and methyl 3,6-anhydro-β-D-glucofuranoside were obtained again as crystals in the same way as described previously.

Partial methanolysis of anhydroamylose. A 4-g. sample of anhydroamylose prepared from A1 was heated under reflux with 50 ml. of 0.1*N* hydrogen chloride in methanol for 3 hr. The acid was removed by neutralization with silver carbonate and filtration, and the filtrate was concentrated to a sirup which weighed 4.2 g. It was chromatographed on a charcoal Celite column (5 × 23 cm.), using successively increasing concentrations of ethanol in water as eluent. Five liters of each eluent was used. The results are shown in Table VIII.

TABLE VIII

CHROMATOGRAPHIC SEPARATION OF PARTIAL-METHANOLYSIS PRODUCTS OF ANHYDROAMYLOSE

Fraction	Eluent[a]	Yield, %	$R_{glucose}$[b]
I	W, and 5% E	43	2.49, 2.78
II	7.5% E	1	1.17, 2.49, 2.78
III	15% E	6	1.78, 2.37
IV	20% E	10	1.08, 1.54, 2.37
V	30% E	13	0.94, 1.19, 1.54
VI	50% E	18	At least 7 spots

[a] W = water; E = ethanol. [b] Paper chromatogram was developed with 1-butanol-ethanol-water (40:11:19 v./v.) and sprayed with *o*-aminophenol reagent.[19]

On the basis of the result of complete methanolysis described above, fraction I is probably a mixture of monosaccharide derivatives. Since fractions V and VI were eluted with 30% and 50% ethanol, these are probably mixtures of higher oligosaccharide derivatives. Disaccharide derivatives would be expected in fractions II, III, or IV; these fractions were obtained in lower yields. Among the several spots observed on paper chromatograms of fractions III and IV, a spot showing an $R_{glucose}$ value of 2.37 seemed to be the most intense. This component was isolated and characterized as described below.

Fractions III and IV were combined, and then separated on several chromatographic papers, the solvent being 1-butanol-ethanol-water (40:11:19 v./v.). The component having an $R_{glucose}$ value of 2.37 was recovered as a sirup which weighed 0.30 g. (7% of the methanolysis products). Crystallization was effected by dissolving it in a small volume of acetone, adding ether until a slight turbidity formed, and placing the resulting solution in a refrigerator; yield 0.21 g.; m.p. 158–160°. The product was twice recrystallized from a mixture of methanol and ether; m.p. 163–165°, $[\alpha]^{25}_{D}$ +19.0° (*c*, 1.0 in water).

Anal. Calcd. for $C_{12}H_{18}O_8\ (OCH_3)_2$: C, 47.72; H, 6.87; OCH_3, 17.62; mol. wt., 352.3. Found: C, 47.92; H, 6.77; OCH_3, 17.46; mol. wt. (Rast), 350.

A 10.30-mg. portion of the crystals obtained above was dissolved in 10 ml. of 0.11*M* sodium metaperiodate solution and the mixture was kept in the dark at room temperature. The residual oxidant was titrated at intervals in the usual manner. The compound consumed 0.99, 1.01, and 1.03 moles of periodate after 7, 15, and 48 hr., respectively.

A 50-mg. portion of the crystals was hydrolyzed with 2 ml. of 0.05*N* sulfuric acid at 100° for 5 hr. The solution was neutralized with barium carbonate, filtered, and evaporated to a sirup (41 mg.). Paper chromatographic examination showed the presence of 3,6-anhydro-D-glucose and 5-(hydroxymethyl)-2-furaldehyde. Crystallization from ethanol-ethyl acetate–petroleum ether (1:1:1 v./v.) afforded 3,6-anhydro-D-glucose; yield 30 mg. (64%); m.p. and mixed m.p. 118°, $[\alpha]^{25}_{D}$ +54.0° (*c*, 0.5 in water).

A similar result was obtained when anhydroamylose prepared from B2 was subjected to partial methanolysis. The yields of chromatographic fractions were 41, 2, 9, 10, 15, and 17% of the methanolyzate, corresponding to fractions I, II, III, IV, V, and VI in Table VIII, respectively.

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LAFAYETTE, IND.

[CONTRIBUTION FROM THE NATIONAL INSTITUTE OF ARTHRITIS AND METABOLIC DISEASES, NATIONAL INSTITUTES OF HEALTH, PUBLIC HEALTH SERVICE, U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE]

2,3,5-Tri-*O*-benzyl-D-ribosyl and -L-arabinosyl Bromides

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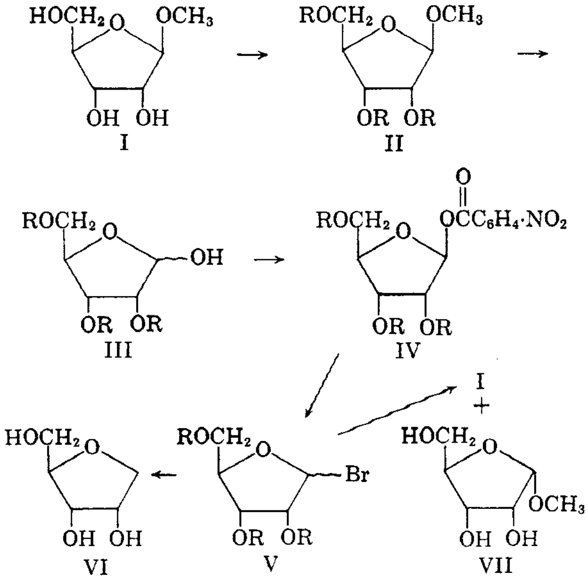
In the D-ribofuranose and L-arabinofuranose series fully benzylated methyl furanosides have been synthesized. Mild acid hydrolysis converts these into 2,3,5-tri-*O*-benzylpentofuranoses, the L-arabinose isomer being obtained in crystalline form. *p*-Nitrobenzoylation of the isomer in each series gave 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoylpentoses, one anomer being obtained in crystalline form in the D-ribofuranose series and both in the L-arabinofuranose series. With a slight excess of hydrogen bromide in methylene chloride these esters were converted to the 2,3,5-tri-*O*-benzylpentosyl bromides. In both series, these highly reactive halides were obtained as sirups. The nature of the D-ribofuranosyl halide was demonstrated through reduction to the known 1,4-anhydro-D-ribitol as well as conversion to the anomeric methyl D-ribofuranosides. The L-arabinofuranosyl bromide was reduced to amorphous 1,4-anhydro-L-arabitol which was characterized as its crystalline tri-*p*-nitrobenzoate. The identity of this ester was confirmed through an independent synthesis from ethyl 5-*O*-benzoyl-1-thio-β-L-arabinoside. Improvements in the preparation of methyl β-D-ribofuranoside are described.

Although the acylated glycosyl halides are vital intermediates in a wide variety of syntheses, their usefulness has certain limitations. First, displacement of the halogen atom often takes place with participation of one of the acyl groups, resulting in the dominance of one anomer among the products. Second, the acylated glycosyl halides are generally unsuitable for the synthesis of those glycosyl derivatives in which alkali-labile substituents are attached to the reducing carbon, the removal of the masking acyl groups tending to eliminate the desired substituent. For these reasons we have investigated the synthesis and behavior of some glycosyl halides in which the hydroxyl groups are masked with other than acyl groups.

In contrast to acyl groups, benzyl ether groups would not be expected to participate in solvolyses of neighboring halogen atoms and may, through catalytic hydrogenation, be removed under mild and essentially neutral conditions. Attention was therefore directed toward the poly-*O*-benzylaldosyl halides. No compound of this type has heretofore been described as far as we are aware. Zemplén, Csürös, and Angyal,[1] however, treated 1,6-di-*O*-acetyl-2,3,4-tri-*O*-benzyl-D-glucose with hydrogen bromide in glacial acetic acid and obtained an amorphous halide having the odor of benzyl bromide. That this, in fact, contained 6-*O*-acetyl-2,3,4-tri-*O*-benzyl-D-glucosyl bromide was demonstrated through reaction with benzyl alcohol in the presence of silver carbonate and subsequent isolation of benzyl 6-*O*-acetyl-2,3,4-tri-*O*-benzyl-β-D-glucoside in 15% yield. Schmidt, Auer, and Schmadel[2] have recently shown that methyl α-D-glucopyranoside may be fully benzylated in high yield and then hydrolyzed to give crystalline 2,3,4,6-tetra-*O*-benzyl-α-D-glucose.

The D-ribofuranose series was chosen initially for an attempt to prepare a poly-*O*-benzylglycosyl halide. Using methanolic sulfuric acid, the free sugar was converted in 79% yield to crystalline methyl β-D-ribofuranoside (I). Complete benzylation of this glycoside was attained in one step using benzyl chloride and powdered potassium hydroxide with tetrahydrofuran as a diluent.[3] The product (II), obtained as a distillable sirup, was hydrolyzed in dioxane solution with aqueous hydrochloric acid to give amorphous 2,3,5-tri-*O*-benzyl-D-ribose (III). *p*-Nitrobenzoylation then afforded a crystalline 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-D-ribose; inasmuch as the material remaining in the mother liquor was more dextrorotatory than this crystalline ester, the latter is tentatively assumed to be the β-anomer (IV). With a slight excess of hydrogen bromide in methylene chloride, either the crystalline ester (IV) or the material in the mother liquor from its preparation rapidly precipitated *p*-nitrobenzoic acid in nearly quantitative yield.[4] Concentration of the filtrate afforded a sirupy, highly reactive 2,3,5-tri-*O*-benzyl-D-ribosyl bromide (V); attempts to crystallize the substance were without success. Reduction, first with lithium aluminum hydride[5] and then with hydrogen over palladium, converted the bromide to the known 1,4-anhydro-D-ribitol (VI). With methanol and silver carbonate the bromide gave, after reductive removal of the benzyl groups, a mixture of the two anomeric methyl D-ribofuranosides, the rotation indicating the predominance of the α-anomer (VII).



$R = C_6H_5CH_2-$

In the L-arabinose series methyl α-L-arabinofuranoside tribenzoate[6] (VIII) was converted to methyl 2,3,5-tri-*O*-benzyl-α-L-arabinoside (IX), obtained as a distillable sirup. Hydrolysis of the methoxyl group afforded a crystalline, weakly dextrorotatory 2,3,5-tri-*O*-benzyl-L-arabinose whose solution in methylene chloride showed a slight levorotation when treated with a trace of aqueous hydrochloric acid. This observation suggests that the substance is the β-L-isomer (X). *p*-Nitrobenzoylation of X gave the two crystalline 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-L-arabinoses (XIa and XIb). When treated in methylene chloride with a slight excess of hydrogen bromide, these promptly precipitated *p*-nitrobenzoic acid in nearly quantitative yield. Concentration of the filtrate gave a reddish sirup which could not be induced to crystallize. That 2,3,5-tri-*O*-benzyl-L-arabinosyl bromide (XII) was present was demonstrated through reduction, first with lithium aluminum hydride, and then with hydrogen in the presence of palladium. The amorphous product thus obtained consumed 0.97 molar equivalent of sodium metaperiodate as expected of a 1,4-anhydropentitol (XIII). On *p*-nitrobenzoylation it gave a crystalline ester, 1,4-

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(1) G. Zemplén, Z. Csürös, and S. Angyal, *Ber.*, **70**, 1848 (1937).

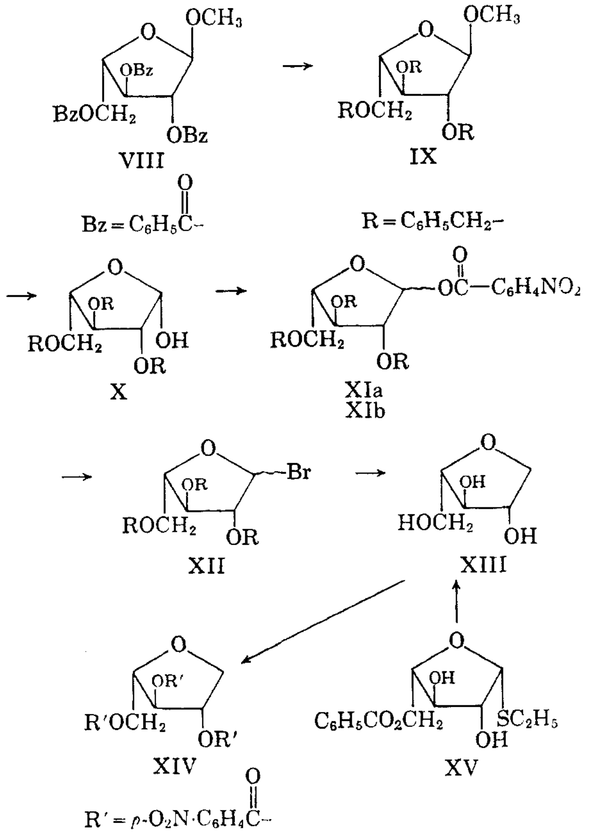
(2) O. Schmidt, T. Auer, and H. Schmadel, *Chem. Ber.*, **93**, 556 (1960).

(3) The use of tetrahydrofuran, both to make the mixture more readily stirrable and, through its comparatively low boiling point, to maintain a constant and moderate reaction temperature, is desirable.

(4) This convenient technique of making substituted glycosyl halides under relatively mild conditions is based on the very low solubility of *p*-nitrobenzoic acid in methylene chloride. See W. W. Zorbach and T. A. Payne, *J. Am. Chem. Soc.*, **80**, 5564 (1958); R. K. Ness and H. G. Fletcher, Jr., *ibid.*, **82**, 3434 (1960).

(5) R. K. Ness, H. G. Fletcher, Jr., and C. S. Hudson, *J. Am. Chem. Soc.*, **72**, 4547 (1950).

(6) The D-isomer of this substance: R. K. Ness and H. G. Fletcher, Jr., *J. Am. Chem. Soc.*, **80**, 2007 (1958); R. S. Wright and H. G. Khorana, *J. Am. Chem. Soc.*, **80**, 1994 (1958).



anhydro-2,3,5-tri-*O*-*p*-nitrobenzoyl-L-arabitol (XIV). By way of confirming the identity of this substance, ethyl 5-*O*-benzoyl-1-thio-β-L-arabinoside[7] (XV) was reductively desulfurized with Raney nickel and then debenzoylated. The sirupy anhydride was then *p*-nitrobenzoylated to give a product identical with that derived from the bromide (XII).

EXPERIMENTAL[8]

Methyl β-D-ribofuranoside (I). Preliminary studies of the behavior of D-ribose in anhydrous methanol containing concentrated sulfuric acid were carried out at 20°, samples of the reaction mixture being removed at intervals and neutralized with barium methoxide. Chromatography of the samples on paper in ethyl acetate–propyl alcohol–water (5:3:1 v./v.) showed that the maximum concentration of methyl β-D-ribofuranoside (R_f 0.61) occurred at the disappearance of the reducing sugar. The only other significant amount of material present was methyl α-D-ribofuranoside (VII) (R_f 0.55). Rotational measurements indicated that the mixture at this point consisted of approximately 80% of the β-anomer and 20% of the α-anomer. On the basis of these studies the following preparation was devised.

A solution of 5 g. of D-ribose in 100 ml. of dry methanol was cooled to 0° and treated with 0.5 ml. of concd. sulfuric acid. After storage at +4° overnight (12–16 hr.) the solution was neutralized by passage through a bed of Amberlite IR-45 in the free base form. The eluate was concentrated to a sirup which crystallized readily on seeding.[9] The crystalline residue was dissolved in 150 ml. of ethyl acetate and decolorizing carbon added. After filtration through a bed of Celite, the solution was concentrated on a steam cone to a volume of approximately 30 ml. It was then cooled to room temperature, seeded and left at +4° overnight to give 3.8 g. of product melting at 79–80° and showing $[\alpha]_{\mathrm{D}}^{20}$ −50° (*c*, 2.0 H_2O). A second crop (0.5 g.), obtained by concentrating the mother liquor, raised the total yield to 79%. Augestad and Berner[10] reported a m.p. of 80° and $[\alpha]_{\mathrm{D}}^{20}$ −49.8° (*c*, 4.2 H_2O) for methyl β-D-ribofuranoside which they had purified by repeated chromatography on cellulose.

Methyl 2,3,5-tri-O-benzyl-D-riboside (II). To a stirred solution of 40 g. of methyl β-D-ribofuranoside in 300 ml. of redistilled tetrahydrofuran was added 180 g. of powdered potassium hydroxide.[11] Benzyl chloride (250 ml.) was then added and the mixture heated under reflux. After 40 min. the gummy mass had broken up and the reaction mixture could then be stirred easily. Stirring and refluxing were continued for 24 hr. The solid matter was then removed by filtration and washed thoroughly with tetrahydrofuran. On concentration (finally at 100° and 15 mm. pressure) the combined mother liquor and washings gave 101 g. of sirup which was fractionally distilled at 0.3 mm. The main fraction, b.p. 235°, 88.9 g. (84%), showed $[\alpha]_{\mathrm{D}}^{20}$ +22.4° (*c*, 3.6, dioxane), $[\alpha]_{\mathrm{D}}^{20}$ +17.5° (*c*, 5.8, tetrahydrofuran) and $[\alpha]_{\mathrm{D}}^{20}$ +13.8° (glacial acetic acid). As its infrared spectrum did not differ significantly from that of other fractions and since the residual distilland was small, the distillation was omitted in subsequent preparations.

Anal. Calcd. for $C_{27}H_{30}O_5$ (434.51): C, 74.63; H, 6.96; CH_3O, 7.14. Found: C, 74.76; H, 7.01; CH_3O, 7.30.

2,3,5-Tri-O-benzyl-D-ribose (III). When 4.46 g. of methyl 2,3,5-tri-*O*-benzyl-β-D-riboside was dissolved in 100 ml. of dioxane and 25 ml. of 0.1*N* hydrochloric acid added, the solution showed a rotation in a 0.5-dm. tube of 0.53°. The solution was boiled gently for 1.5 hr., 25 ml. of distillate being collected. After cooling, it was made up to its original volume with 25 ml. of a mixture of 12 parts of water and 88 parts of dioxane (v./v.); it then showed a rotation (0.5 dm.) of 0.77°. More 0.1*N* hydrochloric acid (25 ml.) was then added and the process repeated to give a solution (150 ml.) showing (0.5 dm.) a rotation of 0.66°. Allowing for the dilution, no rotatory change was caused, therefore, by the second period of heating. After neutralization with 1*N* sodium hydroxide, the solution was concentrated *in vacuo* and the residual sirup, dissolved in methylene chloride, washed three times with water. Moisture was removed with sodium sulfate, the solution decolorized with Darco X and the solvent removed to give 3.6 g. of a yellow sirup which was dissolved in 100 ml. of cyclohexane and adsorbed on a column of 100 g. of Woelm neutral alumina, grade II. The column was washed with benzene and then eluted with ether to give a sirupy fraction (2.2 g.) showing $[\alpha]_{\mathrm{D}}^{20}$ +37° in dioxane (*c*, 4.0). A second amorphous fraction (1.2 g.), showing the same rotation, was obtained by elution with methanol: total yield, 79%. No methyl 2,3,5-tri-*O*-benzyl-β-D-ribofuranoside, which is eluted from grade II alumina by benzene, was obtained.

Anal. Calcd. for $C_{26}H_{28}O_5$ (420.48): C, 74.26; H, 6.71; CH_3O, 0. Found: C, 74.06; H, 6.88; CH_3O, 0.6.

2,3,5-Tri-O-benzyl-1-O-p-nitrobenzoyl-β-D-ribose (IV). 2,3,5-Tri-*O*-benzyl-D-ribose (43.15 g.) was dissolved in 100 ml. of dry methylene chloride and to the cooled solution was added a solution of 21 g. of *p*-nitrobenzoyl chloride in a

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(7) The D-isomer: E. J. Reist, P. A. Hart, L. Goodman, and B. R. Baker, *J. Am. Chem. Soc.*, **81**, 5176 (1959). The L-isomer: C. Pedersen and H. G. Fletcher, Jr., *J. Org. Chem.*, **25**, 1255 (1961).

(8) Melting points are corrected.

(9) Seeds were obtained by dissolving a sample of the sirup in ethyl acetate and cooling and scratching the solution.

(10) I. Augestad and E. Berner, *Acta Chem. Scand.*, **10**, 911 (1956).

(11) The powdered potassium hydroxide available from Hooker Chemical Corp., Niagara Falls, N. Y., is particularly convenient for such benzylations.

mixture of 50 ml. of dry methylene chloride and 15 ml. of pyridine. After 1 hr. at room temperature the reaction mixture was treated with a few chips of ice and stirred. Thirty minutes later the organic layer was washed successively with equal volumes of *N* hydrochloric acid, saturated aqueous sodium bicarbonate and water. Moisture was removed with sodium sulfate and the solution concentrated. The sirupy residue was dissolved in 50 ml. of methylene chloride and cyclohexane added to incipient turbidity. On seeding[12] 32 g. of somewhat sticky crystals was obtained. After two recrystallizations from methanol, the product (19.5 g.) melted at 85–86° and showed $[\alpha]_D^{20}$ +47.5° in carbon tetrachloride (*c*, 2.0). The mother liquor afforded 12.1 g. of equally pure material, raising the yield to 31.6 g. (54%).

Anal. Calcd. for $C_{33}H_{31}NO_8$ (569.59): C, 69.58; H, 5.49; N, 2.46. Found: C, 69.85; H, 5.24; N, 2.53.

The amorphous material remaining in the mother liquor had virtually the same infrared spectrum as the crystalline product and showed $[\alpha]_D^{20}$ + 70° (*c*, 1.3 carbon tetrachloride); it may also be used for the preparation of the halide as described below.

2,3,5-Tri-O-benzyl-D-ribosyl bromide (V). Two grams of 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-β-D-ribose was dissolved in 5 ml. of dry methylene chloride and 1.1 molar equivalents of hydrogen bromide in dry methylene chloride added rapidly. After 2–5 min. the precipitated *p*-nitrobenzoic acid (m.p. 240°) was filtered off and washed with methylene chloride: 560 mg., 95%. The filtrate, protected from atmospheric moisture, was concentrated *in vacuo* to yield a purplish sirup which could not be induced to crystallize and was, therefore, used without further purification for subsequent reactions.

1,5-Anhydro-D-ribitol (VI) *from 2,3,5-tri-O-benzyl-D-ribosyl bromide* (V). To a cooled solution of the bromide (from 2.0 g. of 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-β-D-ribose) in 10 ml. of dry tetrahydrofuran was added 5 ml. of 2*M* lithium aluminum hydride in tetrahydrofuran. The strongly exothermic reaction quickly subsided and, after 30 min., the excess of lithium aluminum hydride was destroyed through the cautious addition of ethyl acetate. Dilute hydrochloric acid (5*N*) was then added and the 1,4-anhydro-2,3,5-tri-*O*-benzyl-D-ribitol extracted with methylene chloride. After the extract had been washed successively with 1*N* hydrochloric acid and aqueous sodium bicarbonate, it was dried with sodium sulfate; removal of solvent then gave a yellow sirup (1.37 g., 96%) which showed no hydroxyl absorption in the infrared. The sirup was dissolved in absolute ethanol and reduced in the presence of 1 g. of freshly prepared 10% palladium on charcoal, 220 ml. of hydrogen being absorbed in 15 min. After removal of the catalyst the solution was concentrated *in vacuo* to give a crystalline residue (450 mg.). Two recrystallizations from isopropyl alcohol gave a product (220 mg., 48%) which melted at 100–101° and showed $[\alpha]_D^{20}$ +67° in water. Kuhn and Wendt[13] reported a m.p. of 99° and $[\alpha]_D^{20}$ +66.7° (water) for 1,4-anhydro-D-ribitol.

The anhydride consumed 1 molar equivalent of sodium metaperiodate, giving a dialdehyde which rotated $[\alpha]_D^{20}$ −10°; Richtmyer and co-workers[14,15] reported $[\alpha]_D^{20}$ −9.4°, −9.7°, and −9.9° for what should be the same product, obtained through the periodate oxidation of various 1,5-anhydro-D-hexitols.

The anomeric methyl-D-ribofuranosides (I and VII) *from 2,3,5-tri-O-benzyl-D-ribosyl bromide* (V). Sirupy 2,3,5-tri-*O*-benzyl-D-ribosyl bromide, prepared from 1 g. of 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-β-D-ribose, was treated with 25 ml. of methanol and 4 g. of finely divided silver carbonate. The reaction mixture was stirred at room temperature for 2.5 hr., the silver salts were removed by filtration and the solution was concentrated *in vacuo* to give 680 mg. of sirup which showed an infrared spectrum similar to that of methyl 2,3,5-tri-*O*-benzyl-β-D-riboside. The material was reduced in dioxane solution in the presence of 1 g. of palladium on charcoal, 140 ml. of hydrogen being absorbed in 1 hr. Removal of the catalyst and concentration of the solution gave a sirup which showed $[\alpha]_D^{20}$ +104° in water (*c*, 2.5). Chromatography on paper, using the ethyl acetate–propyl alcohol–water (5:3:2) system, indicated that the sirup was largely composed of methyl α-D-ribofuranoside, R_f 0.55, with approximately 20% of methyl β-D-ribofuranoside, R_f 0.61. The sirup consumed 1.07 molecular equivalents of sodium metaperiodate.

Methyl 2,3,5-tri-O-benzyl-α-L-arabinoside (IX). Methyl α-L-arabinofuranoside tribenzoate made by the procedure reported earlier for its enantiomorph,[6] melted at 103° and showed $[\alpha]_D^{20}$ +19.9° in chloroform (*c*, 1.56). To a stirred suspension of 110 g. of powdered potassium hydroxide in 500 ml. of dry tetrahydrofuran was added 55 g. of methyl α-L-arabinofuranoside tribenzoate, followed by 165 ml. of benzyl chloride. The reaction mixture was stirred and refluxed for 8 hr., then cooled and filtered through Celite. The precipitate was washed thoroughly with methylene chloride and the combined filtrate and washings were concentrated, finally at 100° and aspirator pump pressure. Distillation of the residue *in vacuo* afforded a main fraction (45 g., 90%), b.p.$_{0.25}$ 217–220° and $[\alpha]_D^{20}$ −44.6° (*c*, 6.0 methylene chloride). The infrared spectrum of this product was very similar to that of the corresponding D-ribose derivative, there being no absorption due to either hydroxyl or carbonyl groups.

Anal. Calcd. for $C_{27}H_{30}O_5$ (434.51): C, 74.63; H, 6.96; CH_3O, 7.14. Found: C, 74.93; H, 7.03; CH_3O, 7.17.

2,3,5-Tri-O-benzyl-β-L-arabinose (X). Methyl 2,3,5-tri-*O*-benzyl-α-L-arabinoside (36.7 g.) was dissolved in 450 ml. of dioxane and 125 ml. of 3*N* hydrochloric acid added. The solution was boiled for 5 hr., approximately 150 ml. of distillate being collected; it was then cooled and neutralized with aqueous sodium hydroxide. The solvent was removed *in vacuo* and the residue extracted with methylene chloride, the extract then being washed thoroughly with water and dried with sodium sulfate. Upon removal of solvent a sirup was obtained which was dissolved in isopropyl ether. Addition of pentane to the solution and seeding[16] gave 12.0 g. of slightly gummy crystals. Recrystallized from the same solvent mixture, the product (10.6 g., 30%) melted at 83–84° and showed $[\alpha]_D^{20}$ +3.3° in methylene chloride (*c*, 5.0); upon the addition of a trace of 5*N* hydrochloric acid the rotation changed to $[\alpha]_D^{20}$ −4.4° within 10 min., no further change being observed on standing overnight.

Anal. Calcd. for $C_{26}H_{28}O_5$ (420.48): C, 74.26; H, 6.71; CH_3O, 0. Found: C, 74.01; H, 6.75; CH_3O, 0.22.

The mother liquor from the above preparation contained both starting material and product and could be heated again with acid to give further quantities of the 2,3,5-tri-*O*-benzyl-β-L-arabinose. The presence of a substantial quantity of the unchanged glycoside in the mother liquor suggests that an equilibrium favorable to the glycoside is established during the hydrolysis despite the large molar excess of water.

The two anomeric 2,3,5-tri-O-benzyl-1-O-p-nitro-benzoyl-L-arabinoses (XIa and XIb). 2,3,5-Tri-*O*-benzyl-β-L-ara-

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(12) Seeds were initially obtained by chromatographing a sample of the sirupy material on neutral alumina, the α-anomer being eluted with benzene and the β-anomer with ether. The latter crystallized spontaneously from its sirupy form.

(13) R. Kuhn and G. Wendt, *Chem. Ber.*, **81**, 553 (1948).

(14) N. K. Richtmyer and C. S. Hudson, *J. Am. Chem. Soc.*, **65**, 64 (1943).

(15) E. Zissis and N. K. Richtmyer, *J. Am. Chem. Soc.*, **77**, 5154 (1955).

(16) Seed crystals were obtained by chromatographing a sample of the crude material on Woelm, grade II, alumina, the unhydrolyzed material being eluted with benzene and the desired product (which crystallized spontaneously from the sirupy form) with methanol.

binose (4.00 g.) was dissolved in 15 ml. of methylene chloride and the solution treated with a solution of 1.9 g. of *p*-nitrobenzoyl chloride in a mixture of 10 ml. of methylene chloride and 3 ml. of dry pyridine. After standing overnight at room temperature the methylene chloride solution was washed successively with 1*N* hydrochloric acid, aqueous sodium bicarbonate, and water. Moisture was removed with sodium sulfate and the solution concentrated to give 5.4 g. of sirup which crystallized spontaneously. Recrystallization from methanol afforded 4.64 g. (86%) of a mixture of the anomeric esters melting at 75–92° and showing $[\alpha]_D^{20}$ +11.0° in methylene chloride (*c*, 6.8).

Through fractional crystallization from ether-pentane the anomers were separated. The less soluble anomer crystallized as large plates, m.p. 77–78° and $[\alpha]_D^{20}$ +43.9° (*c*, 5.4 methylene chloride). The more soluble anomer crystallized as long needles, m.p. 96–97°, $[\alpha]_D^{20}$ −59° (*c*, 2.0 methylene chloride). In accord with the usual convention, the dextrorotatory isomer is designated the *β*-anomer (XIb) and the levorotatory isomer designated the *α*-anomer (XIa). From the rotations of the two pure substances it is apparent that the original mixture consisted of approximately 68% of the *β*-anomer.

Anal. Calcd. for $C_{33}H_{31}NO_8$ (569.59): C, 69.58; H, 5.49; N, 2.46. Found: (*β*-anomer) C, 69.86; H, 5.60; N, 2.42; (*α*-anomer) C, 69.65; H, 5.59; N, 2.49.

1,4-Anhydro-L-arabitol tri-p-nitrobenzoate (XIV). (*a*) *via 2,3,5-tri-O-benzyl-L-arabinosyl bromide* (XII). Two grams of a mixture of the anomeric 2,3,5-tri-*O*-benzyl-1-*O*-*p*-nitrobenzoyl-L-arabinofuranoses, dissolved in methylene chloride, was treated with 30 ml. of a 0.15*N* solution of hydrogen bromide in methylene chloride. After 5 min. the precipitated *p*-nitrobenzoic acid was filtered off and washed with methylene chloride; yield 565 mg. (96%). The filtrate and washings were concentrated to a reddish sirup which was dissolved in 10 ml. of tetrahydrofuran and treated with 5 ml. of a 2.0*M* solution of lithium aluminum hydride in tetrahydrofuran. When the reaction mixture had cooled to room temperature ethyl acetate was added cautiously to destroy the excess of reducing agent. It was then acidified with 50 ml. of 5*N* hydrochloric acid and extracted twice with 50-ml. portions of methylene chloride. The combined extracts were washed with saturated aqueous sodium bicarbonate and with water. Moisture was removed with sodium sulfate and the solvent removed to leave 1.31 g. of a sirup which showed only minor hydroxyl absorption in the infrared. Adsorption of the whole sample on alumina, followed by elution with methylene chloride, afforded a colorless sirup (1.15 g.) showing neither hydroxyl nor carbonyl components in the infrared. It was then dissolved in absolute ethanol and reduced in the presence of palladium on charcoal. Hydrogen absorption was slow, several hours being required to reach the theoretical value. The catalyst was removed and the filtrate concentrated to give a sirup which failed to crystallize. Chromatography, using Whatman No. 1 paper and *n*-butyl alcohol–water (86:14), revealed only one component, having an R_f of 0.6. On the basis of a molecular weight of 134, the sirup consumed 0.97 molar equivalent of sodium metaperiodate. Acylation of 910 mg. of this 1,4-anhydro-L-arabitol (prepared in a similar run) with *p*-nitrobenzoyl chloride in the usual manner afforded 3.49 g. (88%) of crystalline product which was recrystallized successively from benzene, chloroform–carbon tetrachloride and aqueous acetone: m.p. 80–82°; $[\alpha]_D^{20}$ +85.1° in chloroform (*c*, 0.5).

Anal. Calcd. for $C_{26}H_{19}N_3O_{13}$ (581.43): C, 53.71; H, 3.29; N, 7.23. Found: C, 53.75; H, 3.52; N, 7.00.

(b) *From ethyl 5-O-benzoyl-1-thio-β-L-arabinoside* (XV). Ethyl 5-*O*-benzoyl-1-thio-*β*-L-arabinoside[7] (587.1 mg.) was suspended in *ca.* 20 ml. of absolute alcohol with two teaspoonfuls of freshly prepared W-2 Raney nickel[17] and the mixture stirred for 13 hr. It was then boiled under reflux for 5.5 hr. and filtered, the nickel being washed generously with hot alcohol. On concentration *in vacuo*, there was obtained a sirup (378.2 mg.) which was dissolved in absolute methanol and debenzoylated with barium methoxide. The solution was deionized with a mixed-bed ion exchange resin, filtered and concentrated *in vacuo* to give a sirup: 226.1 mg. Acylation with *p*-nitrobenzoyl chloride in the usual manner gave 394.1 mg. (34%, based on the thioarabinoside) of crystalline material. Recrystallized twice from aqueous acetone it melted at 81–82° and showed $[\alpha]_D^{20}$ +85.1° in chloroform (*c*, 0.87). Mixed with the ester obtained in (a) above it melted at 80–82°.

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[17] R. Mozingo, *Org. Syntheses*, Coll. Vol. III, 181 (1955).

[CONTRIBUTION FROM DEPARTMENT OF AGRICULTURAL BIOCHEMISTRY, UNIVERSITY OF MINNESOTA]

Synthesis of Xylobiose (4-*O*-β-D-Xylopyranosyl-D-xylose)[1]

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The synthesis of xylobiose (4-*O*-*β*-D-xylopyranosyl-*β*-D-xylose) (IX) has been achieved by condensing benzyl 2,3-di-*O*-benzyl-D-xylopyranoside (V), with 2,3,4-tri-*O*-acetyl-*α*-D-xylosyl bromide (VI) to give benzyl 4-*O*-(2,3,4-tri-*O*-acetyl-D-xylosyl)-2,3-di-*O*-benzyl-D-xyloside (VII). Saponification to remove acetyl groups followed by hydrogenation to remove the benzyl groups yielded xylobiose (IX).

Chemical or biochemical hydrolysis of polysaccharides leading to the formation of disaccharides provides a valuable approach to the determination of the general structure of polysaccharides.[2] Thus

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[2] F. Smith and R. Montgomery, *Plant Gums and Mucilages*, Reinhold Publishing Corp., New York, 1959, p. 133: R. L. Whistler and C. L. Smart, *Polysaccharide Chemistry*, Academic Press, Inc., New York, N. Y., 1953.