131. *Deoxy-sugars. Part IX. Some Properties and Reactions of 2-Deoxy-*D*-galactose.*

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2-Deoxy-D-galactose, conveniently synthesised by the glycal method, gives an interesting series of highly crystalline derivatives. The reactions and general properties of the oxidation product are closely similar to those described for other 2-deoxy-hexoses and -pentoses. The synthesis and determination of the structure of the methyl-glycopyranosides and -glycofuranosides of 2-deoxy-D-galactose are described.

We have extended our studies of deoxy-sugars, and in particular of 2-deoxy-pentoses and -hexoses to include 2-deoxy-D-galactose; the preparation of this compound was reported by Isbell and Pigman (*J. Res. Nat. Bur. Stand.*, 1939, **22**, 397) but not its derivatives or reactions. We found that 2-deoxy-D-galactose could be synthesised in satisfactory yield from D-galactose by the improved glycal method. We noted that the Zemplén method for the deacetylation of 3 : 4 : 6-triacetyl D-galactal gave a better yield than that employing barium hydroxide as the deacetylating agent. Treatment of D-galactal with 5% sulphuric acid gave 2-deoxy-D-galactose. We observed that catalytic reduction of 3 : 4 : 6-triacetyl D-galactal yielded 3 : 4 : 6-*triacetyl* 1 : 2-*dideoxy*-D-*galactose*, deacetylation of which, using sodium in methanol, afforded 1 : 2-*dideoxy*-D-*galactose*, which was also obtained by catalytic reduction of D-galactal. Further investigations of these interesting dideoxy-sugars will form the subject of a later communication.

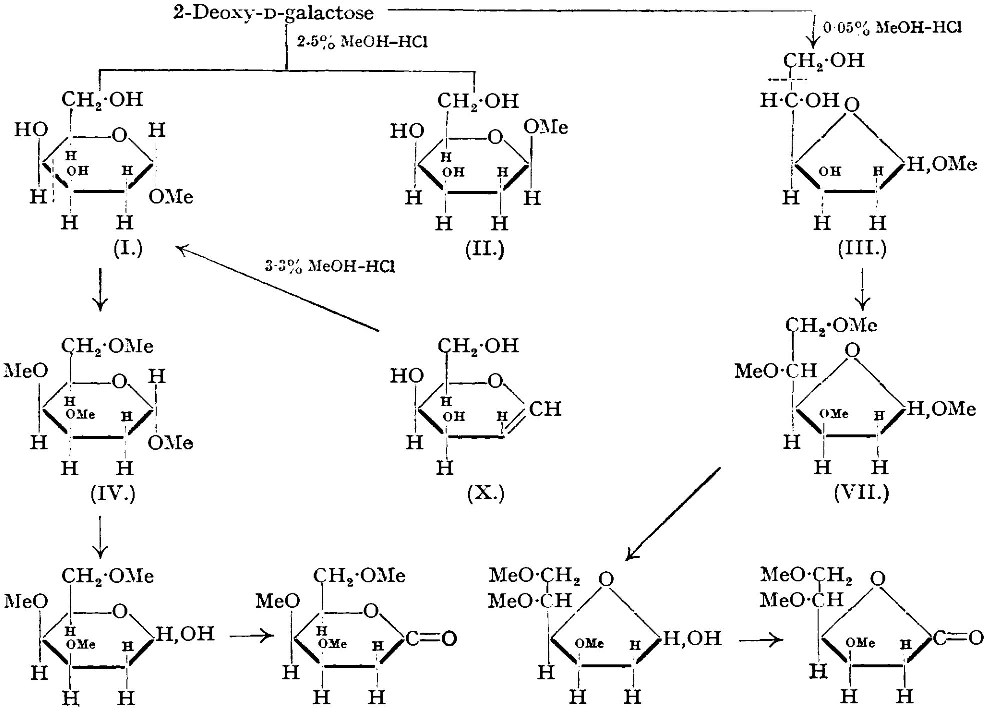
2-Deoxy-D-galactose exhibited mutarotation in water and in methanol. It formed a crystalline 2 : 4-*dinitrophenylhydrazone* and when treated with *p*-toluidine in ethanol gave 2-*deoxy*-D-*galactose* p-*toluidide*. Both derivatives are particularly useful for characterising the sugar. On acetylation with acetic anhydride in pyridine, 2-deoxy-D-galactose was converted into 1 : 3 : 4 : 6-*tetra-acetyl* 2-*deoxy*-α-D-*galactose*, whereas when fused sodium acetate and acetic anhydride were used as acetylating agents the β-isomer of the *tetra-acetate* was obtained. It was shown that 2-deoxy-D-galactose could react in its *aldehydo*-form, since when treated with ethanethiol and concentrated hydrochloric acid it gave crystalline 2-*deoxy*-D-*galactose diethyl mercaptal*. Oxidation of the deoxy-sugar with bromine in water was easily effected, the product being 2-*deoxy*-D-*galactonolactone*. Treatment of this lactone with liquid ammonia gave the corresponding *amide* which on being heated evolved ammonia. 2-Deoxy-D-galactonolactone was extremely stable and underwent no apparent hydrolysis in aqueous solution in 3 days, indicating that it was probably a furanolactone.

Methyl glyco-pyranosides of	Isomer.	M. p.	$[\alpha]_D$.	$[M]$.	$[M]_\alpha - [M]_\beta$.	Ref.
L-Arabinose	α	131°	+ 17·3°	2,840	−37,420	*a*
	β	169	+245·5	40,260		
2-Deoxy-L-ribose	α	99—100	− 43·4	− 6,420	−36,360	*b*
	β	83—84	+202·3	29,940		
D-Glucose	α	168	+158·9	30,830	+37,030	*c, d*
	β	110	− 31·97	− 6,200		
2-Deoxy-D-glucose	α	91—92	+138	+24,600	+33,180	*e, f*
	β	122—123	− 48·2	− 8,500		
D-Galactose	α	111	+178·8	33,300	+33,380	*g, h*
	β	178	− 0·42	−80·5		
2-Deoxy-D-galactose ...	α	112—113	+170	+30,300	+30,300	
	β	Syrup	± 0	0		

a, Hudson, *J. Amer. Chem. Soc.*, 1925, **47**, 270. *b*, Deriaz, Overend, Stacey, and Wiggins, *J.*, 1949, 2836. *c*, Rüber, *Ber.*, 1924, **57**, 1797. *d*, Patterson and Robertson, *J.*, 1929, 300. *e*, Bergmann *et al.*, *Ber.*, 1922, **55**, 158. *f*, *Idem*, *ibid.*, 1920, **53**, 545. *g*, Fischer and Beensch, *ibid.*, 1894, **27**, 2480; 1895, **28**, 1145; Voss, *Annalen*, 1931, **485**, 283; Micheel and Littman, *ibid.*, 1928, **466**, 115. *h*, Müller, *Ber.*, 1931, **64**, 1820.

When 2-deoxy-D-galactose was treated with 2·5% methanolic hydrogen chloride for three hours it yielded a syrup from which was isolated a crystalline methyl-2-deoxygalactoside. This, as is subsequently described, was identified as α-methyl-2-deoxy-D-galactopyranoside (I) which was conveniently characterised by conversion into its 3 : 4 : 6-*tritoluene*-p-*sulphonyl* derivative. In addition to (I) a syrupy glycoside was obtained which in all probability consisted mainly of β-*methyl*-2-*deoxy*-D-*galactopyranoside* (II). Tamm and Reichstein (*Helv. Chim. Acta*, 1948, **31**, 1630) described the isolation of similar compounds but did not investigate their structures. Polarimetric observations on the specific rotations, in methanol, of the two glycosides served to differentiate between the α- and β-isomers in accordance with the well-known convention, first introduced by Hudson (*J. Amer. Chem. Soc.*, 1909, **31**, 66) (cf. Deriaz, Overend, Stacey, and Wiggins, *J.*, 1949, 2836). Moreover the αβ-relation of the two isomeric glycosides was further confirmed by the observations which were made (polarimetrically) that 2% methanolic hydrogen chloride converts each glycoside into an αβ-mixture similar to that from which they were initially isolated (Fig. 1). Finally the αβ-relation between the two glycosides is evident from a consideration of the difference in molecular rotations. The molecular rotations of the α- and β-forms ($[M]_\alpha$ and $[M]_\beta$ respectively) of the methylglycopyranosides of L-arabinose, 2-deoxy-L-ribose, D-glucose, 2-deoxy-D-glucose, D-galactose, and 2-deoxy-D-galactose are compared in the annexed table (cf. Deriaz *et al.*, *loc. cit.*). There is good agreement between the difference in the molecular rotations of the respective α- and β-forms of methyl-2-deoxy-D-galactopyranoside and of methyl-D-galactoside.

When 2-deoxy-D-galactose was treated with 0·05% methanolic hydrogen chloride for a very short period, another methyl-2-deoxy-D-galactoside (III) was formed. This has been shown to be *αβ-methyl-2-deoxy-*D*-galactofuranoside* (cf. Deriaz *et al.*, *loc. cit.*, and Hughes, Overend, and Stacey, *J.*, 1949, 2846, for analogous results with 2-deoxy-D-ribose and 2-deoxy-D-glucose respectively).



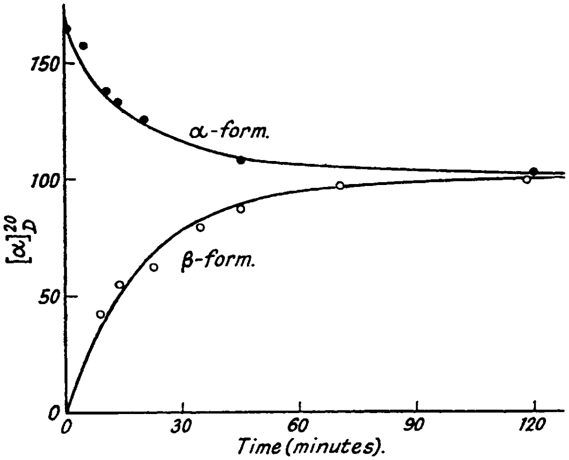
The following observed facts have led to the glycosides (I) and (III) being assigned the structures described.

(*a*) The glycoside (III) was much more rapidly hydrolysed with hydrochloric acid than glycoside (I). In Fig. 2 the rates of hydrolysis of the glycosides (I) and (III) and of αβ-methyl-D-galacto-pyranoside and -furanoside are compared. It is a general property of methylglycofuranosides to have a greater lability to acids than the corresponding pyranosides and this effect is enhanced in the series of 2-deoxy-sugars (Overend, Stacey, and Staněk, *J.*, 1949, 2841). This result indicates that the glycosides (I) and (III) are of the pyranose and furanose type respectively.

(*b*) When D-galactal (X) was treated with 3·3% methanolic hydrogen chloride it yielded the crystalline glycoside (I) (33%). Since D-galactal is known to have the pyranose structure (Levene and Tipson, *J. Biol. Chem.*, 1931, **93**, 631) it is likely that (I) also has a pyranose structure (cf. Fischer, Bergmann, and Schotte, *Ber.*, 1920, **53**, 509, for a similar approach in the glucose series).

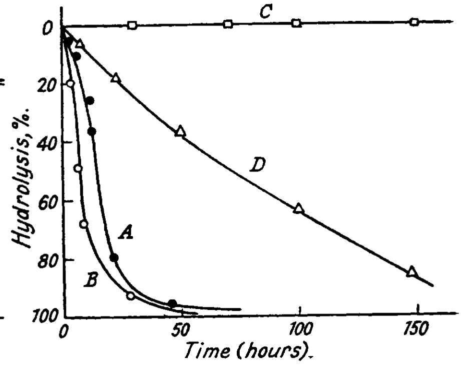
(*c*) It is well established (Hockett and McClenahan, *J. Amer. Chem. Soc.*, 1939, **61**, 1667) that adjacent hydroxyl groups are readily oxidised by lead tetra-acetate and that *cis-* are more rapidly oxidised than *trans*-hydroxyl groups. Oxidation of the glycosides (I) and (III) with lead tetra-acetate resulted in both cases in the uptake of 1 mole of oxidant. The rate of oxidation was slightly faster for (I) than for (III) (see Fig. 3). Similarly adjacent hydroxyl groups may be oxidised by sodium metaperiodate (Jackson and Hudson, *J. Amer. Chem. Soc.*, 1939, **61**, 1530).

FIG. 1.



Isomerisation of α- *and* β-*methyl-2-deoxy-*D-*galactopyranoside by* 2·5% HCl *in* MeOH.

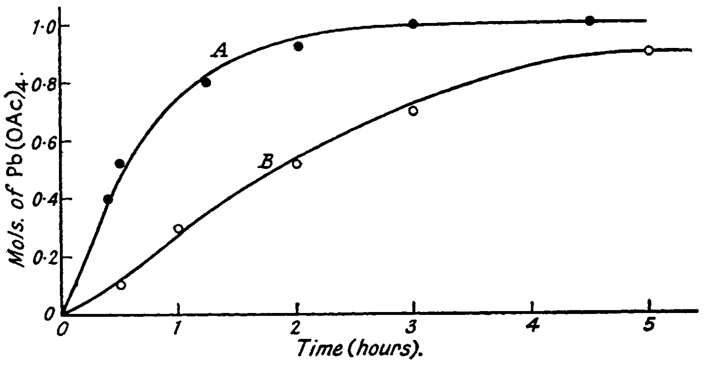
FIG. 2.



A. αβ-*Methyl-2-deoxy-*D-*galactofuranoside* (0·02N-HCl).
B. α-*Methyl-2-deoxy-*D-*galactopyranoside* (N-HCl).
C. αβ-*Methyl-*D-*galactopyranoside* (0·5N-HCl).
D. αβ-*Methyl-*D-*galactofuranoside* (N-HCl).

FIG. 3.

Oxidation by lead tetra-acetate.



A. α-*Methyl-2-deoxy-*D-*galactopyranoside.*
B. αβ-*Methyl-2-deoxy-*D-*galactofuranoside.*

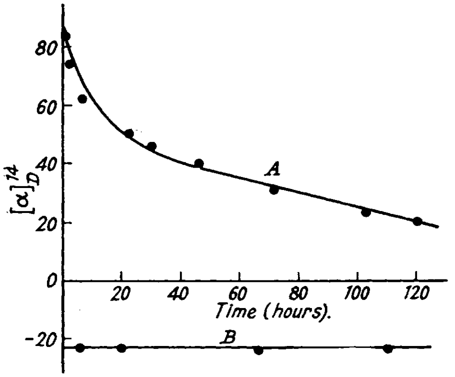
If one of the hydroxyl groups is primary then formaldehyde is formed. Both glycosides absorbed 1 mole of sodium metaperiodate, but formaldehyde resulted only from (III), thereby indicating that this glycoside was methyl-2-deoxy-D-galactofuranoside. The formaldehyde was determined as its dimedon derivative (Reeves, *J. Amer. Chem. Soc.*, 1941, **63**, 1476).

(*d*) Finally, conclusive proof of the structures of the glycosides was obtained by the classical methods of carbohydrate chemistry, involving methylation of the glycoside, hydrolysis of the fully methylated derivative, oxidation of the products to methylated lactones, study of the rates of hydrolysis of the methylated lactones in water, etc. (Carter, Robinson, and Haworth, *J.*, **1930**, 2125).

Thus α-methyl-2-deoxy-D-galactopyranoside (I) was methylated by the liquid ammonia technique (Muskat, *J. Amer. Chem. Soc.*, 1934, **56**, 693, 2449; Freudenberg and Boppel, *Ber.*, 1938, **71**, 2505). Smooth methylation occurred and 3 : 4 : 6-*trimethyl α-methyl-2-deoxy-*D-*galactopyranoside* (IV) was obtained as a colourless liquid. On treatment with N-hydrochloric acid at 70° it gave 3 : 4 : 6-*trimethyl 2-deoxy-*D-*galactopyranose* (V) as a colourless syrup. Oxidation of this with bromine in water afforded 3 : 4 : 6-*trimethyl 2-deoxy-*D-*galactonolactone* (VI). A similar series of reactions was carried out on αβ-methyl-2-deoxy-D-galactofuranoside (III). This was methylated in liquid ammonia with sodium and methyl iodide and 3 : 5 : 6-*trimethyl αβ-methyl-2-deoxy-*D-*galactofuranoside* (VII) was isolated. Hydrolysis of the glycosidic group by 0·01N-hydrochloric acid at 100° (20 minutes) gave 3 : 5 : 6-*trimethyl 2-deoxy-*D-*galactofuranose* (VIII) as a colourless syrup, whence oxidation in the normal way with bromine water gave 3 : 5 : 6-*trimethyl 2-deoxy-*D-*galactonolactone* (IX). The rate of hydrolysis of each of the lactones obtained was measured polarimetrically at room temperature. Hydrolysis of 3 : 4 : 6-trimethyl 2-deoxy-D-galactonolactone (VI) was complete in approximately 100 hours, whereas 3 : 5 : 6-trimethyl 2-deoxy-D-galactonolactone (IX) was hydrolysed exceedingly slowly (see Fig. 4), thereby showing that the original methylglycosides from which they were derived must have had the pyranose (I) and the furanose structure (III) respectively.

FIG. 4.

Hydrolysis of the lactones.



A. 3 : 4 : 6-*Trimethyl 2-deoxy-*D-*galactonolactone* (δ-*type*).
B. 3 : 5 : 6-*Trimethyl 2-deoxy-*D-*galactonolactone* (γ-*type*).

Thus it was apparent that the above reactions of 2-deoxy-D-galactose are closely analogous to those of 2-deoxy-D-ribose and 2-deoxy-D-glucose, and it seems that these will be typical for most 2-deoxy-hexoses and -pentoses.

EXPERIMENTAL.

3 : 4 : 6-*Triacetyl* D-*Galactal*.—Dry powdered 1-bromo 2 : 3 : 4 : 6-tetra-acetyl D-galactose (110 g.) was suspended in 50% acetic acid (1·6 l.), and the suspension was rapidly stirred. Zinc dust (300 g.) was slowly added during 2 hours. At intervals throughout the addition of the zinc a few drops of a 3% solution of platinic chloride were added. Stirring was continued for 3 hours and then the zinc was filtered off, and the filtrate concentrated to 500 c.c. and then poured into water (1 l.). The solution was extracted with chloroform (4 × 250 c.c.), and the extract washed first with aqueous sodium hydrogen carbonate and then with water. After being dried ($MgSO_4$) the solvent was evaporated and the syrupy residue distilled. Two fractions were obtained, (i) 48 g. (69%), b. p. 145—150° (bath temp.)/0·001 mm., n_D^{18} 1·4677, m. p. *ca.* 30°, $[\alpha]_D^{18}$ ±0° (*c*, 1·0 in ethanol) {this was triacetyl D-galactal (cf. Levene and Tipson, *J. Biol. Chem.*, 1931, **93**, 631, who give m. p. 30° and $[\alpha]_D^{20}$ −12·4° in chloroform, and Komada, *Bull. Jap. Chem. Soc.*, 1932, **7**, 211, who gives b. p. 138—140°/0·2—0·3 mm; Pigman and Isbell, *J. Res. Nat. Bur. Stand*, 1937, **19**, 204, who record b. p. 140—155°/0·005 mm.)}, and (ii) 1·1 g., b. p. 180—210° (bath temp.)/0·001 mm. (Found: C, 50·9; H, 6·3%). Trituration of (ii) with ethanol induced a portion to crystallise. This was separated and shown to be penta-acetyl D-galactose, m. p. 142° alone or on admixture with an authentic specimen. In addition some polymeric material remained undistilled. If the addition of platinic chloride solution was omitted the yield of triacetyl D-galactal was much reduced (*ca.* 30%) and much more penta-acetyl D-galactose was obtained.

3 : 4 : 6-*Triacetyl* 1 : 2-*Dideoxy-*D-*galactose*.—3 : 4 : 6-Triacetyl D-galactal (0·5 g.) was dissolved in dry methanol (50 c.c.) and hydrogenated at room temperature with a platinum oxide catalyst. The solution was filtered and evaporated to dryness. The syrupy residue was distilled and 3 : 4 : 6-*triacetyl* 1 : 2-*dideoxy-*D-*galactose* (0·45 g.) obtained as a colourless syrup, b. p. 120—130° (bath temp.)/1 mm., n_D^{21} 1·4558, $[\alpha]_D^{20}$ +55·9° (*c*, 0·32 in chloroform) (Found: C, 52·5; H, 6·8. $C_{12}H_{18}O_7$ requires C, 52·5; H, 6·6%).

D-*Galactal*.—(*a*) 3 : 4 : 6-Triacetyl D-galactal (32 g.) was added to a solution of barium hydroxide (90 g.) in water (450 c.c.). The solution was kept overnight at 0° and then heated for 30 minutes at 80°. Carbon dioxide was passed through the solution after cooling and the precipitated barium carbonate filtered off. The filtrate was evaporated at 55° to half its volume and then refiltered through a charcoal pad. Further evaporation gave crystals which were recrystallised from ethyl acetate. D-Galactal (10 g., 59%) had m. p. 104° and $[\alpha]_D^{18}$ +5° (*c*, 1·2 in methanol) (cf. Levene and Tipson, *loc. cit.*, and Komada *loc. cit.*, who give m. p. 100°, and Tamm and Reichstein, *Helv. Chim. Acta*, 1948, **31**, 1630, who give m. p. 90—92°).

(*b*) 3 : 4 : 6-Triacetyl D-galactal (87 g.) was dissolved in absolute methanol (1 l.), and sodium (0·2 g.) was added. The solution was kept for 48 hours and then solid carbon dioxide was added. The solution was evaporated to dryness, the residue was recrystallised from ethyl acetate, and D-galactal (38 g., 81%), m. p. 104°, was obtained.

1 : 2-*Dideoxy*-D-*galactose*.—(*a*) D-Galactal (0·5 g.) was dissolved in methanol (25 c.c.) and hydrogenated at room temperature with a Raney nickel catalyst. After cessation of the uptake of hydrogen the catalyst was filtered off and the filtrate was evaporated to dryness. The syrupy residue crystallised from aqueous ethanol in plates. 1 : 2-*Dideoxy*-D-*galactose* (0·4 g.) had m. p. 128—129° and $[\alpha]_{\mathrm{D}}^{20}$ +41·8° (*c*, 0·526 in water) (Found : C, 48·7; H, 7·9. $C_6H_{12}O_4$ requires C, 48·6; H, 8·1%). (*b*) 3 : 4 : 6-Triacetyl 1 : 2-dideoxy-D-galactose (1·0 g.) was dissolved in dry methanol (15 c.c.) and sodium (15 mg.) was added. The solution was kept at room temperature for 48 hours and then evaporated to dryness. The residue was extracted with a small amount of ethanol, and the solvent was re-evaporated. Repeated recrystallisation of the product from ethanol afforded 1 : 2-dideoxy-D-galactose identical with the product above. Reacetylation of 1 : 2-dideoxy-D-galactose (1 g.) with acetic anhydride (5 c.c.) in pyridine (10 c.c.) regenerated 3 : 4 : 6-triacetyl 1 : 2-dideoxy-D-galactose, b. p. 120—125° (bath temp.)/1 mm., n_{D}^{21} 1·4560.

2-*Deoxy*-D-*galactose*.—D-Galactal (6·1 g.) was dissolved in 5% sulphuric acid (85 c.c.) and the solution was kept at 0° for 24 hours. Then the solution was warmed to 60° and neutralised with barium carbonate which was added portionwise. The solution was filtered and decolorised by stirring it with charcoal. It was concentrated under reduced pressure to a syrup which was taken up in methanol (3 vols.) and set aside. 2-Deoxy-D-galactose (4·5 g.) crystallised from solution and was recrystallised from methanol as colourless needles (3·4 g.) which had m. p. 110° and $[\alpha]_{\mathrm{D}}^{21}$ +57° ±2° (equilibrium) (*c*, 1·0 in water) (Found : C, 43·9; H, 7·1. Calc. for $C_6H_{12}O_5$: C, 43·9; H, 7·3%) [cf. Isbell and Pigman, *J. Res. Nat. Bur. Stand.*, 1939, **22**, 397, who give m. p. 120—121° and $[\alpha]_{\mathrm{D}}$ $+40·8° \longrightarrow +60·5°$ (equilibrium in 30 minutes; *c*, 4·0 in water); Tamm and Reichstein, *loc. cit.*, who give m. p. 105—106° and $[\alpha]_{\mathrm{D}}^{18}$ +60·7° in water]. 2-Deoxy-D-galactose exhibited mutarotation in several solvents :

(*a*) Methanol as solvent (*c*, 0·58) :

Time, mins.	1·5	2·5	5·5	9·5	11·0
$[\alpha]_{\mathrm{D}}^{22}$ ………	+3·44°	+17·25°	+32·2°	+32·2°	+32·2°

(*b*) Water as solvent (*c*, 1·19) :

Time, mins.	2	3	4·5	7	13	19	30	40	46	50
$[\alpha]_{\mathrm{D}}^{17}$ ………	+33·6°	+35·2°	+37°	+38·6°	+46·2°	+50·2°	+54·5°	+56·2°	+57°	+57°

2-*Deoxy*-D-*galactose* 2 : 4-*Dinitrophenylhydrazone*.—2-Deoxy-D-galactose (0·3 g.) in water (10 c.c.) was added to a solution of 2 : 4-dinitrophenylhydrazine (0·7 g.) in glacial acetic acid (10 c.c.), and the mixture was warmed at 90° for 30 minutes. The solvents were then removed under diminished pressure and the residue was crystallised by trituration with ethanol. Recrystallisation from aqueous ethanol gave 2-*deoxy*-D-*galactose* 2 : 4-*dinitrophenylhydrazone*, m. p. 124°, and $[\alpha]_{\mathrm{D}}^{22}$ +30° in methanol (Found : C, 41·5; H, 4·9. $C_{12}H_{16}O_8N_4$ requires C, 41·8; H, 4·7%).

2-*Deoxy*-D-*galactose* p-*Toluidide* [with A. B. FOSTER].—2-Deoxy-D-galactose (0·3 g.) dissolved in ethanol (7 c.c.; 95%) was added to *p*-toluidine (0·23 g., 1·1 mols.), and the solution boiled under reflux for 2 hours. When kept overnight at room temperature the product separated in large prisms. Recrystallisation from ethanol gave 2-*deoxy*-D-*galactose* p-*toluidide* (0·25 g.; 54%) as white prisms, m. p. 142—143°, $[\alpha]_{\mathrm{D}}^{20}$ −149° (*c*, 0·8 in pyridine) (Found : C, 61·9; H, 7·6; N, 5·2. $C_{13}H_{19}O_4N$ requires C, 61·6; H, 7·5; N, 5·5%).

1 : 3 : 4 : 6-*Tetra-acetyl* 2-*Deoxy*-α-D-*galactose*.—2-Deoxy-D-galactose (0·41 g.) was added to a mixture of freshly distilled acetic anhydride (2·0 g.) in dry pyridine (10 c.c.). The mixture was kept for 2 days and then poured into water. The turbid solution was extracted with chloroform, and the extract washed with dilute sulphuric acid and then water. After being dried ($MgSO_4$) the solvent was evaporated and the residue was distilled. 1 : 3 : 4 : 6-*Tetra-acetyl* 2-*deoxy*-α-D-*galactose* (0·4 g.) was obtained as a thick colourless syrup, b. p. 160—170°/0·01 mm., n_{D}^{25} 1·4618, $[\alpha]_{\mathrm{D}}^{20}$ +67° in methanol (Found : C, 51·1; H, 6·3. $C_{14}H_{20}O_9$ requires C, 50·6; H, 6·1%).

1 : 3 : 4 : 6-*Tetra-acetyl* 2-*Deoxy*-β-D-*galactose*.—2-Deoxy-D-galactose (0·41 g.), freshly fused and powdered sodium acetate (0·5 g.), and redistilled acetic anhydride (7 c.c.) were heated together under reflux for 30 minutes. The resulting solution was then poured into ice-cold water (100 c.c.) which was extracted with chloroform. The extract was washed with dilute aqueous sodium hydrogen carbonate and with water. After drying ($MgSO_4$) the solvent was removed by evaporation and the residue distilled. 1 : 3 : 4 : 6-*Tetra-acetyl* 2-*deoxy*-β-D-*galactose* (0·5 g.) was obtained as a thick colourless syrup, b. p. 195° (bath temp.)/0·001 mm., n_{D}^{23} 1·4580, $[\alpha]_{\mathrm{D}}^{20}$ +40·6° in methanol (Found : C, 51·0; H, 6·1%).

2-*Deoxy*-D-*galactose Diethyl Mercaptal*.—Finely divided 2-deoxy-D-galactose (0·5 g.) was added to concentrated hydrochloric acid (0·5 c.c.) at 0°. Ethanethiol (1 c.c.) was added and the mixture was shaken for 4 hours. Water was added and the insoluble material collected. Crystallisation from aqueous ethanol gave 2-*deoxy*-D-*galactose diethyl mercaptal* (0·27 g.), m. p. 107—108°, $[\alpha]_{\mathrm{D}}^{20}$ +40° (*c*, 0·25 in methanol) (Found : C, 44·7; H, 8·0; S, 23·4. $C_{10}H_{22}O_4S_2$ requires C, 44·4; H, 8·2; S, 23·6%).

2-*Deoxy*-D-*galactonolactone*.—2-Deoxy-D-galactose (2·59 g.) was dissolved in water (25 c.c.), and bromine (5 c.c.) was added. The mixture was kept at 37° for 1 day or at room temperature for 1 week. After these periods the solution no longer reduced Fehling's solution. The excess of bromine was removed by aeration and the hydrogen bromide by precipitation with silver carbonate. Silver in solution was removed by treatment with hydrogen sulphide. After filtration through charcoal the solution was evaporated to dryness and the residue triturated with absolute methanol. Crystallisation from dry acetone gave beautiful crystals of 2-*deoxy*-D-*galactonolactone* (1·8 g.), m. p. 97—98°, $[\alpha]_{\mathrm{D}}^{18}$ −12·1° in water (Found : C, 44·4; H, 6·3. $C_6H_{10}O_5$ requires C, 44·4; H, 6·2%). This lactone apparently underwent no hydrolysis in water in 3 days.

*2-Deoxy-*D*-galactonamide.*—2-Deoxy-D-galactonolactone (0·45 g.) was dissolved in absolute methanol (10 c.c.) in a Dewar flask. Liquid ammonia was added and the mixture was kept until all the ammonia had evaporated (48 hours). The methanol was evaporated and the syrupy residue was triturated with acetone. After recrystallisation from aqueous acetone, *2-deoxy-*D*-galactonamide monohydrate* (0·14 g.) was obtained as a colourless powder, m. p. (indefinite) 90—102° with decomposition and evolution of ammonia, $[\alpha]_D^{18}$ +5·3° (*c*, 0·38 in methanol) (Found : C, 36·8; H, 7·4. $C_6H_{13}O_5N,H_2O$ requires C, 36·5; H, 7·6%).

*α-Methyl-2-deoxy-*D*-galactopyranoside.*—2-Deoxy-D-galactose (10 g.) was dissolved in 2·5% methanolic hydrogen chloride (200 c.c.) and the reaction was followed polarimetrically. When reaction was complete (2 days), the solution was neutralised with silver carbonate and filtered. The filtrate was evaporated, and on addition of ethyl acetate to the residue part of it crystallised. The solid was separated and repeatedly recrystallised from ethyl acetate. α-Methyl-2-deoxy-D-galactopyranoside (4·2 g.) was obtained as colourless plates, m. p. 112—113°, $[\alpha]_D^{18}$ +169·6° ± 2° (*c*, 0·38 in methanol) (Found: C, 47·2; H, 8·2; OMe, 17·8. Calc. for $C_7H_{14}O_5$: C, 47·2; H, 7·8; OMe, 17·4%) [cf. Tamm and Reichstein (*Helv. Chim. Acta*, 1948, **31**, 1640) who give m. p. 109—110° and $[\alpha]_D^{18}$ +71·8° ± 2° in methanol]. To the syrupy product remaining after the separation of the solid α-methyl-2-deoxy-D-galactopyranoside, ethyl acetate was added, and the solution was passed through a column of activated alumina. A syrupy product was isolated, which did not reduce Fehling's solution and was presumably *β-methyl-2-deoxy-*D*-galactopyranoside* (4 g.), n_D^{19} 1·4869, $[\alpha]_D^{20}$ ±0° in methanol (Found : C, 47·0; H, 7·2; OMe, 17·0. $C_7H_{14}O_5$ requires C, 47·2; H, 7·8; OMe, 17·4%).

Action of Methanolic Hydrogen Chloride on D*-Galactal.*—D-Galactal (1·66 g.) in 3·3% methanolic hydrogen chloride (10 c.c.) was kept for 1·5 hours, and then the solution was neutralised with silver carbonate. The product was isolated in the manner described above and recrystallised repeatedly from ethyl acetate. *α-Methyl-2-deoxy-*D*-galactopyranoside* (0·64 g.) was obtained having m. p. 112—113°, $[\alpha]_D^{20}$ +170° (*c*, 0·32 in methanol) (Found : C, 47·2; H, 8·4%).

*αβ-Methyl-2-deoxy-*D*-galactofuranoside.*—2-Deoxy-D-galactose (2·5 g.) was dissolved in absolute methanol (60 c.c.), and 5·0% methanolic hydrogen chloride (0·6 c.c.) was added. The reaction ensuing was followed polarimetrically and was arrested at the maximum lævorotatory value by addition of silver carbonate and silver oxide. The solution was filtered through a charcoal pad and then concentrated under diminished pressure. The syrupy residue did not reduce Fehling's solution and was *αβ-methyl-2-deoxy-*D*-galactofuranoside*, n_D^{22} 1·4828, $[\alpha]_D^{17}$ −68° (*c*, 0·68 in methanol) (Found : C, 48·5; H, 8·3; OMe, 17·7%). Attempts to distil this compound resulted in a change which is being further investigated, but on rapid distillation a small portion did distil [b. p. 170° (bath temp.)/0·001 mm., n_D^{22} 1·4830, $[\alpha]_D^{21}$ −81·2° (*c*, 1·0 in methanol) (Found : C, 46·98; H, 7·8; OMe, 17·0. $C_7H_{14}O_5$ requires C, 47·2; H, 7·8; OMe, 17·4%)].

*Treatment of α- and β-Methyl-2-deoxy-*D*-galactopyranoside with Methanolic Hydrogen Chloride.*—(*a*) α-Methyl-2-deoxy-D-galactopyranoside was dissolved in 2% methanolic hydrogen chloride (*c*, 8·0) and the change in optical rotation was observed at intervals. The following results were noted.

Time, mins.	0	5	9	14	20	53	124
$[\alpha]_D^{20}$	+170°	160°	135°	130°	124°	110°	102°

(*b*) A similar procedure was carried out with β-methyl-2-deoxy-D-galactopyranoside. The results obtained were as follows.

Time, mins.	0	5	9	14	22	35	50	80	110
$[\alpha]_D^{20}$	±0°	+10°	47°	53°	64°	80°	90°	96°	98°

Lead Tetra-acetate Oxidations.—(a) *Pyranoside.* α-Methyl-2-deoxy-D-galactopyranoside (0·0278 g.) was dissolved in glacial acetic acid (20 c.c.), and a solution of freshly prepared lead tetra-acetate in glacial acetic acid (25 c.c. of 0·069 N.) was added. The final volume was made up to 50 c.c. with glacial acetic acid. The oxidation was followed titrimetrically by withdrawing 5-c.c. samples at intervals and estimating iodometrically the unused lead tetra-acetate.

Time, hours	0·30	0·45	1·0	1·3	2·18	3·0	4·6	5·4
Uptake of $Pb(OAc)_4$, mol. equiv.	0·40	0·58	0·64	0·82	0·92	1·03	1·15	1·15

(b) *Furanoside.* A similar procedure was carried out on αβ-methyl-2-deoxy-D-galactofuranoside (0·0289 g.), with results as follows.

Time, hours	0·5	1·0	2·0	3·0	5·0	10·0
Uptake of $Pb(OAc)_4$, mol. equiv.	0·10	0·33	0·52	0·70	0·90	1·00

Sodium Metaperiodate Oxidations.—(*a*) αβ-Methyl-2-deoxy-D-galactofuranoside (0·0234 g.) was added to N-sodium hydrogen carbonate (5 c.c.), and 0·173N-sodium metaperiodate (5 c.c.) was added. The mixture was set aside for 2 hours and then sodium arsenite (0·084N.; 15 c.c.) and N-hydrochloric acid (5 c.c.) were added. After the disappearance of the yellow colour, N-sodium acetate (5 c.c.) and a dimedon solution [2 c.c. of a solution of dimedon (0·8 g.) in ethanol (10 c.c.)] were added and the solution was heated at 100° for 10 minutes. After 1 hour the precipitate was collected and weighed after being thoroughly washed with water and dried at 90—95° for 20 minutes. The precipitate (m. p. 189—190°; cf. Reeves, *J. Amer. Chem. Soc.*, 1941, **63**, 1476, who reports m. p. 189—190° for this complex), corresponded in weight (0·04 g.) to the formation of 1 mole of formaldehyde. In a separate experiment it was shown that 1 mole of oxidising agent was consumed by the furanoside in 4 hours.

(*b*) When a similar procedure was carried out with α-methyl-2-deoxy-D-galactopyranoside, no precipitate was formed on addition of the dimedon reagent showing that no formaldehyde had been liberated.

3 : 4 : 6-*Tritoluene*-p-*sulphonyl α-Methyl-2-deoxy*-D-*galactopyranoside*.—α-Methyl-2-deoxy-D-galactopyranoside (0·185 g.) was added to a solution of toluene-*p*-sulphonyl chloride (3·3 mols., 0·7 g.) in dry pyridine (7 c.c.). After being kept for 2 days the solution was poured into ice-water and the precipitate collected. Crystallisation from methanol gave 3 : 4 : 6-*tritoluene*-p-*sulphonyl α-methyl-2-deoxy*-D-*galactopyranoside* (0·25 g.), m. p. 147°, $[\alpha]_D^{18}$ +52° (*c*, 0·076 in methanol) (Found : C, 52·1; H, 4·8. $C_{28}H_{32}O_{11}S_3$ requires C, 52·4; H, 5·0%).

3 : 4 : 6-*Trimethyl α-Methyl-2-deoxy*-D-*galactopyranoside*.—α-Methyl-2-deoxy-D-galactopyranoside (2·8 g.) was added to liquid ammonia (200 c.c.), and sodium (1·5 g.) was added in small pieces. After 20 minutes methyl iodide (15 c.c.) was added. When the liquid ammonia had evaporated, anhydrous magnesium sulphate was added to the residue which was extracted with ether (1 l.). The solvent was evaporated and the syrupy residue was methylated twice more by the same procedure. The crude product obtained was distilled and 3 : 4 : 6-*trimethyl α-methyl-2-deoxy*-D-*galactopyranoside* (0·96 g.) was obtained as a colourless mobile liquid, b. p. 95—105° (bath temp.)/0·001 mm., n_D^{19} 1·4445, $[\alpha]_D^{17\cdot5}$ +138·5° in methanol (Found : C, 54·5; H, 9·2; OMe, 56·7. $C_{10}H_{20}O_5$ requires C, 54·5; H, 9·1; OMe, 56·3%).

3 : 4 : 6-*Trimethyl 2-Deoxy*-D-*galactopyranose*.—The fully methylated glycoside (2·8 g.) and N-hydrochloric acid (25 c.c.) were heated together at 70° for 5 hours and at 90° for 1 hour. The hydrolysis was followed polarimetrically and was complete after this time. The solution was neutralised with silver carbonate, filtered, and evaporated. Ethanol was added to the residue which was re-evaporated after filtering. After similar treatment with ether the residue was distilled and 3 : 4 : 6-*trimethyl 2-deoxy*-D-*galactopyranose* (0·518 g.) obtained as a clear colourless viscous liquid, b. p. 150—160° (bath temp.)/0·001 mm., n_D^{22} 1·4637, $[\alpha]_D^{24}$ +41° in methanol (Found : C, 52·2; H, 8·2; OMe, 43·4. $C_9H_{18}O_5$ requires C, 52·4; H, 8·7; OMe, 45·1%).

3 : 4 : 6-*Trimethyl 2-Deoxy*-D-*galactonolactone* (δ-*Type*).—3 : 4 : 6-Trimethyl 2-deoxy-D-galactopyranose (0·36 g.) in aqueous solution (15 c.c.) and bromine (3 c.c.) were kept at 37° for 3 days. The excess of bromine was removed by aeration, and hydrogen bromide by silver oxide. Passage of hydrogen sulphide removed silver ions in solution. After filtration the solution was evaporated to dryness and the residue distilled. 3 : 4 : 6-*Trimethyl 2-deoxy*-D-*galactonolactone* was obtained as a colourless liquid, b. p. 154—161° (bath temp.)/0·001 mm., $[\alpha]_D^{18}$ +81·7° in water (Found : C, 52·3; H, 8·0; OMe, 45·6. $C_9H_{16}O_5$ requires C, 52·9; H, 7·9; OMe, 45·1%). Polarimetric observations indicated that in aqueous solution (*c*, 1·125) it was hydrolysed in 4 days.

Time, hours	0	1	6	22	30	47	72	103	130
$[\alpha]_D^{18}$	+82°	75°	63°	51°	46°	41°	32°	22°	22°

3 : 5 : 6-*Trimethyl αβ-Methyl-2-deoxy*-D-*galactofuranoside*.—αβ-Methyl-2-deoxy-D-galactofuranoside (1·6 g.) was added to liquid ammonia (200 c.c.), and then sodium (1·2 g.) was added. After 20 minutes methyl iodide (8 c.c.) was added. The product was isolated as already described and was methylated twice more. 3 : 5 : 6-*Trimethyl αβ-methyl-2-deoxy*-D-*galactofuranoside* (0·64 g.) was obtained as a pale straw-coloured liquid, b. p. 130—135° (bath temp.)/12 mm., n_D^{22} 1·4421, $[\alpha]_D^{21}$ −29·7° in water (Found : C, 54·3; H, 9·4; OMe, 54·7. $C_{10}H_{20}O_5$ requires C, 54·5; H, 9·1; OMe, 56·3%).

3 : 5 : 6-*Trimethyl 2-Deoxy*-D-*galactofuranose*.—3 : 5 : 6-Trimethyl αβ-methyl-2-deoxy-D-galactofuranoside (0·47 g.) and 0·01N-hydrochloric acid (45 c.c.) were heated together under reflux for 20 minutes. After neutralisation (Ag_2CO_3) and filtration the solution was concentrated under diminished pressure. Addition of ethanol served to remove colloidal silver. After filtration, benzene was added and the solution concentrated. Distillation of the residue gave 3 : 5 : 6-*trimethyl 2-deoxy*-D-*galactofuranose* (0·375 g.) as a clear, thick syrup, which strongly reduced Fehling's solution, m. p. 105—110° (bath temp.)/0·001 mm., n_D^{20} 1·4535, $[\alpha]_D^{19}$ −35·1° (*c*, 2·05 in methanol), $[\alpha]_D^{21}$ −24° (*c*, 1·0 in water; mutarotation complete in 7 minutes) (Found : C, 52·5; H, 8·8; OMe, 46·0. $C_9H_{18}O_5$ requires C, 52·4; H, 8·7; OMe, 45·1%).

3 : 5 : 6-*Trimethyl 2-Deoxy*-D-*galactonolactone* (γ-*Type*).—3 : 5 : 6-Trimethyl 2-deoxy-D-galactofuranose (0·15 g.) in water (5 c.c.) was treated with bromine (1 c.c.) for 2 weeks. The product was isolated in the usual manner, and 3 : 5 : 6-*trimethyl 2-deoxy*-D-*galactonolactone* (46 mg.) was obtained as a colourless liquid, b. p. 140—151° (bath temp.)/0·001 mm., n_D^{19} 1·4520 (Found : C, 52·2; H, 8·2; OMe, 43·8. $C_9H_{16}O_5$ requires C, 52·9; H, 7·9; OMe, 45·1%).

Polarimetric observations on an aqueous solution of this lactone indicated that no detectable hydrolysis occurred in over 100 hours.

Time, hours	0·5	4·5	21·5	68·75	93·75	110
$[\alpha]_D^{18}$	−24·9°	−24·9°	−25°	−25·6°	−25°	−25·8°

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