PREPARATION OF 6-AMINO-6-DEOXY-D-ALTRONIC ACID AND THEIR DERIVATIVES

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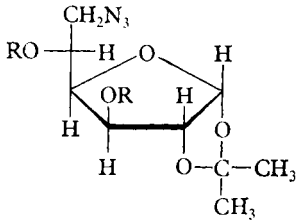
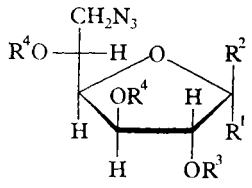
Methyl 6-azido-3,5-di-O-benzoyl-6-deoxy-α- and -β-D-glucofuranosides (*III* and *IV*), obtained by methanolysis of 1,2-O-isopropylidene derivative *II* were converted *via* 2-O-methanesulfonyl esters *V* and *VI* to methyl 2,3-anhydro-6-azido-6-deoxy-α- and -β-D-mannofuranosides (*VII* or *VIII*, respectively). Epoxide *VII* when submitted to alkaline hydrolysis gave methyl 6-azido-6-deoxy--α-D-altrofuranoside (*IX*) exclusively, while epoxide *VIII* afforded a mixture of methyl 6-azido--6-deoxy-β-D-furanosides of *altro* (*X*) and *gluco* (*XI*) configuration in a 5 : 4 ratio. Altrofuranosides *IX* and *X* were converted to 6-azido-6-deoxy-D-altrose (*XII*) the oxidation of which with bromine and catalytic reduction with hydrogen afforded amorphous amino acid *XIV*, characterized as its tetraacetyllactam *XVI*. The structural changes of the compounds from individual steps of the synthesis were checked by IR and ^{1}H NMR spectra which are discussed.

In connection with our study of ω-aminoaldonic acids it was desirable to obtain further configurational isomers of 6-amino-6-deoxyhexonic acid. For the preparation of isomers of D-*altro*- or D-*manno*-configuration we tried to use 6-azido-6-deoxy--1,2-O-isopropylidene-α-D-glucofuranose (*I*) which was found useful as a well accessible intermediate in the synthesis of D-*gluco*-isomer described earlier[1,2]. Benzoylation of *I* gave 3,5-di-O-benzoyl ester *II* which when methanolysed gave a mixture of methyl 6-azido-3,5-di-O-benzoyl-6-deoxy-α-D-glucofuranoside (*III*) and its β-anomer *IV* in an approximately 2 : 3 ratio. Both substances were separated by preparative column chromatography. The configuration of the anomeric carbon atom in glycosides *III* and *IV* was assigned on the basis of their optical rotation according to Hudson's rules[3] and the ^{1}H NMR data which will be discussed later. On reaction with methanesulfonyl chloride in pyridine glycosides *III* and *IV* gave 2-O-methanesulfonyl derivatives *V* and *VI*. For achieving a change of configuration on atoms $C_{(2)}$ or $C_{(3)}$ in compounds *V* and *VI* either direct nucleophilic substitution of the methanesulfonyloxy group by the benzoate anion (with a possible participation of the neighbouring benzoate group) could be envisaged, leading primarily to the derivatives of *manno* configuration, or the formation of 2,3-anhydro cycle and its subsequent hydrolysis with the possibility of the formation of derivatives of *altro* or *gluco* configuration. In our attempts at the conversion according to the first procedure the formerly known experience[4-6] was confirmed concerning the very

difficult course of the S_N2 substitution of the *p*-toluenesulfonyloxy- or methanesulfonyloxy group bound in glycosides on $C_{(2)}$ atom of the pyranoid or furanoid ring. The reaction of glycoside *V* or *VI* with sodium benzoate in dimethylformamide did not take place at temperatures up to 130°C; at still higher temperature a considerable decomposition of the thermolabile azido derivative took place. In contrast to this the second procedure took place in both esters *V* and *VI* easily under formation of methyl 2,3-anhydro-6-azido-6-deoxy-α-D-mannofuranoside (*VII*) or methyl 2,3-anhydro-6-azido-6-deoxy-β-D-mannofuranoside (*VIII*). On hydrolysis of the oxirane cycle in aqueous sodium hydroxide anhydro derivative *VII* afforded methyl 6-azido-6-deoxy-α-D-altrofuranoside (*IX*) as the sole product, while the β-anomer *VIII* gave by the same reaction a mixture of methyl 6-azido-6-deoxy-β-D-altrofuranoside (*X*) and methyl 6-azido-6-deoxy-β-D-glucofuranoside (*XI*), in an approximately 5 : 4



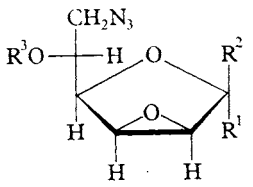


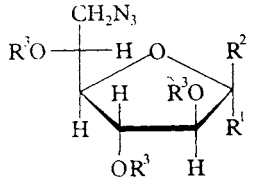
I, R = H
II, R = COC_6H_5

III, $R^1 = OCH_3$, $R^2 = R^3 = H$, $R^4 = COC_6H_5$
IV, $R^1 = R^3 = H$, $R^2 = OCH_3$, $R^4 = COC_6H_5$
V, $R^1 = OCH_3$, $R^2 = H$, $R^3 = SO_2CH_3$, $R^4 = COC_6H_5$
VI, $R^1 = H$, $R^2 = OCH_3$, $R^3 = SO_2CH_3$, $R^4 = COC_6H_5$
XI, $R^1 = R^3 = R^4 = H$, $R^2 = OCH_3$
XVII, $R^1 = OCH_3$, $R^2 = H$, $R^3 = R^4 = COC_6H_5$
XVIII, $R^1 = H$, $R^2 = OCH_3$, $R^3 = R^4 = COC_6H_5$

ratio. The result of the hydrolysis of epoxides *VII* and *VIII* corresponds in principle to the rules, generalizing the so far described examples of nucleophilic cleavage of the oxirane ring in the series of 2,3-anhydropentofuranosides[7]. According to them the stereochemical course of this reaction is controlled mainly by the inductive effect of the anomeric centre, enhancing the opening of the oxirane cycle in the position 3 and by the stereopolar effect of the vicinal substituents in *trans* position with respect to the epoxide ring, hindering the opening of the ring in neighbouring position. In hydrolytic opening of the anhydro cycle of compound *VII* the carbon atom $C_{(3)}$ was distinctly preferred by simultaneous effect of both above mentioned effects. This preference is weakened in the case of the anomeric epoxide *VIII* by the absence of the steric hindrance to the access of the hydroxyl anion in position 2. The selectivity of the epoxide ring opening in compounds *VII* and *VIII* may be compared with the examples described of analogous reactions in structurally close methyl 2,3-anhydro-α-

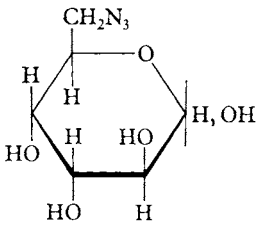
or -β-D-lyxofuranosides (Table in ref.[7]). The configuration of glycosides *IX* and *X* is confirmed both by the ^{1}H NMR spectra discussed below and by the IR spectra of their tribenzoates *XXI* and *XXII*, compared with the standard tribenzoates *XVII* and *XVIII* of *gluco* configuration. In these generally different IR spectra the derivatives *XVIII* and *XXI* with a *trans* arrangement of the substituents on $C_{(1)}$ and $C_{(2)}$ display two typical bands in the region of bending vibrations of the C—H bond with ν 970 and 940 cm^{-1} which are absent in the spectra of compounds *XVII* and

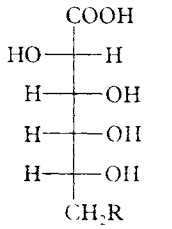


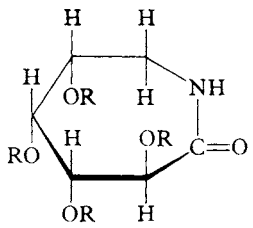


VII, $R^1 = OCH_3$, $R^2 = R^3 = H$
VIII, $R^1 = R^3 = H$, $R^2 = OCH_3$
XIX, $R^1 = OCH_3$, $R^2 = H$, $R^3 = COC_6H_5$
XX, $R^1 = H$, $R^2 = OCH_3$, $R^3 = COC_6H_5$

IX, $R^1 = OCH_3$, $R^2 = R^3 = H$
X, $R^1 = R^3 = H$, $R^2 = OCH_3$
XXI, $R^1 = OCH_3$, $R^2 = H$, $R^3 = COC_6H_5$
XXII, $R^1 = H$, $R^2 = OCH_3$, $R^3 = COC_6H_5$







XII

XIII, $R = N_3$
XIV, $R = NH_2$

XV, $R = H$
XVI, $R = COCH_3$

XXII. The tribenzoate prepared from compound *XI* afforded an IR spectrum identical with that of the tribenzoate of β-D-*gluco* configuration, *XVIII*. On acid hydrolysis of altrofuranosides *IX* and *X* a syrupy 6-azido-6-deoxy-D-altrose (*XII*) was obtained which on oxidation with bromine gave 6-azido-6-deoxy-D-altronic acid (*XIII*) in a mixture with lactones. After unsuccessful attempts at the isolation of some of these compounds from the equilibrium mixture in pure state the mixture was reduced to corresponding 6-amino-6-deoxy-D-altronic acid (*XIV*). In contrast to the so far described isomers of *galacto*-[8], *gluco*-[1,8] and *allo*-[1] configuration the acid *XIV* was very easily soluble in water and it could not be obtained in crystalline state in the form of an internal salt or in the form of hydrochloride either. When the aqueous solution was lyophilized, analytically pure acid *XIV* in the form

of a foam was obtained, the IR spectrum of which had characteristic bands similar to those of the 6-amino-6-deoxyhexonic acids described earlier. A part of acid *XIV* was converted using a procedure described in ref.[2] to lactam *XV*, which, when acetylated, gave crystalline 2,3,4,5-tetra-O-acetyl-6-amino-6-deoxy-D-altronolactam (*XVI*). The ^{1}H NMR spectrum of this compound[9] confirms the *altro* configuration of the sugar chain and the predominating $^{1,N}C_4$ conformation of the lactam ring.

The values of the chemical shifts and the coupling constants, obtainable by 1st order analysis of the ^{1}H NMR spectra of the investigated substances, are listed in Table I. Their utilization for structural analysis of substances with a furanoid ring is based on the present data[10–21] concerning the NMR data of hydrogen atoms in *cis* or *trans* position on the C—C bond of the five-membered ring. According to refs[10–14] the value $J_{1,2}$ 0–3 Hz is typical of the H-1 and H-2 atoms in *trans* position, and 4–5 Hz in *cis* position. Since exceptions have been described[16–21] from this generalization, the assignment of relative configuration on $C_{(1)}$ and $C_{(2)}$ is usually considered as certain only in cases when the value of $J_{1,2}$ is less than 1 Hz. The different shielding of H-1 by the neighbouring *cis* or *trans* located hydroxyl group permits the assignment of the relative configuration on the $C_{(1)}$—$C_{(2)}$ bond to the anomeric pair of compounds with a free OH group in position 2 also on the basis of the chemical shift values of H-1 (ref.[22]). In agreement with the above mentioned data the compounds of α-D-*gluco* and β-D-*altro* configuration *II*, *III*, *V*, *XVII*, and *X* (H-1 and H-2 *cis*) displayed a higher $J_{1,2}$ value (3·5–4·5 Hz), and the compounds of β-D-*gluco* and α-D-*altro* configuration *IV*, *VI*, *XVIII*, *IX*, and *XXI* (H-1 and H-2 *trans*) a lower value of $J_{1,2}$ (0–0·8 Hz). The anomeric anhydro derivatives *VII* and *VIII* or their 5-O-benzoyl derivatives *XIX* and *XX* could not be differentiated reliably either by means of $J_{1,2}$ values (close to zero in all instances) or on the basis of the very slightly different chemical shift value of H-1. The low efficiency of the NMR spectrometry for a reliable differentiation of the anomeric bands of 2,3-anhydro furanosides has already been observed[23] during the measurement of the resonance of ^{13}C-nuclei. A similar generalization concerning the ^3J constants, *i.e.* such as already mentioned for H-1 and H-2, has already been expressed[19] for other pairs of vicinal hydrogen atoms on the furanoside cycle. The overlapping ranges of the presented[19–21] values of ^3J for hydrogen atoms in the *cis* position (4·3–6·8 Hz) and *trans* position (0–7·2 Hz) do not permit an assignment of the relative configuration, if $^3J > 4$ Hz. A coupling constant value less than 4 Hz is considered characteristic of the *trans* position of the hydrogen atoms on the furanoside cycle[19]. This requirement is fulfilled by the majority of $J_{2,3}$ constants of substances of *gluco* and α-*altro* configuration in Table I, while the $J_{3,4}$ constants of these compounds occur rather in the region of the above-mentioned overlap and therefore they are not sufficiently reliable for the confirmation of the relative configuration of H-3 and H-4. In view of the fact that in the course of our synthesis changes of configuration took place only on the second and the third carbon atom, the determination

TABLE I

^{1}H NMR spectra of substituted methyl 6-azido-6-deoxy-D-hexofuranosides

Configuration	Compound	Chemical shifts δ (ppm)[a]									Coupling constants (Hz)[b]					
		H-1	H-2	H-3	H-4	H-5	H-6	H-6′	OCH_3	others[c]	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	$J_{5,6}$	$J_{5,6'}$
α-*gluco*	*II*	5·98	4·64	5·53	4·74	5·53	3·90	3·66	—	1·34 1·61 ($C(CH_3)_2$)	3·5	0	3	9	3	4
	III	5·02	4·21	5·49	4·68	5·34	3·77	3·57	3·54	2·74[d]	4·5	3·5	5	9	3	3·5
	V	5·04	5·13	5·90	4·78	5·40	3·84	3·62	3·54	3·08[e]	4·5	4·5	6	9	2·5	3·5
	XVII	5·28—5·41		6·13	4·84	5·55	3·88	3·70	3·44	—	4	3·5	6·5	9	3	3·5
α-*manno*	*VII*	4·94	3·88	3·68	3·94	3·30—3·60			3·42	2·63/37°[d] 2·52/60°	0	3	*f*	*f*	*f*	*f*
	XIX	4·94	3·64	3·71	4·26	5·32	3·30—3·86		3·42	—	0	3	1	7·5	3	4·5
α-*altro*	*IX*	4·85	3·80—4·28				*f*	*f*	3·38	*f*	0	*f*	*f*	*f*	*f*	*f*
	XXI	5·10	5·41	5·72	4·63	5·62	3·82	3·67	3·48	—	0	1·5	5	7	4	6
β-*gluco*	*IV*	4·84	4·18	5·29	4·78	5·43	3·84	3·63	3·40	3·74/35°[d] 3·30/60°	0·8	1·5	5	9	3	4·5
	VI	5·16	5·02	5·60	4·89	5·55	3·92	3·69	3·46	3·18[e]	0	1·5	5·5	9	3·5	4
	XVIII	5·13	5·45	5·89	4·99	5·57	3·96	3·72	3·50	—	0	1·5	5·5	9	2·5	3·5
β-*manno*	*VIII*	5·00	3·88	3·75	3·83	3·92	3·62	3·34	3·50	2·86/20°[d] 2·52/60°	0·8	2·5	1	8	3·5	5·5
	XX	5·03	3·64—3·80		4·20	5·42	3·88	3·63	3·38	—	0	5·0	4·5	8·5	3·5	4·5
β-*altro*	*X*	4·83	4·10	4·32	4·17	3·93—3·68			3·50	3·52	2·38/20°[d] 2·50/60°	4·5	6·5	*f*	*f*	*f*	*f*
	XXII	5·28—5·36		6·10	4·74	5·46	3·88	3·63	3·38	—	*f*	5·5	5·0	8·5	3·5	4·5

[a] Accuracy of the readings ±0·02 ppm; [b] accuracy of the readings ±0·5 Hz; [c] the signals of the protons on the aromatic ring are not indicated; [d] OH group; [e] SO_2CH_3 group; [f] the values are in the part of the higher order spectrum.

of the relative configurations on the $C_{(1)}$—$C_{(2)}$—$C_{(3)}$ sequence, following from the above mentioned evaluation of the spectral data, suffices for reliable assignments of configurations to the molecules of the substances measured.

EXPERIMENTAL

The melting points were measured on a Kofler block and they are not corrected. Optical rotations were measured on an Opton instrument, with subjective readings. The IR spectra were recorded on a Perkin–Elmer 325 instrument in KBr pellets (solid substances) or in chloroform solution. The ^{1}H NMR spectra were measured on Varian XL-100-15 and Tesla BS 567 instruments in deuteriochloroform, using tetramethylsilane as internal reference. Thin-layer chromatography for the monitoring of chemical reactions was carried out on 25 × 75 mm plates with a silica gel G (Merck) layer 0·2—0·3 mm thick, using the following solvent systems: Chloroform–methanol 100 : 1 (S_1), chloroform–methanol 100 : 5 (S_2), chloroform–methanol 100 : 10 (S_3), chloroform–methanol 100 : 20 (S_4), ethyl acetate–methanol 100 : 1 (S_5). The substances were detected by spraying the plates with 1% solution of cerium sulfate in 10% sulfuric acid and carbonization. For thin-layer chromatography of amino acids the Lucefol–Quick foils (Kavalier) were used, developed in 1-butanol–acetic acid–water 4 : 1 : 5 (S_6) and detected by drawing the foil through a 0·25% ninhydrin solution in acetone and heating. Preparative chromatographies were carried out on silica gel CH 100—200 μm (Lachema).

6-Azido-3,5-di-O-benzoyl-6-deoxy-1,2-O-isopropylidene-α-D-glucofuranose (*II*)

Benzoyl chloride (7 ml, *i.e.* 8·4 g, 60 mmol) was added dropwise to a cooled solution of 6·9 g (28 mmol) of 6-azido-6-deoxy-1,2-O-isopropylidene-α-D-glucofuranose (*I*, ref.[1]) in 75 ml of pyridine and the mixture stirred at 0°C for 2 h and eventually allowed to stand at 5°C for 12 h under occasional control of the reaction course by thin-layer chromatography in S_1. After working up 14·5 g of a syrupy product were obtained which was chromatographed on 350 g of silica gel with benzene–ethanol 100 : 1 to give an individual compound. Its crystallization from ethanol afforded 10·8 g (88·6%) of diester *II*, m.p. 69·5°C, $[\alpha]_D^{18}$ −70·9 ± 1° (*c* 1·9, chloroform). For $C_{23}H_{23}N_3O_7$ (453·5) calculated: 60·92% C, 5·11% H, 9·26% N; found: 60·85% C, 5·17% H, 9·23% N.

Methyl 6-Azido-3,5-di-O-benzoyl-6-deoxy-α-D-glucofuranoside (*III*) and its β-Anomer *IV*

A solution of 13·1 g (29 mmol) of *II* in 220 ml of 1% methanolic hydrogen chloride solution was stirred at 50 °C. The course of the methanolysis was monitored by thin-layer chromatography in S_1. After 5 h the mixture was neutralized with solid lead carbonate, filtered, and evaporated. The residue was extracted with benzene and the residue of the extract (12·8 g) was separated chromatographically on silica gel, using chloroform–diethyl ether 40 : 1 for elution. From this chromatography 6·57 g (53%) of syrupy β-anomer *IV*, $[\alpha]_D^{21}$ −132 ± 1·5° (*c* 0·5, chloroform) were obtained. For $C_{21}H_{21}N_3O_7$ (427·4) calculated: 59·00% C, 4·95% H, 9·83% N; found: 59·05% C, 5·13% H, 9·51% N. The fraction containing the α-anomer was purified by chromatography on silica gel with benzene–ethyl acetate 40 : 1, giving a syrupy compound *III* (4·5 g, 36%), $[\alpha]_D^{20}$ +85·2 ± 1° (*c* 0·8, chloroform). For $C_{21}H_{21}N_3O_7$ (427·4) found: 59·04% C, 4·82% H, 10·16% N.

Methyl 6-azido-2,3,5-tri-O-benzoyl-6-deoxy-α-D-glucofuranoside (*XVII*) was prepared by benzoylation of glucoside *III* and crystallized from diethyl ether–light petroleum 1 : 2 to give

a product with m.p. 72–74°C and $[\alpha]_D^{20}$ +105·7 ± 1·5° (*c* 0·4, chloroform); IR spectrum: 3 010, 2 940, 2 110, 1 728, 1 600, 1 450, 1 000, 905, 860 cm^{-1}. For $C_{28}H_{25}N_3O_8$ (531·5) calculated: 63·27% C, 4·74% H, 7·90% N; found: 63·14% C, 4·73% H, 7·96% N. Benzoylation of glycoside *IV* gave methyl 6-azido-2,3,5-tri-O-benzoyl-6-deoxy-β-D-glucofuranoside (*XVIII*) in the form of a syrup, with $[\alpha]_D^{20}$ +18·5 ± 1·5° (*c* 0·8, chloroform); IR spectrum: 3 010, 2 940, 2 100, 1 728, 1 605, 1 450, 1 020, 970, 940, 900, 850, 800 cm^{-1}. For $C_{28}H_{25}N_3O_8$ (531·5) found: 63·24% C, 4·75% H, 7·67% N.

Methyl 6-Azido-3,5-di-O-benzoyl-6-deoxy-2-O-methanesulfonyl-α-D-glucofuranoside (*V*)

Methanesulfonyl chloride (2·3 g; 20 mmol) was added under stirring to a cooled (0°C) solution of glycoside *III* (7·07 g; 16·6 mmol) in 80 ml pyridine and the mixture was allowed to stand in the cold overnight. After evaporation of pyridine in a vacuum crushed ice (40 g) was added to the residue and the mixture extracted with 50 ml of chloroform. The chloroform extract was washed, dried, and evaporated. The syrupy, chromatographically pure methanesulfonate *V* (8·1 g; 97%) had $[\alpha]_D^{20}$ +32·0 ± 1° (*c* 0·8, chloroform). For $C_{22}H_{23}N_3O_9S$ (505·5) calculated: 52·27% C, 4·59% H, 8·31% N, 6·34% S; found: 51·99% C, 4·80% H, 8·16% N, 6·21% S.

Methyl 6-Azido-3,5-di-O-benzoyl-6-deoxy-2-O-methanesulfonyl-β-D-glucofuranoside (*VI*)

Using the above described procedure 6·27 g (14·7 mmol) of glycoside *IV* were converted to 7·16 g (96·5%) of methanesulfonyl derivative *VI* with m.p. 109–111°C (benzene–light petroleum, to incipient turbidity), $[\alpha]_D^{20}$ −82·8 ± 1° (*c* 0·5, chloroform). For $C_{22}H_{23}N_3O_9S$ (505·5) found: 52·38% C, 4·69% H, 8·47% N, 6·59% S.

Methyl 2,3-Anhydro-6-azido-6-deoxy-α-D-mannofuranoside (*VII*)

Methanolic 1M-$NaOCH_3$ (18 ml) was added under stirring to a solution of 8·3 g (16·4 mmol) of compound *V* in 80 ml of benzene and the mixture was refluxed for 30 min. After cooling it was saturated with a current of carbon dioxide. The inorganic salts precipitated were filtered off and washed with diethyl ether. The combined filtrates were evaporated to give 2·99 g (92%) of anhydro derivative *VII* which was crystallized from diethyl ether–light petroleum until the melting point was constant, 56°C; $[\alpha]_D^{20}$ +76·2 ± 2° (*c* 1, chloroform). For $C_7H_{11}N_3O_4$ (201·2) calculated: 41·79% C, 5·51% H, 20·89% N; found: 41·63% C, 5·52% H, 21·06% N.

Benzoylation of 74 mg of anhydro derivative *VII* with benzoyl chloride in pyridine gave 94 mg (84%) of syrupy methyl 2,3-anhydro-6-azido-5-O-benzoyl-6-deoxy-α-D-mannofuranoside (*XIX*). For $C_{14}H_{15}N_3O_5$ (305·3) calculated: 55·08% C, 4·95% H, 13·77% N; found: 55·19% C, 5·14% H, 13·93% N.

Methyl 2,3-Anhydro-6-azido-6-deoxy-β-D-mannofuranoside (*VIII*)

Using a procedure as for α-anomer 5·9 g (11·7 mmol) of derivative *VI* were converted to anhydro derivative *VIII* (2·28 g; 97·5% yield). The syrupy product was purified by chromatography on silica gel (elution with benzene–ethanol 100 : 1). The chromatographically pure compound had $[\alpha]_D^{20}$ −71·4 ± 1° (*c* 1, chloroform). For $C_7H_{11}N_3O_4$ (201·2) calculated: 41·79% C, 5·51% H, 20·89% N; found: 42·03% C, 5·51% H, 21·12% N.

Benzoylation of 107 mg of anhydro derivative *VIII* with benzoyl chloride in pyridine gave 159 mg (98%) of benzoyl derivative *XX*, syrup. For $C_{14}H_{15}N_3O_5$ (305·3) calculated: 55·08% C, 4·95% H, 13·77% N; found: 55·09% C, 5·11% H, 13·85% N.

Methyl 6-Azido-6-deoxy-α-D-altrofuranoside (*IX*)

A solution of 1·0 g (4·97 mmol) of anhydro derivative *VII* was refluxed in 20 ml of 1M-NaOH and the reaction monitored by thin-layer chromatography in S_3. After 6 h boiling the mixture was allowed to stand overnight, then neutralized by filtration through a column of Amberlite IRC-50 (H^+) which was washed with 250 ml of water. The combined eluate was evaporated and the residue chromatographed on silica gel using the solvent system S_2 for elution. Yield, 636 mg (58·3%) of syrupy glycoside *IX*, $[\alpha]_D^{23}$ +101·3 ± 1° (*c* 1, ethanol). For $C_7H_{13}N_3O_5$ (219·2) calculated: 38·36% C, 5·98% H, 19·17% N; found: 38·26% C, 6·02% H, 19·20% N.

Benzoylation of glycoside *IX* with benzoyl chloride in pyridine gave syrupy methyl 6-azido-2,3,5-tri-O-benzoyl-6-deoxy-α-D-altrofuranoside (*XXI*) in 87% yield; $[\alpha]_D^{20}$ −5·4 ± 2° (*c* 0·7, chloroform); IR spectrum: 3 020, 2 940, 2 110, 1 725, 1 600, 1 450, 970, 940, 850 cm^{-1}. For $C_{28}H_{25}N_3O_8$ (531·5) calculated: 63·27% C, 4·74% H, 7·90% N; found: 63·48% C, 4·82% H, 7·70% N.

Methyl 6-Azido-6-deoxy-β-D-altrofuranoside (*X*) and Methyl 6-Azido-6-deoxy-β-D-glucofuranoside (*XI*)

A solution of 1·85 g (9·2 mmol) of anhydro derivative *VIII* in 35 ml of 1M-NaOH was refluxed (bath temp. 130°C) and analysed from time to time by thin-layer chromatography in S_3. After 120 min the starting compound was no longer present in the mixture and the product gave in addition to trace impurities only one long spot which was separated in S_5 to two approximately equally strong spots. After cooling the mixture was neutralized by filtration through a column of 25 ml of Amberlite IRC-50 (H^+) and washing with 500 ml of water. The eluate was concentrated and the residue (1·83 g; 90·5%) consisted of a mixture of glycosides *X* and *XI*. Both isomers were separated by chromatography using benzene–ethyl acetate 2 : 3 for elution. Altrofuranoside *X* (681 mg; 33·8% yield) had R_F 0·32 (S_5), m.p. 95·5°C (benzene–ethyl acetate), $[\alpha]_D^{20}$ −107·9 ± 2° (*c* 0·8, ethanol). For $C_7H_{13}N_3O_5$ (219·2) calculated: 38·36% C, 5·98% H, 19·17% N; found: 38·60% C, 6·08% H, 19·32% N. Glucofuranoside *XI* (504 mg of a syrup; 25% yield) had R_F 0·49 (S_5), $[\alpha]_D^{20}$ −92·2 ± 2° (*c* 0·7, ethanol). For $C_7H_{13}N_3O_5$ (219·2) found: 38·39% C, 6·18% H, 19·40% N. Mixed fractions were chromatographed repeatedly to give further amounts of glycosides *X* and *XI*, so that the approximate weight ratio of both glycosides was 5 : 4.

For spectral analysis both glycosides were converted to tribenzoates. Methyl 6-azido-2,3,5-tri-O-benzoyl-6-deoxy-β-D-altrofuranoside (*XXII*), a syrup, had $[\alpha]_D^{20}$ −102·3 ± 1·5° (*c* 0·7, chloroform) and the following IR spectrum: 3 070, 3 020, 2 990, 2 840, 2 100, 1 745, 1 605, 1 450 1 025, 1 000, 705 cm^{-1}. For $C_{28}H_{25}N_3O_8$ (531·5) calculated: 63·27% C, 4·74% H, 7·90% N; found: 63·22% C, 4·66% H, 7·28% N. The tribenzoate prepared from glycoside *XI* was according to its physical properties and IR spectrum identical with compound *XVIII*.

6-Azido-6-deoxy-D-altrose (*XII*)

An approximately 5% solution of glycoside *IX* or *X* in 1M-HCl was stirred at 90°C and checked by thin-layer chromatography in S_3. After 45 min the reaction mixture no longer contained the starting compound. The mixture was cooled, neutralized by filtration through a column of Amberlite IR-4B (OH^-) anion exchanger and the filtrate and washing water were combined and decolorized with charcoal and evaporated. The syrupy aldose *XII* was obtained in 80—90% yield and it was purified by chromatography on silica gel (elution with S_4), $[\alpha]_D^{20}$ +24 ± 1° (*c* 0·5, ethanol). For $C_6H_{11}N_3O_5$ (205·2) calculated: 35·12% C, 5·40% H, 20·48% N; found: 35·14% C, 5·43% H, 20·54% N.

6-Amino-6-deoxy-D-altronic Acid (*XIV*)

A solution of 570 mg (2·8 mmol) of azido-altrose *XII* in 10 ml of water was stirred at room temperature with 200 µl of bromine in the presence of 1 g of barium carbonate. The oxidation course was monitored by thin-layer chromatography in S_3. After 90 min the spot of the aldose (R_F 0·10) disappeared and the product was a mixture of an acid (R_F 0) and a lactone (R_F 0·19). The reaction mixture was filtered through a column of Dowex 50 W (H^+) and the eluate was concentrated to 10 ml and transferred to another column (20 ml) with Dowex 2 (OH^-) anion exchanger. The azido-altronic acid *XIII* retained was displaced from the column by elution with 15% acetic acid. Evaporation of the eluate gave a syrupy mixture (457 mg) of acid *XIII* and its lactones (detection by carbonization and hydroxamate test). Attempts at the separation of some of these compounds by crystallization failed. Therefore the mixture was reduced in aqueous solution (25 ml) with hydrogen at atmospheric pressure on 150 mg of 5% palladium on charcoal. The reduction course was monitored by thin-layer chromatography in S_3. After 3·5 h the catalyst was filtered off and the solution evaporated first on a vacuum rotatory evaporator and finally by freeze-drying. Yield, 355·5 mg (89%) of amino acid *XIV* in the form of a dry foam, $[\alpha]_D^{20}$ −3·8 ± 2°, $[\alpha]_{578}^{20}$ −6·6°, $[\alpha]_{405}^{20}$ −10·3° (*c* 0·7, water). On a thin layer of cellulose in S_6 amino acid *XIV* gave a spot with R_F 0·20. For $C_6H_{13}NO_6$ (195·2) calculated: 36·92% C, 6·71% H, 7·18% N; found: 36·71% C, 6·61% H, 7·42% N.

2,3,4,5-Tetra-O-acetyl-6-amino-6-deoxy-D-altronolactam (*XVI*)

A solution of 339 mg (1·73 mmol) of amino acid *XIV* in 30 ml of a 1·7% methanolic hydrogen chloride was refluxed under stirring for 5 h, decolorized with charcoal, and filtered. The filtrate was evaporated and the foamy methyl ester of 6-amino-6-deoxy-D-altronic acid hydrochloride (402 mg; 80%) was dissolved in 20 ml of methanol and combined with 1·55 ml of 1M-$NaOCH_3$ in methanol. The mixture was evaporated and the syrupy lactam *XV* (in the presence of inorganic salt) was acetylated with an excess of acetic anhydride in pyridine. After working up 524 mg of a semisolid were obtained, which after purification by preparative chromatography (chloroform–methanol 100 : 2) and crystallization from ethyl acetate–light petroleum gave 335·3 mg of tetraacetyllactam *XVI*, m.p. 204°C, $[\alpha]_D^{20}$ + 36·8 ± 1° (*c* 1, chloroform); IR spectrum: 3 365, 3 000, 2 960, 1 750, 1 700, 1 450, 1 370, 1 230 cm^{-1}. For $C_{14}H_{19}NO_9$ (345·3) calculated: 48·70% C, 5·55% H, 4·06% N; found: 48·74% C, 5·59% H, 4·09% N.

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REFERENCES

1. Kefurt K., Čapek K., Kefurtová Z., Jarý J.: This Journal *44*, 2526 (1979).
2. Kefurt K., Kefurtová Z., Jarý J.: This Journal *49*, 2665 (1984).
3. Hudson C. S.: J. Amer Chem. Soc. *31*, 66 (1909).
4. Richardson A. C.: Carbohyd. Res. *10*, 395 (1969).
5. Buchanan J. G. in the book: *International Review of Science, Organic Chemistry Series One*, Vol. 7., *Carbohydrate Chemistry* (G. O. Aspinall, Ed.), p. 33. Butterworths, London 1972.
6. Černý I., Trnka T., Černý M.: This Journal *49*, 433 (1984).
7. Williams N. R.: Advan. Carbohyd. Chem. *25*, 155 (1970).

8. Hanessian S.: J. Org. Chem. *34*, 675 (1969).
9. Kefurt K., Kefurtová Z., Jarý J.: This Journal, in press.
10. Lemieux R. U., Lineback D. R.: Annu. Rev. Biochem. *32*, 155 (1963).
11. Reinehart K. L. jr, Chilton W. S., Histens M., v. Phillipsborne W.: J. Amer. Chem. Soc. *84*, 3216 (1962).
12. Casini G., Goodman L.: J. Amer. Chem. Soc. *86*, 1 427 (1964).
13. Capon B., Thacker D.: Proc. Chem. Soc., London *1964*, 369.
14. Čapek K., Jarý J., Samek Z.: This Journal *40*, 149 (1974).
15. Kam B. L., Barascut J. L., Imbach J. L.: Carbohyd. Res. *69*, 135 (1979).
16. Jardetzky C. D.: J. Amer. Chem. Soc. *84*, 62 (1962).
17. Nishimura T., Shimizu B., Imay J.: Chem. Pharm. Bull. *12*, 1471 (1964).
18. Nishimura T., Shimizu B.: Chem. Pharm. Bull. *13*, 803 (1965).
19. Stevens J. P., Ness R. K., Fletcher H. G. jr: J. Org. Chem. *33*, 1806 (1968).
20. Haga M., Ness R. K., Fletcher H. G. jr: J. Org. Chem. *33*, 1810 (1968).
21. Zajíček J., Buděšínský M., Farkaš J.: This Journal *49*, 235 (1984).
22. Hruska F. E., Grey A. A., Smith I. C. P.: J. Amer. Chem. Soc. *92*, 4088 (1970).
23. Kim K. S., Vyas D. M., Szarek W. A.: Carbohyd. Res. *72*, 25 (1979).

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