713. *The Synthesis of* 4-O-β-D-*Xylopyranosyl*-D-*xylose and* 3-O-*Methyl*-4-O-(β-D-*xylopyranosyl*)-D-*xylose.*

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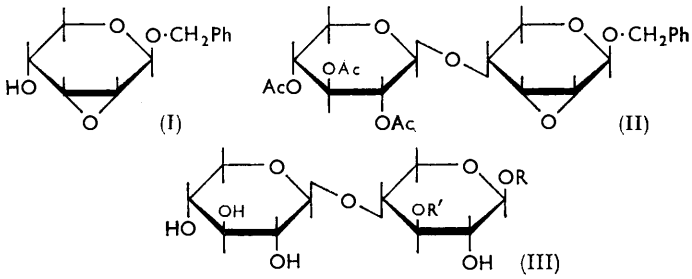
A Koenigs–Knorr condensation of 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide with benzyl 2,3-anhydro-β-D-ribopyranoside (I) affords benzyl 2,3-anhydro-4-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-ribopyranoside (II). Treatment of the disaccharide epoxide (II) with sodium hydroxide, followed by hydrogenation, furnishes 4-*O*-β-D-xylopyranosyl-D-xylose (III; R = R′ = H); treatment with sodium methoxide, followed by hydrogenation, furnishes 3-*O*-methyl-4-*O*-(β-D-xylopyranosyl)-D-xylose (III; R = H, R′ = Me). Methanol and D-xylose are formed amongst the products of alkaline degradation of the disaccharide methyl ether (III; R = H, R′ = Me).

The need for a 3,4-di-*O*-substituted pentose carrying two different substituents as a model compound for branched arabinoxylans arose from studies on the degradation of such

polysaccharides with alkali.[1] The present paper describes the synthesis of a suitable model compound, 3-*O*-methyl-4-*O*-(β-D-xylopyranosyl)-D-xylose (III; R = H, R′ = Me). The parent disaccharide, 4-*O*-β-D-xylopyranosyl-D-xylose (xylobiose) (III; R = H, R′ = H), which has been isolated as a partial acid-hydrolysis product from several xylans,[2] has also been synthesised in a parallel series of reactions.

The starting material for the syntheses, benzyl 2,3-anhydro-β-D-ribopyranoside [3] (I), was prepared by the action of dilute sodium hydroxide on benzyl 2-*O*-methanesulphonyl-β-D-arabinopyranoside.[4] A Koenigs–Knorr condensation of 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide with the epoxide (I) furnished benzyl 2,3-anhydro-4-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-ribopyranoside (II) in much better yield than is often



obtained in disaccharide syntheses involving condensations of " acetohalogen sugars " with secondary hydroxyl groups of sugar derivatives. The hydroxyl group in the epoxide (I) is much less sterically hindered than most secondary hydroxyl groups in otherwise fully substituted sugar derivatives. It is noteworthy that Jones and Curtis [5] have made a similar observation with regard to the condensation of " acetohalogen sugars " with secondary hydroxyl groups in acyclic derivatives of sugars. Treatment of the condensation product (II) with sodium hydroxide resulted in deacetylation and opening of the epoxide ring to give benzyl 4-*O*-β-D-xylopyranosyl-D-β-xylopyranoside (III; R = CH_2Ph, R′ = H), and similar reaction of the disaccharide epoxide with sodium methoxide gave benzyl 3-*O*-methyl-4-*O*-(β-D-xylopyranosyl)-D-β-xylopyranoside (III; R = CH_2Ph, R′ = Me). In both cases opening of the epoxide ring proceeded with formation of the D-xylose derivative, and no trace of the D-arabinose derivative could be detected. The relation between the two benzyl glycosides was confirmed since both afforded the same crystalline pentamethyl ether on methylation with methyl sulphate and sodium hydroxide, and since hydrolysis of benzyl 3-*O*-methyl-4-*O*-(β-D-xylopyranosyl)-β-D-xylopyranoside gave D-xylose and 3-*O*-methyl-D-xylose. Both benzyl glycosides, on hydrogenation over palladium–charcoal, furnished the corresponding disaccharides. Although neither disaccharide was obtained crystalline, the identity of 4-*O*-β-D-xylopyranosyl-D-xylose with the xylobiose formed on partial acid hydrolysis of oak heartwood xylan [6] and other xylans [2] was established by paper chromatography of the sugar and by conversion into the crystalline phenylosazone.

When 3-*O*-methyl-4-*O*-(β-D-xylopyranosyl)-D-xylose was treated with cold dilute sodium hydroxide, the disaccharide was almost completely destroyed after 6 hr. with the elimination of the 3- and the 4-substituent. Under the conditions employed in the reaction no further degradation of xylose could be detected. Methanol was identified by

[1] Aspinall, Greenwood, and Sturgeon, preceding paper.
[2] Whistler and Tu, *J. Amer. Chem. Soc.*, 1952, **94**, 3609; 1953, **75**, 645; for other references see Aspinall, *Adv. Carbohydrate Chem.*, 1959, **14**, 429.
[3] After the completion of this work, the preparation of this compound was reported independently by Garegg (*Acta Chem. Scand.*, 1960, **14**, 957).
[4] Wood and Fletcher, *J. Amer. Chem. Soc.*, 1958, **80**, 5242.
[5] Jones and Curtis, *Canad. J. Chem.*, 1959, **37**, 358.
[6] Aspinall, Carter, Laidlaw, and Sandström, unpublished results.

conversion into methyl iodide and by oxidation to formaldehyde, and D-xylose was identified as the di-*O*-benzylidene dimethyl acetal. The nature of the degradation products from the reducing xylose moiety in the disaccharide has not yet been established. The observation that both substituents are rapidly eliminated when this 3,4-di-*O*-substituted D-xylose is treated with alkali provides clear support for the " by-passing " mechanism proposed to account for the results of the alkaline degradation of branched arabinoxylans.[1]

Experimental

Evaporations were carried out under reduced pressure, and the light petroleum used had b. p. 60—80°. Alumina, type H, 100/200 S mesh, supplied by Peter Spence and Sons, Ltd., was shaken with N-acetic acid, washed with water by decantation until free from acid, and dried at 260°. Optical rotations were observed at 18° ± 2°. Paper chromatography was carried out on Whatman Nos. 1 and 3MM papers with the following solvent systems (v/v): (A) ethyl acetate–pyridine–water (10 : 4 : 3); (B) butan-1-ol–ethanol–water (4 : 1 : 5, upper layer); (C) ethyl acetate–acetic acid–formic acid–water (18 : 3 : 1 : 4).

Benzyl 2,3-*Anhydro*-β-D-*ribopyranoside* (I).—2N-Sodium hydroxide was added with stirring to benzyl 2-*O*-methanesulphonyl-β-D-arabinopyranoside (30·5 g.; prepared by Wood and Fletcher's method [4]) in ethanol (80 ml.) at 75° until the solution was permanently alkaline. Sodium methanesulphonate was filtered off and the filtrate was taken to dryness. The residue was extracted several times with warm ethyl acetate, and after removal of solvent the resulting solid was recrystallised from light petroleum to give *benzyl* 2,3-*anhydro*-β-D-*ribopyranoside* (I) (18·4 g.), m. p. 75—76°, $[\alpha]_D$ −58° (*c* 0·66 in $CHCl_3$) (Found: C, 64·7; H, 6·3. $C_{12}H_{14}O_4$ requires C, 64·8; H, 6·3%) {Garegg [3] gives m. p. 76—77°, $[\alpha]_D$ −67° (in $CHCl_3$)}.

Benzyl 2,3-*Anhydro*-4-O-(2,3,4-*tri*-O-*acetyl*-β-D-*xylopyranosyl*)-β-D-*ribopyranoside* (II).—Benzyl 2,3-anhydro-β-D-ribopyranoside (18·2 g.), freshly prepared silver carbonate (32·5 g.), and anhydrous calcium sulphate (100 g.) were shaken overnight in benzene (250 ml.). After addition of iodine (6 g.), 2,3,4-tri-*O*-acetyl-α-D-xylopyranosyl bromide (27·6 g.) in benzene (250 ml.) was added slowly with stirring during 1 hr. The mixture was shaken in the dark for 3 days (with occasional release of carbon dioxide); the benzene solution then gave no opalescence with ethanolic silver nitrate. The filtered solution was concentrated to a syrup which was chromatographed in benzene on alumina, and elution with light petroleum–benzene (1 : 1) furnished *benzyl* 2,3-*anhydro*-4-O-(2,3,4-*tri*-O-*acetyl*-β-D-*xylopyranosyl*)-β-D-*ribopyranoside* (II) (9·1 g.), m. p. 131—132° [from light petroleum–ethanol (2 : 1)], $[\alpha]_D$ −48° (*c* 0·66 in $CHCl_3$) (Found: C, 56·7; H, 5·7. $C_{23}H_{28}O_{11}$ requires C, 57·5; H, 5·8%).

Benzyl 3-O-*Methyl*-4-O-(β-D-*xylopyranosyl*)-β-D-*xylopyranoside* (III; R = CH_2Ph, R′ = Me).—The disaccharide epoxide (II) (6 g.) was refluxed in methanol (180 ml.) containing sodium methoxide (13·9 g.) for 24 hr., and the cooled solution was diluted with water, neutralised with N-sulphuric acid, and evaporated to dryness. The residue was extracted with hot acetone, giving syrupy *benzyl* 3-O-*methyl*-4-O-(β-D-*xylopyranosyl*)-β-D-*xylopyranoside* (3·8 g.), $[\alpha]_D$ −115° (*c* 2·0 in H_2O) (Found: OMe, 8·1. $C_{18}H_{26}O_9$ requires OMe, 8·0%). Acetylation of the benzyl glycoside gave *benzyl* 2-O-*acetyl*-3-O-*methyl*-4-O-(2,3,4-*tri*-O-*acetyl*-β-D-*xylopyranosyl*)-β-D-*xylopyranoside*, m. p. 154—156°, $[\alpha]_D$ −101° (*c* 0·66 in $CHCl_3$) (Found: C, 56·3; H, 6·0; OMe, 5·6. $C_{26}H_{34}O_{13}$ requires C, 56·4; H, 6·1; OMe, 5·6%). Methylation of the benzyl glycoside gave *benzyl* 2,3-*di*-O-*methyl*-4-O-(2,3,4-*tri*-O-*methyl*-β-D-*xylopyranosyl*)-β-D-*xylopyranoside*, m. p. 88—90°, $[\alpha]_D$ −80° (*c* 0·4 in $CHCl_3$) (Found: C, 59·8; H, 7·5; OMe, 35·0. $C_{22}H_{34}O_9$ requires C, 59·7; H, 7·7; OMe, 35·1%).

Hydrolysis of the benzyl glycoside (75 mg.) with N-sulphuric acid at 100° for 2 hr., followed by neutralisation with barium carbonate gave two sugar components which were separated chromatographically by solvent B. The sugars were characterised as (*a*) 3-*O*-methyl-D-xylose by formation of the phenylosazone, m. p. and mixed m. p. 170°, and (*b*) D-xylose by conversion into the di-*O*-benzylidene dimethyl acetal, m. p. and mixed m. p. 211°, $[\alpha]_D$ −9° (*c* 0·66 in $CHCl_3$). Chromatography of the periodate oxidation products [7] of the 3-*O*-methylxylose fraction showed no methoxymalondialdehyde which would be formed from 2-*O*-methylarabinose.

3-O-*Methyl*-4-O-(β-D-*xylopyranosyl*)-D-*xylose* (III; R = H, R′ = Me).—The above benzyl glycoside (3·1 g.) in ethanol–water (120 ml.) was shaken in hydrogen at atmospheric pressure

[7] Lemieux and Bauer, *Canad. J. Chem.*, 1953, **31**, 814.

over 10% palladium–charcoal (3 g.) for 48 hr. Catalyst was filtered off and concentration of the filtrate afforded chromatographically pure syrupy 3-O-*methyl*-4-O-(β-D-*xylopyranosyl*)-D-*xylose* (1·9 g.), $[\alpha]_D$ −18° (*c* 2·0 in H_2O), R_{xylose} 0·61 in solvent C (Found: OMe, 10·4. $C_{11}H_{20}O_9$ requires OMe, 10·5%).

Benzyl 4-O-(β-D-*Xylopyranosyl*)-β-D-*xylopyranoside* (III; R = CH_2Ph, R′ = H).—The disaccharide epoxide (II) (1 g.) was heated in 2N-sodium hydroxide (50 ml.) on the boiling-water bath for 16 hr. The cooled solution was de-ionised with Amberlite resins IR-120(H) and IR-45(OH) and concentrated to give syrupy benzyl 4-*O*-(β-D-xylopyranosyl)-β-D-xylopyranoside (0·81 g.), $[\alpha]_D$ −120° (*c* 1·6 in H_2O). The benzyl glycoside was chromatographically homogeneous (R_{xylose} 1·58 in solvent C), hydrolysis gave xylose only, and methylation with methyl sulphate and sodium hydroxide afforded the pentamethyl ether, m. p. and mixed m. p. 88—90°.

4-O-β-D-*Xylopyranosyl*-D-*xylose* (III; R = R′ = H).—The foregoing benzyl glycoside (0·6 g.) in ethanol–water (25 ml.) was shaken in hydrogen at atmospheric pressure over 10% palladium–charcoal (0·6 g.) for 48 hr. Catalyst was filtered off and concentration of the filtrate gave a syrup (0·4 g.) which contained xylobiose (R_{xylose} 0·31 in solvent C) and a trace of xylose. Chromatographically pure 4-*O*-β-D-xylopyranosyl-D-xylose (0·22 g.), $[\alpha]_D$ −22° (*c* 2·0 in H_2O), was isolated after separation on filter sheets with solvent C, and the disaccharide was characterised by conversion into the phenylosazone, identified by m. p. and mixed m. p. 207° (decomp.), $[\alpha]_D$ −6° (5 min.) ⟶ −50° (24 hr., constant) [*c* 0·7 in C_5H_5N–EtOH (7 : 3)], and by *X*-ray powder photograph.

Alkaline Degradation of 3-O-*Methyl*-4-O-(β-D-*xylopyranosyl*)-D-*xylose*.—The disaccharide (100 mg.) was treated with oxygen-free N-sodium hydroxide (20 ml.) at room temperature for 6 hr. and the solution was shaken with Amberlite resin IR-120(H) to remove sodium ions. Paper chromatography showed formation of xylose and almost complete destruction of the disaccharide. The solution was evaporated to a syrup under reduced pressure, the receiver being cooled with ice to trap volatile products. Methanol was characterised in the first few drops of distillate by oxidation to formaldehyde (dimedone derivative, m. p. and mixed m. p. 189°) and by distillation with hydriodic acid to give methyl iodide (kindly identified by Dr. D. M. W. Anderson by its infrared spectrum). The residual syrup was separated by chromatography in solvent C and D-xylose was characterised as the di-*O*-benzylidene dimethyl acetal, m. p. and mixed m. p. 210°.

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