Synthesis and Chemistry of 4-Amino-4,6-dideoxy Sugars. VII. 4-Amino-4,6-dideoxy-D-altrose Derivatives[1,2]

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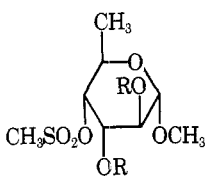
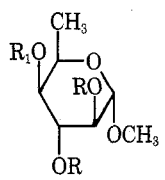
Methyl 4-amino-4,6-dideoxy-α-D-altropyranoside (8) was synthesized starting from methyl 6-deoxy-2,3-di-*O*-benzyl-4-*O*-methylsulfonyl-α-D-altropyranoside (1) employing a double inversion sequence at C-4. Preparations of several derivatives of 8, including *N*-acetate 9, triacetate 10, and the dimethylamino derivative, 12 are discussed. Hydrolysis of 12 with 1 *N* hydrochloric acid provided the crystalline free sugar hydrochloride, 13. The structure of 9 was confirmed by mass spectral analysis and also by its degradation to D-allothreoninol. Methyl 4,6-dideoxy-4-dimethylamino-α-D-altropyranoside (12) is shown to exist in the *C1* conformation in solution by NMR.

In view of the potential physiological activity of 4-amino-4,6-dideoxy hexoses,[1,4] the synthesis of several members of this class of carbohydrates was necessary both for their identification from natural sources and a complete evaluation of their biological activity. Here we describe the stereospecific synthesis of the derivatives of 4-amino-4,6-dideoxy-D-altrose. The amine function was introduced by utilizing a double inversion sequence[5] at carbon 4 of a 6-deoxy-D-altrose derivative.

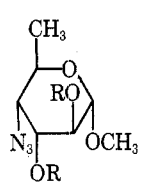
A displacement reaction of methyl 6-deoxy-2,3-di-*O*-benzyl 4-*O*-methylsulfonyl-α-D-altropyranoside[1] (1) with sodium benzoate in dimethylformamide to give 2 and subsequent hydrolysis of 2 with sodium hydroxide solution provided methyl 6-deoxy-2,3-di-*O*-benzyl-α-D-idopyranoside (3). Treatment of 3 with methanesulfonyl chloride in pyridine gave the inverted mesylate, 4. In order to establish that no carbon skeleton rearrangement had taken place during the benzoate displacement of 1, the methylsulfonyl group in 4 was displaced with sodium benzoate, the intermediate benzoyl derivative was hydrolyzed, and the resulting alcohol was treated with methanesulfonyl chloride in pyridine. The isolation of the original mesylate, 1, in 60% yield for the three steps provided evidence that the benzoate displacement reactions took place with inversion of configuration and without any structural rearrangement.



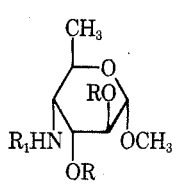
1, R = $CH_2C_6H_5$



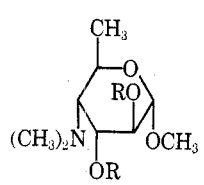
2, R = $CH_2C_6H_5$; R_1 = COC_6H_5
3, R = $CH_2C_6H_5$; R_1 = H
4, R = $CH_2C_6H_5$; R_1 = SO_2CH_3



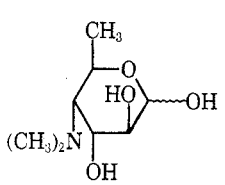
5, R = $CH_2C_6H_5$



6, R = $CH_2C_6H_5$; R_1 = H
7, R = $CH_2C_6H_5$; R_1 = Ac
8, R = R_1 = H
9, R = H; R_1 = Ac
10, R = R_1 = Ac



11, R = $CH_2C_6H_5$
12, R = H



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Treatment of 4 with sodium azide in dimethylformamide gave the azido derivative 5, which was hydrogenated in the presence of 10% Pd/C under neutral conditions to give the 4-amino sugar, 6. Compound 6 was also characterized as its *N*-acetate, 7. Hydrogenolysis of 6 in the presence of 10% Pd/C and hydrochloric acid as catalysts provided methyl 4-amino-4,6-dideoxy-α-D-altropyranoside (8). The *N*-acetate 9 was obtained both by the reductive debenzylation of 7 and by the selective N-acetylation of 8. Aminoglycoside 8 was further characterized as the triacetate 10 by acetylation with excess of acetic anhydride in pyridine. Attempted hydrolysis of 8 to obtain the corresponding free sugar under a variety of acid conditions was unsuccessful.

Treatment of 6 with formaldehyde and formic acid (Clark–Eschweiler conditions) provided the dimethylamino derivative, 11, which was characterized both as its crystalline hydrochloride and the quaternary salt with methyl iodide. Debenzylation of 11 by hydrogenation in the presence of 10% Pd/C and HCl as catalysts gave methyl 4,6-dideoxy-4-(*N,N*-dimethylamino)-α-D-altropyranoside (12). Hydrolysis of 12 with 1 *N* hydrochloric acid at 100° for 8 hr gave the free sugar 13, which was characterized as its crystalline hydrochloride. The synthesis of the dimethylamino sugar, 13, is significant, as an analogous compound, 4,6-dideoxy-4-(*N,N*-dimethylamino)-D-glucose, has been isolated from the antitumor antibiotic, amicetin.[6,7]

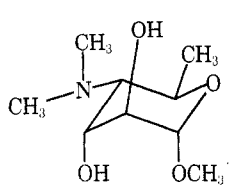
Although the displacement of a methylsulfonyl group with azide anion at position 4 of hexopyranosides has been known to proceed with inversion of configuration and without carbon skeleton rearrangement,[5,6] formation of a 5-azido furanose in the displacement of a pyranose-4-mesylate has also been reported.[9] It was, therefore, necessary to confirm the structure of the amino sugar derivatives discussed above by additional means. Degradation of 9 by a previously reported procedure[10] gave D-allothreoninol, confirming the D-erythro stereochemistry at C-4 and C-5, as required for a D-altrose derivative. Also, a comparison of the mass spectrum of 9 with seven other methyl 4-acetamido-4,6-dideoxy-D-hexopyranosides (see Table I) showed that the fragmentation pattern was nearly identical for all the eight isomeric 4-amino sugar derivatives.[11] On the other hand, similar 5-acetamido furanose derivatives produced a significantly different fragmentation pattern[12] in their mass spectra, thus showing that 9 is indeed a 4-amino-4,6-dideoxyhexopyranosyl derivative.

Table I
Mass Spectra of Methyl 4-Acetamido-4,6-dideoxy-α-D-hexopyranosides

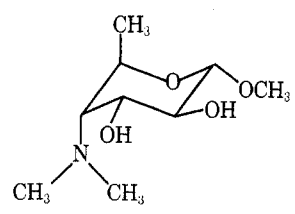
	Rel abundance							
m/e	Gluco[a]	Galacto[b]	Manno[c]	Talo[d]	Allo[e]	Gulo[f]	Altro	Ido[g]
41	10	13	12	15	9	8	12	6
42	10	16	12	17	6	10	10	6
43	73	80	100	100	55	94	80	65
44	16	11	44	12	22	10	17	5
45	10	11	13	19	8	15	21	8
56	19	21	23	28	17	23	23	23
57	64	47	71	50	100	67	78	60
58	29	24	25	27	42	28	33	25
59	93	70	99	80	78	88	88	47
60	100	80	95	80	82	100	100	100
61	7	6	6	11	6	8	8	6
70	5	6	4	10	4	4	4	4
71	9	9	6	10	6	9	9	8
72	9	7	7	9	16	9	18	6
73	9	7	8	15	6	14	9	4
74	75	78	72	60	34	49	60	51
75	5	6	5	12	3	8	4	3
82	9	11	7	10	12	8	7	9
84	6	18	7	10	8	4	6	12
85	4	6	2	5	3	6	4	5
86	14	22	11	21	7	11	12	9
87	27	14	20	20	11	19	17	15
98	7	9	7	9	8	8	7	8
99	61	37	66	45	96	98	76	56
100	22	19	19	18	33	32	40	40
101	60	43	46	45	38	43	66	20
102	83	76	60	58	40	52	75	21
114	14	7	7	7	16	13	20	15
115	26	13	13	16	33	28	29	28
128	10	15	11	11	2	7	12	11
142	22	5	11	5	25	11	29	1
146	17	100	16	70	2	9	6	1
159	6	1	1	4	15	2	14	4
170	1	6	6	4	1	3	7	8
188	18	7	4	13	1	2	9	1

[a] Reference 5b. [b] Reference 8. [c] Reference 10a. [d] C. L. Stevens, R. P. Glinski, and K. G. Taylor, *J. Org. Chem.*, 33, 1586 (1968). [e] β-methyl glycoside, ref 4. [f] J. P. Dickerson, Ph.D. Dissertation, Wayne State University, 1966. [g] Reference 1.

A NMR analysis of the dimethylamino sugar, **12**, in $CDCl_3$ showed that the anomeric proton appeared as a doublet ($J_{1,2}$ = 3 Hz) at τ 5.4, indicating a diequatorial coupling. This means that **12** exists in solution as the *C1*(D) conformer, **14** (*CA* in the Isbell–Tipson system of conformational nomenclature[13] and $^4C_1$ according to the new British–U.S. rules[14]) and not as the *1C*(D) conformer, **15** ($^1C_4$),[14] which would require diaxial coupling between C-1 H and C-2 H. This finding is in total agreement with previ-



14 (*C1*)



15 (*1C*)

ous reports that both α-D-altropyranose pentaacetate[15] and α-D-idopyranose pentaacetate[16] exist in the *C1*(D) conformation in solution. Further, methyl 4-acetamido-2,3-di-*O*-acetyl-4,6-dideoxy-α-D-idopyranoside has also been found to exist in solution as the *C1*(D) conformer.[1]

Experimental Section

Melting points were taken on a Thomas-Hoover capillary melting point apparatus and are uncorrected. Thin layer chromatography was carried out using silica gel H from Brinkmann Instruments on 5 × 20 glass plates. A solvent system consisting of diethyl ketone, diisopropyl ketone, and ligroin (6:3:1) was used unless otherwise mentioned. The NMR spectra were taken on a Varian A-60 spectrometer using tetramethylsilane as an internal standard. Infrared spectra were recorded on a Perkin-Elmer Infracord instrument. Specific rotations were measured using a Perkin-Elmer 141 polarimeter. The pK_a's were determined in 50% aqueous methanol. Elemental analyses were performed by Midwest Microlab, Inc., Indianapolis, Ind.

Methyl 4-*O*-Benzoyl-6-deoxy-2,3-di-*O*-benzyl-α-D-idopyranoside (2). A mixture of 34.0 g (0.08 mol) of methyl 6-deoxy-2,3-di-*O*-benzyl-4-*O*-methylsulfonyl-α-D-altropyranoside[1] (1) and 34.0 g of sodium benzoate in 500 ml of DMF was heated under reflux with vigorous stirring for 50 hr. A TLC analysis indicated that the reaction was complete. The mixture was poured into 2.5 l. of water and extracted with ether (3 × 200 ml), and the ether layer was dried (Na_2SO_4) and evaporated under vacuum to give 32.8 g (91.3%) of **2** as a pale yellow oil. A small portion was evaporatively distilled (110°, 10^{-3} mmHg) for analysis, $[\alpha]^{24}D$ +78.3° (*c* 1.6, MeOH).

Anal. Calcd for $C_{28}H_{30}O_6$: C, 72.70; H, 6.53. Found: C, 72.88; H, 6.83.

Methyl 6-Deoxy-2,3-di-*O*-benzyl-α-D-idopyranoside (3). A

solution of 7.9 g (17 mmol) of **2** in 200 ml of ethanol and 100 ml of water containing 16 g (0.4 mol) of NaOH was heated under reflux on a steam bath for 8 hr. A TLC analysis showed that the hydrolysis was complete. Most of the solvents were removed under vacuum and the residue was diluted with 80 ml of water. The mixture was extracted with ether, dried (K_2CO_3), and evaporated to dryness to yield 4.6 g (75.2%) of **3** as an oil. Evaporative distillation (100°, 10^{-3} mmHg) of a small sample gave a colorless liquid for analysis, $[\alpha]^{24}D$ +33.6° (*c* 1.43, MeOH).

Anal. Calcd for $C_{21}H_{26}O_5$: C, 69.37; H, 7.31. Found: C, 69.45; H, 7.22.

Methyl 6-Deoxy-2,3-di-*O*-benzyl-4-*O*-methylsulfonyl-α-D-idopyranoside (4). Methanesulfonyl chloride (5.8 g, 15 mmol) was added dropwise to a solution of 4.6 g (12.8 mmol) of **3** in 200 ml of pyridine cooled in a Dry Ice bath. After the addition was complete, the mixture was allowed to warm up to 0° and then left at that temperature for 3 days. The mixture was poured into 1 l. of ice–water. An oily layer was formed which crystallized on standing, 4.58 g (82%), mp 82–85°. It was recrystallized from 2-propanol to give 4.1 g (74%) of **4**: mp 85–86°; NMR ($CDCl_3$) τ 8.75 (d, $J_{5,6}$ = 7 Hz, 3, CCH_3), 7.20 (s, 3, SO_2CH_3), 6.55 (s, 3, OCH_3), 2.65 (d, 10, aromatic); $[\alpha]^{26}D$ +34.5° ($CHCl_3$). A mixture melting point with **1** was depressed to 67–68°.

Anal. Calcd for $C_{22}H_{28}O_7S$: C, 60.53; H, 6.62; S, 7.35. Found: C, 60.73; H, 6.66; S, 7.15.

Treatment of 1.3 g (3 mmol) of **4** with sodium benzoate in DMF and subsequent hydrolysis of the benzoyl derivative with NaOH and mesylation of the alcohol provided 780 mg (60%) of **1**, mp 85–86°, $[\alpha]^{25}D$ +53.9° (*c* 1.0, $CHCl_3$).[1]

Methyl 4-Azido-2,3-di-*O*-benzyl-4,6-dideoxy-α-D-altropyranoside (5). A solution of 4.0 g (9.2 mmol) of **4** and 3.0 g (47 mmol) of NaN_3 in 75 ml of DMF was heated under reflux for 2 hr. After cooling, the reaction mixture was poured into 375 ml of water, extracted with petroleum ether, dried (Na_2SO_4), and concentrated in vacuo to yield 3.2 g (91.5%) of a slightly yellow oil. Column chromatography over Woelm grade I neutral alumina using ether–petroleum ether (1:4) as eluent gave 2.5 g (71.4%) of **5**, homogeneous by TLC, $[\alpha]^{26}D$ +39.8° (*c* 1.0, $CHCl_3$), $n^{27}D$ 1.5358.

Anal. Calcd for $C_{21}H_{25}N_3O_4$: C, 65.77; H, 6.57; N, 10.96. Found: C, 65.90; H, 6.69; N, 10.69.

Methyl 4-Amino-2,3-di-*O*-benzyl-4,6-dideoxy-α-D-altropyranoside (6). A solution of 2.45 g (6.4 mmol) of **5** in 50 ml of methanol was hydrogenated in the presence of 100 mg of 10% Pd/C for 18 hr at slightly above atmospheric pressure. Filtration of the catalyst followed by removal of the solvent under vacuum gave 1.6 g (70%) of **6** as a gum, one spot on TLC. A small portion was evaporatively distilled (100–105°, 10^{-3} mmHg) for analysis: NMR ($CDCl_3$) τ 8.75 (d, $J_{5,6}$ = 7 Hz, 3, CCH_3), 6.65 (s, 3, OCH_3), 2.7 (s, 10, aromatic); $[\alpha]^{25}D$ +64.5° (*c* 1.4, CH_3OH); pK_a = 7.65.

Anal. Calcd for $C_{21}H_{27}NO_4$: C, 70.56; H, 7.61; N, 3.92. Found: C, 70.30; H, 7.84; N, 3.94.

Methyl 4-Acetamido-2,3-di-*O*-benzyl-4,6-dideoxy-α-D-altropyranoside (7). A solution of 500 mg (1.4 mmol) of **6** in 5 ml of pyridine was treated with 5 ml of acetic anhydride overnight. The solvents were removed in vacuo, and the residue was partitioned between water and $CHCl_3$. The chloroform solution was dried (Na_2SO_4) and evaporated to dryness. The residue which crystallized on standing was recrystallized from ethanol–ether to give 338 mg (60%) of **7**, mp 99–100°.

Anal. Calcd for $C_{23}H_{29}NO_5$: C, 69.15; H, 7.32; N, 3.50. Found: C, 69.03; H, 7.45; N, 3.52.

Methyl 4-Amino-4,6-dideoxy-α-D-altropyranoside (8). A solution of 500 mg (1.4 mmol) of **6** in 50 ml of methanol was hydrogenated in the presence of 100 mg of 10% Pd/C and 5 drops of concentrated HCl at slightly above atmospheric pressure for 10 hr. The catalyst was filtered and the filtrate was passed over a column of 4 ml of Dowex-I (^-OH). The solution was then passed over a column of 4 ml of Dowex-50 (H^+). The free amine was liberated with 200 ml of ethanol containing 3% ammonium hydroxide. The solvents were removed under vacuum and the residue was triturated with ether. The white solid obtained was recrystallized from 1-propanol–ether to give 161 mg (61%) of **8**, mp 116–117°, $[\alpha]^{24}D$ +128.5° (*c* 0.85, MeOH).

Anal. Calcd for $C_7H_{15}NO_4$; C, 47.42; H, 8.54; N, 7.91. Found: C, 47.17; H, 8.46; N, 8.13.

Methyl 4-Acetamido-4,6-dideoxy-α-D-altropyranoside (9). A. By Hydrogenation of Compound 7. A solution of 330 mg (0.8 mmol) of **7** in 50 ml of methanol containing 3 drops of concentrated HCl was hydrogenated at slightly above atmospheric pressure with 75 mg of 10% Pd/C as catalyst for 8 hr. The catalyst was removed by filtration, the acid was neutralized by passing over Dowex-I (OH^-), and the solution was evaporated to dryness. The residue which solidified on trituration was recrystallized from 2-propanol–ether to give 102 mg (67%) of **9**, mp 151–153°, $[\alpha]^{22}D$ +198.3° (*c* 1.0, MeOH).

Anal. Calcd for $C_9H_{17}NO_5$: C, 49.31; H, 7.82; N, 6.39. Found: C, 49.50; H, 7.67; N, 6.13.

B. By Selective Acetylation of 8. A solution of 160 mg (0.74 mmol) of **8** in 50 ml of MeOH was cooled to 0° and 16 drops of acetic anhydride was added 2 drops at a time at 10-min intervals. Evaporation of the solvent in vacuo followed by trituration of the residue with ether gave a crystalline material which was recrystallized from 2-propanol–ether to give 128 mg (7) of **9**, mp 151–153°. A mixture melting point of this sample with the previously analyzed sample was undepressed.

Degradation of 100 mg (0.45 mmol) of **8** according to a previously reported procedure[10] gave 23 mg (26% for four steps) of D-allothreoninol hydrogen oxalate, mp 172–173° dec. A mixture melting point with an authentic sample was unchanged.

Methyl 4-Acetamido-2,3-di-*O*-acetyl-4,6-dideoxy-α-D-altropyranoside (10). A solution of 120 mg (0.33 mmol) of **6** in 5 ml of pyridine was treated with 5 ml of acetic anhydride at room temperature for 24 hr. The solvents were removed in vacuo and the residue was diluted with 10 ml of ice–water. The mixture was extracted with $CHCl_3$, dried (Na_2SO_4), and evaporated to dryness. The residue was recrystallized from 2-propanol–pentane to give 152 mg (87%) of **30**, mp 168–169°, $[\alpha]^{24}D$ +129.2° (*c* 1.0, $CHCl_3$).

Anal. Calcd for $C_{13}H_{21}NO_7$: C, 51.48; H, 6.98; N, 4.62. Found: C, 51.49; H, 7.12; N, 4.64.

Methyl 2,3-Di-*O*-benzyl-4,6-dideoxy-4-dimethylamino-α-D-altropyranoside (11). A solution of 4.0 g (13.2 mmol) of **6** in 15 ml of 88% formic acid and 2.5 ml of 37% formalin was heated on a steam bath for 10 hr. The solvents were removed under vacuum, and the residue dissolved in 50 ml of methanol was passed over a column of Dowex-I (^-OH). The solution was then passed over a column of Dowex-50$X_2(H^+)$ and the free amine was liberated by elution with 100 ml of methanol containing 5 ml of ammonium hydroxide. The solution was concentrated and the oily residue was evaporatively distilled (110–115°, 10^{-3} mmHg) to give 3.6 g (67%) of **11** as a colorless oil, $[\alpha]^{26}D$ +76.1° (*c* 1.3, CH_3OH), pK_a = 7.25.

Anal. Calcd for $C_{23}H_{31}NO_4$: C, 71.66; H, 8.11; N, 3.63. Found: C, 71.42; H, 7.97; N, 3.69.

Treatment of 200 mg of **10** with HCl in 2-propanol and recrystallization from 2-propanol–ether gave 201 mg (88%) of the hydrochloride salt of **11**, mp 154–155°, $[\alpha]^{26}D$ 0.6° (*c* 1.0, CH_3OH).

Anal. Calcd for $C_{23}H_{32}ClNO_4$: C, 65.44; H, 7.65; Cl, 8.41; N, 3.32. Found: C, 65.37; H, 7.65; Cl, 8.35; N, 3.17.

A small portion of **10** was also converted to the quaternary salt by treatment with methyl iodide in methanol. The salt was recrystallized from absolute ethanol, mp 159–161°, $[\alpha]^{26}D$ +63.1° (*c* 1.0, CH_3OH).

Anal. Calcd for $C_{24}H_{34}INO_4$: C, 54.65; H, 6.49; I, 24.07; N, 2.66. Found: C, 54.39; H, 6.69; I, 24.14; N, 2.86.

Methyl 4,6-Dideoxy-4-dimethylamino-α-D-altropyranoside (12). A solution of 550 mg (1.4 mmol) of **11** in 150 ml of methanol containing 10 drops of concentrated HCl was hydrogenated at slightly above atmospheric pressure in the presence of 150 mg of 10% Pd/C. The hydrogenation was complete in 20 hr. The catalyst was filtered and the filtrate was passed over Dowex-I (^-OH). The solution was evaporated to dryness and the residue which solidified on trituration with petroleum ether was recrystallized from ether–petroleum ether to give 188 mg (83%) of **12**: mp 110–112°; NMR ($CDCl_3$) 7.65 (d, $J_{5,6}$ = 7 Hz, 3, CCH_3), 7.50 [s, 6, $N(CH_3)_2$], 6.55 (s, 3, OCH_3), 5.4 (d, $J_{1,2}$ = 3 Hz, 1, C-1 H); pK_a = 7.52.

Anal. Calcd for $C_9H_{19}NO_4$: C, 52.67; H, 9.33; N, 6.82. Found: C, 52.74; H, 9.43; N, 6.67.

A small portion of **12** was converted to its hydrochloride salt and recrystallized from ethanol–ether, mp 156–158°, $[\alpha]^{26}D$ +132.9° (*c* 1.0, CH_3OH).

Anal. Calcd for $C_9H_{20}ClNO_4$: C, 44.70; H, 8.34; Cl, 14.67; N, 5.79. Found: C, 44.47; H, 8.29; Cl, 14.88; N, 5.77.

4,6-Dideoxy-4-dimethylamino-D-altrose Hydrochloride (13). A solution of 50 mg of the hydrochloride of **12** in 7.5 ml of 1 *N* HCl was heated on an oil bath at 95–98° for 8 hr. The solution was evaporated to dryness and then repeatedly azeotroped with absolute ethanol. The residue was triturated with ether to give 28 mg (61%) of **13**, mp 174–177°. Recrystallization from 2-propanol–ether gave 24 mg of **13**, mp 176–177°, $[\alpha]^{25}D$ +86.8° (initial −43.9°)

(final, 2.5 hr) (c 1.0, H_2O). The material also traveled as a single spot on paper chromatography using 2-propanol–water–ammonia (7:2:1) and 1-butanol–water–ammonia (7:2:1) systems.

Anal. Calcd for $C_8H_{18}ClNO_4$: C, 42.19; H, 7.97; N, 6.15. Found: C, 42.18; H, 8.03; N, 6.40.

Acknowledgment. Financial support from the National Institutes of Health, Grant GM 11520, is gratefully acknowledged.

Registry No.—**1**, 53951-08-9; **2**, 55570-34-8; **3**, 55570-35-9; **4**, 53928-92-0; **5**, 55570-36-0; **6**, 55570-37-1; **7**, 55570-38-2; **8**, 55637-43-9; **9**, 51255-06-2; **10**, 51209-16-0; **11**, 55570-39-3; **11** HCl, 55605-89-5; **11** methiodide, 55605-90-8; **12**, 55570-40-6; **12** HCl, 55570-41-7; **13**, 55570-42-8; sodium benzoate, 532-32-1; methanesulfonyl chloride, 124-63-0; acetic acid, 64-19-7.

References and Notes

(1) Part VI: C. L. Stevens, J. P. Dickerson, K. G. Taylor, P. Blumbergs, and P. M. Pillai, *J. Org. Chem.*, preceding paper in this issue.
(2) For a preliminary account of this work see C. L. Stevens, P. Blumbergs, J. P. Dickerson, and D. Chitharanjan, Abstracts, 149th National Meeting of the American Chemical Society, Detroit, Mich., April 4–9, 1965, p 5C.
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Synthesis and Reactions of Methyl 2,3-Di-*O*-benzyl-4,6-dideoxy-α-D-*threo*-hex-4-enopyranoside[1]

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The syntheses of a 4,6-unsaturated sugar derivative, methyl 2,3-di-*O*-benzyl-4,6-dideoxy-α-D-*threo*-hex-4-enopyranoside (**5**), by a Cope elimination of methyl 2,3-di-*O*-benzyl-4,6-dideoxy-4-(*N*,*N*-dimethylamino)-*N*-oxo-α-D-altropyranoside (**2**) and by a Hofmann elimination of methyl 2,3-di-*O*-benzyl-4,6-dideoxy-4-(*N*,*N*-dimethylamino)-α-D-idopyranoside methiodide (**4**) are described. Hydroboration of **5** and subsequent oxidation with hydrogen peroxide yielded methyl 6-deoxy-2,3-di-*O*-benzyl-α-D-altropyranoside (**7**), whereas hydroboration of **5** followed by hydrolysis with acetic acid provided methyl 2,3-di-*O*-benzyl-4,6-dideoxy-α-D-*arabino*-hexopyranoside (**8**).

Unsaturated sugars, although neglected for a long time, are gaining importance recently because of their potential value in synthetic carbohydrate chemistry.[3] In addition, it has been suggested that some unsaturated sugars play significant biological roles in metabolic pathways.[4,5] Unsaturated sugars also occur naturally, for example, ascorbic acid and the nucleoside antibiotic, blasticidin S.[6] We now describe the synthesis of a 4,5-unsaturated hexose derivative and its hydroboration reactions under oxidative and nonoxidative conditions.

Treatment of methyl 2,3-di-*O*-benzyl-4,6-dideoxy-4-(*N*,*N*-dimethylamino)-α-D-altropyranoside[7] (**1**) with freshly purified *m*-chloroperbenzoic acid[8] afforded the *N*-oxide **2**, which was characterized as its crystalline hydrochloride. Pyrolysis of **2** at 98–100° under reduced pressure (Cope elimination) gave the unsaturated sugar, 2,3-di-*O*-benzyl-4,6-dideoxy-α-D-*threo*-hex-4-enopyranoside (**5**), in 72% yield. Compound **5** was also prepared by a Hofmann elimination reaction as follows. Conversion of methyl 2,3-di-*O*-benzyl-4,6-dideoxy-4-(*N*,*N*-dimethylamino)-α-D-idopyranoside[9] (**3**) to the quaternary ammonium iodide (**4**) followed by treatment of **4** with silver oxide in methanol provided **5** in 52% yield. The structure of **5** was established by its analysis and spectral data.

Attempted synthesis of **5** by base-catalyzed elimination of methyl 2,3-di-*O*-benzyl-6-deoxy-4-*O*-methylsulfonyl-α-D-idopyranoside[7,9] (**9**) and from methyl 2,3-di-*O*-benzyl-6-deoxy-6-iodo-4-*O*-methylsulfonyl-α-D-altropyranoside[7] (**10**) according to the procedure of Helferich and Himmen[10] were unsuccessful.

Hydroboration of **5** with a mixture of sodium borohydride and boron trifluoride etherate and subsequent treatment with hydrogen peroxide provided methyl 6-deoxy-2,3-di-*O*-benzyl-α-D-altropyranoside (**6**) in 72% yield. The structure of **6** was confirmed by its conversion to the crystalline methylsulfonate **7** and its identification with an authentic sample.[7] The formation of **6** as the major product in this reaction suggests that the addition of diborane takes