10.1071/CH20184_AC

Australian Journal of Chemistry 2020, 73(12), 1292-1295

SUPPLEMENTARY MATERIAL FOR

Studies on Thiourea Catalysed Bromocycloetherification and Bromolactonisations

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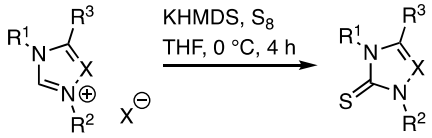
Contents

I. General information

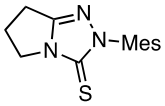
NMR spectra were recorded in $CDCl_3$ on a Bruker DRX400-NMR spectrometer operating at 400 MHz for proton and 101 MHz for carbon nuclei, or Bruker DRX600-NMR spectrometer operating at 600 MHz for proton and 151 MHz for carbon nuclei. Residual $CHCl_3$ was used as the internal standard for proton-NMR spectra (7.26 ppm), and the central peak in $CDCl_3$ triplet used for carbon-NMR spectra (77.16 ppm). Residual DMSO was used as the internal standard for proton-NMR spectra (3.34 ppm), and the central peak in DMSO septet used for carbon-NMR spectra (39.52 ppm). NMR data recorded as follows: chemical shift (δ) [multiplicity, coupling constant(s) *J* (Hz), relative integral], where multiplicity is defined: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, q = quintet, sept = septet or combinations thereof, and prefixed br = broad. Infrared spectra (υ_{max}) were recorded on a Perkin-Elmer RXI FTIR Spectrometer. High resolution mass spectrometry (HRMS, ESI) was performed on a Bruker BioApex 47e FTMS fitted with an Analytical electrospray source (ESI) and atmospheric pressure chemical ionization (APCI) using NaI for accurate mass calibration. Low resolution mass spectrometry (LRMS) was performed on Agilent 6120 Single Quadrupole fitted with multimode ionization source. Analytical chiral HPLC was performed with a Perkin Elmer Series 200 HPLC using a Chiralpak AD-H column (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd. with visualization at 210 nm. Flash column chromatography was performed on silica gel (Davsil LC60A, 40-63 μm silica media) using compressed air. Thin layer chromatography (TLC) was performed using aluminium-backed plates coated with 0.2 mm silica (Merck, DC-Platten, Kieselgel; 60 F254 plates). Eluted plates were visualised using a 254 nm UV lamp and/or by developing with a suitable stain following heating. Starting materials and reagents were purchased from Sigma-Aldrich, Oakwood Chemicals, Merck or Alfa-Aesar and were used as supplied without further purification. Dichloromethane (CH_2Cl_2) and tetrahydrofuran (THF) were purified prior to use by passing over activated alumina. HPLC grade chloroform was used directly for the reaction. 1,2-Dichloroethane was dried and distilled from calcium hydride (CaH_2). Concentration under reduced pressure was performed on a rotary evaporator with a water bath temperature of 40 °C, except for toluene where temperature was set to 60 °C.

II. General procedure for the synthesis of thiourea catalysts



To a stirred solution of the appropriate azolium salt **SI-I** (0.40 mmol, 1.0 equiv.) and sulfur (0.62 mmol, 1.5 equiv.) in dry THF was added KHMDS (0.5 M soln. in toluene, 1.20 mmol, 3.0 equiv.) dropwise at 0 ºC and the reaction mixture was allowed to stir at room temperature for 4 h. Upon completion, the reaction was quenched using sat. NH_4Cl (2.0 mL) and the solvents were evaporated. The aqueous layer was extracted with EtOAc (2 x 50 mL). Combined organic layers was washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography (0 – 20%, EtOAc:hexanes) to afford corresponding thiourea derivatives **A**-**D**. Thiourea catalysts **A1**,[1] **A2**,[2] **B**,[3] **C1**[4] have been previously reported.

2-Mesityl-2,5,6,7-tetrahydro-3*H*-pyrrolo[2,1-*c*][1,2,4]triazole-3-thione (C2)



Following the general procedure, the title compound was obtained as white solid (71% yield);

Melting Point: 114 – 116 ºC;

R_f = 0.21 (1:1 v/v EtOAc:hexanes);

IR υ_{max} 2986, 1587, 1386, 1304, 1013, 849 cm^{-1};

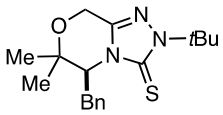
^{1}H-NMR (400 MHz, $CDCl_3$) δ 6.96 (s, 2H), 4.04 (t, *J* = 7.2 Hz, 2H), 3.06 (t, *J* = 7.8 Hz, 2H), 2.72 (pent, *J* = 7.6 Hz, 2H), 2.31 (s, 3H), 2.09 (s, 6H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 164.3, 157.0, 139.9, 136.3, 133.6, 129.2, 44.1, 26.1, 23.1, 21.3, 18.0;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 260.1201, $C_{14}H_{17}N_3S$ $[M+H]^+$, requires 260.1216.

1) T. K. Das, A. T. Biju, *Eur. J. Org. Chem.* **2017**, 4500
2) T. Horibe, Y. Tsuji, K. Ishihara, *ACS Catal*. **2018**, *8*, 6362.
3) D. Yang, Y. –C. Chen, N. Zhu, *Org. Lett.* **2004**, *6*, 1577
4) D. Enders, K. Breuer, G. Raabe, J. Runsink, J. Henrique Teles, J. P. Melder, K. Ebel, S. Brode, *Angew. Chem. Int. Ed. Engl*. **1995**, *34*, 1021.

(*S*)-5-Benzyl-2-(*tert*-butyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D1)



Following the general procedure, the title compound was obtained as white solid (71% yield);

Melting Point: 97 – 100 ºC;

R$_f$ = 0.55 (1:4 v/v EtOAc:hexanes);

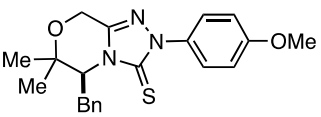
IR υ$_{max}$ 2981, 1455, 1365, 1087, 748, 704 cm^{-1};

^{1}H-NMR (600 MHz, $CDCl_3$) δ 7.36 – 7.31 (m, 2H), 7.25 – 7.20 (m, 2H), 7.20 – 7.15 (m, 1H), 4.59 – 4.46 (m, 3H), 3.31 – 3.17 (m, 2H), 1.80 (s, 9H), 1.30 (s, 3H), 1.19 (s, 3H);

^{13}C-NMR (151 MHz, $CDCl_3$) δ 163.6, 142.6, 138.0, 129.8, 128.2, 126.5, 74.9, 62.4, 59.9, 57.0, 34.8, 28.0, 26.5, 23.6;

HRMS (APCI) *m*/*z* found $[M+H]^+$, 332.1750, $C_{18}H_{25}N_3OS$ $[M+H]^+$, requires 332.1791.

(*S*)-5-Benzyl-2-(4-methoxyphenyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D2)



Following the general procedure, the title compound was obtained as white solid (87% yield);

Melting Point: 133 – 136 ºC;

R$_f$ = 0.38 (3:7 v/v EtOAc:hexanes);

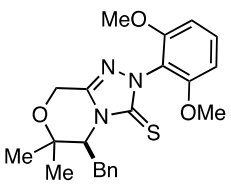
IR υ$_{max}$ 2979, 1512, 1448, 1344, 1250, 1063, 833 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.90 – 7.86 (m, 2H), 7.43 – 7.40 (m, 2H), 7.29 – 7.26 (m, 2H), 7.23 – 7.19 (m, 1H), 7.02 – 6.99 (m, 2H), 4.72 – 4.62 (m, 2H), 4.52 (dd, *J* = 6.3, 4.7 Hz, 1H), 3.86 (s, 3H), 3.32 – 3.28 (m, 2H), 1.31 (s, 3H), 1.28 (s, 3H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 164.9, 159.3, 145.0, 138.0, 131.2, 129.8, 128.4, 126.7, 125.6, 114.1, 75.0, 60.8, 57.0, 55.7, 35.1, 26.5, 23.6;

HRMS (APCI) *m*/*z* found $[M+H]^+$, 382.1539, $C_{21}H_{23}N_3O_2S$ $[M+H]^+$, requires 382.1584.

(*S*)-5-Benzyl-2-(2,6-dimethoxyphenyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D3)



Following the general procedure, the title compound was obtained as white solid (79% yield);

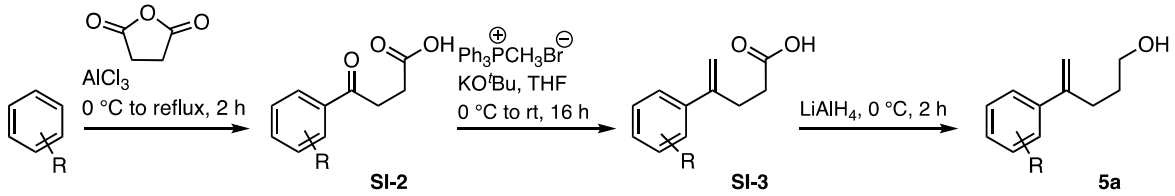
R$_f$ = 0.21 (3:7 v/v EtOAc:hexanes);

IR υ$_{max}$ 2977, 1601, 1482, 1262, 1113, 732 cm^{-1};

^{1}H-NMR (600 MHz, $CDCl_3$) δ 7.42 (t, *J* = 8.5 Hz, 1H), 7.37 – 7.32 (m, 2H), 7.27 – 7.23 (m, 2H), 7.22 – 7.17 (m, 1H), 6.70 (ddd, *J* = 8.5, 5.5, 1.0 Hz, 2H), 4.65 (d, *J* = 16.3 Hz, 1H), 4.49 (dd, *J* = 8.1, 1.9 Hz, 1H), 4.44 (d, *J* = 16.3 Hz, 1H), 3.88 (s, 3H), 3.82 (s, 3H), 3.48 (dd, *J* = 14.6, 8.1 Hz, 1H), 3.25 (dd, *J* = 14.7, 1.9 Hz, 1H), 1.39 (s, 3H), 1.29 (s, 3H);
^{13}C-NMR (151 MHz, $CDCl_3$) δ 167.7, 157.0, 156.9, 145.6, 137.7, 131.8, 130.0, 128.2, 126.5, 115.0, 104.7, 74.8, 60.7, 57.1, 56.5, 56.4, 34.5, 26.4, 23.9;
HRMS (ESI) *m/z* found $[M+H]^+$, 412.1654, $C_{22}H_{25}N_3O_3S$ $[M+H]^+$, requires 412.1689.

III. General procedure for the synthesis of olefinic alcohols 5

The olefinic alcohols **5** were prepared using a modified literature procedure[5] outlined below

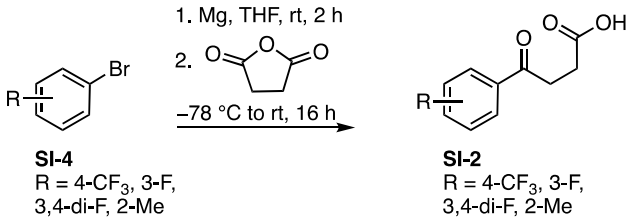


Preparation of keto acid SI-2

To a stirred solution of succinic anhydride (1.0 equiv.) and arene (1.0 equiv.) in dry CH_2Cl_2 under N_2 atmosphere anhydrous $AlCl_3$ (1.5 equiv.) was added in portions at 0 °C. The reaction mixture was stirred at the same temperature for 2 h and at room temperature for 16 h. Upon completion of reaction, the mixture was slowly poured onto ice and HCl (10 mL of concentrated) was added. The organic layer was separated and the aqueous layer was extracted with CH_2Cl_2 (2 x 30 mL). The combined organic layers were washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography (0 – 25%, EtOAc:hexanes) to afford **SI-2**.

5) D. Kawauchi, H. Ueda, H. Tokuyama, *Eur. J. Org. Chem*, **2019**, *10*, 2056

Preparation of keto acids SI-2 (Alternate method):



The series of keto acids **SI-2** displayed above were prepared using an alternate modified literature procedure.[6] Thus, to a stirred solution of aryl bromide (12.8 mmol, 1.0 equiv.) in dry THF (20 mL) Mg turnings (1.0 equiv.) was added and the reaction mixture was stirred at room temperature for 2 h. The resulting aryl magnesium bromide solution was added to a solution of succinic anhydride (1.0 equiv.) in dry THF (10 mL) at –78 °C. The reaction mixture was stirred at room temperature for 16 h, after 2 M HCl was added. The resulting white mass was filtered under diatomaceous earth and washed thoroughly with EtOAc. The organic layer was separated, washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography (0 – 35%, EtOAc:hexanes) to afford keto acid **SI-2**.

Preparation of olefins SI-3

To a stirred solution of KO^{t}Bu (2.6 equiv.) in dry THF (8 mL) was added bromo(methyl)triphenylphosphorane (1.3 equiv.) in portions at 0 °C and the resulting yellow reaction mixture was stirred for 0.5 h. A solution of keto acid, **SI-2** (4.0 mmol, 1.0 equiv.) in dry THF was added dropwise and the reaction mixture was stirred at 0 °C for 1 h and at room temperature for 16 h. Upon completion of the reaction, 2 M HCl was added and the aqueous layer was extracted with EtOAc. The organic layer was washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by silica-gel chromatography (0 – 30%, EtOAc:hexanes) to afford olefin carboxylic acid **SI-3**.

Preparation of alcohols 5

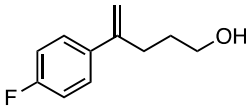
To a stirred solution of appropriate acid **SI-3** (1.0 mmol, 1.0 equiv.) in dry THF (4 mL) was added $LiAlH_4$ (2.1 equiv.) at 0 °C in portions and the reaction mixture was stirred at same temperature for 2 h. Upon completion of the reaction, NaOH (3.0 mL of a 2M aqueous solution)

6) N. Sakai, S. Horikawa, Y. Ogwara. *RSC Adv.* **2016**, *6*, 81763.

was added and the resulting curdy white precipitate was filtered under diatomaceous earth and washed with EtOAc. The organic layer was separated, washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography (0 – 25%, EtOAc:hexanes) to afford the corresponding alcohol.

Compounds **5a**,[7] **5b-5d**,[8] **5f**,[8] **5h**,[9] **5i-5j**,[8] **5k**[7] have been previously reported.

4-(4-Fluorophenyl)pent-4-en-1-ol (**5e**)



Following the general procedure, the title compound was obtained as colourless oil (78% yield);

$\mathbf{R_f}$ = 0.35 (2:3 v/v, EtOAc:hexanes);

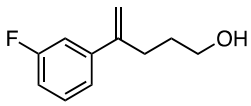
IR υ_{max} 3341, 2941, 1601, 1508, 1223, 1160, 837, 740 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.35 (m, 2H), 7.03 – 6.98 (m, 2H), 5.24 (d, *J* = 1.3 Hz, 1H), 5.08 (d, *J* = 1.3 Hz, 1H), 3.66 (t, *J* = 6.4 Hz, 2H), 2.60 – 2.55 (m, 2H), 1.74 – 1.67 (m, 2H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 163.5 (d, *J* = 247 Hz), 147.0, 137.1 (d, *J* = 3.2 Hz), 127.7 (d, *J* = 8.0 Hz), 115.3 (d, *J* = 21 Hz), 112.5 (d, *J* = 1.3 Hz), 62.5, 31.8, 31.2;

HRMS (ESI) *m/z* found $[M–OH]^+$, 163.0921, $C_{11}H_{13}FO$ $[M–OH]^+$, requires 163.0918.

4-(3-Fluorophenyl)pent-4-en-1-ol (**5g**)



Following the general procedure, the title compound was obtained as clear colourless oil (79% yield);

$\mathbf{R_f}$ = 0.36 (2:3 v/v, EtOAc:hexanes);

IR υ_{max} 3322, 2940, 1610, 1578, 1487, 1265, 873, 786 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.27 (m, 1H), 7.19 – 7.17 (m, 1H), 7.12 – 7.08 (m, 1H), 6.96 (td, *J* = 8.3, 2.6, 1H), 5.32 (d, *J* = 1.2 Hz, 1H), 5.14 (d, *J* = 1.3 Hz, 1H), 3.68 (t, *J* = 6.4 Hz, 2H), 2.63 – 2.54 (m, 2H), 1.77 – 1.68 (m, 2H);

7) A. Takemiya, J. F. Hartwig, *J. Am. Chem. Soc.* **2006**, *128*, 6042

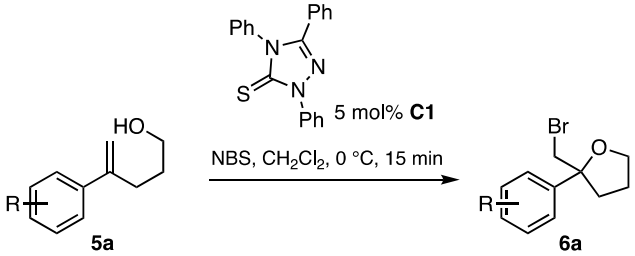
8) N. Tsuji, J. L. Kennemur, T. Buyck, S. Lee, S. Prévost, P. S. J. Kaib, D. Bykov, C. Farés, B. List, *Science*, **2018**, *359*, 1501.

9) A. –H. Ye, Y. Zhang, Y. –Y. Xie, H.-Y. Luo, J.-W. Dong, X. –D. Liu, X. –F. Song, T. Ding, Z. –M. Chen, *Org. Lett.* **2019**, *21*, 5106.

^{13}C-NMR (101 MHz, $CDCl_3$) δ 164.3 (d, *J* = 246 Hz), 147.0 (d, *J* = 2.1 Hz), 143.6 (d, *J* = 7.3 Hz), 129.9 (d, *J* = 8.4 Hz), 121.9 (d, *J* = 2.7 Hz), 114.4 (d, *J* = 21 Hz), 113.6, 113.3 (d, *J* = 21 Hz), 62.4, 31.6, 31.2;

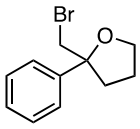
HRMS (ESI) *m*/*z* found $[M–OH]^+$, 163.0920, $C_{11}H_{13}FO$ $[M–OH]^+$, requires 163.0918.

IV. General procedure for bromocycloetherification of olefinic alcohols



To a stirred solution of 4-phenylpent-4-en-1-ol, **5a** (0.1 mmol) in CH_2Cl_2 (2 mL) at 0 ºC, was added catalyst **C1** (5 mol%) followed by NBS (1.1 equiv.) and the reaction mixture was stirred at 0 ºC for 15 min. Upon completion of the reaction, the mixture was diluted with CH_2Cl_2, washed with sat. Na_2SO_3 solution, H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under pressure. The crude residue was purified by column chromatography (0 – 10%, EtOAc:hexanes) to afford corresponding bromomethyl tetrahydrofuran derivatives. Compound **6a** has been previously reported.[10]

2-(Bromomethyl)-2-phenyltetrahydrofuran (6a)



Following the general procedure, the title compound was obtained as clear colourless oil (94% yield);

$\mathbf{R}_f$ = 0.58, (1:4 v/v, EtOAc:hexanes);

IR υ_{max} 2961, 1447, 1218, 1051, 759, 668 cm^{-1};

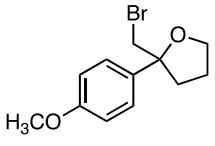
^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.39 (m, 2H), 7.38 – 7.32 (m, 2H), 7.31 – 7.27 (m, 1H) 4.12 – 4.06 (m, 1H), 3.96 – 3.93 (m, 1H), 3.65 (s, 2H), 2.46 – 2.39 (m, 1H), 2.29 – 2.23 (m, 1H), 2.09 – 2.02 (m, 1H), 1.88 – 1.81 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 144.1, 128.4, 127.5, 125.7, 85.4, 68.8, 42.3, 36.5, 26.3;

LRMS (ESI) *m*/*z* found $[M–^{79/81}Br]^+$, 161.1, $C_{11}H_{13}BrO$ $[M–^{79/81}Br]^+$, requires 161.1.

2-(Bromomethyl)-2-(4-methoxyphenyl)tetrahydrofuran (6b)

10) D. Böse, S.E. Denmark, *Synlett*, **2018**, *29*, 433.



Following the general procedure, the title compound was obtained as clear colourless oil (91% yield);

R_f = 0.54 (1:4 v/v, EtOAc:hexanes);

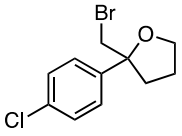
IR υ_{max} 2955, 2874, 1610, 1510, 1248, 1034, 831 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.33 (d, *J* = 8.7 Hz, 2H), 6.88 (d, *J* = 8.7 Hz, 2H), 4.12 – 4.02 (m, 1H), 3.94 – 3.88 (m, 1H), 3.81 (s, 3H), 3.62 (s, 2H), 2.43 – 2.36 (m, 1H), 2.24 – 2.20 (m, 1H), 2.08 – 2.01 (m, 1H), 1.88 – 1.81 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 159.0, 136.0, 126.9, 113.7, 85.1, 68.7, 55.4, 42.4, 36.3, 26.2;

HRMS (ESI) *m/z* found $[M+H]^+$, 271.0331, $C_{12}H_{15}{}^{81}BrO_2$ requires $[M+H]^+$, 271.0328.

2-(Bromomethyl)-2-(4-chlorophenyl)tetrahydrofuran (**6c**)



Following the general procedure, the title compound was obtained as clear colourless oil (82% yield);

R_f = 0.55, (1:4 v/v, EtOAc:hexanes);

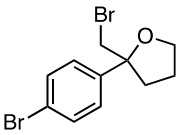
IR υ_{max} 2977, 1489, 1043, 823, 729 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.30 (m, 4H), 4.10 – 4.05 (m, 1H), 3.95 – 3.89 (m, 1H), 3.60 (s, 2H), 2.43 – 2.36 (m, 1H), 2.24 – 2.18 (m, 1H), 2.10 – 2.01 (m, 1H), 1.89 – 1.79 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 142.6, 133.4, 128.5, 127.2, 85.1, 68.8, 41.8, 36.7, 26.2;

HRMS (ESI) *m/z* found $[M-{}^{79/81}Br]^+$, 195.0566, $C_{11}H_{12}{}^{79/81}Br^{35}ClO$ $[M-{}^{79/81}Br]^+$, requires 195.0571.

2-(Bromomethyl)-2-(4-bromophenyl)tetrahydrofuran (**6d**)



Following the general procedure, the title compound was obtained as light-yellow oil (75% yield);

R_f = 0.46 (1:9 v/v, EtOAc:hexanes);

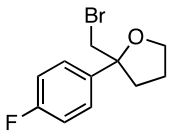
IR υ_{max} 2955, 2871, 1485, 1050, 817, 724, 683 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.48 – 7.46 (m, 2H), 7.31 – 7.28 (m, 2H), 4.10 – 4.05 (m, 1H), 3.95 – 3.90 (m, 1H), 3.60 (d, *J* = 1.2 Hz, 2H), 2.43 – 2.36 (m, 1H), 2.24 – 2.18 (m, 1H), 2.04 – 2.02 (m, 1H), 1.89 – 1.78 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 143.2, 131.5, 127.6, 121.6, 85.1, 68.8, 41.7, 36.7, 26.2;

HRMS (ESI) *m/z* Found $[M-{}^{79/81}Br]^+$, 239.0061, $C_{11}H_{12}{}^{79/81}Br_2O$ requires $[M-{}^{79/81}Br]^+$, 239.0066.

2-(Bromomethyl)-2-(4-fluorophenyl)tetrahydrofuran (6e)



Following the general procedure, the title compound was obtained as white solid (78% yield);

Melting Point: 64 – 66 ºC;

R_f = 0.58 (1:4 v/v, EtOAc:hexanes);

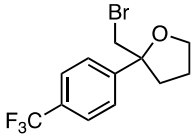
IR υ_{max} 2956, 1602, 1506, 1220, 1158, 833, 731 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.35 (m, 2H), 7.07 – 7.00 (m, 2H), 4.10 – 4.05 (m, 1H), 3.95 – 3.89 (m, 1H), 3.60 (s, 2H), 2.45 – 2.38 (m, 1H), 2.26 – 2.19 (m, 1H), 2.11 – 2.02 (m, 1H), 1.88 – 1.81 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 163.4 (d, *J* = 246 Hz), 139.8 (d, *J* = 3.0 Hz), 127.5 (d, *J* = 8.0 Hz), 115.2 (d, *J* = 21 Hz), 85.1, 68.8, 42.1, 36.6, 26.2;

HRMS (ESI) *m*/*z* found $[M-^{79/81}Br]^+$, 179.0866, $C_{11}H_{12}{}^{79/81}BrFO$ $[M-^{79/81}Br]^+$, requires 179.0867.

2-(Bromomethyl)-2-(4-(trifluoromethyl)phenyl)tetrahydrofuran (6f)



Following the general procedure, the title compound was obtained as clear colourless oil (74% yield);

R_f = 0.60 (1:4 v/v, EtOAc:hexanes);

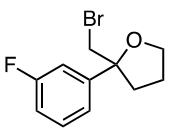
IR υ_{max} 2962, 1327, 1165, 1068, 846, 759 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.2 Hz, 2H), 7.54 (d, *J* = 8.2 Hz, 2H), 4.14 – 4.08 (m, 1H), 3.98 – 3.92 (m, 1H), 3.63 (d, *J* = 0.8 Hz, 2H), 2.47 – 2.41 (m, 1H), 2.28 – 2.22 (m, 1H), 2.12 – 2.05 (m, 1H), 1.90 – 1.82 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 148.2, 129.6, 126.2, 125.4 (q, *J* = 4.0 Hz), 122.9, 85.2, 69.0, 41.5, 36.9, 26.2;

LRMS (ESI) *m*/*z* found $[M-^{79/81}Br]^+$, 229.1, $C_{12}H_{12}{}^{79/81}BrF_3O$ $[M-^{79/81}Br]^+$, requires 229.1.

2-(Bromomethyl)-2-(3-fluorophenyl)tetrahydrofuran (6g)



Following the general procedure, the title compound was obtained as clear colourless oil (77% yield);

R_f = 0.52 (1:4 v/v, EtOAc:hexanes);

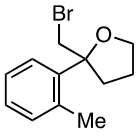
IR υ_{max} 2956, 1602, 1506, 1220, 1049, 833, 731 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.28 (m, 1H), 7.18 – 7.14 (m, 2H), 6.98 – 6.93 (m, 1H), 4.11 – 4.06 (m, 1H), 3.97 – 3.91 (m, 1H), 3.62 (s, 2H), 2.44 – 2.37 (m, 1H), 2.26 – 2.20 (m, 1H), 2.09 –2.03 (m, 1H), 1.88 – 1.83 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 164.2 (d, J = 246 Hz), 147.0 (d, J = 6.5 Hz), 129.9 (d, J = 8.1 Hz), 121.3 (d, J = 2.8 Hz), 114.5 (d, J = 21 Hz), 113.2 (d, J = 23 Hz), 85.1 (d, J = 1.8 Hz), 68.9, 41.7, 36.8, 26.2;

HRMS (ESI) *m*/*z* found $[M-^{79/81}Br]^+$, 179.0862, $C_{11}H_{12}{}^{79/81}BrFO$ requires $[M-^{79/81}Br]^+$, 179.0867.

2-(Bromomethyl)-2-(o-tolyl)tetrahydrofuran (**6h**)



Following the general procedure, the title compound was obtained as clear colourless oil (94% yield);

R$_f$ = 0.55 (1:4 v/v, EtOAc:hexanes);

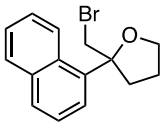
IR υ$_{max}$ 2973, 1453, 1046, 986, 761, 730, 667 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.62 (m, 1H), 7.21 – 7.15 (m, 3H), 4.15 – 4.10 (m, 1H), 3.81 – 3.75 (m, 2H), 3.67 (d, J = 8.0 Hz, 1H), 2.57 – 2.50 (m, 1H), 2.41 (s, 3H), 2.30 – 2.22 (m, 1H), 2.16 – 2.05 (m, 1H), 1.91 – 1.82 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 142.1, 134.2, 132.3, 127.7, 126.4, 126.0, 85.7, 68.0, 41.3, 36.5, 27.2, 21.5;

HRMS (ESI) *m*/*z* found $[M-^{79/81}Br]^+$, 175.1113, $C_{12}H_{15}{}^{79/81}BrO$ requires $[M-^{79/81}Br]^+$, 175.1117.

2-(Bromomethyl)-2-(naphthalen-1-yl)tetrahydrofuran (**6i**)



Following the general procedure, the title compound was obtained as light-yellow oil (96% yield).

R$_f$ = 0.58 (1:4 v/v, EtOAc:hexanes);

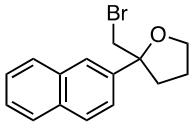
IR υ$_{max}$ 2970, 1509, 1215, 1046, 803, 776, 675 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 8.00 (d, J = 8.4 Hz, 1H), 7.89 (m, 2H), 7.79 (d, J = 8.1 Hz, 1H), 7.54 – 7.45 (m, 3H), 4.23 – 4.14 (m, 2H), 3.89 – 3.83 (m, 2H), 2.86 – 2.80 (m, 1H), 2.58 – 2.50 (m, 1H), 2.23 – 2.12 (m, 1H), 1.94 – 1.85 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 139.5, 134.9, 129.9, 129.6, 128.9, 125.9, 125.4, 125.3, 124.9, 124.2, 85.8, 67.8, 42.4, 37.0, 27.4;

HRMS (ESI) *m/z* found $[M-^{79/81}Br]^+$, 211.1113, $C_{15}H_{15}{}^{79/81}BrO$ requires $[M-^{79/81}Br]^+$, 211.1117.

2-(Bromomethyl)-2-(naphthalen-2-yl)tetrahydrofuran (6j)



Following the general procedure, the title compound was obtained as light-yellow oil (84% yield);

$\mathbf{R}_f$ = 0.60 (1:4 v/v, EtOAc:hexanes);

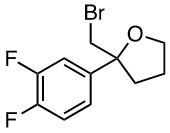
IR υ_{max} 2953, 1506, 1165, 1049, 816, 746, 674 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 1.0 Hz, 1H), 7.89 – 7.80 (m, 3H), 7.53 – 7.43 (m, 3H), 4.18 – 4.13 (m, 1H), 4.05 – 3.99 (m, 1H), 3.74 (s, 2H), 2.53 – 2.46 (m, 1H), 2.40 – 2.34 (m, 1H), 2.14 – 2.05 (m, 1H), 1.93 –1.84 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 141.3, 133.2, 132.7, 128.3, 128.2, 127.6, 126.3, 126.1, 124.6, 123.8, 85.5, 68.9, 42.1, 36.6, 26.3;

HRMS (ESI) *m/z* found $[M-^{79/81}Br]^+$, 211.1110, $C_{15}H_{15}{}^{79}BrO$ requires $[M-^{79/81}Br]^+$, 211.1117.

2-(Bromomethyl)-2-(3,4-difluorophenyl)tetrahydrofuran (6k)



Following the general procedure, the title compound was obtained as light-yellow oil (72% yield);

$\mathbf{R}_f$ = 0.55 (1:4 v/v, EtOAc:hexanes);

IR υ_{max} 2963, 1514, 1283, 1053, 774, 668 cm^{-1};

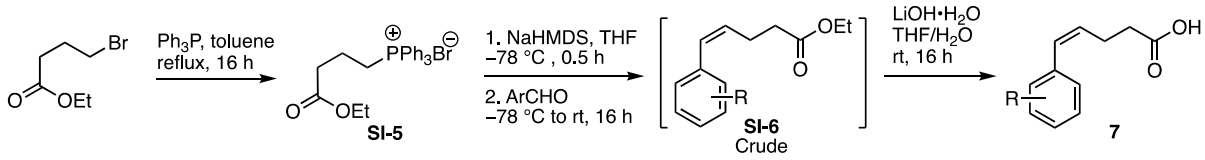
^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.24 (m, 1H), 7.16 – 7.09 (m, 2H), 4.10 – 4.04 (m, 1H), 3.96 – 3.90 (m, 1H), 3.61 – 3.55 (m, 2H), 2.42 – 2.35 (m, 1H), 2.23 – 2.17 (m, 1H), 2.11 – 2.01 (m, 1H), 1.90 – 1.80 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 151.2 (dd, *J* = 53.3, 12.7 Hz), 148.7 (dd, *J* = 53.3, 12.7 Hz), 141.3 (t, *J* = 4.1 Hz), 121.7 (dd, *J* = 6.3, 3.6 Hz), 117.1 (d, *J* = 17.3 Hz), 115.2 (d, *J* = 18.4 Hz), 84.8 (d, *J* = 1.4 Hz), 68.9, 41.5, 36.8, 26.2;

HRMS (ESI) *m/z* found $[M-^{79/81}Br]^+$, 197.0758, $C_{11}H_{11}{}^{79/81}BrF_2O$ requires $[M-^{79/81}Br]^+$, 197.0772.

V. General procedure for the synthesis of carboxylic acids 7

Following modified procedures reported by Yeung[11] and co-workers, carboxylic acids **7** were obtained in 3 steps. Compounds **7a-b**[11], **7d**[11] and **7f**[11] have been previously reported.



Preparation of ylide SI-5

To a solution of ethyl 4-bromobutyrate (10 mmol, 1.0 equiv.) in toluene (20 mL) was added triphenylphosphine (12.30 mmol, 1.2 equiv.) and the reaction mixture was allowed to stir at reflux for 16 h. Upon completion of reaction, Et_2O was added and the white solid was filtered and dried to obtain (4-ethoxy-4-oxobuty)triphenyl phosphonium bromide **SI-5** which was directly used for the next step without further purification.

Preparation of esters SI-6

To a solution of (4-ethoxy-4-oxobutyl)triphenylphosphonium bromide **SI-5** (1.66 mmol, 1.0 equiv.) in THF (8 mL) at –78 ºC was added sodium bis(trimethylsilyl) amide (1.0 M solution in THF, 1.2 equiv.) and the reaction was allowed to stir for 0.5 h. After this time, a solution of benzaldehyde (1.0 equiv.) in THF (3 mL) was added dropwise and the reaction mixture was slowly warmed to room temperature and stirred for 16 h. The reaction was quenched using NH_4Cl (4 mL of a saturated aqueous solution) and extracted with EtOAc (2X10 mL). The organic layer was separated and washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude product was directly used for the next step without purification.

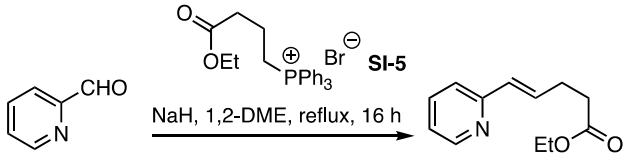
Preparation of acid 7

To a stirred solution of ester **SI-6** (0.5 mmol, 1.0 equiv.) in THF/H_2O (4 mL of a 1:1 mixture) was added LiOH•H_2O (2.0 equiv.) and the reaction mixture was stirred at room temperature for 16 h. Upon completion of the reaction, the organic solvent was removed under reduced pressure and the aqueous layer acidified to pH 3 with HCl (2M aqueous solution) and extracted using EtOAc (2X10 mL). The organic layer was separated and washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue

11) C. K. Tan, C. Le, Y. –Y. Yeung, *Chem. Commun*, **2012**, *48*, 5793.

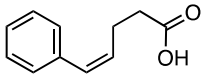
was purified by silica-gel chromatography (0–40% EtOAc:hexanes) to afford (*Z*)-olefin carboxylic acids **7**.

Preparation of Ethyl (*E*)-5-(pyridin-2-yl)pent-4-enoate



Ethyl (*E*)-5-(pyridin-2-yl)pent-4-enoate was obtained by following the procedure from Pertz, Elz[12] and co-workers. Thus, to a stirred suspension of NaH (60% dispersion in mineral oil, 2.3 mmol, 1.0 equiv.) in dry 1,2-DME (12 mL) at room temperature was added (4-ethoxy-4 oxobutyl)triphenylphosphonium bromide **SI-5** (2.3 mmol, 1.0 equiv.) and the reaction mixture was stirred for 0.5 h. Then, pyridine-2-carboxaldehyde (2.3 mmol, 1.0 equiv.) was added and the reaction mixture was stirred at reflux for 16 h. Upon completion of the reaction, the mixture was poured onto water and extracted using EtOAc (2 X 15 mL). The organic layer was washed with H_2O, brine, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by silica-gel chromatography (0–10%, EtOAc:hexanes) to afford ethyl (*E*)-5-(pyridin-2-yl)pent-4-enoate as the major product.

(*Z*)-5-Phenylpent-4-enoic acid (7a)[11]



Following the general procedure, the title compound was obtained as colourless oil (35% yield, over 2-steps);

R_f = 0.32 (2:3 v/v, EtOAc:hexanes);

IR υ_{max} 3020, 2924, 1698, 1446, 1210, 769, 699 cm^{-1};

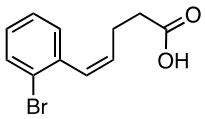
^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.36 – 7.23 (m, 2H), 7.30 – 7.26 (m, 2H), 7.25 – 7.19 (m, 1H), 6.49 (d, *J* = 11.6 Hz, 1H),5.65 – 5.62 (m, 1H), 2.70 – 2.62 (m, 2H), 2.51 – 2.47 (m, 2H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 177.3, 137.2, 130.6, 130.0, 128.8, 128.4, 126.9, 33.9, 23.9;

HRMS (ESI) *m*/*z* found $[M–H]^–$, 175.0753, $C_{11}H_{12}O_2$ requires $[M–H]^–$, 175.0765.

12) S. Menghin, H. H. Pertz, K. Kramer, R. Seifert, W. Schunack, S. Elz, *J. Med. Chem*, **2003**, *46*, 5458.

(*Z*)-5-(2-Bromophenyl)pent-4-enoic acid (7c)



Following the general procedure, the title compound was obtained as yellow oil (41% yield, over 2-stepsas a 1:4 *E*/*Z* mixture of isomers);

R*f* = 0.28 (2:3 v/v, EtOAc:hexanes);

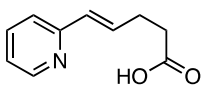
IR υmax 3017, 2915, 1702, 1431, 1277, 759, 701 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.59 – 7.56 (m, 1H), 7.28 – 7.25 (m, 2H), 7.13 – 7.09 (m, 1H), 6.51 (dt, *J* = 11.4, 1.6 Hz, 1H), 5.78 – 5.72 (m, 1H), 2.60 – 2.43 (m, 4H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 178.2, 137.3, 132.7, 131.0, 130.5, 130.3, 128.6, 127.1, 124.0, 33.7, 23.7;

HRMS (ESI) *m*/*z* found $[M–H]^–$, 252.9884, $C_{11}H_{11}{}^{79}BrO_2$ requires $[M–H]^–$, 252.9870.

(*E*)-5-(Pyridin-2-yl)pent-4-enoic acid (7e)



Following the general procedure, the title compound was obtained as white solid (76% yield);

Melting Point: 51 – 54 ºC;

R*f* = 0.15 (1:1 v/v, EtOAc:hexanes);

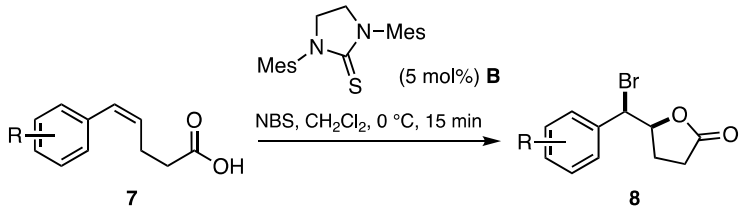
IR υmax 3011, 2932, 1689, 1595, 1434, 963, 756 cm^{-1};

^{1}H-NMR (400 MHz, DMSO-d_6) δ 12.17 (br s, 1H), 8.52 (d, *J* = 4.8 Hz, 1H), 7.75 (td, *J* = 7.7, 1.7 Hz, 1H), 7.39 (d, *J* = 7.9 Hz, 1H), 7.24–7.21 (m, 1H), 6.82–6.75 (m, 1H), 6.51 (d, *J* = 15 Hz, 1H), 2.50–2.45 (m, 4H);

^{13}C-NMR (101 MHz, DMSO-d_6) δ 173.6, 154.9, 149.1, 136.5, 133.5, 130.2, 121.9, 121.0, 33.0, 27.4;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 178.0863, $C_{10}H_{11}NO_2$ requires $[M+H]^+$, 178.0863.

VI. General procedure for bromolactonisation of olefinic acids



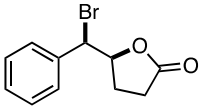
7 8

To a stirred solution of appropriate olefinic acid **7** (0.1 mmol, 1.0 equiv.) in CH_2Cl_2 (1.0 mL) at 0 ºC was added 1,3-dimesitylimidazolidine-2-thione **B** (5 mol%) followed by NBS (1.1 equiv.) and the reaction mixture was stirred for 15 min. Upon completion of reaction, the

mixture was diluted with CH_2Cl_2 and washed with sat. Na_2SO_3 solution, H_2O, brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by silica-gel chromatography (0–40%, EtOAc:hexanes) to afford corresponding lactones.

Compounds **8a-b**,[13] **8d**,[13] **9**[14] have been previously reported.

5-(Bromo(phenyl)methyl)dihydrofuran-2(3*H*)-one (8a)[13]



Following the general procedure, the title compound was obtained as white solid (63% yield);

Melting Point: 132 – 134 ºC;

R_f = 0.42 (2:3 v/v, EtOAc:hexanes);

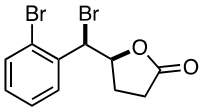
IR υ_{max} 2929, 1771, 1458, 1169, 1028, 915, 703 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.45 (m, 2H), 7.39 – 7.32 (m, 3H), 4.99 (d, *J* = 5.4 Hz, 1H), 4.94 – 4.89 (m, 1H), 2.55 – 2.34 (m, 2H), 2.24 – 2.20 (m, 1H), 2.11 – 2.02 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 176.0, 136.9, 129.3, 129.0, 128.6, 82.1, 55.2, 28.4, 25.7;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 255.0004, $C_{11}H_{11}BrO_2$ requires $[M+H]^+$, 255.0015.

5-(Bromo(2-bromophenyl)methyl)dihydrofuran-2(3*H*)-one (8c)



Following the general procedure, the title compound was obtained as colourless oil (58% yield);

R_f = 0.45 (2:3 v/v, EtOAc:hexanes);

IR υ_{max} 2935, 1778, 1168, 1028, 762, 731 cm^{-1};

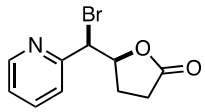
^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.76 (dd, *J* = 7.9, 1.6 Hz, 1H), 7.56 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.36 (td, *J* = 7.6, 1.1 Hz, 1H), 7.19 (ddd, *J* = 8.0, 7.4, 1.6 Hz, 1H), 5.51 (d, *J* = 4.8 Hz, 1H), 4.88 – 4.83 (m, 1H), 2.76–2.67 (m, 1H), 2.61– 2.52 (m, 1H), 2.37 – 2.26 (m, 1H), 2.17 – 2.08 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 175.9, 137.2, 133.1, 131.2, 130.5, 128.5, 123.1, 81.4, 54.3, 28.4, 26.5;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 332.9122, $C_{11}H_{10}{}^{79}Br^{81}BrO_2$ requires $[M+H]^+$, 332.9120.

13) J. D. Griffin, C. L. Cavanaugh, D. A. Nicewicz, *Angew. Chem. Int. Ed.* **2017**, *56*, 2097.
14) S. Einaru, K. Shitamichi, T. Nagano, A. Matsumoto, K. Asano, S. Matsubara, *Angew. Chem. Int. Ed.* **2018**, *57*, 13863.

5-(Bromo(pyridin-2-yl)methyl)dihydrofuran-2(3*H*)-one (8e)



Following the general procedure, the title compound was obtained as white solid (68% yield);

Melting Point: 55 – 59 ºC;

R_f = 0.22 (2:3 v/v, EtOAc:hexanes);

IR υ_{max} 2927, 1777, 1437, 1174, 916, 749 cm^{-1};

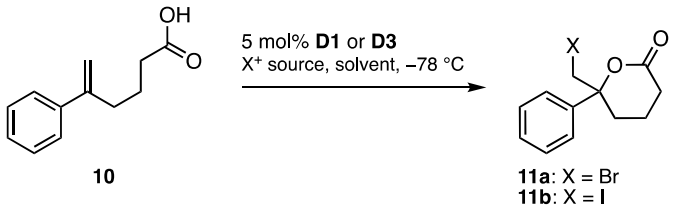
^{1}H-NMR (400 MHz, $CDCl_3$) δ 8.64 – 8.57 (m, 1H), 7.71 (td, *J* = 7.7, 1.8 Hz, 1H), 7.44 (dt, *J* = 7.9, 1.1 Hz, 1H), 7.26 – 7.23 (m, 1H), 5.26 (t, *J* = 7.0 Hz, 1H), 5.09 (d, *J* = 7.2 Hz, 1H), 2.66 – 2.52 (m, 3H), 2.42 – 2.30 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 176.3, 156.2, 149.5, 137.4, 123.8, 123.8, 80.5, 54.9, 28.7, 26.5;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 255.9954, $C_{10}H_{10}{}^{79}BrNO_2$ requires $[M+H]^+$, 255.9968.

VII. General procedure for enantioselective halolactonisation of 10.

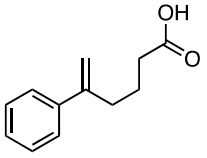
Compound **10**,[15] **11a**[15] and **11b**[16] have been previously reported.



To a stirred solution of olefinic acid **10** (0.1 mmol, 1.0 equiv.) in appropriate solvent (1.0 mL) at –78 ºC was added thiourea catalyst **D1** or **D3** (5 mol%) followed by X^+ source (1.1 equiv.) and the reaction mixture was stirred for 16-48 h. Upon completion of reaction, the mixture was diluted with CH_2Cl_2 and washed with sat. Na_2SO_3 solution, H_2O, brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The crude residue was purified by silica-gel chromatography (0–45%, EtOAc:hexanes) to afford corresponding lactones.

5-Phenylhex-5-enoic acid (10)[15]

15) K. Murai, T. Matsushita, A. Nakamura, S. Fukushima, M. Shimura, H. Fujioka, *Angew. Chem., Int. Ed*, *49*, **2010**, 9174.
16) G. E. Veitch, E. N. Jacobsen, *Angew. Chem. Int. Ed.* **2010**, *49*, 7332.



Following the general procedure, the title compound was obtained as white solid (79% yield);

Melting Point: 52 – 54 ºC;

R_f = 0.28 (3:7 v/v EtOAc:hexanes);

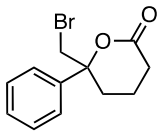
IR υ_{max} 3056, 2932, 1707, 1412, 1260, 899 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.37 (m, 2H), 7.36 – 7.30 (m, 2H), 7.29 – 7.26 (m, 1H), 5.31 (d, *J* = 1.4 Hz, 1H), 5.08 (d, *J* = 1.4 Hz, 1H), 2.58 (t, *J* = 7.4 Hz, 2H), 2.38 (t, *J* = 7.4 Hz, 2H), 1.81 (q, *J* = 7.5 Hz, 2H);

^{13}C-NMR (151 MHz, $CDCl_3$) δ 178.6, 147.4, 140.8, 128.5, 127.6, 126.2, 113.2, 34.6, 33.1, 23.1;

HRMS (ESI) *m*/*z* found $[M–H]^–$, 189.0932, $C_{12}H_{14}O_2$ $[M–H]^–$, requires 189.0921.

6-(Bromomethyl)-6-phenyltetrahydro-2*H*-pyran-2-one (11a)[15]



Following the general procedure, the title compound was obtained as white solid (73% yield);

Melting Point: 80 – 81 ºC;

R_f = 0.46 (2:3 v/v EtOAc:hexanes);

HPLC: Daicel AD-H, hexane : *i*PrOH 95:05, 1.0 ml/min, λ = 210 nm, fraction t_r = 15.70 and 17.08; er = 48.5:51.5;

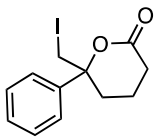
IR υ_{max} 2962, 1740, 1262, 1231, 1045, 769, 703 cm^{-1};

^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.31 (m, 5H), 3.71 – 3.59 (m, 2H), 2.54 – 2.30 (m, 4H), 1.88 – 1.78 (m, 1H), 1.66 – 1.52 (m, 1H);

^{13}C-NMR (101 MHz, $CDCl_3$) δ 170.5, 140.4, 129.1, 128.6, 125.5, 85.2, 41.6, 30.1, 29.2, 16.3;

HRMS (ESI) *m*/*z* found $[M+H]^+$, 269.0175, $C_{12}H_{13}{}^{79}BrO_2$ $[M+H]^+$, requires 269.0172.

6-(Iodomethyl)-6-phenyltetrahydro-2*H*-pyran-2-one (11b)[16]



Following the general procedure, the title compound was obtained as light yellow solid (67%);

R_f = 0.36 (3:7 v/v EtOAc:hexanes);

HPLC: Daicel AD-H, hexane : *i*PrOH 97:03, 1.0 ml/min, λ = 210 nm, fraction t_r = 20.57 and 22.43; er = 48.3:51.7;

IR υ_{max} 2958, 1738, 1258, 1038, 765, 701 cm^{-1};

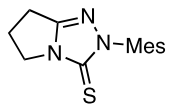
^{1}H-NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.32 (m, 5H), 3.57 (d, *J* = 1.3 Hz, 2H), 2.53 – 2.32 (m, 4H), 1.86 – 1.79 (m, 1H), 1.63 – 1.54 (m, 1H);

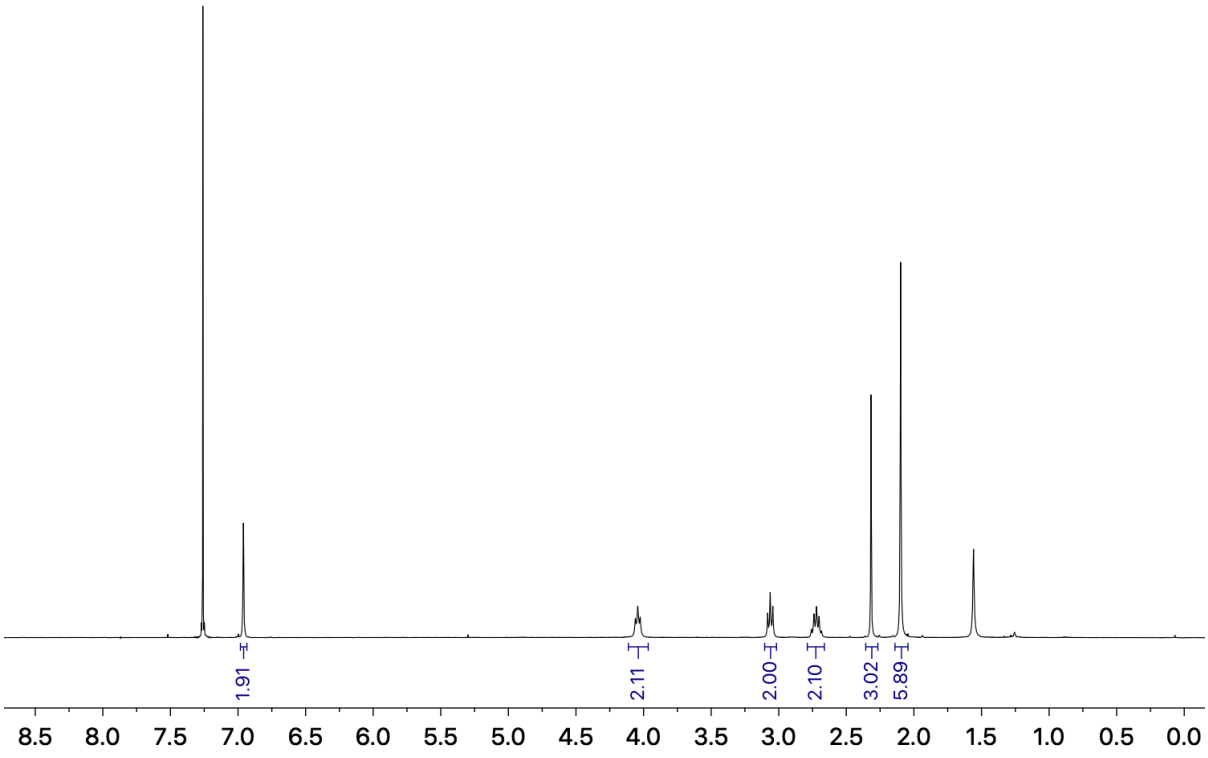
^{13}C-NMR (101 MHz, $CDCl_3$) δ 170.5, 140.3, 129.1, 128.5, 125.3, 84.5, 32.2, 29.1, 17.7, 16.7;

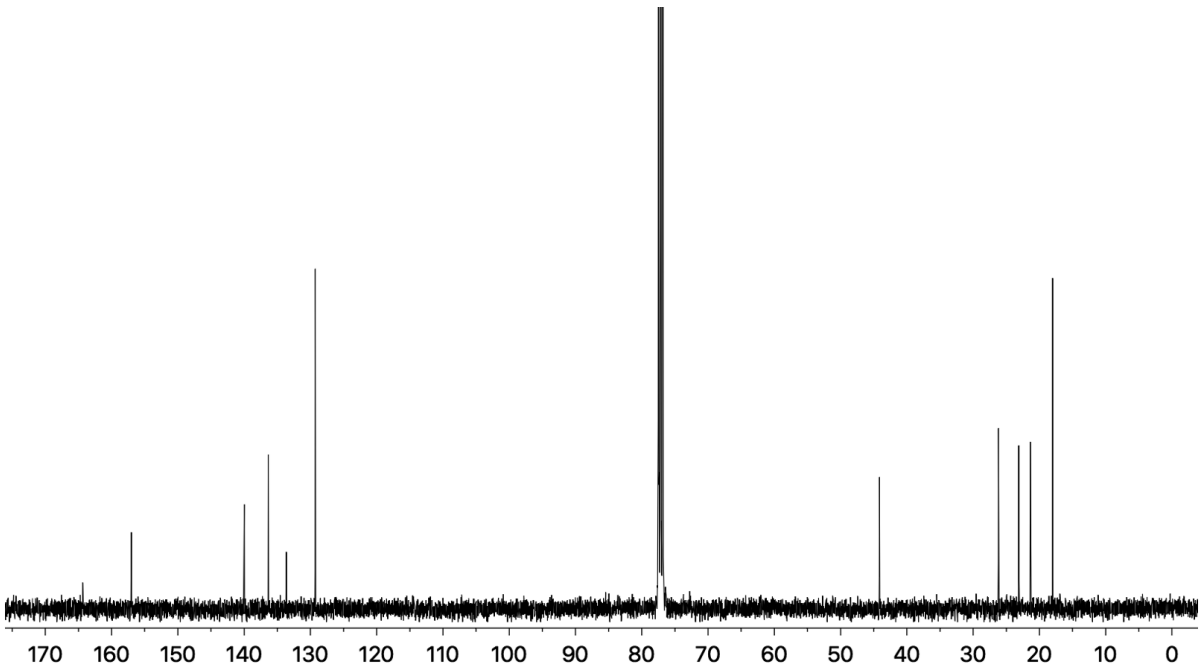
HRMS (ESI) *m*/*z* found $[M+H]^+$, 317.0028, $C_{12}H_{13}IO_2$ $[M+H]^+$, requires 317.0033.

VII. ^{1}H and ^{13}C NMR spectra

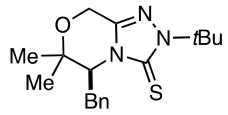
2-Mesityl-2,5,6,7-tetrahydro-3*H*-pyrrolo[2,1-*c*][1,2,4]triazole-3-thione (C2)

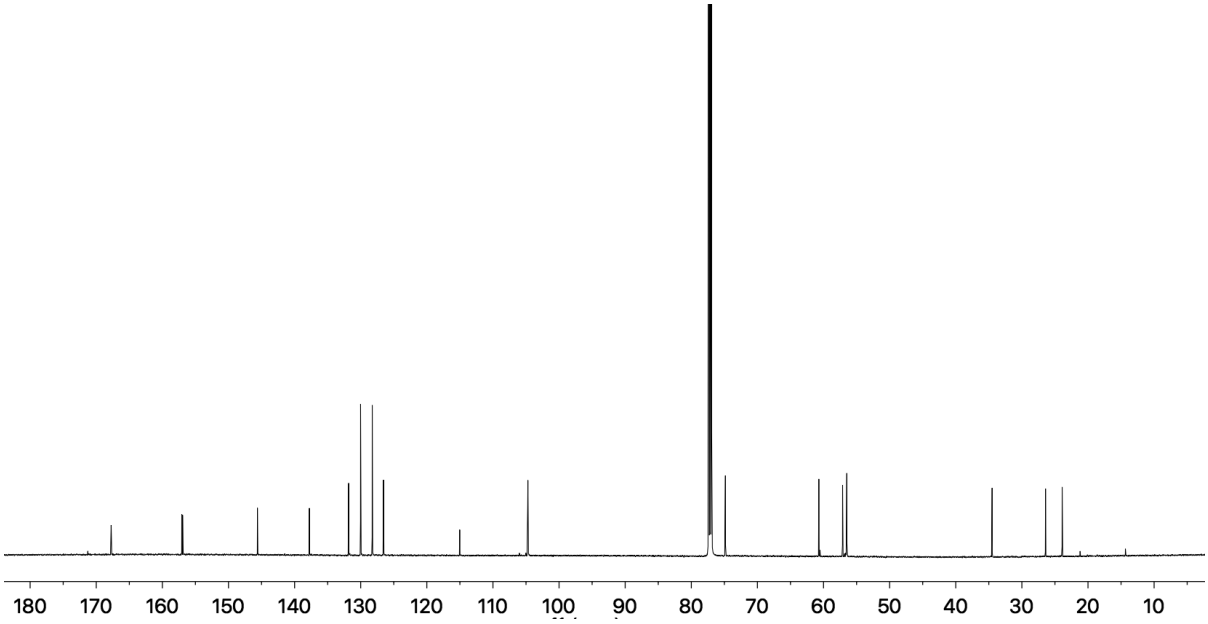




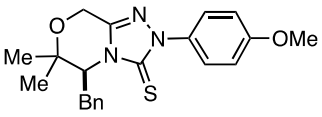


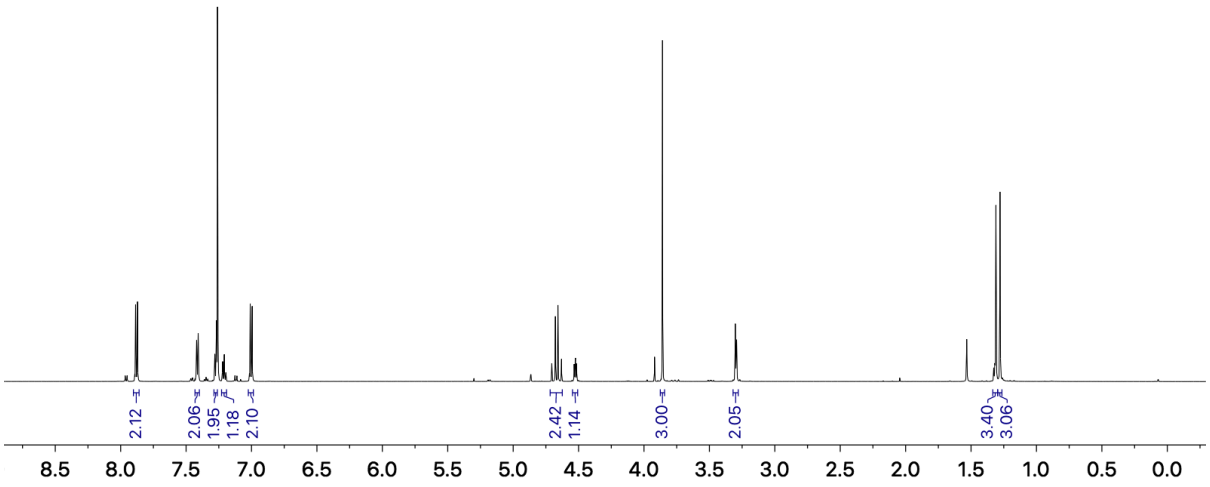
(*S*)-5-Benzyl-2-(*tert*-butyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D1)

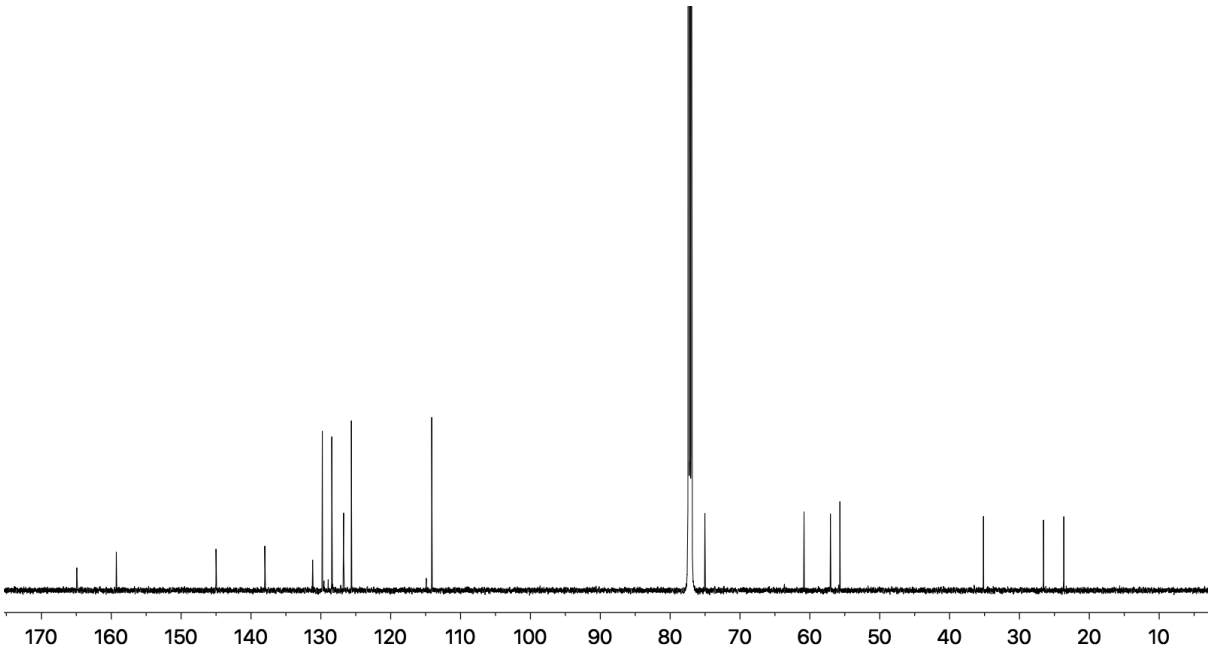




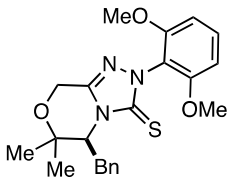
(*S*)-5-Benzyl-2-(4-methoxyphenyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D2)

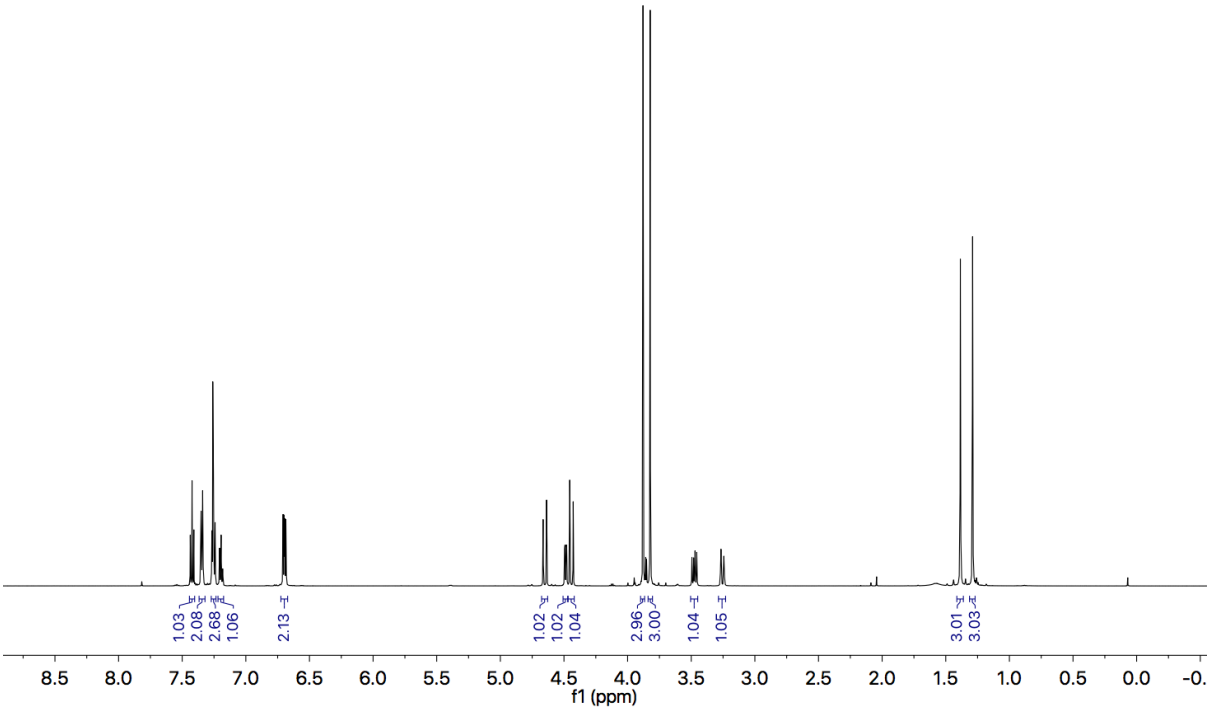


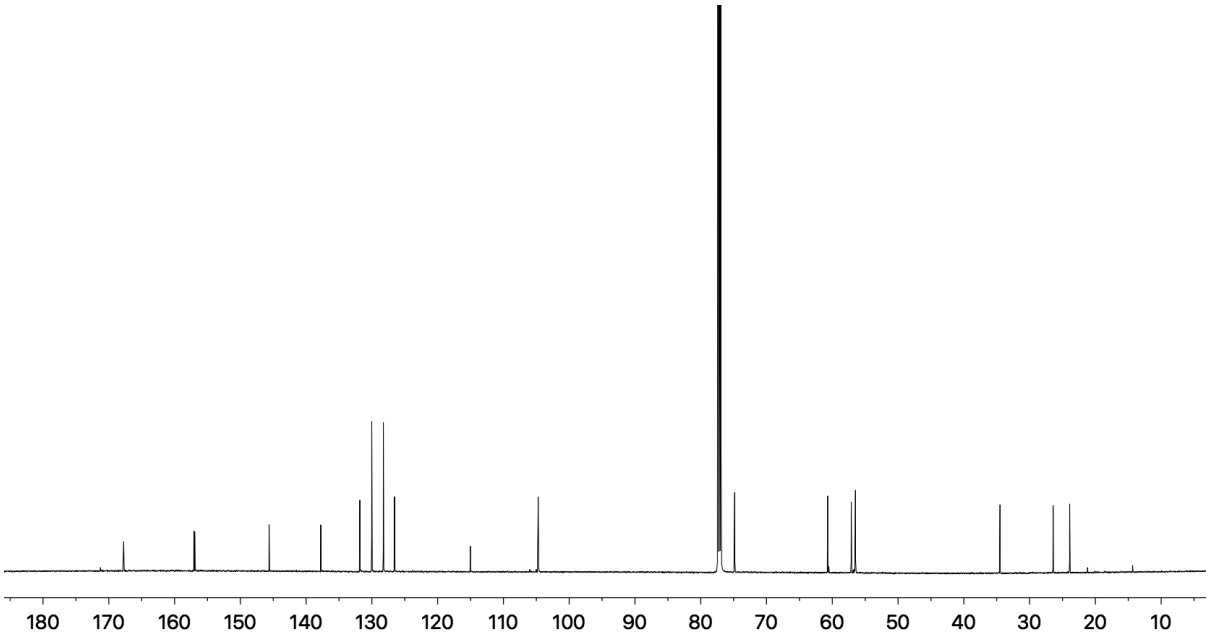




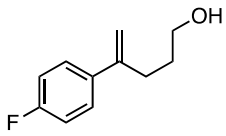
(*S*)-5-Benzyl-2-(2,6-dimethoxyphenyl)-6,6-dimethyl-2,5,6,8-tetrahydro-3*H*-[1,2,4]triazolo[3,4-*c*][1,4]oxazine-3-thione (D3)

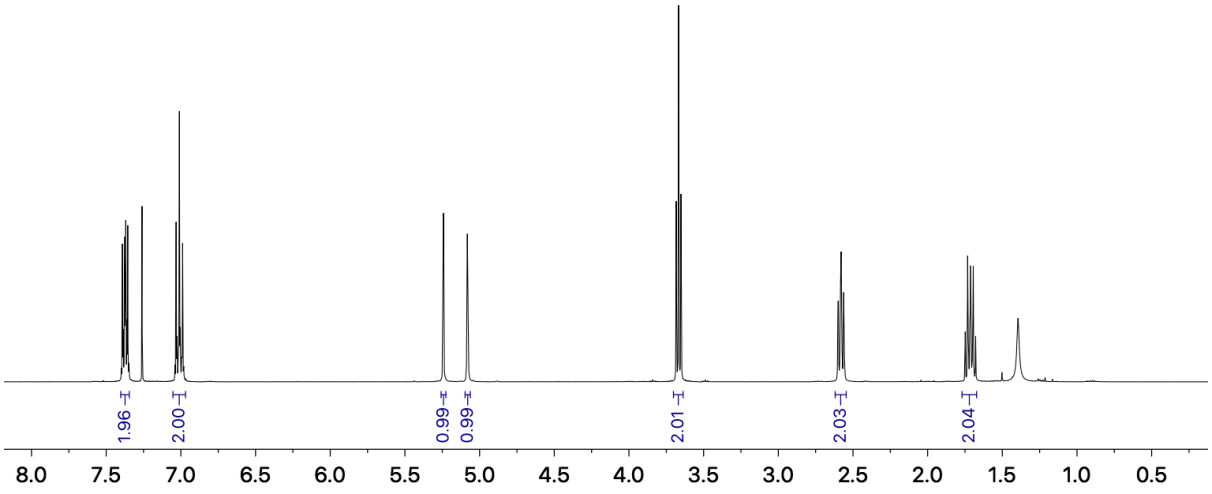


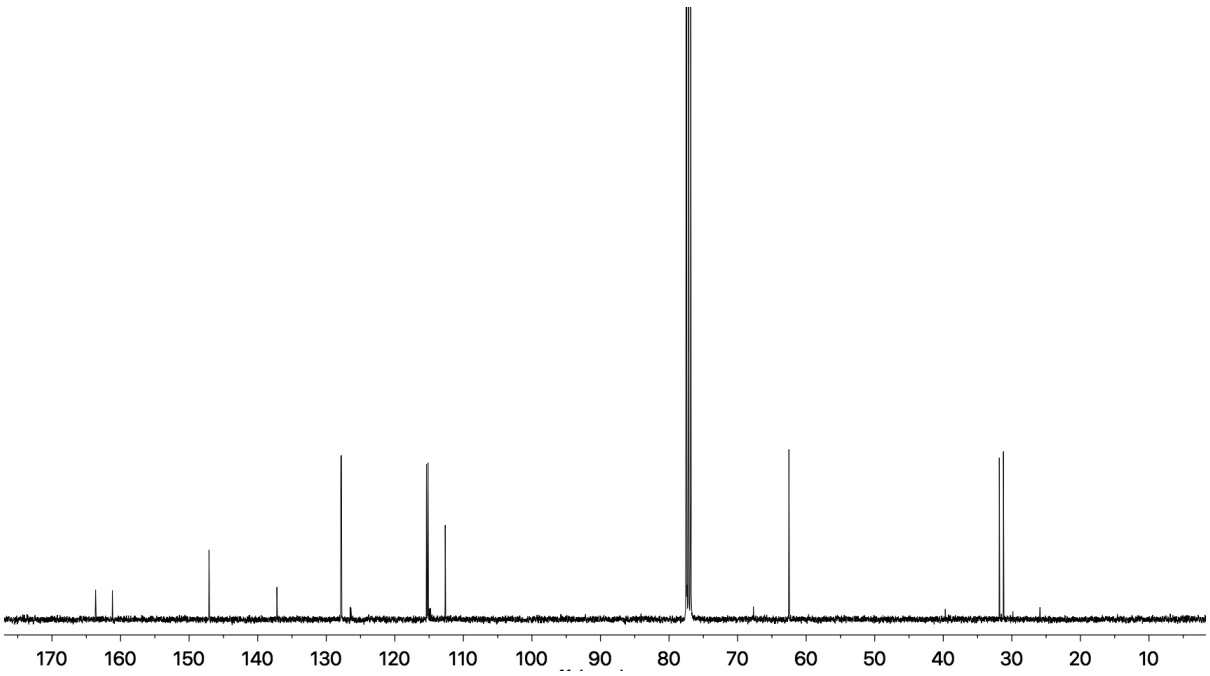




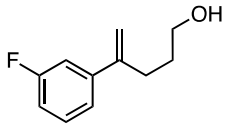
4-(4-Fluorophenyl)pent-4-en-1-ol (5e)

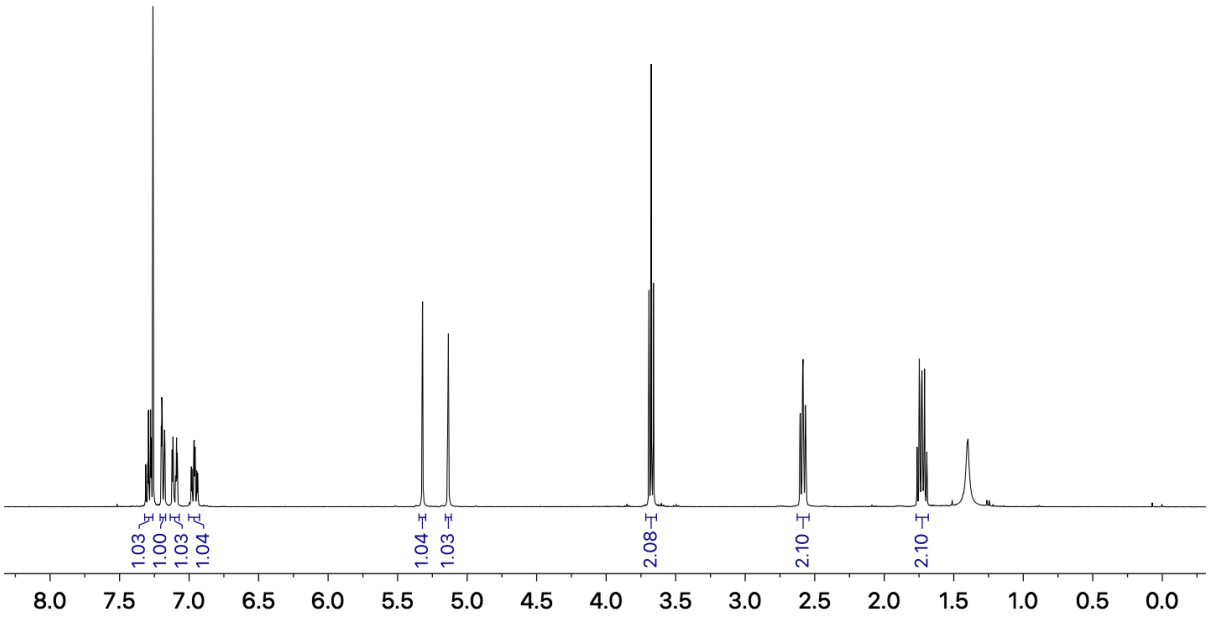


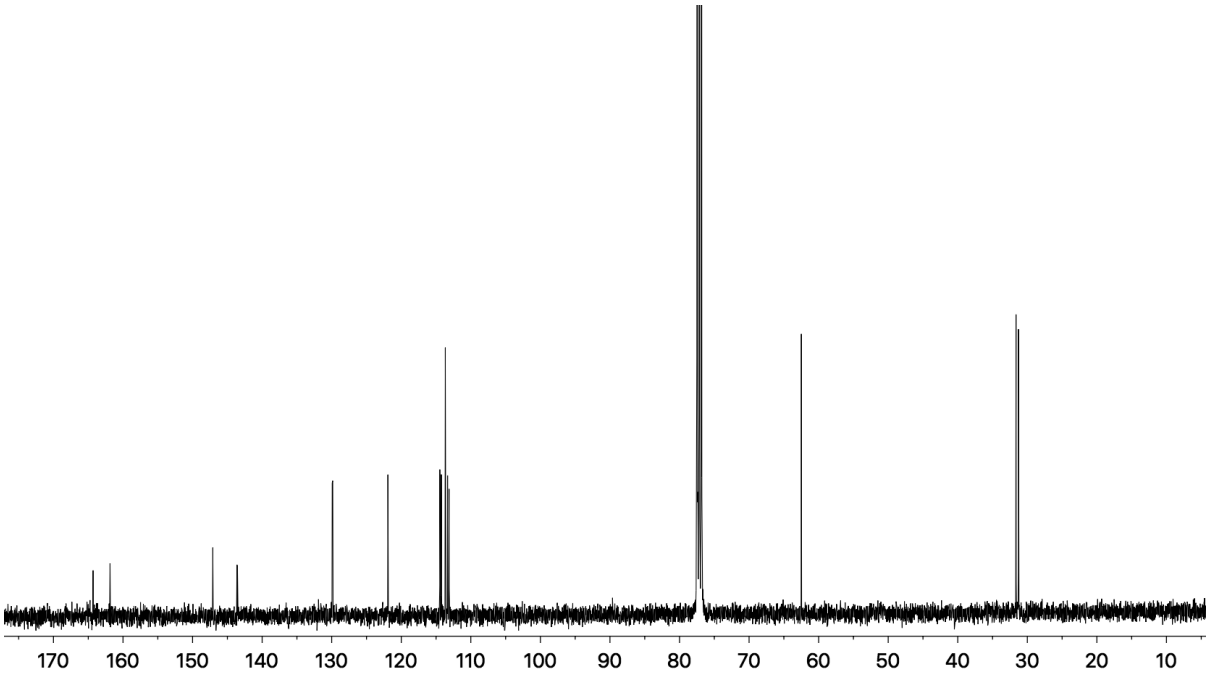




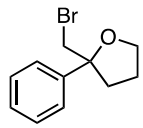
4-(3-Fluorophenyl)pent-4-en-1-ol (5g)

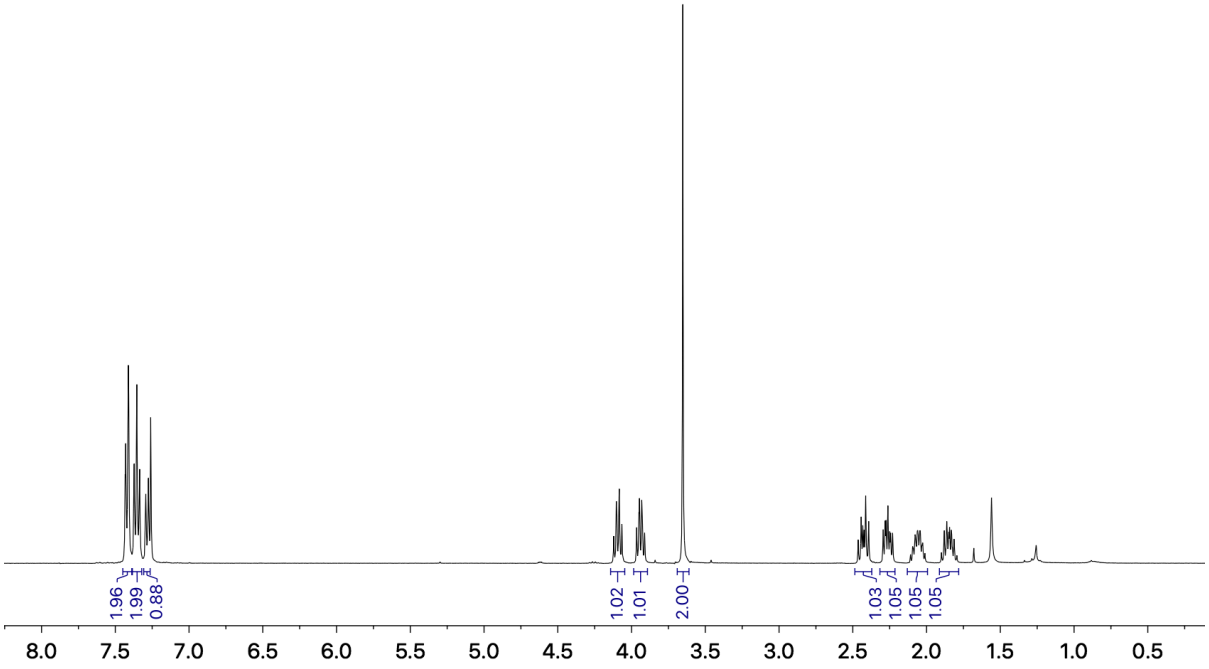


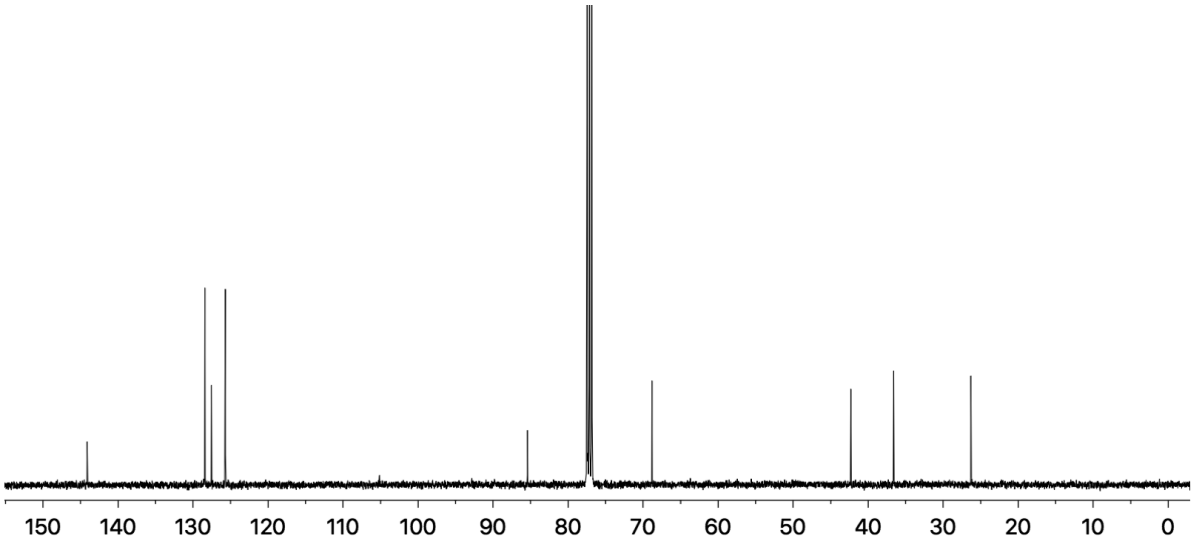




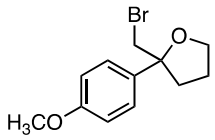
2-(Bromomethyl)-2-phenyltetrahydrofuran (6a)[10]

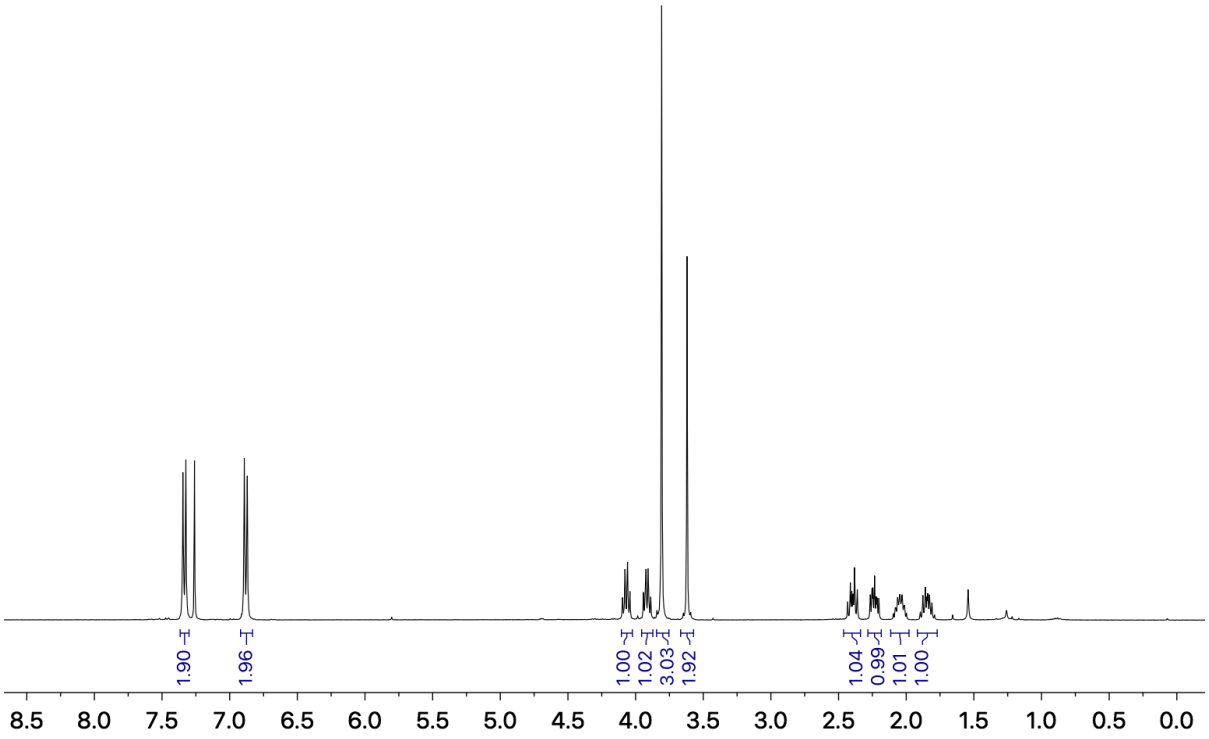


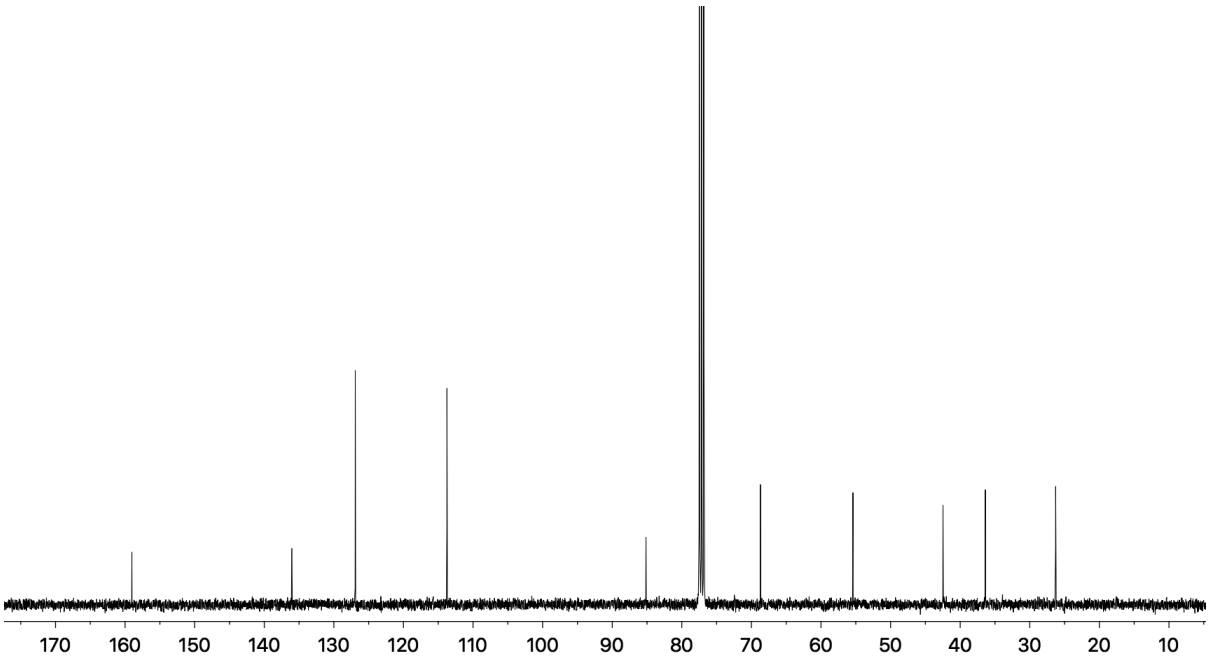




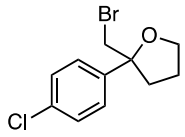
2-(Bromomethyl)-2-(4-methoxyphenyl)tetrahydrofuran (6b)

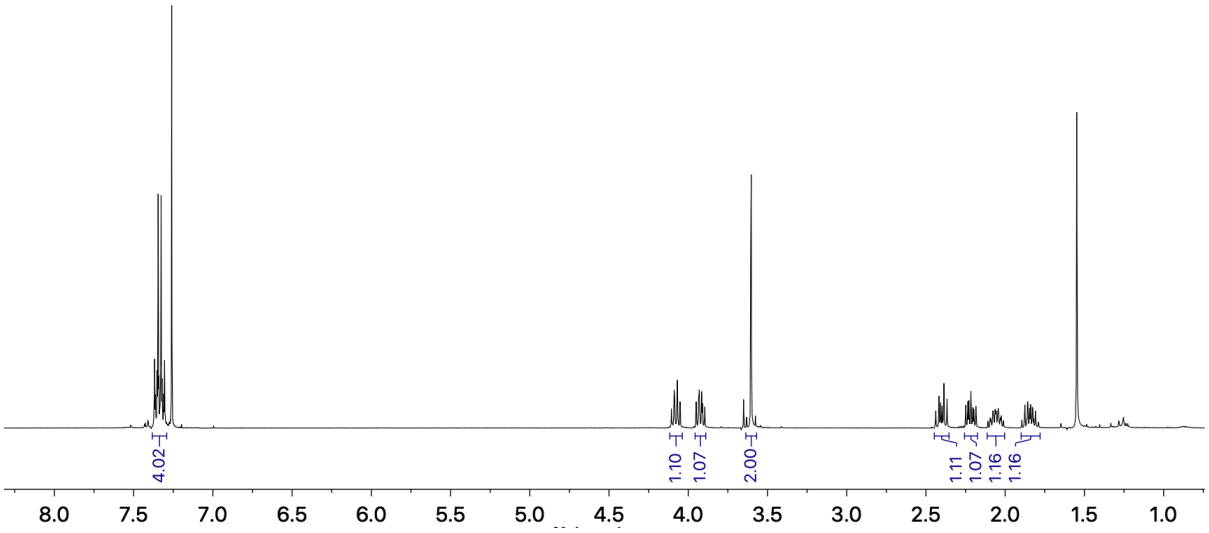


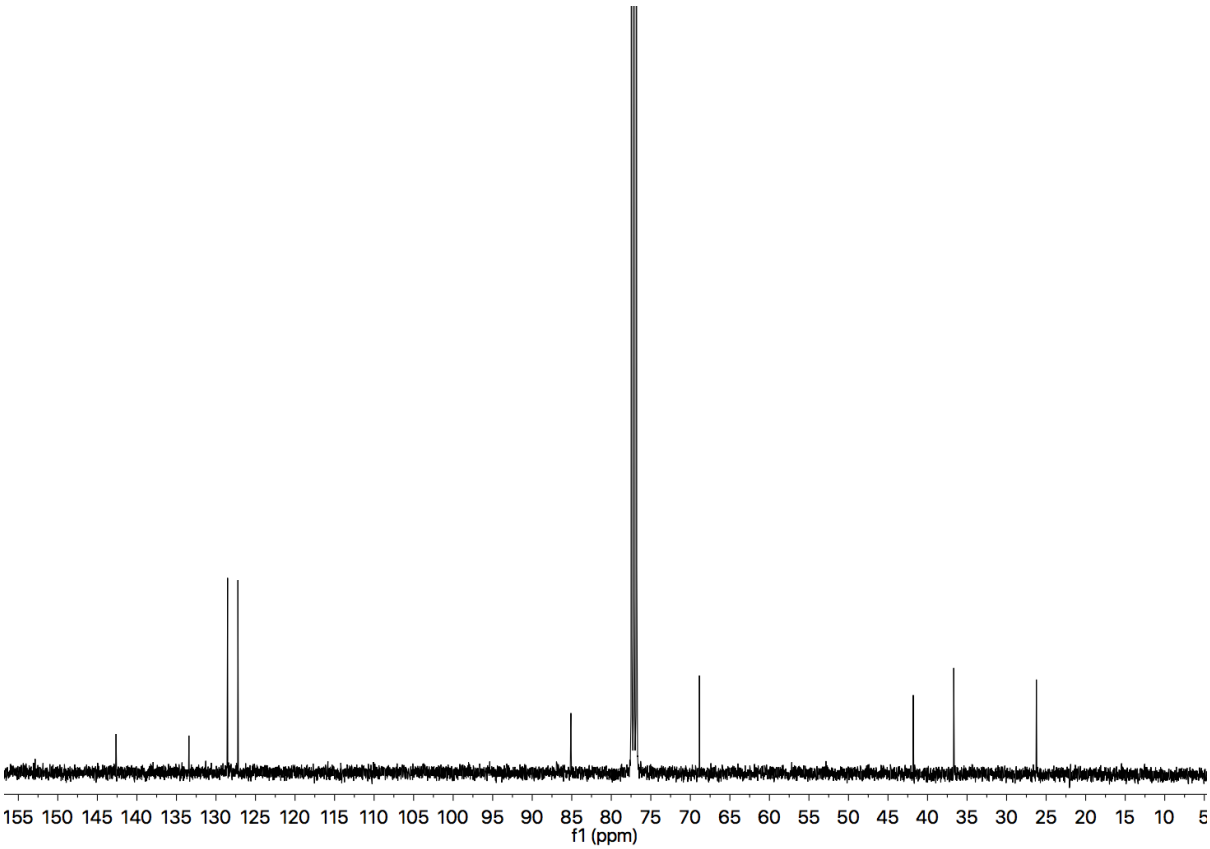




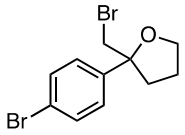
2-(Bromomethyl)-2-(4-chlorophenyl)tetrahydrofuran (6c)

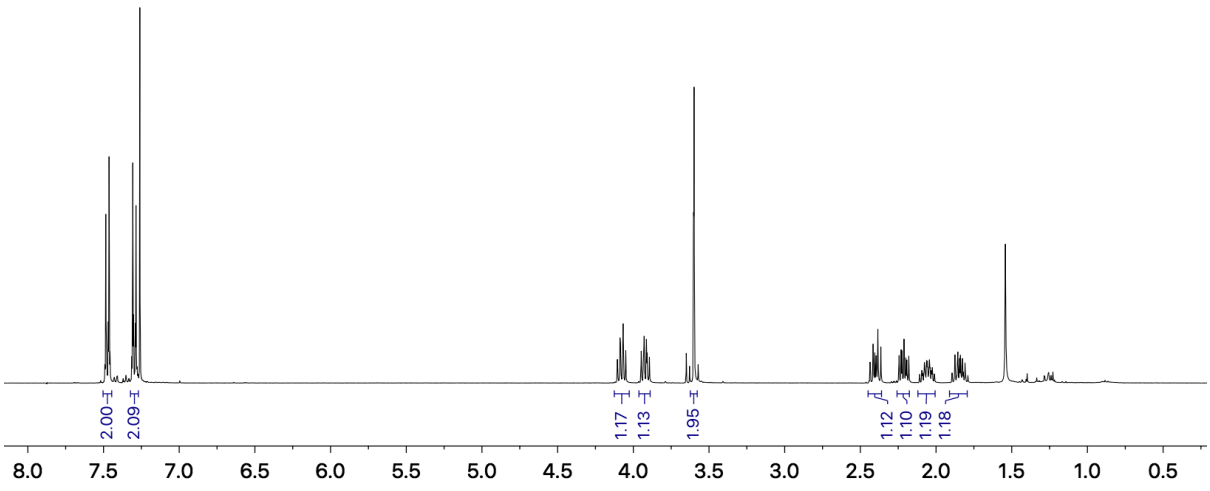


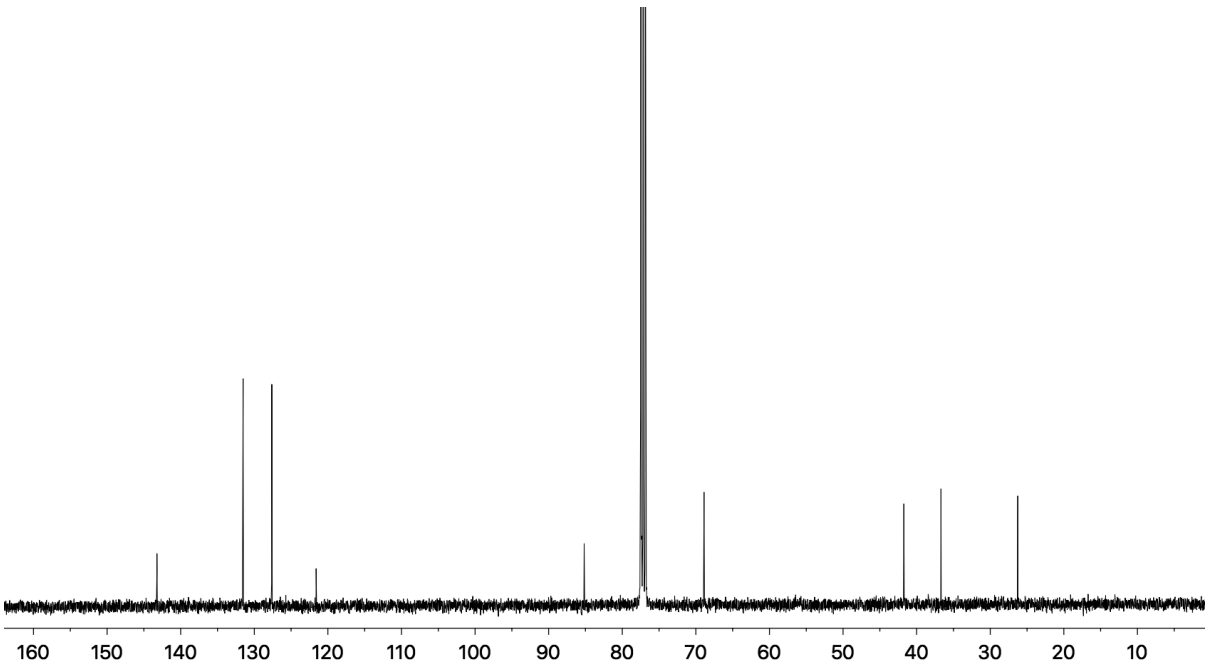




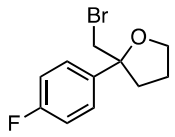
2-(Bromomethyl)-2-(4-bromophenyl)tetrahydrofuran (6d)

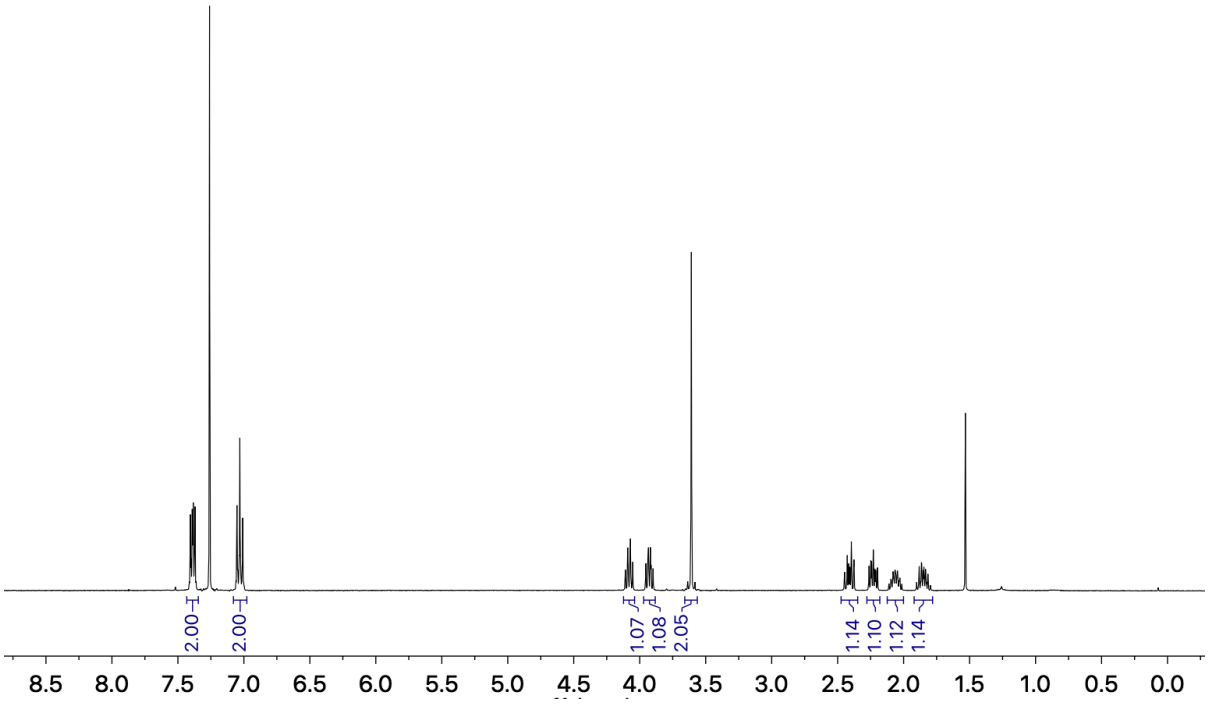


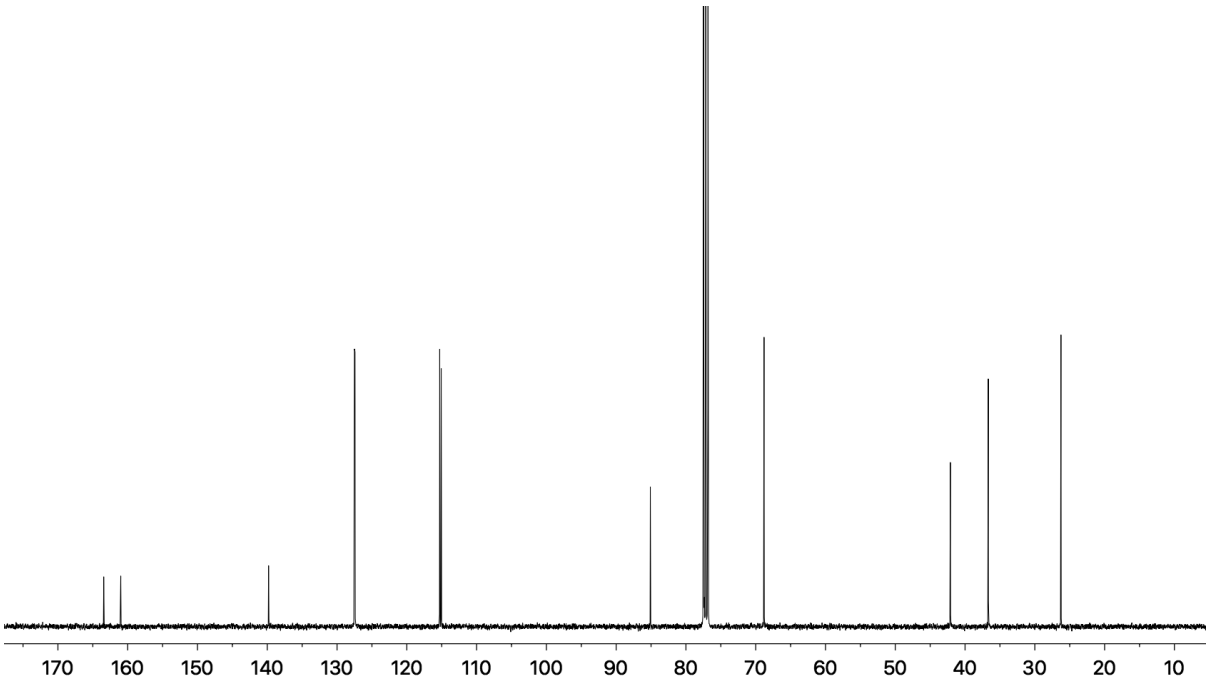




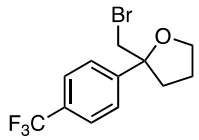
2-(Bromomethyl)-2-(4-fluorophenyl)tetrahydrofuran (6e)

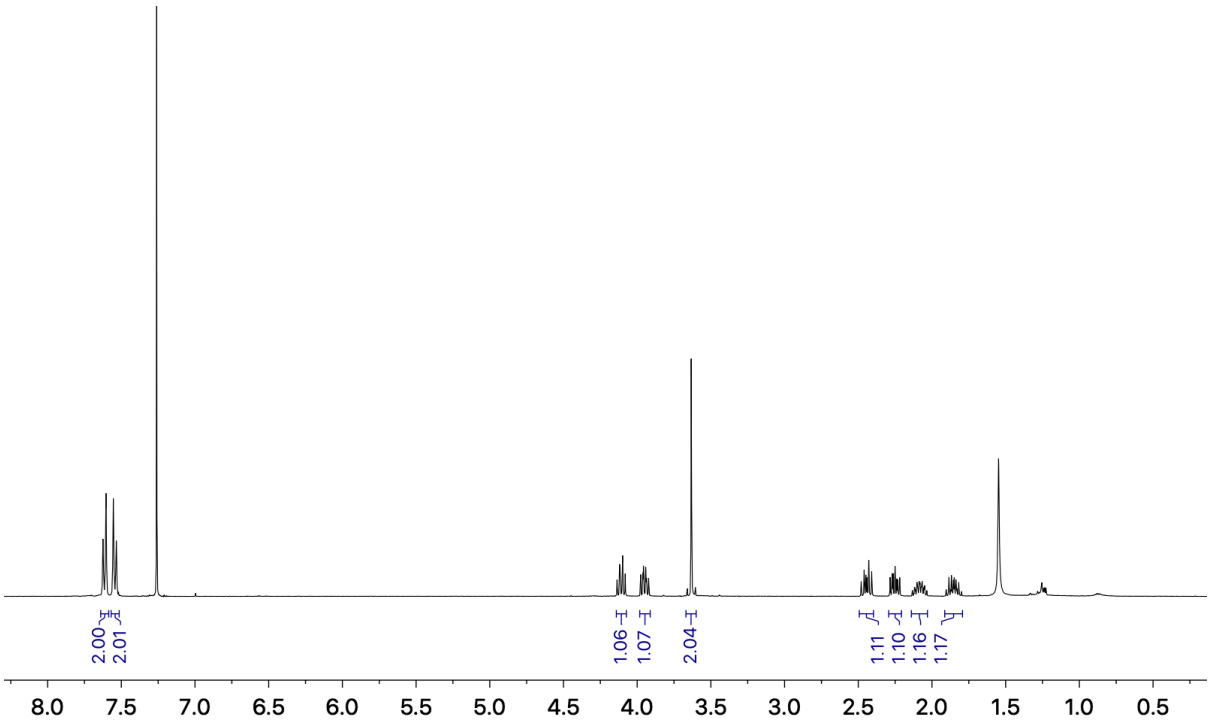


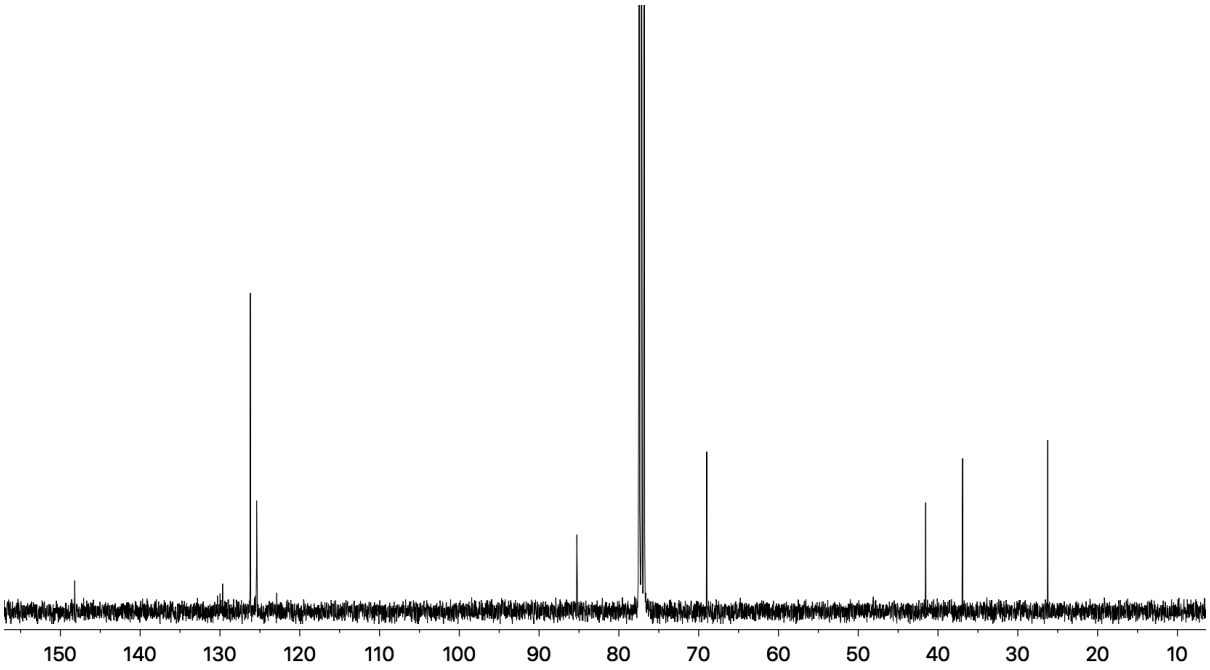




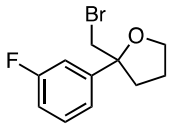
2-(Bromomethyl)-2-(4-(trifluoromethyl)phenyl)tetrahydrofuran (6f)

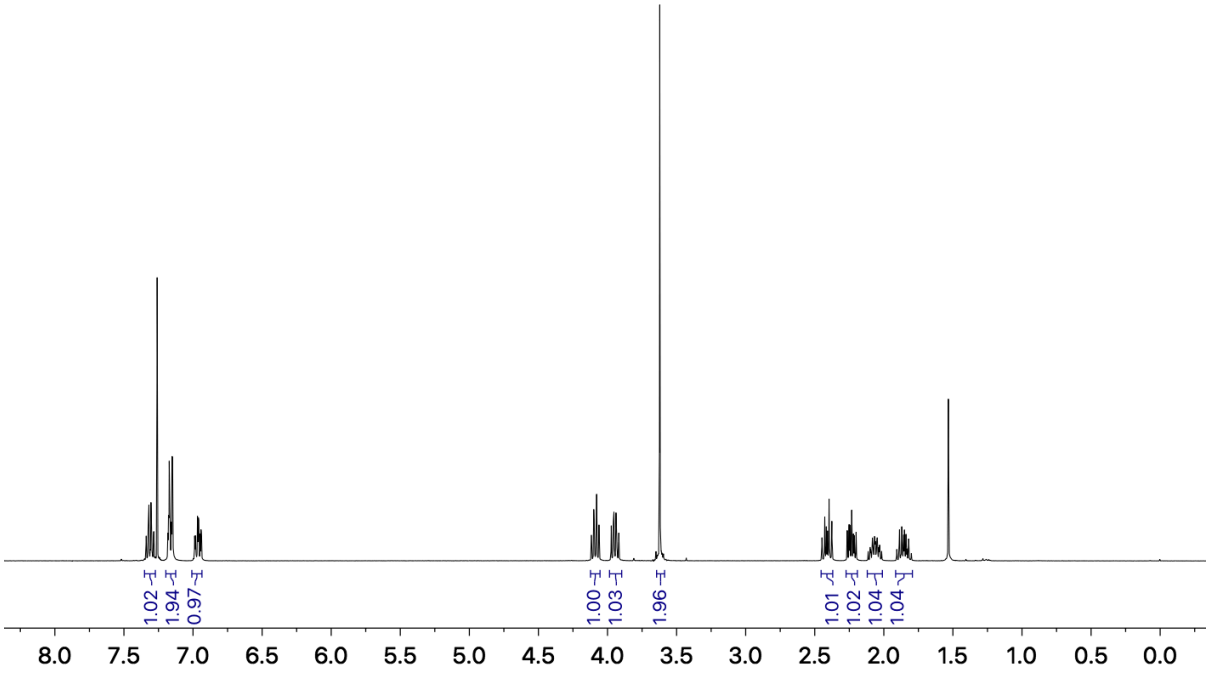


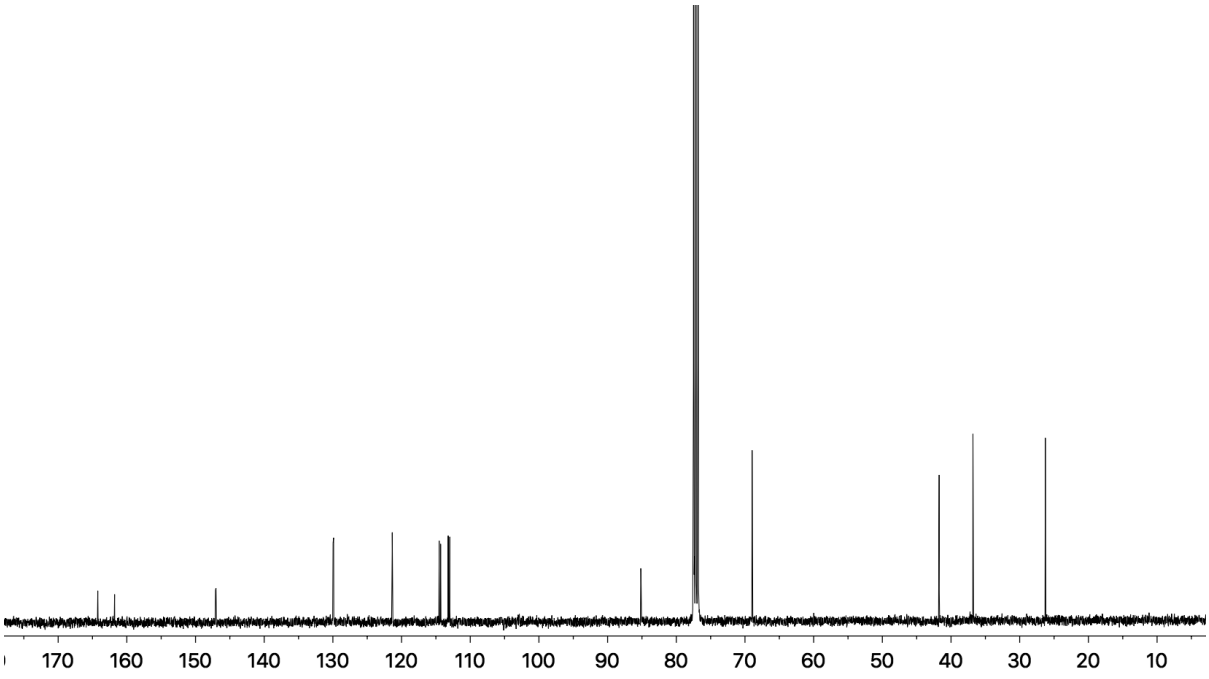




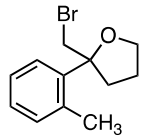
2-(Bromomethyl)-2-(3-fluorophenyl)tetrahydrofuran (6g)

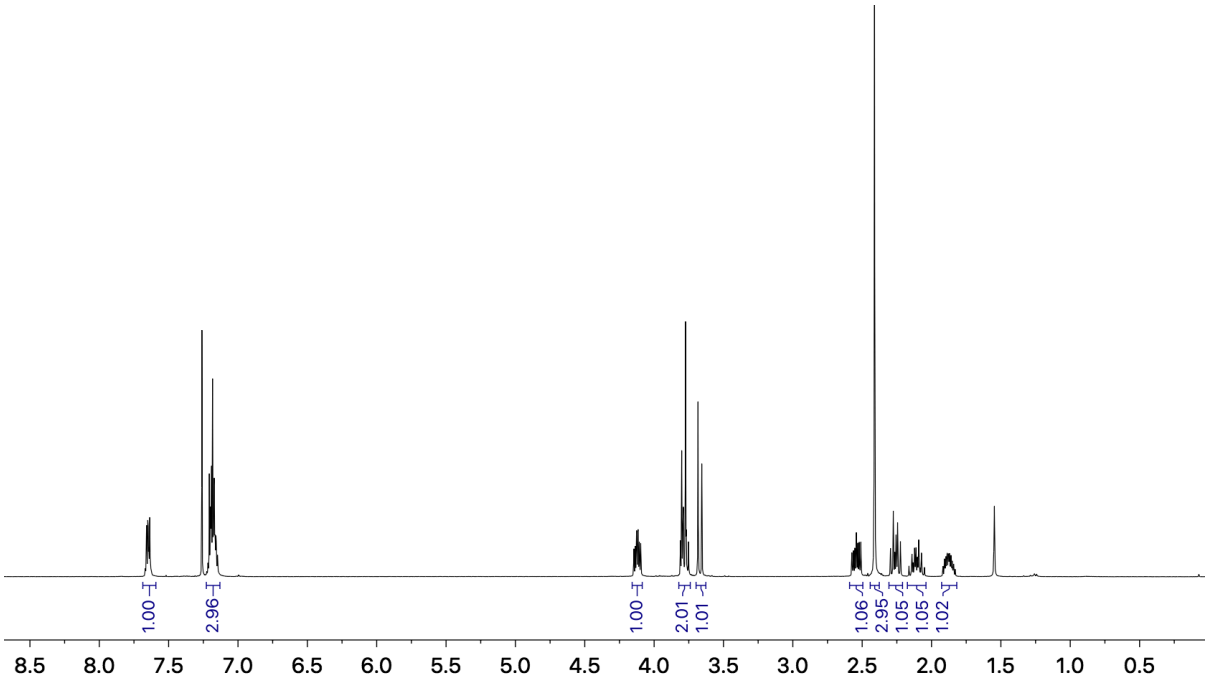


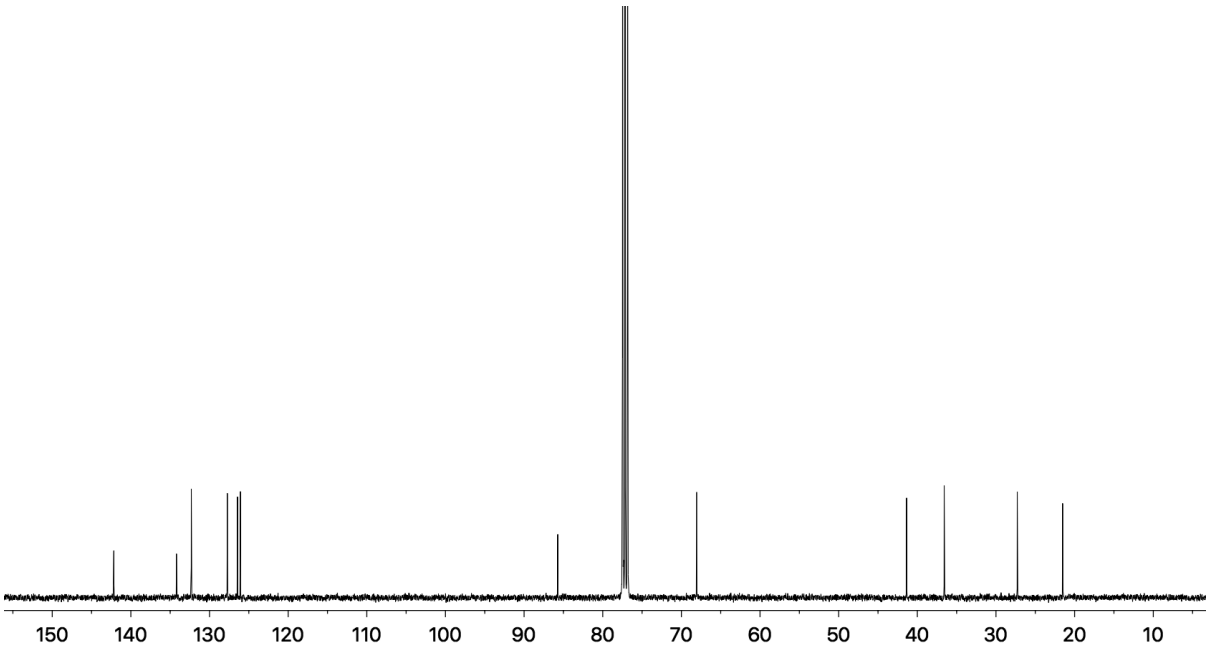




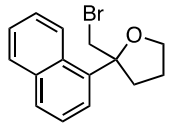
2-(Bromomethyl)-2-(o-tolyl)tetrahydrofuran (6h)

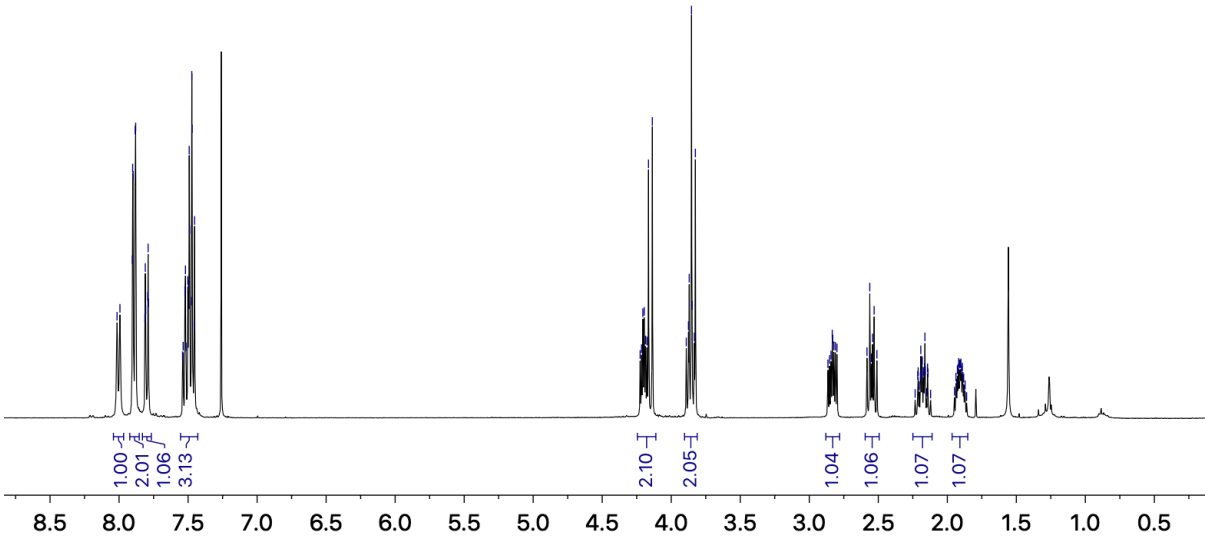


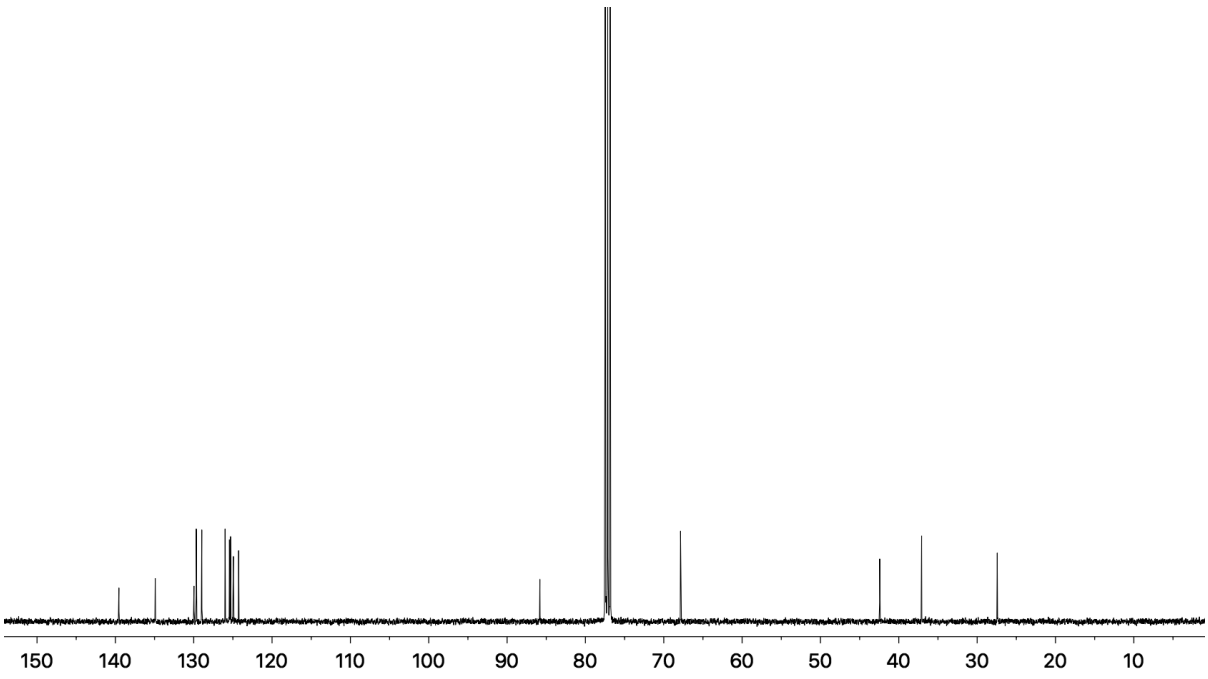




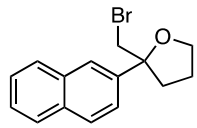
2-(Bromomethyl)-2-(naphthalen-1-yl)tetrahydrofuran (6i)

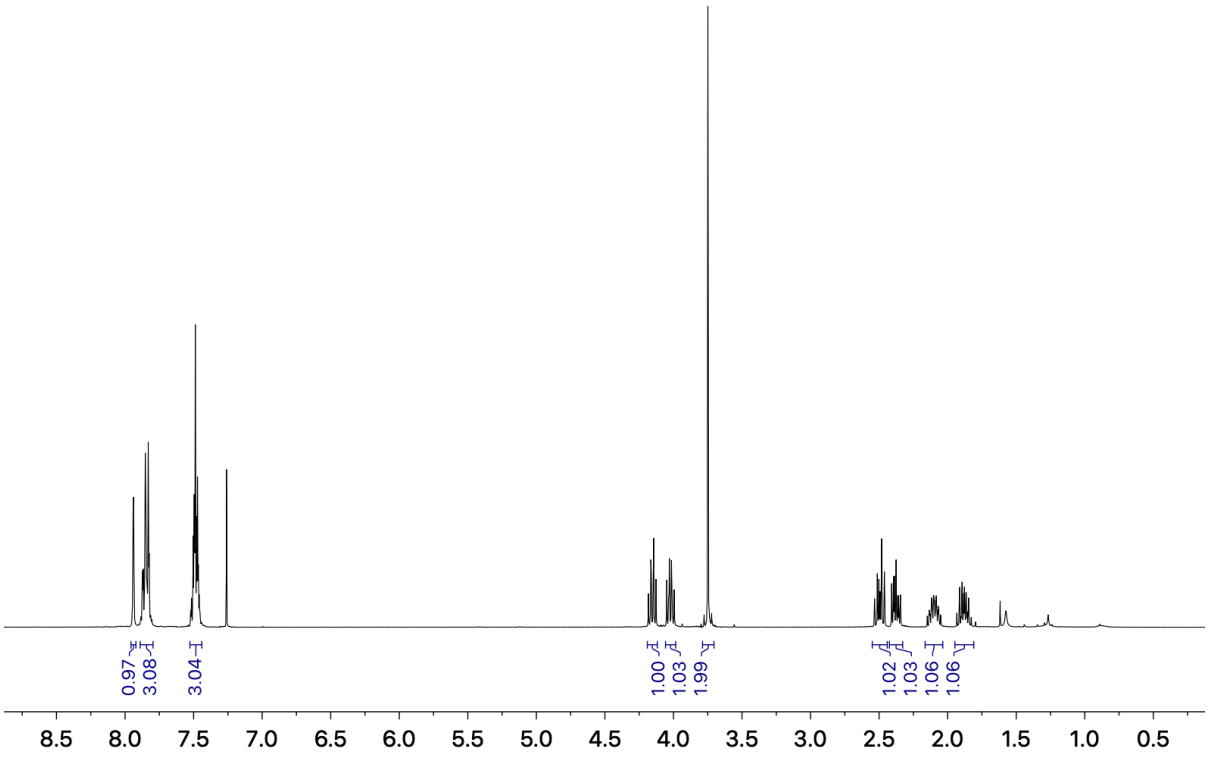


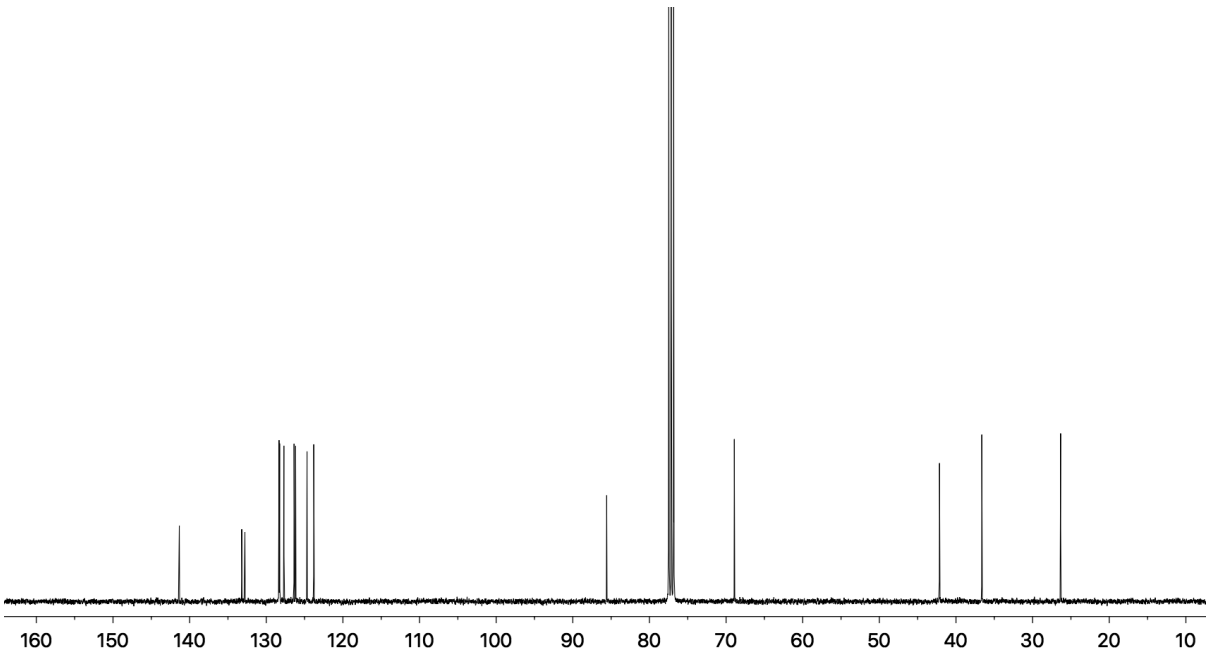




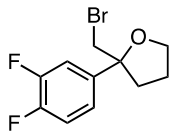
2-(Bromomethyl)-2-(naphthalen-2-yl)tetrahydrofuran (6j)

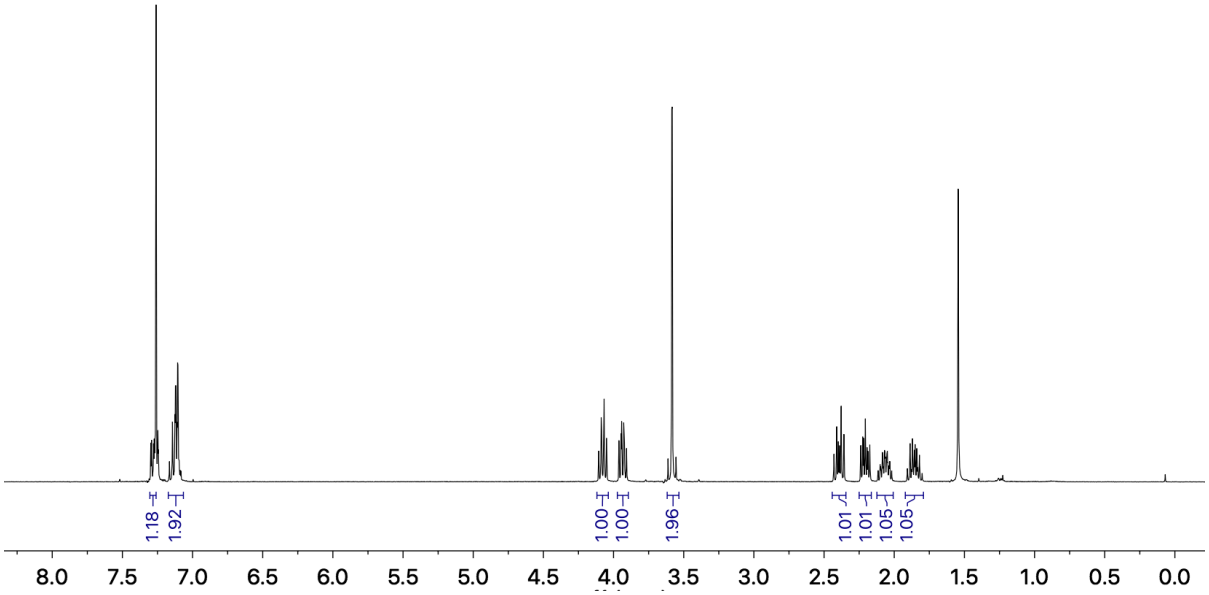


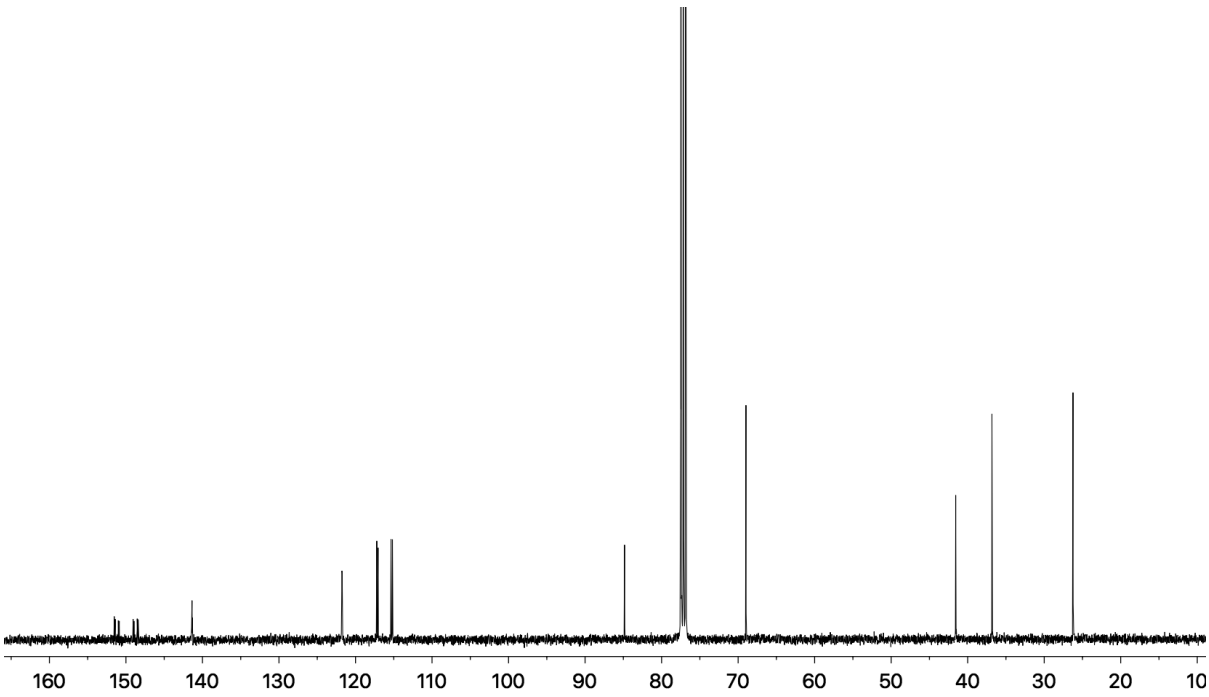




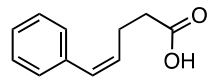
2-(Bromomethyl)-2-(3,4-difluorophenyl)tetrahydrofuran (6k)

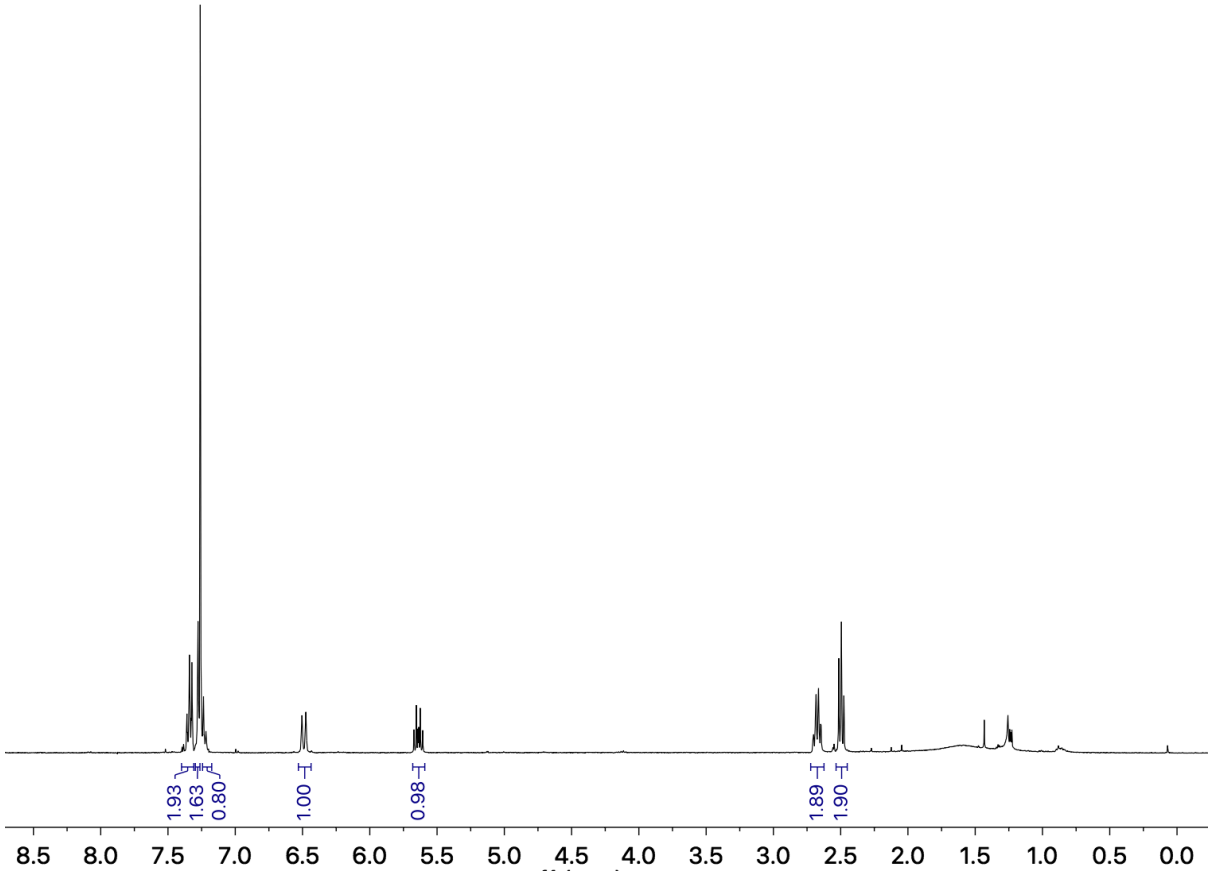


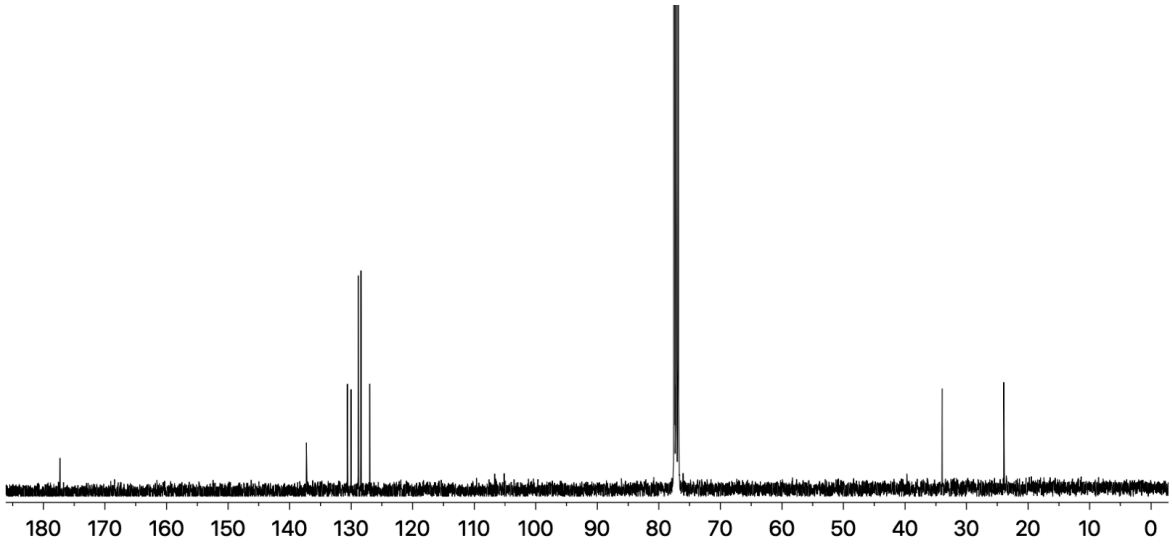




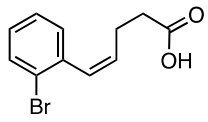
(*Z*)-5-Phenylpent-4-enoic acid (7a)



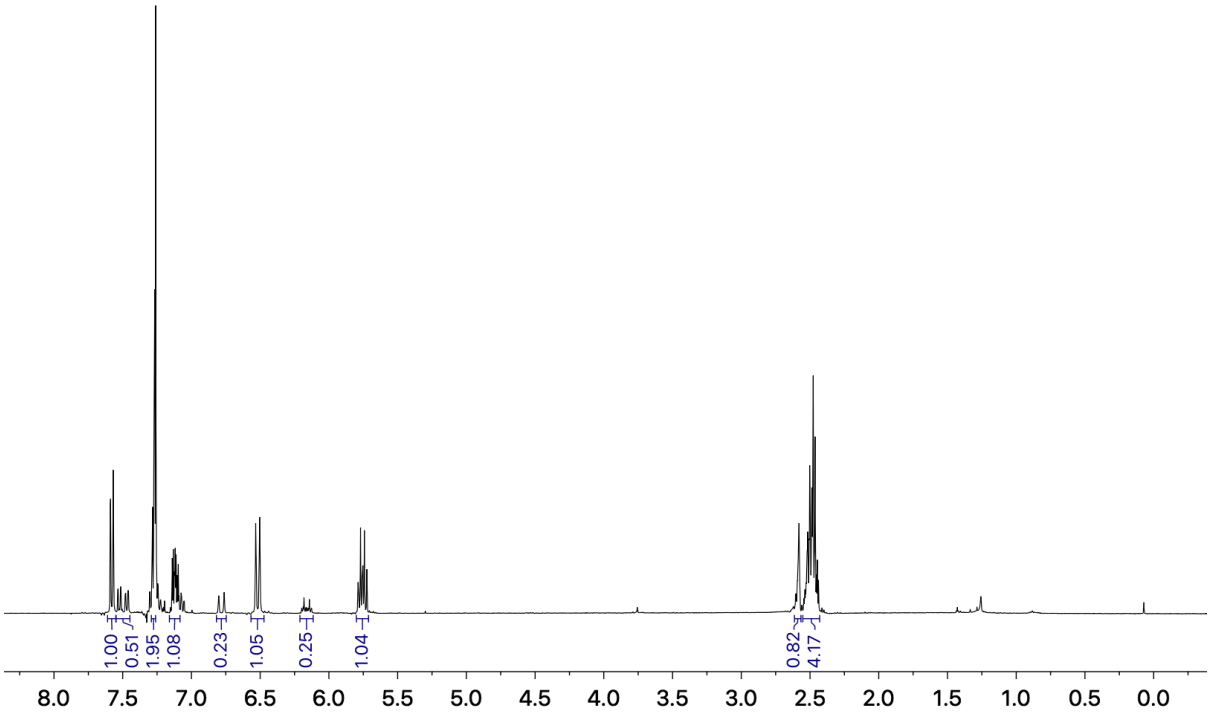


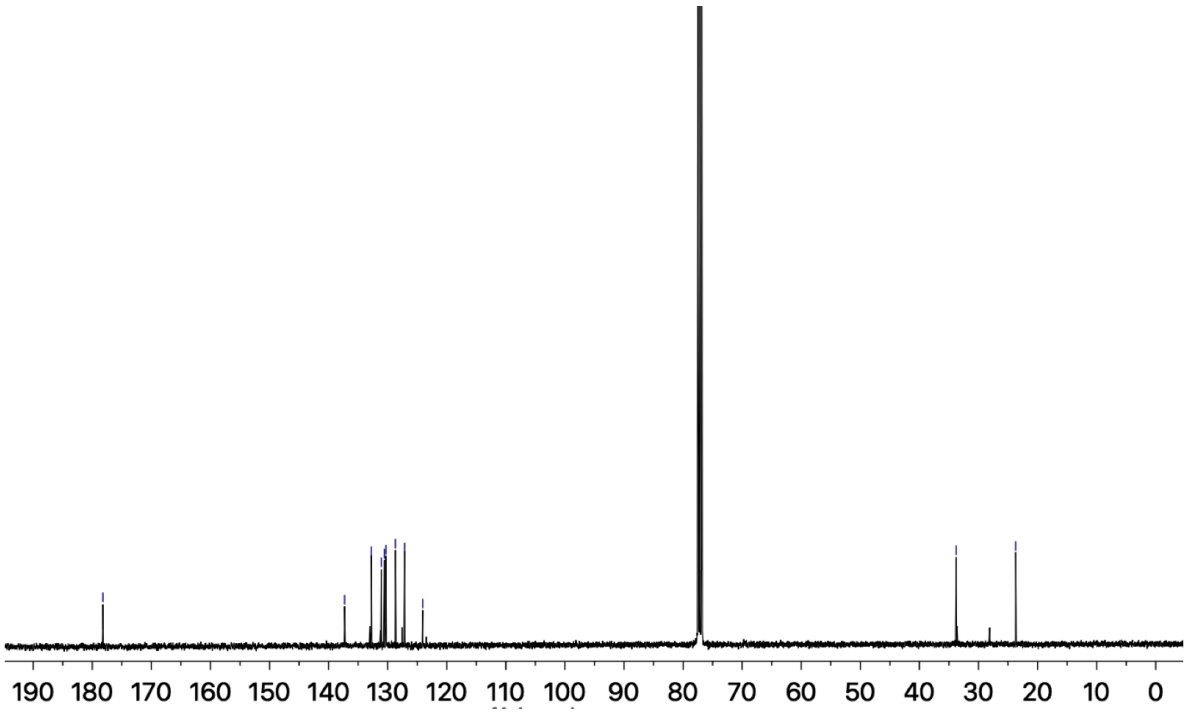


(*Z*)-5-(2-Bromophenyl)pent-4-enoic acid (7c)

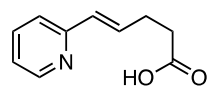


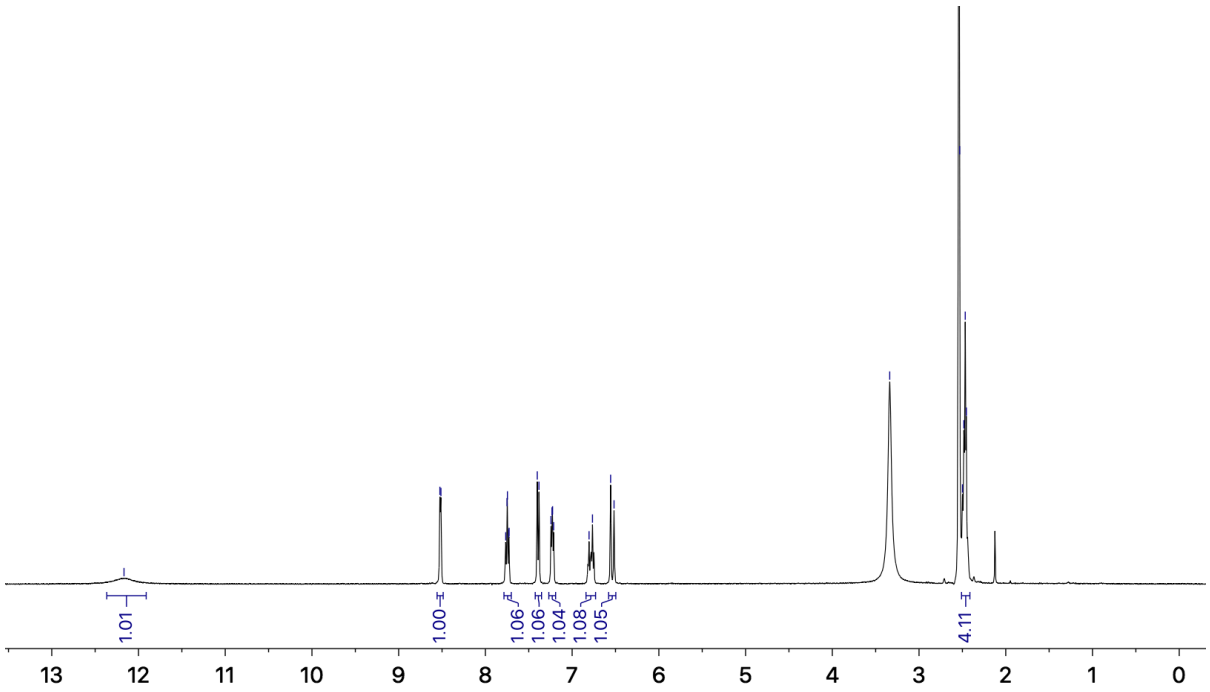
E/*Z*, 1:4 mixture of isomers

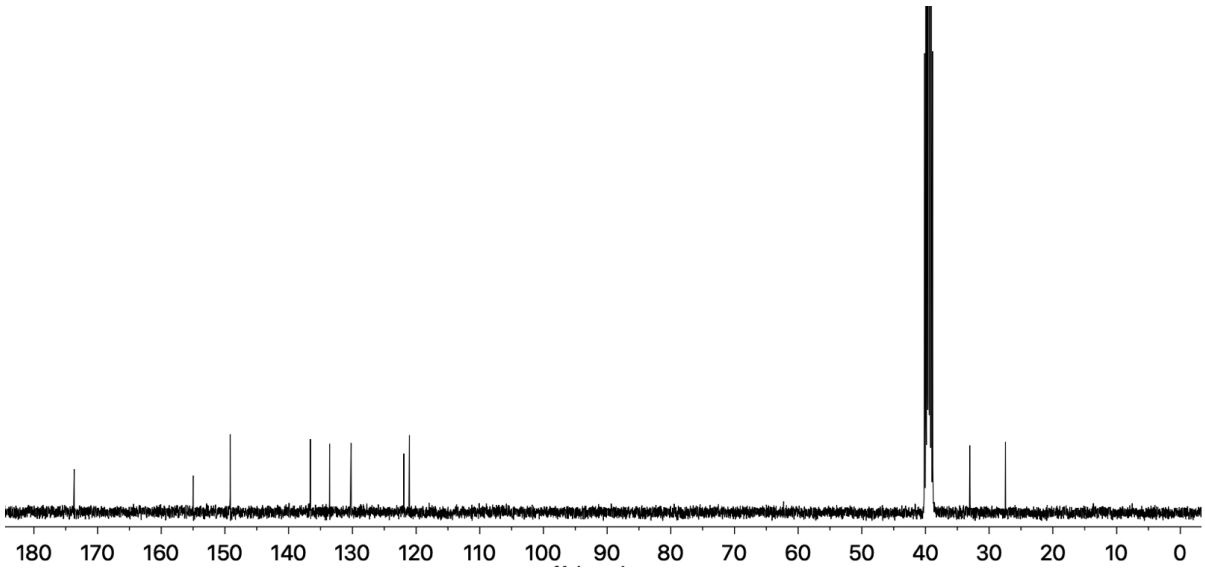




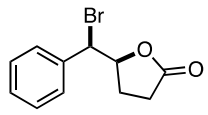
(*E*)-5-(Pyridin-2-yl)pent-4-enoic acid (7e)

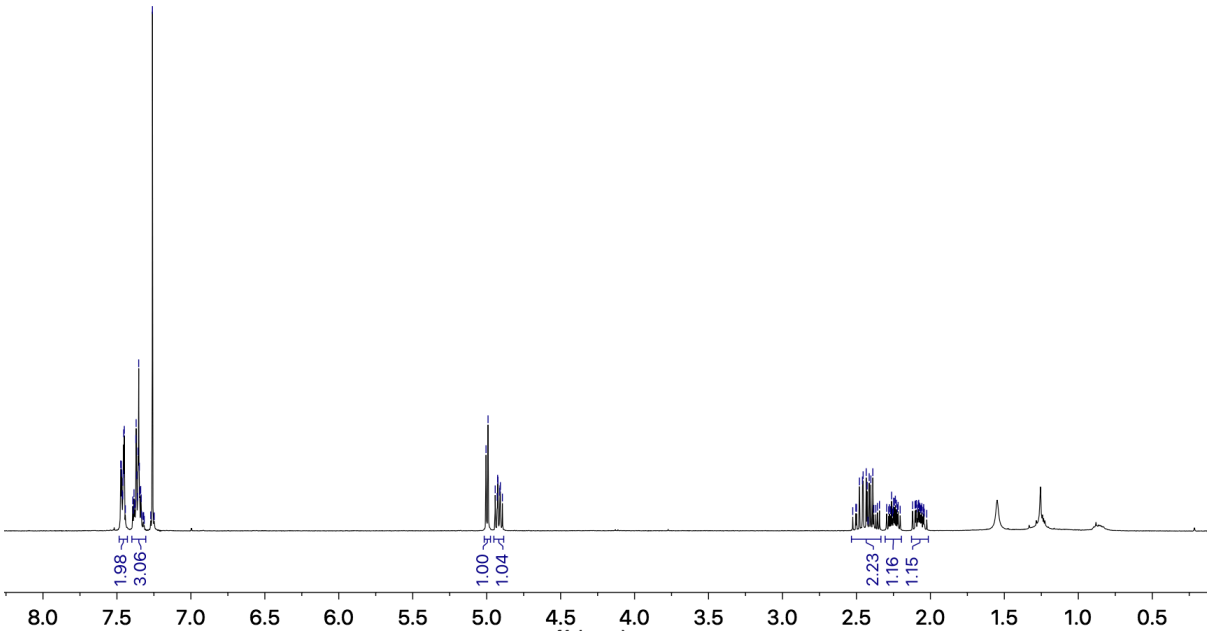


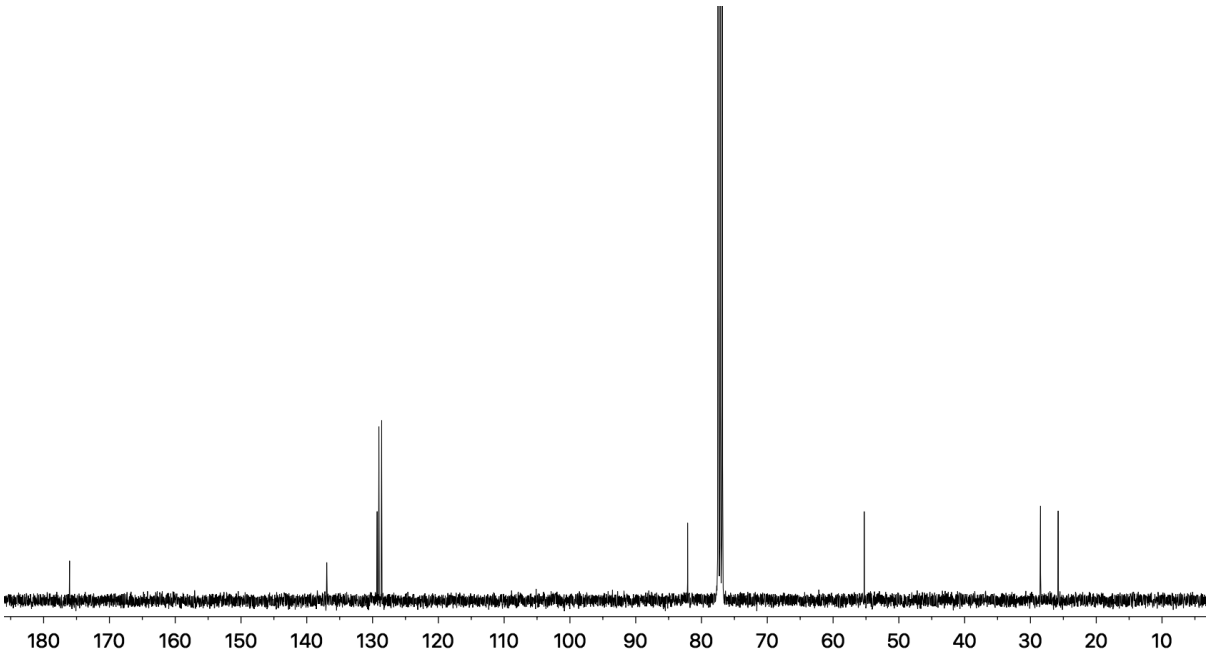




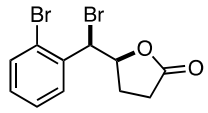
5-(Bromo(phenyl)methyl)dihydrofuran-2(3*H*)-one (8a)

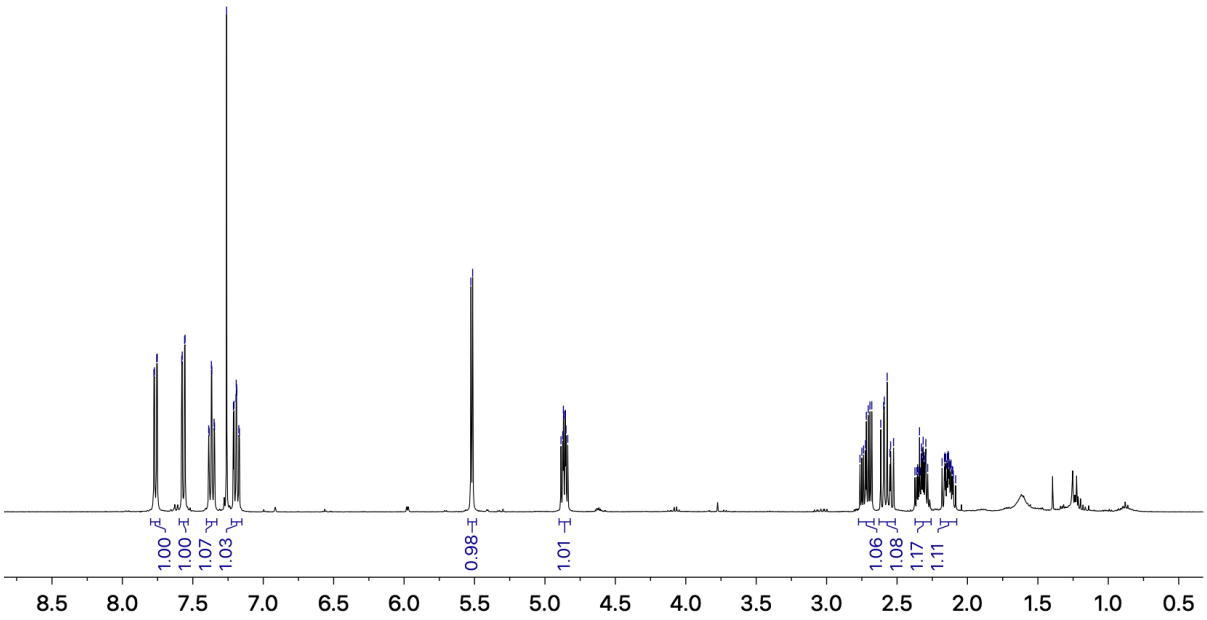


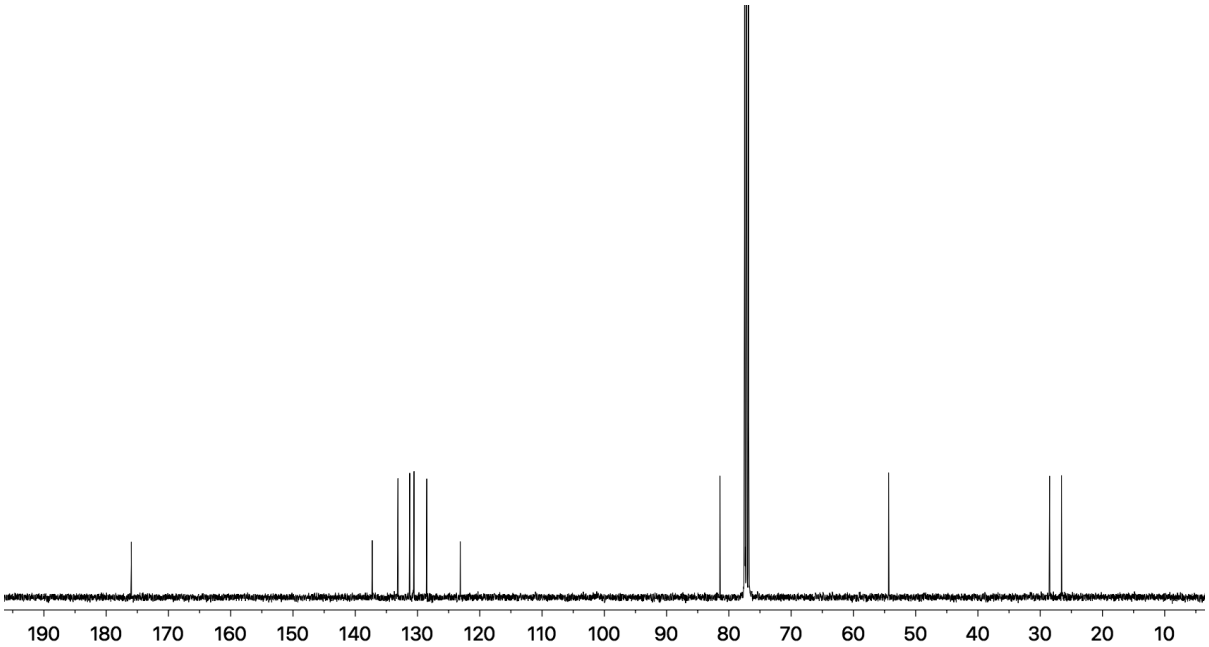




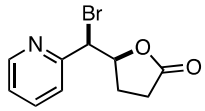
5-(Bromo(2-bromophenyl)methyl)dihydrofuran-2(3*H*)-one (8c)

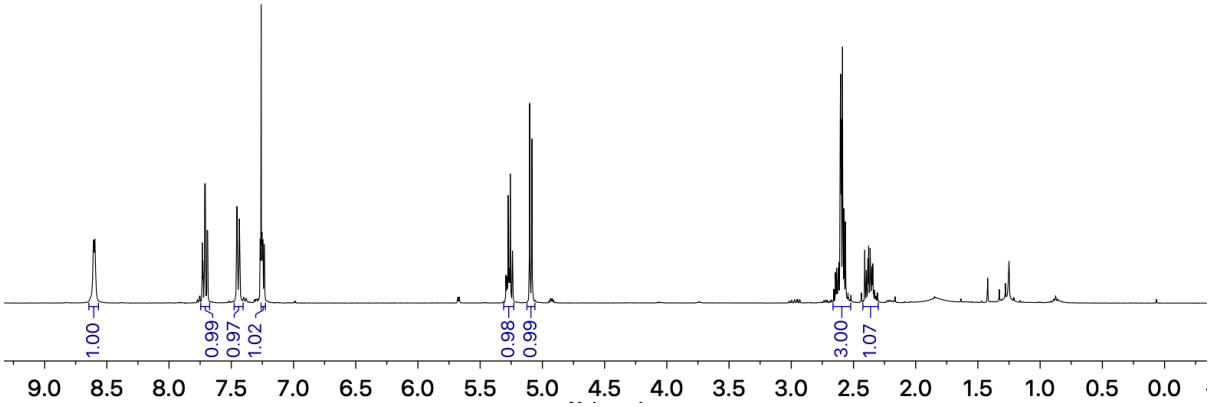


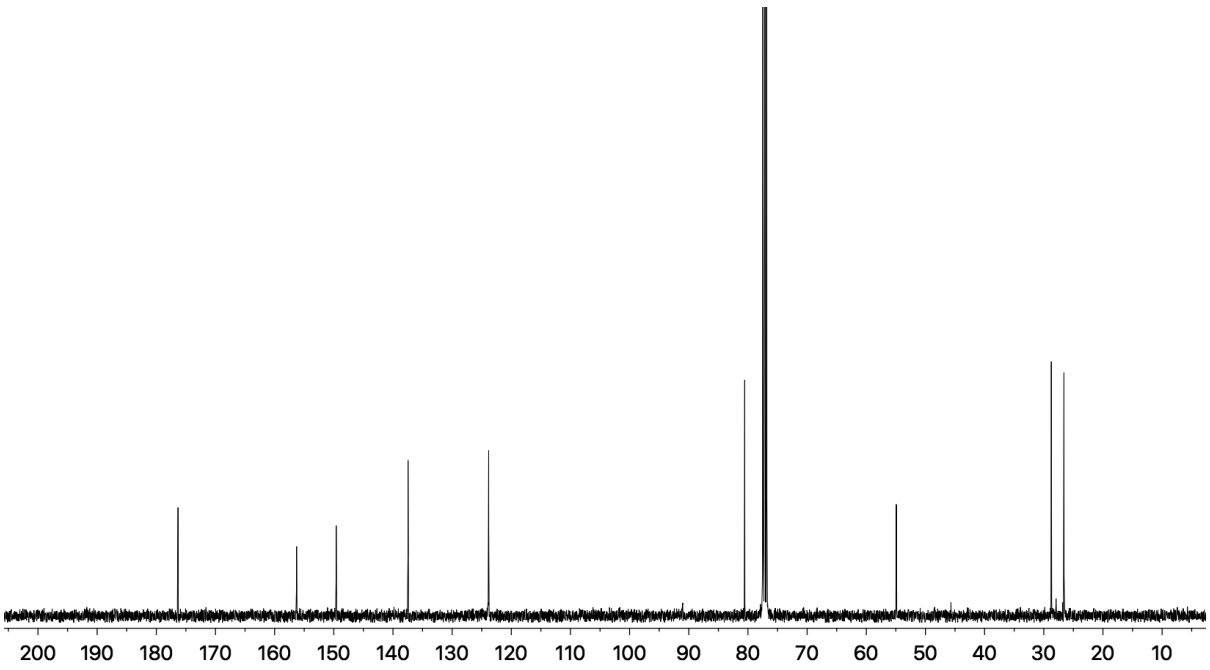




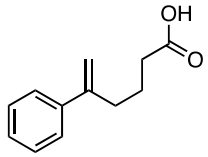
5-(Bromo(pyridin-2-yl)methyl)dihydrofuran-2(3*H*)-one (8e)

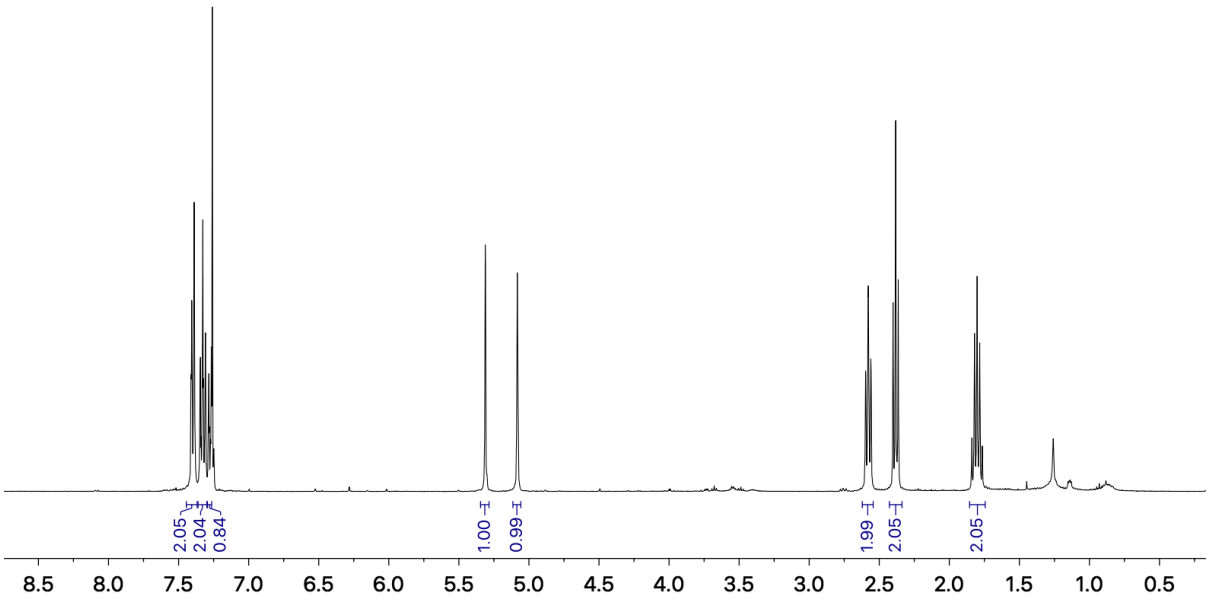


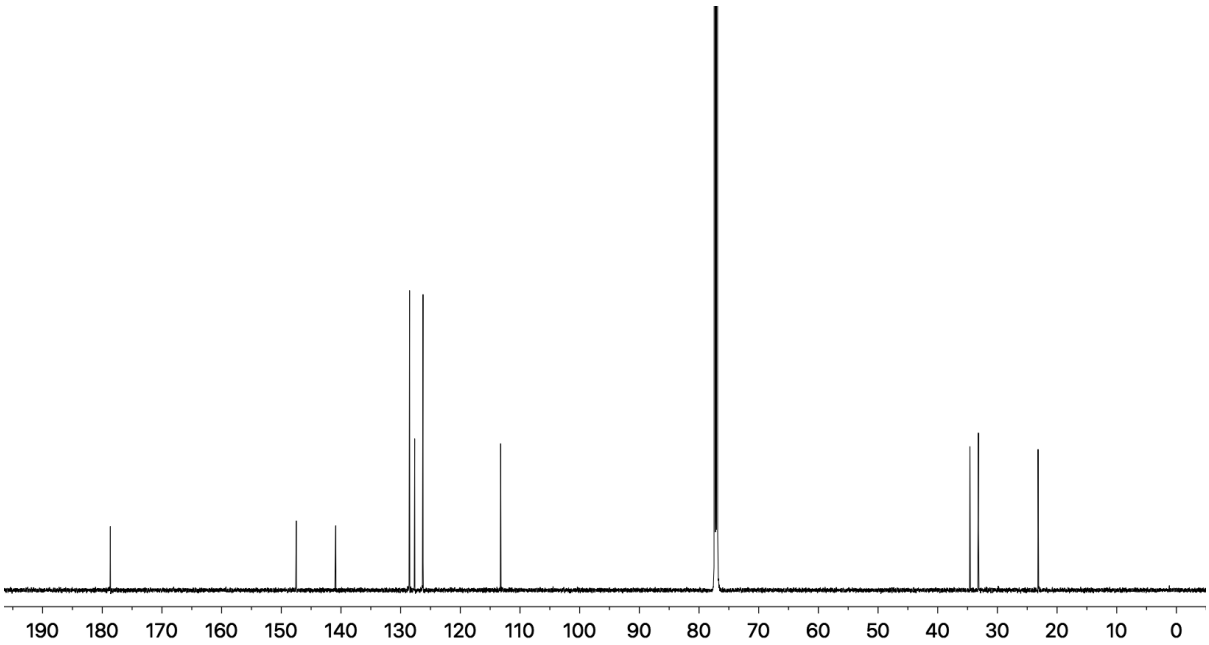




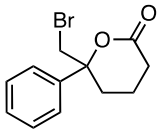
5-Phenylhex-5-enoic acid (10)

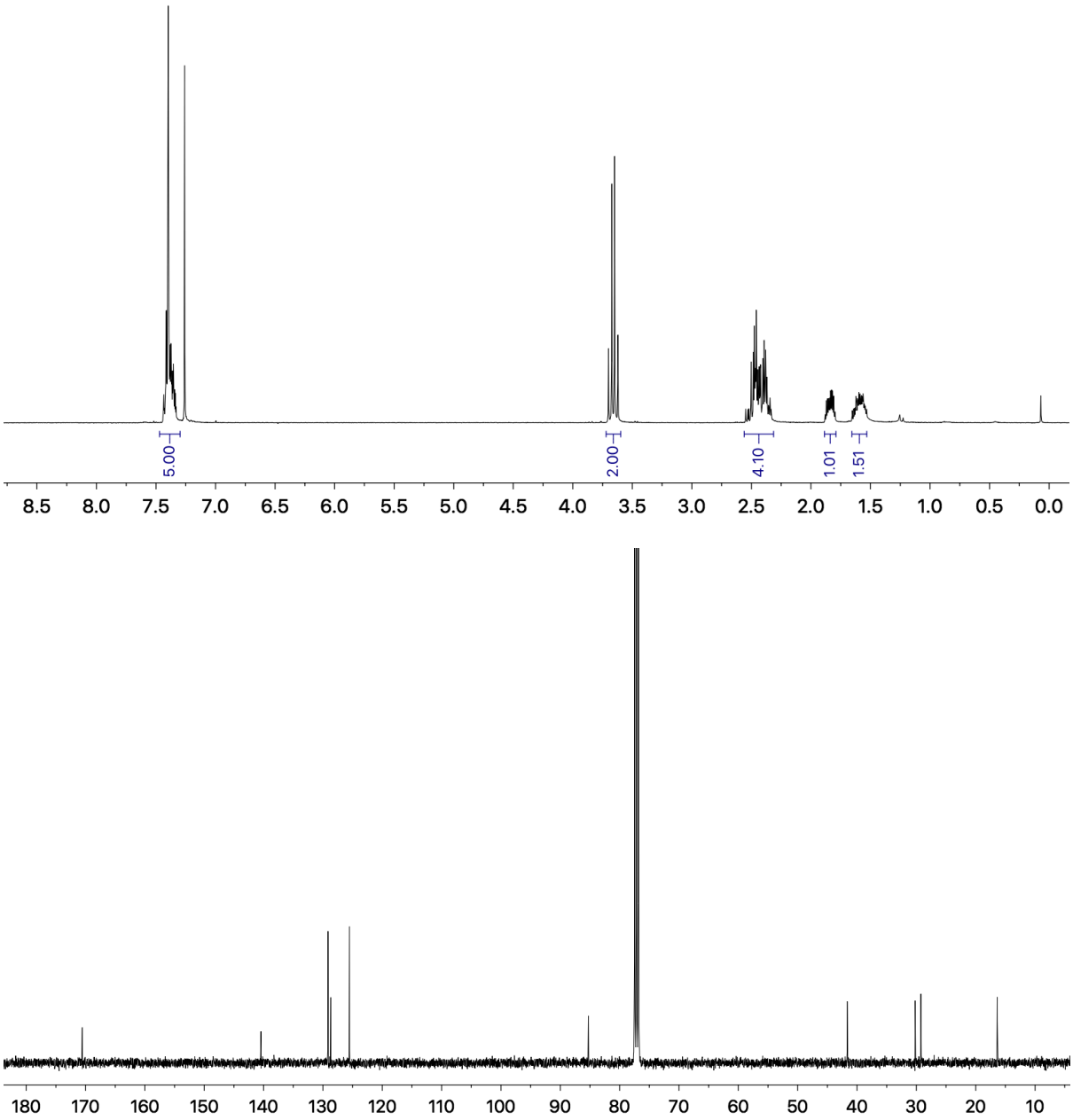


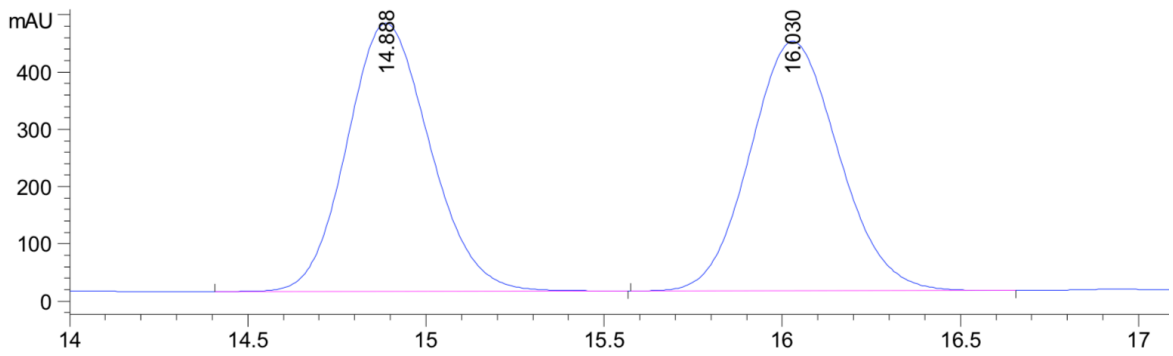




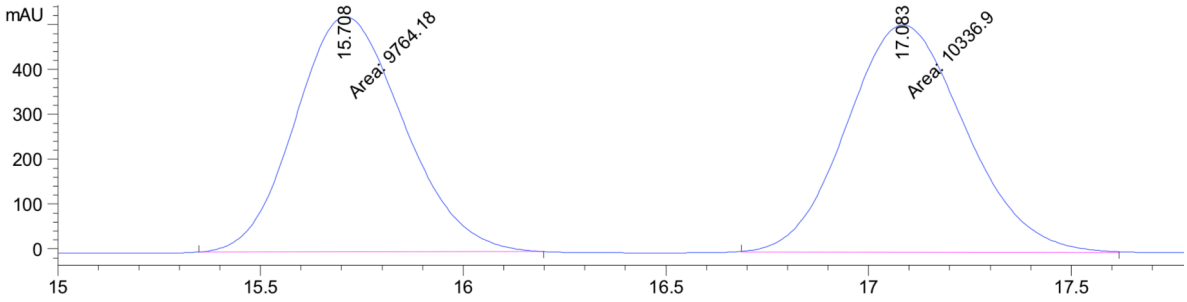
6-(Bromomethyl)-6-phenyltetrahydro-2*H*-pyran-2-one (11a)





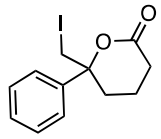


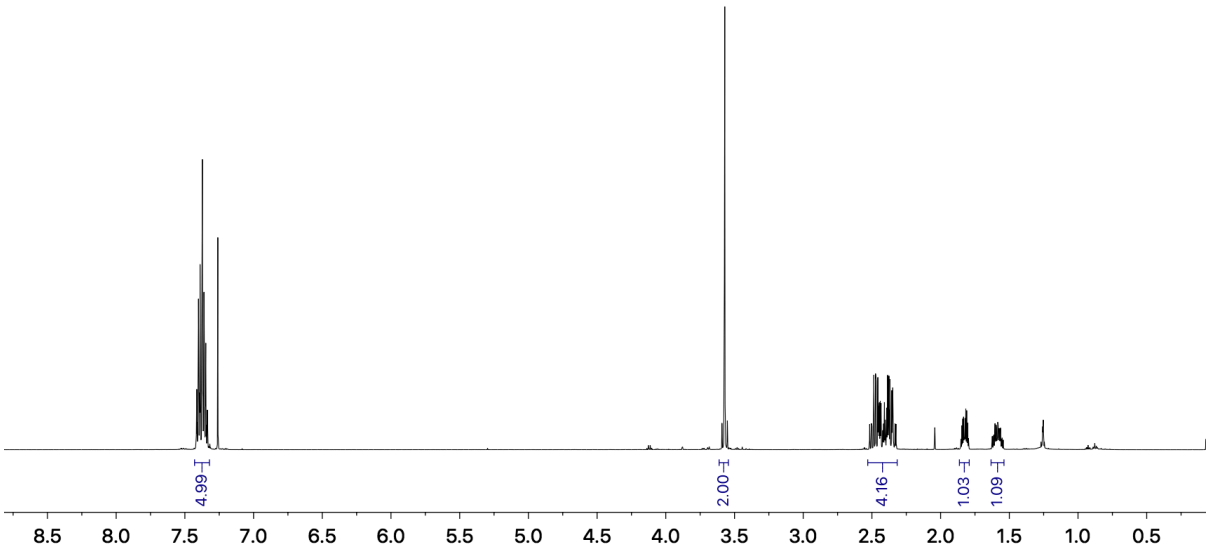
Peak #	Ret Time [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	14.888	BB	0.2507	7580.14795	468.57397	50.0251
2	16.030	BB	0.2708	7572.53809	435.73874	49.9749

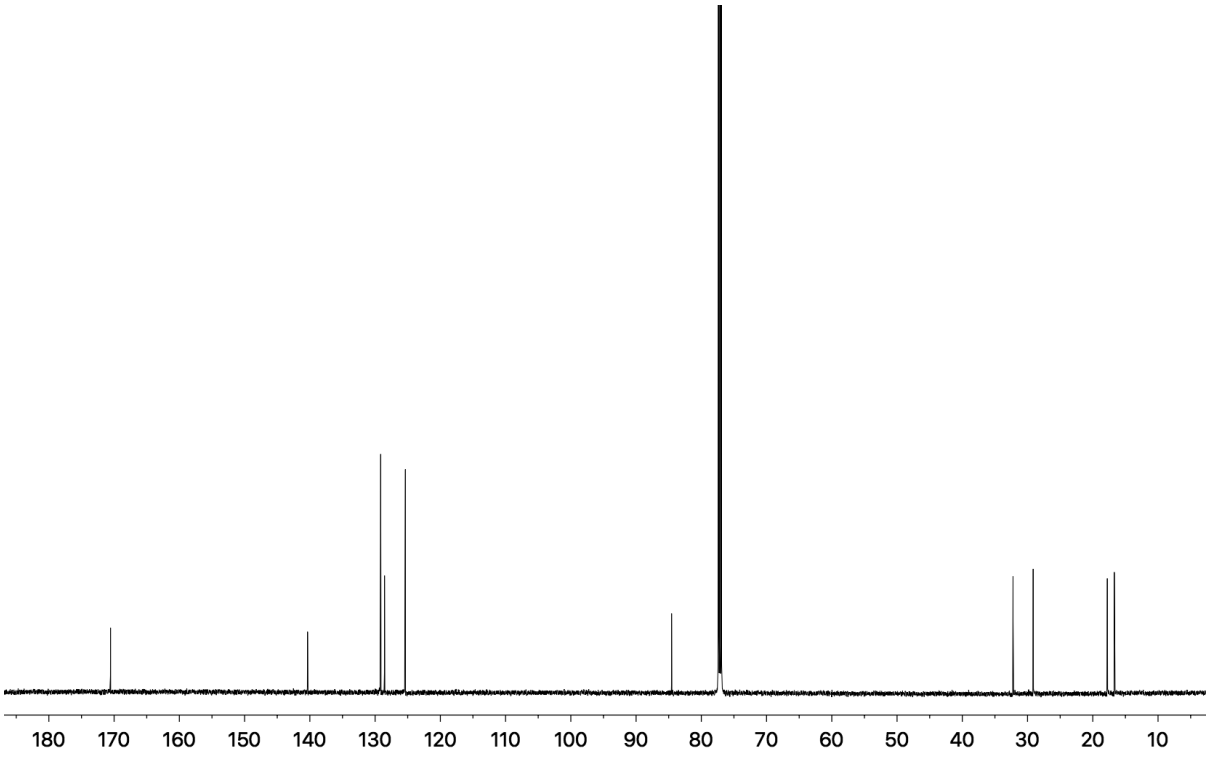


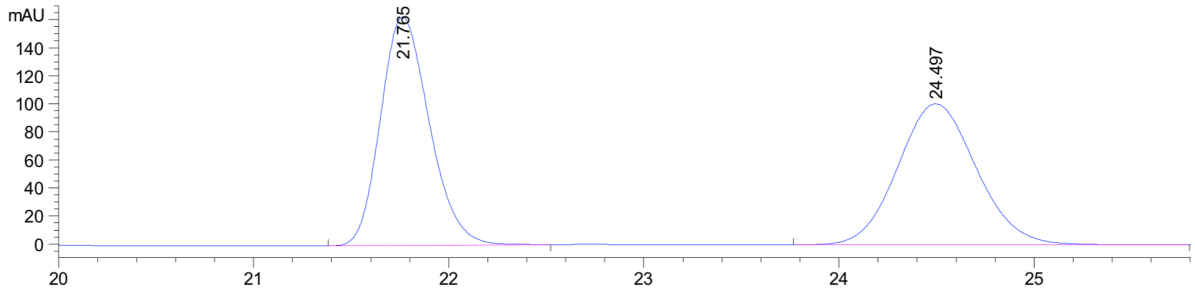
Peak #	Ret Time [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	15.708	MM	0.3101	9764.18164	524.83264	48.5754
2	17.083	MM	0.3399	1.03369e4	506.80786	51.4246

6-(Iodomethyl)-6-phenyltetrahydro-2*H*-pyran-2-one (11b)









Peak #	Ret Time [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
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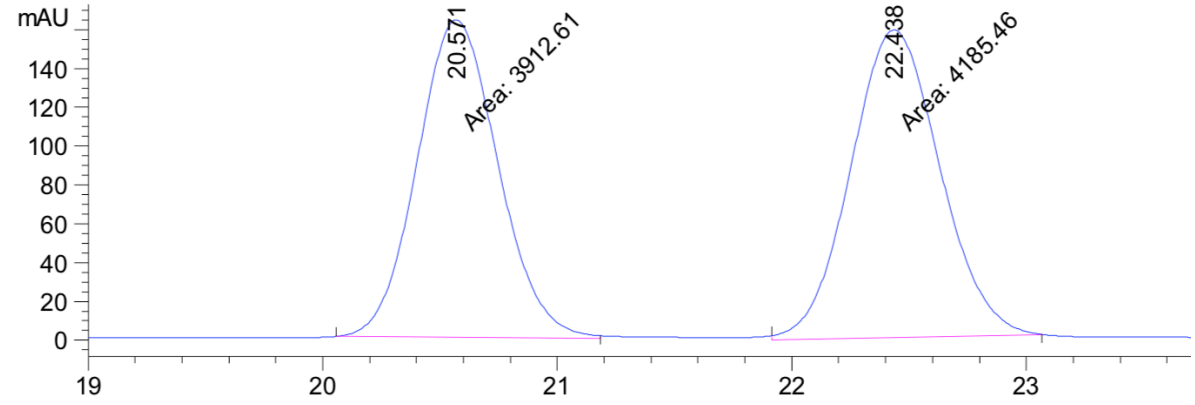
2	24.497	BB	0.4353	2822.49512	100.59980	49.8862



Peak #	Ret Time [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	20.571	MM	0.3990	3912.61426	163.41801	48.3153
2	22.438	MM	0.4405	4185.46387	158.37108	51.6847