Sugar Nitrates. Part II. The Preparation and Reactions of Some Nitrates, Sulphonates, Sulphinates, and other Esters of Methyl* 4 : 6-O-*Benzylidene-*α*-*D*-glucoside.*

By JOHN HONEYMAN and J. W. W. MORGAN.

[Reprint Order No. 6435.]

Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate and other D-glucoside 2 : 3-dinitrates with sodium iodide in acetone or methanol, or with sodium nitrite in aqueous ethanol, give the 3-nitrates. Evidence is given suggesting that the course of the reaction with sodium iodide is :

$$>CH\cdot O\cdot NO_2 \xrightarrow{NaI} >CH\cdot ONa \xrightarrow{MeOH} >CH\cdot OH$$

The de-esterification of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate, 2 : 3-dimethanesulphonate, 2 : 3-dinitrate, 3-nitrate 2-toluene-*p*-sulphonate, and 2-nitrate 3-toluene-*p*-sulphonate with sodium methoxide at 0°, or at room temperature, proceeds by initial removal of the group on $C_{(2)}$. In the hydrolysis of the nitrates, inorganic nitrite is produced and the products are not isolated quantitatively; the 2 : 3-dinitrate gives an α-diketone identified as its quinoxaline derivative. The migration of a nitrate group from $C_{(3)}$ to $C_{(2)}$ is noted.

When the 2 : 3-dinitrate, 3-nitrate, and 3-nitrate 2-toluene-*p*-sulphonate are de-esterified by sodium methoxide in boiling methanol the 2 : 3-anhydro-α-D-alloside and α-D-glucoside, and the 3-nitrate are obtained. The 2-nitrate 3-toluene-*p*-sulphonate gives the anhydro-α-D-alloside only. Except for the 3-nitrate, yields are low.

When heated with sodium benzenesulphinate in acetic anhydride methyl 4 : 6-*O*-benzylidene-α-D-glucoside and its 2 : 3-diacetate both give the 2 : 3-dibenzenesulphinate, which yields the parent D-glucoside when de-esterified by sodium methoxide. The 2 : 3-sulphite and 2 : 3-dichloroacetate are similarly de-esterified.

NITRATE esters of carbohydrates have been prepared by the slow addition of freshly mixed fuming nitric acid and acetic anhydride (Honeyman and Morgan, *Chem. and Ind.*, 1953, 1035) to a solution or suspension of the sugar derivative in acetic anhydride at 0°. Not only were ethylidene and benzylidene groups not removed during esterification, but the aromatic ring in the benzylidene compounds was not nitrated, making methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate readily available.

Reaction of the 2 : 3-dinitrate with sodium iodide in acetone at 100° is the standard method for preparing methyl 4 : 6-*O*-ethylidene-β-D-glucoside 3-nitrate (Bell and Synge, *J.*, 1938, 833). During the present work methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate was conveniently converted into the 3-nitrate by sodium iodide in boiling acetone or methanol, or best by sodium nitrite in boiling aqueous ethanol. The corresponding ditoluene-*p*-sulphonate, dimethanesulphonate, and diacetate were all recovered unchanged when heated with sodium iodide in acetone for 20 hours at 100°. A possible mechanism, suggested in Part I, for removal of a secondary nitrate group by sodium iodide is :

$$>CH\cdot O\cdot NO_2 + NaI \longrightarrow >CHI + NaNO_2$$
$$>CHI + H_2O \longrightarrow >CH\cdot OH + HI$$

The water required in the second stage was presumed to react when the product was being washed with water. This mechanism, which does not account for the invariable production of free iodine and nitric oxide during these reactions, requires that the aqueous extracts of the reaction mixture should be acidic, whereas they were always neutral. Moreover,

* Part I, *J.*, 1952, 2778. A summary was presented at the New York meeting of the American Chemical Society, September, 1954.

similar iodo-compounds are stable to alcohol and to water (Newth, Richards, and Wiggins, *J.*, 1950, 2356).

In view of these discrepancies, and the presence of inorganic nitrite in the products, the following alternative mechanism is suggested :

$$>CH\cdot O\cdot NO_2 + NaI \longrightarrow >CH\cdot ONa + NO_2I$$
$$NO_2I + NaI \longrightarrow NaNO_2 + I_2$$

When acetone was the solvent the products included pungent, lachrymatory iodine-containing acetone derivatives, probably produced in this way :

$$3>CH\cdot ONa + 3I_2 + COMe_2 \longrightarrow 3>CH\cdot OH + CI_3\cdot COMe + 3NaI$$

These side reactions make acetone unsuitable for quantitative investigation of the reaction and, indeed, the perfect solvent was not found. Finally methanol was used; although it does not undergo the iodoform reaction, it is partly oxidised to formaldehyde. The proposed reaction sequence is :

$$2>CH\cdot O\cdot NO_2 + 2NaI \longrightarrow >2CH\cdot ONa + 2NO_2I$$
$$2>CH\cdot ONa + 2MeOH \longrightarrow >2CH\cdot OH + 2NaOMe$$
$$2NO_2I + 2NaI \longrightarrow 2NaNO_2 + 2I_2$$
$$I_2 + 2NaOMe \longrightarrow CH_2O + 2NaI + MeOH$$

i.e., combining these :

$$2>CH\cdot O\cdot NO_2 + 2NaI + MeOH \longrightarrow 2>CH\cdot OH + 2NaNO_2 + I_2 + CH_2O$$

In this scheme each nitrate group yields one sodium nitrite molecule and one iodine atom. The liberated iodine was first estimated by titration against sodium thiosulphate solution. The mixture was then shaken with chloroform and water, the organic products passing into the chloroform. The nitrite present in the aqueous layer was estimated under nitrogen. The results in Table 1 were obtained with methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate (2 g.); the balance of organic compounds is incomplete.

TABLE 1.

	Organic products			Inorganic products	
		3-Nitrate			
Reaction time (hr.)	Unchanged (%)	%	mole	Iodine (g.-atom)	Nitrite (mole)
3	51	27	0·00144	0·00166	0·00130
3	—	—	—	0·0020	0·0020
6	29	43	0·00232	0·00237	0·00167
6	—	—	—	0·0037	0·0034
18	0	60	0·00324	0·00143	0·00128

As far as the inorganic compounds were concerned, the results were not reproducible and reliable quantitative information was not obtained. The course of the reactions leading to the by-products is more complex than represented, and other factors, not yet understood, are involved. Prolonged heating leads to loss of free iodine although the reactions were carried out in sealed tubes; a slow reaction is proceeding in which iodine is consumed with simultaneous loss of nitrite. This, together with the evolution of nitric oxide, may be due to :

$$3NaNO_2 + MeOH + I_2 \longrightarrow NaNO_3 + 2NaI + 2NO + CH_2O$$

Evidence that on $C_{(2)}$ and $C_{(3)}$ one nitrate group activates the other was obtained when the esters of methyl 4 : 6-*O*-benzylidene-α-D-glucoside shown in Table 2 were subjected to the action of sodium iodide in acetone at 100° for 20 hours. Additional results are summarized in Table 3, where, unless stated, the compounds are esters of methyl 4 : 6-*O*-benzylidene-α-D-glucoside. These results indicate that attachment to $C_{(2)}$ of a sulphonate group assists removal of the nitrate on $C_{(3)}$, and that even an acetate group on $C_{(2)}$ has a slight activating effect. The stability of the ditoluene-*p*-sulphonate and the dimethanesulphonate is

explained by the strong deactivation produced on one group by the electron-attracting effect of the other (Winstein, *J. Amer. Chem. Soc.*, 1948, **70**, 821).

No study has been made of the course of removal of a nitrate group by sodium nitrite but the appearance of the reaction and especially the absence of brown fumes suggests a different mechanism.

TABLE 2.

Reactant	Product	
3-Nitrate	Unchanged	(66%)
	Methyl 4 : 6-*O*-benzylidene-α-D-glucoside	(21%)
3-Nitrate 2-toluene-*p*-sulphonate	2-Toluene-*p*-sulphonate	(66%)
2-Methanesulphonate 3-nitrate	2-Methanesulphonate	(73%)
2-Acetate 3-nitrate	Unchanged	(34%)
	Mixture of the 2- and the 3-acetate	(46%)

TABLE 3.

Compound	Reaction conditions	Product
2 : 3-Diacetate	NaI, acetone, 20 hr., ST	Unchanged, 95%
2 : 3-Ditoluene-*p*-sulphonate	NaI, acetone, 21 hr., ST	Unchanged, 88%
2 : 3-Dimethanesulphonate	NaI, acetone, 20 hr., ST	Unchanged, 83%
2 : 3-Dinitrate	NaI, acetone, 20 hr., R	Unchanged, 13% 3-Nitrate, 47%
	Acetone alone, 17 hr., R	Unchanged, 93%
	$NaNO_2$, aq. ethanol, 21 hr., R	3-Nitrate, 70% Glucoside, 5%
Methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-dinitrate	NaI, acetone, 24 hr., ST	3-Nitrate
	NaI, pyridine, 30 min., R	3-Nitrate, 54%
	Pyridine, 30 min., 100°	Unchanged, 77%
Methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate	NaI, pyridine, 17 hr., R	Unchanged, 65%

R = reflux; ST = sealed tube at 100°; glucoside = methyl 4 : 6-*O*-benzylidene-α-D-glucoside.

The results in Part I show that nitrate groups are removed by alkyl–oxygen or nitryl–oxygen fission; from methyl 4 : 6-*O*-alkylidene-D-glucoside 2 : 3-dinitrates the corresponding D-glucoside and 2 : 3-anhydro-D-alloside are obtained. The same conclusion has been reached by Anbar, Dostrovsky, Samuel, and Yoffe (*J.*, 1954, **3603**) who studied the hydrolysis of alkyl mononitrates by the use of ^{18}O. Sodium methoxide in methanol–chloroform at 0°, or at room temperature, or in boiling dry methanol was used for the de-esterifications now to be described. Mild alkaline hydrolysis of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate for 3 days at 0°, or for 5 days at room temperature, gave a small amount of starting compound, the corresponding 3-nitrate (about 25%), and, under the latter conditions, the 2-nitrate (6%). Extensive decomposition occurred when the hydrolysis mixture was boiled for one hour and only minute amounts of methyl 4 : 6-*O*-benzylidene-α-D-glucoside, its 3-nitrate, and methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside were obtained. Pure recrystallized methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate, similarly treated for 7 days at room temperature, yielded starting compound (44%) and methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-nitrate (5%). This is the first recorded instance of the migration of a nitrate group. When the hydrolysis mixture containing the 3-nitrate was boiled for an hour, methyl 4 : 6-*O*-benzylidene-α-D-glucoside (35%) and methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (21%) resulted. Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate was less stable than its 2-methyl ether to alkali; under the same conditions 11% and 66% respectively of each was recovered. These yields are much lower than those reported in Part I, but the earlier results could not be substantiated. Hydrolysis of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate 2-toluene-*p*-sulphonate at 0° gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate (36%), unchanged starting compound (11%), and 2-nitrate (1%): again some migration of the nitrate group from $C_{(3)}$ to $C_{(2)}$ occurred. When the hydrolysis mixture was boiled for an hour, methyl 4 : 6-*O*-benzylidene-α-D-glucoside (10%) and methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (8%) were obtained. Part I included the report that methyl 4 : 6-*O*-propylidene-α-D-glucoside 3-nitrate 2-toluene-*p*-sulphonate was converted, by 24

hours' boiling with sodium methoxide in methanol, almost quantitatively into the anhydro-α-D-alloside. Again this was repeated and found to be false. After 1 hour's boiling, the hydrolysis mixture contained starting compound (10%), 3-nitrate (12%), and a trace of impure anhydro-α-D-alloside. Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-nitrate 3-toluene-*p*-sulphonate hydrolysed at 0° gave methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (32%), methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-toluene-*p*-sulphonate (9%), and starting compound (13%), but when reaction was conducted by boiling under reflux the anhydro-α-D-alloside and a trace of an unidentified crystalline solid were the only products isolated. Despite some discrepancies in detail, these results confirm the general conclusions reached in Part I that nitrate esters can be cleaved by alkali both by nitryl–oxygen and alkyl–oxygen fission, but emphasize that yields are often low.

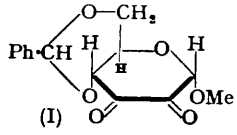
The percentage yields of the products obtained in the de-esterifications are summarized in Table 4. Although reaction conditions for all the hydrolyses were not identical, certain general conclusions can be drawn.

TABLE 4. *Alkaline hydrolysis of esters of methyl* 4 : 6-O-*benzylidene-*α*-*D*-glucoside (*yields, %*).*

Group on $C_{(2)}$:	$O{\cdot}NO_2$		OH		$O{\cdot}SO_2{\cdot}C_7H_7$		$O{\cdot}NO_2$	
Group on $C_{(3)}$:	$O{\cdot}NO_2$		$O{\cdot}NO_2$		$O{\cdot}NO_2$		$O{\cdot}SO_2{\cdot}C_7H_7$	
Products	A	B	A	B	A	B	A	B
Unchanged	16	0	0	0	11	0	13	0
3-Nitrate	21	2	44	11	36	3	0	0
2-Nitrate	6	0	5	0	1	0	0	0
Glucoside	0	2	0	35	0	10	0	0
Anhydro-D-alloside	0	3·5	0	21	0	8	32	21
3-Toluene-*p*-sulphonate	0	0	0	0	0	0	9	0
Total	43	7·5	49	67	48	21	54	21

A = hydrolysis at room temperature or 0°. B = hydrolysis in boiling solvent.
Glucoside = methyl 4 : 6-*O*-benzylidene-α-D-glucoside.

The first three compounds in Table 4, *i.e.*, the dinitrate, 3-nitrate, and 3-nitrate 2-toluene-*p*-sulphonate, each reacted with sodium methoxide at or below room temperature, to give mainly the 3-nitrate, but in contrast with the same reactions carried out in boiling solvent no methyl 4 : 6-*O*-benzylidene-α-D-glucoside nor methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside was isolated. The low overall yields in the other de-esterifications also suggested that another reaction was proceeding, and the presence of much nitrite indicated that this is the reaction in which ketone and nitrite are produced. This was confirmed by the isolation of the quinoxaline derivative of the α-diketone, methyl 4 : 6-*O*-benzylidene-2 : 3-dideoxy-2 : 3-dioxo-α-D-glucoside (I), when the de-esterification of the dinitrate was effected in the presence of *o*-phenylene diamine. The products obtained on hydrolysis in boiling solvent show that with the 3-nitrate 63% of reacted compound was accounted for by reactions leading to methyl 4 : 6-*O*-benzylidene-α-D-glucoside and methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside. When the substituents were a nitrate and a toluene-*p*-sulphonate group, the amount of these products was less, whereas with the dinitrate mere traces of them were isolated. All these reactions in boiling methanol were accompanied by rapid darkening and the production of nitrite, indicating that here also and particularly with the dinitrate, the other reaction was taking place, the ketonic products being decomposed in boiling alkali. Contrasting with these results was the conversion of methyl α-D-glucoside 2 : 3 : 4-triacetate 6-nitrate into methyl 3 : 6-anhydro-α-D-glucoside in high yield, with negligible ketone formation. This confirms Gladding and Purves's results (*J. Amer. Chem Soc.*, 1944, **66**, 76) and shows that in the removal of this nitrate group from a primary carbon atom, alkyl–oxygen fission is the major, if not the only, course of hydrolysis.



(I)

Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate reacts when heated for several hours with pyridine at 100° to give an unidentified syrup unless hydroxylamine hydrochloride was included in the reaction mixture, in which case a small amount of the dioxime of the diketone (I) was isolated.

The almost quantitative conversion of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate into the 2 : 3-anhydro-D-alloside by sodium methoxide in methanol and chloroform (Richtmyer and Hudson, *J. Amer. Chem. Soc.*, 1941, **63**, 1727) illustrates a general property of sulphonates. The course of this hydrolysis, and that of the corresponding dimethanesulphonate, has now been clarified. The first step, removal of the group on $C_{(2)}$ by sulphonyl–oxygen fission without inversion, occurs readily. Mild treatment of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dimethanesulphonate with sodium methoxide gave the corresponding 3-methanesulphonate (40%) and unchanged compound (25%) : longer reaction gave the 2 : 3-anhydro-α-D-alloside (66%) and 3-methanesulphonate (10%). With the ditoluene-*p*-sulphonate extended reaction time leads to the 2 : 3-anhydro-α-D-alloside only (Richtmyer and Hudson, *loc. cit.*), but shorter treatment yielded the 2 : 3-anhydro-α-D-alloside (36%) and the 3-toluene-*p*-sulphonate (18%).

By heating methyl 4 : 6-*O*-benzylidene-α-D-glucoside with sodium benzenesulphinate in acetic anhydride at 100° a reaction ensued which was complete in 18 hours but not after 3 hours; a by-product was precipitated in 30 minutes. If, however, the corresponding 2 : 3-diacetate was used, a precipitate was formed at once, and the reaction was complete in 30 minutes. This suggests that acetylation is first necessary and then the acetate is replaced by sulphinate. Aromatic sulphoxides were not obtained when benzene or anisole was treated with the same reagent, in contrast to the preparation of aromatic sulphones from sulphonic acids and trifluoracetic anhydride (Bourne, Stacey, Tatlow, and Tedder, *J.*, 1951, 718) but phenyl benzenethiolsulphonate was precipitated on pouring each of these reaction solutions into water and also that obtained when only sodium benzenesulphinate and acetic anhydride were heated together. Sodium methoxide in methanol–chloroform converted the 2 : 3-dibenzenesulphinate into methyl 4 : 6-*O*-benzylidene-α-D-glucoside (about 80%), *i.e.*, the sulphinate behaves in this reaction like a carboxylic ester, as was also found by Balfe, Kenyon, and Tarnoky (*J.*, 1943, 446).

When sodium toluene-*p*-sulphonate, sodium sulphite, and benzoic acid were each heated separately with methyl 4 : 6-*O*-benzylidene-α-D-glucoside in acetic anhydride, the only sugar derivative isolated was the 2 : 3-diacetate.

Under controlled conditions, the action of thionyl chloride in pyridine on methyl 4 : 6-*O*-benzylidene-α-D-glucoside has now given a crystalline 2 : 3-sulphite, which was converted into the parent glucoside derivative by sodium methoxide. The sulphite was very sensitive to acid; it decomposed on ordinary storage and was converted quantitatively into methyl α-D-glucoside by a trace of acid in aqueous acetone, showing that the sulphite group renders the benzylidene group unusually labile.

The 2 : 3-dichloroacetates of methyl 4 : 6-*O*-ethylidene- and 4 : 6-*O*-benzylidene-α-D-glucoside were readily prepared from chloroacetic anhydride and sodium chloroacetate, and were reconverted into the glucoside by sodium methoxide. Attempts to prepare similar diesters of methyl 4 : 6-*O*-ethylidene-α-D-glucoside by dichloro- and trichloroacetyl chloride in pyridine led only to the monodichloroacetate and monotrichloroacetate, in low yields.

Experimental

Unless otherwise stated, chloroform solutions were dried over sodium sulphate before being evaporated, evaporations were carried out under reduced pressure, and the light petroleum used had b. p. 60—80°.

Chromatographic separations were carried out with columns of activated alumina, Type H, 100/200 S mesh, supplied by Messrs. Peter Spence and Sons, Ltd.

At the end of the reaction time specified for the preparation of esters in pyridine a little water was added to decompose excess of acid chloride. After a further 15 min. the mixture was poured into ice-water, and the resulting syrup was repeatedly washed with water until it solidified. Nitrates were isolated by pouring the reaction mixture into aqueous potassium carbonate and washing the precipitate repeatedly with water until it crystallized. Exceptional cases are fully described below.

The presence of nitrite was established by the appearance of a red colour after the addition of a solution of sulphanilic acid in acetic acid, followed by a solution of α-naphthylamine.

Identifications were by mixed m. p.

Preparation of Methyl 4 : 6-O-*Ethylidene*-α-D-*glucoside*.—(*a*) Methyl α-D-glucoside (20 g.), paraldehyde (200 ml.), and concentrated sulphuric acid (20 drops) were shaken at room temperature for 1 hr. Solid potassium carbonate was then added to the solution, which had been diluted with chloroform; the whole was filtered, and the filtrate was evaporated, leaving a syrup, which solidified when shaken with water. The solid (4·7 g.), recrystallized from ethanol–acetone, was methyl 4 : 6-*O*-ethylidene-2 : 3-*O*-oxydiethylidene-α-D-glucoside, m. p. 181—182°. The aqueous solution was evaporated to a syrup which was extracted several times with hot ether. The combined ethereal extracts yielded, on concentration, methyl 4 : 6-*O*-ethylidene-α-D-glucoside (11·5 g.), m. p. 75—76°. These yields varied somewhat in different experiments.

(*b*) Methyl 4 : 6-*O*-ethylidene-2 : 3-*O*-oxydiethylidene-α-D-glucoside (2 g.) was shaken with acetone (100 ml.), until almost all the solid had dissolved, and then N-hydrochloric acid (1 ml.) was added. The solution was left at room temperature for several hours, and then neutralized with potassium carbonate. The filtrate was evaporated to a residue which was triturated with water. Undissolved starting compound (0·53 g.) was collected and the aqueous filtrate was evaporated to a solid which was boiled with ether. On concentration and cooling of the ether extract, methyl 4 : 6-*O*-ethylidene-α-D-glucoside (0·76 g.) was obtained.

Preparation of Nitrates with Nitric Acid in Acetic Anhydride.—(1) *Methyl* 4 : 6-O-*ethylidene*-α-D-*glucoside* 2 : 3-*dinitrate*. Fuming nitric acid (2 ml.) in acetic anhydride (5 ml.) was added slowly to a solution of methyl 4 : 6-*O*-ethylidene-α-D-glucoside (2 g.) in acetic anhydride (5 ml.) at 0°. The mixture was allowed to warm to room temperature during 15 min., and then solid potassium carbonate was added. The solid (2·75 g.) obtained by pouring the mixture into ice-water was recrystallized from light petroleum, giving methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-dinitrate, m. p. 101°, $[\alpha]_D^{18}$ +140·5° (*c*, 1·0 in $CHCl_3$).

(2) *Methyl* 4 : 6-O-*ethylidene*-β-D-*glucoside* 2 : 3-*dinitrate*. Fuming nitric acid (6·4 ml.) in acetic anhydride (20 ml.) was added to a suspension of methyl 4 : 6-*O*-ethylidene-β-D-glucoside (7·4 g.) in acetic anhydride (20 ml.) at 0°, and the mixture was kept at 0° for 1 hr. with occasional shaking. The crude solid (9·27 g., 89%) recrystallized from light petroleum or methanol as stout needles of methyl 4 : 6-*O*-ethylidene-β-D-glucoside 2 : 3-dinitrate (7·69 g.), m. p. 88—89°, $[\alpha]_D^{21}$ −21·3° (*c*, 1·0 in $CHCl_3$).

Methyl 4 : 6-*O*-ethylidene-β-D-glucoside (2·2 g.) was added to a solution of chloroform (10 ml.), acetic anhydride (1·5 ml.), and fuming nitric acid (1·9 ml.) at 0°. The solution was allowed to warm to room temperature in 5 min., and then shaken with aqueous potassium carbonate. The chloroform layer was evaporated to a syrup, which gave a solid (1·1 g., 35%) when stirred under water. Recrystallization from light petroleum yielded the dinitrate, m. p. 88—89°. With reaction times of 15 min. and 1 hr., the yields were 32% and 29% respectively.

(3) *Methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*dinitrate*. Ice-cold fuming nitric acid (8 ml.) in acetic anhydride (20 ml.) was added slowly to methyl 4 : 6-*O*-benzylidene-α-D-glucoside (10 g.) suspended in acetic anhydride (20 ml.) at 0°. The product obtained after 15 min. at 0° gave, after recrystallizing from methanol or light petroleum, prisms of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*dinitrate* (8·3 g.), m. p. 124—125°, $[\alpha]_D^{19}$ +87·8° (*c*, 1·1 in $CHCl_3$) (Found : C, 45·0; H, 4·2. $C_{14}H_{16}O_{10}N_2$ requires C, 45·2; H, 4·3%).

Conversion of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Dinitrate into the* 4 : 6-O-*Ethylidene Analogue*.—Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate (1 g.) in paraldehyde (10 ml.) containing concentrated sulphuric acid (2 drops) was shaken for 30 min. at room temperature. The solution was neutralized with solid potassium carbonate and filtered, and the filtrate was evaporated to a syrup, which solidified when stirred with water. Two recrystallizations of the solid (0·75 g.) from light petroleum gave needles of methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-dinitrate, m. p. 100—101°.

Preparation of Esters of Methyl 4 : 6-O-*Ethylidene*-α-D-*glucoside*.—(1) 2 : 3-*Diacetate*. Methyl 4 : 6-*O*-ethylidene-α-D-glucoside (5 g.) and sodium acetate (1·5 g.) in acetic anhydride (15 ml.) were heated at 100° for 1 hr. Pouring the mixture into ice-water and adding solid potassium carbonate precipitated an oil, which solidified on stirring. This product (5·95 g.), recrystallized from light petroleum, was *methyl* 4 : 6-O-*ethylidene*-α-D-*glucoside* 2 : 3-*diacetate*, m. p. 81°, $[\alpha]_D^{16}$ +117° (*c*, 1·0 in $CHCl_3$) (Found : C, 51·9; H, 6·8; OMe, 9·9. $C_{13}H_{20}O_8$ requires C, 51·3; H, 6·6; OMe, 10·2%).

(2) 2 : 3-*Ditoluene*-p-*sulphonate*. Toluene-*p*-sulphonyl chloride (5·7 g.) in pyridine (10 ml.) was added to the glucoside (2·2 g.) in pyridine (10 ml.) and the solution kept for 3 days at room temperature. The solid product (4·3 g.), recrystallized from ethanol, gave methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate, m. p. 155°, $[\alpha]_D^{19}$ +50·9° (*c*, 1·2 in $CHCl_3$).

(3) 2 : 3-*Dichloroacetate*. The glucoside (10 g.), chloroacetic anhydride (30 g.), and sodium chloroacetate (3 g.) were heated at 100° for 1 hr., then poured into a concentrated, iced solution of potassium carbonate. After several changes of water a solid was obtained, a methanolic solution of which was decolorized with charcoal, concentrated, and cooled to 0°. The resulting fine needles (12 g.), recrystallized from aqueous methanol, yielded stout needles of *methyl* 4 : 6-O-*ethylidene*-α-D-*glucoside* 2 : 3-*dichloroacetate*, m. p. 75—76°, $[\alpha]_D^{21}$ +104° (*c*, 1·1 in $CHCl_3$) (Found : C, 41·4; H, 4·8. $C_{13}H_{18}O_8Cl_2$ requires C, 41·8; H, 4·8%). The fine needles when kept at room temperature melted and changed into the other form. If the stout needles were cooled in methanol at 0° and seeded with the fine form, complete conversion into the fine form was observed.

(4) *Monodichloroacetate*. Dichloroacetyl chloride (10 ml.) in pyridine (10 ml.) at 0° was added slowly to the glucoside (5 g.) in pyridine (10 ml.), cooled in ice. When the initial reaction had subsided, the mixture was kept at room temperature for 24 hr., before being poured into ice-water. The syrup which separated was dissolved in chloroform, and washed with 10% hydrochloric acid, sodium hydrogen carbonate solution, and water. Evaporation gave a solid, which recrystallized from methanol, as *methyl* 4 : 6-O-*ethylidene*-α-D-*glucoside monodichloroacetate* (0·2 g.), m. p. 201° (Found : C, 40·3; H, 4·5. $C_{11}H_{16}O_7Cl_2$ requires C, 39·9; H, 4·8%).

(5) *Monotrichloroacetate*. Trichloroacetyl chloride (11 g.) was added slowly to the glucoside (4·4 g.) in pyridine (20 ml.) at 0°. After 16 hr. at 0° the mixture was poured into ice-water. The resulting syrup (5·7 g.) was washed repeatedly with water, then with light petroleum. Recrystallization of the resulting solid from methanol gave needles of *methyl* 4 : 6-O-*ethylidene*-α-D-*glucoside monotrichloroacetate* (0·76 g.), m. p. 206—207°, $[\alpha]_D^{20}$ +110° (*c*, 1·0 in $CHCl_3$) (Found : C, 36·0; H, 4·2. $C_{11}H_{15}O_7Cl_3$ requires C, 36·1; H, 4·1%).

Preparation of Esters of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside*.—(1) 2 : 3-*Dimethanesulphonate*. Methanesulphonyl chloride (85 g.) was added slowly to a solution of methyl 4 : 6-*O*-benzylidene-α-D-glucoside (70 g.) in pyridine (200 ml.), cooled in ice, and the mixture was kept at 0° for 20 hr. The product recrystallized from chloroform as prisms of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*dimethanesulphonate* (103 g.), m. p. 188—189°, $[\alpha]_D^{20}$ +49° (*c*, 1·4 in $CHCl_3$) (Found : C, 43·6; H, 5·1. $C_{16}H_{22}O_{10}S_2$ requires C, 43·8; H, 5·0%).

(2) 2-*Toluene*-p-*sulphonate*. The solution obtained by mixing toluene-*p*-sulphonyl chloride (9·5 g.) in pyridine (10 ml.) with methyl 4 : 6-*O*-benzylidene-α-D-glucoside (14 g.) in pyridine (10 ml.) was kept at 0° for 22 hr. Most of the solid obtained by stirring the mixture into ice-water dissolved when it was boiled with aqueous potassium carbonate (200 ml.; 2%). The insoluble part was filtered off, and when the filtrate cooled unchanged starting compound (6·9 g.), m. p. 162—163°, was obtained. The residue, washed with water, and recrystallized twice from methanol, gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-toluene-*p*-sulphonate (2·1 g.), $[\alpha]_D^{25}$ +63·5° (*c*, 0·9 in $CHCl_3$), m. p. 155°.

(3) 2 : 3-*Sulphite*. Thionyl chloride (6·5 ml., 1·5 mol.) was added gradually to a solution of glucoside (10 g.) in pyridine (50 mol.) at 0°. After 15 min. at 0° the mixture was poured into ice-water, giving a solid (10·5 g.) which was recrystallized twice from ethanol–acetone, yielding crystals (3·6 g.), m. p. 187—192°. A further recrystallization gave stout needles of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*sulphite*, m. p. 192—193°, $[\alpha]_D^{23}$ +148·4° (*c*, 0·9 in $CHCl_3$) (Found : C, 51·0; H, 5·1. $C_{14}H_{16}O_7S$ requires C, 51·2; H, 4·9%). The compound decomposes at room temperature.

(4) 2 : 3-*Dibenzenesulphinate*. A solution of the glucoside (5·6 g.) and sodium benzenesulphinate (9·8 g.) in acetic anhydride (30 ml.) was heated on a steam-bath. A solid began to separate after 30 min., and heating was continued for 18 hr. before the mixture was poured into ice-water. The resulting crystalline solid was dried, and recrystallized from methanol as plates of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*dibenzenesulphinate* (6·15 g.), m. p. 115—116°, $[\alpha]_D^{20}$ +44·1° (*c*, 1·3 in $CHCl_3$) (Found : C, 58·5; H, 5·3. $C_{26}H_{26}O_8S_2$ requires C, 58·9; H, 4·9%). Concentration of the recrystallization mother-liquor gave more compound (1·44 g.). When this preparation was carried out with reaction times of 30 min. and 3 hr., a syrup was obtained on pouring the mixture into ice-water. Only in the latter case was a small amount of the dibenzenesulphinate (17%) obtained. Methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-diacetate (3·7 g.), sodium benzenesulphinate (4·9 g.), and acetic anhydride (15 ml.) were heated at 100°. A precipitate was immediately formed, and after 30 min. at 100° the mixture was decomposed with ice-water. The resulting solid, recrystallized from methanol, was methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dibenzenesulphinate (3·8 g.), m. p. and mixed m. p. 116—117°.

(5) 2 : 3-*Dichloroacetate*. The glucoside (5 g.), chloroacetic anhydride (15 g.), and sodium

chloroacetate (1·5 g.) were heated at 100° for 1 hr. The white solid obtained on pouring the mixture into iced potassium carbonate solution was recrystallized from methanol, yielding fine needles of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2 : 3-*dichloroacetate* (5·9 g.), m. p. 147°, $[\alpha]_D^{20}$ +67·3° (*c*, 1·1 in $CHCl_3$) (Found : C, 50·0; H, 4·4. $C_{18}H_{20}O_8Cl_2$ requires C, 49·7; H, 4·6%).

Reaction between Acetic Anhydride and Sodium Benzenesulphinate.—When sodium benzenesulphinate (8·2 g.) and acetic anhydride (30 ml.) were mixed at room temperature, an exothermic reaction took place accompanied by dissolution of the sodium salt and precipitation of another solid. The mixture after 20 hr. at 100° was poured into ice-water, to yield a syrup which crystallized. This solid (3·26 g.) recrystallized from light petroleum as long needles of phenyl benzenethiolsulphonate (1·67 g.), m. p. 35—36° (Found : C, 57·6; H, 4·0; S, 25·7. Calc. for $C_{12}H_{10}O_2S_2$: C, 57·6; H, 4·0; S, 25·6%). This compound, when mixed with an authentic sample, m. p. 43—44°, supplied by Dr. Cymerman-Craig, had m. p. 43—44°. Further recrystallization and seeding with the higher-melting form gave the compound with m. p. 43—44°. The reaction, repeated with benzene (4·5 ml.) or anisole (5 ml.) also present, again gave phenyl benzenethiolsulphonate (1·1 g.), m. p. 35—36°.

Preparation of Methyl 4 : 6-O-*Propylidene*-α-D-*glucoside* 3-*Nitrate* 2-*Toluene*-p-*sulphonate.*—Methyl 4 : 6-*O*-propylidene-α-D-glucoside 2 : 3-dinitrate (2 g.) was boiled under reflux for 18 hr. with sodium nitrite (1 g.) in ethanol (20 ml.) and water (5 ml.). Chloroform and water were then added. Evaporation of the chloroform layer gave a solid which, recrystallized from light petroleum (b. p. 80—100°), was crude methyl 4 : 6-*O*-propylidene-α-D-glucoside 3-nitrate (1·3 g.), m. p. 148—156°. This and toluene-*p*-sulphonyl chloride (1·3 g.) were kept at room temperature for 4 days in pyridine (10 ml.). The solid product, recrystallized twice from ethanol, gave methyl 4 : 6-*O*-propylidene-α-D-glucoside 3-nitrate 2-toluene-*p*-sulphonate (1·39 g.), m. p. 99°, $[\alpha]_D^{16}$ +109·5° (*c*, 0·9 in $CHCl_3$).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Propylidene*-α-D-*glucoside* 3-*Nitrate* 2-*Toluene*-p-*sulphonate.*—A solution of the 3-nitrate 2-toluene-*p*-sulphonate (1 g.) in methanol (20 ml.) containing sodium methoxide in methanol (2·7 ml.; 2·6N), was boiled under reflux for 1·5 hr. The dark solution was neutralized with acetic acid and evaporated. The residue, after extraction with boiling benzene, contained nitrite. The cooled benzene solution, chromatographed on alumina, gave from the first fractions starting compound (0·10 g.), m. p. and mixed m. p. 99—100°. Further elution with benzene–chloroform (1 : 1) yielded a sticky solid (0·24 g.), which was recrystallized from light petroleum to give methyl 4 : 6-*O*-propylidene-α-D-glucoside 3-nitrate (0·08 g.). No product was obtained by elution with ethanol. The light petroleum recrystallization mother-liquor was evaporated and the residue in benzene was re-chromatographed. This gave crude methyl 2 : 3-anhydro-4 : 6-*O*-propylidene-α-D-alloside (0·025 g.), m. p. 124—126°, mixed m. p. with pure compound (m. p. 136°), 126—129° (Found : C, 54·7; H, 7·4. Calc. for $C_{10}H_{16}O_5$: C, 55·6; H, 7·4%).

Conversion of Methyl 2 : 3-*Anhydro*-4 : 6-O-*benzylidene*-α-D-*alloside into the* 4 : 6-O-*Propylidene Analogue.*—A solution of methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·9 g.) in propaldehyde (10 ml.) and concentrated sulphuric acid (2 drops) was kept at room temperature for 30 min. The solution was neutralized with potassium carbonate and filtered, and the residue was washed with chloroform. The combined filtrate and washings, evaporated almost to dryness, left a residue, which, crystallized from ethanol–light petroleum, was methyl 2 : 3-anhydro-4 : 6-*O*-propylidene-α-D-alloside (0·46 g.), identical with that prepared by Ansell and Honeyman (*loc. cit.*).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Ethylidene*-α-D-*glucoside* 2 : 3-*Dinitrate.*—The 2 : 3-dinitrate (1·4 g.) was boiled under reflux for 24 hr. in methanol (40 ml.), containing sodium (0·2 g.). The dark mixture, which smelled strongly of paraldehyde and contained nitrite, was neutralized with acetic acid and evaporated to a syrup. The filtered chloroform extract of this was evaporated to a brown syrup, which apart from a little tar was dissolved in benzene and chromatographed on alumina. Nothing was eluted with benzene but elution with chloroform gave methyl 4 : 6-*O*-ethylidene-α-D-glucoside 3-nitrate (0·10 g.). No products were eluted with ethanol.

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Dichloroacetate,* 2 : 3-*Sulphite, and* 2 : 3-*Dibenzenesulphinate.*—Sodium methoxide in methanol (16 ml.; 2·6N) was added to the 2 : 3-dichloroacetate (3·7 g.) in chloroform (62 ml.) and the mixture was kept at 0° for 3 days. The chloroform solution was then shaken with water (3 × 50 ml.) and evaporated to a solid (2·05 g.), m. p. 158—162°, which after recrystallization from water was methyl 4 : 6-*O*-benzylidene-α-D-glucoside.

The analogues gave the same product.

Acid Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Sulphite*.—A solution of the sulphite (1 g.) in acetone (50 ml.) and water (4 ml.) containing hydrogen chloride (0·001N) was kept at room temperature for 30 min. The large crystals which had separated were collected, washed with acetone, and identified as methyl α-D-glucoside, m. p. and mixed m. p. 164—165°, $[\alpha]_D^{19}$ +158·2° (*c*, 0·2 in H_2O).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Dimethanesulphonate*.—This 2 : 3-dimethanesulphonate (14·8 g.) was dissolved in chloroform (250 ml.), and sodium methoxide in methanol (63 ml.; 2·6N) was added. The solution was kept for 20 hr. at 0° and then shaken with water until the washings were no longer alkaline. The dried chloroform solution was evaporated to a syrup, which was shaken with cold methanol (50 ml.). The residue (6·5 g.) was filtered off and washed with a little cold methanol. Evaporation of the filtrate and methanolic washings left a solid which, recrystallized from chloroform–light petroleum, was *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 3-*methanesulphonate* (4·3 g.), m. p. 142—143°, $[\alpha]_D^{17}$ +90° (*c*, 1·0 in $CHCl_3$) (Found : C, 50·0; H, 5·5; S, 9·2. $C_{15}H_{20}O_8S$ requires C, 50·0; H, 5·6; S, 8·9%). Concentration of the recrystallization liquors gave a further 0·4 g. Recrystallization of the above residue from chloroform gave unchanged starting compound (3·7 g.), m. p. and mixed m. p. 188—189°. Concentration of the chloroform gave a mixture of starting compound and methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside.

In another experiment, the same reaction mixture, in half the above quantities, was left for 6 days at 0° and one day at room temperature, then treated as before. It gave, from the chloroform solution, a white solid which, after recrystallization from chloroform–light petroleum, was methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (2·35 g.). The mother-liquor from this recrystallization was evaporated, and the residue was extracted with methanol (20 ml.), leaving a solid which, after recrystallization, was shown to be anhydro-alloside (0·5 g.). Evaporation of the methanol solution gave a syrup which, crystallized from chloroform–light petroleum, was methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-methanesulphonate (0·53 g.).

Characterization of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Methanesulphonate*.—(*a*) Methanesulphonyl chloride (4 drops) was added to a solution of the 3-methanesulphonate (0·15 g.) in pyridine (1 ml.), and the mixture was kept at 0° for 20 hr. The solid, recrystallized from methanol, was methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dimethanesulphonate (0·13 g.), m. p. 188°.

(*b*) A suspension of the 3-methanesulphonate (1·5 g.) in acetic anhydride (2 ml.) was mixed at 0° with fuming nitric acid (0·5 ml.) dissolved in acetic anhydride (2 ml.). The solid rapidly dissolved, and after 5 min. the product began to separate. Precipitation was completed 10 min. later by addition of ice-water. Recrystallization of the washed and dried product from methanol–acetone gave needles of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 3-*methanesulphonate* 2-*nitrate* (1·34 g.), m. p. 185°, $[\alpha]_D^{18}$ +75° (*c*, 1·0 in $CHCl_3$) (Found : C, 45·0; H, 4·6; N, 3·3. $C_{15}H_{19}O_{10}NS$ requires C, 44·5; H, 4·7; N, 3·5%).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Ditoluene*-p-*sulphonate*.—(*a*) The 2 : 3-ditoluene-*p*-sulphonate (10 g.) in chloroform (125 ml.) was mixed with sodium methoxide in methanol (31·5 ml.; 2·6N) at 0°. After 17 hr. at this temperature, the solution was shaken with water (3 × 100 ml.), the last aqueous extract being neutral to litmus. The chloroform solution was evaporated and the resulting solid was washed with cold methanol (10 ml.). The solid was then extracted with cold benzene (20 ml.). Evaporation of the benzene, followed by recrystallization of the resulting solid from benzene, gave *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 3-*toluene*-p-*sulphonate* (1·27 g.), m. p. 164°, $[\alpha]_D^{23}$ +32·5° (*c*, 0·9 in $CHCl_3$) (Found : C, 58·6; H, 5·7; S, 7·7. $C_{21}H_{24}O_8S$ requires C, 57·8; H, 5·5; S, 7·4%).

(*b*) A similar mixture containing 2 : 3-ditoluene-*p*-sulphonate (50 g.) was kept at 0° for 2 days. The crude product obtained in the same way was extracted with benzene (5 × 100 ml.) at room temperature. The residue, recrystallized from benzene, was methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (6·55 g.), m. p. 198—199°. The solid obtained by evaporation of the benzene extracts was dissolved in hot methanol (100 ml.). The cooled filtered solution deposited crystals which, twice recrystallized from benzene, were methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-toluene-*p*-sulphonate (3·75 g.). The benzene mother-liquors from the recrystallizations of the 3-toluene-*p*-sulphonate were combined and evaporated, and fuming nitric acid (5 ml.) in acetic anhydride (20 ml.) was added to the resulting solid suspended in acetic anhydride (20 ml.) at 0°. After 15 min. at 0°, undissolved solid was filtered off, washed with water, dried, and shown to be the anhydro-alloside (1·2 g.), m. p. 196—198°. The reaction solution was poured into ice-water, and the precipitated solid was recrystallized twice from ethanol–acetone, giving methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-nitrate 3-toluene-*p*-sulphonate (2·84 g.), m. p.

and mixed m. p. with authentic compound described below, 155—156°. Evaporation of the mother-liquors gave a solid which, purified by chromatography of its benzene solution on alumina, gave more (0·54 g.) of the 2-nitrate 3-toluene-*p*-sulphonate.

Characterization of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Toluene*-p-*sulphonate*.—Toluene-*p*-sulphonyl chloride (0·3 g.) was added to the 3-toluene-*p*-sulphonate (0·5 g.) in pyridine (2 ml.), and the mixture was kept at room temperature for 4 days. The product, recrystallized twice from ethanol, gave the 2 : 3-ditoluene-*p*-sulphonate (0·37 g.), m. p. 146—147°.

A suspension of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-toluene-*p*-sulphonate (0·94 g.) in acetic anhydride (2 ml.) dissolved after the addition of fuming nitric acid (0·5 ml.) in acetic anhydride (2 ml.) at 0°. The product obtained after 15 min. recrystallized from methanol as plates (0·73 g.), m. p. 153—155°. Another recrystallization gave *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2-*nitrate* 3-*toluene*-p-*sulphonate*, m. p. 155—156°, $[\alpha]_D^{19}$ +45·4° (*c*, 1·0 in $CHCl_3$) (Found : C, 52·8; H, 4·7; N, 2·9. $C_{21}H_{23}O_{10}SN$ requires C, 52·4; H, 4·8; N, 2·9%). This m. p. was depressed to 130—140° when the compound was mixed with methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate 2-toluene-*p*-sulphonate, m. p. 161—162°, the preparation of which is described below.

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Dinitrate*.—(*a*) A 2·6N-solution of sodium methoxide in methanol (31·5 ml.) was added to methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate (6·3 g.), dissolved in chloroform (125 ml.), and the mixture was left at 0° for 3 days. The chloroform solution was then washed free from alkali with water (3 × 100 ml.) and evaporated. The solid left after extraction of the residue with boiling light petroleum (100 ml.) was recrystallized from methanol, to give needles of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 3-*nitrate* (1·55 g.), m. p. 174°, $[\alpha]_D^{23}$ +113·5° (*c*, 1·0 in $CHCl_3$) (Found : C, 51·4; H, 4·9; N, 3·9. $C_{14}H_{17}O_8N$ requires C, 51·4; H, 5·2; N, 4·3%). The cooled light petroleum extract deposited crystals (1·6 g.) which, recrystallized twice from methanol, were starting compound (0·70 g.).

(*b*) The same reaction mixture was left at room temperature for 5 days. The inorganic precipitate was then filtered off and found to contain much nitrite. The chloroform solution was washed with water (3 × 100 ml.). The first aqueous washing, which extracted the yellow colour from the chloroform and smelled strongly of benzaldehyde, had α_D +1·8° (2 dm. tube). The second and third aqueous washings were colourless and optically inactive. The chloroform solution was evaporated to yield a sticky solid, which was extracted with boiling light petroleum (25 ml.). The solid which remained recrystallized from methanol, to give methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate (0·7 g.). The brown unstable solid, obtained by evaporation of the methanolic mother-liquor at room temperature, was extracted with hot carbon tetrachloride. The cooled, concentrated carbon tetrachloride solution deposited needles (0·3 g.), which, recrystallized from methanol, gave more 3-nitrate (0·16 g.). The light petroleum extract was evaporated to a syrup which was dissolved in ether, and chromatographed on alumina. Elution with ether gave, in the early fractions, unchanged starting compound (1·0 g.). Later fractions gave, after evaporation and recrystallization of the residue from chloroform–light petroleum, *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2-*nitrate* (0·35 g.), m. p. 136°, $[\alpha]_D^{24}$ +109·6° (*c*, 0·57 in $CHCl_3$) (Found : C, 51·9; H, 5·7; N, 3·8. $C_{14}H_{17}O_8N$ requires C, 51·4; H, 5·2; N, 4·3%). Elution with ether–chloroform (1 : 1) and finally with chloroform gave the 3-nitrate (0·32 g.). No further products were obtained when the column was washed with ethanol.

(*c*) A 2·6N-solution of sodium methoxide in methanol (3·6 ml.) was boiled with the 2 : 3-dinitrate (1·2 g.) in methanol (10 ml.) for 1 hr. under reflux. The dark solution was neutralized with acetic acid, and evaporated. Extraction of the residue with chloroform, followed by evaporation of the extract, gave a syrup which was chromatographed in benzene on alumina. Successive elution with benzene, chloroform, and ethanol gave methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·03 g.), methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate (0·02 g.), and methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·02 g.).

(*d*) The dinitrate (6·3 g.) and *o*-phenylene diamine (2·8 g.) were dissolved in chloroform (125 ml.), and sodium methoxide in methanol (31·5 ml.; 2·6N) was added. After 4 days at room temperature, the chloroform solution was washed free from alkali with water (3 × 100 ml.), and then evaporated to a syrup, most of which dissolved in methanol. The undissolved solid was purified by precipitation from chloroform with light petroleum, giving the *quinoxaline derivative* of methyl 4 : 6-*O*-benzylidene-2 : 3-dideoxy-2 : 3-dioxo-α-D-glucoside (0·11 g.), $[\alpha]_D^{18}$ −90° (*c*, 0·3 in $CHCl_3$) (Found : C, 68·8; H, 5·0; N, 7·8. $C_{20}H_{18}O_4N_2$ requires C, 68·6; H, 5·1; N, 8·0%). This compound decomposed between 230° and 240° without melting.

Characterization of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Nitrate*.—Fuming nitric acid (0·5 ml.) in acetic anhydride (1·5 ml.) was added slowly to a suspension of the 3-nitrate (0·5 g.) in acetic anhydride (1·5 ml.), at 0°. The resulting solid, recrystallized from methanol, gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dinitrate (0·36 g.), m. p. 122—123°.

A suspension of the 3-nitrate (0·1 g.) in paraldehyde (1 ml.) and concentrated sulphuric acid (0·2 drop) was shaken until the solid had dissolved (5 min.). The mixture was left for 30 min. more at room temperature, then chloroform and potassium carbonate were added. Evaporation of the filtered solution gave a solid (0·06 g.), which was recrystallized from ether–light petroleum as fine needles of methyl 4 : 6-*O*-ethylidene-α-D-glucoside 3-nitrate, m. p. 176°.

Characterization of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2-*Nitrate*.—A mixture of methanesulphonyl chloride (0·1 g.), the 2-nitrate (0·1 g.), and pyridine (1 ml.) was kept for 20 hr. at 0°. The product yielded a solid (0·09 g.), which after two recrystallizations from methanol was shown to be methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-methanesulphonate 2-nitrate, m. p. 185°.

Derivatives of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Nitrate*.—(*a*) Fused sodium acetate (1 g.), 3-nitrate (2 g.), and acetic anhydride (10 ml.) were heated together for 1 hr. at 100° and then poured into ice-water. The resulting solid was recrystallized from light petroleum, to give thin plates of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2-*acetate* 3-*nitrate* (1·83 g.), m. p. 110°, $[\alpha]_D^{18}$ +83·7° (*c*, 1·0 in $CHCl_3$) (Found : C, 51·8; H, 5·3. $C_{16}H_{19}O_9N$ requires C, 52·0; H, 5·2%).

(*b*) A solution of the 3-nitrate (1 g.) and toluene-*p*-sulphonyl chloride (1 g.) in pyridine (5 ml.) was left at room temperature for 5 days. The product, recrystallized from methanol, was thin plates of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 3-*nitrate* 2-*toluene*-p-*sulphonate* (1·15 g.), m. p. 161—162°, $[\alpha]_D^{16}$ +59° (*c*, 0·9 in $CHCl_3$) (Found : C, 52·2; H, 5·0; S, 6·7. $C_{21}H_{23}O_{10}NS$ requires C, 52·4; H, 4·8; S, 6·7%).

(*c*) Methanesulphonyl chloride (3 ml.) was added dropwise to a solution of the 3-nitrate (5 g.) in pyridine (25 ml.) at 0°. The mixture was kept at 0° for 20 hours. Recrystallized from methanol, the product yielded needles of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2-*methanesulphonate* 3-*nitrate* (5·82 g.), m. p. 129—130°, $[\alpha]_D^{15}$ +68·8° (*c*, 1·0 in $CHCl_3$) (Found : C, 44·8; H, 4·9. $C_{15}H_{19}O_{10}NS$ requires C, 44·5; H, 4·7%).

(*d*) Silver oxide (6 g.) was added in portions during 3 hr. to a suspension of the 3-nitrate (3 g.) in boiling methyl iodide (15 ml.). The mixture was boiled for a further 19 hr. before the silver residue was filtered off. The residue was washed with methanol, and the washings and filtrate were combined and evaporated. The resulting solid (3 g.), m. p. 114—115°, recrystallized from light petroleum, was *methyl* 4 : 6-O-*benzylidene*-2-O-*methyl*-α-D-*glucoside* 3-*nitrate*, m. p. 116—117°, $[\alpha]_D^{20}$ +83·7° (*c*, 1·0 in $CHCl_3$) (Found : C, 53·4; H, 5·6. $C_{15}H_{19}O_8N$ requires C, 52·8; H, 5·6%).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Nitrate*.—(*a*) A 2·6N-solution of sodium methoxide in methanol (9 ml.) was added to a solution of carefully purified methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate (1·5 g., 1 mol.) in chloroform (37·5 ml.), and the mixture was kept for 7 days at room temperature. The colourless mixture was then shaken with water to remove alkali. Sodium nitrite was present in the aqueous layer. Evaporation of the chloroform layer gave a solid, which was chromatographed on alumina in benzene. The first fractions eluted with benzene gave an unidentified syrup (0·13 g.), then, after a distinct break, more syrup was obtained, which crystallized from light petroleum as granular crystals of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-nitrate (0·07 g.), m. p. and mixed m. p. 134—135°. Subsequent fractions, including those obtained by washing the column with chloroform, were combined and recrystallized from carbon tetrachloride to give unchanged 3-nitrate (0·66 g.), m. p. and mixed m. p. 171—172°. A mixture of the 3-nitrate (0·02 g.), m. p. 174°, and the 2-nitrate (0·001 g.), m. p. 136°, softened at 130°, and melted at 145—165°.

(*b*) Sodium methoxide in methanol (2·4 ml.; 2·6N) was boiled under reflux for 1 hr. with the 3-nitrate (1 g.) in methanol (10 ml.). The brown solution, cooled to 0°, deposited methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·17 g.). The filtered solution, after neutralization with acetic acid, was evaporated to a residue, whose chloroform extract was chromatographed on alumina. The early fractions eluted by chloroform gave solid (0·19 g.), which, twice recrystallized from carbon tetrachloride, was unchanged 3-nitrate (0·11 g.). Subsequent fractions, including that obtained by washing of the column with ethanol, were combined and identified as methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·30 g.).

(*c*) 3-Nitrate (2 g.) in methanol (40 ml.) was boiled for 24 hr. with sodium methoxide in

methanol (4·7 ml.; 2·6N). The dark, neutralized solution was evaporated to a tar which was extracted with chloroform (50 ml.). Evaporation of the chloroform solution left a brown, partly solid mass, which was chromatographed on alumina (70 g.) in chloroform solution. First fractions gave, after recrystallization from methanol, methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·15 g.). Subsequent fractions yielded an unidentified syrup (0·36 g.). When the column was washed with alcohol methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·60 g.) was obtained.

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-2-O-*methyl*-α-D-*glucoside* 3-*Nitrate*.—Sodium methoxide in methanol (2·4 ml.; 2·6N) was boiled under reflux for 1 hr. with methyl 4 : 6-*O*-benzylidene-2-*O*-methyl-α-D-glucoside 3-nitrate (1 g.) in methanol (10 ml.). The dark, cold solution deposited crystals of starting compound (0·54 g.). The mother-liquor, neutralized with acetic acid, was evaporated to a solid, to which chloroform was added. The insoluble inorganic residue, containing nitrite, was filtered off. Evaporation of the filtrate left a residue, which was chromatographed in benzene solution on alumina. First fractions eluted with benzene gave a solid which, recrystallized from light petroleum, was starting compound (0·12 g.). When the eluant was changed to chloroform, a solid (0·08 g.) was obtained, which was recrystallized from chloroform–light petroleum and identified as methyl 4 : 6-*O*-benzylidene-2-*O*-methyl-α-glucoside, m. p. 166—168°, undepressed on admixture with an authentic sample supplied by Dr. D. J. Bell.

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Nitrate* 2-*Toluene*-p-*sulphonate*.—(*a*) The 3-nitrate 2-toluene-*p*-sulphonate (1·0 g.) in chloroform (10 ml.) was mixed with sodium methoxide in methanol (2·0 ml.; 2·6N) and kept for 24 hr. at 0°. The solution, diluted with chloroform, was washed free from alkali with water and evaporated. The aqueous washings, which contained nitrite, were optically inactive. Evaporation of the chloroform solution left a residue which was chromatographed in ether on alumina. The first fractions eluted with ether gave a solid (0·45 g.), which, after recrystallization from methanol, yielded starting compound (0·25 g.). Further elution with ether–chloroform gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-nitrate (0·22 g.).

(*b*) Sodium methoxide in methanol (3·6 ml.; 2·6N) was added to the ester (1·5 g.) in chloroform (10 ml.), and the mixture was kept at 0° for 48 hr. The crude products were isolated as in (*a*) and chromatographed in benzene on alumina. Benzene, followed by chloroform, eluted starting compound (0·17 g.), methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-nitrate (0·10 g.), and the 3-nitrate (0·37 g.).

(*c*) The quantities of reactants used in (*b*) but dissolved in methanol (10 ml.) only were boiled under reflux for 1·75 hr. Methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·5 g.) was deposited from the cooled solution, neutralized with acetic acid. The residue from the evaporated solution was extracted with chloroform, and the chloroform solution was evaporated to a dark syrup, which was chromatographed from benzene on alumina. After an unidentified syrup (0·07 g.), the benzene eluate yielded crystals (0·015 g.) which, recrystallized, proved to be the anhydro-alloside. Elution with chloroform gave slightly impure 3-nitrate (0·03 g.), m. p. and mixed m. p. 169—170°, and finally elution with ethanol gave crystals (0·12 g.) which, recrystallized from chloroform–light petroleum, were methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·09 g.).

(*d*) The ester (2 g.) in methanol (50 ml.), and sodium methoxide in methanol (4·8 ml.; 2·6N), were boiled under reflux for 24 hr. The dark brown solution was then neutralized with acetic acid and evaporated. The residue, containing nitrite, was extracted with chloroform (50 ml.), and the chloroform solution was chromatographed on alumina. First fractions yielded, after recrystallization from chloroform–light petroleum, methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·06 g.). Subsequent elution with ethanol followed by recrystallization from water gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·13 g.).

Alkaline Hydrolysis of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2-*Nitrate* 3-*Toluene*-p-*sulphonate*.—(*a*) The 2-nitrate 3-toluene-*p*-sulphonate (1·5 g.) in chloroform (10 ml.) was kept with sodium methoxide in methanol (3·6 ml.; 2·6N), at 0° for 48 hr. The colourless solution was diluted with chloroform, washed with water, and evaporated to a solid. The aqueous washings contained nitrite, and had a small positive optical rotation. A benzene solution of the solid was chromatographed on alumina. Benzene eluted first unchanged starting compound (0·19 g.), then a solid (0·40 g.), which, recrystallized from benzene, gave methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·26 g.). Final elution with chloroform gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-toluene-*p*-sulphonate (0·13 g.).

(*b*) The ester (1·5 g.) in methanol (10 ml.) was boiled under reflux with sodium methoxide

in methanol (3·6 ml.; 2·6N) for 1·5 hr. The dark solution, on cooling, deposited methyl 2 : 3-anhydro-4 : 6-*O*-benzylidene-α-D-alloside (0·16 g.). The filtrate was neutralized with acetic acid and evaporated to a syrup, whose benzene solution was chromatographed on alumina. No products were eluted with benzene, but with chloroform more anhydro-alloside (0·015 g.) was obtained, followed by a syrup (0·45 g.). No products were eluted with ethanol. The syrup was dissolved in chloroform–benzene (1 : 1) and rechromatographed, this solvent mixture being used as eluant. The resulting syrup crystallized (0·38 g.), and was recrystallized several times from ether–light petroleum, to give an unidentified product, m. p. 112° (Found : C, 59·5; H, 6·65%).

Alkaline Hydrolysis of Methyl α-D-*Glucoside* 2 : 3 : 4-*Triacetate* 6-*Nitrate*.—Sodium methoxide in methanol (12·5 ml.; 2·6N) was added to methyl α-D-glucoside 2 : 3 : 4-triacetate 6-nitrate (2·47 g.) in methanol (62·5 ml.), and the solution was boiled under reflux for 24 hr. The solution was neutralized with glacial acetic acid and then evaporated. The filtered chloroform solution of the residue, chromatographed on alumina, yielded a product (0·88 g.), m. p. 103—106°, which after recrystallization from chloroform–light petroleum was methyl 3 : 6-anhydro-α-D-glucopyranoside, m. p. 106—108°, $[\alpha]_D^{18}$ +53° (*c*, 0·1 in H_2O).

Reactions of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2 : 3-*Dinitrate*.—(a) ***With sodium iodide in acetone.*** Sodium iodide (21 g.) and the 2 : 3-dinitrate (10·5 g.) were boiled in acetone (87 ml.) for 20 hr. Nitric oxide was evolved, and iodine was liberated. Evaporation of the acetone gave a nitrite-containing lachrymatory solid, which was extracted several times with chloroform. The combined extracts were washed with water and with aqueous sodium thiosulphate, decolorized with charcoal, and evaporated. The residue was extracted with boiling light petroleum (100 ml.), and the insoluble portion was recrystallized from carbon tetrachloride to yield 3-nitrate (4·4 g.). When the light petroleum extract was cooled, a syrup separated, which partly crystallized. Recrystallization from methanol gave prisms of starting compound (1·35 g.).

(b) ***With sodium iodide in methanol.*** A sealed tube containing the 2 : 3-dinitrate (2 g.) and sodium iodide (2 g.) dissolved in methanol (15 ml.) was heated at 100° for 20 hr. Chloroform and water were added and the mixture was titrated with 0·2036N-sodium thiosulphate. The chloroform layer was then separated, and the aqueous layer was extracted once more with chloroform. Water was added to the aqueous layer to make 250 ml. Potassium iodide solution (10 ml.; 10%) was added to portions (50 ml.) of this solution, and nitrogen was bubbled through it. Hydrochloric acid (20 ml.; 2N) was introduced below the liquid surface, and the liberated iodine was titrated with 0·0504N-sodium thiosulphate. When a portion of the solution was boiled with ammonium chloride (1 g.) for 5 min. before addition of the potassium iodide and acid, no iodine was liberated.

The combined chloroform extracts were evaporated to a residue, whose benzene solution was chromatographed on alumina. The benzene eluant gave starting compound : the 3-nitrate was obtained when the column was subsequently eluted with chloroform. No further products were obtained on elution with ethanol. The compounds were identified by m. p. and mixed m. p. with an authentic specimen. The results are recorded in Table 1.

(c) ***With sodium nitrite in aqueous ethanol.*** The 2 : 3-dinitrate (8 g.) and sodium nitrite (4 g.) were boiled in ethanol (40 ml.) and water (10 ml.) for 21 hr. The solvent was evaporated, and the white solid residue was extracted with chloroform. The chloroform extracts were washed with water, and evaporated to a white solid, which was boiled with potassium carbonate solution (50 ml.; 2%). The solid which remained undissolved was filtered off and recrystallized from methanol, to give needles of 3-nitrate (4·96 g.). The solid obtained by concentration and cooling of the potassium carbonate solution was, after recrystallization from chloroform–light petroleum, methyl 4 : 6-*O*-benzylidene-α-D-glucoside (0·3 g.).

When the 2 : 3-dinitrate (2 g.) alone was boiled with aqueous ethanol for 20 hr., starting compound (1·7 g.) was the only product isolated.

Reactions of Methyl 4 : 6-O-*Ethylidene*-α-D-*glucoside* 2 : 3-*Dinitrate*.—(a) ***With sodium iodide in acetone.*** The 2 : 3-dinitrate (3 g.) in acetone (25 ml.) containing sodium iodide (6 g.) was heated in a sealed tube at 100° for 24 hr. The evaporated mixture was extracted with chloroform, and the extract was washed successively with water, sodium thiosulphate solution, and sodium hydrogen carbonate solution, and evaporated. The white solid (1·45 g.) obtained was recrystallized from ether–light petroleum as fine needles of 3-nitrate.

(b) ***With sodium iodide in pyridine.*** Sodium iodide (4 g.) and the 2 : 3-dinitrate (2 g.) were boiled for 30 min. in pyridine (20 ml.). Oxides of nitrogen were evolved, and iodine was liberated. When the mixture was poured into water, no solid separated but, when the solution

was concentrated and cooled, fine needles (0·92 g.) appeared. These, recrystallized from ether–light petroleum, were 3-nitrate. Concentration of the aqueous-pyridine solution gave more 3-nitrate (0·1 g.).

When the 2 : 3-dinitrate (2 g.) was heated to 100° for 30 min. in pyridine (20 ml.) alone, the solution darkened. The mixture was poured into ice-water; a solid (1·7 g.) separated, which recrystallized from light petroleum as stout needles (1·54 g.) of starting compound.

(c) *With sodium nitrite in aqueous ethanol.* A solution of the 2 : 3-dinitrate (4·3 g.) and sodium nitrite (2·5 g.) in ethanol (20 ml.) and water (5 ml.) was boiled for 17 hr. The concentrated solution was shaken with chloroform and water, and the chloroform layer was evaporated. The solid residue, recrystallized from ether, gave 3-nitrate (2·5 g.).

Attempted Reaction of Sulphonates and Acetate with Sodium Iodide.—(*a*) Methyl 4 : 6-*O*-ethylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate (2 g.) and sodium iodide (4 g.) were boiled for 17 hr. in dry pyridine (20 ml.). Pouring the mixture into ice-water gave a white solid which was filtered off and recrystallized from methanol as thin plates of starting compound (1·3 g.).

(*b*) When methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-diacetate (2·0 g.) was heated with sodium iodide in acetone in a sealed tube at 100° for 20 hr., starting compound (1·9 g.) was recovered.

(*c*) After similar treatment of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-dimethanesulphonate (3·0 g.) with sodium iodide in acetone starting compound (2·5 g.) was obtained.

(*d*) After methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2 : 3-ditoluene-*p*-sulphonate was heated with sodium iodide and acetone in a sealed tube at 100° for 21 hr. the starting compound (88%) was recovered.

Unchanged 2 : 3-ditoluene-*p*-sulphonate was also recovered (90%) after being boiled with sodium nitrite in ethanol for 48 hr.

Reactions of Sodium Iodide in Acetone with Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 3-*Nitrate*, 3-*Nitrate* 2-*Toluene*-p-*sulphonate*, 3-*Nitrate* 2-*Methanesulphonate*, *and* 2-*Acetate* 3-*Nitrate*.—A solution of the 3-nitrate (2 g.) and sodium iodide (4 g.) in acetone (15 ml.) was heated in a sealed tube at 100° for 20 hr. The solid obtained on evaporation was extracted with chloroform, and the chloroform solution was washed with water and aqueous sodium thiosulphate and decolorized with charcoal. Evaporation left a white solid, which was extracted with hot aqueous potassium carbonate (25 ml.; 2%). The insoluble part (1·22 g.), after recrystallization from methanol, was starting compound. The needles (0·37 g.), m. p. 160—161°, which separated from the cold potassium carbonate extract were, after recrystallization from chloroform–light petroleum, methyl 4 : 6-*O*-benzylidene-α-D-glucoside.

The 3-nitrate 2-toluene-*p*-sulphonate was treated as in the previous experiment. Chloroform and water were added to the evaporated reaction products, which did not include nitrite, and the mixture was then shaken with aqueous sodium thiosulphate. The chloroform layer was evaporated to a syrup which, crystallized and recrystallized from methanol, gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-toluene-*p*-sulphonate (1·19 g.).

The 2-methanesulphonate 3-nitrate (2 g.) was treated as in the previous experiments. Again the products did not contain nitrite. The washed chloroform extract afforded crystals which were washed with boiling light petroleum, and then recrystallized twice from methanol to give needles (1·31 g.) of *methyl* 4 : 6-O-*benzylidene*-α-D-*glucoside* 2-*methanesulphonate*, m. p. 132—133° (depressed to 105—115° when mixed with starting compound, m. p. 129—130°), $[\alpha]_D^{23}$ +72° (*c*, 1·2 in $CHCl_3$) (Found: C, 49·8; H, 5·4. $C_{15}H_{20}O_8S$ requires C, 50·0; H, 5·6%). The 2-acetate 3-nitrate (1·5 g.) was similarly treated. The residue obtained by evaporation of the reaction mixture was extracted with chloroform. The chloroform solution was washed with aqueous sodium thiosulphate and evaporated to a syrup, which, dissolved in benzene, was chromatographed on alumina. First fractions gave starting compound (0·51 g.). Further elution with chloroform gave a solid (0·61 g.), which was recrystallized from chloroform–light petroleum to give needles (0·28 g.), found after two more recrystallizations to be methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-acetate, m. p. 182°, $[\alpha]_D^{18}$ +115° (*c*, 0·9 in $CHCl_3$), mixed m. p. 174—180° with an authentic compound of m. p. 173° [Bourne *et al.* (*loc. cit.*)]. Concentration of the first recrystallization mother-liquor gave methyl 4 : 6-*O*-benzylidene-α-D-glucoside 3-acetate (0·09 g.), m. p. 131°, $[\alpha]_D^{17}$ +110° (*c*, 0·65 in $CHCl_3$), mixed m. p. 128—130° with an authentic sample of m. p. 128°.

Characterization of Methyl 4 : 6-O-*Benzylidene*-α-D-*glucoside* 2-*Methanesulphonate*.—Fuming nitric acid (0·2 ml.) in acetic anhydride (1·0 ml.) was added to a suspension of the 2-methanesulphonate (0·2 g.) in acetic anhydride (0·5 ml.) at 0°. After 15 min. at 0°, the mixture was

poured into ice-water, a syrup separating. The aqueous solution was decanted and sufficient hot methanol was added to dissolve the syrup. Cooling afforded needles of methyl 4 : 6-*O*-benzylidene-α-D-glucoside 2-methanesulphonate 3-nitrate (0·07 g.), m. p. 126—127°, which after a recrystallization had m. p. and mixed m. p. 129°.

Reaction of Methyl 4 : 6-O-*Benzylidene-α-D-glucoside* 2 : 3-*Dinitrate with Pyridine containing Hydroxylamine Hydrochloride.*—When the 2 : 3-dinitrate (2 g.) in pyridine (20 ml.) was heated to 100° for 4·5 hr. crystals appeared in the condenser and brown fumes were evolved. No product separated when the dark brown mixture was poured into water.

When the 2 : 3-dinitrate (2 g.) in pyridine (20 ml.) containing hydroxylamine hydrochloride (2 g.) was heated at 100° for 4 hr. the solution was not coloured, no brown fumes were evolved, and pouring the mixture into water gave a syrup which solidified after several changes of water. This solid, recrystallized from ethanol–light petroleum, gave a compound (0·05 g.) which after recrystallization from chloroform was *methyl* 4 : 6-O-*benzylidene*-2 : 3-*dideoxy*-2 : 3-*dioxo*-α-D-*glucoside* 2 : 3-*dioxime* (Found : C, 54·4; H, 5·1; N, 8·6. $C_{14}H_{16}O_6N_2$ requires C, 54·5; H, 5·2; N, 9·1%). The compound sublimed in the m. p. tube at 170—180° and decomposed at 180°. Some starting compound was recovered from the recrystallization mother-liquors.

Extraction of the aqueous pyridine mother-liquor with chloroform gave, in both experiments, a dark syrup.

The dinitrate was recovered (77%) after 24 hr. at room temperature in pyridine containing hydroxylamine hydrochloride.

The authors thank Drs. D. J. Bell, J. Cymerman-Craig, and D. Lloyd, and Professor M. Stacey for supplying authentic samples for identification purposes, and the Department of Scientific and Industrial Research for a Maintenance Allowance awarded to J. W. W. M. The work was completed during the tenure (by J. H.) of the Harold Hibbert Memorial Fellowship of McGill University, Montreal, and (by J. W. W. M.) of a Post-doctoral Fellowship of Ohio State University.

KING'S COLLEGE, STRAND, LONDON, W.C.2.
McGILL UNIVERSITY, MONTREAL, P.Q., CANADA. [*Received, May 16th,* 1955.]