156. cyclo*Hexylidene Derivatives of Mannitol.*

By E. J. Bourne, W. M. Corbett, and D. Erilinne.

Concentrated acids catalyse the formation of *tri*cyclo*hexylidene mannitol* from mannitol and *cyclo*hexanone. Hydrolysis of the tri*cyclo*hexylidene compound affords a *di-* and a *mono-*cyclo*hexylidene mannitol.* Conclusive evidence is presented to show that these compounds are, respectively, the 1 : 2-3 : 4-5 : 6-, 1 : 2-3 : 4-, and 3 : 4-*cyclo*hexylidene derivatives.

As part of a wider study of the various cyclic structures which result from the condensation of hexitols with aldehydes and ketones, we have examined *tri*cyclo*hexylidene mannitol,* and have obtained unequivocal proof that the three *cyclo*hexylidene residues in this compound are attached to the 1 : 2-, 3 : 4-, and 5 : 6-positions, respectively. Thus, it is a five-membered-ring structure which is favoured in each case. We believe this to be the first occasion on which the synthesis of a *cyclo*hexylidene derivative of a hexitol has been reported.

Tri*cyclo*hexylidene mannitol was obtained as long needles when commercial D-mannitol was shaken with *cyclo*hexanone in the presence of concentrated hydrobromic or 5N-hydrochloric acid. Since dilute aqueous acid normally favours the hydrolysis of cyclic acetals, it is probable that the high proportion of the tri*cyclo*hexylidene compound present at equilibrium can be attributed to its extremely small solubility in water. When a solution of tri*cyclo*hexylidene mannitol in hot aqueous alcohol was treated with hydrochloric acid, mannitol was regenerated, an observation which clearly showed that the new compound could not have arisen from the impurities known to contaminate hexitols prepared industrially (see Bourne and Wiggins, *J.*, 1948, 1933).

Graded hydrolysis of tri*cyclo*hexylidene mannitol with aqueous hydrochloric acid in alcohol–dioxan gave a crystalline *di-* and a syrupy *mono-*cyclo*hexylidene mannitol,* together with a small amount of mannitol. The products were separated by virtue of their relative solubilities in water, acetone, and alcohol. On appropriate treatment the mono- or the di-*cyclo*hexylidene compound regenerated the tri*cyclo*hexylidene derivative.

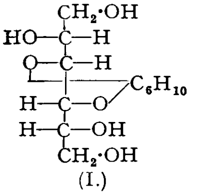
The presence of four free alcohol groups in the mono*cyclo*hexylidene mannitol was demonstrated by its conversion into three crystalline esters, namely the *tetra-acetate*, the *tetrabenzoate*, and the *tetratoluene-*p*-sulphonate*. Catalytic deacetylation of the tetra-acetate afforded a syrup whose properties were very similar to those of the original mono*cyclo*hexylidene mannitol. This fact, together with the observation that chromatography on alumina yielded only one component, indicated that the syrupy mono*cyclo*hexylidene mannitol was not a mixture.

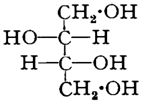
Proof that the *cyclo*hexylidene residue bridged positions 3 and 4 as in (I), was obtained from two different lines of approach, one involving synthesis and the other oxidative degradation. First, the well-known 1 : 2 : 5 : 6-tetrabenzoyl mannitol, prepared by Fischer (*Ber.*, 1915, **48**, 266) from 3 : 4-*iso*propylidene mannitol, was converted, by treatment with *cyclo*hexanone and hydrobromic acid, into a crystalline tetrabenzoyl mono*cyclo*hexylidene mannitol, identical with that already prepared from the syrupy mono*cyclo*hexylidene compound by benzoylation. The structures of 1 : 2 : 5 : 6-tetrabenzoyl mannitol and of the parent 3 : 4-*iso*propylidene mannitol have been well authenticated (see, *e.g.*, *Ber.*, 1932, **65**, 1055; 1933, **66**, 931, and *Helv. Chim. Acta*, 1934, **17**, 1574) and it follows that, unless acyl migration had occurred, our product was 1 : 2 : 5 : 6-tetrabenzoyl 3 : 4-*cyclo*hexylidene mannitol.

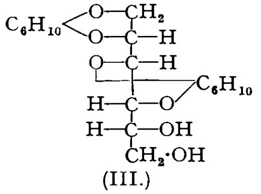
Secondly, 2 atomic proportions of oxygen were taken up when mono*cyclo*hexylidene mannitol was oxidised with either lead tetra-acetate or sodium metaperiodate. The formaldehyde liberated was isolated, as its dimedone compound, in sufficient quantity to prove that two glycol groups occupied terminal positions in the mannitol molecule. Furthermore, the larger moiety resulting from the oxidation gave rise, by hydrolysis and catalytic hydrogenation, to D-threitol (II), identified as its crystalline dibenzylidene derivative. Thus the possibility of the *cyclo*hexanone residue spanning any positions other than 3 and 4 cannot be entertained.

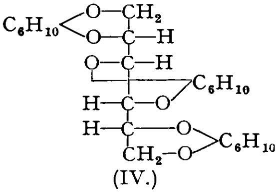
Such a structure, possessing two unsubstituted primary alcohol groups, explains the ready formation of a ditrityl derivative (cf. Helferich, *Advances in Carbohydrate Chem.*, 1948, Vol. **3**, p. 88). Furthermore, since the tetratoluene-*p*-sulphonate would have contiguous ester groups at positions 1 : 2 and 5 : 6, it can be seen why almost four moles of sodium toluene-*p*-sulphonate were formed when this ester was treated with sodium iodide in dry acetone (cf. Hann, Ness, and Hudson, *J. Amer. Chem. Soc.*, 1944, **66**, 73).

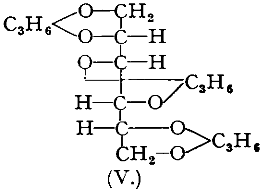
Attention was now directed to the di*cyclo*hexylidene mannitol, in which two free alcohol groups were detected by the isolation of a syrupy *diacetate* and a syrupy *dibenzoate*. Since the di*cyclo*hexylidene compound consumed one atomic proportion of oxygen and gave one molecular proportion of formaldehyde when treated with lead tetra-acetate or sodium metaperiodate, these hydroxy-groupings constituted a terminal α-glycol group. Consequently, the compound under examination was the 1 : 2 : 3 : 4-derivative, for the stereochemistry of mannitol obviates any necessity to distinguish between the 1 : 2- and the 5 : 6-positions. The larger fragment arising from the oxidative scission should then be a *di*cyclo*hexylidene* aldehydo-D-*arabinose*, and a syrup which analysed correctly for this compound was in fact isolated. When hydrolysed with acid, it afforded D-arabinose, which was converted into D-arabinosazone.

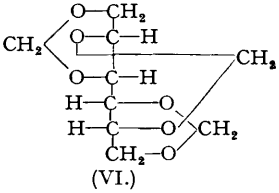

(I.)


(II.)


(III.)


(IV.)


(V.)


(VI.)

Regarding the finer structure of di*cyclo*hexylidene mannitol, three possibilities remained, *iz.* : the 1 : 2-3 : 4-, the 1 : 3-2 : 4-, and the 1 : 4-2 : 3-derivative. However, graded hydrolysis and subsequent benzoylation yielded 1 : 2 : 5 : 6-tetrabenzoyl 3 : 4-*cyclo*hexylidene D-mannitol, identical with the material already prepared by two different routes, thus eliminating all but the first possibility (III). Since the mono- and di-*cyclo*hexylidene mannitols had been derived from tri*cyclo*hexylidene mannitol, the last must have been the 1 : 2-3 : 4-5 : 6-compound (IV).

The general pattern in the tri*cyclo*hexylidene mannitol molecule is thus the same as that in tri*iso*propylidene mannitol (V) (Wiggins, *J.*, 1946, 13), but different from that in trimethylene mannitol (VI) (Ness, Hann, and Hudson, *J. Amer. Chem. Soc.*, 1943, **65**, 2215). In both the *cyclo*hexylidene and the *iso*propylidene series, it is the 3 : 4-derivative which is most stable under acid conditions. It is noteworthy that *cyclo*hexanone and acetone are similar also in their reactions with glucose, the 1 : 2-5 : 6-derivative being produced in each case (Hockett, Miller, and Scattergood, *J. Amer. Chem. Soc.*, 1949, **71**, 3072).

EXPERIMENTAL.

Attempts to purify by distillation, in a high vacuum, the syrupy *cyclo*hexylidene compounds mentioned below invariably resulted in their decomposition.

1 : 2-3 : 4-5 : 6-*Tri*cyclo*hexylidene* D-*Mannitol from Mannitol*.—Commercial mannitol (50 g.), *cyclo*hexanone (106 c.c.), and hydrobromic acid (1·25 l.; *d* 1·4) were shaken together for 20 hours and then poured into ice-water. The precipitated 1 : 2-3 : 4-5 : 6-*tri*cyclo*hexylidene* D-*mannitol* was separated by filtration, washed with dilute sodium hydroxide solution and then with water, and crystallised 3 times from alcohol in long needles (35 g.), m. p. 82·5—83·5°, $[\alpha]_D^{22}$ +15·4° (*c*, 1·24 in chloroform) [Found : C, 68·3; H, 9·25%; *M*, *ca.* 440 (Rast). $C_{24}H_{38}O_6$ requires C, 68·3; H, 9·1%; *M*, 422].

Mannitol Hexa-acetate from 1 : 2-3 : 4-5 : 6-*Tri*cyclo*hexylidene* D-*Mannitol*.—A solution of tri*cyclo*hexylidene mannitol (1·00 g.) in alcohol (36 c.c.) was heated with 2N-hydrochloric acid (24 c.c.) in a water-bath at 100° for 2 hours, before being diluted with water and extracted with ether to remove the *cyclo*hexanone produced. The residue obtained when the aqueous layer was evaporated at 60°/12 mm. was refluxed for 2 hours with acetic anhydride (8·0 c.c.) in the presence of fused sodium acetate (2 g.), poured into ice-water, and extracted with chloroform. The extract was washed with sodium hydrogen carbonate solution and then with water, dried ($MgSO_4$), and concentrated to a syrup, which crystallised from alcohol. Recrystallised from alcohol, the product (0·45 g.) had m. p. 123°, alone or on admixture with an authentic specimen of mannitol hexa-acetate

Graded Hydrolysis of 1 : 2-3 : 4-5 : 6-*Tri*cyclo*hexylidene* D-*Mannitol*.—A suspension of tri*cyclo*hexylidene mannitol (45 g.) in a mixture of dioxan (230 c.c.), alcohol (100 c.c.), and 5N-hydrochloric acid (70 c.c.) was kept at 35°, with occasional shaking, for 2 hours, by which time dissolution was complete. The solution was neutralised with lead carbonate, and the lead salts were removed by filtration before being washed with a little water and then with acetone. The filtrate and washings were combined and concentrated at 40°/12 mm. to a syrup, which was extracted several times with water. Trituration of the insoluble residue with acetone afforded tri*cyclo*hexylidene mannitol as needles (8·84 g.), m. p. and mixed m. p. 82·5°. The acetone-soluble fraction was crystallised once from aqueous alcohol and twice from light petroleum, giving 1 : 2-3 : 4-*di*cyclo*hexylidene* D-*mannitol* (8·62 g.), m. p. 52—54°, $[\alpha]_D^{20}$ +11·2° (*c*, 1·07 in chloroform) (Found : C, 63·1; H, 9·0. $C_{18}H_{30}O_6$ requires C, 63·1; H, 8·8%).

The combined aqueous extracts were concentrated to a clear syrup, which deposited crystals of mannitol (4·0 g.) (confirmed by acetylation) from absolute alcohol. Evaporation of the alcoholic mother-liquors left 3 : 4-cyclo*hexylidene* D-*mannitol* (10·0 g.) as a syrup which, when dried at 65°/0·05 mm. for 1 hour, had n_D^{35} 1·4925, $[\alpha]_D^{19}$ +17·4° (*c*, 1·99 in chloroform) (Found : C, 55·0; H, 8·4. $C_{12}H_{22}O_6$ requires C, 54·9; H, 8·5%).

1 : 2-3 : 4-5 : 6-*Tri*cyclo*hexylidene* D-*Mannitol from* 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol*.—Di*cyclo*hexylidene mannitol (0·04 g.), *cyclo*hexanone (0·20 c.c.), and 5N-hydrochloric acid (3·0 c.c.) were shaken together for 30 minutes and the solid product was removed by filtration. After being washed with water, it recrystallised from aqueous alcohol in needles, m. p. 80—82°, alone or on admixture with 1 : 2-3 : 4-5 : 6-tri*cyclo*hexylidene mannitol prepared directly from mannitol.

1 : 2-3 : 4-5 : 6-*Tri*cyclo*hexylidene* D-*Mannitol from* 3 : 4-cyclo*Hexylidene* D-*Mannitol*.—3 : 4-*cyclo*-Hexylidene mannitol (0·50 g.), *cyclo*hexanone (0·70 c.c.), and 5N-hydrochloric acid (4·0 c.c.) were shaken together for 20 hours. The solid product was removed by filtration, washed with sodium hydrogen carbonate solution and then with water, and crystallised from aqueous alcohol in needles (0·39 g.), m. p. 82—83°, alone or on admixture with 1 : 2-3 : 4-5 : 6-tri*cyclo*hexylidene mannitol prepared directly from mannitol.

1 : 2 : 5 : 6-*Tetra-acetyl* 3 : 4-cyclo*Hexylidene* D-*Mannitol*.—3 : 4-*cyclo*Hexylidene mannitol (3·06 g.) was treated with pyridine (12·0 c.c.)–acetic anhydride (6·0 c.c.) for 48 hours at 18°. The oil which separated when the solution was poured into ice-water crystallised after several hours. Recrystallised 3 times from aqueous alcohol, the *acetate* (3·07 g.) had m. p. 67—68·5°, $[\alpha]_D^{20}$ +50·7° (*c*, 1·12 in chloroform) (Found : C, 55·5; H, 7·0; Ac, 39·1. $C_{20}H_{30}O_{10}$ requires C, 55·8; H, 7·0; Ac, 40·0%).

Regeneration of 3 : 4-cyclo*Hexylidene* D-*Mannitol from its Tetra-acetate*.—The tetra-acetate (0·552 g.) was treated for 48 hours with a trace of sodium in absolute methanol (10 c.c.). Carbon dioxide was bubbled through the solution, and the solvent was removed by distillation. The dry residue was extracted with chloroform. Concentration of the extracts afforded 3 : 4-*cyclo*hexylidene D-mannitol as a syrup (0·286 g.), n_D^{25} 1·4965, $[\alpha]_D^{20}$ +17·7° (*c*, 1·18 in chloroform).

1 : 2 : 5 : 6-*Tetrabenzoyl* 3 : 4-cyclo*Hexylidene* D-*Mannitol*.—Benzoyl chloride (1·50 c.c.) was added to a cooled solution of 3 : 4-*cyclo*hexylidene mannitol (0·659 g.) in pyridine (3·0 c.c.). After 18 hours at room temperature, the solution was poured into water and the precipitate collected. Three crystallisations from acetone–alcohol gave 1 : 2 : 5 : 6-*tetrabenzoyl* 3 : 4-cyclo*hexylidene* D-*mannitol*

(0·806 g.), m. p. 147·5—148·5°, $[\alpha]_D^{26}$ −7·7° (*c*, 1·16 in chloroform) (Found : C, 71·0; H, 5·8. $C_{40}H_{38}O_{10}$ requires C, 70·8; H, 5·65%).

1 : 2 : 5 : 6-*Tetratoluene*-p-*sulphonyl* 3 : 4-cyclo*Hexylidene* D-*Mannitol.*—3 : 4-*cyclo*Hexylidene mannitol (0·829 g.) was treated with toluene-*p*-sulphonyl chloride (2·66 g.) in pyridine (10 c.c.) at 35° for 72 hours, before being poured into ice-water and extracted with chloroform. The extract was washed with dilute hydrochloric acid, sodium hydrogen carbonate solution and water, dried ($MgSO_4$), filtered, and concentrated to a syrup, which crystallised from absolute alcohol. After 3 more crystallisations, the *product* (0·385 g.) had m. p. 135—137°, $[\alpha]_D^{23}$ +4·9° (*c*, 1·03 in chloroform) (Found : C, 54·9; H, 5·4; S, 14·0. $C_{40}H_{46}O_{14}S_4$ requires C, 54·7; H, 5·3; S, 14·6%).

Reaction of 1 : 2 : 5 : 6-*Tetratoluene*-p-*sulphonyl* 3 : 4-cyclo*Hexylidene* D-*Mannitol with Sodium Iodide in Acetone.*—The toluene-*p*-sulphonate (0·1007 g.) and sodium iodide (0·204 g.) were dissolved in dry acetone (15 c.c.) and heated in a sealed tube at 100—110° for 8 hours. The precipitated sodium toluene-*p*-sulphonate (0·0833 g.) represented an exchange of 3·75 ester groups per molecule.

1 : 6-*Ditrityl* 3 : 4-cyclo*Hexylidene* D-*Mannitol.*—3 : 4-*cyclo*Hexylidene mannitol (0·350 g.) and triphenylmethyl chloride (0·745 g.) were dissolved in pyridine (3·0 c.c.) and kept at room temperature for 48 hours. The sticky solid ether (0·950 g.), which separated when the solution was poured into ice-water, could not be crystallised. It had $[\alpha]_D^{23}$ +12·5° (*c*, 1·12 in chloroform).

2 : 5-*Diacetyl* 1 : 6-*Ditrityl* 3 : 4-cyclo*Hexylidene* D-*Mannitol.*—1 : 6-Ditrityl 3 : 4-*cyclo*hexylidene mannitol (0·706 g.) was dissolved in pyridine (2·0 c.c.) and acetic anhydride (0·5 c.c.) was added. After 18 hours, the mixture was poured into ice-water and extracted with chloroform. The extracts were washed with dilute acid, sodium hydrogen carbonate solution, and water, dried ($MgSO_4$), filtered, and evaporated. The residual solid, crystallised 3 times from acetone–alcohol–water, afforded 2 : 5-*diacetyl* 1 : 6-*ditrityl* 3 : 4-cyclo*hexylidene* D-*mannitol* (0·532 g.), m. p. 197—198°, $[\alpha]_D^{20}$ ±0·0° (*c*, 0·93 in chloroform) (Found : C, 78·0; H, 6·6. $C_{54}H_{54}O_8$ requires C, 78·0; H, 6·6%).

1 : 2 : 5 : 6-*Tetrabenzoyl* D-*Mannitol.*—Hydrolysis of 1 : 2 : 5 : 6-tetrabenzoyl 3 : 4-*iso*propylidene D-mannitol (0·503 g.; m. p. 121°) by the method of Fischer (*loc. cit.*) gave 1 : 2 : 5 : 6-tetrabenzoyl D-mannitol (0·387 g.), m. p. 117—119°, $[\alpha]_D^{18}$ +7·9° (*c*, 1·3 in tetrachloroethane) (Found : C, 68·3; H, 5·2. Calc. for $C_{34}H_{30}O_{10}$: C, 68·2; H, 5·1%). Fischer (*loc. cit.*) gave m. p. 122—123°, $[\alpha]_D^{18}$ +7·83° in tetrachloroethane.

Treatment of 1 : 2 : 5 : 6-*Tetrabenzoyl* D-*Mannitol with* cyclo*Hexanone.*—The tetrabenzoate (0·050 g.), *cyclo*hexanone (2·0 c.c.), and hydrobromic acid (0·5 c.c.; *d* 1·4) were shaken together for 18 hours. The heavy oil, which separated when the reaction mixture was poured into ice-water, crystallised when triturated with alcohol. Recrystallisation from acetone–alcohol gave 1 : 2 : 5 : 6-tetrabenzoyl 3 : 4-*cyclo*hexylidene D-mannitol (0·049 g.), m. p. 147·5—148·5° (alone or on admixture with the compound mentioned above), $[\alpha]_D^{25}$ −7·7° (*c*, 0·65 in chloroform).

Lead Tetra-acetate Oxidation of 3 : 4-cyclo*Hexylidene* D-*Mannitol.*—Tetra-acetyl *cyclo*hexylidene mannitol (3·93 × 10^{-4} mole) was deacetylated with sodium in methanol, and the product was oxidised with lead tetra-acetate according to the procedure of Hockett and McClenahan (*J. Amer. Chem. Soc.*, 1939, **61**, 1667). The number of g.-atoms of oxygen taken up per g.-mol. was 0·37 (10 minutes), 1·26 (60 minutes), 1·64 (120 minutes), 1·84 (180 minutes), and 1·98 (300 minutes).

Periodate Oxidation of 3 : 4-cyclo*Hexylidene* D-*Mannitol.*—(a) *Isolation of formaldehyde.* 3 : 4-*cyclo*-Hexylidene mannitol (0·4 × 10^{-4} moles) was oxidised under the conditions recommended by Reeves (*J. Amer. Chem. Soc.*, 1941, **63**, 1476), and, in 4 hours, 0·673 × 10^{-4} mole of formaldehyde, isolated as its dimedone derivative (m. p. 189°), was liberated. This represented 1·68 moles of formaldehyde per mole of *cyclo*hexylidene mannitol. Longer periods of oxidation resulted in somewhat lower yields of formaldehyde, presumably because this initial product was slowly oxidised to formic acid (cf. Hirst and Jones, *J.*, 1949, 1659).

(b) *Isolation of dibenzylidene* D-*threitol.* 3 : 4-*cyclo*Hexylidene mannitol (3·310 g.) was dissolved in the minimum volume of water and an aqueous solution (50 c.c.) of sodium metaperiodate (5·12 g.) was added. After 24 hours at room temperature, the solution was saturated with salt and extracted with chloroform. The extract was dried ($MgSO_4$), filtered, and concentrated to a syrup (0·847 g.) which showed positive Schiff's and Fehling's tests and had n_D^{21} 1·4845, $[\alpha]_D^{20}$ (equilibrium) −23·1° (*c*, 1·17 in chloroform). This probably was 2 : 3-*cyclo*hexylidene D-*threo*dihydroxysuccinic dialdehyde.

The syrup (0·574 g.) was hydrolysed with N-sulphuric acid (12·5 c.c.) at 100° for 3 hours. The solution was neutralised with barium carbonate, filtered, and evaporated at 35°/12 mm. The residue was extracted with absolute methanol, and evaporation of the solution left a resinous residue (0·173 g.), which rapidly reduced Fehling's solution.

The D-*threo*dihydroxysuccinic dialdehyde was hydrogenated with Raney nickel in alcohol (50 c.c.) at 40°/30 atm. for 20 hours. The catalyst was removed by filtration and the filtrate was concentrated to a syrup, which was dissolved in absolute methanol (25 c.c.). The solution was saturated with dry hydrogen chloride, benzaldehyde (10 c.c.) was added, and the mixture was shaken for 20 hours, before being neutralised with sodium hydrogen carbonate and filtered. The filtrate was evaporated at 40°/12 mm. and the solid residue was extracted with chloroform. Removal of the solvent left a solid, which afforded dibenzylidene D-threitol (0·050 g.), m. p. 227°, $[\alpha]_D^{18}$ −94·5° (*c*, 0·275 in pyridine), when crystallised twice from alcohol and once from dioxan. Haskins, Hann, and Hudson (*J. Amer. Chem. Soc.*, 1943, **65**, 1663) give m. p. 231°, $[\alpha]_D^{20}$ −90·2° (*c*, 0·80 in pyridine), for dibenzylidene D-threitol.

5 : 6-*Diacetyl* 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol.*—Di*cyclo*hexylidene mannitol (0·508 g.) was acetylated with acetic anhydride (1·10 c.c.) in pyridine (2·50 c.c.). After 20 hours, the solution was poured into ice-water and extracted with chloroform. The extract was washed with dilute hydrochloric acid, sodium hydrogen carbonate solution, and water, dried (Na_2SO_4), filtered, and concentrated to a clear syrup, from which the last traces of solvent were removed at 65°/0·1 mm. The *product* (0·464 g.) had n_D^{21} 1·4798, $[\alpha]_D^{20}$ +24·9° (*c*, 1·33 in chloroform) (Found : C, 61·9; H, 8·3; Ac, 19·4. $C_{22}H_{34}O_8$ requires C, 61·9; H, 8·0; Ac, 20·2%).

5 : 6-*Dibenzoyl* 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol.*—Di*cyclo*hexylidene mannitol (0·219 g.) was treated for 18 hours with benzoyl chloride (0·76 c.c.) in pyridine (1·5 c.c.) and then poured into ice-water.

The aqueous solution was extracted with chloroform. The extract was washed with dilute sulphuric acid, sodium hydrogen carbonate solution, and water. It was dried (Na_2SO_4), filtered, and evaporated to a syrup, from which all residual solvent was removed at 60°/0·05 mm. during 1 hour. The *product* (0·146 g.) showed $[\alpha]_D^{15}$ +7·4° (*c*, 1·1 in chloroform) and n_D^{13} 1·5475 (Found: C, 69·7; H, 6·9. $C_{32}H_{38}O_8$ requires C, 69·8; H, 7·0%).

Lead Tetra-acetate Oxidation of 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol*.—When di*cyclo*hexylidene mannitol (4·83 × 10^{-4} moles) was oxidised with lead tetra-acetate, according to the method of Hockett and McClenahan (*loc. cit.*), the number of g.-atoms of oxygen taken up per g.-mol. was 0·46 (30 minutes), 0·56 (80 minutes), 0·78 (140 minutes), 0·88 (210 minutes), 0·95 (260 minutes), and 1·02 (320 minutes).

Periodate Oxidation of 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol*.—(a) *Isolation of formaldehyde*. Di*cyclo*hexylidene mannitol, oxidised for 4 hours under the conditions recommended by Reeves (*loc. cit.*), gave, per mole, 1·04 moles of formaldehyde, isolated as its dimedone derivative (m. p. 189°).

(b) *Isolation of* 2 : 3-4 : 5-*di*cyclo*hexylidene* aldehydo-D-*arabinose*. Di*cyclo*hexylidene mannitol (1·00 g.) was dissolved in alcohol (3·0 c.c.), and water was added until there was a slight turbidity. Potassium metaperiodate (1·345 g.) was introduced and the mixture was shaken for 18 hours, before being saturated with sodium chloride and extracted with chloroform. The extract was dried (Na_2SO_4), filtered, and concentrated to a syrup, from which all the residual solvent was removed at 85°/0·005 mm. The *product* (0·78 g.), which restored the colour to decolorised magenta, had n_D^{27} 1·4890, $[\alpha]_D^{25}$ −5·3° (*c*, 0·94 in chloroform) (Found: C, 65·5; H, 8·6. $C_{17}H_{26}O_5$ requires C, 65·7; H, 8·4%).

(c) *Isolation of* D-*arabinose*. A portion of the di*cyclo*hexylidene *aldehydo*-D-arabinose (0·392 g.) was hydrolysed with N-sulphuric acid (7·5 c.c.) at 100° for 2 hours. The solution was neutralised with barium carbonate and filtered, and the filtrate concentrated at 35°, leaving a white solid. This was extracted with absolute methanol, from which crystals were deposited when the volume was reduced. Recrystallised from absolute methanol, the product (0·150 g.) had m. p. 158—159°, alone or on admixture with D-arabinose, $[\alpha]_D^{19}$ (equilibrium) −101·5° (*c*, 0·61 in water), compared with accepted values m. p. 159—160°, $[\alpha]_D^{20}$ (equilibrium) −104·5° (in water). With phenylhydrazine, under the usual conditions, it yielded D-arabinosazone, m. p. 162—163°.

3 : 4-cyclo*Hexylidene* D-*Mannitol from* 1 : 2-3 : 4-*Di*cyclo*hexylidene* D-*Mannitol*.—Di*cyclo*hexylidene D-mannitol (1·08 g.) was dissolved in alcohol (80 c.c.), and concentrated hydrochloric acid (20 c.c.) was added. After 150 minutes, the solution was neutralised with lead carbonate. The lead salts were removed bv filtration and washed, first with a little water and then with acetone. The combined filtrate and washings were concentrated, the residue being extracted with water. The aqueous solution was evaporated, leaving a syrup, from which a little mannitol crystallised on trituration with acetone. Concentration of the acetone solution yielded a syrup, which was treated for 48 hours with benzoyl chloride (0·75 c.c.) in pyridine (1·50 c.c.). The product was precipitated with alcohol. Recrystallisation from acetone–alcohol gave 1 : 2 : 5 : 6-tetrabenzoyl 3 : 4-*cyclo*hexylidene D-mannitol (0·443 g.), m. p. 147·5—148·5°, alone or on admixture with either of the compounds mentioned above.

The authors thank Professor M. Stacey for his valued advice and criticism, and the British Cotton Industry Research Association for a scholarship which enabled one of them (W. M. C.) to take part in this work. Thanks are also offered to Messrs. Imperial Chemical Industries Ltd. for a grant to cover the expenses of this investigation.

THE UNIVERSITY, EDGBASTON, BIRMINGHAM, 15.

[*Received, December 7th*, 1949.]