Electronic Supplementary Information

Easily accessible non-aromatic heterocycles with handles: 4-Bromo-2,3-dihydrofurans from 1,2-dibromohomoallylic alcohols

Jason An, Jose Intano, Jr., Alissa Richard, Taehyun Kim, José A. Gascón*, and Amy R. Howell*

Department of Chemistry, University of Connecticut

Storrs, Connecticut 06269-3060 United States

Email: amy.howell@uconn.edu

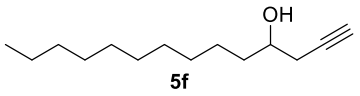
I. General Information

All moisture sensitive reactions were run in a flame-dried reaction vessel under N_2. Tetrahydrofuran (THF) was dried using a J. C. Meyer Solvent Dispensing System (SDS) and dispensed under N_2. All other solvents were dried over CaH_2 or 4 Å molecular sieves. Deuterated chloroform ($CDCl_3$), was dried over 4 Å molecular sieves. All starting materials and reagents were purchased from commercial sources and used as received, with the exception of Zn, which was activated prior to use. ^{1}H NMR experiments were recorded on a 400 MHz spectrometer, ^{13}C NMR experiments were recorded at 100 MHz and ^{19}F experiments were recorded at 376 MHz. Chemical shifts (δ) are given in ppm, and coupling constants (*J*) are given in Hz. The 7.26 resonance of residual $CHCl_3$ for proton spectra and the 77.23 ppm resonance of $CDCl_3$ for carbon spectra were used as internal references. Infrared spectra were obtained on a FTIR spectrometer. High-resolution mass spectra (HRMS, ESI-TOF) data were obtained with electrospray ionization and a time-of-flight analyzer. Unless otherwise stated, reaction progress was monitored by thin layer chromatography (TLC) performed on glass plates coated with silica gel UV254. Visualization was achieved by ultraviolet light (254 nm), 0.5% $KMnO_4$ in 0.1 M aqueous NaOH solution and/or 5% phosphomolybdic acid in ethanol. Column chromatography was performed using silica gel, 40 microns flash silica. Homopropargyl alcohols **5a-e**, **5g-j**, and **5l-n** were prepared by a literature procedure,[1] and their ^{1}HNMR spectra data match the values reported in the literature.[2]

II. General procedure for the synthesis of homopropargyl alcohols 5f, 5k and 5o.[1]

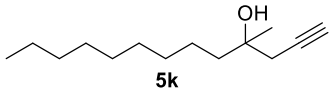
Activated zinc powder (5.0 equiv), anhydrous THF (to make the overall concentration [0.4 M] with respect to aldehyde), aldehyde or ketone (1.0 equiv), 3-bromo-1-propyne (1.5 equiv) and 1,2-diiodoethane (1.0 equiv) were added to an oven-dried Erlenmeyer flask. The reaction mixture was sonicated for 2.5 h. After sonication, aqueous HCl (2 M, 2 mL/1.0 mmol of aldehyde/ketone) was added. The mixture was decanted, and the solution was extracted with

Et_2O (3x). The combined organic extracts were washed with saturated aqueous $Na_2S_2O_3$ and brine, dried ($MgSO_4$), and concentrated. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/EtOAc 80:20) to give homopropargyl alcohol **5f**, **5k** or **5o**.[3]



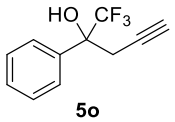
5f

1-Tetradecyn-4-ol (5f). The general procedure was followed, and purification gave **5f** as a clear oil (0.238 g, 67%, 84:16 of **5f**:allene).[4] Characterization data for **5f**: IR (neat) 3314, 2922, 2853, 1709 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.77 (m, 1H), 2.44 (ddd, *J* = 16.7, 4.6, 2.6 Hz, 1H), 2.32 (ddd, *J* = 16.7, 6.8, 2.6 Hz, 1H), 2.05 (dd, *J* = 2.6, 2.6 Hz, 1H), 1.85 (d, *J* = 5.1 Hz, 1H), 1.58–1.40 (m, 3H), 1.32–1.23 (m, 15H), 0.88 (t, *J* = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 81.2, 71.0, 70.2, 36.5, 32.1, 29.8, 29.8, 29.8, 29.6, 27.6, 25.8, 22.9, 14.3; HRMS (ESI^+) calcd for *m/z* $C_{14}H_{26}NaO$ $[M + Na]^+$ *m/z* 233.1876, found 233.1870.



5k

4-Methyl-1-tridecyn-4-ol (5k). The general procedure was followed, and purification gave **5k** as a yellow oil (0.229 g, 62%, 86:14 of **5k**:allene).[4] Characterization data for **5k**: IR (neat) 3410 (br), 3313, 2923, 2854, 1462, 1376 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 2.38 (dd, *J* = 16.6, 2.6 Hz, 1H), 2.34 (dd, *J* = 16.6, 2.6 Hz, 1H), 2.07 (dd, *J* = 2.6, 2.6 Hz, 1H), 1.74 (s, 1H), 1.59–1.53 (m, 2H), 1.36–1.25 (m, 17H), 0.88 (t, *J* = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 81.1, 71.9, 71.3, 41.4, 32.6, 32.1, 30.3, 29.8, 29.7, 29.5, 26.5, 24.2, 22.9, 14.3; HRMS (ESI^+) calcd for *m/z* $C_{14}H_{26}NaO$ $[M + Na]^+$ *m/z* 233.1876, found 233.1871.

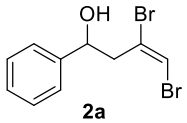


5o

1-Phenyl-1-trifluoromethyl-3-butyn-1-ol (5o). The general procedure was followed, and purification gave **5o** as a yellow oil (0.436 g, 85%, 90:10 of **5o**:allene).[4] Characterization data for **5o**: IR (neat) 3532 (br), 3302, 1154 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.68–7.60 (m, 2H), 7.47–7.40 (m, 3H), 3.17 (dd, *J* = 17.1, 2.6 Hz, 1H), 3.14 (s, 1H), 3.10 (dd, *J* = 17.1, 2.6 Hz, 1H), 2.07 (dd, *J* = 2.6, 2.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 136.4, 129.2, 128.6, 126.6, 125.0 (q, J_{C-F} = 270 Hz), 76.8, 75.7 (q, J_{C-F} = 28.4 Hz), 73.7, 29.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ –79.1; HRMS (ESI^+) calcd for $C_{11}H_9FO$ $[M]^+$ *m/z* 214.0605, found 214.0616.

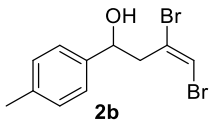
III. General procedure for *E*-dibromination of homopropargyl alcohols.

Following the method of Xiang *et al*.,[5] homopropargyl alcohol **5**[6] (1.0 equiv), activated molecular sieves (18% of the $CuBr_2$ mass used), $CuBr_2$ (2.5 equiv) and CH_3CN (to make the overall concentration [0.4 M]) were added to a flame dried test tube. The reaction mixture was stirred until the starting material was consumed (based on TLC, minimum 24 h). The mixture was diluted with Et_2O, filtered, and concentrated *in vacuo.* The crude product was purified by gravity column chromatography on silica gel (hexanes/EtOAc 90:10, except where noted) to give (*E*)-dibromohomoallylic alcohols **2**.



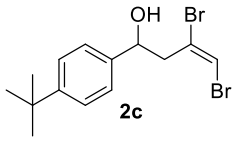
2a

(*E*)-3,4-Dibromo-1-phenyl-3-buten-1-ol (2a). The general procedure was followed, and purification gave **2a** as a white solid (0.604 g, 89%):[7] ^1H NMR (400 MHz, $CDCl_3$) δ 7.41 (m, 5H), 6.57 (s, 1H), 5.13 (m, 1H), 3.25 (dd, *J* = 14.3, 8.3 Hz, 1H), 2.89 (dd, *J* = 14.3, 4.9 Hz, 1H) 2.01 (d, *J* = 3.4 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 142.6, 128.6, 128.1, 125.9, 122.2, 105.4, 72.2, 46.3.



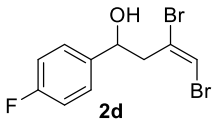
2b

(*E*)-3,4-Dibromo-1-(4-methylphenyl)-3-buten-1-ol (2b). The general procedure was followed, and purification gave **2b** as a white solid (1.55 g, 78%): mp 50–51 ◦C; IR (neat) 3301 (br), 3083, 2921, 1422, 1032 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35–7.26 (d, *J* = 8.0 Hz, 2H), 7.18 (d, *J* = 7.9 Hz, 2H), 6.55 (s, 1H), 5.07 (ddd, *J* = 8.5, 4.1, 4.1 Hz, 1H), 3.21 (dd, *J* = 14.4, 8.6 Hz, 1H), 2.86 (dd, *J* = 14.4, 4.8 Hz, 1H), 2.36 (s, 3H), 1.95 (d, *J* = 3.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.8, 138.0, 129.4, 126.1, 122.5, 105.3, 72.3, 46.4, 21.4; HRMS (ESI^+) calcd for $C_{11}H_{12}Br_2O$ $[M]^+$ *m/z* 319.9234, found 319.9189.



2c

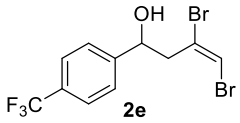
(*E*)-3,4-Dibromo-1-(4-*tert*-butylphenyl)-3-buten-1-ol (2c). The general procedure was followed and purification gave **2c** as a white solid (0.361 g, 89%): mp 55–56 ◦C; IR (neat) 3323 (br), 2954, 1411, 1030 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46–7.32 (m, 4H), 6.57 (s, 1H), 5.08 (dd, *J* = 8.9, 4.5 Hz, 1H), 3.24 (dd, *J* = 14.5, 8.8 Hz, 1H), 2.84 (ddd, *J* = 14.5, 4.5, 0.7 Hz, 1H), 1,95 (bs, 1H) 1.33 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.3, 139.9, 125.8, 125.7, 122.6, 105.4, 72.2, 46.4, 34.8, 31.5; HRMS (ESI^+) calcd for $C_{14}H_{18}Br_2NaO$ $[M + Na]^+$ *m/z* 382.9617, found 382.9610.



2d

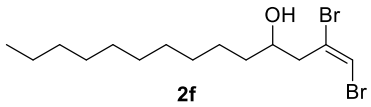
(*E*)-3,4-Dibromo-1-(4-fluorophenyl)-3-buten-1-ol (2d). The general procedure was followed, and purification gave **2d** as a clear yellow oil (0.59 g, 86%): IR (neat) 3379 (br), 1604, 1508, 1221 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45–7.35 (m, 2H), 7.11–7.00 (m, 2H), 6.55 (s, 1H), 5.09 (ddd, *J* = 8.5, 5.1, 3.7 Hz, 1H), 3.18 (dd, *J* = 14.3, 8.2 Hz, 1H), 2.88 (dd, *J* = 14.4, 5.2 Hz,

1H), 2.02 (d, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.7 (d, $J_{C\text{-}F}$ = 245.8 Hz), 138.4 (d, $J_{C\text{-}F}$ = 2.8 Hz), 127.9 (d, $J_{C\text{-}F}$ = 8.4 Hz), 121.9, 115.6 (d, $J_{C\text{-}F}$ = 21.9 Hz), 105.7, 71.8, 46.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ –114.2; HRMS (ESI^+) calcd for $C_{10}H_9Br_2FO$ $[M]^+$ *m/z* 321.9004, found 321.8996.



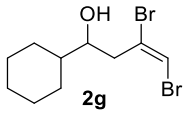
2e

(*E*)-3,4-Dibromo-1-(4-trifluoromethylphenyl)-3-buten-1-ol (2e). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc 95:5) gave **2e** as a yellow oil (0.569 g, 82%): IR (neat) 3330 (br), 1322, 1164, 1112, 1065 cm^{-1}; (400 MHz, $CDCl_3$) δ 7.63 (d, J = 8.3 Hz, 2H), 7.55 (d, J = 8.1 Hz, 2H), 6.58 (s, 1H), 5.17 (ddd, J = 8.3, 4.1, 4.1 Hz 1H), 3.19 (dd, J = 14.4, 8.4 Hz, 1H), 2.89 (dd, J = 14.5, 4.9 Hz, 1H), 2.14 (d, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.6, 130.3 (q, $J_{C\text{-}F}$ = 32.1 Hz), 126.3, 125.6 (q, $J_{C\text{-}F}$ = 3.5 Hz), 124.3, (q, $J_{C\text{-}F}$ = 270 Hz), 121.6, 106.1, 71.8, 46.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ –284.8; HRMS (ESI^+) calcd for $C_{11}H_9Br_2F_2O$ $[M]^+$ *m/z* 352.8977, found 352.8983.



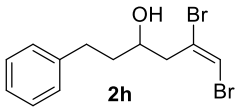
2f

(*E*)-1,2-Dibromo-1-tetradecen-4-ol (2f). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc, 95:5) gave **2f** as a clear oil (0.370 g, 85%): IR (neat) 3344 (br), 2922, 2852, 1464, 1016 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.57 (s, 1H), 4.01 (m, 1H), 2.92 (dd, J = 14.4, 8.3 Hz, 1H), 2.64 (dd, J = 14.4, 4.4 Hz, 1H), 1.61 (s, 1H), 1.57–1.45 (m, 2H), 1.41–1.24 (m, 16H), 0.88 (t, J = 6.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 123.2, 104.9, 70.1, 44.9, 36.9, 32.1, 29.8, 29.7, 29.7, 29.5, 25.7, 22.8, 14.3; HRMS (ESI^+) calcd for $C_{14}H_{26}OBr_2$ $[M]^+$ *m/z* 370.0331, found 370.0300.



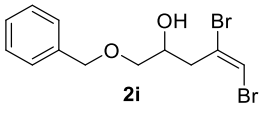
2g

(*E*)-3,4-Dibromo-1-cyclohexyl-3-buten-1-ol (2g). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc, 95:5) gave **2g** as a clear oil (0.445 g, 80%): IR (neat) 3385 (br), 2921, 2850, 1448, 1102 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.59 (s, 1H), 3.85–3.79 (m, 1H), 2.97 (dd, *J* = 14.4, 9.2 Hz, 1H), 2.64 (ddd, *J* = 14.3, 3.6, 0.8 Hz, 1H), 1.90–1.87 (m, 1H), 1.82–1.77 (m, 2H), 1.71–1.68 (m, 2H), 1.54–1.53 (m, 1H), 1.48–1.39 (m, 1H), 1.33–1.02 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 124.1, 105.0, 74.2, 43.6, 42.3, 29.6, 28.1, 26.8, 26.6, 26.4; HRMS (ESI^+) calcd for $C_{10}H_{15}Br_2$ $[M - OH]^+$ *m/z* 294.9520, found 294.9479.



2h

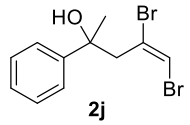
(*E*)-5,6-Dibromo-1-phenyl-5-hexen-3-ol (2h). The general procedure was followed, and purification gave **2h** as a yellow oil (0.522 g, 84%): IR (neat) 3364 (br), 2919, 1495, 1042 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.32–7.28 (m, 2H), 7.23–7.18 (m, 3H), 6.58 (s, 1H), 4.09–4.03 (m, 1H), 2.97 (dd, *J* = 14.4, 8.2 Hz, 1H), 2.90–2.83 (m, 1H), 2.76–2.66 (m, 2H), 1.91–1.85 (m, 2H), 1.65 (d, *J* = 5.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.8, 128.7, 128.6, 126.2, 122.8, 105.2, 69.6, 44.9, 38.4, 32.1. HRMS (ESI^+) calcd for $C_{12}H_{14}Br_2NaO$ $[M + Na]^+$ *m/z* 354.9304, found 354.9308.



2i

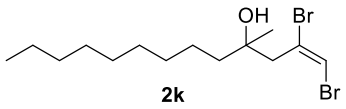
(*E*)-1-Benzyloxy-4,5-dibromo-4-buten-2-ol (2i). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc, 85:15) gave **2i** as an orange oil (0.080 g, 25%): IR (neat) 3437 (br), 2922, 2858, 1453, 1089; ^1H NMR (400 MHz, $CDCl_3$) δ 7.39–7.29

(m, 5H), 6.56 (s, 1H), 4.58 (s, 2H), 4.24–4.17 (m, 1H), 3.60 (dd, *J* = 9.6, 3.4 Hz, 1H), 3.47 (dd, *J* = 9.4, 6.4 Hz, 1H), 2.97 (dd, *J* = 14.4, 7.6 Hz, 1H), 2.74 (dd, *J* = 14.4, 5.8 Hz, 1H), 2.36 (d, *J* = 4.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.0, 128.7, 128.1, 128.0, 122.3, 105.2, 73.7, 73.2, 68.8, 41.2; HRMS (ESI^+) calcd for $C_{12}H_{14}Br_2NaO_2$ $[M + Na]^+$ *m/z* 370.9253, found 370.9258.



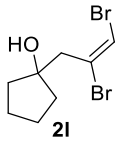
2j

(*E*)-4,5-Dibromo-2-phenylpent-4-en-2-ol (2j). The general procedure was followed, and purification gave **2j** as a yellow oil (0.489 g, 85%): IR (neat) 3453 (br), 2975, 1445, 1069 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54–7.47 (m, 2H), 7.36–7.34 (m, 2H), 7.33–7.23 (m, 1H), 6.63 (s, 1H), 3.26 (d, *J* = 14.7 Hz, 1H), 3.13 (d, *J* = 14.7 Hz, 1H), 2.36 (s, 1H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.0, 128.4, 127.3, 124.9, 120.9, 106.7, 75.3, 50.1, 29.8; HRMS (ESI^+) calcd for $C_{11}H_{11}Br_2$ $[M – OH]^+$ *m/z* 302.9207, found 302.9183.

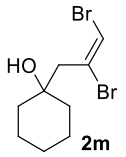


2k

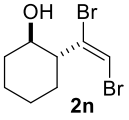
(*E*)-1,2-Dibromo-4-methyl-1-tridecen-4-ol (2k). The general procedure was followed, and purification gave **2k** as a yellow oil (0.482 g, 86%): IR (neat) 3410 (br), 3313, 2923, 2854, 1462, 1377 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.66 (s, 1H), 2.93 (d, *J* = 14.5 Hz, 1H), 2.84 (d, *J* = 14.5 Hz, 1H), 1.76 (s, 1H), 1.58–1.54 (m, 2H), 1.42–1.39 (m, 2H), 1.30–1.27 (m, 15H), 0.89 (t, *J* = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 121.7, 106.0, 74.0, 48.0, 42.9, 32.1, 30.3, 29.8, 29.7, 29.5, 26.9, 23.9, 22.9, 14.3; HRMS (ESI^+) calcd for $C_{14}H_{24}Br_2$ $[M – H_2O]^+$ *m/z* 352.0200, found 352.0225.



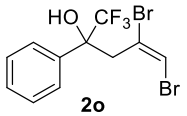
1-[(*E*)-2,3-Dibromoprop-2-enyl]cyclopentanol (2l). The general procedure was followed, and purification gave **2l** as a yellow oil (0.388 g, 85%): IR (neat) 3429 (br), 2957, 1087 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.64 (s, 1H), 3.03 (s, 2H), 1.86–1.66 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 122.0, 105.7, 82.6, 47.2, 40.2, 23.5; HRMS (ESI^+) calcd for $C_8H_{11}Br_2$ $[M - OH]^+$ *m/z* 266.9207, found 266.9192.



1-[(*E*)-2,3-Dibromoprop-2-enyl]cyclohexanol (2m). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc, 95:5) gave **2m** as a pale yellow liquid (0.621 g, 69%): IR (neat) 3456 (br), 2927, 1446, 1150 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.66 (s, 1H), 2.88 (s, 2H), 1.75 (s, 1H), 1.69–1.47 (m, 9H), 1.27–1.18 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 121.3, 106.0, 72.4, 49.1, 37.9, 25.7, 22.0; HRMS (ESI^+) calcd for $C_9H_{13}Br_2O$ $[M - H]^+$ *m/z* 294.9333, found 294.9332.



***trans*-2-[(*E*)-1,2-Dibromoethenyl]cyclohexanol (2n).** The general procedure was followed, and purification gave **2n** as a pale yellow oil (0.201 g, 61%): IR (neat) 3374 (br), 2930, 2856, 1447, 1026 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.55 (s, 1H), 3.67 (ddd, *J* = 9.7, 9.7, 4.0 Hz, 1H), 2.82 (ddd, *J* = 13.0, 9.5, 3.7 Hz, 1H), 2.08–2.04 (m, 1H), 1.79–1.63 (m, 4H), 1.52–1.28 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 130.2, 104.0, 71.7, 50.9, 34.3, 29.4, 24.8, 24.7; HRMS (ESI^+) calcd for $C_8H_{12}Br_2O$ $[M]^+$ *m/z* 281.9255, found 281.9257.



2o

(*E*)-4,5-Dibromo-1,1,1-trifluoro-2-phenylpent-4-en-2-ol (2o). The general procedure was followed, and purification by gravity chromatography (hexanes/EtOAc, 90:10) gave **2o** as a yellow oil (0.324 g, 46%, *E*/*Z* 20:1). Characterization of *E*-isomer (**3o**): IR (neat) 3563, 1152; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64–7.62 (m, 2H), 7.44–7.38 (m, 3H), 6.62 (s, 1H), 3.59 (d, *J* = 15.2 Hz, 1H), 3.49 (d, *J* = 15.2 Hz, 1H), 3.10 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ135.5, 129.2, 128.5, 126.7, 125.47 (q, J_{C-F} = 286.2 Hz), 117.6, 108.6, 77.6 (q, J_{C-F} = 28.5 Hz), 42.2; ^{19}F NMR (100 MHz, $CDCl_3$) δ –79.8; HRMS (ESI^+) calcd for $C_{11}H_9Br_2F_3O$ $[M]^+$ *m/z* 371.8972, found 371.8960.

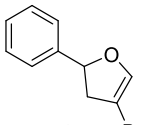
IV. General procedures for Cu-mediated cyclization

Procedure A. For dibromohomoallylic alcohols (2a-e, 2j and **2o) derived from aryl aldehydes/ketones.** CuI (10 mol%), 1,10-phenanthroline (20 mol%), and Cs_2CO_3 (1.2 equiv) were added to a flame dried test tube, and the tube was capped with a septum. The system was backfilled 3x with N_2, and *E*-dibromohomoallylic alcohol **2a-e**, **2j** or **2o** (1.0 equiv) in CH_3CN (to make the overall concentration [0.05 M]) was added in one portion. The mixture was placed in an oil bath (80 °C) and stirred for 16 h. The resulting mixture was allowed to cool to rt, and Et_2O (10 mL) was added. The mixture was then stirred for 30 min. It was filtered, and the filtrate was concentrated. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/Et_2O 97.5:2.5) to give 4-bromo-2,3-dihydrofurans **3a-e**, **3j** or **3o**.

Procedure B. For dibromohomoallylic alcohols (2f-i and 2k-n) derived from alkyl aldehydes/ketones. CuI (10 mol%), 1,10-phenanthroline (20 mol%), and Cs_2CO_3 (1.5 equiv) were added to a flame dried test tube, and the tube was capped with a septum. The system was

backfilled 3x with N_2, and *E*-dibromohomoallylic alcohol **2f-i** or **2k-n** (1.0 equiv) in 1,4-dioxane (to make the overall concentration [0.05 M]) was added in one portion. The mixture was placed in an oil bath (115 °C) and stirred for 16 h. The resulting mixture was allowed to cool to rt, and Et_2O (10 mL) was added. The mixture was then stirred for 30 min. It was filtered, and the filtrate was concentrated. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/Et_2O 97.5:2.5) to give 4-bromo-2,3-dihydrofurans **3f-i** or **3k-n**.

Procedure C. CuBr mediated cyclization for selected dibromohomoallylic alcohols. CuBr (10 mol%), 1,10-phenanthroline (20 mol%), and Cs_2CO_3 (1.5 equiv) were added to a flame dried test tube, and the tube was capped with a septum. The system was backfilled 3x with N_2, and *E*-dibromohomoallylic alcohol **2** (1.0 equiv) in 1,4-dioxane (to make the overall concentration [0.05 M]) was added in one portion. The mixture was placed in an oil bath (115 °C) and stirred for 16 h. The resulting mixture was allowed to cool to rt, and Et_2O (10 mL) was added. The mixture was then stirred for 30 min. It was filtered, and the filtrate was concentrated. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/Et_2O 97.5:2.5) to give 4-bromo-2,3-dihydrofurans **3**.

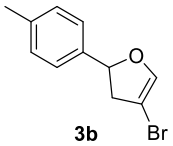


3a

4-Bromo-2,3-dihydro-2-phenylfuran (3a). General procedure A was followed to provide **3a** as a yellow oil (0.058 g, 78%; also contains 0.001 g of **6a**—2%: based on GC/MS ratio of 98:2 of **3a:6a**): IR (neat) 2922, 1629, 1450, 1100 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.31 (m, 5H), 6.52 (dd, *J* = 1.9, 1.9 Hz, 1H), 5.60 (dd, *J* = 10.5, 8.9 Hz, 1H), 3.26 (ddd, *J* = 14.7, 10.7, 1.9 Hz, 1H), 2.86 (ddd, *J* = 14.8, 8.8, 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6, 141.7, 129.0,

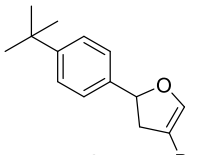
128.5, 125.9, 92.0, 83.6, 44.0; HRMS (ESI$^+$) calcd for $C_{10}H_9BrO$ [M]$^+$ *m/z* 223.9837, found 223.9827.

4-Bromo-2,3-dihydro-2-phenylfuran (3a). General procedure C was followed to provide **3a** as a yellow oil (0.033 g, 88%).



3b

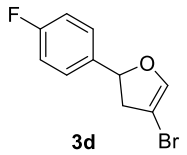
4-Bromo-2,3-dihydro-2-(4-methylphenyl)furan (3b). General procedure A was followed to provide **3b** as a yellow oil (0.063g, 86%; also contains 0.002 g of **6b**—2%: based on GC/MS ratio of 98:2 of **3b:6b**): IR (neat) 2921, 1628, 1515, 1092 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (d, *J* = 7.2 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 6.50 (dd, *J* = 2.2, 2.2 Hz, 1H), 5.56 (dd, *J* = 10.5, 9.1 Hz, 1H), 3.23 (ddd, *J* = 14.8, 10.7, 2.1 Hz, 1H), 2.86 (ddd, *J* = 14.8, 8.8, 2.2 Hz, 1H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.5, 138.6, 138.2, 129.6, 126.0, 91.9, 83.6, 43.9, 21.4; HRMS (ESI$^+$) calcd for $C_{11}H_{11}BrO$ [M]$^+$ *m/z* 239.9974, found 239.9980.



3c

4-Bromo-2-(4-*tert*-butylphenyl)-2,3-dihydrofuran (3c). General procedure A was followed to provided **3c** as a clear oil (0.057 g, 74%; also contains 0.003 g of **6c**—3%: based on GC/MS ratio of 96:4 of **3c:6c**): IR (neat) 2961, 1629, 1267, 1094 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42–7.39 (m, 2H), 7.30–7.28 (m, 2H), 6.50 (dd, *J* = 2.3, 2.3 Hz, 1H), 5.58 (dd, *J* = 10.6, 8.9 Hz, 1H), 3.23 (ddd, *J* = 14.8, 10.6, 2.1 Hz, 1H), 2.89 (ddd, *J* = 14.8, 8.8, 2.2 Hz, 1H), 1.32 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.5, 144.5, 138.5, 125.8, 125.8, 91.9, 83.5, 43.7, 34.8, 31.5; HRMS (ESI$^+$) calcd for $C_{14}H_{17}BrO$ [M]$^+$ *m/z* 280.0463, found 280.0471.

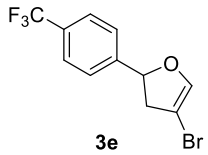
4-Bromo-2-(4-*tert*-butylphenyl)-2,3-dihydrofuran (3c). General procedure C was followed to provide **3c** as a clear oil (0.034 g, 87%).



3d

4-Bromo-2-(4-fluorophenyl)-2,3-dihydrofuran (3d). General procedure A was followed to provide **3d** as a yellow oil (0.169 g, 67%; also contains 0.008 g of **6d**—3%: based on GC/MS ratio of 96:4 of **3d:6d**): IR (neat) 2925 1605, 1510, 1223, 1089 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35–7.31 (m, 2H), 7.09–7.04 (m, 2H), 6.51 (dd, *J* = 2.0, 2.0 Hz, 1H), 5.58 (dd, *J* = 10.6, 8.9 Hz, 1H), 3.25 (ddd, *J* = 14.9, 10.7, 2.2 Hz, 1H), 2.83 (ddd, *J* = 14.9, 10.7, 2.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3 (d, J_{C-F} = 247.6 Hz), 144.4, 137.4 (d, J_{C-F} = 8.4 Hz), 127.7 (d, J_{C-F} = 8.4 Hz), 115.8 (d, J_{C-F} = 21.7 Hz), 91.9, 82.9, 43.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ –113.8; HRMS (ESI^+) calcd for $C_{10}H_8BrFO$ $[M]^+$ *m/z* 243.9723, found 243.9722.

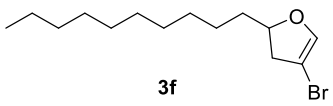
4-Bromo-2-(4-fluorophenyl)-2,3-dihydrofuran (3d). General procedure C was followed to provide **3d** as a yellow oil (0.023 g, 62%).



3e

4-Bromo-2-(4-trifluoromethylphenyl)-2,3-dihydrofuran (3e). General procedure A was followed to provide **3e** as a yellow oil (0.053 g, 69%; also contains 0.004 g of **6e**—4%: based on GC/MS ratio of 94:6 of **3e:6e**): IR (neat) 2927, 1620, 1322, 1066 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.2 Hz, 2H), 7.46 (d, *J* = 8.1 Hz, 2H), 6.54 (dd, *J* = 2.2, 2.2 Hz, 1H), 5.66 (dd, *J* = 10.7, 8.6 Hz, 1H), 3.32 (ddd, *J* = 14.8, 10.8, 2.2 Hz, 1H), 2.81 (ddd, *J* = 14.8, 8.5, 2.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ145.7, 144.4, 130.5 (q J_{C-F} = 32.4 Hz), 126.0, 125.9 (q,

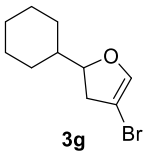
$J_{C\text{-}F}$ = 3.5 Hz), 124.2 (q, J = 270 Hz), 91.9, 82.6, 43.9; ^{19}F NMR (376 MHz, $CDCl_3$) δ –62.6; HRMS (ESI$^+$) calcd for $C_{11}H_8BrF_3O$ $[M]^+$ *m/z* 293.9691, found 293.9684.



3f

4-Bromo-2-decyl-2,3-dihydrofuran (3f). General procedure B was followed to provide **3f** as a yellow oil (0.050 g, 63%; also contains 0.005 g of **6f**—5%: based on GC/MS ratio of 93:7 of **3f:6f**): IR (neat) 2922, 2852, 1463, 1101 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.33 (dd, J = 2.1, 2.1 Hz, 1H), 4.64–4.56 (m, 1H), 2.88 (ddd, J = 14.5, 10.1, 2.1 Hz, 1H), 2.49 (ddd, J = 14.5, 8.3, 2.2 Hz, 1H), 1.77–1.70 (m, 1H), 1.61–1.54 (m, 1H), 1.43–1.26 (m, 16 H), 0.88 (t, J = 6.6 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.3, 92.1, 83.1, 41.3, 36.3, 32.1, 29.8, 29.8, 29.8, 29.7, 29.5, 25.2, 22.9, 14.3; HRMS (ESI$^+$) calcd for $C_{14}H_{25}BrO$ $[M]^+$ *m/z* 288.1089, found 288.1086.

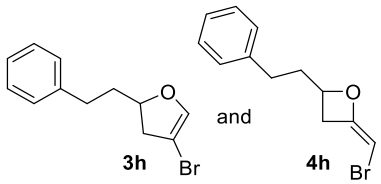
4-Bromo-2-decyl-2,3-dihydrofuran (3f). General procedure C was followed to provide **3f** as a yellow oil (0.027 g, 70%).



3g

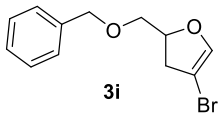
4-Bromo-2-cyclohexyl-2,3-dihydrofuran (3g). General procedure B was followed to provide **3g** (0.048 g, 65%; also contains 0.002 g of **6g**—2%: based on GC/MS ratio of 97:3 of **3g:6g**): IR (neat) 2922, 2852, 1448, 1100 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.34 (dd, J = 2.1, 2.1 Hz, 1H), 4.35 (ddd, J = 16.9, 9.6, 6.9 Hz, 1H), 2.77 (ddd, J = 14.6, 10.3, 2.1 Hz, 1H), 2.60 (ddd, J = 14.6, 9.1, 2.2 Hz, 1H), 1.87–1.84 (m, 1H), 1.78–1.75 (m, 2H), 1.70–1.62 (m, 2H) 1.59–1.50 (m, 1H), 1.31–1.17 (m, 3H), 1.07–0.94 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.5, 92.2, 87.2, 43.1, 38.9, 28.3, 28.2, 26.6, 26.1, 25.9; HRMS (ESI$^+$) calcd for $C_{10}H_{15}BrO$ $[M]^+$ *m/z* 230.0306, found 230.0316.

4-Bromo-2-cyclohexyl-2,3-dihydrofuran (3g). General procedure C was followed to provide **3g** as a yellow oil (0.021 g, 57%).



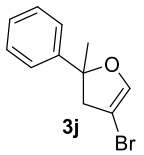
4-Bromo-2,3-dihydro-2-(2-phenylethyl)furan (3h) and (*E*)-2-(bromomethylidene)-4-(2-phenylethyl)oxetane (4h). General procedure B was followed to provide **3h** as a yellow oil (0.054 g, 72%; also contains 0.008 g of **6h**—9%: based on GC/MS ratio of 89:11 of **3h:6h**): IR (neat) 2926, 1628, 1453, 1099 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.33–7.29 (m, 2H), 7.23–7.20 (m, 3H), 6.38 (dd, *J* = 2.2, 2.2 Hz, 1H), 4.63 (dddd, *J* = 10.1, 7.9, 7.9, 5.3 Hz, 1H), 2.94 (ddd, *J* = 14.6, 10.2, 2.2 Hz, 1H), 2.82–2.67 (m, 2H), 2.53 (ddd, *J* = 14.6, 8.1, 2.2 Hz, 1H), 2.14–2.05 (m, 1H), 1.90 (dddd, *J* = 16.1, 9.6, 6.6, 5.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.3, 141.4, 128.7, 128.7, 126.2, 92.1, 82.0, 41.3, 37.9, 31.6; HRMS (EI^+) calcd for $C_{12}H_{13}BrO$ $[M]^+$ *m/z* 252.0150, found 252.0174. (*E*)-2-(Bromomethylidene)-4-(2-phenylethyl)oxetane (**4h**), a clear yellow oil, could also be isolated from general procedure B using purification by gravity column chromatography on deactivated silica (98:1:1 Hexanes/EtOAc/TEA). Characterization for (*E*)-2-(bromomethylidene)-4-(2-phenylethyl)oxetane (**4h**): ^1H NMR (400 MHz, $CDCl_3$) δ 7.32–7.28 (m, 2H), 7.23–7.17 (m, 3H), 5.31 (dd, *J* = 2.4, 2.4 Hz, 1H), 4.83–4.77 (m, 1H), 3.20 (ddd, *J* = 15.4, 6.5, 2.3 Hz, 1H), 2.82–2.73 (m, 2H), 2.70–2.62 (m, 1H), 2.20 (dddd, *J* = 13.8, 8.8, 7.9, 5.7 Hz, 1H), 2.04 (dddd, *J* = 14.6, 9.3, 7.0, 5.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.1, 140.8, 128.8, 128.6, 126.4, 79.6, 75.8, 37.8, 34.2, 30.8; HRMS (ESI^+) calcd for $C_{12}H_{13}BrO$ $[M]^+$ *m/z* 252.0150, found 252.0155.

4-Bromo-2,3-dihydro-2-(2-phenylethyl)furan (3h). General procedure C was followed to provide **3h** as a yellow oil (0.028 g, 74%).



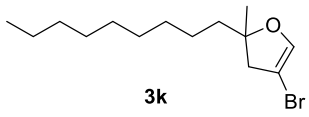
3i

2-Benzyloxymethyl-4-bromo-2,3-dihydrofuran (3i). General procedure B was followed to provide **3i** as a yellow oil (0.063 g, 82%; also contains 0.002 g of **6i**—2%: based on GC/MS ratio of 98:2 of **3i:6i**): IR (neat) 2923, 2856, 1453, 1095 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.38–7.29 (m, 5H), 6.36 (dd, *J* = 2.2, 2.2 Hz, 1H), 4.81 (dddd, *J* = 10.4, 7.8, 6.4, 4.5 Hz, 1H), 4.62 (d, *J* = 12.3 Hz, 1 H), 4.58 (d, *J* = 12.1 Hz, 1H), 3.63 (dd, *J* = 10.5, 6.4 Hz, 1H), 3.55 (dd, *J* = 10.4, 4.4 Hz, 1H), 2.89 (ddd, *J* = 14.7, 10.5, 2.1 Hz, 1H), 2.65 (ddd, *J* = 14.8, 7.9, 2.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.3, 138.0, 128.7, 128.0, 127.9, 92.4, 81.2, 73.7, 71.9, 38.1; HRMS (ESI^+) calcd for $C_{12}H_{13}BrO_2$ $[M]^+$ *m/z* 268.0099, found 268.0100.



3j

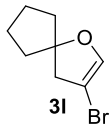
4-Bromo-2,3-dihydro-2-methyl-2-phenylfuran (3j). General procedure A was followed to provide **3j** as a yellow oil (0.059 g, 79%; also contains 0.001 g of **6j**—1%: based on GC/MS ratio of 99:1 of **3j:6j**): IR (neat) 2975, 2926, 1632, 1118 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.28–7.13 (m, 5H), 6.37 (dd, *J* = 1.8, 1.8 Hz, IH), 2.95 (dd, *J* = 14.7, 2.1 Hz, 1H), 2.85 (dd, *J* = 14.7, 2.0 Hz, 1H), 1.59 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.6, 143.5, 128.6, 127.5, 124.5, 91.1, 88.9, 50.3, 29.5; HRMS (ESI^+) calcd for $C_{11}H_{11}BrO$ $[M]^+$ *m/z* 239.9973, found 239.9985.



3k

4-Bromo-2,3-dihydro-2-methyl-2-nonylfuran (3k). General procedure B was followed to provide **3k** as a clear oil (0.058 g, 74%; also contains 0.001 g of **6k**—1%: based on GC/MS ratio

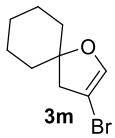
of 98:2 of **3k:6k**): IR (neat) 2923, 2853, 1629, 1140, 1115 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.28 (dd, *J* = 2.1, 2.1 Hz, 1H), 2.69 (dd, *J* = 14.6, 2.3 Hz, 1H), 2.50 (dd, *J* = 14.6, 2.1 Hz, 1H), 1.63–1.59 (m, 2H), 1.34 (s, 3H), 1.29–1.27 (m, 14H), 0.88 (t, *J* = 6.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.6, 90.9, 88.9, 46.8, 41.4, 32.1, 30.2, 29.8, 29.5, 26.8, 24.0, 22.9, 14.3; HRMS (ESI^+) calcd for $C_{14}H_{25}BrO$ $[M]^+$ *m/z* 288.1089, found 288.1099.



3l

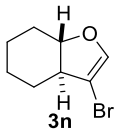
3-Bromo-1-oxaspiro[4.4]non-2-ene (3l). General procedure B was followed to provide **3l** as a clear oil (0.048 g, 68%; also contains 0.003 g of **6l**—3%: based on GC/MS ratio of 95:5 of **3l:6l**): IR (neat) 2958, 2924, 1628, 1110 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.29 (t, *J* = 1.9 Hz, 1H), 2.79 (d, *J* = 2.1 Hz, 2H), 2.07–2.02 (m, 2H), 1.81–1.59 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.6, 96.5, 91.0, 45.7, 40.1, 23.8; HRMS (ESI^+) calcd for $C_8H_{11}BrO$ $[M]^+$ *m/z* 203.9993, found 203.9980.

3-Bromo-1-oxaspiro[4.4]non-2-ene (3l). General procedure C was followed to provide **3l** as a yellow oil (0.018 g, 52%).



3m

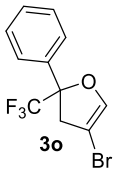
3-Bromo-1-oxaspiro[4.5]dec-2-ene (3m). General procedure B was followed to provide **3m** as a clear oil (0.049 g, 67%; also contains 0.004 g of **6m**—5%: based on GC/MS ratio of 94:6 of **3m:6m**): IR (neat) 2975, 2926, 1632, 1118 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.31 (t, *J* = 2.1 Hz, 1H), 2.58 (d, *J* = 2.2 Hz, 2H), 1.78–1.60 (m, 8H), 1.45–1.43 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.4, 91.1, 88.4, 46.9, 37.3, 25.1, 22.8; HRMS (ESI^+) calcd for $C_9H_{13}BrO$ $[M]^+$ *m/z* 216.0150, found 216.0153.



3n

***trans*-3-Bromo-3a,4,5,6,7,7a-hexahydrobenzofuran (3n)**. General procedure B was followed to provide **3n** as a clear oil (0.058 g, 80%; also contains 0.005 g of **6n**—6%: based on GC/MS ratio of 94:6 of **3n:6n**): IR (neat) 2938, 2860, 1065 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.52 (d, *J* = 2.6 Hz, 1H), 3.67 (ddd, *J* = 14.9, 11.8, 3.4 Hz, 1H), 2.48 (dddd, *J* = 14.2, 11.6, 2.9, 2.9 Hz, 1H), 2.23–2.17 (m, 1H), 2.05–2.02 (m, 1H), 1.92–1.87 (m, 1H), 1.81–1.78 (m, 1H), 1.67 (dddd, *J* = 11.8, 11.8, 11.8, 3.9 Hz, 1H), 1.43–1.13 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.9, 101.9, 90.1, 51.7, 30.5, 28.3, 25.4, 24.8; HRMS (ESI^+) calcd for $C_8H_{11}BrO$ $[M]^+$ *m/z* 201.9993, found 201.9994.

***trans*-3-Bromo-3a,4,5,6,7,7a-hexahydrobenzofuran (3n)**. General procedure C was followed to provide **3n** as a clear oil (0.032 g, 88%).

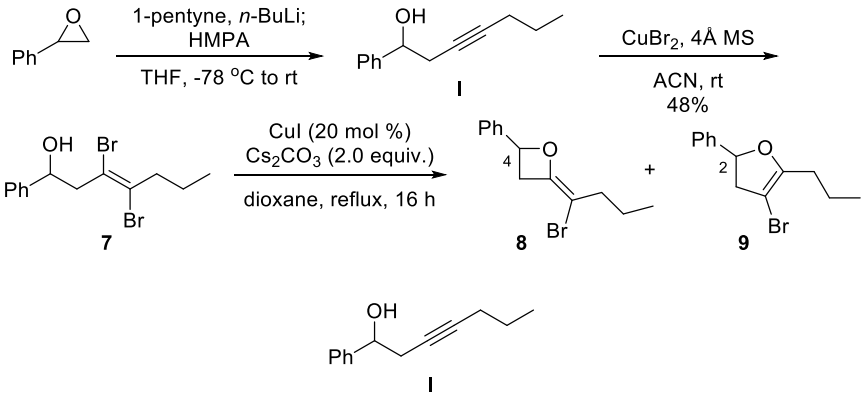


3o

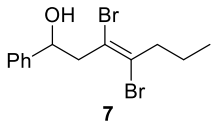
4-Bromo-2,3-dihydro-2-phenyl-2-(trifluoromethyl)furan (3o). General procedure A was followed to provide **3o** as a yellow oil (0.046 g, 60%; also contains 0.009 g of **6o**—10%: based on GC/MS ratio of 83:14 of **3o:6o**): IR (neat) 2926, 2855, 1304, 1163, 1034 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.52–7.50 (m, 2H), 7.45–7.41 (m, 3H), 6.52 (t, *J* = 2.0 Hz, 1H), 3.60 (dd, *J* = 15.5, 2.4 Hz, 1H), 3.24 (dd, *J* = 15.5, 1.1 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 136.9, 129.5, 128.7, 126.4, 124.3 (q, $J_{C\text{-}F}$ = 283.3 Hz), 91.9, 88.0 (q, $J_{C\text{-}F}$ = 30.8 Hz), 44.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ –81.5; HRMS (ESI^+) calcd for $C_{11}H_8BrF_3O$ $[M]^+$ *m/z* 291.9711, found 291.9720.

4-Bromo-2,3-dihydro-2-phenyl-2-(trifluoromethyl)furan (3o). General procedure C was followed to provide **3o** as a yellow oil (0.062 g, 79%).

V. Synthesis and [Cu] mediated cyclization of internal alkene, (*E*)-3,4-dibromo-1-phenyl-3-hepten-1-ol (7).

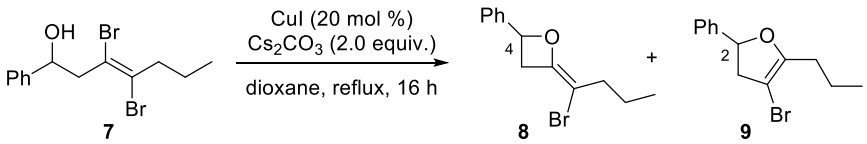


1-Phenyl-3-heptyn-1-ol (I). Pentyne (1.44 mL, 14.7 mmol) and THF (55 mL) were added to a flame dried flask. The stirring solution was cooled to –78 °C and *n*-BuLi (5.86 mL, 14.7 mmol, 2.5 M in hexanes) was added dropwise under N_2. The solution was stirred for 90 min at –78 °C, followed by the sequential addition of HMPA (5.10 mL, 29.3 mmol) and styrene oxide (1.68 mL, 14.7 mmol). The solution was allowed to warm to rt overnight. Saturated aqueous NH_4Cl (55 mL) was added, and the organic layer was separated. The aqueous layer was extracted with Et_2O (3 x 50 mL), and the combined organic extracts were washed with brine (100 mL), dried ($MgSO_4$) and concentrated. The crude product was purified by gravity chromatography on silica gel (hexanes/EtOAc 80:20) to give **I** as yellow oil (1.10 g, 40%): IR (neat) 3389 (br), 3031, 1494, 1454 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.26 (m, 5H), 4.81 (dd, *J* = 7.5, 5.3 Hz, 1H), 2.63–2.58 (m, 2H), 2.51 (brs, 1H), 2.17–2.12 (m, 2H), 1.56–1.46 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.0, 128.6, 127.9, 126.0, 83.7, 76.3, 72.8, 30.3, 22.5, 20.9, 13.7; HRMS (ESI^+) calcd for $C_{13}H_{16}O$ $[M]^+$ *m/z* 188.1201, found 188.1205.



7

(*E*)-3,4-Dibromo-1-phenyl-3-hepten-1-ol (7). The general procedure for dibromination was followed with 1-phenyl-3-heptyn-1-ol (**I**), and purification gave **7** as a yellow oil (0.534 g, 48%):[8] IR (neat) 3380 (br), 2961, 1039 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.43–7.28 (m, 5H), 5.11 (dd, *J* = 8.4, 5.1 Hz, 1H), 3.29 (dd, *J* = 14.4, 8.5 Hz, 1H), 3.00 (dd, *J* = 14.5, 5.0 Hz, 1H), 2.75–2.62 (m, 2H), 2.15 (brs, 1H), 1.60 (sextet, *J* = 7.4 Hz, 2H), 0.93 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.0, 128.6, 128.0, 126.1, 124.9, 117.2, 72.8, 50.2, 42.8, 20.9, 13.1; HRMS (ESI^+) calcd for $C_{13}H_{14}Br_2O$ $[M - H_2O]^+$ *m/z* 327.9462, found 327.9453.

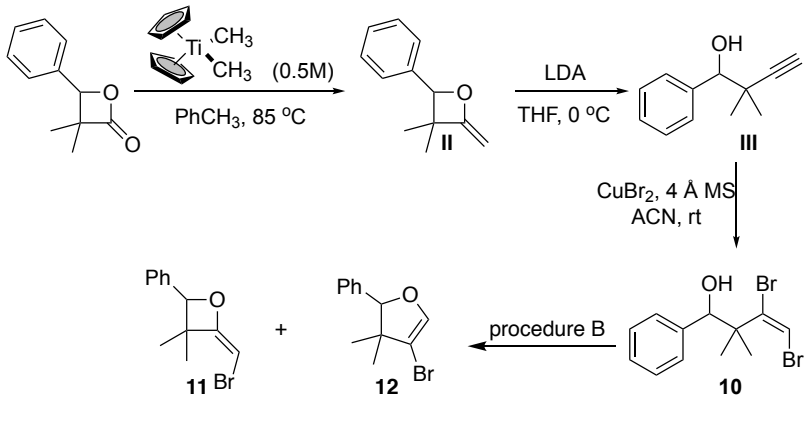


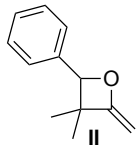
7 **8** **9**

(*E*)-2-(1-Bromobutylidene)-4-phenyloxetane (8) and 4-bromo-2-phenyl-5-propyl-2,3-dihydrofuran (9). CuI (0.0050 g, 0.029 mmol) and Cs_2CO_3 (0.091 g, 0.28 mmol) were added to a flame dried test tube. The system was backfilled 3x with N_2, and (*E*)-3,4-dibromo-1-phenyl-3-hepten-1-ol (**7**) (0.050 g, 0.14 mmol) in dioxane (2.8 mL) was added in one portion. The mixture was placed in an oil bath (100 °C) and stirred for 16 h. The resulting mixture was cooled to rt, and Et_2O (10 mL) was added. The mixture was then stirred for 30 min and filtered, and the filtrate was concentrated. ^1H NMR of the crude product showed a 1:1 ratio of **8** and **9**, as well as ~50% of the starting material. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/Et_2O/TEA, 98:1:1) to give **8/9** (1:1) as a clear yellow oil (0.019 g, 50%). (*E*)-2-(1-Bromobutylidene)-4-phenyloxetane (**8**) was separable by careful column chromatography using the same solvent system (hexanes/Et_2O/TEA, 98:1:1): ^1H NMR (400 MHz, $CDCl_3$) δ 7.44–7.34 (m, 5H), 5.65 (dd, *J* = 6.8, 5.4 Hz, 1H), 3.56 (dd, *J* = 15.3, 7.1 Hz, 1H),

3.11 (dd, *J* = 15.3, 5.2 Hz, 1H), 2.41–2.37 (m, 2H), 1.56 (sextet, *J* = 7.3 Hz, 2H), 0.96 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.7, 140.2, 128.9, 128.9, 125.9, 97.3, 78.5, 37.9, 32.8, 21.2, 13.2. 4-Bromo-2-phenyl-5-propyl-2,3-dihydrofuran (**9**) was isolated by gravity column chromatography on silica gel (hexanes/Et_2O/TEA, 98:1:1): IR (neat) 3032, 2960, 1197, 1075 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35–7.28 (m, 5H), 5.50 (dd, *J* = 10.5, 8.5 Hz, 1H), 3.28 (m, 1H), 2.88 (m, 1H), 2.29 (m, 2H), 1.62 (sextet, *J* = 7.3 Hz, 2H), 0.97 (t, *J* = 7.3 Hz); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.3, 142.4, 129.0, 128.2, 125.6, 87.3, 81.5, 45.0, 28.5, 20.0, 13.9; HRMS (ESI^+) calcd for $C_{13}H_{15}BrO$ $[M]^+$ *m/z* 266.0306, found 266.0320.

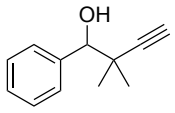
VI. Synthesis and [Cu] mediated cyclization of allyl-substituted dibromoalkene, (*E*)-3,4-dibromo-2,2-dimethyl-1-phenyl-3-buten-1-ol (10).





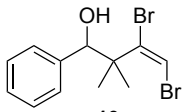
3,3-Dimethyl-2-methylene-4-phenyloxetane (II). A solution of dimethyltitanocene (11.4 mL, 0.50 M in toluene, 5.70 mmol) and 3,3-dimethyl-4-phenyloxetan-2-one[9, 10] (0.500g, 2.84 mmol) was stirred in the dark at 85 °C in a pressure tube. The reaction was monitored by TLC until the disappearance of the starting material (8 h). The reaction mixture was poured into petroleum

ether (100 mL) and stirred overnight. The orange precipitate was filtered through a pad of Celite, and washed with petroleum ether until the filtrate was colorless. The filtrate was concentrated to ~one-tenth the volume, and the residue was purified by gravity column chromatography on silica gel (hexanes/NEt_3 96:4) to give compound **II** as a yellow oil (0.212 g, 49%): IR ($CHCl_3$): 2963, 2929, 1692, 1461, 908, 734, 650 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.28 (m, 5H), 5.50 (s, 1H), 4.16 (d, *J* = 3.7 Hz, 1H), 3.78 (d, *J* = 3.7 Hz, 1H), 1.49 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.5, 138.2, 128.5, 128.0, 125.5, 90.5, 76.4, 47.2, 26.7, 22.0; HRMS (FAB) calcd for $C_{12}H_{15}O$ $[M + H]^+$ *m/z* 175.1122, found 175.1115.



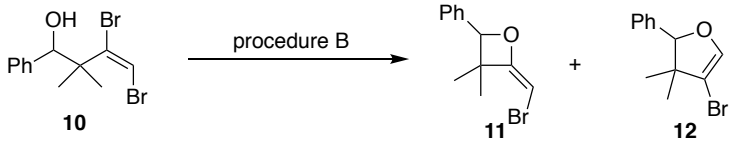
III

2,2-Dimethyl-1-phenyl-3-butyn-1-ol (III). *n*-BuLi (1.5 mL, 2.5 M, 3.66 mmol) was added dropwise to a solution of diisopropylamine (0.59 mL, 4.15 mmol) in dry THF (8 mL) at 0 °C under N_2. The solution was allowed to warm to ambient temperature over 30 min and then cooled to 0 °C. 3,3-Dimethyl-2-methylene-4phenyloxetane (**II**) (0.212 g, 1.22 mmol) in THF (4 mL) was then added dropwise to the resulting solution. The reaction was monitored by TLC until the disappearance of starting material (30 min). H_2O (10 mL) and Et_2O (10 mL) were added and the organic layer separated. The aqueous layer was extracted with Et_2O (3 x 5 mL), and the combined organic extracts were dried ($MgSO_4$) and concentrated. The crude mixture was purified by gravity column chromatography on silica gel (hexanes/EtOAc 80:20) to give **III** as a yellow oil (0.175 g, 83%).[11] ^1H NMR (400 MHz, $CDCl_3$) δ 7.42–7.28 (m, 5H), 4.51 (d, *J* = 4.0 Hz, 1H), 2.42 (d, *J* = 4.0 Hz, 1H), 2.26 (s, 1H), 1.28 (s, 3H), 1.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.8, 127.9, 127.7, 127.7, 80.3, 80.2, 70.8, 37.7, 26.3, 24.3.



10

(*E*)-3,4-Dibromo-2,2-dimethyl-1-phenyl-3-buten-1-ol (10). The general procedure was followed and purification gave **10** as a clear oil (0.245 g, 73%): IR (neat) 3458 (br), 3077, 2979, 1452, 1026 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.27 (m, 5H), 6.78 (s, 1H), 5.25 (d, *J* = 2.8 Hz, 1H), 2.03 (d, *J* = 3.2 Hz, 1H), 1.49 (s, 3H), 1.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.2, 134.9, 128.0, 127.9, 101.3, 77.7, 49.0, 25.5, 24.4; HRMS (ESI^+) calcd for $C_{12}H_{14}Br_2NaO$ $[M + Na]^+$ *m/z* 354.9304, found 354.9312.

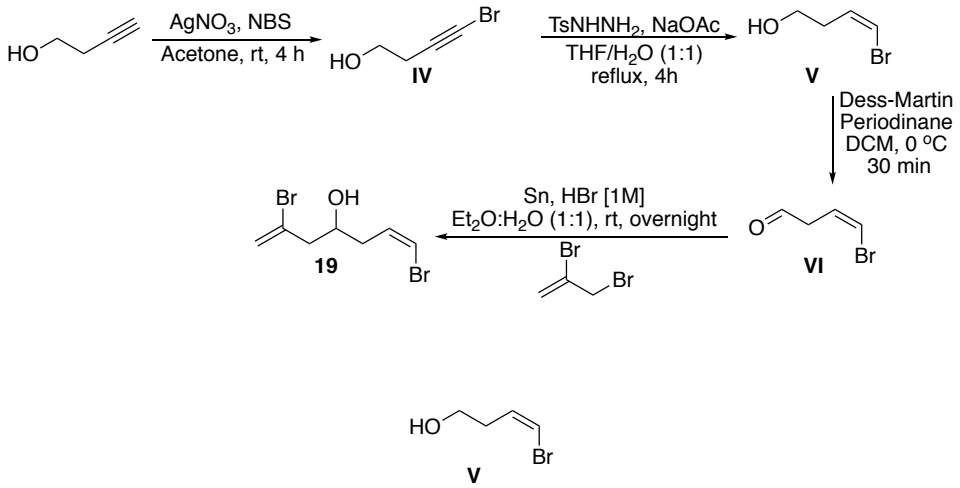


10 **11** **12**

(*E*)-2-(Bromomethylidene)-3,3-dimethyl-4-phenyloxetane (11) and 4-bromo-3,3-dimethyl-2-phenyl-2,3-dihydrofuran (12). General procedure C and was followed and purification by gravity column chromatography on silica gel (hexanes/Et_2O/TEA, 98:1:1) gave **11** and **12** as an inseparable mixture (0.027 g, 73%, 42:58 mixture of **11**:**12**): Characterization of (*E*)-2-(bromomethylidene)-3,3-dimethyl-4-phenyloxetane (**11**): ^1H NMR (400 MHz, $CDCl_3$) δ 7.42–7.28 (m, 5H), 5.52 (s, 1H), 5.34 (s, 1H), 1.65 (s, 3H), 0.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.7, 137.4, 128.4, 128.2, 125.5, 91.1, 73.9, 48.4, 24.4, 19.6. Characterization of 4-bromo-3,3-dimethyl-2-phenyl-2,3-dihydrofuran (**12**): ^1H NMR (400 MHz, $CDCl_3$) δ 7.42–7.28 (m, 5H), 6.53 (s, 1H), 5.19 (s, 1H), 1.28 (s, 3H), 0.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.5, 137.5, 128.6, 128.4, 126.3, 107.3, 92.4, 48.6, 26.5, 22.5; HRMS (ESI^+) of mixture calcd for $C_{12}H_{14}BrO$ $[M + H]^+$ *m/z* 253.0223, found 253.0218.

VII. Competition study

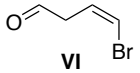
Synthesis of competition substrate 19



V

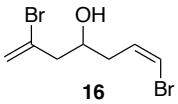
4-Bromo-3-buten-1-ol (V). 3-Butyn-1-ol (1.00 g, 14.3 mmol) was dissolved in acetone (48 mL). *N*-Bromosuccinimide (2.78 g, 15.7 mmol) and $AgNO_3$ (0.242 g, 1.43 mmol) were added. The reaction was stirred for 2 h. The reaction mixture was concentrated under reduced pressure and diluted with Et_2O (50 mL) and water (50 mL). The layers were separated, and the aqueous layer was extracted with Et_2O (2 x 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated to give 4-bromo-3-butyn-1-ol (**IV**), which was used without further purification. 4-Bromo-3-butyn-1-ol (**IV**) (1.00 g, 6.71 mmol), *p*-toluenesulfonyl hydrazine (2.50 g, 13.4 mmol), sodium acetate (1.65 g, 20.1 mmol), and THF/H_2O (1:1, 30 mL) were added to a round bottom flask. The solution was placed in an oil bath and heated at reflux for 4 h. The solution was allowed to cool to rt. Saturated aqueous $Na_2S_2O_3$ (100 mL) was added, and the solution was extracted with Et_2O (3 x 30 mL). The combined organic extracts were washed with H_2O (30 mL) and brine (30 mL), dried ($MgSO_4$), and concentrated. A mixture of hexane/Et_2O (80:20, 50 mL) was added to the crude residue, and the resulting mixture was filtered through a short pad of silica. The eluant was concentrated to obtain **V** as a clear yellow oil (0.628 g, 59%): IR (neat) 3333 (br), 2926, 1623, 1314, 1044 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.29 (dt, *J* = 7.0, 1.4 Hz, 1H), 6.19 (dt, *J* = 7.0, 7.0 Hz, 1H), 3.73 (t, *J* = 6.5 Hz, 2H), 2.48 (ttd, *J* = 6.6, 6.6, 1.4 Hz, 2H);

^{13}C NMR (100 MHz, $CDCl_3$) δ 131.4, 110.2, 61.3, 33.5; HRMS (ESI^+) calcd for C_4H_7BrO $[M]^+$ *m/z* 149.9680, found 149.9672.



VI

(*Z*)-4-Bromo-3-butenal (VI). 4-Bromo-3-buten-1-ol (**V**) (0.579 g, 3.83 mmol) and DCM (28 mL) were added to a flame dried flask. The solution was cooled to 0 °C, and Dess-Martin periodinane (1.79 g, 4.22 mmol) was added in one portion. The solution was stirred for 30 min. Saturated aqueous $Na_2S_2O_3$ (50 mL) and saturated aqueous $NaHCO_3$ (50 mL) were added, and the mixture was stirred until it became clear. The solution was then extracted with DCM (2 x 20 mL). The combined organic extracts were washed with brine (50 mL), dried ($MgSO_4$), and concentrated. A mixture of hexane/Et_2O (80:20, 100 mL) was added to the crude residue, and the resulting mixture was filtered through a short pad of silica. The eluent was concentrated under reduced pressure to give **VI** as a yellow oil (0.390 g, 42%), which was used immediately in the next reaction: ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.73 (m, 1H), 6.47 (m, 1H), 6.40 (m, 1H), 3.40 (ddd, *J* = 8.5, 1.3, 1.3 Hz, 2H).

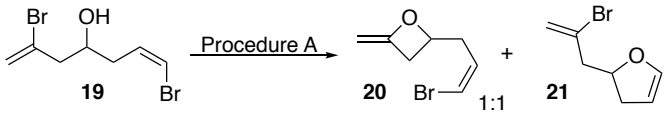


16

(*Z*)-1,6-Dibromo-1,6-heptadiene-4-ol (19). Crude 4-bromo-3-butenal (**VI**) (0.390 g, 2.62 mmol), Sn powder (0.622 g, 5.42 mmol), 2,3-dibromopropene (0.768 mL, 7.85 mmol), and Et_2O/H_2O (1:1 mixture, 5 mL) were added to a round bottom flask. Aqueous HBr (1 M, 4 drops) was added, and the mixture was stirred at rt overnight. The reaction was diluted with Et_2O (20 mL) and filtered through a pad of celite. The filtrate was washed with brine (10 mL), dried ($MgSO_4$), and concentrated. The crude mixture was purified by gravity chromatography on silica gel (hexanes/EtOAc 90:10) to give **19** as a yellow oil (0.418 g, 60%): IR (neat) 3364 (br), 1630, 1051 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.33 (dt, *J* = 7.1, 1.3 Hz, 1H), 6.25 (dt, *J* = 7.0, 7.0 Hz, 1H), 5.73 (s, 1H), 5.57 (d, *J* = 1.5 Hz, 1H), 4.15–4.08 (m, 1H), 2.63–2.55 (m, 2H), 2.49–2.44 (m,

2H), 1.79 (d, *J* = 3.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 130.6, 130.3, 120.3, 110.6, 68.2, 49.0, 36.7; HRMS (ESI$^+$) calcd for $C_7H_8Br_2$ $[M - H_2O]^+$ *m/z* 249.8993, found 249.8997.

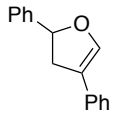
Competition reaction



4-[(*Z*)-3-Bromoprop-2-enyl]-2-methyleneoxetane (20) and 2-(2-bromoprop-2-enyl)-2,3-dihydrofuran (21). The reaction conditions for general procedure A for the copper mediated cyclization were followed. ^{1}H NMR of the crude product mixture showed a 1:1 ratio of **20** and **21**. The crude reaction mixture was purified by gravity column chromatography on silica gel (hexanes/Et_2O/TEA, 98:1:1) to give a mixture of compounds **20** and **21** as a yellow oil (0.054 g, 77%). Clean samples of each compound could be isolated by chromatography under the same conditions. Characterization of 4-[(*E*)-3-bromoprop-2-enyl]-2-methyleneoxetane (**20**): IR (neat) 2923, 2857, 1724, 1051 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.36 (ddd, *J* = 7.1, 1.4, 1.4 Hz, 1H), 6.20 (ddd, *J* = 7.0, 7.0, 7.0 Hz, 1H), 4.87 (dddd, *J* = 6.1, 6.1, 6.1, 6.1 Hz, 1H), 4.15–4.13 (m, 1H), 3.77 (ddd, *J* = 3.5, 1.8, 1.8 Hz, 1H), 3.26 (dddd, *J* = 14.9, 6.6, 2.0, 2.0 Hz, 1H), 2.90 (dddd, *J* = 14.9, 5.0, 2.0, 2.0 Hz, 1H), 2.72–2.69 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.1, 128.5, 111.4, 80.6, 77.1, 36.3, 33.8; HRMS (ESI$^+$) calcd for $C_7H_{10}BrO$ $[M]^+$ *m/z* 188.9910, found 188.9913. Characterization of 2-(2-bromoprop-2-enyl)-2,3-dihydrofuran (**21**): IR (neat) 2922, 2853, 1740, 1461 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.27 (ddd, *J* = 4.8, 2.4, 2.4 Hz, 1H), 5.69–5.68 (m, 1H), 5.53 (d, *J* = 1.6 Hz, 1H), 4.89 (ddd, *J* = 5.0, 2.4, 2.4 Hz, 1H), 4.87–4.81 (m, 1H), 2.84 (dd, *J* = 14.6, 5.8 Hz, 1H), 2.76 (dddd, *J* = 15.2, 10.1, 2.3, 2.3 Hz, 1H), 2.57 (dd, *J* = 14.7, 5.8 Hz, 1H), 2.30 (dddd, *J* = 15.2, 6.9, 2.3, 2.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.1, 129.8, 119.3, 99.2, 78.7, 47.5, 34.2; HRMS (ESI$^+$) calcd for $C_7H_{10}BrO$ $[M]^+$ *m/z* 188.9910, found 188.9905.

VIII. Applications

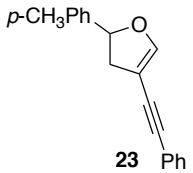
Suzuki-Miyaura Coupling



22

2,3-Dihydro-2,4-diphenylfuran (22). $Pd_2(dba)_3$ (0.002 g, 0.002 mmol), XPhos (0.004 g, 0.009 mmol), K_3PO_4 (0.094 g, 0.44 mmol), and phenylboronic acid (0.041 g, 0.33 mmol) were added to a flame dried Schlenk tube, and the tube was backfilled with N_2 (3x). 4-Bromo-2,3-dihydro-2-phenylfuran (**3a**) (0.050 g, 0.22 mmol) in *n*-butanol (0.44 mL) was added to the tube, and the reaction mixture was stirred at 95 °C for 4 h. It was then allowed to cool to rt, Et_2O (10 mL) was added, and the mixture was filtered through a short pad of celite. The eluent was concentrated under reduced pressure and purified by gravity chromatography on silica gel (hexanes/EtOAc 95:5) to give **22** as a yellow solid (0.030 g, 61%): mp 48.0–49.0 °C; IR (neat) 3029, 2920, 1626, 1104 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.34–7.27 (m, 4H), 7.25–7.15 (m, 5H), 7.09–7.05 (m, 1H), 6.91 (m, 1H), 5.62 (dd, *J* = 10.6, 8.5 Hz, 1H), 3.33 (ddd, *J* = 12.7, 10.7, 2.0 Hz, 1H), 2.91 (ddd, *J* = 10.4, 8.4, 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ142.8, 141.8, 134.2, 128.9, 128.8, 128.1, 126.0, 125.9, 124.3, 115.0, 83.7, 39.1; HRMS (ESI^+) calcd for $C_{16}H_{14}O$ $[M]^+$ *m/z* 222.1045, found 222.1049.

Sonogashira Coupling



23

2,3-Dihydro-2-(4-methylphenyl)-4-(2-phenylethynyl)furan (23). $Pd(OAc)_2$ (~0.5 mg, ~0.002 mmol), CuI (~0.3 mg, ~0.002 mmol), and Cs_2CO_3 (0.14 g, 0.42 mmol) were added to a flame dried test tube under N_2. Phenylacetylene (0.028 mL, 0.25 mmol) and 4-bromo-2,3-dihydro-2-(4-

methylphenyl)furan (**3b**) (0.050 g, 0.21 mmol) in DMF (1 mL) were added. The system was backfilled with N_2 (3x) and placed in an oil bath at 60 °C to stir for 24 h. Et_2O (5 mL) was added, and the mixture was filtered through a short pad of celite. The eluent was concentrated and purified by gravity chromatography on silica gel (hexanes/TEA 99:1) to give **23** as a yellow oil (0.040 g, 74%): IR (neat) 2922, 1515, 1093, 810 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.55–7.52 (m, 2H), 7.40–7.32 (m, 3H), 7.25 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.1 Hz, 2H), 6.50 (dd, *J* = 2.2, 2.2 Hz, 1H), 5.57 (dd, *J* = 10.4, 9.1 Hz, 1H), 3.23 (ddd, *J* = 14.8, 10.7, 2.1 Hz, 1H), 2.86 (ddd, *J* = 14.8, 8.8, 2.2 Hz, 1H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.5, 138.6, 138.3, 132.7, 129.6, 129.4, 128.7 126.0, 122.0, 91.9, 83.6, 81.8, 74.1, 43.9, 21.4; HRMS (ESI^+) calcd for $C_{11}H_{11}O$ $[M - C_8H_5]^+$ *m/z* 159.0810, found 159.0807.

IX. Additional details of the computational methods

10 nanoseconds of Molecular Dynamics simulations at a temperature of 80 °C were conducted for compounds **2a**, **2k**, **7**, **13**, and **19** in a fully solvated box of acetonitrile (see Fig S1). The size of the unit cell was approximately 25 Å×25 Å ×25 Å. Periodic boundary conditions were used within the NVT ensemble. The MD simulations were carried out with Desmond with the force field OPLSA3e,[12] within the Schrodinger 2019-4 suite. This recently developed force field represents the largest concerted parameterization effort aimed at organic molecules and provides extensive parameterization of valence and torsional terms.

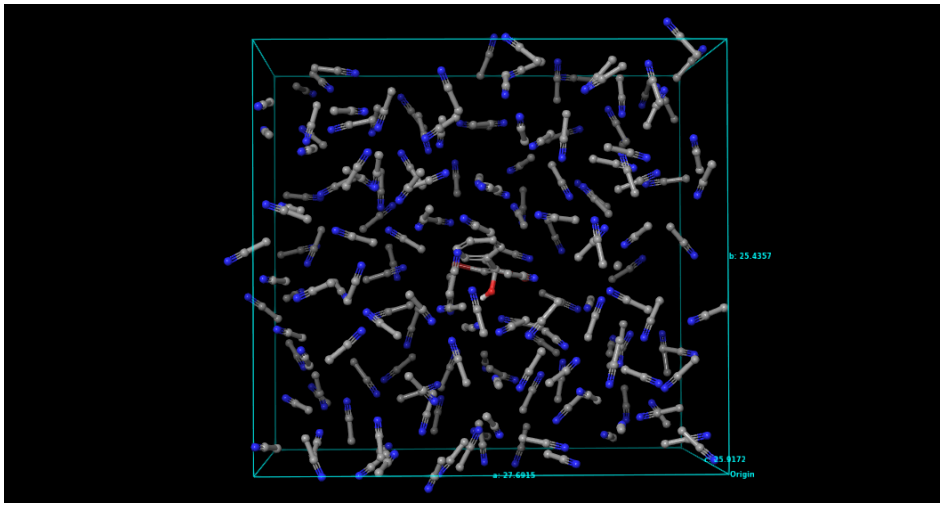


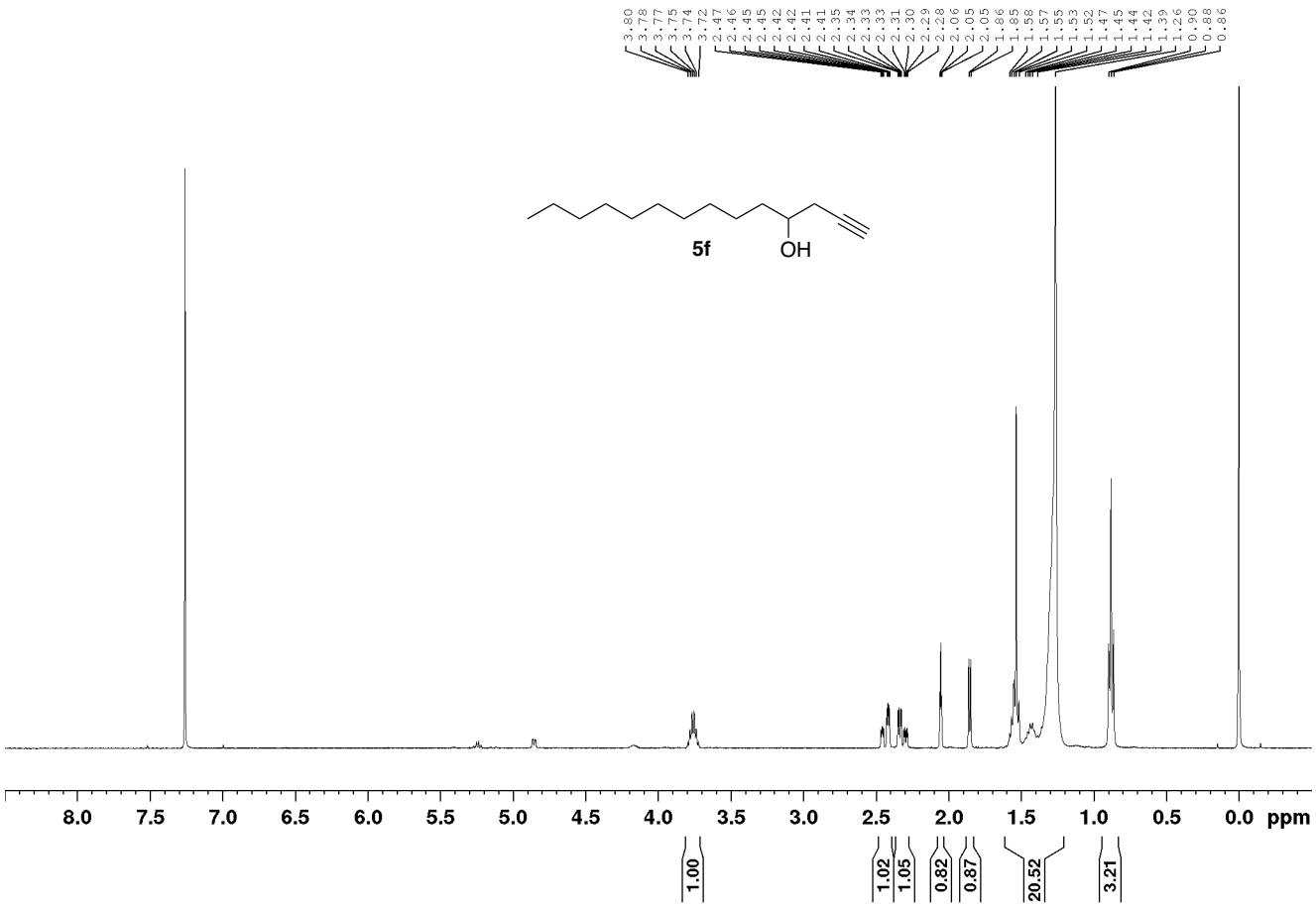
Fig. S1. Example of solvated unit cell for compound **2a** in acetonitrile.

The structure shown in Fig. 3, for which the ESP analysis was performed, is the global minimum at both the oplsa3e level and at the DFT. Indeed, we performed a conformational search at the MM level with oplsa3e and passed the three lowest energy minima (within 1 kcal/mol) to a DFT calculation using Jaguar[13] at the b3lyp-d3/lacvp** level. Both levels of theory maintained the same ranking of energies. This same DFT level of theory was then used to determine ESP charges on the global energy minimum.

X. References

1. Lee, A. S.–Y.; Chu, S.–F.; Chang, Y.–T.; Wang, S.–H. Synthesis of Homopropargyl Alcohols via a Sonochemical Barbier–type Reaction. *Tetrahedron Lett.* **2004**, *45*, 1551–1553.
2. a) Li, Q.–R.; Gu, C.–Z.; Yin, H. Tin-Indium Mediated and Microwave Assisted Propargylation of Aldehydes with Propargyl Bromide. *Chin. J. Chem*. **2006**, *24*, 72**–**78; b) Ma, X.; Wang, J.–X.; Li, S.; Wang, K.–H.; Huang, F. One-pot, Solvent-free Regioselective Addition Reactions of Propargyl Bromide to Carbonyl Compounds Mediated by Zn–Cu Couple. *Tetrahedron* **2009**, *65*, 8683–8689; c) Guo, L.-N.; Gao, H.; Mayer, P.; Knochel, P. Preparation of Organoaluminum Reagents from Propargylic Bromides and Aluminum Activated by $PbCl_2$ and Their Regio– and Diastereoselective Addition to Carbonyl Derivatives. *Chem. Eur. J.* **2010**, *16*, 9829–9834.
3. All homopropargyl alcohols **5** contained 10-20% of the corresponding allene. This mixture was used in the dibromination reactions.
4. The yield given is based on just the homopropargyl alcohol.
5. Xiang, J.; Yuan, R.; Wang, R.; Yi, N.; Lu, L.; Zou, H.; He, W. Method for Transforming Alkynes into (*E*)**-**Dibromoalkenes. *J. Org. Chem*. **2014**, *79*, 11378**–**11382.
6. All homopropargyl alcohols **5** contained 10-20% of the corresponding allene. This mixture was used in the dibromination reactions. The yields for the dibrominations were calculated based on the amount of homopropargyl alcohol in the initial mixtures.
7. Baati, R.; Gouverneur, V.; Mioskowski, C. Nozaki−Hiyama Reactions on Halogenated Allylchromium Reagents: A New Entry for the Preparation of Quaternary Halogenated Carbons. *J. Org. Chem*. **2000**, *65*, 1235–1238.
8. (*E*)-3,4-Dibromo-1-phenylhept-3-en-1-ol (**7**) contained ~8% of the *Z*-diastereomer, which was inseparable from it.
9. Bagwell, C. L.; Moloney, M. G.; Thompson, A. L. On the Antibiotic Activity of Oxazolomycin. *Bioorg. Med. Chem. Lett*. **2008**, *18*, 4081–4086.
10. Shiina, I.; Umezaki, Y.; Kuroda, N.; Iizumi, T.; Nagai, S.; Katoh, T. MNBA-Mediated β-Lactone Formation: Mechanistic Studies and Application for the Asymmetric Total Synthesis of Tetrahydrolipstatin. J. Org. Chem. **2012**, *77*, 4885–4901.
11. Kurono, N.; Sugita, K.; Tokuda, M. Regioselective Propargylation of Aldehydes and Ketones by Electrochemical Reaction using Zinc and Aluminum Anodes. *Tetrahedron* **2000**, *56*, 847–854.
12. Roos, K.; Wu, C.; Damm, W.; Reboul, M.; Stevenson, J. M.; Lu, C.; Dahlgren, M. K.; Mondal, S.; Chen, W.; Wang, L.; Abel, R.; Friesner, R. A.; Harder, E. D., OPLS3e: Extending force field coverage for drug-like small molecules. *J. Chem. Theory Comput.* **2019,** *15* (3), 1863–1874.
13. Bochevarov, A. D.; Harder, E., Hughes, T. F.; Greenwood, J. R.; Braden, D. A.; Philipp, D. M.; Rinaldo, D.; Halls, M. D.; Zhang, J.; Friesner, R. A. Jaguar: A high-performance quantum chemistry software program with strengths in life and materials sciences. *Int. J. Quantum Chem.* **2013**, *113* (18), 2110–2142.

XI. ^{1}H AND ^{13}C NMR SPECTRA OF NEW COMPOUNDS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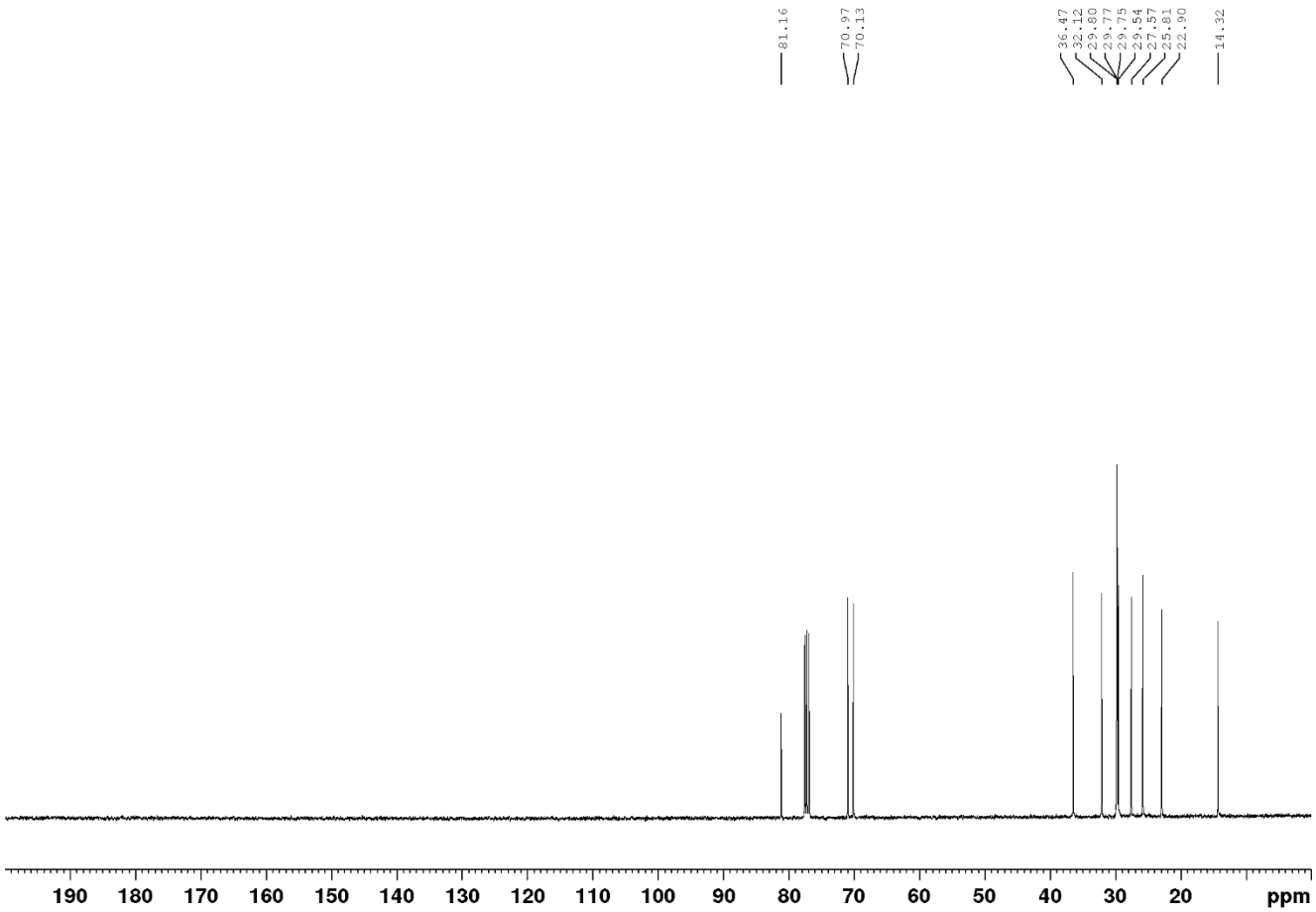
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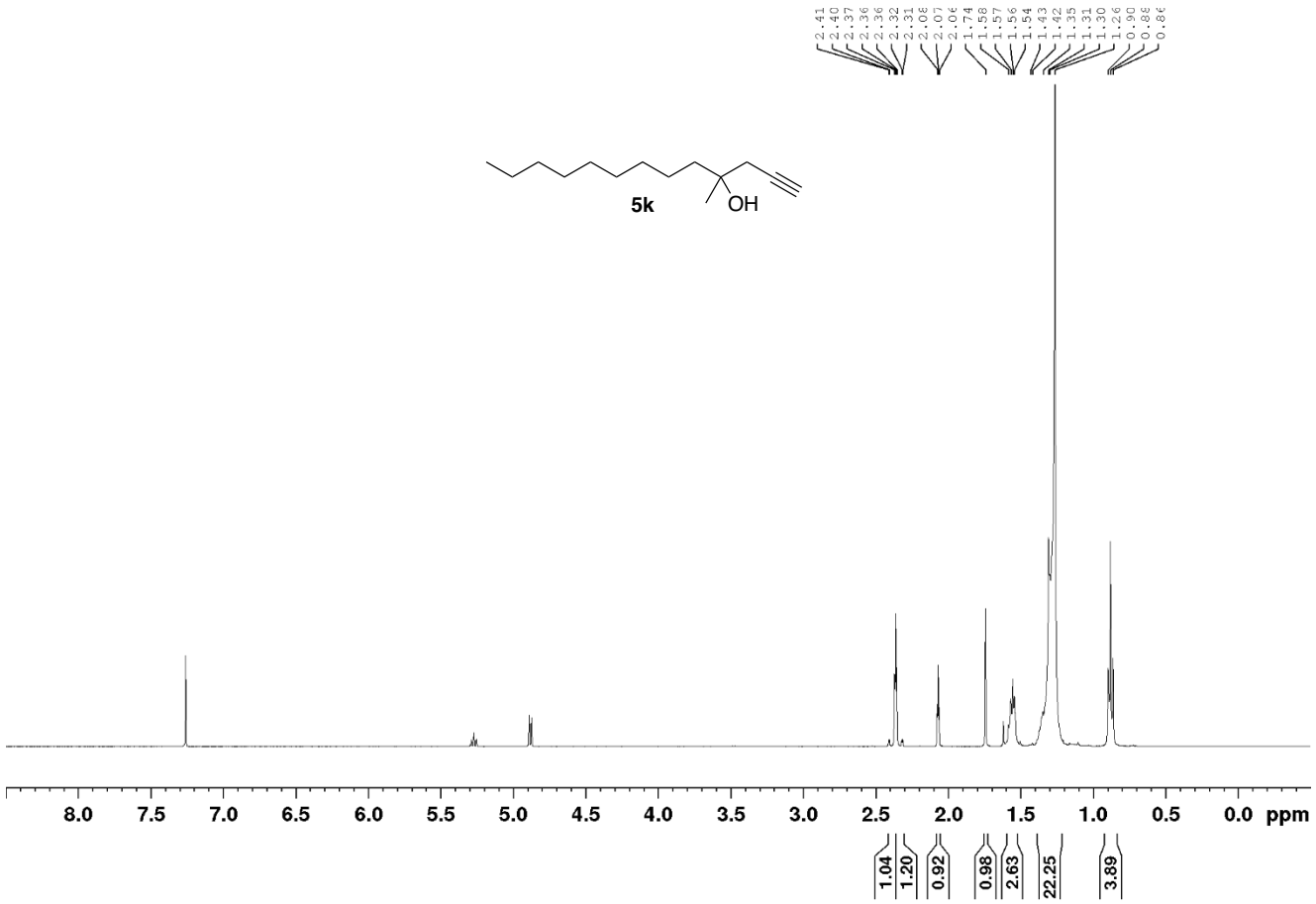
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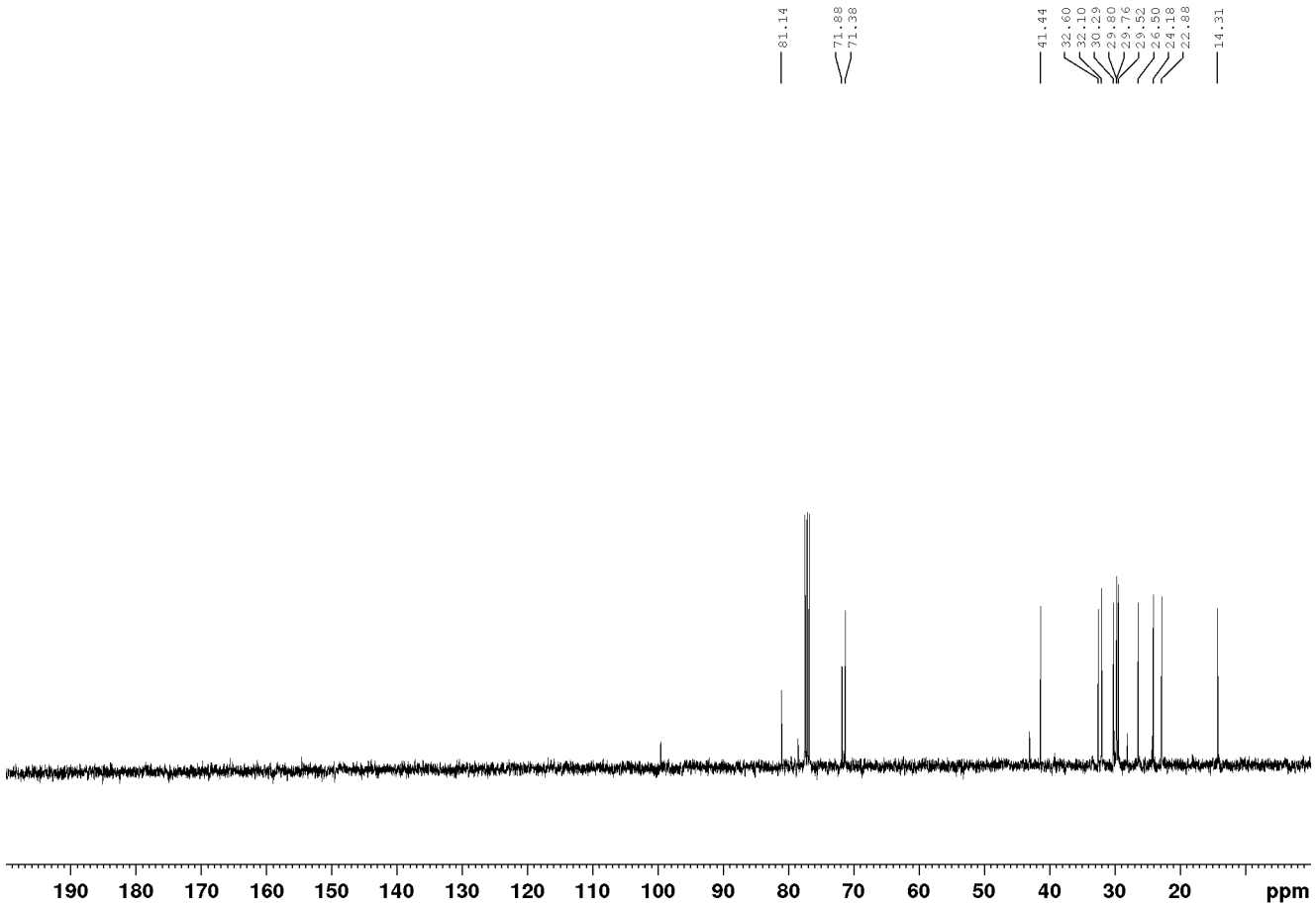
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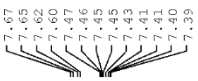
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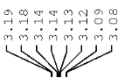
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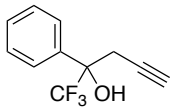
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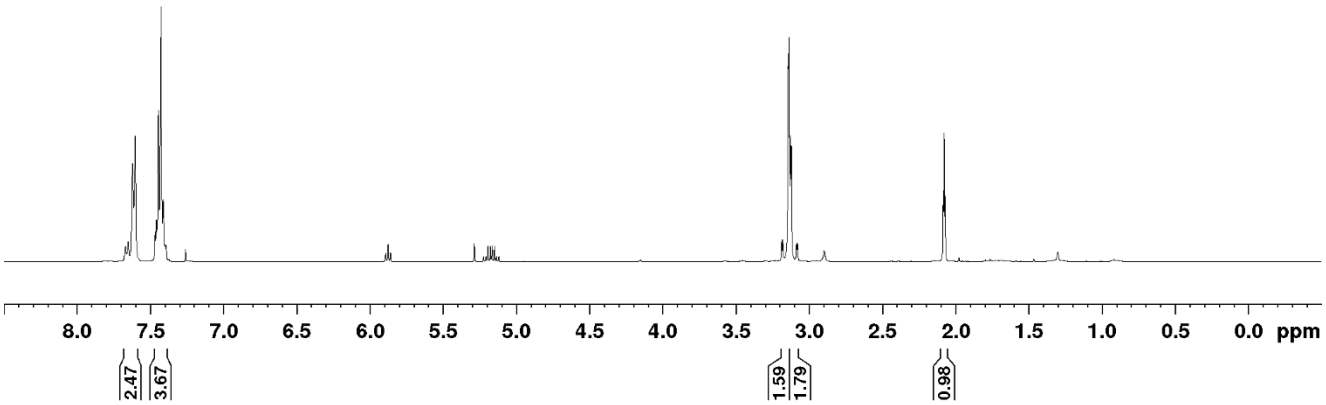
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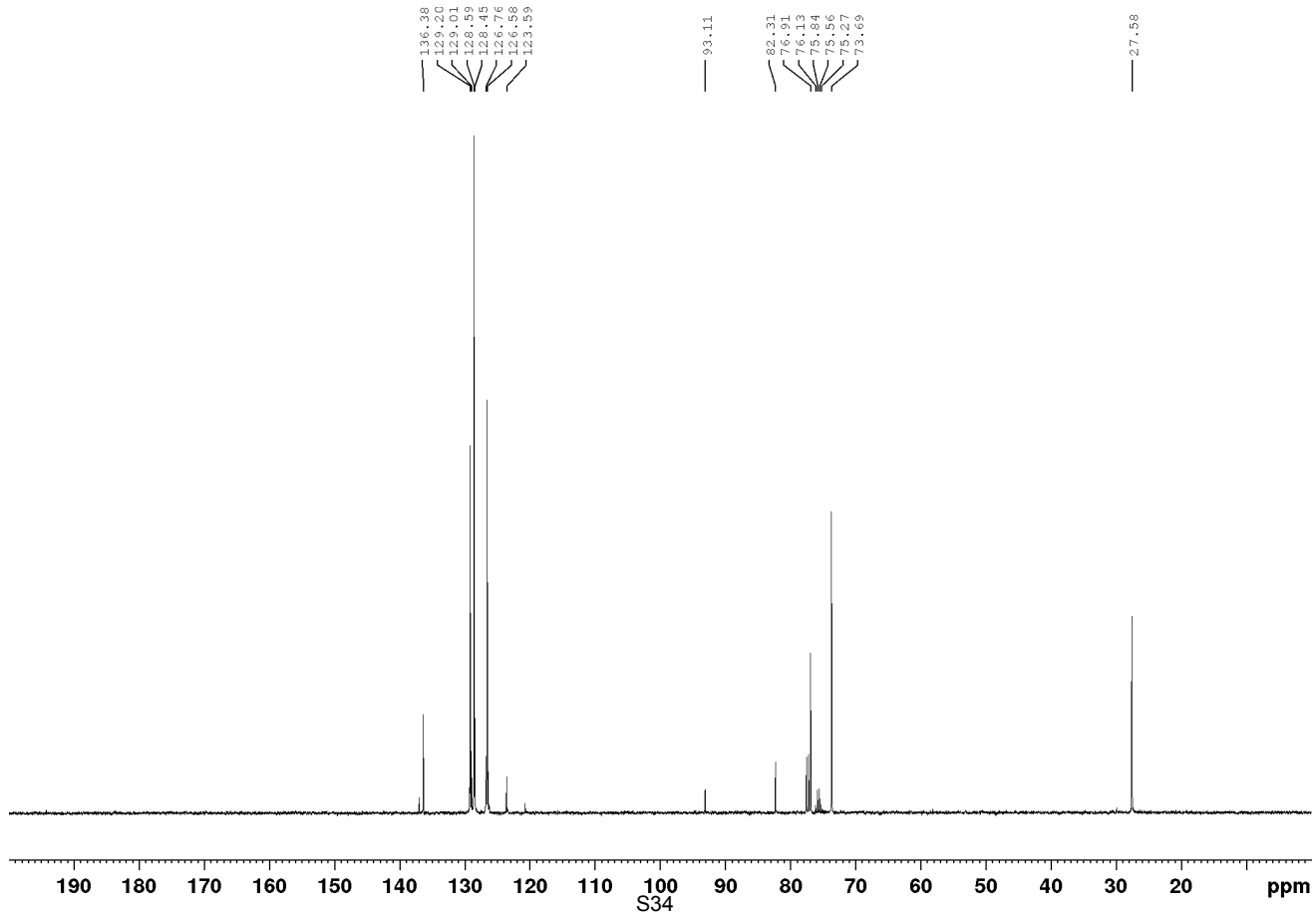
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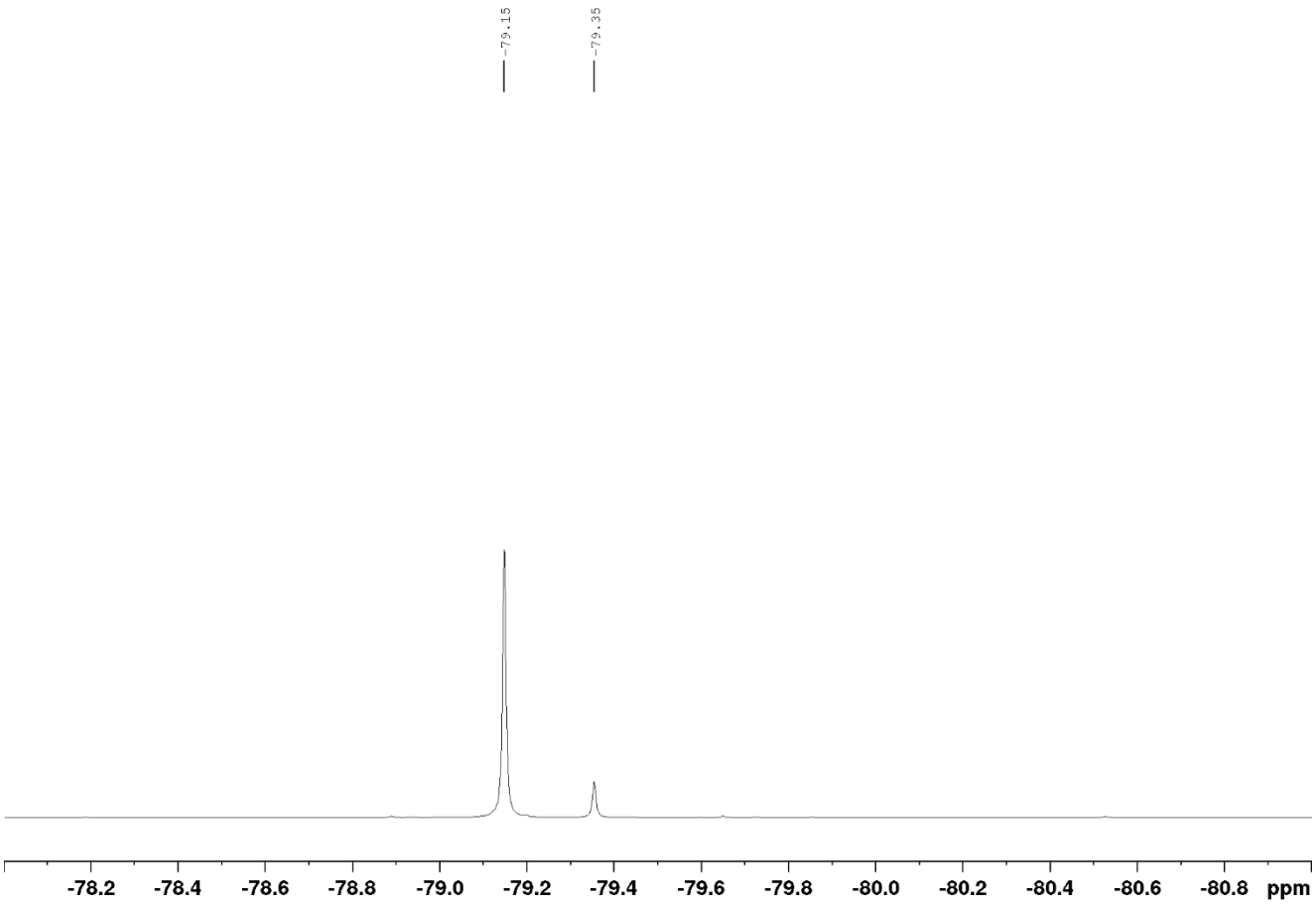
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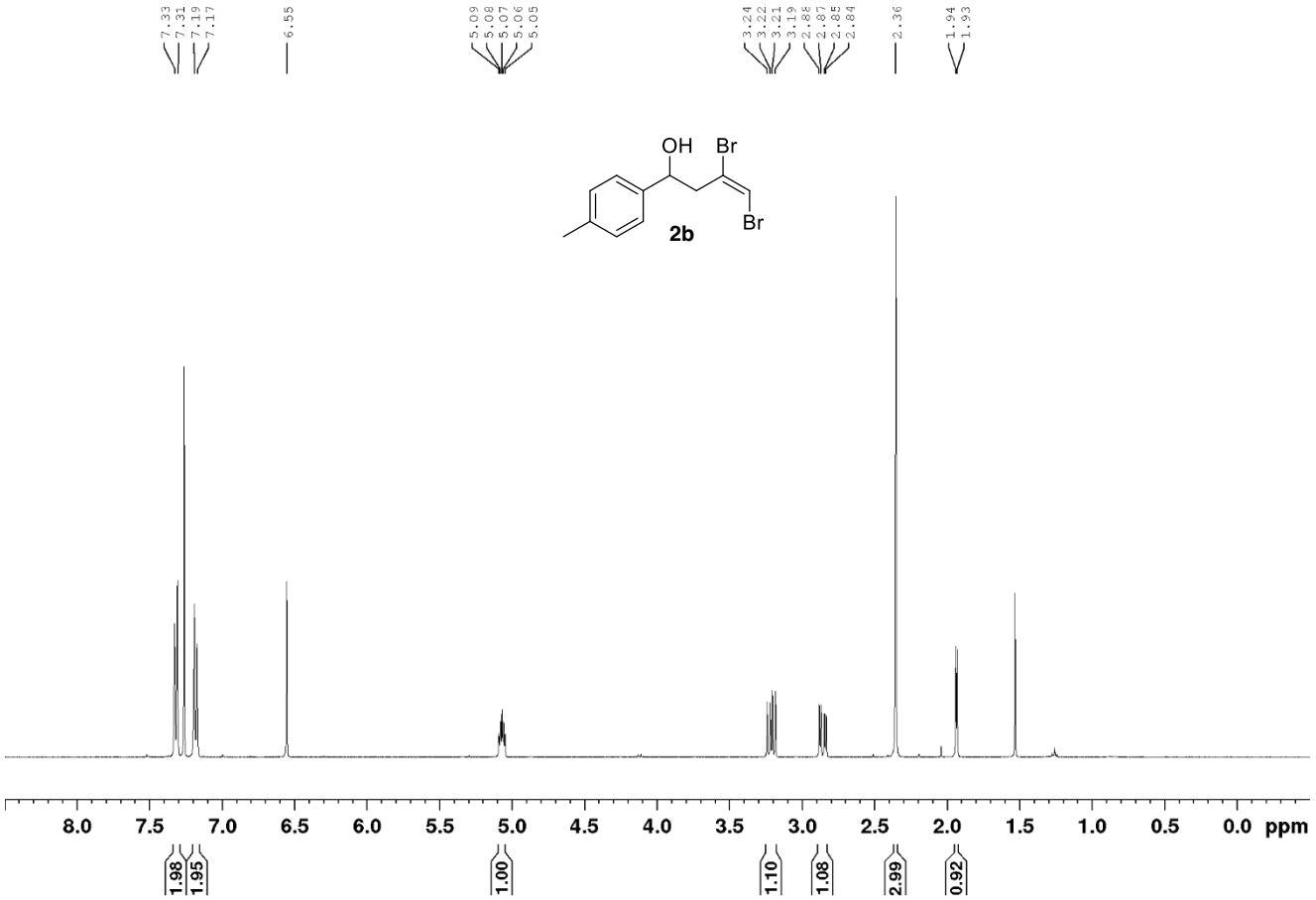
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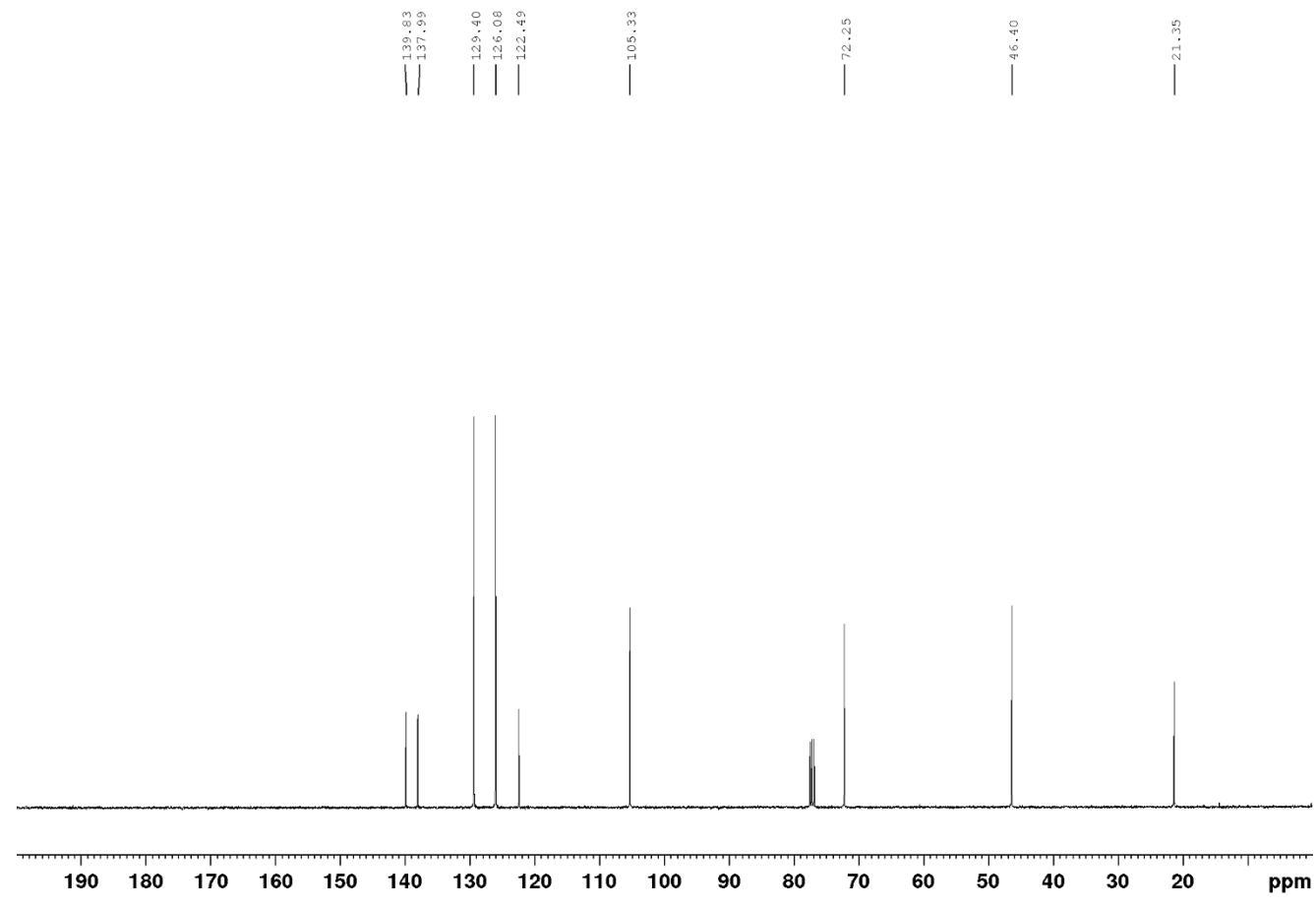
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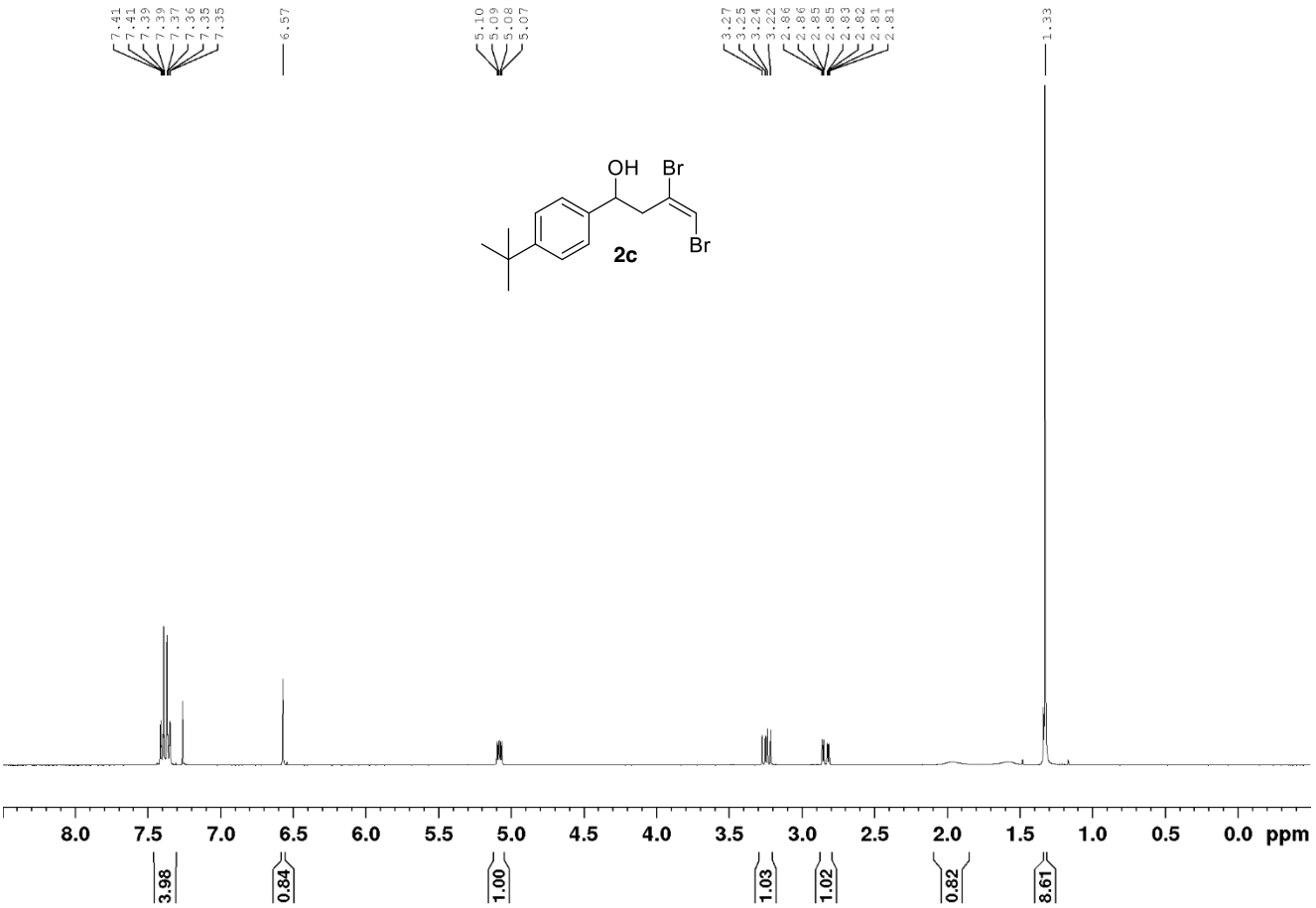
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5.08
5.07
3.27
3.25
3.24
3.22
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2.86
2.85
2.85
2.83
2.82
2.81
2.81
1.33
OH
Br
Br
2c
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
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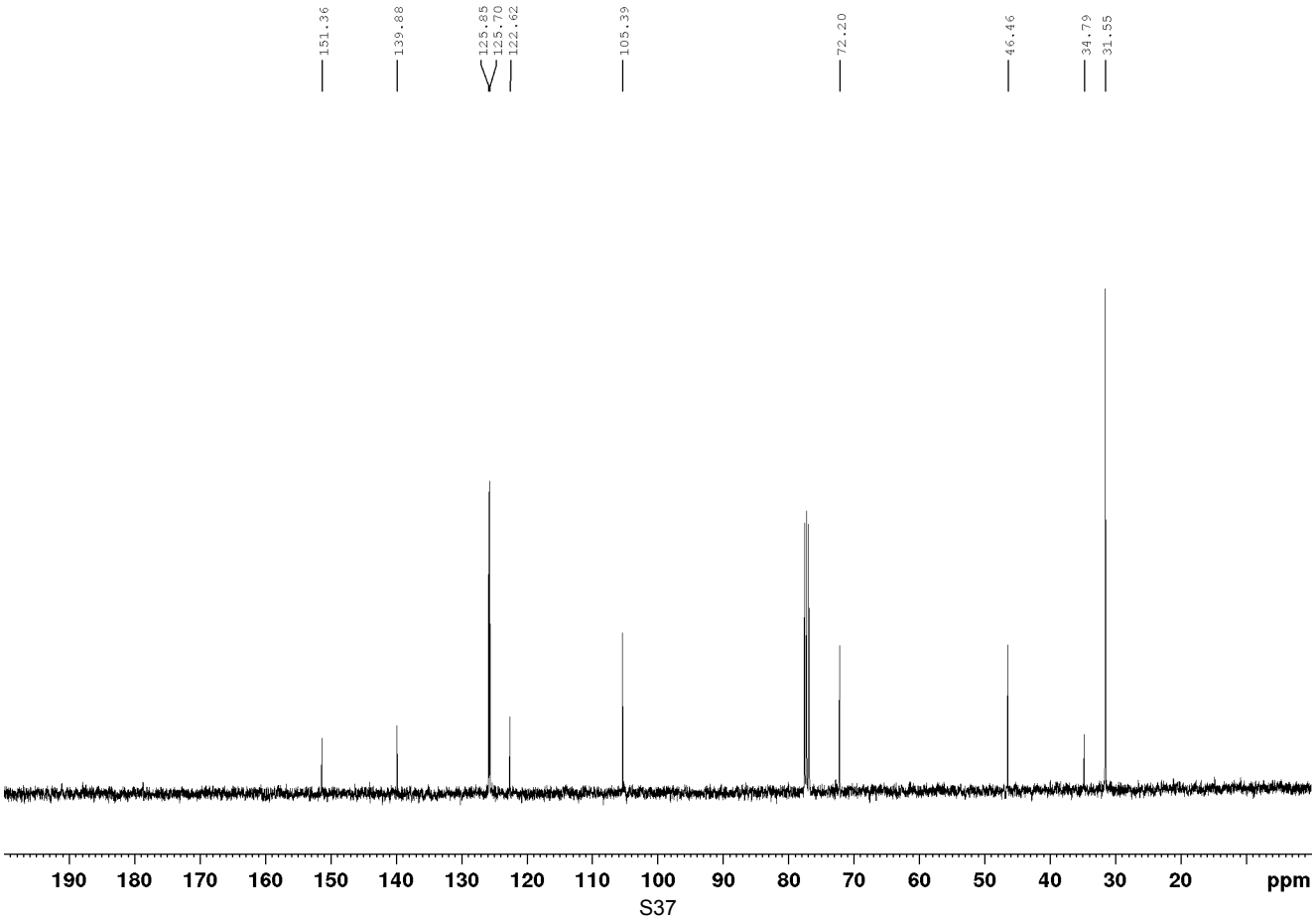
0.82
8.61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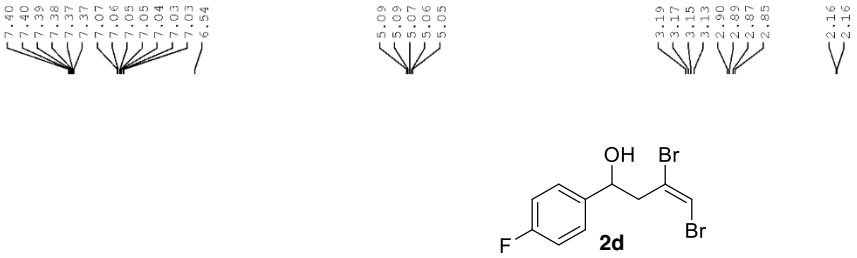
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7.03
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5.09
5.09
5.07
5.06
5.05
3.19
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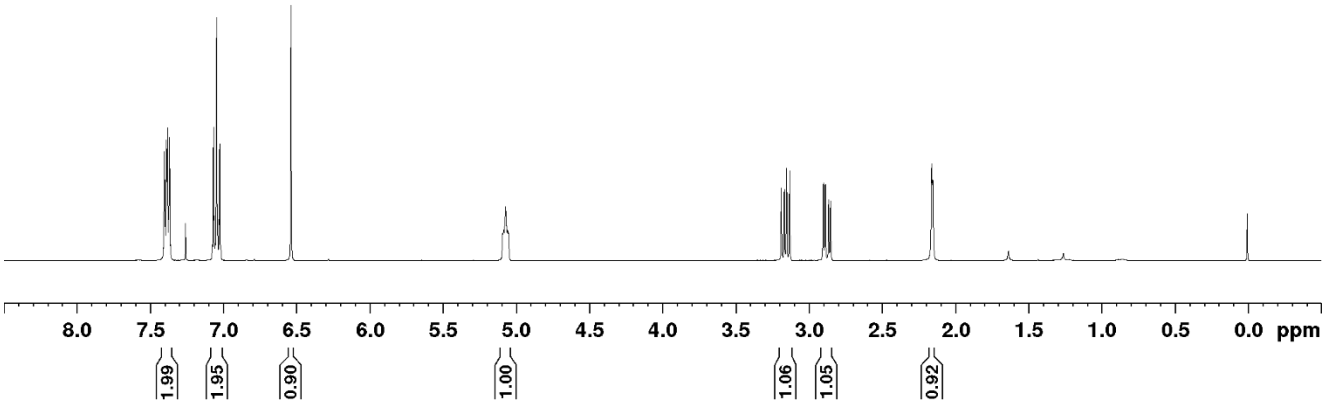
2.89
2.87
2.85
2.16
2.16

OH
Br
Br
F

2d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4.5
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3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.99
1.95
0.90
1.00
1.06
1.05
0.92


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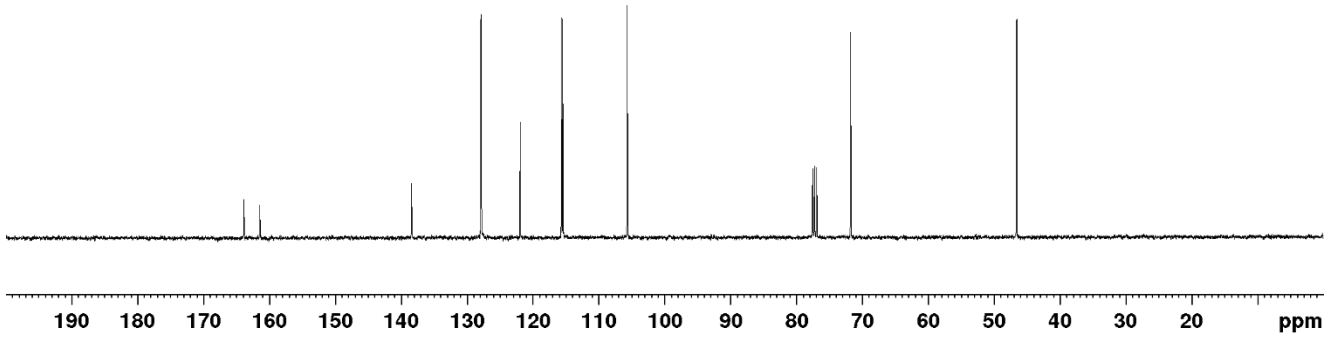
161.46
138.46
138.43
127.92
127.83
121.95
115.70
115.48
105.69
71.77
46.56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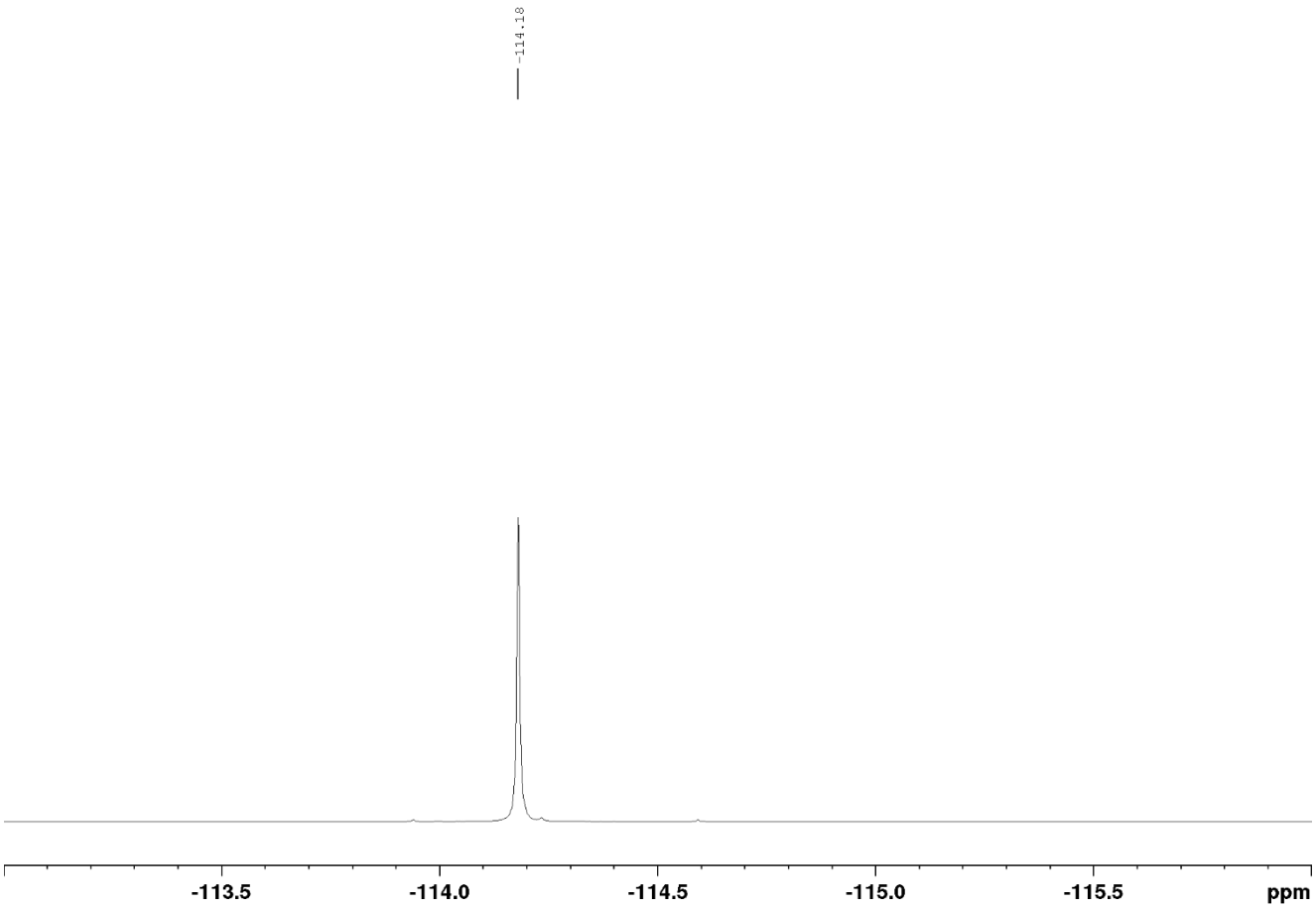
ppm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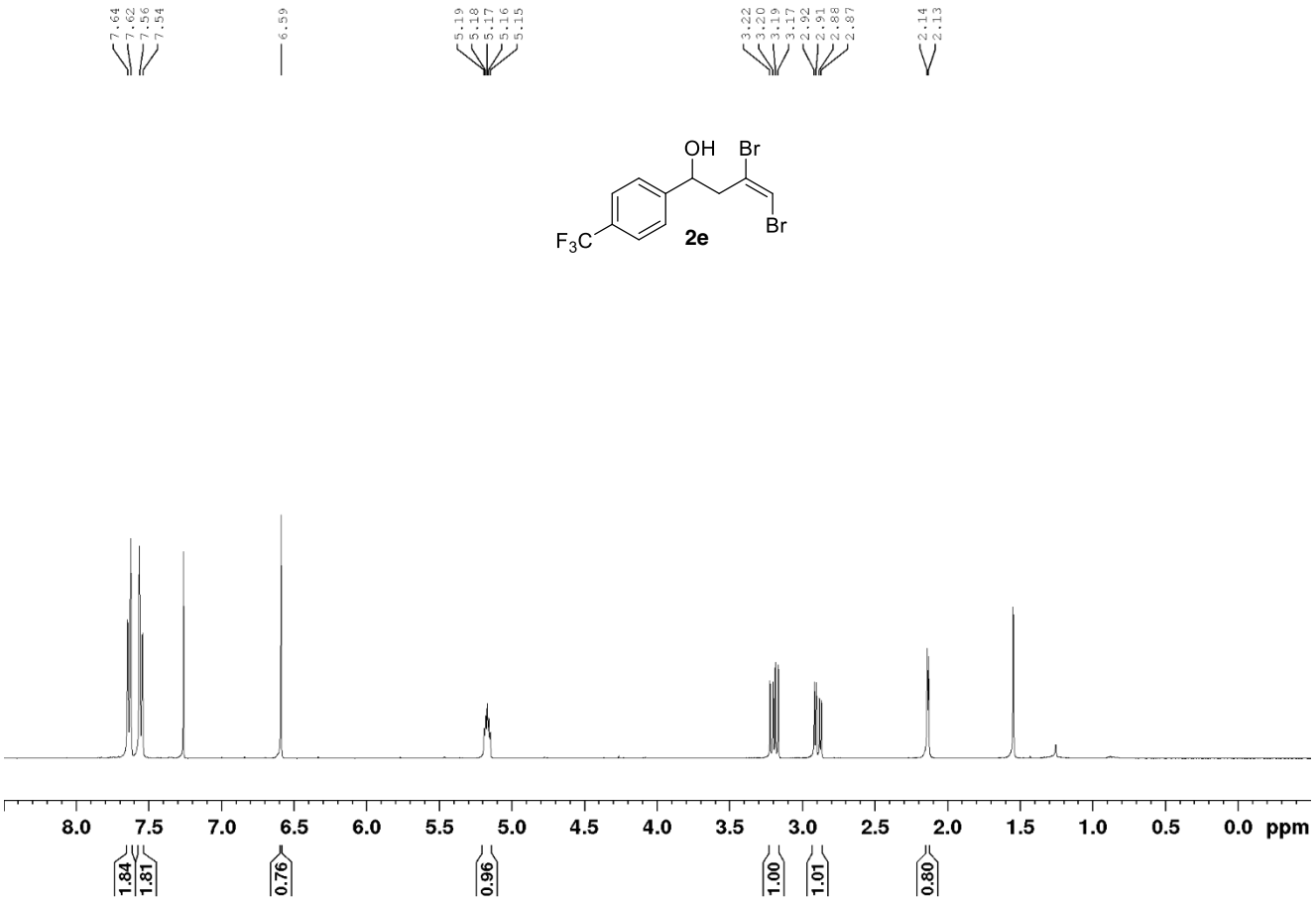
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5.17
5.16
5.15
3.22
3.20
3.19
3.17
2.92
2.91
2.88
2.87
2.14
2.13
OH
Br
Br
F3C
2e
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
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0.5
0.0
ppm
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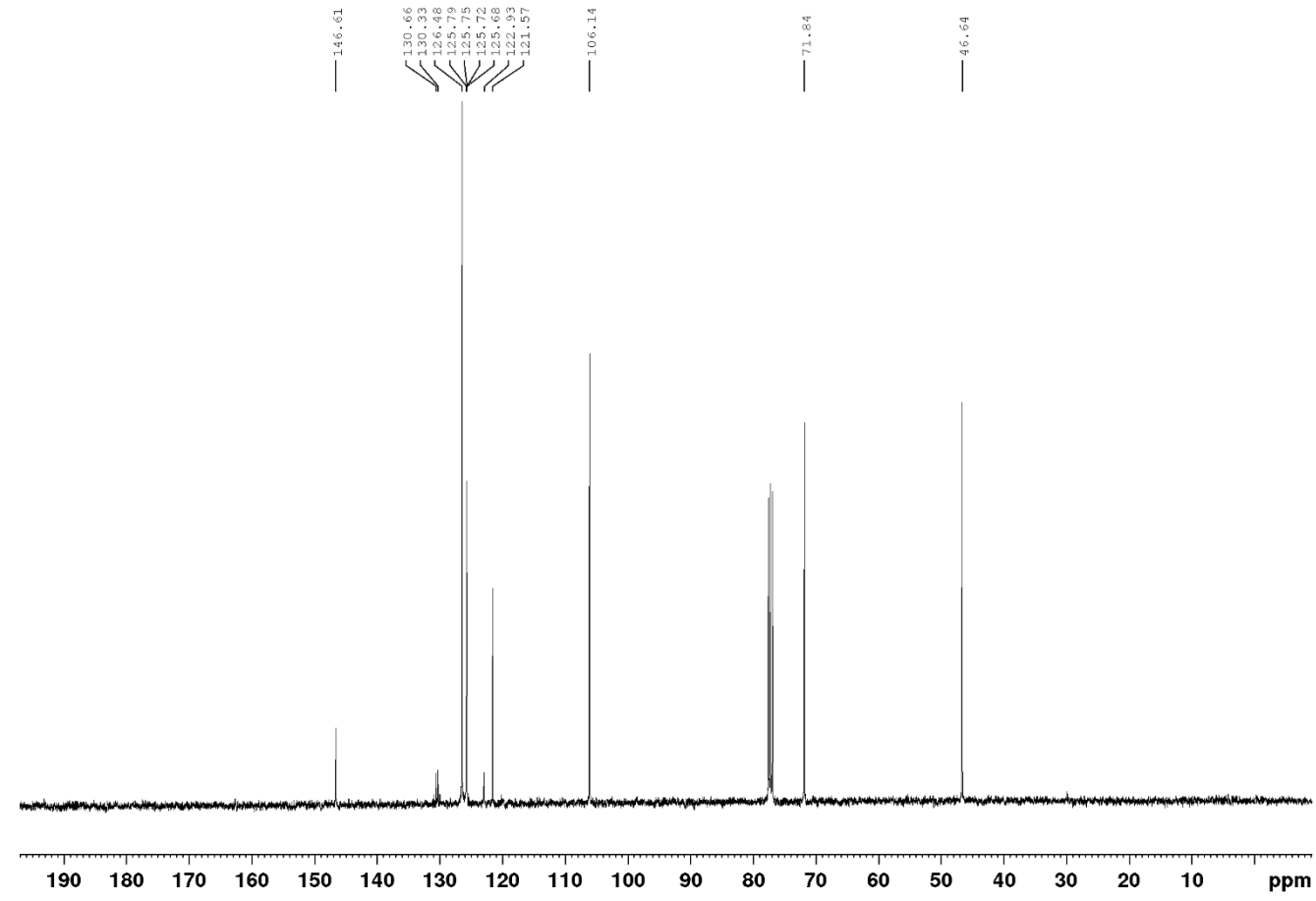
0.76
0.96
1.00
1.01
0.80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125.75
125.72
125.68
122.93
121.57
106.14
71.84
46.64
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150
140
130
120
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70
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30
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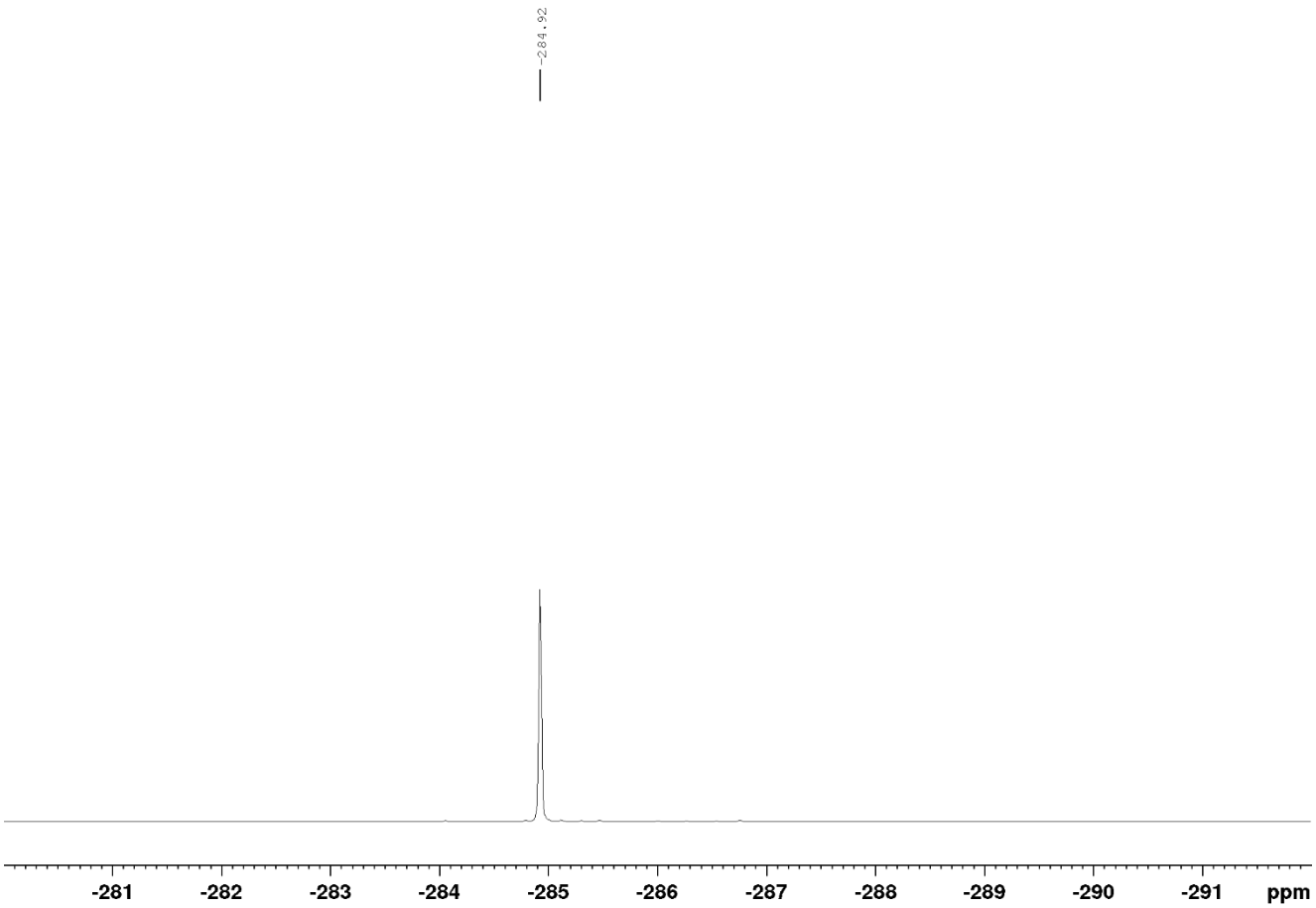
10
ppm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-286
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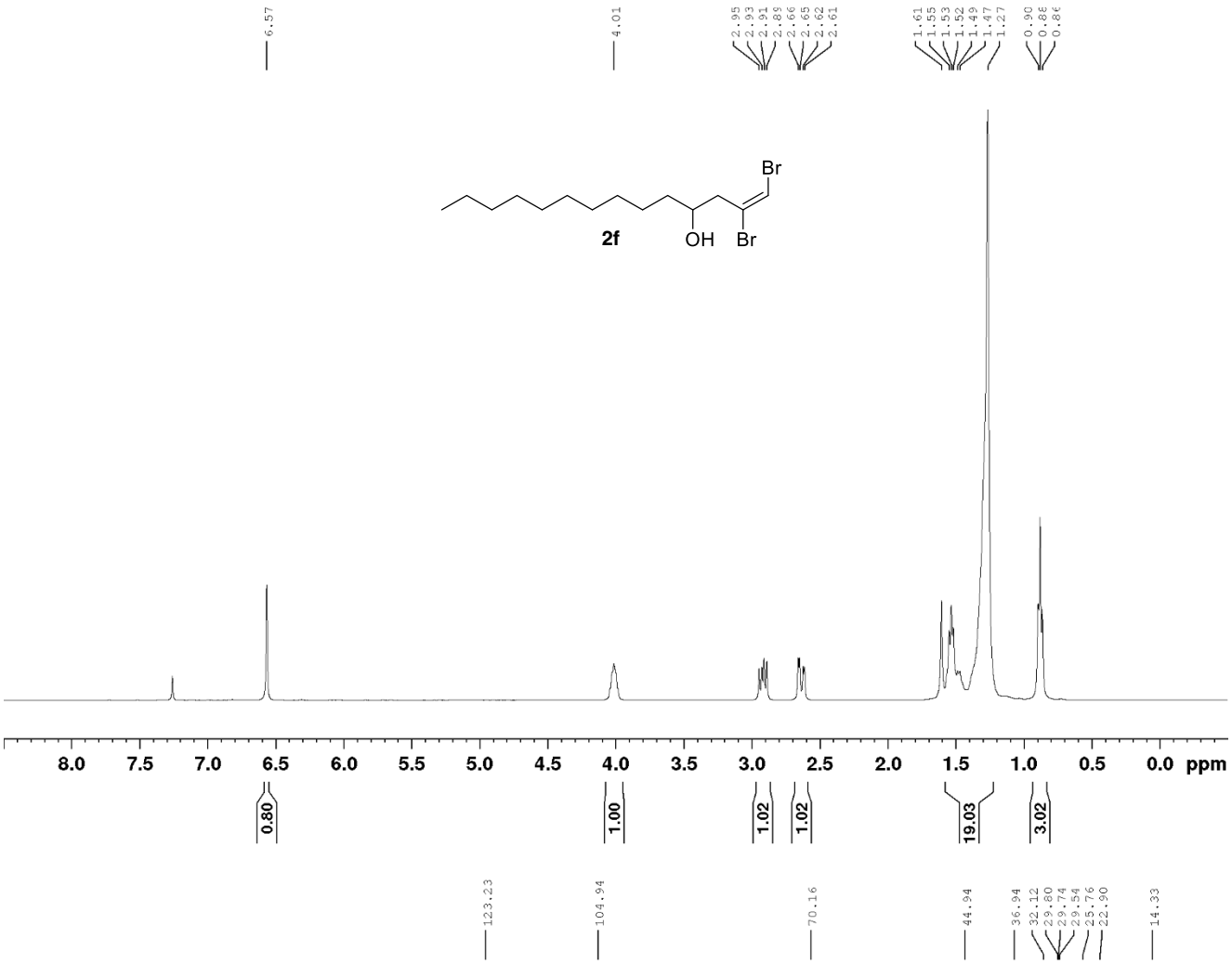
-288
-289
-290
-291
ppm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2.89
2.66
2.65
2.62
2.61
1.61
1.55
1.53
1.52
1.49
1.47
1.27
0.90
0.88
0.86
Br
2f
OH
Br
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
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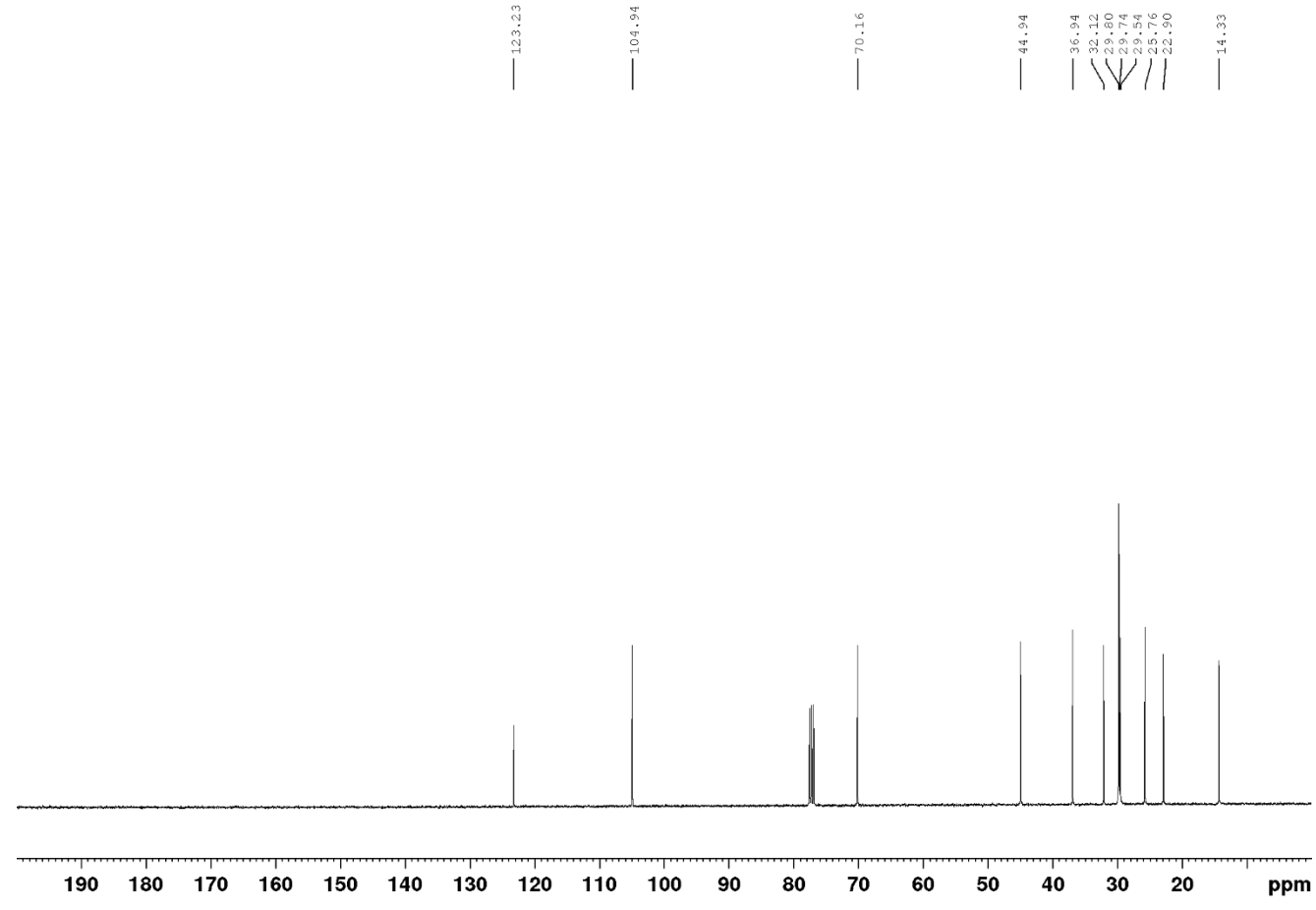
1.0
0.5
0.0
ppm
0.80
1.00
1.02
1.02
19.03
3.02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70.16
44.94
36.94
32.12
29.80
29.74
29.54
25.76
22.90
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160
150
140
130
120
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90
80
70
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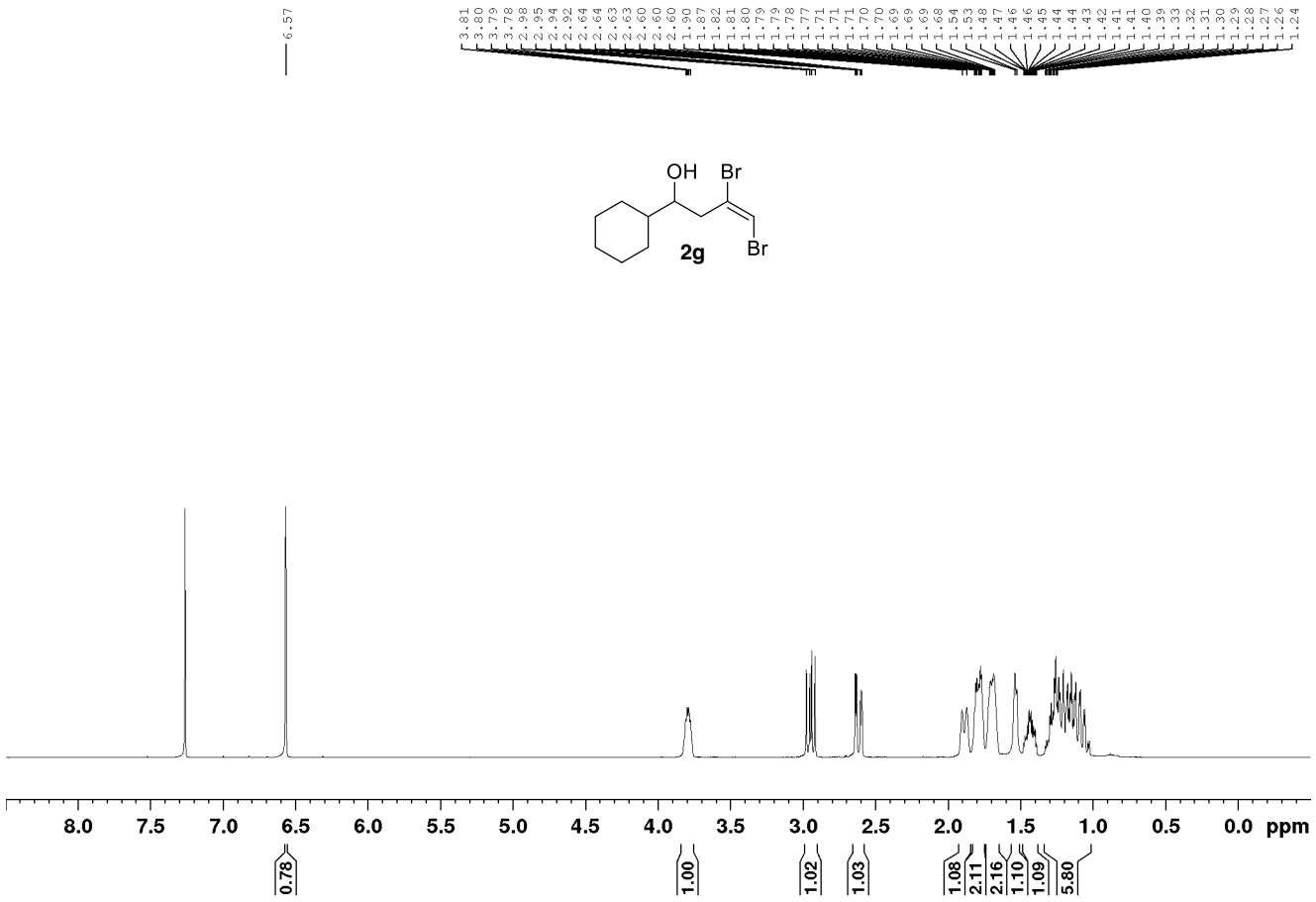
40
30
20
ppm


6.57
3.81 3.80 3.79 3.78 2.98 2.95 2.94 2.92 2.64 2.64 2.63 2.63 2.60 2.60 2.60 1.90 1.87 1.82 1.81 1.80 1.79 1.79 1.78 1.77 1.71 1.71 1.71 1.70 1.70 1.69 1.69 1.69 1.68 1.54 1.53 1.48 1.47 1.46 1.46 1.45 1.44 1.44 1.43 1.42 1.41 1.41 1.40 1.39 1.33 1.32 1.31 1.30 1.29 1.28 1.27 1.26 1.24
OH
Br
Br
2g
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 ppm
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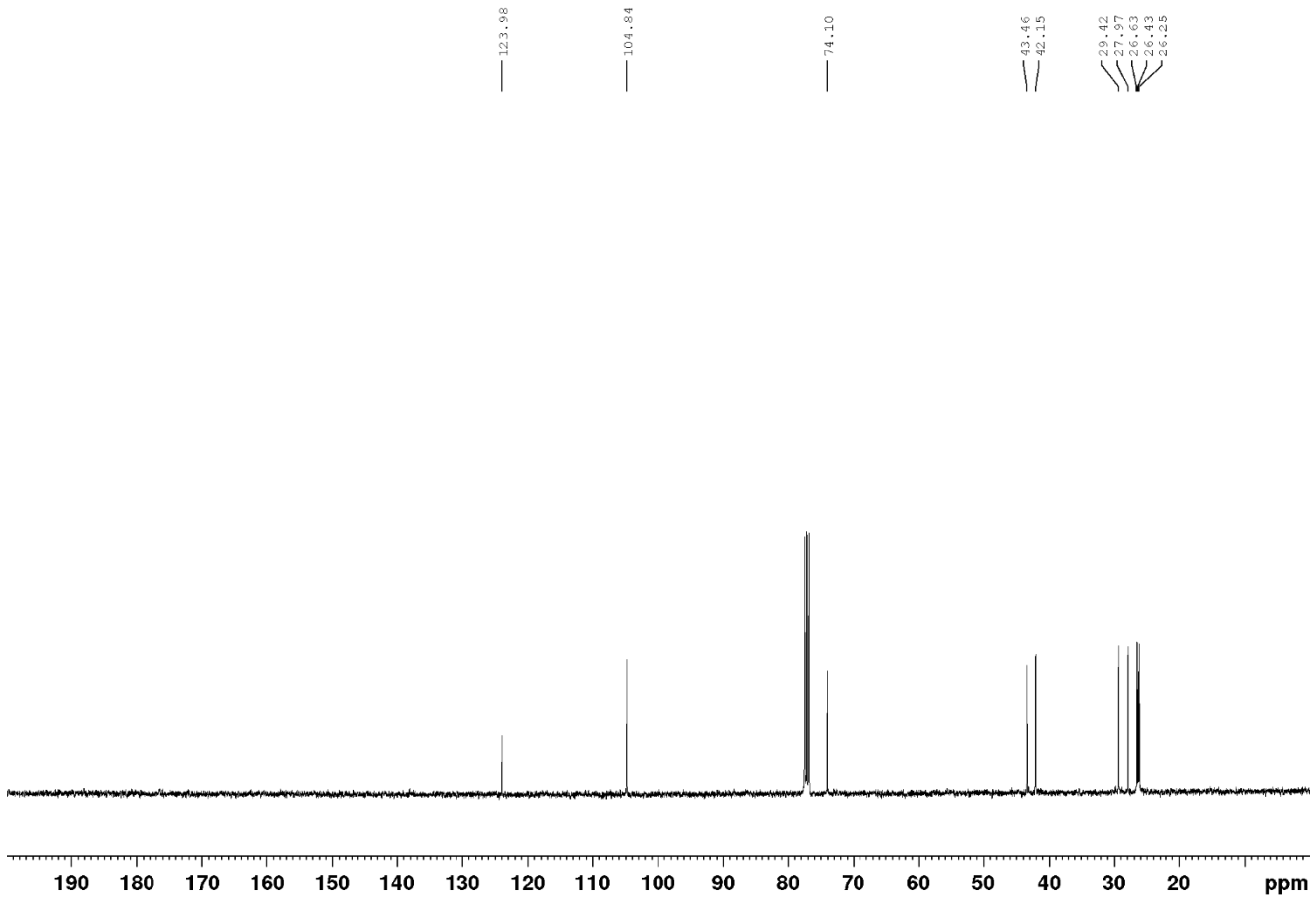
1.00
1.02
1.03
1.08
2.11
2.16
1.10
1.09
5.80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29.42
27.97
26.63
26.43
26.25
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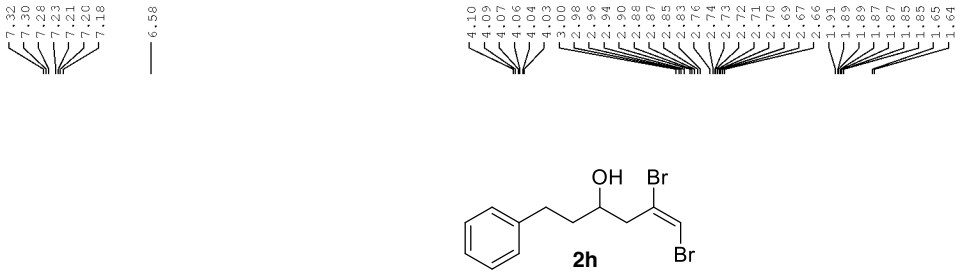
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7.20
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6.58
4.10
4.09
4.07
4.06
4.04
4.03
3.00
2.98
2.96
2.94
2.90
2.88
2.87
2.85
2.83
2.76
2.74
2.73
2.72
2.71
2.70
2.69
2.67
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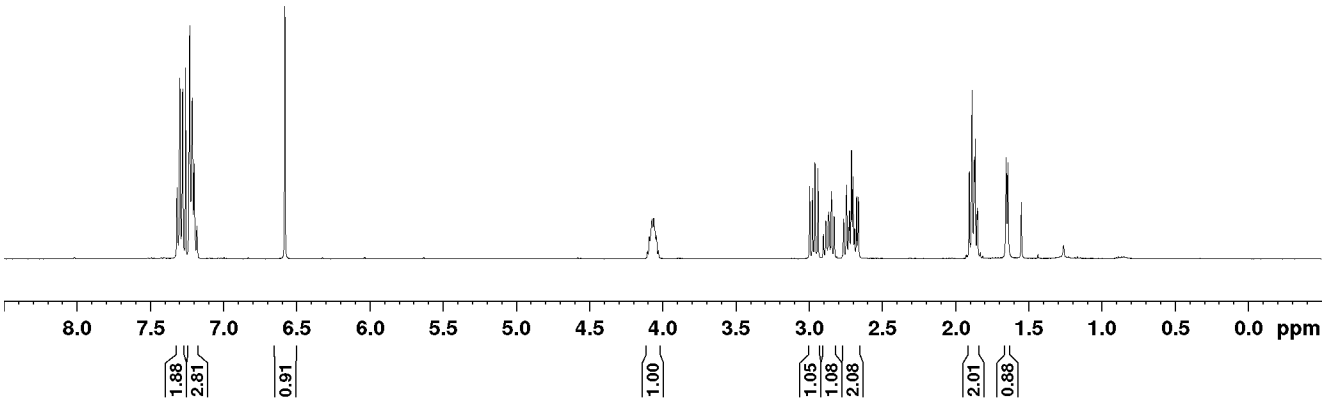
1.89
1.87
1.87
1.85
1.85
1.65
1.64

OH
Br
Br

2h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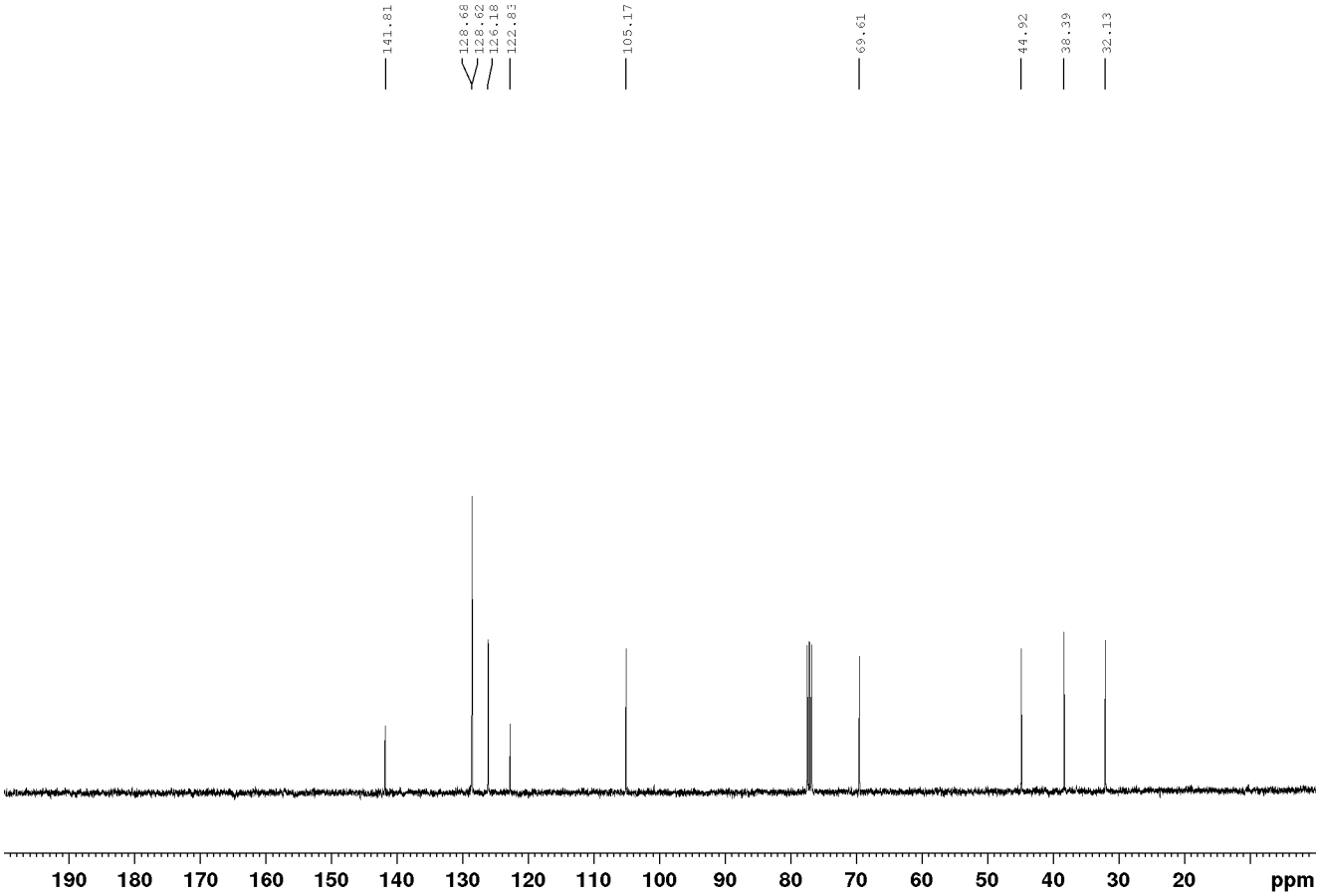
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.88
2.81
0.91
1.00
1.05
1.08
2.08
2.01
0.88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128.62
126.18
122.83
105.17
69.61
44.92
38.39
32.13
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


7.39
7.37
7.37
7.35
7.34
7.34
7.33
7.32
7.31
7.31
7.30
7.29
6.56
4.58
4.24
4.21
4.20
3.61
3.60
3.59
3.58
3.49
3.47
3.46
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3.00
2.98
2.96
2.94
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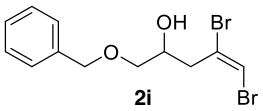
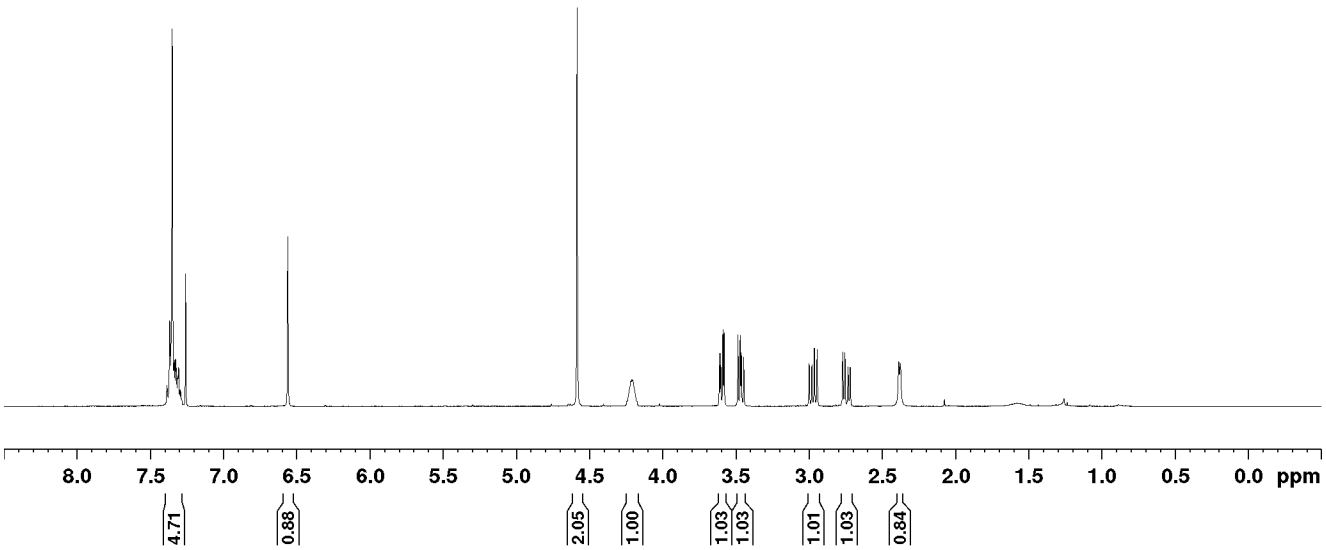
2.75
2.73
2.72
2.39
2.38


OH
Br
O
Br

2i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4.5
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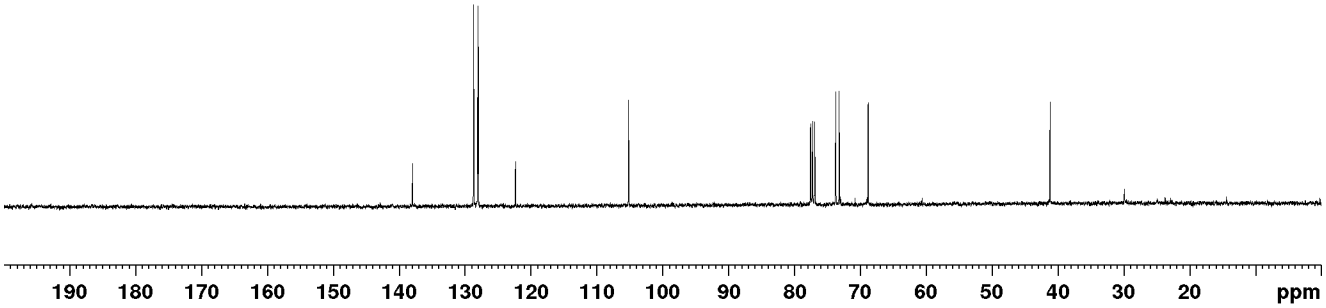
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
4.71
0.88
2.05
1.00
1.03
1.03
1.01
1.03
0.84


137.95
128.70
128.08
128.00
122.34
105.17
73.71
73.20
68.80
41.19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180
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160
150
140
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120
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100
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80
70
60
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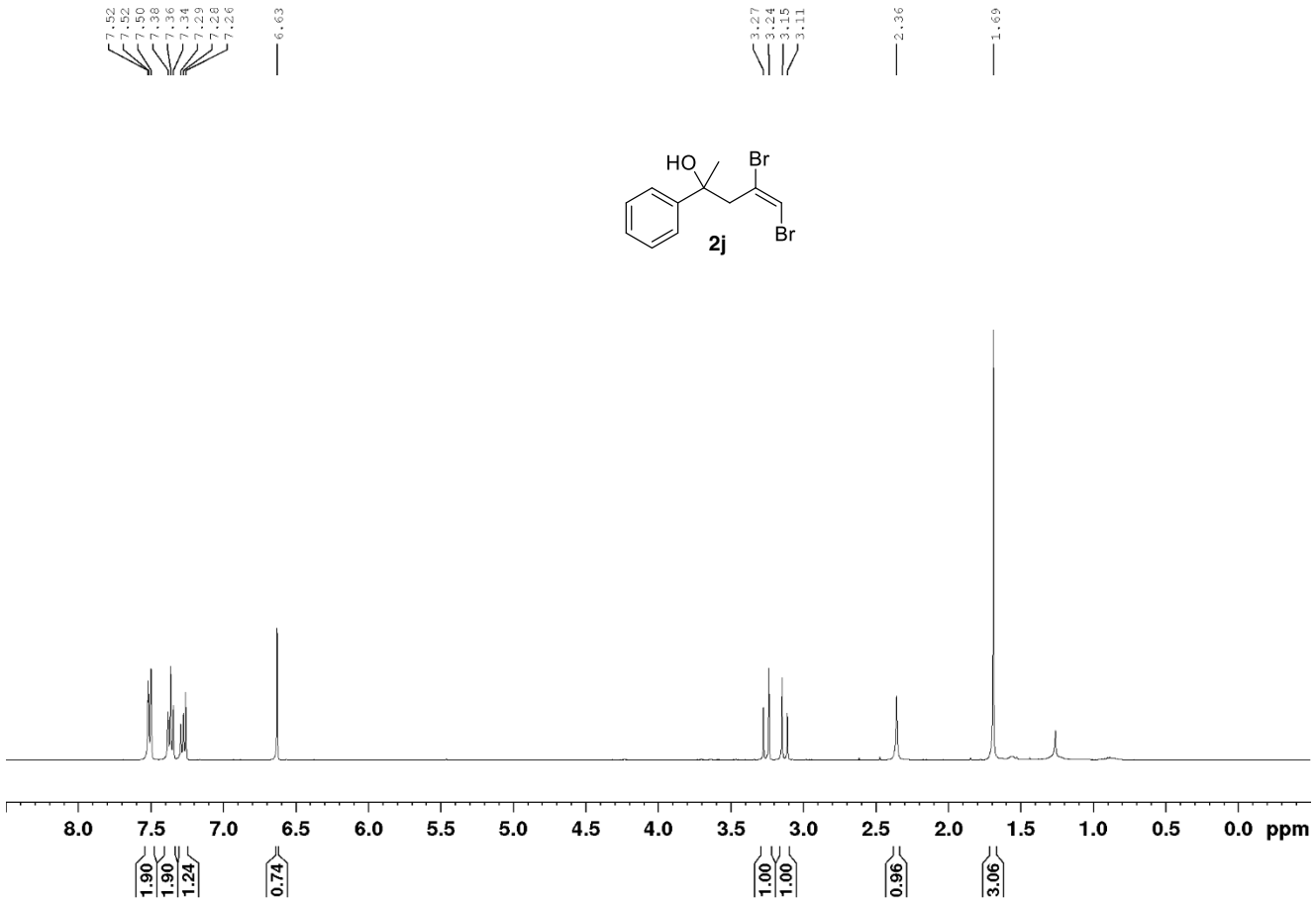
40
30
20
ppm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7.28
7.26
6.63
3.27
3.24
3.15
3.11
2.36
1.69
HO
Br
Br
2j
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
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0.0
ppm
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0.74
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1.00
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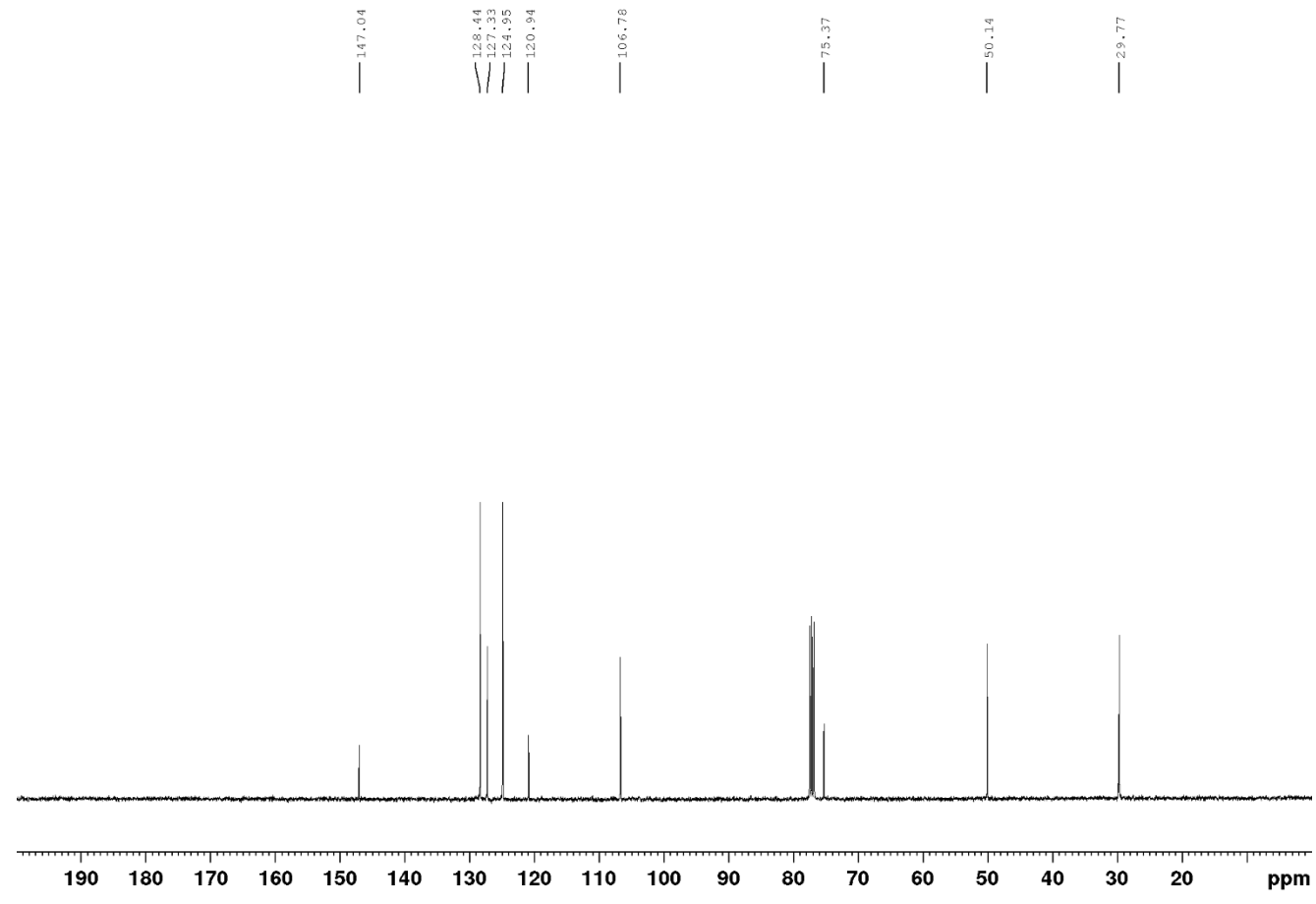
3.06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130
120
110
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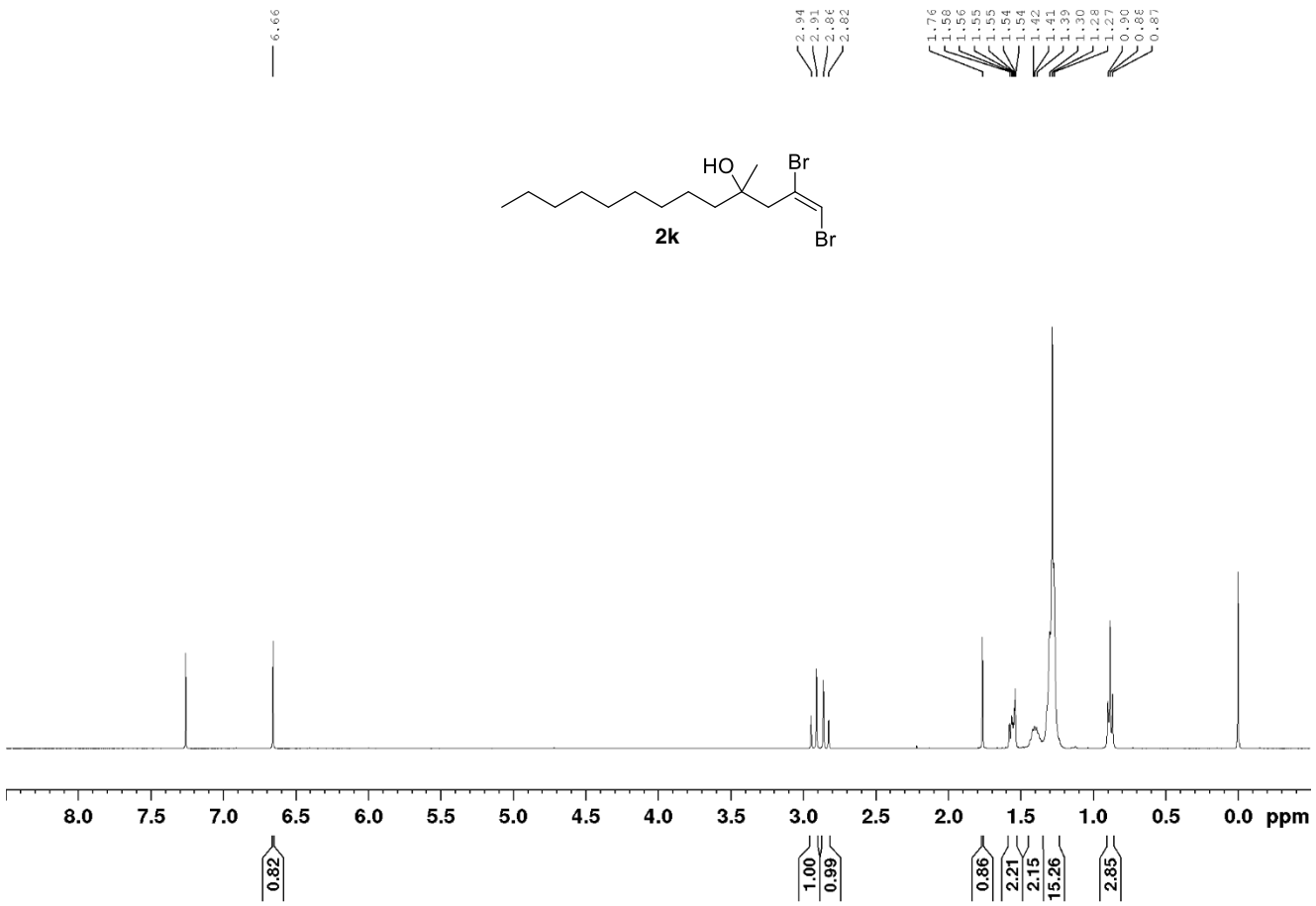
80
70
60
50
40
30
20
ppm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1.56
1.55
1.55
1.54
1.54
1.42
1.41
1.39
1.30
1.28
1.27
0.90
0.88
0.87
HO
Br
Br
2k
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
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0.0
ppm
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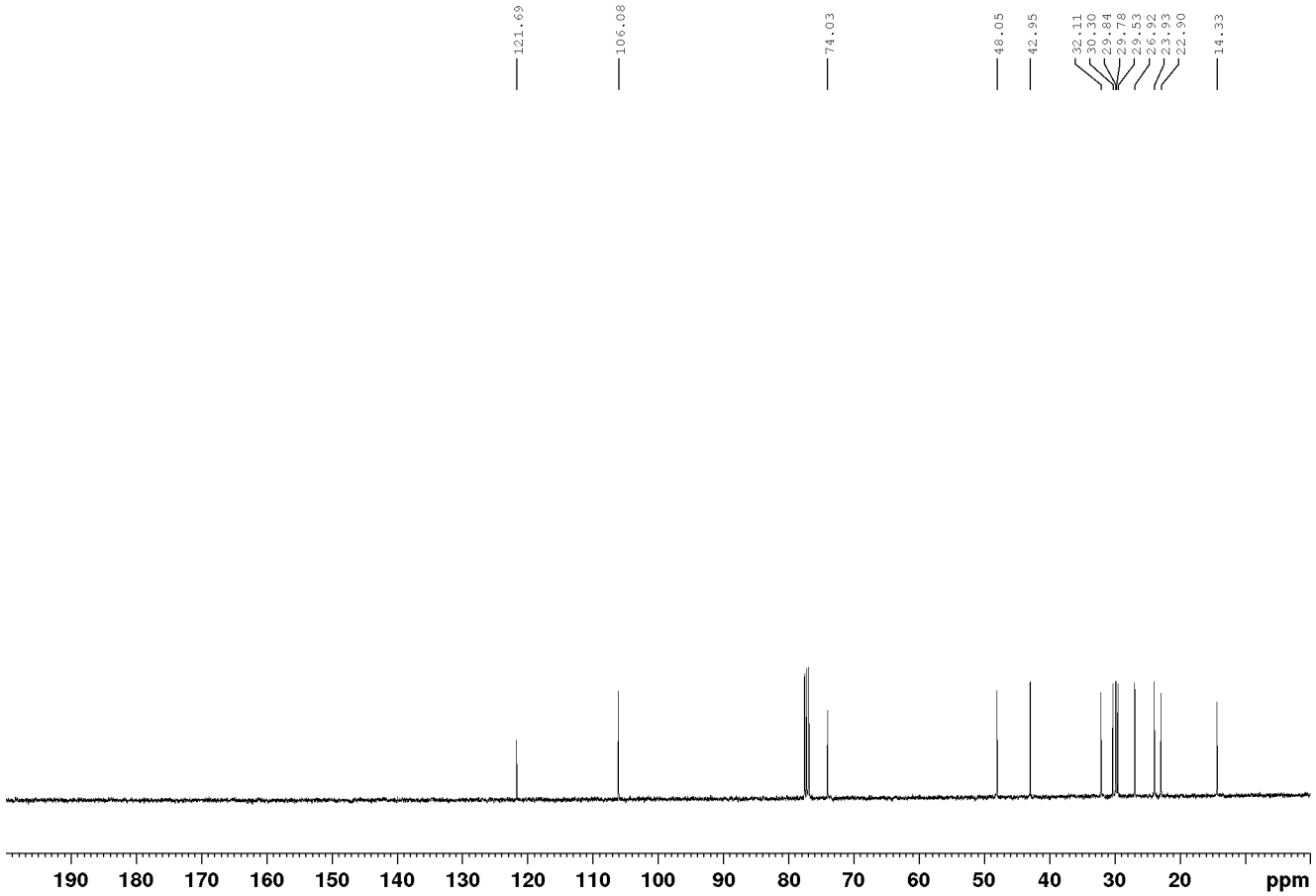
2.85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74.03
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29.78
29.53
26.92
23.93
22.90
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160
150
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80
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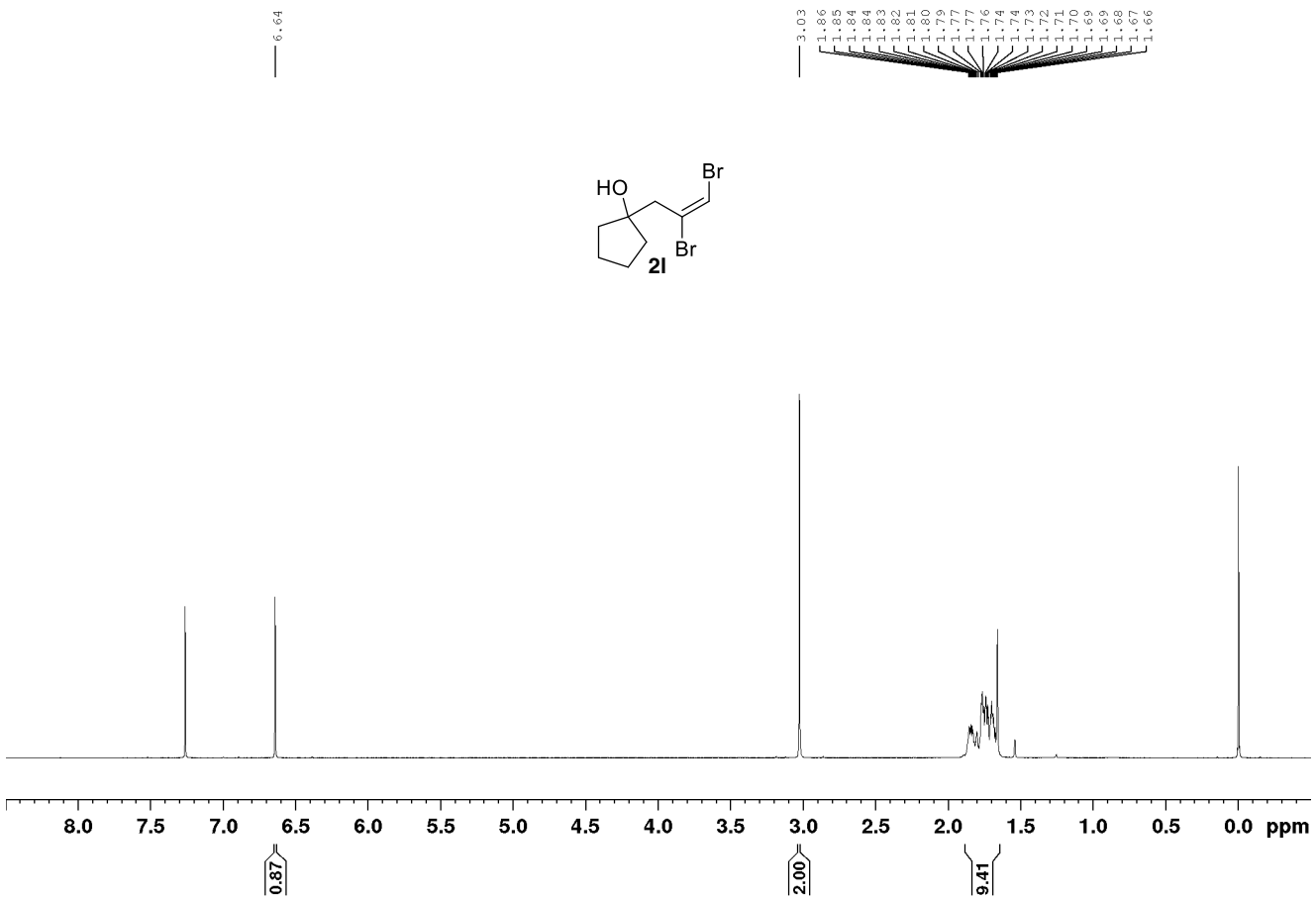
ppm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1.84
1.83
1.82
1.81
1.80
1.79
1.77
1.77
1.76
1.74
1.74
1.73
1.72
1.71
1.70
1.69
1.69
1.68
1.67
1.66
HO
Br
Br
2l
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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2.5
2.0
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1.0
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0.0
ppm
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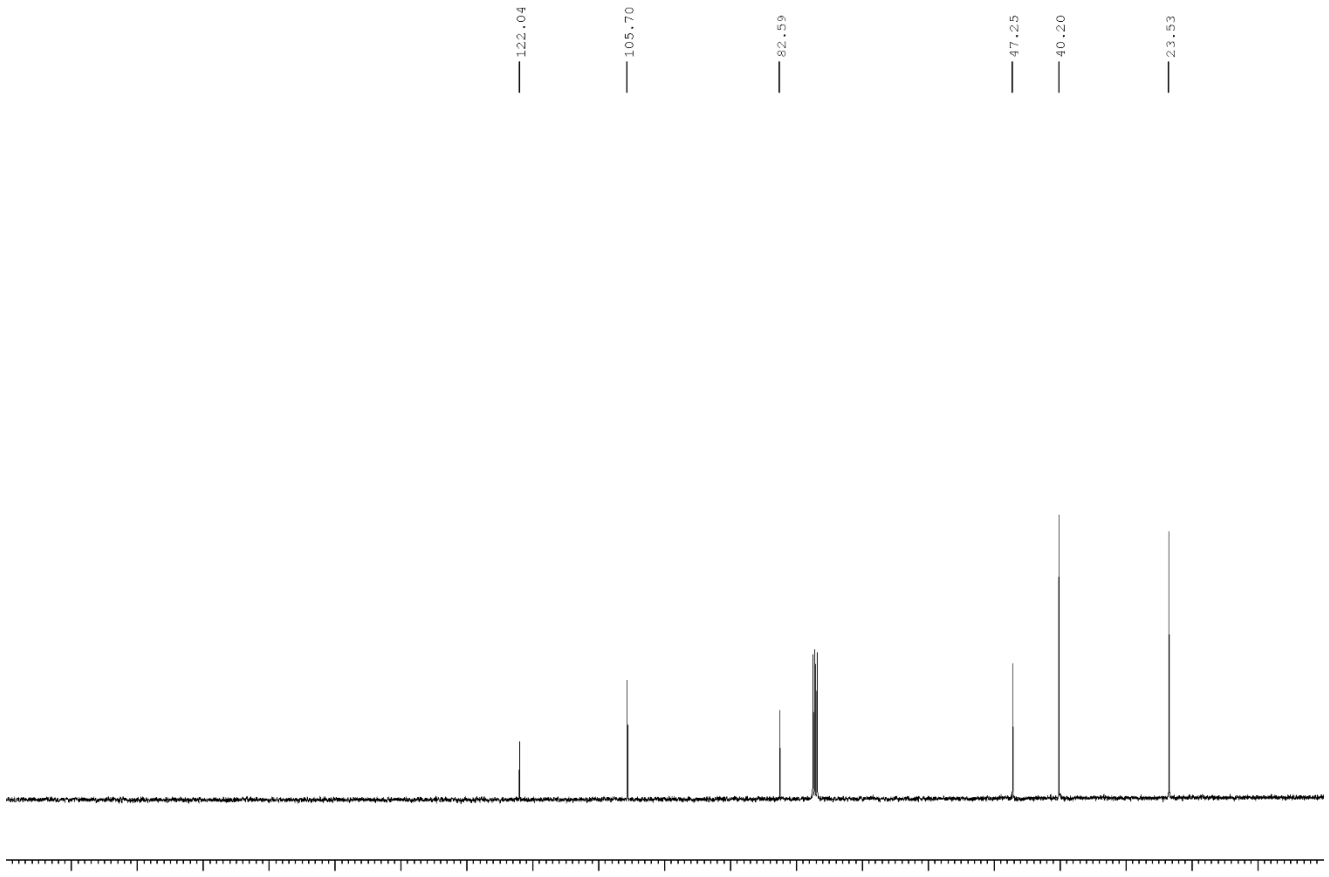
2.00
9.41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120
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100
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80
70
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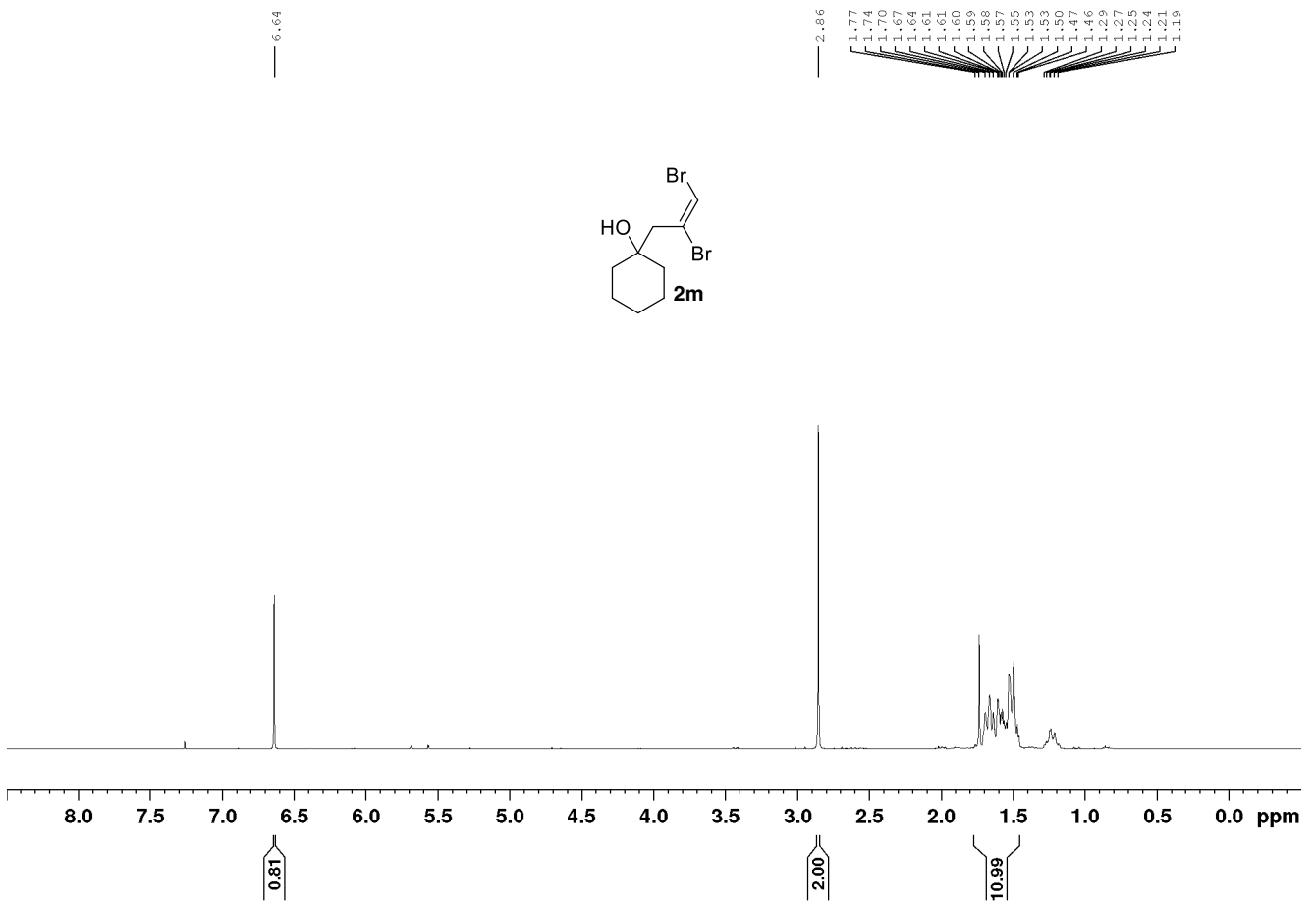
40
30
20
ppm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1.59
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1.57
1.55
1.53
1.53
1.50
1.47
1.46
1.29
1.27
1.25
1.24
1.21
1.19
Br
HO
Br
2m
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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2.0
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0.0
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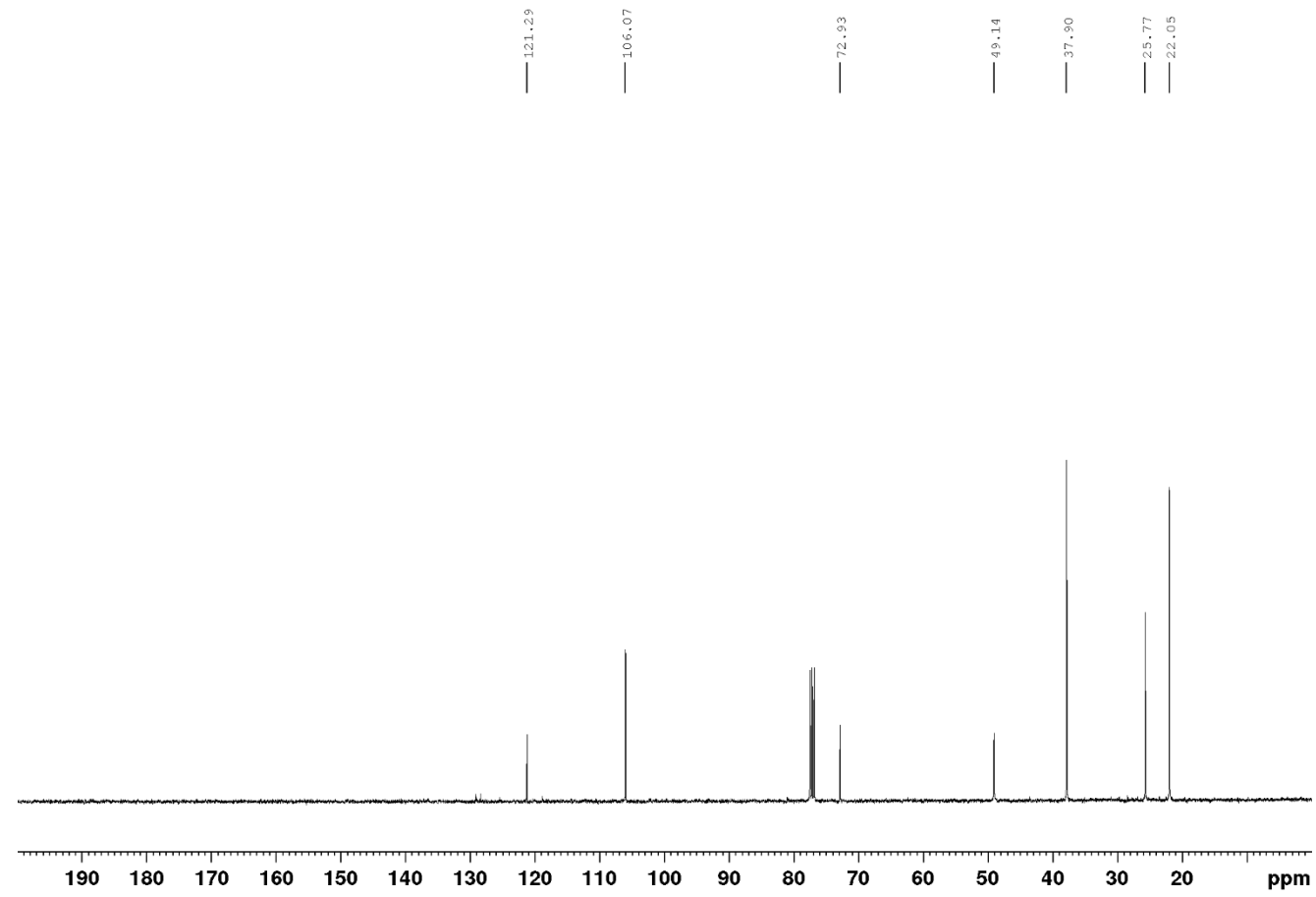
10.99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25.77
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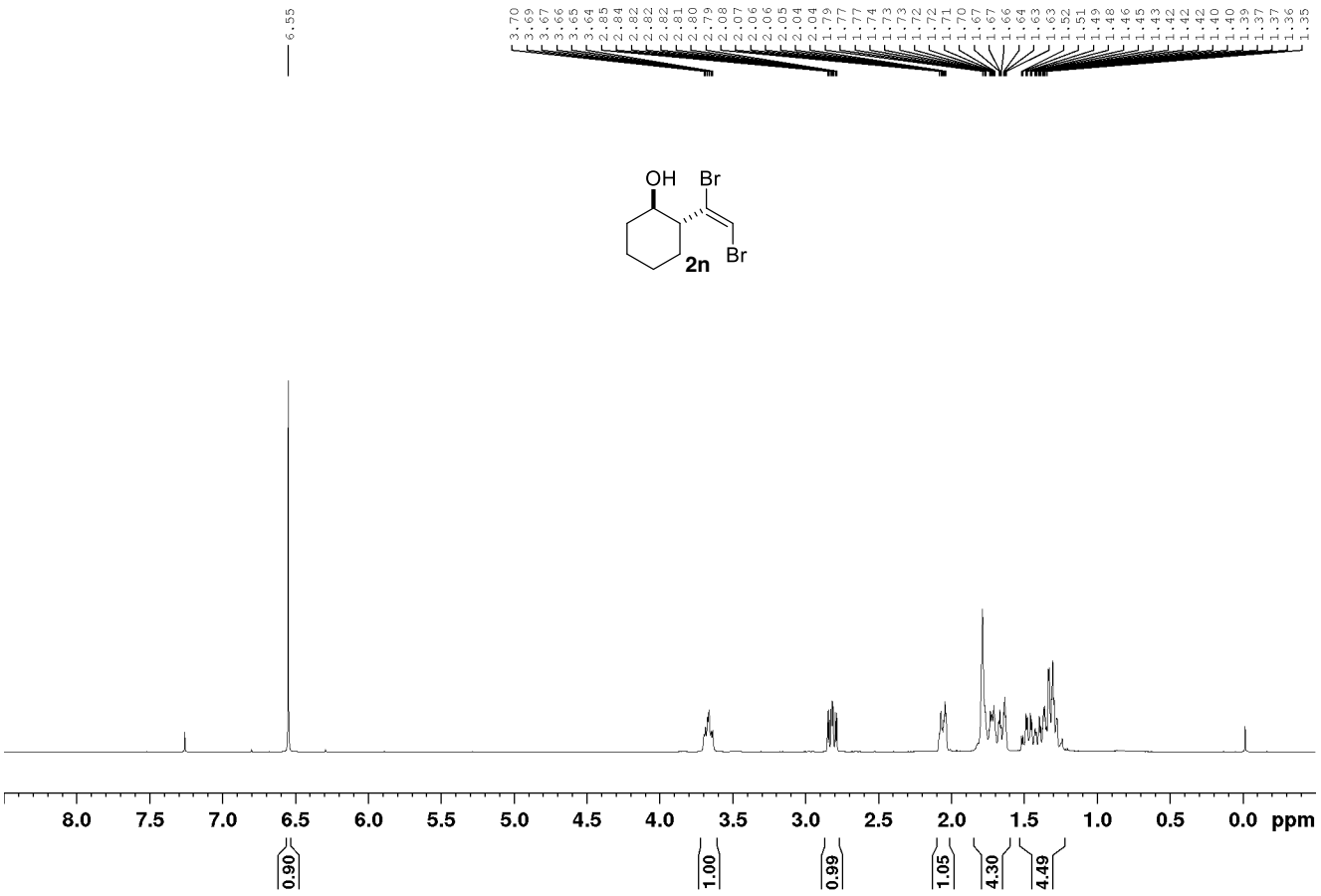
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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3.65
3.64
2.85
2.84
2.82
2.82
2.82
2.81
2.80
2.79
2.08
2.07
2.06
2.06
2.05
2.04
2.04
1.79
1.77
1.77
1.74
1.73
1.73
1.72
1.72
1.71
1.70
1.67
1.67
1.66
1.64
1.63
1.63
1.52
1.51
1.49
1.48
1.46
1.45
1.43
1.42
1.42
1.42
1.40
1.40
1.39
1.37
1.37
1.36
1.35
OH
Br
Br
2n
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
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1.0
0.5
0.0
ppm
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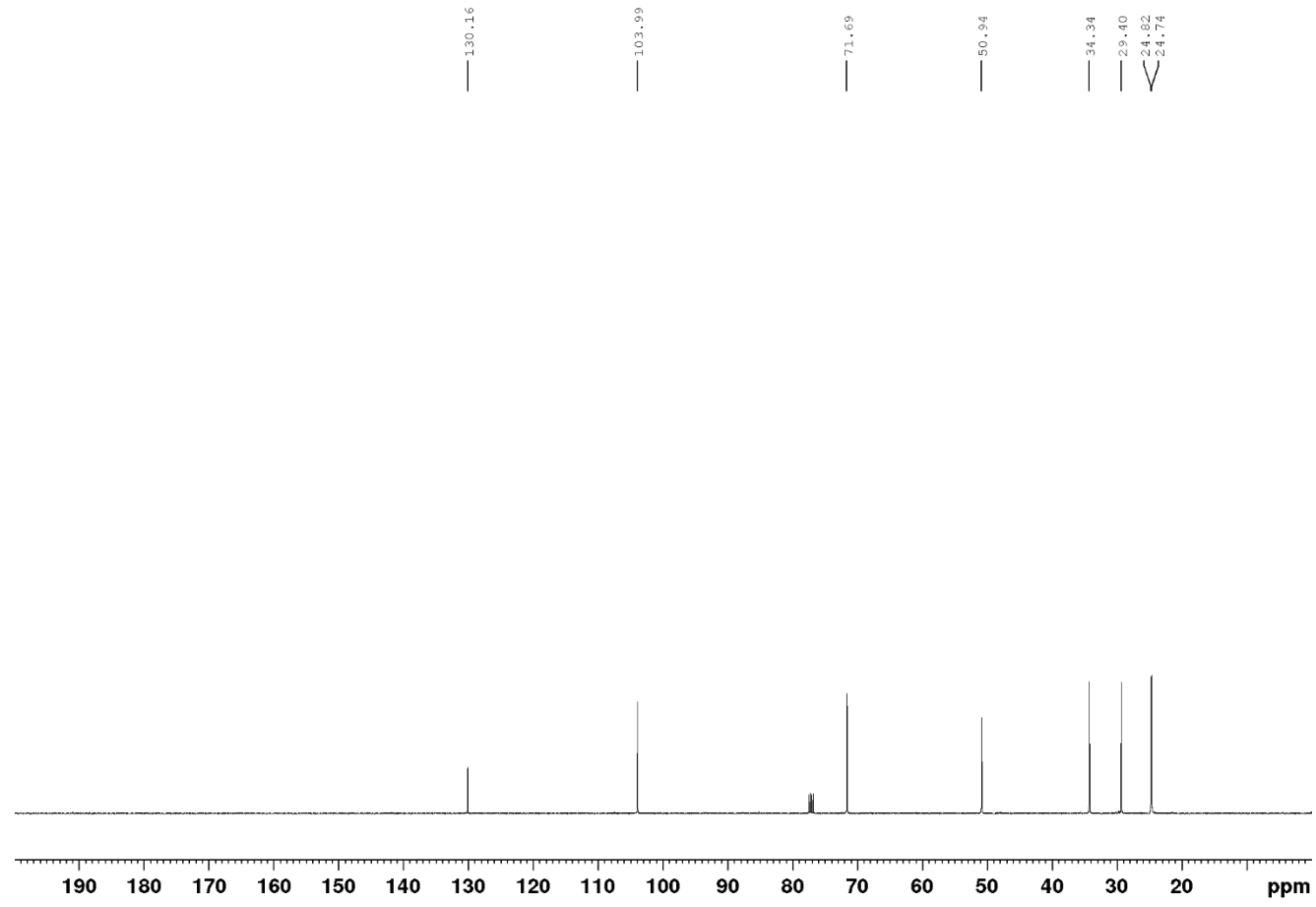
1.00
0.99
1.05
4.30
4.49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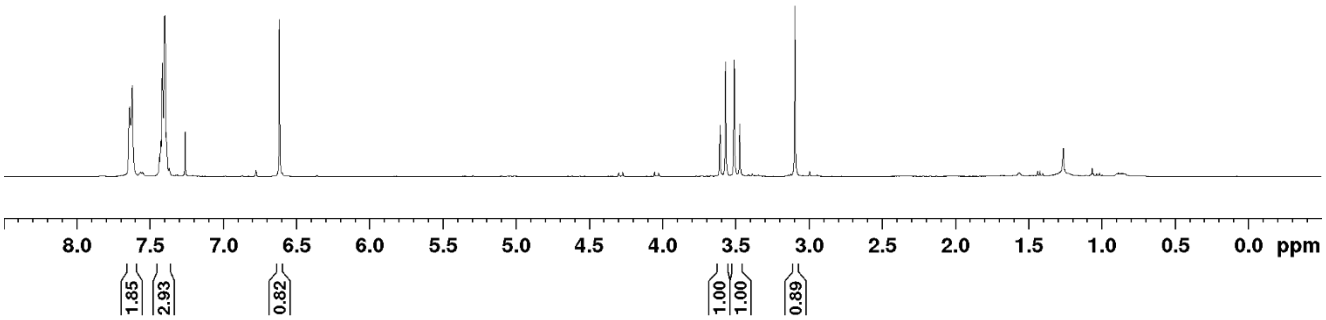
103.99
71.69
50.94
34.34
29.40
24.82
24.74
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


7.64
7.64
7.62
7.44
7.43
7.42
7.41
7.40
7.40
7.39
7.38
6.61
3.61
3.57
3.51
3.47
3.10

HO
CF3
Br
Br

2o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7.5
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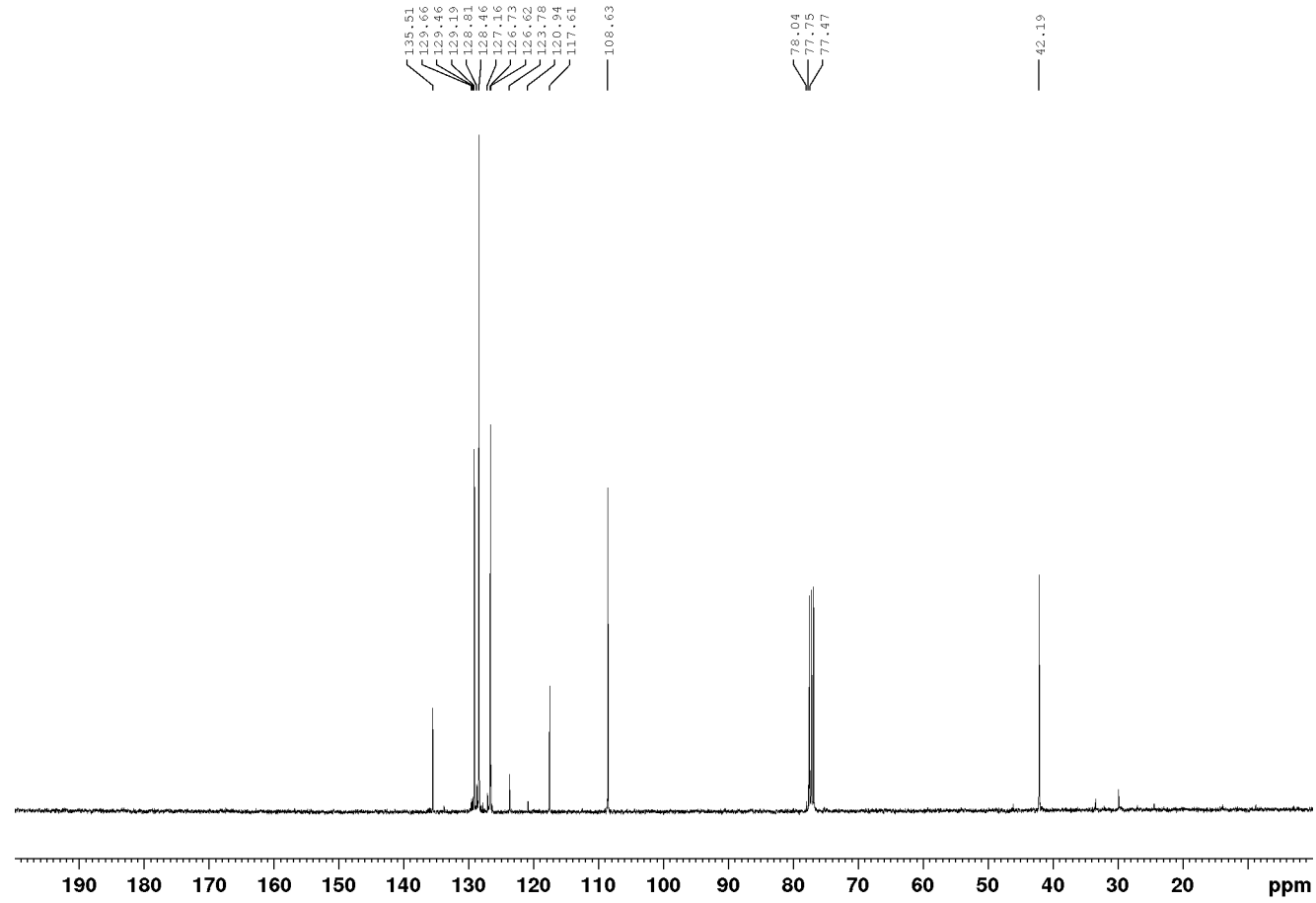
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.85
2.93
0.82
1.00
1.00
0.89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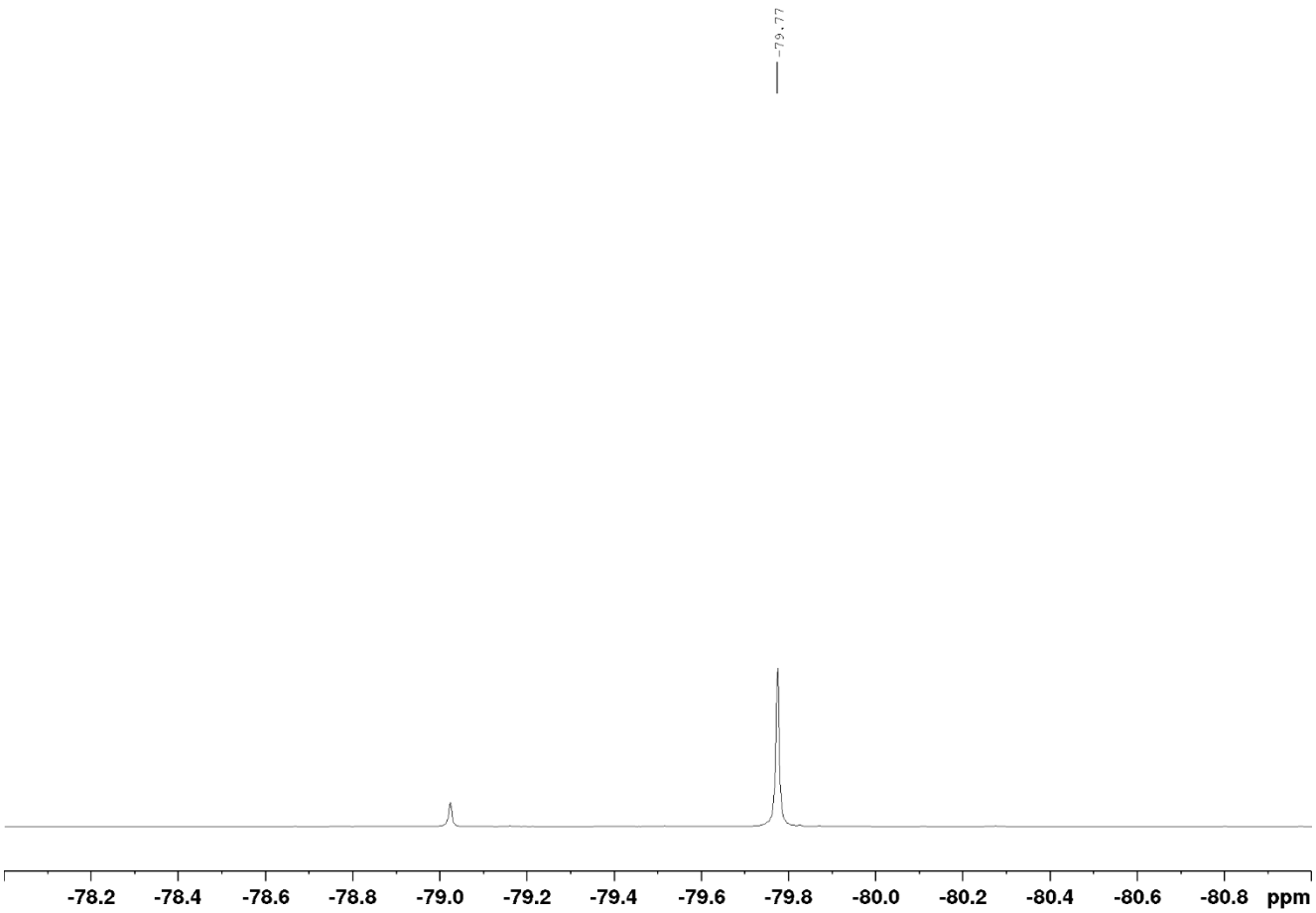
128.46
127.16
126.73
126.62
123.78
120.94
117.61
108.63
78.04
77.75
77.47
42.19
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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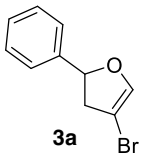
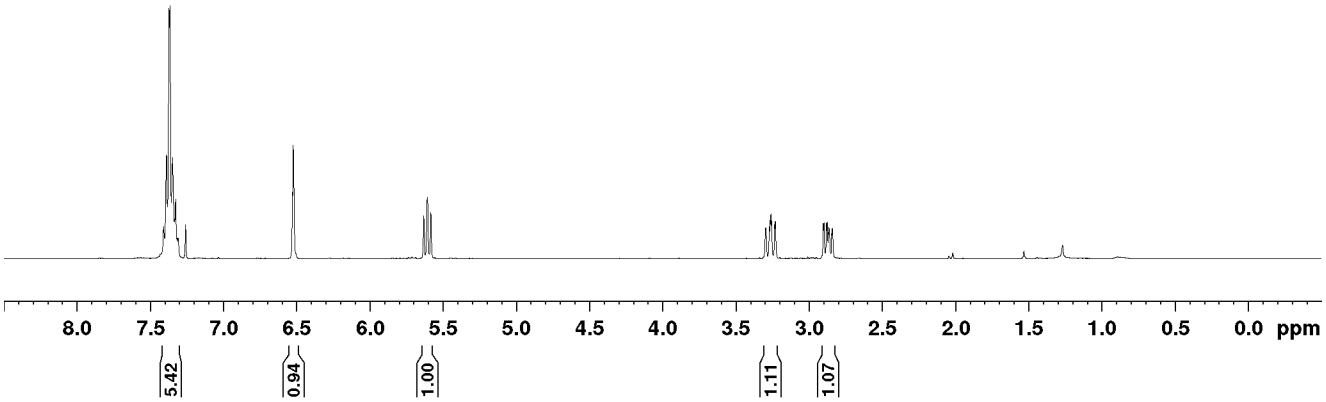
-78.2
-78.4
-78.6
-78.8
-79.0
-79.2
-79.4
-79.6
-79.8
-80.0
-80.2
-80.4
-80.6
-80.8
ppm


7.41
7.39
7.37
7.37
7.35
7.33
7.33
7.32
7.31
6.53
6.52
5.63
5.61
5.58
3.30
3.29
3.27
3.27
3.26
3.26
3.23
3.23
2.90
2.90
2.88
2.88
2.87
2.86
2.84
2.84


O
Br

3a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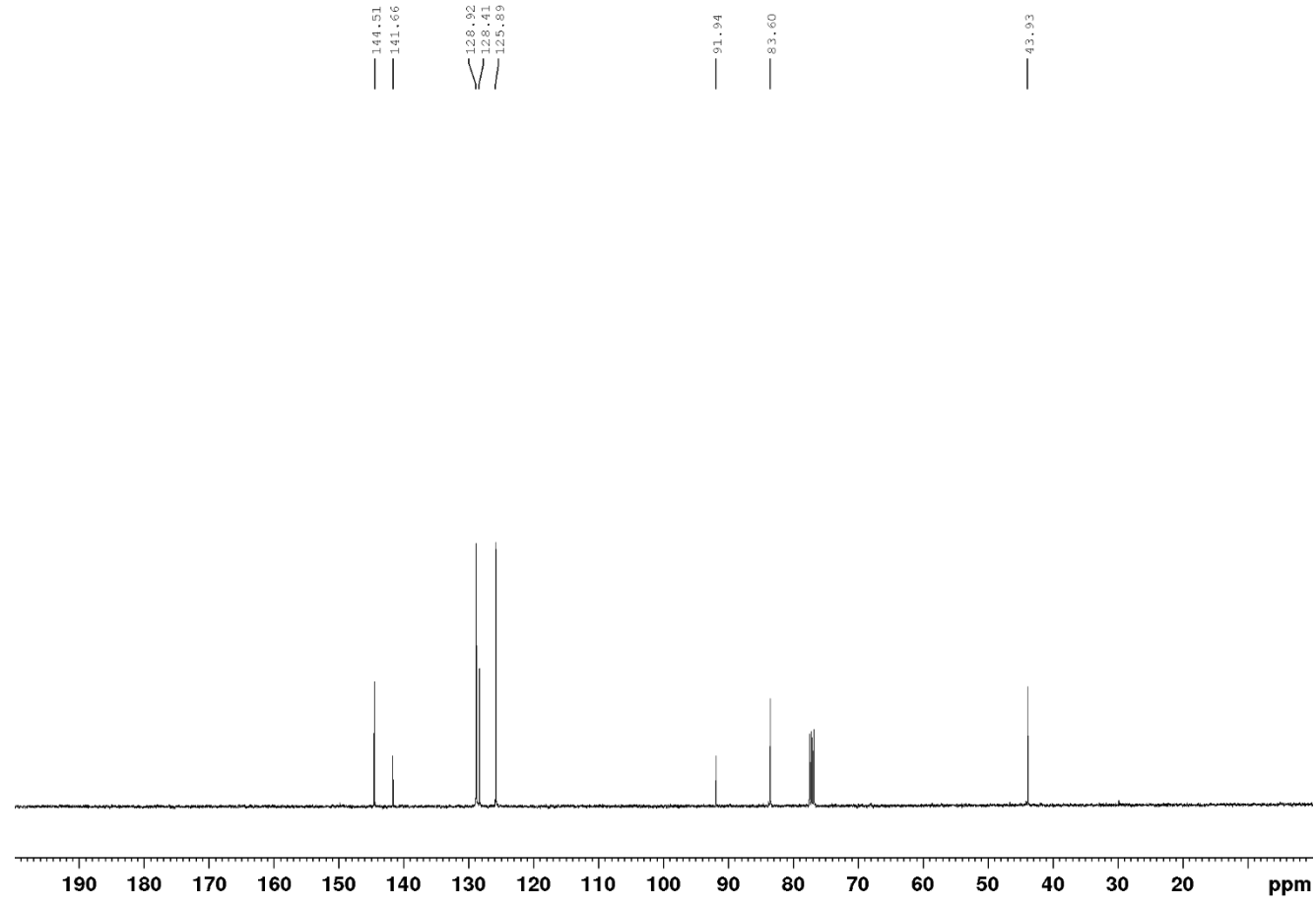
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
5.42
0.94
1.00
1.11
1.07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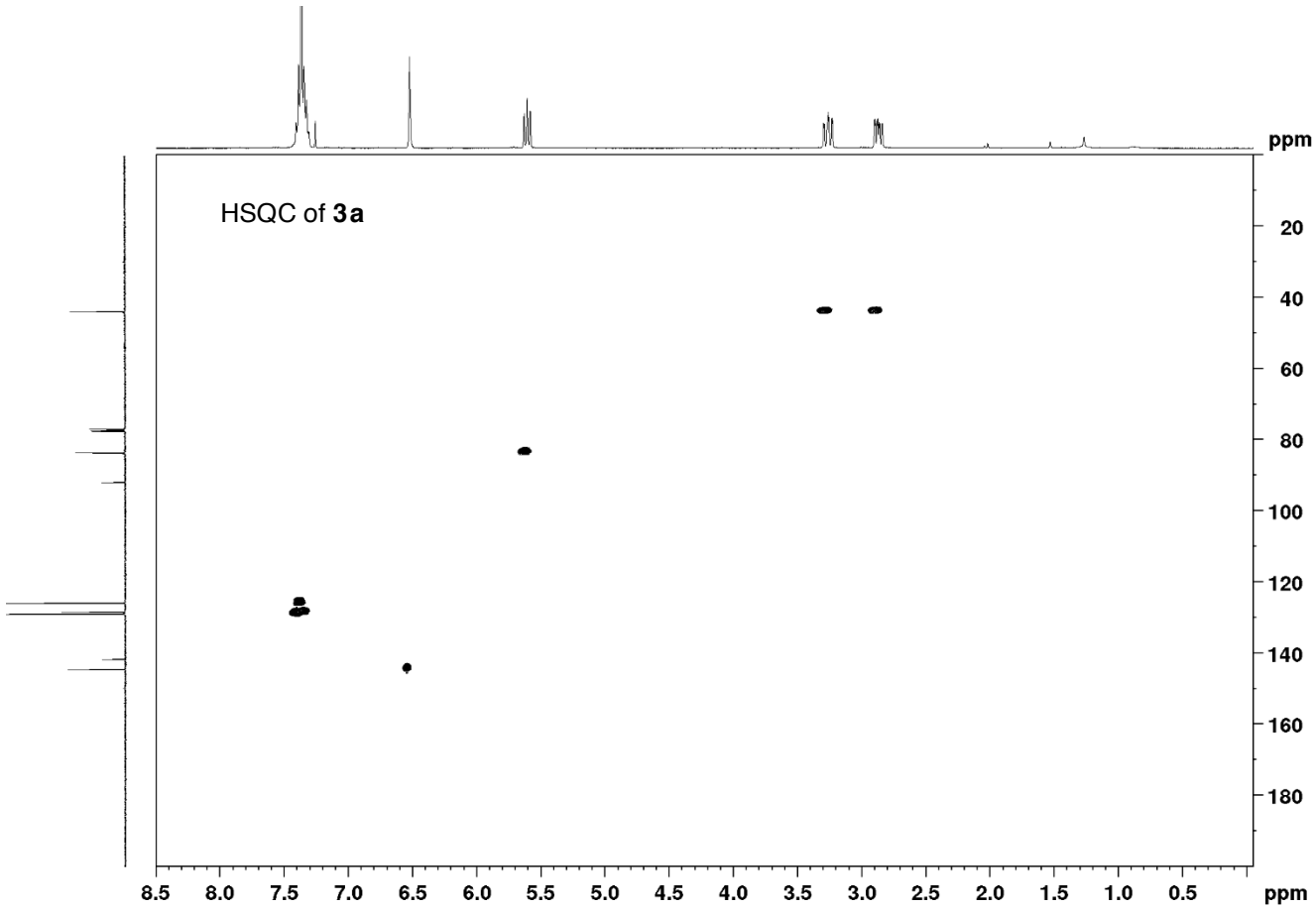
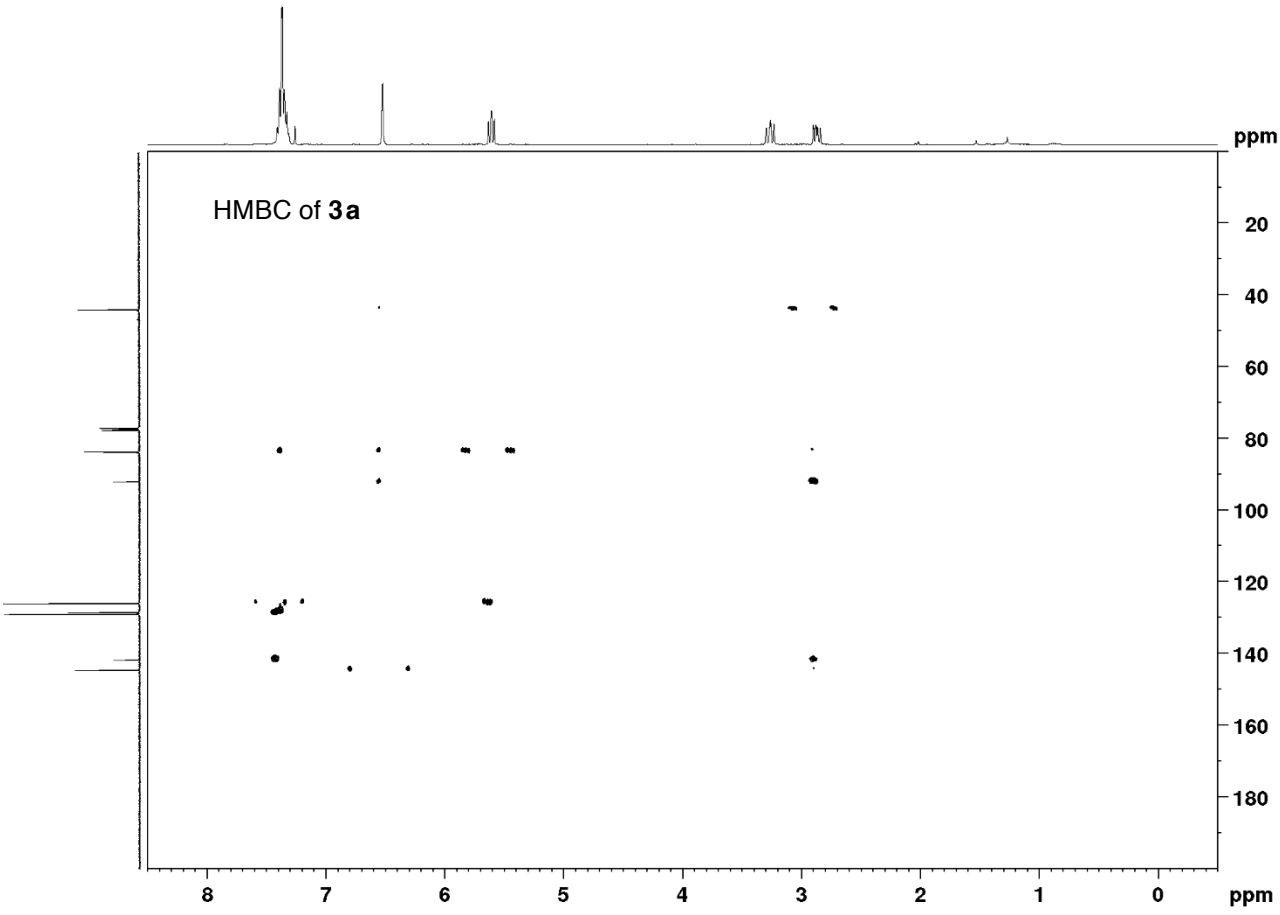
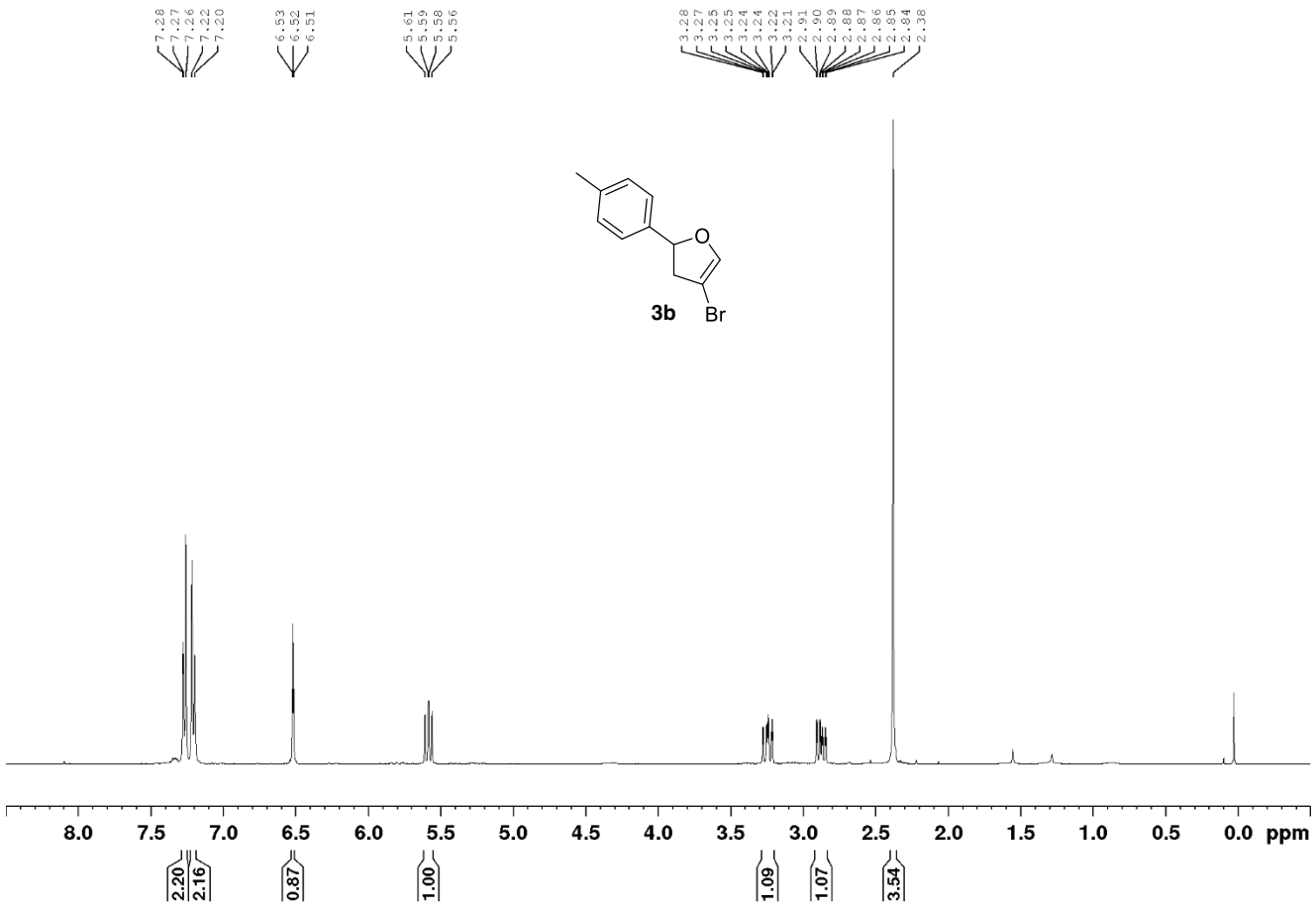
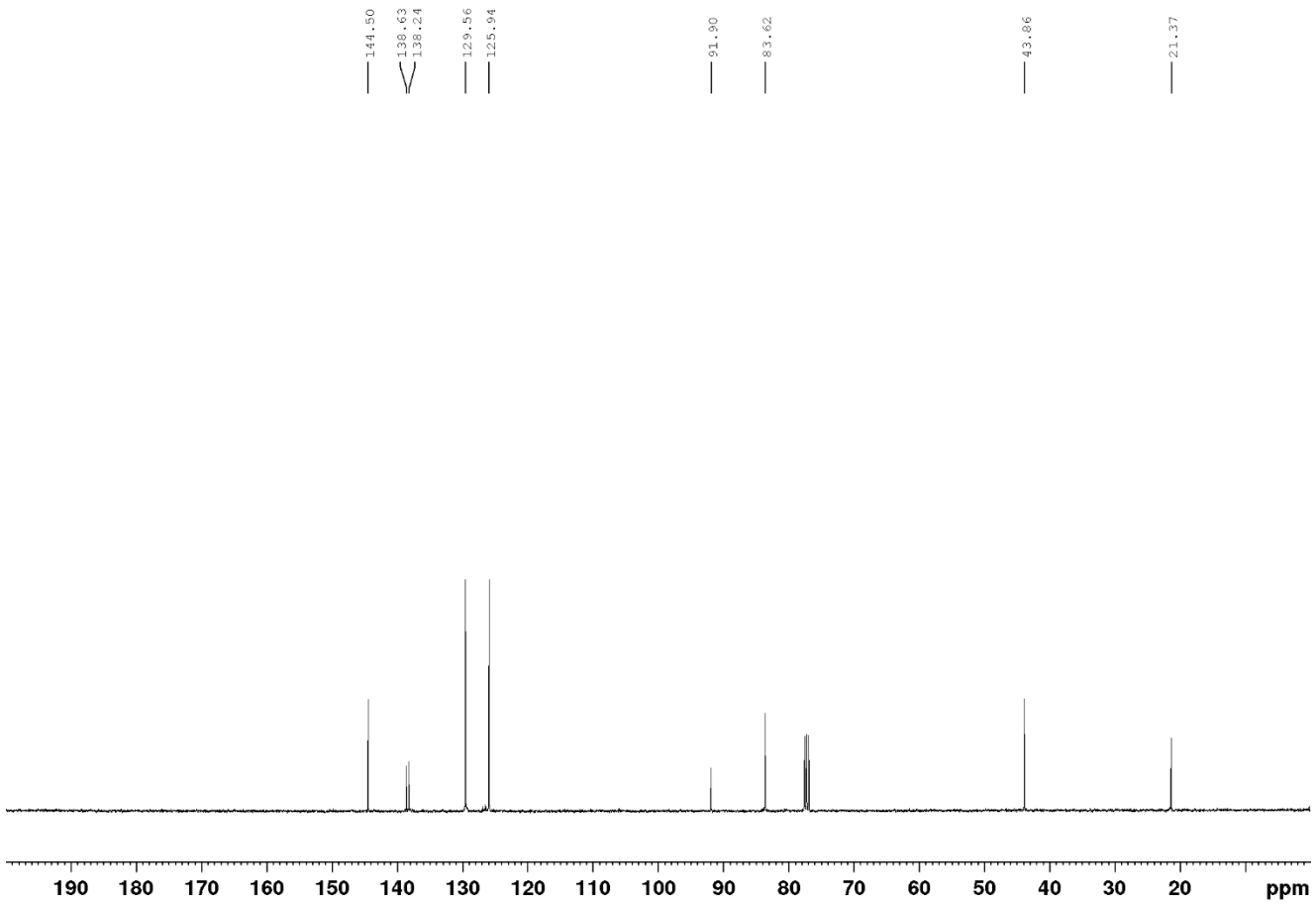
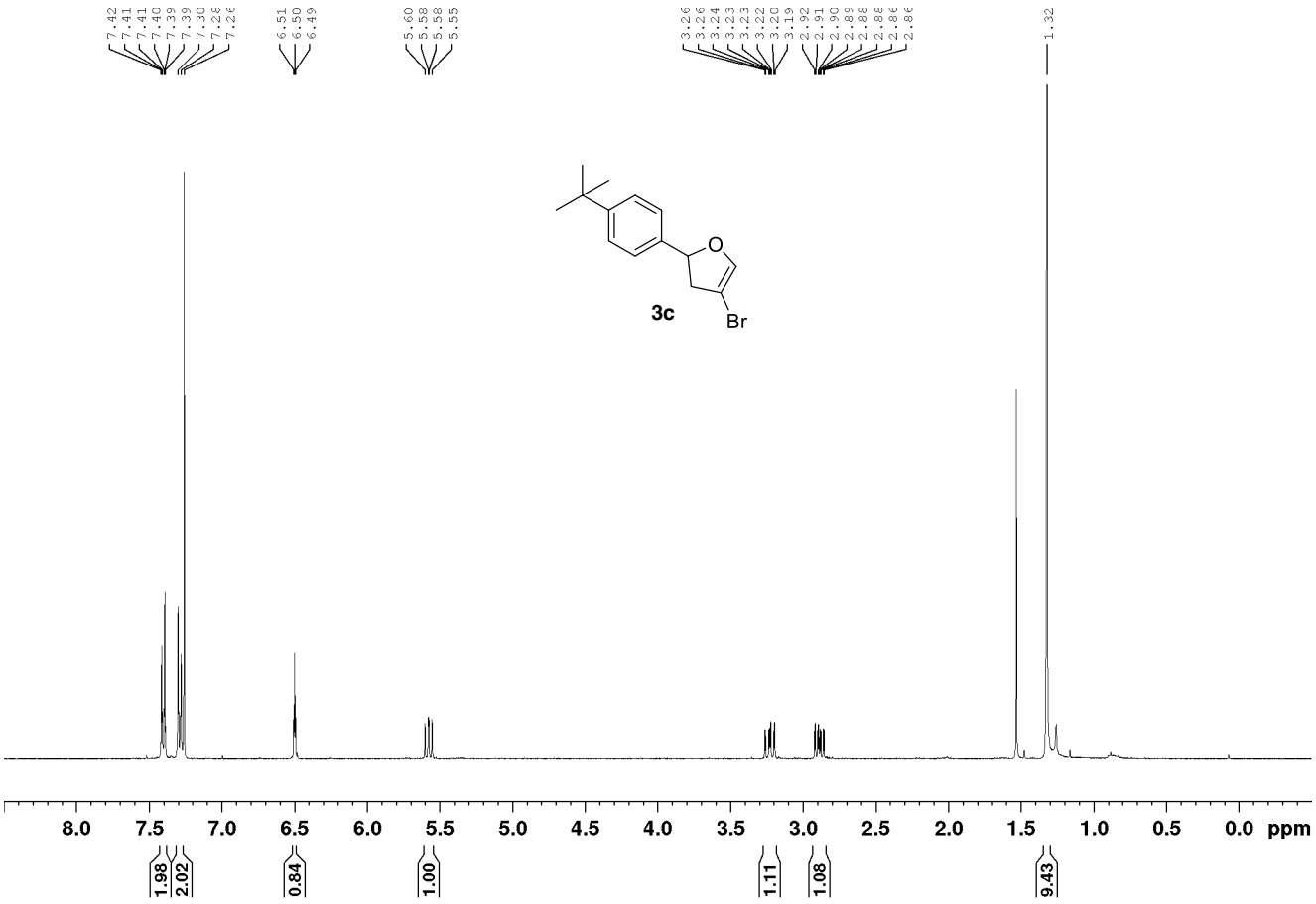
141.66
128.92
128.41
125.89
91.94
83.60
43.93
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


HSQC of **3a**
ppm
20
40
60
80
100
120
140
160
180
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
ppm


HMBC of **3a**
ppm
20
40
60
80
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm


7.28
7.27
7.26
7.22
7.20
6.53
6.52
6.51
5.61
5.59
5.58
5.56
3.28
3.27
3.25
3.25
3.24
3.24
3.22
3.21
2.91
2.90
2.89
2.88
2.87
2.86
2.85
2.84
2.38
O
Br
3b
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
ppm
2.20
2.16
0.87
1.00
1.09
1.07
3.54


144.50
138.63
138.24
129.56
125.94
91.90
83.62
43.86
21.37
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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7.41
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7.39
7.39
7.30
6.51
6.50
6.49
5.60
5.58
5.58
5.55
3.26
3.26
3.24
3.23
3.23
3.22
3.20
3.19
2.92
2.91
2.90
1.32
O
Br
3c
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
ppm
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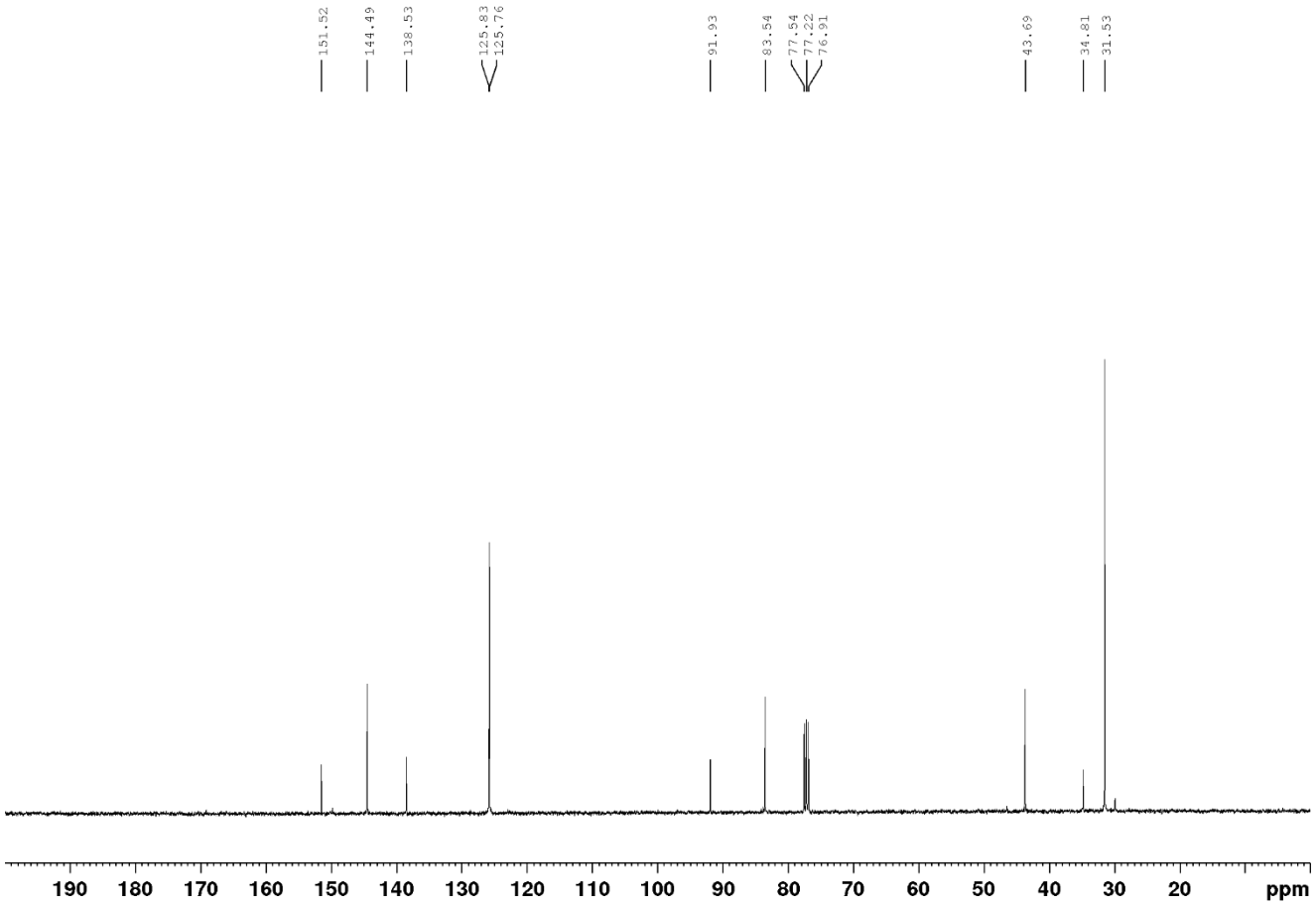
0.84
1.00
1.11
1.08
9.43


151.52
144.49
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125.83
125.76
91.93
83.54
77.54
77.22
76.91
43.69
34.81
31.53
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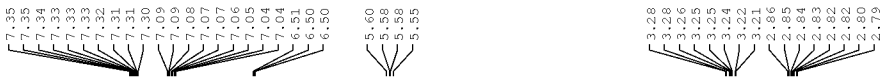
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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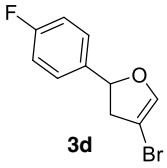
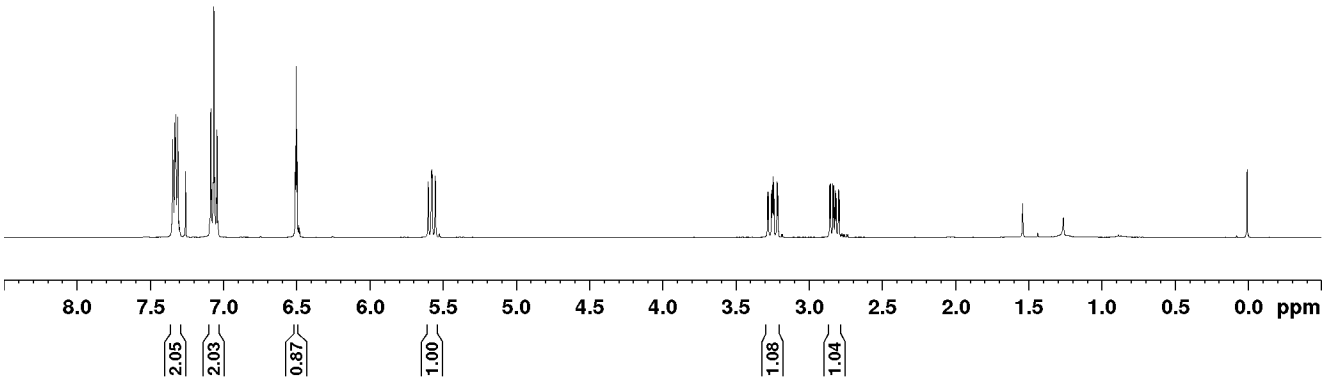
7.35
7.34
7.33
7.33
7.33
7.32
7.31
7.31
7.30
7.09
7.09
7.08
7.07
7.07
7.06
7.05
7.04
7.04
6.51
6.50
6.50
5.60
5.58
5.58
5.55
3.28
3.28
3.26
3.25
3.25
3.24
3.22
3.21
2.86
2.85
2.84
2.83
2.82
2.82
2.80
2.79


F
O
Br

3d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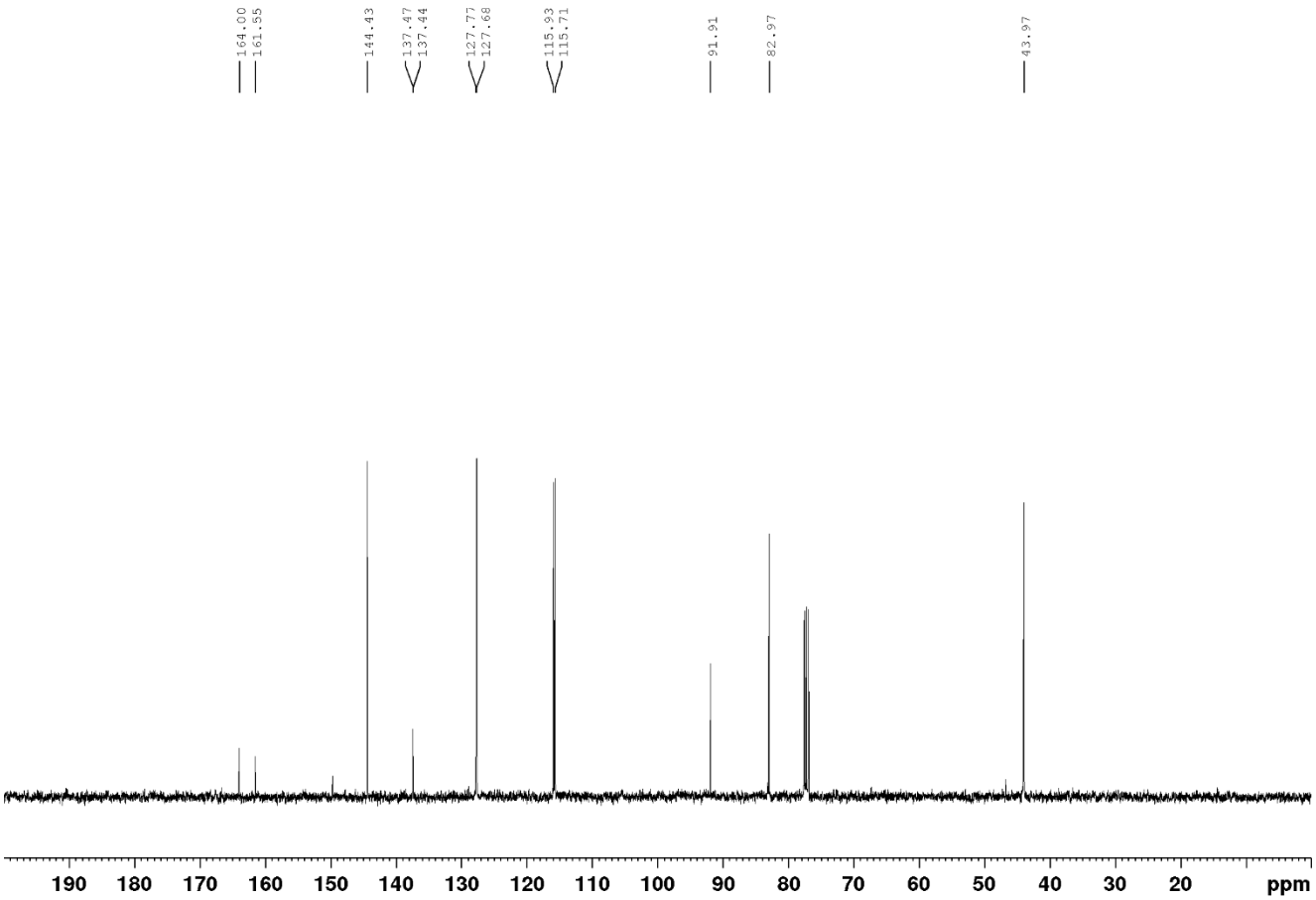
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.05
2.03
0.87
1.00
1.08
1.04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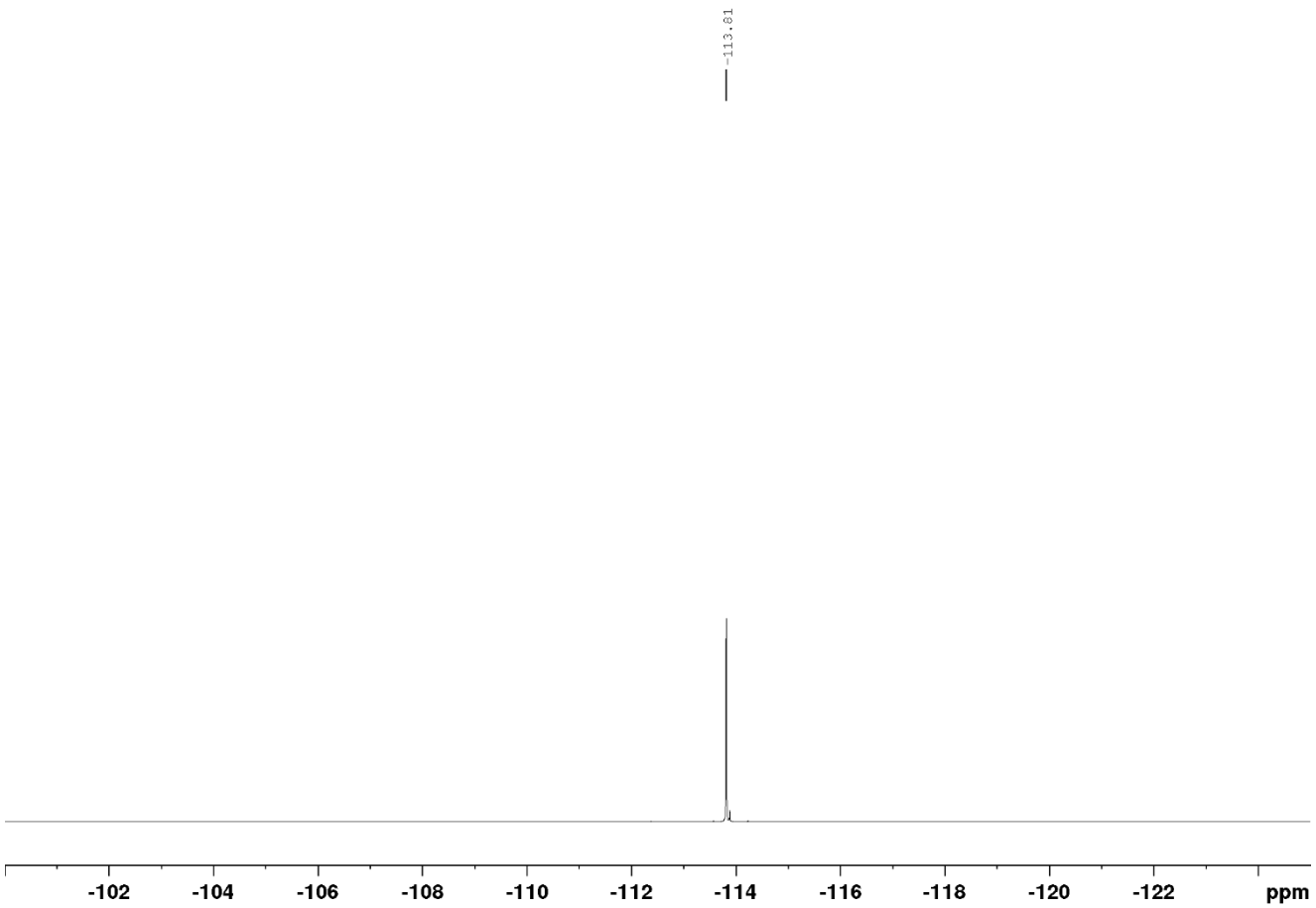
161.55
144.43
137.47
137.44
127.77
127.68
115.93
115.71
91.91
82.97
43.97
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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-102
-104
-106
-108
-110
-112
-114
-116
-118
-120
-122
ppm


7.65
7.63
7.47
7.45
6.54
6.54
6.53
5.68
5.66
5.66
5.63
3.35
3.35
3.32
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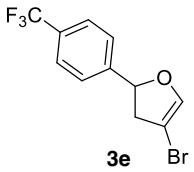
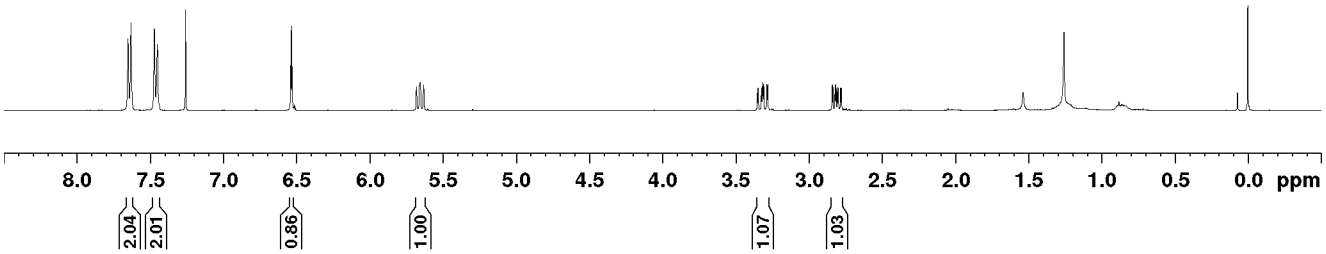
2.82
2.82
2.81
2.80
2.78
2.78


F3C
O
Br

3e


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
ppm
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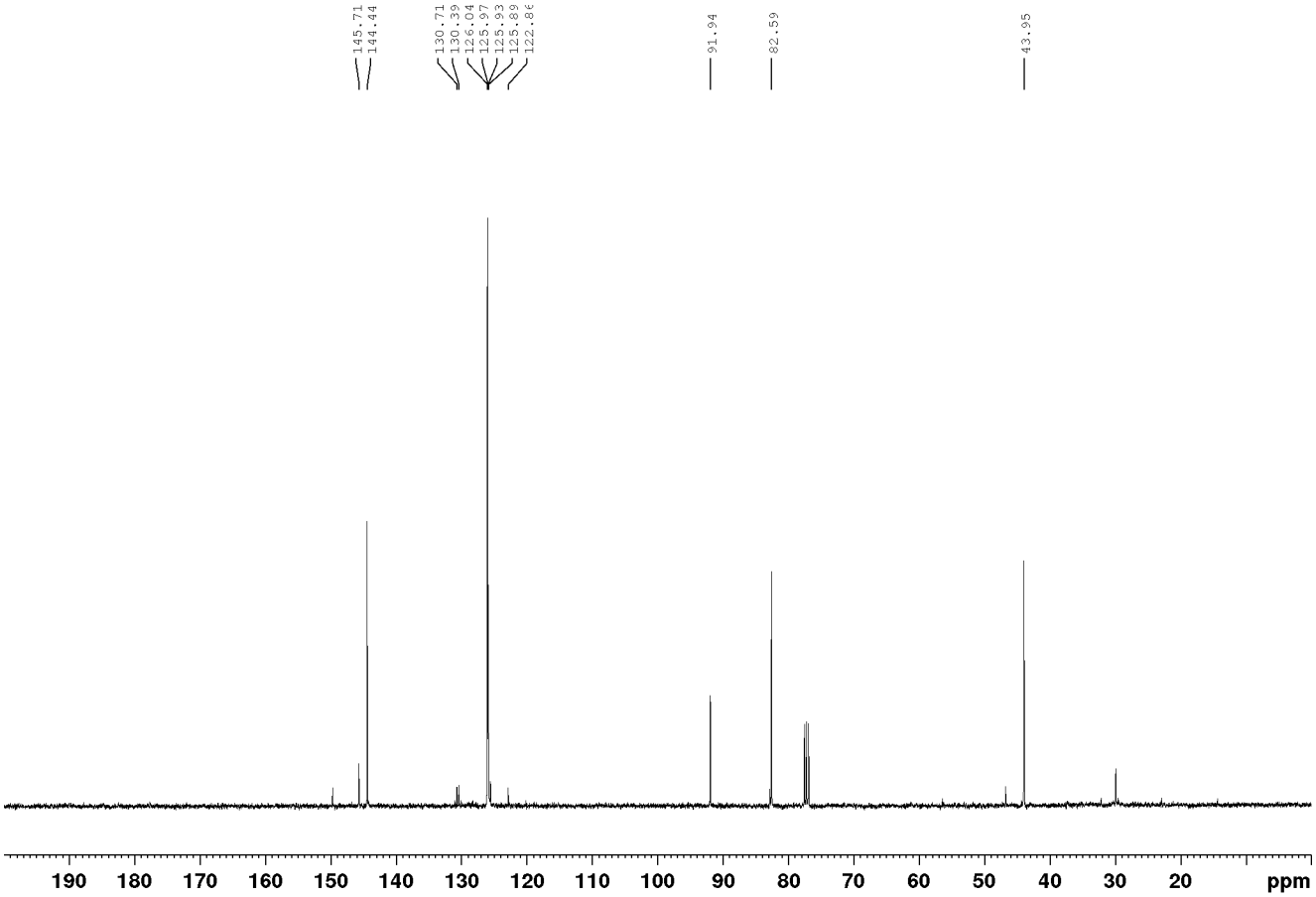
2.01
0.86
1.00
1.07
1.03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144.44
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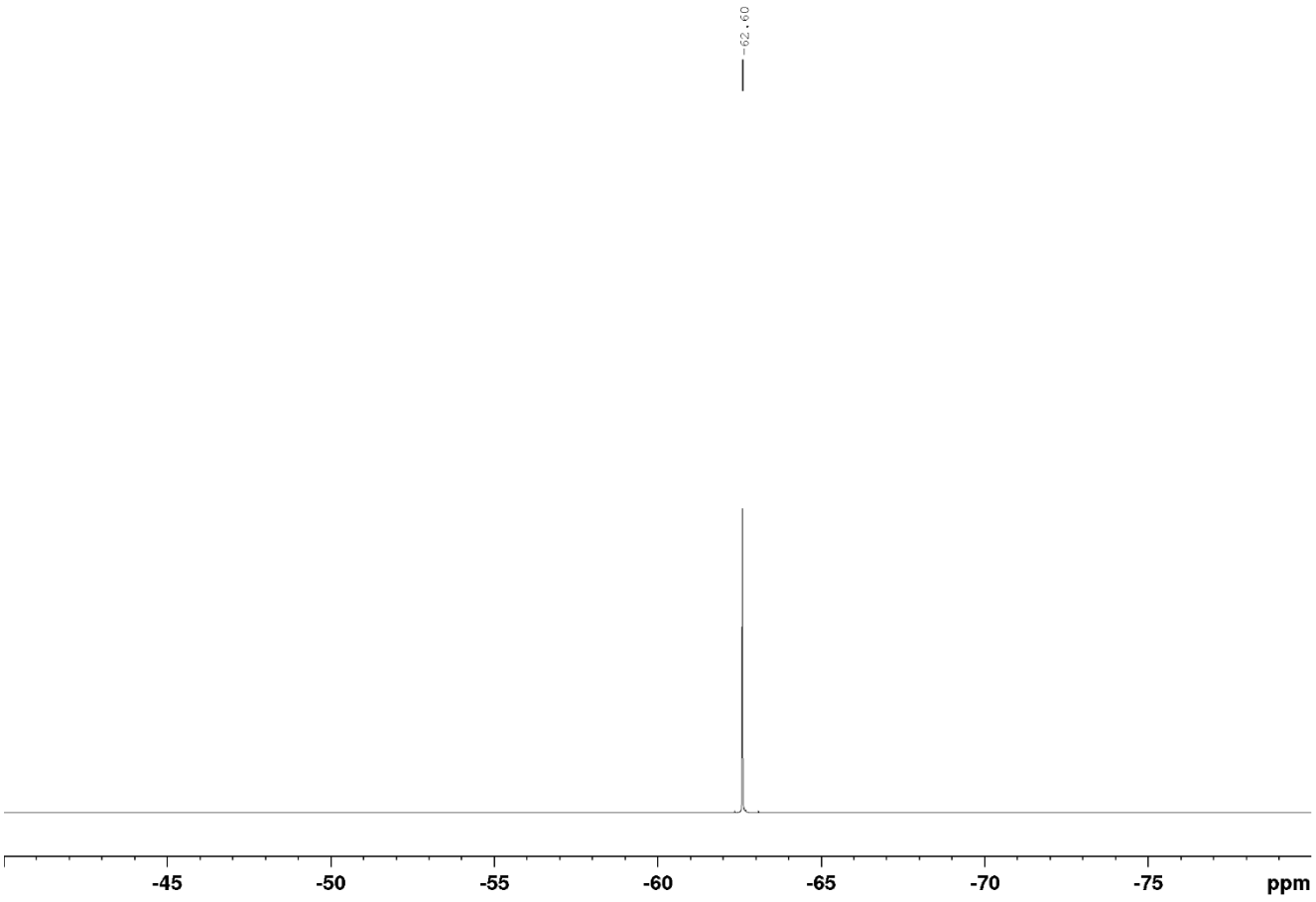
130.39
126.04
125.97
125.93
125.89
122.8
91.94
82.59
43.95
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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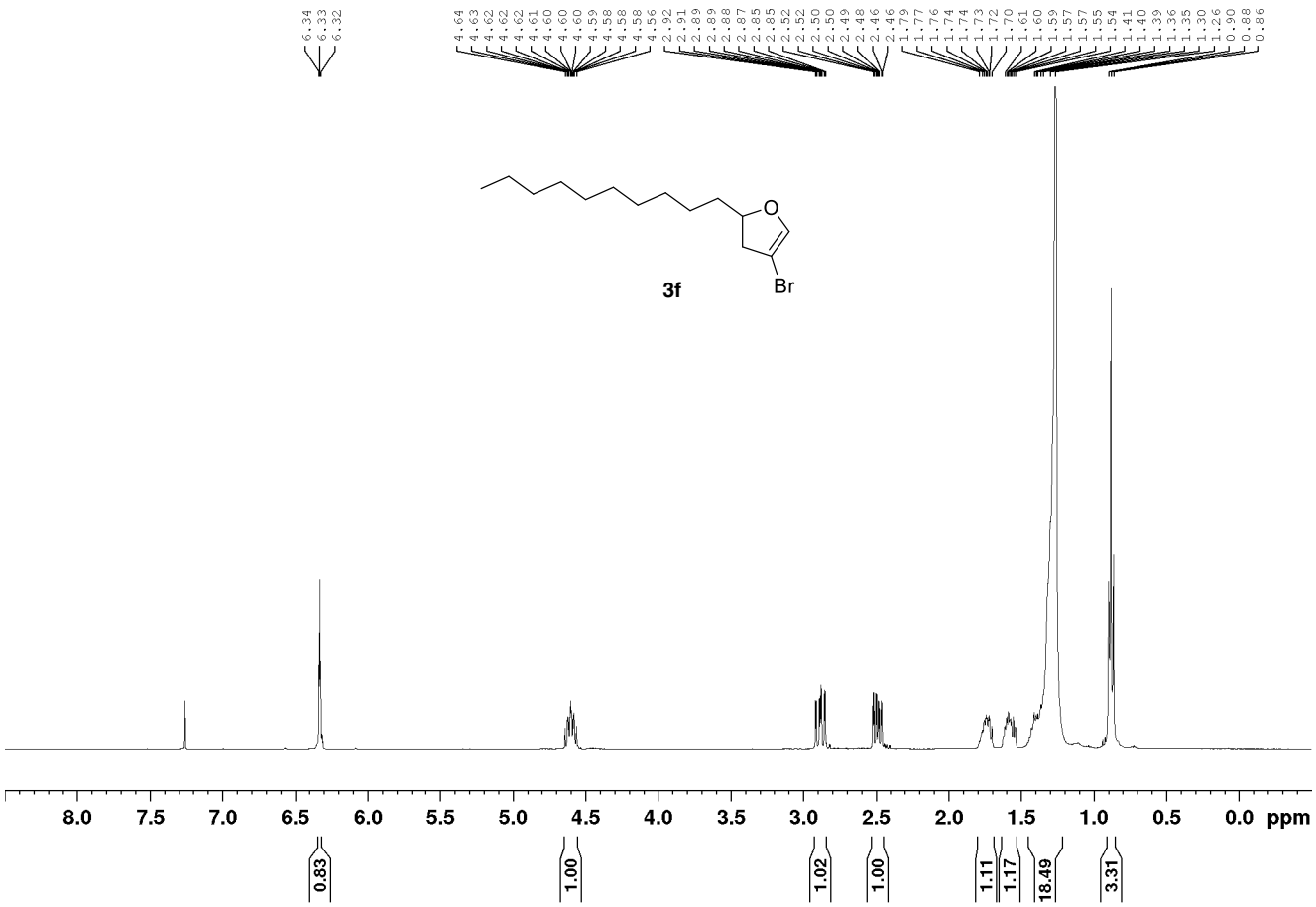
-45
-50
-55
-60
-65
-70
-75
ppm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6.33
6.32
4.64
4.63
4.62
4.62
4.62
4.61
4.60
4.60
4.60
4.59
4.58
4.58
4.58
4.56
2.92
2.91
2.89
2.89
2.88
2.87
2.85
2.85
2.52
2.52
2.50
2.50
2.49
2.48
2.46
2.46
1.79
1.77
1.76
1.74
1.74
1.73
1.72
1.70
1.61
1.60
1.59
1.57
1.57
1.55
1.54
1.41
1.40
1.39
1.36
1.35
1.30
1.26
0.90
0.88
0.86
O
Br
3f
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
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0.0
ppm
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1.00
1.11
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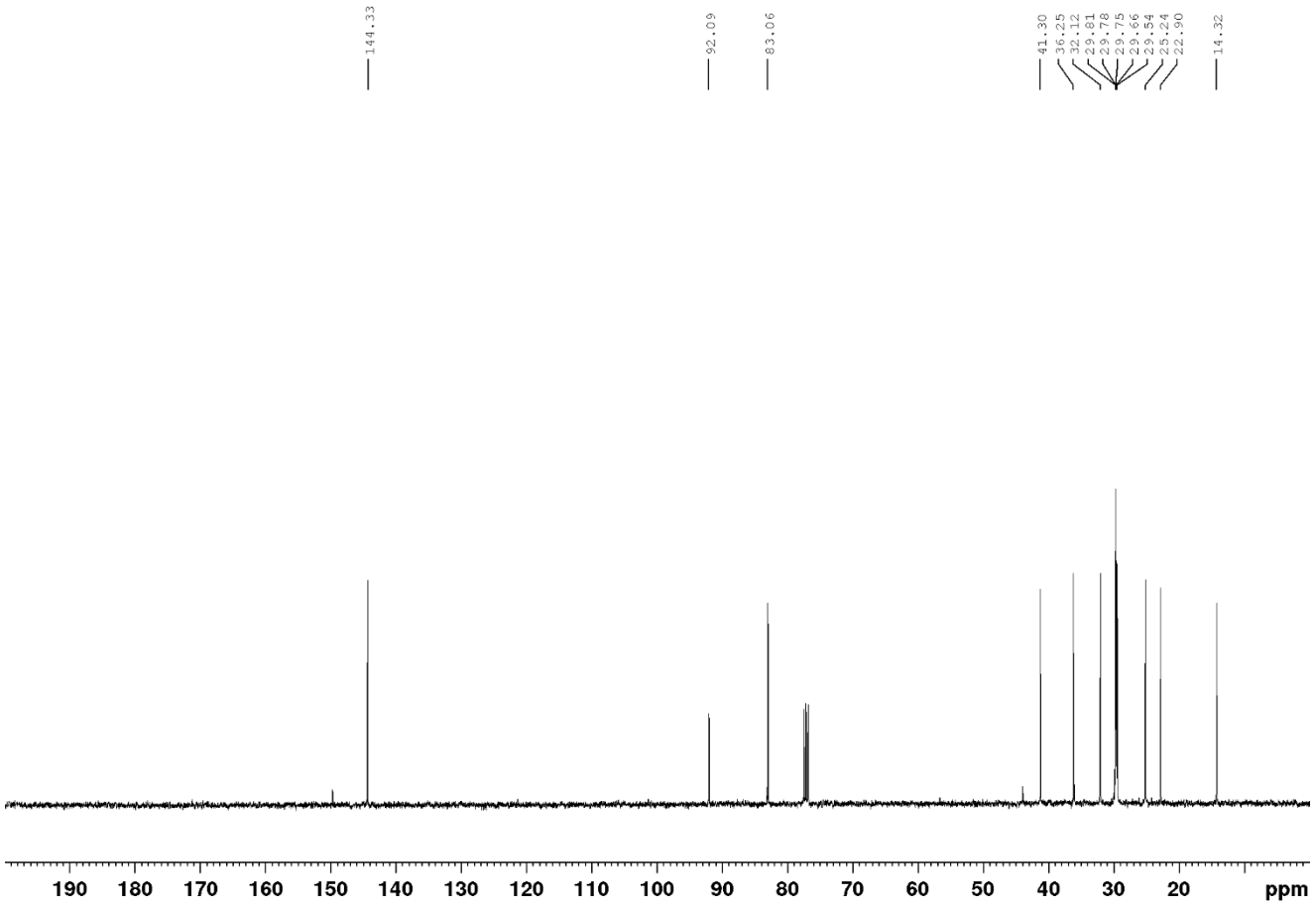
18.49
3.31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92.09
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41.30
36.25
32.12
29.81
29.78
29.75
29.66
29.54
25.24
22.90
14.32
190
180
170
160
150
140
130
120
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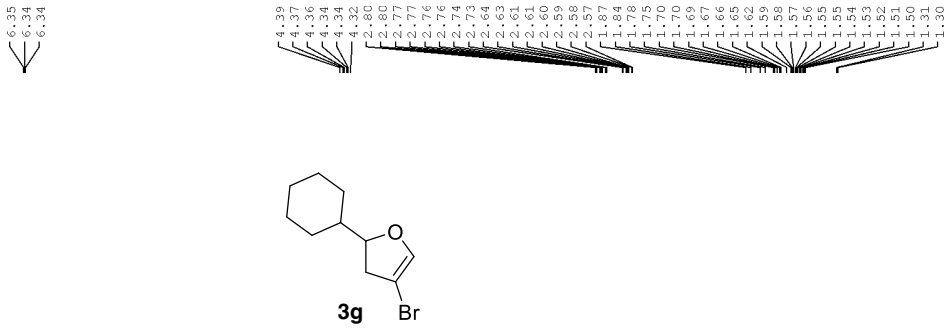
100
90
80
70
60
50
40
30
20
ppm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4.37
4.36
4.34
4.34
4.32
2.80
2.77
2.77
2.76
2.74
2.73
2.64
2.63
2.61
2.61
2.60
2.59
2.58
2.57
1.87
1.84
1.78
1.75
1.70
1.70
1.69
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1.58
1.57
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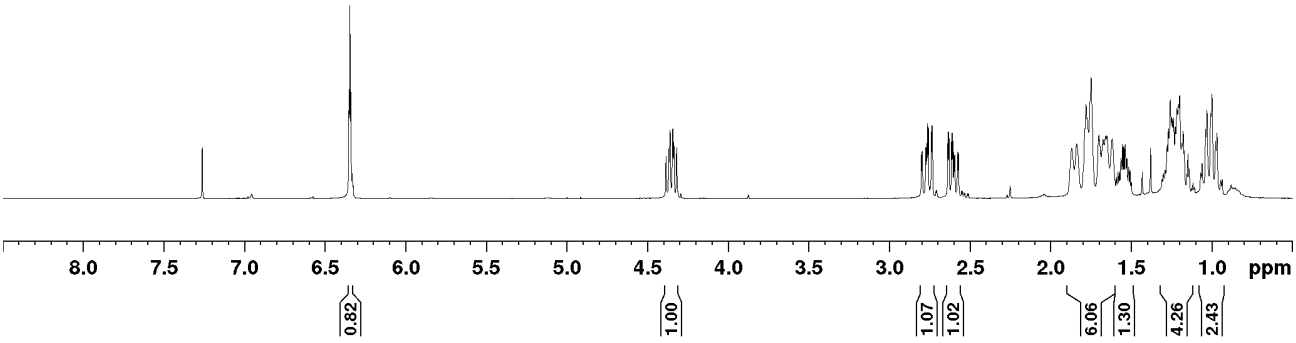
1.54
1.53
1.52
1.51
1.50
1.31
1.30

O
Br

3g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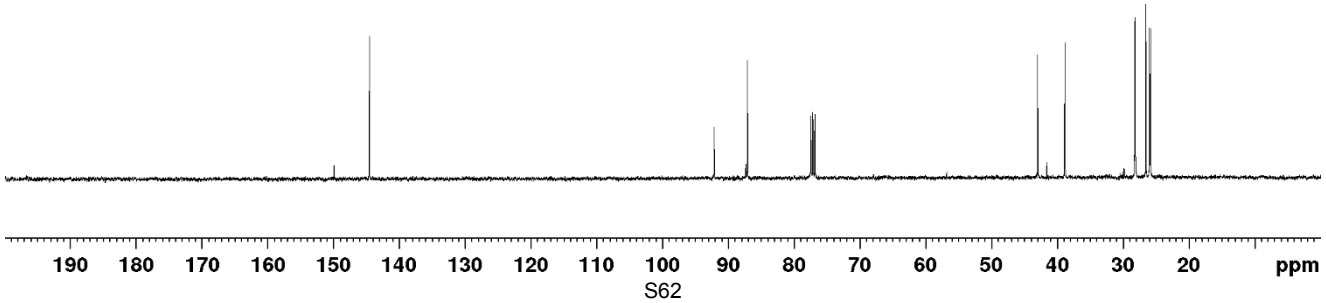
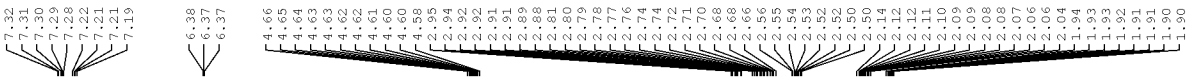
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
ppm
0.82
1.00
1.07
1.02
6.06
1.30
4.26
2.43


144.52
92.21
87.17
43.06
38.91
28.31
28.20
26.63
26.06
25.92


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


7.32
7.31
7.30
7.29
7.28
7.22
7.21
7.21
7.19
6.38
6.37
6.37
4.66
4.65
4.64
4.63
4.63
4.62
4.62
4.61
4.60
4.60
4.58
2.95
2.94
2.92
2.92
2.91
2.91
2.89
2.88
2.81
2.80
2.79
2.78
2.77
2.76
2.74
2.74
2.72
2.71
2.70
2.68
2.68
2.66
2.56
2.55
2.54
2.53
2.52
2.52
2.50
2.50
2.14
2.12
2.12
2.11
2.10
2.09
2.09
2.08
2.08
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2.06
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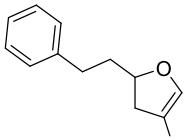
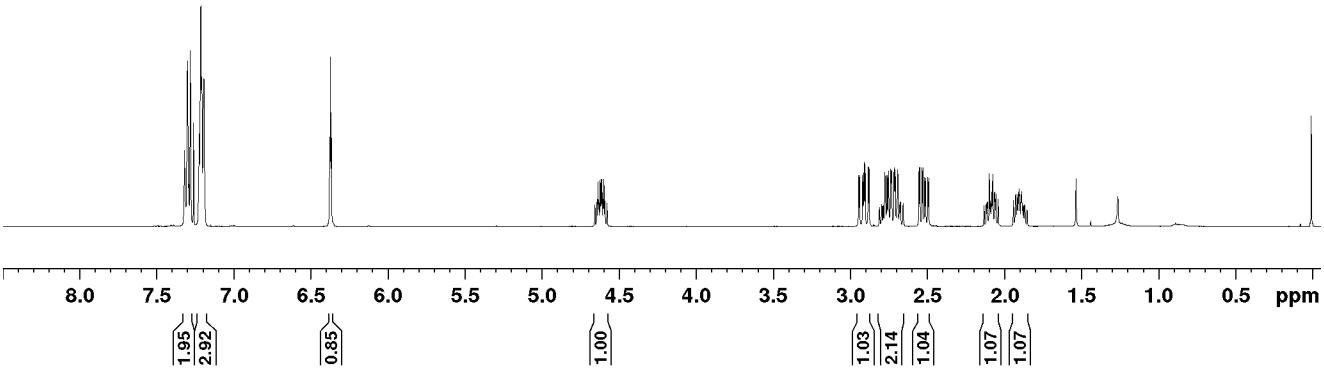
1.92
1.91
1.91
1.90
1.90


O
Br

3h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3.5
3.0
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2.0
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0.85
1.00
1.03
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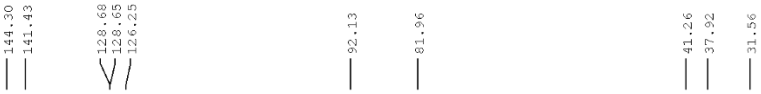
1.07
1.07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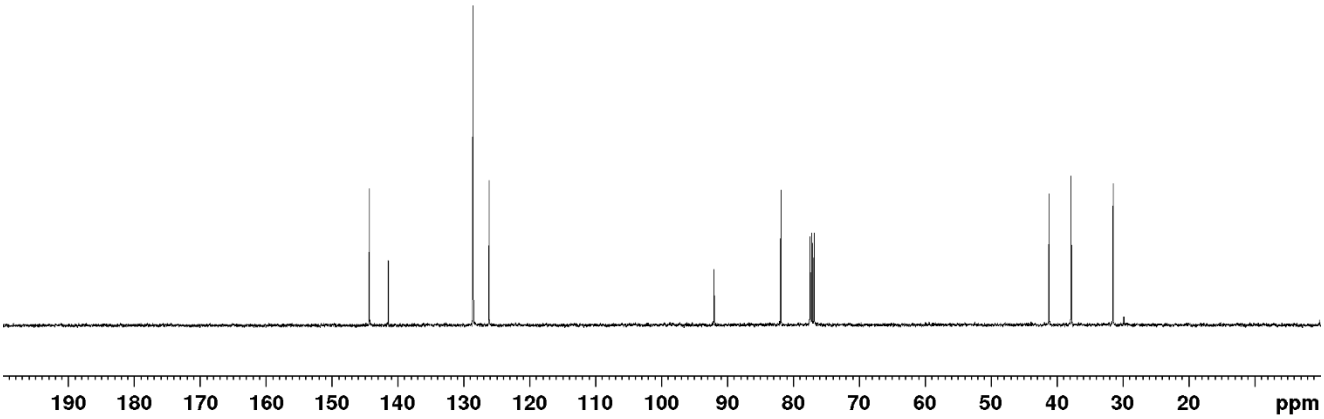
31.56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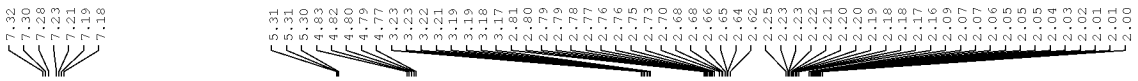
ppm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4.79
4.77
3.23
3.23
3.22
3.21
3.19
3.19
3.18
3.17
2.81
2.80
2.79
2.79
2.78
2.77
2.76
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2.75
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2.64
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2.23
2.22
2.21
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2.19
2.18
2.18
2.17
2.16
2.09
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2.07
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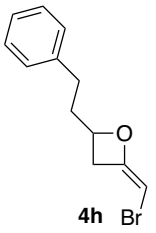
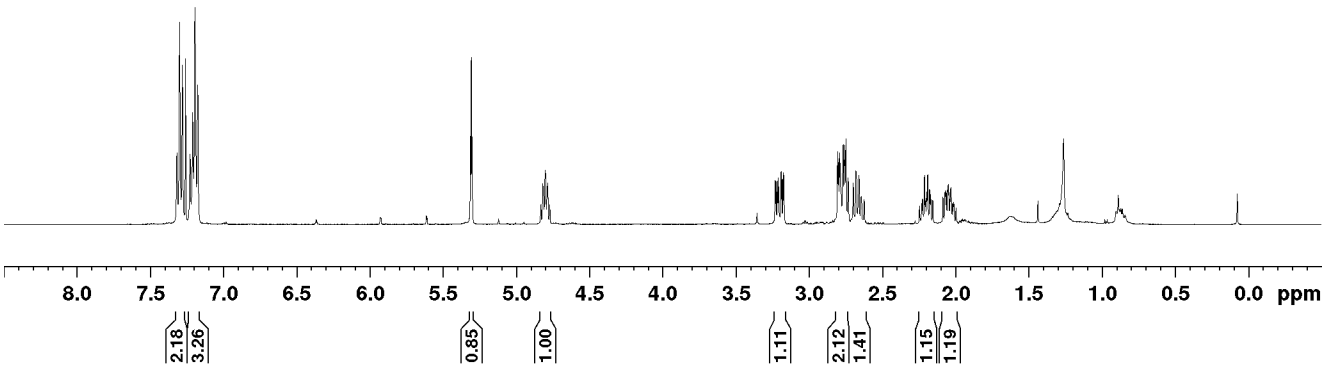
2.04
2.03
2.02
2.01
2.01
2.00


O
Br

4h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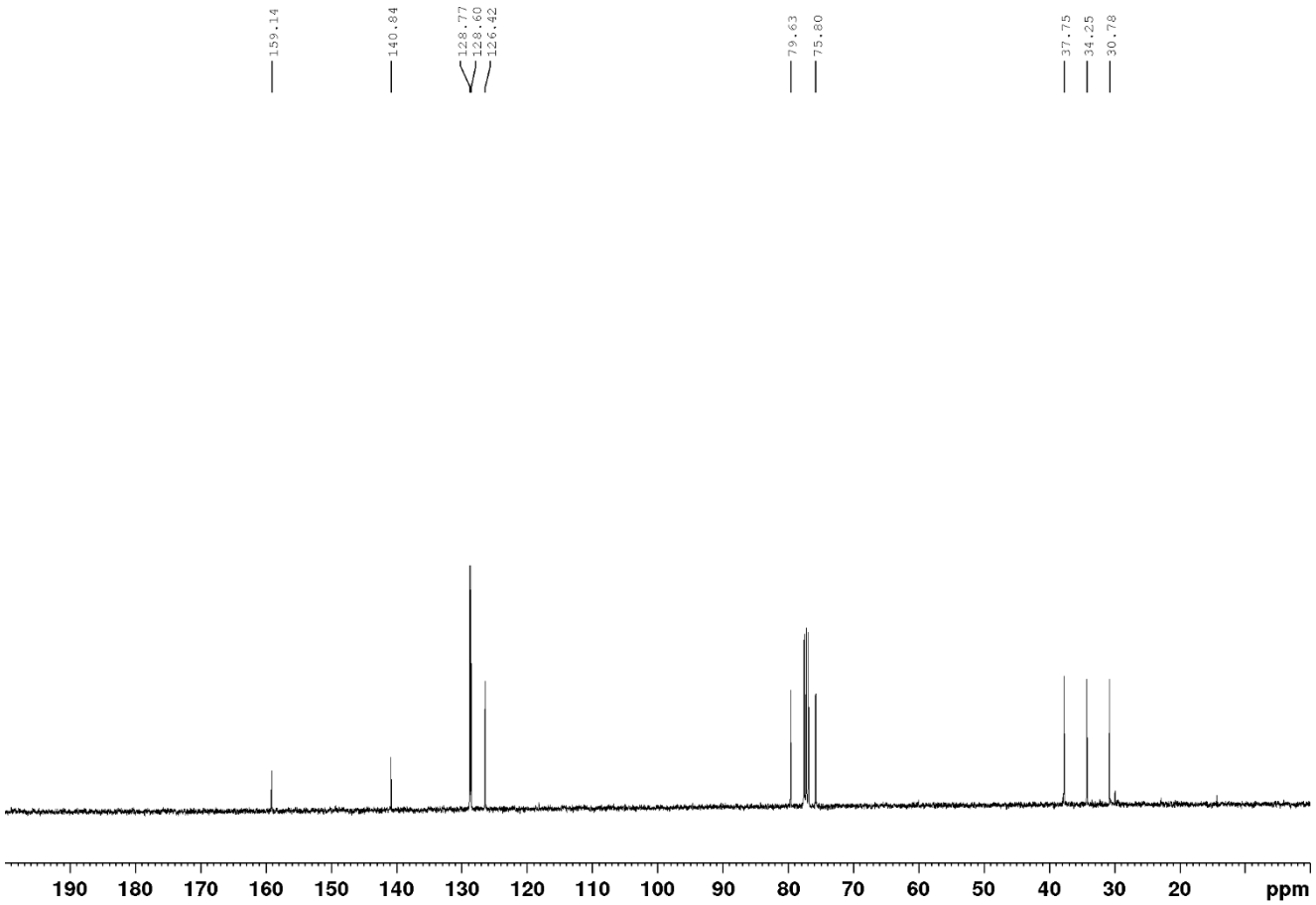
1.15
1.19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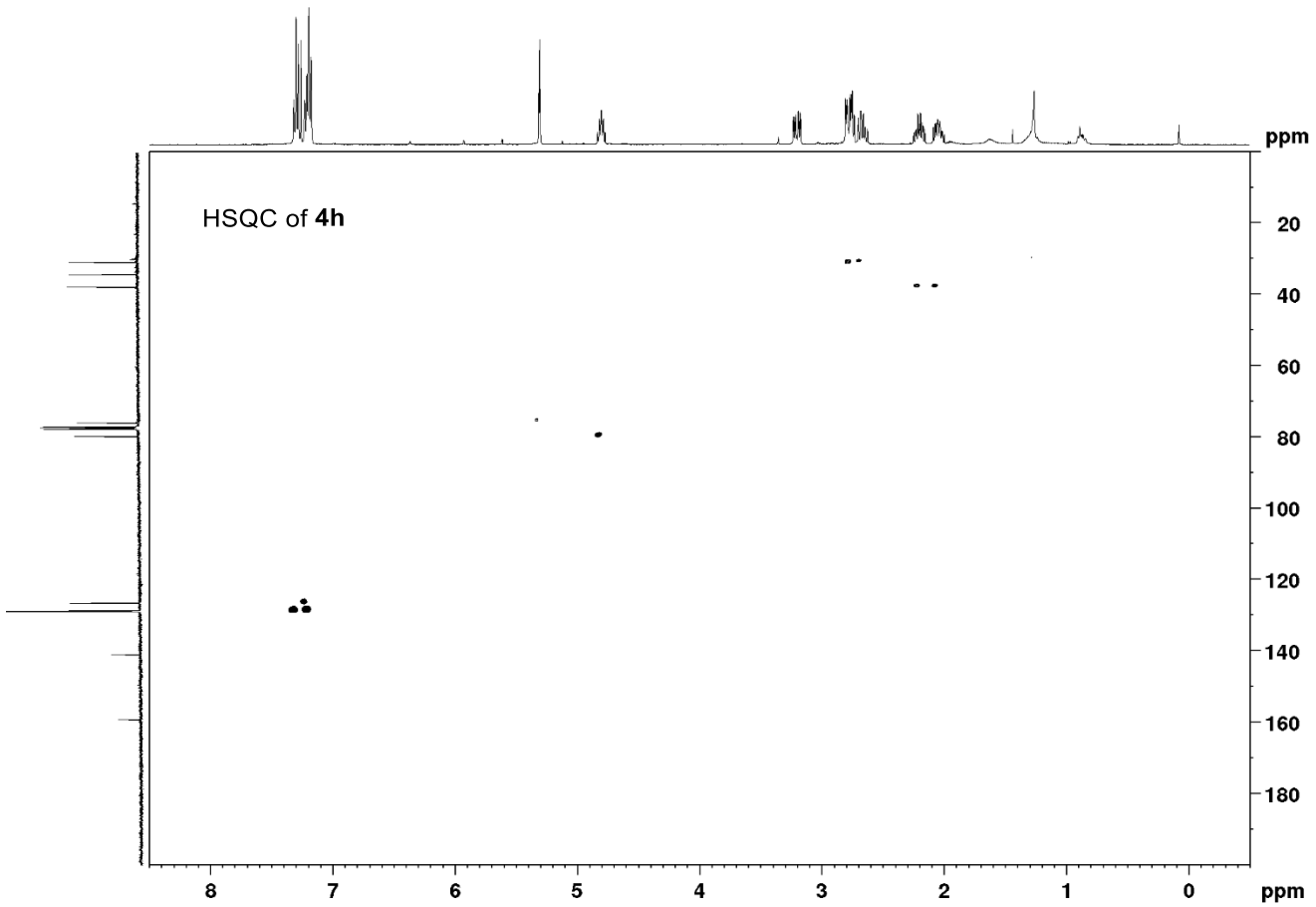
ppm


HSQC of **4h**
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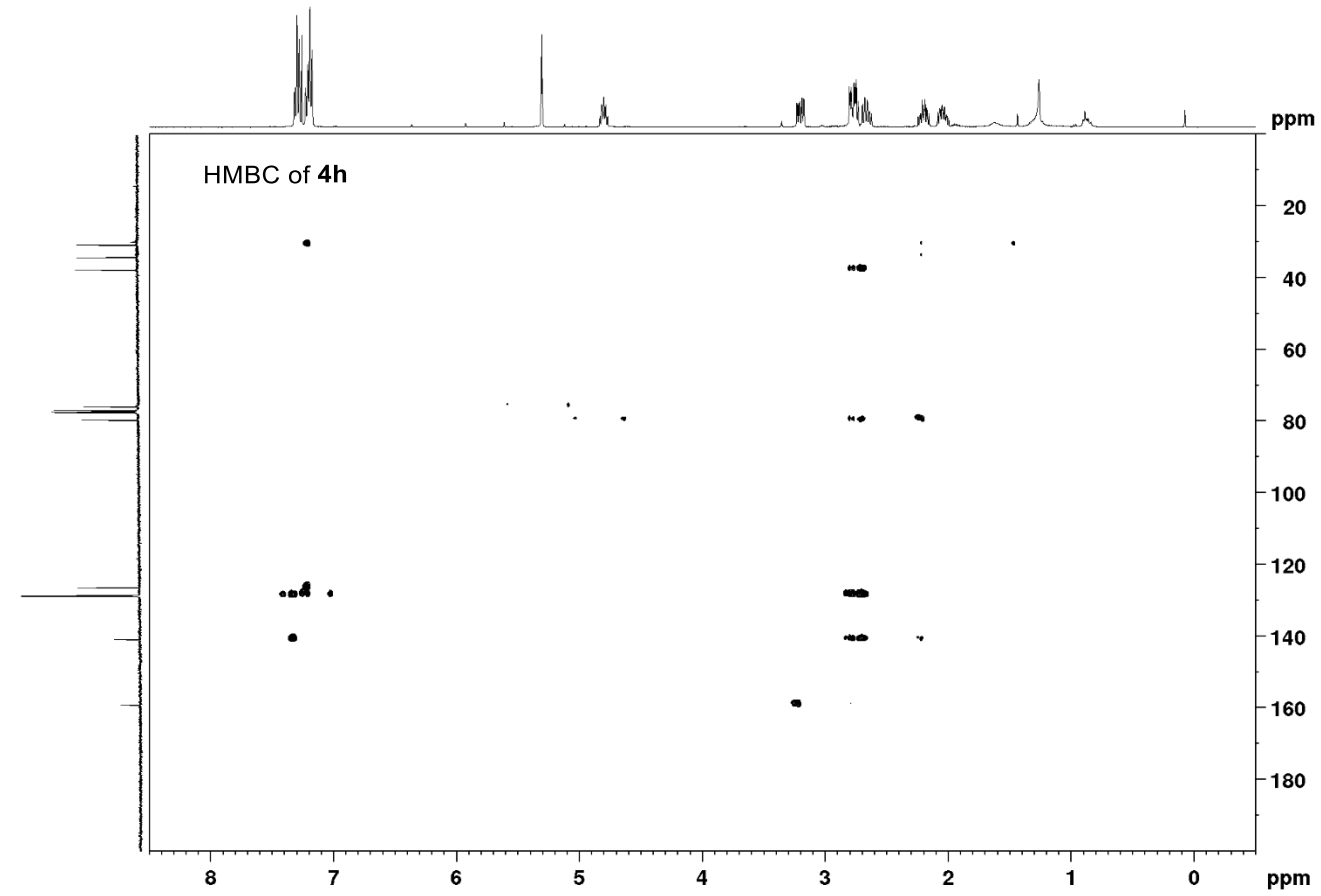
6
5
4
3
2
1
0
ppm


HMBC of **4h**
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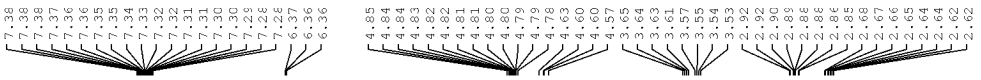
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm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7.30
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4.81
4.80
4.80
4.79
4.79
4.78
4.63
4.60
4.60
4.57
3.65
3.64
3.63
3.61
3.57
3.55
3.54
3.53
2.92
2.92
2.90
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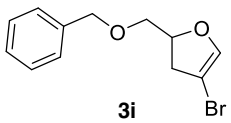
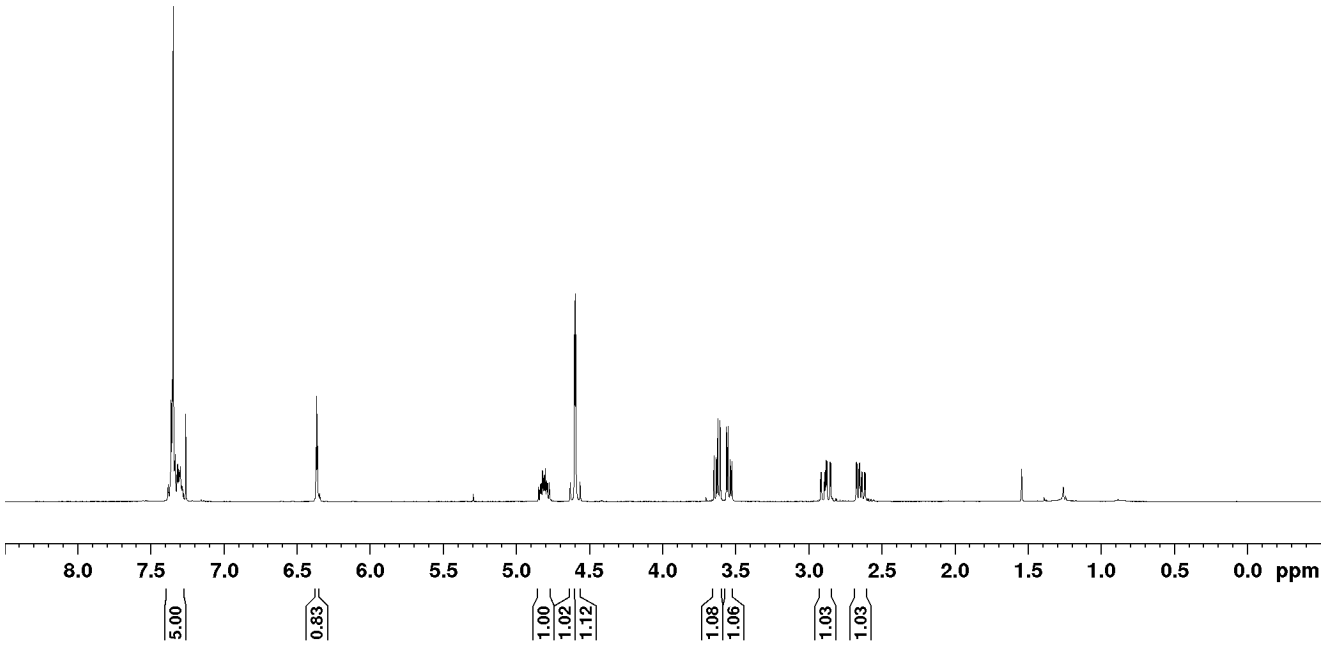
2.65
2.64
2.64
2.62
2.62


O
O
Br

3i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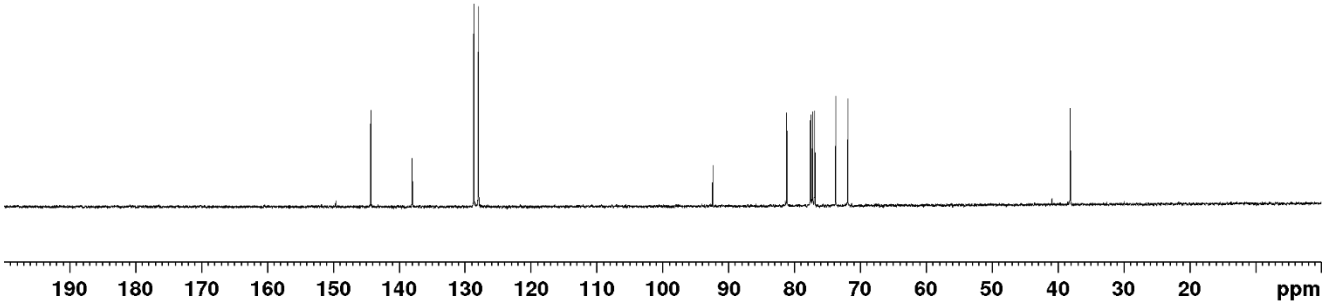
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
5.00
0.83
1.00
1.02
1.12
1.08
1.06
1.03
1.03


144.31
138.04
128.66
128.00
127.95
92.40
81.16
73.72
71.89
38.12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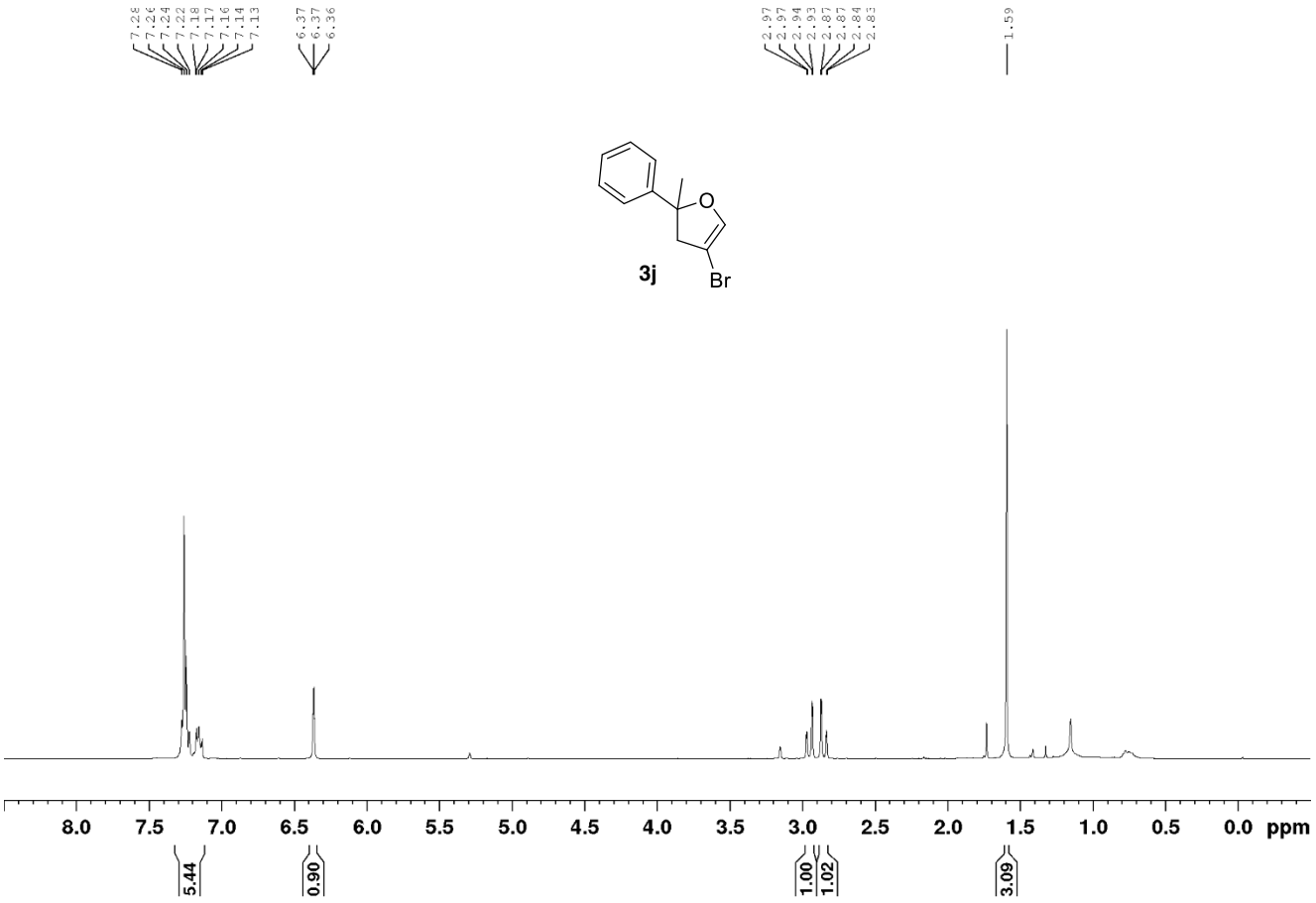
ppm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6.37
6.36
2.97
2.97
2.94
2.93
2.87
2.87
2.84
2.83
1.59
O
Br
3j
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
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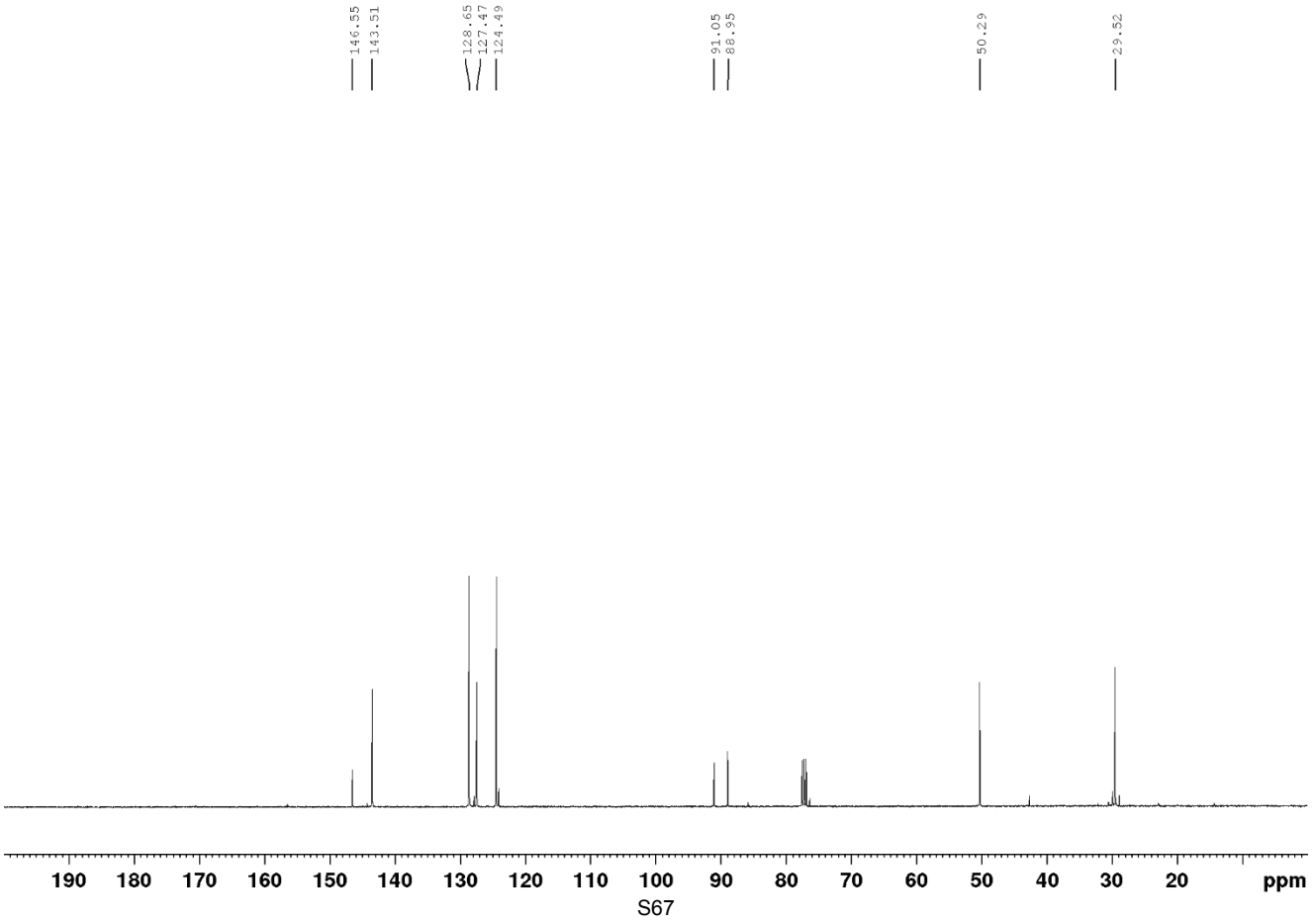
1.00
1.02
3.09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88.95
50.29
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140
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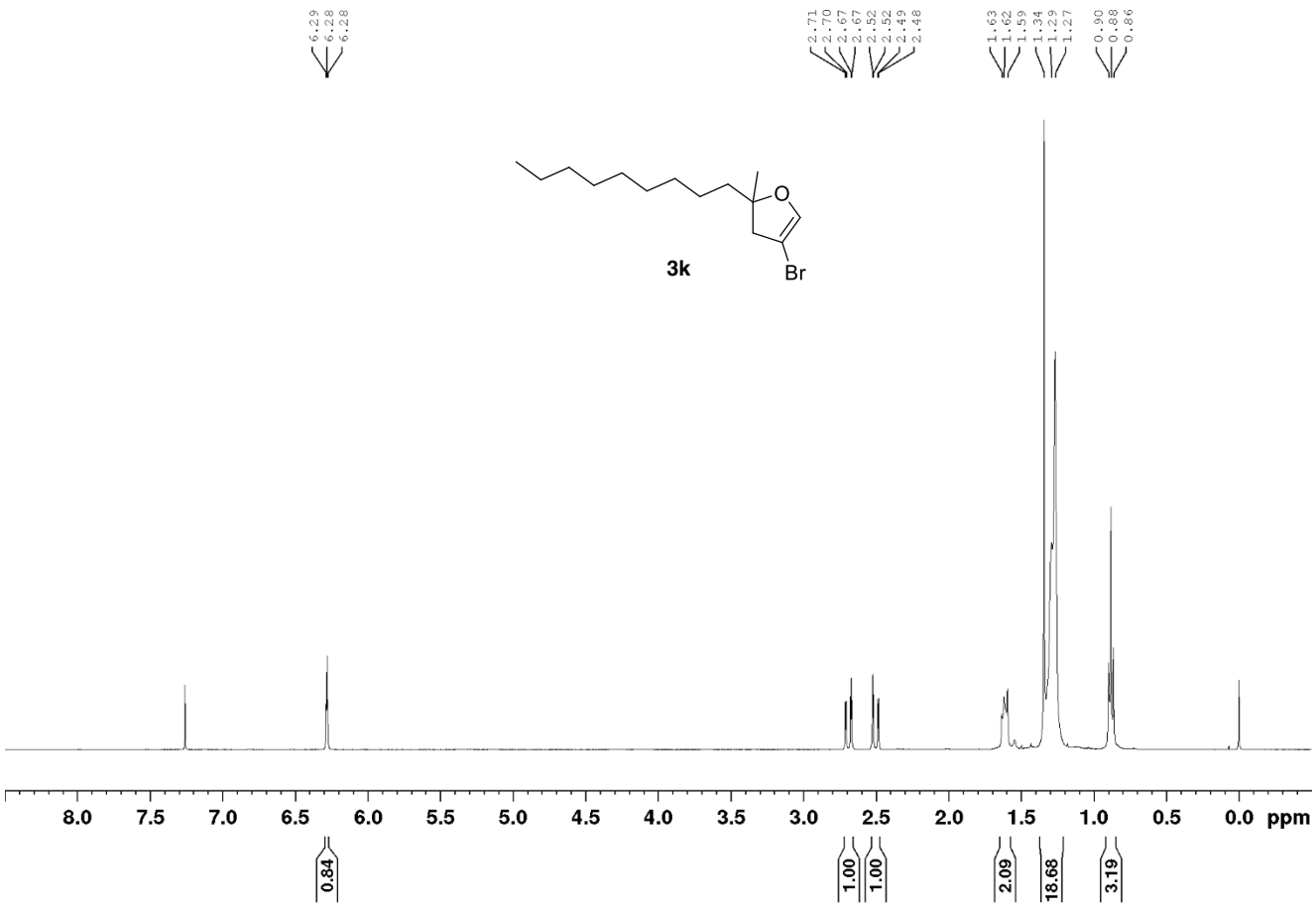
120
110
100
90
80
70
60
50
40
30
20
ppm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2.67
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2.48
1.63
1.62
1.59
1.34
1.29
1.27
0.90
0.88
0.86
O
Br
3k
8.0
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7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
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1.0
0.5
0.0
ppm
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1.00
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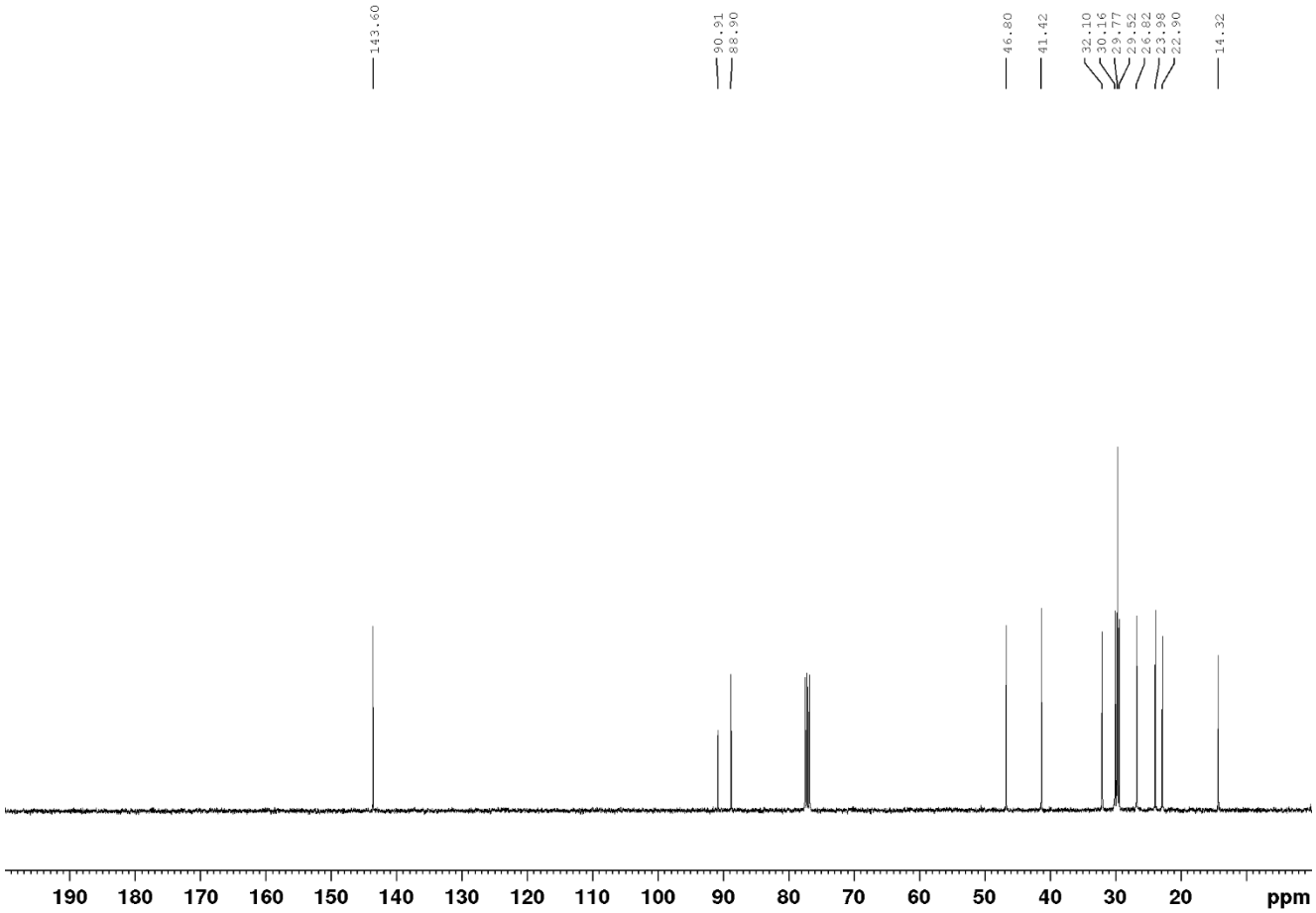
3.19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26.82
23.98
22.90
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80
70
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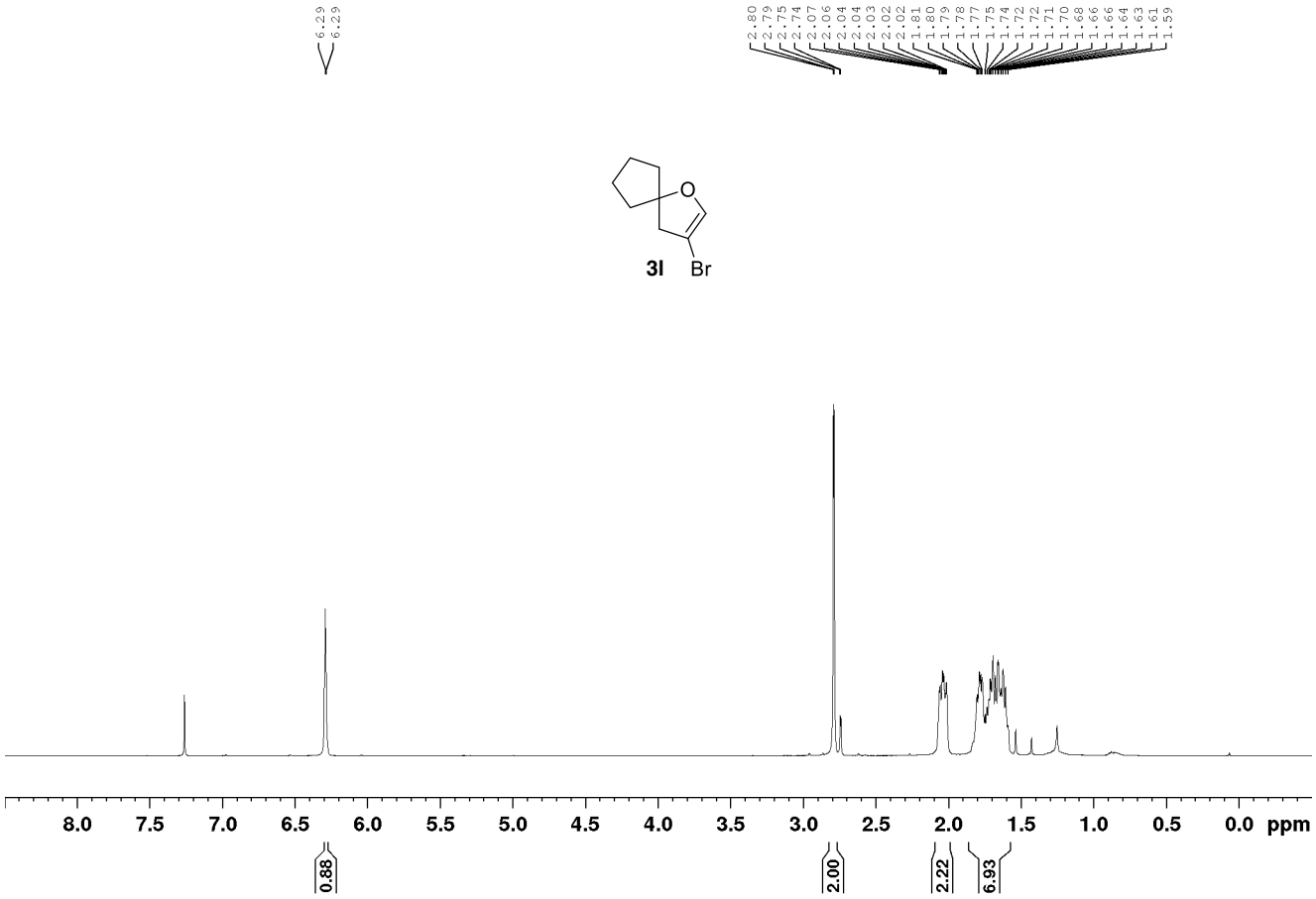
50
40
30
20
ppm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2.06
2.04
2.04
2.03
2.02
2.02
1.81
1.80
1.79
1.78
1.77
1.75
1.74
1.72
1.72
1.71
1.70
1.68
1.66
1.66
1.64
1.63
1.61
1.59
O
Br
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
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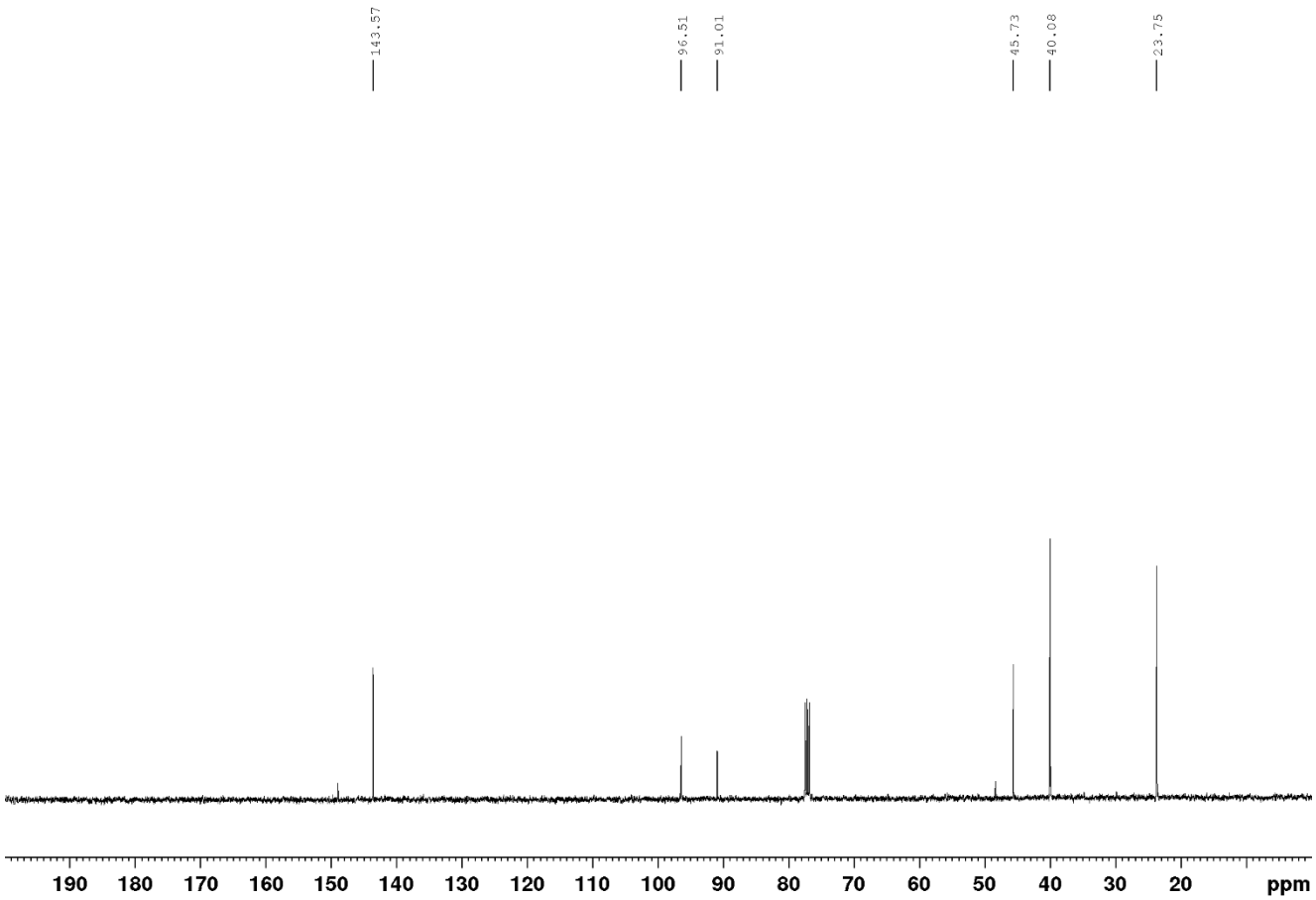
2.22
6.93

3l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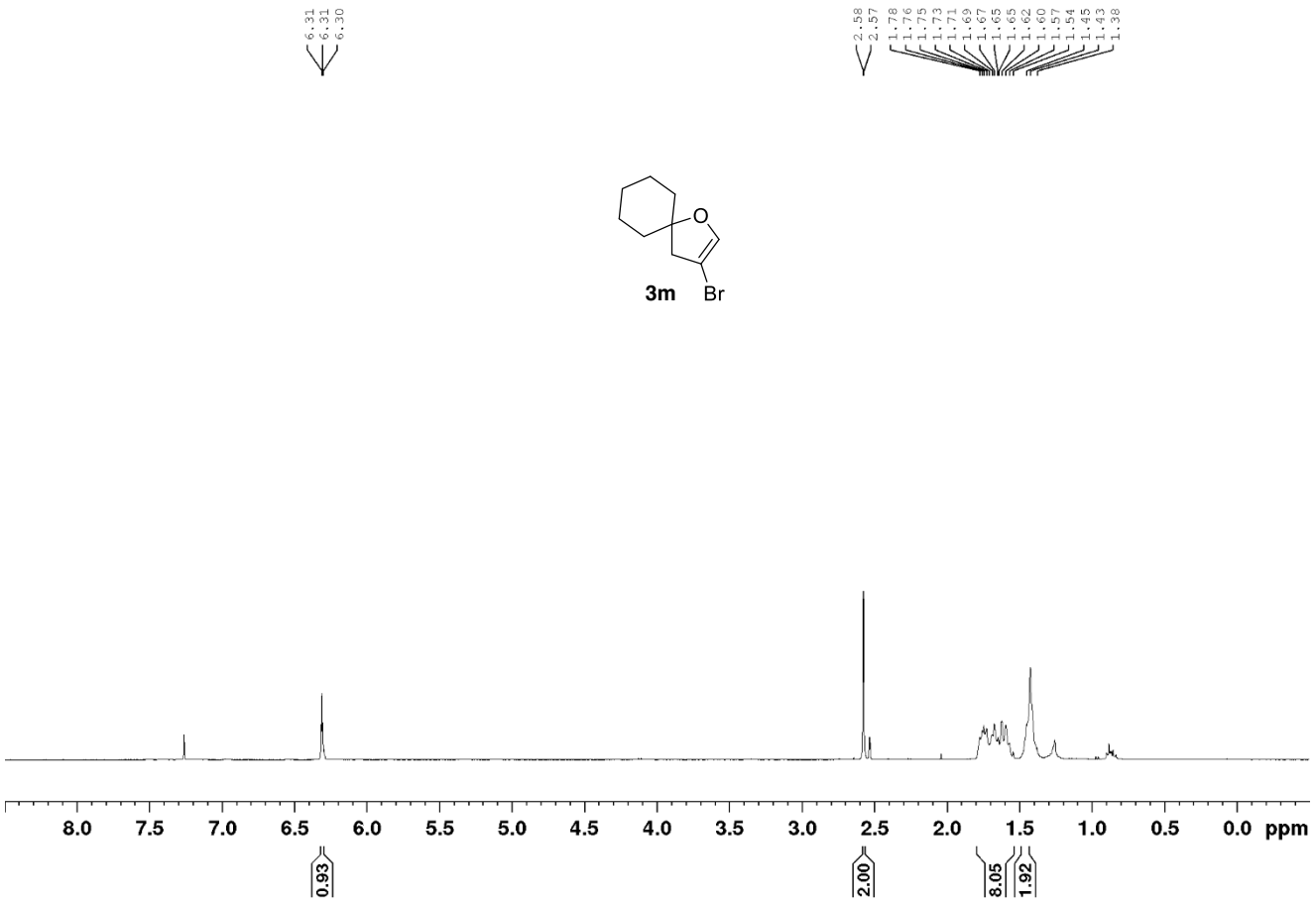
20
ppm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1.65
1.65
1.62
1.60
1.57
1.54
1.45
1.43
1.38
O
Br
3m
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
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2.0
1.5
1.0
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0.0
ppm
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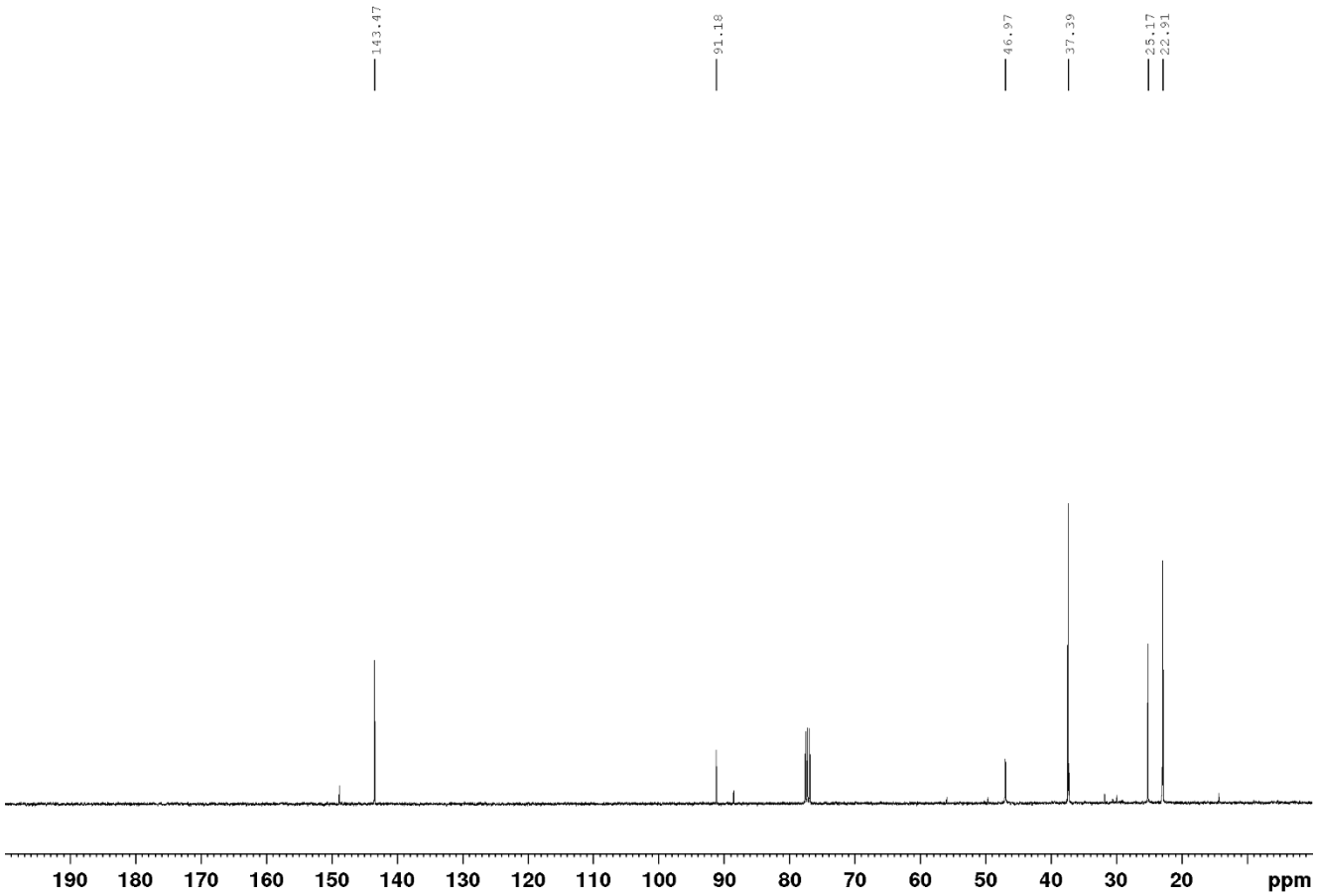
8.05
1.92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120
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80
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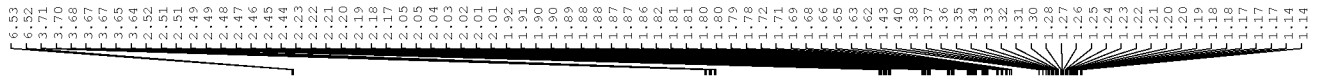
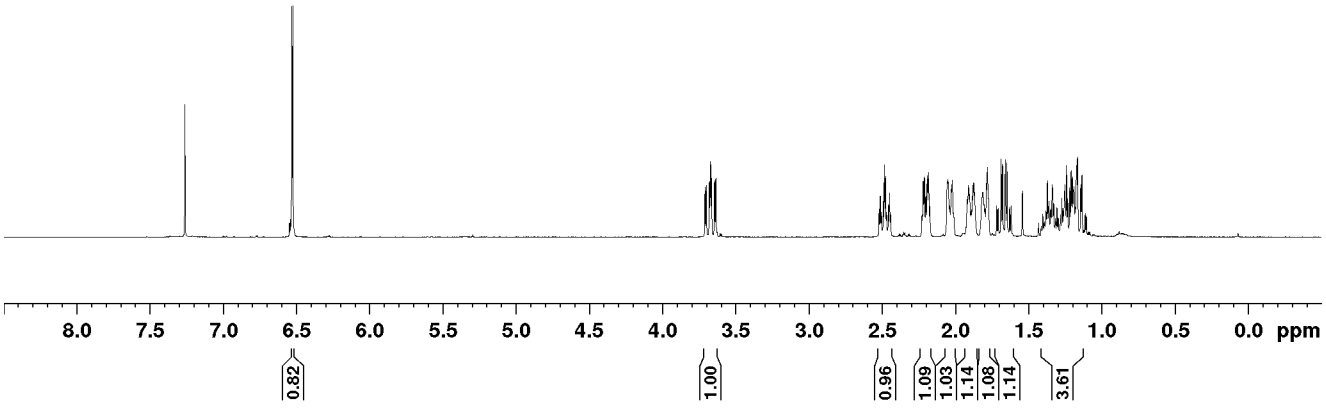
40
30
20
ppm




H
O
H
Br

3n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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
ppm
0.82
1.00
0.96
1.09
1.03
1.14
1.08
1.14
3.61


145.85
101.91
90.09
51.64
30.53
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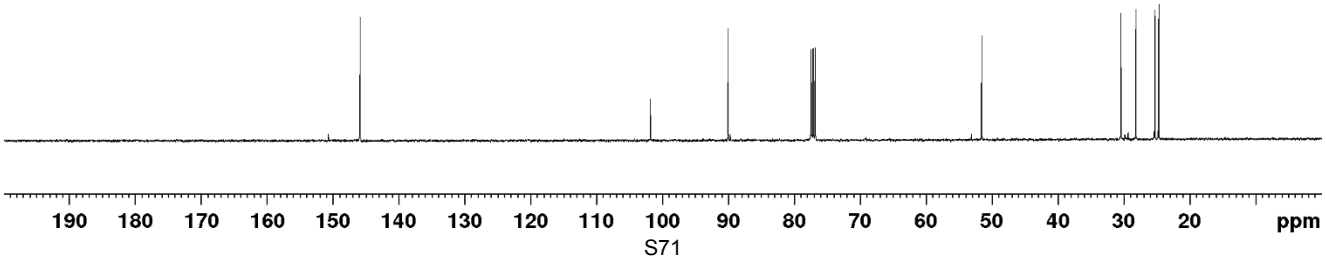
25.35
24.76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150
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80
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60
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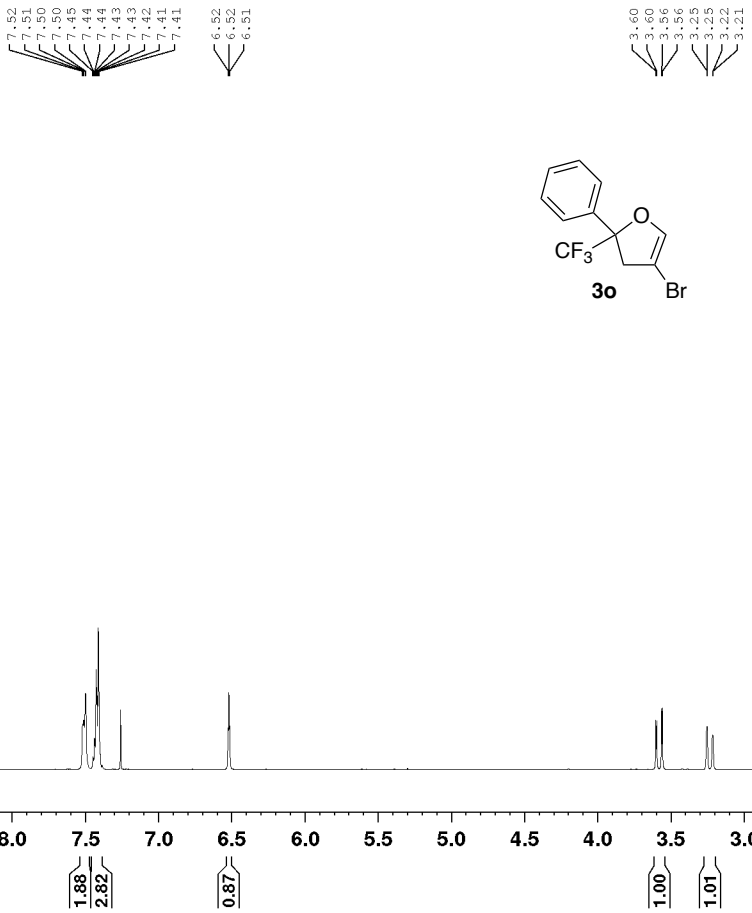
40
30
20
ppm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7.41
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6.52
6.51
3.60
3.60
3.56
3.56
3.25
3.25
3.22
3.21
O
CF3
Br
3o
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6.0
5.5
5.0
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4.0
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3.0
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2.0
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ppm
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1.01
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128.74
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126.39
125.73
122.91
91.94
88.48
88.18
87.87
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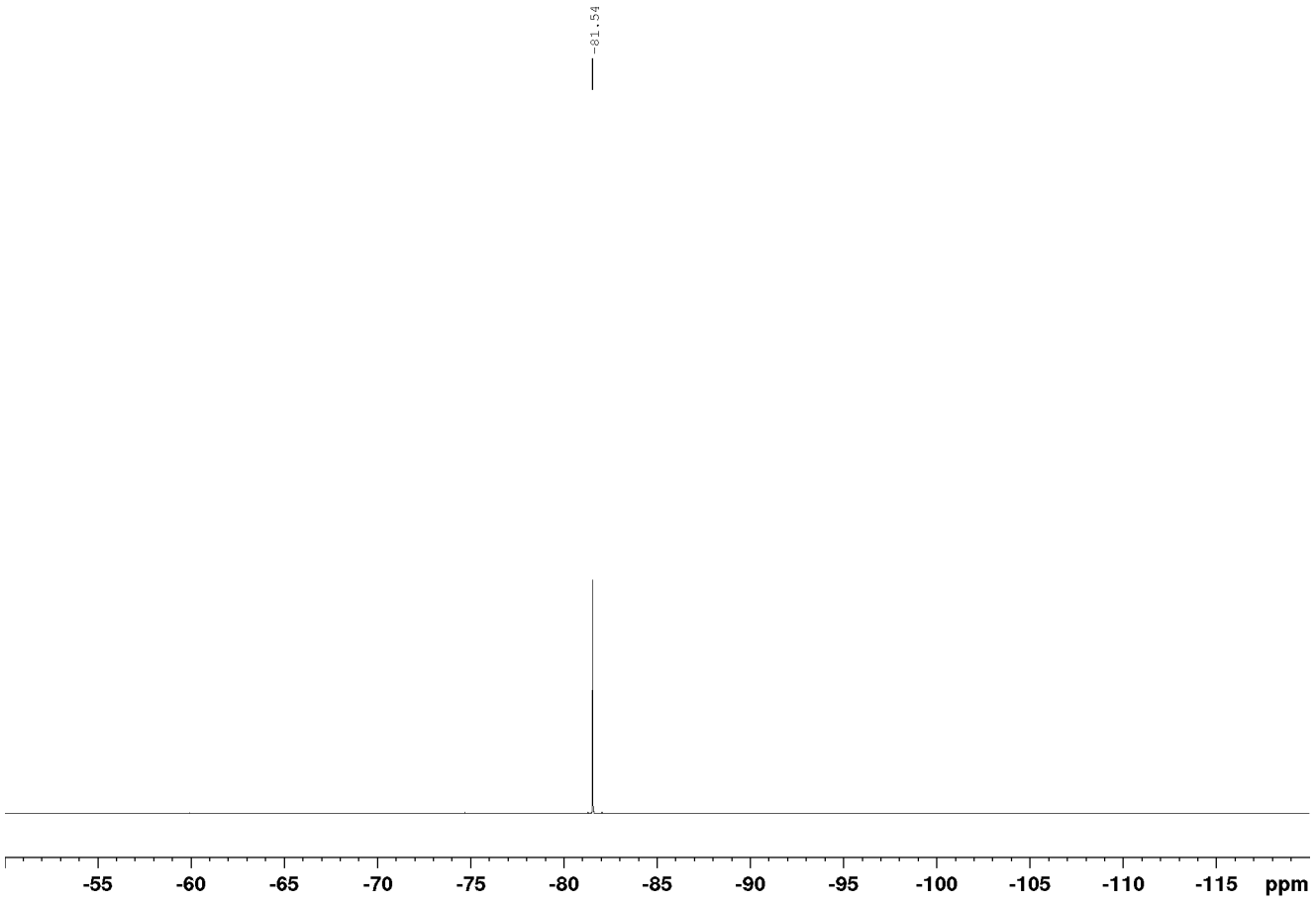
20
ppm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-95
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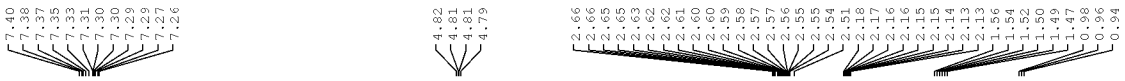
-105
-110
-115
ppm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7.27
7.26
4.82
4.81
4.81
4.79
2.66
2.66
2.65
2.65
2.63
2.62
2.62
2.61
2.60
2.60
2.59
2.58
2.57
2.57
2.56
2.55
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2.54
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2.16
2.15
2.15
2.14
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1.56
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1.52
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1.49
1.47
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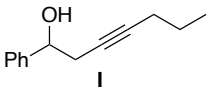
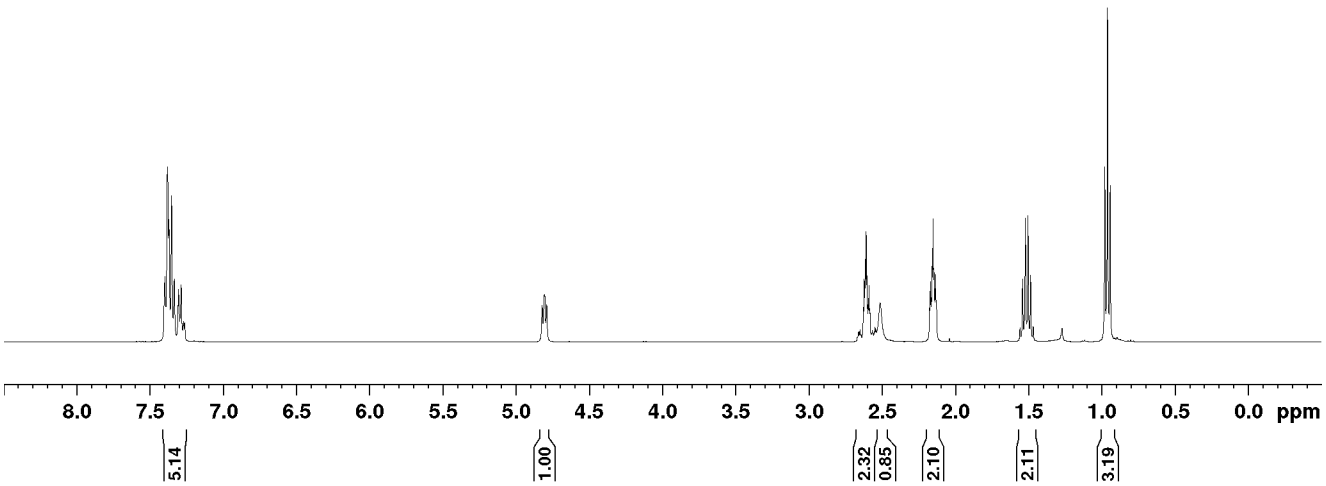
0.96
0.94


OH
Ph

I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6.0
5.5
5.0
4.5
4.0
3.5
3.0
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2.0
1.5
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0.0
ppm
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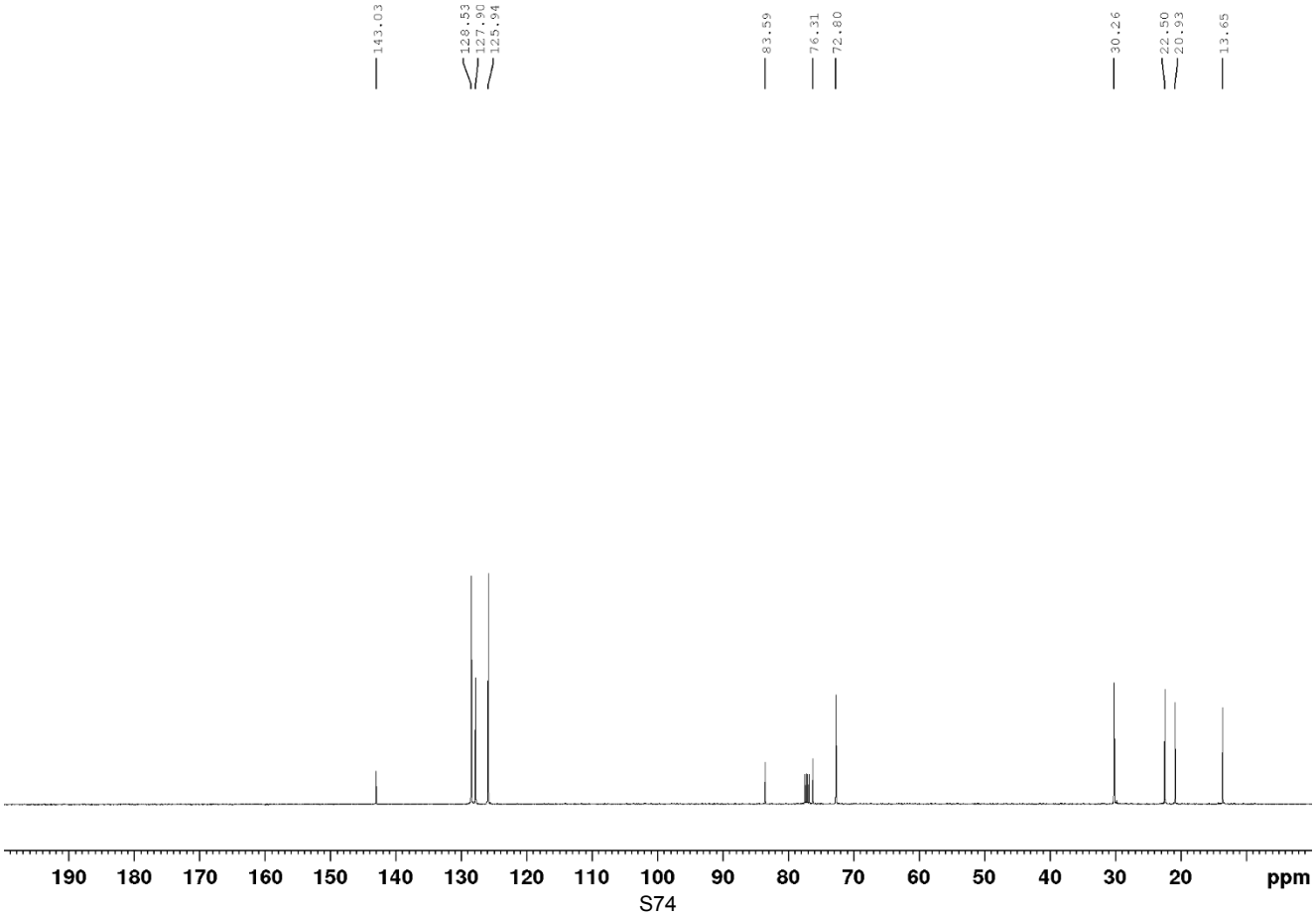
2.10
2.11
3.19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72.80
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22.50
20.93
13.65
190
180
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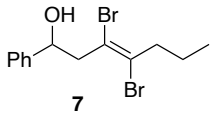
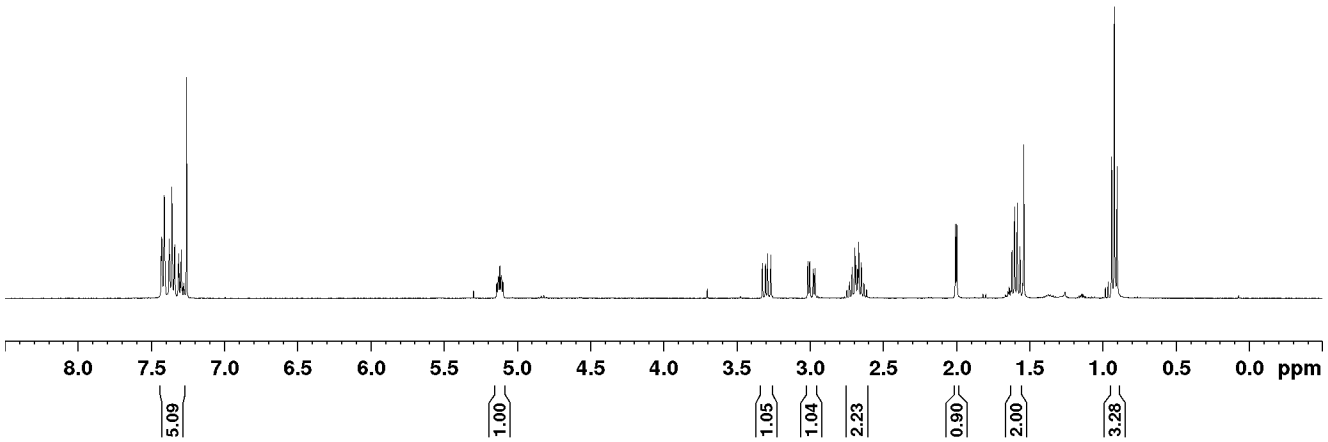
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


7.43
7.43
7.41
7.38
7.38
7.37
7.36
7.36
7.34
7.34
7.32
7.31
7.31
7.30
7.30
7.28
5.14
5.13
5.12
5.11
5.10
3.33
3.30
3.29
3.27
3.01
3.00
2.98
2.97
2.75
2.73
2.71
2.69
2.69
2.67
2.67
2.65
2.63
2.61
2.01
2.00
1.64
1.62
1.60
1.58
1.57
0.94
0.92
0.90


OH
Br
Ph
Br

7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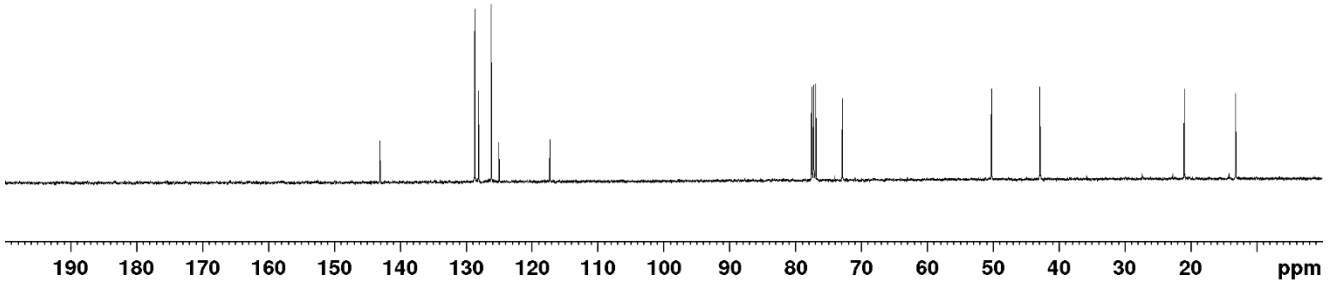
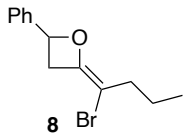
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
5.09
1.00
1.05
1.04
2.23
0.90
2.00
3.28

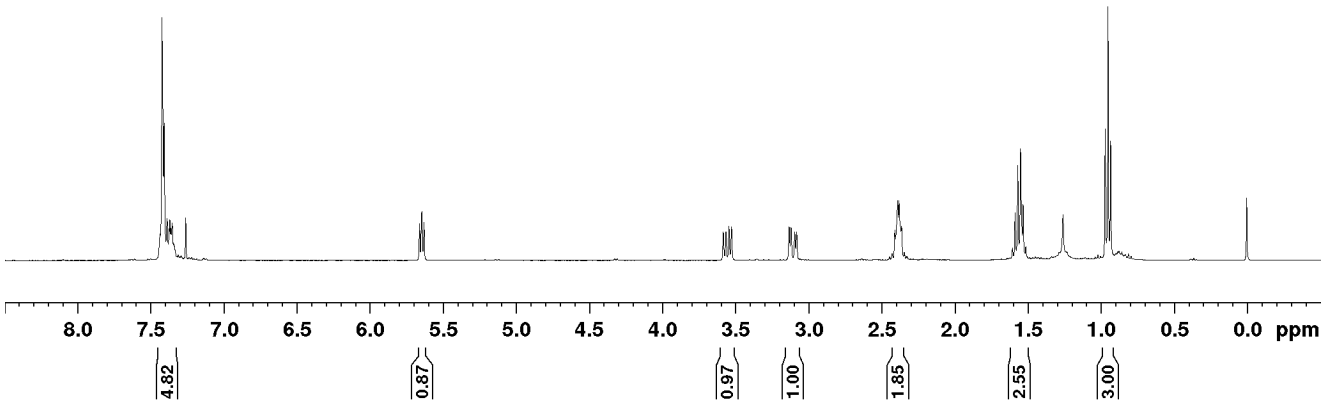

143.10
128.67
128.11
126.16
125.01
117.28
72.88
50.25
42.90
20.99
13.18


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


7.44
7.42
7.41
7.39
7.37
7.37
7.36
7.35
7.34
5.66
5.65
5.64
5.63
3.59
3.57
3.55
3.53
3.14
3.12
3.10
3.09
2.41
2.40
2.39
2.38
2.37
1.61
1.59
1.57
1.56
1.54
1.52
0.98
0.96
0.94


Ph
O
Br

8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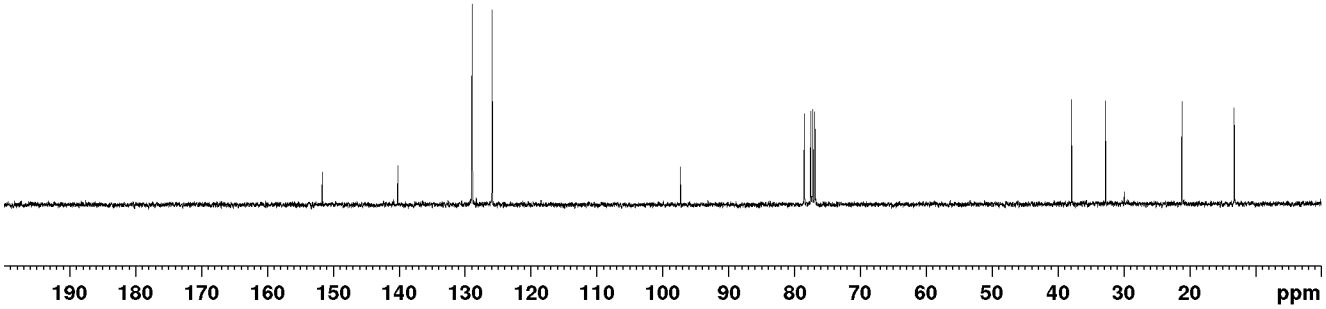
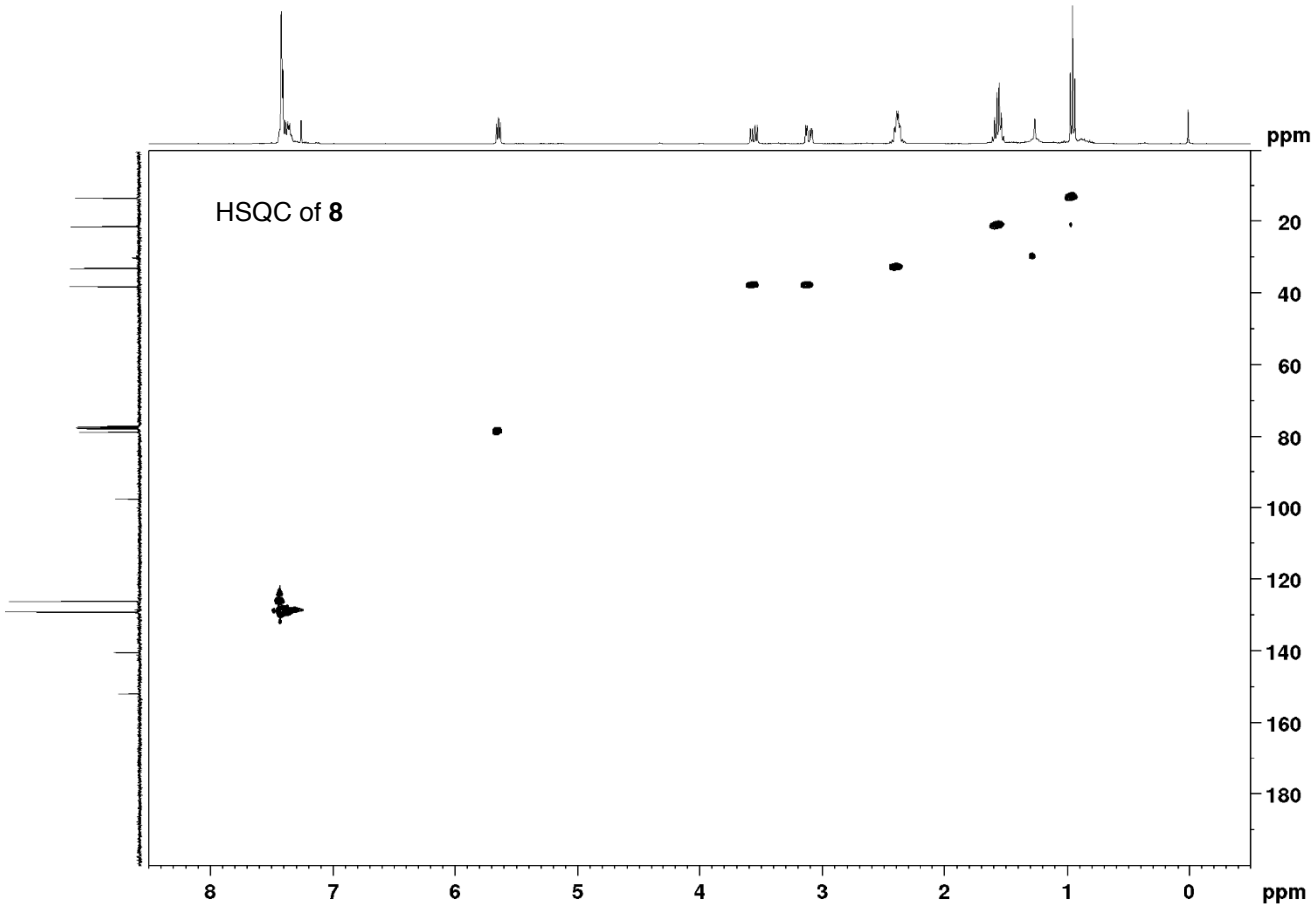
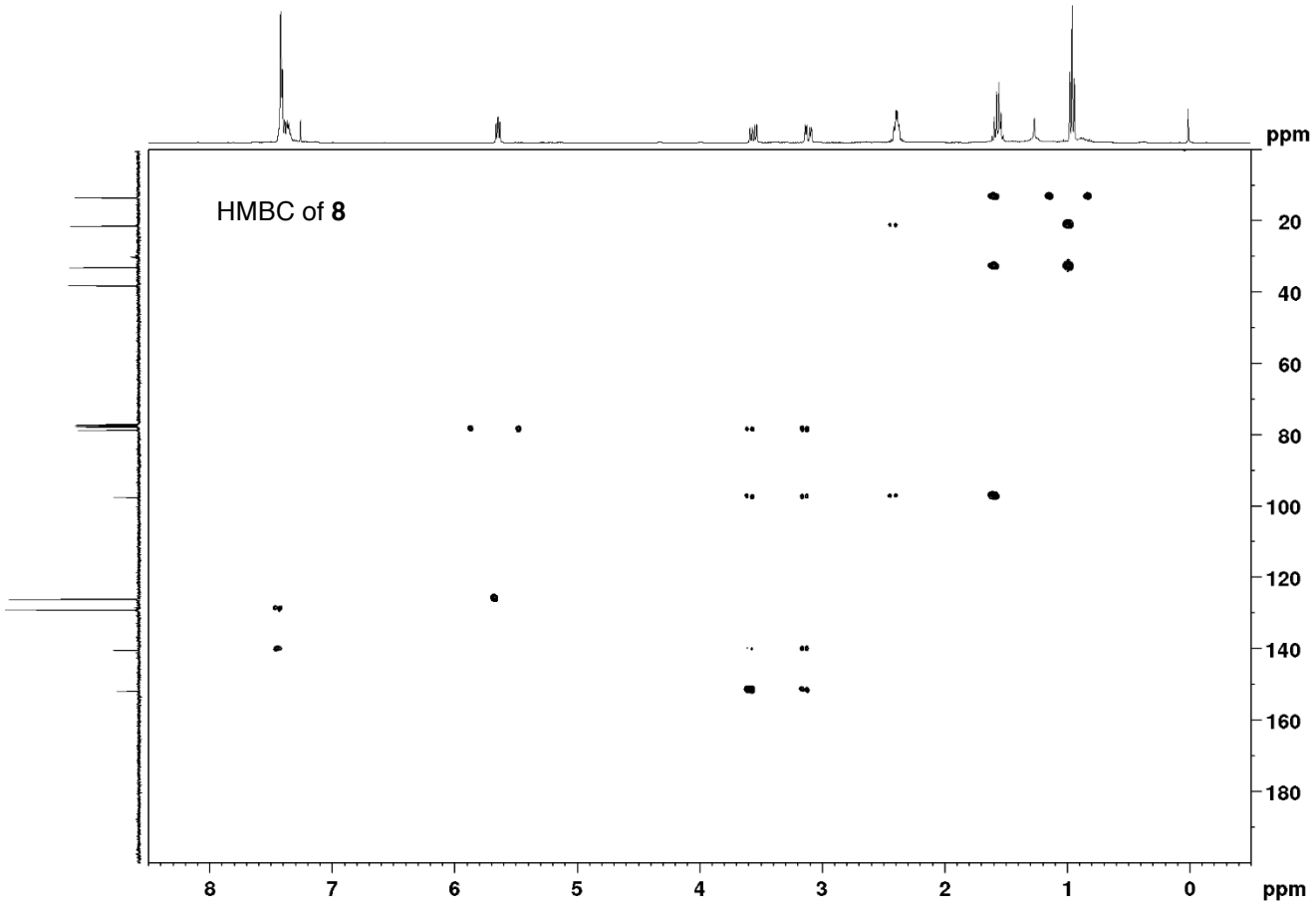
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
4.82
0.87
0.97
1.00
1.85
2.55
3.00

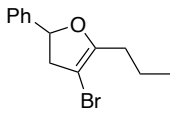

151.68
140.19
128.95
128.89
125.89
97.33
78.50
37.94
32.78
21.17
13.22


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

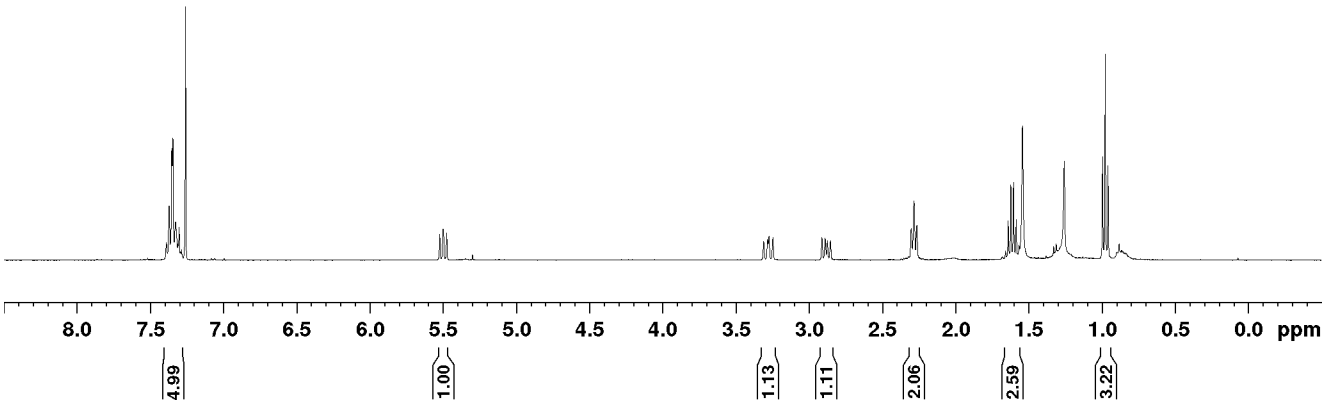

HSQC of **8**
ppm
20
40
60
80
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm


HMBC of **8**
ppm
20
40
60
80
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm


7.39
7.37
7.37
7.35
7.35
7.33
7.33
7.31
7.30
7.29
5.52
5.50
5.50
5.48
3.31
3.28
3.28
3.28
3.27
3.25
2.91
2.89
2.88
2.85
2.30
2.30
2.29
2.28
2.26
1.66
1.64
1.62
1.60
1.58
1.57
1.00
0.98
0.96


Ph
O
Br

9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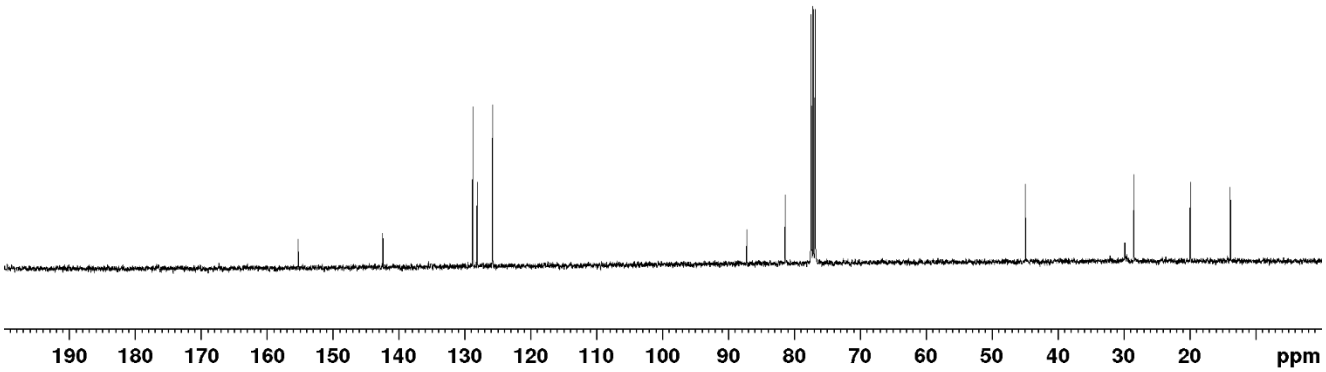
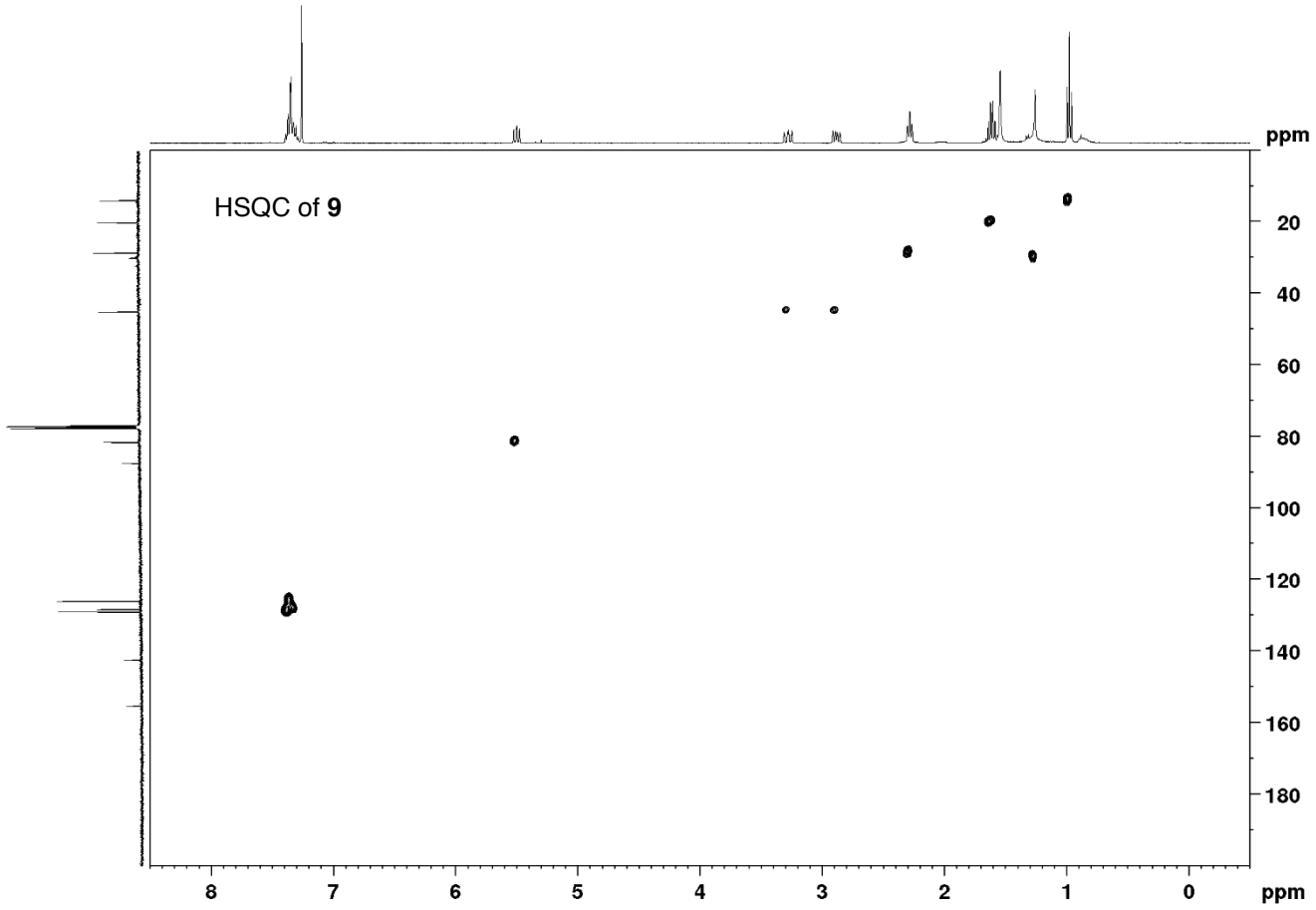
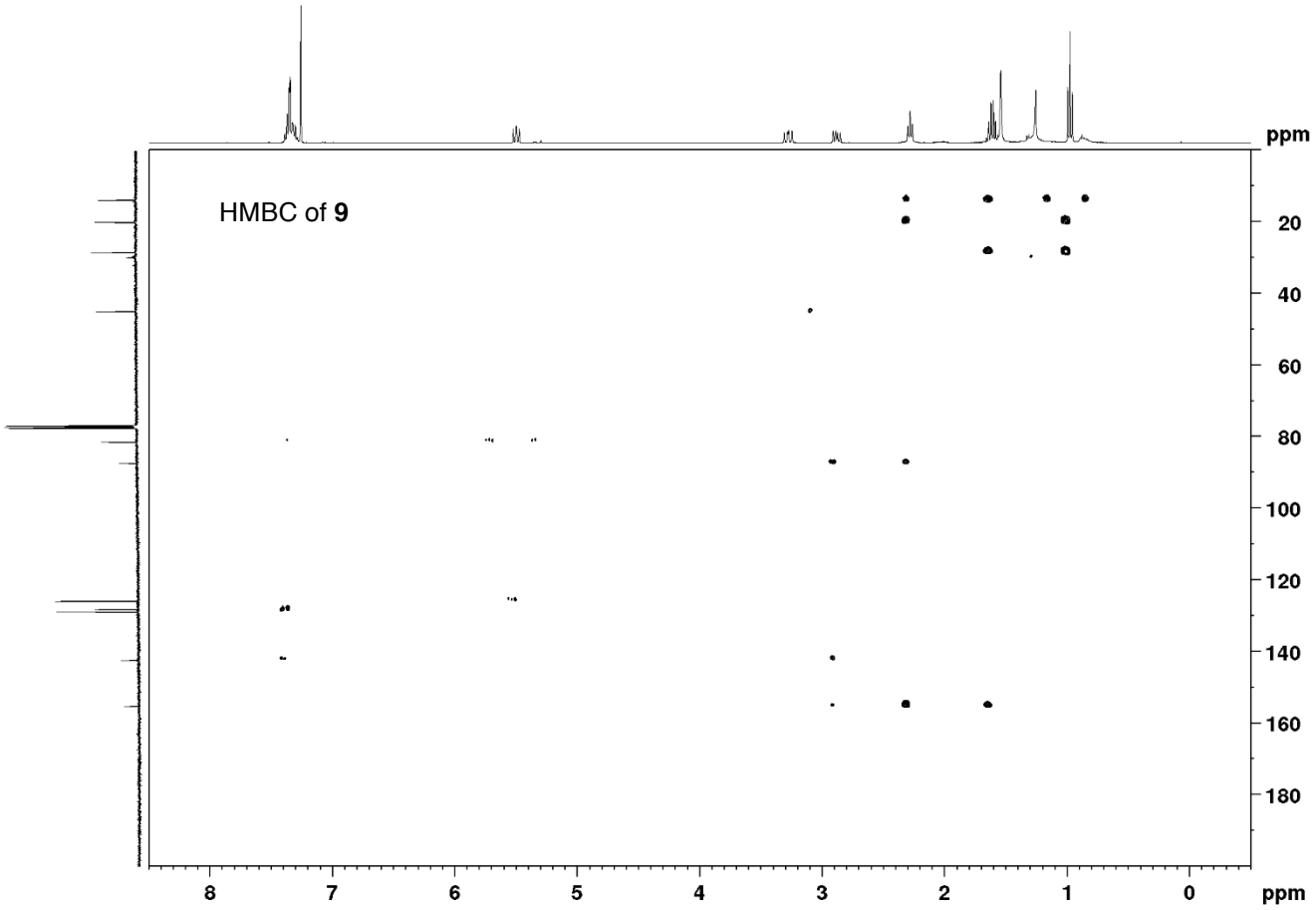
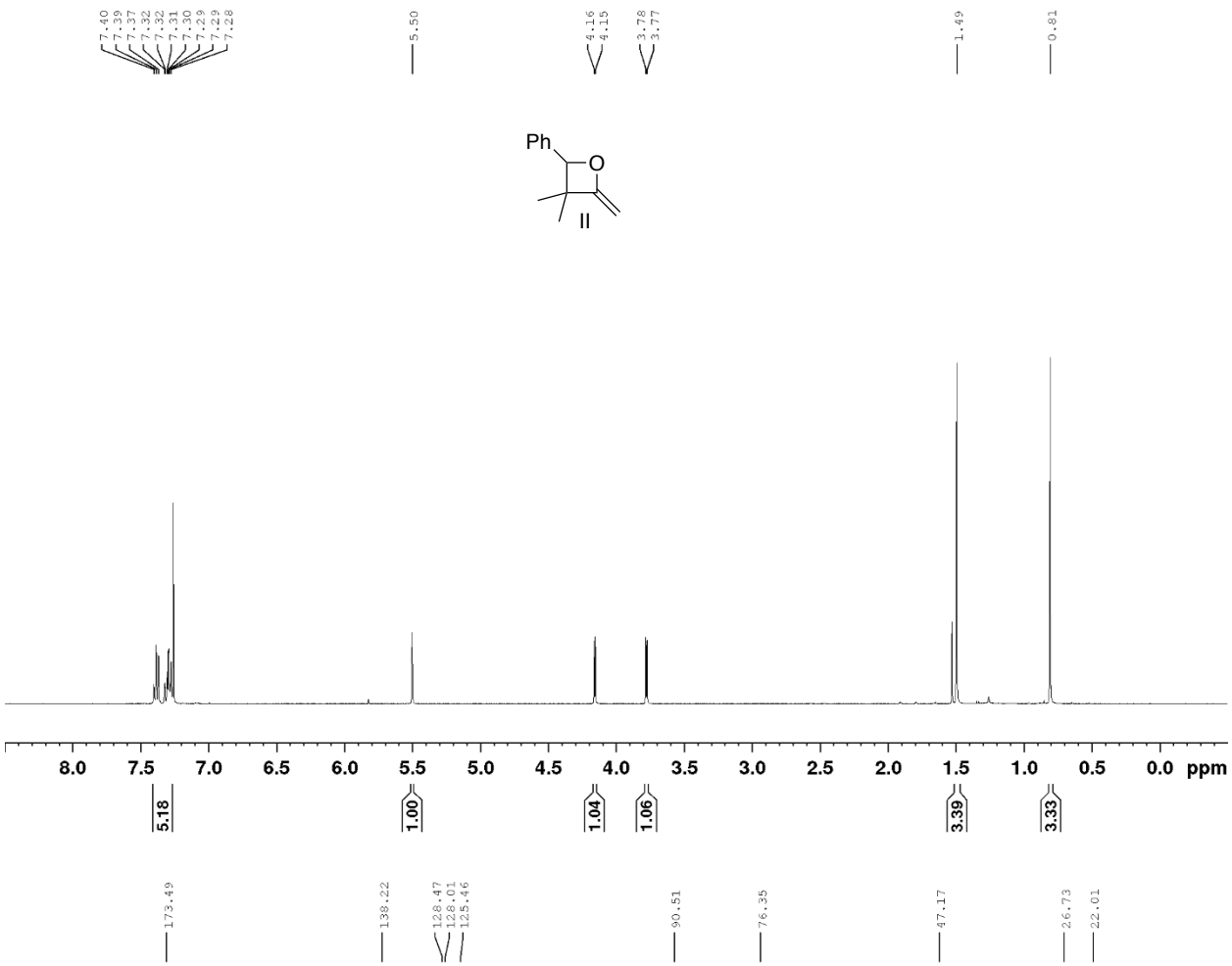
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
4.99
1.00
1.13
1.11
2.06
2.59
3.22

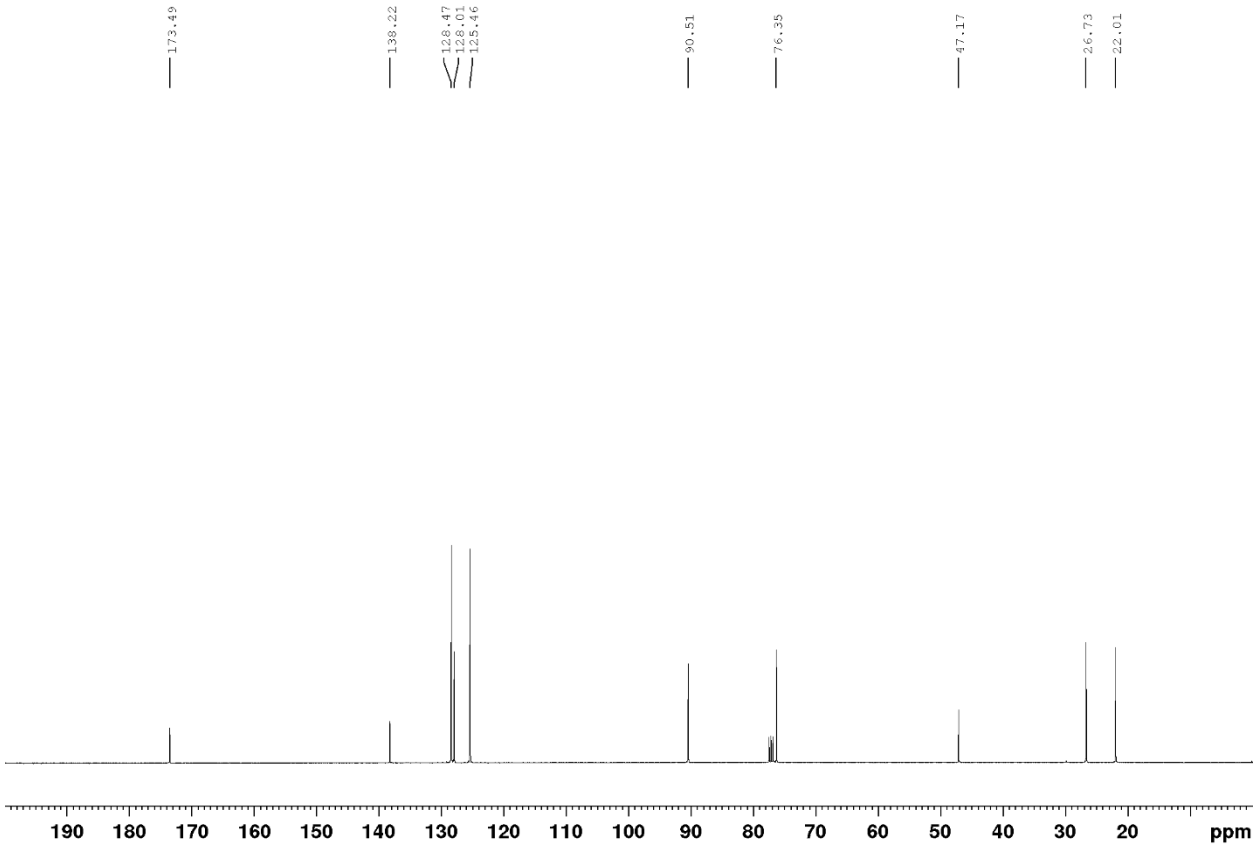

155.26
142.41
128.86
128.20
125.88
87.28
81.46
45.01
28.53
20.00
13.90

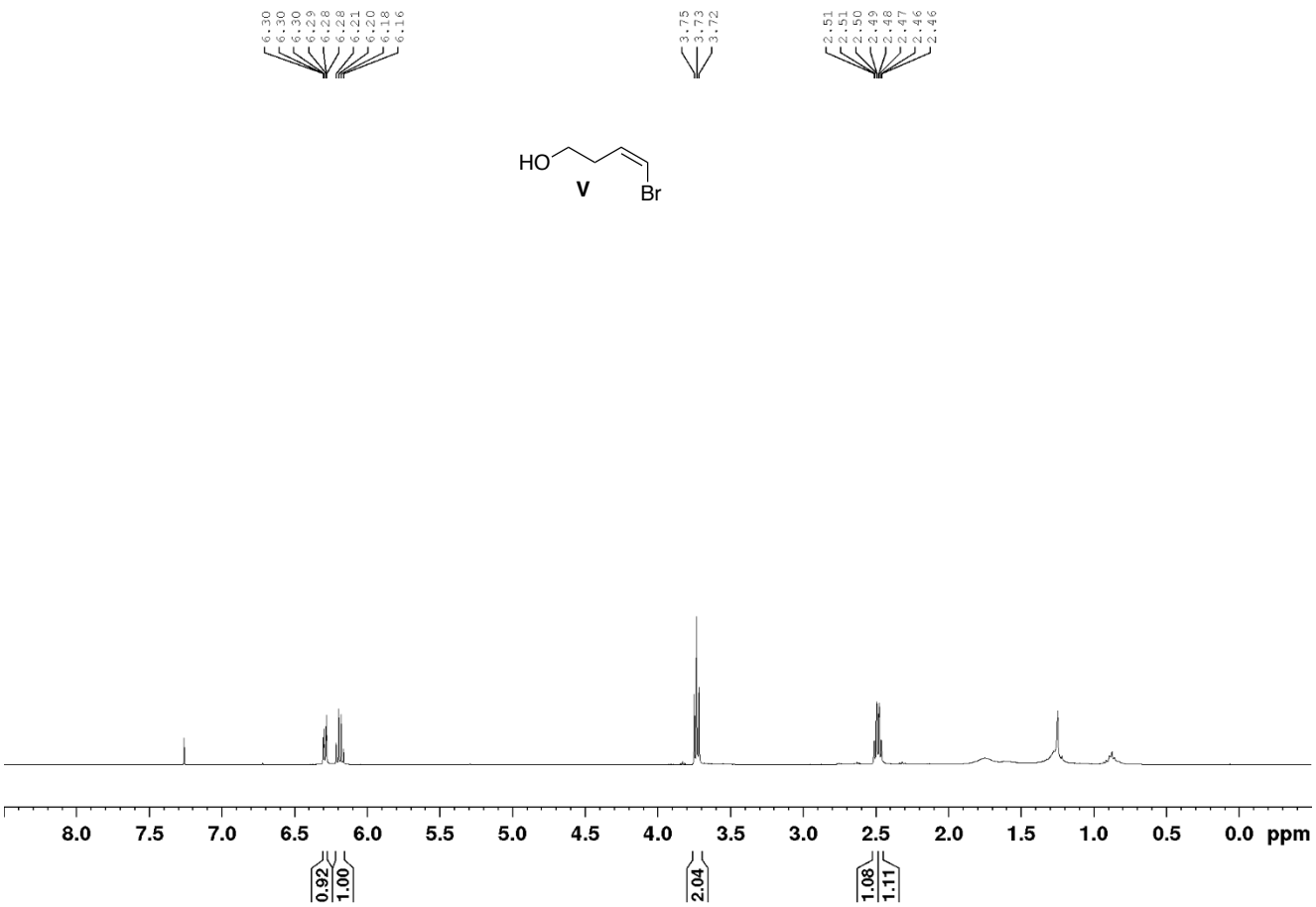

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

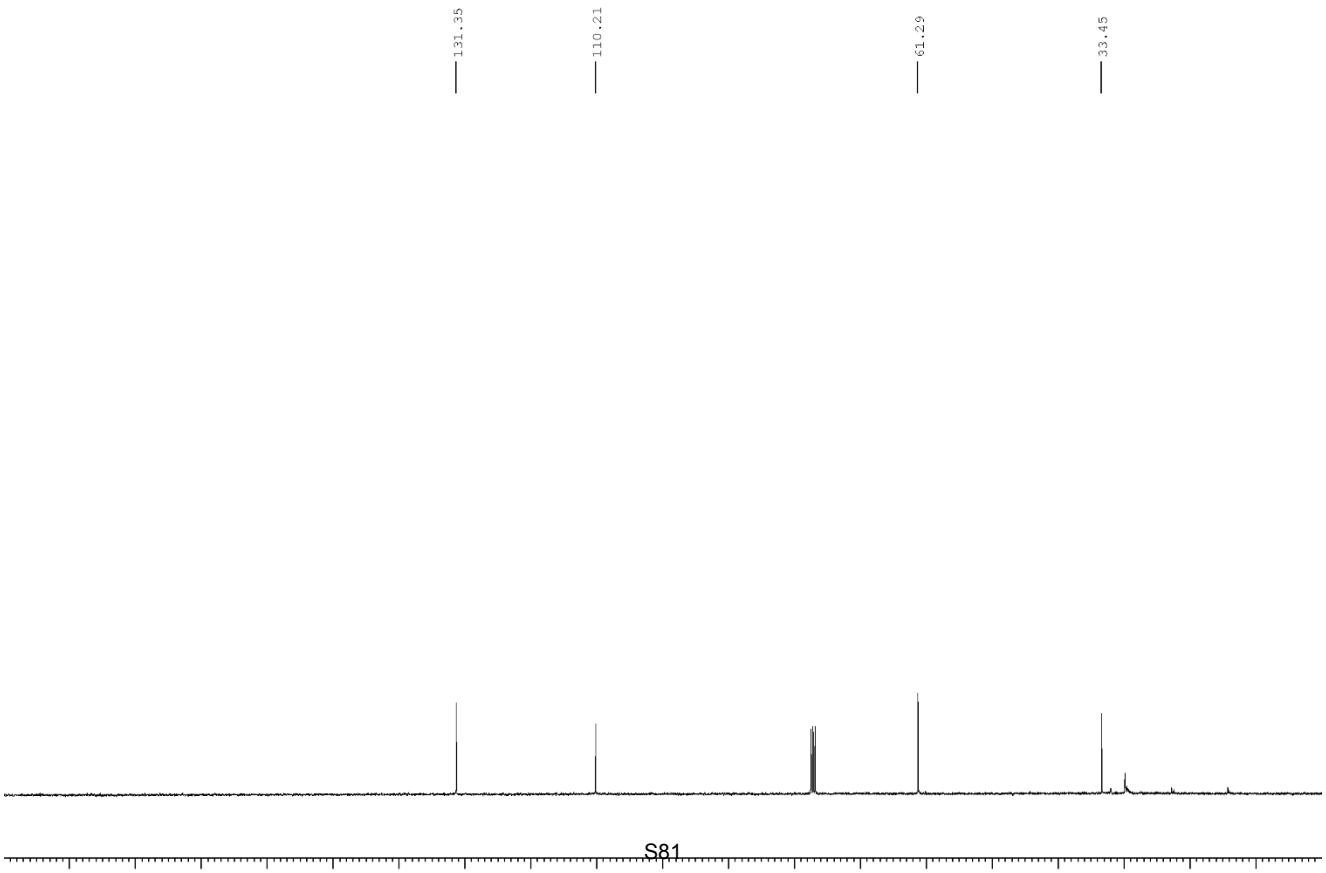

HSQC of **9**
ppm
20
40
60
80
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm

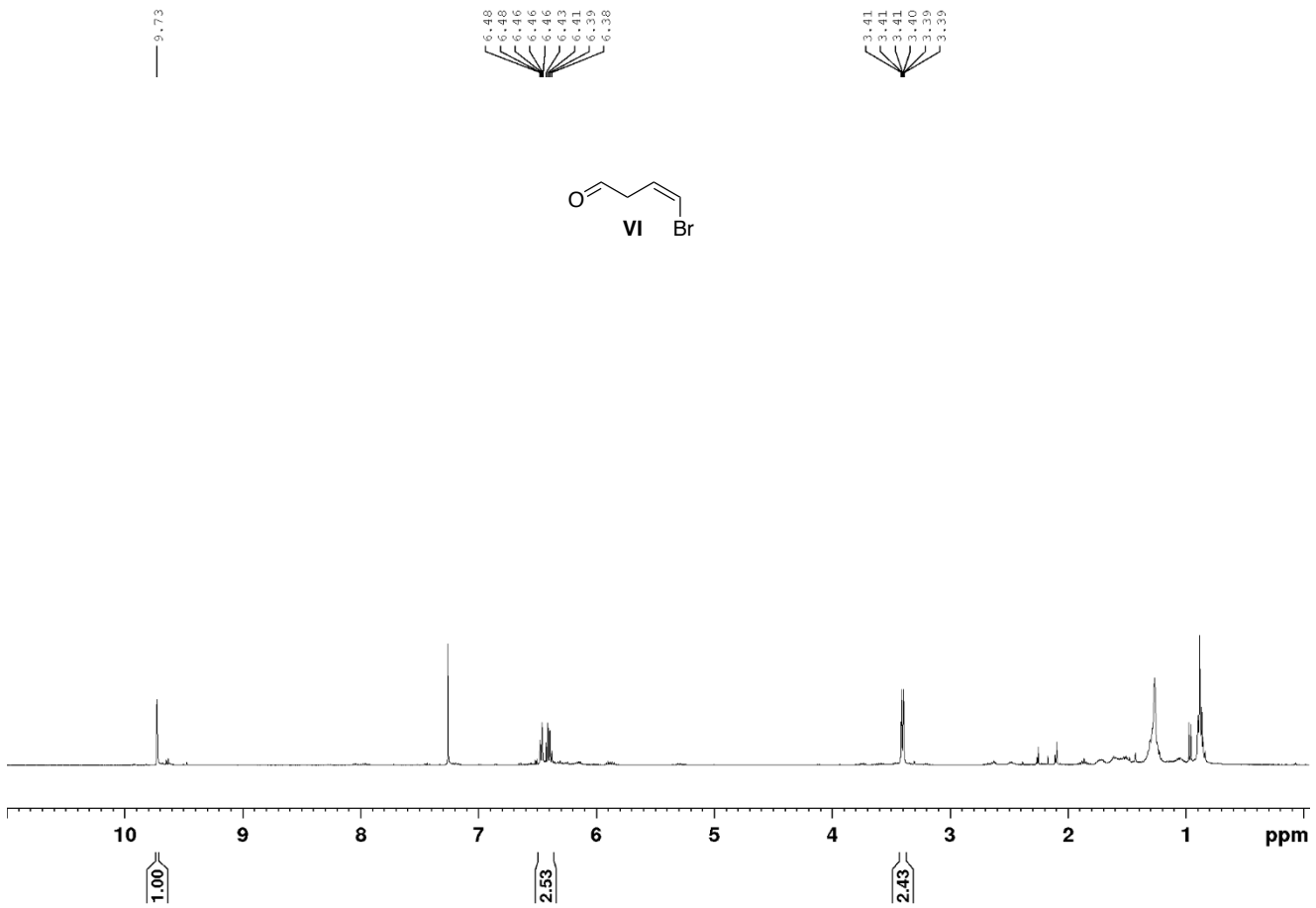

HMBC of **9**
ppm
20
40
60
80
100
120
140
160
180
8
7
6
5
4
3
2
1
0
ppm

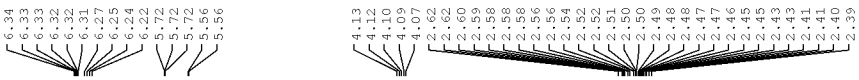

7.40
7.39
7.37
7.32
7.31
7.30
7.29
7.29
7.28
5.50
4.16
4.15
3.78
3.77
1.49
0.81
Ph
O
II
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
5.18
1.00
1.04
1.06
3.39
3.33


173.49
138.22
128.47
128.01
125.46
90.51
76.35
47.17
26.73
22.01
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm


6.30
6.30
6.30
6.29
6.28
6.28
6.21
6.20
6.18
6.16
3.75
3.73
3.72
2.51
2.51
2.50
2.49
2.48
2.47
2.46
2.46
HO
V
Br
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
ppm
0.92
1.00
2.04
1.08
1.11


131.35
110.21
61.29
33.45
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


9.73
6.48
6.48
6.46
6.46
6.46
6.43
6.41
6.39
6.38
3.41
3.41
3.41
3.40
3.39
3.39
O
VI
Br
10
9
8
7
6
5
4
3
2
1
ppm
1.00
2.53
2.43


6.34
6.33
6.33
6.32
6.32
6.31
6.27
6.25
6.24
6.22
5.72
5.72
5.72
5.56
5.56
4.13
4.12
4.10
4.09
4.07
2.62
2.62
2.60
2.59
2.58
2.58
2.58
2.56
2.56
2.54
2.52
2.52
2.51
2.50
2.50
2.49
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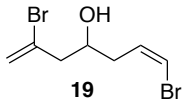
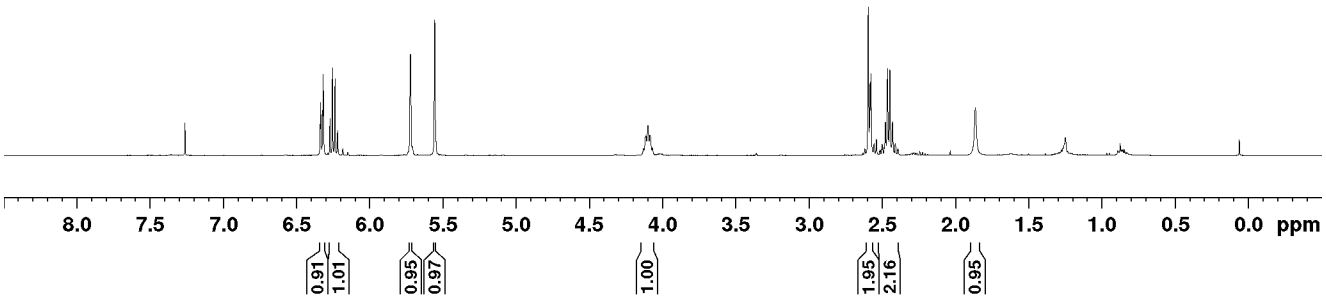
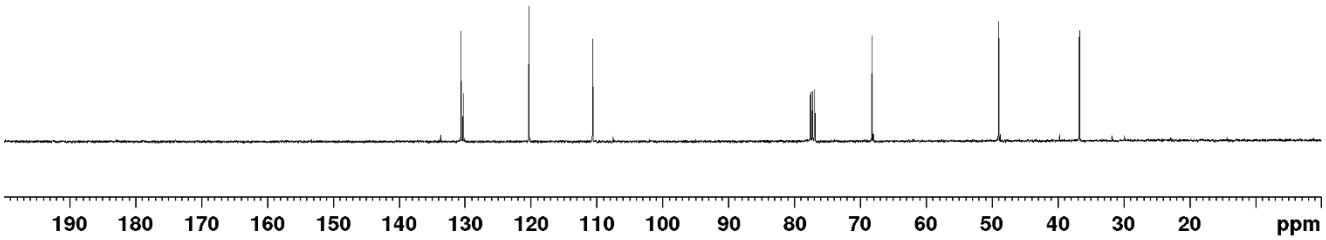
2.43
2.43
2.41
2.41
2.40
2.39


Br
OH
Br

19


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
ppm
0.91
1.01
0.95
0.97
1.00
1.95
2.16
0.95


130.65
130.27
120.28
110.63
68.20
48.99
36.73


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


6.37
6.36
6.22
6.21
6.19
6.17
4.90
4.89
4.87
4.86
4.84
4.15
4.15
4.14
4.14
4.13
3.78
3.78
3.77
3.77
3.76
3.29
3.29
3.28
3.28
3.27
3.27
3.26
3.25
3.25
3.24
3.23
3.23
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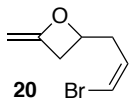
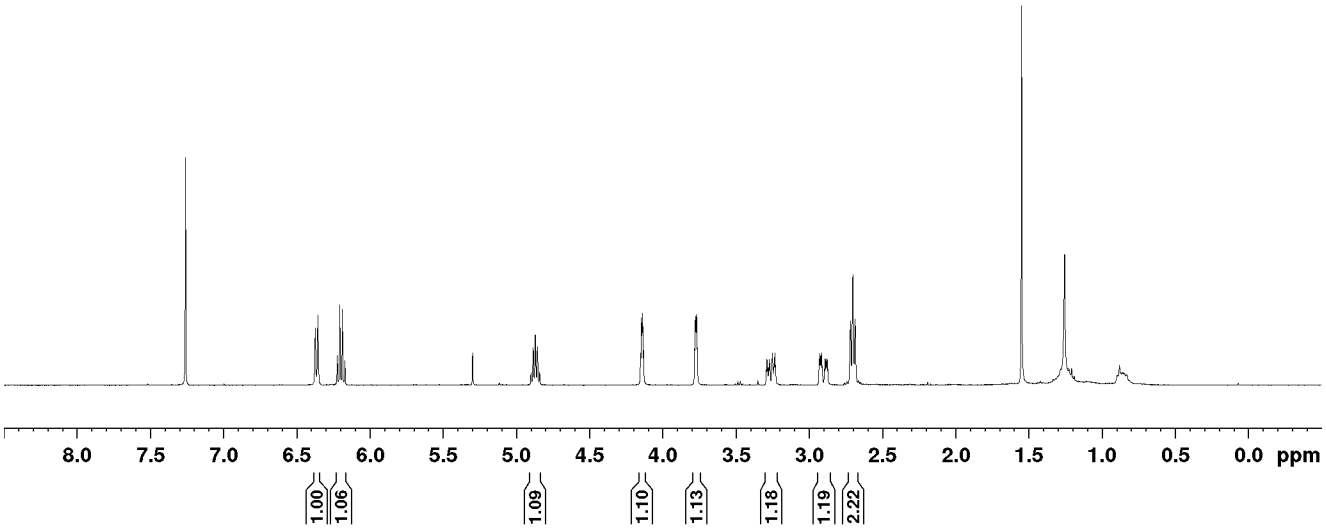
2.92
2.91
2.90
2.89
2.88
2.88
2.87
2.72
2.70
2.69


O
Br

20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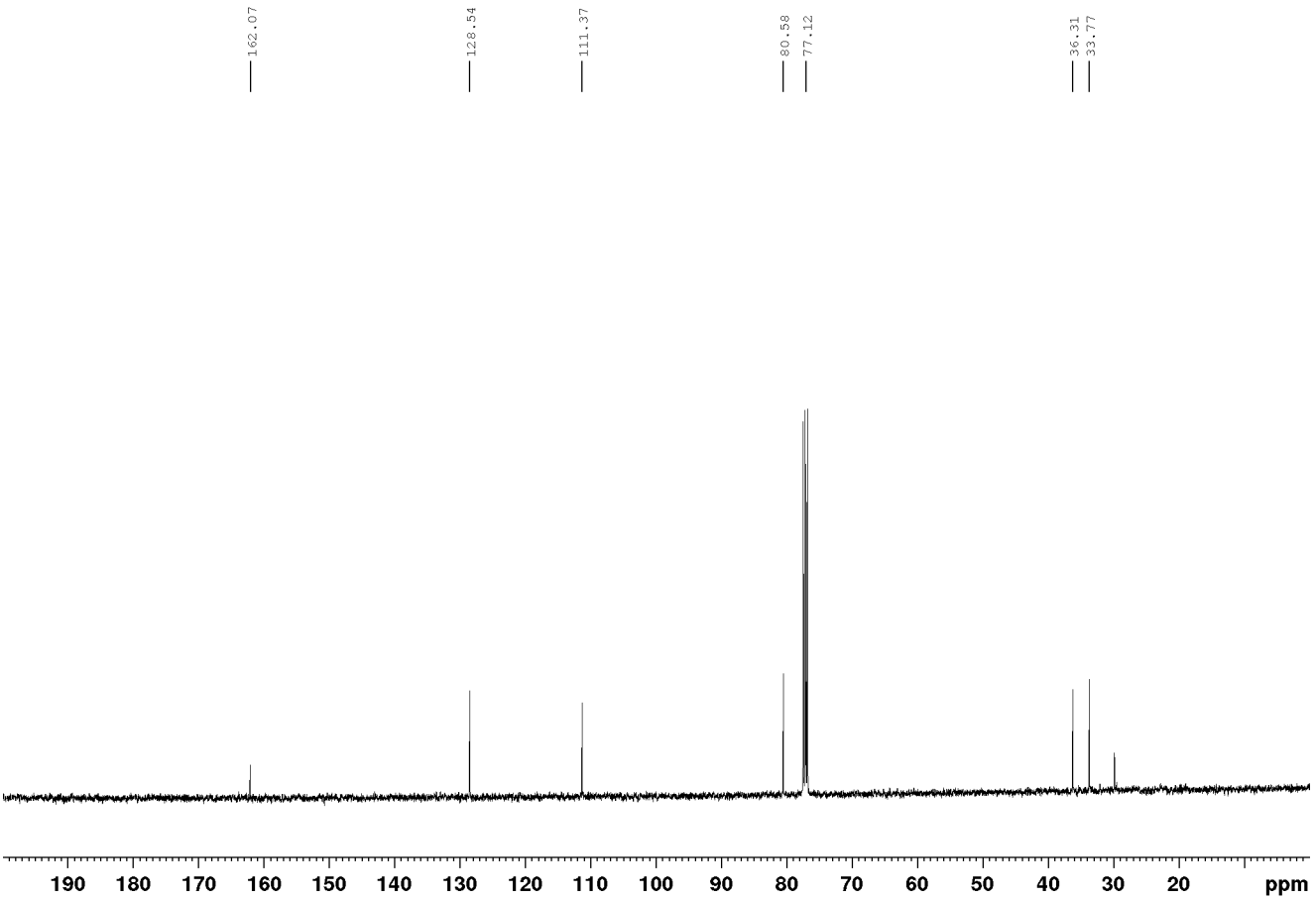
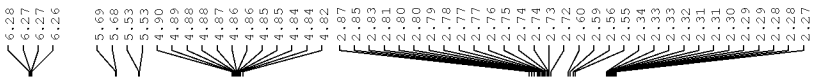
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.06
1.09
1.10
1.13
1.18
1.19
2.22


162.07
128.54
111.37
80.58
77.12
36.31
33.77
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm


6.28
6.27
6.27
6.26
5.69
5.68
5.53
5.53
4.90
4.89
4.88
4.88
4.87
4.86
4.86
4.85
4.85
4.84
4.84
4.82
2.87
2.85
2.83
2.81
2.80
2.80
2.79
2.78
2.77
2.76
2.75
2.74
2.74
2.73
2.72
2.60
2.59
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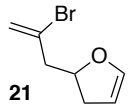
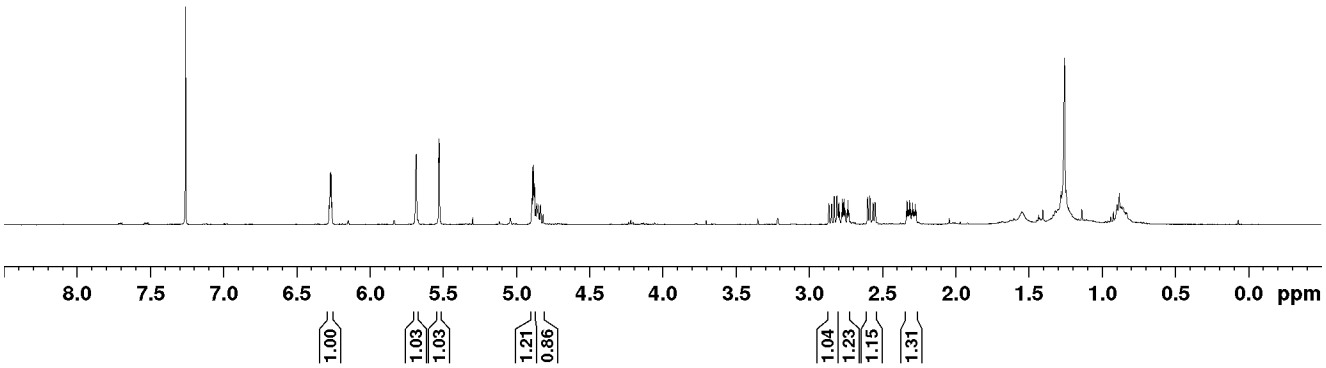
2.30
2.29
2.29
2.28
2.28
2.27


Br
O

21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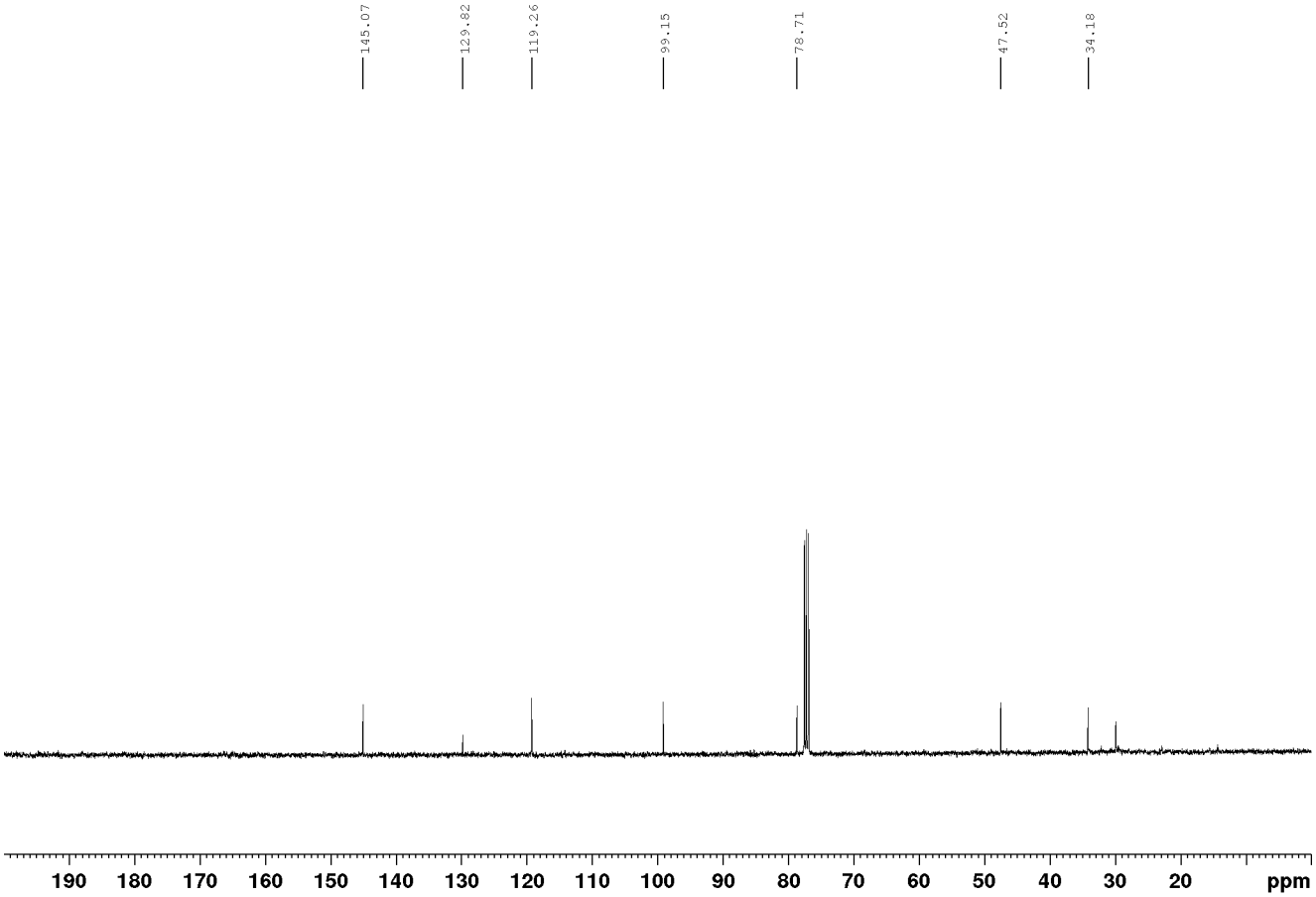
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.03
1.03
1.21
0.86
1.04
1.23
1.15
1.31


145.07
129.82
119.26
99.15
78.71
47.52
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190
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160
150
140
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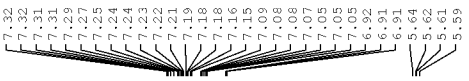
120
110
100
90
80
70
60
50
40
30
20
ppm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7.32
7.31
7.31
7.29
7.27
7.25
7.24
7.24
7.23
7.22
7.21
7.19
7.18
7.18
7.16
7.15
7.09
7.08
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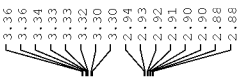
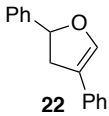
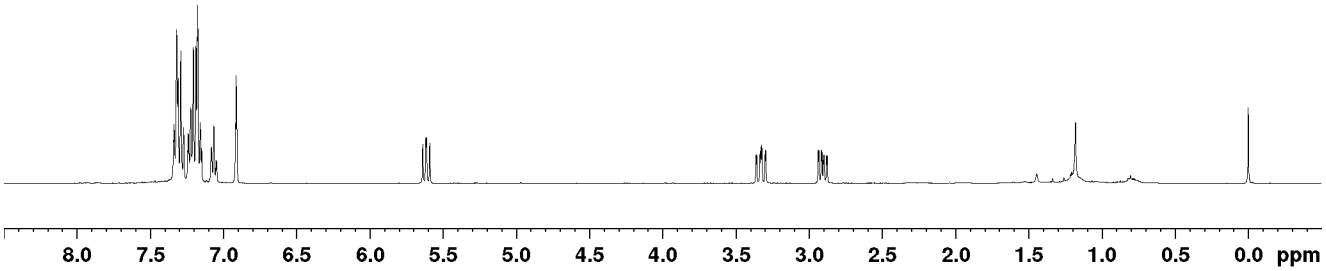
6.91
6.91
5.64
5.62
5.61
5.59


3.36
3.36
3.34
3.33
3.33
3.32
3.30
3.30
2.94
2.93
2.92
2.91
2.90
2.90
2.88
2.88


Ph
O
Ph

22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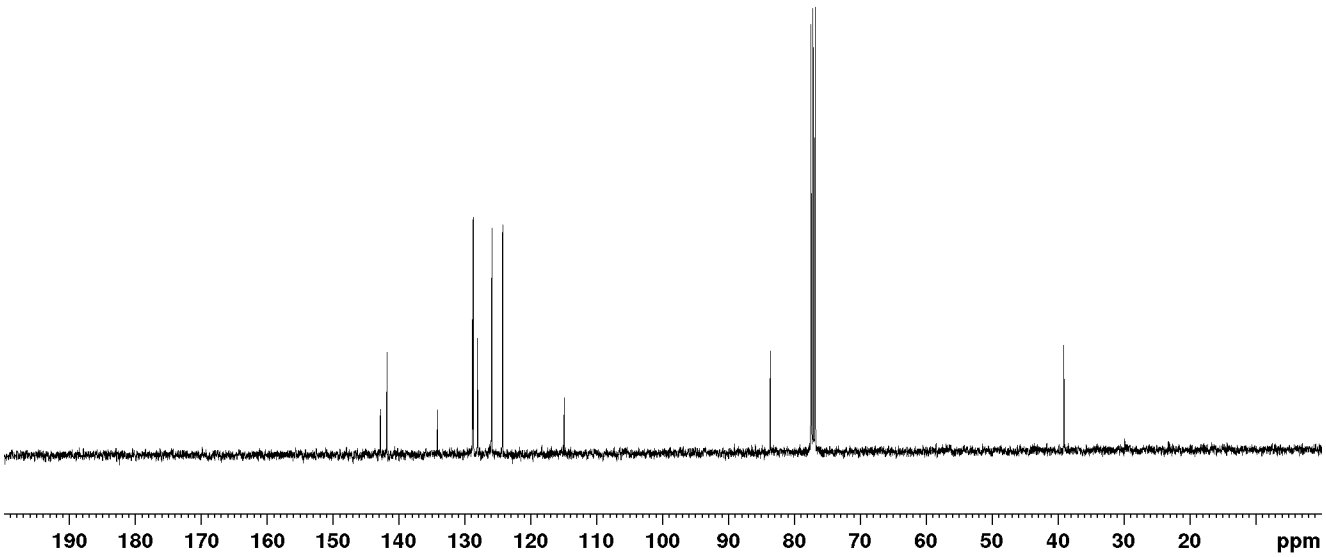
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm


142.78
141.80
134.19
128.87
128.76
128.14
126.03
125.94
124.33
115.00
83.71
39.16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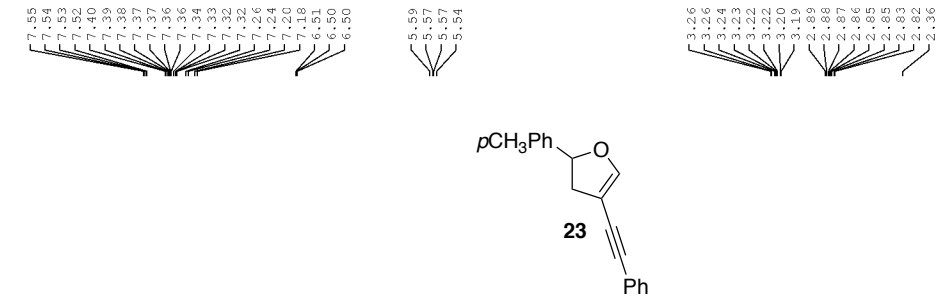
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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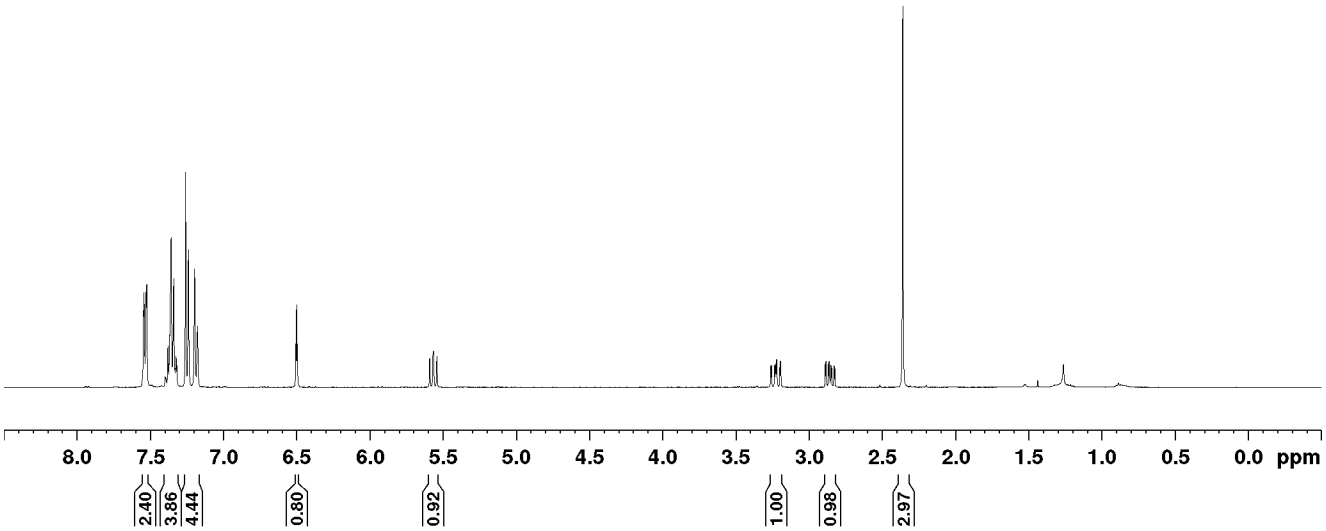
7.54
7.53
7.52
7.40
7.39
7.38
7.37
7.37
7.36
7.36
7.34
7.33
7.32
7.32
7.26
7.24
7.20
7.18
6.51
6.50
6.50
5.59
5.57
5.57
5.54
3.26
3.26
3.24
3.23
3.22
3.22
3.20
3.19
2.89
2.88
2.87
2.86
2.85
2.85
2.83
2.82
2.36

pCH3Ph
O
Ph

23


8.0
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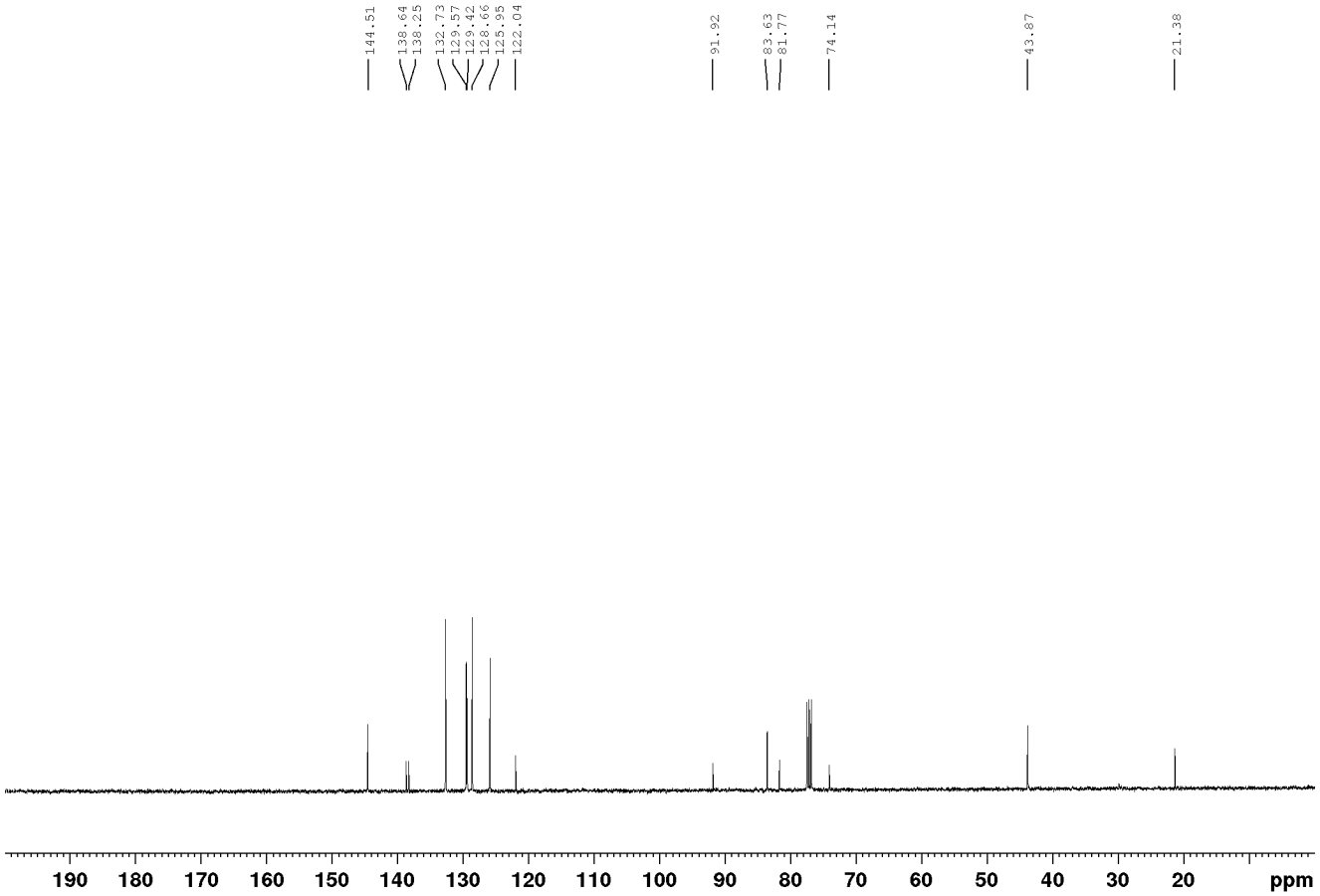
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.40
3.86
4.44
0.80
0.92
1.00
0.98
2.97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138.64
138.25
132.73
129.57
129.42
128.66
125.95
122.04
91.92
83.63
81.77
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43.87
21.38
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm