CCCLII.—*The Structure of Carbohydrates and their Optical Rotatory Power. Part V. The Optical Rotatory Powers of Methylated Lactones derived from the Simple Sugars.*

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THOSE sugars which have *cis*-hydroxyl groups situated on the second and third carbon atoms, namely, mannose, lyxose, and rhamnose, display rotational relationships different from those observed with glucose, galactose, or xylose. The divergence was at first attributed to the effect of configuration on rotation (compare Hudson and Dale, *J. Amer. Chem. Soc.*, 1915, **37**, 1280), but more recently Hudson has reached the view that these rotational divergences have their origin in differences in ring structure and are not due to configurational effects. The subsequent development of this hypothesis has led to a classification of ring structures which is in many vital respects at variance with that deduced by the usual methods of structural determinations (see Part I of the series).

It was therefore a matter of considerable importance to obtain definite information concerning the presence or absence of a configurational effect in cases where both the structure and the configuration of the substance under consideration have been established beyond doubt. In one such case, namely, the α-form of tetramethyl methylmannopyranoside (see Part IV), the anomaly in rotation value has been found to disappear when a suitable change in solvent is made. Accordingly it was decided to study the effect of change of solvent on the rotations of the fully methylated lactones derived from the simple sugars. These form a series of substances well suited to the proposed enquiry. They can be obtained readily in a pure condition, their structures as γ- or δ- lactones and their configurations are accurately known, and they are easily soluble in a wide range of solvents. Each of the lactones was recovered

quantitatively from the solvents, so there could be no question here of interchange of ring structure.

We have used water and chloroform as solvents, since these have been selected as standard by Hudson, and we have also used benzene and ether. Fully methylated γ- and δ-lactones derived from glucose, galactose, mannose, xylose, arabinose, lyxose, and rhamnose were prepared and their rotations measured in all four solvents.

The results were remarkable. It is at once evident from the

FIG. 1.
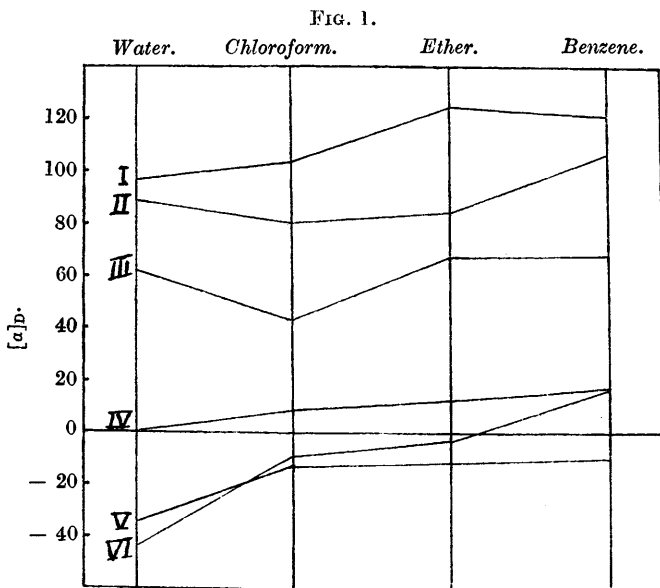
I. *Tetramethyl δ-gluconolactone.*   II. *Trimethyl γ-xylonolactone.*
III. *Tetramethyl γ-gluconolactone.*   IV. *Trimethyl δ-xylonolactone.*
V. *Tetramethyl γ-galactonolactone.*   VI. *Trimethyl γ-arabonolactone* (l).

accompanying diagrams that the lactones can be divided into three groups. The first of these comprises those lactones in which *cis*-methoxy-groups are absent, and in [Fig. 1 it is seen that for such lactones, namely, tetramethyl δ-gluconolactone, tetramethyl γ-gluconolactone, trimethyl δ-xylonolactone, trimethyl γ-xylono-lactone, and tetramethyl γ-galactonolactone, the solvent has comparatively little effect on the rotation value. The variations shown by trimethyl γ-arabonolactone, which also belongs to this group, are obviously of the same type as those of tetramethyl γ-galactonolactone, although numerically somewhat greater.

The second group consists of trimethyl δ-arabonolactone and

tetramethyl δ-galactonolactone, which have *cis*-methoxy-groups situated on the carbon atoms 3 and 4. The variations (Fig. 2) are now of a different kind and extend over a wider range.

When, however, the third group (Fig. 2) is reached, in which are

FIG. 2.
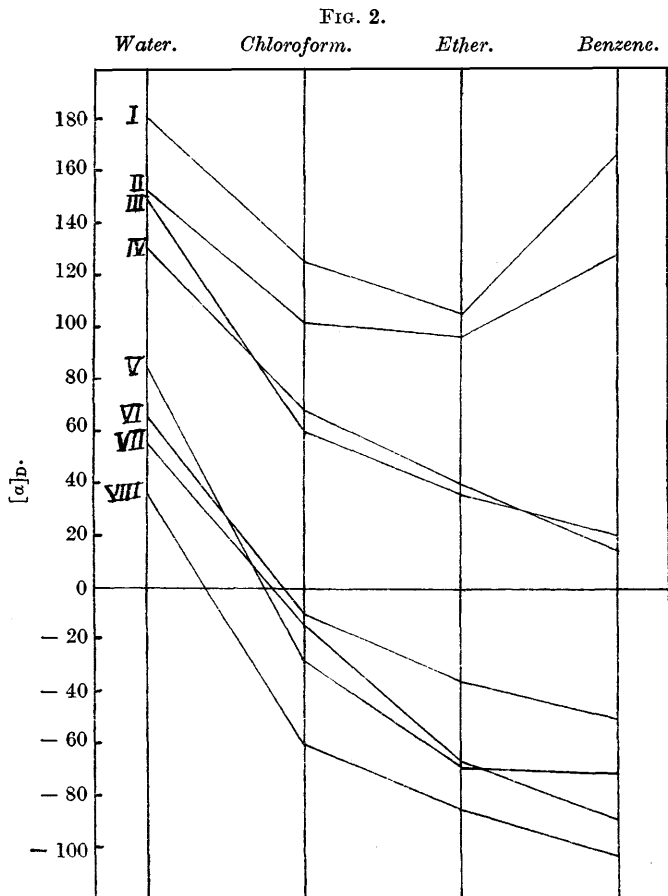
I. *Trimethyl δ-arabonolactone* (l).   II. *Tetramethyl δ-galactonolactone*.
III. *Tetramethyl δ-mannonolactone*.   IV. *Trimethyl δ-rhamnonolactone* (d).
V. *Trimethyl γ-lyxonolactone*.   VI. *Tetramethyl γ-mannonolactone*.
VII. *Trimethyl γ-rhamnonolactone* (d).   VIII. *Trimethyl δ-lyxonolactone*.

found all lactones of the mannose type having *cis*-methoxy-groups on carbon atoms 2 and 3, the variations become enormous in magnitude and frequently involve a reversal of sign. Here again the variations conform to a definite type which differs markedly from that encountered in either of the other groups. It is evident,

therefore, that *cis*-methoxy-groups when present in the molecule have a profound influence on the optical rotatory powers of substances which cannot alter their ring structure under the influence of solvents. Now it is precisely those sugars which possess *cis*-hydroxy-groups on carbon atoms 2 and 3 that require a scheme of rotational relationships different from that found to hold for glucose and other sugars. In view of the evidence now presented, it is clearly impossible to say with any degree of security that configurational effects play no part in the anomalous rotations of α-mannose and its derivatives. Hudson's arbitrary assumption of a different ring structure to account for the rotation divergences is seen therefore to rest on uncertainties, and no necessary validity can be attached to any deductions made from it, more especially when these deductions are completely at variance with the observed chemical facts. A table of rotation values and further implications drawn from the present observations are given in Part I (section 4).

Experimental.

d-2 : 3 : 4 : 6-*Tetramethyl Mannonolactone.*—This crystalline lactone, m. p. 38—40°, was prepared by Drew, Goodyear, and Haworth's method (J., 1927, 1243). $[\alpha]_D^{20°}$ + 150° in water (*c*, 1·0), + 59·5° in chloroform (*c*, 0·6), + 35·0° in ether (*c*, 0·5), + 20° in benzene (*c*, 0·7).

d-2 : 3 : 5 : 6-*Tetramethyl Mannonolactone.*—The crystalline lactone, m. p. 106—107°, was prepared by Levene and Simms's process (*J. Biol. Chem.*, 1925, **65**, 46). $[\alpha]_D^{20°}$ + 65° in water (*c*, 1·0), − 9·7° in chloroform (*c*, 1·7), − 36·3° in ether (*c*, 1·5), − 49·2° in benzene (*c*, 1·2).

d-2 : 3 : 4-*Trimethyl Lyxonolactone.*—This lactone, which is a liquid, was carefully purified before use (Hirst and Smith, J., 1928, 3147). $[\alpha]_D^{20°}$ + 35·5° in water (*c*, 1·2), − 60·4° in chloroform (*c*, 0·8), − 87° in ether (*c*, 0·7), − 102° in benzene (*c*, 0·7).

d-2 : 3 : 5-*Trimethyl Lyxonolactone.* — The crystalline lactone, m.p. 44°, was prepared by Bott, Hirst, and Smith's method (this vol., p. 666). $[\alpha]_D^{20°}$ + 82·5° in water (*c*, 0·5), − 28° in chloroform (*c*, 0·3), − 70° in ether (*c*, 0·4), − 70° in benzene (*c*, 0·2).

l-2 : 3 : 4-*Trimethyl Rhamnonolactone.*—This substance, m. p. 40—41°, was prepared by Avery and Hirst's method (J., 1929, 2467). $[\alpha]_D^{20°}$ − 130° in water (*c*, 1·2), − 67·5° in chloroform (*c*, 0·6), − 39·3° in ether (*c*, 0·5), − 15·0° in benzene (*c*, 0·6).

l-2 : 3 : 5-*Trimethyl Rhamnonolactone.*—This was obtained by the methylation of γ-rhamnonolactone by methyl iodide and silver oxide (Haworth and Peat, forthcoming publication). Recrystallisation from light petroleum gave needles, several cm. in length.

m. p. 75—76°. $[\alpha]_D^{20°}$ − 57° in water (c, 1·9), + 13° in chloroform (c, 1·86), + 65° in ether (c, 1·57), + 87° in benzene (c, 1·97).

d-2 : 3 : 4 : 6-*Tetramethyl Gluconolactone.*—A specially purified sample of the liquid lactone made by Haworth, Hirst, and Miller's method (J., 1927, 2439) was used. $[\alpha]_D^{20°}$ + 98° in water (c, 0·8), + 103° in chloroform (c, 1·18), + 123° in ether (c, 1·23), + 121° in benzene (c, 1·33).

d-2 : 3 : 5 : 6-*Tetramethyl Gluconolactone.*—This had m. p. 26—27° (Drew, Goodyear, and Haworth, *loc. cit.*). $[\alpha]_D^{20°}$ + 62° in water (c, 1·4), + 42° in chloroform (c, 0·5), + 67° in ether (c, 0·5), + 68° in benzene (c, 0·55).

d-2 : 3 : 4-*Trimethyl Xylonolactone.*—The crystalline lactone, m.p. 56°, was prepared by Drew, Goodyear, and Haworth's method (*loc. cit.*). $[\alpha]_D^{20°}$ ± 0° in water (c, 1·9), + 9° in chloroform (c, 0·63), + 12° in ether (c, 0·50), + 17° in benzene (c, 0·56).

d-2 : 3 : 5-*Trimethyl Xylonolactone.*—This was prepared from 2 : 3 : 5-trimethyl xylose by oxidation with bromine water. Since the 2 : 3 : 5-trimethyl xylose contained some of the 2 : 3 : 4-isomeride, the lactone obtained from it was contaminated slightly with the δ-variety. $[\alpha]_D^{20°}$ + 88° in water (c, 1·13), + 81° in chloroform (c, 1·72), + 84° in ether (c, 2·11), + 106° in benzene (c, 2·27).

d-2 : 3 : 4 : 6-*Tetramethyl Galactonolactone.*—This lactone, which was prepared from 2 : 3 : 4 : 6-tetramethyl galactose, was a liquid. Its rotation in water was in good agreement with that of the pure sample prepared by Haworth, Hirst, and Jones (J., 1927, 2430). $[\alpha]_D^{20°}$ + 153° in water (c, 0·91), + 101° in chloroform (c, 1·53), + 96° in ether (c, 1·82), + 128° in benzene (c, 1·53).

d-2 : 3 : 5 : 6-*Tetramethyl Galactonolactone.*—This liquid lactone was prepared by Haworth, Ruell, and Westgarth's method (J., 1924, **125**, 2468). $[\alpha]_D^{20°}$ − 34° in water (c, 1·5), − 13° in chloroform (c, 0·4), − 11° in ether (c, 0·59), − 11° in benzene (c, 1·01).

l-2 : 3 : 4-*Trimethyl Arabonolactone.*—The crystalline lactone, m. p. 45°, was prepared by Drew and Haworth's method (J., 1927, 778). $[\alpha]_D^{20°}$ + 181° in water (c, 0·7), + 125° in chloroform (c, 1·13), + 105° in ether (c, 1·20), + 166° in benzene (c, 1·21).

l-2 : 3 : 5-*Trimethyl Arabonolactone.*—This crystalline substance, m. p. 33°, was made by Haworth and Nicholson's process (J., 1926, 1902). $[\alpha]_D^{20°}$ − 44° in water (c, 0·52), − 9° in chloroform (c, 1·33), − 3° in ether (c, 1·28), + 16° in benzene (c, 1·20).

All the above rotations were observed with a polarimeter tube of length 2 dm.

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