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Metal-Free One-Pot α-Carboxylation of Primary Alcohols

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Supporting Information

Table of contents

1. General information S2
2. General procedures and characterization data S3
   2.1 Synthesis of the non-commercial primary alcohols S3
   2.2 The oxidation/Passerini/hydrolysis sequence S5
   2.3 Synthesis of α-hydroxy esters S9
3. Copies of NMR spectra S11
   3.1 Primary alcohols (**6**) S11
   3.2 α-Hydroxy acids (**1**) S16
   3.3 α-Hydroxy esters (**11**) S28

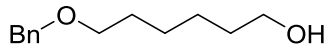
1. General information

Unless stated otherwise, all solvents and commercially available reagents were used as purchased. All reaction were performed under air, unless stated otherwise. Infrared (IR) spectra were recorded neat using a Shimadzu FTIR-8400s spectrophotometer and wavelengths are reported in cm^{-1}. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker Avance 500 (125.78 MHz for ^{13}C) or Bruker Avance 400 (100.62 MHz for ^{13}C) using the residual solvent as internal (^{1}H: δ 7.26 ppm, $^{13}C\{^{1}H\}$: δ 77.16 ppm for $CDCl_3$, ^{1}H: δ 2.50 ppm, $^{13}C\{^{1}H\}$: δ 39.52 ppm for DMSO-d_6 and ^{1}H: δ 3.31 ppm, $^{13}C\{^{1}H\}$: δ 49.00 ppm for MeOD-d_4). Chemical shifts (δ) are given in ppm and coupling constants (*J*) are quoted in hertz (Hz). Resonances are described as s (singlet), d (doublet), t (triplet), q (quartet), bs (broad singlet) and m (multiplet) or combinations thereof. Melting points were recorded on a Büchi M-565 melting point apparatus and are uncorrected. Electrospray Ionization (ESI) high-resolution mass spectrometry was carried out using a Bruker micrOTOF-Q instrument in positive ion mode (capillary potential of 4500 V). Flash chromatography was performed on Silicycle Silia-P Flash Silica Gel (particle size 40-63 µm, pore diameter 60 Å) using the indicated eluent. Thin Layer Chromatography (TLC) was performed using TLC plates from Merck (SiO2, Kieselgel 60 F254 neutral, on aluminium with fluorescence indicator) and compounds were visualized by UV detection (254 nm) and $KMnO_4$ stain.

2. General procedures and characterization data

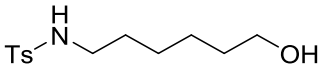
2.1 Synthesis of the non-commercial primary alcohols

6-(Benzyloxy)hexan-1-ol (6g):



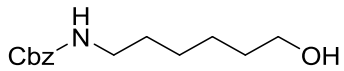
1,6-Hexanediol (1.18 g, 10 mmol, 1 equiv.) was dissolved in anhydrous DMF (30 mL) and cooled to 0 °C. Then, NaH (60% oil dispersion, 460 mg, 11.5 mmol, 1.15 equiv.) was added portion-wise and the mixture was allowed to warm up to room temperature and stirred for 30 minutes. The reaction mixture was cooled again to 0 °C and benzyl bromide (1.19 mL, 10 mmol, 1 equiv.) was added drop-wise and the resulting solution was allowed to warm to room temperature. After 16 h, the mixture was concentrated and partitioned between water and EtOAc. The organic layer was washed with saturated $NH_4Cl_{(aq)}$ and brine, dried with Na_2SO_4, filtered, concentrated and purified with flash chromatography (cyclohexane/EtOAc, 4:1) to obtain 6-(benzyloxy)hexan-1-ol as a colorless oil (930 mg, 4.45 mmol, 45%). TLC (cyclohexane/EtOAc, 4:1 v/v): R_F = 0.25; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.39 – 7.27 (m, 5H), 4.52 (s, 2H), 3.59 (t, *J* = 6.7 Hz, 2H), 3.49 (t, *J* = 6.6 Hz, 2H), 2.56 (bs, 1H), 1.68 – 1.62 (m, 2H), 1.59 – 1.54 (m, 2H), 1.44 – 1.35 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 138.5 (C_q), 128.4 (CH), 127.7 (CH), 127.5 (CH), 72.9 (CH_2), 70.3 (CH_2), 62.6 (CH_2), 32.6 (CH_2), 29.7 (CH_2), 26.0 (CH_2), 25.6 (CH_2).

***N*-(6-Hydroxyhexyl)-4-methylbenzenesulfonamide (6h):**



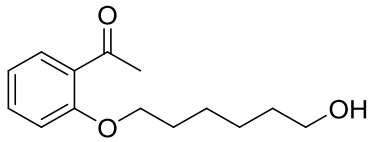
6-Amino-1-hexanol (1.00 g, 8.5 mmol, 1.0 equiv.) and trimethylamine (2.1 mL, 15 mmol, 1.7 equiv.) were dissolved in CH_2Cl_2 (100 mL) and cooled to 0 °C. Then, tosyl chloride (1.91 g, 10 mmol, 1.2 equiv.) was added portion-wise. After 1 h, the mixture was allowed to warm to room temperature and stirred for 16 h. The reaction was quenched with water and the layers were separated. The organic layer was dried with Na_2SO_4, filtered, concentrated and purified with flash chromatography (cyclohexane/EtOAc, 1:1) to obtain N-(6-hydroxyhexyl)-4-methylbenzenesulfonamide as a white solid (900 mg, 3.3 mmol, 39%). TLC (cyclohexane/EtOAc, 1:1 v/v): R_F = 0.30; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 5.20 (bs, 1H), 3.58 (t, *J* = 6.6 Hz, 2H), 2.90 (t, *J* = 7.0 Hz, 2H), 2.42 (s, 3H), 2.13 (bs, 1H), 1.52 – 1.43 (m, 4H), 1.31 – 1.25 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 143.4 (C_q), 136.9 (C_q), 129.7 (CH), 127.1 (CH), 62.6 (CH_2), 43.1 (CH_2), 32.4 (CH_2), 29.4 (CH_2), 26.2 (CH_2), 25.2 (CH_2), 21.6 (CH_3).

Benzyl (6-hydroxyhexyl)carbamate (6i):



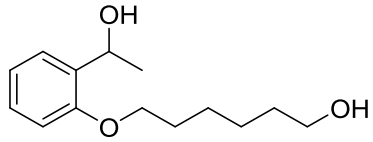
6-Amino-1-hexanol (1.17 g, 10 mmol, 1 equiv.) and sodium carbonate (2.33 g, 22 mmol, 2.2 equiv.) were dissolved in THF/H_2O (1:1, 30 mL) and cooled to 0 °C. Benzyl chloroformate (1.56 mL, 11 mmol, 1.1 equiv.) was added and the reaction mixture was allowed to warm to room temperature. After 16 h, the product was extracted with EtOAc (3×). The combined organic layers were washed with brine, dried with Na_2SO_4, filtered and concentrated to obtain benzyl (6-hydroxyhexyl)carbamate as a white solid (2.38 g, 9.5 mmol, 95%). ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.36 – 7.28 (m, 5H), 5.07 (m, 2H), 4.95 (bs, 1H), 3.59 (t, *J* = 6.6 Hz, 2H), 3.17 (m, 2H), 2.11 (bs, 1H), 1.55 – 1.46 (m, 4H), 1.42 – 1.31 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 156.6 (C_q), 136.7 (C_q), 128.6 (CH), 128.5 (CH), 128.1 (CH), 66.6 (CH_2), 62.6 (CH_2), 40.9 (CH_2), 32.6(CH_2), 30.0 (CH_2), 26.4 (CH_2), 25.4 (CH_2).

1-(2-((6-Hydroxyhexyl)oxy)phenyl)ethan-1-one (6n):



2-Hydroxyacetophenone (1.8 mL, 15 mmol, 1 equiv.), TBAI (0.277 g, 0.75 mmol, 0.05 equiv.) and K_2CO_3 (2.49 g, 18 mmol, 1.2 equiv.) were dissolved in anhydrous DMF (30 mL). 6-chlorohexanol (2.00 mL, 15 mmol, 1 equiv.) was added and the temperature was raised to 100 °C. After 7 h, the reaction mixture was cooled to room temperature and stirred overnight. The mixture was concentrated and partitioned between water and EtOAc. The water layer was extracted with EtOAc (2×) and the combined organic layers were washed with brine, dried with Na_2SO_4, filtered, concentrated and purified with flash chromatography (cyclohexane/EtOAc, 3:2) to obtain 1-(2-((6-hydroxyhexyl)oxy)phenyl)ethan-1-one as a red oil (2.62 g, 11.1 mmol, 74%). TLC (cyclohexane/EtOAc, 3:2 v/v): R_F = 0.23; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.72 (dd, *J* = 7.7, 1.8 Hz, 1H), 7.43 (m, 1H), 6.95 (m, 2H), 4.05 (t, *J* = 6.4 Hz, 2H), 3.65 (t, *J* = 6.5 Hz, 2H), 2.62 (s, 3H), 1.86 (m, 2H), 1.72 (s, 1H), 1.61 – 1.43 (m, 6H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 200.3 (C_q), 158.6 (C_q), 133.8 (CH), 130.5 (CH), 128.3 (C_q), 120.5 (CH), 112.3 (CH), 68.4 (CH_2), 62.9 (CH_2), 32.7 (CH_2), 32.2 (CH_3), 29.3 (CH_2), 26.2 (CH_2), 25.6 (CH_2); IR (neat): ν max (cm^{-1}) = 3396 (w), 2935 (m), 1668 (s), 1592 (s), 1450 (s), 1294 (s), 1236 (s), 756 (s), 594 (m); HRMS (ESI): m/z calculated for $C_{14}H_{20}O_3Na$ [M + Na] 259.1305, found 259.1307.

6-(2-(1-Hydroxyethyl)phenoxy)hexan-1-ol (6o):



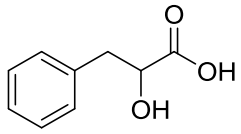
1-(2-((6-Hydroxyhexyl)oxy)phenyl)ethan-1-one (1.06 g, 4.46 mmol, 1 equiv.) was dissolved in MeOH (15 mL) and cooled to 0 °C. Then, $NaBH_4$ (0.28 g, 7.5 mmol, 1.7 equiv.) was added portion-wise and the resulting mixture stirred for 2 h at 0 °C. The mixture was quenched with sat. $NH_4Cl_{(aq)}$, followed by removal of MeOH under reduced pressure. More water was added and the product was extracted with EtOAc (2×). The combined organic layers were washed with brine and dried with Na_2SO_4, filtered and concentrated to obtain 6-(2-(1-hydroxyethyl)phenoxy)hexan-1-ol as a colorless oil (965 mg, 4.05 mmol, 91%). ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.32 (dd, *J* = 7.5, 1.6 Hz, 1H), 7.22 (dt, *J* = 8.1, 1.7 Hz, 1H), 6.95 (dt, *J* = 7.5, 0.9 Hz, 1H), 6.86 (dd, *J* = 8.0, 0.5 Hz, 1H), 5.09 (q, *J* = 6.5 Hz, 1H), 4.02 (t, *J* = 6.3 Hz, 2H), 3.65 (t, *J* = 6.5 Hz, 2H), 2.09 (s, 2H), 1.84 (m, 2H), 1.63 – 1.43 (m, 9H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 156.1 (C_q), 133.4 (C_q), 128.4 (CH), 126.3 (CH), 120.8 (CH), 111.3 (CH), 67.9 (CH_2), 66.9 (CH), 62.9 (CH_2), 32.7 (CH_2), 29.4 (CH_2), 26.2 (CH_2), 25.6 (CH_2), 23.0 (CH_3); IR (neat): ν max (cm^{-1}) = 3352 (w), 2933 (m), 1601 (w), 1490 (m), 1450 (m), 1236 (s), 1076 (s), 752 (s); HRMS (ESI): m/z calculated for $C_{14}H_{22}O_3Na$ [M + Na] 261.1461, found 261.1459.

2.2 The oxidation/Passerini/hydrolysis sequence

General procedure I: Synthesis of α-hydroxy acids 1

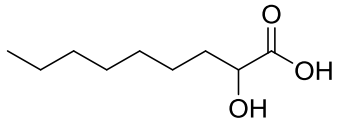
$PhI(OAc)_2$ (339 mg, 1.05 mmol, 1.05 equiv.) and TEMPO (15.6 mg, 0.1 mmol, 0.1 equiv.) were added to the alcohol (1 mmol, 1 equiv.) in CH_2Cl_2 (3 mL) and the resulting mixture stirred for 4 hours at room temperature. Subsequently, 2-bromo-6-isocyanopyridine (228 mg, 1.25 mmol, 1,25 equiv.) was added and the resulting mixture stirred for 60 h (generally over the weekend). Then, MeOH (1 mL) and NaOH (10M, 0.5 mL, 5 mmol, 5 equiv.) were added and the resulting biphasic mixture stirred for another 24 h. Next, the layers were separated and the water layer was washed with CH_2Cl_2 (2×). The organic layers were combined and extracted with NaOH (1M, 1×). Both water layers were combined, acidified with HCl (12M) to pH 1 and saturated with NaCl. Finally, the water layer was extracted with EtOAc (3×). The organic layers were combined, dried with Na_2SO_4, filtered and concentrated to obtain the title product generally as a slowly solidifying oil.

2-Hydroxy-3-phenylpropanoic acid (1a):



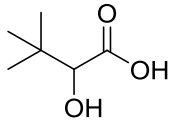
Prepared according to **general procedure I** on a 5 mmol scale: from 2-phenylethenol (598 µL, 5 mmol). Yield: 606 mg, 3.6 mmol, 73%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.38 – 7.22 (m, 5H), 4.51 (dd, *J* = 7.2, 4.2 Hz, 1H), 3.20 (dd, *J* = 14.0, 4.2 Hz, 1H), 2.99 (dd, *J* = 14.0, 7.3 Hz, 1H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.5 (C_q), 136.1 (C_q), 129.6 (CH), 128.6 (CH), 127.2 (CH), 71.1 (CH), 40.2 (CH_2); IR (neat): ν max (cm^{-1}) = 3035 (w), 1718 (s), 1088 (s), 909 (m), 732 (s), 729 (s); HRMS (ESI): m/z calculated for $C_9H_9O_3$ [M – H] 165.0557, found 165.0559.

2-Hydroxynonanoic acid (1b):



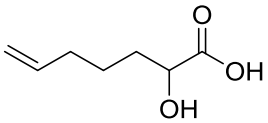
Prepared according to **general procedure I** from 1-octanol (157 µL, 1 mmol). Yield: 115 mg, 0.66 mmol, 66%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 9.00 – 6.00 (bs, 2H), 4.26 (dd, *J* = 7.6, 4.2 Hz, 1H), 1.82 (m, 1H), 1.68 (m, 1H), 1.42 (m, 2H), 1.27 (m, 8H), 0.86 (t, *J* = 6.7 Hz, 3H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 180.1 (C_q), 70.4 (CH), 34.2 (CH_2), 31.9 (CH_2), 29.4 (CH_2), 29.2 (CH_2), 24.9 (CH_2), 22.8 (CH_2), 14.2 (CH_3); IR (neat): ν max (cm^{-1}) = 3390 (w), 2925 (m), 1704 (s), 1227 (m), 1202 (m), 1128 (s), 1085 (s), 917 (m); HRMS (ESI): m/z calculated for $C_9H_{17}O_3$ [M – H] 173.1183, found 173.1185.

2-hydroxy-3,3-dimethylbutanoic acid (1c):



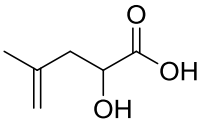
Prepared according to **general procedure I** from 2,2-dimethylpropan-1-ol (88 mg, 1 mmol). The reaction mixture was heated to 65 °C after addition of aqueous NaOH. Yield: 87 mg, 0.66 mmol, 66%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 8.00 – 6.50 (bs, 2H), 3.91 (s, 1H), 1.01 (s, 9H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.6 (C_q), 78.2 (CH), 35.2 (C_q), 25.7 (CH_3); IR (neat): ν max (cm^{-1}) = 3378 (w), 2959 (m), 1713 (s), 1217 (m), 1078 (s), 1022 (m), 702 (m); HRMS (ESI): m/z calculated for $C_6H_{11}O_3$ [M – H] 131.0714, found 131.0711.

2-Hydroxyhept-6-enoic acid (1d):



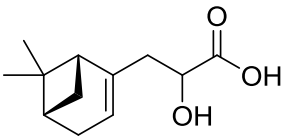
Prepared according to **general procedure I** from hex-5-en-1-ol (120 µL, 1 mmol). Yield: 120 mg, 0.84 mmol, 84%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.70 – 6.30 (br, 2H), 5.78 (m, 1H), 5.00 (m, 2H), 4.28 (dd, *J* = 7.6, 4.2 Hz), 2.09 (m, 2H), 1.85 (m, 1H), 1.70 (m, 2H), 1.55 (m, 2H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 179.9 (C_q), 138.2 (CH), 115.2 (CH_2), 70.3 (CH), 33.6 (CH_2), 33.4 (CH_2), 24.1 (CH_2); IR (neat): ν max (cm^{-1}) = 2927 (w), 1717 (s), 1213 (m), 1089 (m), 1089 (s), 909 (s); HRMS (ESI): m/z calculated for $C_7H_{11}O_3$ [M – H] 143.0714, found 143.0712.

2-Hydroxy-4-methylpent-4-enoic acid (1e):



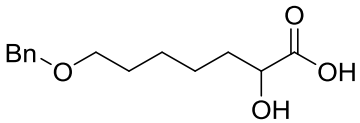
Prepared according to **general procedure I** from 3-methyl-3-buten-1-ol (101 µL, 1 mmol). Yield: 91 mg, 0.70 mmol, 70%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.20 – 6.20 (br s, 2H), 4.92 (s, 1H), 4.86 (s, 1H), 4.39 (dd, *J* = 8.8, 3.9 Hz, 1H), 2.61 (dd, *J* = 14.2, 3.6 Hz, 1H), 2.40 (dd, *J* = 14.2, 8.8 Hz, 1H), 1.80 (s, 3H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.6 (C_q), 140.8 (C_q), 114.7 (CH_2), 68.8 (CH), 42.5 (CH_2), 22.4 (CH_3); IR (neat): ν max (cm^{-1}) = 2918 (w), 1714 (m), 1436 (w), 1218 (w), 1095 (m), 894 (m); HRMS (ESI): m/z calculated for $C_6H_9O_3$ [M – H] 129.0557, found 129.0558.

3-((*1R,5S*)-6,6-Dimethylbicyclo[3.1.1]hept-2-en-2-yl)-2-hydroxypropanoic acid (1f):



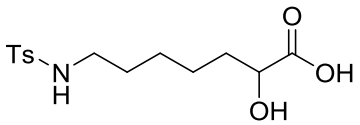
Prepared according to **general procedure I** from (-)-nopol (171 µL, 1 mmol). Yield: 187 mg, 0.89 mmol, 89%. The product exist as a 1:1 mixture of 2 diastereoisomers and contains about 9% of the exocylic (side) product. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 5.42 (bs, 1H), 4.29 (dd, *J* = 8.4, 3.8 Hz, 0.5H), 4.25 (dd, *J* = 7.7, 4.2 Hz, 0.5H), 2.55 (m, 1H), 2.37 (m, 2H), 2.25 (m, 2H), 2.09 (m, 2H), 1.27 (s, 3H), 1.15 (m, 1H), 0.85 (s, 3H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 179.1 (C_q), 179.1 (C_q) ,143.3 (C_q), 142.9 (C_q), 121.8 (CH), 121.7 (CH), 68.8 (CH), 68.6 (CH), 46.0 (CH), 45.4 (CH), 41.8 (C_q), 41.8 (C_q), 40.7 (CH_2), 40.6 (CH_2), 38.2 (C_q), 38.0 (C_q), 31.9 (CH_2), 31.8 (CH_2), 31.8 (CH_2), 31.6 (CH_2), 26.3 (CH_3), 26.3 (CH_3), 21.3 (CH_3), 21.2 (CH_3); IR (neat): ν max (cm^{-1}) = 2920 (m), 1718 (s), 1217 (m), 1083 (s), 907 (s), 731 (s); HRMS (ESI): m/z calculated for $C_{12}H_{17}O_3$ [M – H] 209.1183, found 209.1186.

7-(Benzyloxy)-2-hydroxyheptanoic acid (1g):



Prepared according to **general procedure I** from 6-(benzyloxy)hexan-1-ol (208 mg, 1 mmol). Yield: 184 mg, 0.73 mmol, 73%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.38 – 7.28 (m, 5H), 4.53 (s, 2H), 4.23 (dd, *J* = 7.6, 4.2 Hz, 1H), 3.51 (t, *J* = 6.6 Hz, 2H), 1.83 (m, 1H), 1.69 – 1.64 (m, 3H), 1.48 – 1.39 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.6 (C_q), 138.1 (C_q), 128.5 (CH), 127.9 (CH), 127.8 (CH), 72.9 (CH_2), 70.3 (CH_2), 70.2 (CH), 34.0 (CH_2), 29.4 (CH_2), 25.8 (CH_2), 24.7 (CH_2); IR (neat): ν max (cm^{-1}) = 2941 (br), 2862 (br), 1724 (s), 1448 (m), 1211 (m), 1001 (s), 748 (s), 696 (s) ; HRMS (ESI): m/z calculated for $C_{14}H_{19}O_4$ [M – H] 251.1289, found 251.1300.

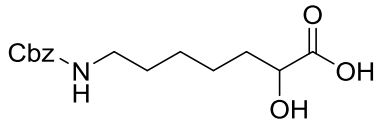
2-Hydroxy-7-((4-methylphenyl)sulfonamido)heptanoic acid (1h):



Prepared according to **general procedure I** from N-(6-hydroxyhexyl)-4-methylbenzenesulfonamide (258 mg, 0.95 mmol). Yield: 270 mg, 0.86 mmol, 90%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 8.2 Hz, 2H), 6.70 – 5.50 (bs, 2H), 5.19 (bs, 1H), 4.25 (dd, *J* = 7.1, 4.0 Hz, 1H), 2.90 (m, 2H), 2.41 (s, 3H), 1.78 (m, 1H), 1.66 (m, 1H), 1.49 – 1.25 (m, 6H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.5 (C_q), 143.6 (C_q), 136.8 (C_q), 129.9 (CH), 127.2 (CH), 70.1 (CH), 43.0 (CH_2), 33.8

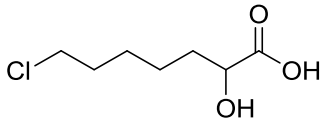
(CH_2), 29.3 (CH_2), 26.0 (CH_2), 24.2 (CH_2), 21.7 (CH_3); IR (neat): ν max (cm^{-1}) = 3274 (w), 2934 (w), 1717 (m), 1429 (w), 1321 (m), 1153 (s), 1090 (s), 908 (s), 813 (s), 727 (s), 663 (s), 546 (s); HRMS (ESI): m/z calculated for $C_{14}H_{20}NO_5S$ [M – H] 314.1068, found 314.1082.

7-(((Benzyloxy)carbonyl)amino)-2-hydroxyheptanoic acid (1i):



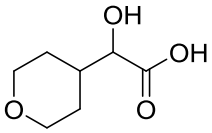
Prepared according to **general procedure I** from benzyl (6-hydroxyhexyl)carbamate (251 mg, 1 mmol). Yield: 168 mg, 0.57 mmol, 57%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.33 (m, 5H), 5.15 – 5.08 (m, 2H), 4.22 (dd, *J* = 6.9, 3.8 Hz, 3H), 3.17 (m, 2H), 1.82 (m, 1H), 1.69 (m, 1H), 1.53 – 1.33 (m, 6H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.4 (C_q), 156.9 (C_q), 136.5 (C_q), 128.7 (CH), 128.3 (CH), 128.1 (CH), 70.1 (CH), 67.0 (CH_2), 40.8 (CH_2), 33.9 (CH_2), 29.8 (CH_2), 26.1 (CH_2), 24.2 (CH_2); m.p.: 76 °C; IR (neat): ν max (cm^{-1}) = 3327 (m), 2929 (w), 1681 (s), 1545 (s), 1271 (s), 1130 (m), 1075 (w), 727 (w), 698 (w); HRMS (ESI): m/z calculated for $C_{14}H_{20}NO_5$ [M – H] 294.1347, found 294.1356.

7-Chloro-2-hydroxyheptanoic acid (1j):



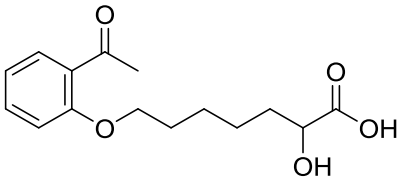
Prepared according to **general procedure I** from 6-chlorohexanol (134 µL, 1 mmol). Yield: 117 mg, 0.65 mmol, 65%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 8.00 – 6.00 (bs, 2H), 4.28 (dd, *J* = 7.6, 4.1 Hz, 1H), 3.53 (t, *J* = 6.7 Hz, 2H), 1.88 – 1.69 (m, 4H), 1.53 – 1.43 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 179.9 (C_q), 70.2 (CH), 45.0 (CH_2), 34.0 (CH_2), 32.4 (CH_2), 26.6 (CH_2), 24.2 (CH_2); m.p.: 54 °C; IR (neat): ν max (cm^{-1}) = 2934 (w), 1714 (s), 1216 (m), 1103 (s), 912 (m), 730 (s); HRMS (ESI): m/z calculated for $C_7H_{12}ClO_3$ [M – H] 179.0480, found 179.0488.

2-Hydroxy-2-(tetrahydro-2*H*-pyran-4-yl)acetic acid (1m):



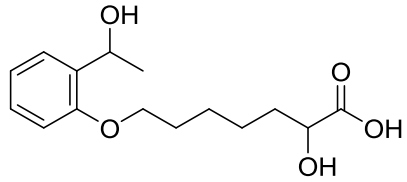
Prepared according to **general procedure I** from (tetrahydro-2*H*-pyran-4-yl)methanol: (116 mg, 1 mmol). The reaction mixture was heated to 50 °C after addition of aqueous NaOH. Yield: 142 mg, 0.89 mmol, 89%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 4.13 (d, J = 3.9 Hz, 1H), 4.11 – 4.04 (m, 2H), 3.48 – 3.39 (m, 2H), 2.05 (m, 1H), 1.76 – 1.60 (m, 3H), 1.50 – 1.42 (m, 1H); 13C{1H}-NMR (CDCl3, 125 MHz): δ 177.4 (C_q), 73.6 (CH), 67.9 (CH_2), 67.7 (CH_2), 39.0 (CH), 28.6 (CH_2), 26.4 (CH_2); IR (neat): ν max (cm^{-1}) = 3375 (w), 2951 (m), 2854 (m), 1720 (s), 1234 (s), 1105 (s), 1083 (s), 1018 (m), 881 (m), 544 (s); HRMS (ESI): m/z calculated for $C_7H_{11}O_4$ [M – H] 159.0663, found 159.0668.

7-(2-Acetylphenoxy)-2-hydroxyheptanoic acid (1n):



Prepared according to **general procedure I** from 1-(2-((6-hydroxyhexyl)oxy)phenyl)ethan-1-one: (236 mg, 1 mmol). Yield: 179 mg, 0.64 mmol, 64%. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.72 (dd, *J* = 7.8, 1.8 Hz, 1H), 7.42 (dt, *J* = 6.9, 1.8 Hz, 1H), 6.95 (m, 2H), 4.27 (dd, *J* = 7.5, 4.2 Hz, 1H), 4.05 (t, *J* = 6.3 Hz, 2H), 2.63 (s, 3H), 1.90 – 1.84 (m, 3H), 1.74 (m, 1H), 1.59 – 1.50 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 201.1 (C_q), 178.9 (C_q), 158.6 (C_q), 134.1 (CH), 130.5 (CH), 128.1 (C_q), 120.5 (CH), 112.4 (CH), 70.2 (CH), 68.4 (CH_2), 34.0 (CH_2), 32.1 (CH_3), 29.1 (CH_2), 26.1 (CH_2), 24.6 (CH_2); IR (neat): ν max (cm^{-1}) = 2935 (w), 1722 (s), 1668 (s), 1595 (s), 1450 (s), 1294 (s), 1236 (s), 1163 (m), 757 (s); HRMS (ESI): m/z calculated for $C_{15}H_{19}O_5$ [M – H] 279.1238, found 279.1251.

2-Hydroxy-7-(2-(1-hydroxyethyl)phenoxy)heptanoic acid (1o):



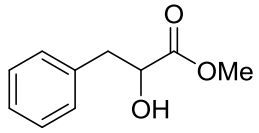
Prepared according to **general procedure I** from 6-(2-(1-hydroxyethyl)phenoxy)hexan-1-ol (238 mg, 1 mmol). Yield: 157 mg, 0.65 mmol, 65%. The product is obtained as a 5:1 mixture with **1m**. ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.72 (dd, *J* = 7.7, 1.8 Hz, 0.2H), 7.46 – 7.41 (m, 0.2H), 7.29 (dd, *J* = 7.5, 1.4 Hz, 1H), 7.22 (t, *J* = 7.8 Hz, 1H), 6.97 – 6.92 (m, 1H), 6.85 (t, *J* = 7.5 Hz, 1H), 6.60 – 5.50 (br, 2H), 5.20 – 5.05 (m, 1H), 4.23 (dd, *J* = 7.0, 3.4 Hz, 1.2H), 4.00 (m, 2.4H), 2.63 (s, 0.6H), 1.83 (m, 3.6H), 1.72 (m, 1.2H), 1.51 (m, 7.8H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 178.5 (C_q), 158.6 (C_q), 156.0 (C_q), 134.0 (CH), 132.6 (C_q), 130.5 (CH), 128.6 (CH), 126.3 (CH), 120.8 (CH), 120.4 (CH), 112.4 (CH), 111.3 (CH), 70.1 (CH), 70.1 (CH), 68.4 (CH_2), 67.9 (CH_2), 67.8 (CH_2), 67.2 (CH), 34.0 (CH_2), 34.0 (CH_2), 33.9 (CH_2), 32.1 (CH_3), 29.1 (CH_2), 26.1 (CH_2), 24.6 (CH_2), 24.6 (CH_2), 22.7 (CH_3); IR (neat): ν max (cm^{-1}) = 2938 (w), 1723 (m), 1599 (m), 1490 (m), 1234 (s), 1075 (s), 907 (s), 727 (s); HRMS (ESI): m/z calculated for $C_{15}H_{21}O_5$ [M – H] 281.1394, found 281.1406.

2.3 Synthesis of α-hydroxy esters

General procedure II: Synthesis of α-hydroxy esters (11)

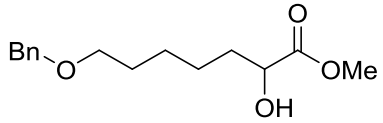
$PhI(OAc)_2$ (339 mg, 1.05 mmol, 1.05 equiv.) and TEMPO (15.6 mg, 0.1 mmol, 0.1 equiv.) were added to the alcohol (1 mmol, 1 equiv.) in CH_2Cl_2 (3 mL) and stirred for 4 h at room temperature. Subsequently 2-bromo-6-isocyanopyridine (228 mg, 1.25 mmol, 1,25 equiv.) was added and the resulting mixture stirred for 60 h. Then, the corresponding alcohol (3 mL) and AcCl (357 µL, 5 mmol, 5 equiv.) were added. After 24 h, the mixture was concentrated and purified by flash chromatography (cyclohexane/EtOAc) to obtain the title compound.

Methyl 2-hydroxy-3-phenylpropanoate (11a):



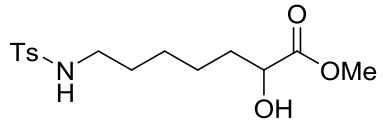
Prepared according to **general procedure II** from 2-phenylethanol (120 µL, 1 mmol) with MeOH as the corresponding alcohol. Purified by flash chromatography using cyclohexane/EtOAc (6:1) and obtained as a colorless oil. Yield: 155 mg, 0.86 mmol, 86%. TLC (cyclohexane/EtOAc, 4:1 v/v): R_F = 0.40; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.33 – 7.22 (m, 5H), 4.48 (m, 1H), 3.77 (s, 3H), 3.13 (dd, *J* = 13.9, 4 Hz, 1H), 2.98 (dd, *J* = 13.9, 6.9 Hz, 1H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 174.6 (C_q), 136.4 (C_q), 129.5 (CH), 128.4 (CH), 126.9 (CH), 71.3 (CH), 52.5 (CH_3), 40.5 (CH_2); IR (neat): ν max (cm^{-1}) = 3384 (w), 1729 (s), 1659 (s), 1437 (m), 1203 (s), 1093 (s), 746 (m), 699 (s); HRMS (ESI): m/z calculated for $C_{10}H_{12}O_3Na$ [M + Na] 203.0679, found 203.0682.

Methyl 7-(benzyloxy)-2-hydroxyheptanoate (11b):



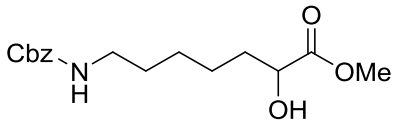
Prepared according to **general procedure II** from 6-(benzyloxy)hexan-1-ol (187 mg, 0.9 mmol) with MeOH as the corresponding alcohol. Purified by flash chromatography using cyclohexane/EtOAc (4:1) and obtained as a yellow oil. Yield: 153 mg, 0.64 mmol, 64%. TLC (cyclohexane/EtOAc, 4:1 v/v): R_F = 0.25; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.38 – 7.28 (m, 5H), 4.52 (s, 2H), 4.20 (m, 1H), 3.79 (s, 3H), 3.48 (t, *J* = 6.6 Hz, 2H), 2.86 (bs, 1H), 1.82 (m, 1H), 1.70 – 1.62 (m, 3H), 1.51 – 1.38 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 175.9 (C_q), 138.7 (C_q), 128.4 (CH), 127.7 (CH), 127.6 (CH), 73.0 (CH_2), 70.4 (CH), 70.3 (CH_2), 52.6 (CH_3), 34.4 (CH_2), 29.7 (CH_2), 26.0 (CH_2), 24.7 (CH_2); IR (neat): ν max (cm^{-1}) = 2940 (w), 2863 (w), 1734 (s), 1455 (w), 1210 (m), 1092 (s), 736 (s), 697 (s); HRMS (ESI): m/z calculated for $C_{15}H_{22}O_4Na$ [M + Na] 289.1404, found 289.1410.

Methyl 2-hydroxy-7-((4-methylphenyl)sulfonamido)heptanoate (11c):



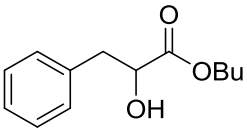
Prepared according to **general procedure II** from N-(6-hydroxyhexyl)-4-methylbenzenesulfonamide (272 mg, 1 mmol) with MeOH as the corresponding alcohol. Purified by flash chromatography using cyclohexane/EtOAc (1:1) and obtained as a yellow oil. Yield: 218 mg, 0.62 mmol, 62%. TLC (cyclohexane/EtOAc, 1:1 v/v): R_F = 0.29; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.71 (d, *J* = 8.2 Hz, 2H), 7.26 (d, *J* = 8.2 Hz, 2H), 5.16 (bs, 1H), 4.13 (dd, *J* = 7.6, 4.1 Hz, 1H), 3.72 (s, 3H), 3.01 (bs, 1H), 2.86 (m, 2H), 2.38 (s, 3H), 1.67 (m, 1H), 1.53 (m, 1H), 1.43 – 1.38 (m, 2H), 1.34 – 1.22 (m, 4H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 175.7 (C_q), 143.3 (C_q), 136.9 (C_q), 129.7 (CH), 127.1 (CH), 70.3 (CH), 52.5 (CH_3), 43.0 (CH_2), 34.0 (CH_2), 29.3 (CH_2), 26.1 (CH_2), 24.2 (CH_2), 21.5 (CH_3); IR (neat): ν max (cm^{-1}) = 3292 (w), 2943 (w), 1731 (s), 1321 (s), 1153 (s), 1091 (s), 910 (s), 813 (s), 727 (s), 549 (s); HRMS (ESI): m/z calculated for $C_{15}H_{23}NO_5SNa$ [M + Na] 352.1189, found 352.1181.

Methyl 7-(((benzyloxy)carbonyl)amino)-2-hydroxyheptanoate (11d):



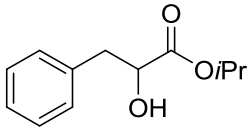
Prepared according to **general procedure II** from benzyl (6-hydroxyhexyl)carbamate (251 mg, 1 mmol). Purified by flash chromatography using cyclohexane/EtOAc (1:1) and obtained as a yellow oil. Yield: 140 mg, 0.45 mmol, 45%. TLC (cyclohexane/EtOAc, 1:1 v/v): R_F = 0.33; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.34-7.29 (m, 5H), 5.07 (s, 2H), 4.86 (bs, 1H), 4.17 (m, 1H), 3.76 (s, 3H), 3.17 (m, 2H), 2.93 (bs, 1H), 1.75 (m, 1H), 1.62 (m, 1H), 1.51 – 1.30 (m, 6H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 175.8 (C_q), 156.5 (C_q), 136.7 (CH), 128.6 (CH), 128.2 (CH), 128.2 (CH), 70.3 (CH), 66.7 (CH_2), 52.6 (CH), 41.0 (CH_2), 34.2 (CH_2), 29.9 (CH_2), 26.4 (CH_2), 24.5 (CH_2); IR (neat): ν max (cm^{-1}) = 3359 (w), 2938 (w), 1688 (s), 1541 (m), 1455 (m), 1235 (s), 1131 m), 697 (s); HRMS (ESI): m/z calculated for $C_{16}H_{23}NO_5Na$ [M + Na] 332.1468, found 332.1468.

Butyl 2-hydroxy-3-phenylpropanoate (11e):



Prepared according to **general procedure II** from 2-phenylethanol (120 µL, 1 mmol). The mixture was heated after addition of anhydrous BuOH and AcCl (714 µL, 10 mmol, 10 equiv.) to 40 °C. Purified by flash chromatography using cyclohexane/EtOAc (6:1) and obtained as a colorless oil. Yield: 167 mg, 0.75 mmol, 75%. TLC (cyclohexane/EtOAc, 6:1 v/v): R_F = 0.28; ^{1}H-NMR ($CDCl_3$, 500 MHz): δ 7.34 – 7.24 (m, 5H), 4.46 (m, 1H), 4.17 (m, 2H), 3.14 (dd, *J* = 14.0, 4.5 Hz, 1H), 2.99 (dd, 14.0, 7.0 Hz, 1H), 2.91 (bs, 1H), 1.65 (p, *J* = 7.5 Hz, 2H), 1.39 (h, *J* = 7.5 Hz, 2H), 0.97 (t, *J* = 7.5 Hz, 3H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 125 MHz): δ 174.3 (C_q), 136.4 (C_q), 129.5 (CH), 128.4 (CH), 126.9 (CH), 71.3 (CH), 65.6 (CH_2), 40.6 (CH_2), 30.6 (CH_2), 19.1 (CH_2), 13.7 (CH_3); IR (neat): ν max (cm^{-1}) = 3475 (br), 2958 (m), 1730 (s), 1454 (m), 1267 (m), 1195 (s), 1091 (s), 746 (m), 698 (s); HRMS (ESI): m/z calculated for $C_{13}H_{18}O_3Na$ [M + Na] 245.1148, found 245.1154.

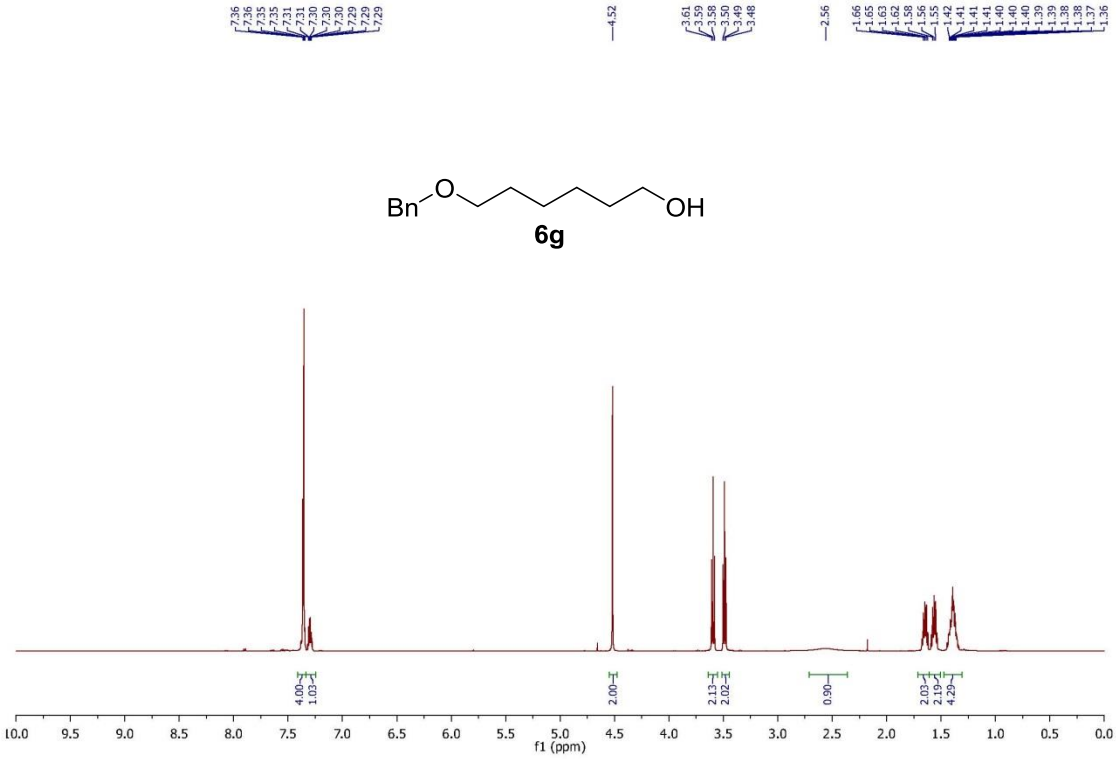
Isopropyl 2-hydroxy-3-phenylpropanoate (11f):

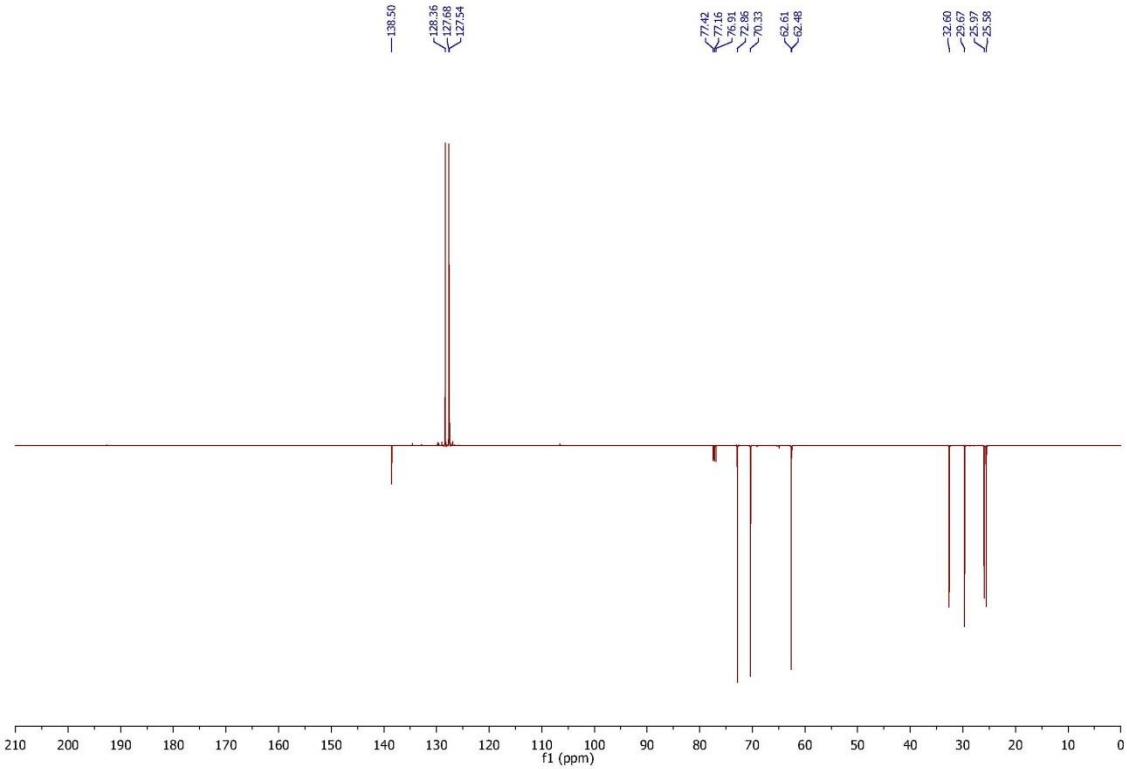


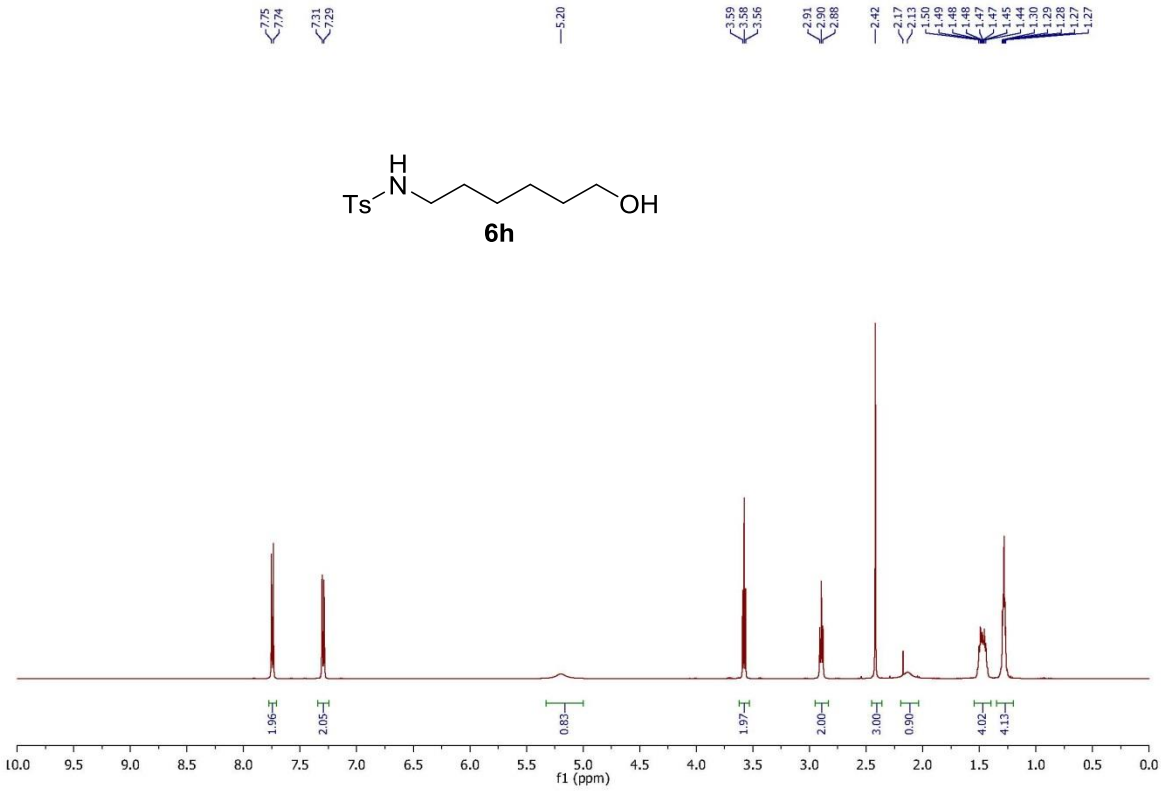
Prepared according to **general procedure II** from 2-phenylethanol (120 µL, 1 mmol). The mixture was heated after addition of anhydrous *i*PrOH and AcCl (714 µL, 10 mmol, 10 equiv.) to 80 °C. Purified by flash chromatography using cyclohexane/EtOAc (6:1) and obtained as a colorless oil. Yield: 131 mg, 0.63 mmol, 63%. TLC (cyclohexane/EtOAc, 6:1 v/v): R_F = 0.33; ^{1}H-NMR ($CDCl_3$, 400 MHz): δ 7.33 – 7.24 (m, 5H), 5.07 (septet, *J* = 6.0 Hz, 1H), 4.41 (m, 1H), 3.13 (dd, *J* = 14.0, 4.8 Hz, 1H), 2.97 (dd, *J* = 14.0, 6.4 Hz, 1H), 2.82 (bs, 1H), 1.26 (m, 6H); ^{13}C{^{1}H}-NMR ($CDCl_3$, 100 MHz): δ 173.7 (C_q), 136.4 (C_q), 129.6 (CH), 128.3 (CH), 126.8 (CH), 71.2 (CH), 69.6 (CH), 40.5 (CH_2), 21.7 (CH_3); IR (neat): ν max (cm^{-1}) = 3475 (br), 2958 (m), 1728 (s), 1454 (m), 1197 (s), 1091 (s), 744 (m), 698 (s); HRMS (ESI): m/z calculated for $C_{12}H_{16}O_3Na$ [M + Na] 231.0992, found 231.0995.

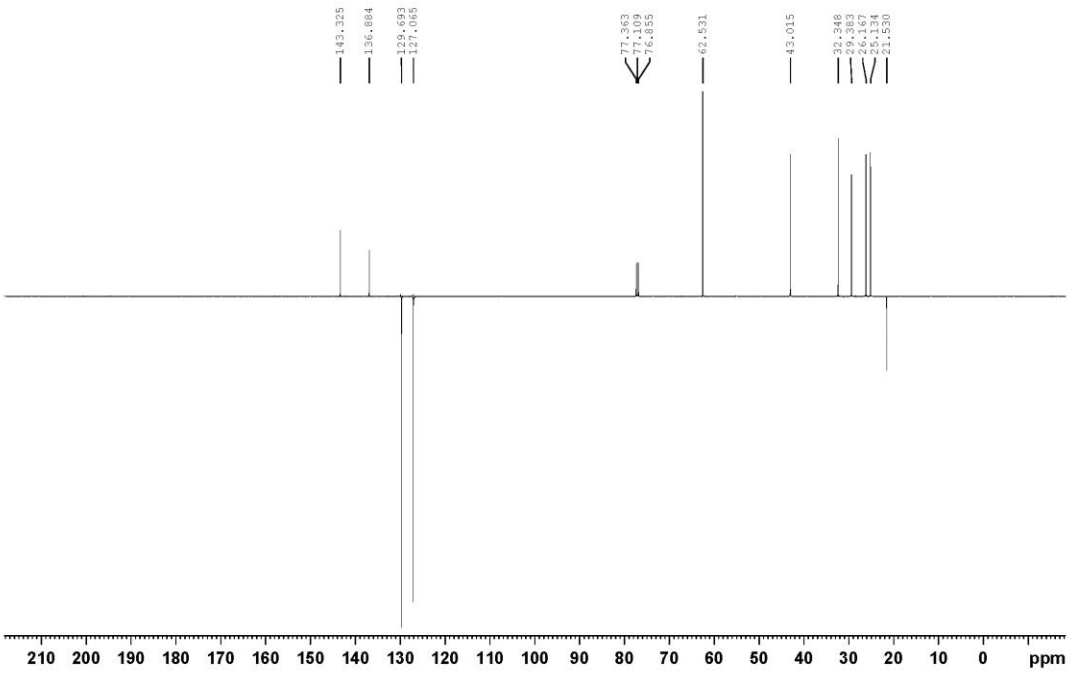
3. Copies of NMR spectra

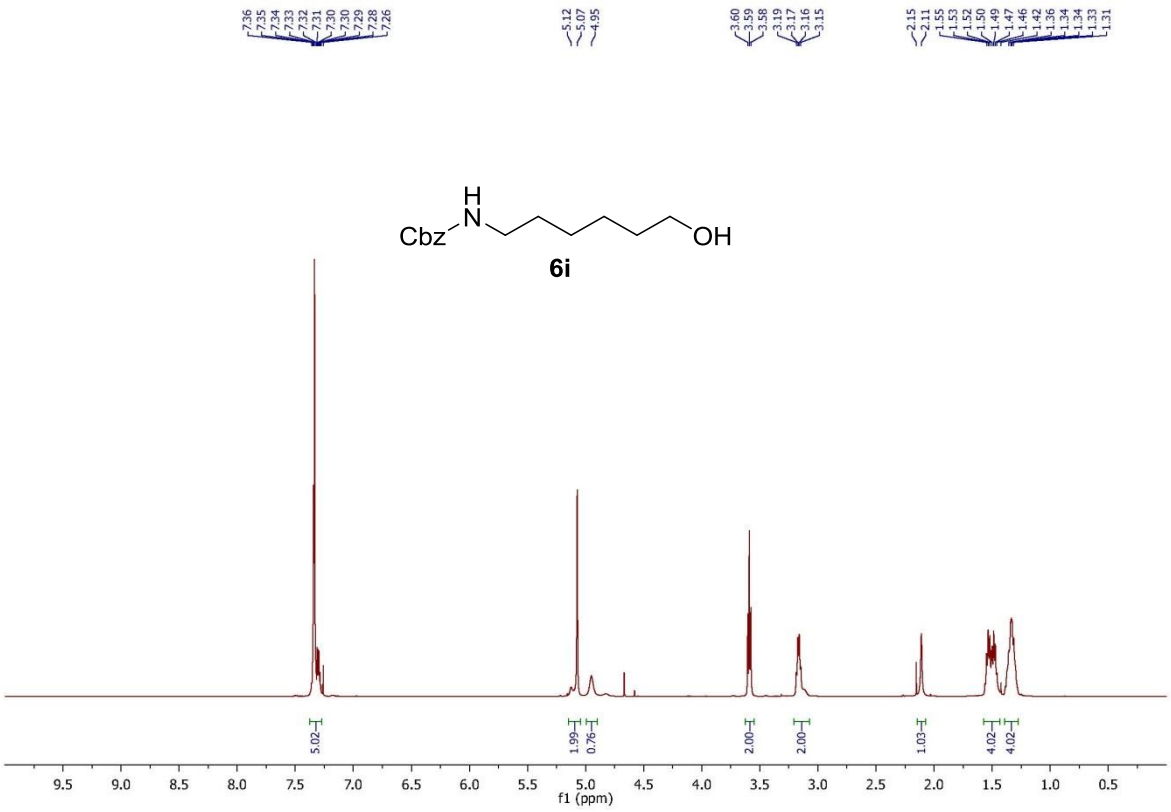
3.1 Primary alcohols (6)

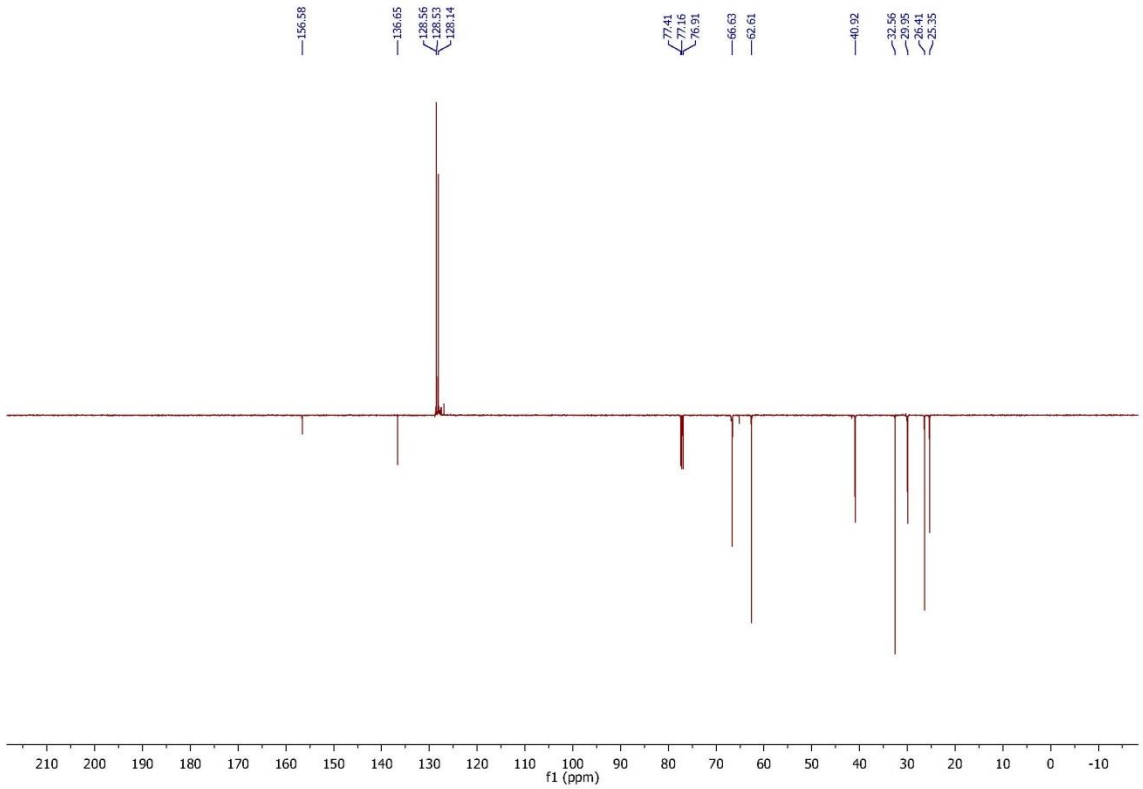


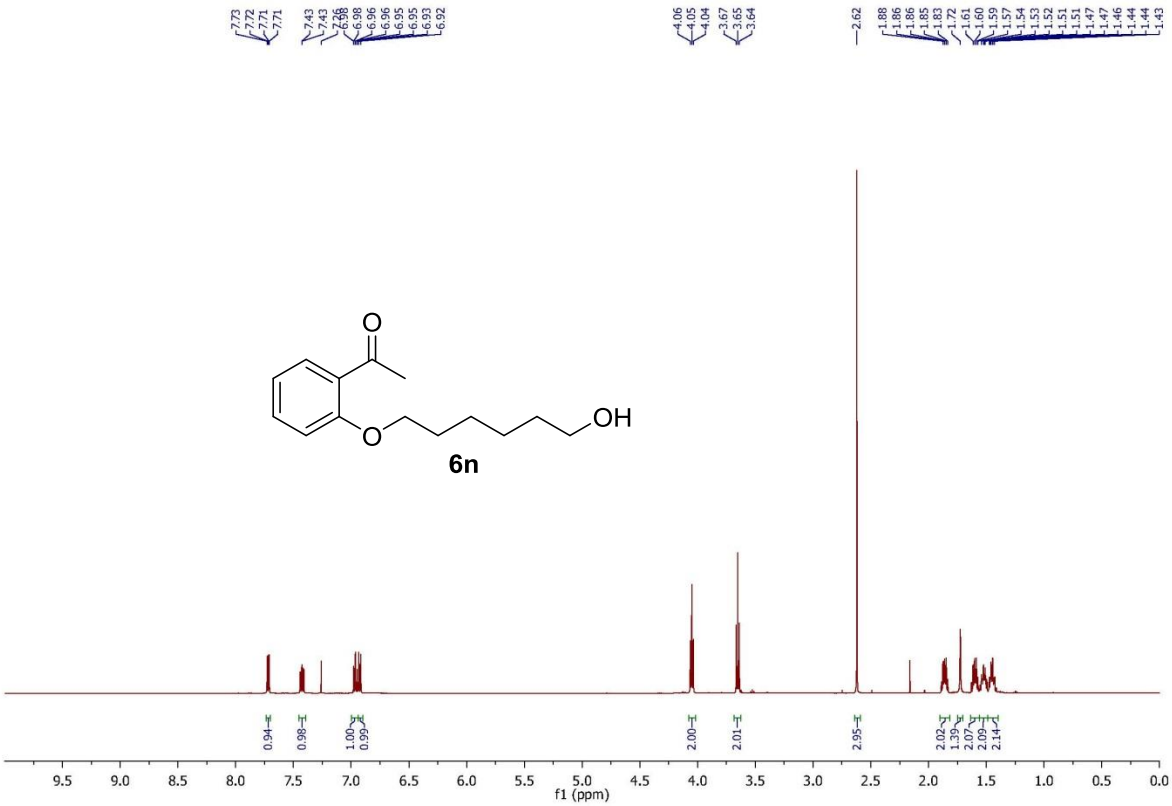


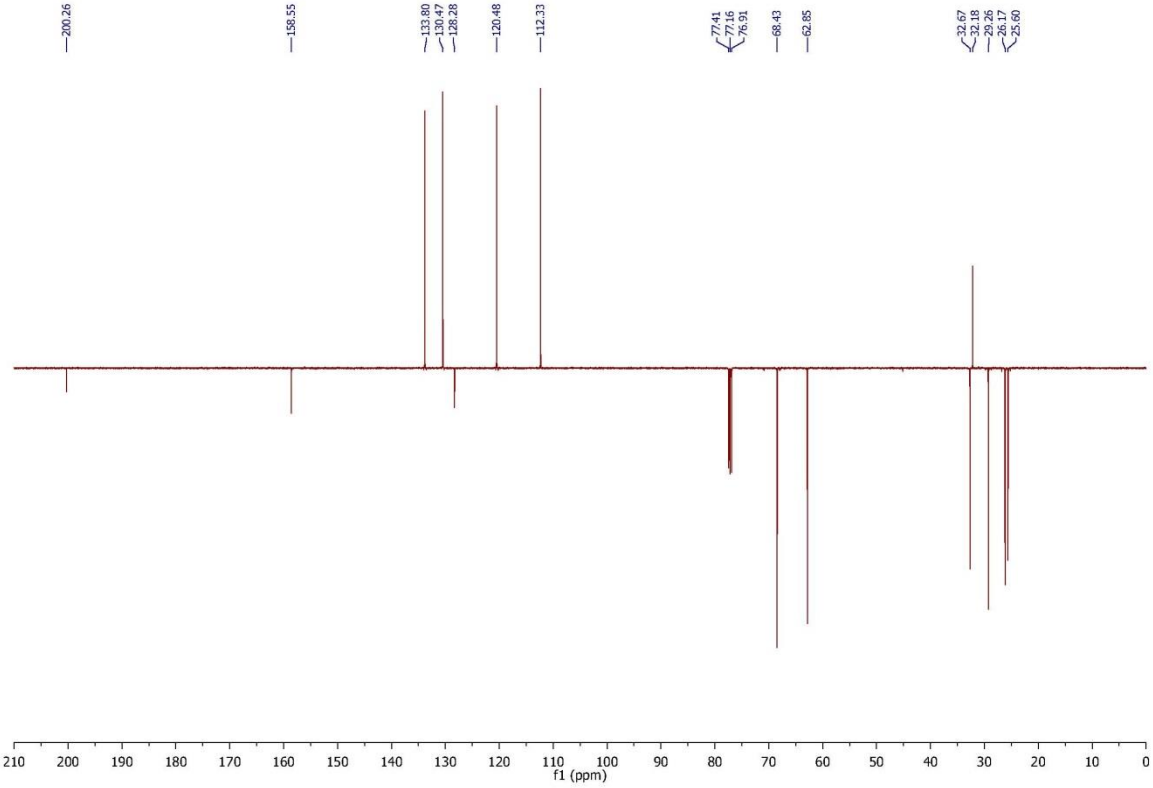

7.75
7.74
7.31
7.29
5.20
3.59
3.58
3.56
2.91
2.90
2.88
2.42
2.17
2.13
1.50
1.49
1.48
1.48
1.47
1.47
1.45
1.44
1.30
1.29
1.28
1.27
1.27
H
N
Ts
OH
6h
1.96
2.05
0.83
1.97
2.00
3.00
0.90
4.02
4.13
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

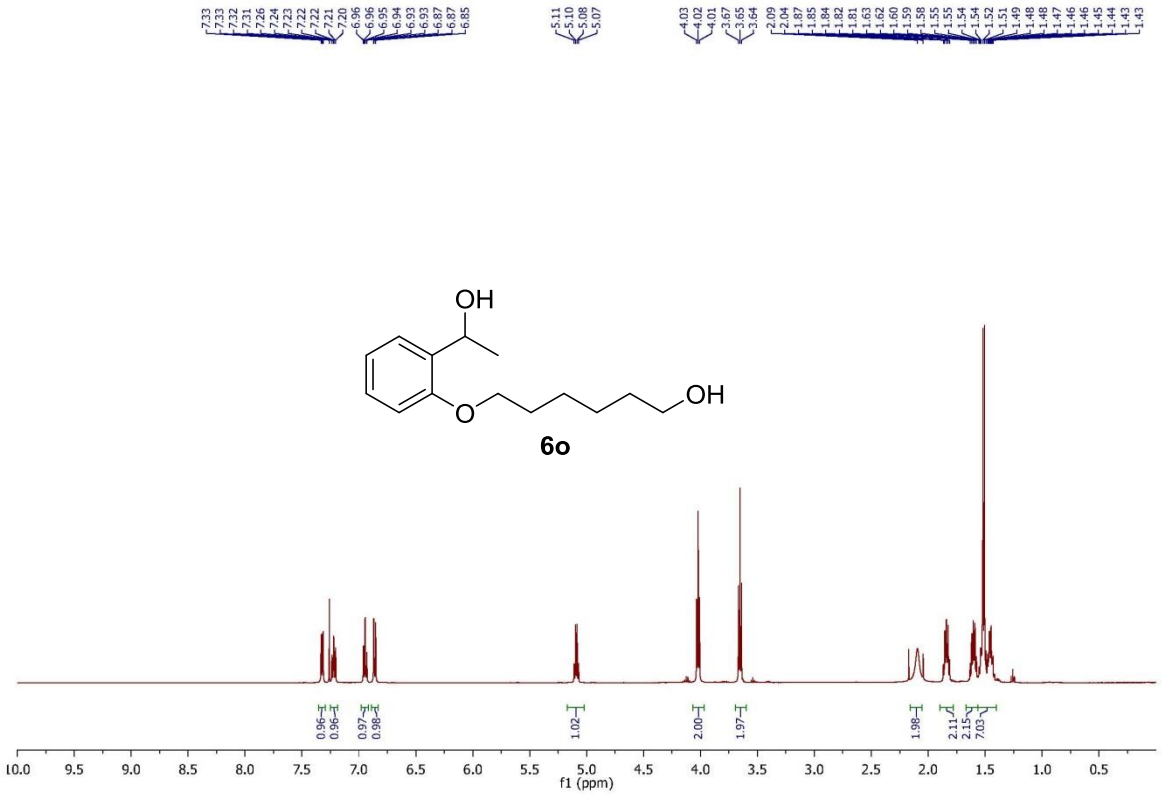

143.325
136.884
129.693
127.065
77.363
77.109
76.855
62.531
43.015
32.348
29.383
26.167
25.134
21.530
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

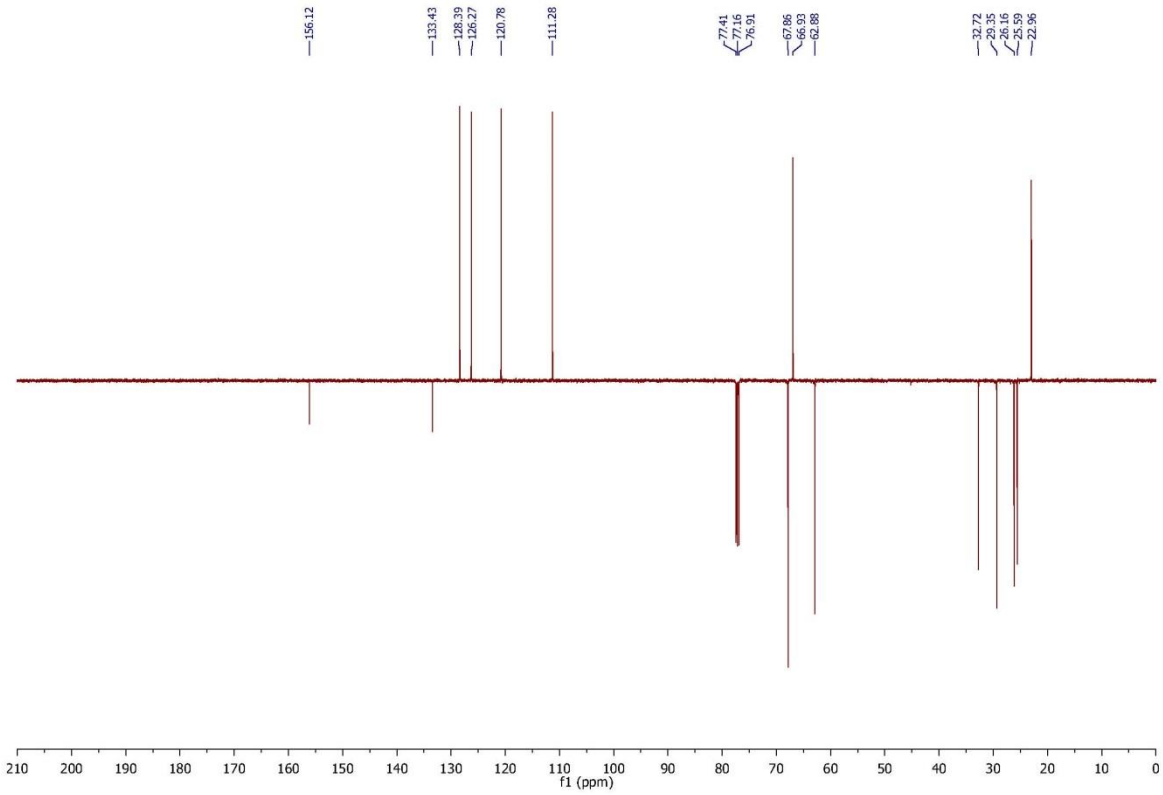

7.36
7.35
7.34
7.33
7.32
7.31
7.30
7.30
7.29
7.28
7.26
5.12
5.07
4.95
3.60
3.59
3.58
3.19
3.17
3.16
3.15
2.15
2.11
1.55
1.53
1.52
1.50
1.49
1.47
1.46
1.42
1.36
1.34
1.34
1.33
1.31
Cbz
N
H
OH
6i
5.02
1.99
0.76
2.00
2.00
1.03
4.02
4.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


156.58
136.65
128.56
128.53
128.14
77.41
77.16
76.91
66.63
62.61
40.92
32.56
29.35
29.41
25.35
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

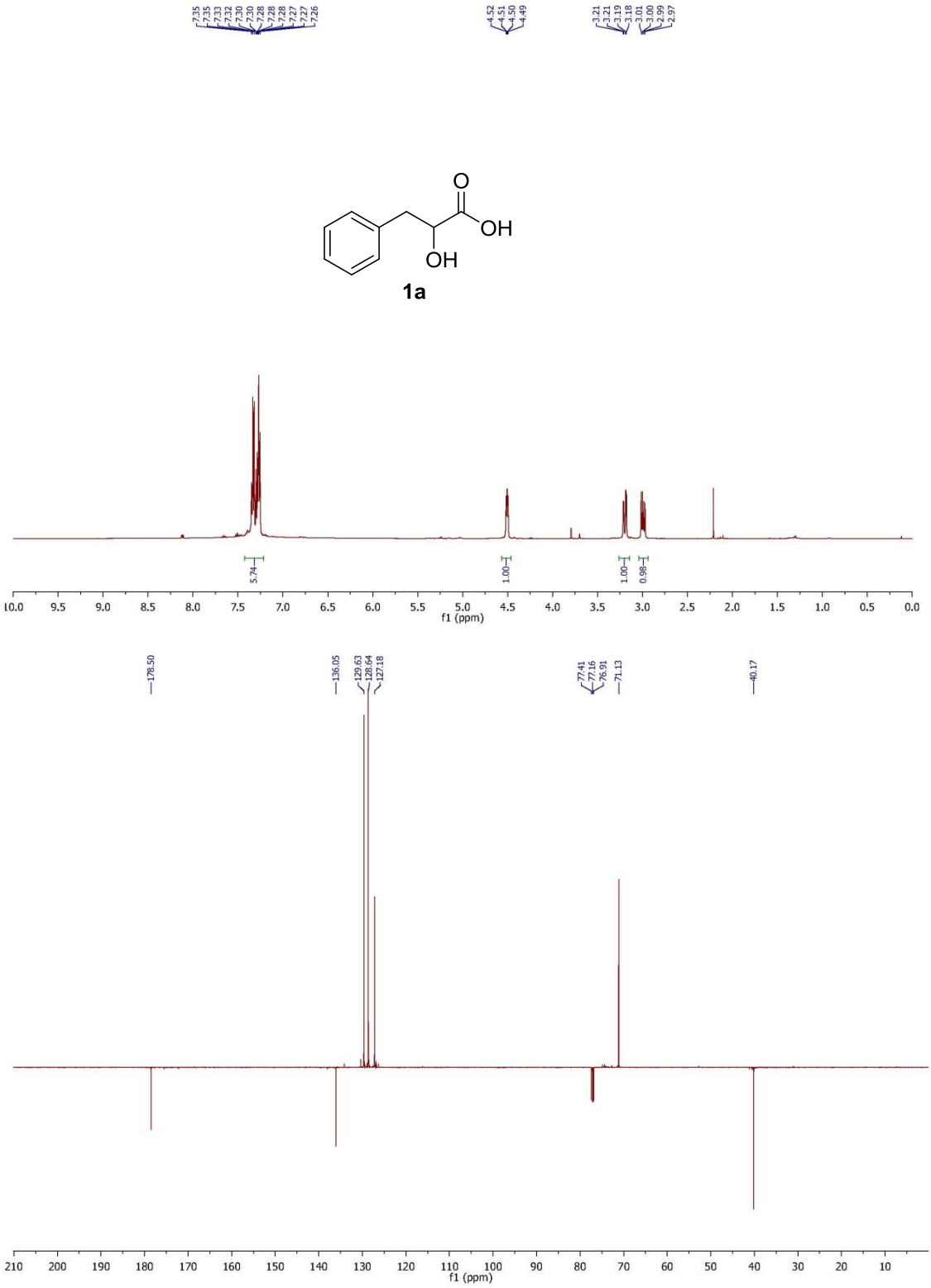

7.73
7.72
7.71
7.71
7.43
7.43
7.26
6.98
6.98
6.96
6.96
6.95
6.95
6.93
6.92
4.06
4.05
4.04
3.67
3.65
3.64
2.62
1.88
1.86
1.86
1.85
1.83
1.72
1.61
1.60
1.59
1.57
1.54
1.53
1.52
1.51
1.51
1.47
1.47
1.46
1.44
1.44
1.43
O
O
OH
6n
0.94
0.98
1.00
0.99
2.00
2.01
2.95
2.02
1.39
2.07
2.09
2.14
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

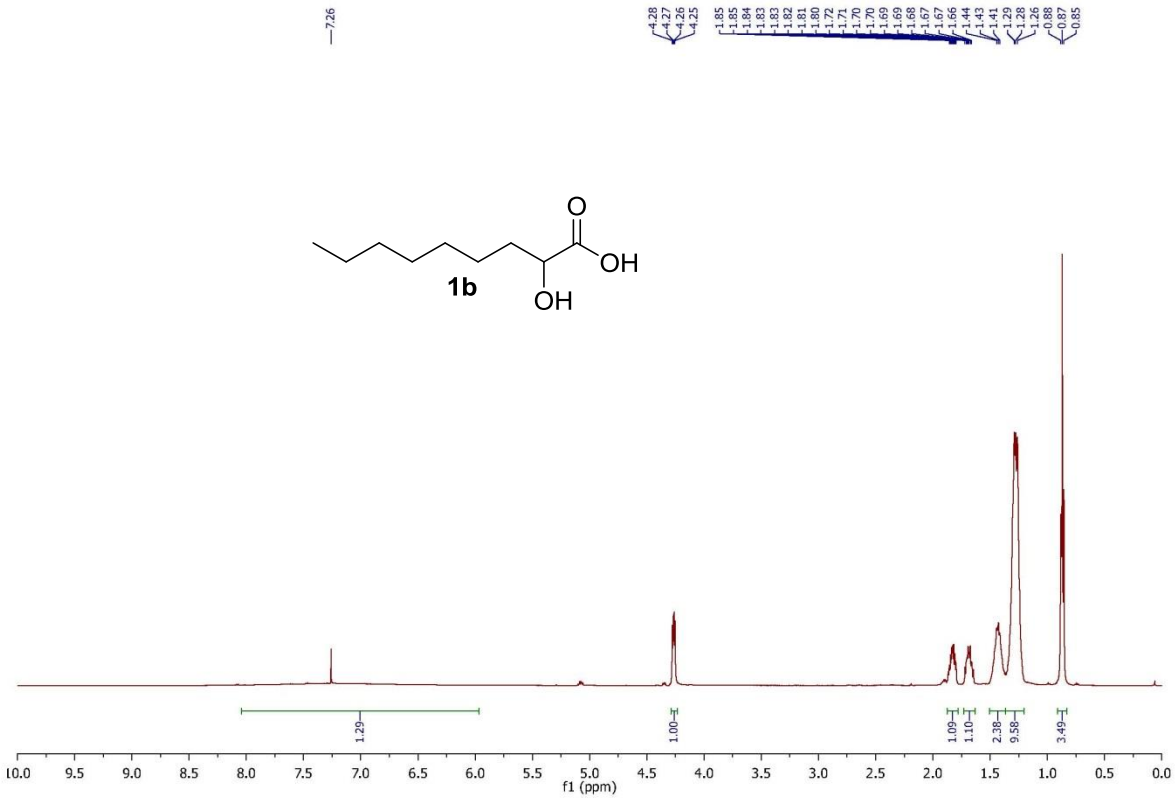

200.26
158.55
133.80
130.47
128.28
120.48
112.33
77.41
77.16
76.91
68.43
62.85
32.67
32.18
29.26
26.17
25.60
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

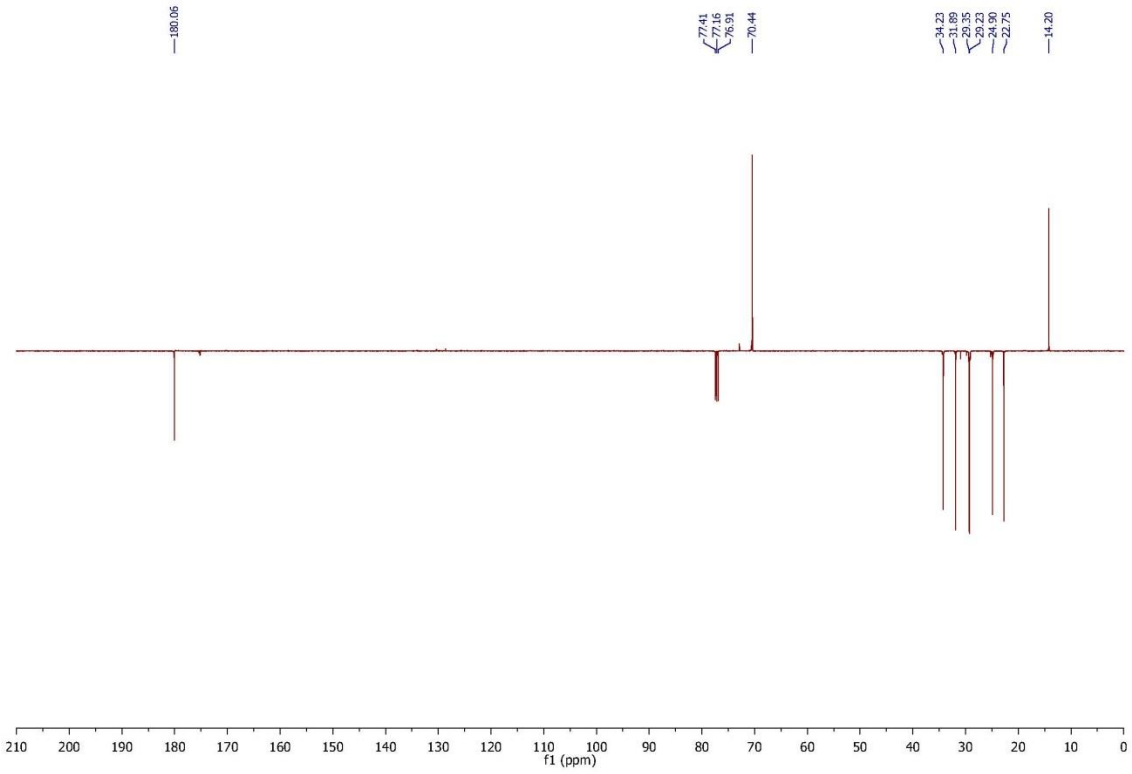

OH
OH
O
6o
f1 (ppm)

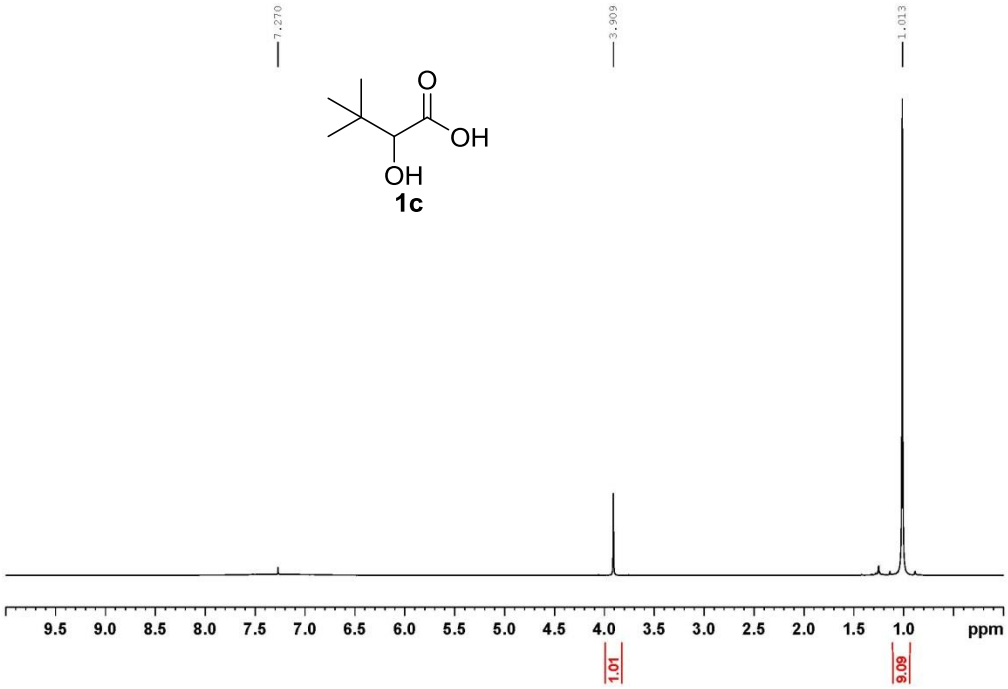

f1 (ppm)

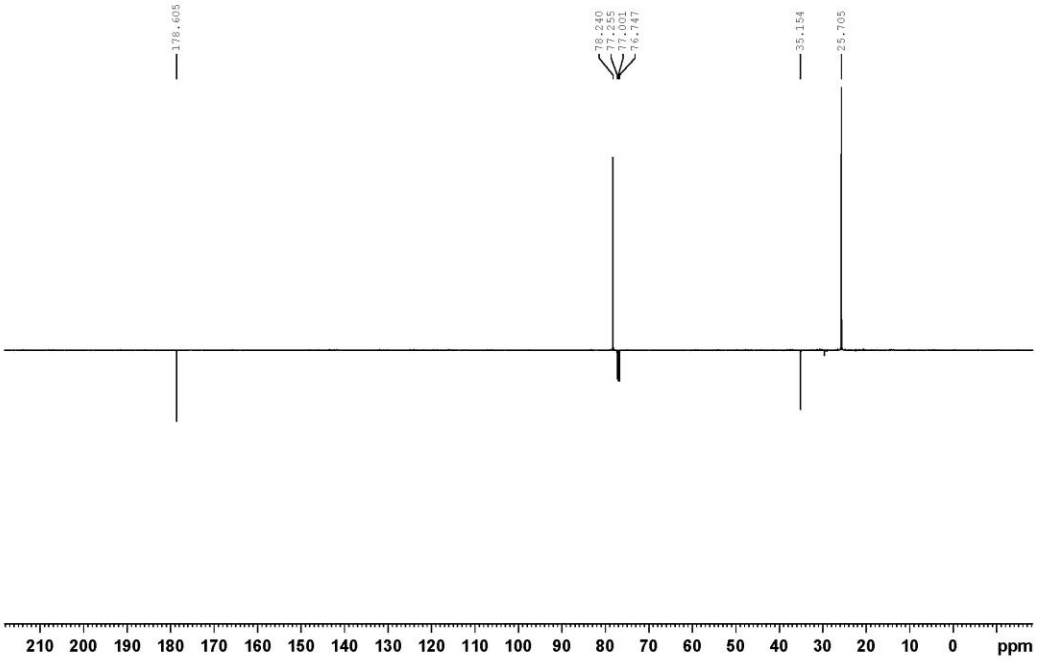
3.2 α-Hydroxy acids (1)



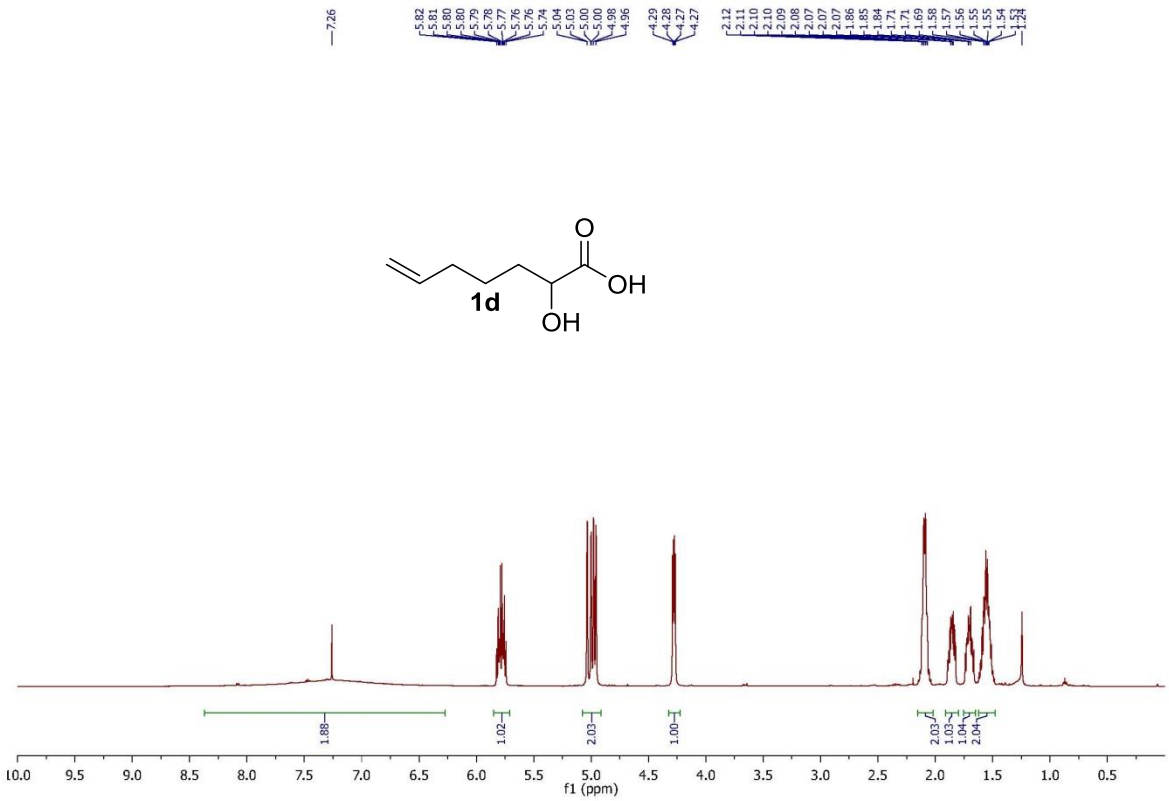

7.26
4.28
4.27
4.26
4.25
1.85
1.85
1.84
1.84
1.83
1.83
1.82
1.81
1.81
1.80
1.72
1.72
1.71
1.71
1.70
1.70
1.69
1.69
1.68
1.67
1.67
1.66
1.44
1.43
1.41
1.29
1.28
1.26
0.88
0.87
0.85
O
OH
1b
OH
1.29
1.00
1.09
1.10
2.38
9.58
3.49
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

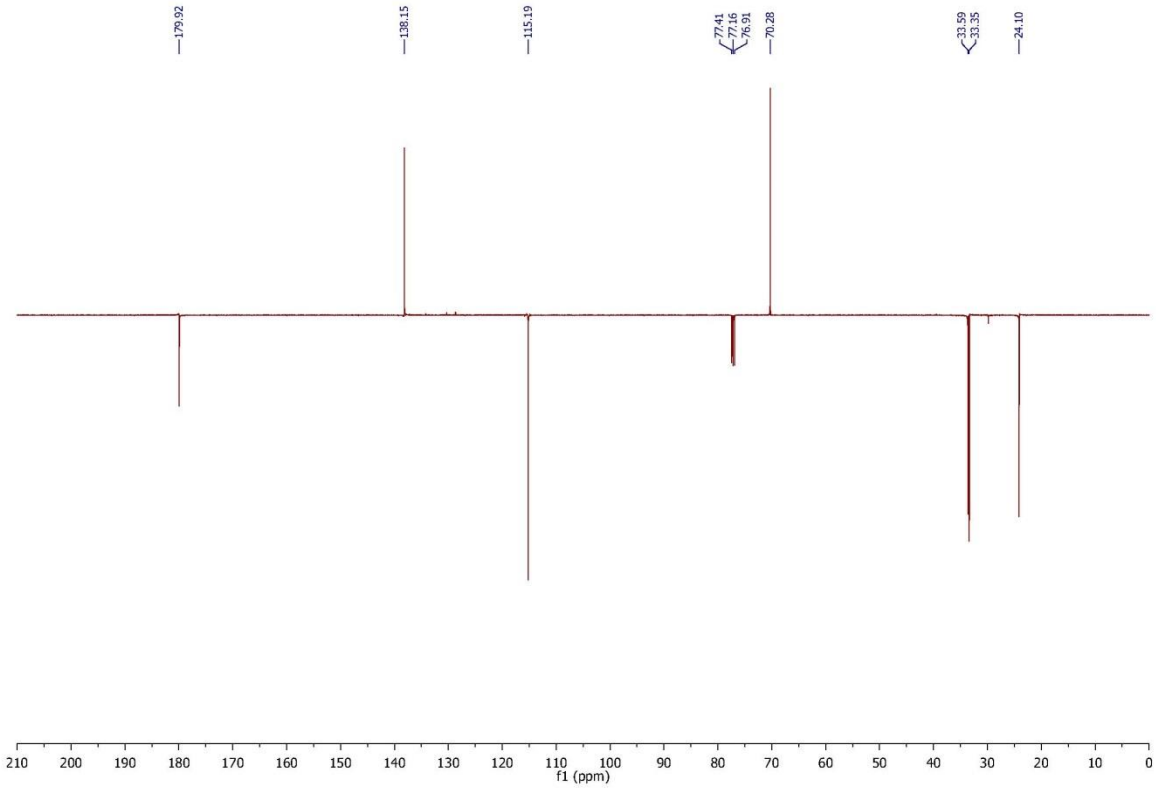

180.06
77.41
77.16
76.91
70.44
34.23
31.89
29.35
29.23
24.90
22.75
14.20
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

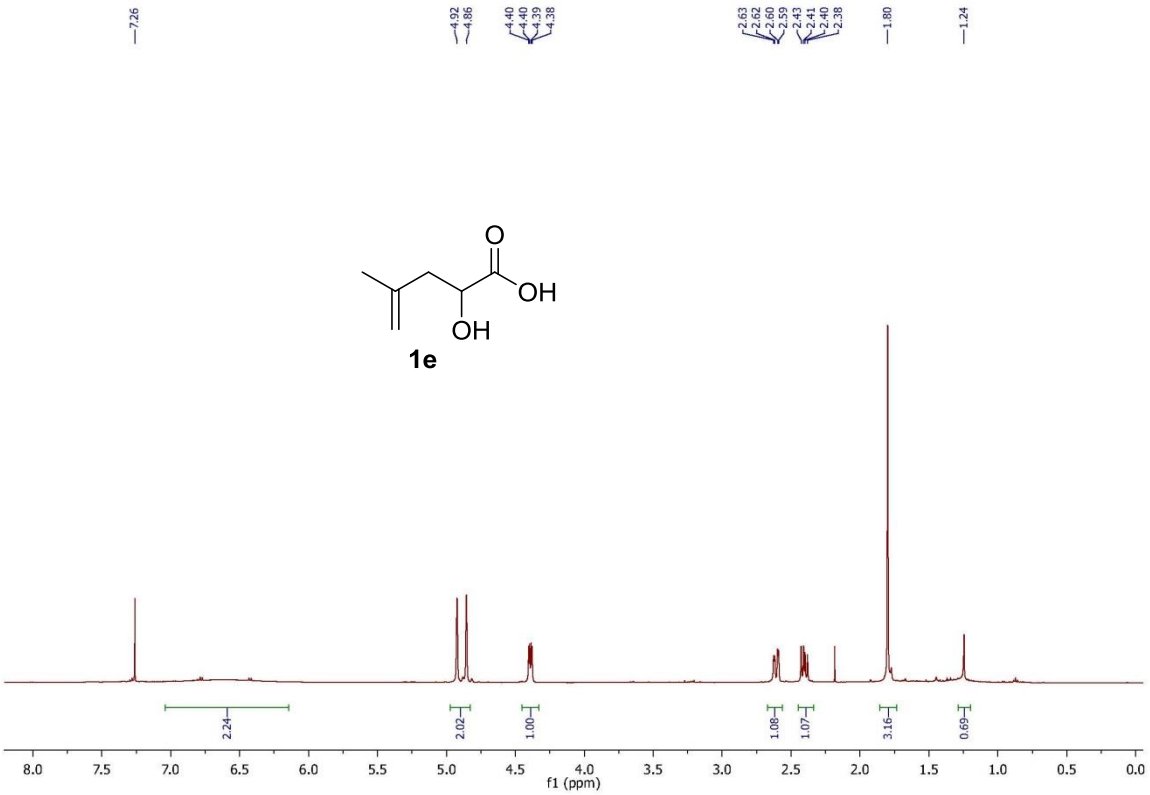

7.270
3.909
1.013
O
OH
OH
1c
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm
1.01
9.09

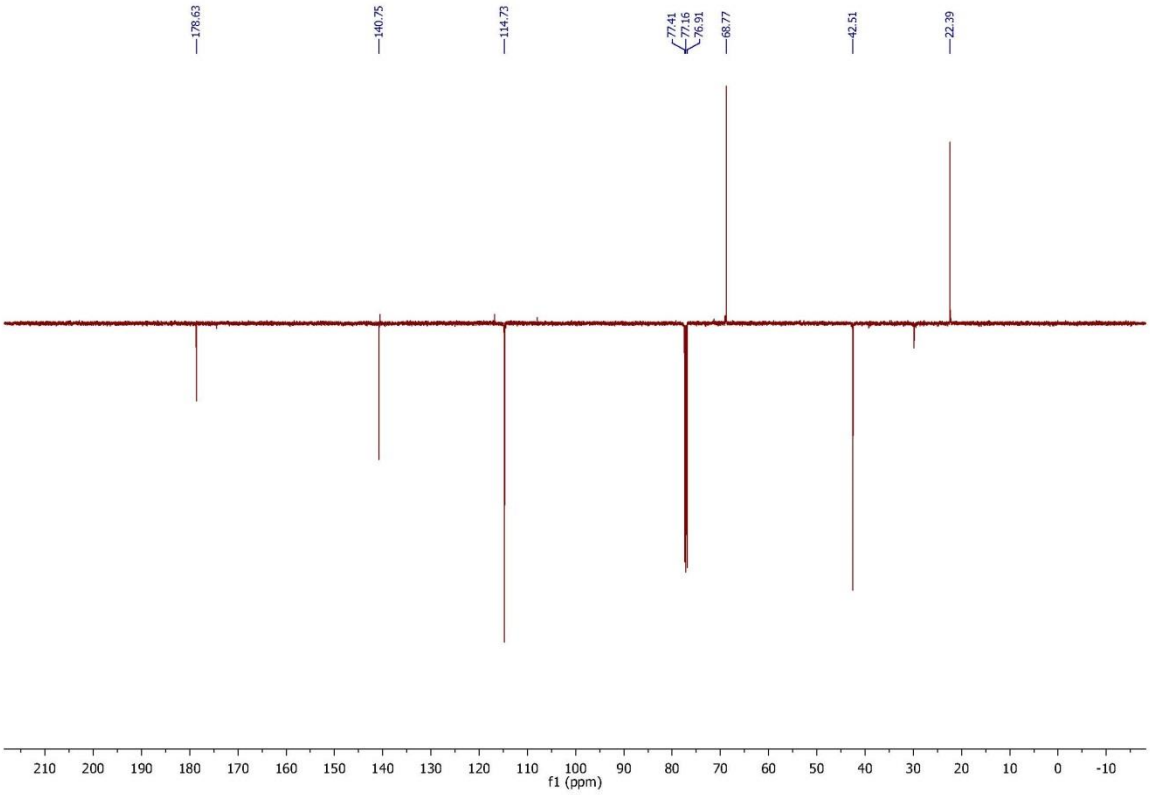

178.605
78.240
77.255
77.001
76.747
35.154
25.705
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

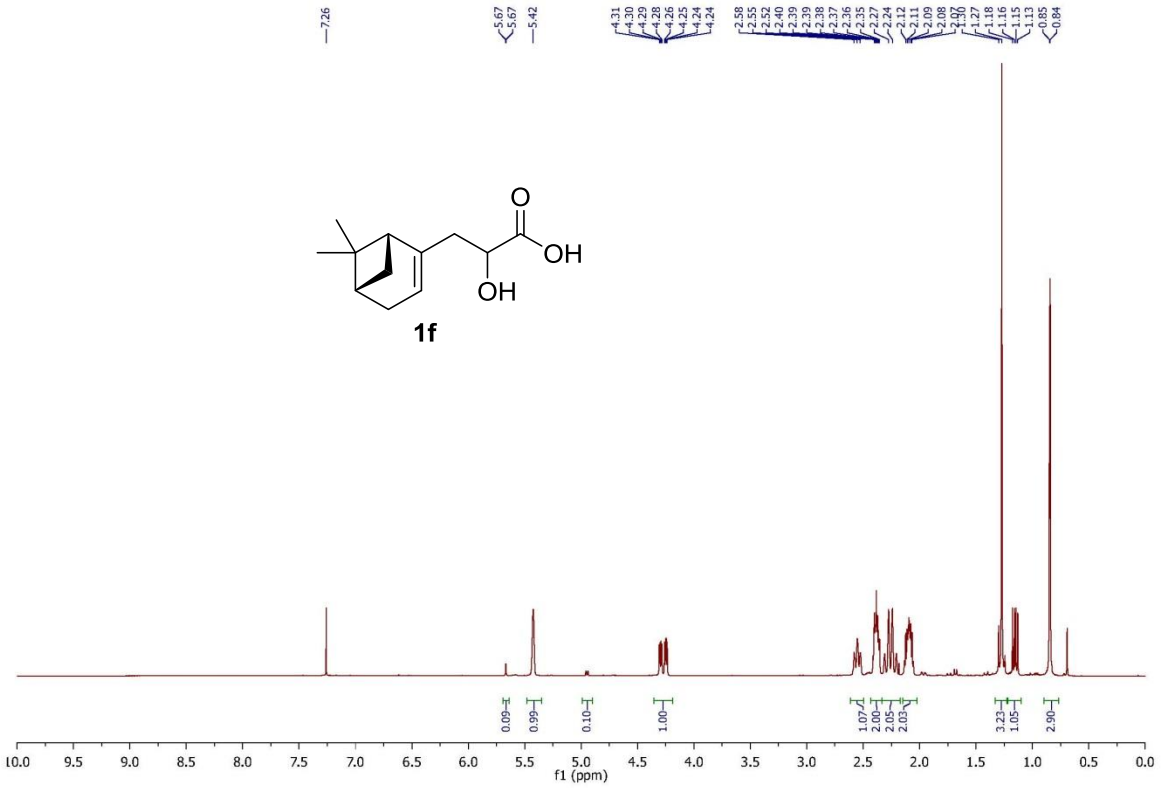
O
OH
1d
OH

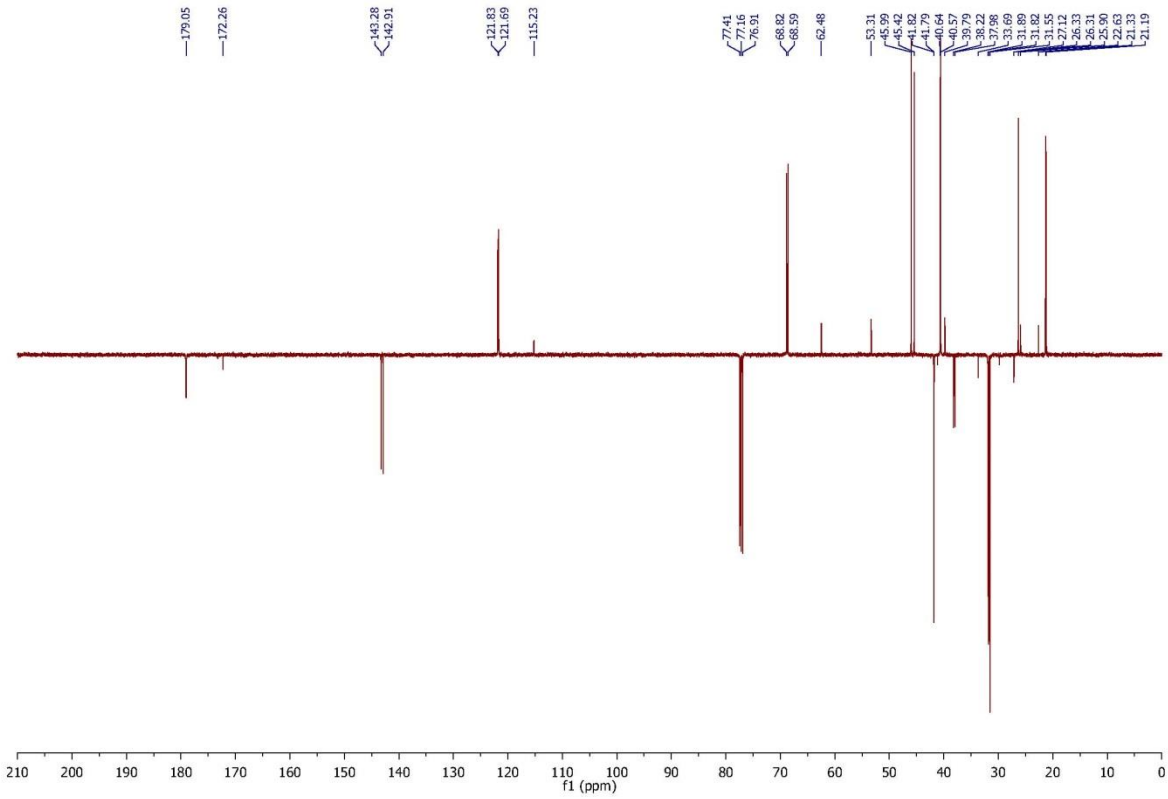

7.26
5.82
5.81
5.80
5.80
5.79
5.78
5.77
5.76
5.76
5.74
5.04
5.03
5.00
5.00
4.98
4.96
4.29
4.28
4.27
4.27
2.12
2.11
2.10
2.10
2.09
2.08
2.07
2.07
2.07
1.86
1.85
1.84
1.71
1.71
1.69
1.58
1.57
1.56
1.55
1.55
1.54
1.53
1.24
1.88
1.02
2.03
1.00
2.03
1.03
1.04
2.04
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

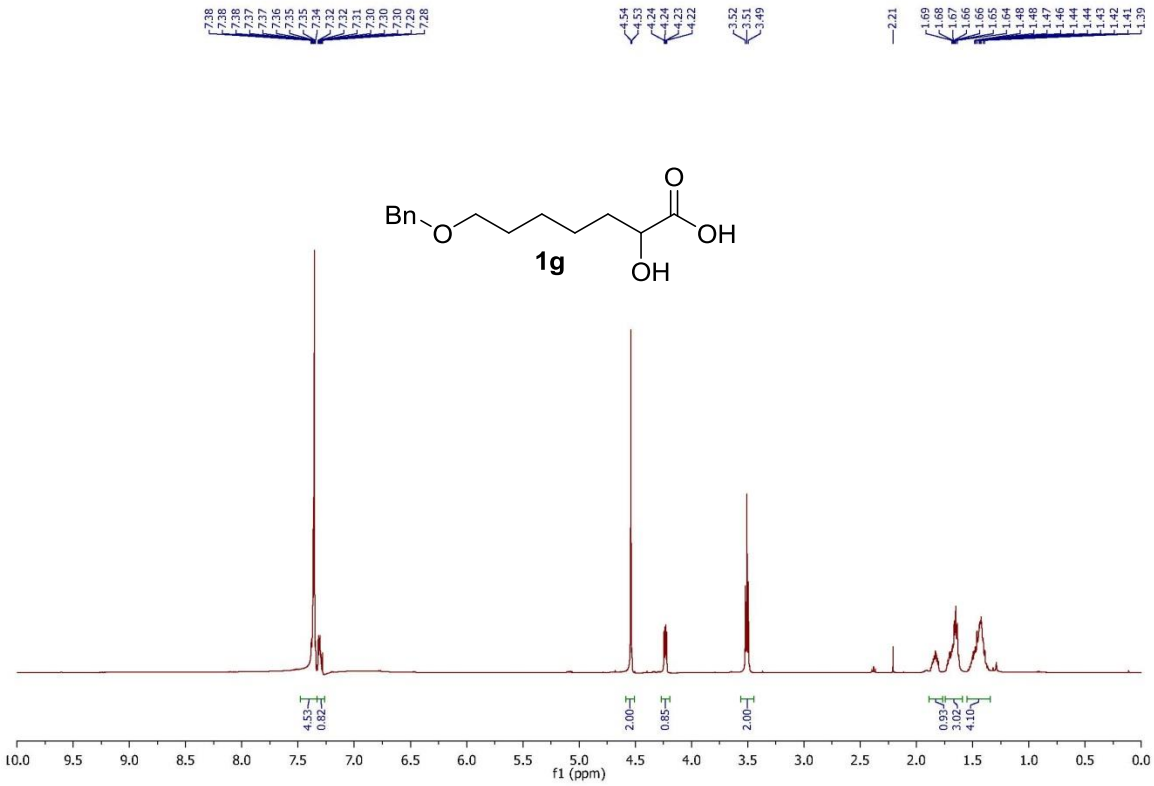

179.92
138.15
115.19
77.41
77.16
76.91
70.28
33.59
33.35
24.10
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

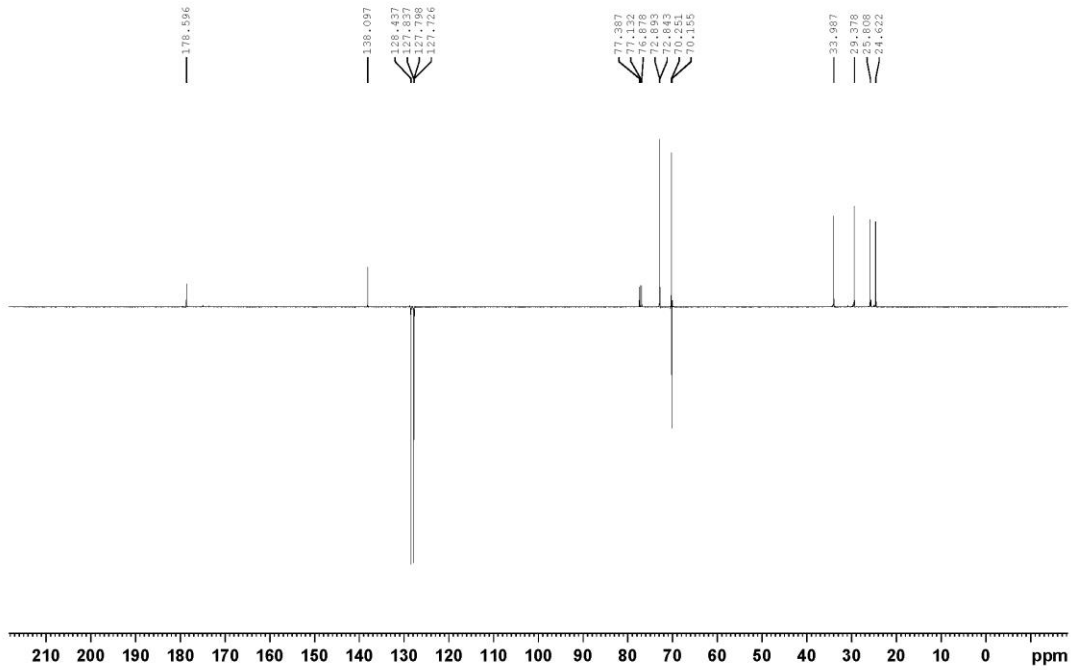

7.26
4.92
4.86
4.40
4.40
4.39
4.38
2.63
2.62
2.60
2.59
2.43
2.41
2.40
2.38
1.80
1.24
O
OH
OH
1e
2.24
2.02
1.00
1.08
1.07
3.16
0.69
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

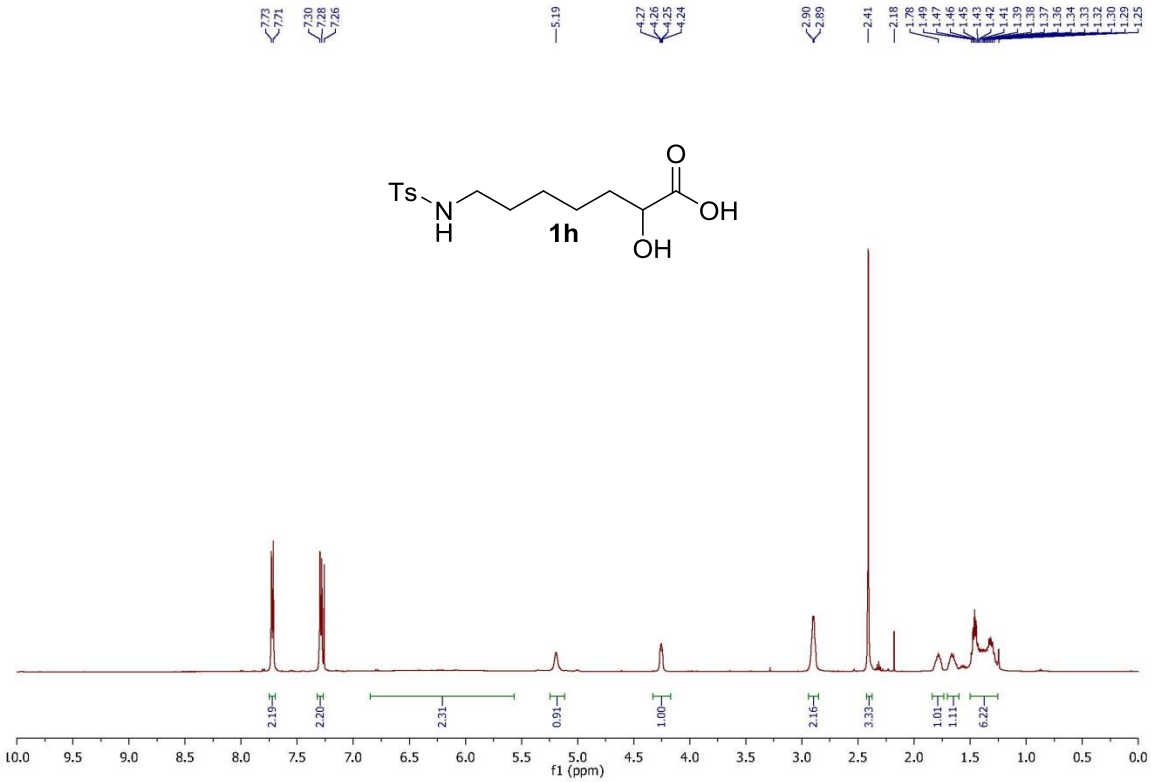

178.63
140.75
114.73
77.41
77.16
76.91
68.77
42.51
22.39
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

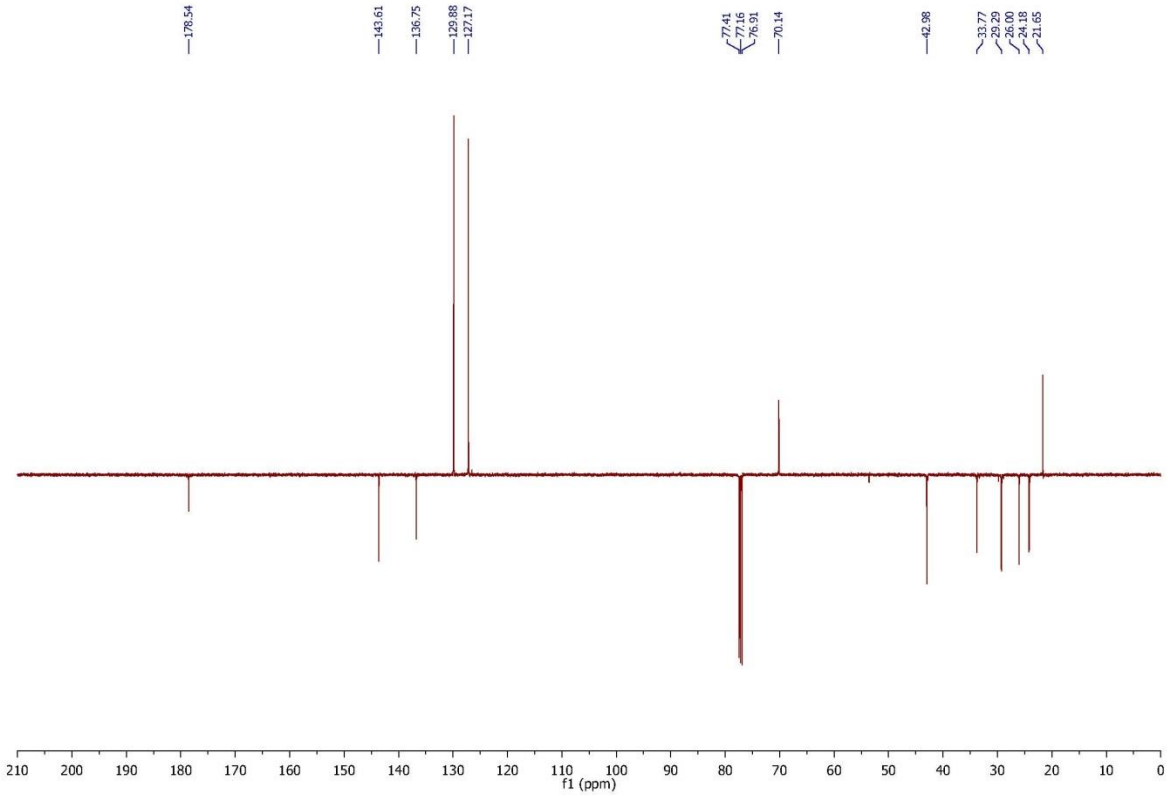

7.26
5.67
5.67
5.42
4.31
4.30
4.29
4.28
4.26
4.25
4.24
4.24
2.58
2.55
2.52
2.40
2.39
2.39
2.38
2.37
2.36
2.35
2.27
2.24
2.12
2.11
2.09
2.08
2.07
2.00
1.27
1.18
1.16
1.15
1.13
0.85
0.84
O
OH
OH
1f
0.09
0.99
0.10
1.00
1.07
2.00
2.05
2.03
3.23
1.05
2.90
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

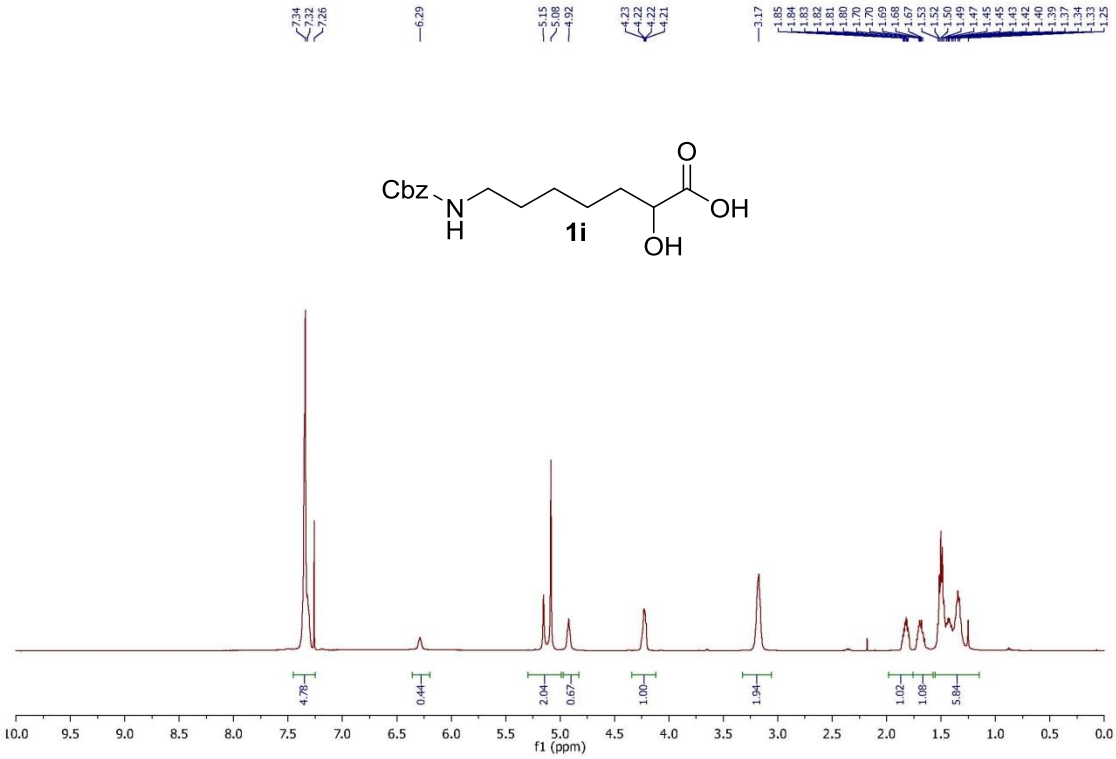

179.05
172.26
143.28
142.91
121.83
121.69
115.23
77.41
77.16
76.91
68.82
68.59
62.48
53.31
45.99
45.42
41.82
41.79
40.64
40.57
39.79
38.22
37.98
33.69
31.89
31.82
31.55
27.12
26.33
26.31
25.90
22.63
21.33
21.19
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

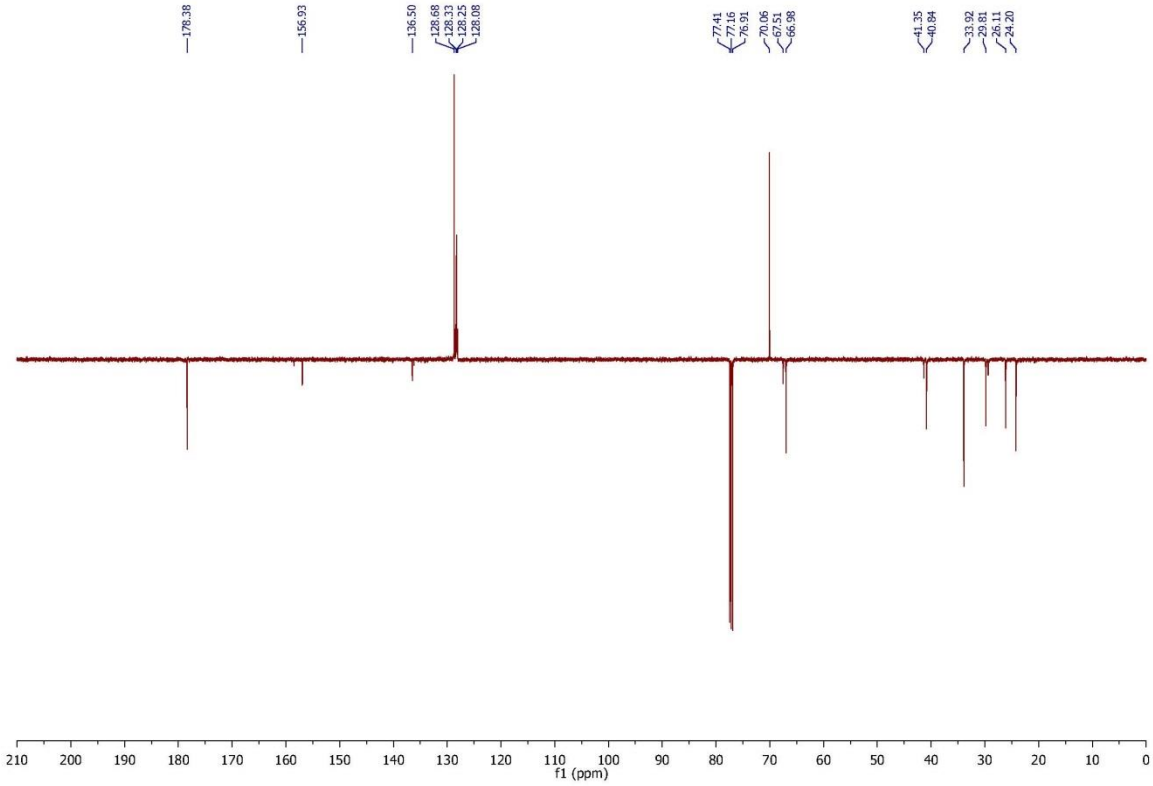

Bn
O
O
OH
OH
1g
f1 (ppm)


ppm


7.73
7.71
7.30
7.28
7.26
5.19
4.27
4.26
4.25
4.24
2.90
2.89
2.41
2.18
1.78
1.49
1.47
1.46
1.45
1.43
1.42
1.41
1.39
1.38
1.37
1.36
1.34
1.33
1.32
1.30
1.29
1.25
Ts
N
H
1h
O
OH
OH
2.19
2.20
2.31
0.91
1.00
2.16
3.33
1.01
1.11
6.22
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

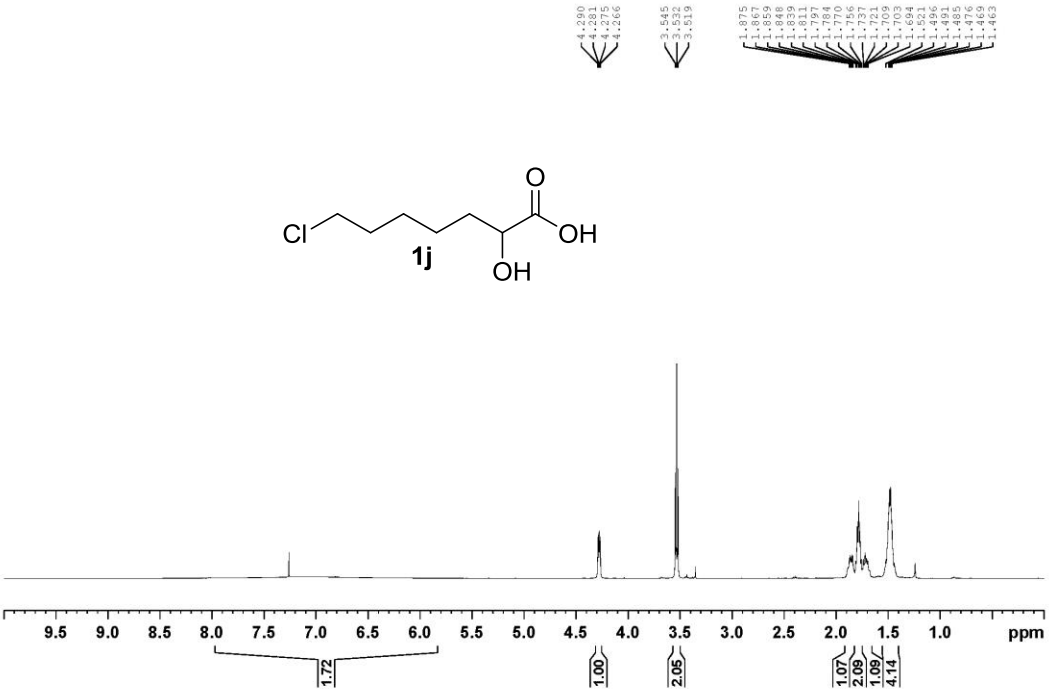

178.54
143.61
136.75
129.88
127.17
77.41
77.16
76.91
70.14
42.98
33.77
29.29
26.00
24.18
21.65
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

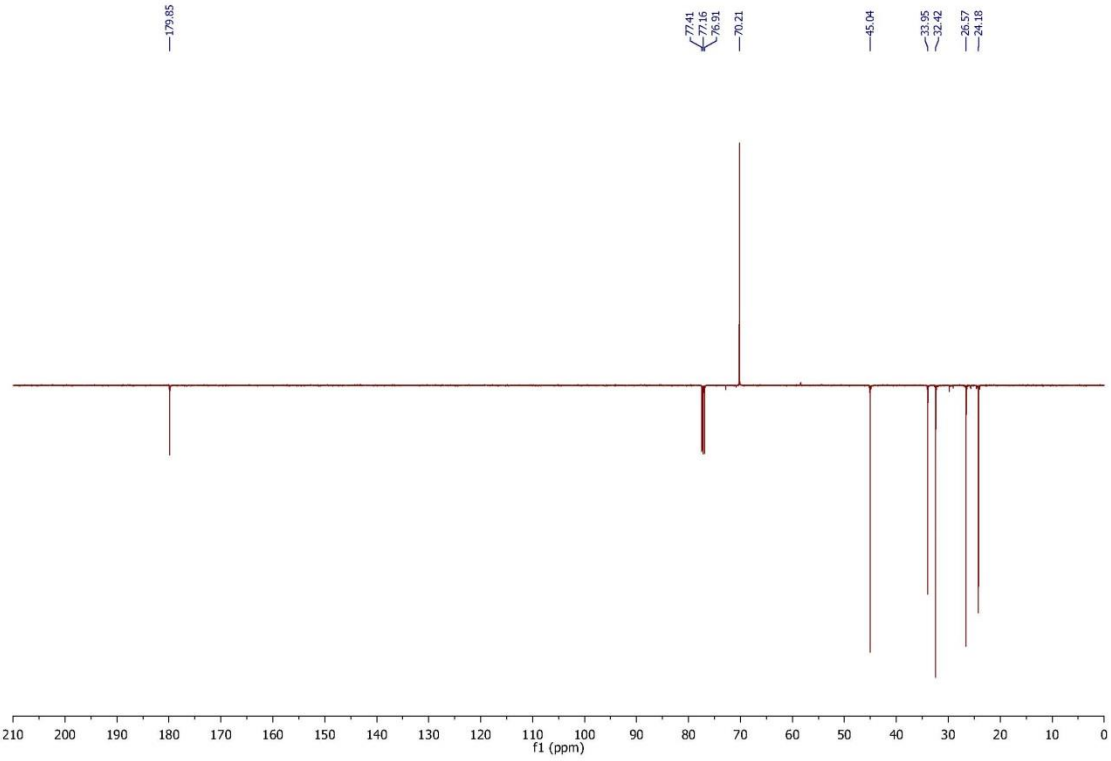

7.34
7.32
7.26
6.29
5.15
5.08
4.92
4.23
4.22
4.22
4.21
3.17
Cbz
N
H
1i
O
OH
OH
4.78
0.44
2.04
0.67
1.00
1.94
1.02
1.08
5.84
f1 (ppm)

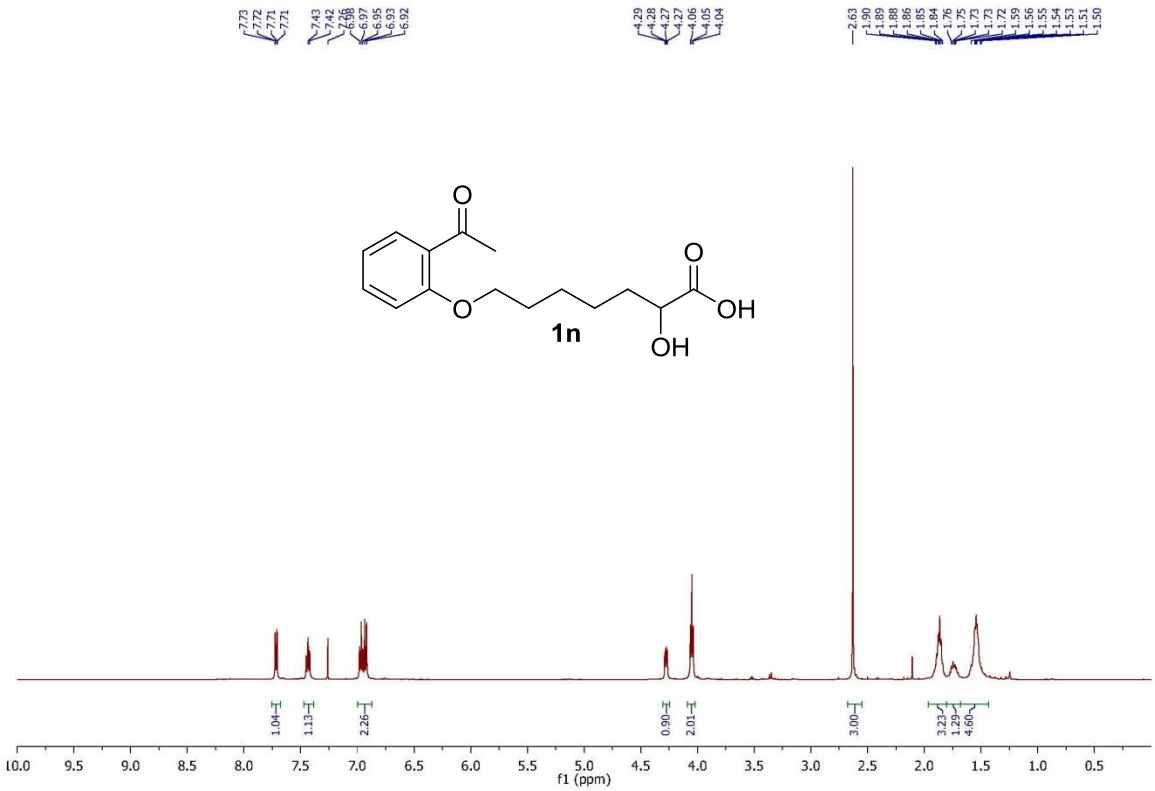

178.38
156.93
136.50
128.68
128.33
128.25
128.08
77.41
77.16
76.91
70.06
67.51
66.98
41.35
40.84
33.92
29.81
26.11
24.20
f1 (ppm)

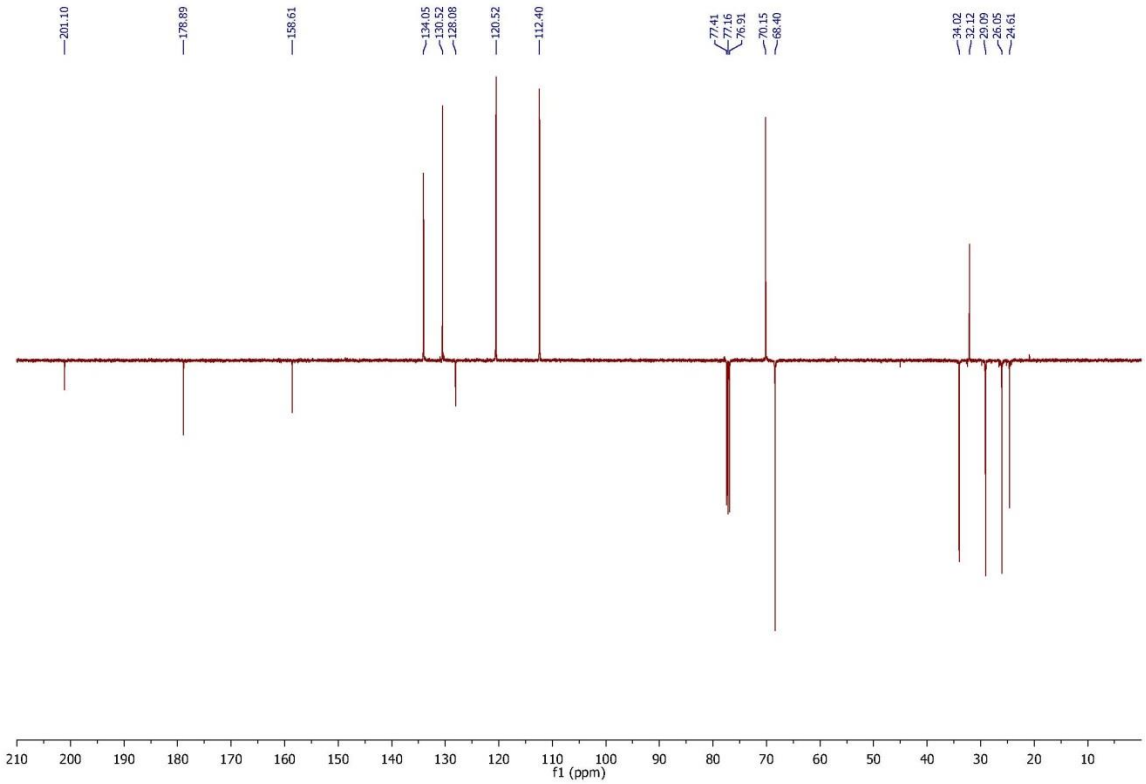
Cl
O
OH
OH

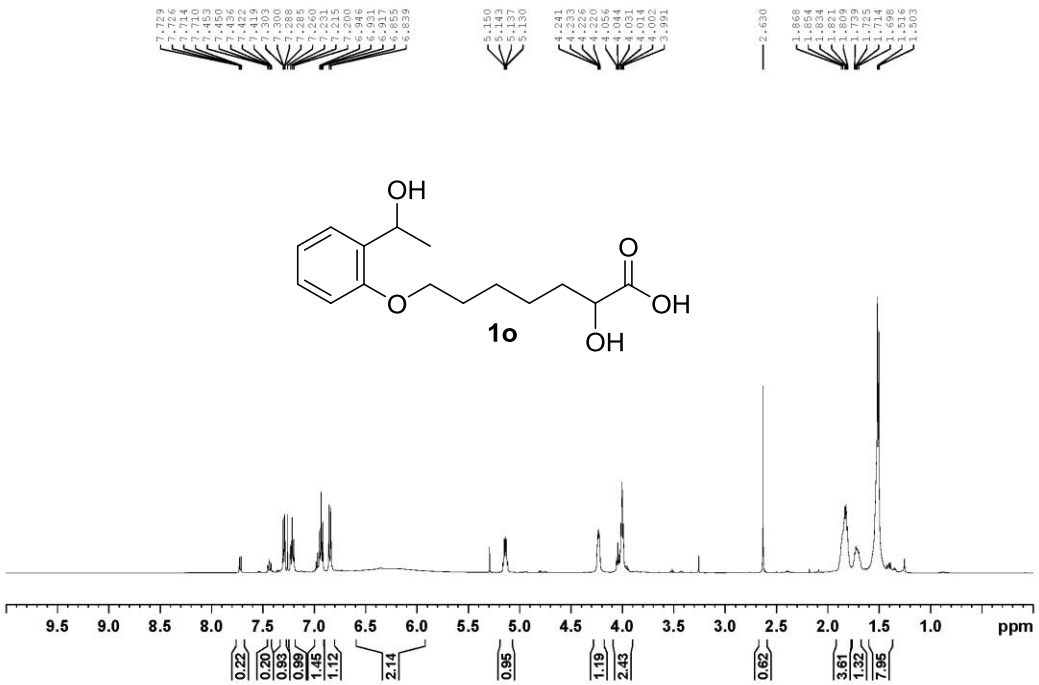
1j

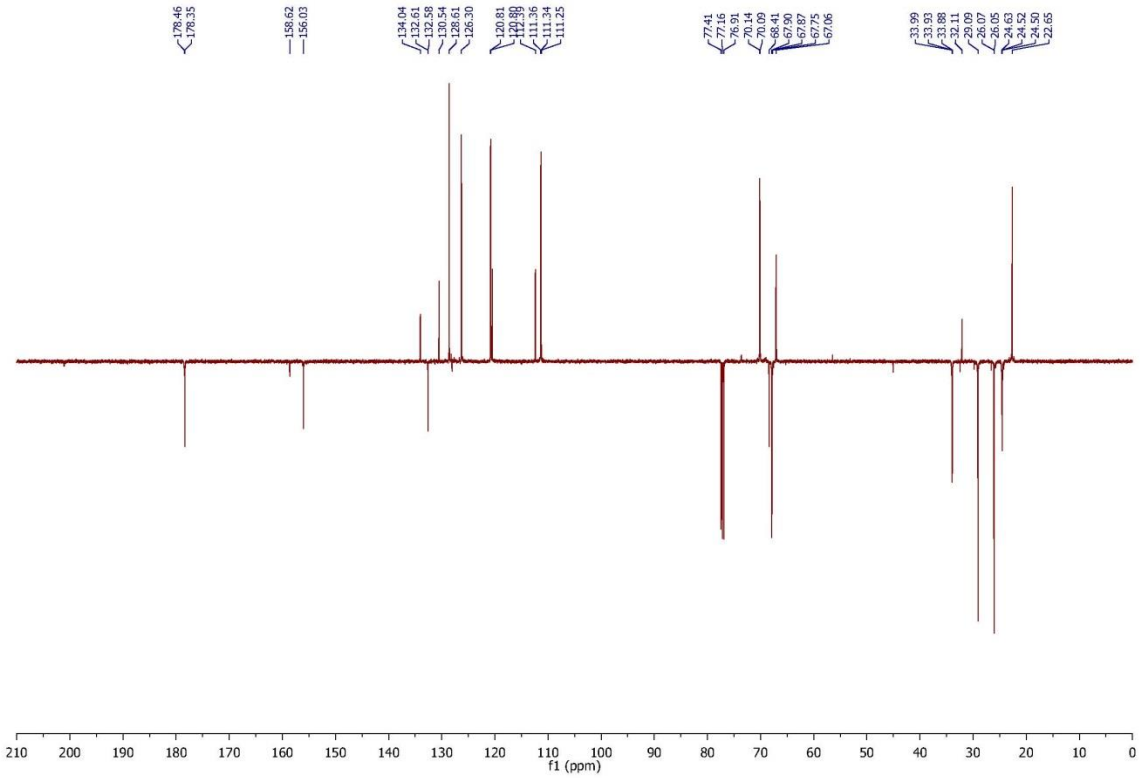

4.290
4.281
4.275
4.266
3.545
3.532
3.519
1.875
1.867
1.859
1.848
1.839
1.831
1.787
1.784
1.770
1.756
1.737
1.721
1.709
1.703
1.694
1.521
1.496
1.481
1.465
1.456
1.469
1.463
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm
1.72
1.00
2.05
1.07
2.09
1.09
4.14


179.85
77.41
77.16
76.91
70.21
45.04
33.95
32.42
26.57
24.18
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

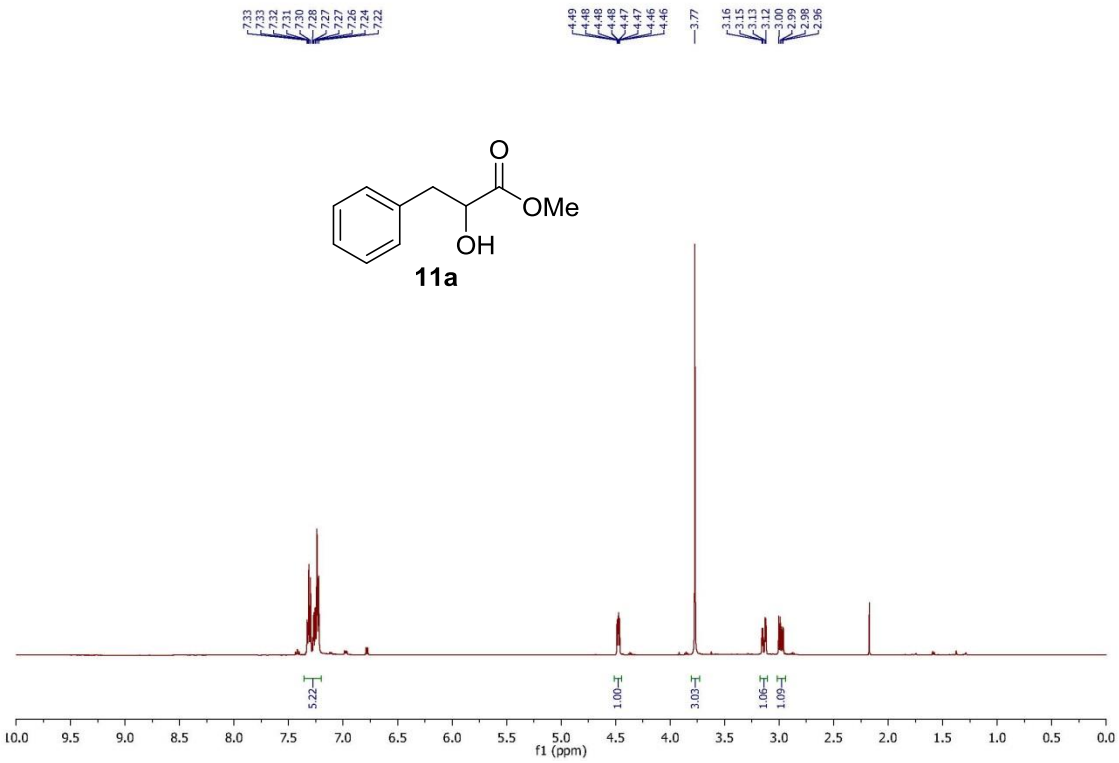

7.73
7.72
7.71
7.71
7.71
7.43
7.42
7.41
7.41
6.98
6.97
6.95
6.93
6.92
4.29
4.28
4.27
4.27
4.06
4.05
4.04
2.63
1.90
1.89
1.88
1.86
1.85
1.84
1.76
1.75
1.73
1.73
1.72
1.59
1.56
1.55
1.54
1.53
1.51
1.50
O
O
O
OH
OH
1n
1.04
1.13
2.26
0.90
2.01
3.00
3.23
1.29
4.60
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

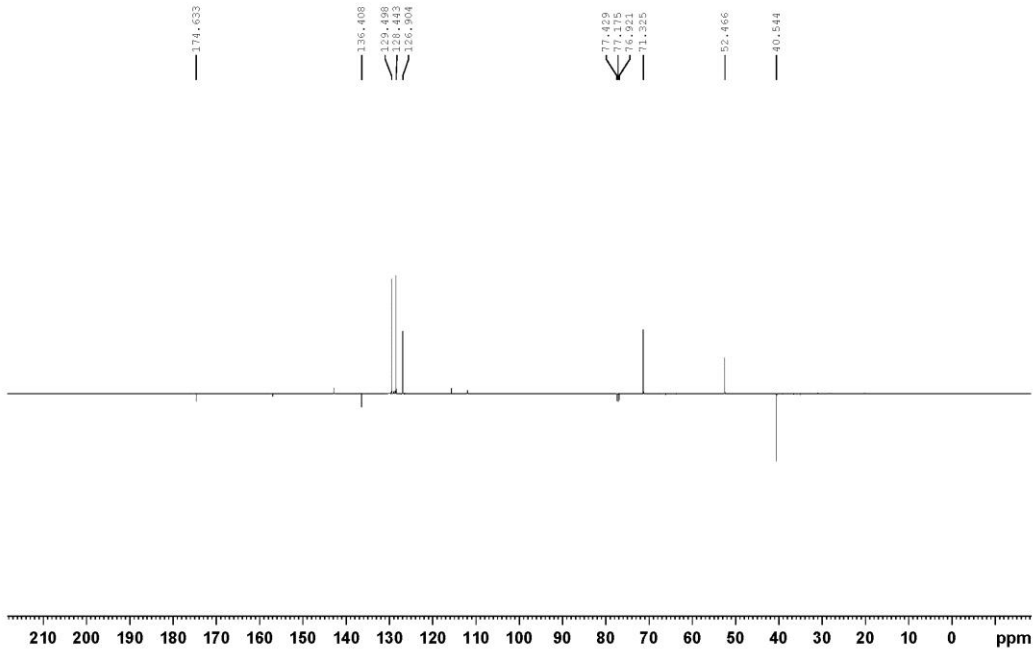

201.10
178.89
158.61
134.05
130.52
128.08
120.52
112.40
77.41
77.16
76.91
70.15
68.40
34.02
32.12
29.09
26.05
24.61
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

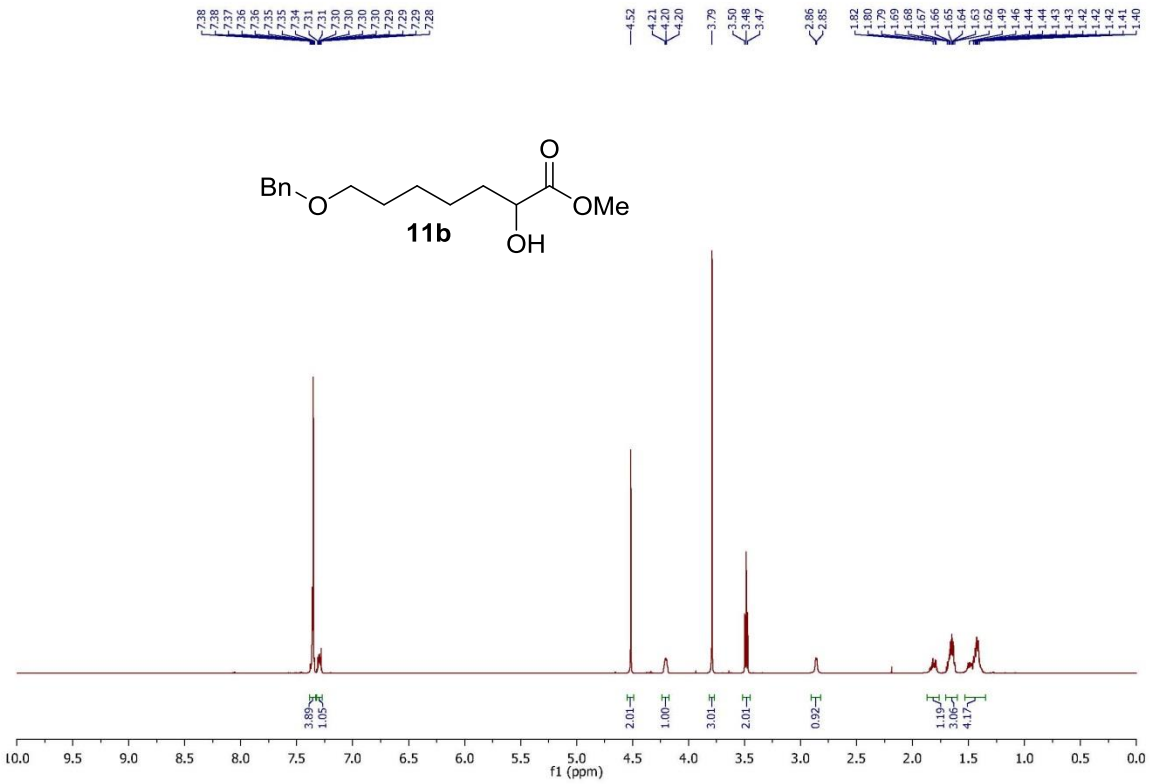

OH
O
O
OH
OH
1o
ppm

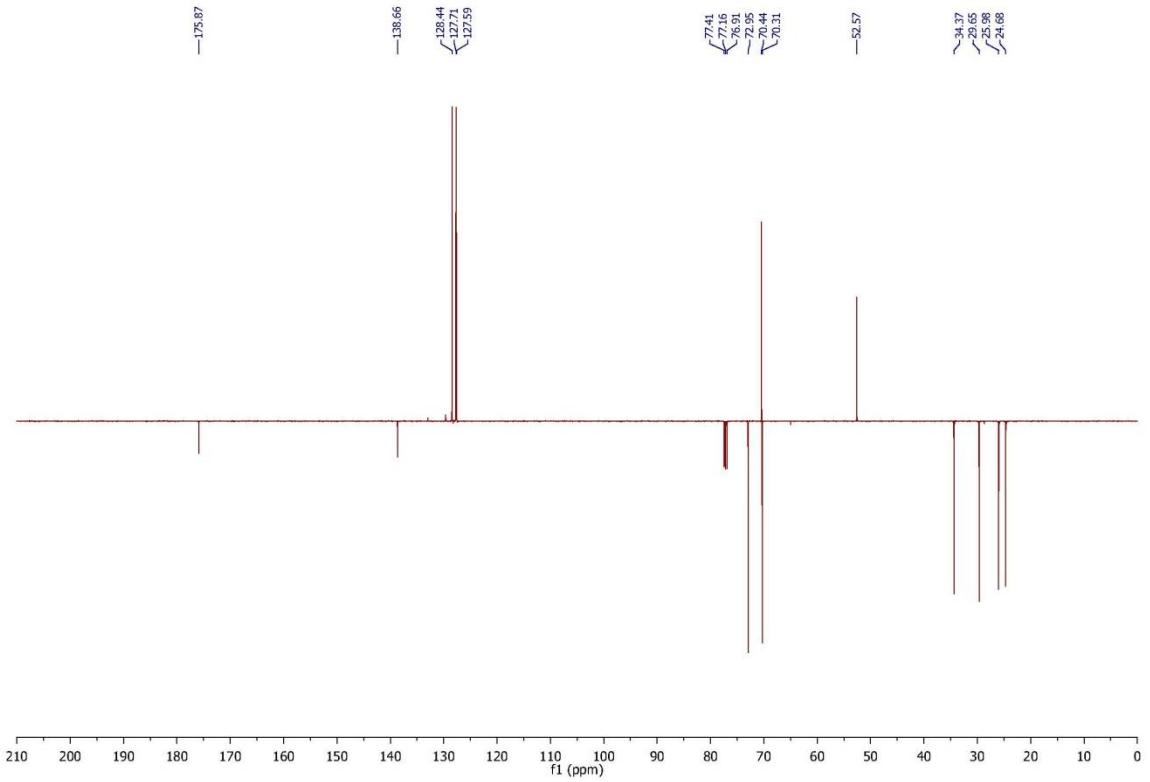

f1 (ppm)

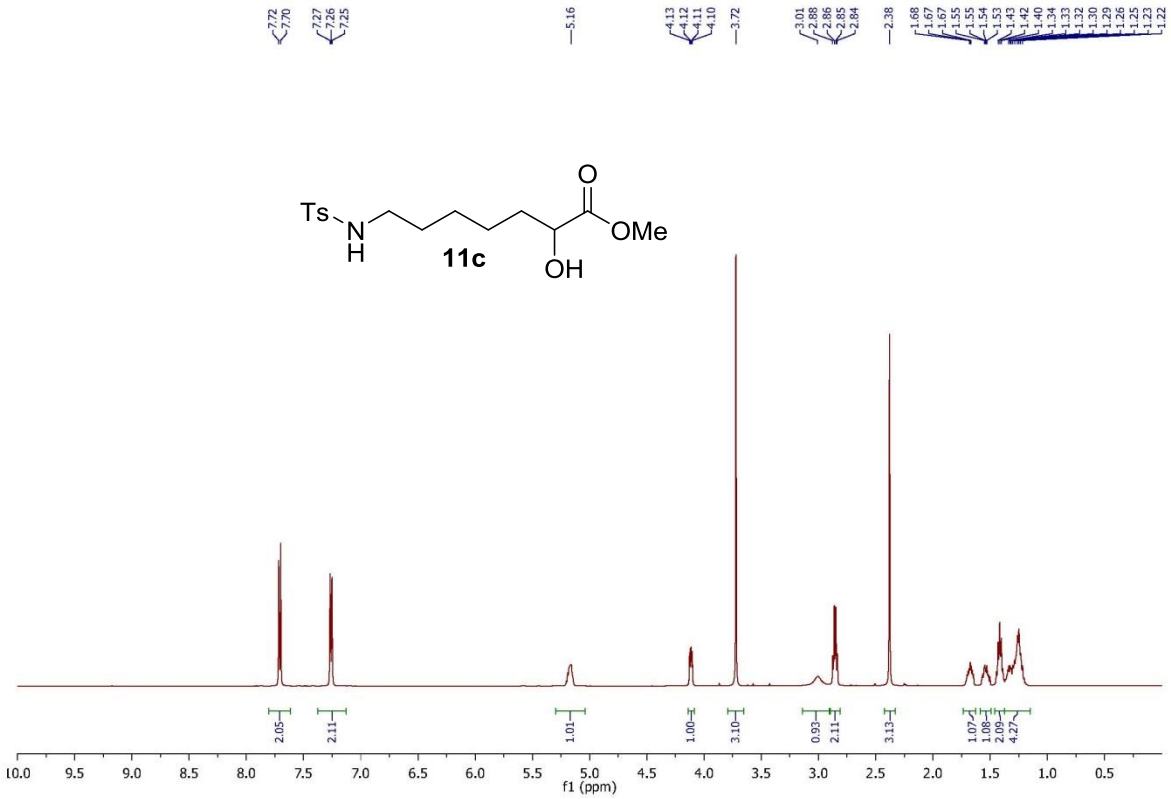
3.3 α-Hydroxy esters (11)

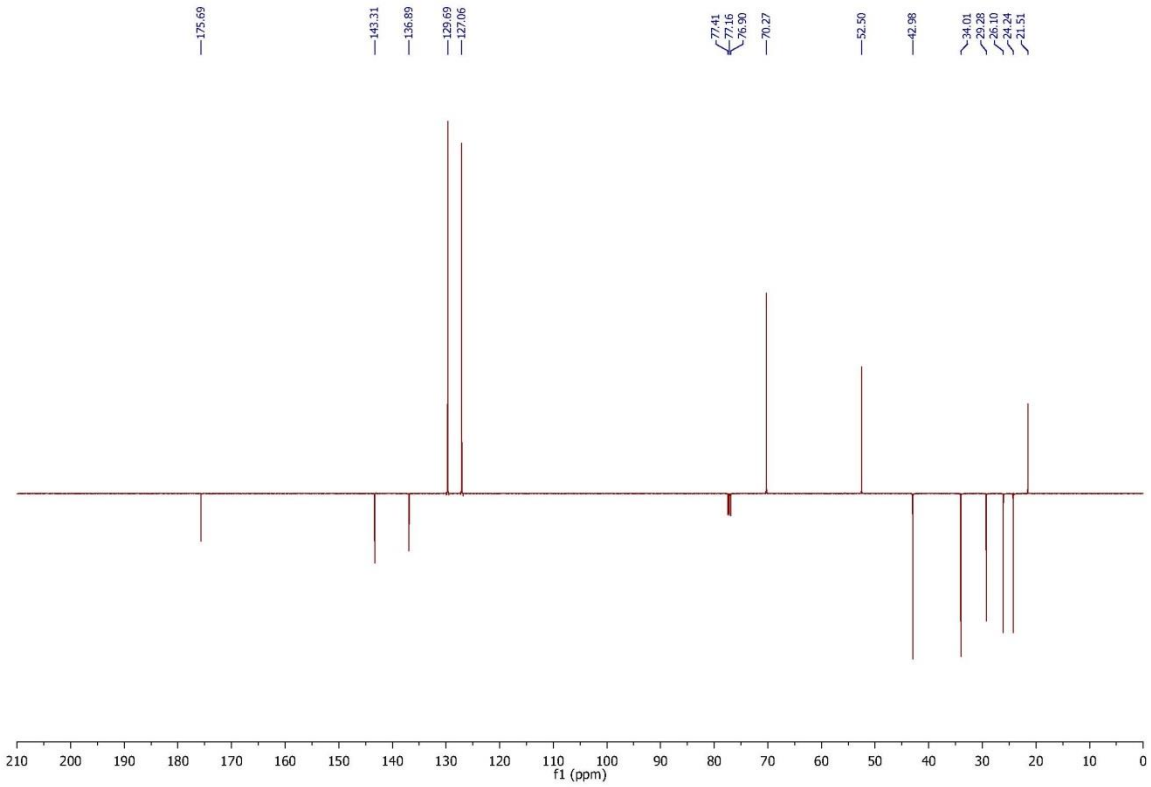


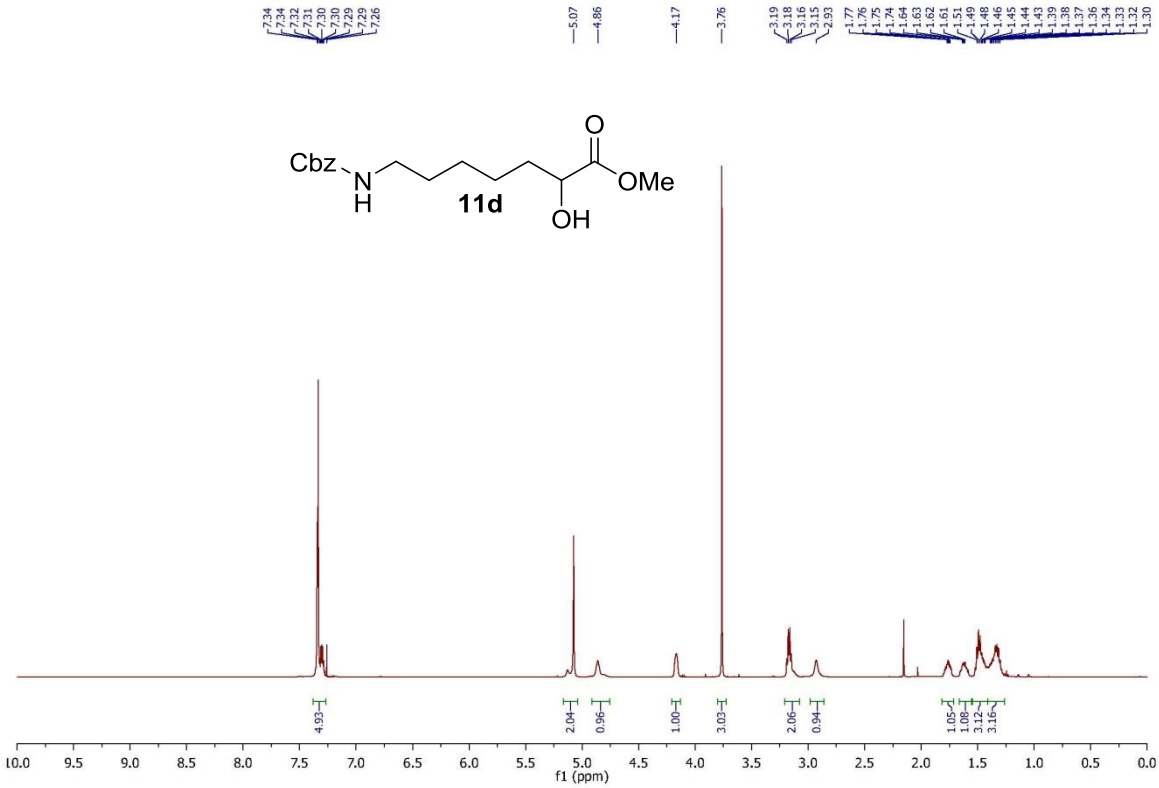


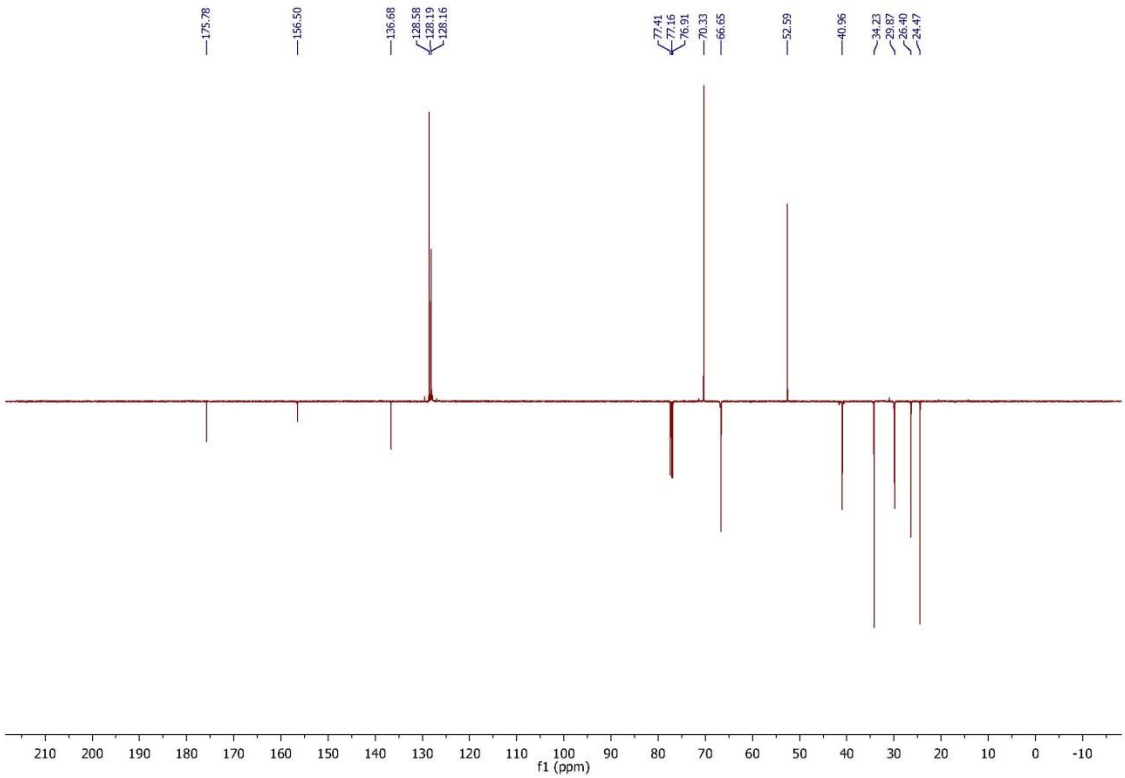

7.38 7.38 7.37 7.36 7.36 7.35 7.35 7.34 7.31 7.31 7.30 7.30 7.30 7.30 7.29 7.29 7.29 7.28
4.52 4.21 4.20 4.20 3.79 3.50 3.48 3.47 2.86 2.85 1.82 1.80 1.79 1.69 1.68 1.67 1.66 1.65 1.64 1.63 1.62 1.49 1.46 1.44 1.44 1.43 1.43 1.42 1.42 1.42 1.41 1.40
Bn
O
O
OMe
11b
OH
3.89 1.05 2.01 1.00 3.01 2.01 0.92 1.19 3.06 4.17
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

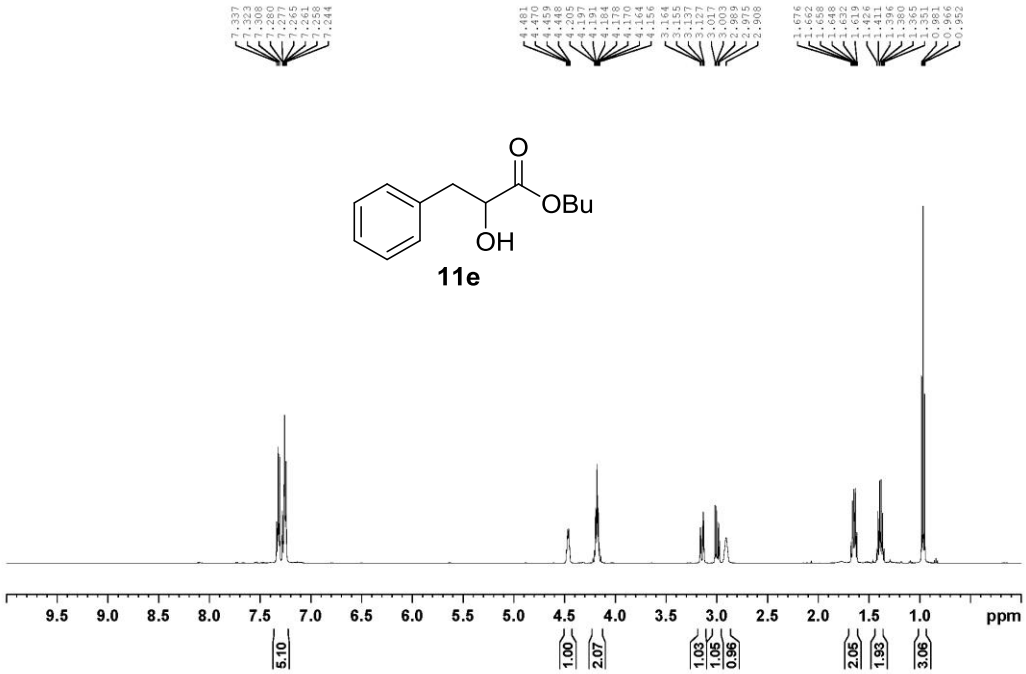

175.87
138.66
128.44 127.71 127.59
77.41 77.16 76.91 72.95 70.44 70.31
52.57
34.37 29.65 25.98 24.88
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

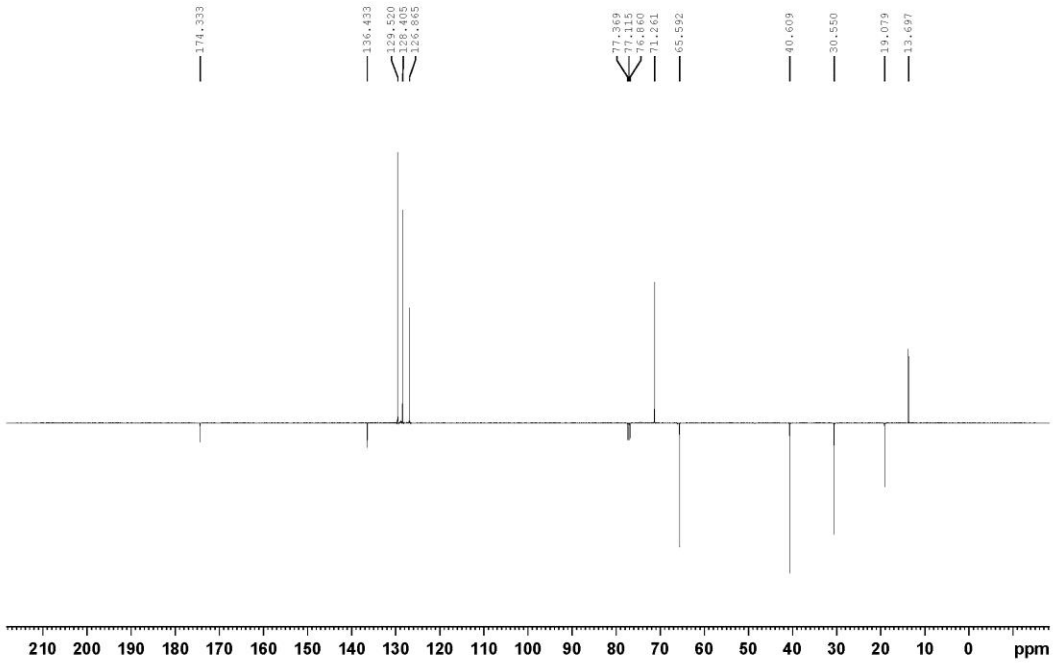

7.72
7.70
7.27
7.26
7.25
5.16
4.13
4.12
4.11
4.10
3.72
3.01
2.88
2.86
2.85
2.84
2.38
1.68
1.67
1.67
1.55
1.55
1.54
1.53
1.43
1.42
1.40
1.34
1.33
1.32
1.30
1.29
1.26
1.25
1.23
1.22
Ts
N
H
11c
O
OMe
OH
2.05
2.11
1.01
1.00
3.10
0.93
2.11
3.13
1.07
1.08
2.09
4.27
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

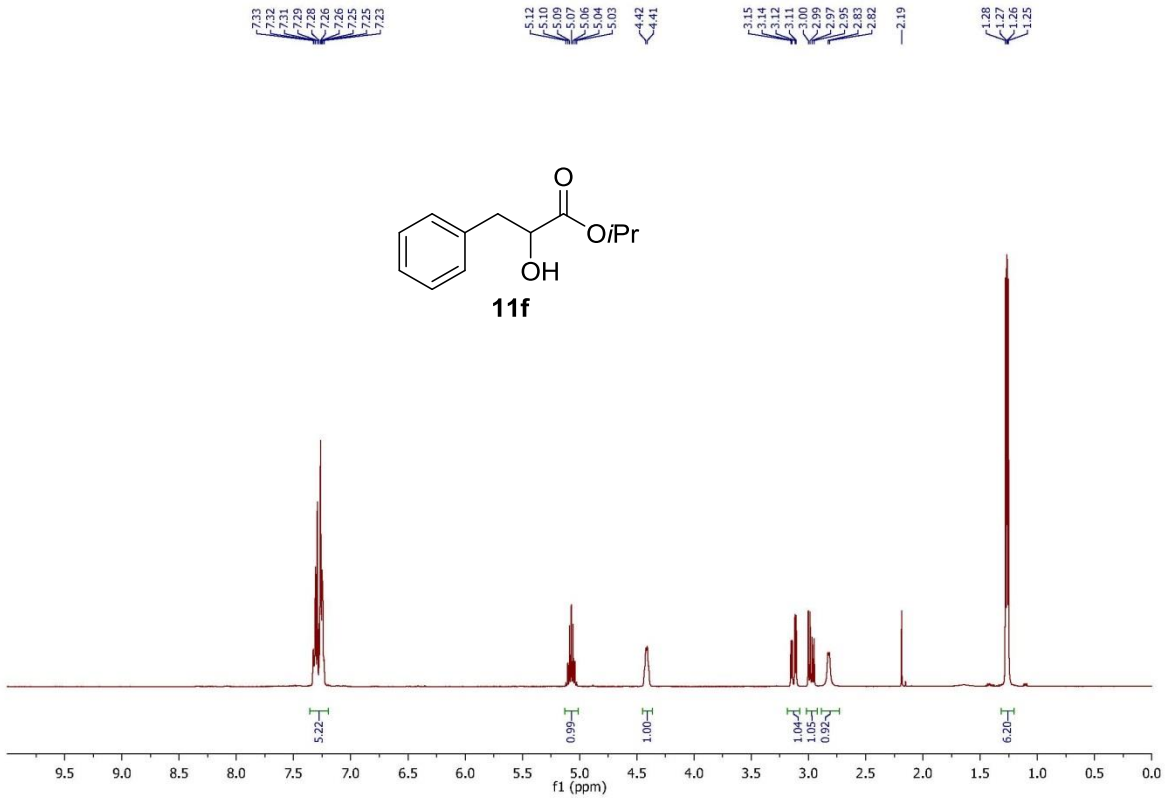

175.69
143.31
136.89
129.69
127.06
77.41
77.16
76.90
70.27
52.50
42.98
34.01
29.28
26.10
24.24
21.51
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

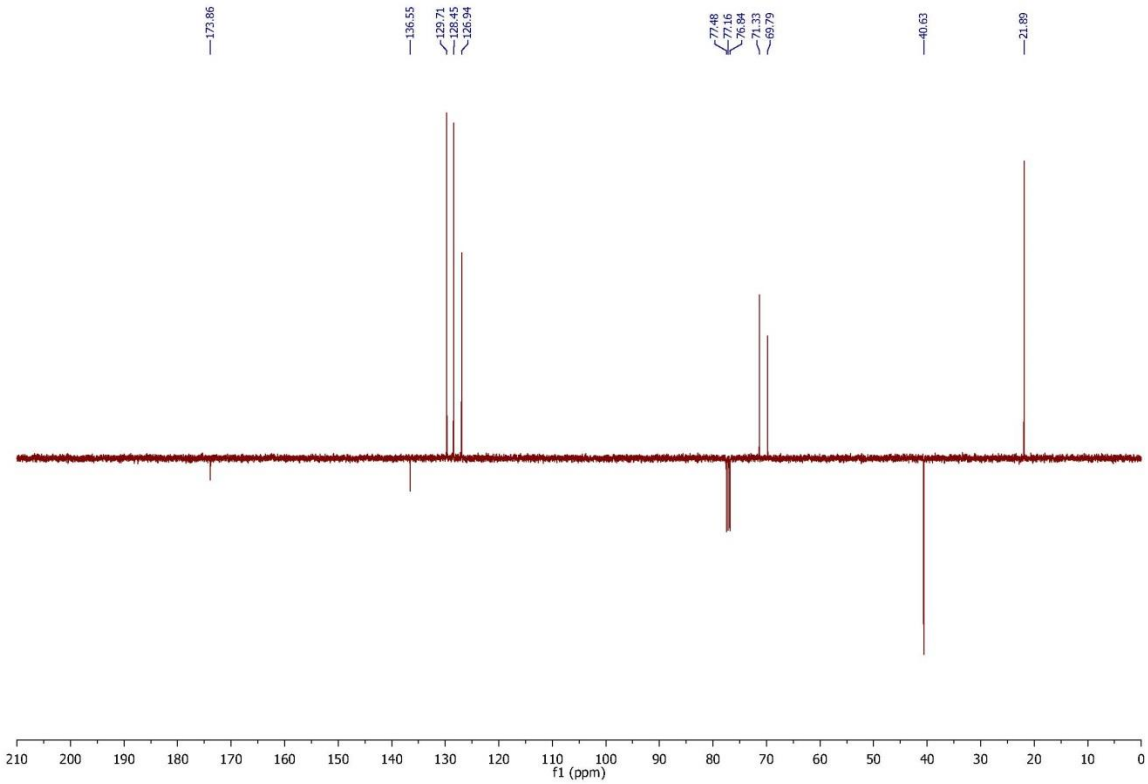

Cbz
N
H
11d
OH
O
OMe
f1 (ppm)


f1 (ppm)


7.337
7.323
7.308
7.280
7.277
7.265
7.261
7.258
7.244
4.481
4.470
4.459
4.448
4.205
4.197
4.191
4.184
4.178
4.170
4.164
4.156
4.164
3.155
3.137
3.127
3.017
3.003
2.989
2.975
2.908
1.676
1.662
1.658
1.648
1.632
1.619
1.426
1.411
1.396
1.380
1.365
1.351
0.981
0.966
0.952
O
OBu
OH
11e
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 ppm
5.10
1.00
2.07
1.03
1.05
0.96
2.05
1.93
3.06


174.333
136.433
129.520
128.405
126.865
77.369
77.115
76.860
71.261
65.592
40.609
30.550
19.079
13.697
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


7.33
7.32
7.31
7.29
7.28
7.26
7.26
7.25
7.25
7.23
5.12
5.10
5.09
5.07
5.06
5.04
5.03
4.42
4.41
3.15
3.14
3.12
3.11
3.00
2.99
2.97
2.95
2.83
2.82
2.19
1.28
1.27
1.26
1.25
O
O*i*Pr
OH
11f
5.22
0.99
1.00
1.04
1.05
0.92
6.20
f1 (ppm)


173.86
136.55
129.71
128.45
126.94
77.48
77.16
76.84
71.33
69.79
40.63
21.89
f1 (ppm)