699. *Nitrogen-containing Carbohydrate Derivatives. Part VII.*[1] *Ring-opening Reactions of Epimino-sugars* *

By R. D. Guthrie and D. Murphy

Methyl 4,6-*O*-benzylidene-2,3-dideoxy-2,3-epimino-α-D-mannoside (I) and the corresponding alloside (II) have been opened with azide ion to give *trans*-diaxial products. Opening of the substituted epimines follows the same pattern with the exception of the *N*-benzoylepimino-alloside which opens diequatorially, to give a D-*gluco*-product. This abnormal opening is discussed.

In Part IV [2] we described a route to methyl 4,6-*O*-benzylidene-2,3-dideoxy-2,3-epimino-α-D-mannoside (I) and the corresponding alloside (II), potential intermediates for the synthesis of amino-deoxy-, amino-mercapto-, and diamino-sugar derivatives. The epimines have now been allowed to react with azide ion to yield amino-azido-derivatives. These reactions are of interest for comparison with the opening of the corresponding epoxides, which have been shown to open to give mainly *trans*-diaxial products (D-*altro*-configuration) [2,3] with a little of the *trans*-diequatorial product (D-*gluco*-configuration).

Hassner and Heathcock [4] have shown, in work concurrent with ours, that the opening of an epimine ring on ring A of the steroid nucleus gave a *trans*-diaxial product.

Reaction of the 2,3-epimino-mannoside (I) with sodium azide in boiling 95% 2-methoxyethanol gave a crystalline methyl amino-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-glycoside (*P*) (54%) and unchanged epimine (15%). No other amino-azido-product could be isolated by column chromatography. Acylation by standard procedures gave the *N*-acetyl and *N*-benzoyl derivatives. Reduction gave a syrupy diamino-derivative which was characterised as a crystalline diacetamido derivative (*PR*).

Similar reaction of the corresponding 2,3-epimino-alloside (II) gave another methyl amino-azido-2,3-dideoxy-α-D-glycoside (*Q*); again no other products were isolated by chromatography. Product (*Q*) was characterised as its *N*-acetyl and *N*-benzoyl derivatives, and by reduction followed by acetylation to give a diacetamido-derivative identical with (*PR*). The formation of the same diamino-compound from both epimines rules out *cis* opening. Thus the observed opening is *trans* and both (*P*) and (*Q*) must have the same basic configuration, namely D-*gluco* or D-*altro* with the amino- and azido-groups on $C_{(2)}$ and $C_{(3)}$ or *vice versa*.

Consider now the two possible structures (III) and (V) of the product (*Q*) from the epimino-alloside. Acid hydrolysis should remove the benzylidene group and give as product either methyl 3-amino-2-azido-2,3-dideoxy-α-D-altroside hydrochloride (IV) or methyl 2-amino-3-azido-2,3-dideoxy-α-D-glucoside hydrochloride (VI). The D-*altro*-product would react with periodate owing to the vicinal amino-alcohol system on $C_{(3)}$ and $C_{(4)}$ whereas the D-*gluco*-product would not.

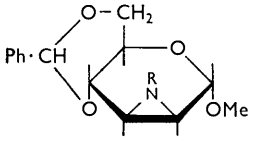
Treatment of product (*Q*) with dilute hydrochloric acid gave a crystalline methyl amino-azido-2,3-dideoxy-α-D-glycoside hydrochloride (85%). Oxidation of this compound by aqueous sodium periodate resulted in the consumption of one mol. of oxidant as determined by the ultraviolet spectrophotometric method,[5] for reasons given elsewhere.[6] Thus

* This work was reported to the International Carbohydrate Chemistry Symposium, Münster, Germany, July 1964.

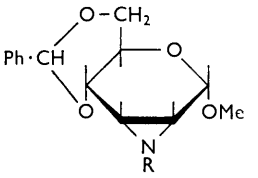
[1] Part VI, R. D. Guthrie, and G. P. B. Mutter, *J.*, 1964, 1614.
[2] R. D. Guthrie and D. Murphy, *J.*, 1963, 5288.
[3] R. H. Newth, *Quart. Rev.*, 1959, **13**, 20.
[4] A. Hassner and C. Heathcock, *Tetrahedron Letters*, 1963, 393.
[5] G. O. Aspinall and R. J. Ferrier, *Chem. and Ind.*, 1956, 1216.
[6] C. B. Barlow, R. D. Guthrie, and D. Murphy, *J.*, 1965, 3870.

product (*Q*) is the expected methyl 3-amino-2-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside, and hence (*P*) is methyl 2-amino-3-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside. The opening of the free epimino-ring is therefore analogous to the opening of the corresponding epoxides.

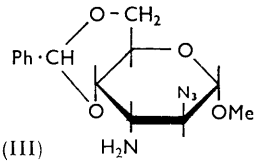
Comparison of the optical rotations of the amino-azido compounds with the corresponding azidohydrins supports the structures assigned above. It has been shown that replacement of a hydroxyl group by an amino-function does not appreciably alter the molecular



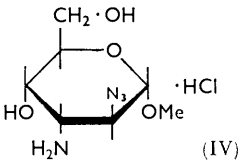
(I: R = H)
(Ia: R = Ac)
(Ib: R = CO·Ph)



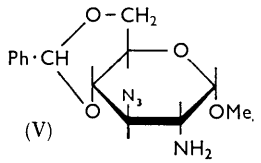
(II: R = H)
(IIa: R = Ac)
(IIb: R = COPh)



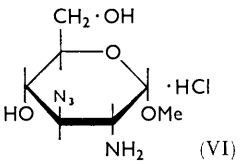
(III)



(IV)



(V)



(VI)

rotation.[7,8] Comparison of the rotation of the product (*Q*) from azidolysis of the epimino-alloside with that of methyl 2-azido-4,6-*O*-benzylidene-2-deoxy-α-D-altroside and that of the corresponding 3-azido-glucoside indicates that product (*Q*) does indeed have the D-*altro*-configuration. Methyl 2-azido-4,6-*O*-benzylidene-2-deoxy-α-D-glucoside is not known, but comparison of product (*P*) with methyl 3-azido-4,6-*O*-benzylidene-3-deoxy-α-D-altroside again suggests an D-*altro*-configuration.

Molecular rotations in chloroform of methyl 4,6-*O*-benzylidene-α-D-glycoside

	[*M*]
2-Azido-2-deoxy-altroside [2]	+200°
3-Azido-3-deoxy-glucoside [2]	+436
3-Amino-2-azido-2,3-dideoxy-altroside (*Q*) (III)	+204
3-Azido-3-deoxy-altroside [2]	+116
2-Amino-3-azido-2,3-dideoxy-altroside (*P*)	+126

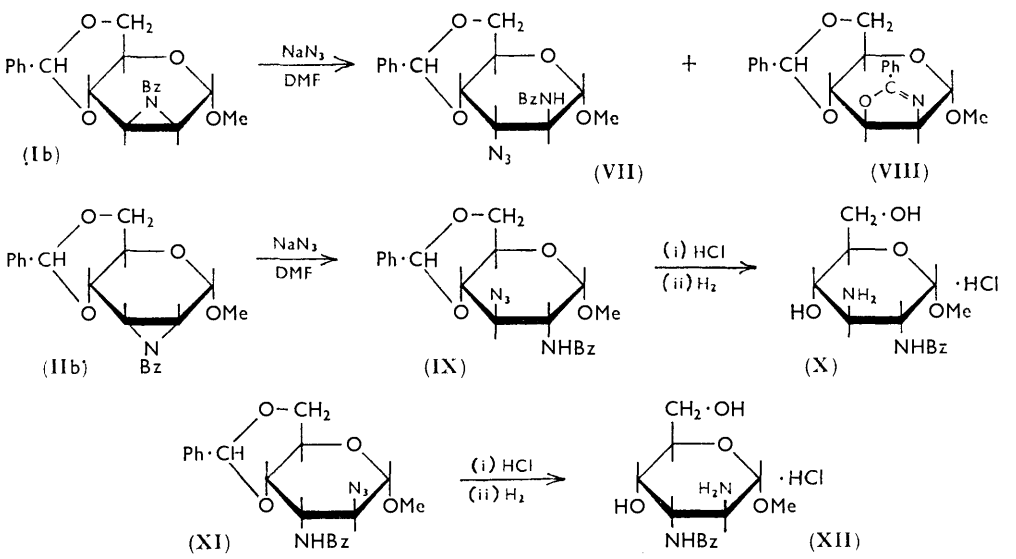
The first attempts to hydrolyse methyl 3-amino-2-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside for the above proof were carried out with 50% aqueous acetic acid. The crystalline product obtained however had an elemental analysis which had $C_2H_4O_2$ greater than that required for methyl 3-amino-2-azido-2,3-dideoxy-α-D-altroside. Treatment of the product with dilute methanolic hydrogen chloride gave the hydrochloride (IV) described above. Thus the hydrolysis product from using aqueous acetic acid appears to be the acetate of methyl 3-amino-2-azido-2,3-dideoxy-α-D-altroside. This assignment is supported by the optical rotations of the two compounds: acetate, $[M]_D$ +72·8°; hydrochloride, $[M]_D$ +78·4°. The agreement is good enough to suggest that both values are for the same species, the protonated amino-azido-altroside. The formation of a stable acetate suggests that the amino-group in this compound is more strongly basic than is normal in amino-sugars.

[7] R. H. Dickey, W. Ficket, and H. J. Lucas, *J. Amer. Chem. Soc.*, 1952, **74**, 944.
[8] B. Lindberg and O. Theander, *Acta Chem. Scand.*, 1959, **13**, 1226.

The work of Heine [9] has shown that simple *N*-acylepimines are relatively unstable substances, subject to rearrangement both thermally, and in the presence of nucleophils under the conditions in which the epimino-glycosides (I) and (II) are opened by azide ion. The reactions of the *N*-acetylepimines (Ia) and (IIa), and the *N*-benzoylepimines (Ib) and (IIb) with sodium azide were therefore investigated.

Treatment of the *N*-acetylepimines with sodium azide in 2-methoxyethanol or in *NN*-dimethylformamide gave only products identical with those obtained on azidolysis of the parent epimines. The ease of hydrolysis of the acetyl groups had already been observed; 1·5-N-aqueous potassium hydroxide converted the *N*-acetylepimino-mannoside (Ia) into the epimine (I) in 10 min.[2] Thus, it appeared that in the attempted azidolyses the first step was hydrolysis of the starting material to the epimines, which then opened as described previously.

Treatment of the *N*-benzoylepimine-mannoside (Ib) with sodium azide and ammonium



chloride in boiling *NN*-dimethylformamide gave a mixture of methyl 3-azido-2-benzamido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside (VII) (20%) and methyl 4,6-*O*-benzylidene-2,3-dideoxy-3,2-(2-phenyl-1-oxa-3-azaprop-2-eno)-α-D-mannoside (VIII) (36%). The oxazoline product had physical constants identical with those reported by Buss *et al.*[10] Thus in the case of the benzoylepimino-mannoside (Ib) there has been competition between "normal" opening, to give diaxial product, by the azide ion, and rearrangement to oxazoline in the way reported by Heine [9] for simple *N*-benzoylepimines.

Similar reaction of the *N*-benzoylepimino-alloside (Ib) with sodium azide gave a crystalline methyl azido-benzamido-benzylidene-dideoxy-α-D-glycoside (70%). This compound was different from methyl 2-azido-3-benzamido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside (XI) [obtained from the parent epimino-alloside (IIb) and subsequent benzoylation]. Therefore it was probably methyl 3-azido-2-benzamido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-glucoside (IX). Treatment of the azido-benzamido-glycosides (IX) and (XI) with boiling 50% acetic acid gave methyl 2-azido-3-benzamido-2,3-dideoxy-α-D-glucoside and methyl 3-azido-2-benzamido-2,3-dideoxy-α-D-altroside, respectively. Catalytic hydrogenation, in the presence of methanolic hydrogen chloride, of these azides gave the corresponding amino-compounds as the hydrochlorides (X) and (XII). The assignments were found to be correct by periodate oxidation of the hydrochlorides (X) and

[9] H. W. Heine, *Angew. Chem.* (*Internat. Edn.*), 1962, **1**, 528.
[10] D. H. Buss, L. Hough, and A. C. Richardson, *J.*, 1963, 5295.

(XII) in solution buffered to pH 6·93. As expected the glucoside (X) reacted with periodate while the altroside (XII), which has no vicinal amino-alcohol system, did not react in 48 hr.

The reaction of the *N*-benzoylepimino-alloside (IIb) with sodium azide is in agreement with the concurrent work of Meyer zu Reckendorf [11] who has recently described the synthesis of methyl 4,6-*O*-benzylidene-2,3-dideoxy-2,3-benzoylepimino-β-D-alloside. He reported that in the β-series the *N*-benzoylepimino-alloside reacted with sodium azide to give exclusively methyl 3-azido-2-benzamido-4,6-*O*-benzylidene-2,3-dideoxy-β-D-glucoside by diequatorial opening. The structure of this compound was proved by its synthesis by another route.

Treatment of the epimines (I) and (II) with toluene-*p*-sulphonyl chloride in pyridine gave the *N*-toluene-*p*-sulphonyl derivatives in good yield. However, reaction of these compounds with sodium azide as described for the benzoyl derivatives gave products identical with those obtained by toluene-*p*-sulphonylation of the amino-azido-altrosides from opening of the free epimines. Thus, the *N*-toluene-*p*-sulphonyl-epimines opened to give diaxial products. Treatment of the epimino-alloside (I) with 1-fluoro-2,4-dinitrobenzene in *NN*-dimethylformamide–sodium carbonate at room temperature gave the *N*-(2,4-dinitrophenyl)epimino-alloside. Reaction of this compound with sodium azide gave only a product identical with that obtained by treating the 3-amino-2-azidoaltroside with 1-fluoro-2,4-dinitrobenzene. From the results obtained so far it appears therefore that the diequatorial opening is peculiar to the *N*-benzoylepimino-alloside (IIb).

The reason for the anomalous diequatorial opening in one case only is not clear. As the *N*-benzoylepimino-mannoside (Ib) opens normally, the mere presence of the benzoyl group cannot account for it. It is possible that both *N*-benzoylepimino-glycosides react *via* similar oxazolinium ion intermediates. Electron withdrawal by the inductive effect of the two oxygen atoms bound to $C_{(1)}$ causes the electron density at $C_{(3)}$ to be greater than that at $C_{(2)}$. Thus, in an intramolecular rearrangement of either epimine derivative, the $C_{(3)}$–N bond should be more easily broken than the $C_{(2)}$–N bond. In such a mechanism, the PhCO group can readily resonance-stabilise the necessary ionic intermediates; in none of the other systems studied is this stabilisation available. Further work is in progress in order to explore this anomalous behaviour.

Experimental

For general details see Part IV.[2] Azides were reduced using methanolic hydrazine hydrate and Raney nickel.[2] Chromatography was on alumina (Spence). Rotations were for chloroform solutions unless otherwise stated. *NN*-Dimethylformamide will be referred to as DMF.

Preparation of N-*Substituted Epimino-glycosides*.—Reaction of the epimino-mannoside (I) with toluene-*p*-sulphonyl chloride–pyridine in the usual way gave a white solid. The product, on recrystallisation from propan-2-ol, gave *methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-*toluene*-p-*sulphonylepimino*-α-D-*mannoside* (90%), m. p. 118—120°, $[\alpha]_D^{25}$ −6·8° (*c* 1·18) (Found: C, 60·3; H, 5·4. $C_{21}H_{23}NO_6S$ requires C, 60·4; H, 5·6%).

Treatment of the epimino-alloside (II) with toluene-*p*-sulphonyl chloride–pyridine in the usual way gave, after recrystallisation from propan-2-ol, *methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-*toluene*-p-*sulphonylepimino*-α-D-*alloside* (85%), m. p. 217—219°, $[\alpha]_D^{20}$ +61·6° (*c* 0·88) (Found: C, 60·6; H, 5·7. $C_{21}H_{23}NO_6S$ requires C, 60·4; H, 5·6%).

The epimino-alloside (II) (0·8 g.) in DMF (10 ml.) was stirred with 1-fluoro-2,4-dinitrobenzene (0·6 g.) and sodium hydrogen carbonate (2 g.) for 16 hr. at room temperature. Pouring into ice–water (200 ml.) and addition of sodium chloride (5 g.) gave a solid product which was well-washed with water. Recrystallisation from propan-2-ol gave *methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-(2,4-*dinitrophenyl*)*epimino*-α-D-*alloside* (78%), m. p. 195—197°, $[\alpha]_D^{21}$ +176° (*c* 1·38) (Found: C, 56·0; H, 4·6. $C_{20}H_{19}N_3O_8$ requires C, 55·9; H, 4·5%).

Azidolysis of the 2,3-*Epimino-glycosides* (I) *and* (II) *and their* N-*Substituted Derivatives*.—(a) *Methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-*epimino*-α-D-*mannoside* (I). Sodium azide (7 g.),

[11] W. Meyer zu Reckendorf, *Chem. Ber.*, 1964, **97**, 325.

ammonium chloride (1·2 g.), and the epimino-mannoside (7 g.) in 2-methoxyethanol (150 ml.) and water (15 ml.) were boiled under reflux for 6 hr. Cooling and evaporation gave a syrupy mass. The syrup was extracted with anhydrous ethyl acetate (3 × 50 ml.), and the extract evaporated to give a syrup which was chromatographed. Elution with benzene–chloroform (10 : 1) gave a solid which on recrystallisation from aqueous ethanol gave unchanged epimino-mannoside (I) (15%), m. p. 145—146°. Elution with benzene–chloroform (1 : 1), followed by recrystallisation from ethanol–light petroleum gave *methyl 2-amino-3-azido-4,6-O-benzylidene-2,3-dideoxy-α-D-altroside* (54%), m. p. 126—127°, $[\alpha]_D^{19}$ +41·1° (*c* 1·07) (Found: C, 54·7; H, 5·8; N, 18·6. $C_{14}H_{18}N_4O_4$ requires C, 54·9; H, 5·9; N, 18·3%).

Acetylation, and recrystallisation of the product from ethanol–light petroleum, gave *methyl 2-acetamido-3-azido-4,6-O-benzylidene-2,3-dideoxy-α-D-altroside* (75%), m. p. 213—214°, $[\alpha]_D^{20}$ +47·5° (*c* 0·78) (Found: C, 55·2; H, 6·0. $C_{16}H_{20}N_4O_5$ requires C, 55·2; H, 5·8%).

Benzoylation of the amino-azido-altroside, and recrystallisation of the product from propan-2-ol gave *methyl 3-azido-2-benzamido-4,6-O-benzylidene-2,3-dideoxy-α-D-altroside* (VII) (60%), m. p. 191—193°, $[\alpha]_D^{22}$ −44·7° (*c* 0·81) (Found: C, 61·4; H, 5·4; N, 13·8. $C_{21}H_{22}N_4O_5$ requires C, 61·5; H, 5·4; N, 13·7%).

Toluene-*p*-sulphonylation of the amino-azido-altroside in pyridine, and recrystallisation of the product from propan-2-ol gave *methyl 3-azido-4,6-O-benzylidene-2,3-dideoxy-2-toluene-p-sulphonamido-α-D-altroside* (86%), m. p. 222—223° (decomp.), $[\alpha]_D^{22}$ +79·6° (*c* 1·02) (Found: C, 54·8; H, 5·4. $C_{21}H_{24}N_4SO_6$ requires C, 54·8; H, 5·3%).

Reduction of the 2-amino-3-azido-altroside gave, after filtration and evaporation, syrupy methyl 2,3-diamino-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside. Acetylation of this product gave, after recrystallisation from ethanol–light petroleum, *methyl 2,3-diacetamido-4,6-O-benzylidene-2,3-dideoxy-α-D-altroside* (58%), m. p. 250° (decomp.), $[\alpha]_D^{19}$ +25·0° (*c* 1·0) (Found: C, 58·8; H, 6·5; N, 7·9. $C_{18}H_{24}N_2O_6$ requires C, 59·3; H, 6·6; N, 7·7%).

(b) *Methyl 4,6-O-benzylidene-2,3-dideoxy-2,3-epimino-α-D-alloside* (II). Sodium azide (4 g.), ammonium chloride (0·6 g.), and the epimino-alloside (4 g.) in 2-methoxyethanol (150 ml.) and water (15 ml.) were boiled under reflux for 6 hr. The solution was evaporated and the residues extracted with ethyl acetate (3 × 50 ml.). Evaporation of the extract gave a brown syrup which was chromatographed. Elution with benzene–chloroform (4 : 1) gave syrupy methyl 3-amino-2-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside (III) (3·8 g.) $[\alpha]_D^{20}$ +66·7° (*c* 3·0).

Acetylation gave syrupy methyl 3-acetamido-2-azido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside. The syrup crystallised on standing (3 days), m. p. 250° (decomp.), but no recrystallisation solvent could be found (Found: C, 55·7; H, 5·8. Calc. for $C_{16}H_{20}N_4O_5$, C, 55·2; H, 5·8%).

Toluene-*p*-sulphonylation of the amino-azido-altroside (III) gave, after recrystallisation from propan-2-ol, *methyl 2-azido-4,6-O-benzylidene-2,3-dideoxy-3-toluene-p-sulphonamido-α-D-altroside* (80%), m. p. 166—168°, $[\alpha]_D^{22}$ +41·8° (*c* 1·15) (Found: C, 55·0; H, 5·3; N, 12·1. $C_{21}H_{24}N_4SO_6$ requires C, 54·8; H, 5·3; N, 12·2%).

Treatment of the amino-azido-altroside (III) with 1-fluoro-2,4-dinitrobenzene and sodium hydrogen carbonate in DMF as above at room temperature gave a yellow product, which on recrystallisation from propan-2-ol gave *methyl 2-azido-4,6-O-benzylidene-2,3-dideoxy-3-(2,4-dinitroanilino)-α-D-altroside* (77%), m. p. 180—182°, $[\alpha]_D^{22}$ −20·3° (*c* 0·98) (Found: C, 50·7; H, 4·4; N, 17·9. $C_{20}H_{20}N_6O_8$ requires C, 50·9; H, 4·3; N, 17·8%).

Reduction of the amino-azido-altroside (III) gave the syrupy 2,3-diamino-altroside, and acetylation of this syrup gave, methyl 2,3-diacetamido-4,6,*O*-benzylidene-2,3-dideoxy-α-D-altroside, m. p. 250° (decomp.), $[\alpha]_D^{20}$ +25·0° (*c* 1·0), identical with that obtained from the 2,3-epimino-mannoside (I).

(c) *Methyl 2,3-acetylepimino-4,6-O-benzylidene-2,3-dideoxy-α-D-alloside* (IIa). The *N*-acetyl-epimino-alloside (1·5 g.) in DMF (50 ml.) was treated with sodium azide (1 g.) and ammonium chloride (0·2 g.), and the mixture boiled 3 hr. under reflux. Evaporation, and passing of the crude product down a short alumina column ($CHCl_3$), gave a syrup which could not be crystallised (0·97 g.). The infrared spectrum of the syrup indicated presence of an azido-group, but no acetamido-group.

(d) *Methyl 2,3-benzoylepimino-4,6-O-benzylidene-2,3-dideoxy-α-D-alloside* (IIb). The *N*-benzoylepimino-alloside (2 g.), in DMF (25 ml.) was treated with sodium azide (1·5 g.) and ammonium chloride (0·5 g.), and the mixture boiled under reflux for 3 hr. Pouring into ice–water (200 ml.) gave a brown solid. Two recrystallisations from propan-2-ol gave *methyl*

3-*azido*-2-*benzamido*-4,6-O-*benzylidene*-2,3-*dideoxy*-α-D-*glucoside* (IX) (70%), m. p. 233—235°, $[\alpha]_D^{20}$ +79·4° (*c* 0·63) (Found: 61·4; H, 5·4; N, 13·8. $C_{21}H_{22}N_4O_5$ requires C, 61·5; H, 5·4; N, 13·7%).

(e) *Methyl* 2,3-*benzoylepimino*-4,6-O-*benzylidene*-2,3-*dideoxy*-α-D-*mannoside* (Ib). The *N*-benzoylepimino-mannoside (2·2 g.) in DMF was treated as described for the *allo*-isomer. The mixture was poured into ice–water and the product recrystallised twice from propan-2-ol to give methyl 4,6-*O*-benzylidene-2,3-dideoxy-3,2-(2-phenyl-1-oxa-3-aza-prop-2-eno),α-D-mannoside (VIII) (36%), m. p. 148—149°, $[\alpha]_D^{21}$ −65·6° (*c* 1·13) {Lit.,[10] m. p. 147—148°, 150—151°, $[\alpha]_D$ −67°}. Evaporation of the combined mother-liquors, and two recrystallisations of the residues from propan-2-ol gave methyl 3-azido-2-benzamido-4,6-*O*-benzylidene-2,3-dideoxy-α-D-altroside (VII) (20%), m. p. 188—190°, shown to be identical with that obtained by azidolysis of the unblocked epimino-mannoside, followed by benzoylation of the product.

(f) *Methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-*toluene*-p-*sulphonylepimino*-α-D-*mannoside*. The *N*-sulphonylepimino-mannoside was treated with sodium azide as described for the *N*-benzoyl derivative. Two recrystallisations of the product from propan-2-ol gave methyl 3-azido-4,6-*O*-benzylidene-2,3-dideoxy-2-toluene-*p*-sulphonamido-α-D-altroside (63%), m. p. 221—223° (decomp.).

(g) *Methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-*toluene*-p-*sulphonylepimino*-α-D-*alloside*. The toluene-*p*-sulphonylepimino-alloside was treated with sodium azide as described for the benzoyl derivative. Recrystallisation of the product from propan-2-ol gave methyl 2-azido-4,6-*O*-benzylidene-2,3-dideoxy-3-toluene-*p*-sulphonamido-α-D-altroside (41%), m. p. 168—170°. No other product could be isolated.

(h) *Methyl* 4,6-O-*benzylidene*-2,3-*dideoxy*-2,3-(2,4-*dinitrophenyl*)*epimino*-α-D-*alloside*. The *N*-(2,4-dinitrophenyl) derivative was treated with sodium azide as described for the *N*-benzoyl compound. Recrystallisation of the product with difficulty from propan-2-ol gave methyl 2-azido-4,6-*O*-benzylidene-2,3-dideoxy-3-(2,4-dinitroanilino)-α-D-altroside (30%), m. p. 178—180°. Column chromatography of the crude solid did not give any other isomer.

Partial Hydrolysis of Amino-azido-glycoside Derivatives.—(a) *Methyl* 3-*amino*-2-*azido*-4,6-O-*benzylidene*-2,3-*dideoxy*-α-D-*altroside* (III). The syrupy 3-amino-2-azido-altroside [from azidolysis of the 2,3-epimino-alloside (II) (5 g.)] in 50% aqueous acetic acid (50 ml.) was boiled under reflux for 30 min. Evaporation to a small bulk, addition of water (100 ml.) and evaporation gave a pale brown solid. The solid, on two recrystallisations from ethanol, gave *methyl* 3-*amino*-2-*azido*-2,3-*dideoxy*-α-D-*altroside acetate* (50%), m. p. 144—145°, $[\alpha]_D^{20}$ +26·2° (*c* 0·99 in H_2O) (Found: C, 38·8; H, 6·6; N, 20·2; O, 34·6. $C_9H_{18}N_4O_6$ requires C, 38·8; H, 6·5; N, 20·2; O, 34·5%).

Drying of the 3-amino-2-azido-altroside acetate at 80° and 20 mm. for 8 hr. gave a brown syrup which could not be characterised. No decomposition occurred when the solid was kept overnight at 75° at atmospheric pressure.

Hydrolysis of the benzylidene compound (III) with dilute aqueous hydrochloric acid gave a white solid, which on recrystallisation from ethanol gave *methyl* 3-*amino*-2-*azido*-2,3-*dideoxy*-α-D-*altroside hydrochloride* (IV) (85%), m. p. 185—187° (decomp.), $[\alpha]_D^{20}$ +30·8° (*c* 0·84 in H_2O) (Found: C, 32·5; H, 6·1. $C_7H_{15}ClN_4O_4$ requires C, 33·0; H, 5·9%).

Treatment of the 3-amino-2-azido-altroside acetate with 0·05N-methanolic hydrochloric acid at room temperature, and evaporation of the solution, gave the hydrochloride (IV) (98%), m. p. 185—187°.

Acetylation of the 3-amino-2-azido-altroside acetate in pyridine–acetic anhydride for 5 min. gave *methyl* 3-*acetamido*-2-*azido*-2,3-*dideoxy*-α-D-*altroside* (60%), m. p. 136·5—137·5°, $[\alpha]_D^{20}$ +85·3° (*c* 0·44 in H_2O) (Found: C, 41·7; H, 6·2. $C_9H_{16}N_4O_5$ requires C, 41·4; H, 6·2%).

Acetylation of the hydrochloride (IV) overnight in pyridine–acetic anhydride, followed by treatment of the product with methanol containing a trace of sodium, gave the acetamido-compound (50%), m. p. 136—137°.

The 3-amino-2-azido-altroside hydrochloride (0·0188 g.) was dissolved in 0·0189M-sodium periodate (100 ml.). At noted intervals portions (10 ml.) were diluted to 250 ml. with water and the optical density of the solution at 223 mμ determined. Comparison of the optical density values obtained with those of standard periodate and iodate solutions led to the following results:

Time (min.)	20	60	150	1200
$NaIO_4$ uptake (mol.)	0·92	0·93	0·96	1·08

(c) *Methyl 2-azido-3-benzamido-4,6-O-benzylidene-2,3-dideoxy-α-D-altroside* (XI). Treatment of the syrupy 3-amino-2-azido-altroside (III) with benzoyl chloride–pyridine gave the syrupy *N*-benzamido-derivative (XI). Treatment of this syrup with 50% aqueous acetic acid as described for the amino-compound (III) gave a dark syrup. Addition of propan-2-ol gave a crystalline solid, which on recrystallisation from the same solvent gave *methyl 2-azido-3-benzamido-2,3-dideoxy-α-D-altroside* (30%), m. p. 143—144°, $[\alpha]_D^{25}$ −11·7° (*c* 0·65) (Found: C, 52·2; H, 5·6; N, 17·6. $C_{14}H_{18}N_4O_5$ requires C, 52·2; H, 5·6; N, 17·4%).

Catalytic hydrogenation of the 2-azido-3-benzamido-altroside at 1 atm. and at room temperature in 0·013% methanolic hydrogen chloride in the presence of 10% palladium on charcoal gave a syrupy 2-amino-altroside hydrochloride (XII). This material crystallised on standing, but could not be recrystallised from a solvent. The 2-amino-3-benzamido-altroside (XII) did not react with sodium periodate under the conditions described for the corresponding 3-amino-2-benzamido-glucoside (X) (see below).

(d) *Methyl 3-azido-2-benzamido-4,6-O-benzylidene-2,3-dideoxy-α-D-glucoside* (IX). The benzylidene compound (IX) (0·7 g.) in 50% aqueous acetic acid (30 ml.) was boiled under reflux for 1 hr. Evaporation gave a white solid, which on recrystallisation from propan-2-ol, gave *methyl 2-azido-2-benzamido-2,3-dideoxy-α-D-glucoside* (50%), m. p. 223° (decomp.), $[\alpha]_D^{25}$ +110° (*c* 0·31 in $Me_2CH{\cdot}OH$) (Found: C, 52·0; H, 5·8; N, 17·5. $C_{14}H_{18}N_4O_5$ requires C, 52·2; H, 5·6; N, 17·4%).

Catalytic hydrogenation of the azido-glucoside in 0·013% methanolic hydrogen chloride at 1 atm. and at room temperature in the presence of 10% palladium on charcoal gave a solid product which, on two recrystallisations from ethanol–ethyl acetate, gave *methyl 3-amino-2-benzamido-2,3-dideoxy-α-D-glucoside hydrochloride* (50%), m. p. 250—260° (decomp. and sublimation), $[\alpha]_D^{25}$ +90·4° (*c* 0·71 in H_2O) (Found: C, 50·5; H, 6·6; N, 8·2. $C_{14}H_{21}ClN_2O_5$ requires C, 50·5; H, 6·4; N, 8·4%).

The product was oxidised in solution *ca.* $9{\cdot}9 \times 10^{-3}$M in sodium periodate, buffered to pH 7 [NaOH (0·035M)–KH_2PO_4 (0·065M)]. The initial ratio of sugar to periodate was 1 : 2·91. Periodate uptake was determined by the Müller–Friedberger method.[12]

Time (min.)	1·5	10·5	19·0	30·25
$NaIO_4$ uptake (mol.)	0·18	0·62	0·88	1·12

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[12] E. Müller and O. Friedberger, *Ber.*, 1902, **35**, 2652.