Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Efficient and Regioselective Synthesis of γ-Lactone Glycosides Through a Novel Debenzylative Cyclization Reaction

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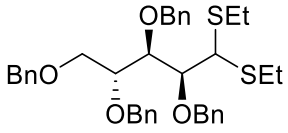
Supporting Information Placeholder

Materials and methods:

All reactions were carried out under an argon atmosphere. Yields refer to chromatographically and spectroscopically homogeneous materials. Reagents and chemicals were purchased from Sigma-Aldrich or Acros at ACS grade and were used without purification. All reactions were performed using purified and dried solvents: tetrahydrofuran (THF) was refluxed over sodium-benzophenone, dichloromethane (CH_2Cl_2), triethylamine (NEt_3), and pyridine were refluxed over calcium hydride (CaH_2). All reactions were monitored by thin-layer chromatography (TLC) carried out on Merck aluminum roll silica gel 60-F254 using UV light and a phosphomolybdic acid solution as revelator. Merck silica gel (60, particle size 40-63 µm) was employed for flash column chromatography and preparative thin layer chromatography using technically solvent distilled prior to use as eluting solvents. NMR spectra were recorded on a JEOL ECX 400 or 500 with solvent peaks as reference. All compounds were characterized by ^{1}H and ^{13}C NMR as well as by ^{1}H-^{1}H and ^{1}H-^{13}C correlation experiments when necessary. The following abbreviations are used to describe the multiplicities: s= singlet, d= doublet, t= triplet, q= quartet, m= multiplet, br= broad. The numbering of the protons and carbons is illustrated in the Scheme below. Aromatic, benzyl and methyl (carbons and protons) are respectively labeled with "Arom", "CH_2^{Bn}", quaternary carbons are indicated with a "q" superscript. Chemical shifts (δ) are reported in ppm and referenced indirectly to residual solvent signals. High-resolution mass spectra (HRMS) were performed on a Bruker maXis mass spectrometer with an accuracy tolerance of 2 ppm by the "Fédération de Recherche" ICOA/CBM (FR2708) platform.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-arabinose, 1a:

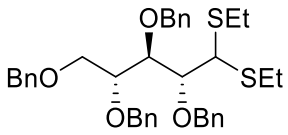


1a

An aqueous solution of concentrated hydrochloric acid (37%, 60 ml, 724 mmol, 1.8 equiv.) was added to D-arabinose (60.1 g, 400 mmol) at room temperature. Then, ethanethiol (60 ml, 810 mmol, 2.0 equiv.) was added dropwise at 0 °C and the product was crystallized after 10 min of stirring at 0 °C. Then, the solid was washed with ice water and cooled diethyl ether to give diethyl dithioacetal D-arabinose as a white powder (73.5 g, 72%).
To a solution of diethyl dithioacetal D-arabinose (36.3 g, 142 mmol) in dry DMF (345 ml) under argon atmosphere was added benzyl bromide (74.6 ml, 624 mmol, 4.4 equiv.) at room temperature. The solution was cooled at 0 °C and NaH (60% in mineral oil, 23.8 g, 595 mmol, 4.2 equiv.) was added portionwise and the reaction was stirred for 48 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 100:5) gave molecule **1a** (79.9 g, 91%).[1]

1a: $[\alpha]^{20}_{D}$: +5.5 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.38-7.26 (m, 20H, H^{arom}), 4.83 (AB, 1H, J_{A-B}= 11.0 Hz, CH_2^{Bn}), 4.78 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.75 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.73 (AB, 1H, J_{A-B}= 11.0 Hz, CH_2^{Bn}), 4.71 (AB, 1H, J_{A-B}= 11.9Hz, CH_2^{Bn}), 4.57 (AB, 1H, J_{A-B}= 11.9 Hz, CH_2^{Bn}), 4.53 (AB, 1H, J_{A-B}= 12.4 Hz, CH_2^{Bn}), 4.50 (AB, 1H, J_{A-B}= 12.4 Hz, CH_2^{Bn}), 4.26 (dd, 1H, J_{2-3} = 5.7 Hz, J_{3-4} = 5.0 Hz, H-3), 4.01 (d, 1H, J_{1-2} = 4.8 Hz, H-1), 3.96 (dd, 1H, J_{1-2} = 4.8 Hz, J_{2-3} = 5.7 Hz, H-2), 3.88-3.85 (m, 2H, H-4, H-5a), 3.69 (ABX, 1H, J_{5a-5b} = 9.9 Hz, J_{4-5b} = 4.6 Hz, H-5b), , 2.70 (dq, 2H, *J* = 2.3 Hz, *J* = 7.3 Hz, SCH_2CH_3), 2.53 (dq, 2H, *J* = 3.4 Hz, *J* = 7.3 Hz, $S\mathbf{CH_2}CH_3$), 1.19 (t, 3H, *J* =7.3 Hz, $SCH_2\mathbf{CH_3}$), 1.15 (t, 3H, *J* =7.3 Hz, $SCH_2\mathbf{CH_3}$). **^{13}C NMR** (125 MHz, $CDCl_3$) δ = 139.0 (C_q^{arom}), 138.9 (C_q^{arom}), 138.6 (C_q^{arom}), 138.3 (C_q^{arom}), 128.6-127.4 (CH^{arom}), 83.1 (C-2), 80.5 (C-3), 79.0 (C-4), 75.4 (CH_2^{Bn}), 74.9 (CH_2^{Bn}), 73.5 (CH_2^{Bn}), 71.8 (CH_2^{Bn}), 69.3 (C-5), 54.0 (C-1), 25.4 ($S\mathbf{CH_2}CH_3$), 25.2 ($S\mathbf{CH_2}CH_3$), 14.6 ($SCH_2\mathbf{CH_3}$), 14.5 ($SCH_2\mathbf{CH_3}$). **HRMS** (ESI+): m/z calculated for $C_{37}H_{44}O_4S_2Na$ $[M+Na]^+$: calc. 639.2573; found : 639.2569.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-ribose, 1b:



1b

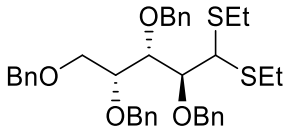
An aqueous solution of concentrated hydrochloric acid (37%, 52.0 ml, 627 mmol, 1.8 equiv.) was added to D-ribose (52.6 g, 350 mmol) at 0 °C and the mixture was stirred for 10 min at 0 °C. Then, ethanethiol (52.0 ml, 702 mmol, 2.0 equiv.) was added and the solution was stirred for 20 min at 0 °C and 18 h at room temperature. Methanol (700 ml) was added and the solution was neutralized with $Na_2CO_{3(s)}$ to pH=7. Filtration on celite, concentration of the filtrate under reduced pressure and recrystallization from hot toluene (50 °C) afforded diethyl dithioacetal D-ribose as an orange powder (32.3 g, 36%).

To a solution of diethyl dithioacetal D-ribose (15.9 g, 62 mmol) in dry DMF (210ml) under argon atmosphere was added benzyl bromide (32.6 ml, 273 mmol, 4.4 equiv.) at room temperature. The solution was cooled at 0 °C and NaH (60% in mineral oil, 12.9 g, 312 mmol, 5.0 equiv.) was added portionwise and the reaction was stirred for 20 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave compound **1b** (37.7 g, 98%).

1b: $[\alpha]^{20}_{D}$: +42.3 (*c* 0.5, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.37-7.26 (m, 20H, H^{arom}), 4.91 (AB, 1H, J_{A-B}= 11.0 Hz, CH_2^{Bn}), 4.81 (AB, 1H, J_{A-B}= 11.2 Hz, CH_2^{Bn}), 4.73 (AB, 1H, J_{A-B}= 11.9 Hz, CH_2^{Bn}), 4.70 (AB, 1H, J_{A-B}= 11.9 Hz, CH_2^{Bn}), 4.64 (AB, 1H, J_{A-B}= 11.0Hz, CH_2^{Bn}), 4.61 (AB, 1H, J_{A-B}= 11.2 Hz, CH_2^{Bn}), 4.48 (AB, 1H, J_{A-B}= 12.1 Hz, CH_2^{Bn}), 4.44 (AB, 1H, J_{A-B}= 12.1 Hz, CH_2^{Bn}), 4.24 (d, 1H, J_{1-2} = 3.0 Hz, H-1), 4.14 (dd, 1H, J_{2-3} = 7.8 Hz, J_{3-4} = 2.5 Hz, H-3), 4.08 (m, 1H, H-4), 3.97 (dd, 1H, J_{1-2} = 3.0 Hz, J_{2-3} = 7.8 Hz, H-2), 3.74 (ABX, , 1H, J_{4-5a} = 4.4 Hz, J_{5a-5b} = 10.5 Hz, H-5a), 3.70 (ABX, , 1H, J_{4-}

$_{5b}$ = 6.2 Hz, J_{5a-5b} = 10.5 Hz, H-5b), 2.67-2.55 (m, 4H, 2 S**CH₂**CH₃), 1.20 (q, 6H, *J*= 7.6 Hz, 2 SCH₂**CH₃**).**^{13}C NMR** (125 MHz, $CDCl_3$): δ = 138.9 (C_q^{arom}), 138.6 (2x C_q^{arom}), 138.4 (C_q^{arom}), 128.6-127.4 (CH^{arom}), 82.3 (C-2), 79.9 (C-3), 79.2 (C-4), 74.7 (CH_2^{Bn}), 73.6 (CH_2^{Bn}), 73.3 (CH_2^{Bn}), 72.6 (CH_2^{Bn}), 70.9 (C-5), 54.0 (C-1), 26.4 (S**CH₂**CH₃), 25.1 (S**CH₂**CH₃), 14.6 (2 SCH₂**CH₃**). **HRMS** (ESI+): m/z calculated for $C_{37}H_{44}O_4S_2Na$ $[M+Na]^+$: calc. 639.2573; found : 639.2573.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-lyxose, 1c:



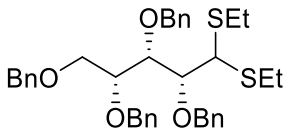
1c

An aqueous solution of concentrated hydrochloric acid (37%, 23.1 ml, 279 mmol, 1.81 equiv.) was added to D-lyxose (23.1 g, 154 mmol) at room temperature. Then, ethanethiol (23.1 ml, 312 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred 2 h at 0 °C without solid formation. The mixture was neutralized carefully with potassium carbonate to reach pH 7 and stirred for 16 h at room temperature. The white solid was filtered, washed with Et_2O (3 times) and the filtrate was stirred with decolorizing carbon for 1 h at r.t. After filtration on celite®, evaporation of solvents, the product was recrystallized in ethanol (95%, 125 ml) at 0 °C. Diethyl dithioacetal D-lyxose was obtained as a white powder (12.8g, 33%).[2,3]

To a solution of diethyl dithioacetal D-lyxose (5.3 g, 21 mmol) in dry DMF (80ml) under argon atmosphere was added benzyl bromide (10.9 ml, 91 mmol, 4.4 equiv.) at r.t. The solution was cooled at 0 °C and NaH (60% in mineral oil, 4.1 g, 103 mmol, 5.0 equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave compound **1c** (11.8g, 92%).

1c: $[\alpha]^{20}_D$: +22.7 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.39-7.26 (m, 20H, H^{arom}), 5.03 (AB, 1H, J_{A-B}= 11.2 Hz, CH_2^{Bn}), 4.74-4.70 (m, 3H, **CH_2^{Bn}**), 4.56 (AB, 1H, J_{A-B}= 11.9 Hz, CH_2^{Bn}), 4.50-4.44 (m, 3H, **CH_2^{Bn}**), 4.26 (d, 1H, J_{1-2} = 2.3 Hz, H-1), 4.20 (dd, 1H, J_{2-3} = 8.0 Hz, J_{3-4} = 2.0 Hz, H-3), 4.06-4.02 (m, 2H, H-2, H-4), 3.71 (ABX, 1H, J_{4-5a} = 5.7 Hz, J_{5a-5b} = 9.9 Hz, H-5a), 3.67 (ABX, 1H, J_{4-5b} = 5.7 Hz, J_{5a-5b} = 9.9 Hz, H-5b), 2.77-2.60 (m, 4H, 2x S**CH₂**CH₃), 1.24 (t, 3H, *J* =7.3 Hz, SCH₂**CH₃**), 1.22 (t, 3H, *J* =7.3 Hz, SCH₂**CH₃**). **^{13}C NMR** (101 MHz, $CDCl_3$): δ = 139.0 (C_q^{arom}), 138.6 (C_q^{arom}), 138.5 (C_q^{arom}), 138.2 (C_q^{arom}), 128.5-127.5 (CH^{arom}), 82.6 (C-3), 79.5 (C-2), 77.7 (C-4), 74.6 (2 x **CH_2^{Bn}**), 73.4 (CH_2^{Bn}), 72.9 (CH_2^{Bn}), 70.6 (C-5), 53.9 (C-1), 26.9 (S**CH₂**CH₃), 25.1 (S**CH₂**CH₃), 14.7 (SCH₂**CH₃**), 14.5 (SCH₂**CH₃**). **HRMS** (ESI+): m/z calculated for $C_{37}H_{44}O_4S_2Na$ $[M+Na]^+$: calc. 639.2573; found : 639.2572.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-xylose, 1d:



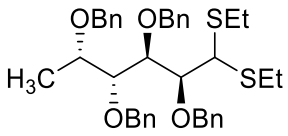
1d

D-xylose (30.0 g, 200 mmol) was dissolved in an aqueous solution of concentrated hydrochloric acid (37%, 25 ml, 302 mmol, 1.5 equiv.) at 0 °C under argon atmosphere. Then, ethanethiol (35 ml, 472 mmol, 2.4 equiv.) was added dropwise at 0 °C over 15 min and the reaction was stirred for 30 min at r.t. The mixture was cooled again to 0 °C and neutralized with NH_4OH solution (28-30 wt%, 35 ml, 14.5 M). The crude was extracted with hexane (4 times) to remove unreacted ethanethiol. The aqueous layer was concentrated to give an impure yellow oil, which was dissolved in a mixture of (acetone/ethyl acetate, 2:1, 700 ml), filtered through a celite® pad and concentrated. The yellow oil was recrystallized from dichloromethane/diethyl ether to yield diethyl dithioacetal D-xylose as a white solid (42.0 g, 82%).[3, 4]

To a solution of diethyl dithioacetal D-xylose (15.7 g, 61 mmol) in dry DMF (210 ml) under argon atmosphere was added benzyl bromide (32.3 ml, 270 mmol, 4.4 equiv.) at r.t. The solution was cooled at 0 °C and NaH (60% in mineral oil, 12.2 g, 306 mmol, 5.0 equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave molecule **1d** (33.6 g, 89%).

1d: $[\alpha]^{20}_D$: -9.2 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.38-7.26 (m, 20H, H^{arom}), 4.86 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.77 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.76 (AB, 1H, $J_{A\text{-}B}$= 11.5 Hz, CH_2^{Bn}), 4.75 (AB, 1H, $J_{A\text{-}B}$= 11.9 Hz, CH_2^{Bn}), 4.64 (AB, 1H, $J_{A\text{-}B}$= 11.5Hz, CH_2^{Bn}), 4.59 (AB, 1H, $J_{A\text{-}B}$= 11.9 Hz, CH_2^{Bn}), 4.46 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.43 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.14 (dd, 1H, $J_{2\text{-}3}$ = 6.6 Hz, $J_{3\text{-}4}$ = 4.1 Hz, H-3), 4.03 (dd, 1H, $J_{1\text{-}2}$ = 4.4 Hz, $J_{2\text{-}3}$ = 6.6 Hz , H-2), 3.87 (d, 1H, $J_{1\text{-}2}$ = 4.4 Hz, H-1), 3.79 (m, 1H, H-4), 3.68 (ABX, 1H, $J_{4\text{-}5a}$ = 5.5 Hz, $J_{5a\text{-}5b}$ = 10.3 Hz, H-5a), 3.64 (ABX, 1H, $J_{4\text{-}5b}$ = 4.1 Hz, $J_{5a\text{-}5b}$ = 10.3 Hz, H-5b), 2.66 (q, 2H, *J* = 7.6 Hz, S**CH_2**CH_3), 2.55-2.49 (m, 2H, S**CH_2**CH_3), 1.18 (t, 3H, *J* =7.6 Hz, SCH_2**CH_3**), 1.15 (t, 3H, *J* =7.6 Hz, SCH_2**CH_3**). **^{13}C NMR** (101 MHz, $CDCl_3$): δ = 138.8 (C_q^{arom}), 138.7 (C_q^{arom}), 138.4 (C_q^{arom}), 138.3 (C_q^{arom}),128.5-127.4 (CH^{arom}), 82.7 (C-2), 80.2 (C-3), 77.8 (C-4), 75.1 (CH_2^{Bn}), 75.0 (CH_2^{Bn}), 73.4 (CH_2^{Bn}), 72.4 (CH_2^{Bn}), 70.4 (C-5), 53.7 (C-1), 25.3 (S**CH_2**CH_3), 25.2 (S**CH_2**CH_3), 14.5 (2 x SCH_2**CH_3**). **HRMS** (ESI+): m/z calculated for $C_{37}H_{44}O_4S_2Na$ $[M+Na]^+$: calc. 639.2573; found : 639.2569.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal L-fucose, 1e:



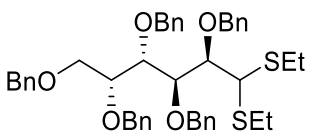
1e

L-Fucose (15.9 g, 97 mmol) was dissolved in an aqueous solution of concentrated hydrochloric acid (37%, 16 ml, 193 mmol, 2.0 equiv.) at r.t. under argon atmosphere. Then, ethanethiol (16 ml, 216 mmol, 2.2 equiv.) was added dropwise at r.t. and the product was crystallized after 10 min of vigorous stirring. Then, the solid was filtered, washed with ice water and cooled diethyl ether (2 times) and dried under reduced pressure to give diethyl dithioacetal L-fucose (17.3 g, 64 mmol, 66%) as a white powder. The analytical data correspond to published one[5] and the product was engaged in the next step without further purification.

To a solution of diethyl dithioacetal L-fucose (16.0 g, 59 mmol) in dry DMF (210 ml) under argon atmosphere was added benzyl bromide (31.1 ml, 260 mmol, 4.4 equiv.) at room temperature. The solution was cooled at 0 °C and NaH (60% in mineral oil, 11.8 g, 296 mmol, 5.0 equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave molecule **1e** (36.0 g, 97%).

1e: $[\alpha]^{20}_D$: +7.6 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$) δ = 7.38-7.23 (m, 20H, H^{arom}), 4.83 (AB, 2H, $J_{A\text{-}B}$= 11.5 Hz, CH_2^{Bn}), 4.77-4.71 (m, 3H, CH_2^{Bn}), 4.66 (AB, 1H, $J_{A\text{-}B}$= 11.9 Hz, CH_2^{Bn}), 4.65 (AB, 1H, $J_{A\text{-}B}$= 11.9 Hz, CH_2^{Bn}), 4.49 (AB, 1H, $J_{A\text{-}B}$= 11.9Hz, CH_2^{Bn}), 4.29 (t, 1H, $J_{2\text{-}3}$ = $J_{3\text{-}4}$ = 5.3 Hz, H-3), 4.06 (m, 2H, H-1, H-2), 3.84 (m, 1H, H-5), 3.67 (dd, 1H, $J_{3\text{-}4}$ = 5.3 Hz, $J_{4\text{-}5}$ = 5.0 Hz, H-4), 2.65 (qd, 2H, *J* = 2.3 Hz, *J* = 7.3 Hz, S**CH$_2$**CH_3), , 2.49 (q, 2H, *J* = 7.3 Hz, S**CH$_2$**CH_3), 1.33 (d, 3H, $J_{5\text{-}6}$ = 6.4 Hz, CH_3), 1.18 (t, 3H, *J* =7.3 Hz, SCH_2**CH$_3$**), 1.11 (t, 3H, *J* =7.3 Hz, SCH_2**CH$_3$**). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 139.1 (2 C_q^{arom}), 138.9 (C_q^{arom}), 138.7 (C_q^{arom}), 128.5-127.4 (CH^{arom}), 83.5 (C-4), 83.1 (C-2), 80.8 (C-3), 75.4 (C-5), 75.0 (CH_2^{Bn}), 74.4 (CH_2^{Bn}), 74.0 (CH_2^{Bn}), 71.2 (CH_2^{Bn}), 54.3 (C-1), 25.3 (S**CH$_2$**CH_3), 25.2 (S**CH$_2$**CH_3), 16.8 (C-6), 14.6 (SCH_2**CH$_3$**), 14.5 (SCH_2**CH$_3$**). **HRMS** (ESI+): m/z calculated for $C_{38}H_{46}O_4S_2Na$ $[M+Na]^+$: calc. 653.2730; found : 653.2724.

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-galactose, 1f:



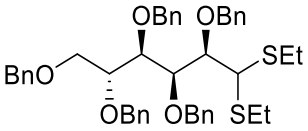
1f

D-galactose (50.0 g, 278 mmol) was dissolved in an aqueous solution of concentrated hydrochloric acid (37%, 75 ml, 905 mmol, 3.25 equiv.) at r.t. under argon atmosphere. Then, ethanethiol (50 ml, 675 mmol, 2.4 equiv.) was added and the mixture was stirred vigorously at r.t. while the pressure was released occasionally. After a few minutes, an increase of the temperature was observed and a small amount of ice were added, which caused almost instantaneously solidification of the reaction mixture. The solid was filtered and washed with ice water (50 ml) and small amount of acetone to afford diethyl dithioacetal D-galactose as a white solid (69.9 g, 88%).[6]

To a solution of diethyl dithioacetal D-galactose (15.5g, 54 mmol) in dry DMF (150 ml) under argon atmosphere was added benzyl bromide (38.8 ml, 325 mmol, 6.0 equiv.) at r.t. The solution was cooled at 0 °C and NaH (60% in mineral oil, 11.9 g, 298 mmol, 5.5 equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave compound **1f** (34.5 g, 86%).

1f: $[\alpha]^{20}_D$: +12.0 (*c* 1.3, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.35-7.22 (m, 25H, H^{arom}), 4.79 (s, 2H, CH_2^{Bn}), 4.76 (AB, 1H, $J_{A\text{-}B}$= 12.0 Hz, CH_2^{Bn}), 4.71 (AB, 2H, $J_{A\text{-}B}$= 11.5 Hz, $J_{A\text{-}B}$= 10.9 Hz, CH_2^{Bn}), 4.70 (AB, 1H, $J_{A\text{-}B}$= 10.9 Hz, CH_2^{Bn}), 4.66 (AB, 1H, $J_{A\text{-}B}$= 12.0 Hz, CH_2^{Bn}), 4.62 (AB, 1H, $J_{A\text{-}B}$= 12.0 Hz, CH_2^{Bn}), 4.49 (AB, 1H, $J_{A\text{-}B}$= 11.5 Hz, CH_2^{Bn}), 4.45 (AB, 1H, $J_{A\text{-}B}$= 12.0 Hz, CH_2^{Bn}), 4.31 (dd, 1H, $J_{2\text{-}3}$ = 6.3 Hz, $J_{3\text{-}4}$ = 4.6 Hz, H-3), 4.05-4.00 (m, 2H, H-1, H-2), 3.93 (dd, 1H, $J_{4\text{-}5}$ = 4.6 Hz, $J_{5\text{-}6a,6b}$ = 9.7 Hz, H-5), 3.86 (t, 1H, $J_{3\text{-}4}$ = $J_{4\text{-}5}$ = 4.6 Hz, H-4), 3.78 (m, 2H, H-6a, H-6b), 2.67 (q, 2H, $J_{CH2\text{-}CH3}$ = 7.5 Hz, S**CH_2**CH_3), 2.44 (dq, 2H, $J_{CH2\text{-}CH2}$ = 2.3 Hz, $J_{CH2\text{-}CH3}$ = 7.5 Hz, S**CH_2**CH_3), 1.17 (t, 3H, $J_{CH2\text{-}CH3}$ =7.5 Hz, SCH_2**CH_3**), 1.09 (t, 3H, $J_{CH2\text{-}CH3}$ =7.5 Hz, SCH_2**CH_3**). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 139.1 (C_q^{arom}), 139.0 (C_q^{arom}), 138.8 (C_q^{arom}), 138.6 (C_q^{arom}), 138.3 (C_q^{arom}), 128.5-127.2 (CH^{arom}), 83.5 (C-2), 81.6 (C-3), 79.4 (C-4), 78.9 (C-5), 75.3 (CH_2^{Bn}), 74.9 (CH_2^{Bn}), 73.4 (CH_2^{Bn}), 73.3 (CH_2^{Bn}), 73.1 (CH_2^{Bn}), 71.0 (C-6), 54.6 (C-1), 25.3 (S**CH_2**CH_3), 25.0 (S**CH_2**CH_3), 14.6 (SCH_2**CH_3**), 14.5 (SCH_2**CH_3**). These analytical data correspond to published ones.[7]

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-glucose, 1g:



1g

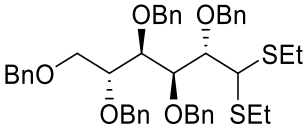
D-glucose (60.0 g, 333 mmol) was dissolved in an aqueous solution of concentrated hydrochloric acid (37%, 51 ml, 615 mmol, 1.85 equiv.) at r.t. under argon atmosphere. Then, ethanethiol (60 ml, 810 mmol, 2.4 equiv.) was added and the mixture was stirred vigorously at r.t. for 15 min. Temperature was maintained below 25 °C by adding small amount of ice and the stirring was continued until crystallization occurs. Then, the mixture was cooled for 30 min in an ice-salt bath, the white solid was filtered, subsequently washed

with cold water and diethyl ether, dried under reduced pressure to afford diethyl dithioacetal D-glucose (83.8 g, 0.293 mol, 88%).[5, 6]

To a solution of diethyl dithioacetal D-glucose (21.3 g, 74 mmol) in dry DMF (250 ml) under argon atmosphere was added benzyl bromide (48.9 ml, 409 mmol, 5.5 equiv.) at room temperature. The solution was cooled at 0 °C and NaH (60% in mineral oil, 16.4 g, 409 mmol, 5.5 equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave molecule **1g** (42.8 g, 78%).

1g: $[\alpha]^{20}_D$: -2.0 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.36-7.24 (m, 25H, H^{arom}), 4.85 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.81 (AB, 1H, $J_{A\text{-}B}$= 11.5 Hz, CH_2^{Bn}), 4.79 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.77 (AB, 1H, $J_{A\text{-}B}$= 11.5 Hz, CH_2^{Bn}), 4.69 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.68 (AB, 1H, $J_{A\text{-}B}$= 12.1 Hz, CH_2^{Bn}), 4.65 (AB, 1H, $J_{A\text{-}B}$= 12.1 Hz, CH_2^{Bn}), 4.53 (AB, 1H, $J_{A\text{-}B}$= 12.4 Hz, CH_2^{Bn}), 4.50 (AB, 1H, $J_{A\text{-}B}$= 12.4 Hz, CH_2^{Bn}), 4.46 (AB, 1H, $J_{A\text{-}B}$= 11.2 Hz, CH_2^{Bn}), 4.22 (dd, 1H, $J_{2\text{-}3}$ = 4.1 Hz, $J_{3\text{-}4}$ = 6.4 Hz, H-3), 4.03 (dd, 1H, $J_{3\text{-}4}$ = 6.4 Hz, $J_{4\text{-}5}$ = 4.6 Hz , H-4), 3.97-3.90 (m, 4H, H-1, H-2, H-5, H-6a), 3.78-3.73 (m, 1H, H-6b), 2.69 (dq, 2H, *J*= 3.2 Hz, *J*= 7.3 Hz, S**CH$_2$**CH_3), 2.58-247 (m, 2H, S**CH$_2$**CH_3), 1.21 (t, 3H, *J* =7.3 Hz, SCH_2**CH_3**), 1.15 (t, 3H, *J* =7.3 Hz, SCH_2**CH_3**). **^{13}C NMR** (101 MHz, $CDCl_3$): δ = 138.9 (C_q^{arom}), 138.8 (C_q^{arom}), 138.7 (C_q^{arom}), 138.5 (C_q^{arom}), 138.4 (C_q^{arom}), 128.5-127.5 (CH^{arom}), 83.0 (C-4), 81.1 (C-3), 79.6 (C-2), 78.9 (C-5), 75.5 (CH_2^{Bn}), 74.8 (CH_2^{Bn}), 73.7 (CH_2^{Bn}), 73.4 (CH_2^{Bn}), 72.1 (CH_2^{Bn}), 70.2 (C-6), 53.7 (C-1), 25.1 (S**CH$_2$**CH_3), 25.0 (S**CH$_2$**CH_3), 14.6 (SCH_2**CH_3**), 14.4 (SCH_2**CH_3**). **HRMS** (ESI+): m/z calculated for $C_{45}H_{52}O_5S_2Na$ $[M+Na]^+$: calc. 759.3148; found : 759.3142. These analytical data correspond to published ones.[8]

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-mannose, 1h:



1h

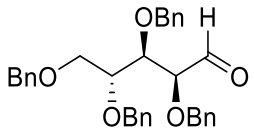
D-Mannose (26.1 g, 145 mmol) was dissolved in an aqueous solution of concentrated hydrochloric acid (37%, 39 ml, 470 mmol, 3.24 equiv.) at r.t. under argon atmosphere. Then, ethanethiol (26 ml, 351 mmol, 2.4 equiv.) was added and the mixture was stirred vigorously at r.t. for 1h. A small amount of ice was added, which causes almost instantaneously solidification of the reaction mixture. The solid was filtered and washed with cold water and cooled diethyl ether to give diethyl dithioacetal D-mannose as a white crystalline solid (28.8 g, 70%).[5]

To a solution of diethyl dithioacetal D-mannose (14.5 g, 0.051 mol) in dry DMF (250 ml) under argon atmosphere was added benzyl bromide (33.3 ml, 278 mmol, 5.5 equiv.) at r.t. The solution was cooled at 0 °C and NaH (60% in mineral oil, 11.1 g, 278 mmol, 5.5

equiv.) was added portionwise and the reaction was stirred for 24 h. Ice water was added carefully and the mixture was diluted with Et_2O and the aqueous phase was extracted with Et_2O (2 times). The combined organic phases were washed with saturated aqueous solution of NH_4Cl (3 times) and brine (3 times), dried over $MgSO_4$ and concentrated. Purification by chromatography on silica gel (Cy/EtOAc 95:5) gave compound **1h** (26.3 g, 71%).

1h: $[\alpha]^{20}_D$: -8.9 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.38-7.26 (m, 25H, H^{arom}), 5.06 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.76 (AB, 1H, J_{A-B}= 11.7 Hz, CH_2^{Bn}), 4.75 (AB, 1H, J_{A-B}= 12.1 Hz, CH_2^{Bn}), 4.70 (AB, 1H, J_{A-B}= 10.0 Hz, CH_2^{Bn}), 4.68 (AB, 1H, J_{A-B}= 10.0 Hz, CH_2^{Bn}), 4.58 (AB, 1H, J_{A-B}= 11.2 Hz, CH_2^{Bn}), 4.56 (AB, 1H, J_{A-B}= 11.7 Hz, CH_2^{Bn}), 4.52 (AB, 1H, J_{A-B}= 12.1 Hz, CH_2^{Bn}), 4.49 (AB, 1H, J_{A-B}= 11.2 Hz, CH_2^{Bn}), 4.47 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.26 (d, 1H, J_{1-2} = 1.8 Hz, H-1), 4.19-4.12 (m, 3H, H-2, H-3, H-4), 4.00 (td, 1H, J_{4-5} = J_{5-6a} = 2.5 Hz, J_{5-6b} = 5.5 Hz , H-5), 3.95 (ABX, 1H, J_{5-6a} = 2.5 Hz, J_{6a-6b} = 10.8 Hz , H-6a), 3.75 (ABX, 1H, J_{5-6b} = 5.5 Hz, J_{6a-6b} = 10.8 Hz , H-6b), 2.75-2.58 (m, 4H, 2 S**CH$_2$**CH_3), 1.22 (t, 3H, *J* =7.3 Hz, SCH_2**CH_3**), 1.21 (t, 3H, *J* =7.3 Hz, SCH_2**CH_3**). **^{13}C NMR** (101 MHz, $CDCl_3$): δ = 139.0 (C_q^{arom}), 138.9 (C_q^{arom}), 138.8 (C_q^{arom}), 138.5 (2 C_q^{arom}), 128.5-127.5 (CH^{arom}), 83.2 (C-4), 79.6 (C-2), 79.4 (C-5), 78.6 (C-3), 74.3 (CH_2^{Bn}), 74.2 (CH_2^{Bn}), 73.6 (CH_2^{Bn}), 73.4 (CH_2^{Bn}), 71.8 (CH_2^{Bn}), 70.2 (C-6), 53.8 (C-1), 27.0 (S**CH$_2$**CH_3), 25.2 (S**CH$_2$**CH_3), 14.7 (SCH_2**CH_3**), 14.5 (SCH_2**CH_3**). **HRMS** (ESI+): m/z calculated for $C_{45}H_{52}O_5S_2Na$ $[M+Na]^+$: calc. 759.3148; found : 759.3144.

2,3,4,5-Tetra-*O*-benzyl aldehydo D-arabinose, 2a:



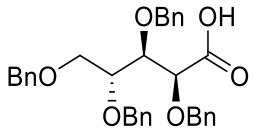
2a

To a solution of $HgCl_2$ (117.2 g, 432 mmol, 2.4 equiv.) in acetonitrile-water (400 ml: 200 ml) was added HgO (46.8 g, 216 mmol, 1.2 equiv.), the mixture was stirred 5 min at r.t and a solution of dithioacetal **1a** (111.4 g, 180 mmol) in acetonitrile (400 ml) was added. The resulting mixture was stirred at room temperature for 15 min and then refluxed for 2h40. Then, after cooling at room temperature, the mixture was filtered through a pad of celite and the residue was washed with ethyl acetate. The filtrate was subsequently washed with a solution of KI (1M), EDTA and water (2 times). Organic phase was dried over $MgSO_4$ and concentrated under reduced pressure. Residual mercury salt was removed by flash chromatography on silica gel (Cy/AcOEt 9:1) to provide 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-arabinose **2a** as a yellow solid (74.4 g, 81%).

2a: $[\alpha]^{20}_D$: -2.6 (*c* 0.9, $CHCl_3$). **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 9.60 (d, 1H, J_{1-2} = 1.4 Hz, H-1), 7.32-7.26 (m, 18H, H^{arom}), 7.21-7.19 (m, 2H, H^{arom}), 4.67 (AB, 1H, J_{A-B}= 11.7 Hz, CH_2^{Bn}), 4.61 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.53-48 (m, 5H, CH_2^{Bn}), 4.35 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.14-4.09 (m, 2H, H-2, H-3), 3.84-3.78 (m, 2H, H-4, H-5$_a$), 3.67 (ABX, 1H, J_{4-5b} = 3.9 Hz, J_{5a-5b} = 10.5 Hz, H-5$_b$). **^{13}C NMR** (125 MHz, $CDCl_3$): δ = 202.3 (C-1), 138.2 (2 C_q^{arom}), 137.7 (C_q^{arom}), 137.4 (C_q^{arom}), 128.6-127.8 (CH^{arom}), 84.2 (C-2), 78.4 (C-3), 77.5 (C-4), 74.2 (CH_2^{Bn}), 73.5 (CH_2^{Bn}), 73.4 (CH_2^{Bn}), 72.1 (CH_2^{Bn}), 68.3 (C-5).

HRMS (ESI+): m/z calculated for $C_{33}H_{34}O_5Na$ $[M+Na]^+$: calc. 533.2298; found : 533.2291. These analytical data correspond to published ones.[1]

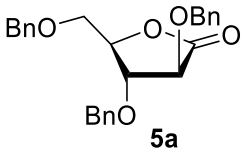
2,3,4,5-Tetra-*O*-benzyl D-arabonic acid, 3a:



3a

To a solution of 2,3,4,5-tetra-*O*-benzyl aldehydo D-arabinose **2a** (0.55 g, 1.08 mmol) in dry DMF (25 ml), was added pyridinium dichoromate PDC (2.43 g, 6.46 mmol, 6.0 equiv.) at r.t. The mixture was stirred for 24 h at r.t. Then, H_2O (50 ml) and HCl (6 M) were added until reach pH = 1. The crude was diluted with Et_2O and the aqueous phase washed 3 times with Et_2O. Organic phase were combined and washed 2 times with brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/Et_2O from 1:1 to 0:1) afforded 2,3,4,5-tetra-*O*-D-arabonic acid **3a** (0.396 g, 70%).
3a: $[\alpha]^{20}_D$: -1.1 (*c* 1.0, $CHCl_3$). **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.34-7.26 (m, 16H, H^{arom}), 7.26-7.19 (m, 4H, H^{arom}), 4.68 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.58 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.55 (AB, 1H, J_{A-B}= 10.9 Hz, CH_2^{Bn}), 4.53 (bs, 2H, CH_2^{Bn}), 4.51 (AB, 1H, J_{A-B}= 10.9 Hz, CH_2^{Bn}), 4.45 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.40 (d, 1H, J_{2-3}= 2.9 Hz, H-2), 4.36 (AB, 1H, J_{A-B}= 11.5 Hz, CH_2^{Bn}), 4.19 (dd, 1H, J_{2-3}= 2.9 Hz, J_{3-4}= 8.0 Hz, H-3), 3.85-3.81 (m, 2H, H-4, H-5a), 3.67 (dd, 1H, J_{4-5b} = 4.0 Hz, J_{5a-5b} = 10.9 Hz, H-5_b). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 175.4 (C-1), 138.3 (C_q^{arom}), 138.1 (C_q^{arom}), 137.6 (C_q^{arom}), 136.9 (C_q^{arom}), 128.6-127.6 (CH^{arom}), 79.0 (C-3), 78.0 (C-2), 77.3 (C-4), 74.7 (CH_2^{Bn}), 73.7 (CH_2^{Bn}), 73.5 (CH_2^{Bn}), 71.9 (CH_2^{Bn}), 68.0 (C-5). **HRMS** (ESI+): m/z calculated for $C_{33}H_{34}O_6Na$ $[M+Na]^+$: calc. 549.2246; found : 549.2248.

2,3,5-tri-*O*-benzyl-D-arabino-1,4-lactone, 5a:



5a

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-arabinose **1a** (374 mg, 0.604 mmol) was dissolved in an acetone/water mixture (4/1, 9.5 ml). Sodium bicarbonate (112 mg, 1.329 mmol, 2.2 equiv.) and iodine (337 mg, 1.329 mmol, 2.2 equiv.) were subsequently added at r.t. The mixture was stirred vigorously for 30 min. at room temperature. Then, saturated solution of sodium bicarbonate (5 ml) and saturated solution of sodium thiosulfate (5 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (5 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-

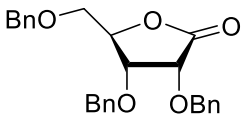
aldehydo-D-arabinose.[9] The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-aldehydo-D-arabinose (0.604 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 3.6 ml) and cooled to 0 °C. Then, TEMPO (19 mg, 0.121 mmol, 0.2 equiv.) and iodobenzene diacetate (487 mg, 1.511 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to room temperature and stirred overnight (~16 h). A saturated solution of sodium thiosulfate (2 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-arabinic acid. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-D-arabonic acid **3a** (0.604 mmol) was dissolved in dry dichloromethane under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (244 µl, 3.022 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (94 µl, 1.209 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-arabino-1,4-lactone **5a** (0.191 g, 76%).

5a: $[\alpha]^{20}_D$: +6.6 (*c* 1.1, $CHCl_3$). **IR** (neat) : 992, 730, 871, 949, 1027, 1130, 1369, 1453, 1495, 1605, 1778, 2870, 3030, 3065 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.41-7.29 (m, 13H, H^{arom}), 7.24-7.22 (m, 2H, H^{arom}), 5.07 (AB, 1H, J_{A-B} = 11.5 Hz, CH_2^{Bn}), 4.78 (AB, 1H, J_{A-B} = 11.5 Hz, CH_2^{Bn}), 4.64 (AB, 1H, J_{A-B} = 12.0 Hz, CH_2^{Bn}), 4.57 (AB, 1H, J_{A-B} = 12.0 Hz, CH_2^{Bn}), 4.54 (AB, 1H, J_{A-B} = 12.0 Hz, CH_2^{Bn}), 4.51 (AB, 1H, J_{A-B} = 12.0 Hz, CH_2^{Bn}), 4.36-4.32 (m, 3H, H-2, H-3, H-4), 3.72 (ABX, 1H, J_{4-5a} = 2.9 Hz, J_{5a-5b} = 11.5 Hz, H-5a), 3.60 (ABX, 1H, J_{4-5b} = 4.0 Hz, J_{5a-5b} = 11.5 Hz, H-5b). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 172.6 (C-1), 137.6 (C_q^{arom}), 137.2 (C_q^{arom}), 136.9 (C_q^{arom}), 128.7-127.9 (CH^{arom}), 79.4 (C-2), 79.3 (C-3), 79.0 (C-2), 73.7 (CH_2^{Bn}), 72.9 (CH_2^{Bn}), 72.6 (CH_2^{Bn}), 68.1 (C-5). **HRMS** (ESI+): m/z calculated for $C_{26}H_{26}NaO_5$ $[M+Na]^+$: calc. 441.1673; found : 441.1672. These analytical data correspond to the published ones.[10]

2,3,5-tri-*O*-benzyl-D-ribono-1,4-lactone, 5b:

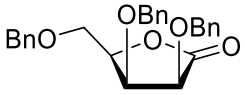


5b

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-ribose **1b** (380 mg, 0.614 mmol) was dissolved in an acetone/water mixture (4/1, 10 ml). Sodium bicarbonate (113 mg, 1.35 mmol, 2.2 equiv.) and iodine (343 mg, 1.35 mmol, 2.2 equiv.) were subsequently added at r.t. The mixture was stirred vigorously for 1 h at room temperature. Then, saturated solution of sodium bicarbonate (5 ml) and saturated solution of sodium thiosulfate (5 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (5 ml) was added and the solution was

stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-ribose.[9] The product was engaged in the next step without further purification.
2,3,4,5-Tetra-*O*-benzyl-aldehydo-D-ribose (0.614 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 2.6 ml) and cooled to 0 °C. Then, TEMPO (19 mg, 0.123 mmol, 0.2 equiv.) and iodobenzene diacetate (495 mg, 1.595 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to room temperature and stirred for 4.5 h. A saturated solution of sodium thiosulfate (2 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-ribonic acid. This product was engaged in the next step without further purification.
2,3,4,5-Tetra-*O*-benzyl-D-ribonic acid (0.614 mmol) was dissolved in dry dichloromethane under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (251 µl, 3.070 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (95 µl, 1.228 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in EtOAc, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under vacuum. Purification by chromatography on silica gel (Cy/EtOAc 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-ribo-1,4-lactone **5b** (0.185 g, 72%).
5b: $[\alpha]^{20}_D$: +67.7 (*c* 1.0, $CHCl_3$). **IR** (neat) : 696, 734, 963, 1025, 1096, 1148, 1332, 1453, 1496, 1782, 2866, 3030 cm^{-1}. **^{1}H NMR** (400 MHz, $CDCl_3$): δ = 7.38-7.28 (m, 13H, H^{arom}), 7.18-7.16 (m, 2H, H^{arom}), 4.95 (AB, 1H, J_{A-B} = 11.9 Hz, CH_2^{Bn}), 4.74 (AB, 1H, J_{A-B} = 11.9 Hz, CH_2^{Bn}), 4.70 (AB, 1H, J_{A-B} = 11.9 Hz, CH_2^{Bn}), 4.56-453 (m, 2H, H-4, CH_2^{Bn}), 4.49 (AB, 1H, J_{A-B} = 11.9 Hz, CH_2^{Bn}), 4.42-4.39 (m, 2H, H-2, CH_2^{Bn}), 4.10 (dd, 1H, J_{2-3} = 5.7 Hz, J_{3-4} = 2.1 Hz, H-3), 3.67 (ABX, 1H, J_{4-5a} = 3.0 Hz, J_{5a-5b} = 11.0 Hz, H-5a), 3.56 (ABX, 1H, J_{4-5b} = 2.8 Hz, J_{5a-5b} = 11.0 Hz, H-5b). **^{13}C NMR** (101 MHz, $CDCl_3$): δ = 173.8 (C-1), 137.4 (C_q^{arom}), 137.2 (C_q^{arom}), 137.1 (C_q^{arom}), 128.7-127.7 (CH^{arom}), 81.9 (C-4), 75.5 (C-3), 73.8 (C-2), 73.8 (CH_2^{Bn}), 72.8 (CH_2^{Bn}), 72.5 (CH_2^{Bn}), 68.9 (C-5). **HRMS** (ESI+): m/z calculated for $C_{26}H_{26}NaO_5$ $[M+Na]^+$: calc. 441.1673; found : 441.1676. These analytical data correspond to the published ones.[11]

2,3,5-tri-*O*-benzyl-D-lyxono-1,4-lactone, 5c:

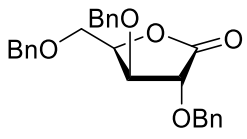


5c

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-lyxose **1c** (560 mg, 0.905 mmol) was dissolved in an acetone/water mixture (4/1, 14.5 ml). Sodium bicarbonate (167 mg, 1.991 mmol, 2.2 equiv.) and iodine (505 mg, 1.991 mmol, 2.2 equiv.) were subsequently added at room temperature. The mixture was stirred vigorously for 1 h at r.t. Then, saturated solution of sodium bicarbonate (8 ml) and saturated solution of sodium thiosulfate (8 ml)

were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (8 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-lyxose.[9] The product was engaged in the next step without further purification.
2,3,4,5-tetra-*O*-benzyl-aldehydo-D-lyxose (0.905 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 5.1 ml) and cooled to 0 °C. Then, TEMPO (28 mg, 0.181 mmol, 0.2 equiv.) and iodobenzene diacetate (728 mg, 2.262 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to room temperature and stirred overnight (~16 h). A saturated solution of sodium thiosulfate (4 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-lyxonic acid. The product was engaged in the next step without further purification.
2,3,4,5-Tetra-*O*-benzyl-D-lyxonic acid (0.905 mmol) was dissolved in dry dichloromethane under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (366 µl, 4.524 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (140 µl, 1.810 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-lyxono-1,4-lactone **5c** (0.271 g, 72%).
5c: $[\alpha]^{20}_D$: -23.9 (*c* 1.0, $CHCl_3$). **IR** (neat) : 693, 736, 994, 1024, 1131, 1214, 1453, 1497, 1803, 2919, 3029 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.39-7.27 (m, 15H, H^{arom}), 5.00 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.86 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.81 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.60 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.58 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.50 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.46 (td, 1H, $J_{3\text{-}4}$ = 3.4 Hz, $J_{4\text{-}5a,5b}$ = 6.3 Hz, H-4), 4.24 (dd, 1H, $J_{2\text{-}3}$ = 4.6 Hz, $J_{3\text{-}4}$ = 3.4 Hz, H-3), 4.20 (d, 1H, $J_{2\text{-}3}$ = 4.6 Hz, H-2), 3.81 (d, 2H, $J_{4\text{-}5a,5b}$ = 6.3 Hz, H-5a, H-5b). **^{13}C NMR** (126 MHz, $CDCl_3$) : δ = 173.2 (C-1), 137.7 (C_q^{arom}), 137.6 (C_q^{arom}), 136.9 (C_q^{arom}), 128.8-127.9 (CH^{arom}), 78.6 (C-4), 76.3 (C-2), 75.1 (C-3), 73.9 (CH_2^{Bn}), 73.8 (CH_2^{Bn}), 72.8 (CH_2^{Bn}), 67.6 (C-5). **HRMS** (ESI+): m/z calculated for $C_{26}H_{26}NaO_5$ $[M+Na]^+$: calc. 441.1673; found : 441.1672. These analytical data correspond to the published ones.[12]

2,3,5-tri-*O*-benzyl-D-xylono-1,4-lactone, 5d:



5d

2,3,4,5-Tetra-*O*-benzyl diethyl dithioacetal D-xylose **1d** (470 mg, 0.759 mmol) was dissolved in an acetone/water mixture (4/1, 12 ml). Sodium bicarbonate (140 mg, 1.671

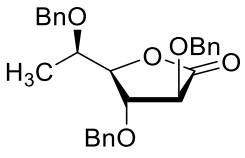
mmol, 2.2 equiv.) and iodine (424 mg, 1.671 mmol, 2.2 equiv.) were subsequently added at room temperature. The mixture was stirred vigorously for 1h at r.t. Then, saturated solution of sodium bicarbonate (7 ml) and saturated solution of sodium thiosulfate (7 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (7 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-xylose. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-aldehydo-D-xylose (0.759 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 4.5 ml) and cooled to 0 °C. Then, TEMPO (24 mg, 0.152 mmol, 0.2 equiv.) and iodobenzene diacetate (611 mg, 1.899 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to r.t. and stirred for 5 h. A saturated solution of sodium thiosulfate (6 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-xylonic acid. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-D-xylonic acid (0.759 mmol) was dissolved in dry dichloromethane (7.8 ml) under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (307 µl, 3.797 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (118 µl, 1.519 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-xylono-1,4-lactone **5d** (0.228 g, 72%).

5d:$[\alpha]^{20}_D$: +91.6 (*c* 1.0, $CHCl_3$). **IR** (neat) : 696, 735, 910, 1027, 1100, 1166, 1453, 1496, 1605, 1784, 2866, 3030 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.38-7.27 (m, 13H, H^{arom}), 7.25-7.23 (m, 2H, H^{arom}), 5.05 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.70 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.66 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.57-4.50 (m, 4H, H-2, 3 CH_2^{Bn}), 4.37 (t, 1H, $J_{2\text{-}3}$ = $J_{3\text{-}4}$ = 7.1 Hz, H-3), 3.77 (ABX, 1H, $J_{4\text{-}5a}$ = 2.9 Hz, $J_{5a\text{-}5b}$ = 10.9 Hz, H-5a), 3.71 (ABX, 1H, $J_{4\text{-}5b}$ = 3.4 Hz, $J_{5a\text{-}5b}$ = 10.9 Hz, H-5b). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 173.5 (C-1), 137.7 (C_q^{arom}), 137.4 (C_q^{arom}), 137.2 (C_q^{arom}), 128.6-127.6 (CH^{arom}), 79.5 (C-3), 77.4 (C-2, C-4), 73.7 (CH_2^{bn}), 72.8 (CH_2^{Bn}), 72.7 (CH_2^{Bn}), 67.2 (C-5). **HRMS** (ESI+): m/z calculated for $C_{26}H_{26}NaO_5$ $[M+Na]^+$: calc. 441.1673; found : 441.1672. These analytical data correspond to the published ones.[13]

2,3,5-tri-*O*-benzyl-L-fucono-1,4-lactone, 5e:



5e

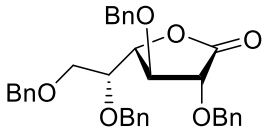
2,3,4,5-Tetra-O-benzyl diethyl dithioacetal L-fucose **1e** (730 mg, 1.157 mmol) was dissolved in an acetone/water mixture (4/1, 19 ml). Sodium bicarbonate (214 mg, 2.546 mmol, 2.2 equiv.) and iodine (646 mg, 2.546 mmol, 2.2 equiv.) were subsequently added at room temperature. The mixture was stirred vigorously for 1 h at r.t. Then, saturated solution of sodium bicarbonate (12 ml) and saturated solution of sodium thiosulfate (12 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (12 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-L-fucose. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-aldehydo-L-fucose (1.157 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 6.6 ml) and cooled to 0 °C. Then, TEMPO (36 mg, 0.231 mmol, 0.2 equiv.) and iodobenzene diacetate (931 mg, 2.892 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to room temperature and stirred for 5 h. A saturated solution of sodium thiosulfate (12 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-L-fuconic acid. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-L-fuconic acid (1.157 mmol) was dissolved in dry dichloromethane (12.0 ml) under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (468 µl, 5.785 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (179 µl, 2.314 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-L-fucono-1,4-lactone **5e** (0.434 g, 87%).

5e: $\mathbf{[\alpha]^{20}_D}$: +4.6 (*c* 1.0, $CHCl_3$). **IR** (neat) : 694, 732, 749, 988, 1005, 1099, 1453, 1496, 1607, 1773, 2878, 3032, 3064 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.42-7.26 (m, 13H, H^{arom}), 7.19-7.17 (m, 2H, H^{arom}), 5.08 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.79 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.61 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.57 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.40 (AB, 2H, $J_{A\text{-}B}$ = 11.5 Hz, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.36 (d, 1H, $J_{2\text{-}3}$ = 7.5 Hz, H-2), 4.30 (t, 1H, $J_{2\text{-}3}$ = $J_{3\text{-}4}$ = 7.5 Hz, H-3), 4.15 (dd, 1H, $J_{3\text{-}4}$ = 7.5 Hz, $J_{4\text{-}5}$ = 3.4 Hz, H-4), 3.67 (qd, 1H, $J_{4\text{-}5}$ = 3.4 Hz, $J_{5\text{-}CH3}$ = 6.9 Hz, H-5), 1.27 (d, 1H, $J_{5\text{-}CH3}$ = 6.9 Hz, CH_3). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 172.7 (C-1), 138.0 (C_q^{arom}), 137.2 (C_q^{arom}), 137.0 (C_q^{arom}), 128.7-127.9 (CH^{arom}), 82.6 (C-4), 79.6 (C-2), 79.0 (C-3), 72.6 (CH_2^{Bn}), 72.5 (CH_2^{Bn}), 72.2 (C-5), 71.2 (CH_2^{Bn}), 15.5 (CH_3). **HRMS** (ESI+): m/z calculated for $C_{27}H_{28}NaO_5$ $[M+Na]^+$: calc. 455.1829; found : 455.1829.

2,3,5-tri-*O*-benzyl-D-galactono-1,4-lactone, 5f:



5f

2,3,4,5-Tetra-O-benzyl diethyl dithioacetal D-galactose **1f** (310 mg, 0.421 mmol) was dissolved in an acetone/water mixture (4/1, 7 ml). Sodium bicarbonate (78 mg, 0.925 mmol, 2.2 equiv.) and iodine (235 mg, 0.925 mmol, 2.2 equiv.) were subsequently added at room temperature. The mixture was stirred vigorously for 1 h at r.t. Then, saturated solution of sodium bicarbonate (4 ml) and saturated solution of sodium thiosulfate (4 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (4 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-galactose. The product was engaged in the next step without further purification.

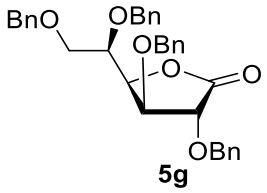
2,3,4,5-Tetra-*O*-benzyl-aldehydo-D-galactose (0.421 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 2.4 ml) and cooled to 0 °C. Then, TEMPO (13 mg, 0.084 mmol, 0.2 equiv.) and iodobenzene diacetate (338 mg, 1.052 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to r.t. and stirred for 5 h. A saturated solution of sodium thiosulfate (4 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-galactonic acid. The product was engaged in the next step without further purification.

2,3,4,5-Tetra-*O*-benzyl-D-galactonic acid (0.421 mmol) was dissolved in dry dichloromethane (4.4 ml) under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (170 µl, 2.103 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (65 µl, 0.841 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-galactono-1,4-lactone **5f** (0.173 g 76%).

5f: $[\alpha]^{20}_D$: -16.2 (*c* 1.0, $CHCl_3$). **IR** (neat) : 696, 734, 820, 912, 1027, 1099, 1208, 1310, 1453, 1496, 1606, 1784, 2867, 3030 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.41-7.24 (m, 18H, H^{arom}), 7.19-7.16 (m, 2H, H^{arom}), 5.06 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.77 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.63 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.51 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.50 (m, 2H, CH_2^{Bn}), 4.40 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.39-4.34 (m, 3H, H-2, H-3, H-4), 4.31 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 3.72-3.67 (m, 3H, H-5, H-6a, H-6b). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 172.6 (C-1), 137.9 (C_q^{arom}), 137.8 (C_q^{arom}), 137.2 (C_q^{arom}), 137.0 (C_q^{arom}), 128.7-127.8 (CH^{arom}), 79.6 (C-4), 79.3 (C-3), 78.4 (C-2), 74.7 (C-5), 73.7 (CH_2^{Bn}), 73.0 (CH_2^{Bn}), 72.5 (2 CH_2^{Bn}), 69.1 (C-6). **HRMS** (ESI+): m/z

calculated for $C_{34}H_{34}NaO_6$ $[M+Na]^+$: calc. 561.2248; found : 561.2244. These analytical data correspond to the published ones.[14]

2,3,5-tri-O-benzyl-D-glucono-1,4-lactone, 5g:

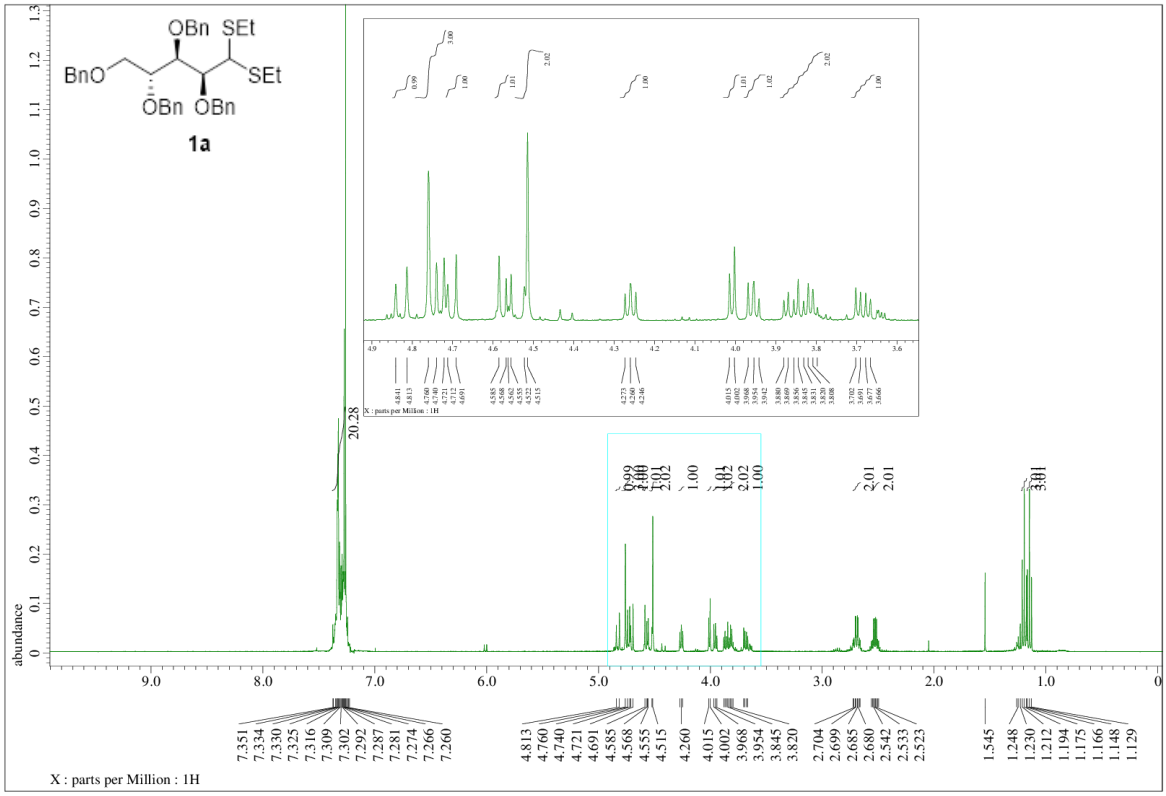


5g

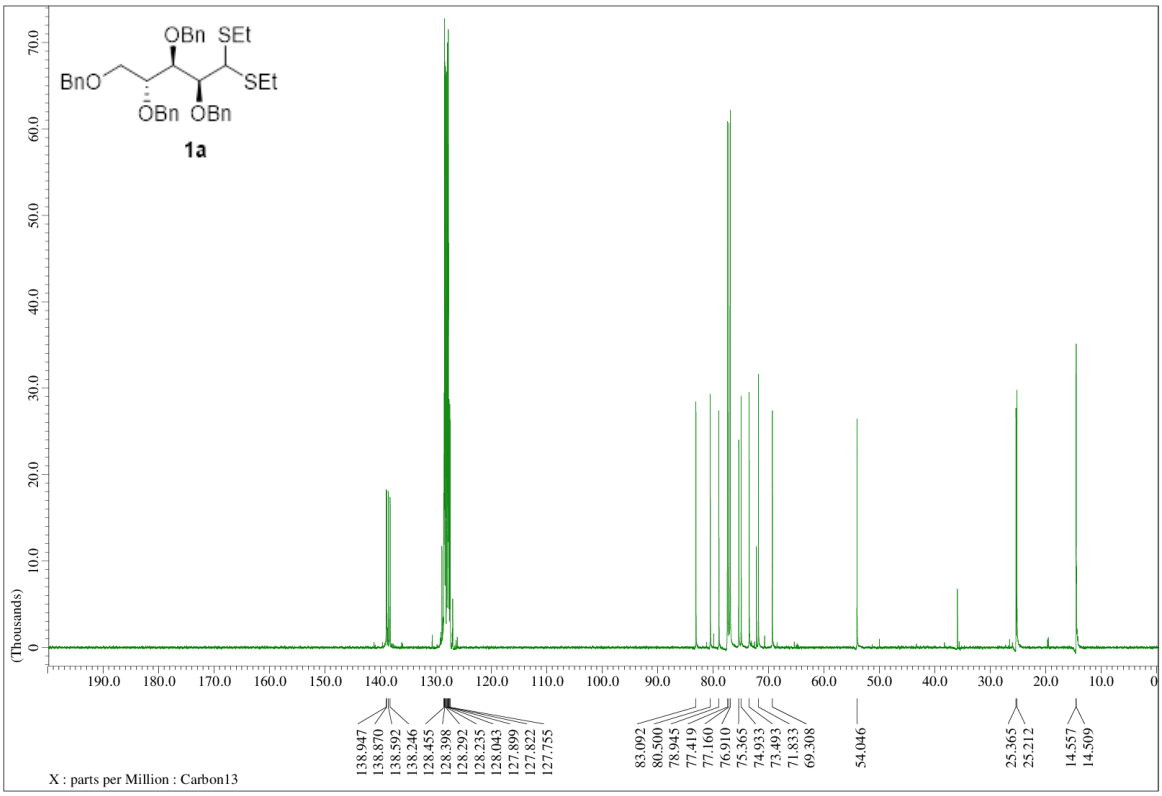
2,3,4,5-Tetra-O-benzyl diethyl dithioacetal D-glucose **1g** (440 mg, 0.597 mmol) was dissolved in an acetone/water mixture (4/1, 9.5 ml). Sodium bicarbonate (111 mg, 1.313 mmol, 2.2 equiv.) and iodine (333 mg, 1.313 mmol, 2.2 equiv.) were subsequently added at room temperature. The mixture was stirred vigorously for 1 h at r.t. Then, saturated solution of sodium bicarbonate (6 ml) and saturated solution of sodium thiosulfate (6 ml) were added and acetone was removed under reduced pressure. The mixture was dissolved in Et_2O, saturated solution of sodium thiosulfate (6 ml) was added and the solution was stirred for 15 min. (until formation of a clear solution). The aqueous phase was extracted with Et_2O and the combined organic layer were washed with brine (2 times), dried over $MgSO_4$ and concentrated under reduced pressure to afford 2,3,4,5-tetra-*O*-benzyl-aldehydo-D-glucose. The product was engaged in the next step without further purification.
2,3,4,5-Tetra-*O*-benzyl-aldehydo-D-galactose (0.597 mmol) was dissolved in a mixture of dichloromethane/water (2/1, 3.6 ml) and cooled to 0 °C. Then, TEMPO (19 mg, 0.119 mmol, 0.2 equiv.) and iodobenzene diacetate (481 mg, 1.492 mmol, 2.5 equiv.) were subsequently added. The mixture was allowed to warm to r.t. and stirred for 5 h. A saturated solution of sodium thiosulfate (6 ml) was added and the dichloromethane was removed under reduced pressure. The mixture was dissolved in ethyl acetate and the organic phase was washed with brine (2 times), dried over $MgSO_4$, and concentrated under reduced pressure to give 2,3,4,5-tetra-*O*-benzyl-D-gluconic acid. The product was engaged in the next step without further purification.
2,3,4,5-Tetra-*O*-benzyl-D-gluconic acid (0.597 mmol) was dissolved in dry dichloromethane (6.2 ml) under argon atmosphere and cooled at 0 °C. Freshly distilled pyridine (241 µl, 2.985 mmol, 5.0 equiv.) was added at 0 °C and the mixture was stirred for 5 min. Thionyl bromide (93 µl, 1.194 mmol, 2.0 equiv.) was added dropwise at 0 °C and the solution was stirred for 1 h at r.t. Solvent was removed under reduced pressure. The mixture was diluted in ethyl acetate, washed with NH_4Cl_{sat} and brine, dried over $MgSO_4$ and concentrated under reduced pressure. Purification by chromatography on silica gel (Cy/AcOEt 9:1) afforded the 2,3,5-tri-*O*-benzyl-D-glucono-1,4-lactone **5g** (0.226 g, 70%).
5g: $[\alpha]^{20}_D$: +38.1 (*c* 1.0, $CHCl_3$). **IR** (neat) : 696, 734, 820, 914, 1026, 1195, 1362, 1453, 1496, 1585, 1784, 2866, 3030 cm^{-1}. **^{1}H NMR** (500 MHz, $CDCl_3$): δ = 7.36-7.23 (m, 18H, H^{arom}), 7.19-7.17 (m, 2H, H^{arom}), 4.89 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.77 (dd, 1H, $J_{3\text{-}4}$ = 5.2 Hz, $J_{4\text{-}5}$ = 6.3 Hz, H-4), 4.73 (AB, 1H, $J_{A\text{-}B}$ = 11.5 Hz, CH_2^{Bn}), 4.60 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.55 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.51 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz,

CH_2^{Bn}), 4.50 (AB, 2H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.46 (AB, 1H, $J_{A\text{-}B}$ = 12.0 Hz, CH_2^{Bn}), 4.30 (dd, 1H, $J_{2\text{-}3}$ = 4.0 Hz, $J_{3\text{-}4}$ = 5.2 Hz, H-3), 4.25 (d, 1H, $J_{2\text{-}3}$ = 4.0 Hz, H-2), 4.07 (ddd, 1H, $J_{4\text{-}5}$ = 6.3 Hz, $J_{5\text{-}6a}$ = 3.4 Hz, $J_{5\text{-}6b}$ = 5.2 Hz, H-5), 3.82 (ABX, 1H, $J_{5\text{-}6a}$ = 3.4 Hz, $J_{6a\text{-}6b}$ = 10.3 Hz, H-6a), 3.71 (ABX, 1H, $J_{5\text{-}6b}$ = 5.2 Hz, $J_{6a\text{-}6b}$ = 10.3 Hz, H-6b). **^{13}C NMR** (126 MHz, $CDCl_3$): δ = 173.1 (C-1), 138.2 (C_q^{arom}), 138.1 (C_q^{arom}), 137.1 (C_q^{arom}), 136.9 (C_q^{arom}), 128.6-127.8 (CH^{arom}), 79.4 (C-3), 79.0 (C-4), 77.0 (C-2), 76.6 (C-5), 73.6 (CH_2^{Bn}), 73.2 (CH_2^{Bn}), 72.6 (CH_2^{Bn}), 72.5 (CH_2^{Bn}), 69.8 (C-6). **HRMS** (ESI+): m/z calculated for $C_{34}H_{34}NaO_6$ $[M+Na]^+$: calc. 561.2248; found : 561.2248. These analytical data correspond to the published ones.[15]

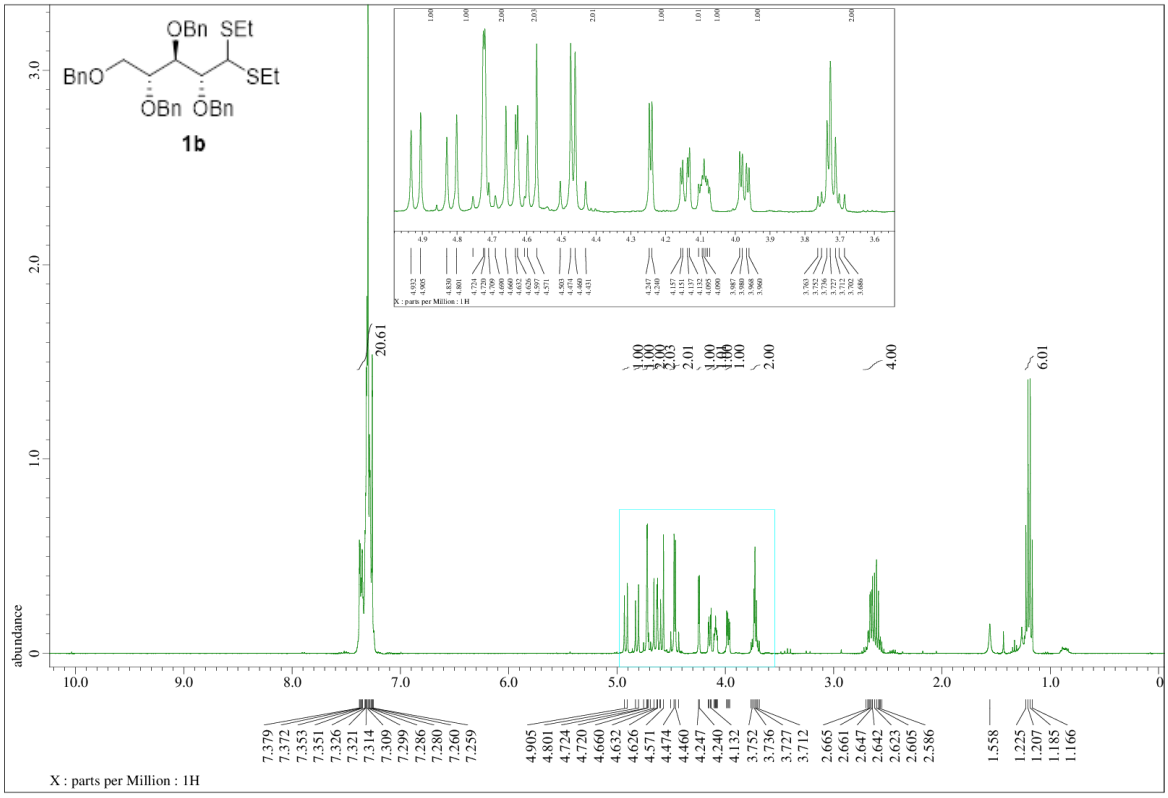
^{1}H NMR (400 MHz, $CDCl_3$):



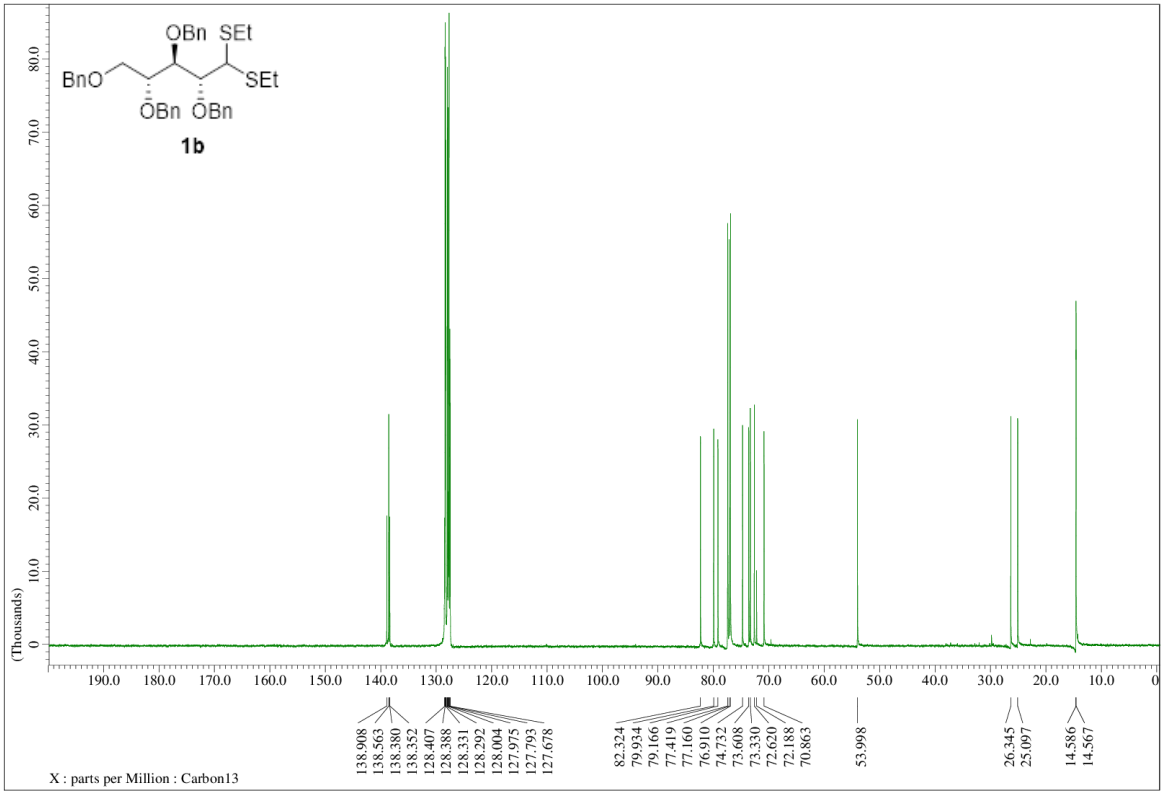
^{13}C NMR (125 MHz, $CDCl_3$)



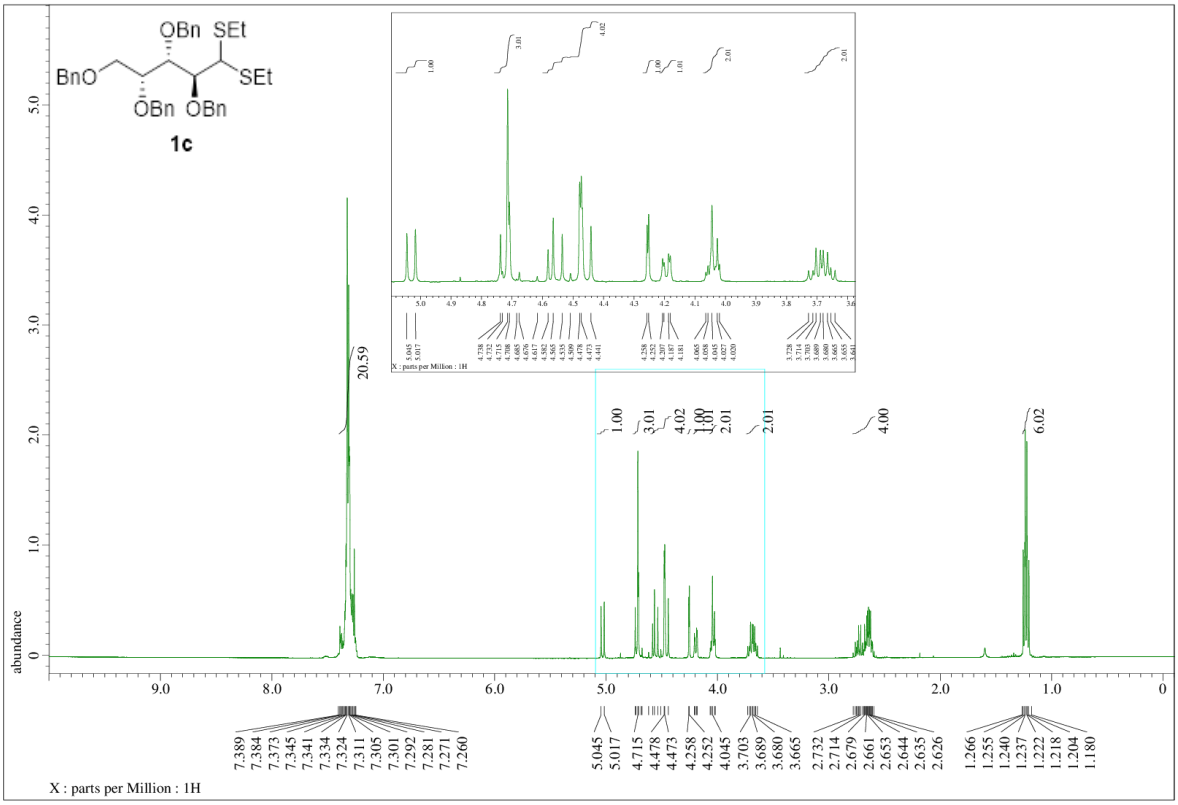
^{1}H NMR (400 MHz, $CDCl_3$):



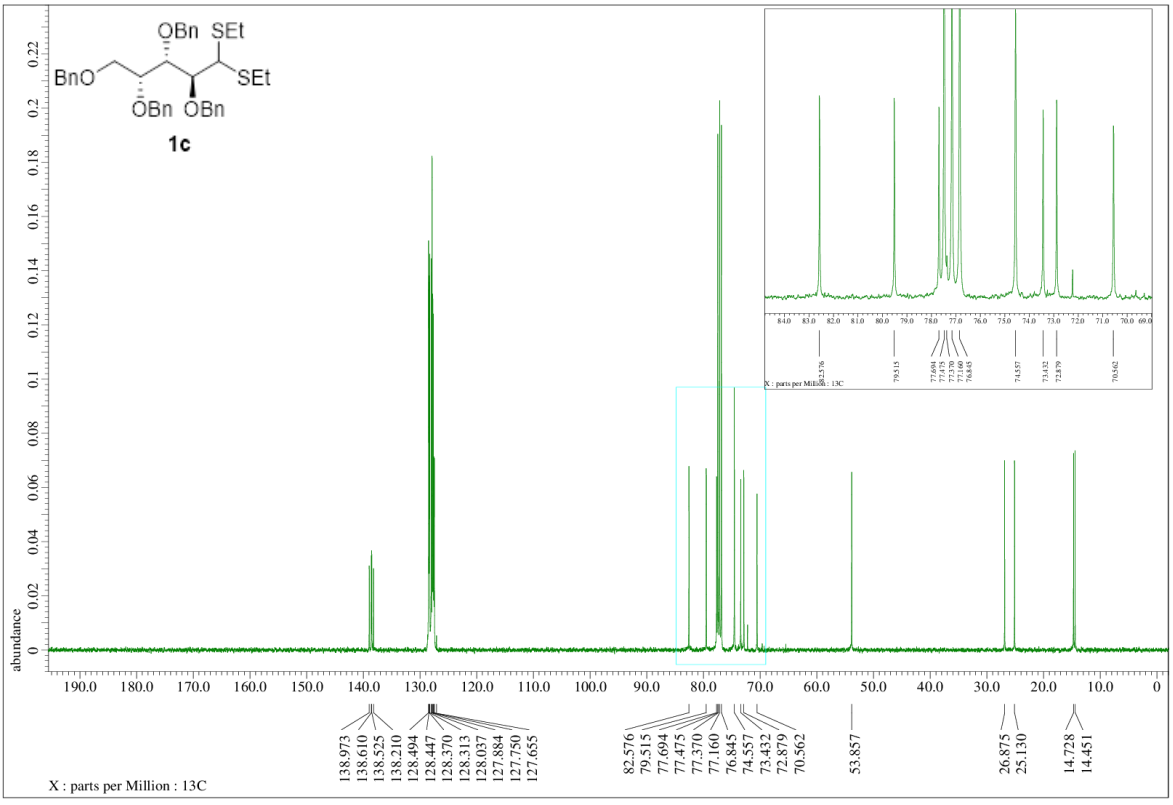
^{13}C NMR (125 MHz, $CDCl_3$):



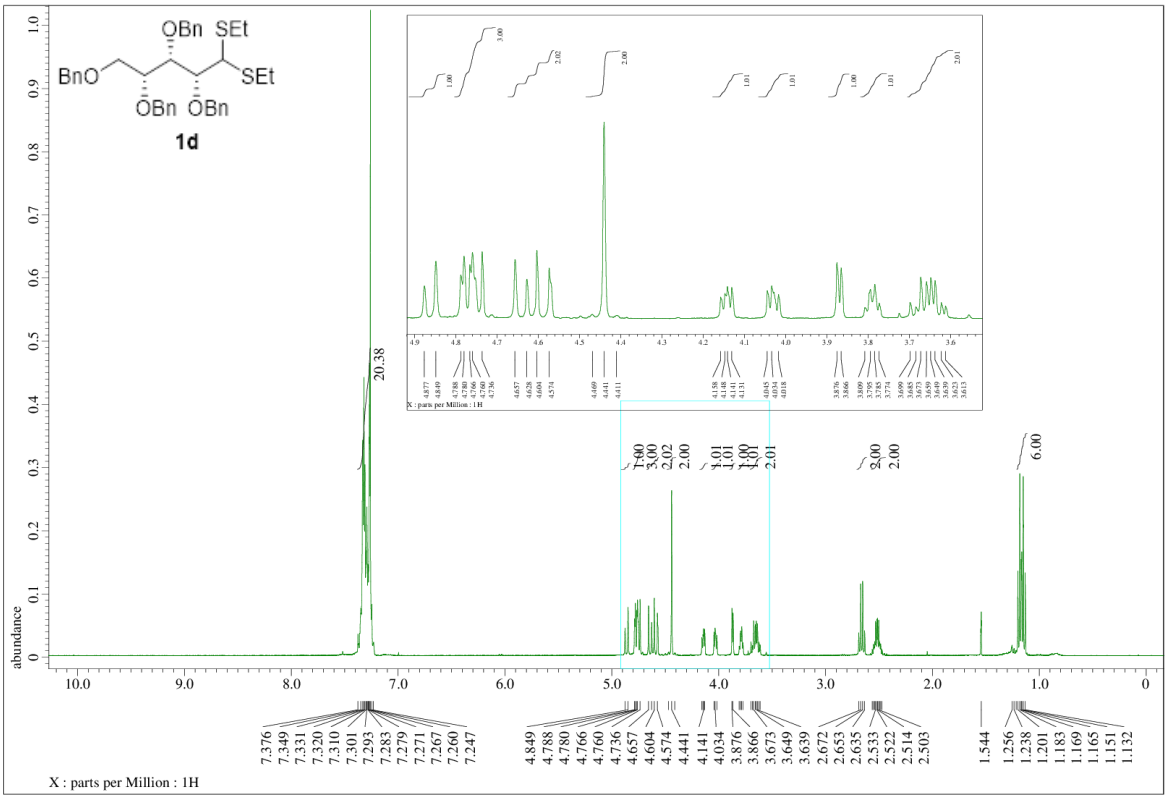
^{1}H NMR (400 MHz, $CDCl_3$):



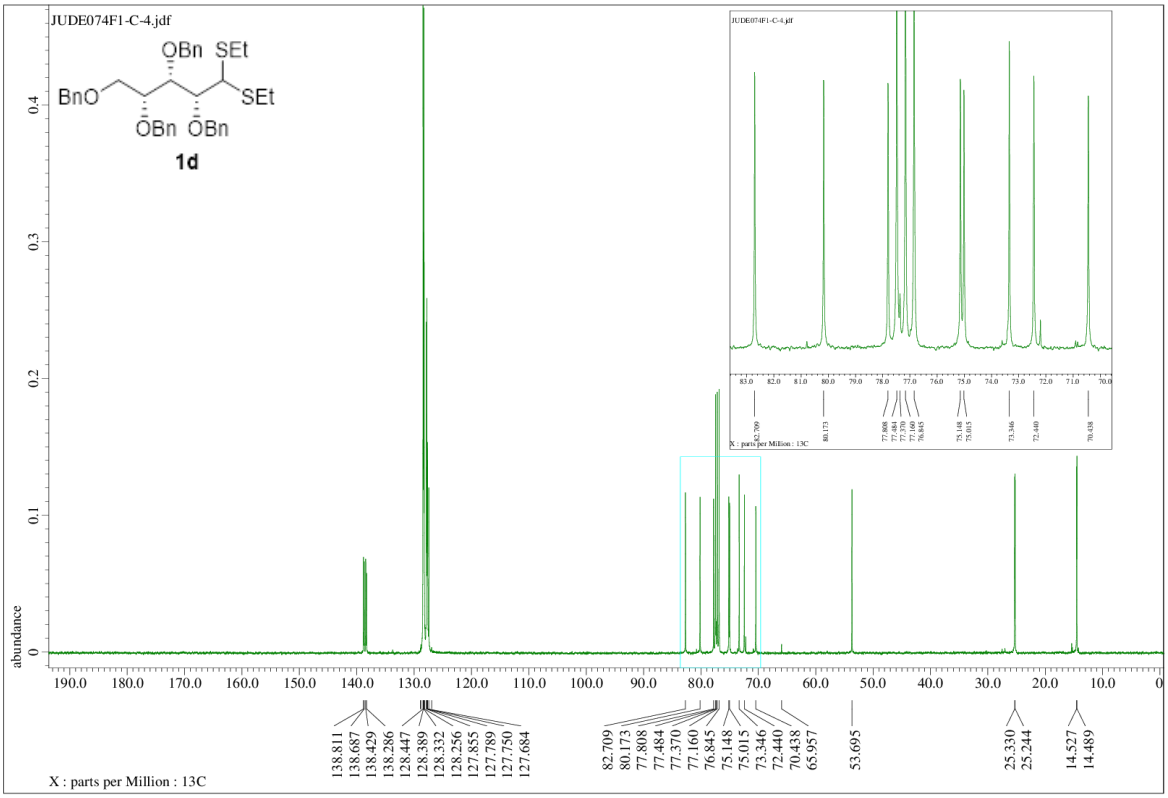
^{13}C NMR (101 MHz, $CDCl_3$):



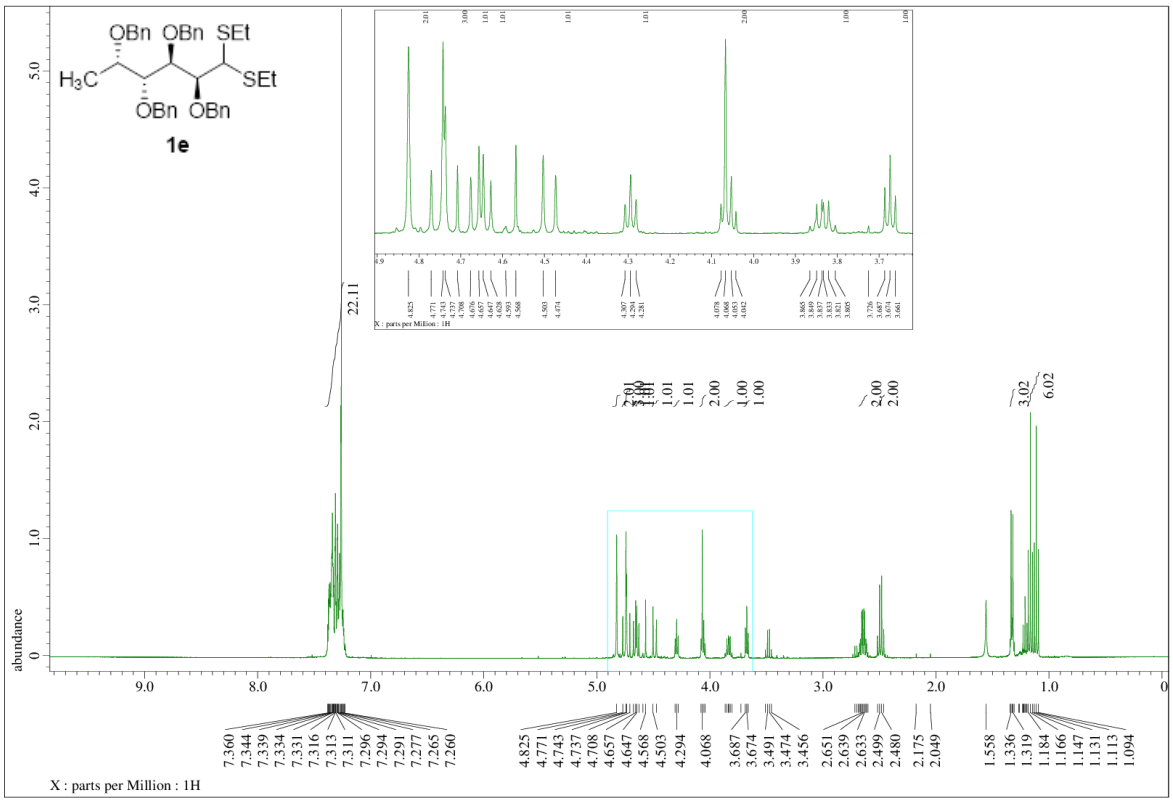
^{1}H NMR (400 MHz, $CDCl_3$):



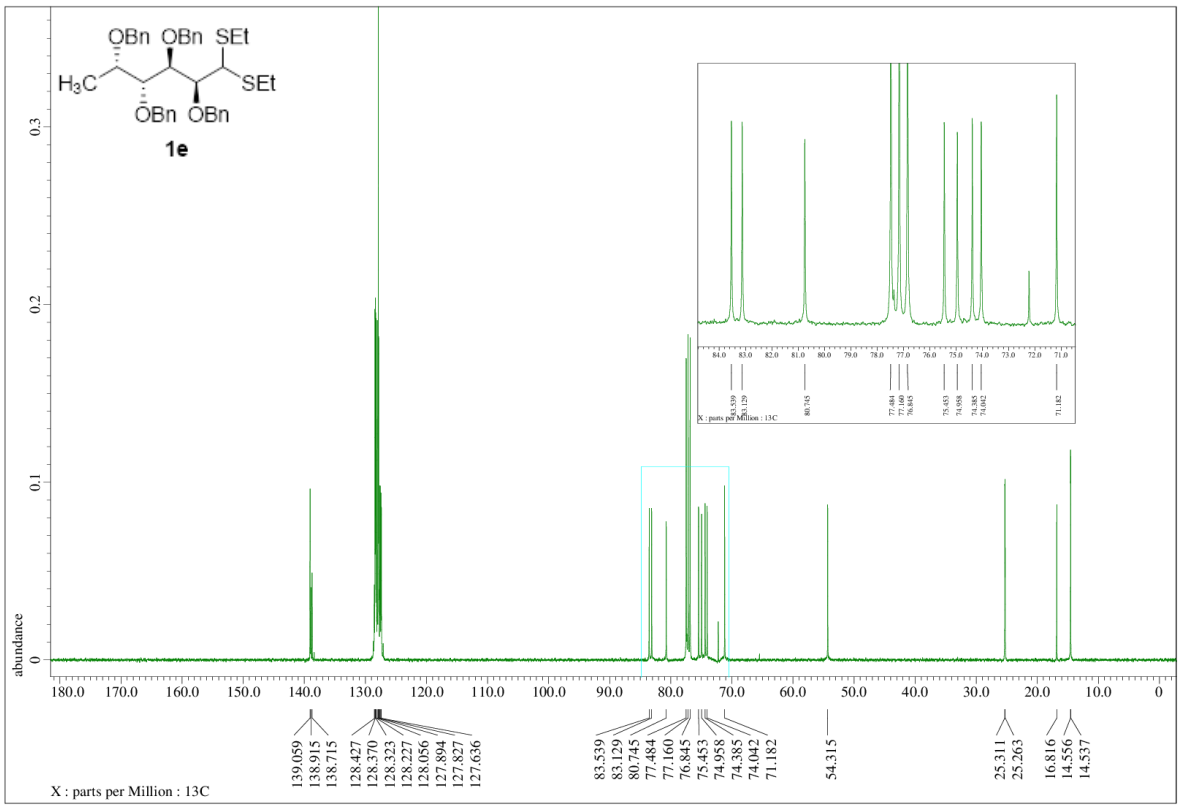
^{13}C NMR (101 MHz, $CDCl_3$):



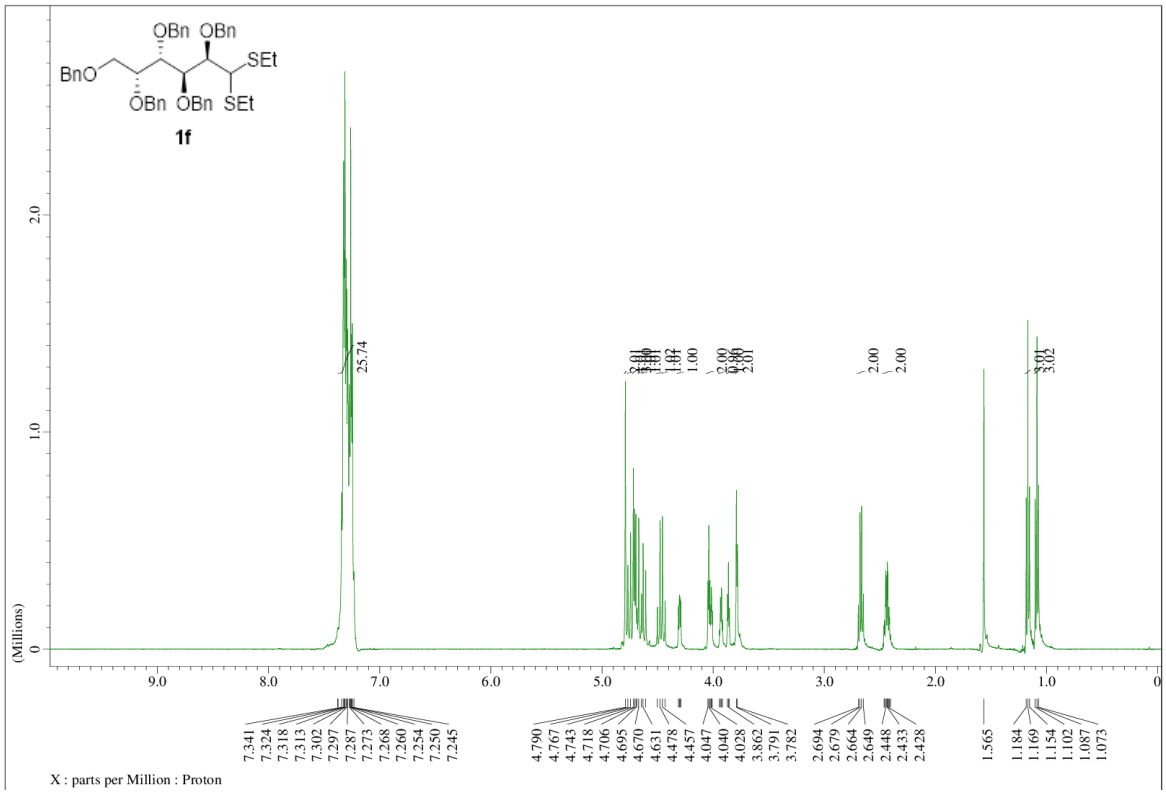
^{1}H NMR (400 MHz, $CDCl_3$):



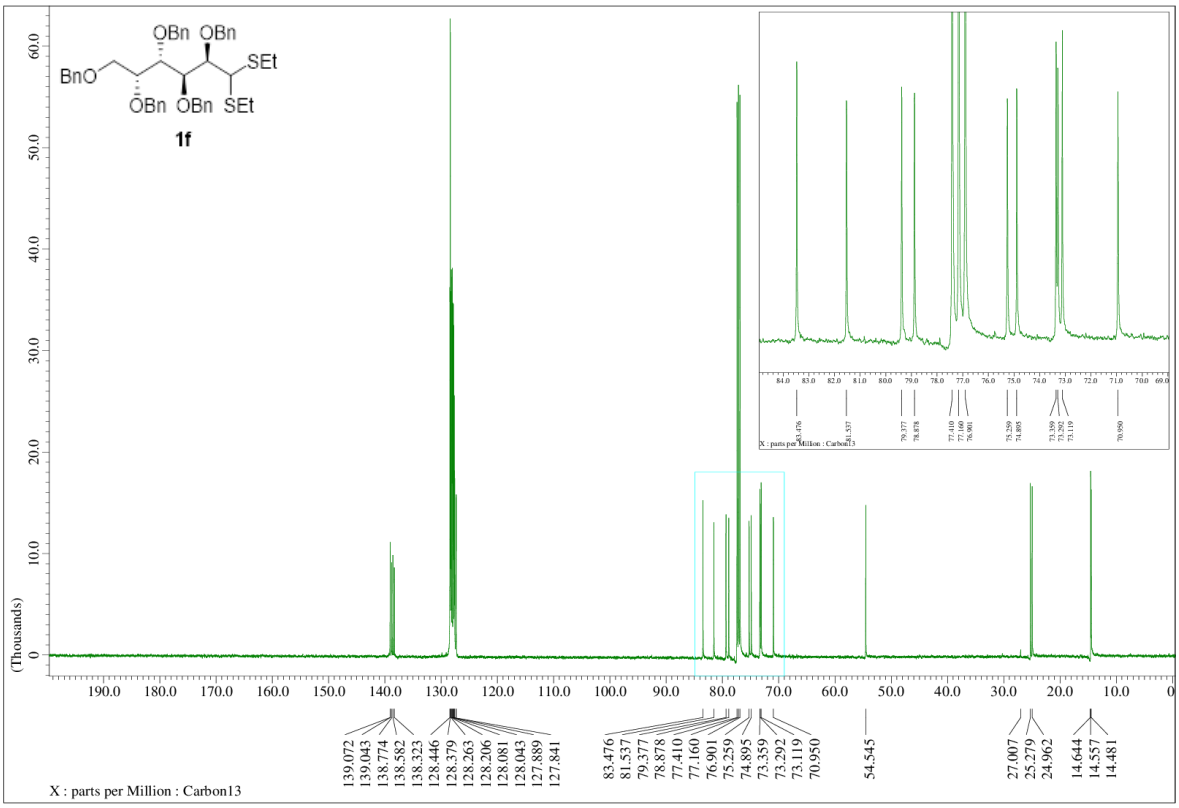
^{13}C NMR (101 MHz, $CDCl_3$):



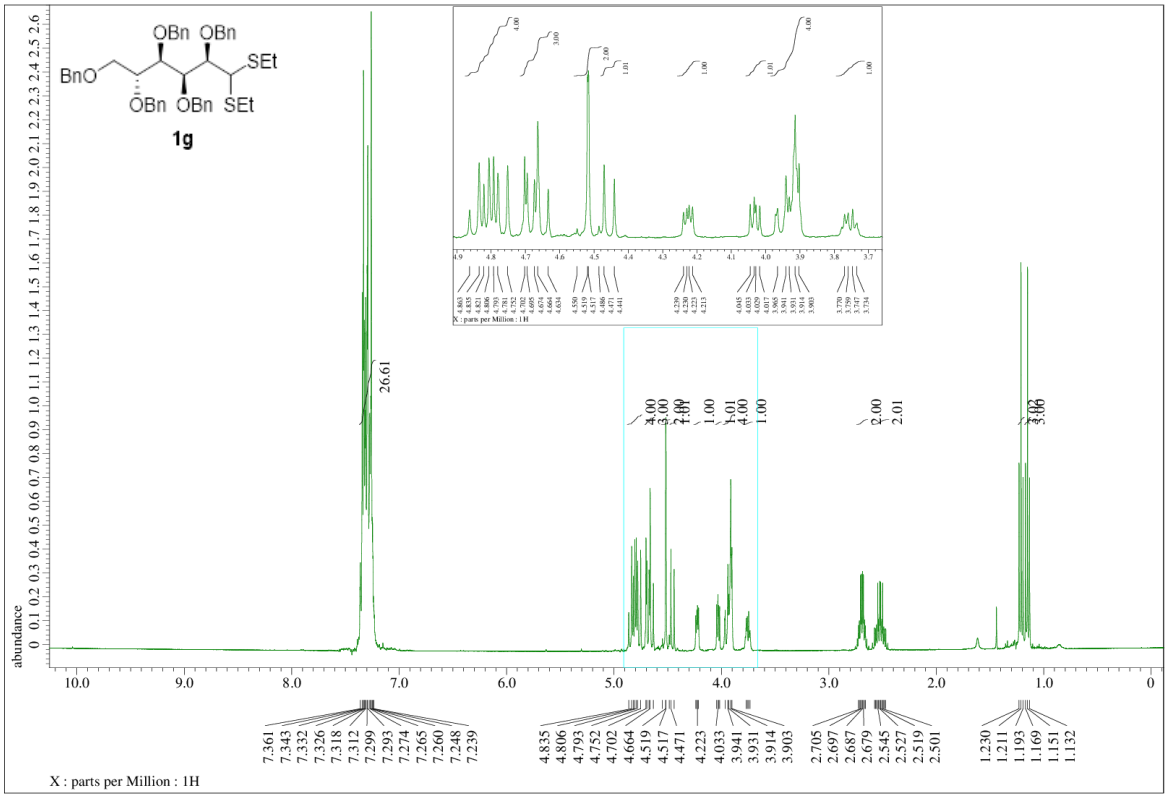
^{1}H NMR (500 MHz, $CDCl_3$):



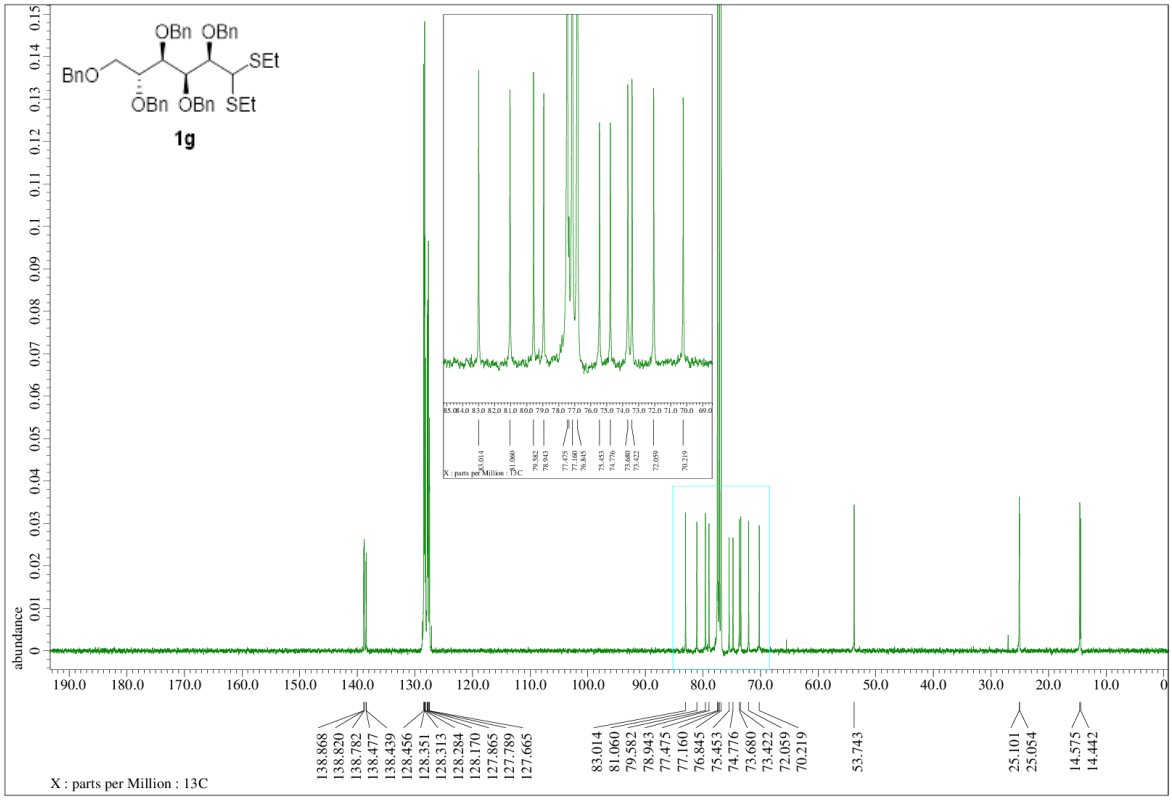
^{13}C NMR (125 MHz, $CDCl_3$):



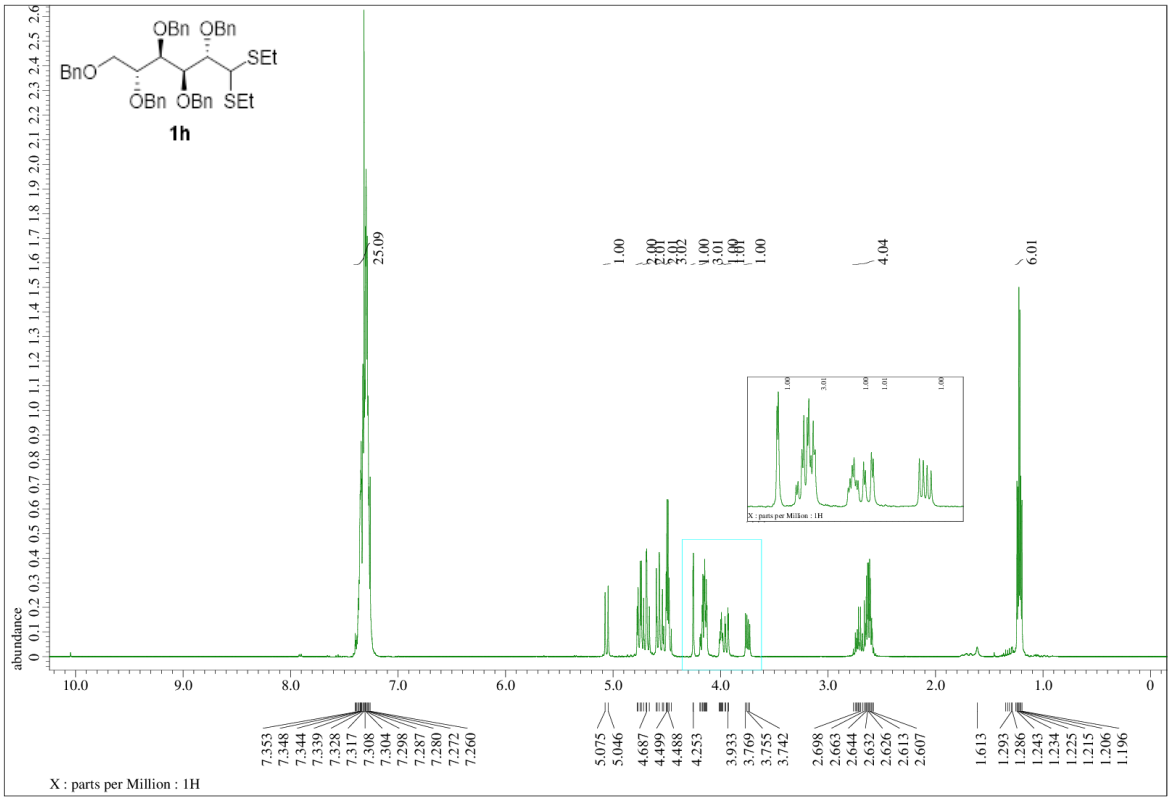
^{1}H NMR (400 MHz, $CDCl_3$):



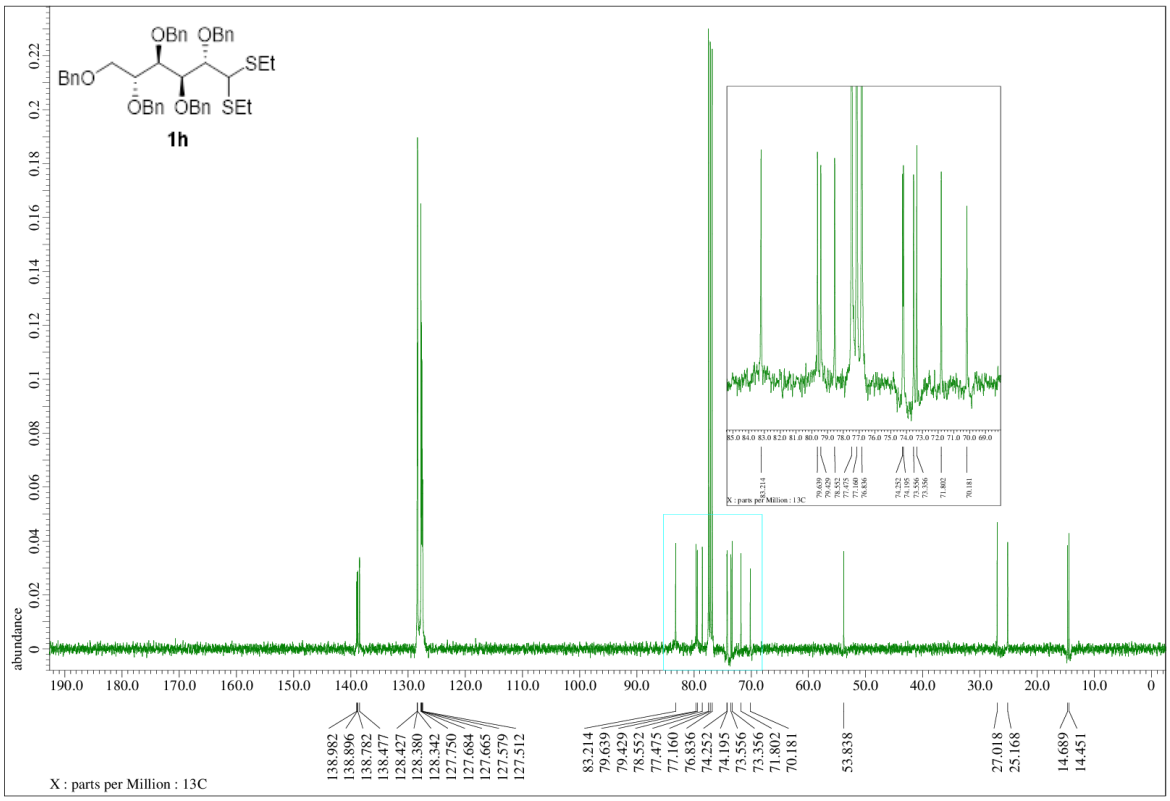
^{13}C NMR (101 MHz, $CDCl_3$):



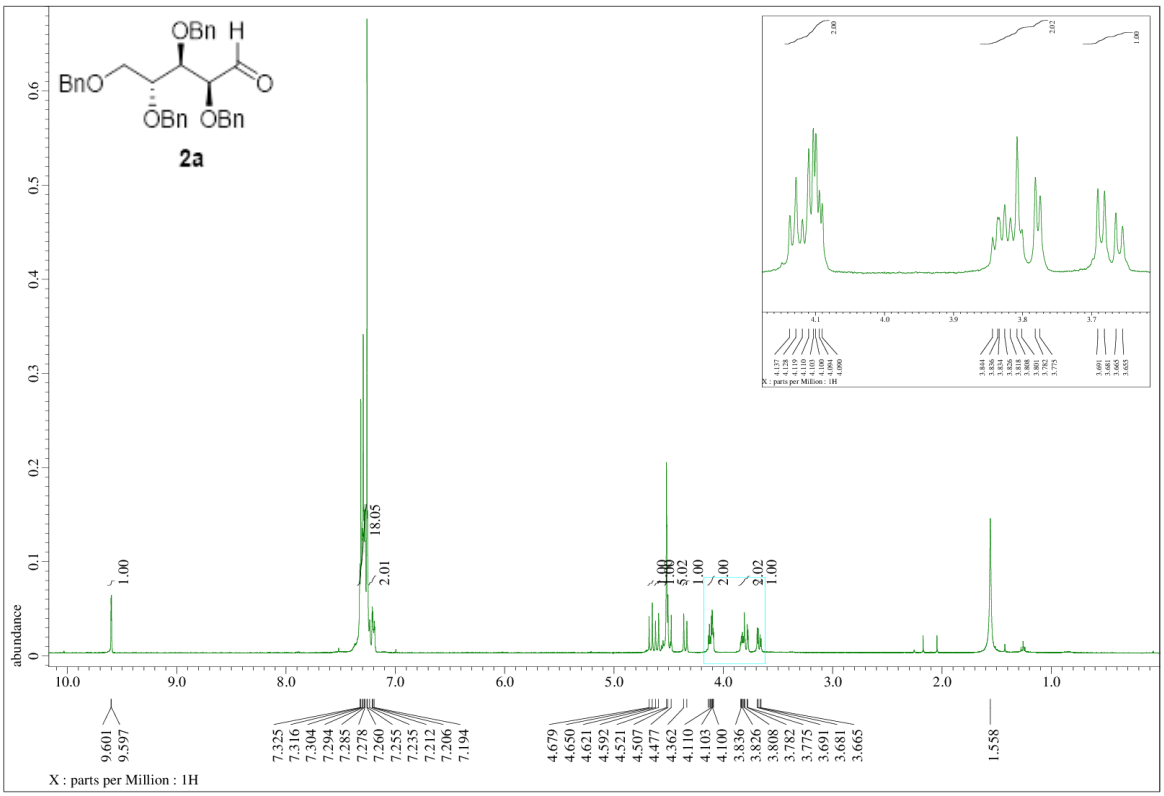
^{1}H NMR (400 MHz, $CDCl_3$):



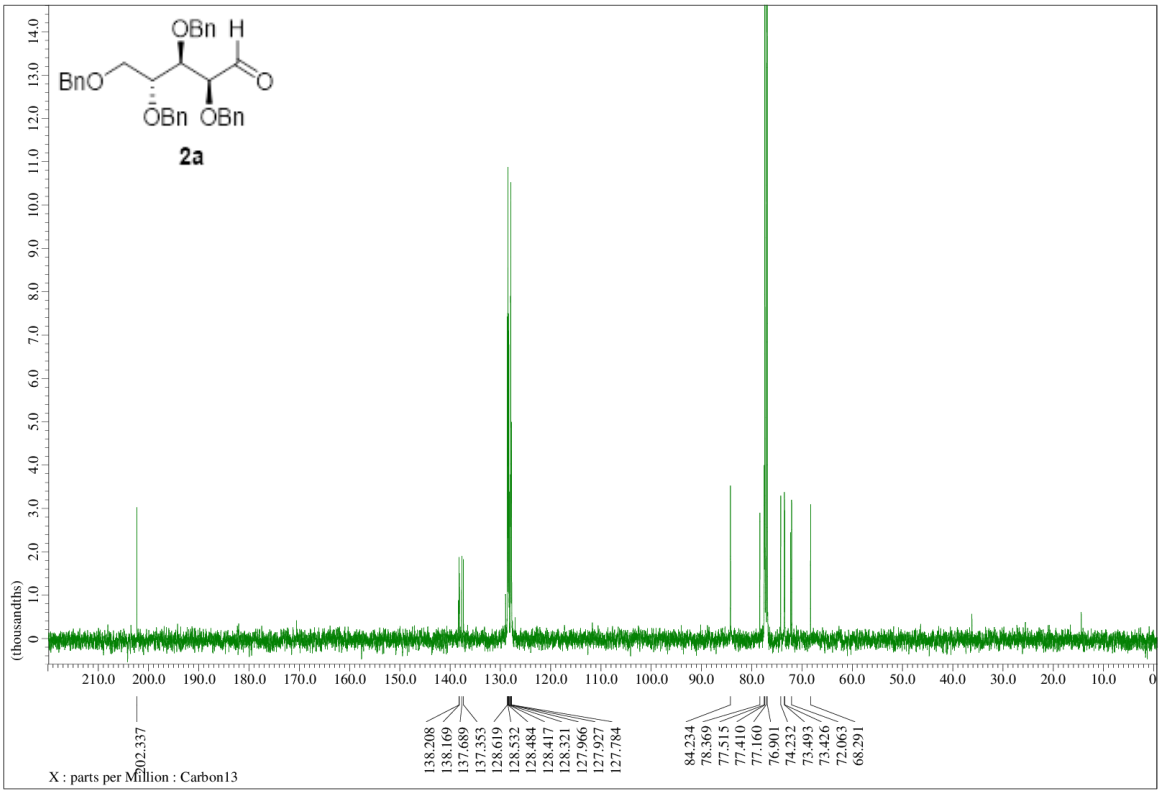
^{13}C NMR (101 MHz, $CDCl_3$):



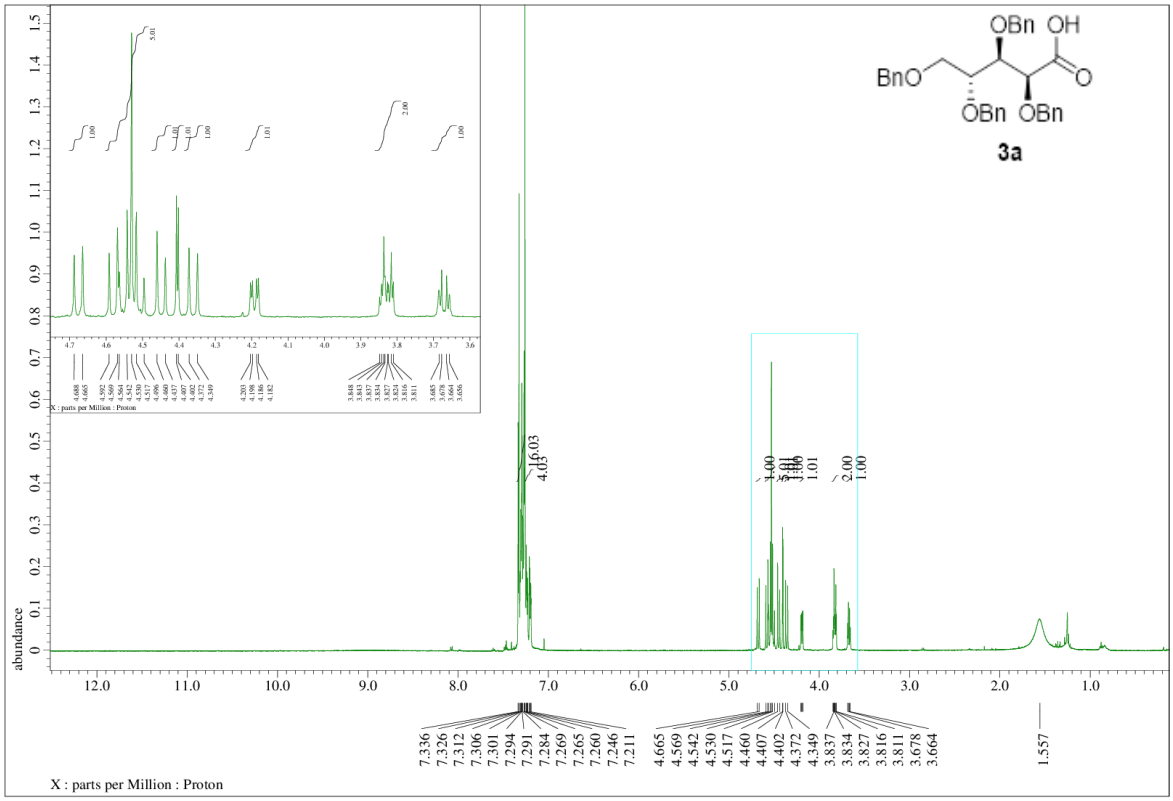
^{1}H NMR (400 MHz, $CDCl_3$):



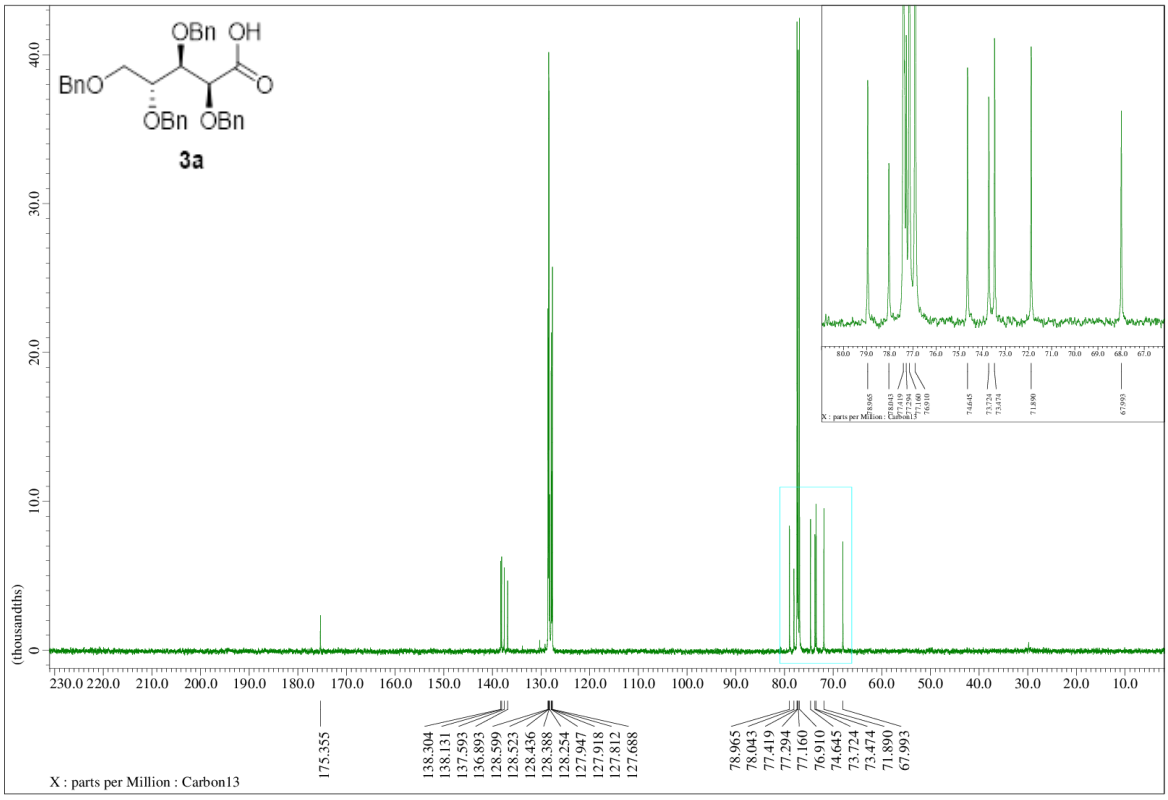
^{13}C NMR (125 MHz, $CDCl_3$):



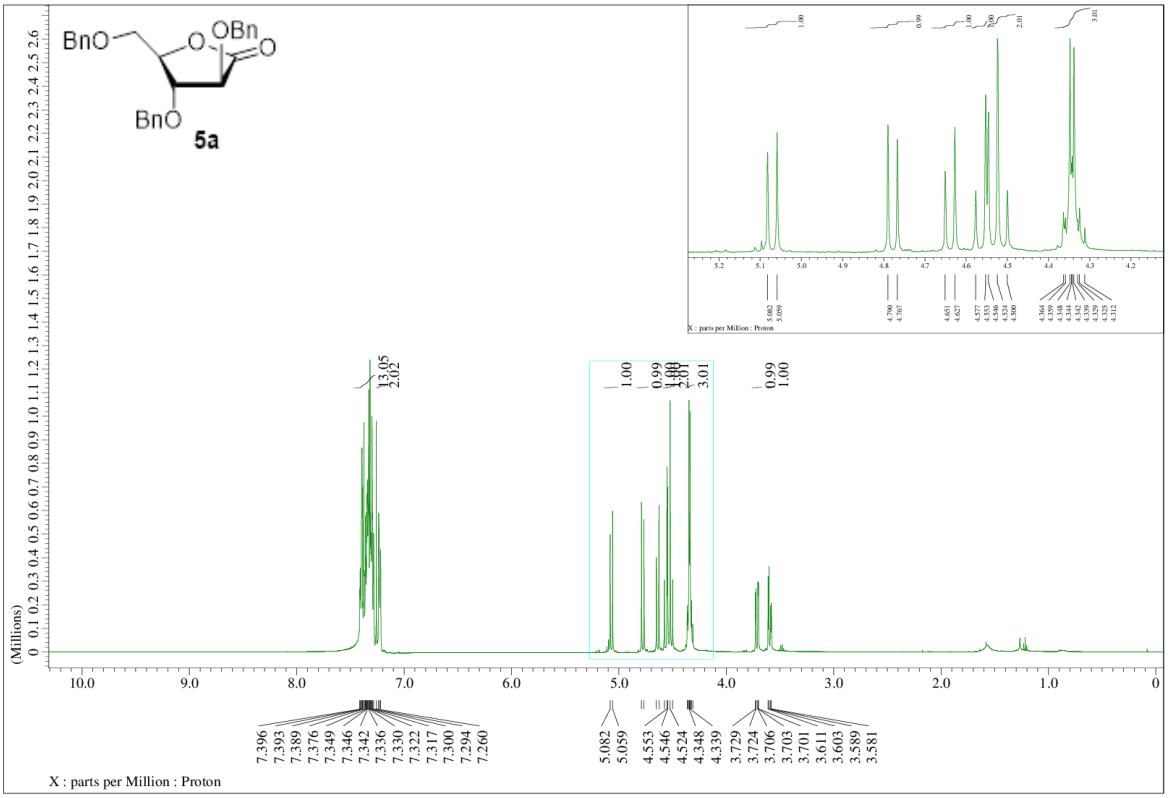
^{1}H NMR (500 MHz, $CDCl_3$):



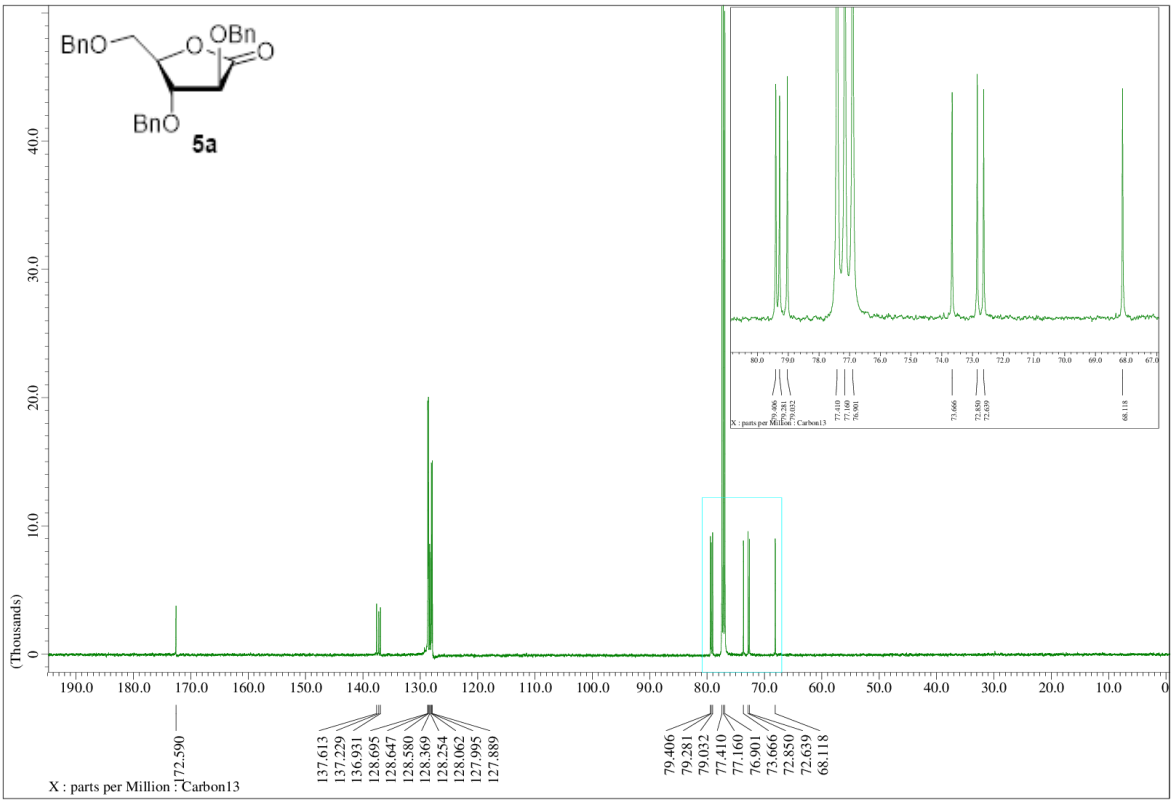
^{13}C NMR (126 MHz, $CDCl_3$):



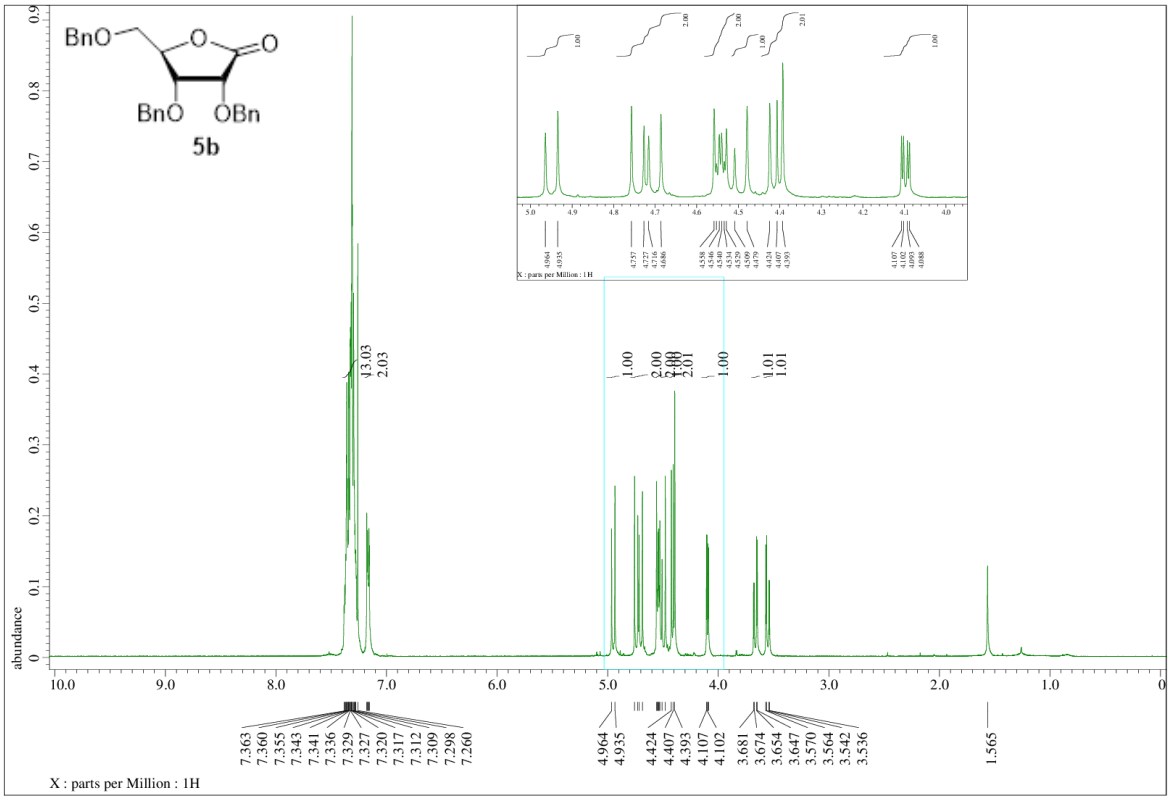
^{1}H NMR (500 MHz, $CDCl_3$):



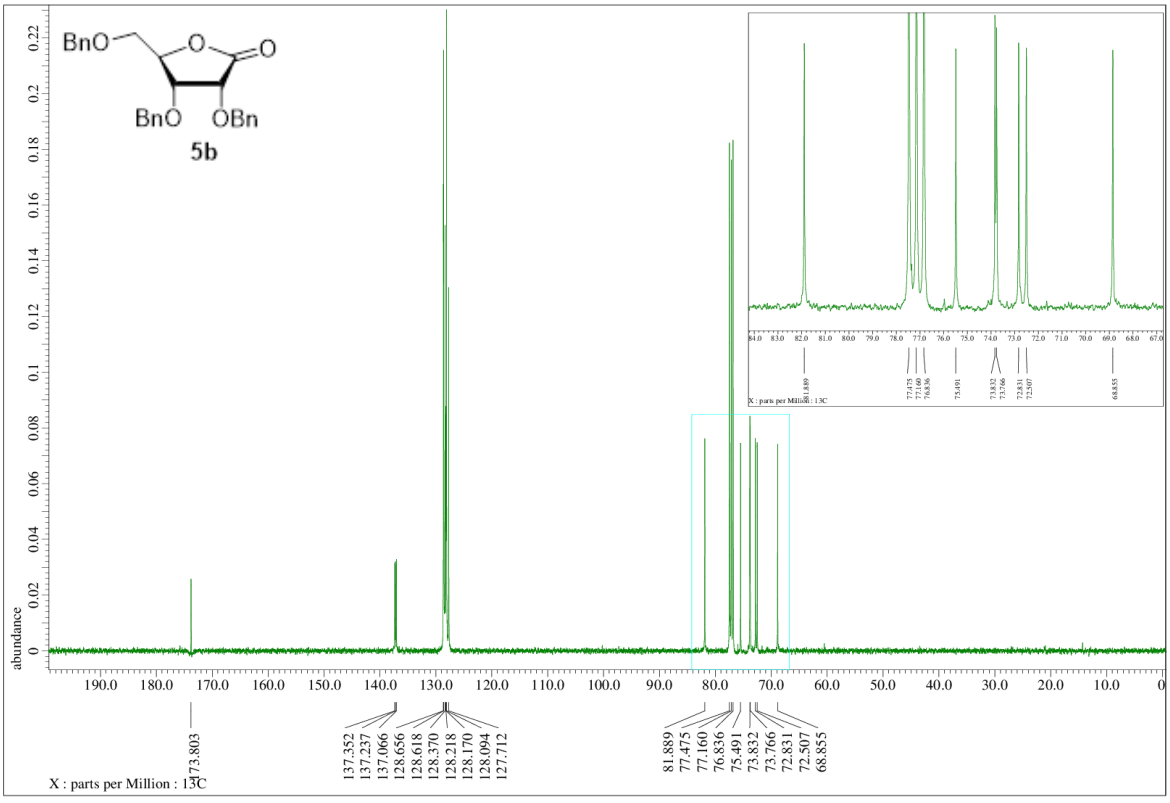
^{13}C NMR (126 MHz, $CDCl_3$):



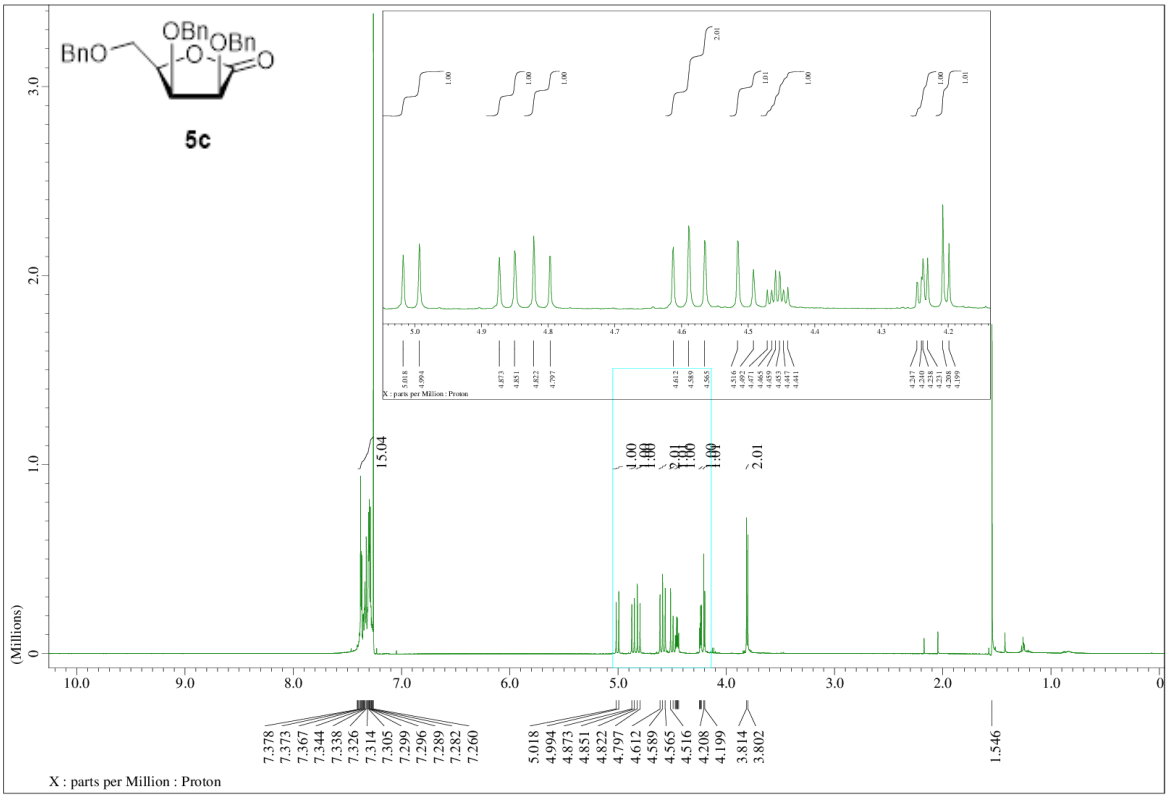
^{1}H NMR (400 MHz, $CDCl_3$):



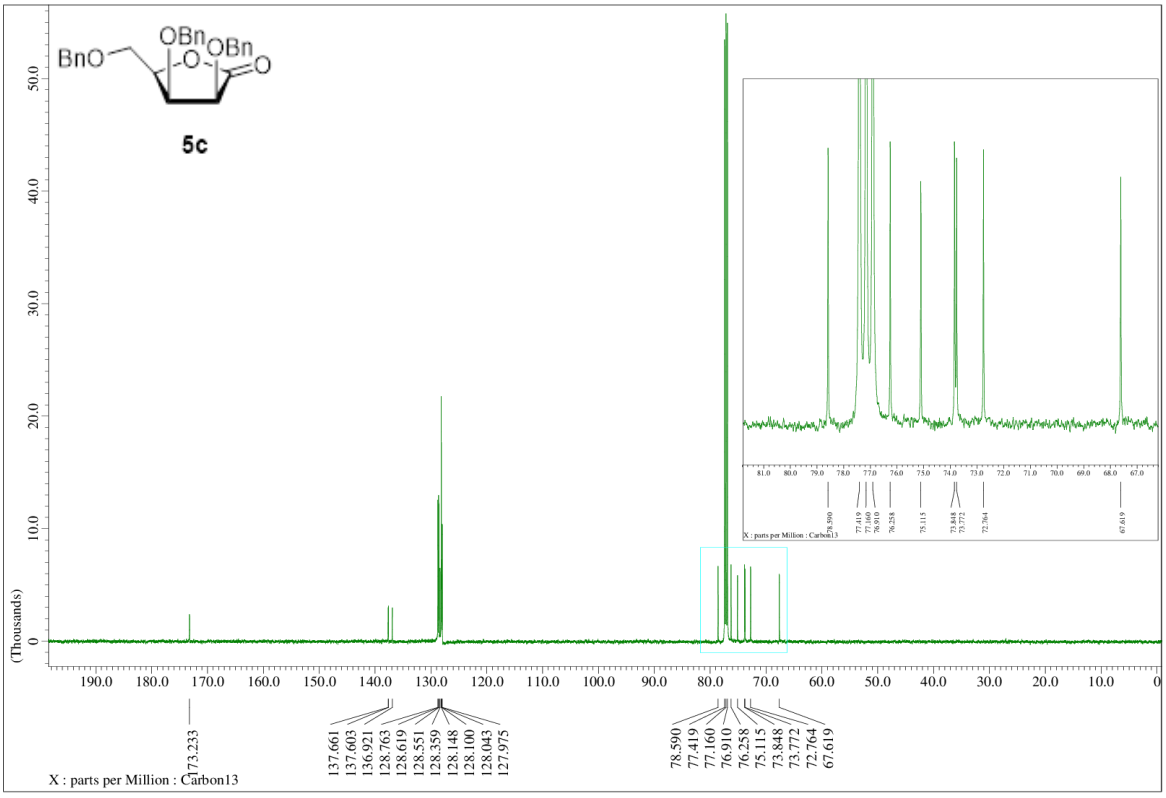
^{13}C NMR (101 MHz, $CDCl_3$):



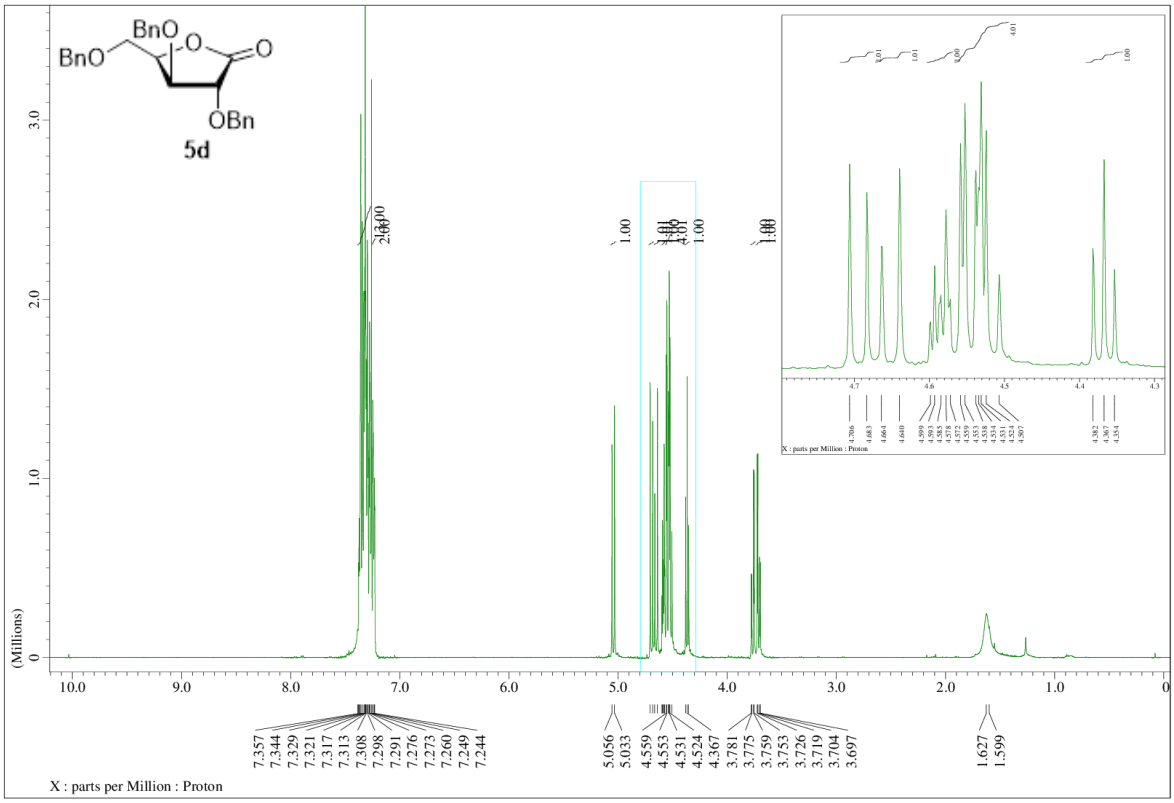
^{1}H NMR (500 MHz, $CDCl_3$):



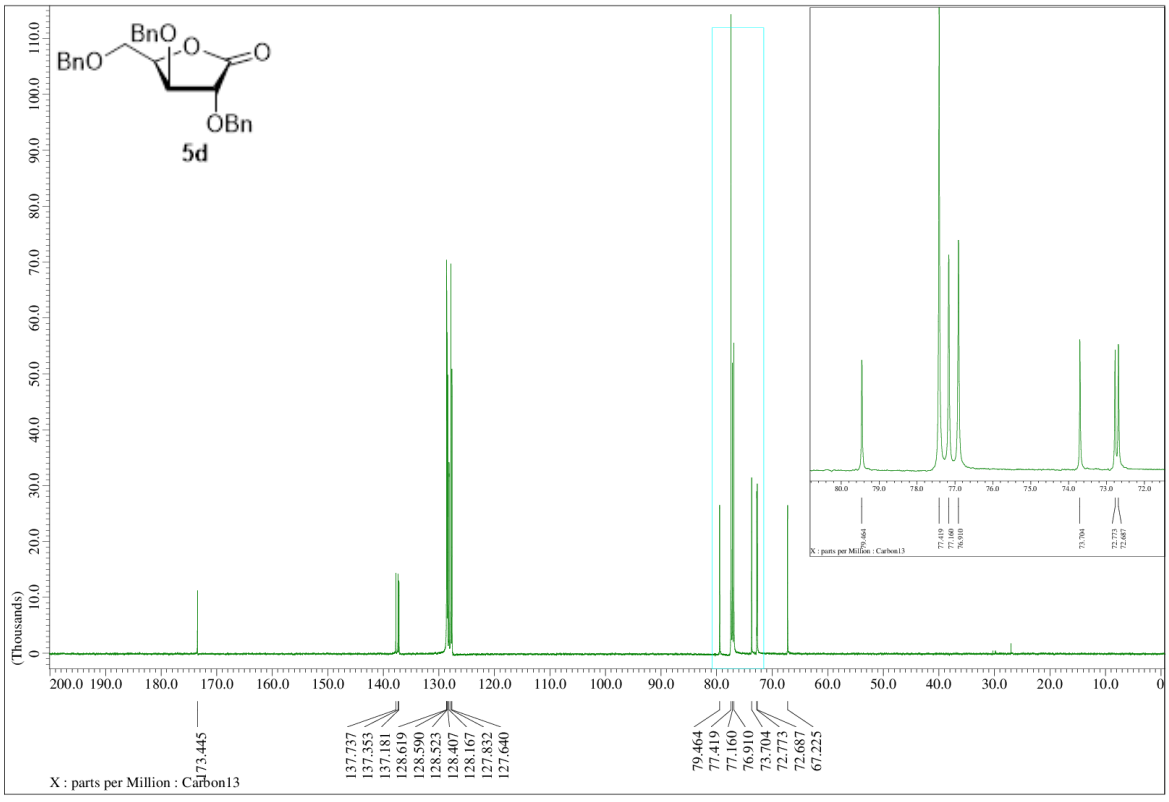
^{13}C NMR (126 MHz, $CDCl_3$):



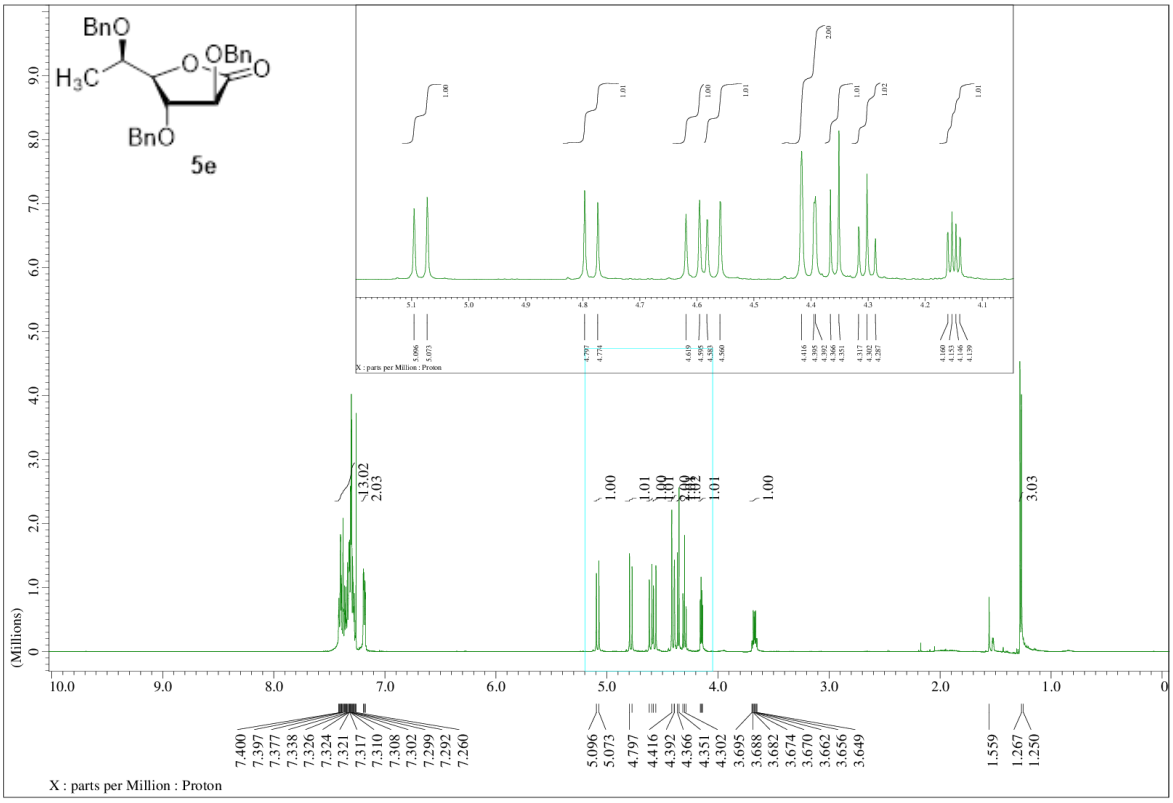
^{1}H NMR (500 MHz, $CDCl_3$):



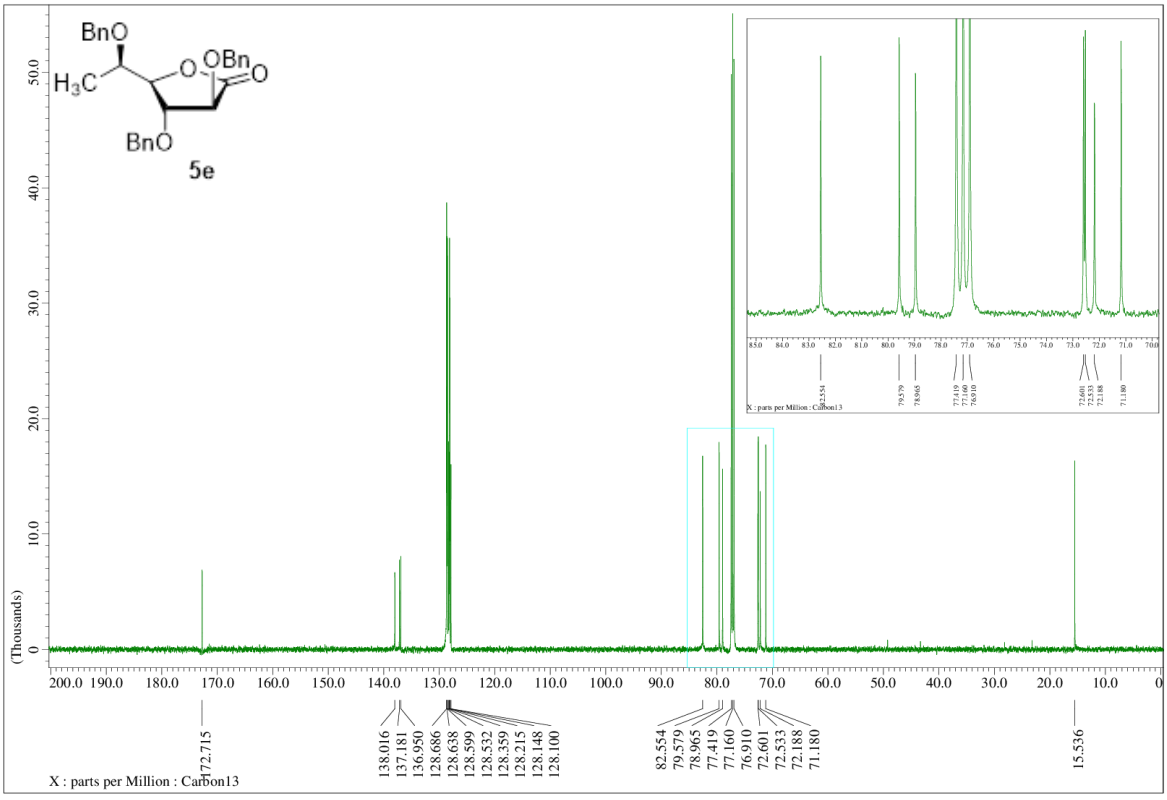
^{13}C NMR (126 MHz, $CDCl_3$):



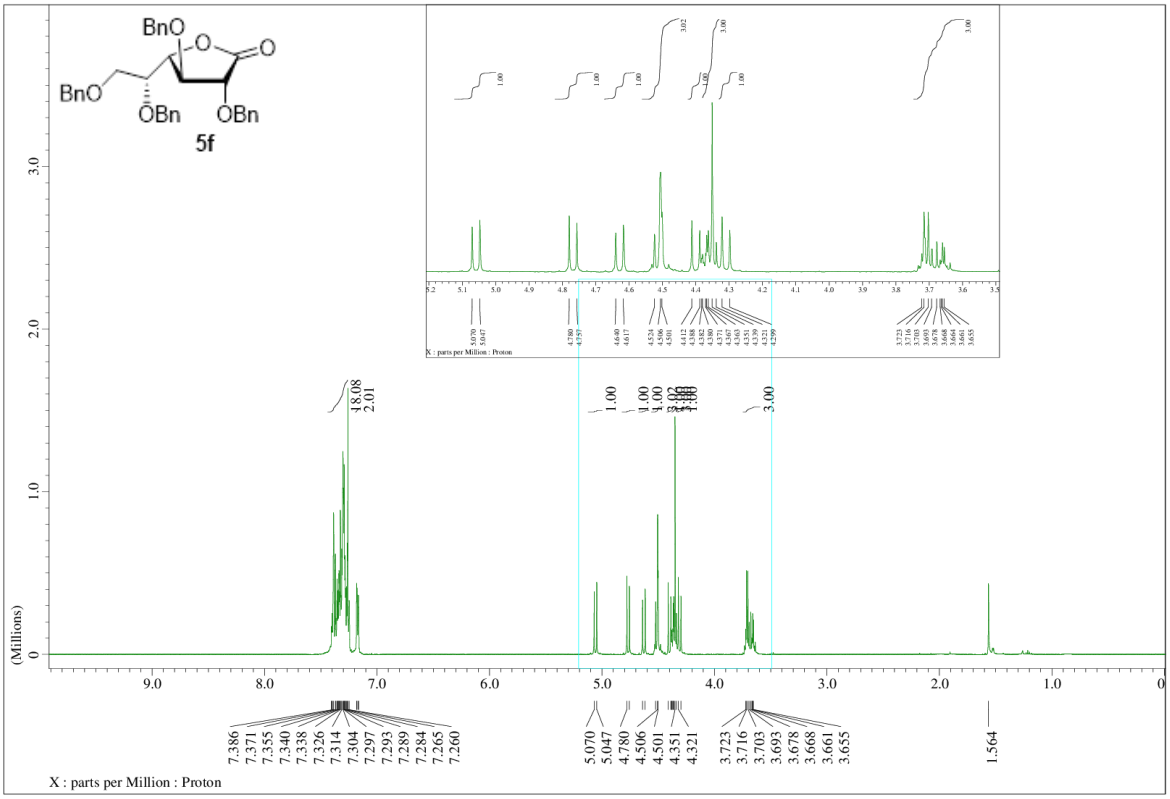
^{1}H NMR (500 MHz, $CDCl_3$):



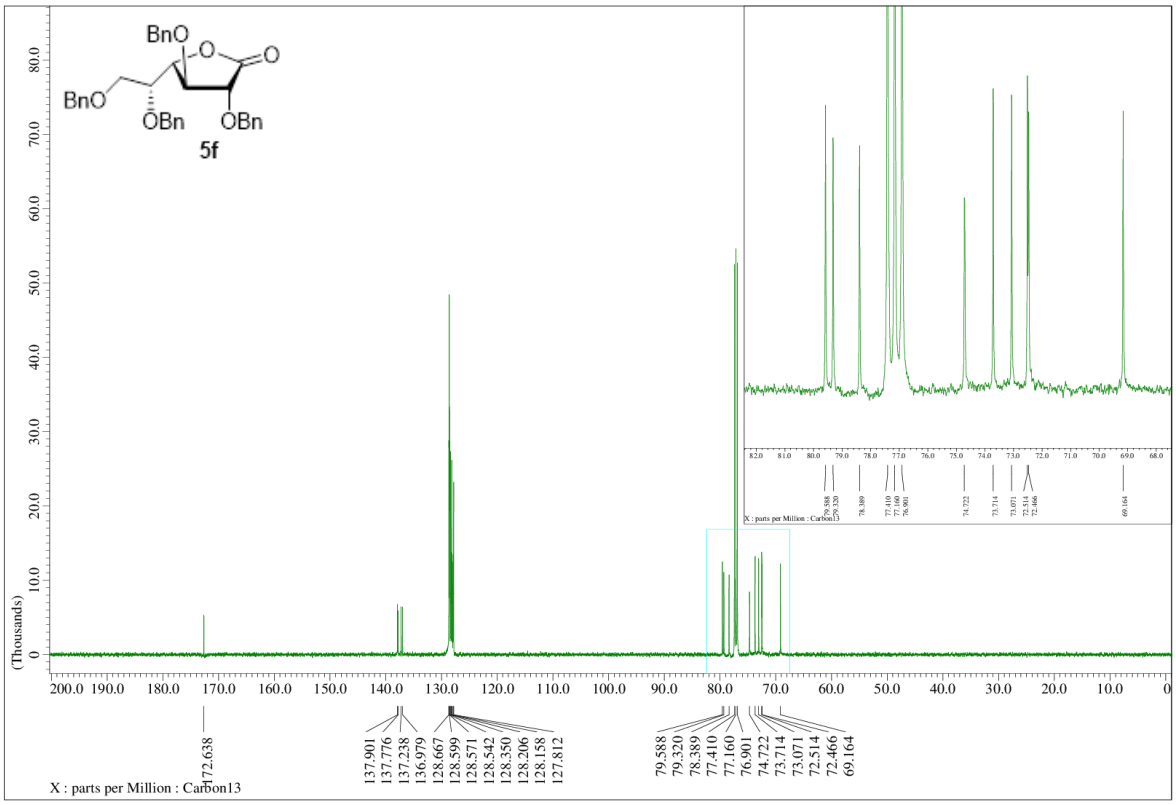
^{13}C NMR (126 MHz, $CDCl_3$):



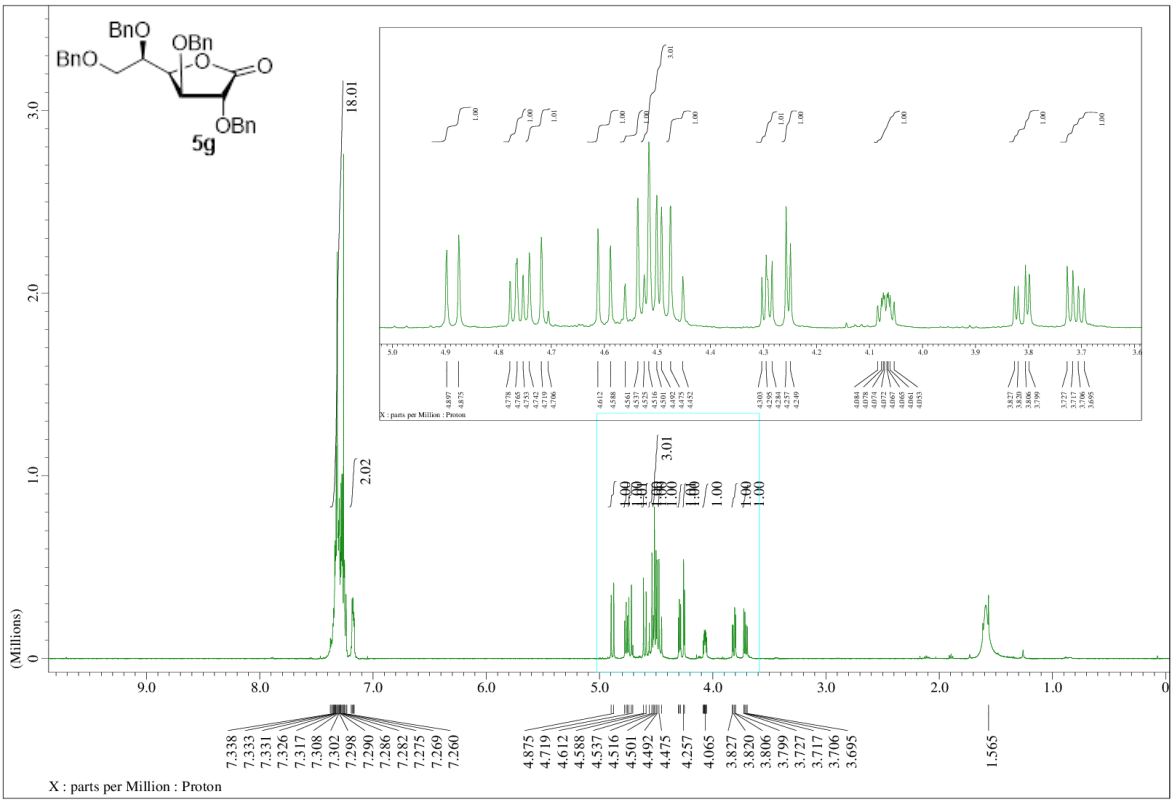
^{1}H NMR (500 MHz, $CDCl_3$):



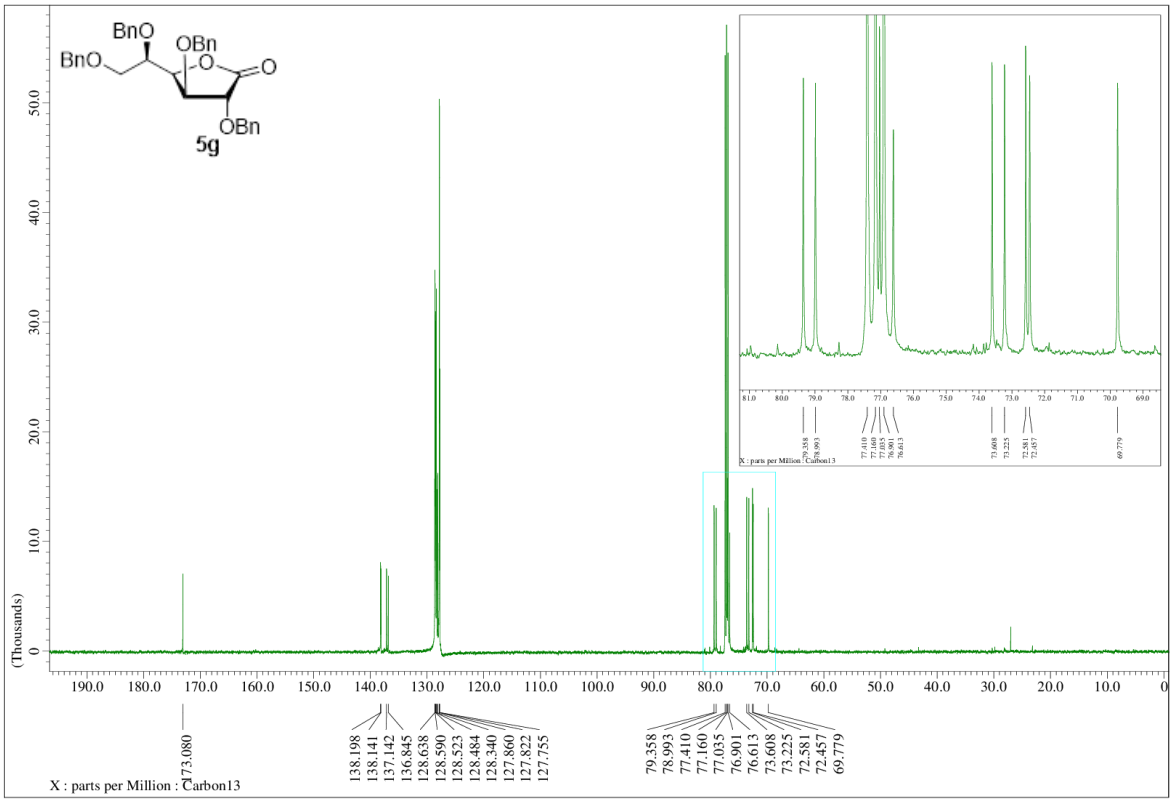
^{13}C NMR (126 MHz, $CDCl_3$):



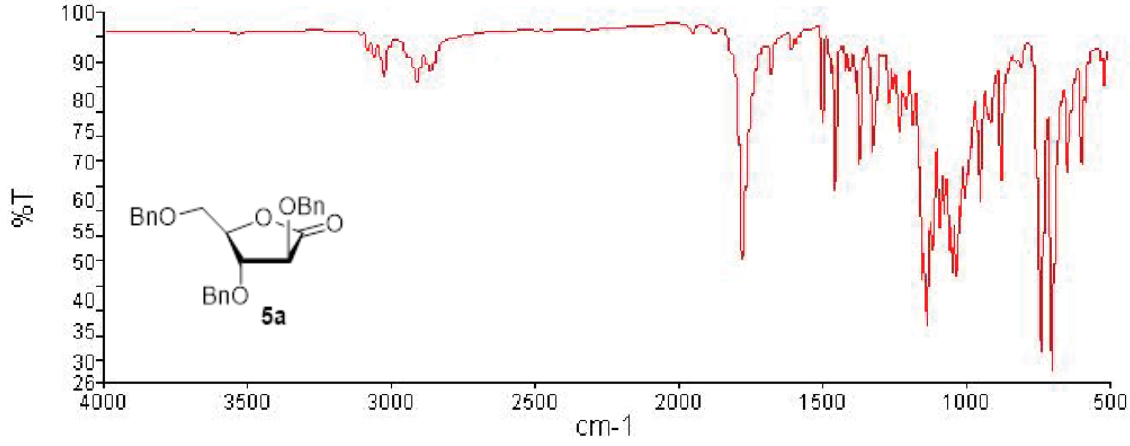
^{1}H NMR (500 MHz, $CDCl_3$):



^{13}C NMR (126 MHz, $CDCl_3$):



IR (neat):



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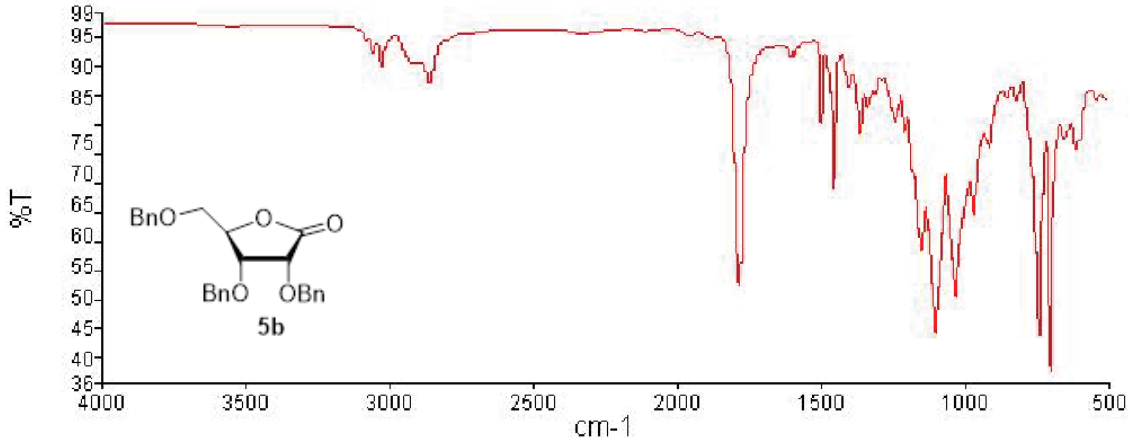

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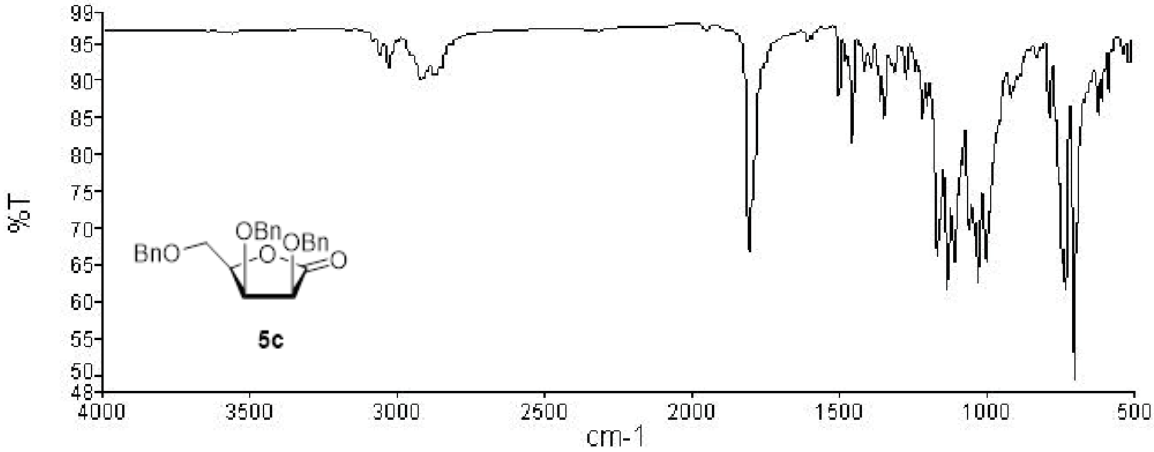

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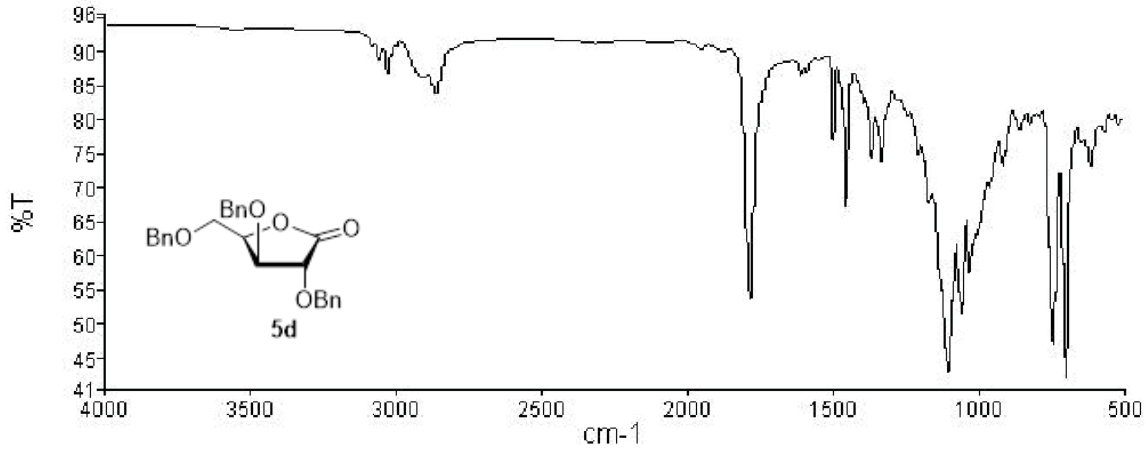

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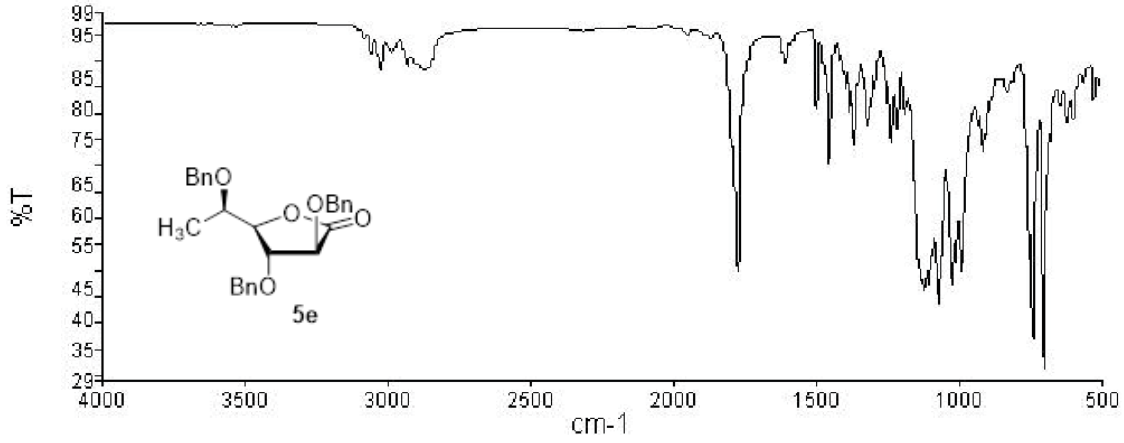

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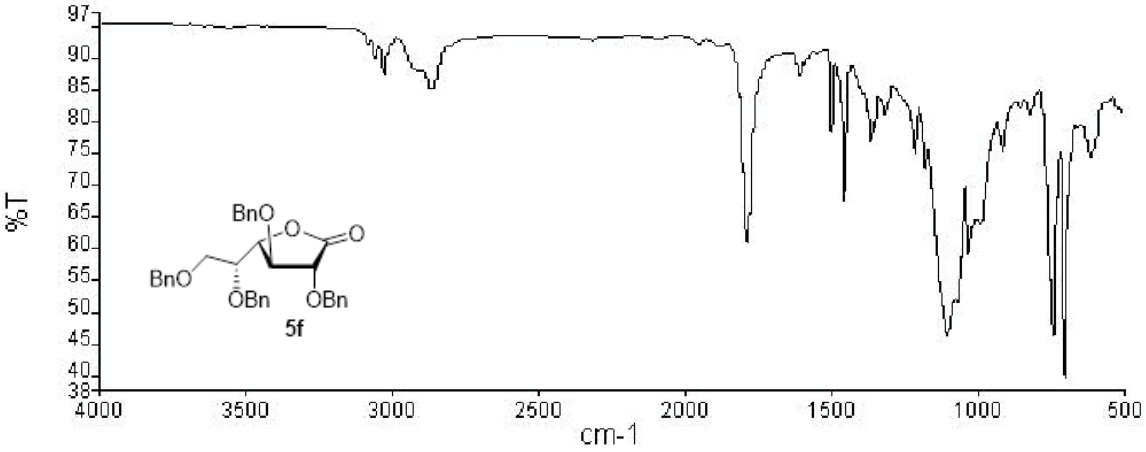

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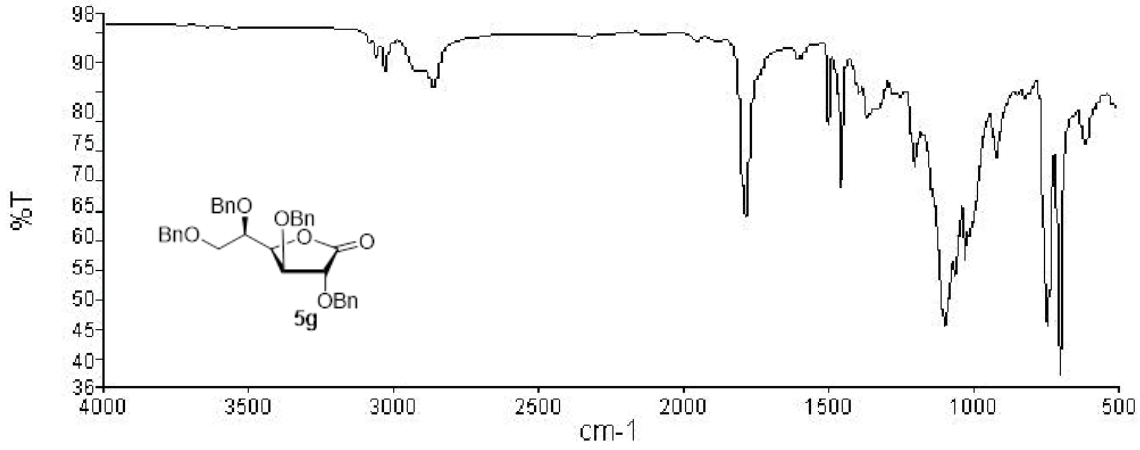

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