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D-Galactosan<1,5>β<1,3>, a New Anhydride of D-Galactose[1]

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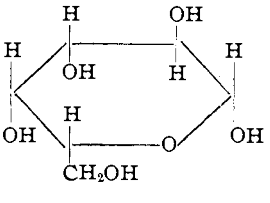
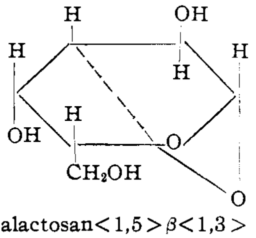
Recently we described[2] a procedure for the preparation of D-glucosan<1,5>β<1,6> and D-galactosan<1,5>β<1,6> by the pyrolysis of lactose. The D-galactosan<1,5>β<1,6> was identical with that first obtained by Micheel[3] from the action of barium hydroxide on tetraacetyl-D-galactosido<1,5>-trimethylammonium bromide. Micheel states that he also obtained a slight amount of this sugar anhydride by the distillation of β-D-galactose at 270–360° under 3 mm. pressure. The pyrolysis of α-D-galactose in the apparatus and under the experimental conditions described by Knauf, Hann and Hudson[4] has been found to yield a sirupy distillate of *positive* rotation in contrast to those obtained from the pyrolysis of starch, ivory nut meal and lactose, all of which exhibited *negative* rotations. The condensation of the distillate with acetone in the customary manner yielded the known[2,3] crystalline 3,4-isopropylidene-D-galactosan<1,5>β<1,6> in an amount of about 5% of the galactose pyrolyzed. From the mother liquor of the acetone condensation a new crystalline substance melting at 174–175° (corr.) and possessing a specific rotation $[\alpha]^{20}\text{D}$ +54.9° in water, was isolated. The analysis of the new compound gave correct values for a hexose anhydride and upon acetylation it yielded a triacetate (m. p. 79–80° (corr.); $[\alpha]^{20}\text{D}$ in chloroform, +144.9°) which agreed in composition with, and had the correct molecular weight for, the triacetyl derivative of a hexose anhydride. Aqueous solutions of the anhydride did not reduce boiling Fehling solution. Solutions of the substance in 0.2 *N* hydrochloric acid showed no change in rotation upon standing for several hours at 20°, but upon heating at 100° for four hours the rotation of the solution increased to a constant value of +79.0° based on its hexose content, and these hydrolyzed solutions upon appropriate treatment with phenylhydrazine or *o*-phenylenediamine[5] yielded D-galactose phenylosazone and 2-[D-*galacto*-pentahydroxypentyl]-benzimidazole. These facts show that the substance is a new D-galactosan.

All of the recorded D-galactosans differ markedly in physical and chemical properties from the present compound. The α-D-galactosan of Pictet and Vernet[6] and the β-D-galactosan of Pictet and Vogel[7] are poorly defined amorphous hygroscopic substances which are said to reduce Fehling solution strongly and to pass to D-galactose by treatment with warm water, and the previously mentioned D-galactosan<1,5>β<1,6> of Micheel, formed concurrently in the pyrolysis under discussion and separated from the new D-galactosan in the form of its crystalline isopropylidene derivative, melts at 220–221° and has a specific rotation $[\alpha]^{20}\text{D}$ −21.9° in water. The new D-galactosan does not form an acetone derivative under the conditions that were used. The structural and stereochemical formula of the new D-galactosan is readily obtainable from the observations (1) that the substance is non-reducing, (2) that the molecular weight of its acetate excludes a polymerized product, and (3) that it is not oxidized by sodium metaperiodate. Interpreting the third fact as proof that the molecule does not contain contiguous hydroxyl groups, the rings can be only in the positions 1,5 and 1,3. The usual perspective formula for β-D-galactose<1,5> (I) carries the hydroxyl groups on carbons one and three in the *cis* position; spacial relations seem thus to be compatible only with a β configuration for the 1,3 ring, as shown in formula II.



β-D-Galactose <1,5>
(I)



D-Galactosan<1,5>β<1,3>
(II)

Experimental

Three 85-g. portions of α-D-galactose were pyrolyzed in the apparatus and under the experimental conditions previ-

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[2] Hann and Hudson, THIS JOURNAL, **63**, 1484 (1941).

[3] Micheel, *Ber.*, **62**, 687 (1929).

[4] Knauf, Hann and Hudson, THIS JOURNAL, **63**, 1447 (1941).

[5] Moore and Link, *J. Biol. Chem.*, **133**, 293 (1940); Haskins and Hudson, THIS JOURNAL, **61**, 1266 (1939).

[6] Pictet and Vernet, *Helv. Chim. Acta*, **5**, 444 (1922).

[7] Pictet and Vogel, *ibid.*, **11**, 209 (1928).

ously described.[4] The pyrolysate was dissolved in 250 cc. of water and the solution filtered through 60 g. of decolorizing carbon to remove a small amount of tar; the filtrate and washings (volume 750 cc.; rotation, +13.9° in a 4-dm. tube) were concentrated *in vacuo* to a nearly dry sirup; the sirup was dissolved in 100 cc. of warm acetone and poured in a thin stream into a further 250 cc. of acetone. After standing at 5° for several hours the clear acetone solution was decanted from a small amount of sirup and was shaken at 20° with 40 g. of anhydrous copper sulfate for twenty-four hours. The copper sulfate was removed and the solution was concentrated to a magma of crystals which was transferred to a beaker with 20 cc. of isopropyl alcohol and placed in the refrigerator at 5° for three hours. The crystals (11.5 g.), which were largely isopropylidene-D-galactosan<1,5>β<1,6>, were removed by filtration and the filtrate returned to the refrigerator for several days when a second crop of crystals (10.6 g.), consisting mostly of the new D-galactosan, was removed; a third fraction (2.8 g.), which was also the new D-galactosan, was obtained from the mother liquor.

Chloroform Separation of 3,4-Isopropylidene-D-galactosan<1,5>β<1,6> and D-Galactosan<1,5>β<1,3>.—The combined second and third fractions (13.4 g.) were refluxed with 65 cc. of chloroform for ten minutes and the undissolved residue (10.5 g.) removed by filtration. The chloroform filtrate was added to the first fraction (11.5 g.), the mixture was refluxed for ten minutes and the undissolved solid (1.6 g.) removed by filtration. The yield of insoluble crude D-galactosan<1,5>β<1,3> was 11.1 g. and the chloroform extract deposited 7.2 g. of pure 3,4-isopropylidene-D-galactosan<1,5>β<1,6> ($[\alpha]^{20}\mathrm{D}$ −72.7°) on cooling, and a fnrther 4.8 g. was recovered from the chloroform mother liquors.

D-Galactosan<1,5>β<1,3>.—The crude D-galactosan, which was slightly yellow in color and contained some gummy material, was reducing to Fehling solution and had a specific rotation of +46 to +50°. Several recrystallizations from five parts of absolute alcohol were required for purification to constant properties; the pure substance, which is non-reducing to Fehling solution, forms well defined prisms which melt at 174–175° (corr.) and show an $[\alpha]^{20}\mathrm{D}$ value of +54.9° (*c*, 0.9; *l*, 4) in water.

Anal. Calcd. for $C_6H_{10}O_5$: C, 44.42; H, 6.22. Found: C, 44.57; H, 6.37.

Hydrolysis of D-Galactosan<1,5>β<1,3> to D-Galactose.—(1) A solution of 0.2248 g. of the D-galactosan in 25 cc. of 0.2 *N* hydrochloric acid changed in specific rotation from +54.8° (calculated as D-galactosan) to a constant value of 79.0° (calculated as hexose) upon heating on the steam-bath for four hours. The hydrolyzed solution, after removal of the hydrochloric acid as silver chloride, was concentrated to a small volume and treated with phenylhydrazine, when D-galactose phenylosazone separated. After purification by recrystallization from 50% alcohol the osazone melted at 202° (corr.) and this melting point was unchanged upon admixture with authentic D-galactose phenylosazone. (2) A sample of 1.0 g. of the D-galactosan was hydrolyzed and the resulting galactose was converted to 2-[D-galactohexahydroxyhexyl]-benzimidazole by the procedure of Moore and Link,[5] yield 0.6 g. (36%). The substituted benzimidazole decomposed at 245–246° (corr.) and this decomposition point was unchanged upon admixture with authentic 2-[D-*galacto*-pentahydroxypentyl]-benzimidazole. Its specific rotation $[\alpha]^{20}\mathrm{D}$ +44.5° in *N* hydrochloric acid (*c*, 0.8; *l*, 4) agreed with the value of +44.4° recorded by Haskins and Hudson.[5]

Action of Sodium Metaperiodate on D-Galactosan<1,5>β<1,3>.—A sample of 0.2723 g. of the galactosan was dissolved in 15 cc. of water, 4 cc. of 0.578 *M* sodium metaperiodate (1.01 moles) added and the solution made up to a volume of 25 cc. and allowed to stand in a 20° constant temperature room. Titration of 5 cc. subsamples at the expiration of one and twenty-four hours indicated the consumption of 0.13 cc. of the periodate, equivalent to a consumption of only 0.03 mole of oxidant. It is evident that the galactosan is not oxidized under conditions by which D-glucosan<1,5>β<1,6>, D-altrosan<1,5>β<1,6> and D-mannosan<1,5>β<1,6> readily reduce periodate.

2,4,6-Triacetyl-D-galactosan<1,5>β<1,3>.—A solution of 1.5 g. of the galactosan in a mixture of 10 cc. of pyridine and 10 cc. of acetic anhydride was allowed to stand overnight at room temperature and then poured upon crushed ice. An immediate crystallization of 1.8 g. of the triacetate occurred and an additional 0.9 g. was obtained from the chloroform extract of the aqueous solution, yield 2.7 g. (quantitative). The substance was readily purified to constant properties by one or two recrystallizations from 10 parts of alcohol; it forms elongated plates, which melt at 79–80° (corr.) and show an $[\alpha]^{20}\mathrm{D}$ value of +144.9° (*c*, 0.9; *l*, 4) in chloroform.

Anal. Calcd. for $C_{12}H_{16}O_8$: C, 50.00; H, 5.60; CH_3CO, 44.8; molecular weight, 288. Found: C, 49.91; H, 5.77; CH_3CO, 44.7; molecular weight by Rast method, 293, 289.

Thanks are expressed to Dr. A. T. Ness for performing the microchemical analyses.

Summary

A new D-galactosan has been obtained from the pyrolysis products of D-galactose. The new substance is a monomeric compound which is non-reducing to Fehling solution and is not oxidized by sodium metaperiodate. These properties limit the structural and stereochemical formula of the compound to that of D-galactosan<1,5>β<1,3>.

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