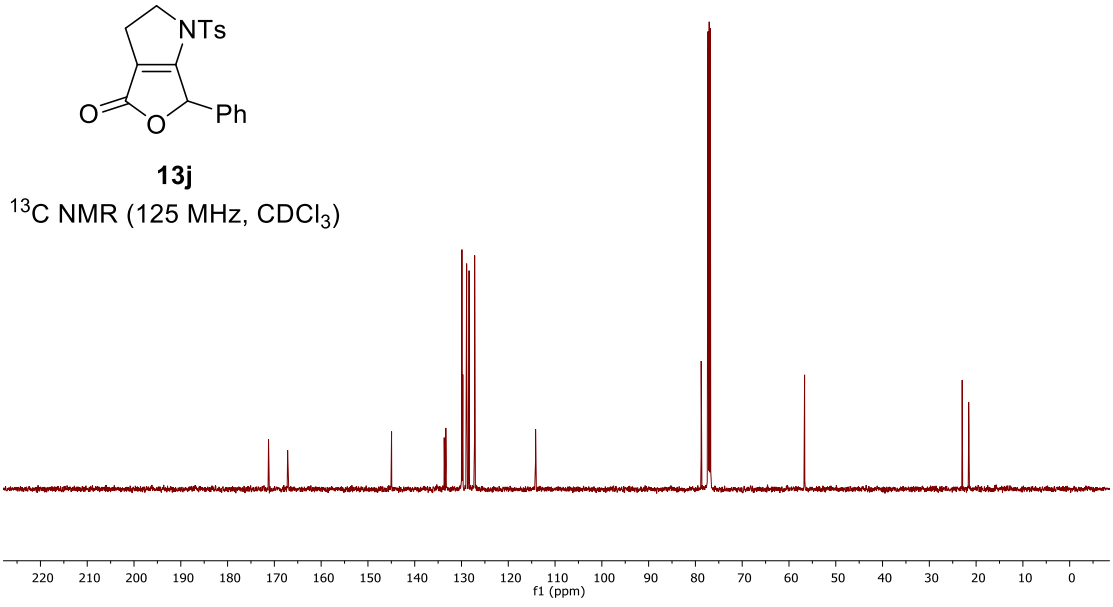

NTs
O
O
13i
1H NMR (500 MHz, CDCl3)
f1 (ppm)


NTs
O
O
13i
13C NMR (125 MHz, CDCl3)
f1 (ppm)



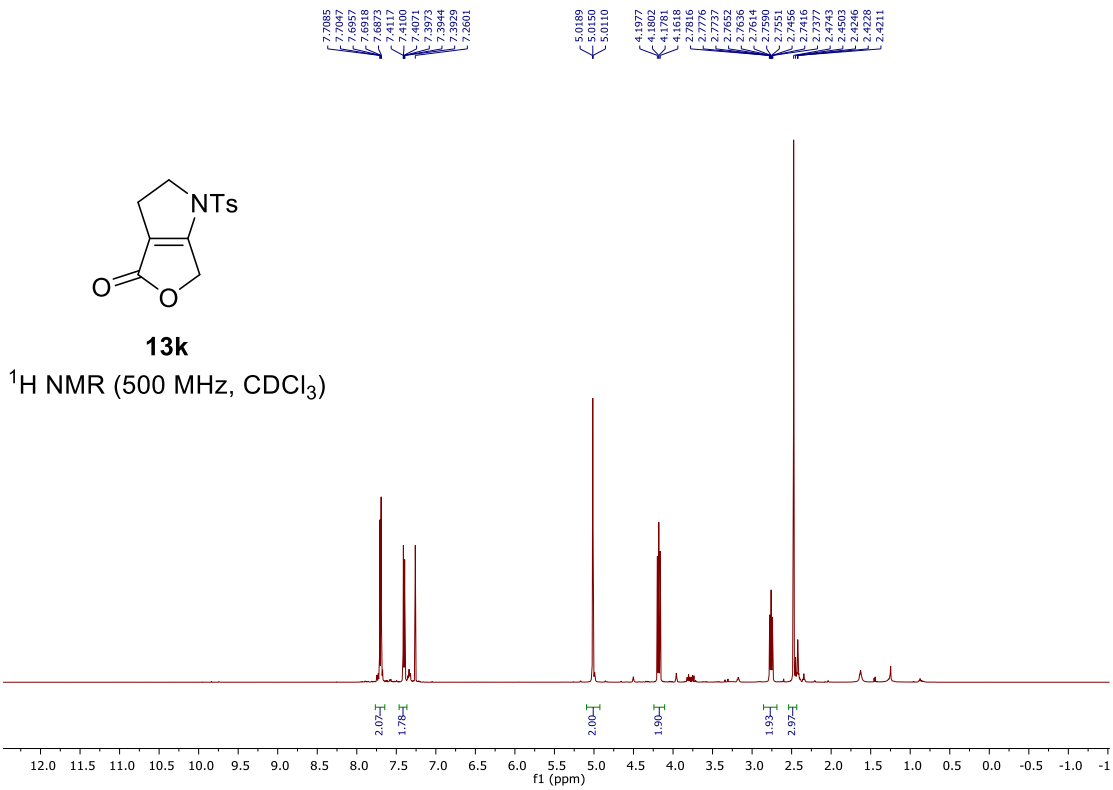
13j

^{1}H NMR (500 MHz, $CDCl_3$)



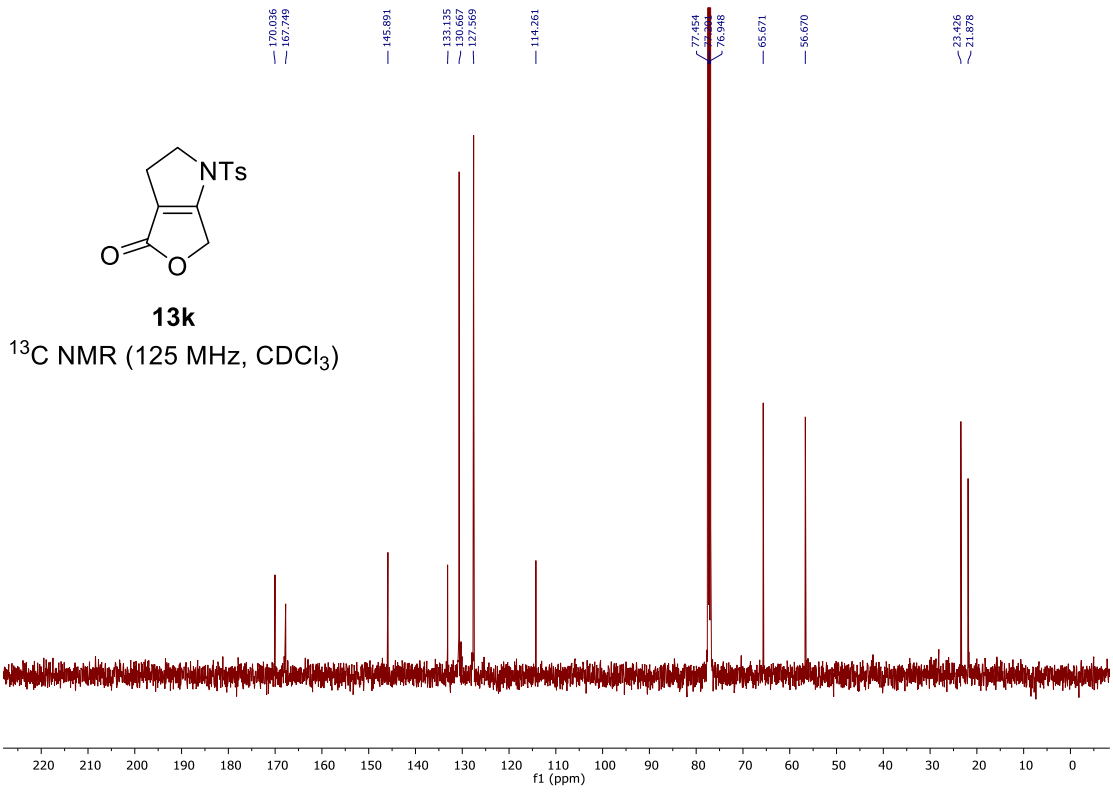
13j

^{13}C NMR (125 MHz, $CDCl_3$)



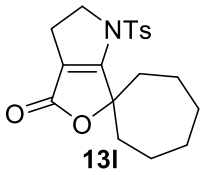
13k

^{1}H NMR (500 MHz, $CDCl_3$)



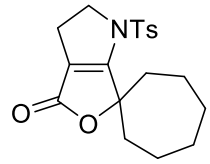
13k

^{13}C NMR (125 MHz, $CDCl_3$)



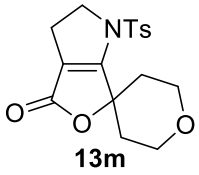
13l

^{1}H NMR (500 MHz, $CDCl_3$)



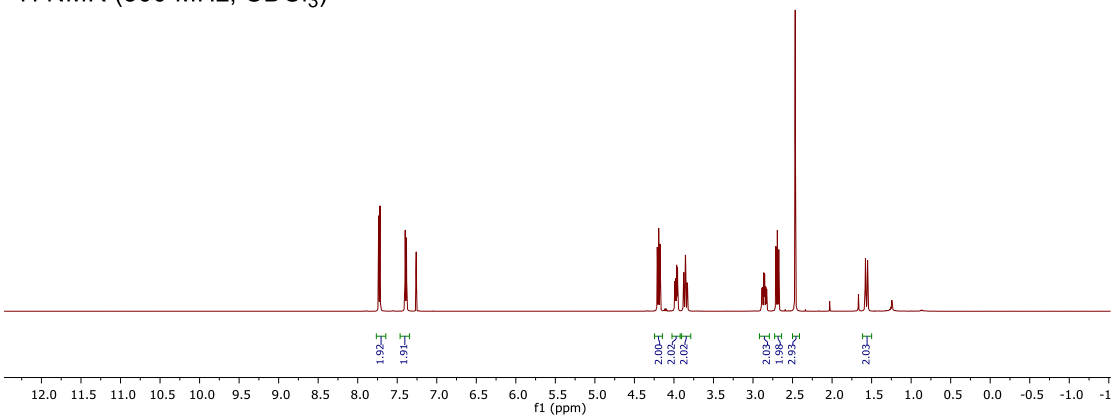
13l

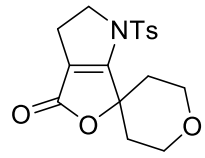
^{13}C NMR (125 MHz, $CDCl_3$)



13m

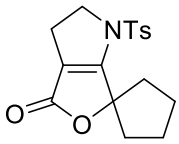
^{1}H NMR (500 MHz, $CDCl_3$)





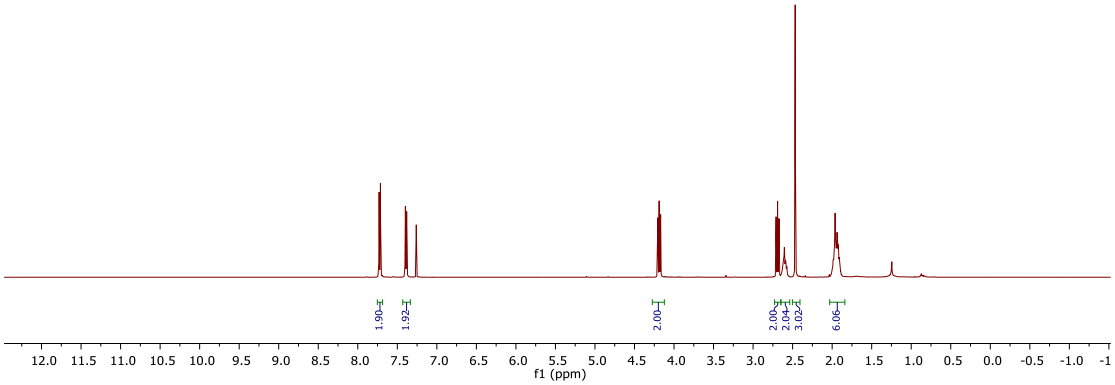
13m

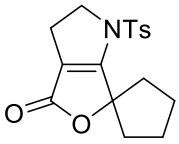
^{13}C NMR (125 MHz, $CDCl_3$)



13n

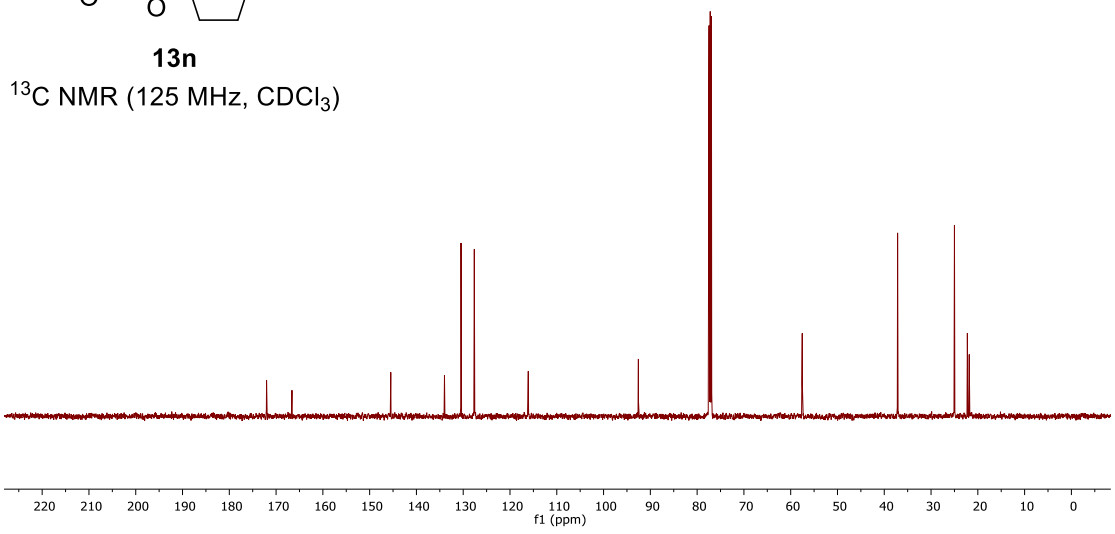
^{1}H NMR (500 MHz, $CDCl_3$)

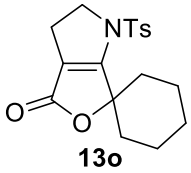




13n

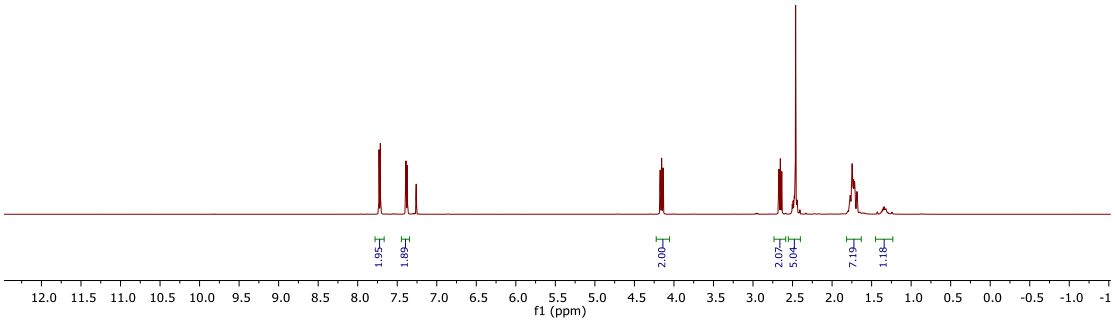
^{13}C NMR (125 MHz, $CDCl_3$)

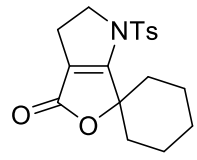




13o

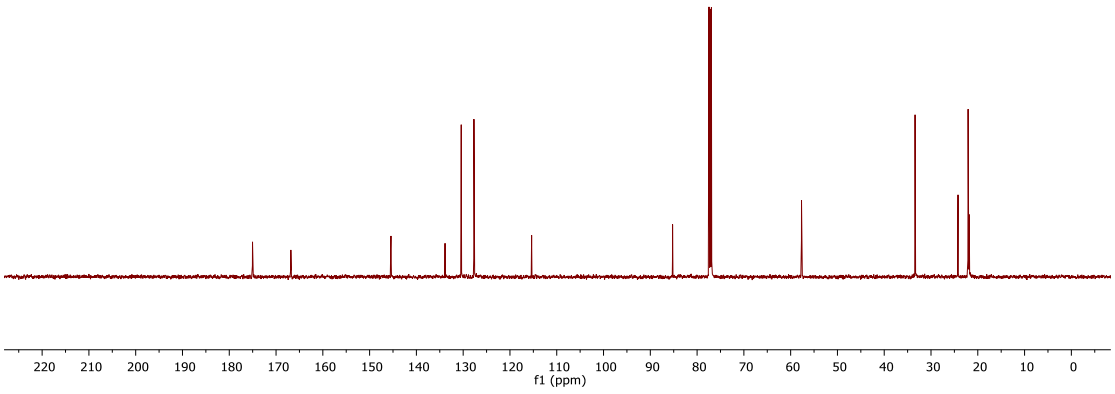
^{1}H NMR (500 MHz, $CDCl_3$)

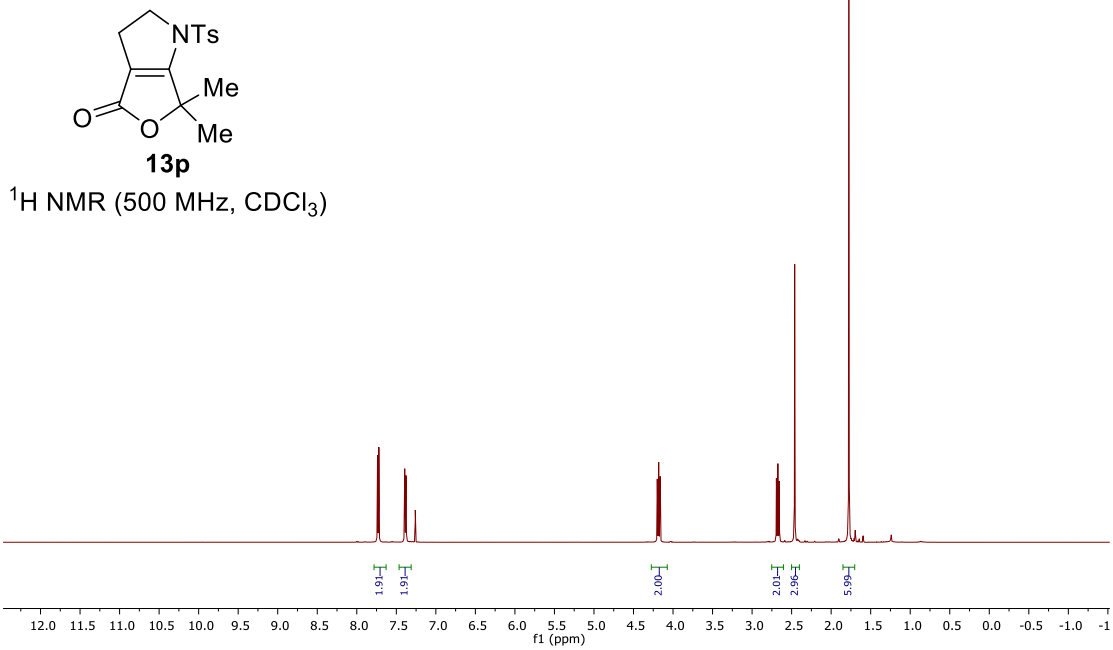




13o

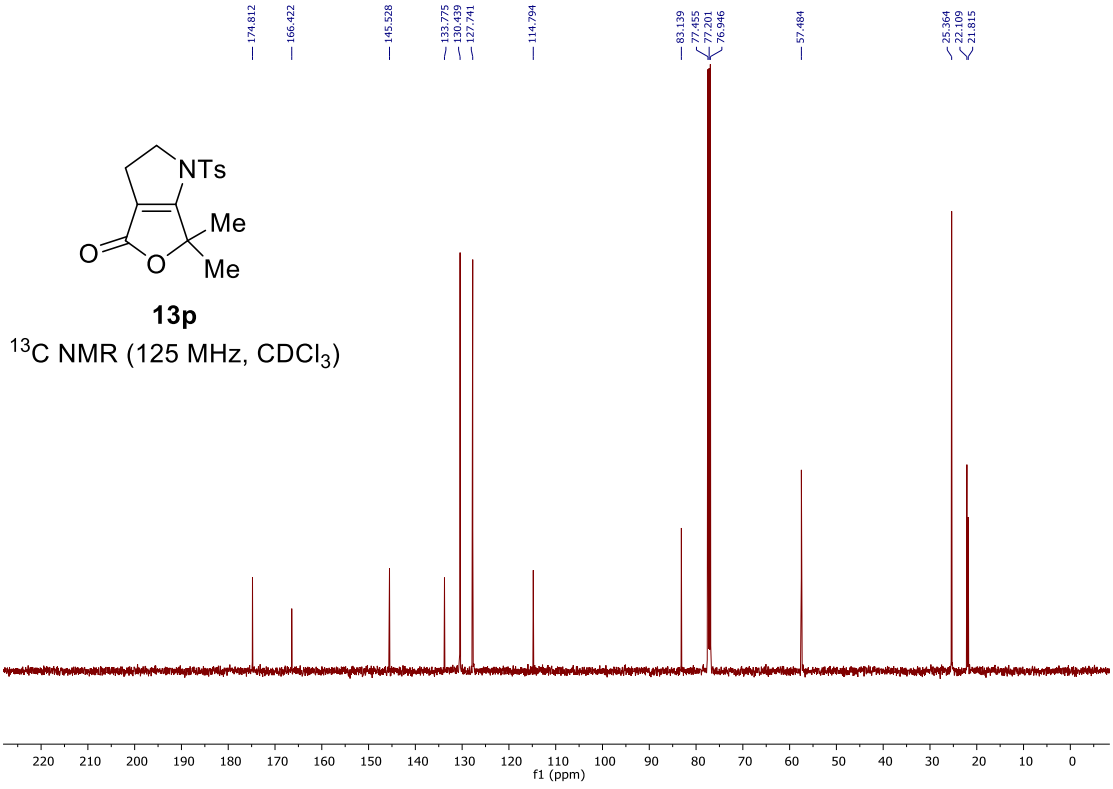
^{13}C NMR (125 MHz, $CDCl_3$)





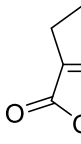
13p

^{1}H NMR (500 MHz, $CDCl_3$)



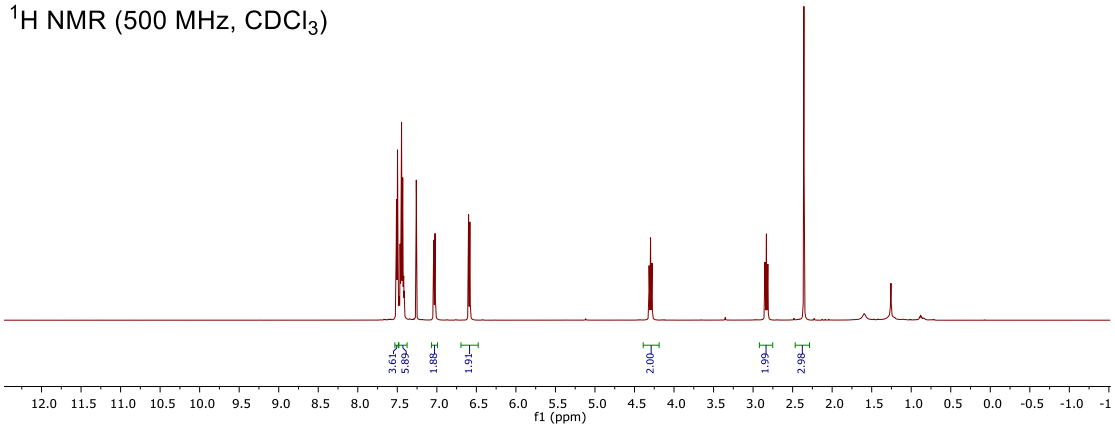
13p

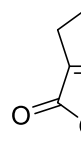
^{13}C NMR (125 MHz, $CDCl_3$)



13q

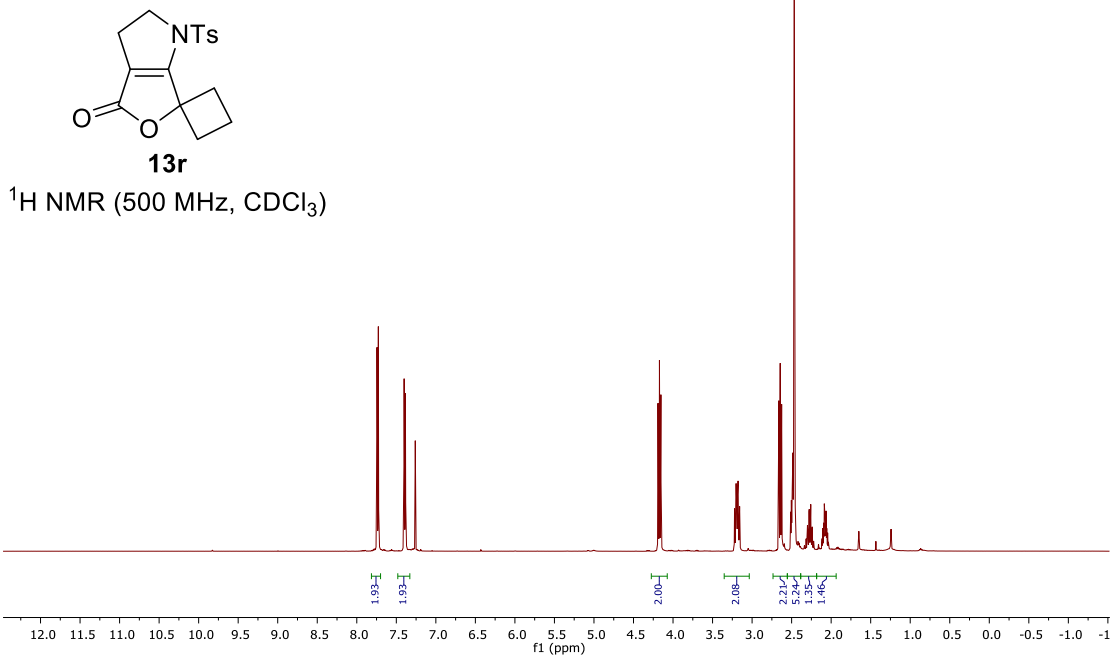
^{1}H NMR (500 MHz, $CDCl_3$)





13q

^{13}C NMR (125 MHz, $CDCl_3$)

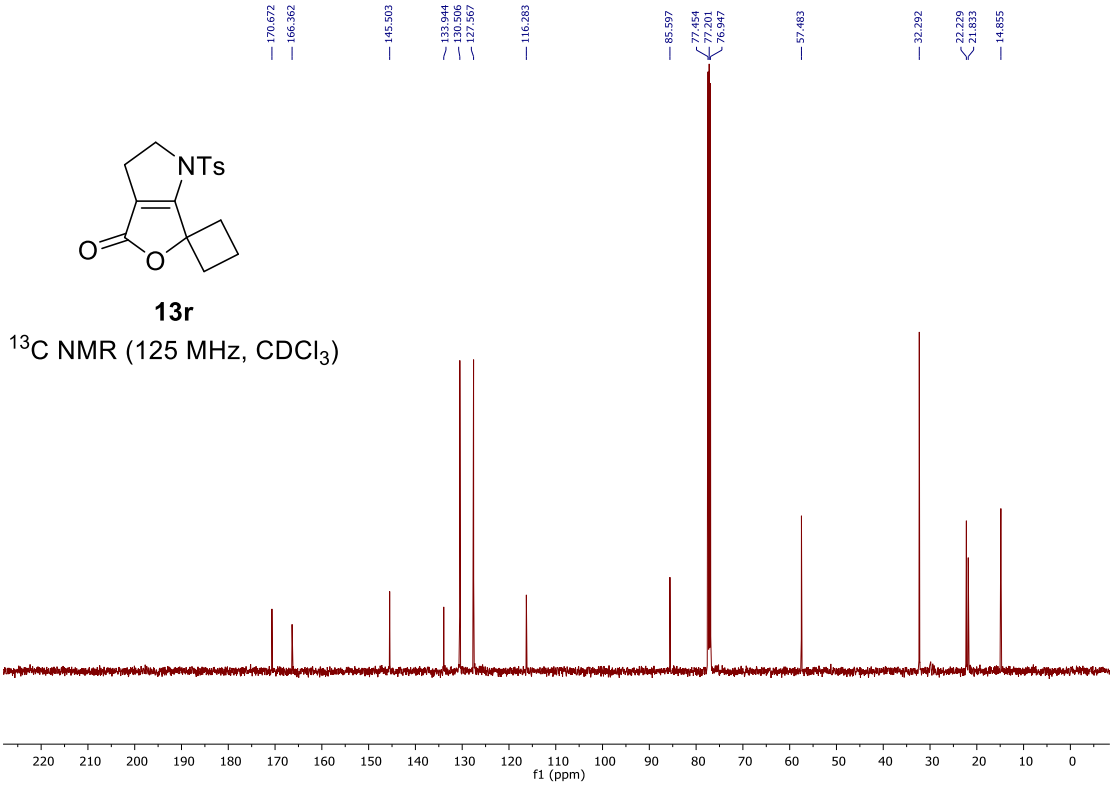


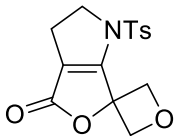
13r

^{1}H NMR (500 MHz, $CDCl_3$)

13r

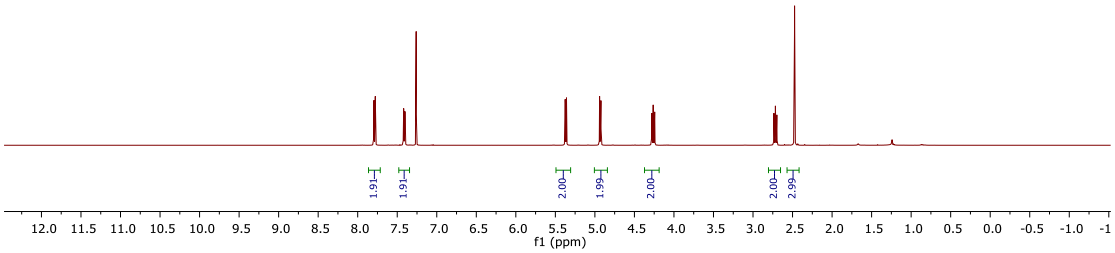
^{13}C NMR (125 MHz, $CDCl_3$)

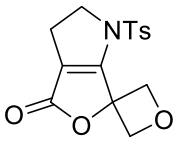




13s

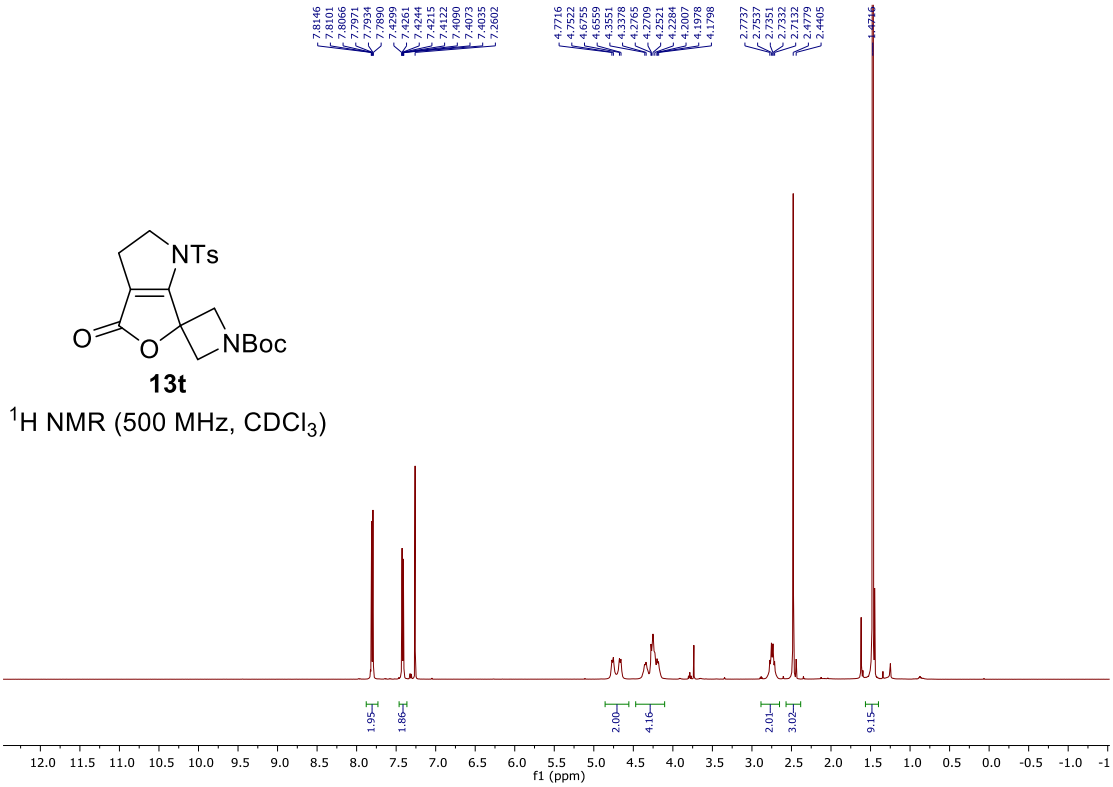
^{1}H NMR (500 MHz, $CDCl_3$)





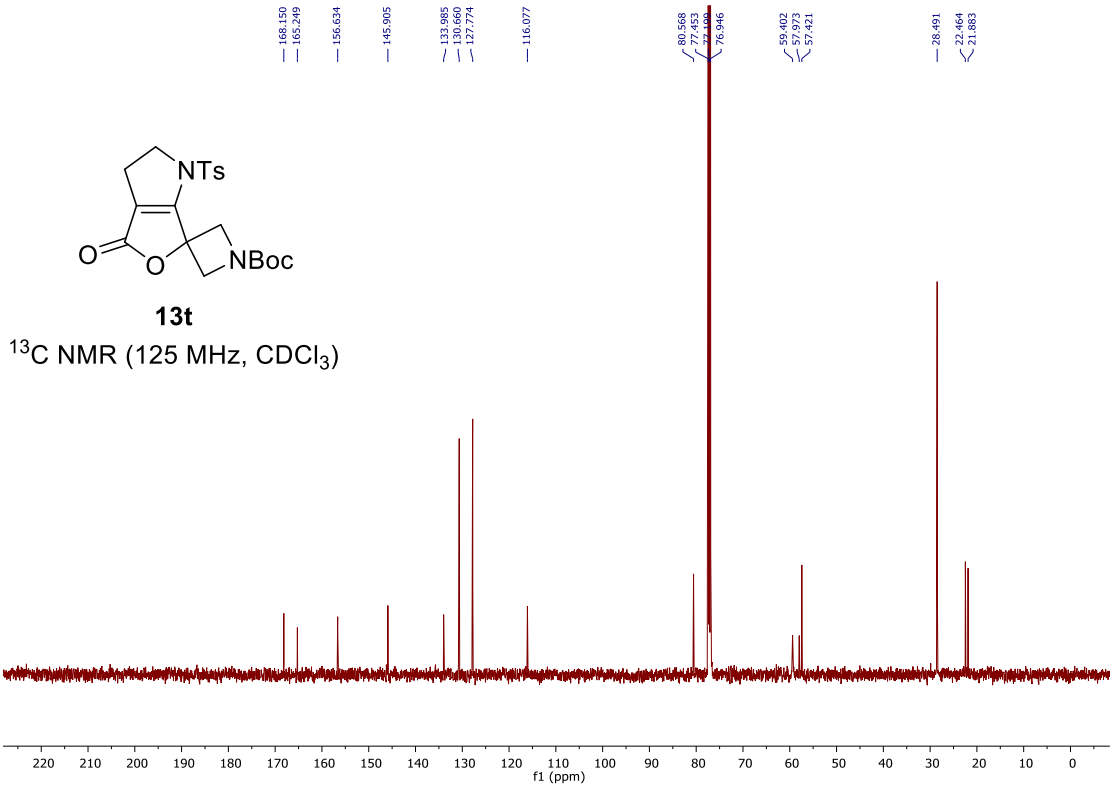
13s

^{13}C NMR (125 MHz, $CDCl_3$)



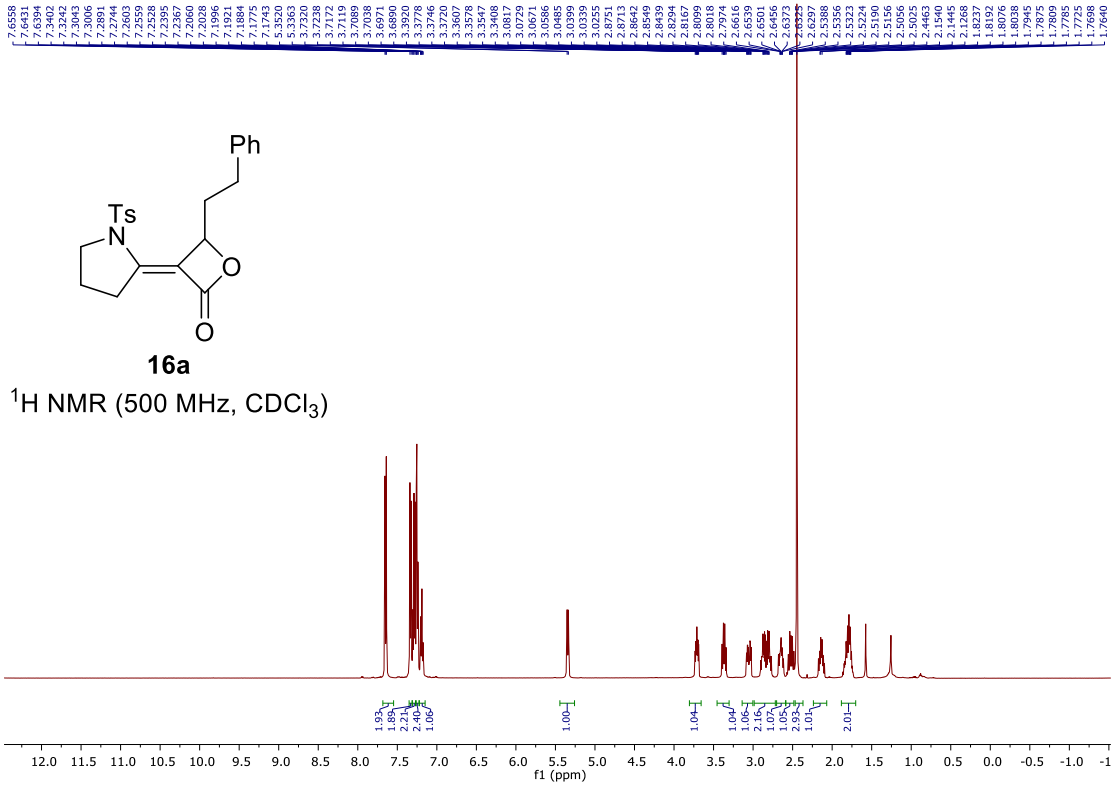
13t

^{1}H NMR (500 MHz, $CDCl_3$)



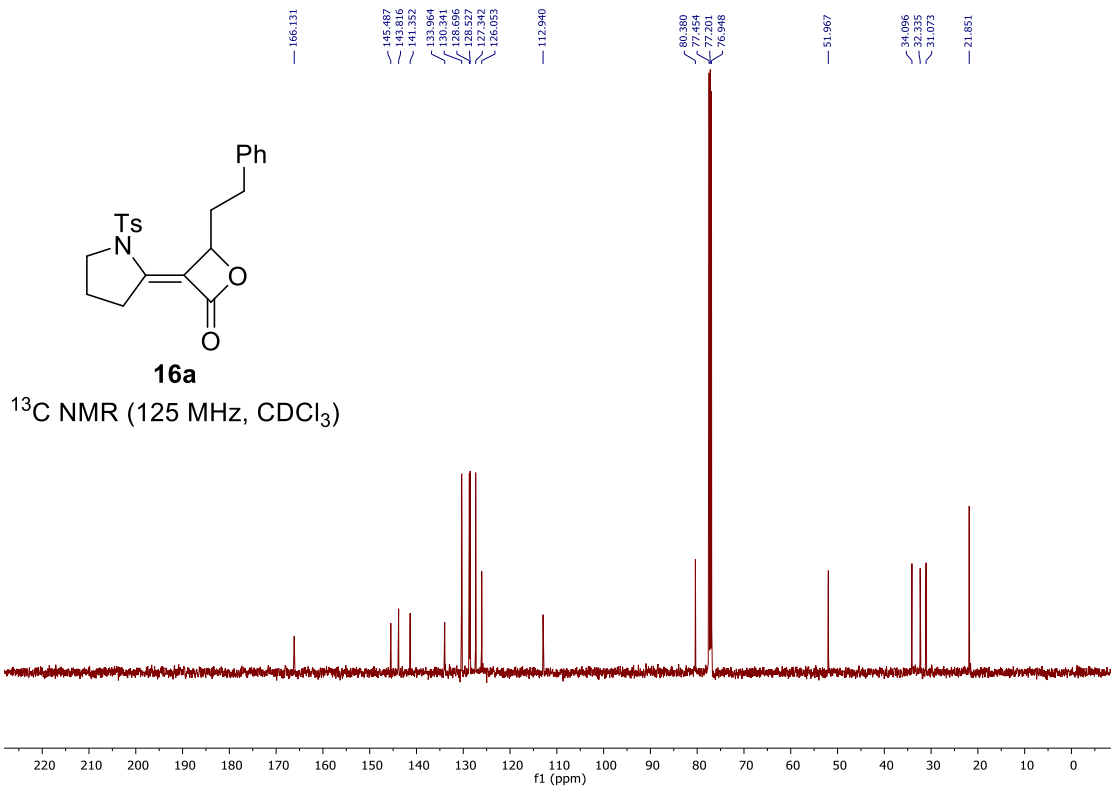
13t

^{13}C NMR (125 MHz, $CDCl_3$)



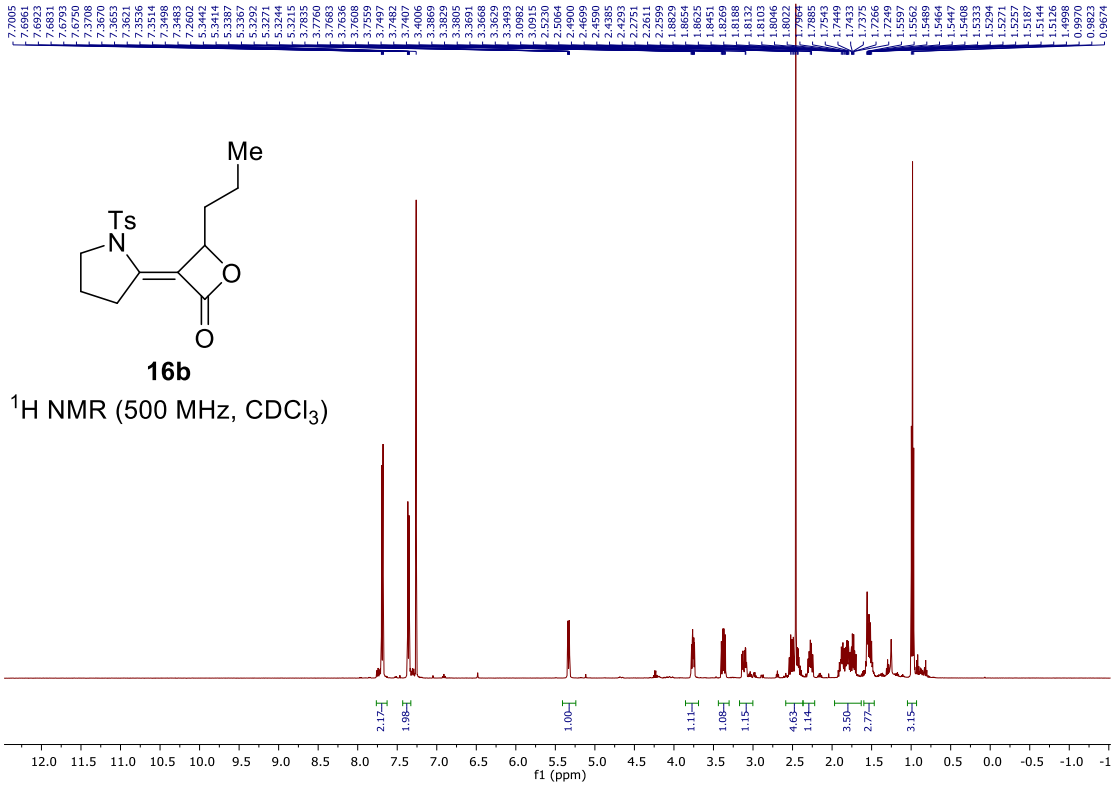
16a

^{1}H NMR (500 MHz, $CDCl_3$)



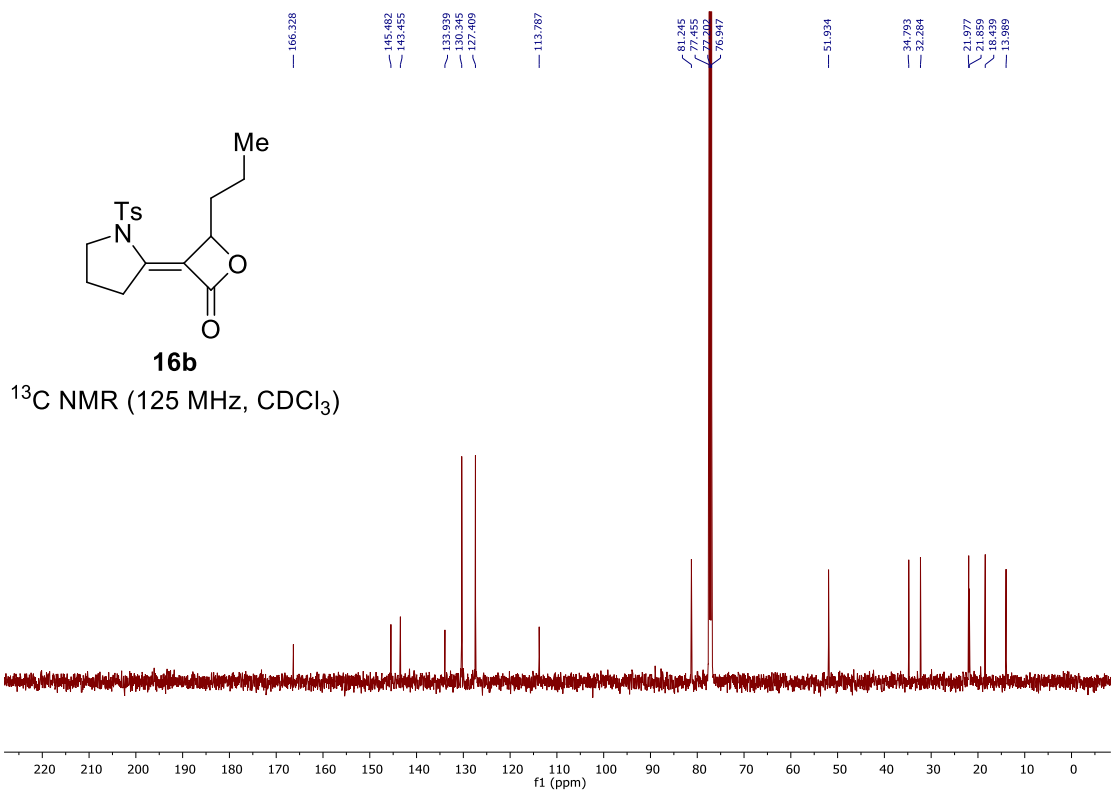
16a

^{13}C NMR (125 MHz, $CDCl_3$)



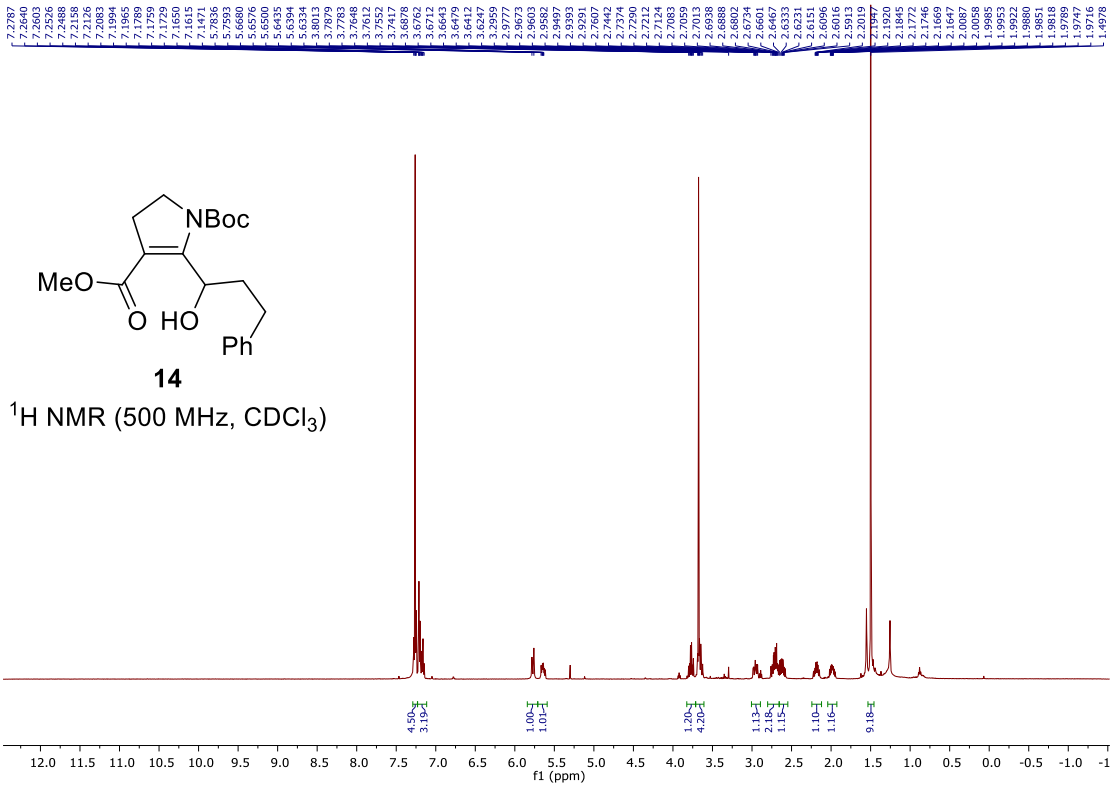
16b

^{1}H NMR (500 MHz, $CDCl_3$)



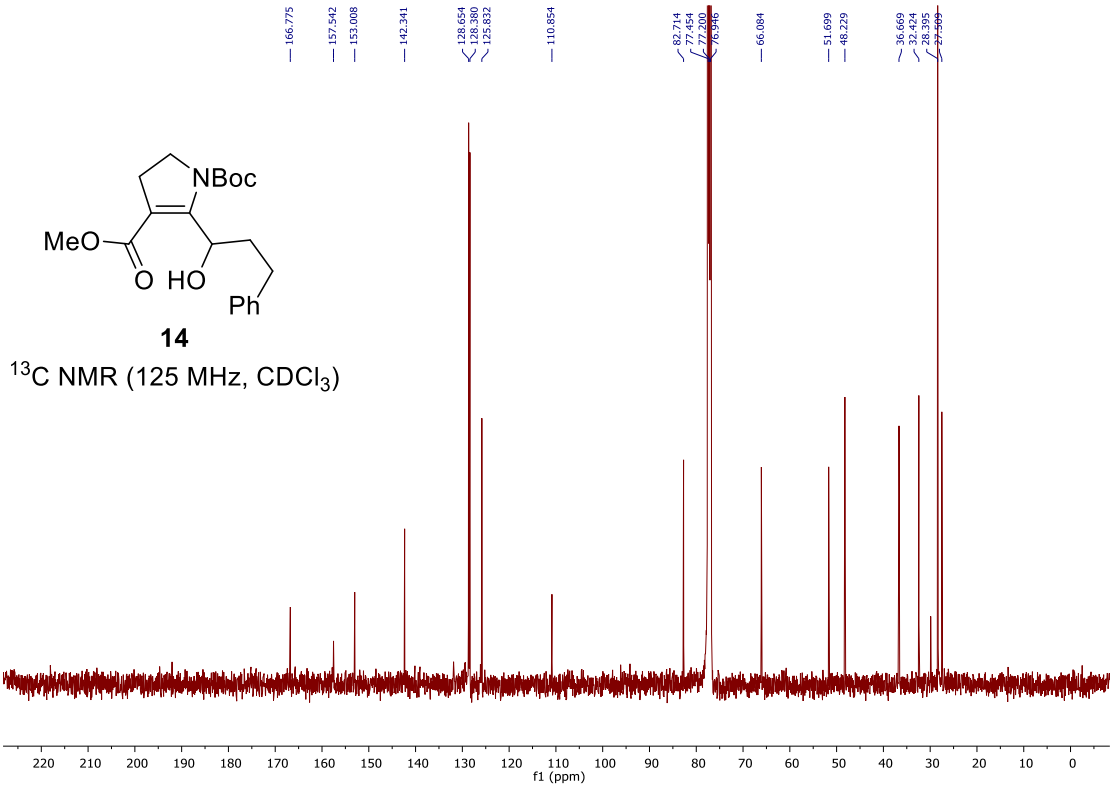
16b

^{13}C NMR (125 MHz, $CDCl_3$)



14

^{1}H NMR (500 MHz, $CDCl_3$)



14

^{13}C NMR (125 MHz, $CDCl_3$)