

Supplementary Information

Site-Selective Benzoin-type Cyclization of Unsymmetrical Dialdoses Catalyzed by N- Heterocyclic Carbene for Divergent Cyclitol Synthesis

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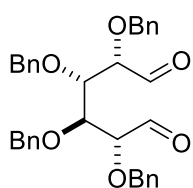
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1. General Information. Reactions were conducted under argon atmosphere and silica gel was used for column chromatography unless otherwise noted. All melting points are uncorrected. NMR (500 and 125 MHz for ^1H and ^{13}C , respectively) was measured in CDCl_3 . Chemical shifts (δ) and coupling constants (J) are presented in parts per million relative to tetramethylsilane and hertz, respectively. Abbreviations are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. ^{13}C peak multiplicity assignments were made based on DEPT. IR spectroscopy was recorded using an attenuated total reflectance FTIR, and the wave numbers of maximum absorption peaks are presented in cm^{-1} . Quadrupole, double-focusing magnetic sector, and TOF mass spectrometers were used for EI-, FAB-, and ESI-MS, respectively.

2. Materials. $(\text{COCl})_2$, Et_3N , 2,6-lutidine, TMSCl , MeOH and CH_2Cl_2 were purchased and distilled prior to use. Other starting materials, reagents and solvents were purchased and used as supplied unless a literature for the preparation is cited. Commercially available anhydrous solvents were used as reaction solvents, except for MeOH and CH_2Cl_2 . DMSO and pyridine utilized in reactions were anhydrous grade. Triazoliums **4**, **5**, *ent*-**5**, **6** and *ent*-**6** were prepared as reported.¹



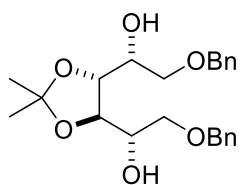
Tetra-O-benzyl-D-sorbo-hexodialdose (1a): To a stirred solution of DMSO (1.03 mL, 14.4 mmol) in CH_2Cl_2 (23 mL) cooled at $-78\text{ }^\circ\text{C}$, was added a solution of $(\text{COCl})_2$ (1.20 mL, 13.9 mmol) in CH_2Cl_2 (11 + 1.5 mL wash). After 2 min, a solution of 2,3,4,5-tetra-O-benzyl-D-sorbitol² (3.00 g, 5.53 mmol) in CH_2Cl_2 (21 + 1.5 mL wash) was added. After 1.5 h, Et_3N (3.52 mL, 25.0 mmol) was added. After 10 min, pentane (56 mL) was added, and the mixture was allowed to warm to rt by removing the cooling bath. The resulting white suspension was filtered through a pad of Na_2SO_4 , which was washed with a 1:1 mixture of pentane and EtOAc (30 mL \times 3). The volume of the combined filtrate and washings was reduced by evaporation to ca. 30 mL, and the resulting suspension was further diluted with pentane (30 mL). The precipitate was removed by filtration and washed with the mixed solvent (10 mL \times 3). Concentration of the combined filtrate and washings gave a 53:35:3:9 mixture of **1a**, EtOAc , toluene and DMSO (3.50 g, containing 2.98 g of **1a**, quant) as a yellow oil: IR: 3086, 3063, 3032, 2932, 2870, 2723, 1732, 1497, 1454, 1396, 1377, 1350, 1331, 1312, 1250, 1211, 1119, 1084, 1072, 1026, 914, 849, 795, 752. ^1H NMR: 3.96 (dd, $J = 5.5, 4.5$, 1H), 3.99 (dd, $J = 4.5, 2.0$, 1H), 4.06 (d, $J = 5.5$, 1H), 4.08 (t, $J = 4.5$, 1H), 4.38 (d, $J = 11.5$, 1H), 4.45 (d, $J = 11.5$, 1H), 4.49 (d, $J = 11.5$, 1H), 4.50 (d, $J = 11.0$, 1H), 4.52

1. H. U. Vora, S. P. Lathrop, N. T. Reynolds, M. S. Kerr, J. Read de Alaniz and T. Rovis, *Org. Synth.*, 2010, **87**, 350.

2. K. P. Stockton, B. W. Greatrex, D. K. Taylor, *J. Org. Chem.*, 2014, **79**, 5088.

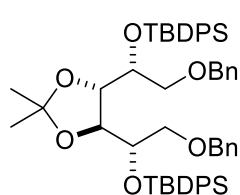
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(d, $J = 11.0$, 1H), 4.53 (d, $J = 11.5$, 1H), 4.64 (d, $J = 11.5$, 1H), 4.75 (d, $J = 11.5$, 1H), 7.17–7.19 (m, 2H), 7.23–7.25 (m, 2H), 7.27–7.36 (m, 16H), 9.67 (d, $J = 2.0$, 1H), 9.69 (s, 1H). ^{13}C NMR: 72.7 (CH₂), 73.0 (CH₂), 73.7 (CH₂), 74.1 (CH₂), 78.7 (CH), 79.5 (CH), 81.5 (CH), 83.4 (CH), 127.9 (CH), 128.0 (CH), 128.07 (CH), 128.10 (CH), 128.31 (CH), 128.34 (CH), 128.4 (CH), 128.45 (CH), 128.48 (CH), 136.91 (C), 136.94 (C), 137.0 (C), 137.1 (C), 199.9 (CH), 200.9 (CH). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₃₄H₃₄NaO₆, 561.2248; found, 561.2247. IR, and ^1H and ^{13}C NMR were in good agreement with those reported.² The mixture was used as **1a** (85% w/w) in the reactions in Table 1.



1,6-Di-O-benzyl-3,4-O-isopropylidene-D-sorbitol (S1): In a flask equipped with a Dean–Stark apparatus, a suspension of 3,4-*O*-isopropylidene-D-sorbitol³ (500 mg, 2.25 mmol) and dibutyltin oxide⁴ (1.2 g, 4.7 mmol) in toluene (23 mL) was heated under reflux for 6 h. Volatile materials were removed by evaporation,

and the residue was dissolved in toluene (11 mL). To the solution, were added benzyl bromide (1.1 mL, 9.0 mmol) and tetrabutylammonium iodide (805 mg, 2.25 mmol), and the mixture was stirred at 70 °C for 22 h. The mixture was concentrated *in vacuo*, and subsequent chromatography of the resulting residue (hexane/EtOAc 5:2) afforded the title compound (652 mg, 71%) as a colorless oil: $[\alpha]_D^{20} + 6.92$ (c 1.48, CHCl₃). IR: 3445, 3086, 3063, 3028, 2986, 2916, 2866, 1497, 1454, 1369, 1315, 1250, 1215, 1165, 1072, 1030, 953, 880, 814, 737. ^1H NMR: 1.37 (s, 3H), 1.40 (s, 3H), 2.60 (br s, 1H), 2.73 (br s, 1H), 3.56 (dd, $J = 10.0$, 6.5, 1H), 3.59 (d, $J = 6.0$, 2H), 3.71 (dd, $J = 10.0$, 3.0, 1H), 3.78–3.85 (br m, 1H), 3.95–4.00 (br m, 1H), 4.05 (t, $J = 7.5$, 1H), 4.10 (dd, $J = 7.5$, 3.0, 1H), 4.54 (d, $J = 12.0$, 1H), 4.56 (s, 2H), 4.58 (d, $J = 12.0$, 1H), 7.26–7.37 (m, 10H). ^{13}C NMR: 26.8 (CH₃), 27.1 (CH₃), 69.2 (CH), 71.5 (CH₂), 71.8 (CH₂), 72.0 (CH), 73.3 (CH₂), 73.4 (CH₂), 76.1 (CH), 79.9 (CH), 109.3 (C), 127.6 (CH), 127.68 (CH), 127.70 (CH), 127.72 (CH), 128.3 (CH), 128.4 (CH), 137.7 (C), 137.9 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₂₃H₃₀NaO₆, 425.1935; found, 425.1935.



1,6-Di-O-Benzyl-2,5-bis-O-tert-butylidiphenylsilyl-3,4-O-isopropylidene-D-sorbitol (S2): To stirred a solution of **S1** (6.30 g, 15.7 mmol) and imidazole (6.40 g, 94.2 mmol) in DMF (35 mL), was added *tert*-butylchlorodiphenylsilane (12.2 mL, 47.0 mmol). After 24 h, water (200 mL) was added and the whole was

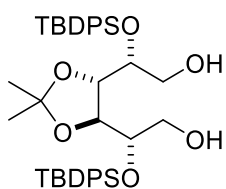
extracted with a 4:1 mixture of hexane and EtOAc (200 mL × 2). The combined organic layers were washed with water and brine (400 mL each), dried over Na₂SO₄ and evaporated. The residue was purified by column chromatography (hexane to hexane/EtOAc 97:3) to yield the title compound (12.4

3. O. Amber, C. Pavlik, M. A. Invernale, I. D. Berghorn, G. A. Sotzing, M. D. Morton and M. B. Smith, *Carbohydr. Res.*, 2011, **346**, 1662.

4. Y. Le Merrer, L. Gauzy, C. Gravier-Pelletier and J.-C. Depezay, *Bioorg. Med. Chem.*, 2000, **8**, 307.

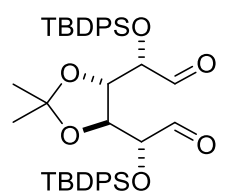
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g, 90%) as a colorless oil: $[\alpha]_D^{20} + 6.8$ (c 1.2, CHCl_3). IR: 3071, 3048, 3032, 2959, 2932, 2893, 2859, 1470, 1458, 1427, 1377, 1366, 1250, 1215, 1142, 1111, 1026, 1007, 968, 937, 914, 880, 822, 741, 702. ^1H NMR: 0.92 (s, 9H), 1.00 (s, 9H), 1.30 (s, 3H), 1.49 (s, 3H), 3.29 (dd, $J = 9.5, 6.0$, 1H), 3.38 (dd, $J = 10.0, 4.5$, 1H), 3.41 (dd, $J = 10.0, 4.0$, 1H), 3.46 (dd, $J = 9.5, 6.0$, 1H), 3.95 (d, $J = 12.0$, 1H), 3.96–4.00 (m, 3H), 4.07 (d, $J = 12.0$, 1H), 4.10 (d, $J = 12.0$, 1H), 4.36 (dd, $J = 6.5, 2.5$, 1H), 4.51 (t, $J = 6.5$, 1H), 6.91–6.94 (m, 2H), 7.04–7.07 (m, 2H), 7.15–7.41 (m, 18H), 7.62–7.69 (m, 8H). ^{13}C NMR: 19.4 (C), 19.5 (C), 27.00 (CH_3), 27.04 (CH_3), 27.3 (CH_3), 27.8 (CH_3), 71.4 (CH_2), 71.6 (CH_2), 72.53 (CH), 72.54 (CH_2), 72.6 (CH_2), 73.9 (CH), 77.2 (CH), 79.2 (CH), 109.5 (C), 127.1 (CH), 127.2 (CH), 127.3 (CH), 127.4 (CH), 127.45 (CH), 127.48 (CH), 127.9 (CH), 128.0 (CH), 129.2 (CH), 129.4 (CH), 129.48 (CH), 129.52 (CH), 133.2 (C), 133.3 (C), 134.3 (C), 135.0 (C), 135.7 (CH), 135.8 (CH), 136.0 (CH), 138.2 (C), 138.4 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{55}\text{H}_{66}\text{NaO}_6\text{Si}_2$, 901.4290; found, 901.4290.



2,5-Bis-*O*-tert-butylidiphenylsilyl-3,4-*O*-isopropylidene-D-sorbitol (S3): A mixture of **S2** (23.1 g, 26.3 mmol), NBS (13.1 g, 73.6 mmol), CaCO_3 (23.2 g, 231 mmol), water (50 mL) and CCl_4 (450 mL) was stirred under the irradiation of a visible light lamp for 24 h at 20–25 °C in a water bath.⁵ The whole was shaken

with a 4:1 mixture of hexane/EtOAc (450 mL) in a separating funnel, and the organic layer was separated and passed through a silica gel pad (600 g), which was eluted with a 4:1 mixture of hexane/EtOAc (5.5 L). The combined elute was evaporated, and the residue was purified by column chromatography (hexane to hexane/EtOAc 5:1) to give the title compound (13.0 g, 71%) as a colorless oil: ^1H NMR: 0.98 (s, 9H), 1.09 (s, 9H), 1.23 (s, 3H), 1.45 (s, 3H), 1.84 (dd, $J = 6.5, 5.5$, 1H), 1.91 (dd, $J = 7.0, 5.5$, 1H), 3.38 (m, 1H), 3.43 (m, 1H), 3.55–3.59 (m, 2H), 3.78 (m, 1H), 3.80 (m, 1H), 4.14 (dd, $J = 6.5, 2.5$, 1H), 4.31 (t, $J = 6.5$, 1H), 7.14–7.19 (m, 2H), 7.24–7.45 (m, 10H), 7.60 (d, $J = 7.5$, 2H), 7.63 (d, $J = 7.5$, 2H), 7.70 (d, $J = 7.5$, 2H), 7.73 (d, $J = 7.5$, 2H). ^1H NMR was in good agreement with that reported.⁶



2,5-Bis-*O*-tert-butylidiphenylsilyl-3,4-*O*-isopropylidene-D-sorbo-hexodialdose (1b): To a stirred solution of DMSO (0.62 mL, 8.8 mmol) in CH_2Cl_2 (13.5 mL) cooled at –78 °C, was added a solution of $(\text{COCl})_2$ (0.72 mL, 9.3 mmol) in CH_2Cl_2 (8.0 + 2.0 mL wash). After 2 min, a solution of **S3** (2.34 g, 3.37 mmol) in

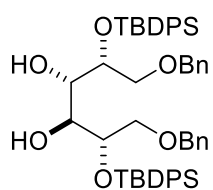
CH_2Cl_2 (11 + 2.5 mL wash) was added. After 1.5 h, Et_3N (0.80 mL, 5.6 mmol) was added. After 10 min, pentane (70 mL) was added, and the mixture was allowed to warm to rt by removing the cooling

5. R. M. Giuliano and F. J. Villani, Jr., *J. Org. Chem.*, 1995, **60**, 202.

6. J. L. Chiara and N. Valle, N., *Tetrahedron: Asymmetry*, 1995, **6**, 1895.

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bath. The resulting suspension was filtered through a pad of Na₂SO₄, which was washed with a 1:1 mixture of pentane and EtOAc (50 mL × 3). The volume of the combined filtrate and washings was reduced by evaporation to ca. 10 mL, and the resulting suspension was further diluted with pentane (20 mL). The precipitate was removed by filtration and washed with the mixed solvent (20 mL × 3). Concentration of the combined filtrate and washings gave a 45:10:45 mixture of **1b**, DMSO and EtOAc (2.72 g, containing 2.34 g of **1b**, quant) as a pale yellow oil: IR: 3071, 3051, 3017, 2986, 2959, 2932, 2959, 2897, 1736, 1489, 1474, 1381, 1323, 1258, 1238, 1219, 1188, 1146, 1111, 1084, 1030, 999, 937, 895, 868, 822, 756, 745. ¹H NMR: 1.06 (s, 9H), 1.09 (s, 9H), 1.31 (s, 3H), 1.45 (s, 3H), 4.09 (dd, *J* = 2.0, 0.5, 1H), 4.33 (dd, 4.5, 1.0, 1H), 4.41 (dd, *J* = 8.0, 2.0, 1H), 4.46 (dd, *J* = 8.0, 4.5, 1H), 7.31–7.46 (m, 12H), 7.58–7.68 (m, 8H), 9.34 (d, *J* = 0.5, 1H), 9.40 (d, *J* = 1.0, 1H). ¹³C NMR: 19.3 (C), 19.4 (C), 26.76 (CH₃), 26.80 (CH₃), 26.86 (CH₃), 26.91 (CH₃), 76.8 (CH), 77.6 (CH), 78.12 (CH), 78.14 (CH), 110.4 (CH), 127.7 (CH), 127.80 (CH), 127.84 (CH), 129.9 (CH), 130.09 (CH), 130.14 (CH), 130.2 (C), 132.0 (C), 132.1 (C), 132.4 (C), 132.9 (CH), 135.7 (CH), 135.76 (CH), 135.81 (CH), 135.84 (CH), 201.00 (CH), 201.04 (CH). HRMS–ESI *m/z*: [M + Na]⁺ calcd for C₄₁H₅₀NaO₆Si₂, 717.3038; found, 717.3035. The mixture was used as **1b** (86% w/w) in the reactions in Table 2.



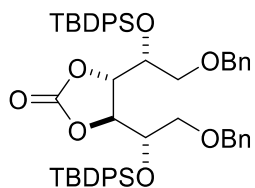
1,6-Di-O-benzyl-2,5-di-O-tert-butyldiphenylsilyl-D-sorbitol (S4): To a stirred solution of **S2** (15.1 g, 17.2 mmol) in CHCl₃ (150 mL), were added silica gel (50 g) and 10% aq. oxalic acid (5 mL), and the suspension was heated at 60 °C.⁷ After 2 d, silica gel (50 g), 10% aq. oxalic acid (5 mL) and CHCl₃ (150 mL) were added.

After 2 d, another portion of silica gel (50 g), 10% aq. oxalic acid (5 mL) and CHCl₃ (150 mL) was added. After additional 2 d, the silica gel was removed by filtration through a glass filter and successively washed with CHCl₃ (1 L). The combined filtrate was evaporated, and the residue was purified by column chromatography (hexane/EtOAc 19:1) to yield the title compound (12.0 g, quant) as a colorless oil: [α]_D²⁰ –6.01 (*c* 1.77, CHCl₃). IR: 3510, 3410, 3071, 3051, 3013, 2959, 2932, 2893, 2859, 1470, 1454, 1427, 1389, 1362, 1261, 1215, 1111, 1026, 1007, 937, 910, 822, 756, 702. ¹H NMR: 1.02 (s, 9H), 1.03 (s, 9H), 2.94 (d, *J* = 5.5, 1H), 3.84–3.48 (m, 5H), 3.93–3.96 (m, 1H), 4.02 (dd, *J* = 9.0, 4.5, 1H), 4.07 (t, *J* = 5.5, 1H), 4.11 (t, *J* = 6.0, 1H), 4.13 (d, *J* = 12.0, 1H), 4.14 (d, *J* = 12.0, 1H), 4.18 (d, *J* = 12.0, 1H), 4.25 (d, *J* = 12.0, 1H), 7.06–7.10 (m, 4H), 7.22–7.24 (m, 6H), 7.27–7.35 (m, 8H), 7.38–7.48 (m, 4H), 7.62–7.63 (m, 2H), 7.67–7.71 (m, 6H). ¹³C NMR: 19.4 (C), 19.5 (C), 27.0 (CH₃ × 2), 70.4 (CH), 70.6 (CH₂), 70.8 (CH), 71.4 (CH₂), 72.9 (CH₂), 73.1 (CH₂), 73.5 (CH), 74.0 (CH), 127.3 (CH), 127.37 (CH), 127.44 (CH), 127.5 (CH), 127.57 (CH), 127.60 (CH), 127.7 (CH), 128.1 (CH), 127.2 (CH), 129.4 (CH), 129.6 (CH), 129.7 (CH), 129.8 (CH), 133.0 (C), 133.1 (C), 134.1

7. F. Huet, A. Lechecallier and J. M. Conia, *Synthesis*, 1978, 63.

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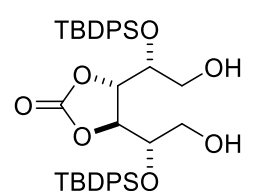
(C), 134.3 (C), 135.7 (CH), 135.8 (CH), 135.9 (CH), 136.1 (CH), 137.7 (C), 138.1 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for $C_{52}H_{62}NaO_6Si_2$, 861.3977; found, 861.3977.



1,6-Di-*O*-benzyl-2,5-bis-*O*-*tert*-butyldiphenylsilyl-3,4-*O*-carbonyl-D-sorbi-

tol (S5): To a stirred solution of S4 (11.6 g, 13.8 mmol) in CH_2Cl_2 (70 mL), was added carbonyldiimidazole (5.59 g, 34.5 mmol). After 20 h, water (70 mL) was added, and the whole was extracted with $CHCl_3$ (70 mL \times 2). The combined

organic layers were washed with brine (210 mL), dried over Na_2SO_4 and evaporated. The residue was purified by column chromatography (hexane/EtOAc 10:1 to 9:1) to yield the title compound (1.90 g, quant) as a colorless oil: $[\alpha]_D^{20} +20.1$ (c 1.07, $CHCl_3$). IR: 3132, 3067, 3048, 3017, 2959, 2932, 2893, 2859, 2801, 2743, 2712, 1798, 1589, 1489, 1474, 1458, 1427, 1381, 1366, 1258, 1215, 1180, 1138, 1111, 1038, 1030, 999, 961, 937, 907, 822, 756, 702. 1H NMR: 1.00 (s, 9H), 1.01 (s, 9H), 3.04 (dd, $J = 10.5, 3.5, 1H$), 3.11 (dd, $J = 10.5, 4.5, 1H$), 3.41 (dd, $J = 9.5, 6.0, 1H$), 3.54 (dd, $J = 9.5, 8.0, 1H$), 3.89 (ddd, $J = 8.0, 6.0, 1.0, 1H$), 3.94 (d, $J = 11.5, 1H$), 3.99 (d, $J = 11.5, 1H$), 4.07 (ddd, $J = 4.5, 3.5, 2.5, 1H$), 4.12 (d, $J = 11.5, 1H$), 4.20 (d, $J = 11.5, 1H$), 4.70 (dd, $J = 4.5, 2.5, 1H$), 5.23 (dd, $J = 4.5, 1.0, 1H$), 6.97–6.99 (m, 2H), 7.01–7.04 (m, 2H), 7.17–7.23 (m, 6H), 7.26–7.45 (m, 12H), 7.59–7.65 (m, 8H). ^{13}C NMR: 19.2 (C), 19.4 (C), 26.7 (CH_3), 26.76 (CH_3), 69.8 (CH_2), 70.3 (CH_2), 71.6 (CH), 72.0 (CH), 73.0 (CH_2), 73.1 (CH_2), 76.8 (CH), 79.4 (CH), 127.40 (CH), 127.43 (CH), 127.5 (CH), 127.8 (CH), 127.9 (CH), 128.15 (CH), 128.22 (CH), 129.72 (CH), 129.74 (CH), 130.0 (CH), 130.1 (CH), 131.7 (C), 132.4 (C), 133.6 (C), 133.9 (C), 135.6 (CH), 135.7 (CH), 135.9 (CH), 136.0 (CH), 137.2 (C), 137.8 (C), 155.2 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for $C_{53}H_{60}NaO_7Si_2$, 887.3770; found, 877.3774.

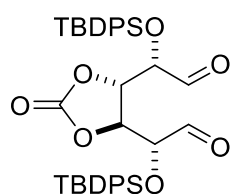


2,5-Di-*O*-*tert*-butyldiphenylsilyl-3,4-*O*-carbonyl-D-sorbitol (S6): To a solution of S5 (11.9 g, 13.8 mmol) in a 1:1 mixture of MeOH and EtOAc (100 mL), was added 20% $Pd(OH)_2/C$ (wetted with 50% water, 1.9 g, 2.8 mmol), and the mixture was stirred under a H_2 atmosphere (4 atm) at 60 °C. After 46 h, the

whole was filtered through celite (15 g), which was washed with EtOAc (100 mL \times 5). The combined filtrate and washings were evaporated, and the residue was purified by column chromatography (hexane/EtOAc 5:1 to 4:1 and then 2:1) to yield the title compound (8.67 g, 92%) as a white solid of mp 142–143 °C: $[\alpha]_D^{20} +38.7$ (c 1.12, $CHCl_3$). IR: 3472, 3071, 3051, 3017, 2959, 2932, 2893, 2859, 1794, 1589, 1474, 1427, 1339, 1362, 1308, 1261, 1215, 1184, 1130, 1111, 1084, 1053, 999, 937, 895, 822, 756, 706. 1H NMR: 1.03 (s, 9H), 1.06 (s, 9H), 1.17–1.19 (m, 1H), 1.46–1.49 (m, 1H), 3.19 (ddd, $J = 11.5, 7.0, 3.5, 1H$), 3.29 (dt, $J = 11.5, 3.5, 1H$), 3.64–3.71 (m, 2H), 3.81 (dd, $J = 6.5, 1.5, 1H$), 3.97 (q, $J = 3.5, 1H$), 4.60 (t, $J = 3.5, 1H$), 5.02 (dd, $J = 3.5, 1.5, 1H$), 7.37–7.41 (m, 8H), 7.44–7.47 (m,

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4H), 7.63–7.67 (m, 6H), 7.72–7.73 (m, 2H). ^{13}C NMR: 19.2 (C), 19.3 (C), 26.8 ($\text{CH}_3 \times 2$), 62.6 (CH_2), 62.8 (CH_2), 72.6 (CH), 73.4 (CH), 76.8 (CH), 78.8 (CH), 127.8 (CH), 127.9 (CH), 128.0 (CH), 130.06 (CH), 130.11 (CH), 130.2 (CH), 131.7 (C), 132.1 (C), 133.46 (C), 133.49 (C), 135.5 (CH), 135.6 (CH), 135.9 (CH), 136.0 (CH), 154.7 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{39}\text{H}_{48}\text{NaO}_7\text{Si}_2$, 707.2831; found, 707.2829.



2,5-Di-*O*-*tert*-butyldiphenylsilyl-3,4-*O*-carbonyl-*D*-sorbo-hexodialdose (**1d**):

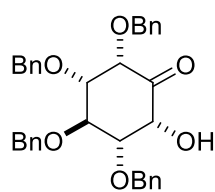
To a stirred solution of DMSO (0.19 mL, 2.7 mmol) in CH_2Cl_2 (4 mL) cooled at -78°C , were added a solution of $(\text{COCl})_2$ (0.22 mL, 2.6 mmol) in CH_2Cl_2 (2.5 + 0.5 mL wash) and, after 2 min, a solution of **S6** (701 mg, 1.02 mmol) in CH_2Cl_2 (3.5 + 0.5 mL wash). After 1.5 h, Et_3N (0.64 mL, 4.6 mmol) was added. After 10 min, pentane (20 mL) was added, and the reaction mixture was allowed to warm to rt by removing the cooling bath. The resulting suspension was filtered through a pad of Na_2SO_4 , which was washed with a 1:1 mixture of pentane and EtOAc (10 mL \times 3). The volume of the combined filtrate and washings was reduced by evaporation to ca. 10 mL, and the resulting suspension was further diluted with pentane (20 mL). The precipitate was removed by filtration and washed with the mixed solvent (10 mL \times 3). Concentration of the combined filtrate and washings gave a 27:10:55:8 mixture of **1d**, DMSO, EtOAc and an unidentified byproduct, which was estimated to be a hydrate, as a pale yellow oil (870 mg, containing 551 mg of **1d**, 79%): IR: 3071, 3051, 3017, 3001, 2959, 2932, 2893, 2859, 1813, 1736, 1473, 1427, 1381, 1366, 1261, 1173, 1134, 1111, 1072, 999, 937, 887, 849, 822, 760, 745. ^1H NMR: 1.10 (s, 9H), 1.12 (s, 9H), 4.06 (dd, $J = 2.0, 1.0$, 1H), 4.45 (d, $J = 2.5$, 1H), 4.78 (dd, $J = 4.5, 2.5$, 1H), 4.89 (dd, $J = 4.5, 2.0$, 1H) 7.37–7.50 (m, 12H), 7.61–7.65 (m, 8H), 9.13 (s, 1H), 9.50 (d, $J = 1.0, 1\text{H}$). ^{13}C NMR: 19.2 (C), 19.4 (C), 26.66 (CH_3), 26.73 (CH_3), 76.8 (CH), 77.11 (CH), 77.13 (CH), 78.0 (CH), 128.10 (CH), 128.12 (CH), 128.14 (CH), 128.19 (CH), 130.5 (CH), 130.57 (CH), 130.59 (CH), 130.7 (CH), 131.2 (CH), 131.8 (CH), 132.3 (CH), 135.7 (CH), 135.9 (CH), 153.6 (C), 199.5 (CH), 200.5 (CH). HRMS–ESI m/z : $[\text{M} + \text{Na} + 2\text{MeOH}]^+$ calcd for $\text{C}_{41}\text{H}_{52}\text{NaO}_9\text{Si}_2$, 767.3042; found, 767.3043. This mixture was used as **1d** (63% w/w) in the reactions in Table 3.

3. Benzoin-type Cyclization of Dialdoses.

General Procedure of the Benzoin-type Cyclization of Dialdoses: Dialdose (**1a**, **1b** or **1d**) was dissolved in toluene (0.050 M) and added to a stirred suspension of triazolium salt (**4**, **5**, *ent*-**5**, **6** or *ent*-**6**), and Cs_2CO_3 or NaOBz in toluene (the same amount as above). After the indicated time, water was added, and the whole was extracted with EtOAc. The organic layer was evaporated to give a crude mixture. Yields and diastereomeric ratios of the products and the recovery yield of **1a**, **1b** and **1d** were determined by ^1H NMR of the crude mixture using Ph_3CH (5.55 ppm) as an internal standard. When

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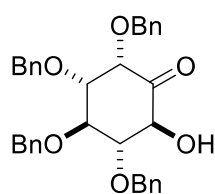
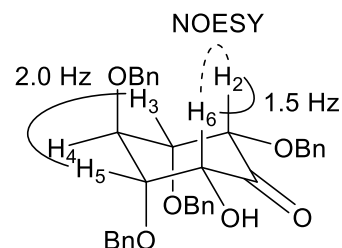
toluene- d_8 was used as a solvent, instead of toluene, ^1H NMR of the reaction mixture was directly measured without any workup. The isolation of each isomers from the crude mixture was performed by column chromatography and/or preparative TLC (*vide infra*).



(2*S*,3*S*,4*R*,5*S*,6*R*)-2,3,4,5-Tetrabenzoyloxy-6-hydroxycyclohexanone (2*aα*):

The title compound was isolated by column chromatography (toluene/MeOH 19:1) after partial separation by column chromatography (hexane/EtOAc 4:1 to 3:1): a colorless syrup. $[\alpha]_D^{27} -27.6$ (c 1.14, CH_2Cl_2) {lit²: $[\alpha]_D^{28} -40.4$ (c 0.6, CH_2Cl_2)}.

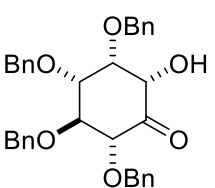
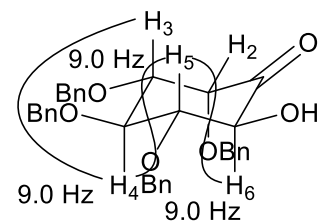
IR: 3468, 3086, 3063, 3028, 2924, 2874, 1744, 1497, 1454, 1396, 1366, 1312, 1261, 1215, 1126, 1076, 1026, 914, 752. ^1H NMR: 3.36 (br s, 1H), 3.79 (t, $J = 3.0$, 1H), 4.15 (ddd, $J = 4.5$, 3.0, 2.0, 1H), 4.22 (dd, $J = 4.0$, 3.0, 2.0, 1H), 4.36 (d, $J = 12.0$, 1H), 4.39 (d, $J = 12.0$, 1H), 4.45 (d, $J = 12.0$, 1H), 4.46 (dd, $J = 4.5$, 1.5, 1H), 4.52–4.54 (br m, 1H), 4.55 (s, 2H), 4.56 (d, $J = 12.0$, 1H), 4.73 (d, $J = 12.0$, 1H), 4.88 (d, $J = 12.0$, 1H), 7.08–7.10 (m, 2H), 7.19–7.21 (m, 2H), 7.29–7.38 (m, 16H). ^{13}C NMR: 72.3 (CH_2), 72.8 (CH_2), 73.0 (CH), 73.2 (CH_2), 73.6 (CH_2), 74.3 (CH), 80.3 (CH), 81.2 (CH), 82.2 (CH), 127.56 (CH), 127.64 (CH), 127.7 (CH), 127.77 (CH), 127.80 (CH), 128.0 (CH), 128.2 (CH), 128.3 (CH), 128.4 (CH), 128.6 (CH), 137.0 (C), 137.68 (C), 137.71 (C), 138.0 (C), 205.4 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{34}\text{H}_{34}\text{NaO}_6$, 561.2248; found, 561.2248. ^1H and ^{13}C NMR were in good agreement with those reported.² The stereochemistry was confirmed by the small coupling constants between the α - and β -protons ($J = 4.5$ and 4.0 Hz) and the long-range couplings of the α -protons and the β -protons ($J = 1.5$ and 2.0 Hz, respectively) as well as the NOESY correlation between the α -protons. These indicate that the α -protons were oriented in the axial positions and β -protons in the equatorial positions.



(2*S*,3*S*,4*R*,5*S*,6*S*)-2,3,4,5-Tetrabenzoyloxy-6-hydroxycyclohexanone (2*aβ*):

The title compound was characterized by ^1H NMR as a mixture with **2aα** and **3aα** because of the instability under purification conditions. ^1H NMR: 3.09 (br s, 1H), 3.30 (t, $J = 9.0$, 1H), 3.44 (dd, $J = 9.0$, 3.0, 1H), 4.07 (d,

$J = 3.0$, 1H), 4.30 (t, $J = 9.0$, 1H), 4.35–4.95 (m, 8H), 4.87 (d, $J = 9.0$, 1H), 7.10–7.38 (m, 20H). The stereochemistry was determined by the large coupling constants of the protons at the 3–6 positions ($J = 9.0$ Hz each), which indicate that these four protons were oriented in the axial positions.

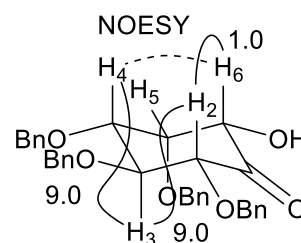


(2*R*,3*S*,4*R*,5*R*,6*S*)-2,3,4,5-Tetrabenzoyloxy-6-hydroxycyclohexanone (3*aα*):

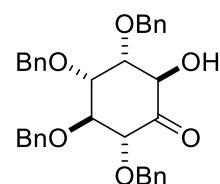
The title compound was isolated by column chromatography (toluene/MeOH 19:1) after partial separation by column chromatography (hexane/EtOAc 4:1 to 3:1).

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Recrystallization from EtOAc/hexane (1:5) gave white solids with mp 127–130 °C: $[\alpha]^{27}_D +9.74$ (c 1.80, CH₂Cl₂) {lit²: mp 129–131 °C, $[\alpha]^{27}_D -6.7$ (c 1.8, CH₂Cl₂)}. IR: 3406, 3086, 3063, 3032, 2913, 2859, 1734, 1497, 1454, 1420, 1400, 1358, 1312, 1211, 1134, 1123, 1096, 1076, 1042, 1026, 976, 914, 883, 733. ¹H NMR: 3.42 (br s, 1H), 3.81 (dd, $J = 9.0, 2.0$, 1H), 4.12 (dd, $J = 9.0, 1.0$, 1H), 4.14 (t, $J = 2.0$, 1H), 4.18 (t, $J = 9.0$, 1H), 4.19 (br s, 1H), 4.59 (d, $J = 11.5$, 1H), 4.67 (d, $J = 12.0$, 1H), 4.73 (d, $J = 12.0$, 2H), 4.86 (d, $J = 11.0$, 1H), 4.88 (d, $J = 12.0$, 1H), 4.90 (d, $J = 11.0$, 1H), 4.93 (d, $J = 11.5$, 1H), 7.28–7.33 (m, 18H), 7.37–7.39 (m, 2H). ¹³C NMR: 73.1 (CH₂), 73.6 (CH₂), 74.7 (CH), 74.9 (CH₂), 76.1 (CH₂), 77.9 (CH), 79.8 (CH), 82.5 (CH), 83.6 (CH), 127.6 (CH), 127.68 (CH), 127.70 (CH), 127.8 (CH), 127.9 (CH), 128.08 (CH), 128.13 (CH), 128.2 (CH), 128.3 (CH), 128.4 (CH), 128.5 (CH), 137.3 (C), 137.9 (C), 138.1 (C), 138.3 (C), 204.2 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₃₄H₃₄NaO₆, 561.2248; found, 561.2249. ¹H and ¹³C NMR were in good agreement with those reported.² The stereochemistry was confirmed by the large coupling constants of the protons at the 2–4 positions ($J = 9.0$ Hz each) and the long-range coupling between the protons at the 2- and 6-positions ($J = 1.0$ Hz) as well as the NOESY correlation between the protons at the 4- and 6-positions, indicating that these protons are oriented in the axial position.

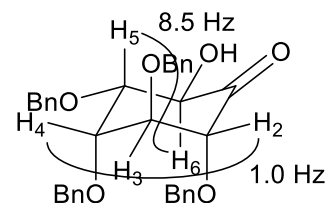


(2*R*,3*S*,4*R*,5*R*,6*R*)-2,3,4,5-Tetrabenzoyloxy-6-hydroxycyclohexanone (**3aβ**):



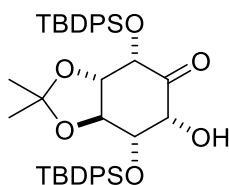
The title compound was isolated by column chromatography (toluene) after partial separation by column chromatography (hexane/EtOAc 4:1), using DIOL silica gel:

$[\alpha]^{20}_D +15.1$ (c 2.21, CHCl₃). IR: 3433, 3090, 3063, 3032, 3009, 2870, 1740, 1497, 1454, 1389, 1366, 1261, 1215, 1096, 1072, 1026, 914, 748. ¹H NMR: 3.05 (br d, $J = 1.5$, 1H), 3.76 (dd, $J = 8.5, 2.5$, 1H), 3.97 (ddd, $J = 4.0, 2.5, 1.0$, 1H), 3.98 (t, $J = 4.0$, 1H), 4.17 (dd, $J = 4.0, 1.0$, 1H), 4.43 (d, $J = 11.5$, 1H), 4.48 (d, $J = 11.5$, 1H), 4.54 (d, $J = 11.5$, 1H), 4.62 (d, $J = 12.0$, 1H), 4.64 (d, $J = 11.5$, 1H), 4.65 (d, $J = 12.0$, 1H), 4.68 (d, $J = 12.0$, 1H), 4.76 (d, $J = 12.0$, 1H), 4.86 (dd, $J = 8.5, 1.5$, 1H), 7.14–7.16 (m, 2H), 7.27–7.33 (m, 18H). ¹³C NMR: 72.7 (CH₂), 72.9 (CH₂), 73.1 (CH₂), 73.3 (CH₂), 74.4 (CH), 76.8 (CH), 76.9 (CH), 79.6 (CH), 81.2 (CH), 127.6 (CH), 127.7 (CH), 127.75 (CH), 127.78 (CH), 127.81 (CH), 127.86 (CH), 127.90 (CH), 128.2 (CH), 128.32 (CH), 128.34 (CH), 128.4 (CH), 137.1 (C), 137.4 (C), 138.0 (C), 138.1 (C), 206.2 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₃₄H₃₄NaO₆, 561.2248; found, 561.2248. The stereochemistry was confirmed by the large coupling constants of the protons at the 5- and 6-positions ($J = 8.5$ Hz), indicating that these protons are oriented in the axial positions, and the other coupling constants within the range between 1.0 to 4.0 Hz as well as the long-range coupling ($J = 1.0$ Hz)



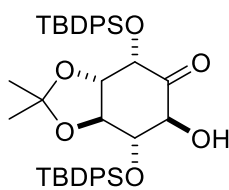
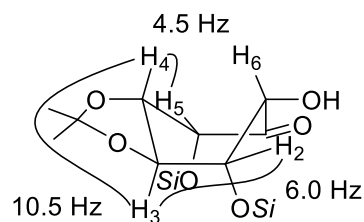
Supplementary Information

between the protons at the 2- and 4-positions, indicating these protons are in the equatorial positions.



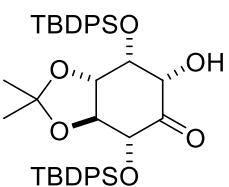
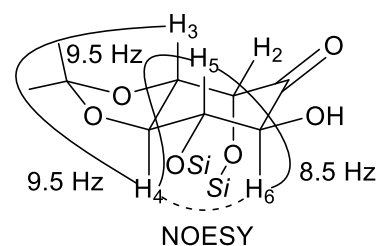
(2*S*,3*S*,4*S*,5*S*,6*R*)-2,5-Bis-*tert*-butyldiphenylsiloxy-6-hydroxy-3,4-isopropylidenedioxycyclohexanone (2*ba*): To a stirred suspension of *ent*-**6** (33 mg, 73 μ mol) and NaOBz (11 mg, 73 μ mol) in toluene (7 mL), was added a solution of

1b (252 mg, 363 μ mol) in toluene (7.5 mL). After 12 h, the whole was concentrated *in vacuo* at 50 °C to give a 74:16:10 mixture of the title compound, **2b β** and **3a α** . The title compound was characterized by ^1H NMR as a mixture with **2b β** and **3a α** because of the instability under purification conditions: ^1H NMR: 1.12 (s, 9H), 1.13 (s, 9H), 1.31 (s, 3H), 1.33 (s, 3H), 3.13 (br d, $J = 7.5$, 1H), 3.77 (dd, $J = 10.5$, 4.5, 1H), 4.06 (dd, $J = 7.5$, 6.0, 1H), 4.30 (t, $J = 6.0$, 1H), 4.33 (dd, $J = 10.5$, 6.0, 1H), 4.37 (d, $J = 4.5$, 1H), 7.10–7.43 (m, 20H). On the basis of the coupling constants, this compound likely takes a boat or twist boat conformation. The stereochemistry was determined after conversion into **2ca** (*vide infra*).



(2*S*,3*S*,4*S*,5*S*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-6-hydroxy-3,4-isopropylidenedioxycyclohexanone (2*b β*): Column chromatography (hexane/EtOAc 97:3) followed by three times preparative TLC (CHCl_3 , pentane/EtOAc 95:5 four-time-

development and hexane/EtOAc 95:5 three-time-development) gave the title compound with some impurity as a colorless oil: ^1H NMR: 1.11 (s, 9H), 1.13 (s, 9H), 1.25 (s, 3H), 1.41 (s, 3H), 2.87 (d, $J = 4.5$, 1H), 3.07 (dd, $J = 9.5$, 2.5, 1H), 3.59 (dd, $J = 9.5$, 8.5, 1H), 4.48 (d, $J = 2.5$, 1H), 4.64 (t, $J = 9.5$, 1H), 4.69 (dd, $J = 8.5$, 4.5, 1H), 7.32–7.80 (m, 20H). The stereochemistry was determined by the large coupling constants between the protons at the 3–6 positions ($J = 9.5$, 9.5 and 8.5 Hz) as well as the NOESY correlation between the protons at the 4- and 6-positions, indicating these four protons were oriented in the axial positions.

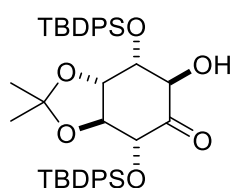
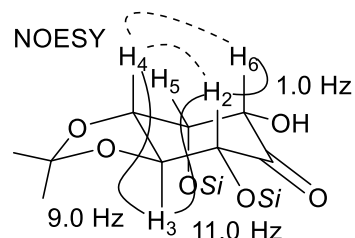


(2*R*,3*S*,4*S*,5*R*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-6-hydroxy-3,4-isopropylidenedioxycyclohexanone (3*ba*): The title compound was isolated by column chromatography (hexane/EtOAc 95:5) as a colorless oil: $[\alpha]_D^{20} +9.70$ (c 1.63, CHCl_3). IR: 3503, 3071, 3051, 3013, 2959, 2932, 2901, 2859, 1736, 1474, 1462,

1427, 1381, 1261, 1219, 1173, 1157, 1111, 1072, 1022, 968, 937, 891, 845, 822, 799, 760, 741. ^1H NMR: 1.08 (s, 9H), 1.16 (s, 9H), 1.38 (s, 3H), 1.43 (s, 3H), 3.00 (d, $J = 6.5$, 1H), 3.69 (dd, $J = 9.0$, 2.0, 1H), 3.76 (ddd, $J = 6.5$, 3.0, 1.0, 1H), 4.34 (dd, $J = 11.0$, 9.0, 1H), 4.42 (dd, $J = 11.0$, 1.0, 1H), 4.50 (dd, $J = 3.0$, 2.0, 1H), 7.32–7.43 (m, 12H), 7.53–7.55 (m, 2H), 7.75–7.78 (m, 6H). ^{13}C NMR: 19.6 (C

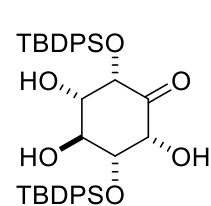
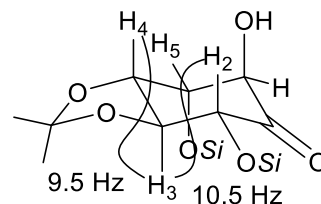
Supplementary Information

× 2), 26.7 (CH₃), 26.9 (CH₃), 27.0 (CH₃), 27.0 (CH₃), 70.2 (CH), 75.8 (CH), 76.0 (CH), 77.8 (CH), 77.9 (CH), 112.6 (C), 127.3 (CH), 127.42 (CH), 127.44 (CH), 127.5 (CH), 129.5 (CH), 129.67 (CH), 129.74 (CH), 129.8 (CH), 132.1 (C), 133.0 (C), 133.1 (C), 133.9 (C), 135.8 (C), 136.1 (CH), 136.2 (CH), 136.7 (CH), 205.3 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₄₁H₅₀NaO₆Si₂, 717.3038; found, 717.3039. The stereochemistry was determined by the large coupling constants of the protons at the 2–4 positions ($J = 11.0$ and 9.0 Hz) and the NOESY correlations between the protons at the 2- and 4-positions and the protons at the 4- and 6-position as well as the long-range coupling ($J = 1.0$ Hz) between the protons at the 2- and 6 positions, indicating these four protons are oriented in the axial positions.



(2*R*,3*S*,4*S*,5*R*,6*R*)-2,5-Bis-*tert*-butyldiphenylsiloxy-6-hydroxy-3,4-isopropylidenedioxycyclohexanone (3bβ): The title compound was not formed in the reaction but found in a crude mixture after several hours and isolated by column chromatography (hexane/EtOAc 97:3), preparative TLC (pentane/EtOAc 19:1

three-time-development) and then preparative DIOL silica TLC (hexane/EtOAc 8:1) as a colorless oil: $[\alpha]_D^{20} +33.9$ (c 0.16, CHCl₃). IR: 3422, 3071, 3051, 3013, 2959, 2928, 2893, 2859, 1740, 1470, 1427, 1381, 1261, 1231, 1192, 1153, 1111, 1076, 1030, 957, 860, 822, 795, 760, 745. ¹H NMR: 1.06 (s, 9H), 1.15 (s, 9H), 1.43 (s, 3H), 1.51 (s, 3H), 1.91 (br d, $J = 3.0$, 1H), 3.61 (br t, $J = 3.0$, 1H), 3.98 (dd, $J = 9.0, 2.5$, 1H), 4.22 (dd, $J = 3.0, 2.5$, 1H), 4.33 (dd, $J = 10.5, 9.5$, 1H), 4.72 (d, $J = 10.5$, 1H), 7.29–7.44 (m, 12H), 7.63–7.65 (m, 2H), 7.73–7.79 (m, 6H). ¹³C NMR: 19.3 (C), 19.6 (C), 26.80 (CH₃), 26.84 (CH₃), 27.0 (CH₃), 27.2 (CH₃), 69.6 (CH), 76.5 (CH), 76.7 (CH), 76.9 (CH), 77.1 (CH), 111.9 (C), 127.2 (CH), 127.3 (CH), 127.5 (CH), 127.8 (CH), 129.5 (CH), 129.6 (CH), 129.8 (CH), 130.0 (CH), 132.4 (C), 133.2 (C), 133.4 (C), 133.5 (C), 135.9 (CH), 136.1 (CH), 136.2 (CH), 136.3 (CH), 204.2 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₄₁H₅₀NaO₆Si₂, 717.3038; found, 717.3037. The stereochemistry was determined by the large coupling constants of the protons at the 2–4 positions ($J = 10.5$ and 9.5 Hz), indicating these three protons are oriented in the axial positions.



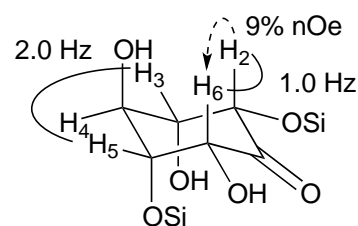
(2*S*,3*S*,4*S*,5*S*,6*R*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4,6-trihydroxycyclohexanone (2cα) (Scheme 2): To a stirred solution of DMSO (0.31 mL, 4.3 mmol) in CH₂Cl₂ (6.6 mL) cooled at -78 °C, was added a solution of (COCl)₂ (0.35 mL, 4.2 mmol) in CH₂Cl₂ (3.4 mL). After 2 min, a solution of **S3** (1.16 g, 1.66 mmol) in

CH₂Cl₂ (5.6 + 1.0 mL wash) was added. After 1 h, Et₃N (1.0 mL, 7.5 mmol) was added. After 10 min, pentane (33 mL) was added, and the mixture was allowed to warm to rt by removing the cooling bath.

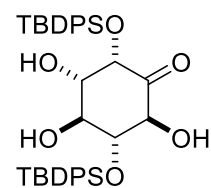
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The resulting suspension was filtered through a pad of Na₂SO₄, which was washed with a 1:1 mixture of pentane and EtOAc (20 mL × 3). The combined filtrate and washings were evaporated, and the resulting residue was further suspended with a 1:1 mixture of pentane and EtOAc (10 mL) and filtered. The removed precipitate was washed with the mixed solvent (2 mL × 3). Concentration of the combined filtrate and washings gave a 62:22:10:6 mixture of **1b**, DMSO, EtOAc and an unidentified impurity, which was estimated to be a hydrate, as pale yellow oil (1.20 g, containing 1.04 g of **1b**, 89%). The oil was dissolved in toluene (29 mL) and added to a stirred suspension of *ent*-**6** (134 mg, 296 μmol) and NaOBz (42.7 mg, 296 μmol) in toluene (30 mL). After 3 h, water (120 mL) was added, the whole was extracted with EtOAc (120 mL), and the organic layer was washed with brine (120 mL), dried over Na₂SO₄ and evaporated to give brown amorphous (1.30 g). To a stirred solution of the amorphous in MeCN (18 mL) cooled at -20 °C, was dropwise added 46% aq. HF (2.0 mL). After 6 h, sat. aq. NaHCO₃ (20 mL) was added, the whole was extracted with EtOAc (20 mL × 2) and the combined organic layers were washed with brine (40 mL), dried over Na₂SO₄ and evaporated. The residue was purified by column chromatography (hexane/EtOAc 5:1 to 3:1) to give the title compound (388 mg, 40%) as a colorless oil along with **2cβ** and **3cα**: [α]_D²⁰ -7 (*c* 0.06, CHCl₃). IR: 3502, 3071, 3051, 3013, 2997, 2959, 2932, 2893, 2859, 1740, 1470, 1427, 1339, 1362, 1261, 1215, 1192, 1157, 1134, 1111, 1076, 1030, 922, 876, 853, 822, 802, 760, 741. ¹H NMR: 1.04 (s, 9H), 1.16 (s, 9H), 1.53 (d, *J* = 4.0, 1H), 3.14 (d, *J* = 8.5, 1H), 3.19 (d, *J* = 7.0, 1H), 4.04 (ddd, *J* = 4.0, 3.0, 2.5, 1H), 4.10 (dddd, *J* = 8.5, 4.5, 2.5, 2.0, 1H), 4.27 (ddd, *J* = 7.0, 4.0, 1.0, 1H), 4.34 (ddd, *J* = 4.0, 3.0, 2.0, 1H), 4.70 (dd, *J* = 4.5, 1.0, 1H), 7.34–7.46 (m, 12H), 7.62–7.64 (m, 2H), 7.69–7.72 (m, 6H). ¹³C NMR: 19.3 (C), 19.4 (C), 26.89 (CH₃), 26.93 (CH₃), 69.4 (CH), 74.0 (CH), 75.9 (CH), 80.08 (CH), 80.13 (CH), 127.7 (CH), 127.75 (CH), 127.82 (CH), 129.9 (CH), 130.0 (CH), 132.1 (CH), 132.4 (CH), 132.8 (C), 133.3 (C), 135.7 (CH), 135.8 (CH), 136.0 (CH), 136.4 (CH), 206.0 (C). HRMS–ESI *m/z*: [M + Na]⁺ calcd for C₃₈H₄₆NaO₆Si₂, 677.2725; found, 677.2723.

The stereochemistry was determined by the long-range coupling (*J* = 1.0 Hz) and the nOe between the protons at the 2- and 6-positions (9%), indicating these protons are oriented in the axial positions.



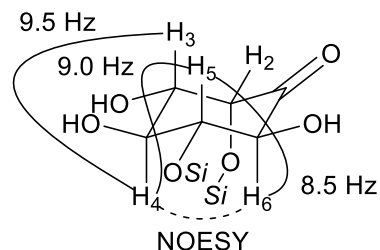
(2*S*,3*S*,4*S*,5*S*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4,6-trihydroxycyclohexanone (**2cβ**):



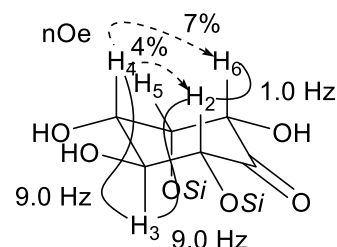
The title compound was isolated by preparative TLC (hexane/EtOAc 3:1) as a colorless oil: [α]_D²⁰ +0.92 (*c* 0.83, CHCl₃). IR: 3445, 3071, 3051, 3017, 2959, 2932, 2897, 2859, 1732, 1470, 1427, 1339, 1366, 1261, 1215, 1111, 1030, 953, 822, 760, 702. ¹H NMR: 1.11 (s, 9H), 1.13 (s, 9H), 3.20 (dd, *J* = 9.5, 3.0, 1H), 3.27 (dd, *J* = 9.0, 8.5, 1H), 4.31 (dd, *J* = 9.5, 9.0, 1H), 4.33 (d, *J* = 3.0, 1H), 4.83 (d, *J* = 8.5, 1H), 7.34–7.45 (m, 14H),

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7.54–7.58 (m, 2H), 7.60–7.64 (m, 2H), 7.67–7.70 (m, 2H). ^{13}C NMR: 19.4 (C), 19.7 (C), 26.9 (CH₃), 27.0 (CH₃), 72.0 (CH), 73.7 (CH), 76.4 (CH), 76.9 (CH), 78.6 (CH), 127.6 (CH), 127.8 (CH), 127.89 (CH), 127.93 (CH), 129.88 (CH), 129.90 (CH), 130.3 (CH), 131.8 (C), 132.0 (C), 132.4 (C), 134.1 (C), 135.6 (CH), 135.8 (CH), 135.9 (CH), 136.2 (CH), 205.2 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₃₈H₄₆NaO₆Si₂, 677.2725; found, 677.2725. The large coupling constants of the protons at the 3–6 positions ($J = 9.5, 9.0$ and 8.5 Hz) as well as the NOESY correlation between the protons at the 4- and 6-position, indicating these protons are oriented in the axial positions, is consistent with the proposed stereochemistry.



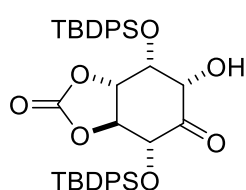
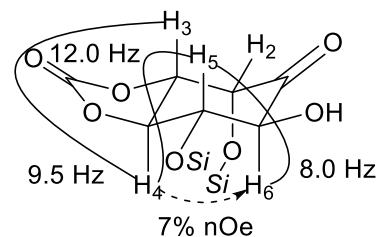
(2*R*,3*S*,4*S*,5*R*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4,6-trihydroxycyclohexanone (3ca): The title compound was isolated by preparative TLC (hexane/EtOAc 2:1) as a colorless solid of mp 153–154 °C: $[\alpha]_D^{20} +49.5$ (c 0.04, CHCl₃). IR: 3429, 3071, 3048, 3017, 2997, 2959, 2928, 2897, 2859, 1744, 1462, 1427, 1339, 1362, 1261, 1215, 192, 1173, 1134, 1111, 1072, 1030, 999, 968, 941, 899, 822, 802, 775, 741. ^1H NMR: 1.07 (s, 9H), 1.17 (s, 9H), 2.01 (d, $J = 5.5$, 1H), 2.39 (d, $J = 2.5$, 1H), 3.05 (d, $J = 6.5$, 1H), 3.62 (ddd, $J = 9.0, 5.5, 2.0$, 1H), 3.89 (ddd, $J = 6.5, 3.0, 1.0$, 1H), 4.14 (td, $J = 9.0, 2.5$, 1H), 4.22 (dd, $J = 9.0, 1.0$, 1H), 4.29 (dd, $J = 3.0, 2.0$, 1H), 7.37–7.46 (m, 12H), 7.58–7.61 (m, 2H), 7.70–7.74 (m, 6H). ^{13}C NMR: 19.7 (C), 27.0 (CH₃), 27.1 (CH₃), 71.6 (CH), 74.7 (CH), 75.6 (CH), 76.7 (CH), 78.8 (CH), 127.63 (CH), 127.64 (CH), 127.8 (CH), 127.9 (CH), 129.8 (CH), 129.97 (CH), 130.02 (CH), 132.4 (C), 132.6 (C), 135.7 (CH), 136.0 (CH), 136.1 (CH), 136.4 (CH), 203.8 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₃₈H₄₆NaO₆Si₂, 677.2725; found, 677.2724. This compound has a similar coupling and nOe correlation patterns to those of **3ba**, which is consistent with the proposed stereochemistry.



(2*S*,3*S*,4*S*,5*S*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4-carbonyldioxy-6-hydroxycyclohexanone (2dβ) (Table 3, entry 1): **1d** (26.0 mg, 38.2 μmol) was dissolved in toluene-*d*₈ (0.75 mL) and added to a stirred suspension of **4** (2.8 mg, 7.6 μmol) and NaOBz (1.1 mg, 7.6 μmol) in toluene-*d*₈ (0.75 mL). After 12 h, the whole was concentrated in *vacuo* to give a 56:44 mixture of the title compound and **3da**. The title compound was characterized by ^1H NMR as a mixture with **3da** because of the instability under purification conditions: ^1H NMR: 1.06 (s, 9H), 1.18 (s, 9H), 3.65 (dd, $J = 12.0, 2.5$, 1H), 3.71 (dd, $J = 9.5, 8.0$, 1H), 3.75 (d, $J = 2.5$, 1H), 4.63 (d, $J = 8.0$, 1H), 5.21 (dd, $J = 12.0, 9.5$, 1H), 7.35–7.78 (m,

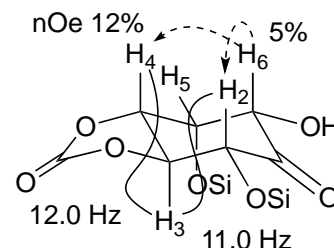
Supplementary Information

20H). The stereochemistry was determined by the large coupling constants of the protons at the 3–6 positions ($J = 12.0, 9.5$ and 8.0 Hz) as well as the nOe between the protons at the 4- and 6-positions (7%), indicating these protons are oriented in the axial positions.



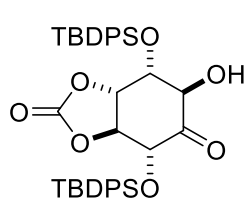
(2*R*,3*S*,4*S*,5*R*,6*S*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4-carbonyldioxy-6-hydroxycyclohexanone (3*da*) (Table 3, entry 6): To a stirred solution of DMSO (0.12 mL, 1.7 mmol) in CH_2Cl_2 (2.8 mL) cooled at -78 °C, was added a solution of $(\text{COCl})_2$ (0.14 mL, 1.6 mmol) in CH_2Cl_2 (2.4 mL). After 2 min, a solution of **S6** (494 mg, 720 μmol) in CH_2Cl_2 (2.4 + 0.5 mL wash) was added. After 1 h, Et_3N (0.42 mL, 3.0 mmol) was added. After 5 min, pentane (8 mL) was added, and the mixture was allowed to warm to rt by removing the cooling bath. The resulting suspension was filtered through a pad of Na_2SO_4 , which was washed with a 1:1 mixture of pentane and EtOAc (5 mL \times 3). The volume of the combined filtrate and washings was reduced by evaporation to ca. 5 mL, and the resulting suspension was further diluted with pentane (5 mL) and filtered. The removed precipitate was washed with the mixed solvent (5 mL \times 3). Concentration of the combined filtrate and washings gave a 50:7:30:23 mixture of **1d**, EtOAc, toluene and an unidentified byproduct, which was estimated to be a hydrate, as a pale yellow oil (527 mg, containing 335 mg of **1d**, 68%). A part of the oil (500 mg) was dissolved in toluene (9.5 mL) and added to a stirred suspension of *ent*-**6** (43.2 mg, 95.4 μmol) and NaOBz (13.7 mg, 95.4 μmol) in toluene (9.5 mL). After 2 h, water (40 mL) was added and the whole was extracted with EtOAc (40 mL \times 2). The combined organic layers were washed with brine and evaporated to give an 87:7:6 mixture of the title compound, **3d β** and **2d β** . The residue was purified by column chromatography (hexane/EtOAc 8:1) using DIOL silica (40 g) to give the title compound (189 mg, 58%) as a white amorphous of mp 53–58 °C: $[\alpha]_D^{20} +4.79$ (c 1.05, CHCl_3). IR: 3497, 3073, 3050, 3017, 3001, 3959, 2932, 2895, 2860, 1827, 1746, 1589, 1489, 1472, 1464, 1449, 1437, 1427, 1393, 1364, 1308, 1261, 1215, 1194, 1171, 1194, 1171, 1115, 1059, 1022, 989, 951, 934, 868, 822, 760, 702, 667, 625, 615, 596. ^1H NMR: 1.06 (s, 9H), 1.18 (s, 9H), 3.07 (d, $J = 6.0$, 1H), 3.76 (dd, $J = 6.0, 3.5$, 1H), 4.25 (dd, $J = 12.0, 2.0$, 1H), 4.51 (d, $J = 11.0$, 1H), 4.58 (dd, $J = 3.5, 2.0$, 1H), 4.91 (dd, $J = 12.0, 11.0$, 1H), 7.36–7.48 (m, 12H), 7.52–7.54 (m, 2H), 7.67–7.70 (m, 4H), 7.73–7.75 (m, 2H). ^{13}C NMR: 19.57 (C), 19.59 (C), 26.8 (CH₃), 26.9 (CH₃), 68.9 (CH), 76.0 (CH), 77.04 (CH), 77.9 (CH), 79.3 (CH), 127.6 (CH), 127.7 (CH), 127.8 (CH), 127.9 (CH), 130.0 (CH), 130.1 (CH), 130.2 (CH), 130.4 (CH), 131.0 (C), 131.9 (C), 132.2 (C), 132.8 (C), 135.6 (C), 135.98 (CH), 136.01 (CH), 136.4 (CH), 153.4 (C), 202.6 (C). HRMS–ESI m/z : $[\text{M} + \text{K}]^+$ calcd for $\text{C}_{39}\text{H}_{44}\text{KO}_7\text{Si}_2$, 719.2257; found, 719.2259. The stereochemistry was

1.06 (s, 9H), 1.18 (s, 9H), 3.07 (d, $J = 6.0$, 1H), 3.76 (dd, $J = 6.0, 3.5$, 1H), 4.25 (dd, $J = 12.0, 2.0$, 1H), 4.51 (d, $J = 11.0$, 1H), 4.58 (dd, $J = 3.5, 2.0$, 1H), 4.91 (dd, $J = 12.0, 11.0$, 1H), 7.36–7.48 (m, 12H), 7.52–7.54 (m, 2H), 7.67–7.70 (m, 4H), 7.73–7.75 (m, 2H). ^{13}C NMR: 19.57 (C), 19.59 (C), 26.8 (CH₃), 26.9 (CH₃), 68.9 (CH), 76.0 (CH), 77.04 (CH), 77.9 (CH), 79.3 (CH), 127.6 (CH), 127.7 (CH), 127.8 (CH), 127.9 (CH), 130.0 (CH), 130.1 (CH), 130.2 (CH), 130.4 (CH), 131.0 (C), 131.9 (C), 132.2 (C), 132.8 (C), 135.6 (C), 135.98 (CH), 136.01 (CH), 136.4 (CH), 153.4 (C), 202.6 (C). HRMS–ESI m/z : $[\text{M} + \text{K}]^+$ calcd for $\text{C}_{39}\text{H}_{44}\text{KO}_7\text{Si}_2$, 719.2257; found, 719.2259. The stereochemistry was



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determined by the large coupling constants of the protons at the 2–4 positions ($J = 12.0$ and 11.0 Hz) and the nOe between the 2- and 6-protons and the 4- and 6-protons (5% and 12%, respectively), indicating these four protons are oriented in the axial positions.



(2*R*,3*S*,4*S*,5*R*,6*R*)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4-carbonyldioxy-6-hy-

droxycyclohexanone (**3dβ**): The title compound was isolated by preparative TLC

(toluene/hexane 4:1) as a colorless oil: $[\alpha]_D^{20} +19$ (c 0.22, CHCl_3). IR: 3449, 3071,

3051, 3021, 2997, 2955, 2928, 2859, 1821, 1751, 1655, 1589, 1462, 1427, 1385,

1366, 1308, 1261, 1192, 1161, 1115, 1057, 1030, 953, 937, 845, 822, 799, 745. ^1H NMR: 1.06 (s, 9H),

1.16 (s, 9H), 2.08 (br d, $J = 2.5$, 1H), 3.72 (dd, $J = 3.0$, 2.5, 1H), 4.35 (dd, $J = 3.0$, 2.5, 1H), 4.62 (dd,

$J = 11.5$, 2.5, 1H), 4.81 (d, $J = 11.0$, 1H), 4.91 (dd, $J = 11.5$, 11.0, 1H), 7.33–7.48 (m, 12H), 7.60–7.64

(m, 4H), 7.68–7.72 (m, 4H). ^{13}C NMR: 19.2 (C), 19.5 (C), 26.8 (CH_3), 26.9 (CH_3), 68.5 (CH), 75.9

(CH), 76.9 (CH), 78.6 (CH), 78.7 (CH), 127.5 (CH), 127.7 (CH), 128.00 (CH), 128.03 (CH), 129.9

(CH), 130.1 (CH), 130.38 (CH), 130.40 (CH), 131.1 (C), 132.30 (C), 132.34 (C), 132.6 (C), 135.7

(CH), 135.9 (CH), 136.0 (CH), 136.1 (CH), 154.0 (C), 200.7 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd

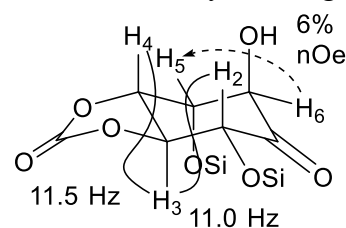
for $\text{C}_{39}\text{H}_{44}\text{NaO}_7\text{Si}_2$, 703.2518; found, 703.2516. The stereochemistry was determined by the large

coupling constants of the protons at the 2–4-positions ($J = 11.0$ and 11.5

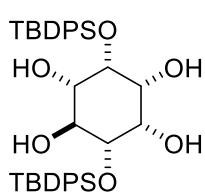
Hz) as well as the nOe between the protons at the 5- and 6-positions (6%),

indicating only the protons at the 2–4-positions are oriented in the axial

positions.



4. Reduction of Inososes.



1,4-Bis-*O-tert*-butyldiphenylsilyl-*L-epi*-inositol (*epi*-7c): To a stirred solution of

2ca (69.8 mg, 107 μmol) in THF (1 mL) cooled in an ice–water bath, was added a 1

M solution of $\text{BH}_3 \cdot \text{THF}$ in THF (0.54 mL, 0.54 mmol), and the mixture was allowed

to warm to rt by removing the cooling bath. After 1 h, 10% aq. HCl (2 mL) was

added, and volatile materials were removed by evaporation. The residue was extracted with EtOAc (2

mL \times 3), and the combined organic layers were washed with sat. aq. NaHCO_3 (2 mL) and brine (2

mL), dried over Na_2SO_4 and evaporated. The residue was purified by column chromatography

(hexane/EtOAc 4:1) to give the title compound (57 mg, 80%) as a white solid of mp 174–176 $^\circ\text{C}$:

$[\alpha]_D^{20} +18.2$ (c 2.43, CHCl_3). IR: 3564, 3507, 3071, 3051, 3013, 2959, 2932, 2893, 2859, 1474, 1427,

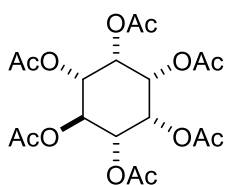
1393, 1362, 1215, 1192, 1111, 1084, 1007, 945, 910, 872, 841, 822, 799, 756. ^1H NMR: 1.12 (s, 18H),

1.62 (br s, 1H), 1.99 (br s, 1H), 2.29 (br s, 1H), 2.73 (d, $J = 8.5$, 1H), 3.18 (br s, 1H), 3.29 (br s, 1H),

3.54 (br s, 1H), 3.70 (d, $J = 7.0$, 1H), 4.06 (br s, 1H), 4.13 (dd, $J = 8.5$, 7.0, 1H), 7.35–7.45 (m, 12H),

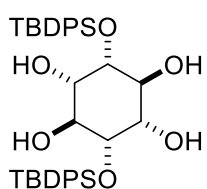
Supplementary Information

7.71–7.76 (m, 8H). ^{13}C NMR: 19.4 (C), 19.6 (C), 27.0 (CH₃), 27.2 (CH₃), 70.0 (CH), 70.8 (CH), 72.5 (CH), 73.5 (CH), 75.0 (CH), 75.2 (CH), 127.7 (CH), 127.81 (CH), 127.83 (CH), 129.9 (CH), 130.0 (CH), 132.6 (C), 132.9 (C), 133.0 (C), 133.3 (C), 135.87 (CH), 135.90 (CH), 136.0 (CH), 136.2 (CH). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₃₈H₄₈NaO₆Si₂, 679.2882; found, 679.2882. The lack of symmetry in ^1H NMR is consistent with the proposed stereochemistry, which was confirmed after conversion into a known compound, *epi*-inositol hexaacetate (*vide infra*).



***epi*-Inositol hexaacetate:** To a stirred solution of *epi*-7c (4.5 mg, 6.8 μmol) in THF (0.2 mL) cooled in an ice–water bath, was added a 1 M solution of TBAF in THF (0.1 mL, 0.1 mmol). After 5 h, volatile materials were removed by evaporation, and to the residue, were added DMAP (5 mg, 0.04 mmol), pyridine

(2.5 mL, 31 mmol) and acetic anhydride (0.4 mL, 4 mmol). The mixture was stirred at 50 °C for 24 h and allowed to cool to rt. After addition of EtOAc (10 mL), the whole was washed with water (10 mL \times 3) and brine (10 mL), dried over Na₂SO₄ and evaporated. The residue was purified by preparative TLC (hexane/EtOAc 2:1 twice-development) to yield the title compound (2.9 mg, 99% over 2 steps) as a white solid of mp 182–184 °C: ^1H NMR: 2.009 (s, 3H), 2.012 (s, 6H), 2.04 (s, 3H), 2.17 (s, 6H), 5.06 (dd, $J = 10.5, 3.0, 2\text{H}$), 5.10 (t, $J = 3.0, 1\text{H}$), 5.60 (t, $J = 3.0, 2\text{H}$), 5.71 (t, $J = 10.5, 1\text{H}$). ^{13}C NMR: 20.4 (CH₃), 20.5 (CH₃), 20.7 (CH₃), 20.8 (CH₃), 65.7 (CH), 67.2 (CH), 68.4 (CH), 68.8 (CH), 169.2 (C), 169.5 (C), 169.8 (C), 170.1 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₁₈H₂₄NaO₁₂, 455.1160; found, 455.1160. The mp, and ^1H and ^{13}C NMR were in good agreement with those reported.^{8,9}



1,4-Bis-*O*-tert-butylidiphenylsilyl-*L*-muco-inositol (*muco*-7c): To a stirred suspension of Me₄N(AcO)₃BH (151 mg, 575 μmol) in a 1:1 mixture of MeCN and AcOH (1.3 mL) cooled at –20 °C, was added a solution of **2ca** (74.5 mg, 114 μmol) in MeCN (0.6 mL \times 3 wash), and the mixture was allowed to warm to rt by removing

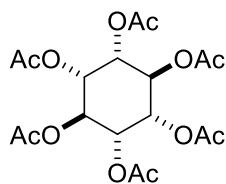
the cooling bath. After 8 h, 10% aq. HCl (3 mL) was added and the mixture was stirred for 30 min. The whole was extracted with EtOAc (3 mL \times 3) and the combined organic layers were washed with sat. aq. NaHCO₃, dried over Na₂SO₄ and evaporated. The residue was purified by column chromatography (hexane/EtOAc 4:1) to give the title compound (69.0 mg, 92%) as a colorless oil: $[\alpha]_D^{20} +2.9$ (c 0.16, CHCl₃). IR: 3449, 3071, 3051, 3013, 2997, 2955, 2928, 2855, 1470, 1427, 1389, 1362, 1261, 1215, 1192, 1138, 1111, 1084, 1061, 957, 918, 872, 856, 822, 791. ^1H NMR: 1.12 (s, 18H), 1.61 (d, $J = 2.0, 1\text{H}$), 2.54 (d, $J = 6.5, 1\text{H}$), 3.58 (dt, $J = 3.0, 6.5, 2\text{H}$), 3.97 (dd, $J = 6.5, 3.0, 2\text{H}$),

8. M. Podeschwa, O. Plettenburg, J. vom Brocke, O. Block, S. Adelt and H.-J. Altenbach, *Eur. J. Org. Chem.*, 2003, 1958.

9. R. Mukherjee and C. L. C. De Medeiros, *Phytochemistry*, 1988, **27**, 279.

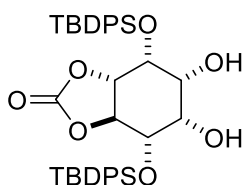
Supplementary Information

4.05 (dt, $J = 2.0, 6.5, 2\text{H}$), 7.36–7.46 (m, 12H), 7.72–7.75 (m, 8H). ^{13}C NMR: 19.5 (C), 27.1 (CH₃), 71.0 (CH), 73.1 (CH), 74.9 (CH), 127.7 (CH), 127.8 (CH), 130.0 (CH), 133.1 (C), 133.2 (C), 136.06 (CH), 136.08 (CH). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₃₈H₄₈NaO₆Si₂, 679.2882; found, 679.2882. The symmetry in ^1H NMR is consistent with the proposed stereochemistry, which was confirmed after conversion into a known compound, *muco*-inositol hexaacetate (*vide infra*).



***muco*-Inositol hexaacetate:** To a stirred solution of *muco*-**7c** (13.1 mg, 20.0 μmol) in THF (0.6 mL) cooled in an ice–water bath, was added a 1 M solution of TBAF in THF (0.3 mL, 0.3 mmol). After 5 h, volatile materials were removed by evaporation, and to the residue, were added DMAP (15 mg, 0.12 mmol), pyridine

(7.5 mL, 93 mmol) and acetic anhydride (1.2 mL, 13 mmol). The mixture was stirred at 50 °C for 24 h and allowed to cool to rt. After addition of EtOAc (20 mL), the whole was washed with water (10 mL \times 3) and brine (10 mL), dried over Na₂SO₄ and evaporated. The residue was purified by preparative TLC (hexane/EtOAc 2:1 twice-development) to yield the title compound (8.0 mg, 93% over 2 steps) as a white solid of 178–180 °C: ^1H NMR: 2.08 (s, 12H), 2.11 (s, 6H), 5.28–5.31 (m, 4H), 5.39–5.44 (br m, 2H). ^{13}C NMR: 20.6 (CH₃), 20.7 (CH₃), 67.4 (CH), 68.7 (CH), 169.0 (C). HRMS–ESI m/z : $[\text{M} + \text{Na}]^+$ calcd for C₁₈H₂₄NaO₁₂, 455.1160; found, 455.1160. The mp, and ^1H and ^{13}C NMR in DMSO-*d*₆ (*vide infra*) were in good agreement with those reported.¹⁰



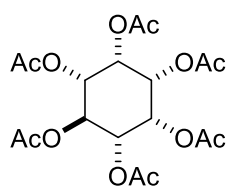
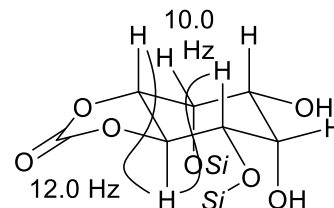
(1*R*,2*S*,3*S*,4*S*,5*S*,6*R*)-3,6-Bis-*tert*-butyldiphenylsiloxy-4,5-carbonyldioxy-cyclohexane-1,2-diol (*epi*-7d**):** To a stirred solution of **3da** (47.8 mg, 70.2 μmol) in THF (0.5 mL) cooled in an ice–water bath, was added a 1 M solution of BH₃·THF in THF (0.35 mL, 0.35 mmol), and the mixture was allowed to warm to rt

by removing the cooling bath. After 4 h, 10% aq. HCl (2 mL) was added, and volatile materials were removed by evaporation. The residue was extracted with EtOAc (2 mL \times 3), and the combined organic layers were washed with sat. aq. NaHCO₃ (2 mL \times 3) and brine (2 mL), dried over Na₂SO₄ and evaporated. The residue was purified by column chromatography (hexane/EtOAc 4:1) to give the title compound (38 mg, 83%) as a colorless solid of mp 64–66 °C: $[\alpha]_D^{20} +9.94$ (c 1.06, CHCl₃). IR: 3553, 3071, 3051, 3017, 2959, 2932, 2897, 2859, 1856, 1813, 1470, 1427, 1393, 1362, 1339, 1254, 1215, 1169, 1111, 1061, 1022, 980, 934, 880, 826, 799, 756, 706. ^1H NMR: 1.11 (s, 9H), 1.16 (s, 9H), 2.72 (d, $J = 12.0, 1\text{H}$), 2.79 (d, $J = 3.0, 1\text{H}$), 3.19 (dt, $J = 12.0, 3.0, 1\text{H}$), 3.60 (dd, $J = 12.0, 3.0, 1\text{H}$), 3.73 (q, $J = 3.0, 1\text{H}$), 3.84 (dd, $J = 10.0, 3.0, 1\text{H}$), 4.32 (t, $J = 3.0, 1\text{H}$), 5.19 (dd, $J = 12.0, 10.0, 1\text{H}$), 7.38–7.48 (m, 12H), 7.67–7.76 (m, 8H). ^{13}C NMR: 19.3 (C), 19.5 (C), 26.9 (CH₃), 27.0 (CH₃), 69.8 (CH), 69.9 (CH), 71.5 (CH), 73.6 (CH), 77.0 (CH), 78.9 (CH), 127.8 (CH), 127.86 (CH), 127.91 (CH), 128.1

10. R. Miethchen, A. Schmidt, K. Neitzel, M. Michalik, T. Pundt and W. Ruth, *Carbohydr. Res.*, 2005, **340**, 741.

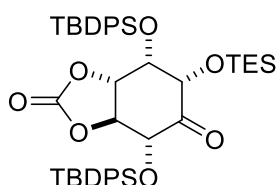
Supplementary Information

(CH), 129.9 (CH), 130.2 (CH), 130.36 (CH), 130.41 (CH), 131.2 (C), 131.5 (C), 132.7 (C), 133.7 (C), 135.5 (CH), 135.6 (CH), 136.0 (CH), 136.5 (CH), 154.1 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for $C_{39}H_{46}NaO_7Si_2$, 705.2674; found, 705.2674. The three sequential axial protons having large coupling constants ($J = 12.0$ and 10.0) were observed in 1H NMR, being consistent with the proposed stereochemistry, which was confirmed after conversion into a known compound, *epi*-inositol hexaacetate (*vide infra*).



***epi*-Inositol hexaacetate:** To a stirred solution of *epi*-**7d** (14.0 mg, 20.5 μ mol) in MeOH (1.0 mL), was added sodium methoxide (14.0 mg, 259 μ mol). After 1 h, water (6 mL) was added, and volatile materials were removed by evaporation. The residual was extracted with EtOAc (6 mL), and the organic layer was washed with

brine (6 mL), dried over Na_2SO_4 and evaporated. The residue was dissolved in THF (0.2 mL) and cooled in an ice–water bath. To the solution, was added a 1 M solution of TBAF in THF (0.1 mL, 0.1 mmol), and the mixture was stirred for 1 h. After removal of solvent by evaporation, to the residue, were added DMAP (5 mg, 0.04 mmol), pyridine (2.5 mL, 31 mmol) and acetic anhydride (0.4 mL, 4 mmol). The mixture was stirred at 50 $^{\circ}C$ for 24 h and allowed to cool to rt. After addition of EtOAc (10 mL), the whole was washed with water (10 mL \times 3) and brine (10 mL), dried over Na_2SO_4 and evaporated. The residue was purified by preparative TLC (hexane/EtOAc 2:1 twice-development) to yield the title compound (6.2 mg, 70% over 3 steps).

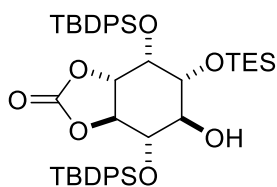


(2*R*,3*S*,4*S*,5*R*,6*S*)-2,5-Bis-*tert*-butyldiphenylsilyloxy-3,4-carbonyldioxy-6-triethylsilyloxycyclohexanone (S7): To a stirred solution of **3da** (47.9 mg, 70.3 μ mol) and pyridine (28 μ L, 0.35 mmol) in CH_2Cl_2 (1 mL) cooled at -78 $^{\circ}C$, was added TESOTf (32 μ L, 0.14 mmol). After 4 h, MeOH (1 mL) and water

(2 mL) were added. Volatile materials were removed by evaporation, and the residue was extracted with EtOAc (2 mL \times 3). The combined organic layers were washed with water (6 mL \times 3) and brine (6 mL) and evaporated. The resulting colorless amorphous, containing the title compound, was used in the next reaction after removal of residual solvent by azeotropic distillation with toluene. The title compound was characterized after purification by column chromatography (hexane/EtOAc 95:5): a colorless solid of mp 125–128 $^{\circ}C$. $[\alpha]_D^{20} -5.55$ (c 1.25, $CHCl_3$). IR: 3071, 3051, 3013, 3001, 2955, 2932, 2878, 2858, 1829, 1809, 1755, 1470, 1427, 1389, 1362, 1188, 1157, 1115, 1061, 1018, 988, 964, 937, 876, 845, 822, 806, 772, 756. 1H NMR: 0.18 (q, $J = 8.0$, 6H), 0.63 (t, $J = 8.0$, 9H), 1.04 (s, 9H), 1.18 (s, 9H), 3.72 (d, $J = 3.0$, 1H), 4.25 (dd, $J = 11.5$, 1.5, 1H), 4.39 (d, $J = 11.5$, 1H), 4.47 (dd, $J = 3.0$, 1.5, 1H), 4.95 (t, $J = 11.5$, 1H), 7.33–7.45 (m, 12H), 7.61–7.65 (m, 4H), 7.69–7.73 (m, 4H). ^{13}C

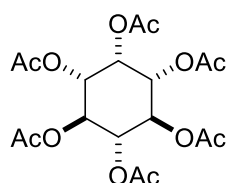
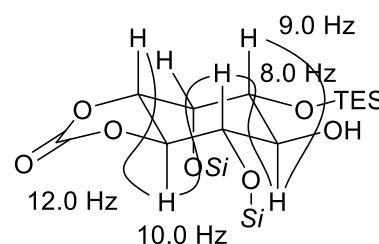
Supplementary Information

NMR: 4.1 (CH₂), 6.5 (CH₃), 19.6 (C), 19.7 (C), 26.91 (CH₃), 26.93 (CH₃), 70.1 (CH), 76.5 (CH), 76.9 (CH), 78.4 (CH), 79.4 (CH), 127.3 (CH), 127.5 (CH), 127.6 (CH), 127.7 (CH), 129.6 (CH), 129.85 (CH), 129.93 (CH), 130.1 (CH), 131.6 (C), 132.1 (C), 132.49 (C), 132.51 (C), 136.0 (CH), 136.1 (CH), 136.2 (CH), 136.3 (CH), 153.8 (C), 199.4 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₄₅H₅₈NaO₇Si₃, 817.3383; found, 817.3385.



(1S,2S,3R,4S,5S,6R)-2,5-Bis-*tert*-butyldiphenylsiloxy-3,4-carbonyldi-oxy-6-triethylsiloxycyclohexanol (*myo*-7d): To a stirred solution of the above crude **S7** in toluene (1 mL), was added *t*-BuNH₂·BH₃ (13.7 mg, 176 μmol). After 1h, 10% aq. HCl (2 mL) was added, and the whole was extracted

with EtOAc (6 mL). The organic layer was washed with sat. aq. NaHCO₃ (6 mL) and brine (6 mL), dried over Na₂SO₄ and evaporated. The residue was purified by column chromatography (hexane/EtOAc 95:5) to give the title compound (39.0 mg, 70% over 2 steps) as a colorless oil: $[\alpha]_D^{20} +8.61$ (c 1.69, CHCl₃). IR: 3561, 3074, 3051, 3017, 3001, 2955, 2932, 2889, 2878, 2859, 1840, 1817, 1470, 1462, 1427, 1362, 1261, 1188, 1165, 1115, 1957, 995, 937, 821, 775. ¹H NMR: 0.21–0.33 (m, 6H), 0.67 (t, $J = 8.0, 9H$), 1.09 (s, 9H), 1.12 (s, 9H), 1.96 (d, $J = 3.5, 1H$), 3.23 (dd, $J = 9.0, 2.5, 1H$), 3.72 (dd, $J = 12.0, 1.5, 1H$), 3.76 (dd, $J = 10.0, 8.0, 1H$), 3.93 (ddd, $J = 9.0, 8.0, 3.5, 1H$), 4.21 (dd, $J = 2.5, 1.5, 1H$), 4.89 (dd, $J = 12.0, 10.0, 1H$), 7.35–7.49 (m, 12H), 7.65–7.67 (m, 2H), 7.74–7.77 (m, 6H). ¹³C NMR: 4.5 (CH₂), 6.6 (CH₃), 19.6 (C), 19.8 (C), 26.9 (CH₃), 27.1 (CH₃), 69.7 (CH), 74.0 (CH), 74.3 (CH), 76.7 (CH), 78.9 (CH), 79.0 (CH), 127.3 (CH), 127.7 (CH), 127.76 (CH), 127.83 (CH), 129.6 (CH), 129.9 (CH), 130.07 (CH), 130.09 (CH), 131.8 (C), 132.0 (C), 132.5 (C), 133.9 (C), 135.6 (CH), 136.3 (CH), 136.32 (CH), 136.33 (CH), 154.2 (C). HRMS–ESI m/z : $[M + Na]^+$ calcd for C₄₅H₆₀KO₇Si₃, 835.3278; found, 835.3278. The five axial protons having large coupling constants were observed in ¹H NMR, being consistent with the proposed stereochemistry, which was confirmed after conversion into a known compound, *myo*-inositol hexaacetate (*vide infra*).



***myo*-Inositol hexaacetate:** To a stirred solution of *myo*-7d (7.3 mg, 9.2 μmol) in MeOH (1 mL), was added sodium methoxide (30 mg, 0.56 mmol). After 6 h, water was added (5 mL), and the whole was extracted with EtOAc (15 mL). The organic layer was washed with brine (5 mL), dried over Na₂SO₄ and evaporated.

The residue was dissolved in THF (0.2 mL) and cooled in an ice–water bath. To the solution, was added a 1 M solution of TBAF in THF (0.1 mL, 0.1 mmol), and after 1 h, volatile materials were removed by evaporation. To the residue, were added DMAP (5 mg, 0.04 mmol), pyridine (2.5 mL, 31

Supplementary Information

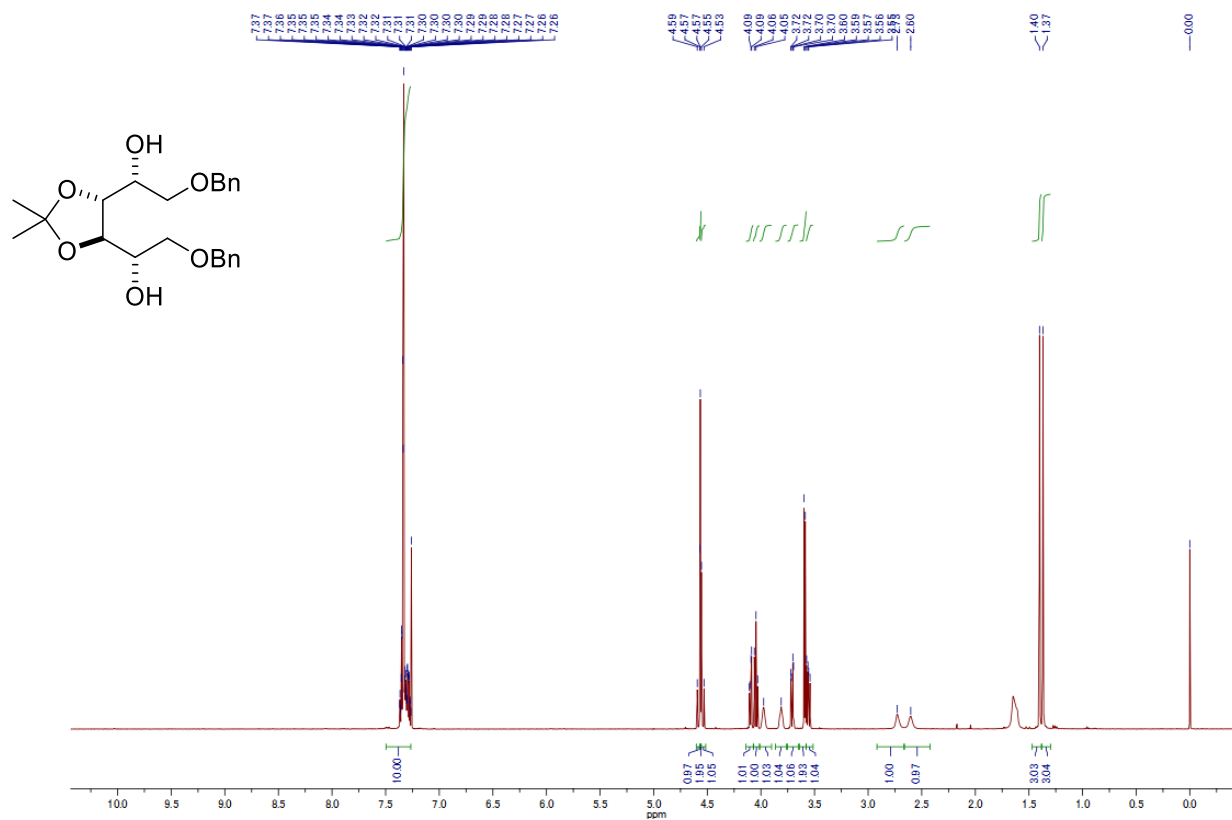
mmol) and acetic anhydride (0.4 mL, 4 mmol). The mixture was stirred at 50 °C for 24 h and allowed to cool to rt. After addition of EtOAc (10 mL), the whole was washed with water (10 mL × 3) and brine (10 mL), dried over Na₂SO₄ and evaporated. The residue was purified by preparative TLC (hexane/EtOAc 2:1 twice-development) to yield the title compound (4.0 mg, quant over 3 steps) as a white solid of mp 216–218 °C: ¹H NMR: 2.00 (s, 6H), 2.017 (s, 6H), 2.020 (s, 3H), 2.21 (s, 3H), 5.09 (dd, *J* = 10.0, 3.0, 2H), 5.18 (t, *J* = 10.0, 1H), 5.50 (t, *J* = 10.0, 2H), 5.60 (t, *J* = 3.0, 1H). HRMS–ESI *m/z*: [M + Na]⁺ calcd for C₁₈H₂₄NaO₁₂, 455.1160; found, 455.1160. The mp and ¹H NMR were in good agreement with those reported.^{9,11}

11. R. Mukherjee and E. M. Axt, *Phytochemistry*, 1988, **23**, 2682.

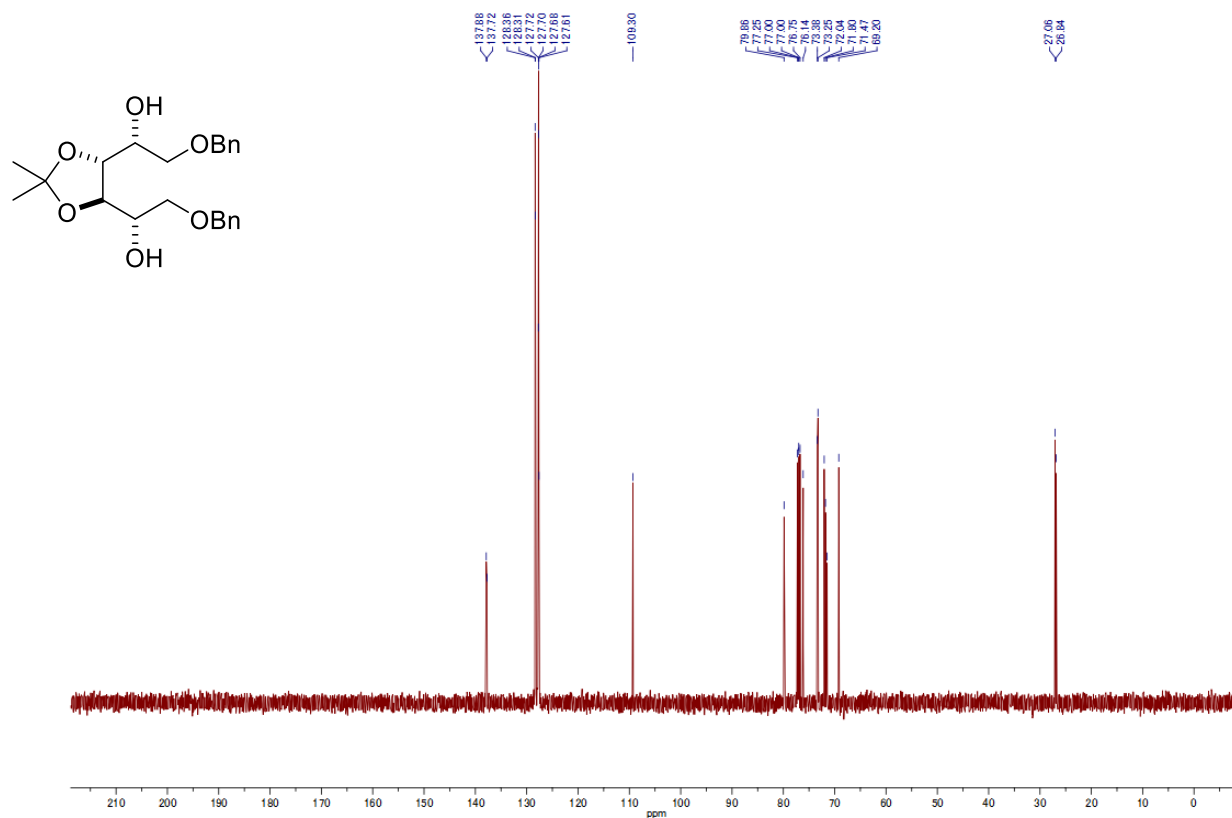
Supplementary Information

5. NMR Spectra.

^1H NMR of S1

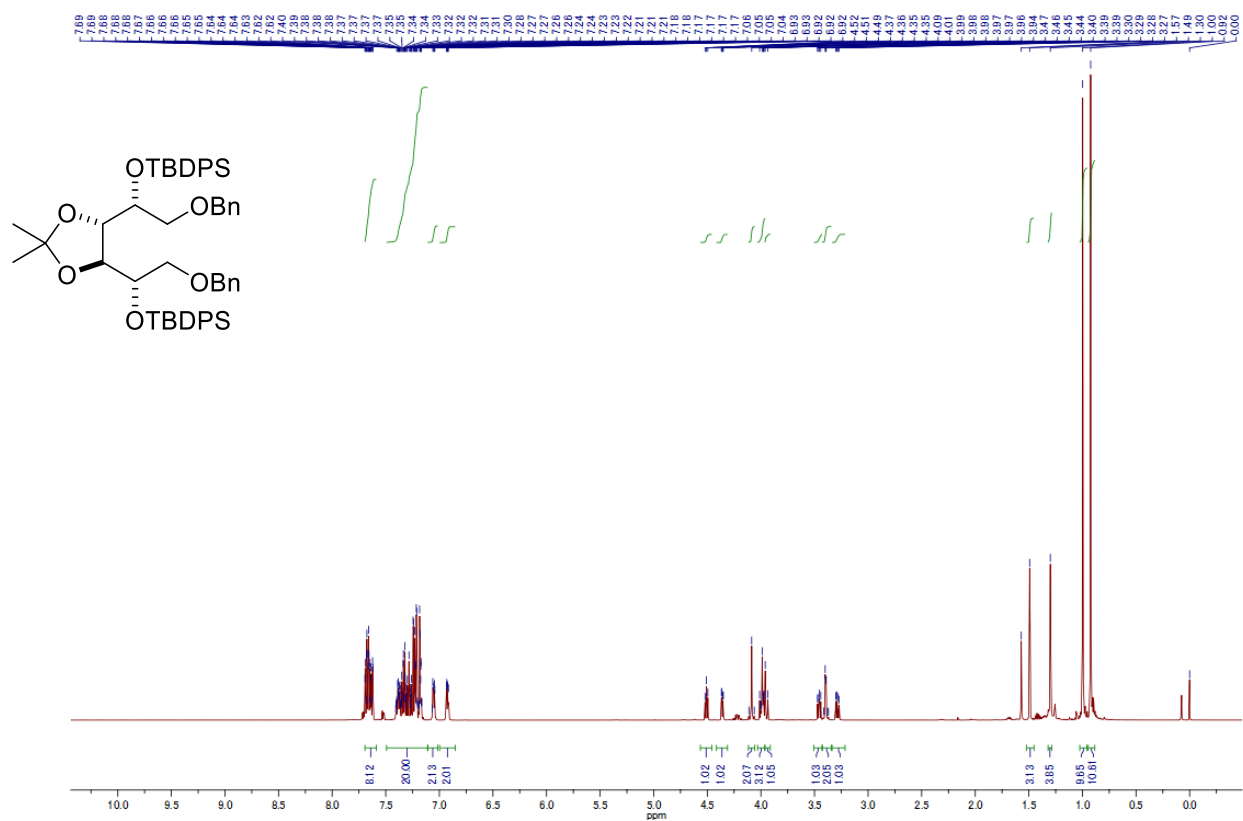


^{13}C NMR of S1

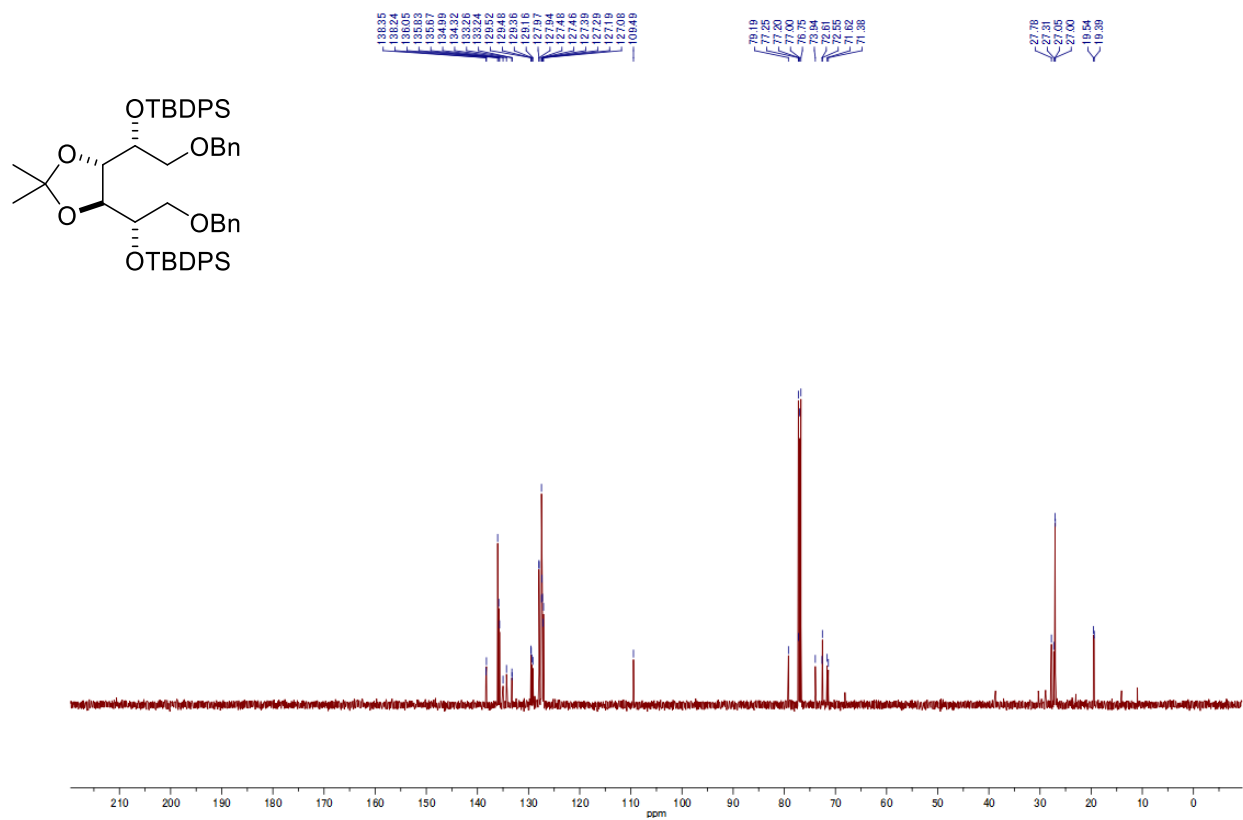


Supplementary Information

¹H NMR of S2

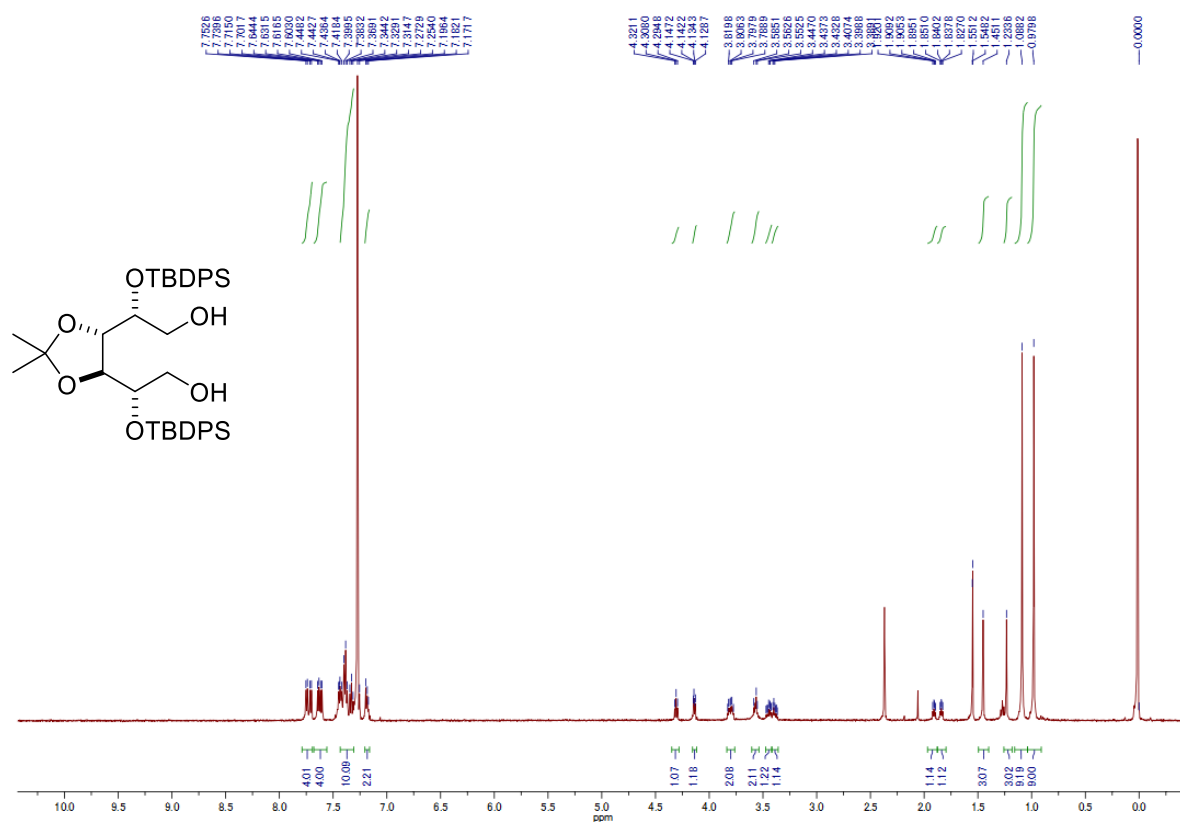


¹³C NMR of S2

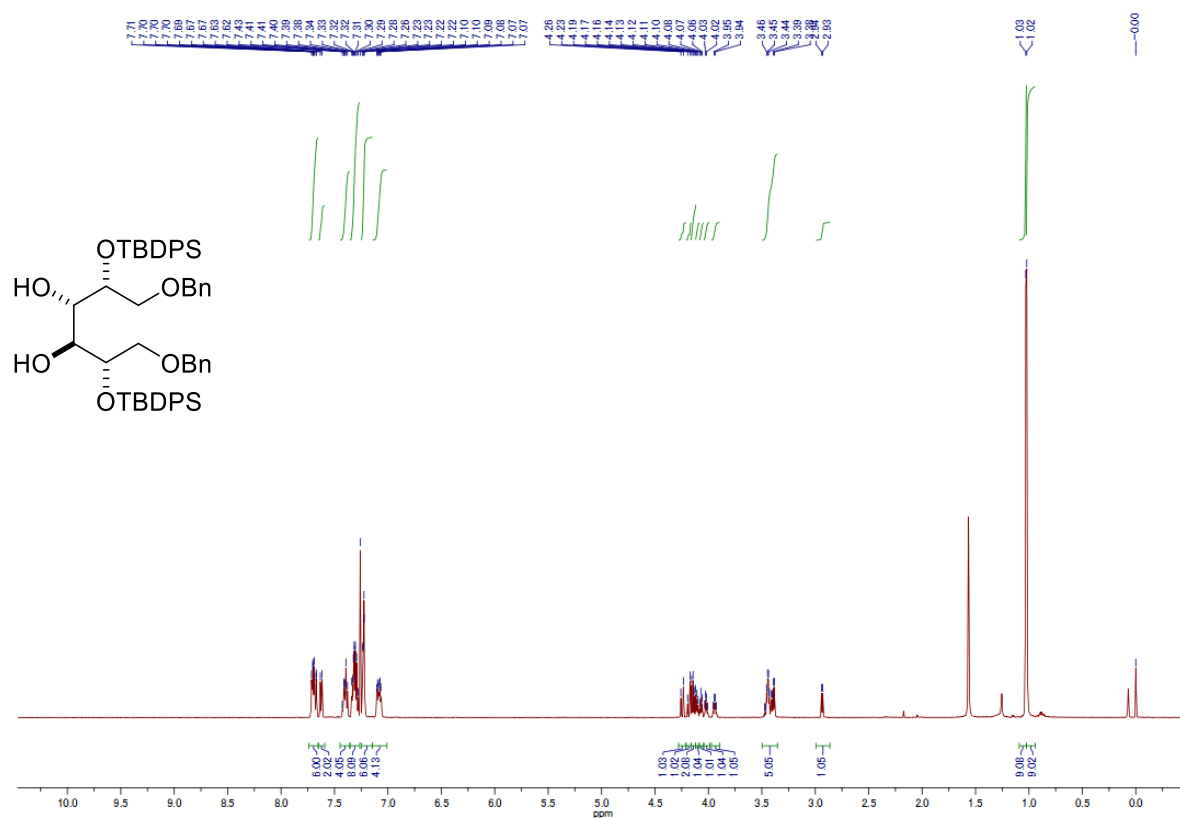


Supplementary Information

¹H NMR of S3

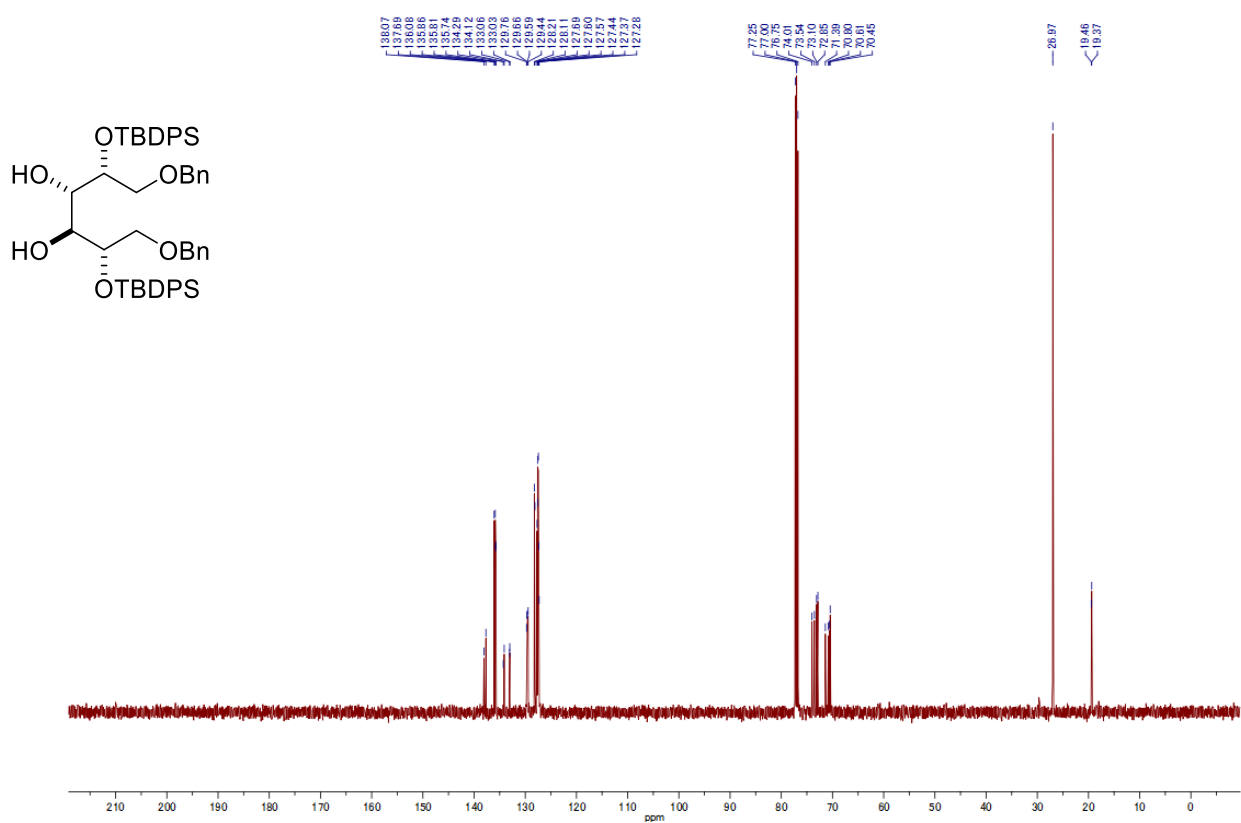


¹H NMR of S4

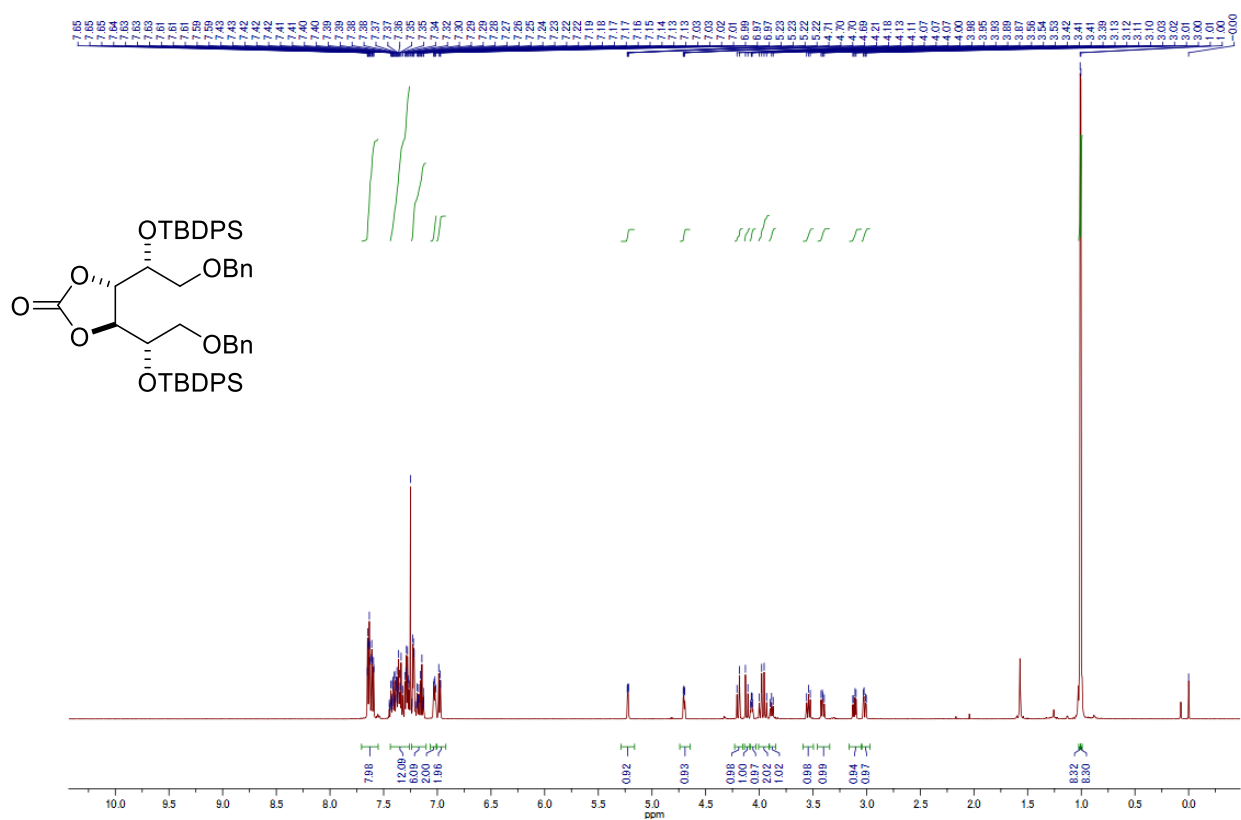


Supplementary Information

^{13}C NMR of **S4**

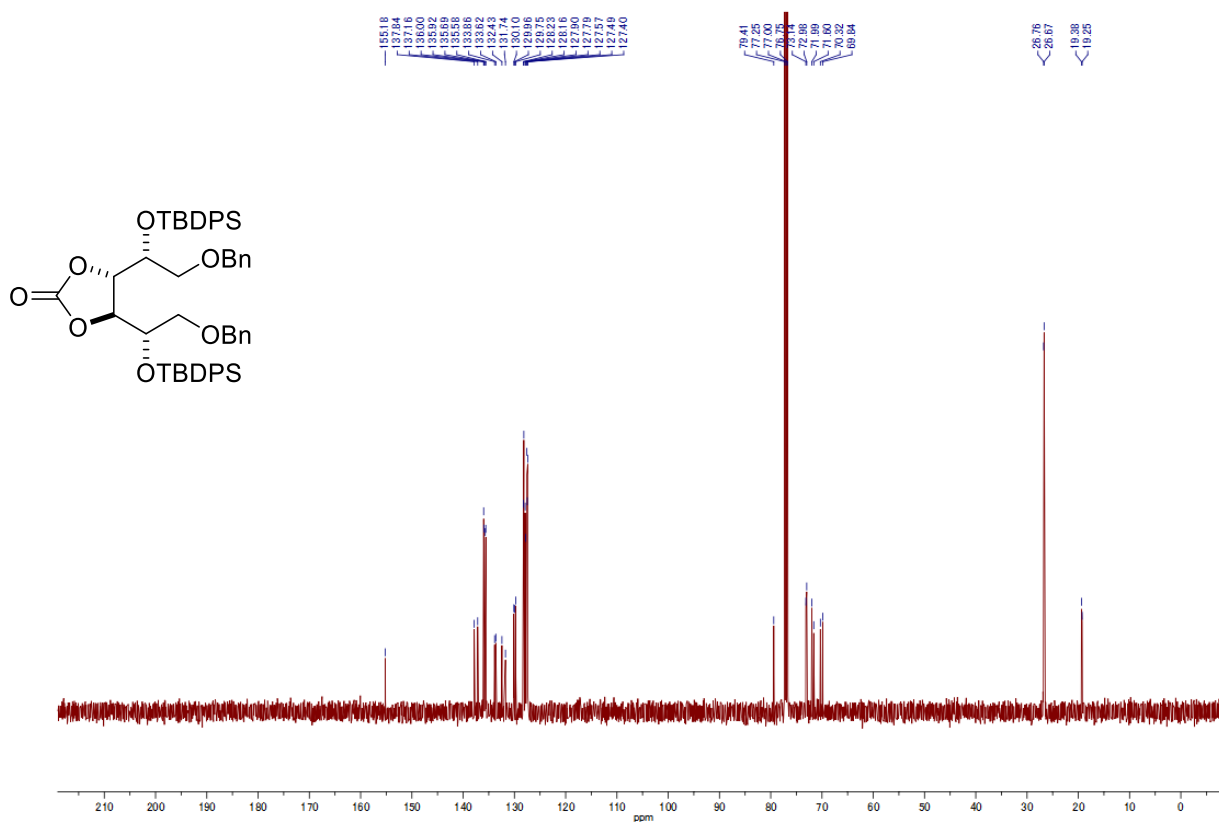


^1H NMR of **S5**

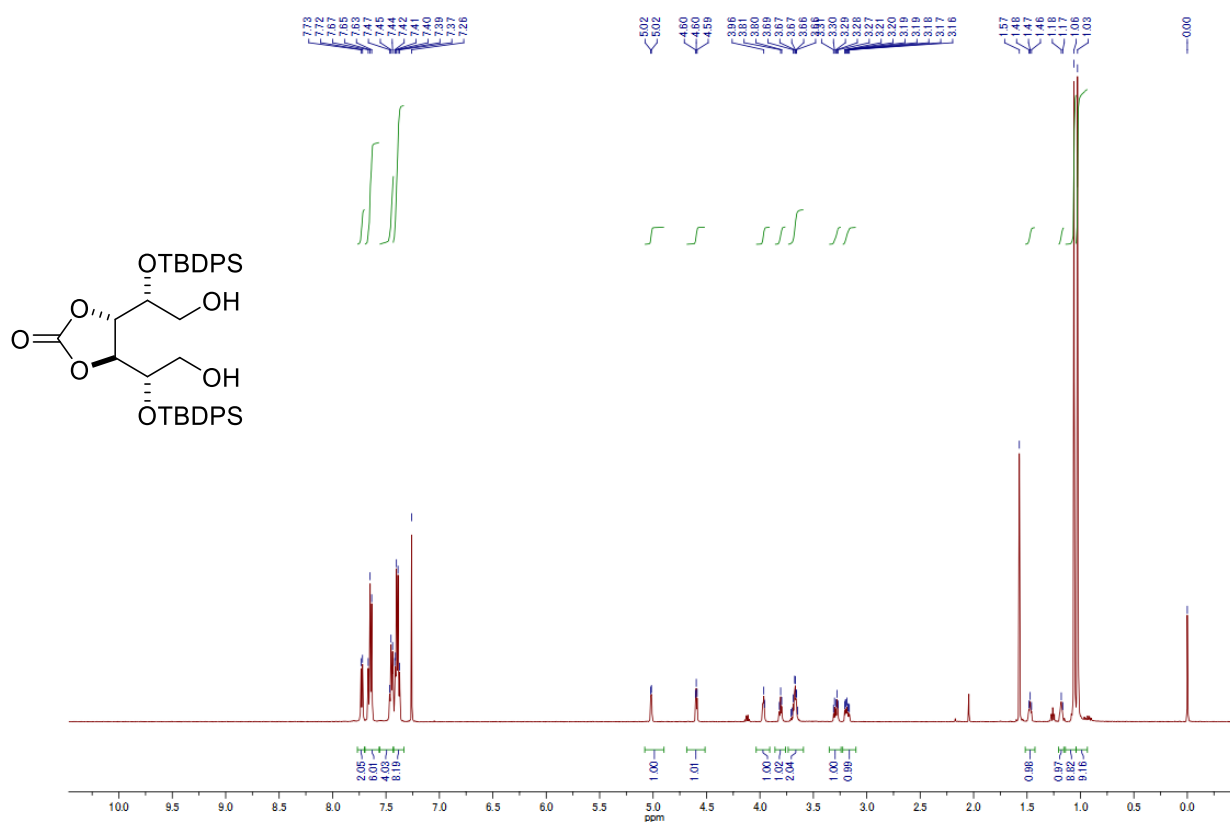


Supplementary Information

¹³C NMR of S5

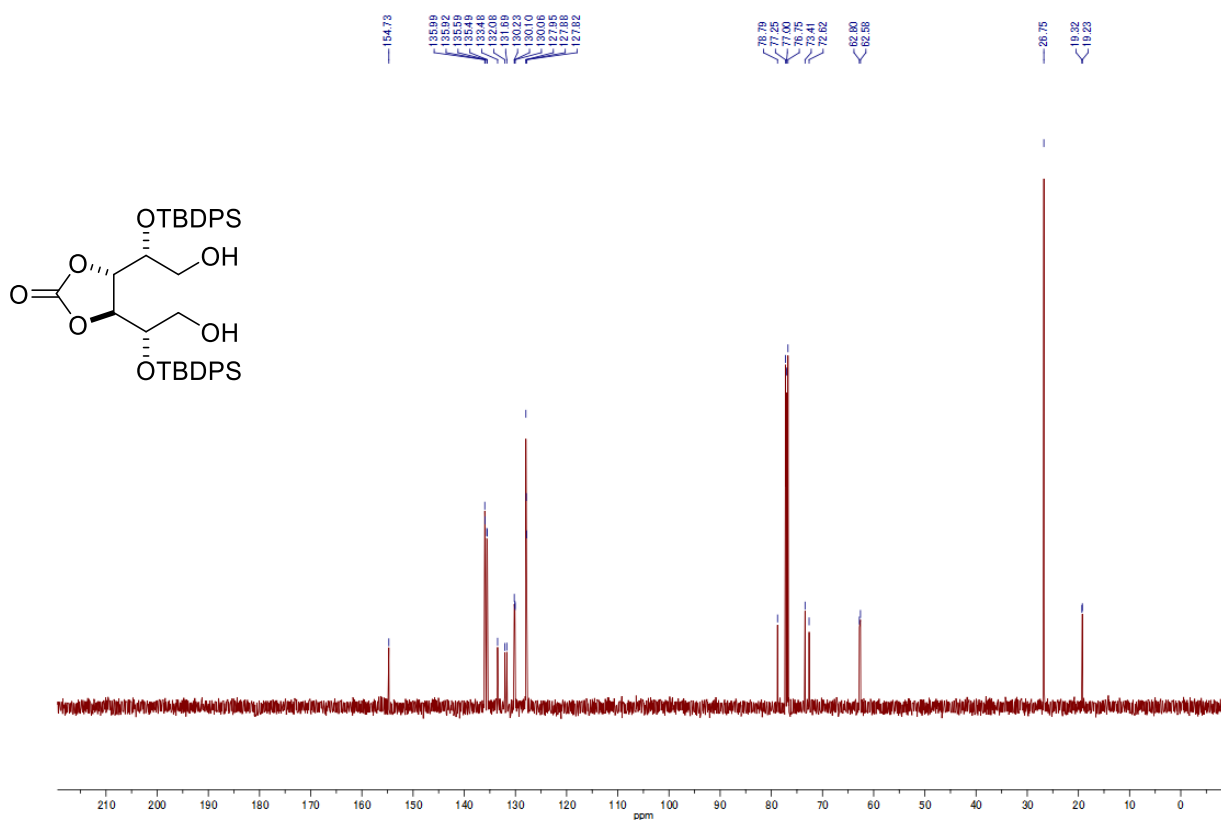


¹H NMR of S6

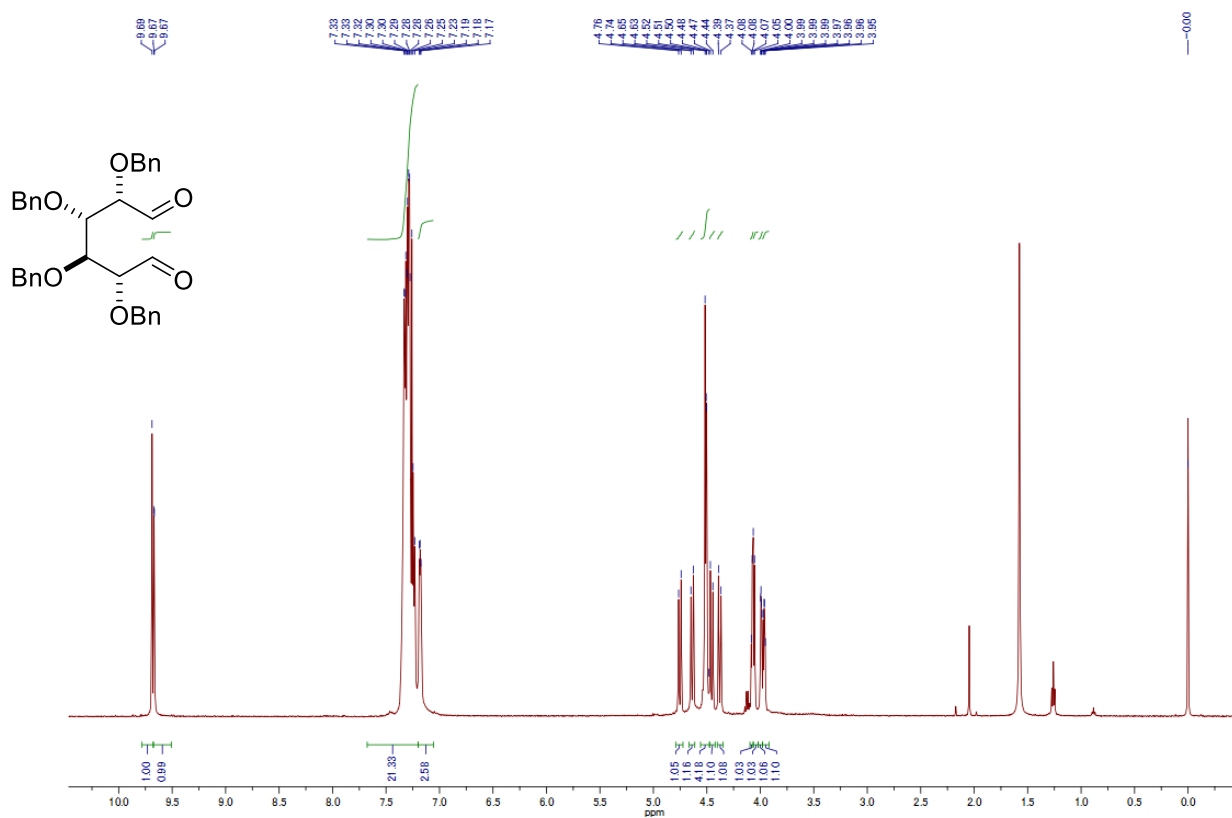


Supplementary Information

^{13}C NMR of **S6**

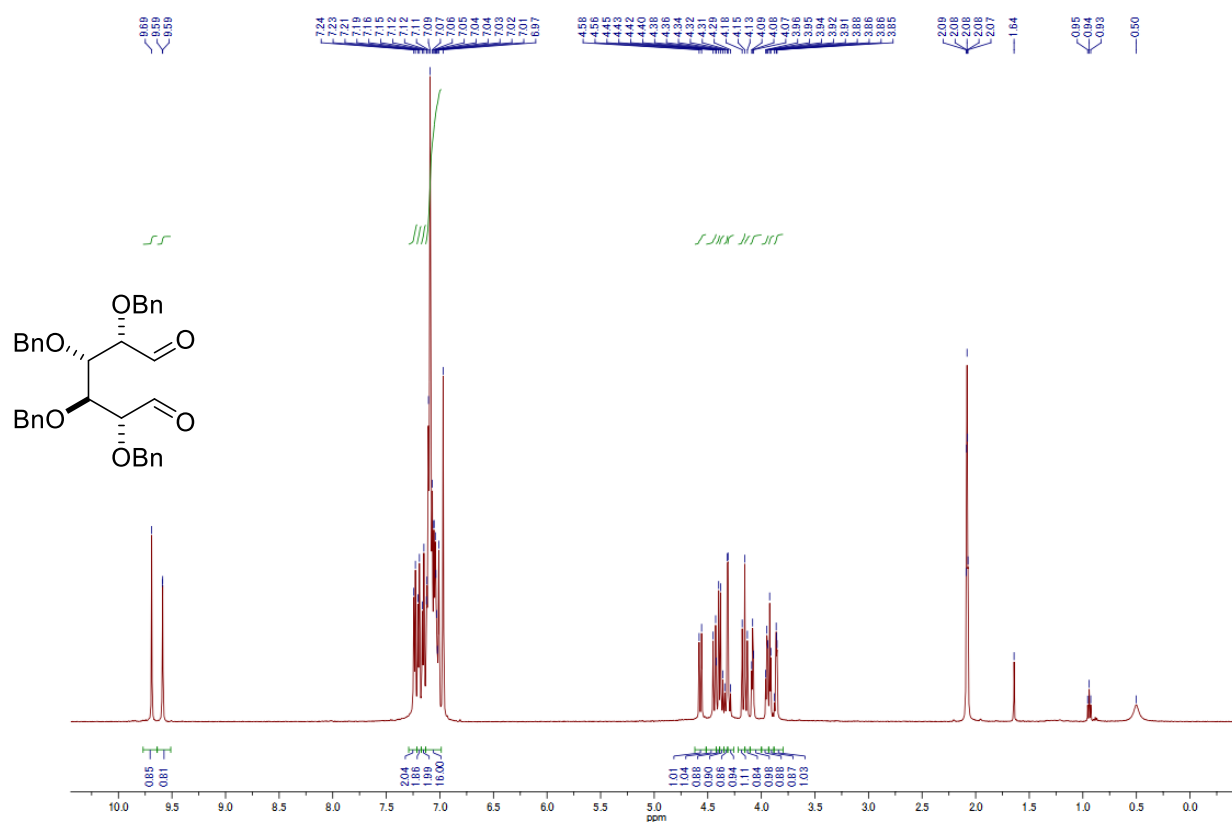


^1H NMR of **1a** (CDCl₃)

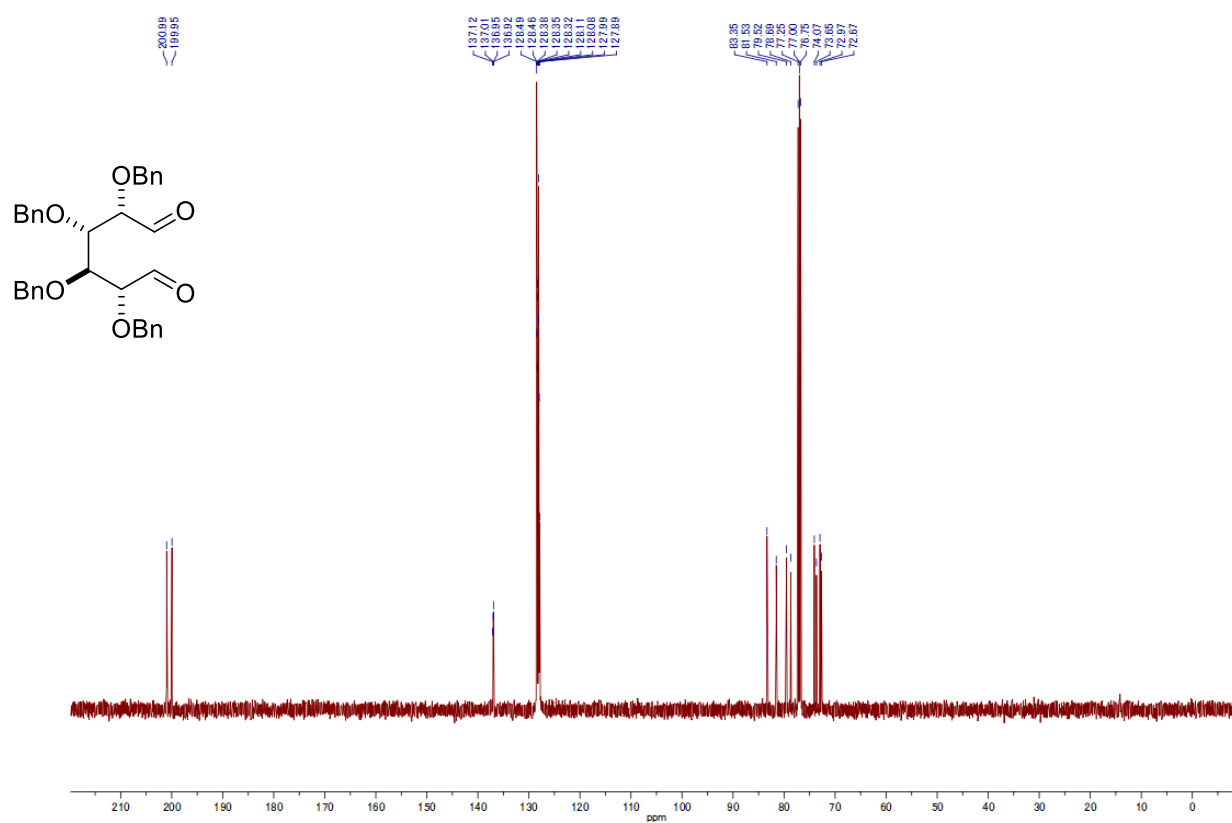


Supplementary Information

^1H NMR of **1a** (toluene- d_8)

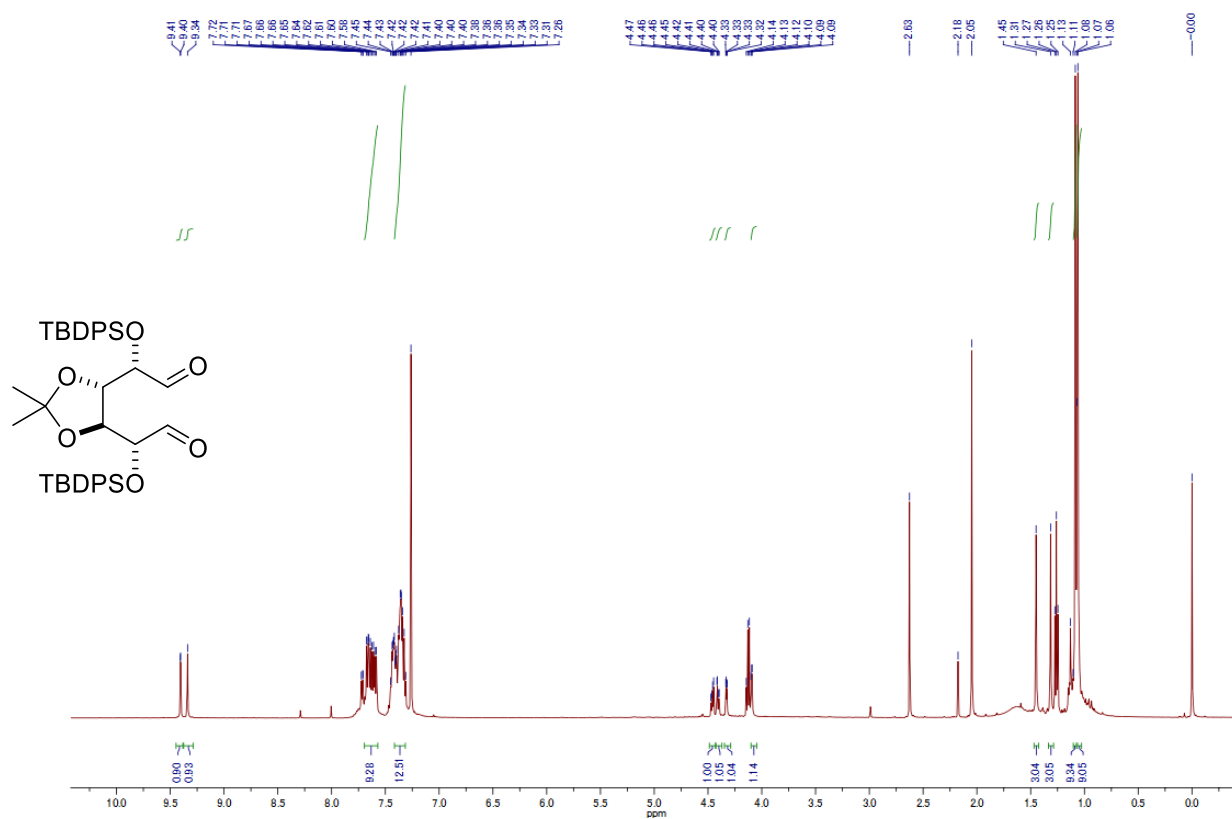


^{13}C NMR of **1a**

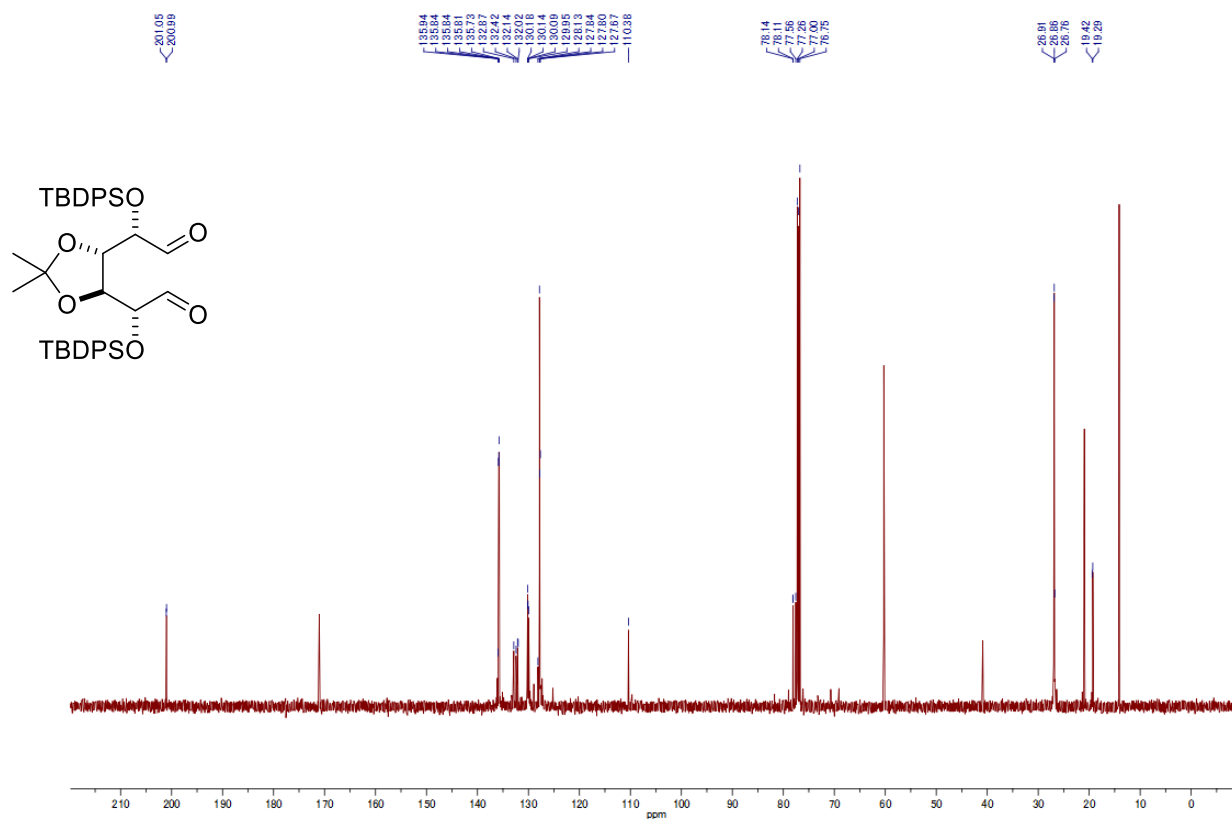


Supplementary Information

¹H NMR of **1b**

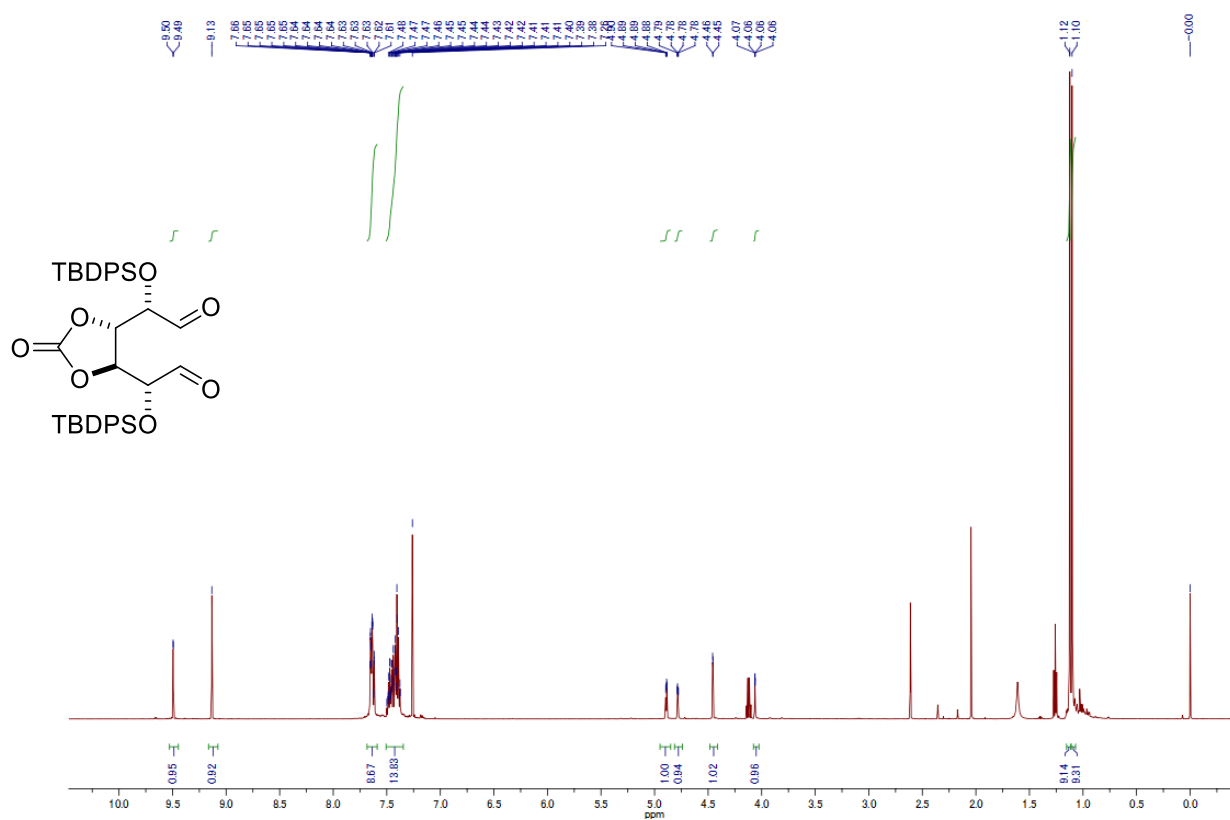


¹³C NMR of **1b**

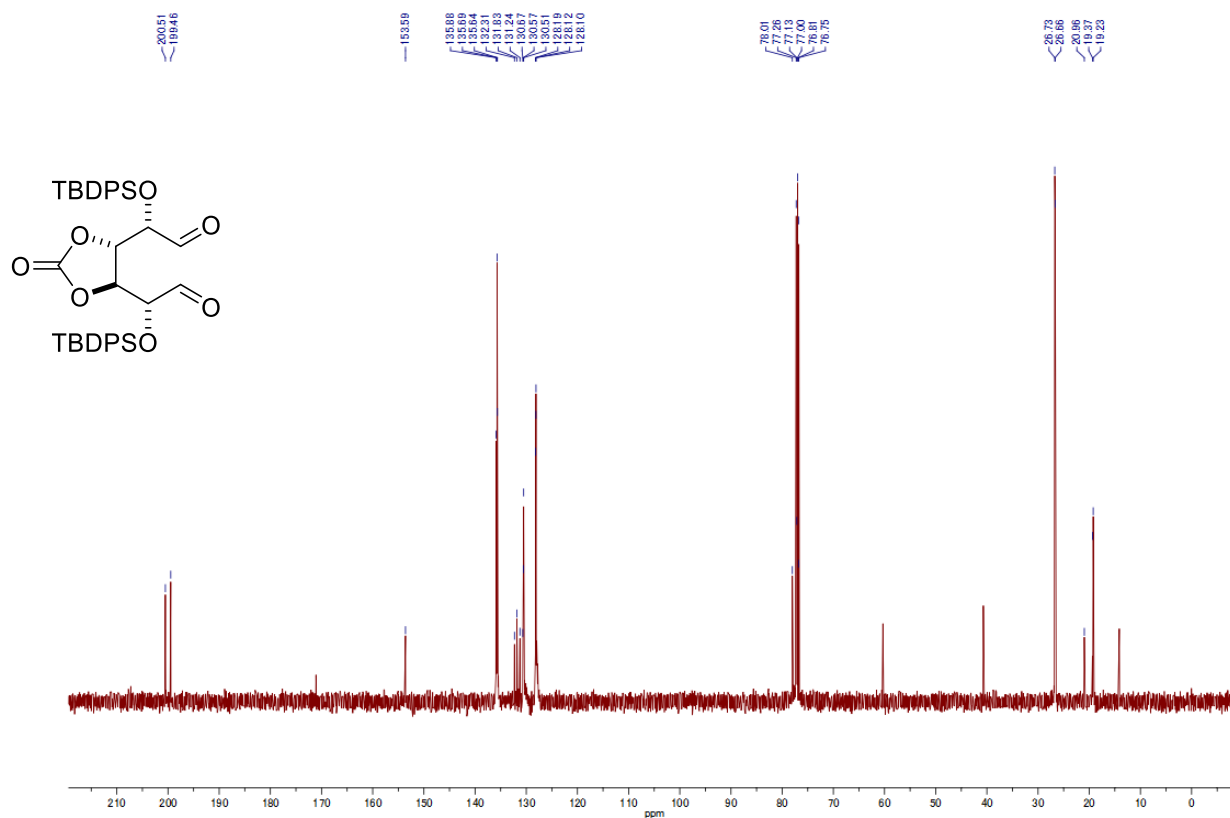


Supplementary Information

^1H NMR of **1d**

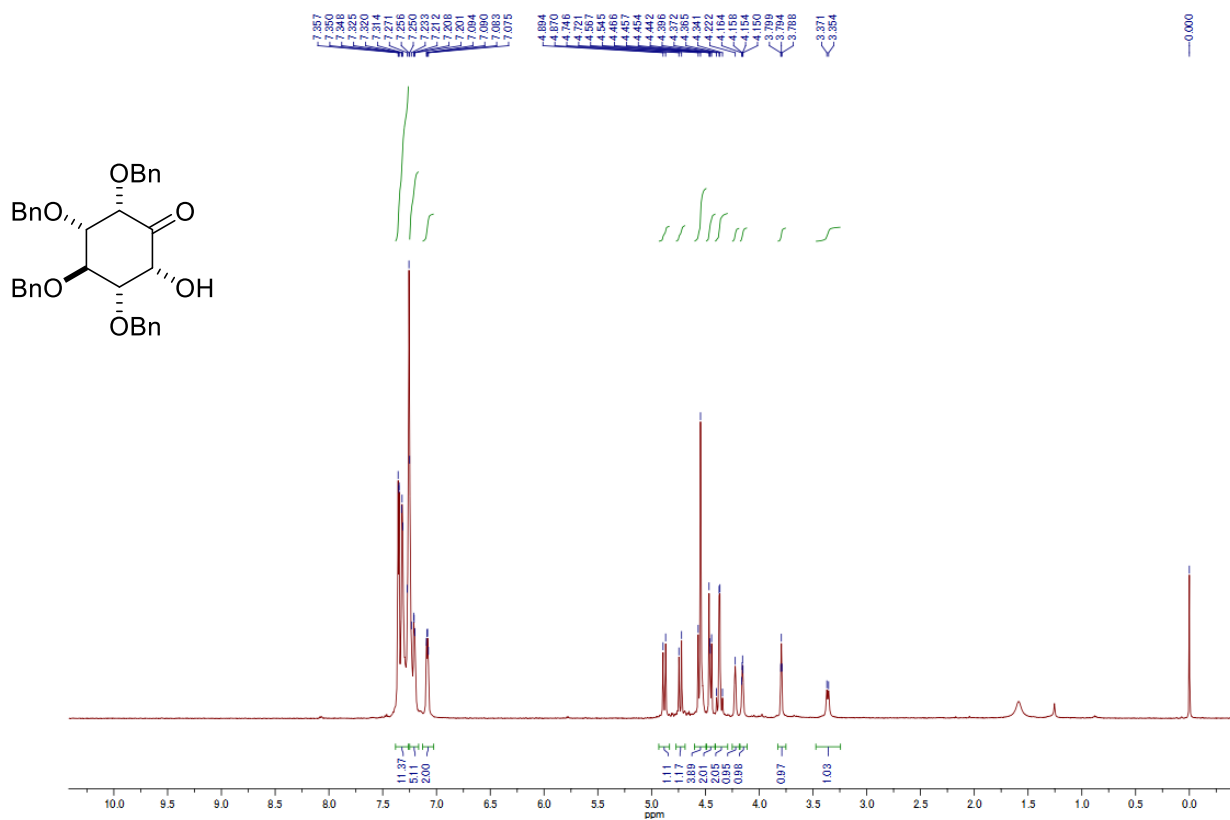


^{13}C NMR of **1d**

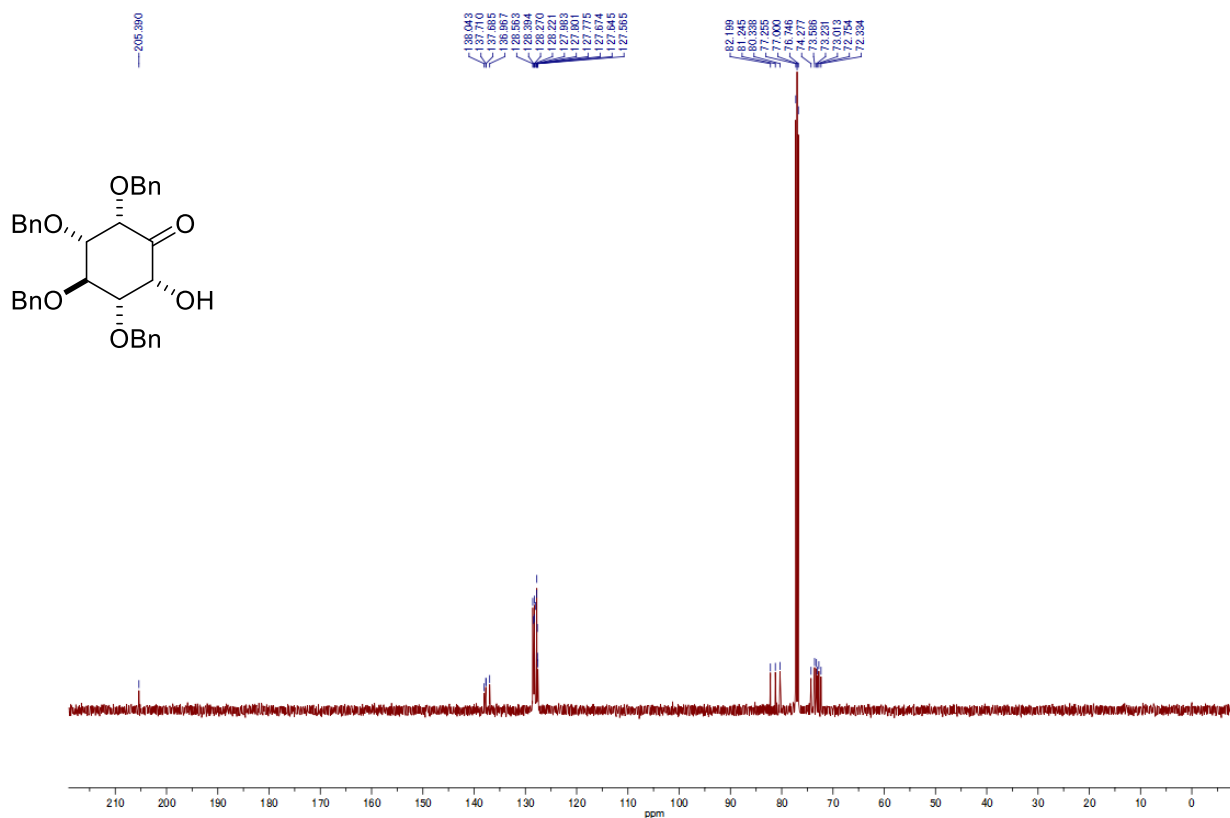


Supplementary Information

¹H NMR of **2aa**

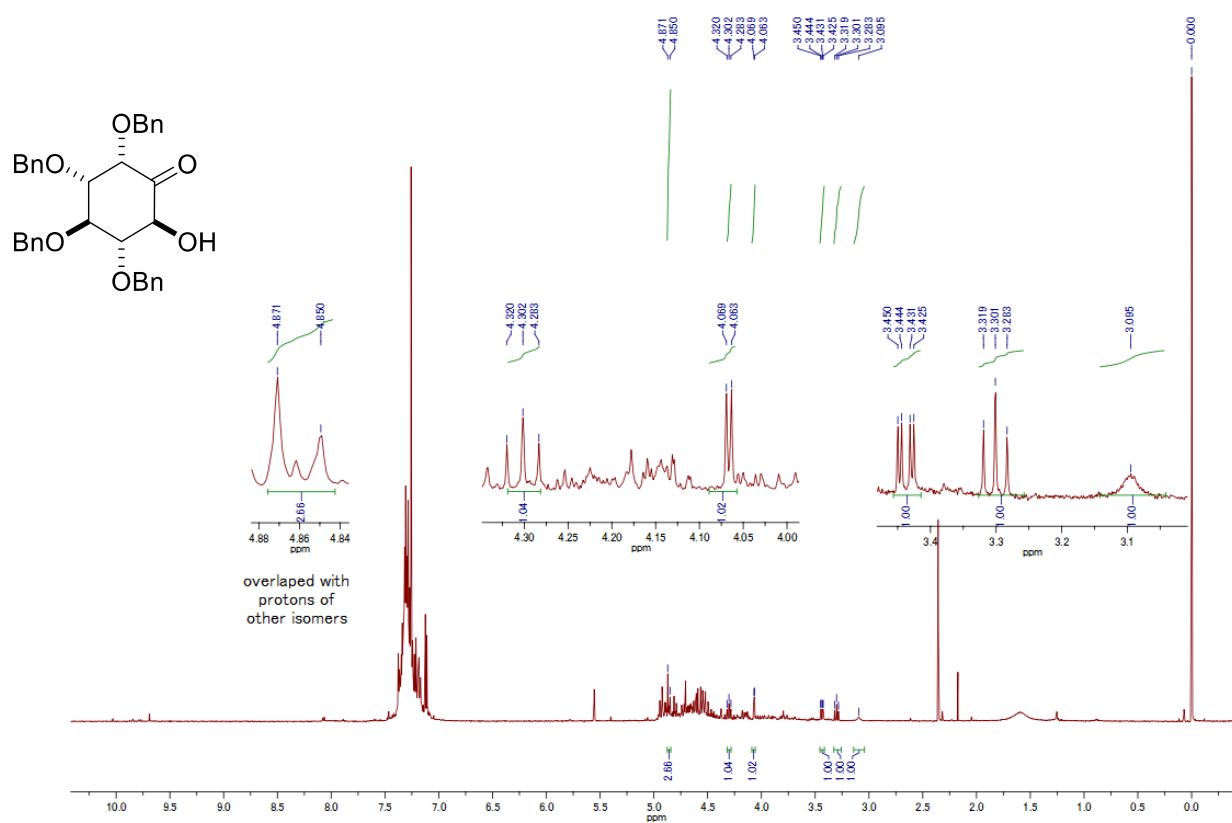


¹³C NMR of **2aa**

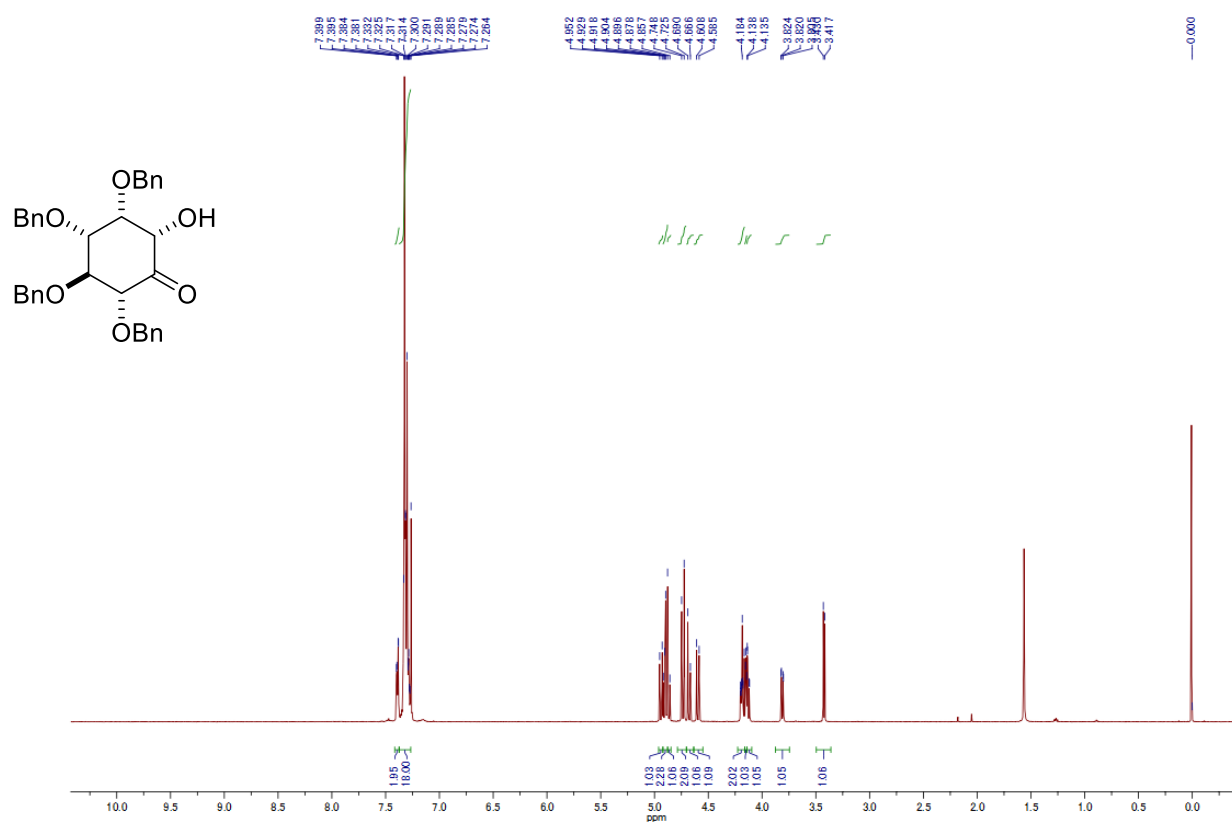


Supplementary Information

^1H NMR of **2a β** (crude)

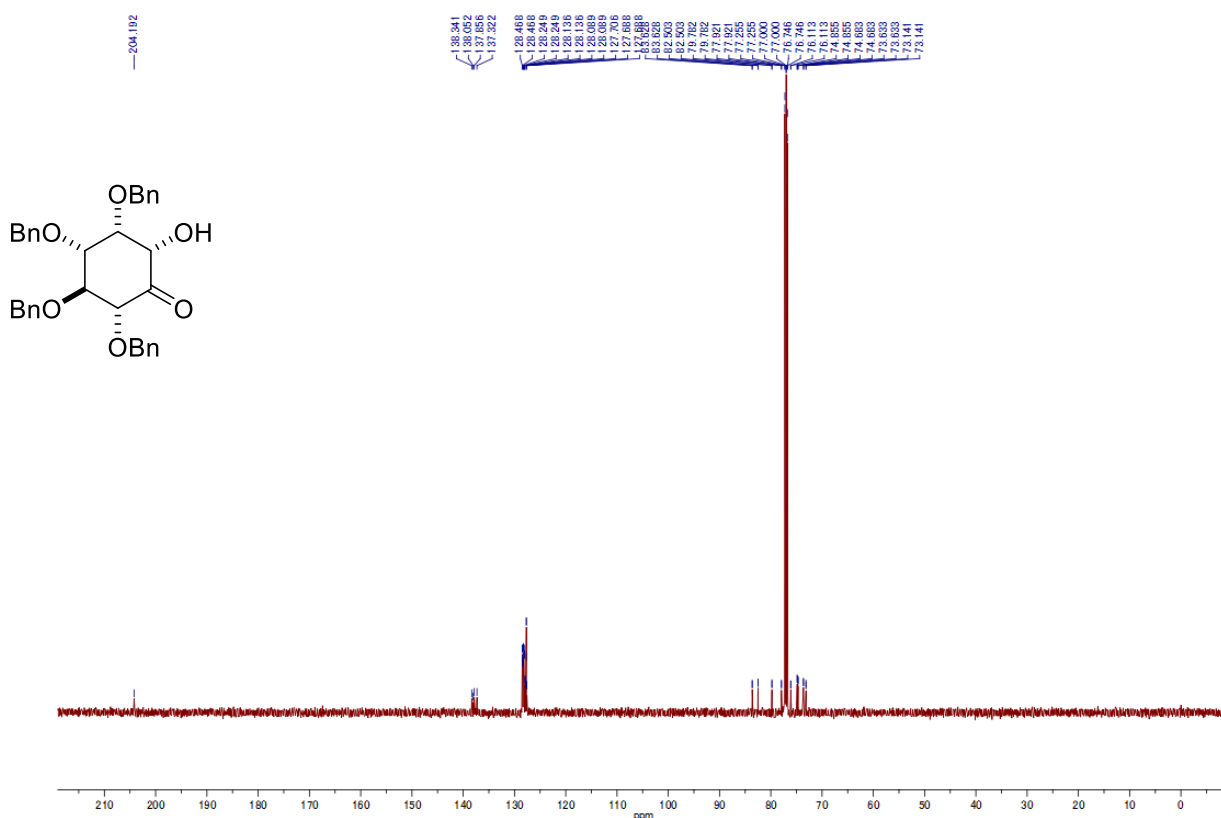


^1H NMR of **3a α**

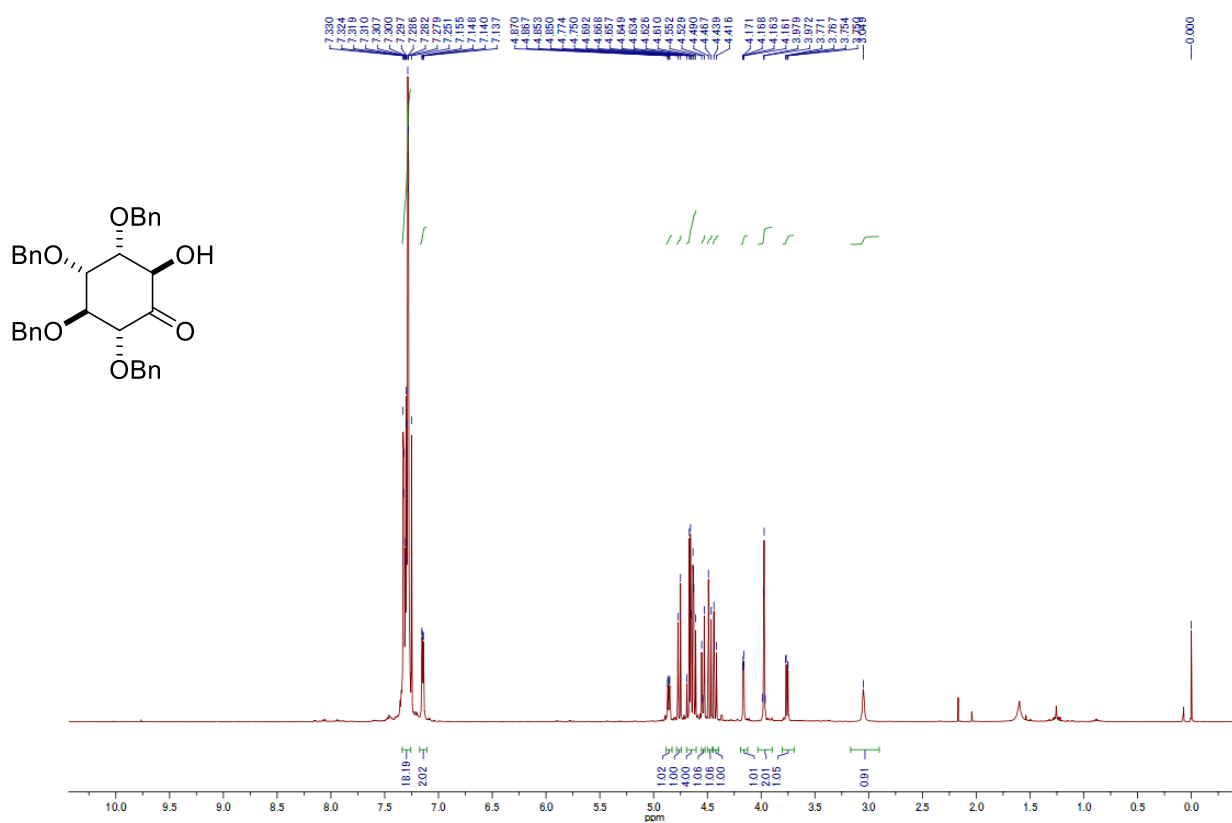


Supplementary Information

^{13}C NMR of **3a α**

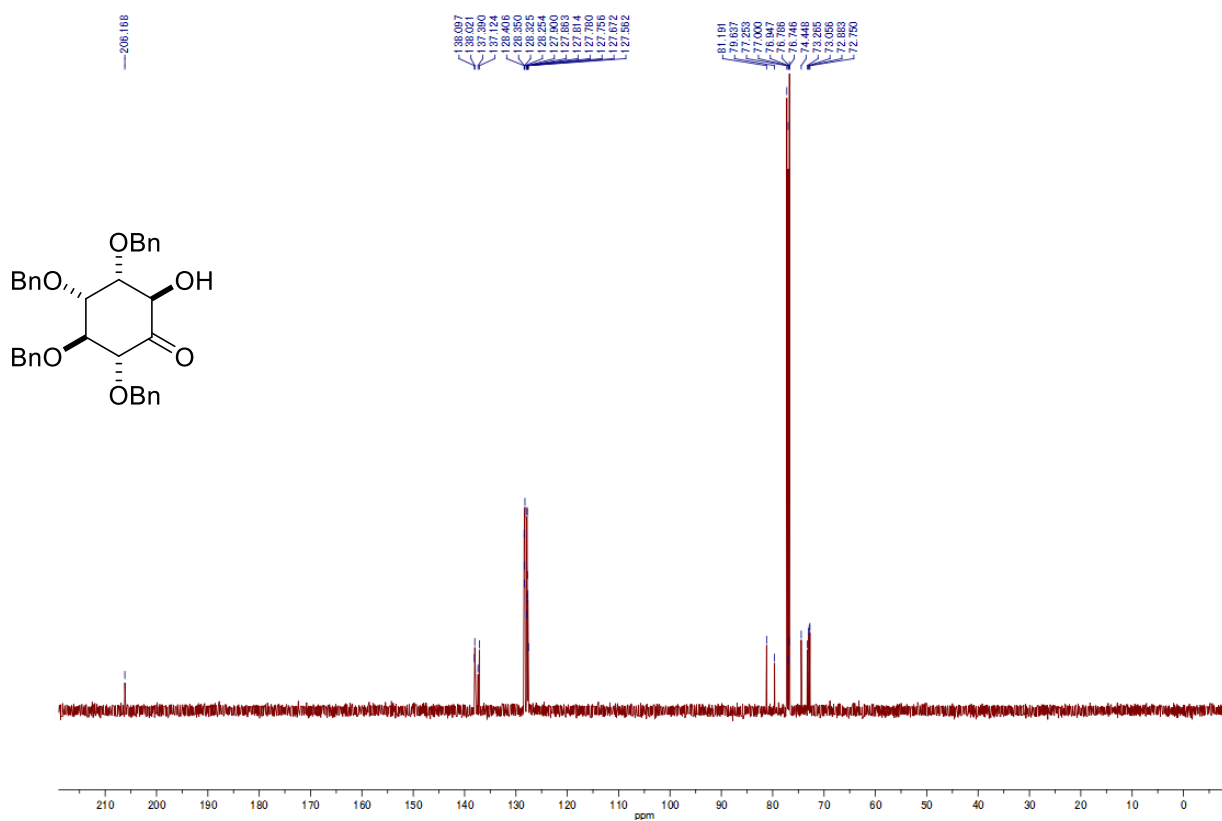


^1H NMR of **3a β**

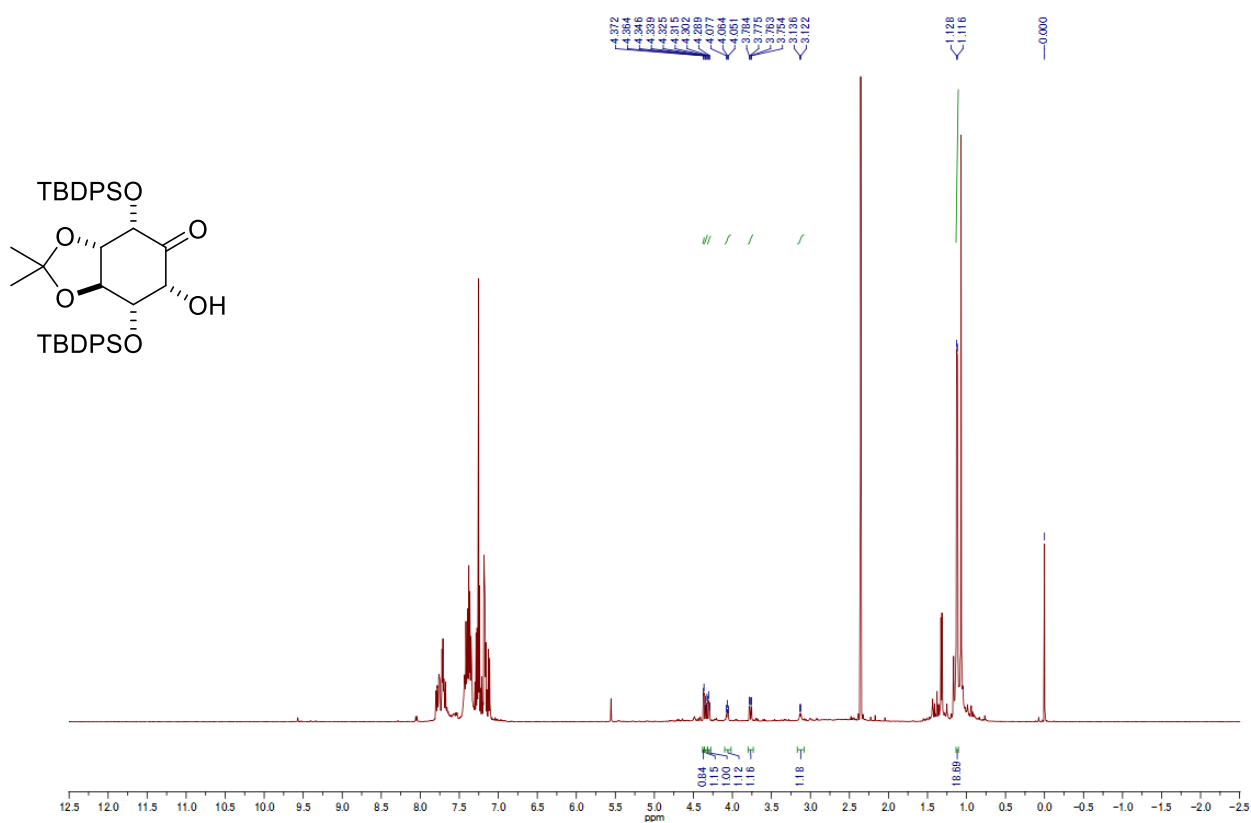


Supplementary Information

^{13}C NMR of **3a β**

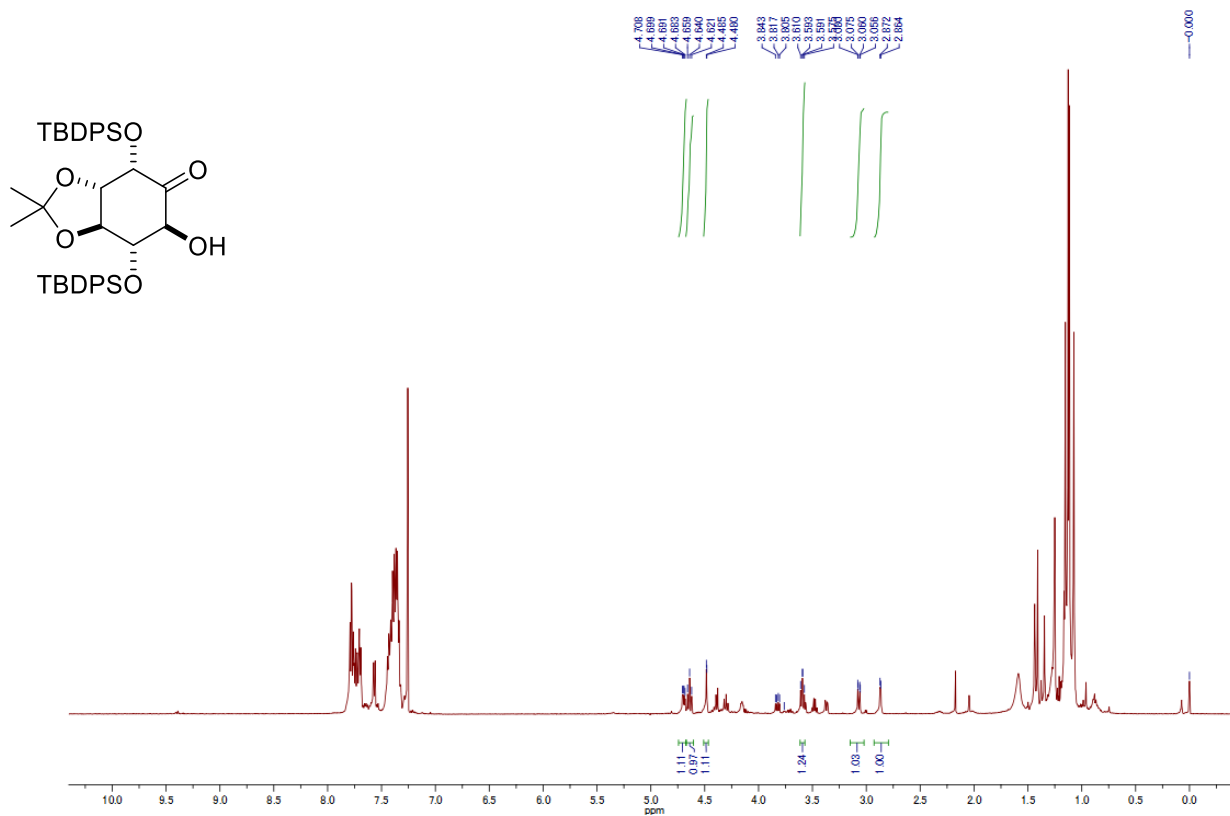


^1H NMR of **2ba** (crude)

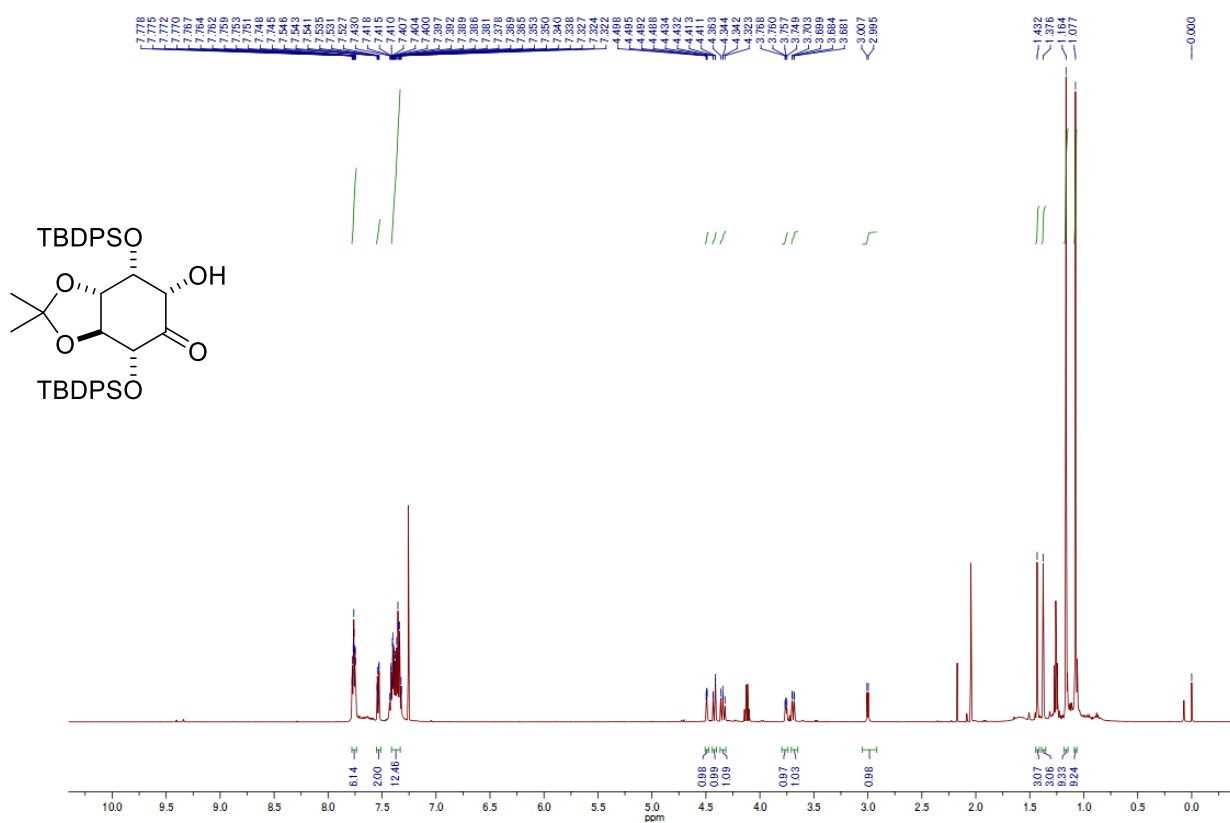


Supplementary Information

^1H NMR of **2b β**

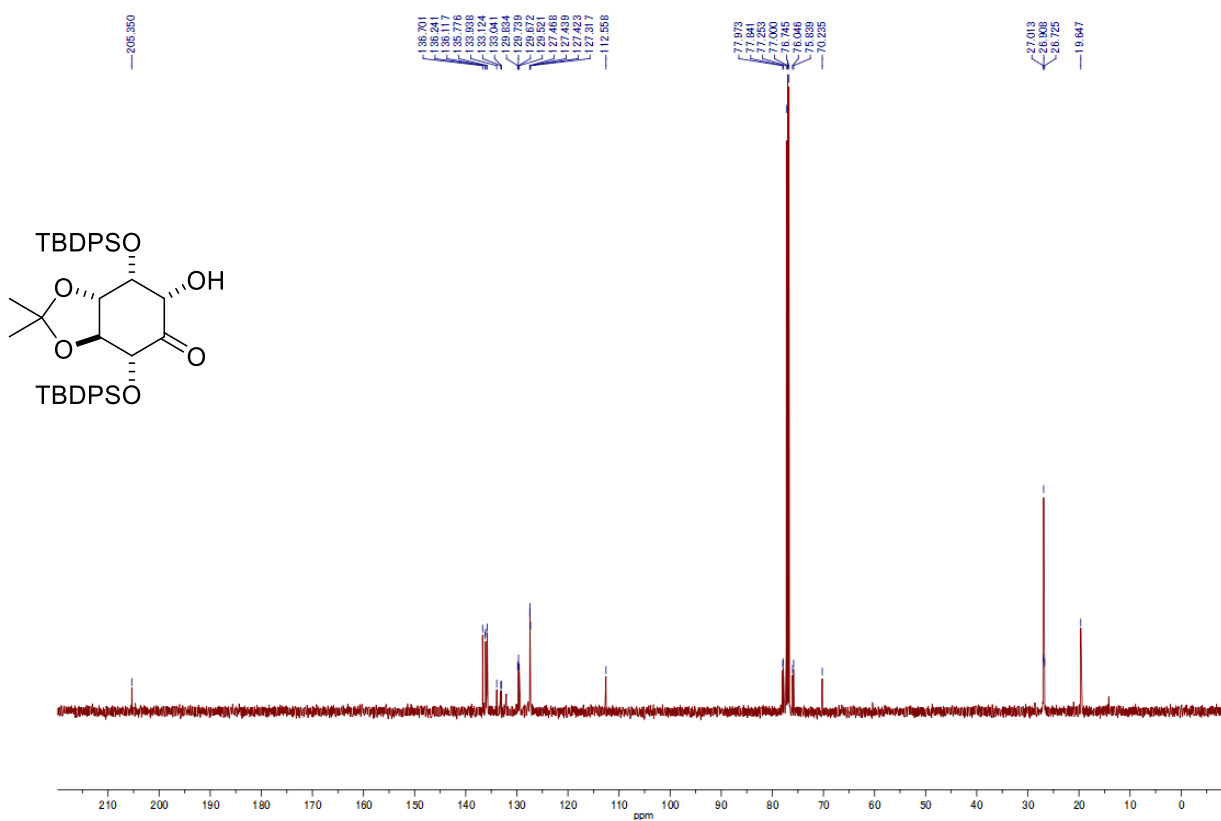


^1H NMR of **3ba**

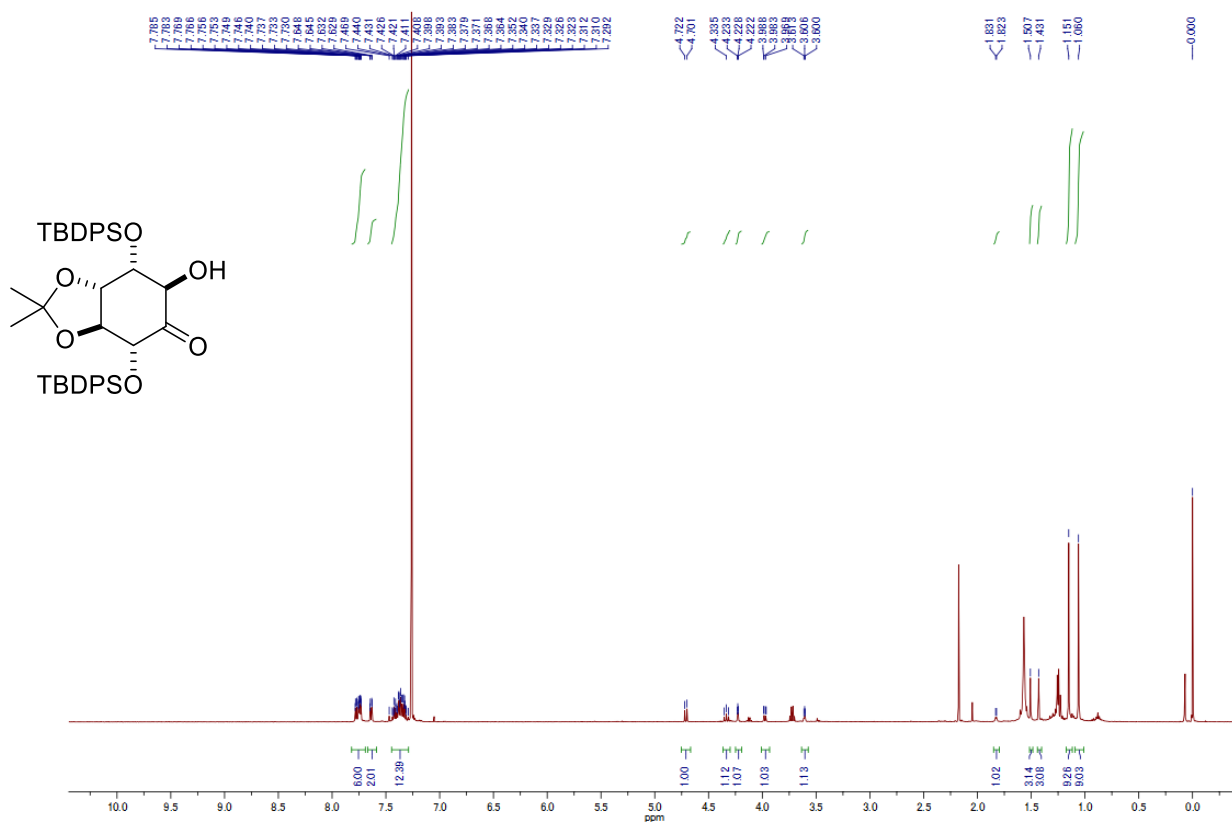


Supplementary Information

^{13}C NMR of **3ba**

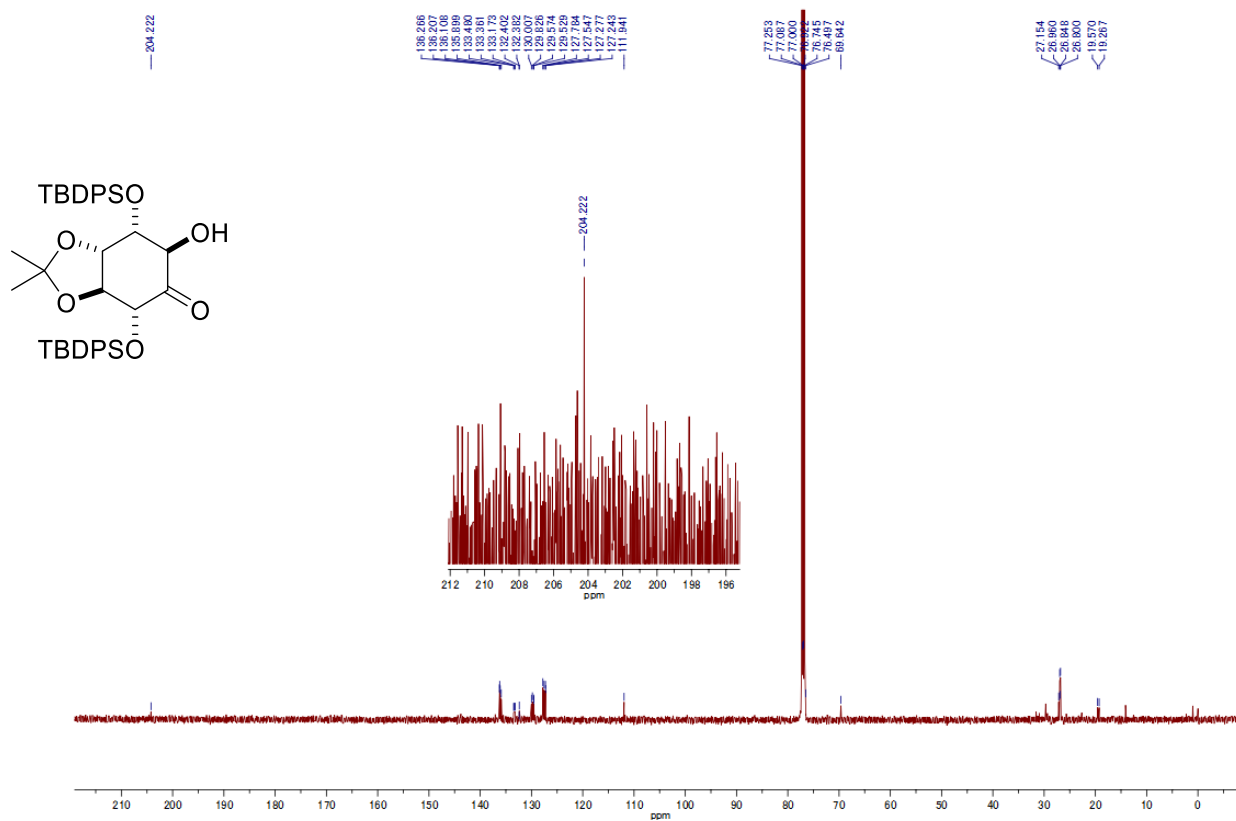


^1H NMR of **3b β**

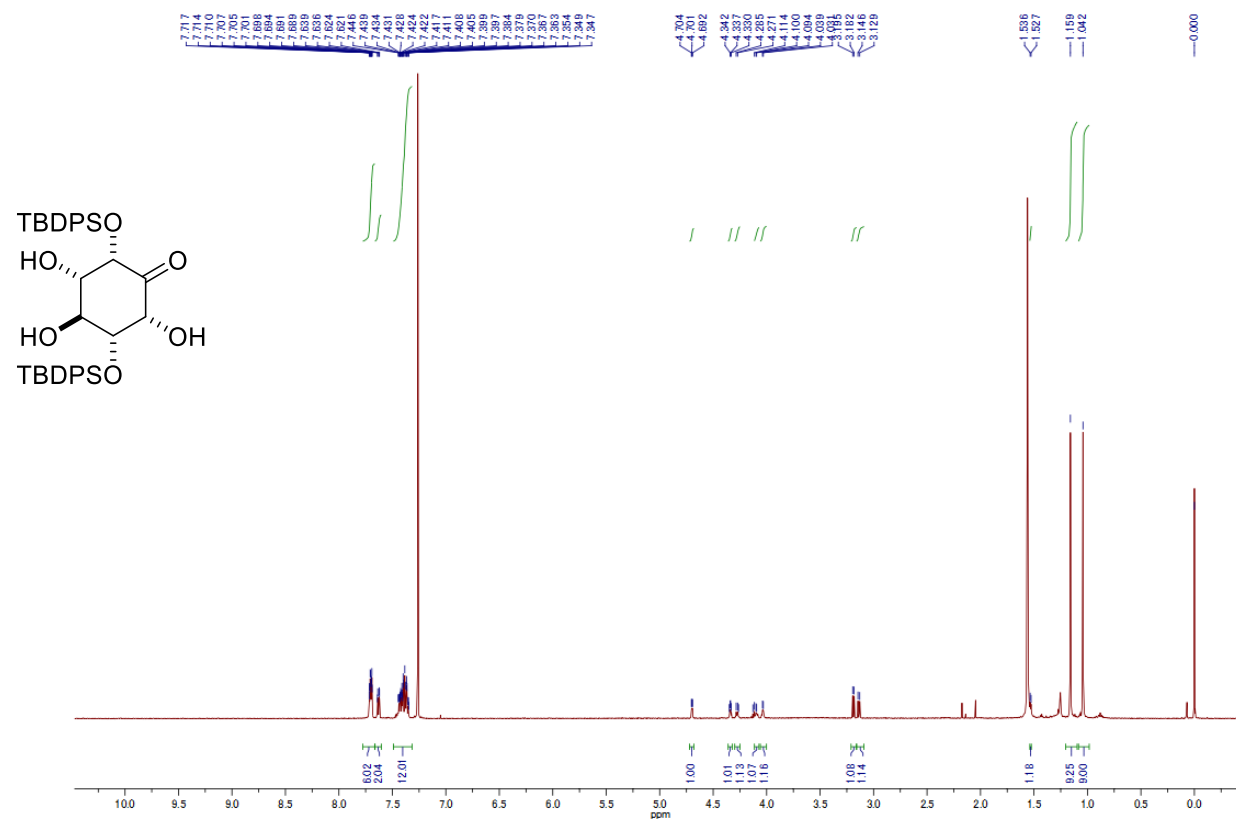


Supplementary Information

^{13}C NMR of **3b β**

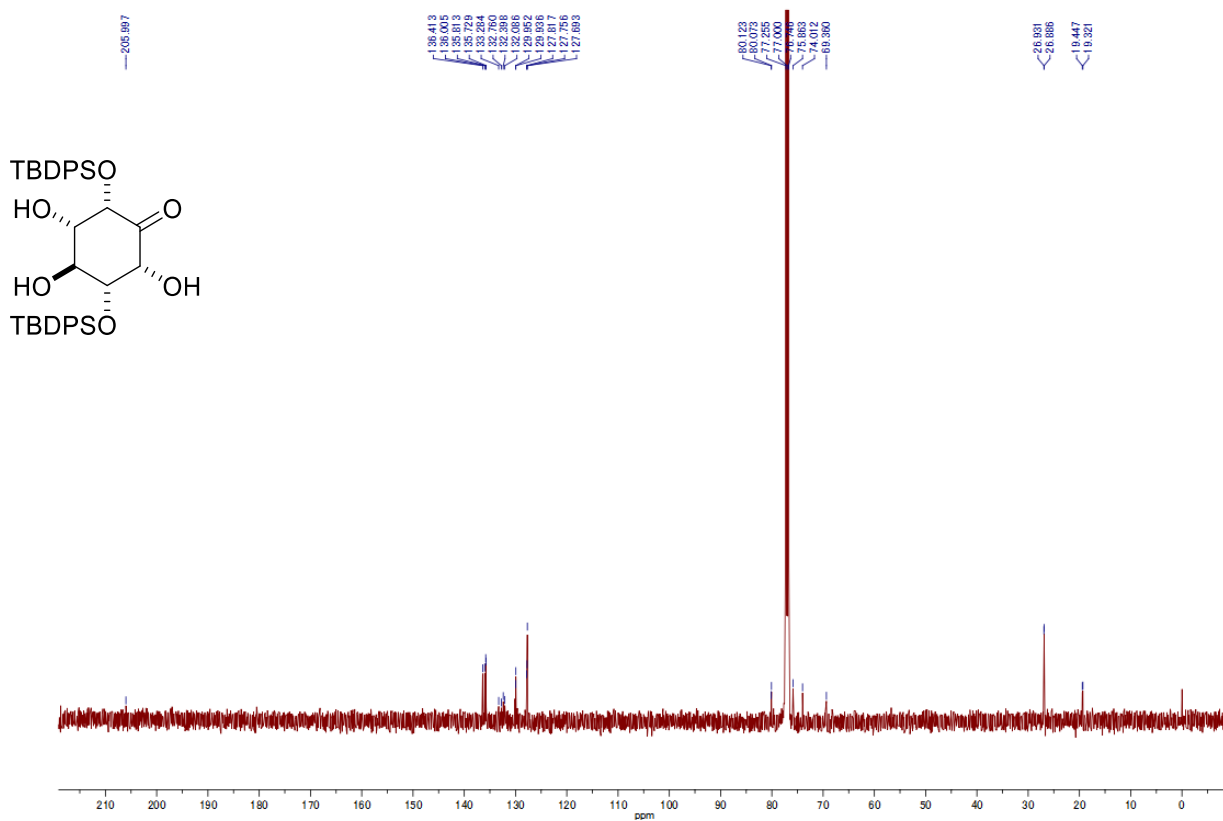


^1H NMR of **2c α**



Supplementary Information

^{13}C NMR of **2ca**

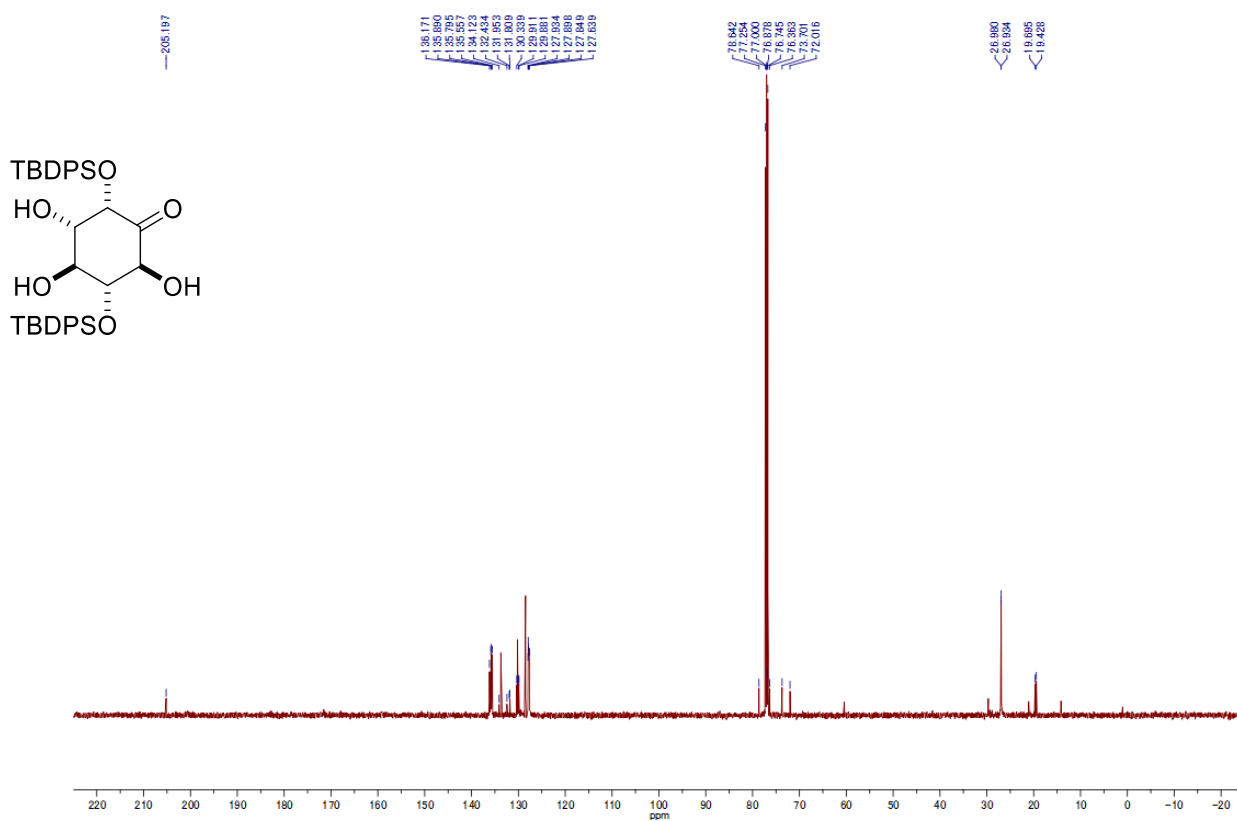


^1H NMR of **2c β**

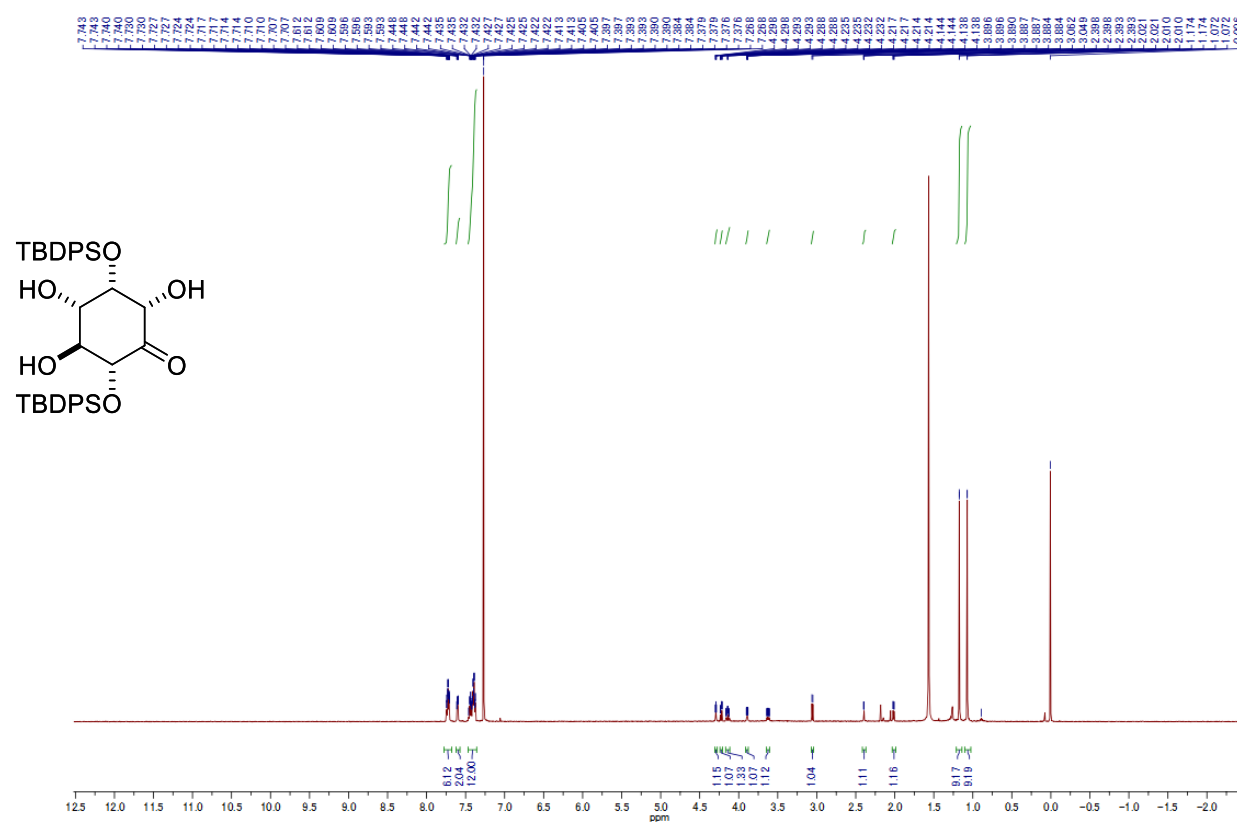


Supplementary Information

^{13}C NMR of **2c β**

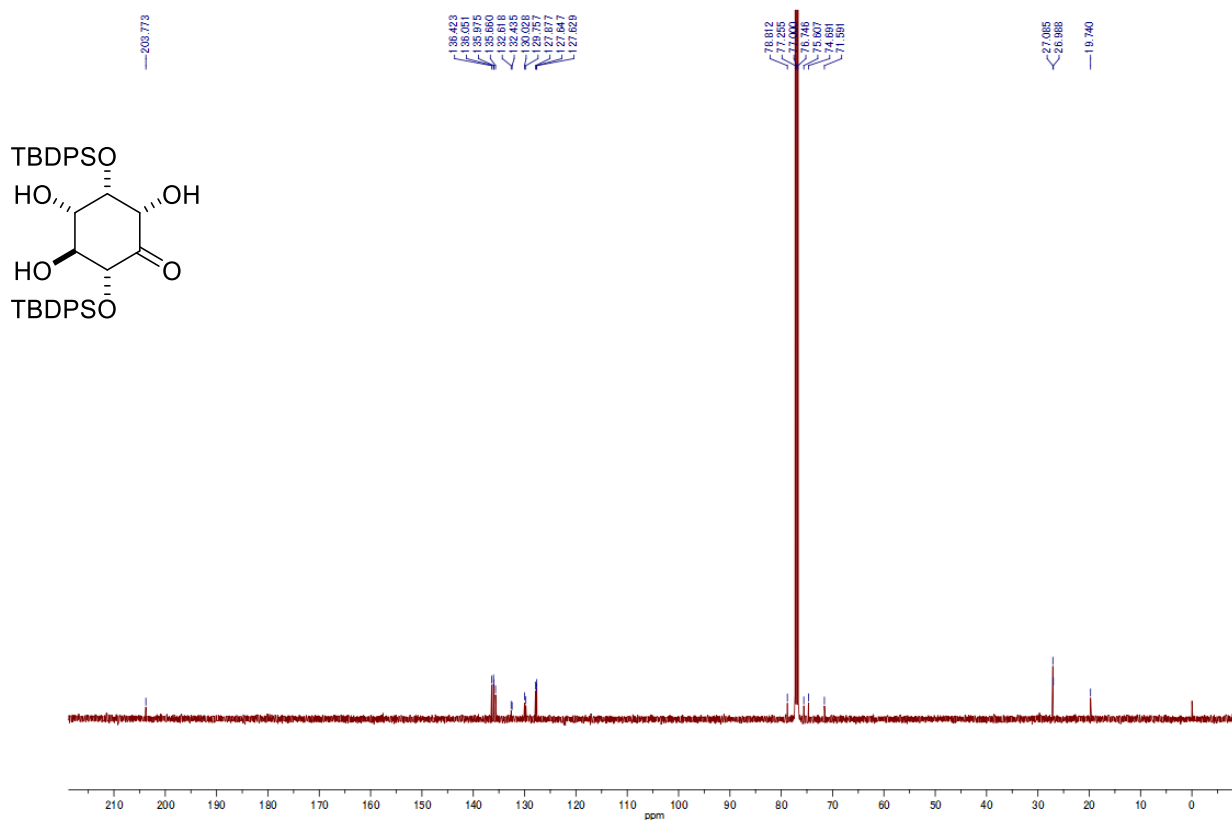


^1H NMR of **3c α**

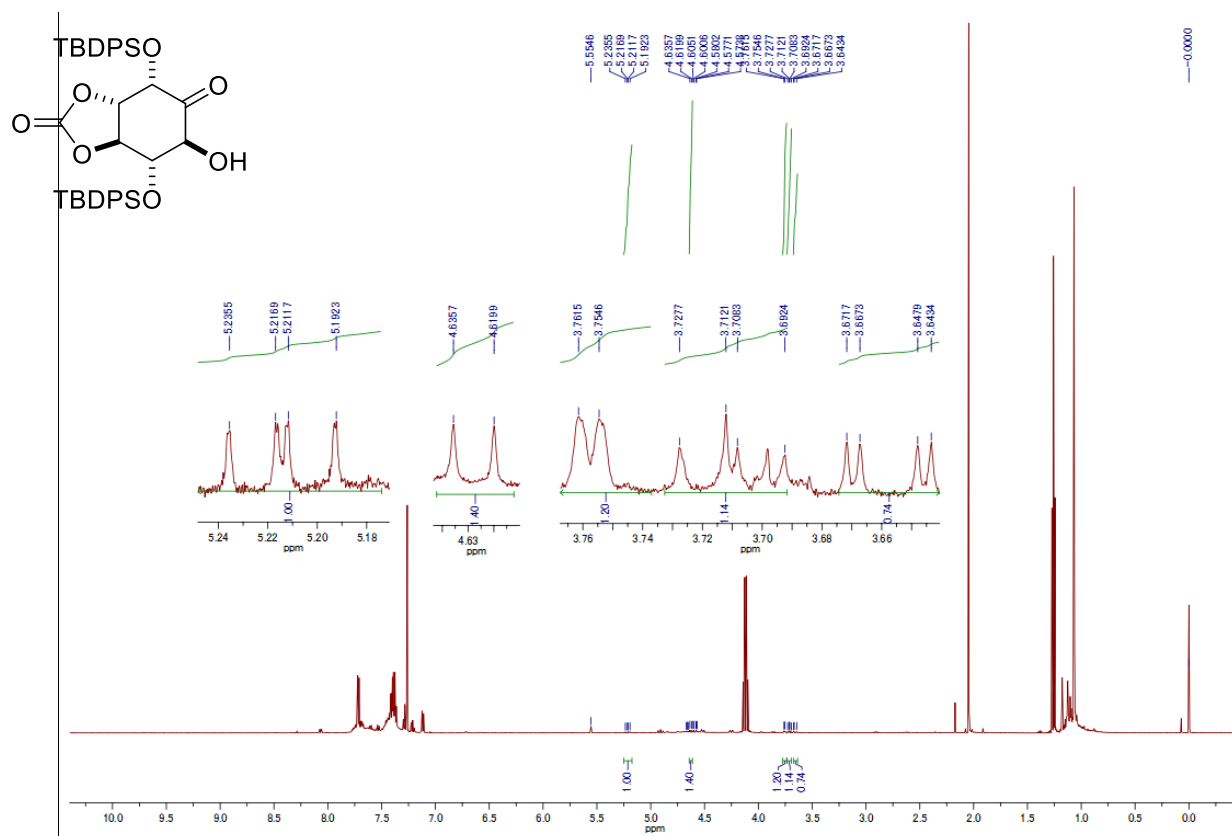


Supplementary Information

^{13}C NMR of **3ca**

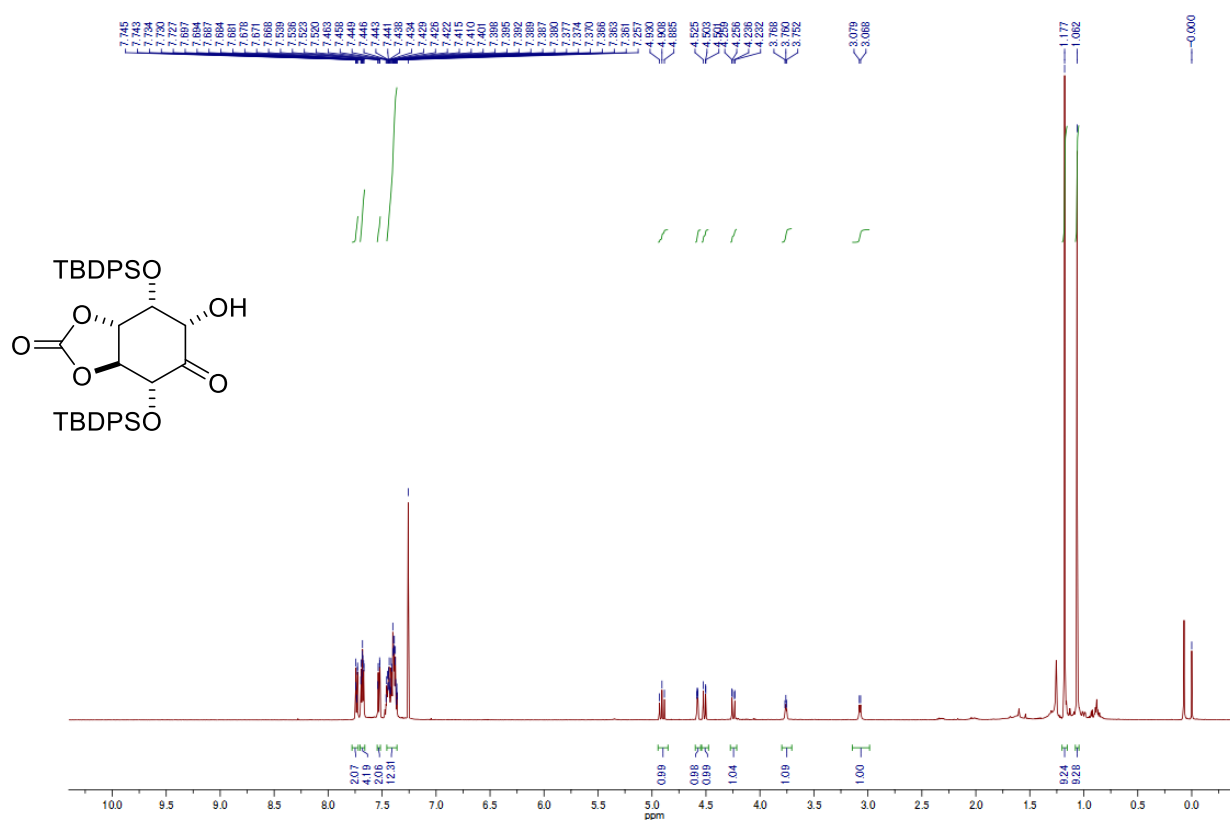


^1H NMR of **2d β**

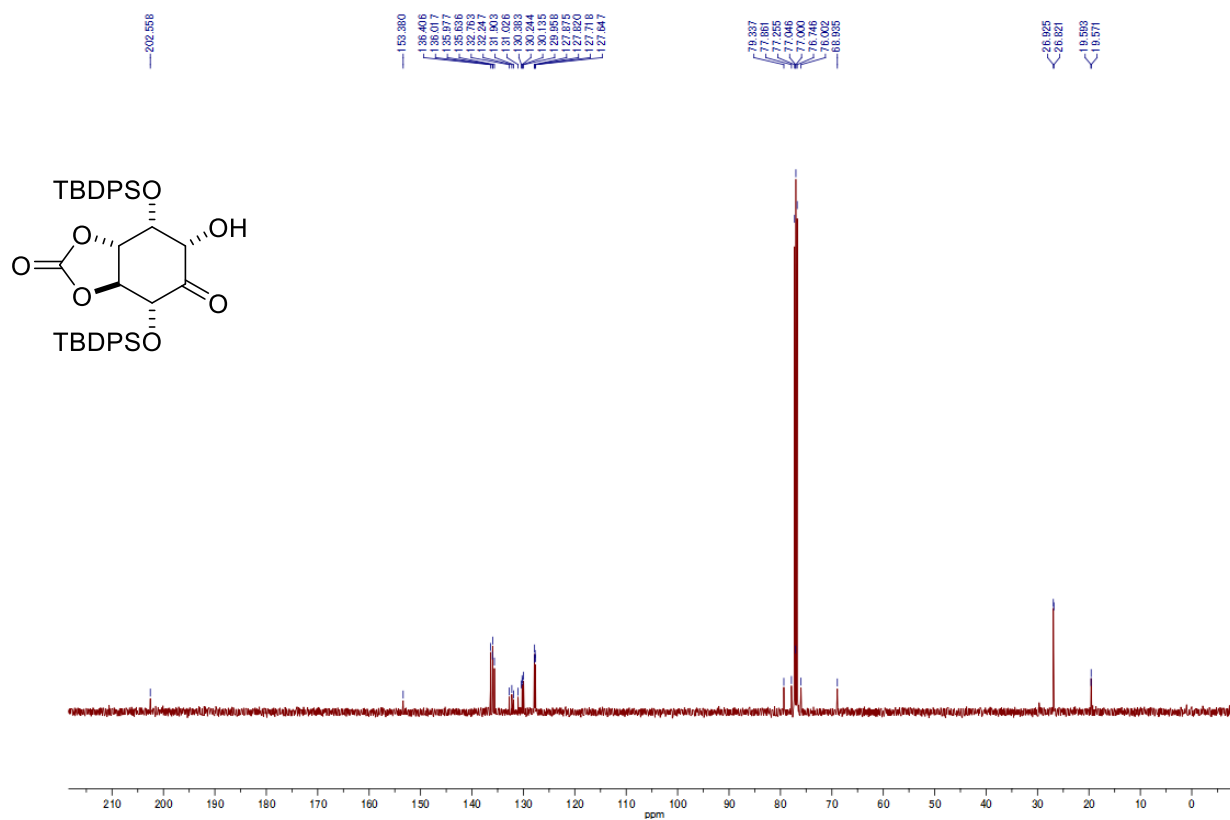


Supplementary Information

¹H NMR of **3da**

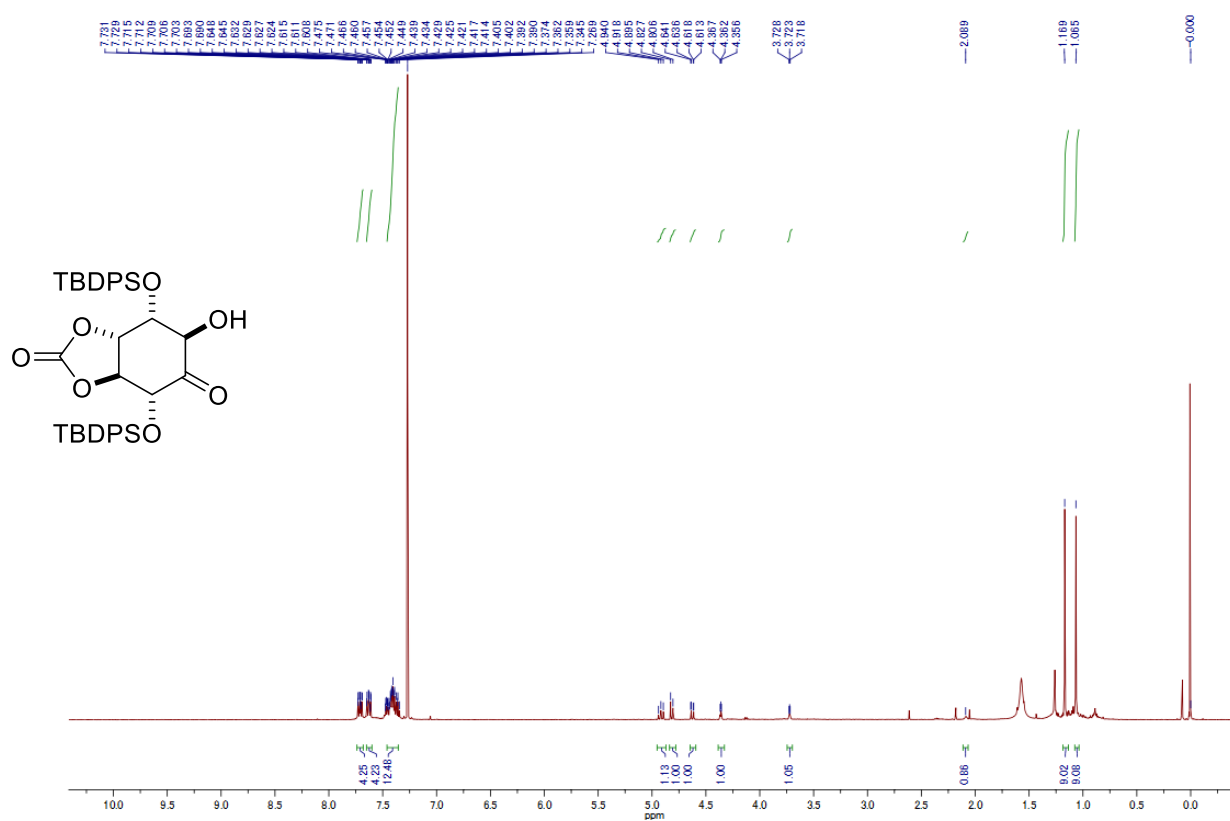


¹³C NMR of **3da**

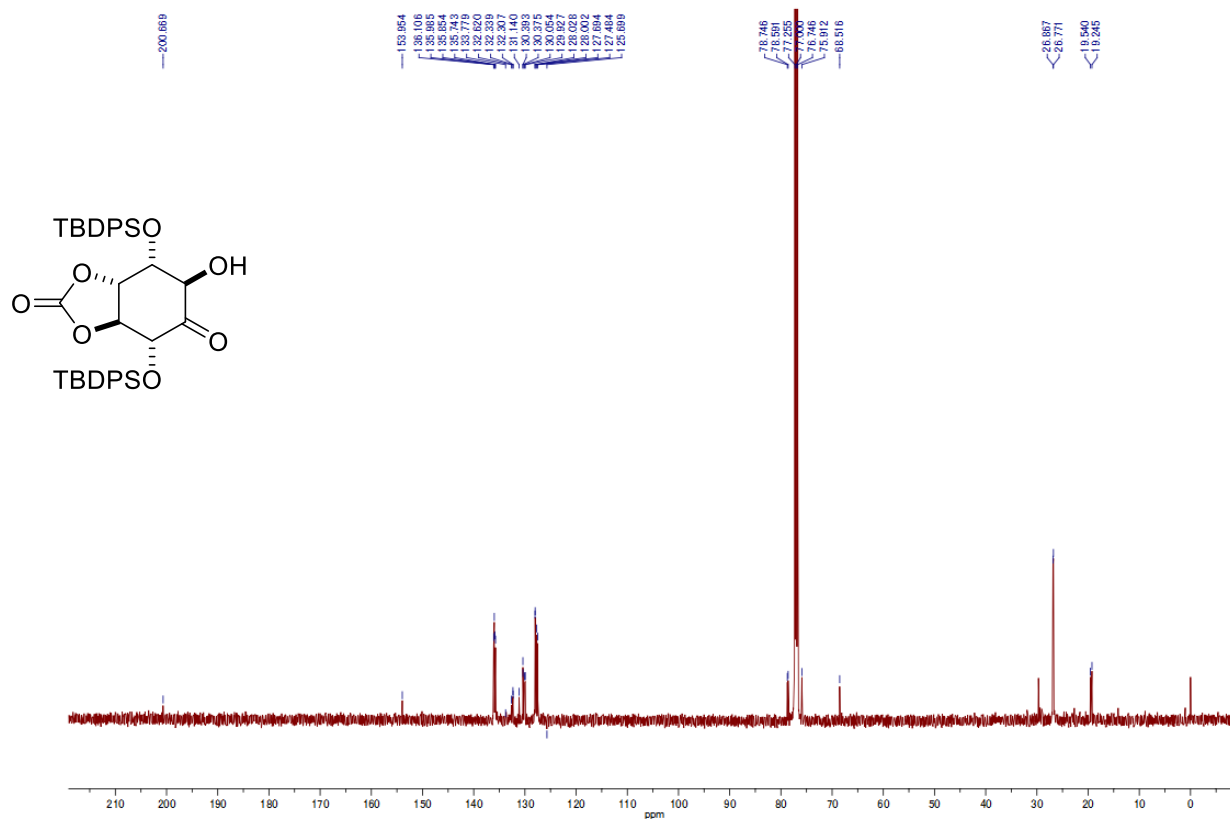


Supplementary Information

¹H NMR of **3dβ**

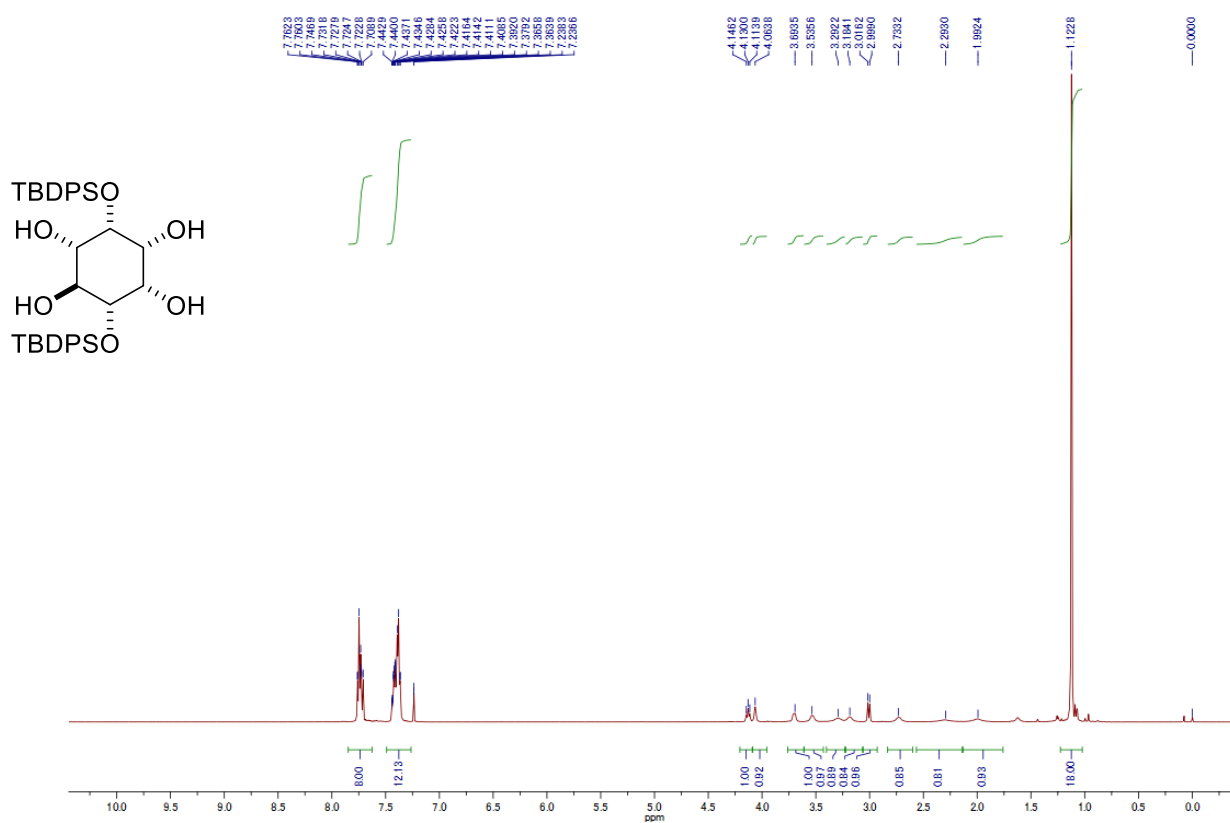


¹³C NMR of **3dβ**

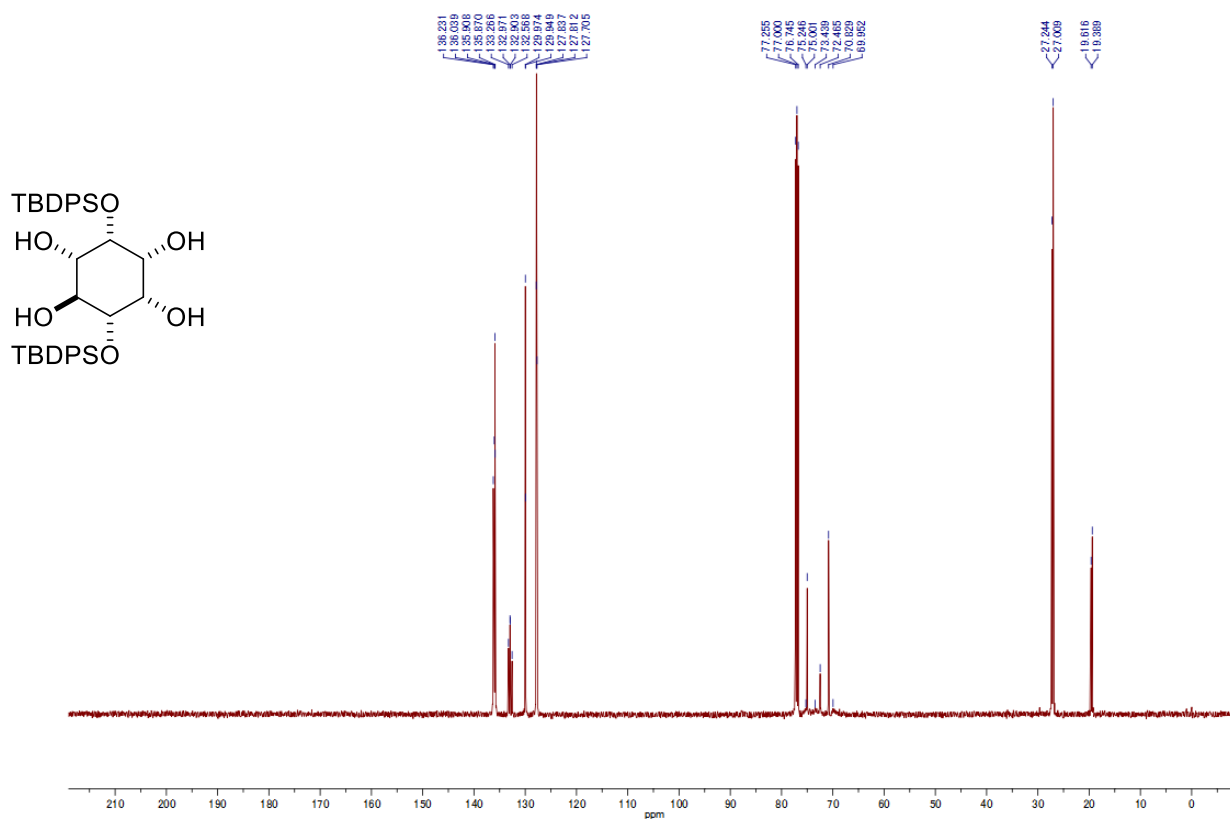


Supplementary Information

¹H NMR of *epi-7c*

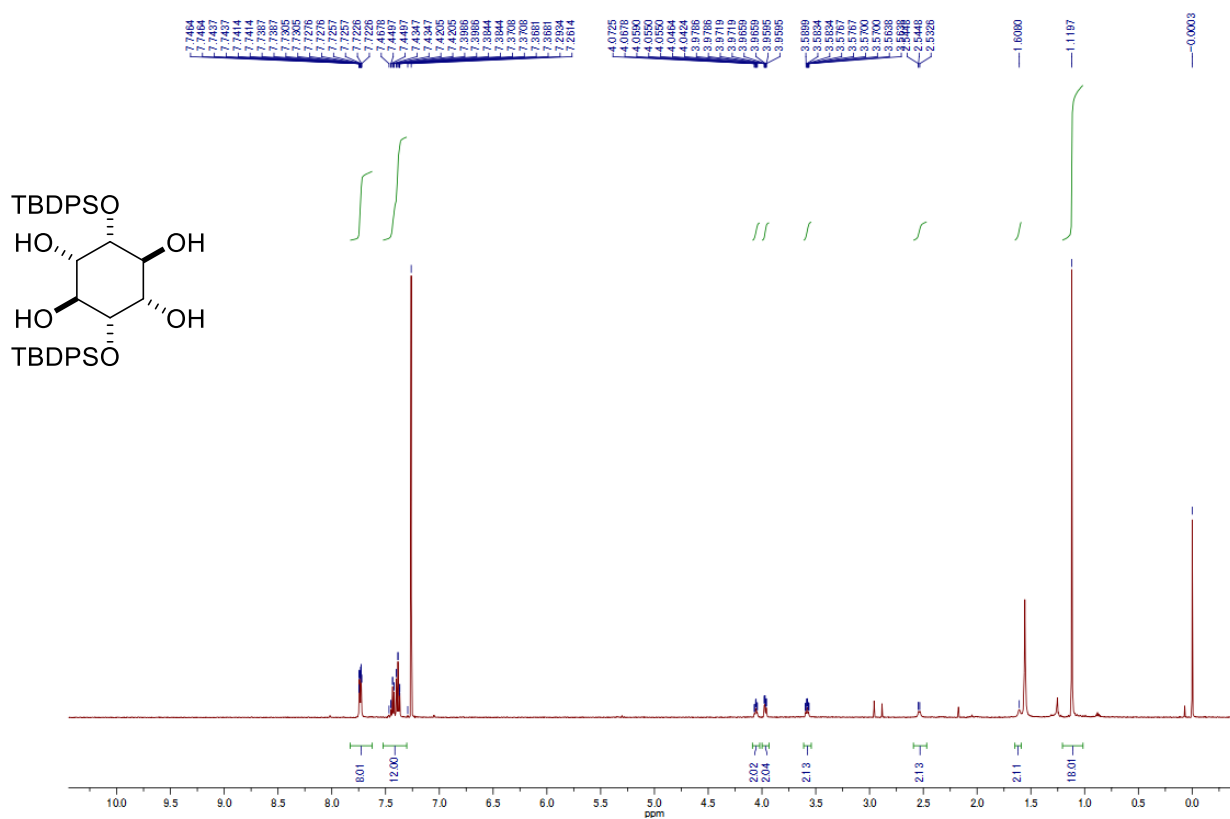


¹³C NMR of *epi-7c*

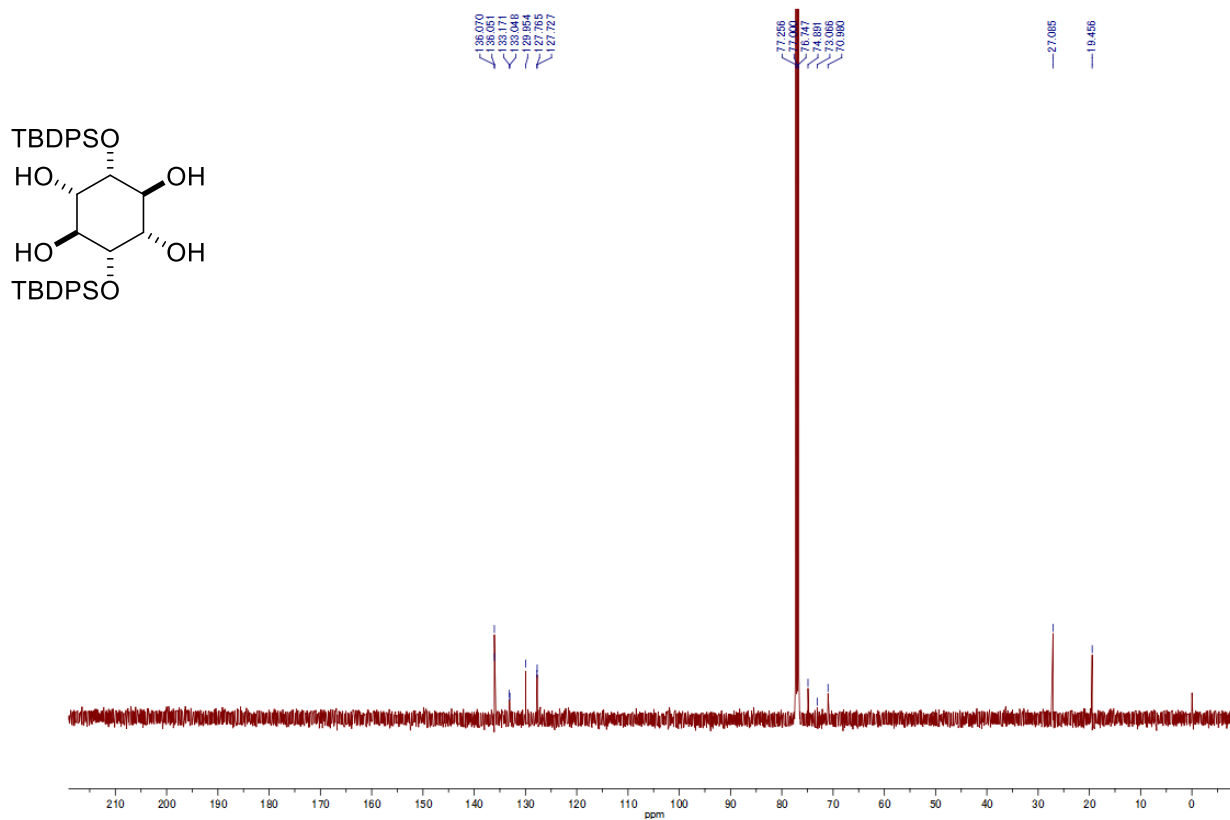


Supplementary Information

¹H NMR of *muco-7c*

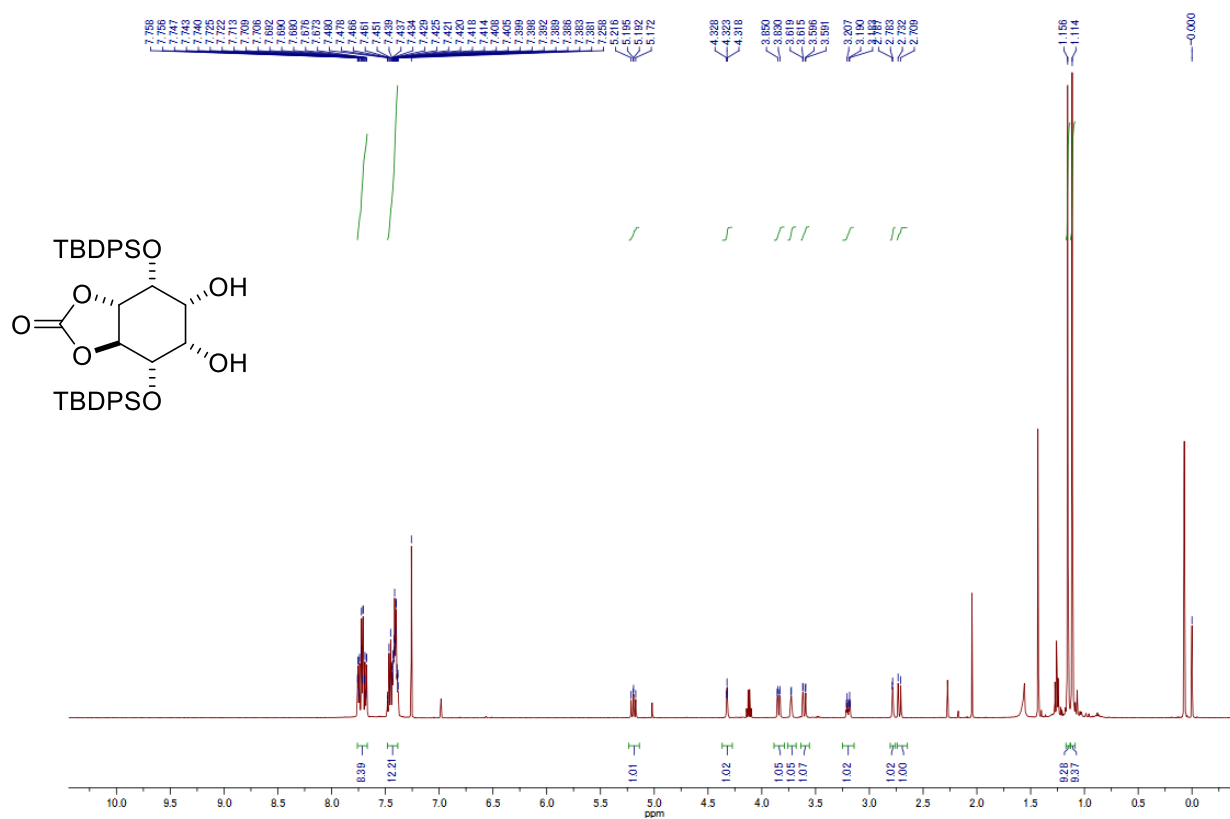


¹³C NMR of *muco-7c*

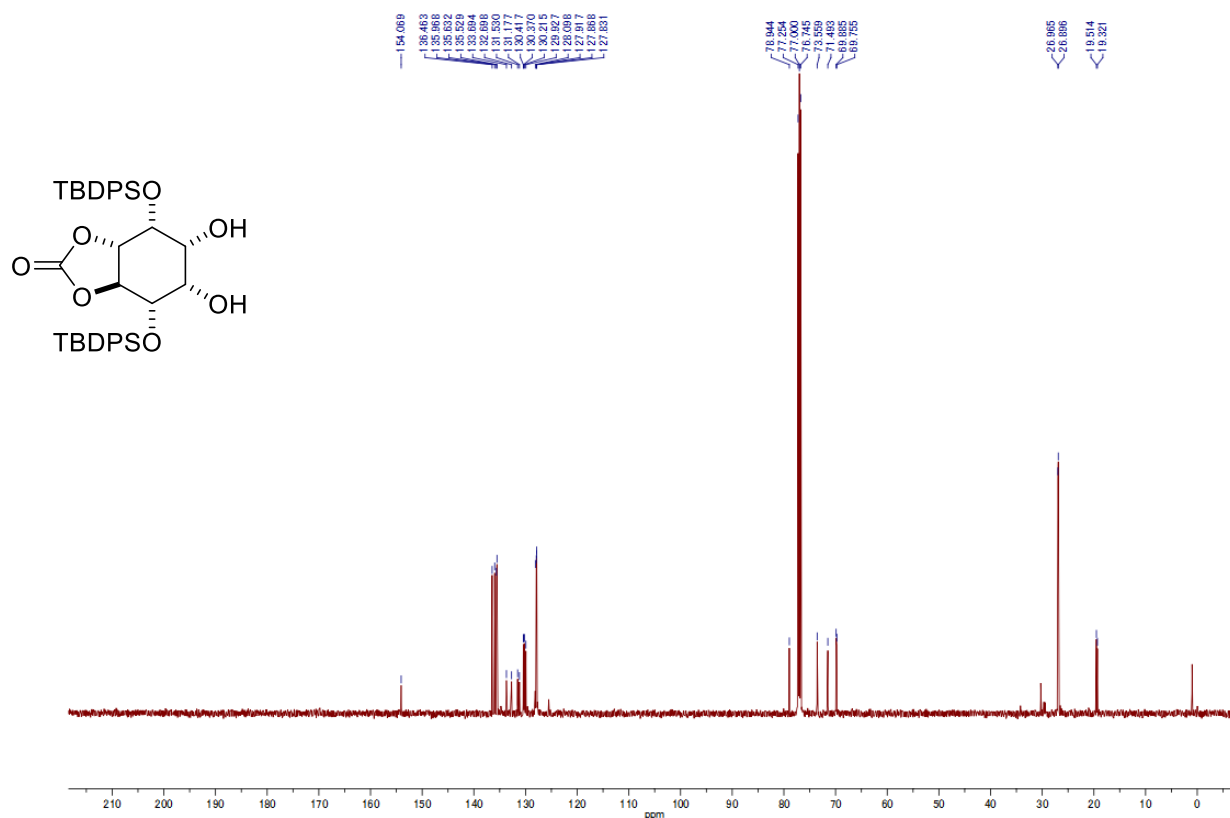


Supplementary Information

^1H NMR of *epi-7d*

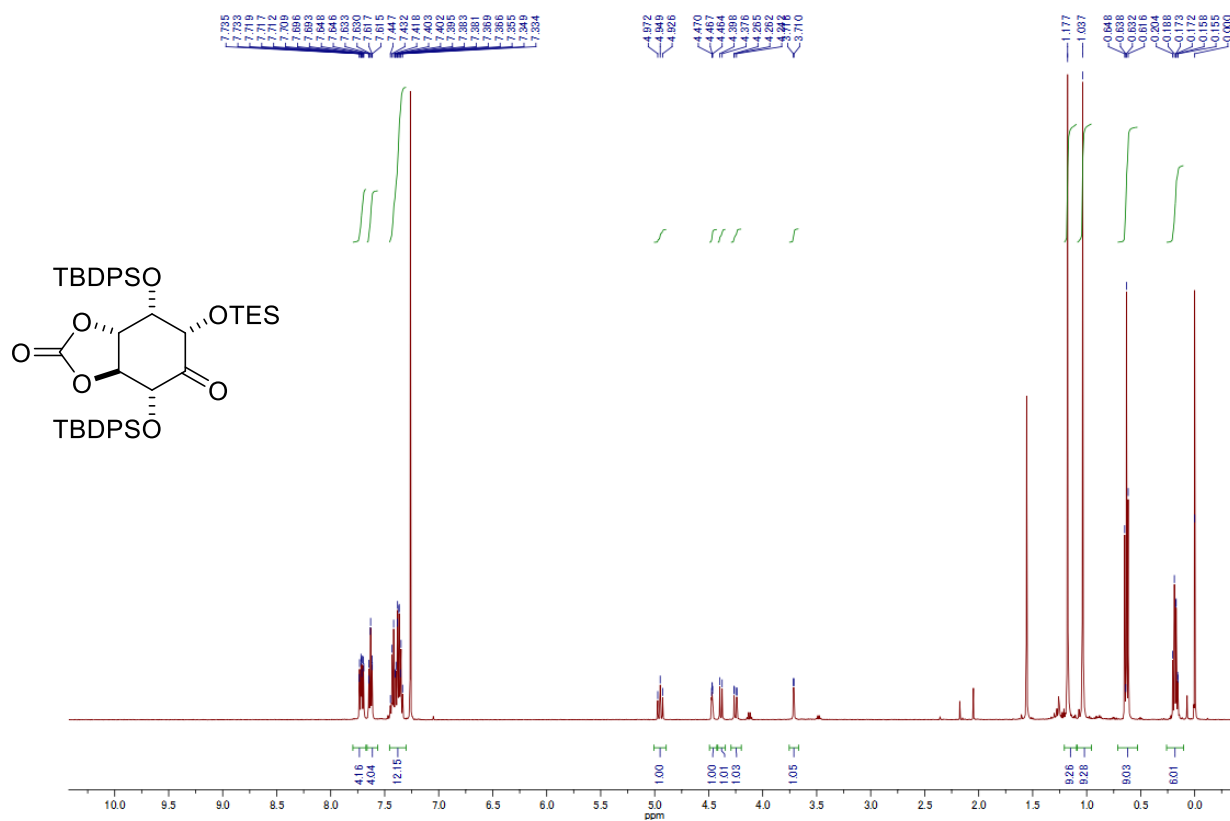


^{13}C NMR of *epi-7d*

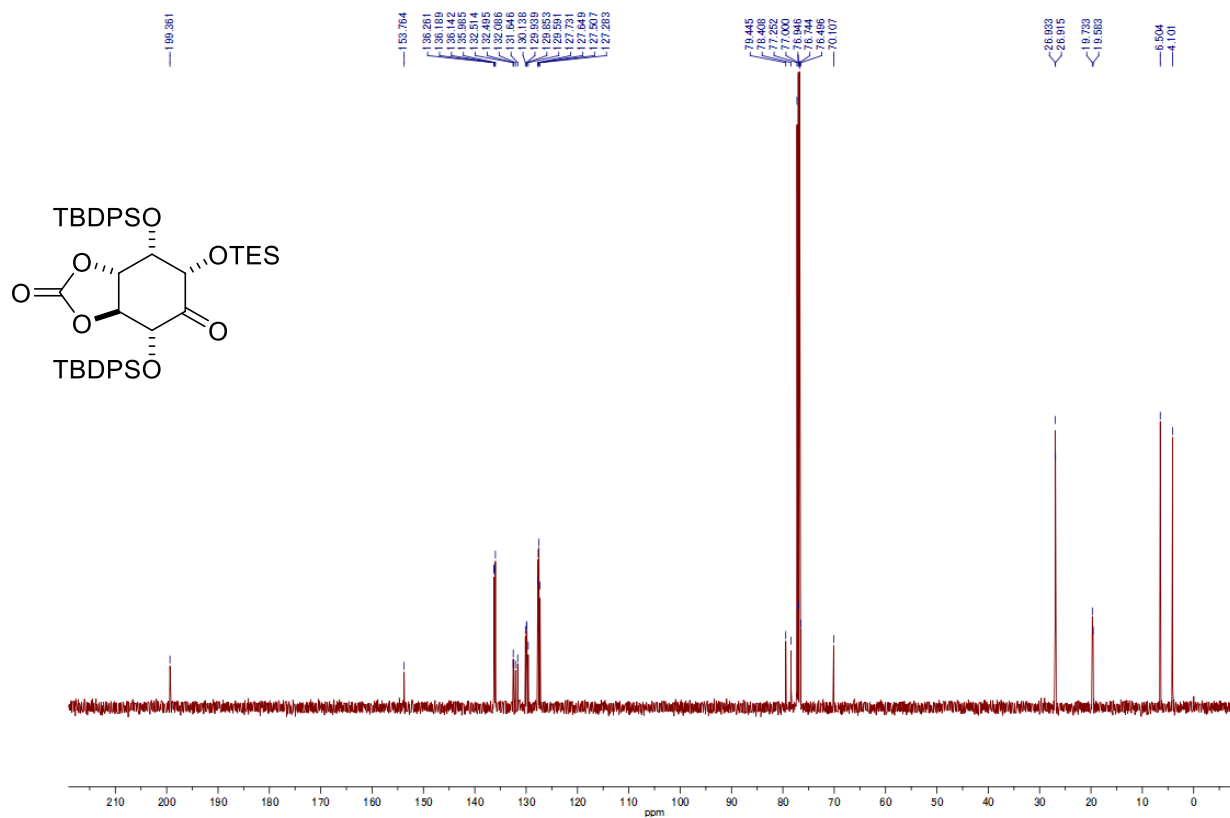


Supplementary Information

^1H NMR of **S7**

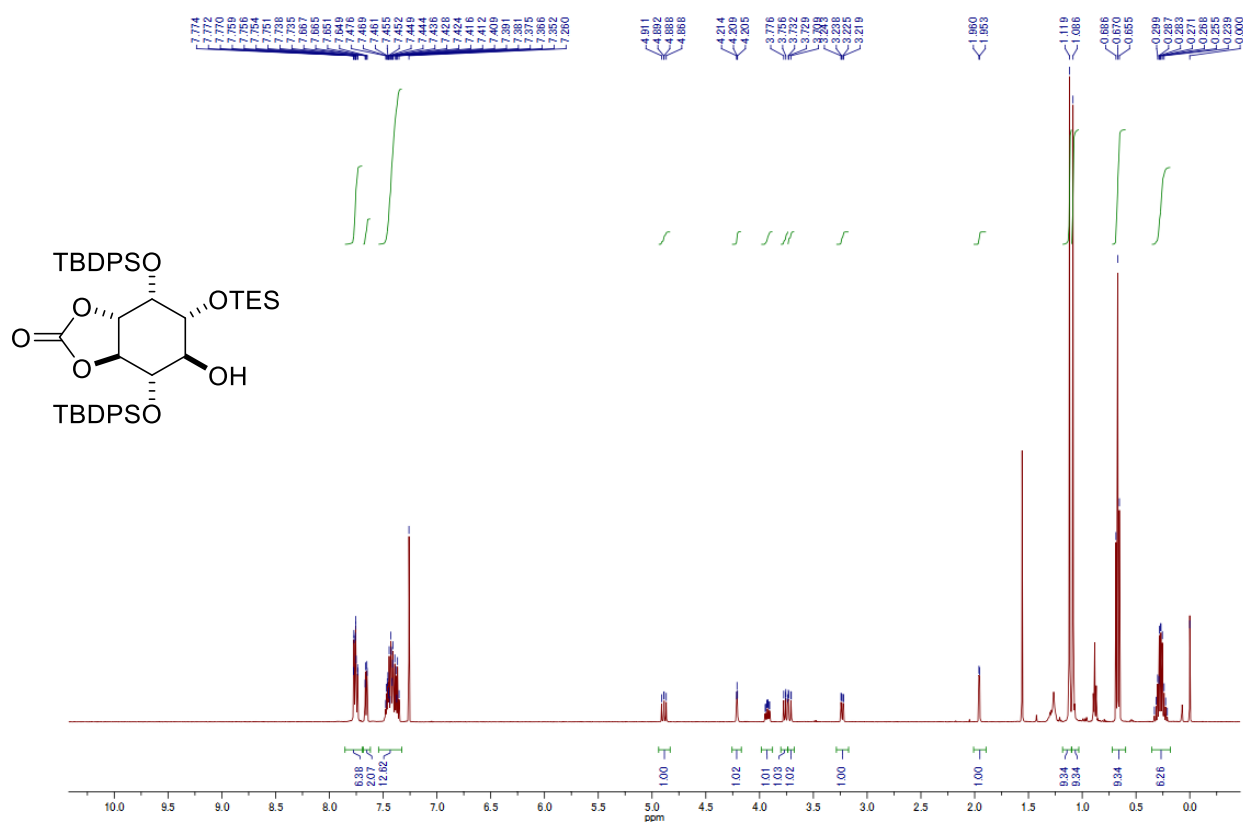


^{13}C NMR of **S7**

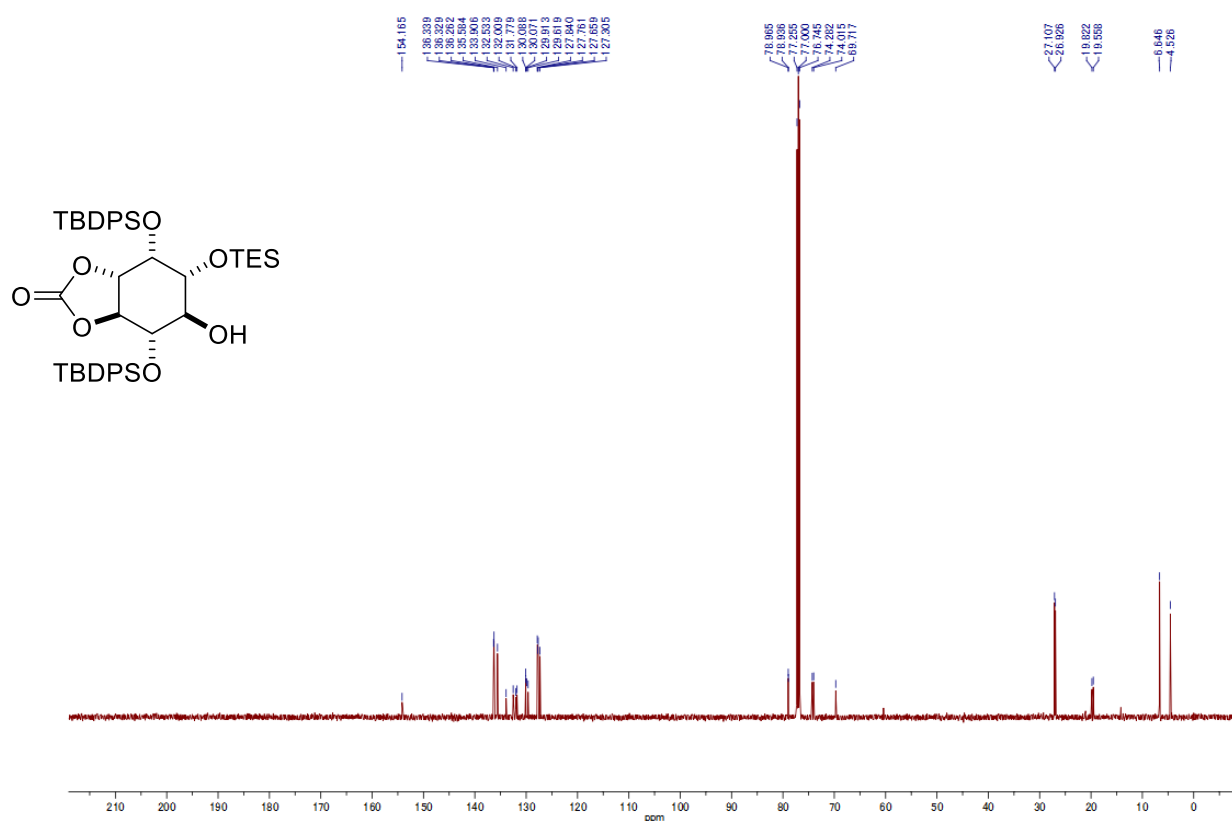


Supplementary Information

^1H NMR of *myo*-7d

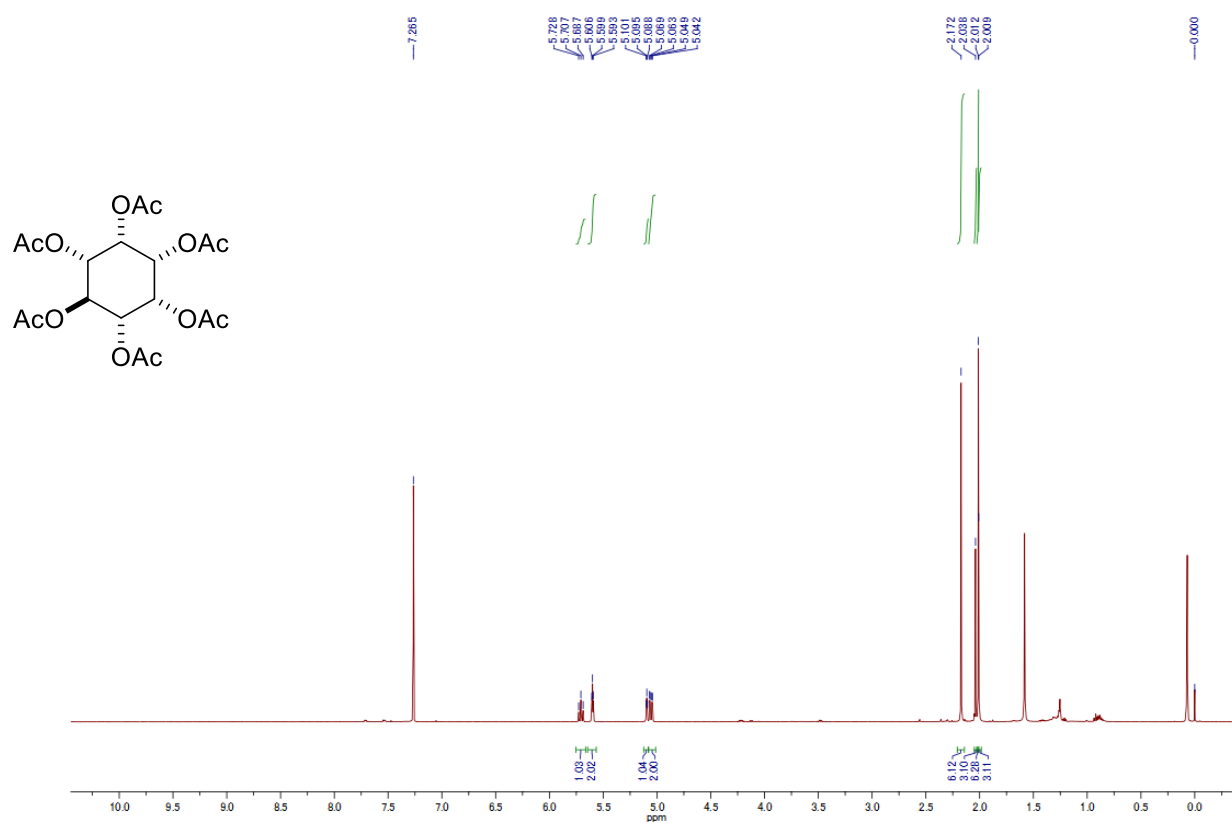


^{13}C NMR of *myo*-7d

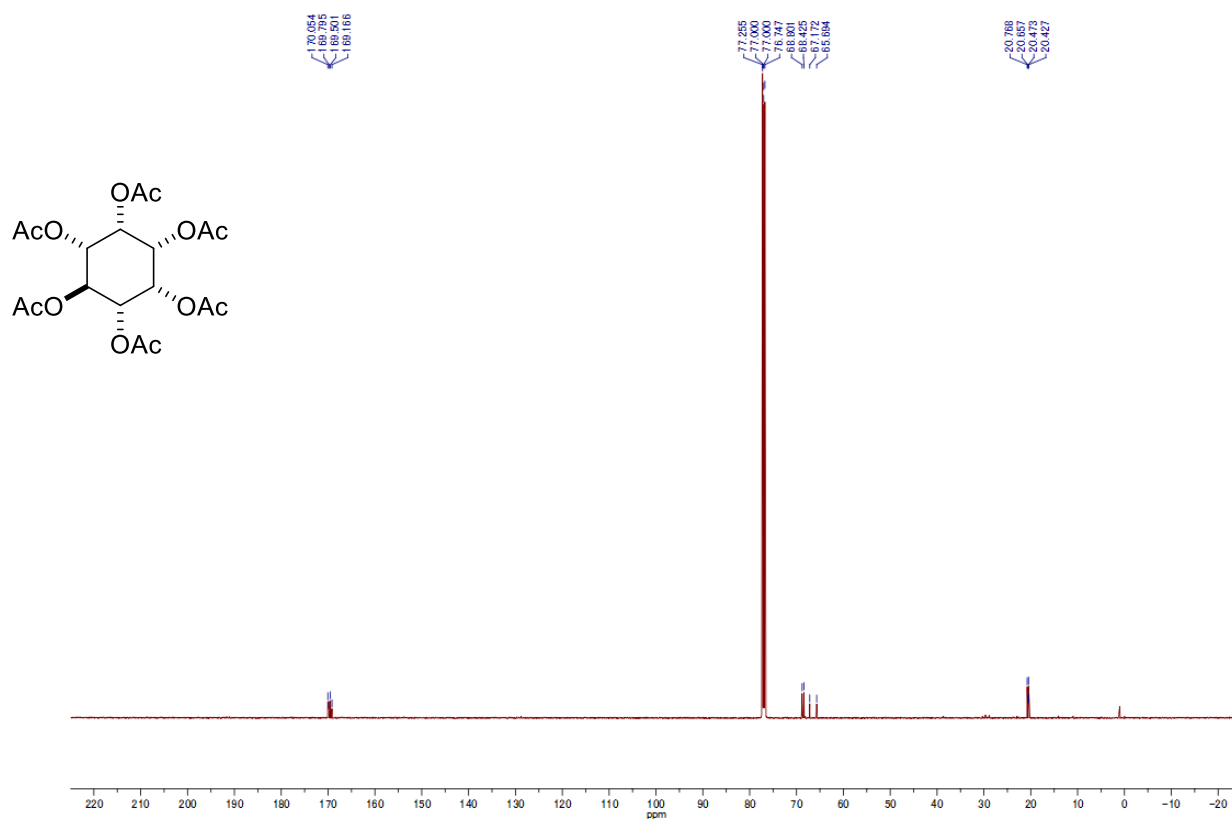


Supplementary Information

^1H NMR of *epi*-inositol hexaacetate

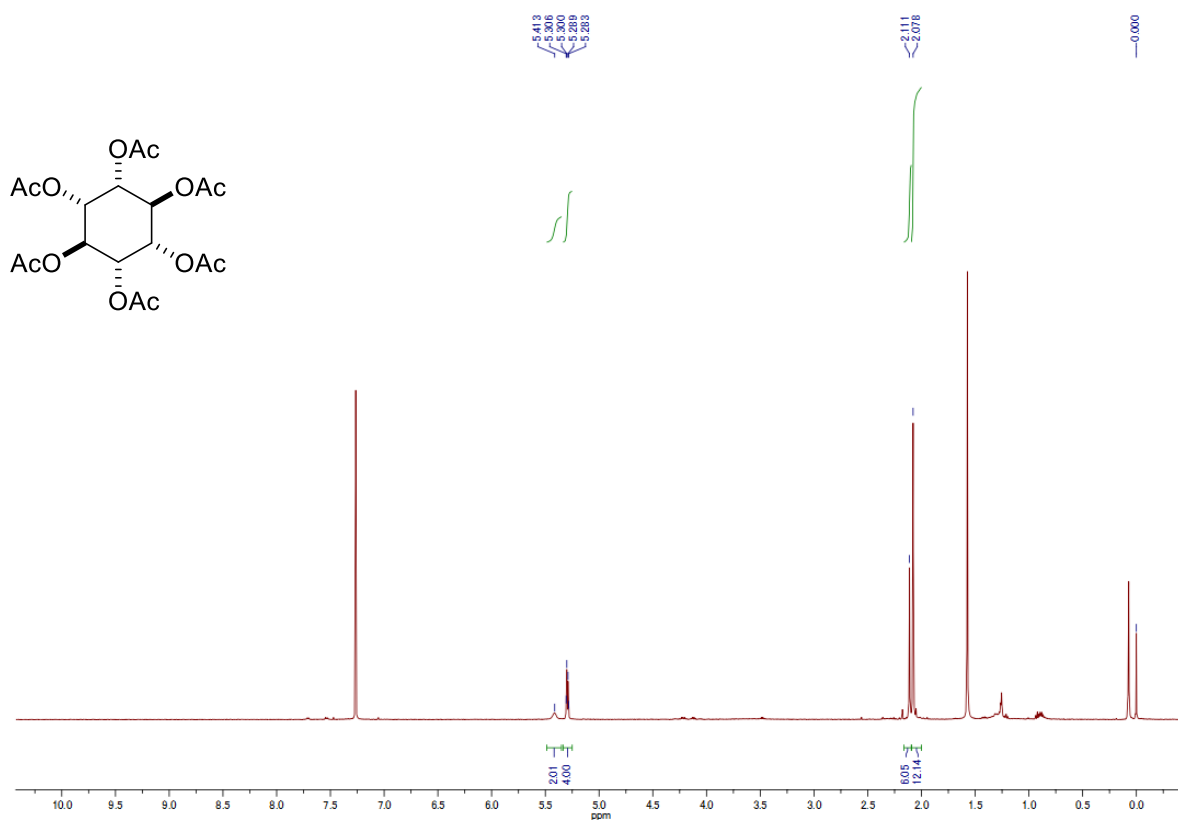


^{13}C NMR of *epi*-inositol hexaacetate

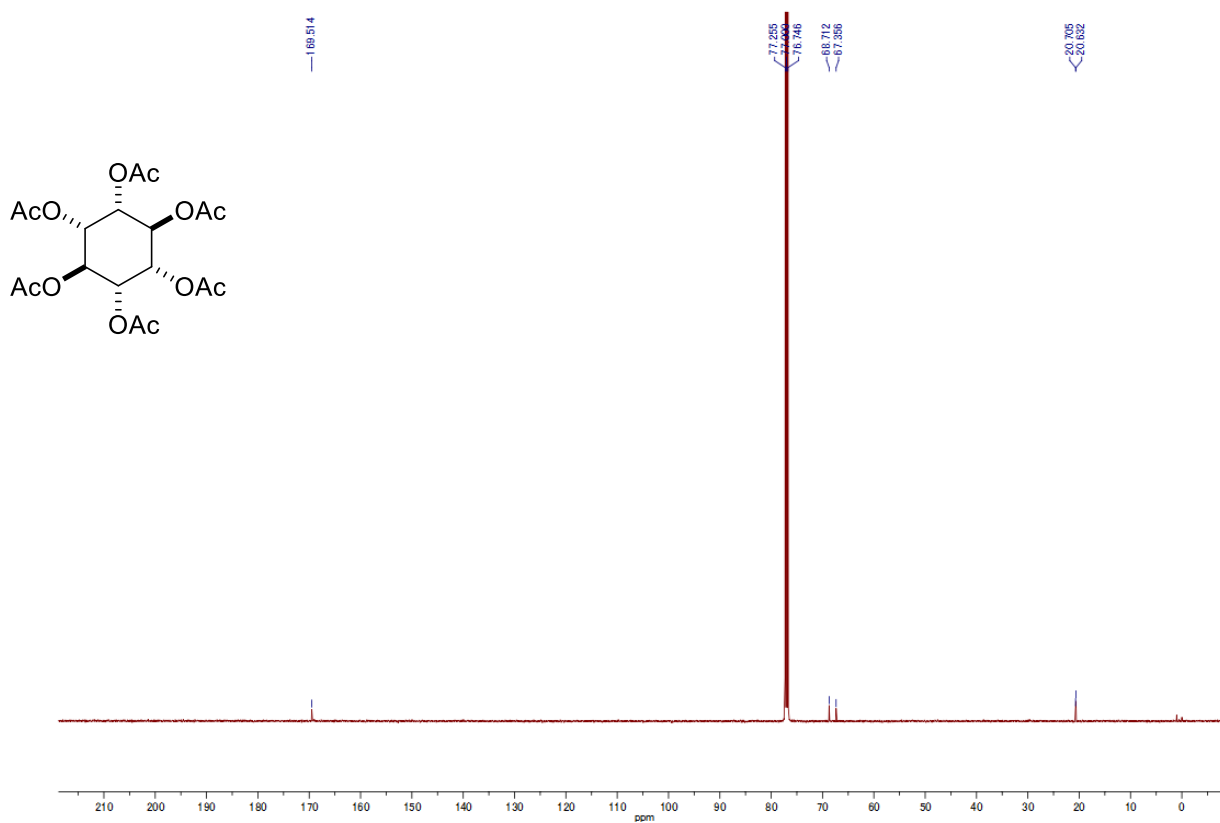


Supplementary Information

^1H NMR of *muco*-inositol hexaacetate (CDCl_3)

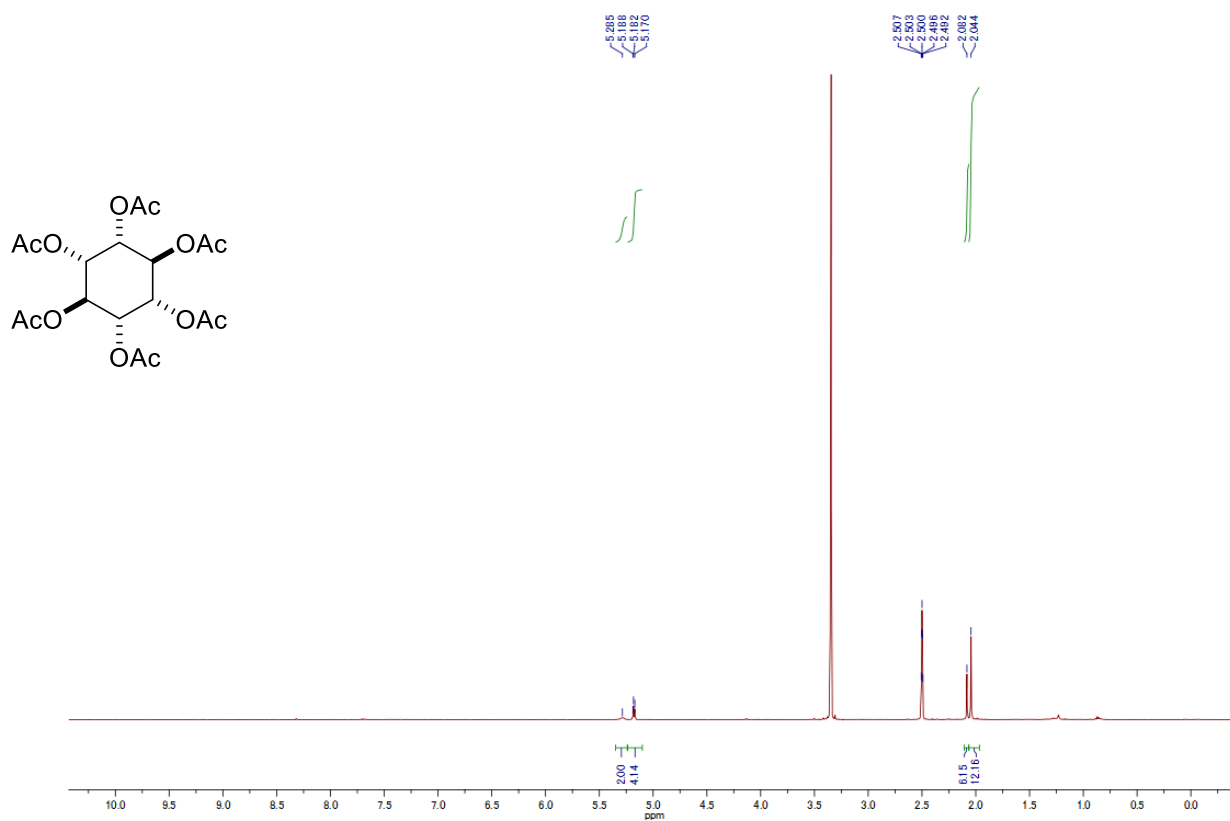


^{13}C NMR of *muco*-inositol hexaacetate (CDCl_3)

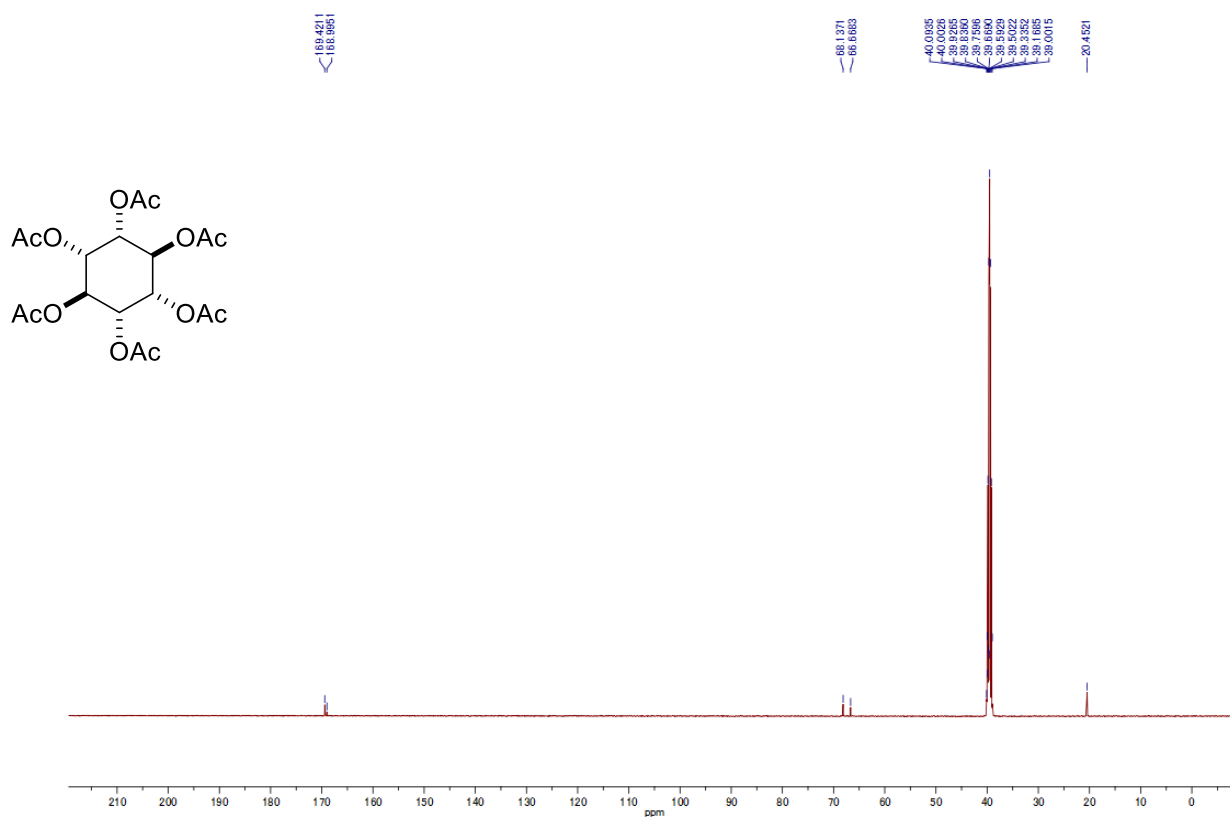


Supplementary Information

^1H NMR of *muco*-inositol hexaacetate (DMSO- d_6)



^{13}C NMR of *muco*-inositol hexaacetate (DMSO- d_6)



Supplementary Information

^1H NMR of *myo*-inositol hexaacetate

