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ADDITION OF HALOGENOAZIDES TO GLYCALS

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ABSTRACT

Addition of chloroazide to 3,4,6-tri-*O*-acetyl-1,5-anhydro-2-deoxy-D-*lyxo*- (**1**) and -D-*arabino*-hex-1-enitol (**2**) under u.v. irradiation proceeds regio- and stereoselectively yielding mainly *O*-acetyl derivatives of 2-azido-2-deoxy-D-galactopyranose and -D-glucopyranose, respectively. 3,4,6-Tri-*O*-acetyl-2-chloro-2-deoxy-α-D-galactopyranosyl azide and 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-α-D-talopyranose (from **1**), and 1,3,4,6-tetra-*O*-acetyl-2-chloro-2-deoxy-α-D-glucopyranosyl azide and 1,3,4,6-tetra-*O*-acetyl-2-azido-2-deoxy-α-D-mannopyranose (from **2**) are byproducts. 1,5-Anhydro-3,4,6-tri-*O*-benzyl-2-deoxy-D-*lyxo*- and -D-*arabino*-hex-1-enitol reacted more rapidly with chloroazide, to give, under irradiation, derivatives of 2-azido-2-deoxy-D-galactose and -D-glucose, respectively. However, reaction in the dark gave mainly *O*-benzyl derivatives of 2-chloro-2-deoxy-α-D-galacto- and -α-D-glucopyranosyl azide. The difference between the products obtained may depend on the existence of two parallel processes, one radical (under irradiation), and the other ionic (reaction in the dark).

INTRODUCTION

The "azide method", recently developed for the synthesis of 2-amino-2-deoxy-α-D-glycosides[1–3], is based on the use of derivatives of 2-azido-2-deoxy-D-glucose and -D-galactose as glycosylating agents. The successful application of the method requires a search for new synthetic ways to prepare 2-azido-2-deoxyhexoses that are more convenient than the multistage procedure currently used[2]. The two methods recently proposed for the preparation of 2-azido-2-deoxy-D-galactose derivatives are based on the addition of an azide radical to the double bond of 3,4,6-tri-*O*-acetyl-1,5-anhydro-D-*lyxo*-hex-1-enitol (**1**). The azide radical was generated by sodium azide and ceric ammonium nitrate[4], or by halogenoazides[5]. The first of these methods[4] has been shown to provide derivatives of 2-azido-2-deoxy-D-galactose exclusively, whereas glycals with *quasi*-equatorial acetoxy groups at C-4 (D-*gluco* and D-*xylo* series) gave, in low yields, compounds having an equatorial N_3-2 group. Data on addition of halogenoazides to glycal **1** were presented in our preliminary communication[5], and this paper reports the synthesis of derivatives of 2-azido-2-deoxy-D-galactose and -D-glucose, based on this method.

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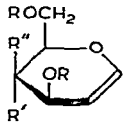
RESULTS AND DISCUSSION

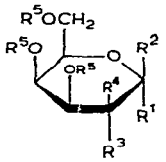
Reactions of a nonsymmetrical reagent, such as a halogenoazide, with nonsymmetrically substituted olefins (to which glycals are related) may lead to a mixture of eight isomers, only two of them (namely the anomers of 2-azido-2-deoxy derivatives with the required configuration at C-2) being the desired products. Nevertheless, a high sterical selectivity of the reactions may be expected if all the factors favoring the synthesis of only these derivatives are considered. These factors are sterical (being screened by substitution at C-3 and C-4 for **1** and by substitution at C-4 for **2**), and energetic (equatorial substitution being favored over axial for D-*galacto* and D-*gluco* in comparison with D-*talo* and D-*manno* configuration). Moreover, the correct choice of experimental conditions allows for the control of the regiospecificity of the reaction. This might vary, in the case of addition of halogenoazides to olefins, as follows[6]: polar solvents and acidic catalysts favor the ionic binding with an increasing effect in the series chloroazide to iodoazide. *Vice versa*, solvents of low polarity, lack of oxygen, radical initiators, and irradiation (especially in the case of chloroazide) lead mainly to the products of radical addition. Polarization of halogenoazide $Hal^{\delta+} \ldots N_3^{\delta-}$ requires ionic conditions to yield glycosyl azides, and radical conditions to yield 2-azido-2-deoxy sugars. Therefore, it is not surprising that the addition of chloroazide (or bromoazide) to **1** in dichloromethane, in the presence of benzoyl peroxide, under nitrogen, and light irradiation led (after treatment of the reaction mixture with mercuric acetate) to acetates of 2-azido-2-deoxy-D-galactopyranose (**5** and **6**) in 47% yield (33% yield in the case of bromoazide)[5]. Further studies of this reaction showed that benzoyl peroxide is not necessary, and that the use of a mercury lamp leads to an increasing yield of the mixture of **5** and **6**, up to 66%. In addition to the main components, two other products were isolated, *i.e.*, the glycosyl azide **7** in 13% yield and the derivative having D-*talo* configuration **8** in 7% yield. In this case, as well as in all reactions of chloroazide addition, the mixture contained (from t.l.c. data) minute proportions of easily separable products having a low R_F value, which, apparently, were the products of glycal degradation. The treatment of the reaction mixture with mercuric acetate was necessary, as the galactosyl azide **7** is chromatographically inseparable from the isomeric 2-azido-2-deoxy-D-galactosyl chloride.

The reaction of **2** with chloroazide under the conditions established for **1** also led to a mixture of four products (**10–13**) in 62, 9, 8, and 11% yield, respectively. Thus, in the case of **2**, the total yield of the desired 2-azido-2-deoxy derivatives was as high as in the reaction of **1**. The results seem encouraging when compared to the results of the "azidonitrate method" applied to the derivatives of D-glucose.

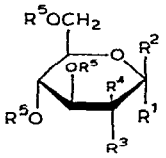
In both cases, the separation of fractions containing products having an equatorial 2-azido group (**5** and **6**, and **10** and **11**, respectively) from other reaction products could easily be performed by chromatography. These mixtures of anomers may be used for further preparation of 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-α-D-galactopyranosyl and -α-D-glucopyranosyl bromides by treatment with titanium



1 R = Ac, R′ = H, R″ = OAc
2 R = Ac, R′ = OAc, R″ = H
3 R = Bzl, R′ = H, R″ = OBzl
4 R = Bzl, R′ = OBzl, R″ = H



5 $R^1 = R^4 = H, R^2 = OAc, R^3 = N_3, R^5 = Ac$
6 $R^1 = OAc, R^2 = R^4 = H, R^3 = N_3, R^5 = Ac$
7 $R^1 = N_3, R^2 = R^4 = H, R^3 = Cl, R^5 = Ac$
8 $R^1 = OAc, R^2 = R^3 = H, R^4 = N_3, R^5 = Ac$
9 $R^1 = N_3, R^2 = R^4 = H, R^3 = Br, R^5 = Ac$
18 $R^1 = R^4 = H, R^2 = OAc, R^3 = N_3, R^5 = Bzl$
19 $R^1 = OAc\ R^2 = R^4 = H, R^3 = N_3\ R^5 = Bzl$
20 $R^1 = N_3, R^2 = R^4 = H, R^3 = Cl, R^5 = Bzl$



10 $R^1 = R^4 = H, R^2 = OAc, R^3 = N_3, R^5 = Ac$
11 $R^1 = OAc, R^2 = R^4 = H, R^3 = N_3, R^5 = Ac$
12 $R^1 = N_3, R^2 = R^4 = H, R^3 = Cl, R^5 = Ac$
13 $R^1 = OAc, R^2 = R^3 = H, R^4 = N_3, R^5 = Ac$
14 $R^1 = N_3, R^2 = R^3 = H, R^4 = Cl, R^5 = Ac$
15 $R^1 = R^4 = H, R^2 = N_3, R^3 = Cl, R^5 = Ac$
16 $R^1 = N_3, R^2 = R^3 = H, R^4 = Br, R^5 = Ac$
17 $R^1 = R^4 = H, R^2 = N_3, R^3 = Br, R^5 = Ac$
21 $R^1 = R^4 = H, R^2 = OAc, R^3 = N_3, R^5 = Bzl$
22 $R^1 = OAc, R^2 = R^4 = H, R^3 = N_3, R^5 = Bzl$
23 $R^1 = N_3, R^2 = R^4 = H, R^3 = Cl, R^5 = Bzl$

TABLE I

CHEMICAL SHIFTS (δ) AND MULTIPLET SPLITTINGS (Hz) FOR THE AZIDES **6–23**[a]

Comp.	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6,6'*	*OAc*[b]				$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$
6	6.34d	3.95dd	5.35dd	5.50dd	4.38m	4.10m	2.04	2.06	2.14	2.15	3.8	11.0	3.4	1.5
7	5.57d	4.29dd	5.22dd	5.44dd	4.40m	4.12m	2.02	2.04	2.12		3.8	11.0	3.5	1.5
8	6.34d	4.15dd	← 5.41m →		4.40m	4.21m	2.04	2.09	2.14	(6H)	1.7	3.5		
9	5.62d	4.32dd	5.26dd	5.42dd	4.88m	4.12m	2.02	2.04	2.12		3.7	11.2	3.5	1.5
10	5.59d	3.70dd	← 5.11m →		3.83m	4.23m	2.02	2.07	2.08	2.19	8.5	10.0		10.0
11	6.34d	3.75dd	5.22t	5.58t	← 4.22m →		2.10	2.13	2.16	2.25	3.8	10.5	10.5	10.5
12	4.88d	3.54dd	5.62t	5.12t	← 4.20m →		1.72	1.78	(6H)		4.0	10.5	10.5	10.5
13	6.14d	3.60dd	5.53dd	5.70t	4.00m	4.29m	1.56	1.72	(9H)		1.8	3.6	10.0	10.0
14	4.95d	4.50dd	5.09dd	5.42t	3.80m	4.10m	2.06	2.09	(6H)		1.3	3.5	10.0	10.0
15	4.99d	3.70t	5.06t	5.31t	3.87m	4.28m	2.03	2.09	(6H)		9.6	9.6	9.6	9.6
16	4.85d	4.55dd	4.99dd	5.45t	3.78m	4.13m	2.09	2.10	2.11		1.5	4.0	9.5	9.5
17	4.92d	3.73t	5.02t	5.31t	3.88m	4.25m	2.03	2.08	(6H)		9.5	9.5	9.5	9.5
18	5.43d	3.98dd	3.44dd				2.12				8.5	10.5	3.0	
19	6.26d	4.12dd					2.11				3.5	10.5		
20	5.49d	4.53dd	3.74dd								3.8	10.5	2.7	
21	5.64d	3.45dd					1.62				8.1	8.5		
22	6.28d	3.61dd					2.12				3.5	9.5		
23	5.47d	3.99dd	3.75m								3.5	10.6	10.5	

[a]For solutions in chloroform-*d*, except for **11**, **13**, and **21** (benzene-d_6). Abbreviations: d, doublet; dd, doublet of doublets; t, triplet; and m, multiplet.
[b]All singlets (3 H), except where indicated in parentheses.

TABLE II

YIELDS OF AZIDES FROM GLYCALS UNDER VARIOUS EXPERIMENTAL CONDITIONS

Experiment No.	*Glycal*	*Halogen-azide*	*Reaction conditions*				*Compounds: types and yield (%) obtained*[a]					
			Solvent	*Light*[b]	*Temp. (degrees)*	*Time (h)*	**A**	**B**	**C**	**D**	**E**	**F**
1	**1**	ClN_3	CCl_4	I	0	1	← **5** + **6** (66) →		**8** (7)	**7** (13)		
2	**1**	BrN_3	CH_2Cl_2	I	0	2	← **5** + **6** (33) →			**7** (45)		
3	**1**	ClN_3	CCl_4	D	0	120	← **5** + **6** (43) →		**8** (5)	**7** (9)		
4	**3**	ClN_3	CCl_4	I	−20	0.1	**19** (37)	**18** (39)		**20** (8)		
5	**3**	ClN_3	CCl_4	D	0	0.1				**20** (90)		
6	**2**	ClN_3	CCl_4	I	0	1	**11** (9)	**10** (62)	**13** (11)	**12** (8)		
7	**2**	ClN_3	CCl_4	D	0	200	**11** (6)	**10** (41)	**13** (8)	**12** (6)		
8	**2**	ClN_3	$MeNO_2$	D	−20	3				**12** (21)	**15** (17)	**14** (26)
9	**2**	BrN_3	$MeNO_2$	D	−20	8					**17**[c]	**16**[c]
10	**4**	ClN_3	CCl_4	I	−20	0.1	**22** (52)	**21** (30)		**23** (5)		
11	**4**	ClN_3	CCl_4	D	0	0.1	**22** (14)	**21** (7)		**23** (62)		

[a]Yield in parentheses. [b]*I*, under irradiation; and *D*, in the dark. [c]See Experimental section.

tetrabromide, as shown[7] for the pure α-D anomers **6** and **11**. Crystallization of the mixture of **10** and **11** allowed the isolation of the pure β-acetate **10**, and treatment of the mixture of anomers with perchloric acid in acetic anhydride led to the α-acetate **11**. In the case of the corresponding D-galactose derivatives **5** and **6**, which were more difficult to crystallize, only the α-D anomer **6** was isolated by treatment of the mixture with perchloric acid in acetic anhydride.

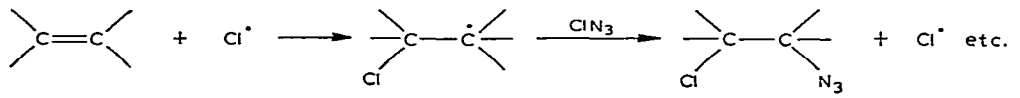
The reaction of addition with chloroazide was also studied with *O*-benzyl analogs, 1,5-anhydro-3,4,6-tri-*O*-benzyl-D-*lyxo*-hex-1-enitol (**3**), and -D-*arabino*-hex-1-enitol (**4**). In tetrachloromethane at −20° under u.v. irradiation, anomeric mixtures of 2-azido-2-deoxy derivatives of D-galactose (**18** and **19**) and D-glucose (**21** and **22**), respectively, were obtained in high yield (82 and 76%, respectively). These azides are potential starting material for 2-azido-3,4,6-tri-*O*-benzyl-2-deoxy-α-D-galactopyranosyl- and α-D-glucopyranosyl bromides. The products of the reverse addition (**20** and **22**) were obtained in low proportions (8 and 5%, respectively), whereas compounds with the D-*talo* or D-*manno* configuration were not isolated at all. The individual compounds **18**, **19**, **21**, and **22** were isolated by chromatography on silica gel. The structures of the *O*-acetyl and *O*-benzyl azides were suggested by the ^{1}H-n.m.r. spectra (see Table I).

Thus, the interaction of *O*-acetyl- as well as *O*-benzyl-glycals with chloroazide resulted in the synthesis of 2-azido-2-deoxy derivatives of D-glucose and D-galactose in high yields under conditions of free radical addition. Table II presents the summary results of the reactions of halogenoazides with **1–4** under various conditions. In understanding the mechanism of the reaction of halogenoazides, it should be emphasized that this complex reaction is complicated by the replacement of an olefin by a vinyl ether. In addition, the reaction is noticeably affected by substitution at C-3, C-4, and C-6 of the glycal compounds. Comparison of the data on addition of chloroazide to glycal acetates in the dark and under light (Table II) shows that irradiation considerably accelerates the reaction while the ratio of the products remains practically constant. Therefore, we propose the same radical mechanism for reactions both under light and in the dark, D-type of compounds being also products of radical addition; otherwise (ionic or concerted mechanism), they would be accumulated in the reaction in the dark.

A B C D E F

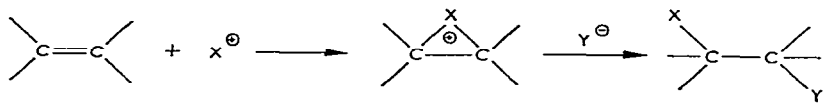
The absence of D-type compounds in the "azidonitrate reaction"[4] depends, apparently, upon the method of generation of the azide radical. In the "azidonitrate reaction", azide radicals only are formed, whereas dissociation of chloroazide leads to the formation of a chlorine radical that is less active than the azide radical, but

contributes to the initiation stage and promotes the chain of reaction illustrated in Scheme 1.



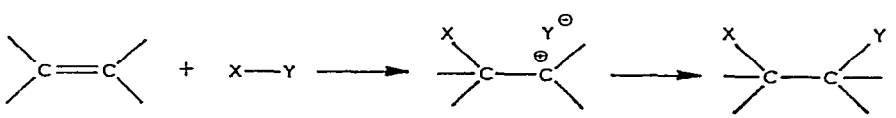
Scheme 1

In a polar solvent (*e.g.* nitromethane), the **E**- and **F**-type of products of *trans*-addition are mainly formed, as expected from the classical ionic mechanism (see Scheme 2).



Scheme 2

A sharp distinction was observed between the products formed in the dark and under light from *O*-benzylglycals. This observation may be explained by the existence of two parallel processes, *i.e.*, radical and ionic. The competition of these two processes permits two alternatives: (*a*) a considerable excess of **D**-type products (up to full regio- and stereo-specificity as in Experiment No. *5*, Table II) by the ionic mechanism; and (*b*) an excess of **A**- and **B**-type compounds by the radical mechanism (Experiments No. *4* and No. *10*). There are two reasons for *cis*-addition by the ionic reaction (Experiment No. *5*): (*a*) The reaction is carried out in a nonpolar solvent, thus a *cis*-addition takes place[8–11] involving also carbohydrate compounds[12]; this may be explained by the formation of the more compact ionic pair in a nonpolar solvent (see Scheme 3); (*b*) the oxygen atom vicinal to the double bond acts as an internal nucleophile, thus facilitating *cis*-addition.



Scheme 3

Finally, another specific feature of the reaction of *O*-benzylglycals with halogenoazides should be emphasized, namely the extremely high addition rate. Benzyl ethers **3** and **4** reacted with chloroazide practically immediately after mixing, whereas acetates **1** and **2** reacted with chloroazide within 2–200 h (under light and in the dark, respectively). The very first t.l.c. probe of the reaction mixture pointed to the absence of an olefin, even at −78°. Thus, the difference in the rate of addition of chloroazide

is of at least two orders of magnitude in case of the radical reaction, whereas the ionic reaction did not occur at all in the case of acetates (in tetrachloromethane). This seems more surprising, for an increase in reaction rate led to an increase in stereoselectivity (see Table II). An explanation of these observations requires further studies on the reaction of glycals with chloroazide.

EXPERIMENTAL

General methods. — Melting points were determined with a Boetius apparatus. Specific optical rotations were measured with a Perkin–Elmer Model 141 polarimeter. T.l.c. was performed on 60 F-254 Silica gel plates (E. Merck, Darmstadt) in the following solvents (v/v): 4:1 toluene–ethyl acetate (reactions of chloroazide with **1** and **2**), 4:1 hexane–ether (reactions of chloroazide with **3** and **4**), and 1:1 hexane–ether (reactions of bromoazide with **1** and **2**). Column chromatography was perfor medon Silica gel L 40–100 μm (Chemapol, Czechoslovakia) in the same solvents. I.r. spectra were recorded with a UR-20 spectrophotometer for suspension in Nujol. ^{1}H-N.m.r. spectra were recorded with Varian XL-100 and Varian XL-200 (100 and 200 MHz) instruments with Me_4Si as internal standard. A mercuric u.v. lamp with wide spectrum was used as irradiation source. Solvents were evaporated *in vacuo* at 30–40°.

Halogenoazides. — Conc. hydrochloric acid (20 mL) was added to a suspension of sodium azide (0.5 mol) in tetrachloromethane (60 mL) at 0°. The mixture was stirred vigorously for 1 h. Then a solution of chlorine (0.05 mol) in tetrachloromethane (or 0.05 mol of bromine) was added, and the mixture was stirred for an additional hour. The solution was decanted, kept for 24 h at 0°, washed twice with ice–water, and dried (magnesium sulfate). The solution obtained contained ~0.04 mol of halogenoazide.

1,5-Anhydro-3,4,6-tri-O-*benzyl*-D-lyxo-*hex-1-enitol* (**3**). — To a solution of **1** (20 mmol) in absolute methanol (100 mL) was added M sodium methoxide (0.3 mL). After *O*-deacetylation, the solution was evaporated, and the residue was dissolved in dry *N,N*-dimethylformamide (100 mL) and subsequently treated with sodium hydride (80 mmol, 80% suspension in mineral oil) and benzyl bromide (80 mmol). After 12 h, the mixture was treated with methanol (10 mL), diluted with chloroform (500 mL), and washed with water. The dried (magnesium sulfate) solution was evaporated, and the residue was dissolved in methanol (40 mL) and kept overnight at −5° to give crystalline **3** (7.4 g, 72%), m.p. 51°, $[\alpha]_D^{20}$ −45° (*c* 1, chloroform); ^{1}H-n.m.r. (CCl_4): δ 6.22 (d, 1 H, $J_{1,2}$ 6.5 Hz, H-1) and 7.25 (s, 15 H, 3 Ph); ν_{max}^{Nujol} 1650 cm^{-1}.

Anal. Calc. for $C_{27}H_{28}O_4$: C, 77.86; H, 6.78. Found: C, 77.71; H, 6.82.

Compound **3** decomposed after 1–2 weeks at room temperature.

1,5-Anhydro-3,4,6-tri-O-*benzyl*-D-arabino-*hex-1-enitol* (**4**). — This compound was obtained from the corresponding acetate **2** in the same way as described for **3** and isolated by column chromatography in 9:1 (v/v) hexane–ethyl acetate in 74%

TABLE III

PHYSICAL PROPERTIES AND ANALYTICAL DATA OF AZIDES **6–23**

Comp.	*M.p. (degrees)*[a]	$[\alpha]_D^{20}$ *(degrees)*[b]	ν_{max}^{Nujol} *(cm^{-1})*	*Formula*	*Analytical data*[c]			
					C	*H*	*Cl*	*N*
6[d]	119	+100	2125 and 1750					
7	111	+225	2150, 2130, and 1750	$C_{12}H_{16}ClN_3O_7$	41.21 41.30	4.61 4.73	10.14 10.20	12.01 11.90
8	83–84	+65	2115 and 1740	$C_{14}H_{19}N_3O_9$	45.04 45.09	5.13 5.18		11.26 11.14
9	115	+195	2130 and 1750	$C_{12}H_{16}BrN_3O_7$	36.56 36.43	4.09 4.20		10.66 10.82
10	97	+8	2120 and 1750	$C_{14}H_{19}N_3O_9$	45.04 45.16	5.13 5.05		11.26 11.09
11[e]	114–115	+130	2115 and 1750					
12	80	+191	2120 and 1760	$C_{12}H_{16}ClN_3O_7$	41.21 41.24	4.61 4.70	10.14 10.30	12.01 11.87
13	132	+79	2110 and 1740	$C_{14}H_{19}N_3O_9$	45.04 45.10	5.13 5.19		11.26 11.08
14	96	−105	2120 and 1750	$C_{12}H_{16}ClN_3O_7$	41.21 41.31	4.61 4.49	10.14 10.25	12.01 11.90
15[f]	126–127	+31	2110 and 1750					
16	105	−53	2115 and 1740	$C_{12}H_{16}BrN_3O_7$	36.56 36.61	4.09 3.92		10.66 10.80
17	121	+34	2110 and 1750	$C_{12}H_{16}BrN_3O_7$	36.56 36.70	4.09 3.97		10.66 10.58
18	71	+5	2115 and 1760	$C_{29}H_{31}N_3O_6$	67.30 67.51	6.04 6.25		8.12 7.90
19	88–90	+65	2115	$C_{29}H_{31}N_3O_6$	67.30 66.90	6.04 5.79		8.12 7.91
20	84	+133	2125	$C_{27}H_{28}ClN_3O_4$	65.65 65.59	5.71 5.63	7.18 6.99	8.51 8.48
21	67	−11	2130 and 1755	$C_{29}H_{31}N_3O_6$	67.30 67.22	6.04 5.96		8.12 7.99
22	75	+48	2120 and 1755	$C_{29}H_{31}N_3O_6$	67.30 67.49	6.04 5.86		8.12 7.91
23	86	+166	2120	$C_{27}H_{28}ClN_3O_4$	65.65 65.71	5.71 5.63	7.18 7.03	8.51 8.40

[a]Crystallized from ether–hexane. [b]For solutions in chloroform (*c* 1.0). [c]Upper line, calc. value; lower line, found value. [d]Lit.[7] m.p. 117°, $[\alpha]_D^{20}$ +109° (*c* 0.8, chloroform). [e]Lit.[14] m.p. 118–120°, $[\alpha]_D^{20}$ +125° (*c* 0.5, chloroform). [f]Lit.[15] m.p. 121°, $[\alpha]_D^{20}$ +32° (*c* 1.45, acetone).

yield, m.p. 56° (from ether–hexane), $[\alpha]_D^{20}$ −4° (*c* 1, chloroform); lit.[13] m.p. 55°, $[\alpha]_D^{20}$ −2.7° (*c* 1.65, chloroform).

Compound **4** is stable in the crystalline state.

Reactions of halogenoazides with glycals **1–4**. — To a solution of glycal (10

mmol) in a solvent (40–150 mL) flushed with dry nitrogen, a solution of halogenoazide (20–25 mmol) in tetrachloromethane (40–50 mL) was added at 0 or −20° (if irradiation was necessary, a u.v. lamp was used at the start of mixing). The reactions under irradiation were carried out in a quartz vessel. After the reaction was complete (t.l.c.), the mixture was evaporated, the residue dissolved in glacial acetic acid (100 mL), mercuric acetate (5 g) added, and the mixture kept overnight at room temperature. The mixture was diluted with chloroform (500 mL), washed with water, sodium hydrogencarbonate, and water, dried (calcium chloride), and evaporated. The products were isolated by column chromatography. The yields and characteristics of the materials obtained are presented in Tables I–III.

In Experiment No. *1* (Table II), the mixture of **5** and **6** (5.2 g) was kept for 16 h in acetic anhydride (100 mL) containing a few drops of perchloric acid. The mixture was diluted with chloroform (1 L) and washed as described above. T.l.c. detected only traces of **5**. Compound **6** was obtained from the syrup by crystallization from ether–hexane.

In Experiment No. *6*, the chromatographically separated mixture of **10** and **11** was crystallized from ether–hexane to obtain the major part of the β-D anomer **10**. After evaporation of the mother liquor, the residue was treated with acetic anhydride as described earlier. Crystallization yielded the α-D anomer **11**.

In Experiment No. *9*, a multicomponent mixture was formed. Only minute proportions of the individual compounds **16** and **17** were isolated chromatographically. The major portion of these compounds was inseparable from the admixtures.

In Experiment No. *5*, the reaction mixture was filtered through a silica gel layer, the filtrate was evaporated, and, after crystallization of the syrup from ether–hexane, **20** was obtained.

3,4,6-Tri-O-acetyl-2-azido-2-deoxy-α-D-glucopyranosyl bromide. — A solution of a mixture of **10** and **11** (3 g) in absolute chloroform (150 mL) was kept with titanium tetrabromide (3 g) for 15–20 days at room temperature. The mixture was diluted with cold chloroform (300 mL), washed with water, sodium hydrogencarbonate, and water, dried (calcium chloride), and evaporated. The residue was crystallized from ether–hexane in 75% yield, m.p. 71–72°, $[\alpha]_D^{20}$ +187° (*c* 1, chloroform); lit.[7] syrup, $[\alpha]_D^{20}$ +155° (*c* 0.7, acetonitrile).

3,4,6-Tri-O-acetyl-2-azido-2-deoxy-α-D-galactopyranosyl bromide. — This bromide was obtained in 80% yield in the same way as described for the glucopyranosyl analog, m.p. 101.5° (ether–hexane), $[\alpha]_D^{20}$ +181° (*c* 1, chloroform); lit.[7] m.p. 90°, $[\alpha]_D^{20}$ +104° (*c* 1.2, acetonitrile); lit.[4] m.p. 97–98°, $[\alpha]_D^{20}$ +188.6° (*c* 1.95, chloroform).

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