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Chromic Acid Oxidation of 1,2-*O*-Isopropylidene-α-D-glucofuranose

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1,2-*O*-Isopropylidene-α-D-glucofuranose (I) has been oxidised with chromium trioxide in water-butanone. The three possible dicarbonyl sugar derivatives, 1,2-*O*-isopropylidene-α-D-*ribo*-hexofuranos-3-ulose (III), 1,2-*O*-isopropylidene-α-D-*xylo*-hexofuranos-5-ulose (IV) and 1,2-*O*-isopropylidene-α-D-*gluco*-hexodialdo-1,4-furanose (V), of which III and V were crystalline, were isolated and characterised. Three other, previously known, oxidation products, 1,2-*O*-isopropylidene-α-D-glucofuranurono-6,3-lactone (VI), 1,2-*O*-isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (VII) and 1,2-*O*-isopropylidene-D-xyluronic acid (VIII) as well as 5,6-*O*-isobutylidene-1,2-*O*-isopropylidene-α-D-glucofuranose (II) were isolated. Borohydride reduction of III gave almost exclusively 1,2-*O*-isopropylidene-α-D-allofuranose and of IV gave 1,2-*O*-isopropylidene-β-L-idofuranose and I, with the former predominating.

Acidic degradation of the 2-keto and 3-keto derivatives of methyl β-D-glucopyranoside[1] (methyl β-D-*arabino*-hexopyranosidulose and methyl β-D-*ribo*-hexopyranosid-3-ulose) yielded a complex mixture. Under the same conditions methyl β-D-glucopyranoside gave almost exclusively D-glucose. Reductic acid was isolated from the reaction products of both keto compounds, and the 2-keto derivative also afforded, as expected, D-glucosone. Attempts to isolate any corresponding D-*ribo*-hexos-3-ulose ("3-keto-D-glucose") from the 3-keto derivative were unsuccessful. This indicates that the sugar is very acid-labile. Aldos-3-uloses have hitherto not been prepared*. It is also possible that the initial stages of the main reactions, as for instance those leading to the formation of reductic acid, occur before the methoxyl is split off. To get more information about the mechanism of this degradation and about the chemistry of the "3-keto-D-glucose" unit in general, it was desirable to prepare the unsubstituted D-*ribo*-hexos-3-ulose.

* *Added in proof:* Fukui and Hochster (*J. Am.Chem. Soc.* **85** (1963) 1697) report the preparation of D-*ribo*-hexos-3-ulose by enzymatic hydrolysis of D-*ribo*-hexopyranosyl-3-ulose β-D-fructofuranoside.

The chromium trioxide oxidation of the readily available 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose and removal of the isopropylidene groups from the oxidation product by mild acid hydrolysis seemed a feasible route to the preparation of the desired compound. The chromium trioxide-pyridine system is known as a useful oxidising agent for primary and secondary alcohols containing acidsensitive groups [2]. It has been used in the carbohydrate field for the introduction of keto groups in hexitol derivatives [3] and for the oxidation of exocyclic alcohol groups [4,5]. With this reagent applied to some glycopyranosides, having only one unprotected hydroxyl group attached to the ring, reasonable yields of keto derivatives have been obtained [6]. Chromium trioxide in acetone has been used to introduce keto groups into glycopyranosides having two or more unproteoted hydroxyl groups [7,8]. The introduction of keto groups into furanosidic rings however has not been reported.

When 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose was treated with chromium trioxide-pyridine at room temperature for one day, conditions which have been used in previous oxidations, no oxidation products were detected. Even with prolonged time and higher temperatures, the yield of material, arising from oxidation, was very small. The use of the more powerful chromium trioxide-acetone reagent resulted in complications caused by partial hydrolysis and acetonation, and gave only a low degree of oxidation.

Brown and Garg [9] recently reported a procedure, using a two layer system of water and ether for the chromium trioxide (from sodium dichromate and sulphuric acid) oxidation. By this means the carbonyl compounds were given protection from further oxidation. Although some partial hydrolysis was expected, the procedure, involving 2 1/4 h treatment at 25°, was tried. A considerable proportion of di-*O*-isopropylidene compounds survived hydrolysis. The amount of the supposed 3-keto derivative was now higher than by the previous oxidations, but was still small. Attempts to isolate it in a pure state failed. More interesting was the rather large quantity of compounds, supposedly mono-*O*-isopropylidene derivatives, some of which showed reducing properties and gave positive reactions towards anisidine hydrogen chloride. They were probably mainly produced after the removal of the 5,6-*O*-isopropylidene group. Main interest was subsequently focused on this group of products, *i.e.* the mono-isopropylidene compounds. It should also be mentioned that the use of potassium permanganate, buffered to pH 6, was tried instead of chromium trioxide, but only traces of the 3-keto compound were formed.

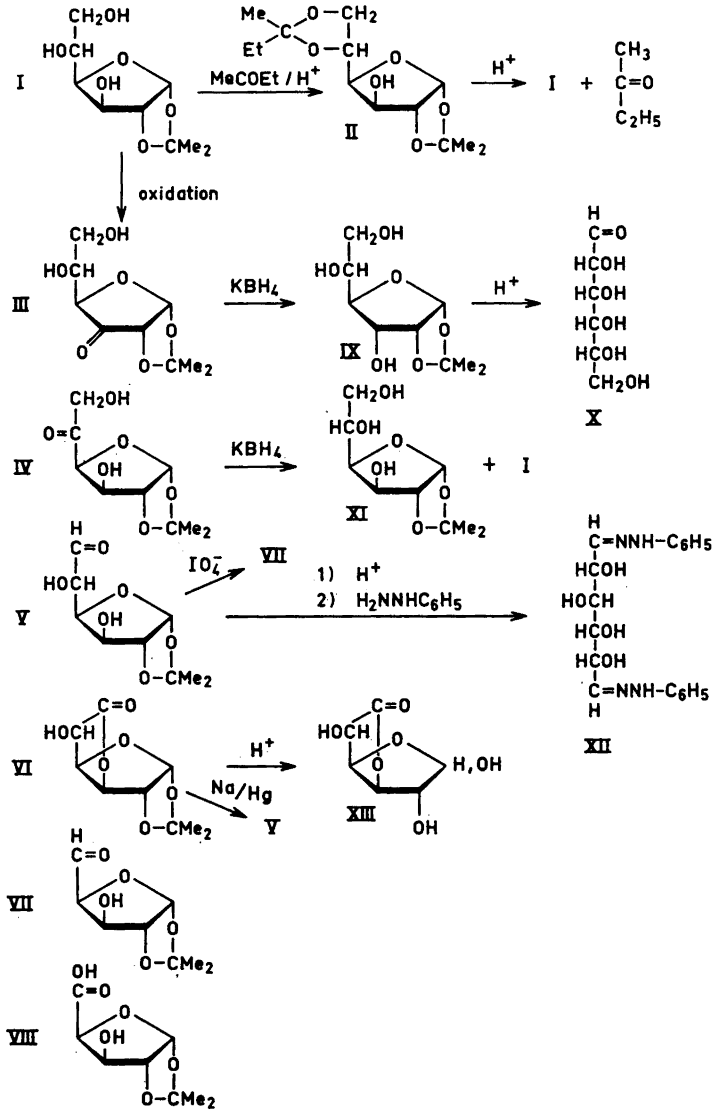
When 1,2-*O*-isopropylidene-α-D-glucofuranose (I) was oxidised directly, a similar distribution of products was found. After some preliminary experiments a larger-scale experiment, using butanone instead of ether, was performed. The reaction products were divided into a larger fraction containing butanone-soluble compounds (representing, after removal of acids as salts, 48 % of I used) and a smaller fraction containing water-soluble compounds (9 % of I). In the latter complex mixture, two of the main components were D-xyluronic acid and its 1,2-*O*-isopropylidene derivative (VIII) (together representing ca. 3 % of I). The latter was characterised as the crystalline potassium 1,2-*O*-isopropylidene-D-xyluronate. Otherwise this fraction was not further studied.

Table I. Reaction products and their reduction products.

Compound	Amount(g) isolated from 70 g of I	M.p. (degrees)	$[\alpha]_D$ (degrees in water)	Electrophoresis in hydrogen sulphite M_V values [13]	Paper chromatography R_F-values Solvent A	Paper chromatography R_F-values Solvent D	Thin-layer chromatography[a]	Colour reactions Spray b[b]	Colour reactions Spray c	Development time on thin-layer chromatograms[c]
1,2-*O*-Isopropylidene-α-D-*ribo*-hexofuranos-3-ulose (III)	0.36	80 – 81	+ 29.9 (5 min) → + 36.7	0.12	0.73	0.60	0.59	Khaki (f)	Orange-brown	2
1,2-*O*-Isopropylidene-α-D-*xylo*-hexofuranos-5-ulose (IV)	0.95	Amorphous	−31	0.17	0.74	0.63	0.64	Brickred (a)	Pink (strong reaction)	1
1,2-*O*-Isopropylidene-α-D-*gluco*-hexodialdo-1,4-furanose (V)	5.18	125 – 126	+ 27.3 (3 min) → + 34.2	1.11	0.74	0.64	0.41	Brickred (a)	Pink (weak reaction)	1
1,2-*O*-Isopropylidene-α-D-*xylo*-pentodialdo-1,4-furanose (VII)	4.25	162 – 164	−25.7	1.36	0.86	0.81	0.83	Grey → yellow (f)	Grey (f)	3
1,2-*O*-Isopropylidene-α-D-glucofuranurono-6,3-lactone (VI)	1.29	122 – 123	+ 70.2	–	0.77	0.71	0.96	Orange-red (f)	–	4
5,6-*O*-Isobutylidene-1,2-*O*-isopropylidene-α-D-glucofuranose (II)	0.63	113 – 114	−30.1	–	0.94	0.89	1.08	Yellow (f)	–	6
1,2-*O*-Isopropylidene-α-D-glucofuranose (I)	11.87	161 – 162	−11.8	–	0.71	0.53	0.15	Yellow (f)	–	6
1,2-*O*-Isopropylidene-α-D-allofuranose (IX)	–	133 – 134	+ 44.0	–	0.61	0.44	0.11	Yellow (f)	–	6
1,2-*O*-Isopropylidene-β-L-idofuranose (XI)	–	110 – 112	−29.5	–	0.68	0.51	0.13	Yellow (f)	–	6
As comparison: 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose	–	110 – 111	−18.5	–	0.88	0.86	1 [a]	Yellow (f)	–	6

a Migration relative to that of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose.
b All except the first four needed preliminary hydrolyses on the chromatograms (see EXPERIMENTAL). f = fluorescence and a = absorption in UV-light
c For details see EXPERIMENTAL.

A thin-layer chromatographic study of the butanone fraction revealed the presence of unchanged I and significant quantities of five other components. Small amounts of more lipophilic compounds and some slow-moving material, probably salts and completely hydrolysed compounds were also present. The six main components could be isolated in pure state (all except one being crystalline) after a series of separations on silicic acid columns. Yields and properties are given in Table 1.

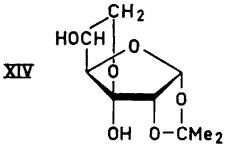


The most lipophilic substance was shown to be a product of a side-reaction with butanone: 5,6-*O*-isobutylidene-1,2-*O*-isopropylidene-α-D-glucofuranose (II). Butanone, as its crystalline 2,4-di-nitrophenylhydrazone, and crystalline I were isolated after partial hydrolysis of II.

Three other substances represent the possible primary oxidation products of I, having a carbonyl group at either C-3, C-5 or C-6. The yields (calculated on oxidised I), which are of course much dependent on secondary reactions, were 0.6; 1.6 and 8.9 %, respectively.

1,2-*O*-Isopropylidene-α-D-*ribo*-hexofuranos-3-ulose (III) showed mutarotation. No Cotton effect was observed in the spectral-range 313—589 mμ. The IR- and UV-spectra revealed no carbonyl peaks. These facts indicate that the structure of the substance and its configuration at C-3 (evident from the molecular model) is as shown in XIV.

XIV

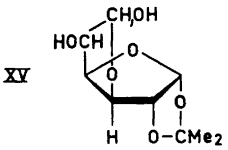


The position of the keto group was proved by the isolation of a crystalline substance, shown to be 1,2-*O*-isopropylidene-α-D-allofuranose (IX), after borohydride reduction of III. Substance IX when hydrolysed yielded crystalline D-allose (X), which was further reduced to crystalline allitol. The yield of the D-glucose isomer on borohydride reduction of III was less than 1 % showing that the steric effect caused by the isopropylidene-acetal ring is stronger than that of the axial methoxyl group in methyl α-D-*ribo*-hexopyranosid-3-ulose [10].

1,2-*O*-Isopropylidene-α-D-*xylo*-hexofuranos-5-ulose (IV) was an amorphous slightly yellow compound, chromatographically pure and showing a strong carbonyl absorption in the IR. This indicates that it exists largely in the free keto-form. Hemi-ketal formation as in the 3-keto compound (XIV) is excluded. The position of the ketogroup was proved by the isolation of crystalline 1,2-*O*-isopropylidene-β-L-idofuranose (XI) and glucofuranose derivative I after borohydride reduction. The two isomers were formed in the ratio 69:31. Wolfrom and Hanessian [5] also found a preponderance of the idose-isomer after borohydride reduction of 3-*O*-benzyl-6-deoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hexofuranos-5-ulose.

1,2-*O*-Isopropylidene-α-D-*gluco*-hexodialdo-1,4-furanose (V) showed mutarotation. No Cotton effect was observed in the spectralrange 313—589 mμ. The IR- and UV-spectra revealed no carbonyl peaks. On this evidence the structure XV was allocated in analogy with that of the 3-keto compound (XIV). There are, however, two possible configurations at C-6.

XV



The position of the carbonyl group was proved by the following reactions: Hydrolysis of the acetal (V) produced the free D-*gluco*-hexodialdose, which was isolated as a crystalline bis(phenylhydrazone) (XII). Borohydride reduction yielded only the acetal (I) and periodate oxidation gave 1,2-*O*-isopropylidene-*α*-D-*xylo*-pentodialdo-1,4-furanose (VII). Furthermore the 6-aldehydo compound (V) was obtained by controlled reduction of 1,2-*O*-isopropylidene-*α*-D-glucofuranurono-6,3-lactone (VI) with sodium amalgam.

The free D-*xylo*-hexos-5-ulose and D-*gluco*-hexodialdose and some of their derivatives were already known as well as the methyl pyranosides of D-*ribo*-hexos-3-ulose (see a review [11]).

Of the other two components one was 1,2-*O*-isopropylidene-*α*-D-glucofuranurono-6,3-lactone (VI) having identical physical properties with those given in the literature. The lactone was also transferred to the crystalline free acid. D-Glucurono-6,3-lactone (XIII) was isolated after hydrolysis of VI and by controlled reduction VI was transferred to the 6-aldehydo compound (V).

The other component, which after borohydride reduction and hydrolysis gave only xylose, was identical with an authentic sample of 1,2-*O*-isopropylidene-*α*-D-*xylo*-pentodialdo-1,4-furanose (VII). This compound had previously been prepared by periodate or lead tetraacetate oxidation of I (reviewed in Ref.[11]).

Cleavage between C-5 and C-6, yielding VII and VIII, proceeds to a rather large extent under the conditions used. Similarly Ohle and coworkers [12] obtained the acid VIII as the main reaction product when oxidising the glucofuranose derivative I with potassium permanganate (slightly alkaline conditions) at room temperature In preliminary experiments, samples of III, IV and V were treated under similar conditions to those used for their preparation and the reaction studied by thin-layer chromatography. It was shown that the 6-aldehydo compound (V) reacted rather readily to give, almost exclusively, the lactone (VI), which did not seem to react further. The two keto compounds reacted much slower and the formation from IV of some 5-aldehydo compound (VII) was observed. Preliminary acidic hydrolyses of III, IV and V showed that the stability of their corresponding free dicarbonyl sugars followed the sequence D-*gluco*-hexodialdose > D-*xylo*-hexos-5-ulose > D-*ribo*-hexos-3-ulose.

The mobilities of the four dicarbonyl sugar derivatives on hydrogen sulphite electrophoresis [13] (M_V-values) are noteworthy. Although the keto group in the 3-keto compound is probably involved in ketal formation and the 5-keto compound predominantly exists with a free keto group they both have similar, rather low M_V-values (0.12 and 0.17, respectively). On the other hand, the 6-aldehydo compound, which like the 3-keto compound, has a masked carbonyl group, has a high M_V-value (1.11) of the same order as that of aldehydo-D-glucopentaacetate (1.18). This suggests that the mobilities of the two keto-compounds are significantly influenced by steric hindrance. The high M_V-value of the 6-aldehydo compound, in spite of its high tendency to hemiacetal formation, can probably be correlated with its rate of mutarotation (this was rather high for both III and V) as can be done with the aldoses [13]. The higher the mutarotation constant the lower the equilibrium constant of the hydrogen sulphite adduct and the higher the M_V-value. The high M_V-value (1.36) of the 5-aldehydo compound (VIII) is significant.

EXPERIMENTAL

Concentrations were carried out under reduced pressure below 45°. All melting points are corrected. The optical rotations were measured in a Perkin-Elmer polarimeter 141.

Solvents for paper chromatography and electrolytes for electrophoresis (on Whatman No. 1 paper):

A. Butan-1-ol-ethanol-water, 10:3:5.
B. Ethyl acetate-acetic acid-water, 3:1:1.
C. Ethyl acetate-pyridine-water 8:2:1.
D. Toluene-ethanol-water, 10:7:1.
E. Hydrogen sulphite pH 4.7, 0.1 M (used at 50°).

Thin-layer chromatography was carried out using ethyl acetate-light petroleum (b.p. 40—60°), 3:1, as solvent and "Kiselgel G nach Stahl" as adsorbent. The latter was also used for one of the column separations, otherwise "Malinckrodt Silicic Acid, analytical reagent, 100 mesh" (heated at 150° for 17 h before use) was used. The solvents for the adsorption chromatography were distilled before use.

The spray reagents used were: (*a*) silver nitrate-sodium hydroxide, (*b*) anisidine hydrogen chloride, and (*c*) resorcinol-hydrochloric acid. The thin-layer chromatograms were sprayed with 5 % hydrogen chloride in methanol, heated at 120° for 2 min, sprayed with (*b*) and heated again. The substances appeared after different times (see Table 1) and the colours also changed during the heating in a characteristic manner. In the table is given brief description of the colours after 8 min. These resemble fairly well the colours appearing on papers developed with (*b*) in the usual way. In order to detect noncarbonyl compounds on papers with spray (*b*), they were, after the usual spraying and heating, given an extra spray with the methanolic hydrochloric acid and left at room temperature over night.

Oxidation of 1,2-*O*-isopropylidene-α-D-glucofuranose (I)

A solution of potassium dichromate (78.00 g) in aqueous sulphuric acid (340 ml water and 30 ml sulphuric acid) was added dropwise (over 0.5 h) to a stirred solution of 1,2-*O*-isopropylidene-α-D-glucofuranose (70.00 g) in water-saturated butanone (1250 ml). The mixture, kept at 25°, was stirred for another 1.5 h after the addition. Chromium salts were then filtered off and the two phases were separated. The water-phase was extracted with butanone (6 × 500 ml). The combined butanone solutions were neutralised with barium carbonate, filtered, dried and evaporated to dryness. The residue was extracted with warm ethyl acetate (4 × 250 ml). The light-green syrup (33.54 g) obtained by evaporation of these extracts crystallised partially and by recrystallisation from ethyl acetate some I (8.87 g) was recovered. The chromatographic resolutions of the components in the mother liquor will be described separately.

No systematic study of the acids was made. Some of them were removed, in the form of barium salts, from the butanone fraction. An aliquot of the water fraction was neutralised with barium carbonate, filtered, treated with cation exchange resin (Dowex-50, H^+) and evaporated to a small volume. Part of the solution was evaporated to a syrup, the weight of which corresponded to a total amount of 6.22 g material in the water phase. A paper chromatographic examination revealed a complex mixture of mainly acidic components, two of which were indistinguishable from D-xyluronic acid and its 1,2-*O*-isopropylidene derivative (VIII).

1,2-O-Isopropylidene-D-xyluronate (VIII). The main part of the cation exchanged solution was adjusted to pH 7 with potassium carbonate, and the potassium salt of VIII was isolated as described previously by Ohle *et al.*[12] Fractional precipitations with ethanol removed potassium salts of D-xyluronic acid. The potassium salt of the acetal had $[\alpha]_D^{22}$ −51.4° (water, *c* 0.5) (Lit-value [12] −52.6°) and identical IR-spectrum with that of an authentic sample. Cation exchanged samples of isolated and authentic salts were chromatographically indistinguishable.

Another part of the solution was adjusted to a sulphuric acid concentration of 0.5 N and treated at 96° for 0.5 h. After neutralising with barium carbonate, filtration, treatment with cation exchange resin and evaporation, the D-xyluronic acid was isolated by

chromatography on Whatman No. 3 MM paper using solvent B. Its weight corresponded to a total amount of 2.2 g of 1,2-*O*-isopropylidene-D-xyluronic acid in the water-phase.

Chromatographic resolution of the reaction products

The syrup obtained (24.32 g) from the butanone-phase after removing the crystalline I contained some I and five other major components. The mixture could be resolved after nine silicic acid column separations which will not be described in detail. Minor quantities of more lipophilic compounds and of strongly adsorbed materials were not examined. The latter were probably salts and completely hydrolysed compounds, and had to be eluted from the column with ethanol. The total amounts of the different compounds obtained are given in Table 1. The amounts of I given includes also that which crystallised before the chromatographic separations. The amounts given in the table refer mainly to pure isolated substances. The distribution in some smaller overlapping fractions was determined by refractionating on thin-layer chromatograms. Narrow plates were run simultaneously as guide chromatograms. After developing the guide-plates, the powder corresponding to the various components was scraped off, eluted with methanol and the extract evaporated and weighed. The yields of carbonyl compounds in another larger-scale experiment were similar.

A crude fractionation was first made (after dividing the mixture into two equal parts) on a column (7 × 73 cm), eluted with ethyl acetate. From these two separations two main fractions were collected. The first one (9.32 g) contained all II and VI and most of VII and the second one (11.81 g) contained some VII and all the remaining components.

A part (60 %) of the first fraction was resolved after two fractionations on a column (5 × 105 cm) using in the first run ethyl acetate as eluant and in the next run ethyl acetate-light petroleum (b.p. 40–60°) (1:1) followed by ethyl acetate. This procedure gave crystalline fractions of II, VI, and VII.

The second main fraction was resolved by an initial crude fractionation on a column (7 × 75 cm), from which part of I, V, and VII were obtained in crystalline form. Three subfractionations on another column (5 × 105 cm) gave almost complete separation of the remaining mixture. In these fractionations the eluent was ethyl acetate. The 3-keto compound (III) could not be completely separated from the 6-aldehydo compound (V) on this adsorbent. However, by a final fractionation on a column (2.5 × 40 cm) packed with the same adsorbent as used for the thin-layer chromatography and with ethyl acetate-light petroleum (3:1) as eluant it was completely purified giving a crystalline product.

The only component, which could not be induced to crystallise was the 5-keto compound (IV). The physical data, chromatographic and electrophoretic properties and colour reactions of the components are given in Table 1. The Table also includes their reduction products. The properties of di-*O*-isopropylidene-glucose are given for purposes of comparison.

5,6-O-Isobutylidene-1,2-O-isopropylidene-α-D-glucofuranose (II), m.p. 113–114° (recrystallised from benzene-light petroleum); $[\alpha]_D^{23}$ −30.1° (*c* 0.3, water); (Found: C 57.1; H 8.36. $C_{13}H_{22}O_6$ requires C 57.0; H 8.04).

A sample of II (80 mg) in 0.2 N hydrochloric acid (4 ml) was kept at 50° for 15 min, a solution of 2,4-dinitrophenylhydrazine (55 mg) in methanol (15 ml) was then added and the mixture was kept for another 5 min at 50°. The mixture was left in the refrigerator some hours and the precipitate was filtered off and recrystallised twice from aqueous methanol. The 2,4-dinitrophenylhydrazone (15 mg) obtained, m.p. 114–115° (m.p. and mixed m.p. identical with an authentic sample) was indistinguishable from an authentic sample on thin-layer chromatography using propanol as solvent. Under these conditions the acetone and butanone derivatives were well separated. The mother liquor from the hydrazone precipitate was deionised and evaporated, yielding a crystalline residue, from which pure 1,2-*O*-isopropylidene-*α*-D-glucofuranose (35 mg), m.p. 159–160°, was obtained by crystallisation from ethyl acetate.

1,2-O-Isopropylidene-α-D-ribo-hexofuranos-3-ulose (III), m.p. 80–81° (recrystallised from benzene); $[\alpha]_D^{23}$ + 29.9° (5 min) → + 36.7° (2 h, equil.) (*c* 0.5, water), $[\alpha]^{23}$ (equil.): + 37.9 (578 mμ), + 42.2 (546 mμ), + 65.8 (436 mμ), + 90.3 (364 mμ) and + 110.6 (313 mμ). (Found: C 49.2; H 6.36; O 44.5. $C_9H_{14}O_6$ requires C 49.5; H 6.46; O 44.0). Neither IR-nor UV-spectra revealed carbonyl peaks.

A sample of III (70 mg) was reduced with an excess of potassium borohydride in aqueous solution of pH 9.5. After deionisation (by cation-exchange resin) removal of boric acid as methyl ester and evaporation, a crystalline residue was obtained. Crystallisation from ethyl acetate gave 47 mg of a substance, m.p. 124–126°, which yielded on hydrolysis only allose and its 1,6-anhydride as shown paper chromatographically. The substance, evidently *1,2-O-isopropylidene-α-D-allofuranose*, after recrystallisations from ethyl acetate had m.p. 133–134°; $[\alpha]_D^{23}$ + 44.0° (*c* 0,5, water); (Found: C 49.3; H 7.34. $C_9H_{16}O_6$ requires C 49.2; H 7.32). The mother liquor from the first crystallisation, containing the allose derivative and small amounts of I, was treated with 0.5 N sulphuric acid at 96° for 30 min, deionised and evaporated. A semi-quantitative paper chromatographic examination (solvent C) showed that the amount of glucose present corresponded to somewhat less than 1 % of (I) in the original reduction mixture. On standing with ethanol, the product crystallised giving D-allose (10 mg), m.p. 127–128° (m.p. and mixed m.p. identical with an authentic sample). After removal of the crystalline allose the mother liquor was reduced with aqueous borohydride and after deionisation and evaporation, allitol crystallised from ethanol, m.p. 148–149° (m.p. and mixed m.p. identical with an authentic sample).

1,2-O-Isopropylidene-α-D-xylo-hexofuranos-5-ulose (IV) was an amorphous, light yellow product with no impurities detectable by chromatography when fresh but giving traces of decomposition products on storing; $[\alpha]_D^{23}$ −31° (*c* 0.5, water). IR λ_{max}^{KBr} 5.78 μ (carbonyl, strong). A sample of IV (100 mg) was reduced with an excess of potassium borohydride in aqueous solution of pH 9.5. After deionisation and evaporation 1,2-*O*-isopropylidene-*α*-D-glucofuranose (14 mg), m.p. 160–161° (m.p. and mixed m.p. identical with I), crystallised from ethyl acetate. Evaporation of the mother liquor, and crystallisation from ethyl acetate yielded 1,2-*O*-isopropylidene-*β*-L-idofuranose. After recrystallisation 21 mg was obtained, m.p. 110–112° (m.p. and mixed m.p. identical with an authentic sample), $[\alpha]_D^{23}$ −29.5° (*c* 0.5, water) (lit. value [14] −29°). The mother liquors were hydrolysed (0.5 N sulphuric acid, 96°, 0.5 h) and paper chromatography revealed the presence of glucose and idose with traces only of other components. The two components were separated on Whatman No. 3 MM paper using solvent C. The amounts of sugars isolated, corresponded to 10 mg and 32 mg of the 1,2-*O*-isopropylidene derivatives of glucose and idose, respectively. Altogether the ratio of the glucose- and idose-isomers was thus 31:69.

1,2-O-Isopropylidene-α-D-gluco-hexodialdo-1,4-furanose (V), m.p. 125–126° (recrystallised from ethyl acetate); $[\alpha]_D^{23}$ + 27.3° (3 min) → + 34.2° (2 h, equil.) (*c* 0.5 ,water); $[\alpha]^{23}$ (equil.): + 35.2 (578 mμ), + 38.7° (546 mμ), + 60.1° (436 mμ), + 79.0° (364 mμ) and + 92.3° (313 mμ). (Found: C 49.9; H 6.53. $C_9H_{14}O_6$ requires C 49.5; H 6.46). Neither IR-nor UV-spectra revealed carbonyl peaks.

A sample of V (300 mg) was hydrolysed in 0.2 N sulphuric acid (12 ml) at 96° for 45 min. The solution was neutralised with barium carbonate, filtered and evaporated. The product which mainly contained the supposedly free D-*gluco*-hexodialdose was fractionated on Whatman 3 MM papers (pre-washed with water) using solvent A. A chromatographically pure fraction (249 mg) of this dialdose which crystallised from its syrup (m.p. 90–92°: lit. value [15] for the monohydrate 80–83°) was obtained. Some of the compound was converted to the bis-phenylhydrazone in the usual way and after recrystallisation from ethanol gave colourless crystals, m.p. (decomp.) 169–171° (lit. value [15] 170–172°). (Found: C 60.2; H 6.18; N 15.6. $C_{18}H_{22}O_4N_4$ requires C 60.3; H 6.21; N 15.4).

Another sample of V (80 mg) was reduced with an excess of borohydride in aqueous solution of pH 9.5. Deionisation, evaporation and recrystallisation from ethyl acetate yielded the glucofuranose derivative (I) (61 mg), m.p. 161–162° (m.p. and mixed m.p. identical with an authentic sample). The mother liquor after hydrolysis showed no sugar other than glucose.

A sample of V (125 mg) was oxidised with periodate and the product worked up as described for the preparation of 1,2-*O*-isopropylidene-*α*-D-*xylo*-pentodialdo-1,4-furanose (VII) from I [16]. The product obtained consisted mostly of VII and some unchanged V.

The former crystallised from a small amount of water, when kept in the refrigerator for some time. Recrystallised it amounted to 29 mg of VII, m.p. 180—182° (m.p. and mixed m.p. identical with an authentic sample).

1,2-O-Isopropylidene-α-D-glucofuranurono-6,3-lactone (VI), m.p. 122—123° (recrystallised from benzene and light petroleum); $[\alpha]_D^{23}$ + 70.2° (*c* 0.5, water) (lit. values [17]: m.p. 120°; $[\alpha]_D^{18}$ + 70°).

Part of VI was neutralised with aqueous sodium bicarbonate at 40°. Cations were removed from the solution which was then evaporated to dryness yielding a crystalline product. After two recrystallisations from ethyl acetate 1,2-*O*-isopropylidene-α-D-glucuronic acid, m.p. 144—145° (lit. value [17]: m.p. 145—146°) was obtained.

A sample of VI (50 mg) in 0.5 N sulphuric acid (2.5 ml) was treated at 96° for 15 min. The solution was neutralised with barium carbonate, filtered, treated with cation exchange resin and evaporated to dryness. On addition of ethanol the product started to crystallise. After some days, the D-glucurono-6,3-lactone was collected and crystallised giving 12 mg, m.p. 174—176° (m.p. and mixed m.p. identical with an authentic sample). The mother liquor consisted only of lactone and the corresponding acid.

A sample of VI (100 mg) was reduced with sodium amalgam of pH 3—4 essentially as described for the reduction of D-glucurono-6,3-lactone to D-*gluco*-hexodialdose [15]. The reaction product consisted mainly of VI and 1,2-*O*-isopropylidene-α-D-*gluco*-hexodialdo-1,4-furanose (V). The reduction was incomplete (*ca.* 30 %) but after separation on thin-layer chromatograms *ca.* 10 mg of crystalline V was obtained, having m.p. and mixed m.p. identical with the directly isolated substance.

1,2-O-isopropylidene-α-D-xylo-pentodialdo-1,4-furanose (VII), m.p. 162—164° (recrystallised from benzene); m.p. 162—164° (recrystallised from water, m.p. and mixed m.p. identical with an authentic hydrate); $[\alpha]_D^{23}$ —25.7° (*c* 0.5, water) (lit. value [16] —25.6°).

The only component present after borohydride reduction and subsequent acidic hydrolysis was indistinguishable from xylose on paper chromatography in solvents A—C.

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