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UNSATURATED SUGARS

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INTRODUCTION AND DISCUSSION

The unsaturated sugars have been reviewed recently[1], and a recent publication[2] prompted the author to report the following results.

In an attempt to form sugars containing selenium in the pyranoid ring, 5,6-anhydro-1,2-*O*-isopropylidene-α-D-glucofuranose was treated with potassium selenocyanate in methanol at room temperature. The expected episelenide was not formed, but selenium separated and 1,2-*O*-isopropylidene-5,6-dideoxy-α-D-*xylo*-hex-5-enofuranose was isolated in good yield. The same product was obtained from 5,6-anhydro-1,2-*O*-isopropylidene-α-L-idofuranose. Under similar conditions, 5,6-dideoxy-5,6-epithio-1,2-*O*-isopropylidene-α-D-glucofuranose did not react. When the reaction was repeated with potassium selenocyanate in the presence of ammonium chloride, no selenium separated. The crude product contained neither the 5-enose nor any selenocyanate group as shown by t.l.c. and infrared spectroscopy, respectively. When 1,2-*O*-isopropylidene-5,6-di-*O*-toluene-*p*-sulphonyl-α-D-glucofuranose was treated with a boiling solution of potassium selenocyanate in methanol for six hours, no reaction occurred. When *N*,*N*-dimethylformamide was used, the 5-enose was formed in good yield, but some 3,6-anhydro-1,2-*O*-isopropylidene-5-*O*-toluene-*p*-sulphonyl-α-D-glucofuranose was also isolated.

It was shown[3] that methyl 2,3-anhydro-4,6-*O*-benzylidene-α-D-mannopyranoside (**1**) reacted with potassium thiocyanate to give a 10% yield of methyl 4,6-*O*-benzylidene-2,3-dideoxy-2,3-epithio-α-D-glucopyranoside; when ammonium chloride was added, the yield of episulphide was increased to 20%. With ammonium thiocyanate in 2-methoxyethanol, compound **1** gave a mixture of the 2- and 3-thiocyanato compounds. Treatment of the methanesulphonic ester of this crude mixture with base gave the episulphide[4]. When **1** was treated with a boiling solution of potassium selenocyanate in aqueous 2-methoxyethanol, methyl 4,6-*O*-benzylidene-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranoside was obtained. When the reaction was repeated in the presence of ammonium chloride, a mixture of two compounds, probably methyl 4,6-*O*-benzylidene-2-deoxy-2-selenocyanato-α-D-glucopyranoside and methyl 4,6-*O*-benzylidene-3-deoxy-3-selenocyanato-α-D-altropyranoside was formed. The latter compound was preponderant, and its structure was assumed by analogy with the findings of Christensen and Goodman[4]. The crude mixture of selenocyanates was treated with toluene-*p*-

sulphonyl chloride, and the resulting ester, on treatment with alkali, gave the 2-enoside and selenium. However, when methyl 4,6-*O*-benzylidene-2,3-di-*O*-toluene-*p*-sulphonyl-α-D-glucopyranoside was treated with a boiling solution of potassium selenocyanate in *N*,*N*-dimethylformamide or 2-methoxyethanol, no reaction occurred.

Formation of unsaturated compounds by means of the selenocyanate reagent was also applied to an acyclic system. It has been shown[5] that 1,2:5,6-di-*O*-isopropylidene-D-mannitol 3,4-thionocarbonate, with trimethyl phosphite, gave 1,2: 5,6-di-*O*-isopropylidene-*trans*-3-hexene-D-*threo*-1,2,5,6-tetrol, and the corresponding *cis* compound was also prepared. Further, 1,2:5,6-di-*O*-isopropylidene-3,4-di-*O*-toluene-*p*-sulphonyl-D-mannitol, on treatment with boiling *N*,*N*-dimethylformamide, sodium iodide, and zinc dust, has been shown[6] to give the *trans* compound. Treatment of the above disulphonate with potassium selenocyanate in refluxing *N*,*N*-dimethylformamide or of 3,4-anhydro-1,2:5,6-di-*O*-isopropylidene-D-talitol with potassium selenocyanate in methanol at room temperature gave 1,2:5,6-di-*O*-isopropylidene-*cis*-3-hexene-D-*threo*-1,2,5,6-tetrol. The above anhydro compound, with potassium selenocyanate in refluxing 2-methoxyethanol, gave a better yield of the *cis* 3-ene. 5,6-Anhydro-1,2:3,4-di-*O*-isopropylidene-D-mannitol gave 3,4:5,6-di-*O*-isopropylidene-1-hexene-D-*arabino*-3,4,5,6-tetrol on treatment with potassium selenocyanate in methanol.

EXPERIMENTAL

Melting points are uncorrected. Known compounds were identified by melting points, mixed melting points, and infrared spectra. T.l.c. was performed on Merck Kieselgel G with benzene–methanol (9:1) as irrigant. The plates were sprayed with 10% ethanolic sulphuric acid and heated.

5,6-Dideoxy-1,2-O-isopropylidene-α-D-xylo-hex-5-enofuranose.—(*a*) A mixture of 5,6-anhydro-1,2-*O*-isopropylidene-α-D-glucofuranose[7] (or the corresponding L-*ido*[8] compound; 2.02 g, 0.01 mole), methanol (50 ml), and potassium selenocyanate[9] (2.88 g, 0.02 mole) was kept at room temperature overnight. Selenium started to separate immediately. The solution was filtered, diluted with water, and repeatedly extracted with chloroform. The chloroform extracts were dried (Na_2SO_4) and evaporated. The residue crystallised and was recrystallised from hexane to give the title compound (1.2 g, 64%), m.p. 64° (lit.[10] m.p. 58–60°). T.l.c. of the crude compound showed a weak spot at R_F 0.18 and an intense spot of the 5-enose (R_F 0.40).

When the reaction was repeated in the presence of ammonium chloride (1.07 g) dissolved in water (5 ml), no selenium separated. T.l.c. showed a weak spot at R_F 0.32 and a strong spot at R_F 0.18.

(*b*) 1,2-*O*-Isopropylidene-5,6-di-*O*-toluene-*p*-sulphonyl-α-D-glucofuranose[11] (1.06 g, 0.002 mole), potassium selenocyanate (1.0 g), and *N*,*N*-dimethylformamide (10 ml) were refluxed for 2 h. The reaction mixture was poured into water (40 ml), and 3,6-anhydro-1,2-*O*-isopropylidene-5-*O*-toluene-*p*-sulphonyl-α-D-glucofuranose[12] (0.10 g), m.p. 132–133°, separated. The filtrate was extracted with chloroform, and evaporation of the dried extracts gave a syrup (0.27 g, 73%) that crystallised on standing. Recrystallisation from hexane gave the 5-enose, m.p. 64°.

Reactions of methyl 2,3-anhydro-4,6-O-benzylidene-α-D-mannopyranoside. — (*a*) *Potassium selenocyanate.* The 2,3-anhydro compound[13] (2.64 g, 0.01 mole), potassium selenocyanate (3.0 g), 2-methoxyethanol (25 ml), and water (3 ml) were refluxed for 6 h. Selenium separated. The reaction mixture was poured into water, and the solid which separated was crystallised from dilute, aqueous alcohol to give methyl 4,6-*O*-benzylidene-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranoside (1.90 g, 81%), m.p. 119–120° (lit.[4] m.p. 117–119°).

(*b*) *Potassium selenocyanate in the presence of ammonium chloride.* The reaction mixture was prepared as in (*a*), except that ammonium chloride (1.1 g) was added. Water was added to the reaction mixture to give a solid (2.4 g, 65%), m.p. 207–220°; λ_{max}^{KBr} 2.98 (OH), 4.69 (SeCN), 13.03 and 14.19 μ (monosubst. phenyl). T.l.c. showed a minor component at R_F 0.42 and a major component at R_F 0.26.

Anal. Calc. for $C_{15}H_{16}O_5NSe$: Se, 21.4. Found: Se, 21.2%.

The crude mixture (1.0 g), dry pyridine (5 ml), and toluene-*p*-sulphonyl chloride (0.7 g) were kept for 60 h at 40°. Water (0.5 ml) was added, and, after 0.5 h, the reaction mixture was diluted with excess water. The solid (1.1 g), m.p. 192–194°, was filtered off. Its infrared spectrum (KBr) showed the absence of hydroxyl absorption and had λ_{max}^{KBr} 4.69 (SeCN), 7.32 and 8.44 μ (>SO_2).

The crude sulphonate (512 mg) was dissolved in warm methanol (10 ml), and (3 ml) sodium methoxide (100 mg) in methanol (3 ml) was added. Selenium separated immediately. After 1 h, the solution was filtered, and diluted with water to give the 2-enoside (200 mg, 85%), m.p. 119–121° (from dilute alcohol).

1,2:5,6-Di-O-isopropylidene-cis-3-hexene-D-threo-1,2,5,6-tetrol. — (*a*) 1,2:5,6-Di-*O*-isopropylidene-3,4-di-*O*-toluene-*p*-sulphonyl-D-mannitol[14] (1.12 g, 0.002 mole), potassium selenocyanate (1.0 g), and *N*,*N*-dimethylformamide (10 ml) were refluxed for 4 h. The solution was diluted with water and extracted with chloroform. The extracts were washed with water, dried, and evaporated. The syrup was taken up in light petroleum (15 ml, b.p. 40–60°); starting material (0.10 g) crystallised. The mother liquor was evaporated to give a syrup that was chromatographed on silica gel to give the title compound (0.20 g, 45%); $[\alpha]_D^{20}$ −6° (*c* 2.0, chloroform); $b.p._5$ 100–103° {lit.[5], $[\alpha]_D^{20}$ −8.1° (chloroform), $b.p._1$ 84–86°}; $\lambda_{max}^{CHCl_3}$ 6.23 (*cis* C=C), 8.69 and 9.28μ (isopropylidene).

Anal. Calc. for $C_{12}H_{20}O_4$: C, 63.2; H, 8.8. Found: C, 62.9; H, 8.8%.

(*b*) 3,4-Anhydro-1,2:5,6-di-*O*-isopropylidene-D-talitol[15] (1.22 g, 0.005 mole), potassium selenocyanate, and methanol (15 ml) were kept at room temperature for two days. Selenium slowly separated. By the usual isolation procedure and chromatography, the title compound (0.35 g, 32%) was isolated.

The experiment was repeated, but 2-methoxyethanol (12 ml) and water (1.5 ml) replaced the methanol. The solution was refluxed for 6 h. A syrup (1.20 g) was isolated, which, after chromatography, gave the title compound (1.0 g, 88%).

3,4:5,6-Di-O-isopropylidene-1-hexene-D-arabino-3,4,5,6-tetrol. — 5,6-Anhydro-1,2:3,4-di-*O*-isopropylidene-D-mannitol[16] (1.22 g, 0.005 mole), methanol (20 ml), and potassium selenocyanate (2.0 g) were kept at room temperature overnight. The

usual isolation procedure yielded a syrup (1.39 g). T.l.c. showed the presence of a major component (R_F 0.80; the desired olefin) and a minor component (R_F 0.70). The olefin (0.87 g, 76%), isolated by column chromatography on silica gel, had $[\alpha]_D^{20}$ −5° (*c* 1.0, chloroform).

The compound was hydrolysed by heating it on a boiling-water bath for 7 h with 0.3N sulphuric acid to give 1-hexene-D-*arabino*-3,4,5,6-tetrol[16], m.p. 145–147°, λ_{max}^{KBr} 2.98 (OH), 5.43, 6.07, 7.05, 9.94, and 10.83 μ ($CH_2=C\langle^H$).

SUMMARY

Terminal epoxides of sugars react readily with potassium selenocyanate in methanol at room temperature to give unsaturated sugars. Non-terminal epoxides of sugars with potassium selenocyanate in boiling, aqueous 2-methoxyethanol also gave the corresponding unsaturated sugar. Terminal or acyclic, vicinal di-*O*-toluene-*p*-sulphonyl esters gave the unsaturated sugar when treated with potassium selenocyanate in boiling *N*,*N*-dimethylformamide. Vicinal, *trans* toluene-*p*-sulphonate and selenocyanate groups eliminate selenium, on treatment with base, to give the unsaturated sugar.

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