The Allyl Ether as a Protecting Group in Carbohydrate Chemistry. Part II [1a]

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Mercuric chloride in the presence of mercuric oxide was used to hydrolyse prop-1-enyl ethers of carbohydrates. Under these non-acidic conditions, 4,6-*O*-benzylidene-D-galactose and 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-D-galactose were prepared from the corresponding prop-1-enyl glycosides and a mixture of the anomers of methyl 2,3,6-tri-*O*-benzyl-D-glucofuranoside was prepared from the corresponding 5-*O*-prop-1′-enyl ether. Acid-catalysed cyclisation of prop-1′-enyl 4,6-*O*-benzylidene-α-D-galactopyranoside gave 4,6-*O*-benzylidene-1,2-*O*-propylidene-D-galactose which was converted into 1,2-*O*-propylidene-D-galactose. Preferential rearrangement of the 2-*O*-allyl group in methyl 2,3-di-*O*-allyl-4,6-*O*-benzylidene-α-D-glucopyranoside gave methyl 3-*O*-allyl-4,6-*O*-benzylidene-2-*O*-prop-1′-enyl-α-D-glucopyranoside which was converted into 4,6-*O*-benzylidene-2-*O*-methyl-α-D-glucopyranoside. The rearrangement of an allyl group to a prop-1-enyl group in a carbohydrate derivative containing a benzamido-group occurred without hydrolysis of the amide linkage. The elimination of butadiene from 3-methylallyl (crotyl) ethers by the action of potassium t-butoxide in dimethyl sulphoxide suggests that the crotyl ether may provide a useful protecting group in carbohydrate chemistry. The action of potassium t-butoxide in dimethyl sulphoxide on an oxazoline derived from D-glucosamine produced a rearrangement to give an oxazole. The monoprop-1′-enyl ethers of 1,2-diols give 2′-chloromercuripropylidene acetals when treated with mercuric chloride in the presence of mercuric oxide. Reduction of these acetals with sodium borohydride regenerates monoprop-1′-enyl ethers of the glycol.

We have previously [1] described the application of the allyl ether as a protecting group in carbohydrate chemistry and other workers [2] have also used the method. We now report procedures for extending the use of this protecting group.

The allyl group is conveniently removed by isomerisation [3] to the *cis*-prop-1-enyl group and subsequent acid hydrolysis, but in the case of carbohydrate derivatives containing other acid-labile groupings we have used ozonolysis followed by alkaline hydrolysis or oxidation with alkaline permanganate for the selective removal of the prop-1-enyl group. As both of these methods suffer from disadvantages, a convenient non-acidic method was required and the reaction of mercuric chloride with the prop-1-enyl group was therefore investigated.

The reaction of ionised mercuric salts (*e.g.*, mercuric acetate) with isolated ethylenic bonds is well documented [4] and they are also known to react with the double bonds of enol ethers.[5,6] However, mercuric

[1] (*a*) Part I, J. Gigg and R. Gigg, *J. Chem. Soc.* (*C*), 1966, 82; (*b*) J. Cunningham, R. Gigg, and C. D. Warren, *Tetrahedron Letters*, 1964, 1191; (*c*) R. Gigg and C. D. Warren, *J. Chem. Soc.*, 1965, 2205; (*d*) R. Gigg and C. D. Warren, *Tetrahedron Letters*, 1966, 2415.

[2] A. L. Bullock, V. O. Cirino, and S. P. Rowland, *Canad. J. Chem.*, 1967, **45**, 255; S. J. Angyal and T. S. Stewart, *Austral. J. Chem.*, 1966, **19**, 1683; D. E. Hoiness, C. P. Wade, and S. P. Rowland, *Abst. 151st Meeting Amer. Chem. Soc.*, 1966, K21.

[3] (*a*) T. J. Prosser, *J. Amer. Chem. Soc.*, 1961, **83**, 1701; (*b*) C. C. Price and W. H. Snyder, *J. Amer. Chem. Soc.*, 1961, **83**, 1773.

[4] J. Chatt, *Chem. Rev.*, 1951, **48**, 7; A. Polgár and J. L. Jungnickel, *Org. Analysis*, 1956, **3**, 301.

[5] A. N. Nesmeyanov, I. F. Lutsenko, and N. I. Vereshchagina, *Bull. Acad. Sci. U.R.S.S., Classe sci. chim.*, 1947, 63 (*Chem. Abs.*, 1948, **42**, 4148); A. N. Nesmeyanov, I. F. Lutsenko, and R. M. Khomutov, *Izvest. Akad. Nauk S.S.S.R., Otdel. khim. Nauk*, 1957, 942 (*Chem. Abs.*, 1958, **52**, 4476).

[6] (*a*) J. B. Johnson and J. P. Fletcher, *Analyt. Chem.*, 1959, **31**, 1563; (*b*) G. R. Inglis, J. C. P. Schwarz, and L. McLaren, *J. Chem. Soc.*, 1962, 1014; (*c*) P. T. Manolopoulos, M. Mednick, and N. N. Lichtin, *J. Amer. Chem. Soc.*, 1962, **84**, 2203.

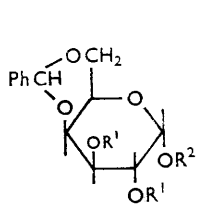
chloride is reported [4] to be unreactive towards isolated double bonds. A very slow reaction of allyl ethers with mercuric chloride in the presence of mercuric oxide was observed in the present work. The very rapid reaction between mercuric chloride and vinyl ethers was probably first observed by Feulgen and his co-workers [7] during histochemical studies on the plasmalogens. Although at that time Feulgen was unaware of the nature of the reaction, subsequent work has shown that the plasmalogens contain a vinyl ether linkage and the reaction has been rationalised as the hydrolysis (1) of a vinyl ether by mercuric chloride to give a chloromercurialdehyde.[8]

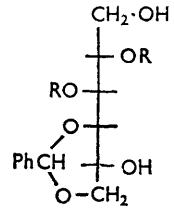
$$R^1\text{–O–CH=CH–}R^2 + HgCl_2 + H_2O \longrightarrow R^1OH + OHC\text{–}CH(HgCl)R^2 + HCl \quad (1)$$

The very rapid rate of reaction of mercuric chloride with vinyl ethers and the very slow rate of reaction with isolated double bonds suggested that it would be a more useful reagent than mercuric acetate for our purposes and we reported [9] the application of this method for the removal of the prop-1-enyl group from carbohydrate derivatives containing other acid-labile groupings. The hydrogen chloride liberated in the reaction was conveniently removed by yellow mercuric oxide. Excess of mercuric chloride was removed at the end of the reaction by washing a solution of the product in an organic solvent with aqueous potassium iodide. The chloromercuripropionaldehyde formed was degraded by this treatment producing some metallic mercury and a volatile unsaturated product which was not further investigated. 2-Chloromercuripropionaldehyde was isolated as an oil from the reaction between 1-*O*-prop-1′-enyl-2,3-*O*-isopropylideneglycerol [10] and mercuric chloride. The product slowly crystallised and the solid had a similar m.p. to that reported [11] for this compound. Chloromercuriacetaldehyde [5] was prepared from mercuric chloride and ethyl vinyl ether in the presence of mercuric oxide and this compound was also degraded by potassium iodide solution to metallic mercury. When a water-soluble product was obtained after the removal of the prop-1-enyl group the excess of mercuric chloride was removed by passage of hydrogen sulphide (with sodium hydrogen carbonate present to retain a neutral medium). The 2-chloromercuripropionaldehyde and chloromercuriacetaldehyde were also decomposed by this procedure.

Initial experiments on the removal of the prop-1-enyl group were carried out on compounds containing other easily hydrolysable groupings and it was found that the labile isopropylidene groups in 1,2-*O*-isopropylidene-3-*O*-prop-1′-enylglycerol [10] and 1,2:5,6-di-*O*-isopropylidene-3-*O*-prop-1′-enyl-D-glucofuranose [1a] were stable to the conditions required for the removal of the prop-1-enyl groups by the mercuric chloride procedure. Of greater interest was the mercuric chloride hydrolysis of prop-1-enyl glycosides containing other acid-labile groupings since in this case neither acid hydrolysis nor oxidation with permanganate was applicable.

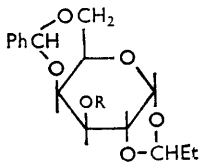
Prop-1′-enyl 4,6-*O*-benzylidene-α-D-galactopyranoside (II) was prepared by the isomerisation of the allyl

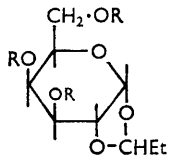


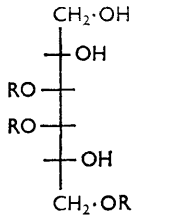


(I) $R^1 = H$; $R^2 = CH_2\text{–}CH=CH_2$
(II) $R^1 = H$; $R^2 = CH=CH\text{–}CH_3$
(III) $R^1 = R^2 = H$
(IV) $R^1 = CH_2Ph$; $R^2 = CH_2\text{–}CH=CH_2$
(V) $R^1 = CH_2Ph$; $R^2 = CH=CH\text{–}CH_3$
(VI) $R^1 = CH_2Ph$; $R^2 = H$

(VII) $R = CH_2Ph$



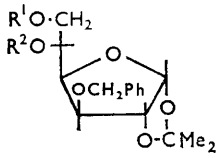


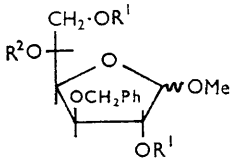


(VIII) R = H
(IX) R = Ac

(X) R = H
(XI) $R = CH_2Ph$

(XII) $R = CH_2Ph$





(XIII) $R^1 = CPh_3$; $R^2 = H$
(XIV) $R^1 = CPh_3$; $R^2 = CH_2\text{–}CH=CH_2$

(XV) $R^1 = H$; $R^2 = CH_2\text{–}CH=CH_2$
(XVI) $R^1 = CH_2Ph$; $R^2 = CH_2CH=CH_2$
(XVII) $R^1 = CH_2Ph$; $R^2 = CH=CH\text{–}CH_3$
(XVIII) $R^1 = CH_2Ph$; $R^2 = H$
(XIX) $R^2 = CH_2Ph$; $R^2 = Me$

glycoside (I) which was prepared from allyl α-D-galactopyranoside [12] by the action of benzaldehyde in the presence of zinc chloride. Compound (II) was rapidly converted into 4,6-*O*-benzylidine-D-galactose (III) [13] by the mercuric chloride procedure and a by-product which was considered to be the 2-chloromercuripropylidene acetal was also formed at the same time (see below). Similarly the dibenzyl ether (V) was converted into the free sugar (VI) by these conditions without loss of the

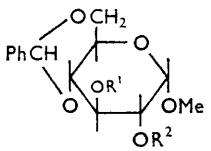
[7] R. Feulgen and K. Voit, *Pfluger's Arch. ges. Physiol.*, 1924, **206**, 389.
[8] W. T. Norton, *Nature*, 1959, **184**, 1144.
[9] R. Gigg and C. D. Warren, *Tetrahedron Letters*, 1967, 1683.
[10] J. Cunningham and R. Gigg, *J. Chem. Soc.*, 1965, 2968.
[11] D. Y. Curtin and M. J. Hurwitz, *J. Amer. Chem. Soc.*, 1952, **74**, 5381.
[12] E. A. Talley, M. D. Vale, and E. Yanovsky, *J. Amer. Chem. Soc.*, 1945, **67**, 2037.
[13] (*a*) J. Pacák and M. Černý, *Coll. Czech. Chem. Comm.*, 1961, **26**, 2212; 1963, **28**, 541; (*b*) E. G. Gros and V. Deulofeu, *Chem. and Ind.*, 1962, 1502.

benzylidene group. The free sugar (VI) was reduced by sodium borohydride to give 2,3-di-*O*-benzyl-4,6-*O*-benzylidene-D-galactitol (VII) which was required as an intermediate for synthetic studies in connection with the sphingolipids. Acid hydrolysis and subsequent catalytic hydrogenation of compound (VII) gave galactitol.

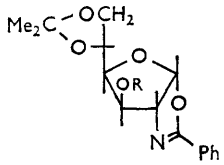
Monovinyl ethers of 1,2-diols are rapidly cyclised to acetals in the presence of acidic catalysts [14] and it was considered that the prop-1-enyl ethers of carbohydrates might be cyclised similarly in appropriate cases to give useful synthetic intermediates. In compound (II) the C(2) hydroxyl group is in a suitable position for acetal formation and this compound was cyclised to the acetal (VIII) by heating in ethyl acetate with an acid catalyst. Catalytic hydrogenation of compound (VIII) gave crystalline 1,2-*O*-propylidene-D-galactose (X) which was characterised by conversion into the tri-*O*-benzyl ether (XI) followed by acid hydrolysis and sodium borohydride reduction to give 3,4,6-tri-*O*-benzyl-D-galactitol (XII) which was identical with the material which has been prepared and characterised previously.[1a]

A mixture of the anomers of methyl 2,3,6-tri-*O*-benzyl-D-glucofuranoside (XVIII) was required as an intermediate for synthetic studies in connection with the sphingolipids and a route to this compound by use of the allyl ether was investigated. The triphenylmethyl ether (XIII) [15] was converted into the allyl ether (XIV) and the product was hydrolysed with methanolic hydrogen chloride to give a mixture of the anomers of methyl 5-*O*-allyl-3-*O*-benzyl-D-glucofuranoside (XV). After benzylation and removal of the allyl group by isomerisation and mercuric chloride hydrolysis the required compound (XVIII) was obtained in good yield as a syrup. This compound was characterised by methylation, followed by catalytic hydrogenation and acid hydrolysis to give the known 5-*O*-methyl-D-glucofuranose which was converted into the crystalline 3,6-di-*O*-acetyl-5-*O*-methyl-1,2,-*O*-isopropylidene-D-glucofuranose.[16]

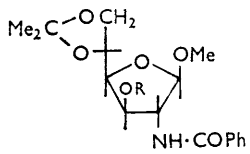
Brimacombe and his co-workers recently described [17] the rearrangement of methyl 2,3-di-*O*-allyl-4,6-*O*-benzylidene-α-D-glucopyranoside (XXI) to the di-*O*-prop-1-enyl ether (XXII). The yield of compound (XXII) reported was very low (*ca.* 4%) and we have therefore reinvestigated the rearrangement of compound (XXI). At 100° the rearrangement to the di-*O*-prop-1-enyl derivative (XXII) was complete within 40 min. as observed by t.l.c. and the product was readily hydrolysed to methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (XX) by mercuric chloride. When compound (XXI) was rearranged at 40°, t.l.c. showed that a partial rearrangement to a monoallyl monopropenyl derivative occurred fairly rapidly and the product was isolated at this stage. The subsequent discussion will show that the product was compound (XXIII). The prop-1-enyl group was removed from this compound by mercuric chloride without affecting the allyl group to give compound (XXIV) which was isomerised to compound (XXV) and methylated to give compound (XXVI). Hydrolysis of the prop-1-enyl group in compound (XXVI) with mercuric



(XX) $R^1 = R^2 = H$
(XXI) $R^1 = R^2 = CH_2CH{=}CH_2$
(XXII) $R^1 = R^2 = CH{=}CH{-}CH_3$
(XXIII) $R^1 = CH_2{-}CH{=}CH_2$; $R^2 = CH{=}CH{-}CH_3$
(XXIV) $R^1 = CH_2CH{=}CH_2$; $R^2 = H$
(XXV) $R^1 = CH{=}CH{-}CH_3$; $R^2 = H$
(XXVI) $R^1 = CH{=}CH{-}CH_3$; $R^2 = Me$
(XXVII) $R^1 = H$; $R^2 = Me$
(XXVIII) $R^1 = CH{=}CH{-}CH_3$; $R^2 = CH_2{-}CH{=}CH_2$
(XXIX) $R^1 = H$; $R^2 = CH_2{-}CH{=}CH_2$
(XXX) $R^1 = H$; $R^2 = CH{=}CH{-}CH_3$
(XXXI) $R^1 = Me$; $R^2 = CH{=}CH{-}CH_3$
(XXXII) $R^1 = Me$; $R^2 = H$



(XXXIII) R = H
(XXXIV) R = CH_2Ph
(XXXV) R = $CH_2CH{=}CH_2$



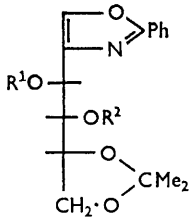
(XXXVI) R = $CH_2CH{=}CH_2$
(XXXVII) R = $CH{=}CH{-}CH_3$
(XXXVIII) R = H

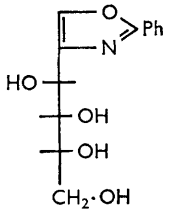
chloride gave methyl 4,6-*O*-benzylidene-2-*O*-methyl-α-D-glucopyranoside (XXVII) with the same m.p. as reported previously [18] for this compound. Allylation of the prop-1-enyl ether (XXV) gave the isomeric allyl prop-1-enyl ether (XXVIII) which was hydrolysed with mercuric chloride to give the 2-*O*-allyl ether (XXIX). Isomerisation of compound (XXIX) followed by methylation and removal of the prop-1-enyl group gave 4,6-*O*-benzylidene-3-*O*-methyl-α-D-glucopyranoside (XXXII) with the same properties as those reported [18b,19] for this material. Since the isomeric allyl ethers (XXIV) and (XXIX) were resolved by t.l.c. and only compound (XXIV) was observed after the hydrolysis of the initial product, this indicates that the initial product was not a mixture of compounds (XXIII) and (XXVIII).

In order to use the allyl ether as a protecting group in the amino-sugar series it was necessary to show that the amido-group was stable to the strongly basic conditions of the isomerisation. For this purpose the allyl ether

[14] H. S. Hill and L. M. Pidgeon, *J. Amer. Chem. Soc.*, 1928, **50**, 2718.
[15] R. E. Gramera, R. M. Bruce, S. Hirase, and R. L. Whistler, *J. Org. Chem.*, 1963, **28**, 1401.
[16] (*a*) L. v. Vargha, *Ber.*, 1936, **69**, 2098; (*b*) O. T. Schmidt, G. Zinke-Allmang, and U. Holzach, *Chem. Ber.*, 1957, **90**, 1331.
[17] J. S. Brimacombe, B. D. Jones, M. Stacey, and J. J. Willard, *Carbohydrate Res.*, 1966, **2**, 167.
[18] (*a*) E. J. Bourne, A. J. Huggard, and J. C. Tatlow, *J. Chem. Soc.*, 1953, 735; (*b*) E. J. Bourne, M. Stacey, C. E. M. Tatlow, and J. C. Tatlow, *J. Chem. Soc.*, 1951, 826.
[19] (*a*) K. S. Ennor and J. Honeyman, *J. Chem. Soc.*, 1958, 2586; (*b*) A. F. Krasso, E. Weiss, and T. Reichstein, *Helv. Chim. Acta*, 1963, **46**, 2538; (*c*) H. R. Bollinger and D. A. Prins, *Helv. Chim. Acta*, 1945, **28**, 465.

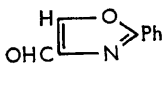
(XXXV) was hydrolysed by methanolic hydrogen chloride, under the very mild conditions described previously,[20a] to give the methyl glycoside (XXXVI) and this compound was isomerised to the prop-1-enyl ether (XXXVII) without evidence of decomposition of the amide linkage. Hydrolysis of the prop-1-enyl group in compound (XXXVII) by mercuric chloride gave compound (XXXVIII) which was identical with the material obtained by the direct methanolysis of the oxazoline (XXXIII).[20a,b] Compound (XXXV) was treated with potassium t-butoxide in dimethyl sulphoxide



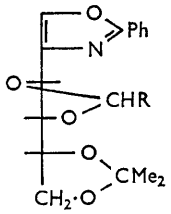


(XLIV)

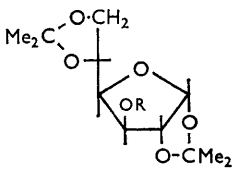
(XXXIX) $R^1 = CH_2{-}CH{=}CH_2$; $R^2 = H$
(XL) $R^1 = CH{=}CH{-}CH_3$; $R^2 = H$
(XLI) $R^1 = CH{=}CH{-}CH_3$; $R^2 = Ac$
(XLII) $R^1 = H$; $R^2 = Ac$
(XLIII) $R^1 = R^2 = H$

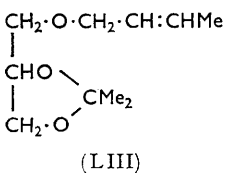


(XLV)



(XLVI) R = $CH(HgCl)CH_3$
(XLVII) R = $CH(HgI)CH_3$
(XLVIII) R = CH_2CH_3





(LIII)

(XLIX) R = $CH_2{-}C(Me){=}CH_2$
(L) R = $CH{=}CMe_2$
(LI) R = $CH_2{-}CH{=}CH_2$
(LII) R = $CH_2{-}CH{=}CH{-}CH_3$

to investigate the stability of the oxazoline ring in carbohydrate derivatives to the isomerisation conditions. At 20° a reaction to a more slowly moving compound (XXXIX) was observed by t.l.c. At 50° compound (XXXIX) was slowly converted into compound (XL) which had the same mobility on t.l.c. as the starting material (XXXV); thus under the normal conditions of the rearrangement (100°/15 min.) it appeared that no reaction had occurred. The rearrangement of compound (XXXV) presumably occurs by removal of the proton at C(4) of the oxazoline ring, under the strongly basic conditions, with concomitant rupture of the O–C bond of the furanose ring to give the oxazole (XXXIX). This reaction is followed by a normal rearrangement of the allyl ether to give the prop-1-enyl ether (XL). The structure of the crystalline compound (XL) was established by conversion to a crystalline acetate (XLI) followed by hydrolysis of the prop-1-enyl group with mercuric chloride and basic hydrolysis of the acetate group to give the crystalline diol (XLIII). Oxidation of this diol with sodium metaperiodate gave crystalline 4-formyl-2-phenyloxazole (XLV) with the properties reported previously.[21] Basic hydrolysis of compound (XLV) gave benzamidomalondialdehyde as reported.[21] Hydrolysis of the diol (XLIII) or of the prop-1-enyl ether (XL) with acid gave the oxazole (XLIV) derived from 2-benzamido-2-deoxy-D-glucose. The lability of the proton in the 4-position of 2-phenyloxazolines in the presence of potassium t-butoxide in dimethyl sulphoxide suggests that isomerisations might occur in other carbohydrate derivatives containing this grouping under these conditions and this subject is being investigated further. Isomerisations at the 4-position of 2-phenyloxazolines under milder basic conditions have been observed with derivatives of 4-ethoxycarbonyl-2-phenyloxazoline.[22]

When compound (XL) was treated with mercuric chloride in an attempt to remove the prop-1-enyl group, the major product was the chloromercuripropylidene derivative (XLVI) and only a small amount of the diol (XLIII) was formed. Compound (XLVI) was converted into the crystalline iodomercuri-derivative (XLVII) after washing a solution of the product with potassium iodide solution. In an attempt to prepare the propylidene acetal (XLVIII), compound (XLVII) was reduced with sodium borohydride as described previously [6b,23] for the replacement of the chloromercuri-group by hydrogen. The product was mainly a monoprop-1-enyl ether of the diol (XLIII) which cochromatographed with compound (XL). However, only a small amount of the crystalline compound (XL) was obtained from the product and it is assumed that a mixture of the *cis*- and *trans*-isomers of compound (XL) was produced whereas in the isomerisation which produced compound (XL) from the allyl ether only the *cis*-isomer is produced.[3] The mechanism of the action of sodium borohydride with the 2-iodomercuripropylidene derivative is presumably similar to the action [14,24] of alkali

[20] (*a*) S. Konstas, I. Photaki, and L. Zervas, *Chem. Ber.*, 1959, **92**, 1288; (*b*) R. Gigg and C. D. Warren, *J. Chem. Soc.*, 1965, 1351; (*c*) B. Lindberg and H. Agback, *Acta Chem. Scand.*, 1964, **18**, 185.

[21] J. W. Cornforth, E. Fawaz, L. J. Goldsworthy, and R. Robinson, *J. Chem. Soc.*, 1949, 1549.

[22] D. F. Elliott, *J. Chem. Soc.*, 1949, 589; 1950, 62; E. E. Hamel and E. P. Painter, *J. Amer. Chem. Soc.*, 1953, **75**, 1362; H. E. Carter, J. B. Harrison, and D. Shapiro, *J. Amer. Chem. Soc.*, 1953, **75**, 4705.

[23] H. B. Henbest and B. Nicholls, *J. Chem. Soc.*, 1959, 227; H. B. Henbest and R. S. McElhinney, *J. Chem. Soc.*, 1959, 1834.

[24] (*a*) J. Wislicenus, *Annalen*, 1878, **192**, 106; H. S. Hill, *J. Amer. Chem. Soc.*, 1928, **50**, 2725; J. F. Arens and D. A. van Dorp, *Rec. Trav. chim.*, 1946, **65**, 729; C. Piantadosi, A. F. Hirsch, C. L. Yarbro, and C. E. Anderson, *J. Org. Chem.*, 1963, **28**, 2425; (*b*) J. C. Craig and D. P. G. Hamon, *ibid.*, 1965, **30**, 4168; (*c*) J. C. Craig, D. P. G. Hamon, H. W. Brewer, and H. Härle, *ibid.*, 1965, **30**, 907.

metals on 2-halogenoalkylidene acetals of diols. In the latter reaction a mixture of *cis*- and *trans*-isomers of the two possible vinyl ethers is produced.[24b,c] The simple addition products of mercuric salts with olefins in alcohols can also be reduced with hydrazine or with sodium in ethanol to give some of the original olefin.[23]

The 2-methylallyl ether (XLIX) of 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose was prepared and the rates of isomerisation of this compound and of the allyl ether (LI) were compared. The allyl ether was isomerised about twenty times more quickly than compound (XLIX) which was converted into the crystalline ether (L).

We have shown [10] that γ-substituted allyl ethers are eliminated to give dienes by treatment with potassium t-butoxide in dimethyl sulphoxide and this has been confirmed by others.[25] The action of these basic conditions on the 3-methylallyl (crotyl) ether (LII) [26] of 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose was investigated. At 50° elimination was complete in 1 hr. whilst at 20° elimination was complete in 30 hr. The same behaviour was observed with the crotyl ether (LIII) although a previous report [24b] indicated that this compound was stable to these conditions. The ease of elimination of butadiene from the ether (LII) indicates that the crotyl ether should provide a further useful protecting group in the carbohydrate series and this subject is being investigated.

EXPERIMENTAL

T.l.c. was as described previously.[10] Light petroleum had b.p. 40—60° unless otherwise stated. Specific rotations were measured at 22—24° on a Bendix Automatic Polarimeter. Solvents were evaporated under reduced pressure.

Action of Mercuric Chloride–Mercuric Oxide on 3-O-*Prop*-1′,*enyl*-1,2:5,6-*di*-O-*isopropylidene*-D-*glucofuranose and* 3-O-*Allyl*-1,2:5,6-*di*-O-*isopropylidene*-D-*glucofuranose* (*General Procedure for the Hydrolysis of Prop*-1-*enyl Ethers by Mercuric Chloride*).—A solution of mercuric chloride (900 mg., 3·3 mmoles) in acetone–water (10 : 1, 10 ml.) was added dropwise with stirring to a mixture of 3-*O*-prop-1′-enyl-1,2:5,6-di-*O*-isopropylidene-D-glucofuranose [1a] (1 g., 3·3 mmoles), yellow mercuric oxide (900 mg.), and acetone–water (10 : 1, 30 ml.) during 3 min. When the addition was complete, t.l.c. (ether–light petroleum, 3 : 1) showed complete conversion of the starting material (R_f 0·9) into the product (R_f 0·58) and 2-chloromercuripropionaldehyde (R_f 0·1) (detected with the potassium permanganate spray [10]). The mercuric oxide was removed by filtration through Celite, the acetone was evaporated, and ether was added to the residue. The ether layer was washed with a semisaturated aqueous solution of potassium iodide (10 ml.), dried (K_2CO_3), and the solvent evaporated. Recrystallisation of the residue from cyclohexane gave 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose (800 mg.), m.p. and mixed m.p. 108—110°. In smaller scale reactions the mercuric oxide was not removed but the acetone was evaporated and a mixture of the residue with ether was washed directly with potassium iodide solution which dissolved all of the mercury derivatives.

When 3-*O*-allyl-1,2:5,6-di-*O*-isopropylidene-D-glucofuranose was subjected to the same treatment, t.l.c. (ether–light petroleum, 1 : 1) showed no reaction of the starting material (R_f 0·7) until 30 min. after the addition of the mercuric chloride whereupon a trace of product (R_f 0·1) was detected. After 60 hr. the starting material was completely converted into the product (R_f 0·1) which was not further investigated.

Allyl 4,6-O-*Benzylidene*-α-D-*galactopyranoside* (I) (with J. Gigg).—A mixture of allyl α-D-galactopyranoside [12] (50 g.), anhydrous zinc chloride (50 g.), and benzaldehyde (100 ml.) was stirred at room temperature for 3 hr. and then poured with stirring into a mixture of ice–water and light petroleum. The solid product was filtered off, washed with light petroleum, and dissolved in chloroform. The solution was dried (K_2CO_3), the solvent evaporated, and the crude product (70 g.) triturated with light petroleum to remove benzaldehyde. Recrystallisation from ethyl acetate–light petroleum gave the *product*, m.p. 115—117°, $[\alpha]_D$ +121° (*c* 1·9 in $CHCl_3$) [Found: C, 60·45; H, 6·5. $(C_{16}H_{20}O_6)_2,H_2O$ requires C, 60·5; H, 6·7%] (Found, after drying at 100° under high vacuum for 3 hr.: C, 62·1; H, 6·6. $C_{16}H_{20}O_6$ requires C, 62·3; H, 6·5%).

Prop-1′-*enyl* 4,6-O-*Benzylidene*-α-D-*galactopyranoside* (II) (with J. Gigg).—The allyl galactoside (I) (20 g.) was isomerised with potassium t-butoxide (20 g.) in dry dimethyl sulphoxide (100 ml.) at 100° for 2 hr. whereupon t.l.c. (ethyl acetate) showed complete conversion of the starting material (R_f 0·7) into the product (R_f 0·8). After addition of water and extraction with ether, the *product* (19 g.) was recrystallised from ethyl acetate–light petroleum, and had m.p. 114—115°, $[\alpha]_D$ +58° (*c* 1 in $CHCl_3$) (Found: C, 58·9; H, 6·8. $C_{16}H_{20}O_6,H_2O$ requires C, 58·9; H, 6·8%). The *diacetate* was prepared by the action of acetic anhydride in pyridine and when recrystallised from ethyl acetate–light petroleum had m.p. 165°, $[\alpha]_D$ +207° (*c* 1 in $CHCl_3$) (Found: C, 61·0; H, 6·1. $C_{20}H_{24}O_8$ requires C, 61·2; H, 6·2%).

1,2-O-*Propylidene*-D-*galactopyranose* (X).—The prop-1-enyl galactoside (II) (7·5 g.) was fused under high vacuum and dried for 5 hr. at 120°, then dissolved in dry ethyl acetate (50 ml.) and anhydrous toluene-*p*-sulphonic acid (50 mg.) was added. After heating under reflux for 3 hr., t.l.c. (ether) showed conversion of the starting material (R_f 0·4) into a product (R_f 0·8). After neutralisation of the acid (K_2CO_3) and evaporation of the solvent the crude product was chromatographed on alumina and elution with ethyl acetate gave 4,6-*O*-benzylidene-1,2-*O*-propylidene-D-galactopyranose (VIII) (4·3 g.) as a syrup which gave a non-crystalline *acetate* (IX), $[\alpha]_D$ −54° (*c* 0·4 in $CHCl_3$) (Found: C, 61·4; H, 6·2. $C_{18}H_{22}O_7$ requires C, 61·7; H, 6·3%). Compound (VIII) (2 g.) was hydrogenated in glacial acetic acid at atmospheric pressure in the presence of palladium–charcoal until uptake was complete. After evaporation of the solvent the residue was recrystallised from ethyl acetate to give 1,2-O-*propylidene*-D-*galactopyranose* (X) (0·8 g.) as needles, m.p. 115—116°, $[\alpha]_D$ +93·2° (*c* 0·75 in MeOH) (Found: C, 49·0; H, 7·2. $C_9H_{16}O_6$ requires C, 49·1; H, 7·3%). Acetylation with acetic anhydride and pyridine gave the *triacetate* as a syrup $[\alpha]_D$ +96·8° (*c* 0·6 in $CHCl_3$) (Found: C, 52·1; H, 6·4. $C_{15}H_{22}O_9$ requires C, 52·0; H, 6·4%).

[25] G. Kesslin and C. M. Orlando, *J. Org. Chem.*, 1966, **31**, 2682; G. M. Mkryan, N. A. Papazyan, and A. A. Pogosyan, *Zhur. org. Khim.*, 1967, **3**, 1160 (*Chem. Abs.*, 1967, **67**, 90,349).

[26] W. M. Corbett and J. E. McKay, *J. Chem. Soc.*, 1961, 2930.

3,4,6-*Tri*-O-*benzyl*-D-*galactitol* (XII).— 1,2-*O*-Propylidene-D-galactopyranose (X) (150 mg.) was benzylated with sodium hydride and benzyl chloride in refluxing benzene until t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion into the tri-*O*-benzyl ether (XI) (R_f 0·85). The excess of sodium hydride was decomposed by the addition of methanol and the benzene solution was washed with water and dried ($MgSO_4$). Evaporation of the solvents gave compound (XI) as a syrup which was hydrolysed in dioxan–N-sulphuric acid (5 : 1) until t.l.c. showed that hydrolysis to the free sugar was complete (R_f 0·4 in ether). The acid was neutralised ($BaCO_3$), the solvent evaporated, and the crude product was chromatographed on neutral alumina. After removal of impurities by elution with ether–methanol (10 : 1) the 3,4,6-tri-*O*-benzyl-D-galactopyranose [1a] (200 mg.) was obtained as a syrup by elution with methanol. This was reduced with sodium borohydride in ethanol at room temperature for 8 hr. Glacial acetic acid was added and the solvent was evaporated. Several portions of methanol were evaporated from the residue to remove boric acid and water was added to the residue and the product filtered off. Recrystallisation from ethyl acetate–light petroleum gave 3,4,6-tri-*O*-benzyl-D-galactitol (120 mg.), m.p. and mixed m.p. with material prepared previously [1a] 98—100° (Found: C, 71·5; H, 7·0. Calc. for $C_{27}H_{32}O_6$ C, 71·6; H, 7·1%).

Allyl 2,3-*Di*-O-*benzyl*-4,6-O-*benzylidene*-α-D-*galactopyranoside* (IV).—Compound (I) (3 g.) was benzylated with powdered sodium hydroxide and benzyl chloride until t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion into the di-*O*-benzyl ether (R_f 0·6). After washing with water and drying and evaporation of the solvent, the residue was recrystallised from light petroleum (b.p. 80—100°) to give the *product* (IV) (3·8 g.) as plates, m.p. 123—125°, $[\alpha]_D$ +82·4° (*c* 1 in $CHCl_3$) (Found: C, 73·9; H, 6·6. $C_{30}H_{32}O_6$ requires C, 73·75; H, 6·6%).

Prop-1′-*enyl* 2,3-*Di*-O-*benzyl*-4,6-O-*benzylidene*-α-D-*galactopyranoside* (V).—Compound (IV) (3 g.) was isomerised with potassium t-butoxide in dimethyl sulphoxide as described previously [1a] until t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion of the starting material (R_f 0·6) into the product (R_f 0·7). After dilution with water and extraction with ether the *product* (2·5 g.) was recrystallised from light petroleum (b.p. 60—80°) and had m.p. 122—124°, $[\alpha]_D$ +81° (*c* 1 in $CHCl_3$) (Found: C, 73·7; H, 6·4. $C_{30}H_{32}O_6$ requires C, 73·75; H, 6·6%).

2,3-*Di*-O-*benzyl*-4,6-O-*benzylidene*-D-*galactopyranose* (VI).—The propenyl group was removed from compound (V) and the product isolated as described above in the general procedure. T.l.c. (ether–light petroleum, 1 : 1) showed complete conversion of the starting material (R_f 0·7) into the free sugar (VI) (R_f 0·1—0·2). Recrystallisation from benzene gave the *product* (VI) as needles, m.p. 153—155°, $[\alpha]_D$ +78·4° (*c* 0·5 in $CHCl_3$) (Found: C, 72·0; H, 5·95. $C_{27}H_{28}O_6$ requires C, 72·3; H, 6·3%).

2,3-*Di*-O-*benzyl*-4,6-O-*benzylidene*-D-*galactitol* (VII).—Compound (VI) (1 g.) was dissolved in ethanol (10 ml.) and sodium borohydride (200 mg.) was added. After 4 hr. at 20° the solution was diluted with water and the crystalline material which separated was collected. Recrystallisation from methanol gave the *product* (VII) (800 mg.), m.p. 157—159°, $[\alpha]_D$ +41° (*c* 1 in $CHCl_3$) (Found: C, 71·7; H, 7·0. $C_{27}H_{30}O_6$ requires C, 72·0; H, 6·7%). For characterisation, compound (VII) was hydrolysed with N-sulphuric acid–methanol (1 : 10) for 30 min. at reflux whereupon t.l.c. (chloroform–ethyl acetate, 1 : 2) showed complete conversion of the starting material (R_f 0·7) into 2,3-di-*O*-benzyl-D-galactitol (R_f 0·2) which was obtained as a syrup after neutralisation ($BaCO_3$) and evaporation of the solution. The syrup was dissolved in glacial acetic acid and hydrogenated at atmospheric pressure over palladium–charcoal until uptake was complete. The catalyst was filtered off and washed with water. Evaporation of the filtrate gave a solid residue which was recrystallised from glacial acetic acid to give galactitol, m.p. and mixed m.p. 186—188° (lit.,[27] m.p. 185—186°).

Methyl 4,6-O-*Benzylidene*-2,3-*di*-O-*prop*-1′-*enyl*-α-D-*glucopyranoside* (XXII).—The di-*O*-allyl ether (XXI) [17] (2 g.) was treated with potassium t-butoxide (2 g.) in dimethyl sulphoxide (50 ml.) at 100° for 40 min. whereupon t.l.c. (ether–light petroleum, 1 : 2) showed conversion of the starting material (R_f 0·4) into the di-*O*-prop-1-enyl ether (R_f 0·6). After dilution with water and extraction with ether the product was recrystallised from light petroleum to give needles (1·35 g.), m.p. 99—100°, $[\alpha]_D$ +90° (*c* 1 in $CHCl_3$) (Found: C, 66·0; H, 6·95. Calc. for $C_{20}H_{26}O_6$ C, 66·3; H, 7·2%) [lit.,[17] m.p. 94—95, $[\alpha]_D^{23}$ +41° ± 5° (*c* 0·024 in $CHCl_3$)]. The prop-1-enyl groups were removed with mercuric chloride and the product isolated as described above to give methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (80%), m.p. and mixed m.p. 158—159°.

Methyl 3-O-*Allyl*-4,6-O-*benzylidine*-α-D-*glucopyranoside* (XXIV).—The di-*O*-allyl ether (XXI) (1 g.) in dimethyl sulphoxide (10 ml.) with potassium t-butoxide (0·5 g.) was kept at 40° and the reaction followed by t.l.c. (ether–light petroleum, 1 : 1). After 30 min. there was a major product (R_f 0·55) together with traces of starting material (R_f 0·4) and di-*O*-prop-1-enyl ether (R_f 0·6). Water was added and the product (0·95 g.) was extracted with ether and treated with mercuric chloride as described above. T.l.c. (ether) showed complete removal of the prop-1-enyl groups to give a major product (R_f 0·7) and traces (R_f 0·2 and 0·95). Chromatography on alumina and elution with ether removed the material R_f 0·95 (compound XXI) and further elution with ether–methanol (50 : 1) gave the major product (R_f 0·7) (0·54 g.). This compound was recrystallised from methanol to give *compound* (XXIV), m.p. 154—155°, $[\alpha]_D$ +104° (*c* 0·7 in $CHCl_3$) (Found: C, 63·3; H, 6·7. $C_{17}H_{22}O_6$ requires C, 63·3; H, 6·9%). Compound (XXIV) (1·5 g.) was isomerised as described previously [1a] and the product was recrystallised from methanol to give *compound* (XXV) (1·3 g.), m.p. 182—184°, $[\alpha]_D$ +31·7° (*c* 1 in $CHCl_3$) (Found: C, 63·15; H, 6·8. $C_{17}H_{22}O_6$ requires C, 63·3; H, 6·9%).

Methyl 4,6-O-*Benzylidene*-2-O-*methyl*-α-D-*glucopyranoside* (XXVII).—Compound (XXV) (150 mg.) was methylated with methyl iodide and sodium hydride in benzene and the product was recrystallised from methanol to give *compound* (XXVI) (120 mg.) as needles, m.p. 92—93°, $[\alpha]_D$ +21·9° (*c* 0·7 in $CHCl_3$) (Found: C, 64·3; H, 7·1. $C_{18}H_{24}O_6$ requires C, 64·3; H, 7·2%). Compound (XXVI) (100 mg.) was hydrolysed with mercuric chloride as described above. Recrystallisation of the product from light petroleum (b.p. 60—80°) gave compound (XXVII) (50 mg.) as needles, m.p. 165—166°, $[\alpha]_D$ +95·4° (*c* 0·6 in $CHCl_3$), $[\alpha]_D$ +81·8° (*c* 1 in ethanol) (Found: C, 60·4; H, 6·6. Calc. for $C_{15}H_{20}O_6$: C, 60·8; H, 6·8% {lit.,[18a] m.p. 167—

[27] J. V. Karabinos and A. T. Ballun, *J. Amer. Chem. Soc.*, 1953, **75**, 4501.

168°, $[\alpha]_D^{15}$ +74·5° (*c* 1·18 in ethanol), lit.,[18b] m.p. 168°, $[\alpha]_D^{17}$ +78·9° (*c* 1·19 in ethanol)}.

Methyl 2-O-*Allyl*-4,6-O-*benzylidene*-α-D-*glucopyranoside* (XXIX).—Compound (XXV) (1 g.) was allylated with powdered sodium hydroxide and allyl bromide in benzene and the product was recrystallised from methanol to give *compound* (XXVIII) (0·9 g.) as needles, m.p. 75—76°, $[\alpha]_D$ +3·6° (*c* 1 in $CHCl_3$) (Found: C, 66·1; H, 7·15. $C_{20}H_{26}O_6$ requires C, 66·3; H, 7·2%). The prop-1-enyl group was removed from compound (XXVIII) as described above and recrystallisation of the product from methanol gave *compound* (XXIX) as needles, m.p. 115—116°, $[\alpha]_D$ +75·8° (*c* 0·8 in $CHCl_3$) (Found: C, 63·2; H, 6·7. $C_{17}H_{22}O_6$ requires C, 63·3; H, 6·9%). T.l.c. (ether) of compound (XXIX) (R_f 0·85) together with the isomer (XXIV) (R_f 0·7) showed a good separation and no contamination of either compound with its isomer.

Methyl 4,6-O-*Benzylidene*-3-O-*methyl*-α-D-*glucopyranoside* (XXXII).—Compound (XXIX) was isomerised to the prop-1-enyl derivative as described previously [1a] and the product was recrystallised from methanol to give *compound* (XXX) as needles, m.p. 128—129°, $[\alpha]_D$ +58·6° (*c* 1 in $CHCl_3$) (Found: C, 63·1; H, 6·6. $C_{17}H_{22}O_6$ requires C, 63·3; H, 6·9%). Compound (XXX) was methylated as described above and the product was crystallised from methanol to give *compound* (XXXI) as needles, m.p. 108—110°, $[\alpha]_D$ +81·5° (*c* 0·8 in $CHCl_3$) (Found: C, 64·2; H, 6·8. $C_{18}H_{24}O_6$ requires C, 64·3; H, 7·2%). Compound (XXXI) was hydrolysed with mercuric chloride and the product isolated as described above. Recrystallisation from light petroleum (b.p. 60—80°) gave *compound* (XXXII) as needles, m.p. 145—146°, $[\alpha]_D$ +113·2° (*c* 0·5 in $CHCl_3$) (Found: C, 60·7; H, 6·9. Calc. for $C_{15}H_{20}O_6$: C, 60·8; H, 6·8%) {lit.,[19a] m.p. 146—147°, $[\alpha]_D^{18}$ +117° (*c* 1 in tetrachloroethane); lit.[19b] m.p. 148—149°, $[\alpha]_D^{20}$ +122·4° (*c* 0·79 in $CHCl_3$); lit.,[19c] m.p. 150—151° $[\alpha]_D^{14}$ +119·5° (*c* 1·61 in tetrachloroethane)}. T.l.c. (ether) of compound (XXXII) (R_f 0·7) and compound (XXVII) (R_f 0·65) showed no contamination of the isomers with each other.

Anomers of Methyl 2,3,6-*Tri*-O-*benzyl*-D-*glucofuranoside* (XVIII).— 3-*O*-Benzyl-1,2-*O*-isopropylidene-6-*O*-triphenylmethyl-D-glucofuranoside (XIII) [15] (100 g.) in tetrahydrofuran (100 ml.) was added slowly to a mixture of tetrahydrofuran (500 ml.), sodium hydride (6 g.), and allyl bromide (40 ml.) and when the initial reaction had subsided, the mixture was heated under reflux until t.l.c. (ether–light petroleum 1 : 3) showed complete conversion of the starting material (R_f 0·25) into the allyl ether (XIV) (R_f 0·5). The excess of sodium hydride was destroyed by the addition of methanol and the solvent was evaporated and the product extracted with ether, washed, and dried (K_2CO_3). Evaporation gave the allyl ether (XIV) as a syrup which was dissolved in methanolic 0·1N-hydrogen chloride (500 ml.) and the solution was heated under reflux for 1 hr. whereupon t.l.c. (ether–light petroleum, 2 : 1) showed complete hydrolysis of the starting material (R_f 0·95) to the methyl glycosides (XV) (R_f's 0·05—0·2). The acid was neutralised (K_2CO_3) and the solution kept at room temperature overnight, after which much of the methyl triphenylmethyl ether crystallised and was separated by decantation. The methanol was evaporated and the product was taken up in ether and the ether solution was passed through a column of alumina (4 in. × 4 in.) to elute the remaining methyl triphenylmethyl ether. Further elution with ether–methanol (2 : 1) gave the methyl glycosides (XV) (50 g.) as a syrup. The syrup was dissolved in benzyl chloride (250 ml.) and stirred with powdered sodium hydroxide (100 g.) and the mixture was heated at 120° until t.l.c. (ether–light petroleum 1 : 2) showed complete conversion into the tri-*O*-benzyl ethers (XVI) (R_f's 0·5 and 0·6). After addition of water and separation of the layers, the solvents were evaporated under high vacuum to give the products (XVI) (75 g.) as an oil contaminated with a little dibenzyl ether. The allyl group in compounds (XVI) was isomerised to give the prop-1-enyl ethers (XVII) (R_f's 0·6 and 0·65) and the prop-1-enyl group was removed by mercuric chloride as described above to give the anomers of methyl 2,3,6-tri-*O*-benzyl-D-glucofuranoside (XVIII) (65 g.) (R_f 0·05—0·1) as a syrup. For analysis, a small portion was chromatographed on alumina. Elution with ether removed dibenzyl ether and further elution with ether–methanol (4 : 1) gave the products (XVIII). The syrup was heated under high vacuum before analysis (Found: C, 72·5; H, 6·8. Calc. for $C_{28}H_{32}O_6$: C, 72·4; H, 6·9%).

3,6-*Di*-O-*acetyl*-5-O-*methyl*-1,2-O-*isopropylidene*-D-*glucofuranoside*.—The mixed anomers (XVIII) (6 g.) were methylated with methyl iodide and sodium hydride in tetrahydrofuran at room temperature for 30 min. followed by 30 min. at reflux temperature whereupon t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion of the starting material (R_f's 0·25 and 0·35) into the methyl ethers (XIX) (R_f's 0·4 and 0·55). The product was isolated and dissolved in glacial acetic acid and hydrogenated at atmospheric pressure over palladium–charcoal until uptake was complete. After filtration and evaporation of the solvent the anomers of methyl 5-*O*-methyl-D-glucofuranoside were obtained as a syrup which was hydrolysed in N-sulphuric acid at reflux for 1 hr. The acid was neutralised ($BaCO_3$) and the solution filtered and evaporated to dryness. The residue was dissolved in dry acetone (300 ml.) and toluene-*p*-sulphonic acid (500 mg.) was added and the solution was kept at 20° for 18 hr. whereupon t.l.c. (ethyl acetate) showed conversion of the starting material (R_f 0·05) into a product (R_f 0·5). The acid was neutralised (K_2CO_3), the solvent evaporated, and the residue was extracted with ether and chromatographed on alumina. Elution with ether–methanol (9 : 1) gave the product (1 g.) (R_f 0·5) free from starting material. Acetylation of this material with acetic anhydride and pyridine gave a crystalline product which was recrystallised from light petroleum (b.p. 60—80°) to give 4,6-di-*O*-acetyl-5-*O*-methyl-1,2-*O*-isopropylidene-D-glucofuranose (800 mg.), m.p. 87—89°, $[\alpha]_D$ −14·3° (*c* 1 in $CHCl_3$) {lit.,[16a] m.p. 87°, $[\alpha]_D^{20}$ −15·2° (*c* 2·6 in $CHCl_3$); lit.,[16b] m.p. 88° $[\alpha]_D^{20}$ −13·4° (*c* 2·7 in $CHCl_3$)}.

Oxazolines (XXXIV) *and* (XXXV) (with J. Gigg).—The oxazoline (XXXIII) [20] (10 g.) was heated at reflux with powdered sodium hydroxide, allyl bromide, and benzene until t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion of the starting material (R_f 0·1) into the product (R_f 0·6). After washing of the solution with water and evaporation of solvents, the residue was recrystallised from light petroleum (b.p. 60—80°) to give the *oxazoline* (XXXV) (10 g.), m.p. 80—81°, $[\alpha]_D$ −4° (*c* 1 in $CHCl_3$) (Found: C, 66·1; H, 6·5; N, 4·1. $C_{19}H_{23}NO_5$ requires C, 66·1; H, 6·7; N, 4·0%), $\lambda_{max.}$ 207 and 244 mμ; $\nu_{max.}$ 1630 cm.$^{-1}$ (C=N). In a similar way the *oxazoline* (XXXIV), prepared by benzylation of the oxazoline (XXXIII) and recrystallisation from light petroleum (b.p. 60—80°), had m.p. 84—86°, $[\alpha]_D$ −1·5° (*c* 2 in $CHCl_3$) (Found: C, 70·0; H, 6·3;

N, 3·5. $C_{23}H_{25}NO_5$ requires C, 69·85; H, 6·4; N, 3·5%). Hydrolysis of compound (XXXIV) with N-hydrochloric acid–acetone (1 : 4) and recrystallisation of the product from ethyl acetate gave *2-benzamido-3-O-benzyl-2-deoxy-D-glucose*, m.p. 205—208° (decomp.), $[\alpha]_D$ +100° (*c* 2 in methanol) (Found: C, 64·2; H, 6·4; N, 3·6. $C_{20}H_{23}NO_6$ requires C, 64·3; H, 6·2; N, 3·75%).

Methyl 3-O-Allyl-2-benzamido-2-deoxy-5,6-O-isopropylidene-β-D-glucofuranoside (XXXVI) (with J. Gigg).—The allyl ether (XXXV) (6 g.) was kept at 20° in methanolic 0·0005N-hydrogen chloride (200 ml.) for 6 hr. whereupon t.l.c. (ether) showed complete conversion of the starting material (R_f 0·9) into the product (R_f 0·65). The acid was neutralised (K_2CO_3), the methanol evaporated, and the residue was recrystallised from benzene–cyclohexane to give the *product* (XXXVI) (5·7 g.), m.p. 113—113·5°, $[\alpha]_D$ −50° (*c* 2 in $CHCl_3$) (Found: C, 63·9; H, 7·3; N, 3·6. $C_{20}H_{27}NO_6$ requires C, 63·65; H, 7·2; N, 3·7%).

Methyl 2-Benzamido-2-deoxy-3-O-prop-1′-enyl-5,6-O-isopropylidene-β-D-glucofuranoside (XXXVII) (with J. Gigg).—The allyl ether (XXXVI) (1 g.) was isomerised at 100° for 15 min. as described previously [1a] and t.l.c. (ether) showed conversion of the starting material (R_f 0·65) into a product (R_f 0·7) without evidence of other decomposition. After extraction, the product was recrystallised from benzene–cyclohexane to give the *product* (XXXVII) (750 mg.), m.p. 128—129°, $[\alpha]_D$ +44·5° (*c* 1 in $CHCl_3$) (Found: C, 63·6; H, 7·3; N, 3·8. $C_{20}H_{27}NO_6$ requires C, 63·65; H, 7·2; N, 3·7%). Compound (XXXVII) (440 mg.) was hydrolysed with mercuric chloride and the product isolated as described above. Recrystallisation from ethyl acetate gave methyl 2-benzamido-2-deoxy-5,6-*O*-isopropylidene-β-D-glucofuranoside (310 mg.), m.p. and mixed m.p. with material prepared previously [20b] 132—134°.

3-O-(2-Methylprop-2-enyl)-1,2:5,6-di-O-isopropylidene-D-glucofuranose (XLIX).—1,2:5,6-Di-*O*-isopropylidene-D-glucofuranose (5 g.), benzene (50 ml.), powdered sodium hydroxide (10 g.), and 2-methylallyl chloride (10 ml.) were heated under reflux with stirring until t.l.c. (ether–light petroleum, 1 : 1) showed complete conversion of the starting material (R_f 0·25) into the product (R_f 0·7). After washing with water, the solvent was evaporated and the *product* (XLIX) (5 g.) was distilled, b.p. 120°/0·1 mm. (bath temperature). The distillate crystallised, m.p. 31—33°, $[\alpha]_D$ −27·8° (*c* 1 in $CHCl_3$) (Found: C, 60·9; H, 8·3. $C_{16}H_{26}O_6$ requires C, 61·1; H, 8·3%).

Comparative Rates of Isomerisation of Compounds (XLIX) *and* (LI).—Potassium t-butoxide (1 g.) was dissolved in dry dimethyl sulphoxide (25 ml.). The allyl ether (LI) (500 mg.) and the 2-methylallyl ether (XLIX) (500 mg.) were dissolved in separate portions (10 ml.) of the above solution and the isomerisation of these compounds at 20° was followed by t.l.c. After 2 hr. the allyl ether (LI) was completely converted into the corresponding prop-1-enyl ether [1a] whereas the ether (XLIX) was completely isomerised after 40 hr. The product from the isomerisation of compound (XLIX) was isolated as described previously. Recrystallisation from light petroleum gave the *ether* (L), m.p. 50—52°, $[\alpha]_D$ +4° (*c* 1 in $CHCl_3$) (Found: C, 61·0; H, 8·0. $C_{16}H_{26}O_6$ requires C, 61·1; H, 8·3%).

Cleavage of 3-O-(But-2-enyl)-1,2:5,6-di-O-isopropylidene-D-glucofuranose (LII) *by Potassium t-Butoxide in Dimethyl Sulphoxide*.—The ether (LII) [26] (1 g.) and potassium t-butoxide (1 g.) in dry dimethyl sulphoxide (20 ml.) was kept at 50° and the course of the reaction followed by t.l.c. (ether–light petroleum, 1 : 2). After 1 hr., the starting material (R_f 0·7) was completely degraded to a product (R_f 0·1). The solution was diluted with water and extracted with ether. Evaporation of the ether gave a crystalline residue which was recrystallised from cyclohexane to give 1,2:5,6-di-*O*-isopropylidene-D-glucofuranose (600 mg.), m.p. and mixed m.p. 108—110°. At 20° under the same conditions the ether (LII) was degraded in 28 hr. Similarly the ether (LIII) [24b] was degraded at 50° during 2 hr. to 1,2-*O*-isopropylidene glycerol.

Cleavage of the Oxazoline (XXXV) *with Potassium t-Butoxide in Dimethyl Sulphoxide*.—The oxazoline (XXXV) (1 g.) and potassium t-butoxide (1 g.) in dry dimethyl sulphoxide (20 ml.) was kept at 20° and the reaction followed by t.l.c. (ether–light petroleum, 1 : 1). During 4 hr., the starting material (R_f 0·6) was completely converted into a product (R_f 0·5). After dilution with water and extraction with ether the oxazole (XXXIX) (1 g.) was obtained as an oil [$\nu_{max.}$ 3420 cm.$^{-1}$ (OH) and no absorption between 1600 and 1700 cm.$^{-1}$ indicating the absence of oxazoline or vinyl ether groups; $\lambda_{max.}$ 208 and 270 mμ]. The oxazole (XXXIX) was taken up in a similar solution of potassium t-butoxide in dimethyl sulphoxide and kept at 50° for 5 hr. whereupon t.l.c. showed complete conversion into a new product (R_f 0·6) which was isolated as above and recrystallised from light petroleum to give the *oxazole* (XL) (700 mg.), m.p. 80—82°, $[\alpha]_D$ +32° (*c* 1 in $CHCl_3$) (Found: C, 66·1; H, 6·8; N, 4·0. $C_{19}H_{23}NO_5$ requires C, 66·1; H, 6·7; N, 4·0%), $\nu_{max.}$ 3420 cm.$^{-1}$ (OH), 1660 cm.$^{-1}$ (−O−CH=CH−); $\lambda_{max.}$ 208 and 270 mμ. After acetylation with acetic anhydride and pyridine the product was recrystallised from light petroleum to give the *acetate* (XLI), m.p. 66—68°, $[\alpha]_D$ +44·8° (*c* 1 in $CHCl_3$) (Found: C, 65·3; H, 6·55; N, 3·6. $C_{21}H_{25}NO_6$ requires C, 65·1; H, 6·5; N, 3·6%).

Oxazole (XLIII).—The acetate (XLI) (2 g.) was treated with mercuric chloride and the product isolated as described above to give the acetate (XLII) which was hydrolysed in methanolic N-potassium hydroxide to remove the acetate group. Recrystallisation of the product from light petroleum (b.p. 80—100°) gave the *oxazole* (XLIII) (1 g.), m.p. 96—98°, $[\alpha]_D$ +2·8° (*c* 1 in $CHCl_3$) (Found: C, 62·6; H, 6·2; N, 4·6. $C_{16}H_{19}NO_5$ requires C, 62·9; H, 6·3; N, 4·6%).

Oxazole (XLIV).—The oxazoles (XL) or (XLIII) were hydrolysed in methanolic 0·1N-hydrogen chloride at reflux for 30 min. The acid was neutralised (K_2CO_3), the solution diluted with water, and the product which separated was recrystallised from methanol to give the *oxazole* (XLIV), m.p. 206—208°, $[\alpha]_D$ −50° (*c* 1 in dimethylformamide) (Found: C, 58·7; H, 5·65; N, 5·3. $C_{13}H_{15}NO_5$ requires C, 58·9; H, 5·7; N, 5·3%).

4-Formyl-2-phenyloxazole (XLV).—The oxazole (XLIII) (2 g.) was dissolved in aqueous methanol and a solution of sodium metaperiodate (2 g.) in aqueous methanol was added. After 2 hr. at 20° the methanol was evaporated and the aqueous solution was extracted with chloroform. After drying ($MgSO_4$) and evaporation of the solvent, the residue (1 g.) was recrystallised from light petroleum (b.p. 60—80°) to give 4-formyl-2-phenyloxazole (XLV), m.p. 94—95° (Found: C, 69·9; H, 4·2; N, 8·1. Calc. for $C_{10}H_7NO_2$: C, 69·4; H, 4·1; N, 8·1%) (lit.,[21] m.p. 94°). When this compound was treated with alkali as described previously,[21] benzamidomalondialdehyde, m.p. 75—77° was formed (lit.,[21] m.p. 76—77°).

Iodomercuri-derivative (XLVII).—When the oxazole

(XL) (500 mg.) was treated with mercuric chloride and mercuric oxide as described above, t.l.c. (ether–light petroleum, 2 : 1) showed that the starting material (R_f 0·74) was converted into a major product (R_f 0·5) and a minor product (R_f 0·25) which cochromatographed with the diol (XLIII). After isolation of the product as described above (*i.e.*, washing with potassium iodide solution), the major product now had R_f 0·75 and another minor product (R_f 0·85) as well as the product (R_f 0·25) was present. Recrystallisation from aqueous methanol and light petroleum (b.p. 80—100°) gave *compound* (XLVII) (200 mg.) (R_f 0·75), softening 123° and forming a meniscus at 128°, $[\alpha]_D$ +58·5° (*c* 0·76 in $CHCl_3$) (Found: C, 34·1; H, 3·4; N, 2·4; I, 17·5. $C_{19}H_{22}HgINO_5$ requires C, 34·0; H, 3·3; N, 2·1; I, 18·9%).

Action of Sodium Borohydride on Compound (XLVII).—Compound (XLVII) (160 mg.) was dissolved in a solution of sodium borohydride (100 mg.) in ethanol (10 ml.). Mercury was immediately precipitated and after 1 hr. at 20° the solution was diluted with water and extracted with ether. T.l.c. (ether–light petroleum, 2 : 1) showed a major product (R_f 0·74) [which cochromatographed with the oxazole (XL) and gave an immediate colour reaction with the potassium permanganate spray [10]] and two minor products (R_f 0·3 and 0·85). The i.r. spectrum of the product was similar to that of the oxazole (XL) showing strong absorption at 1660 cm.$^{-1}$ (–O–CH=CH–). Crystallisation from light petroleum gave the oxazole (XL) (25 mg.), m.p. and mixed m.p. 80—82°.

4,6-O-*Benzylidene*-D-*galactopyranose* (III).—Prop-1′-enyl-4,6-*O*-benzylidene-α-D-galactopyranoside (II) (500 mg.) was treated with mercuric chloride and mercuric oxide as described above. T.l.c. (ethyl acetate) showed conversion of the starting material (R_f 0·7) into a major product (R_f 0·1) and another product (R_f 0·8) (chloromercuripropylidene acetal?). The solution was filtered and the acetone evaporated. Water (10 ml.) and sodium hydrogen carbonate (500 mg.) were added and hydrogen sulphide was passed to precipitate mercuric sulphide. After filtration and evaporation, the residue was extracted with hot ethyl methyl ketone and on cooling a crystalline product (100 mg.) was obtained. Recrystallisation from ethyl methyl ketone gave compound (III), m.p. 192—194°, $[\alpha]_D$ +127·5° (10 min.) ⟶ +96·9° (6 hr.) (*c* 0·5 in H_2O) (Found: C, 58·1; H, 6·0. Calc. for $C_{13}H_{16}O_6$ C, 58·2; H, 6·0%) {lit.,[13a] m.p. 188—194°, $[\alpha]_D^{18}$ +130° ⟶ +100° (*c* 2 in H_2O); lit.,[13b] m.p. 190—191°, $[\alpha]_D^{18}$ +118·5°}.

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