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Crystalline *alpha* and *beta* Forms of 3-O-α-D-Glucopyranosyl-D-arabinopyranose

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Crystalline 3-*O*-α-D-glucopyranosyl-α-D-arabinopyranose monohydrate, mp 120 to 121 °C, and 3-*O*-α-D-glucopyranosyl-β-D-arabinopyranose, mp 155 to 157 °C, were prepared from a sirup obtained by the Ruff degradation of calcium maltobionate. For the *alpha* monohydrate, $[\alpha]_D^{20} = +16.7 \times 10^{-0.024t} - 9.6 \times 10^{-0.098t} + 46.6$, and for the anhydrous *beta* form, $[\alpha]_D^{20} = -25.6 \times 10^{-0.025t} - 9.4 \times 10^{-0.097t} + 49.2$. The structure of the sugar was established by converting it into maltose.

Treatment of the *alpha* form with pyridine–acetic anhydride gave a heptaacetate, mp 127 to 128 °C, $[\alpha]_D^{20} + 62.4°$ (*c* 2.5, chloroform). The *beta* form gave a heptaacetate, mp 194.5 – 195.5° C, $[\alpha]_D^{20} + 13.4°$ (*c* 2.5, chloroform).

Key Words: Anomeric sugars; calcium maltobionate; 3-*O*-α-D-glucopyranosyl-D-arabinopyranose; maltose-*1*-^{14}C; mutarotation of 3-*O*-α-D-glucopyranosyl-D-arabinopyranose; Ruff

1. Introduction

3-*O*-α-D-Glucopyranosyl-D-arabinose was required for the synthesis of maltose-*1*-^{14}C [1][1] and recently for a study of the behavior of sugars in alkaline solutions [2]. Products purported to be 3-*O*-α-D-glucopyranosyl-D-arabinose had been reported by Zemplén [3] and Gakhokidze [4]. Zemplén's product, a sirup obtained by degradation of octa-*O*-acetylmaltobiononitrile, was amorphous, and had an equilibrium rotation of + 72°. Gakhokidze's compound (mp 172 °C, equilibrium rotation + 16.5°) was obtained by ozonolysis of hexa-*O*-acetylmaltal.

In view of the discrepancy in the properties of the two products, preparation of the compound from calcium maltobionate was undertaken by the degradation method of Ruff [5] as modified by Hockett and Hudson [6]. After several months, our sirupy product yielded crystals (I) that, when purified, proved to be a monohydrate of the expected 3-*O*-α-D-glucopyranosyl-D-arabinose; mp 120 to 121 °C; $[\alpha]_D^{20} + 53.7 \rightarrow + 46.6°$ (56.8 → + 49.3°, anhydrous basis). Its structure was proved by converting it to maltose [1].

In an attempt to obtain an anomeric modification of the sugar, the hydrate was recrystallized from ethyl alcohol. The crystals that formed in the course of several days had variable compositions and contained alcohol of crystallization. However, two recrystallizations of these crystals from methanol yielded an anhydrous form (II); mp 155 to 157 °C; $[\alpha]_D^{20} + 14.2 \rightarrow + 49.2°$.

It is now established that 3-*O*-α-D-glucopyranosyl-D-arabinose has an equilibrium rotation of + 49.2°, and that neither Zemplén's product, $[\alpha]_D = +72°$, nor Gakhokidze's compound, $[\alpha]_D = +16.2°$, was the purported compound.

2. Assignment of Anomeric Configuration

The mutarotation of I (see fig. 1) shows a striking similarity to the complex mutarotations of α-L-arabinopyranose, β-D-galactopyranose, and D-*glycero*-β-D-*galacto*-heptopyranose [7]. Similarly, the mutarotation of II (see fig. 2) is in qualitative agreement with the mutarotations of β-L-arabinopyranose, α-D-galactopyranose, D-*glycero*-α-D-*galacto*-heptopyranose, and D-*glycero*-α-L-*galacto*-heptopyranose. As in the curves representing the mutarotations of α- and β-L-arabinose and related sugars, the deviation from linearity in the first portion presumably arises from a rapid pyranose-furanose interconversion, and the linear portion from a slower α-β-pyranose anomerization. The character of the mutarotations supports the conclusion that the monohydrate (I) is an α-D-pyranose, and the anhydrous form (II) is a β-D-pyranose. However, the dif-

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[1] Figures in brackets indicate the literature references at the end of this paper.

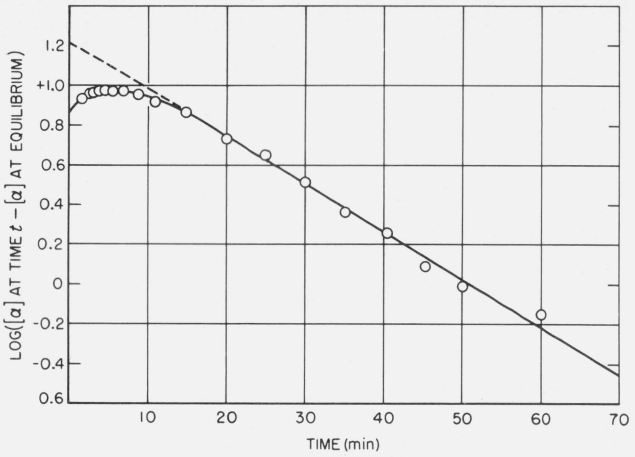

FIGURE 1. *Mutarotation of* 3-O-α-D-*glucopyranosyl*-α-D-*arabinopyranose in water at 20 °C.*

ference between the initial molecular rotations, Hudson's 2A, is only + 13,290, compared with + 16,950 for the anomeric forms of D-arabinopyranose [8].

The anomeric assignments are further substantiated by low-temperature acetylation of the sugars with pyridine and acetic anhydride. Under the acetylation conditions used, little anomeric change occurs, and the configuration of the main product is the same as that of the parent sugar. Compound I yielded principally a heptaacetate of $[\alpha]_D^{20} + 62.4°$, whereas II gave a heptaacetate of $[\alpha]_D^{20} + 13.4°$. The difference between the molecular rotations of the two heptaacetates (+31,720) is in good agreement with the difference (−33,400) that Hudson and Dale found for the tetraacetates of L-arabinopyranose [9].

3. Experimental Details

3.1. 3-O-α-D-Glucopyranosyl-α-D-arabinopyranose Monohydrate (I)

Calcium maltobionate was prepared from maltose by electrolytic oxidation in the presence of calcium carbonate and calcium bromide [10]. The amorphous calcium maltobionate was degraded as follows. A stirred mixture of 5 g of barium acetate monohydrate, 3.1 g of hydrated ferric sulfate [$Fe_2(SO_4)_3 \cdot ca\ 6H_2O$], and 100 g of calcium maltobionate in 500 ml of water was heated almost to boiling, cooled to 35 °C, and treated with 30 ml of 30-percent hydrogen peroxide. Completion of the ensuing reaction (during which the temperature rose to 50 °C) was indicated by the darkening of the solution. The reaction mixture was then cooled to 40 °C, and re-treated with 30 ml of the hydrogen peroxide. When the solution had again darkened, about 10 g of a decolorizing carbon was added, and the suspension was filtered. The filtrate was concentrated under vacuum to a sirup (n_D^{20} 1.46, or about 70 percent total solids); then 200 ml of methanol was slowly added with vigorous stirring. The resulting precipitate was filtered off, washed with two 100-ml portions of methanol, and discarded. The alcoholic filtrate and washings were combined and evaporated to a thick sirup. This sirup was diluted with 200 ml of methanol, and isopropyl alcohol was added to the incipient separation of a second liquid phase. The salts that precipitated were filtered off, thoroughly washed with methanol, and discarded. The filtrate and washings were combined, and concentrated under vacuum to a thin sirup, which was then diluted with water and passed through a column containing 100 ml of mixed cation- and anion-exchange resins. (A test with a conductivity meter showed that the effluent was substantially free from ionic impurities.) The effluent was concentrated under vacuum to a thick sirup, which was diluted with several volumes of methanol, and kept over calcium chloride in a desiccator.

The first crystals of I (17.6 g, 18.3%) formed only after several months (but their use in the nucleation of other syrupy preparations readily caused crystallization). After two recrystallizations from water, plus methanol to incipient turbidity, the compound contained 1 molecule of water of crystallization per molecule; mp 120 to 121 °C; $[\alpha]_D^{20} + 53.7 \rightarrow + 46.6°$ (*c* 4, water).

Anal.: Calc. for $C_{11}H_{20}O_{10} \cdot H_2O$: C, 40.0; H, 6.7. Found: C, 40.0; H, 6.7.

A solution of 0.4 g of I in 10 ml of water saturated with carbon dioxide showed a complex mutarotation. The data, analyzed by the method of Isbell and Pigman [11], follow the equation

$$[\alpha]_D^{20} = + 16.7 \times 10^{-0.024t} - 9.6 \times 10^{-0.098t} + 46.6,$$

in which time (t) is expressed in minutes. The data are presented graphically in figure 1.

3.2. 3-O-α-D-Glucopyranosyl-β-D-arabinopyranose (II)

A finely powdered sample of I (7 g) was dissolved in 700 ml of boiling, absolute ethyl alcohol, and the solution was boiled for 15 min, cooled to 25 °C, and kept at room temperature for one day and in a refrigerator for three days. The resulting crystalline product (apparently a mixture of an ethyl alcoholate and the anhydrous sugar) was twice recrystallized from methanol with the addition of isopropyl alcohol; mp 155 to 157 °C; $[\alpha]_D^{20} + 14.2 \rightarrow + 49.2°$ (*c* 4, water).

Anal.: Calc. for $C_{11}H_{20}O_{10}$: C, 42.3; H, 6.4. Found: C, 42.4; H, 6.5.

A solution of 0.4 g of II in 10 ml of water saturated with carbon dioxide exhibited the complex mutarotation expressed by the equation

$$[\alpha]_D^{20} = - 25.6 \times 10^{-0.025t} - 9.4 \times 10^{-0.097t} + 49.2.$$

The data are presented graphically in figure 2.

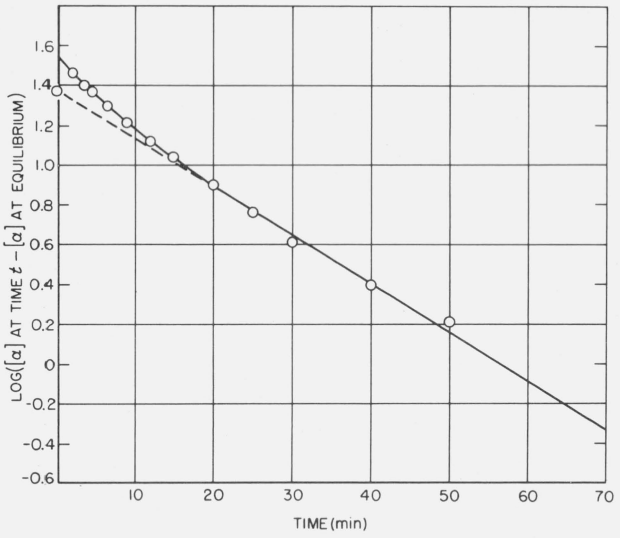

FIGURE 2. *Mutarotation of* 3-O-α-D-*glucopyranosyl*-β-D-*arabinopyranose in water at 20 °C.*

3.3. Hepta-*O*-acetyl-3-*O*-α-D-glupyranosyl-α-D-arabinopyranose

One gram of I was added, with mechanical stirring, to 20 ml of 1:1 (v/v) pyridine-acetic anhydride precooled in an ice-salt mixture. After being kept for 18 hr at 0 °C and 4 hr at room temperature, the mixture was poured into 400 ml of ice-water and stirred for 2 hr. The resulting crystals (0.9 g) were separated by filtration. The filtrate was extracted with chloroform, and the extract, after concentration, gave a second crop of crystals (0.8 g). The two crops were combined and recrystallized three times from ethyl alcohol by addition of water; yield, 1.3 g (67%); mp 127–128 °C; $[\alpha]_D^{20} + 62.4°$ (*c* 2.5, chloroform).

Anal.: Calc. for $C_{25}H_{34}O_{17}$: C, 49.5; H, 5.6. Found: C, 49.5; H, 5.7.

3.4. Hepta-*O*-acetyl-3-*O*-α-D-glycopyranosyl-β-D-arabinopyranose

A sample of finely powdered II (0.84 g) was acetylated in the manner described for the acetylation of I. The crude crystalline compound (1.15 g) was recrystallized three times from ethyl alcohol; mp 194.5–195.5 °C; $[\alpha]_D^{20} + 13.4°$ (*c* 2.5, chloroform).

Anal.: Calc. for $C_{25}H_{34}O_{17}$: C, 49.5; H, 5.6. Found: C, 49.3; H, 5.6.

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