Supporting Information

© Wiley-VCH 2006

69451 Weinheim, Germany
Polyol Synthesis via Hydrocarbon Oxidation: De Novo Synthesis of 1-Galactose

Dustin J. Covell, Nicolaas A. Vermeulen, Nathan A. Labenz, and M. Christina White

General Information: All commercially obtained reagents were used as received: 2-phenyl-1,4-benzoquinone (ACROS); Pd(OAc)₂, K₂OsO₄ - 2H₂O, (1R,2R)-(−)-[1,2-Cyclohexanediamino-N,N’-bis(3,5-di-t-butylsalicylidene)]Cobalt(II) (Strem Chemicals). Pd(OAc)₂ was stored in a glove box under a nitrogen atmosphere and weighed out in the air prior to use. Solvents tetrahydrofuran (THF), diethyl ether (Et₂O), and methylene chloride (CH₂Cl₂) were purified prior to use by passage through a bed of activated alumina (Glass Contour, Laguna Beach, California). Anhydrous N, N-dimethylformamide (DMF) (Sure/Seal) was obtained from Sigma-Aldrich and used as received. (Z)-2-butene-1,4-diol (Fluka) was used as received. All allylic oxidation reactions were run under air with no precautions taken to exclude moisture. All other reactions were run under a balloon of argon gas unless otherwise stated. Achiral gas chromatographic (GC) analyses were performed on an Agilent Technologies 6890N Series instrument equipped with FID detectors using a HP-5 (5%-Phenyl)-methylpolysiloxane column (30m, 0.32mm, 0.25µm). HPLC analysis was performed on an Agilent Technologies 1100 HPLC system with a model 1100 Quaternary Pump, Diode Array Detector, Thermostat, and Autosampler. Thin-layer chromatography (TLC) was conducted with E. Merck silica gel 60 F254 precoated plates (0.25 mm) and visualized with UV, potassium permanganate, and ceric ammonium molybdate staining. Flash column chromatography was performed as described by Still et al.[1] using EM reagent silica gel 60 (230-400 mesh). ¹H NMR spectra were recorded on a Varian Unity 400 (400 MHz) or a Varian Unity 500 (500 MHz), or a Varian Unity Inova 500NB spectrometer and are reported in ppm using solvent as an internal standard (CDCl₃ at 7.26 ppm). Data reported as: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad; coupling constant(s) in Hz; integration, corresponding carbon atom. Proton-decoupled ¹³C- NMR spectra were recorded on a Varian Unity-500 (125 MHz) spectrometer and are reported in ppm using solvent as an internal standard (CDCl₃ at 77.0 ppm). IR spectra were recorded as thin films on NaCl plates on a Perkin-Elmer Spectrum BX and are reported in frequency of absorption (cm⁻¹). All optical rotations were determined on a Perkin Elmer 341 Polarimeter using the sodium D line (589 nm). High-resolution mass spectra were obtained at the University of Illinois Mass Spectrometry Laboratory.

(3-Hydroxymethyl-oxiranyl)-methanol (8)

To 35 g of ≤77% pure m-chloroperbenzoic acid (Aldrich) in a 1 L separatory funnel was added dry CH₂Cl₂ (250 mL). The solution was washed with: 1 sat. aq. NaHCO₃-H₂O solution (2 x 100 mL) and then dried over Na₂SO₄ until the liquid became translucent (~ 1 hr). The solution was then filtered into a clean, dry 1 L round bottom flask premarked at approximately 380 mL volume. Dry CH₂Cl₂ was added to bring the total volume up to this mark and a 0.65 ml aliquot was removed and titrated using No-D NMR with a known amount of CHCl₃ (~50 µl) as the internal standard.[2] By this analysis, the solution was determined to contain 15 g (87.2 mmol, 1.1 equiv.) of mCPBA. A Teflon® stir bar was added and the atmosphere exchanged for nitrogen. The solution was cooled to 0°C and (Z)-2-buten-1,4-diol (7) (6.85 mL, 79.3 mmol, 1 equiv.) was added via syringe. The reaction was allowed to warm to room temperature and became a milky color within one hour. After 16 hours of stirring, the CH₂Cl₂ was removed via rotary evaporation, dry ether (300 mL) was added, and the material was stirred 3 hours at room temperature, after which the reaction flask was placed in a -20°C freezer for 1 hour. The resulting solids were filtered off and rinsed with cold, dry ether (5 x 50 mL). The filtrate was left in the freezer overnight to give a second harvest of crystals which were also filtered and washed with dry, cold ether to give a total of 6.16 g of a fine white powder (8) (74%).

¹H NMR (500 MHz, CD₂OD) δ 3.73 (dd, J = 3.5, 12.3 Hz, 2H, C1), 3.59 (dd, J = 7.0, 12.3 Hz, 2H, C1), 3.14 - 3.11 (m, 2H, C2); ¹³C NMR (125 MHz, CD₂OD) δ 61.2, 57.8.[3]

(2S,3S)-3,4-epoxy-1,2-di-O-isopropylidenebutane-1,2-diol (9)

Method A: [oligomeric (R,R)-(Salen)-Co(III)OTf]

To a clean, dry 100 mL round bottom flask with a Teflon® stir bar was added (8) (5.0 g, 48.0 mmol, 1 equiv.), oligomeric (R,R)-(Salen)Co(III)OTf (0.019 g, 0.05 mol%), and CH₂CN (24 mL). The reaction was vigorously stirred under air until ~70% conversion of starting material was observed (¹H NMR of an aliquot from the reaction mixture in CD₂OD; ratio of m @ 3.12 ppm vs. dd @ 2.69 ppm + dd @ 2.76 ppm) (~12 hrs). The reaction mixture was then cooled to 0°C and 2-
methoxypropene (5.53 mL, 5.77 mmol, 1.2 equiv.) was added followed by p-TsOH · H₂O (0.091 g, 0.480 mmol, 0.01 equiv.). The reaction was stirred at 0°C for 1 hour and then the solvents removed slowly (~45 min.) via rotary evaporation at 0°C. The reaction mixture was loaded neat onto a silica column and purified via flash silica gel chromatography (10%-20%-30%-40% Et₂O/pentane). Removal of the column solvent via distillation at 55°C gave a crude mixture of (9) (~4.67 g, 68% yield by ¹H NMR) and the seven-membered ketal product that was taken forward without further purification.¹⁴ (Note: The purity of the starting material for this reaction has a large effect on catalyst loading and overall yield. Inferior batches of (8) should be purified via flash silica gel chromatography in 10%-15% MeOH/CH₂Cl₂ prior to use.)

**Method B:** [commercial (R,R)-(Salen)-Co(III)OAc][¹⁵]

To a clean, dry 250 mL round-bottom flask was added (8) (2.0 g, 19.2 mmol, 1 equiv.) and (R,R)-(Salen)Co(III)OAc (0.255 g, 2 mol%). THF (9.6 mL) was added and the reaction was vigorously stirred under air until ~70% conversion of starting material was observed (¹H NMR of an aliquot from the reaction mixture in CD₂OD; ratio of m @ 3.12 ppm vs. dd @ 2.69 ppm + dd @ 2.76 ppm)(~12 hrs). The solvent was then removed via rotary evaporation, and dry acetone (9.6 mL) was added. The reaction flask was cooled to 0°C and 2,2-dimethoxypropane (5.7 mL, 48.0 mmol, 2.5 equiv.) was added followed by slow addition of pyridinium p-toluenesulfonic acid (1.21 g, 4.80 mmol, 25 mol%). The reaction was allowed to warm to room temperature and then taken to 50°C for 24 hours. After stirring 24 hours, the reaction mixture was cooled to room temperature, transferred to a 1 L separatory funnel, and Et₂O (200 mL) and sat. aq. NaHCO₃ (25 mL) were added. The aqueous layer was then back extracted [5 x (100 mL Et₂O + 4 mL THF)] and the combined organics distilled slowly away at 55°C. Flash silica gel chromatography (10%-20%-30% Et₂O/pentane) followed by distillation of the column solvent at 55°C afforded a crude mix of (9) (~1.35 g, 49% yield by ¹H NMR) and the seven-membered ketal product that was taken on without further purification.¹⁵ ¹⁷ Rᵣ = 0.206 (20% Et₂O/Pentane); ¹H NMR (500 MHz, CDCl₃) δ 4.10 (dd, J = 6.5, 8.5 Hz, 1H, C1), 3.97 (app. q, J = 6.5, 1H, C2), 3.85 (dd, J = 6.5, 8.5 Hz, 1H, C1), 1.03 (dd, J = 2.5, 4.3, 5.6 Hz, 1H, C3), 2.80 (dd, J = 4.0, 5.0 Hz, 1H, C4), 2.67 (dd, J = 2.5, 5.3 Hz, 1H, C4), 1.44 (s, 3H, acetonide CH₃), 1.36 (s, 3H, acetonide CH₃), ¹³C NMR (125 MHz, CDCl₃) δ 110.0, 76.2, 65.9, 52.0, 43.8, 26.4, 25.5; LRMS (Cl)/m/z calculated for C₈H₁₃O₃ [M + H⁺]: 145.1; found 145.1.[¹⁰]

![Diagram](image)

**(2S,3S)-3-O-benzy-1,2-di-O-isopropylidene-5-hexen-1,2,3-triol (-)-(4)**

To a clean, dry 100 mL flask with a Teflon® stir bar was added copper (I) bromide (0.228 g, 1.59 mmol, 0.1 equiv.) and anhydrous DMF (50 mL). This flask was cooled to 0°C and then reduced atmosphere was added sodium hydride (0.762 g, 31.8 mmol, 2 equiv.) and (R,R)-(Salen)Co(III)OAc (0.255 g, 2 mol%). THF (9.6 mL) was added and the reaction was allowed to warm to room temperature and then taken to 50°C for 12 hours, the reaction mixture was allowed to warm to room temperature and then taken to 50°C for 24 hours. After stirring 24 hours, the reaction mixture was cooled to room temperature, transferred to a 1 L separatory funnel, and Et₂O (200 mL) and sat. aq. NaHCO₃ (25 mL) were added. The aqueous layer was then back extracted [5 x (100 mL Et₂O + 4 mL THF)] and the combined organics distilled slowly away at 55°C. Flash silica gel chromatography (10%-20%-30% Et₂O/pentane) followed by distillation of the column solvent at 55°C afforded a crude mix of (9) (~1.35 g, 49% yield by ¹H NMR) and the seven-membered ketal product that was taken on without further purification.¹⁵ ¹⁷ Rᵣ = 0.206 (20% Et₂O/Pentane); ¹H NMR (500 MHz, CDCl₃) δ 4.10 (dd, J = 6.5, 8.5 Hz, 1H, C1), 3.97 (app. q, J = 6.5, 1H, C2), 3.85 (dd, J = 6.5, 8.5 Hz, 1H, C1), 1.03 (dd, J = 2.5, 4.3, 5.6 Hz, 1H, C3), 2.80 (dd, J = 4.0, 5.0 Hz, 1H, C4), 2.67 (dd, J = 2.5, 5.3 Hz, 1H, C4), 1.44 (s, 3H, acetonide CH₃), 1.36 (s, 3H, acetonide CH₃), ¹³C NMR (125 MHz, CDCl₃) δ 110.0, 76.2, 65.9, 52.0, 43.8, 26.4, 25.5; LRMS (Cl)/m/z calculated for C₈H₁₃O₃ [M + H⁺]: 145.1; found 145.1.[¹⁰]

To a clean, dry 250 mL round-bottom flask was added sodium hydride (0.762 g, 31.8 mmol, 2 equiv.), TBAI (0.507 g, 1.6 mmol, 0.1 equiv.), and anhydrous DMF (50 mL). This flask was cooled to 0°C, and then the reaction mixture containing the crude alcohol from above in DMF (10 mL initial volume, 2 x 2.1 mL rinses) at ~40°C was then added via cannula, and the reaction stirred at ~40°C in the dark for 1 hour. A quench of sat. aq. NH₄Cl solution (15 mL) was added and stirred vigorously as the reaction was allowed to warm to room temperature. Et₂O (100 mL) was added, and the aqueous layer extracted [5 x (50 mL Et₂O + 4 mL THF)]. The combined organics were washed with H₂O (50 mL) and the aqueous layer again back extracted [3 x (50 mL Et₂O + 4 mL THF)]. After drying (Na₂SO₄) and filtering, the solvent was distilled away at 65°C.

To a clean, dry 250 mL round-bottom flask was added sodium hydride (0.762 g, 31.8 mmol, 2 equiv.), TBAI (0.507 g, 1.6 mmol, 0.1 equiv.), and anhydrous DMF (50 mL). This flask was cooled to 0°C, and then the reaction mixture containing the crude alcohol from above in DMF (10 mL initial volume, 2 x 5 mL rinses) at ~0°C was added dropwise via cannula. The reaction was stirred 1 hour at 0°C and then benzyl bromide (2.02 mL, 16.7 mmol, 1.05 equiv.) was added dropwise. The reaction mixture was allowed to warm to room temperature and stirred until TLC revealed complete conversion of starting material (~1 hr). Upon completion, the reaction flask was cooled to 0°C and H₂O (50 mL) was added. The flask was stirred an additional 5 minutes, and then Et₂O (200 mL) was added. The aqueous layer was extracted with Et₂O (3 x 50 mL), the combined organic layers were dried (MgSO₄), filtered, and reduced in vacuo. Flash silica gel chromatography (1%-2%-3%-5% EtOAc/hexanes) afforded 3.32 g of (2S,3S)-3-O-benzy-1,2-di-O-isopropylidene-5-hexen-1,2,3-triol (-)-(4) (80% 2 steps) as a clear liquid in 99% ee (HPLC, Chiralcel AD-RH, 50% CH₃CN/H₂O, 0.5 mL/min., tᵣ(minor) = 14.2 min., tᵣ(major) = 15.5 min.). ¹⁷ Rᵣ = 0.392 (10% EtOAc/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 7.38-7.31 (m, 4H, C12,C13), 7.30-7.26 (m, 1H, C14), 5.88 (ddt, J = 7.5, 10.0, 17.0 Hz, 1H, C5), 5.11 (dm, J = 17 Hz, 1H, C6), 5.07 (dm, J = 17 Hz, 1H, C6), 4.72 (d, J = 12.0 Hz, 1H, C10), 4.66 (d, J = 11.5 Hz, 1H, C10), 4.21
To a 40 mL borosilicate vial was added sequentially the following: Pd(OAc)$_2$ (0.0224 g, 0.1 mmol, 10 mol%), phenyl benzoquinone (0.368 g, 2.0 mmol, 2 equiv.), p-anisic acid (0.456 g, 3.0 mmol, 3 equiv.), 4Å molecular sieves (0.200 g), (-)-(4) (0.262 g, 1 mmol, 1 equiv.), and a Teflon® stir bar. The vial was then capped and stirred at 41°C for 72 hours. Care was taken in charging and stirring to keep all reagents off of the walls and contained at the bottom of the vial in maintaining the temperature centered at 41°C (i.e. 40°C-43°C). Upon completion, the reaction was quenched with sat. aq. NH$_4$Cl solution (1 mL), stirred for 30 minutes, and then transferred to a separatory funnel using ethyl acetate (10 mL). Hexanes (40 mL) was added and the organics were washed with H$_2$O (50 mL) and 5% aq. Na$_2$CO$_3$ solution (2 x 50 mL). (Note: Upon addition of hexanes a significant amount of phenyldihydroquinone will crash out of solution as a black solid. This solid is readily removed in the next step during filtration.) The organic layer was dried (MgSO$_4$), filtered, and reduced in vacuo. Subsequent transfers were all performed using ether to minimize transfer of phenyldihydroquinone. Purification via flash silica gel chromatography (30% Et$_2$O/hexanes) gave 0.309 g of (E)-(6) as an amber oil. (Run 1 = 74% yield; run 2 = 76% yield) *Average = 75% yield*. Linear to branched ratios (>300:1) were determined by HPLC using authentic branched allylic product$^{10}$ (Agilent Zobrax Eclipse XDB-C8, 35% i-PrOH/H$_2$O, 1 mL/min., $t_R$ (linear) = 15.7 min., $t_R$ (branched) = 18, 19 min. (two diastereomers)). E:Z (30:1) ratios were determined by HPLC using acetone deprotected E and authentic Z isomers (Symmetry C-18, 40%CH$_3$CN/H$_2$O, 1.0 mL/min., $t_R$ (E) = 10.1 min., $t_R$ (Z) = 11.3 min.) Using this procedure, 0.032 g (10%) of the linear acetate product was also formed and could not be readily separated from (+)-(6).

Method $B$: [Pd(CH$_3$CN)$_4$](BF$_4$)$_2$ To a 40 mL borosilicate vial was added sequentially the following: [Pd(CH$_3$CN)$_4$](BF$_4$)$_2$ (0.044 g, 0.1 mmol, 0.1 equiv.), phenyl benzoquinone (0.368 g, 2.0 mmol, 2 equiv.), p-anisic acid (0.456 g, 3.0 mmol, 3 equiv.), 4Å molecular sieves (0.200 g), DMSO (0.380 mL), CH$_2$Cl$_2$ (0.120 mL), diisopropylethylamine (0.087 mL, 0.5 mmol, 0.5 equiv.) and a Teflon® stir bar. The vial was then capped and stirred at 41°C for 72 hours. Care was taken in maintaining the temperature centered at 41°C (i.e. 40°C-43°C) and in charging and stirring to keep all reagents off of the walls and contained at the bottom of the vial. After 72 hours, the reaction was quenched with sat. aq. NH$_4$Cl solution (1 mL), stirred for 30 minutes, and then transferred via pipette to a separatory funnel using ethyl acetate (10 mL). Hexanes (40 mL) was added and the organics were washed with H$_2$O (50 mL) and 5% aq. Na$_2$CO$_3$ solution (2 x 50 mL). The organic layer was dried (MgSO$_4$), filtered, and reduced in vacuo. Purification via flash silica gel chromatography (30% Et$_2$O/hexanes) gave 0.293 g of (+)-(6) as an amber oil with 13% recovered starting material. (Run 1 = 71% yield; run 2 = 69% yield; run 3 = 74% yield) *Average = 71% yield*. Linear to branched and E:Z ratios were determined as described above and found to be similar to those determined for Pd(OAc)$_2$ (L:B = >300:1; E:Z = 36:1). $R_f$ = 0.17 (30% Et$_2$O/hexanes); $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.0 (app. dt, J = 2.5, 9.0 Hz, 2H, C17), 7.36-7.25 (m, 5H, C12, 13, 14), 6.93 (app. dt, J = 2.5, 9.0 Hz, 2H, C18), 5.97 (ddt, J = 1.0, 5.5, 15.8 Hz, 1H, C5), 5.74 (ddt, J = 1.5, 8.0, 15.8 Hz, 1H, C4), 4.82 (app. d, J = 5.5 Hz, 2H, C6), 4.68 (d, J = 12.0 Hz, 1H, C10), 4.50 (d, J = 12.0 Hz, 1H, C10), 4.22 (app. q, J = 6.5 Hz, 1H, C2), 3.96 (dd, J = 6.5, 8.5 Hz, 1H, C1), 3.91 (app. t, J = 7.0 Hz, 1H, C1), 3.87 (s, 3H, C20), 3.77 (dd, J = 6.0, 8.8 Hz, 1H, C3), 1.39 (s, 3H, acetone CH$_3$), 1.35 (s, 3H, acetone CH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 165.9,163.4, 138.1, 131.7, 129.9, 129.8, 128.3, 127.8, 127.6, 122.4, 113.6, 109.7, 79.7, 77.3, 70.5, 65.7, 64.0, 55.4, 26.4, 25.3; IR (neat, cm$^{-1}$) 2985.3, 2934.8, 2873.4, 1713.2, 1606.5, 1511.5,
1256.9; HRMS (ESI) m/z calculated for: C_{24}H_{29}O_6 [M + H]^+: 413.1964, observed: 413.1960; [α]^{22}_D = +72.5° (c = 1.0, CHCl₃).

3-O-benzyl-1,2-di-O-isopropylidene-6-(4-methoxyphenylbenzoate)-L-galactitol (--)-(10)
To a clean, dry 50 mL recovery flask was added sequentially the following: K₂OsO₄ · 2H₂O (0.007 g, 0.019 mmol, 1 mol%), (DHQD)₂PHAL (0.076 g, 0.095 mmol, 5 mol%), K₂Fe(CN)₆ (1.89 g, 5.72 mmol, 3 equiv.), K₂CO₃ (0.792 g, 5.72 mmol, 3 equiv.), a Teflon© stir bar, deionized water (9.5 mL), and tert-butanol (5 mL). The reaction flask was stirred vigorously until both layers became translucent, at which time MeSO₃O (1 x 5 mL) was added and the reaction was cooled to 0°C. After the solution became opaque, olefin (+)-(6) (0.787 g, 1.91 mmol, 1 equiv.) was added dropwise via pipette in tert-butanol (1.5 mL initial volume, 2 x 1 mL rinses) and the reaction was stirred vigorously at 0°C until completion as indicated by TLC (~3.5 hr). Upon completion, sodium bisulfite (1.81 g) was added slowly and the reaction was allowed to warm to room temperature and stir for 1 hour. EtOAc (10 mL) was added and the aqueous layer was extracted with additional EtOAc (3 x 15 mL). The combined organic layers were washed with 2N KOH (1 x 10 mL), dried (MgSO₄), filtered, and concentrated in vacuo. Purification via flash silica gel chromatography (40% EtOAc/hexanes) afforded 0.818 g (96%) of (--)(10) as a clear, viscous oil. Rₚ = 0.190 (40% EtOAc/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 87.99 (app. dt, J = 2.5, 9.0 Hz, 2H, C17), 7.37-7.28 (m, 5H, C12, C13, C14), 6.92 (app. dt, J = 2.5, 9.0 Hz, 2H, C18), 4.79 (dd, J = 6.5 Hz, 1H, C5), 4.00 (dd, J = 6.5 Hz, 1H, C10), 3.69 (m, 2H, C3/C4), 3.11 (d, J = 5.5 Hz, 1H, OH), 2.81 (d, J = 6.0 Hz, 1H, OH), 1.45 (s, 3H, acetonide CH₃), 1.37 (s, 3H, acetonide CH₃), 1.37 (s, 3H, acetonide CH₃), 1.37 (s, 3H, acetonide CH₃); ¹³C NMR (125 MHz, CDCl₃) δ 166.6, 163.6, 138.9, 131.6, 128.2, 127.7, 122.8, 113.7, 109.3, 78.9, 77.0, 74.4, 70.5, 68.7, 66.0, 65.9, 55.4, 26.3, 25.3; IR (neat, cm⁻¹) 3455.5, 2985.2, 2935.9, 1713.2, 1606.5, 1581.4, 1512.3, 1258.5; HRMS (ESI) m/z calculated for C_{24}H_{29}O_6 [M + H]: 447.1924; found: 447.1922; [α]^{22}_D = -16.5° (c = 1.0, CHCl₃).

3-O-benzyl-4,5-di-O-(tert-butyldimethylsilyloxy)-1,2-di-O-isopropylidene-6-(4-methoxyphenylbenzoate)-L-galactitol
To (--)(10) (0.818 g, 1.91 mmol, 1 equiv.) was added dry CH₂Cl₂ (12.2 mL). The flask was cooled to 0°C and 2,6-lutidine (1.28 mL, 11.00 mmol, 6 equiv.) was added. Tert-butyldimethylsilyl triflate (1.26 mL, 5.50 mmol, 3 equiv.) was then added dropwise over 15 minutes with vigorous stirring. The reaction was stirred at 0°C for 20 minutes, then allowed to warm to room temperature and monitored via TLC. Upon completion (~40 min.), the reaction was again cooled to 0°C, H₂O (5 mL) was added slowly, and the reaction stirred 15 minutes to quench. EtOAc (10 mL) was added and the aqueous layer was extracted with additional EtOAc (3 x 15 mL). The combined organic layers were washed with H₂O (1 x 5 mL), sat. aq. NaHCO₃ solution, with H₂O (1 x 5 mL), then dried (Na₂SO₄), filtered, and reduced in vacuo. Purification via flash silica gel chromatography (2%-3%-5% EtOAc/hexanes) afforded 1.11 g (90%) of the title compound as a clear, viscous oil.

Rₚ = 0.320 (10% EtOAc/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 7.99 (app. d, J = 8.5 Hz, 2H, C17), 7.40 (d, J = 7.5 Hz, 2H, C12), 7.31 (t, J = 7.5 Hz, 2H, C13), 7.26-7.22 (m, 1H, C14), 6.91 (app. d, J = 8.5 Hz, C18), 4.83 (d, J = 12.0 Hz, 1H, C10), 4.80 (d, J = 12.0 Hz, 1H, C10), 4.62 (dd, J = 3.5, 11.5 Hz, 1H, C6), 4.52 (dd, J = 7.0, 9.0 Hz, 1H, C2), 4.50 (dd, J = 7.5, 14.8 Hz, 1H, C6), 4.09 (dt, J = 3.4, 7.0 Hz, 1H, C5), 4.06 (dd, J = 6.5 Hz, 9.0 Hz, 1H, C1), 3.86 (s, 3H, C20), 3.77 (app. t, J = 3.5 Hz, 1H, C4), 3.69 (app. t, J = 7.0 Hz, 1H, C1), 3.60 (dd, J = 3.5, 7.8 Hz, 1H, C3), 1.43 (s, 3H, acetonide CH₃), 1.35 (s, 3H, acetonide CH₃), 0.93 (s, 9H, TBS CH₂), 0.87 (s, 9H, TBS CH₂), 0.13 (s, 3H, TBS CH₃), 0.12 (s, 3H, TBS CH₃), 0.06 (s, 3H, TBS CH₃), 0.05 (s, 3H, TBS CH₃); ¹³C NMR (125 MHz, CDCl₃) δ 166.1, 163.2, 138.9, 131.6, 128.2, 127.7, 127.3, 122.8, 113.5, 108.9, 83.7, 76.6, 74.9, 74.6, 73.8, 66.7, 66.7, 55.4, 26.8, 25.9, 25.7, 25.3, 18.2, 18.0, -4.0, -4.4, -4.7, -4.8; IR (neat, cm⁻¹) 2954.9,
3-O-benzyl-4,5-di-O-(tert-butyldimethylsilyloxy)-1,2-di-O-isopropylidene-1-galacitol

To the fully protected 1-galactitol (1.05 g, 1.56 mmol, 1 equiv.) in a clean, dry 50 mL flask with a Teflon stir bar under an argon atmosphere was added dry CH₂Cl₂ (2.85 mL) and the flask was cooled to -78°C. Disobutylaluminum hydride (1.0 M in CH₂Cl₂, 3.89 mL, 2.5 equiv.) was added dropwise and the reaction was stirred vigorously at -78°C. Upon completion (~1 hr), -78°C EtOAc (5 mL) was added followed by sat. aq. Rochelle’s salts (15 mL). The reaction was allowed to warm to room temperature and then stirred an additional thirty minutes. H₂O (25 mL) and CH₂Cl₂ (20 mL) were added and the aqueous layer extracted with CH₂Cl₂ (3 x 15 mL). The combined organic layers were dried (Na₂SO₄), filtered, and reduced in vacuo.

The residue was purified via flash silica gel chromatography (7% EtOAc/hexanes) to give 0.823 g (~90%) of the title compound as a clear oil. Rf = 0.267 (10% EtOAc/hexanes); 1H NMR (500 MHz, CDCl₃) δ 7.40 (app. d, J = 7.0 Hz, 2H, C12), 7.32 (app. t, J = 7.0 Hz, 2H, C13), 7.29-7.24 (m, 1H, C14), 4.90 (d, J = 11.5 Hz, 1H, C10), 4.77 (d, J = 11.0 Hz, C10), 4.60 (dt, J = 7.0, 8.3 Hz, 1H, C2), 4.08 (dd, J = 7.0, 8.3 Hz, 1H, C1), 3.80 (dd, J = 3.0, 5.5, 11.6 Hz, 1H, C6), 3.73 (app. q, J = 4.0 Hz, 1H, OH), 3.70-3.64 (m, 1H, C6), 3.66, (dd, J = 3.0, 4.5 Hz, 1H, C4), 3.61 (dd, J = 3.0, 9.0 Hz, 1H, C3), 3.58 (app. t, J = 8.0 Hz, 1H, C1), 3.26 (app. dd, J = 5.5, 7.8 Hz, 1H, C5), 1.44 (s, 3H, C8/C9), 1.35 (s, 3H, C8/C9), 0.91 (s, 9H, TBS C(CH₃)₃), 0.90 (s, 3H, TBS C(CH₃)₂), 0.10 (s, 6H, TBS CH₃), 0.08 (s, 3H, TBS CH₃); 13C NMR (125 MHz, CDCl₃) δ 138.3, 128.3, 127.9, 127.6, 108.9, 85.5, 76.5, 75.9, 75.2, 74.8, 66.9, 62.0, 26.9, 25.9, 25.8, 25.4, 18.2, 18.0, -4.2, -4.7, -4.9, -4.9; IR (neat, cm⁻¹): 3474.6, 2954.3, 2930.5, 2886.5, 2858.1, 1472.0; HRMS (ESI) m/z calculated for C₂₈H₃₅O₅Si₂ [M + H⁺]: 541.3381; found 541.3376; [α]D²⁰ = +7.2° (c = 1.0, CHCl₃).

4-O-benzyl-2,3-di-O-(tert-butyldimethylsilyloxy)-1-galactopyranose

(-)-(11)

To a clean, dry 10 mL round bottom flask with a Teflon stir bar and an argon atmosphere was added oxalyl chloride (0.161 mL, 1.9 mmol, 1.25 equiv.) and dry CH₂Cl₂ (4.9 mL). The reaction flask was cooled to -65°C (CHCl₃, dry ice) and 0.671 mL of a 5.1M DMSO solution (3.42 mmol, 2.25 equiv.) in dry CH₂Cl₂ (3 x 10 mL). The reaction was then added dropwise and the reaction was stirred vigorously at -65°C. Upon stirring at -65°C, the reaction mixture was then added dropwise via cannula, and the reaction stirred for 20 minutes. Triethylamine (0.90 mL, 6.47 mmol, 4.25 equiv.) was added dropwise, the reaction was stirred 15 minutes at -65°C, then allowed to warm to room temperature and stirred an additional 10 minutes. Water (5 mL) was added and the reaction mixture transferred to a separatory funnel. The aqueous layer was extracted with CH₂Cl₂ (3 x 15 mL), the combined organics were dried (Na₂SO₄), filtered, and reduced in vacuo.

Conversion of the primary alcohol to the aldehyde was checked by ¹H NMR in C₆D₆ and determined to be ~90%.

To the crude aldehyde was added CH₂CN (6.6 mL) and Zn(NO₃)₂·6H₂O (1.25 g, ~5 equiv.) and the reaction was then taken to 50°C and monitored via TLC. Upon completion (~12hrs) the flask was cooled and the CH₂CN removed via rotary evaporation. Water (3 mL) and CH₂Cl₂ (10 mL) were added and the aqueous layer extracted with CH₂Cl₂ (3 x 10 mL). The combined organics were then dried (MgSO₄), filtered, and reduced in vacuo. Purification by flash chromatography (1% MeOH/CH₂Cl₂) gave 0.637 g of a white crystalline solid (~)-(11) (84% 2-steps). Rf = 0.104 (1%CH₂Cl₂); (Note: The product exists as a mixture of anomers, α:β = 3:2, with the β anomer as a mixture of two conformers) ¹H NMR (500 MHz, CDCl₃) δ 7.37-7.42 (m, 5H α, 10H β), 5.21 (t, J = 3.5 Hz, 1H, C1), 4.98 (d, J = 11.0 Hz, 1H, Cβ), 4.93 (d, J = 11.5 Hz, 1H, C7 α), 4.75 (d, J = 11.5 Hz, 1H β), 4.69 (dd, J = 3.5, 9.8 Hz, 1H β), 4.61-4.56 (m, 2H β), 4.59 (d, J = 12.0 Hz, 1H, C1), 4.34 (d, J = 10.0 Hz, 1H β), 4.08 (dd, J = 2.0, 5.0, 7.1 Hz, 1H, C6 α), 4.03-3.96 (m, 2H β), 4.01 (dd, J = 3.0, 8.0 Hz, 1H, C2/C3 α), 3.98 (dd, J = 2.5, 8.0 Hz, 1H, C2/C3 α), 3.96-3.91 (m, 2H β), 3.91-3.86 (m, 2H β), 3.88 (ddd, J = 4.0, 7.0, 11.4 Hz, 1H, C6 α), 3.84-3.82 (m, 2H β), 3.81-3.78 (m, 1H β), 3.80 (t, J = 2.5 Hz, 1H, C4 α), 3.75-3.65 (m, 3H β), 3.65 (ddd, J = 5.0, 8.5, 11.5 Hz, 1H, C6 α).
To a clean, dry 10 mL recovery flask under a nitrogen atmosphere with a Teflon© stir bar was added (-)-(11) (0.200 g, 0.401 mmol, 1 equiv.) and CH₂Cl₂ (2 mL). The reaction flask was cooled to 0°C and acetic anhydride (0.190 mL, 2.01 mmol, 5 equiv.), triethylamine (0.560 mL, 4.01 mmol, 10 equiv.) and 2,2-dimethyloxypyrindine (0.005 g, 0.04 mmol, 0.1 equiv.) were added. The reaction was then stirred at 0°C for 30 minutes, room temperature for 1 hour, and then at reflux for 5 hours. The reaction mixture was then transferred to a separatory funnel and EtOAc (15 mL) was added. The organic layer was washed with 1 M HCl (1 x 15 mL), 10% aq. NaHCO₃ solution (5 mL) and brine (15 mL). The organic layer was then dried (Na₂SO₄), filtered, and reduced in vacuo. THF (0.5 mL) was added to this crude residue along with a Teflon© stir bar and the reaction flask was cooled to 0°C. Tetra-n-butyrammonium fluoride (1.0 M in THF, 1.9 mL, 4.75 equiv.) was added slowly, and then the reaction was allowed to warm to room temperature and monitored via TLC. Upon completion, sat. aq. NH₄Cl solution (5 mL) was added and the aqueous layer extracted with CH₂Cl₂ (3 x 10 mL). The combined organic layers were dried (Na₂SO₄), filtered, and reduced in vacuo to give a brown residue, which was subsequently dissolved in CH₂Cl₂ (2 mL) and cooled to 0°C. A Teflon© stir bar acetic anhydride (0.190 mL, 2.01 mmol, 5 equiv.), triethylamine (0.560 mL, 4.01 mmol, 10 equiv.) and 2,2-dimethyloxypyrindine (0.005 g, 0.04 mmol, 0.1 equiv.) were added. The reaction mixture was again stirred at 0°C for 30 minutes, room temperature for 1 hour, and then at reflux for 5 hours. The reaction mixture was then cooled to room temperature and transferred to a separatory funnel with EtOAc (15 mL). The reaction mixture was then washed with 1 M HCl (1 x 15 mL), 10% aq. NaHCO₃ solution (15 mL), and brine (15 mL). The organic layer was then dried (Na₂SO₄), filtered, and reduced in vacuo to give a thick brown oil. Purification via flash silica gel chromatography (40%EtOAc/hexanes) afforded 0.173 g of a white, foamy oil (98%) as a mixture of anomers (α:β = 55:45). \( R_f = 0.434 \) (40%EtOAc/hexanes); \( \text{¹H NMR} \) (500 MHz, CDCl₃) \( \delta \) 7.38-7.30 (m, 5H α and 5H β), 6.36 (d, \( J = 3.5 \) Hz, 1H α), 5.16 (d, \( J = 8.0 \) Hz, 1H β), 5.53 (dd, \( J = 3.5, 11.0 \) Hz, 1H α), 5.50 (dd, \( J = 8.0, 10.5 \) Hz, 1H β), 5.29 (dd, \( J = 3.0, 11.0 \) Hz, 1H α), 5.01 (dd, \( J = 3.0, 10.5 \) Hz, 1H β), 4.75 (d, \( J = 11.5 \) Hz, 1H β), 4.73 (d, \( J = 11.0 \) Hz, 1H β), 4.55 (d, \( J = 11.5 \) Hz, 1H α), 4.54 (d, \( J = 11.5 \) Hz, 1H α), 4.24-4.15 (m, 2H α and 1H β), 4.13-4.05 (m, 2H α and 1H β), 3.98-3.94 (m, 1H β), 3.86-3.83 (m, 1H β), 2.13, 2.10, 2.05, 2.04, 2.02, 2.01, 2.0 (8s, 12 H α and 12H β); \( \text{¹³C NMR} \) (125 MHz, CDCl₃) \( \delta \) 170.4, 170.3, 170.3, 170.2, 169.8, 169.3, 169.1, 169.0, 137.2, 137.1, 128.6, 128.5, 128.5, 128.3, 128.1, 128.1, 92.1, 89.9, 75.2, 75.0, 74.2, 73.6, 73.1, 73.0, 70.4, 70.3, 68.4, 66.9, 62.2, 62.0, 20.9, 20.8, 20.7, 20.6, 20.5; \( \text{HRMS} \) (ESI) \( m/z \) calculated for \( \text{C}_{25}\text{H}_{26}\text{O}_{10}\text{Na} [\text{M} + \text{Na}]^{+} \): 461.1424, observed: 461.1431.\(^{[11]}\)
1H, C4), 4.86 (app. dd, J = 1.5, 5.5 Hz, 2H, C6), 4.67 (d, J = 11.0 Hz, 1H, C7), 4.38 (d, J = 11.5 Hz, 1H, C7), 3.94 (app. t, J = 7.5 Hz, 1H, C3), 3.87 (s, 3H, C17), 3.74-3.69 (m, 1H, C1/C2), 3.62-3.57 (m, 1H, C1/C2), 2.84 (d, J= 3.0 Hz, 1H, OH), 2.07 (t, J = 6.0 Hz, 1H, OH); 13C NMR (125 MHz, CDCl3) δ 165.9, 163.5, 137.6, 131.7, 130.5, 129.9, 128.5, 128.0, 128.0, 122.3, 113.7, 80.2, 73.7, 70.6, 63.9, 63.0, 55.4; HRMS (ESI) m/z calculated for: C21H25O6 [M + H]+: 373.1651, observed: 373.1654.

(2S,3S)-(Z)-3-O-benzyl-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Authentic Z isomer of (+)-(6) for determination of the E:Z selectivity of the linear allicylic C-H oxidation reaction was prepared through the following sequence: (-)-(10) was subjected to periodate cleavage to give a terminal aldehyde,12 followed by Still-Gennari olefination to give the (Z)-α,β-unsaturated methyl ester,13 which was reduced to the alcohol with diisobutylaluminum hydride, converted to the 4-methoxyphenylbenzoate derivative through dicyclohexylcarbodiimide assisted coupling with p-anisic acid, and finally acetoniode deprotected with Zn(NO3)2 · 6H2O. Rf = 0; 1H NMR (500 MHz, CDCl3) δ 8.00 (app. dt, J = 3.0, 9.0 Hz, 2H, C14), 7.37-7.28 (m, 5H, C9/C10/C11), 9.92 (app. dt, J = 3.0, 9.0 Hz, 2H, C13), 6.02 (dt, J = 6.5, 11.0 Hz, 1H, C5), 5.63 (dt, J = 1.5, 10.5 Hz, 1H, C4), 4.90 (ddd, J = 1.5, 7.0, 13.4 Hz, 1H, C6), 4.84 (ddd, J = 1.5, 6.5, 13.5 Hz, 1H, C6), 4.67 (d, J = 11.5 Hz, 1H, C7), 4.42 (d, J = 11.5 Hz, 1H, C7), 4.38 (dd, J = 7.5, 9.5 Hz, 1H, C2), 3.86 (s, 3H, C17), 3.72-3.78 (m, 1H, C1), 3.70-3.64 (m, 1H, C3), 3.63-3.56 (m, 1H, C1), 2.93 (b s, 1H, OH), 2.25 (b s, 1H, OH); 13C NMR (125 MHz, CDCl3) δ 166.1, 163.5, 137.6, 131.8, 131.7, 130.6, 128.6, 128.0, 127.7, 122.2, 113.7, 75.4, 73.7, 70.7, 62.8, 60.5, 55.4.

[5] Commercially available (1R,2R)-(−)-(1,2-Cyclohexanediamino-N,N’-bis(3,5-di-t-butylsalicylidene))Cobalt(II) can be oxidized to the Co(III)OAc species using AcOH in CH2Cl2, see ref. [3]
(3-Hydroxymethyl-oxiranyl)-methanol

Pulse Sequence: z2pul
Solvent: CD3OD
Ambient temperature
File:
INOVA-500 "sunds1"

Relax. delay 15 000 sec
Pulse 45.0 degrees
Acq. time 4.665 sec
Width 7024.9 Hz
2 repetitions
OBSERVE H1. 499.6984165 MHz
DATA PROCESSING
FT size 65536
Total time 0 min. 39 sec
{(2S,3S)-3,4-epoxy-1,2-di-O-isopropyldenebutane-1,2-diol

Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
File:
INOVA-500 "sunds1"

Relax. delay 15 000 sec
Pulse 45.0 degrees
Acq. time 4.665 sec
Width 7024.9 Hz
16 repetitions
OBSERVE  H1.  499.6964453 MHz
DATA PROCESSING
FT size 65536
Total time 5 min. 14 sec
(2S,3S)-3,4-epoxy-1,2-di-O-isopropylidenebutane-1,2-diol

Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: INOVA-500 "sunsol1"

Relax. delay 2.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
288 repetitions
OBSERVE C13, 125.5832517 MHz
DECOUPLE H1, 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 8 hr, 25 min, 29 sec
(2S,3S)-3-O-benzyl-1,2-di-O-isopropylidene-5-hexene-1,2,3-triol

Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
File:
INOVA-500 "sunds1"

Relax. delay 20000 sec
Pulse 45.0 degrees
Acq. time 4.096 sec
Width 8000.0 Hz
2 repetitions
OBSERVE H1 499.4358718 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 0 min. 48 sec
(2S,3S)-3-O-benzyl-1,2-di-O-isopropylidene-5-hexen-1,2,3-triol

Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: INOVA-500 "sundm1"

Relax. delay 2.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
448 repetitions

OBSERVE C13: 125.5832507 MHz
DECOUPLE H1: 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated

DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 8 hr. 25 min. 29 sec
(2S,3S)-(E)-3-O-benzyl-1,2-di-O-isopropylidene-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
File: NV.linear_product.proton
INOVA-500 "sunds1"

Relax. delay 15.000 sec
Pulse 45.0 degrees
Acq. time 4.096 sec
Width 8000.0 Hz
2 repetitions
OBSERVE  H1, 499.4358718 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 2 min. 32 sec
{2S,3S}-[E]-3-O-benzyl-1,2-di-O-isopropylidene-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
User: 1-34-87
File: NV linear product carbon
INOVA-500 "sundo1"

Relax. delay 1.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
288 repetitions
OBSERVE C13. 125.5832199 MHz
DECOUPLE H1. 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 33 min, 52 sec
(2S,3S)-(E)-3-O-benzyl-1,2-di-O-isopropylidene-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Pulse Sequence: gCOSY
Solvent: CDCl3
Ambient temperature
File: INOVA-500 "sundsl"

Relax. delay 2.000 sec
Acq. time 0.245 sec
Width 4196.7 Hz
2D Width 4196.7 Hz
Single scan
128 increments
OBSERVE H1, 500.0729779 MHz
DATA PROCESSING
Sq. sine bell 0.122 sec
F1 DATA PROCESSING
Sq. sine bell 0.031 sec
FT size 2048 x 2048
Total time 5 min. 27 sec
(2S,3S)-(E)-3-O-benzyl-1,2-di-O-isopropylidene-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Pulse Sequence: gCOSY
Solvent: CDC13
Ambient temperature
File: INOVA-500 "sunds1"

Relax. delay 2.000 sec
Acq. time 0.245 sec
Width 4186.7 Hz
2D Width 4186.7 Hz
Single scan
128 increments

OBSERVE H1, 500.0729779 MHz
DATA PROCESSING
  Sq. sine bell 0.122 sec
  F1 DATA PROCESSING
    Sq. sine bell 0.031 sec
    FT size 2048 x 2048
    Total time 5 min. 27 sec
3-O-benzyl-1,2-di-O-isopropylidene-6-[4-methoxyphenylbenzoate]-L-galactitol

Pulse Sequence: m2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-37
File: INOVA-500 "sundsl"

Relax. delay 2.000 s
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
272 repetitions
OBSERVE C13 125.5832517 MHz
DECOUPLE H1 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 8 hr. 25 min. 29 sec
3-O-benzyl-1,2-di-O-isopropylidene-6-[4-methoxyphenyl]benzoate]-L-galactitol

Pulse Sequence: relayh
Solvent: CDCl3
Ambient temperature
File: DJC-3-177-COSY
INOVA-500 "sundsl"

Relax. delay 2.000 sec
COSY 90-90
Acq. time 0.213 sec
Width 3599.4 Hz
2D Width 3599.4 Hz
4 repetitions
300 increments
OBSERVE H1, 399.9496762 MHz
DATA PROCESSING
Sq. sine bell 0.083 sec
F1 DATA PROCESSING
Sq. sine bell 0.083 sec
FT size 2048 x 2048
Total time 45 min, 22 sec
3-O-benzyl-1,2-di-O-isopropyldene-6-[4-methoxyphenylbenzoate]-L-galactitol

Pulse Sequence: relayh
3-O-benzyl-4,5-di-O-(tert-butyldimethylsilyloxy)-1,2-di-O-isopropylidene-6-(4-methoxyphenylbenzoate)-L-galactitol

Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
File: INOVA-500 "sundet1"

Relax. delay 30.000 sec
Pulse 45.0 degrees
Acq. time 4.096 sec
Width 6000.0 Hz
8 repetitions

OBSERVE H1, 499.4358708 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 4 min. 32 sec
3-O-benzyl-4,5-di-O-(tert-butyldimethylsilyloxy)-1,2-di-O-isopropylidene-6-(4-methoxyphenylbenzoate)-L-galactitol

Pulse Sequence: s2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-97
File: INOVA-500 "sunds"1

Relax. delay 2.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
1440 repetitions
OBSERVE C13. 125.5832497 MHz
DECOUPLE H1. 49.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
PT size 65536
Total time 42 hr. 7 min. 25 sec
3-O-benzyl-4,5-di-O-(tert-butylidimethylsilyl)oxy)-1,2-di-O-isopropylidene-6-(4-methoxyphenylbenzoate)-L-galactitol

Pulse Sequence: relayh
Solvent: CDC13
Ambient temperature
File: DJC-3-181-COSY
INOVA-500 "sunder"

Relax. delay 2.000 sec
COSY 90-90
Acq. time 0.163 sec
Width 3831.4 Hz
2D Width 3831.4 Hz
4 repetitions
320 increments
OBSERVE H1 399.940 MHz
DATA PROCESSING
Sq. sine bell 0.093 sec
F1 DATA PROCESSING
Sq. sine bell 0.084 sec
FT size 2048 x 2048
Total time 47 min, 19 sec
3-O-benzyl-4.5-di-O-(tertbutyldimethylsilanyloxy)-1,2-di-O-isopropylidene-L-galactitol

Pulse Sequence: m2pul
Solvent: CDC13
Ambient temperature
File: DJC-3-93-1H
INOVA-500 “sundst1”

Relax. delay 25.000 sec
Pulse 45.0 degrees
Acq. time 4.096 sec
Width 6000.0 Hz
16 repetitions
OBSERVE H1. 499.4358713 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 7 min. 45 sec

11 10 9 8 7 6 5 4 3 2 1 -0 -1 ppm
3-O-benzyl-4.5-di-O-(tert-butyldimethylsilylanyloxy)-1,2-di-O-isopropylidene-L-galactitol

Pulse Sequence: s2pul
Solvent: CDC13
Ambient temperature
User: 1-14-87
File:
INOVA-500 "sunds1"

Relax. delay 1.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
1040 repetitions

OBSERVE C13, 125.5832497 MHz
DECCUPLE H1, 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated

DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 56 hr, 28 min, 10 sec
Pulse Sequence: relayh
Solvent: CDC13
Ambient temperature
File: DJC-3-183-COSY
INOVA-500 “sunda1”

Relax. delay 2.000 sec
COSY 90-90
Acq. time 0.170 sec
Width 3529.5 Hz
2D Width 3529.5 Hz
4 repetitions
300 increments

OBSERVE H1, 399.9486781 MHz
DATA PROCESSING
SQ. sine bell 0.083 sec
F1 DATA PROCESSING
SQ. sine bell 0.085 sec
FT size 2048 x 2048
Total time 44 min, 31 sec
3-O-benzyl-4,5-di-O-(tert-butyldimethylsilyloxy)-1,2-di-O-isopropylidene-L-galactitol

Pulse Sequence: relayh
4-O-benzyl-2,3-di-O-(tert-butyldimethylsilyloxy)-L-galactopyranose

Pulse Sequence: a2pul

Solvent: CDC13
Ambient temperature
File: DJC-2-191-1H-0
INOVA-500 "sunds1"

Relax. delay 10.000 s
Pulse 50.0 degrees
Acq. time 4.096 sec
Width 6000.0 Hz
10 repetitions
OBSERVE H1. 500.0729754 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 3 min. 45 sec
Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
User: 1-14-87
File: INOVA-500 "sundsl"

Relax. delay 2.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
1236 repetitions

OBSERVE C13, 125.5832566 MHz
DECOUPLE H1, 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 8 hr, 25 min, 29 sec
Pulse Sequence: gCOSY
Solvent: CDCl3
Ambient temperature
File: DJIC3-145-2-COSY
INOVA-500 "sundet1"

Relax. delay 2.000 sec
Acq. time 0.229 sec
Width 4473.3 Hz
2D Width 4473.3 Hz
Single scan
256 increments
OBSERVE H1. 500.0729754 MHz
DATA PROCESSING
Sq sine bell 0.114 sec
F1 DATA PROCESSING
Sq sine bell 0.057 sec
FT size 2048 x 2048
Total time 10 min. 17 sec

![Chemical structure image]
4-O-benzyl-2,3-di-O-(tert-butyldimethylsilyloxy)-L-galactopyranose

Pulse Sequence: gCOSY
1,2,3,6-O-tetraacetyl-4-O-benzyl-L-galactopyranose

**Sample**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Aug 9 2006</td>
</tr>
<tr>
<td>Solvent</td>
<td>CDCl3</td>
</tr>
<tr>
<td>File</td>
<td>/export/home/<em>dpwr</em></td>
</tr>
<tr>
<td>Data</td>
<td>/xox/503/vermei</td>
</tr>
<tr>
<td>len/DJC.201</td>
<td>499.438</td>
</tr>
<tr>
<td>Acquisition</td>
<td>dm 1</td>
</tr>
</tbody>
</table>

**Flags**

- sp <-1000.0
- wp 7001.2
- w 151
- s 0
- wc 250
- hzmm 28.00
- is 33.52
- rfp 5134.9
- th 9
- Inc 1.000

**Diagram**

[Chemical structure diagram showing the molecular structure of 1,2,3,6-O-tetraacetyl-4-O-benzyl-L-galactopyranose]
(2S,3S)-(E)-3-O-benzyl-4-hexen-6-(4-methoxyphenyl)benzoate-1,2,3-triol

Pulse Sequence: z2pul
Solvent: CDCl3
Ambient temperature
File: NV11150.colunmed
INOVA-500 “sundsl”

Relax. delay 20.000 sec
Pulse 45.0 degrees
Acq. time 4.096 sec
Width 8000.0 Hz
9 repetitions
OBSERVE H1. 499.4358718 MHz
DATA PROCESSING
Line broadening 0.3 Hz
FT size 65536
Total time 40 min. 10 sec
{(2S,3S)-(E)-3-O-benzylo-4-hexen-6-(4-methoxyphenylbenzoate)-1,2,3-triol

Pulse Sequence: a2pul
Solvent: CDCl₃
Ambient temperature
User: 1-14-87
File: NVII150.cOLUMNED.carbon
INOVA=500 "mursel"

Relax. delay 1.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
154 repetitions
OBSERVE C13. 125.5832199 MHz
DECOUPLE H1. 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 33 min, 52 sec
Pulse Sequence: zlpal
Solvent: CDCl3
Ambient temperature
S/N ratio = 1500:1

Delay, delay 5.300 msec
Pulse 90.0 degrees
Acq. time 4.096 msec
Width 0.080 Hz
3 repetitions

Observations: 360.000769754 MHz
Data Processing:
Line broadening 0.3 Hz

Total time: 15 min, 10 sec
(2S,3S)-2-O-benzyl-3-hexene-6-(4-methoxyphenyl)benzate-1,2,3-triol

Pulse Sequence: s2pul

Solvent: CDCl3
Ambient temperature
User: L-14-97
File: NV-2-116-carbon
INOVA-500 "sundet"

Relax. delay 2.000 sec
Pulse 55.4 degrees
Acq. time 1.024 sec
Width 32000.0 Hz
368 repetitions
OBSERVE C13. 125.5832517 MHz
DECOUPLE H1. 499.4375375 MHz
Power 44 dB
continuously on
WALTZ-16 modulated
DATA PROCESSING
Line broadening 1.0 Hz
FT size 65536
Total time 84 hr. 14 min. 50 sec
HPLC Trace for the determination of d.r. for the Linear Allylic Oxidation
Mixture of Diastereomers
Agilent Zorbax Eclipse XDB-C8 (achiral)

Area Percent Report

Sorted By : Signal
Calib. Data Modified : Sunday, March 12, 2006 10:33:01 PM
Multiplier : 1.0000
Dilution : 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD1 A, Sig=254,4 Ref=off

<table>
<thead>
<tr>
<th>Peak</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area [mAU*sec]</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.911</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Dimethylphthalate</td>
</tr>
<tr>
<td>2</td>
<td>1.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Diethylphthalate</td>
</tr>
<tr>
<td>3</td>
<td>2.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Biphenyl</td>
</tr>
<tr>
<td>4</td>
<td>4.138</td>
<td>BV</td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>o-Terphenyl</td>
</tr>
<tr>
<td>5</td>
<td>24.363</td>
<td></td>
<td>0.7932</td>
<td>33787.61719</td>
<td>43.7591</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>27.270</td>
<td></td>
<td>0.9999</td>
<td>4795.17969</td>
<td>56.2409</td>
<td></td>
</tr>
</tbody>
</table>

Totals : 8472.79688

Results obtained with standard integrator:
1 Warnings or Errors :

Warning : Calibrated compound(s) not found

*** End of Report ***
HPLC Trace for the determination of d.r. for the Linear Allylic Oxidation
Reaction Mixture
Agilent Zorbax Eclipse XDB-C8 (achiral)

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000

Use Multiplier & Dilution Factor with ISIDs

Signal 1: DAD1 A, Sig=254.4 Ref=off

<table>
<thead>
<tr>
<th>Peak</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area [mAU]</th>
<th>Height [mAU]</th>
<th>Area [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.532</td>
<td>PB</td>
<td>0.074</td>
<td>14.61847</td>
<td>2.79001</td>
<td>0.0758</td>
</tr>
<tr>
<td>2</td>
<td>2.197</td>
<td>BB</td>
<td>0.077</td>
<td>9.90529</td>
<td>1.97520</td>
<td>0.0513</td>
</tr>
<tr>
<td>3</td>
<td>2.621</td>
<td>BV</td>
<td>0.043</td>
<td>4.80573</td>
<td>1.56789</td>
<td>0.0249</td>
</tr>
<tr>
<td>4</td>
<td>2.754</td>
<td>VV</td>
<td>0.066</td>
<td>86.77944</td>
<td>19.93310</td>
<td>0.4497</td>
</tr>
<tr>
<td>5</td>
<td>2.854</td>
<td>VV</td>
<td>0.073</td>
<td>54.13873</td>
<td>10.93784</td>
<td>0.2806</td>
</tr>
<tr>
<td>6</td>
<td>4.401</td>
<td>BB</td>
<td>0.112</td>
<td>59.89391</td>
<td>8.07902</td>
<td>0.3064</td>
</tr>
<tr>
<td>7</td>
<td>5.180</td>
<td>BB</td>
<td>0.141</td>
<td>35.75315</td>
<td>3.64962</td>
<td>0.1653</td>
</tr>
<tr>
<td>8</td>
<td>7.837</td>
<td>BV</td>
<td>0.295</td>
<td>611.49951</td>
<td>45.73174</td>
<td>3.1689</td>
</tr>
<tr>
<td>9</td>
<td>9.018</td>
<td>BB</td>
<td>0.215</td>
<td>17.37919</td>
<td>1.13523</td>
<td>0.0901</td>
</tr>
<tr>
<td>10</td>
<td>11.765</td>
<td>BB</td>
<td>0.300</td>
<td>167.80394</td>
<td>8.45830</td>
<td>0.8696</td>
</tr>
<tr>
<td>11</td>
<td>27.641</td>
<td>BB</td>
<td>0.741</td>
<td>1.82348e4</td>
<td>376.32697</td>
<td>94.4936</td>
</tr>
</tbody>
</table>

Totals: 1.92972e4 480.80022

Results obtained with standard integrator:

*** End of Report ***
HPLC Trace for the determination of E to Z selectivity for the Linear Allylic Oxidation Mixture of stereoisomers
Waters Corp. Symmetry - C18 (achiral)

![HPLC Trace](image)

---

### Area Percent Report

**Sorted By:** Signal  
**Calib. Data Modified:** Sunday, March 12, 2006 10:33:01 PM  
**Multiplier:** 1.0000  
**Dilution:** 1.0000

Use Multiplier & Dilution Factor with ISSTDs

**Signal 1: DAD1 D, Sig=205,4 Ref=off**

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.119</td>
<td>BV</td>
<td>0.2093</td>
<td>1532.99863</td>
<td>26.5769</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>11.293</td>
<td>VB</td>
<td>0.2311</td>
<td>4232.67871</td>
<td>73.4231</td>
<td></td>
</tr>
</tbody>
</table>

**Totals:** 5764.77734

**Results obtained with standard integrator:**

**Signal 2: DAD1 A, Sig=254,4 Ref=off** not found

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.911</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Dimethylphthalate</td>
</tr>
<tr>
<td>2</td>
<td>1.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Diethylphthalate</td>
</tr>
<tr>
<td>3</td>
<td>2.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Biphenyl</td>
</tr>
<tr>
<td>4</td>
<td>4.138</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>α-Terphenyl</td>
</tr>
</tbody>
</table>

**Totals:** 0.00000

---

HPLC Trace for the determination of E to Z selectivity for the Linear Allylic Oxidation Reaction Mixture
Waters Corp. Symmetry - C18 (achiral)

---

Area Percent Report

Sorted By: Signal
Calib. Data Modified: Sunday, March 12, 2006 10:33:01 PM
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISIDs

Signal 1: DAD1 D, Sig=205,4 Ref=off

<table>
<thead>
<tr>
<th>Peak RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td># [min]</td>
<td></td>
<td>[min]</td>
<td>[mAU*s]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 10.155 VV</td>
<td></td>
<td>0.2163</td>
<td>2.74342e4</td>
<td>96.7249</td>
<td></td>
</tr>
<tr>
<td>2 11.340 VV</td>
<td></td>
<td>0.2448</td>
<td>813.51147</td>
<td>2.8682</td>
<td></td>
</tr>
<tr>
<td>3 18.159 BB</td>
<td></td>
<td>0.3522</td>
<td>115.39488</td>
<td>0.4068</td>
<td></td>
</tr>
</tbody>
</table>

Totals: 2.83531e4

Results obtained with standard integrator:

Signal 2: DAD1 A, Sig=254,4 Ref=off not found

<table>
<thead>
<tr>
<th>Peak RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td># [min]</td>
<td></td>
<td>[min]</td>
<td>[mAU*s]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 0.911</td>
<td></td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Dimethylphthalate</td>
</tr>
<tr>
<td>2 1.207</td>
<td></td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Diethylphthalate</td>
</tr>
<tr>
<td>3 2.207</td>
<td></td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Biphenyl</td>
</tr>
<tr>
<td>4 4.138</td>
<td></td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>o-Terphenyl</td>
</tr>
</tbody>
</table>

Totals: 0.00000

Results obtained with standard integrator:

White Group HPLC 8/3/2006 2:17:30 PM Nicolaas Vermeulen
HPLC Trace for the determination of ee% of the (2S,3S)-3-O-benzyl-1,2-di-O-isopropylidene-5-hexen-1,2,3-triol

Mixture of Enantiomers

Diacel Chemical Ind. Chiralcel AD-RH (chiral)

---

Area Percent Report
---

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD1 D, Sig=205.4 Ref=off

Peak RetTime Type Width Area Height Area
# [min] [min] [mAU*s] [mAU] %  
---|--------|-----|--------|-----|--------|---
1  14.165 BV 0.3514 2.05778e4 894.34869 68.0142
2  15.503 VB 0.3637 9232.37598 389.26544 30.5150
3  17.485 BB 0.3836 444.98227 18.02574 1.4708

Totals: 3.02552e4 1301.63988

Results obtained with standard integrator!

*** End of Report ***
HPLC Trace for the determination of ee% of the (2S,3R)-3-O-benzyl-1,2-di-O-isopropylidene-5-hexen-1,2,3-triol
Reaction Mixture
Diacel Chemical Ind. Chiralcel AD-RH (chiral)

Area Percent Report

Sorted By: Signal
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISTDs

Signal 1: DAD1 D, Sig=205.4, Ref=off

<table>
<thead>
<tr>
<th>Peak</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area</th>
<th>Height</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.459</td>
<td>BB</td>
<td>0.2316</td>
<td>584.35138</td>
<td>38.52291</td>
<td>2.2179</td>
</tr>
<tr>
<td>2</td>
<td>14.158</td>
<td>MH T</td>
<td>0.3759</td>
<td>216.29025</td>
<td>9.58872</td>
<td>0.8209</td>
</tr>
<tr>
<td>3</td>
<td>15.396</td>
<td>BB</td>
<td>0.3784</td>
<td>2.55465e4</td>
<td>1037.43579</td>
<td>96.9612</td>
</tr>
</tbody>
</table>

Totals:
2.63471e4 1085.54742

Results obtained with standard integrator;

*** End of Report ***
HPLC Trace for the determination of the linear to branched ratio for the Linear Allylic Oxidation Mixture of isomers
Agilent Zorbax Eclipse XDB-C8 (achiral)

---

**Area Percent Report**

---

Sorted By : Signal  
Calib. Date Modified : Sunday, March 12, 2006 10:33:01 PM  
Multiplier : 1.0000  
Dilution : 1.0000  
Use Multiplier & Dilution Factor with ISTDs

**Signal 1: DAD1 A, Sig=254,4 Ref=off**

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime</th>
<th>Type</th>
<th>Width</th>
<th>Area [nAU*%]</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.911</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Dimethylphthalate</td>
</tr>
<tr>
<td>2</td>
<td>1.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Diethylphthalate</td>
</tr>
<tr>
<td>3</td>
<td>2.207</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>Biphenyl</td>
</tr>
<tr>
<td>4</td>
<td>4.138</td>
<td></td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
<td>o-Terphenyl</td>
</tr>
<tr>
<td>5</td>
<td>15.884 M</td>
<td>0.4544</td>
<td>1585.45728</td>
<td>85.3016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>18.725 M</td>
<td>0.4930</td>
<td>30.60897</td>
<td>1.6460</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>19.740 M</td>
<td>0.5472</td>
<td>242.58266</td>
<td>13.0516</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Totals : 1858.64890

Results obtained with standard integrator:
1 Warnings or Errors :

Warning : Calibrated compound(s) not found

*** End of Report ***
HPLC Trace for the determination of the linear to branched ratio for the Linear Allylic Oxidation Reaction Mixture
Agilent Zorbax Eclipse XDB-C8 (achiral)

Area Percent Report

Sorted By: Signal
Calib. Data Modified: Sunday, March 12, 2006 10:33:01 PM
Multiplier: 1.0000
Dilution: 1.0000
Use Multiplier & Dilution Factor with ISIDs

Signal 1: DAD1 A, Sig=254,4 Ref=off

<table>
<thead>
<tr>
<th>#</th>
<th>RetTime [min]</th>
<th>Type</th>
<th>Width [min]</th>
<th>Area [mAU*s]</th>
<th>Area %</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.911</td>
<td>------</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Dimethylphthalate</td>
</tr>
<tr>
<td>2</td>
<td>1.207</td>
<td>------</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Diethylphthalate</td>
</tr>
<tr>
<td>3</td>
<td>2.207</td>
<td>------</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>Biphenyl</td>
</tr>
<tr>
<td>4</td>
<td>4.138</td>
<td>------</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>α-Terphenyl</td>
</tr>
<tr>
<td>5</td>
<td>15.785 BB</td>
<td>------</td>
<td>0.4115</td>
<td>1.18309e+4</td>
<td>100.000</td>
<td>?</td>
</tr>
</tbody>
</table>

Totals: 1.18309e+4

Results obtained with standard integrator:
1 Warnings or Errors:
Warning: Calibrated compound(s) not found

*** End of Report ***