PREPARATION OF METHYL 2,4-DIACETAMIDO-2,4,6-TRIDEOXY--α-D-IDO-, α-D-TALO-, α-D-ALTRO-, AND α-D-MANNOPYRANOSIDE

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Received October 24th, 1986

Title compounds were prepared from methyl 2-O-acetyl-3,4-anhydro-6-deoxy-α-D-galactopyranoside (*I*). Solvolysis of *I* afforded methyl 3-O-acetyl-6-deoxy-α-D-gulopyranoside (*II*) from which in turn was prepared its 2,4-di-O-methanesulfonyl derivative *III*. The reaction of *III* with sodium azide undergoes under participation of the O-acetyl group in the position 3 and produces methyl 2,4-diazido-2,4,6-trideoxy-α-D-idopyranoside (*V*) that after hydrogenation and acetylation yields methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-idopyranoside (*VIII*). Methyl 2,4-diacetamido-2,4,6--trideoxy-α-D-talopyranoside (*XI*) was prepared by its mesylation and by solvolysis of the product. Azidolysis of *I*, followed by hydrogenation and acetylation gave methyl 4-acetamido-4,6-dideoxy-α-D-glucopyranoside (*XII*). Its subsequent reaction with diethyl azodicarboxylate–triphenylphosphine mixture led to methyl 4-acetamido-2,3-anhydro-4,6-dideoxy-α-D-allopyranoside (*XV*). Mixture of methyl 4-acetamido-2-azido-2,4,6-trideoxy-α-D-altropyranoside (*XVII*) and its gluco- isomer *XVIII* is formed in the reaction of *XV* with sodium azide. Hydrogenation of *XVII* yields amino derivative *XIX* that in turn gives methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-altropyranoside (*XXI*) by acetylation. Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-mannopyranoside (*XXII*) was prepared by its mesylation and solvolysis. All structures were confirmed by ^{1}H and ^{13}C NMR spectra.

Since the time when 2,4-diamino-2,4,6-trideoxy-D-glucose was isolated from *Bacillus subtilis*[1,2] and later identified[3], many papers were published, describing the occurence of this aminosaccharide, its N-acetyl derivative[4–9] as well as its D-galacto--isomer[10–12]. Syntheses of benzyl or methyl glycosides of 2,4-diacetamido-2,4,6--trideoxyhexoses were described[13–18]. In order to extend our studies of physico--chemical properties of aminodeoxysaccharides[19–22], we deal in this paper with the preparation of methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-ido-, α-D-talo-, α-D--altro-, and α-D-manno-pyranoside. These compounds could serve as model compounds for the study of bacterial polysaccharides and could be also used for the synthesis or biosynthesis of 5,7-diamino-3,5,7,9-tetradeoxynonulosonic acids, recently identified in bacterial polysaccharides[23].

Readily available methyl 2-O-acetyl-3,4-anhydro-6-deoxy-α-D-galactopyranoside (*I*)[24] was used as the starting material for the preparation of all the above mentioned methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-hexopyranosides. Its solvolysis provides methyl 3-O-acetyl-6-deoxy-α-D-gulopyranoside (*II*)[25], from that we obtained methyl 3-O-acetyl-6-deoxy-2,4-di-O-methanesulfonyl-α-D-gulopyranoside (*III*) by reaction with methanesulfonyl chloride in pyridine. S_N2 displacement of the mesyloxy groups in compound *III* by azide ion should give in the case of no other group participation the methyl 2,4-diazido-2,4,6-trideoxy-α-D-altropyranoside. However, trans orientation of mesyloxy group in *III* with respect to the acetoxy group allows hydrolysis of an O-acetyl group under the conditions of azidolysis and the oxirane ring formation leading to methyl 3,4-anhydro-6-deoxy-2-O-methanesulfonyl-α-D-allopyranoside (*IV*). Diaxial opening of the oxirane ring[26] and the displacement of the mexyloxy group in the position 2 by an azide ion should transform *IV* to methyl 2,4-diazido--2,4,6-trideoxy-α-D-idopyranoside (*V*). Using a similar mechanism, Paulsen and Koebernick[18] explained the formation of 2,4-diamino-2,4,6-trideoxy-α-D-idopyranoside from methyl 4-O-acetyl-2,3-di-O-methanesulfonyl-6-deoxy-α-D-glucopyranoside (and 4-O-benzoyl analogue, respectively) by treatment with hydrazine followed by hydrogenolysis. Zehavi and Sharon[16] also supposed that methyl 3,4-anhydro-2--azido-2,6-dideoxy-α-L-altropyranoside was an intermediate in the azidolysis of methyl 2,3-anhydro-6-deoxy-4-O-methanesulfonyl-α-L-gulopyranoside leading besides the 2,4-diazido-2,4,6-trideoxy-α-L-altropyranoside also to 2,4-diazido-2,4,6--trideoxy-α-L-idopyranoside. Therefore, we first prepared the anhydro derivative *IV* from the dimesyl derivative *III* by treatment with sodium methoxide. Compound *IV* was then subjected to the reaction with sodium azide in 2-methoxyethanol. We obtained the methyl 4-azido-4,6-dideoxy-2-O-methanesulfonyl-α-D-gulopyranoside (*VI*) in 82% yield. This compound is a product of a diaxial opening of the anhydro ring of compound *IV* in its $^0H_1$ conformation. The structure of *VI* was confirmed by its hydrogenation followed by acetylation (acetic anhydride–pyridine) that gave methyl 4-acetamido-3-O-acetyl-4,6-dideoxy-2-O-methanesulfonyl-α-D-gulopyranoside (*VII*).

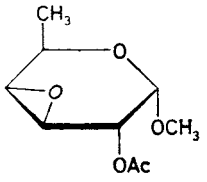
The reaction of anhydro derivative *IV* with sodium azide in N,N-dimethylformamide produced a sirupy diazido derivative *V*. Its ^{1}H NMR spectrum was identical to that published[18] for methyl 2,4-diazido-2,4,6-trideoxy-α-D-idopyranoside (*V*). Hydrogenation of this compound, followed by acetylation (acetic anhydride–methanol) gave methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-idopyranoside (*VIII*, ref.[18]). The same product was obtained by reaction of dimesyl derivative *III* with sodium azide in N,N-dimethylformamide, hydrogenation and acetylation with acetic anhydride in methanol. To investigate the mechanism of the diazido derivative *V* formation from the dimesyl derivative *III*, we shortened the reaction time in an another experiment. The reaction mixture contained at least six components according to thin-layer chromatography; four of them were isolated. The compound

having highest R_F value exhibited a presence of an O-acetyl group in its IR spectrum, and its ^{1}H NMR spectrum was identical with that published[18] for methyl 2,4-diazido-3-O-acetyl-2,4,6-trideoxy-α-D-idopyranoside (*IX*). The second compound was identical with the diazido derivative *V*; it gave the compound *VIII* upon hydrogenation and acetylation by acetanhydride in methanol. The third compound contained according to its IR spectrum O-acetyl, methanesulfonyl, and azido groups. Its hydrogenation and acetylation provided the compound *VII*. Therefore, it was assigned the structure of methyl 3-O-acetyl-4-azido-4,6-dideoxy-2-O-methanesulfonyl-α-D-gulopyranoside (*X*). The last compound isolated was the compound *VI*. We failed to isolate or detect the anhydro derivative *IV* in the reaction mixture. The presence of the four mentioned compounds in the reaction mixture from the azidolysis of dimesyl derivative *III* suggests that the azidolysis of *III* starts at the position 4 under the participation of the O-acetyl group[27] in the position 3. Thus, the 4-azido derivative *X* with retention of configuration at C-4 is formed from the compound *III*. This compound is partly transformed to the diazido derivative *IX* by the displacement of the mesyloxy group in the position 2, partly deacetylated to the compound *VI*. The later compound then provides compound *V* through the displacement of the mesyloxy group in the position 2 by the azido group. Compound *V* is also formed by deacetylation of *IX*.

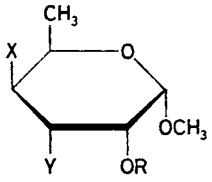
We intended to prepare 3-O-methanesulfonyl derivative of the diacetamido compound *VIII* and through its solvolysis[28] to obtain the methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-talopyranoside *XI*. We found that the solvolysis took place already during the work-up of the reaction mixture after the treatment of compound *VIII* with methanesulfonyl chloride. Therefore, the mesyl derivative was not isolated in the next experiment but instead subjected to the reaction with sodium acetate in aqueous methanol so that compounds *XI* was obtained.

In our earlier experiments, we have found that the oxirane ring in methyl 3,4-anhydro-6-deoxy-α-D-galactopyranoside is opened predominantly at the position 3 during the reaction with sodium azide in aqueous 2-methoxyethanol[29], whereas with methyl 3,4-anhydro-6-deoxy-2-O-methanesulfonyl-α-D-galactopyranoside the reaction took place at the position 4 (ref.[30]). Were the effect of the O-acetyl group in compound *I* on the regioselectivity of the oxirane ring opening similar to that of methanesulfonyl group, it would be possible to use the compound *I* for the preparation of another configurational isomers of methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-hexopyranosides. Therefore, the compound *I* was treated with sodium azide in aqueous 2-methoxyethanol, the mixture of products was hydrogenated and then acetylated by acetic anhydride in methanol. The chromatography on silica gel afforded a mixture of two compounds, one of them having the R_F value identical to that of methyl 3-acetamido-3,6-dideoxy-α-D-gulopyranoside, together with methyl 4-acetamido-4,6-dideoxy-α-D-glucopyranoside (*XII*) (ref.[29]) (in 46% yield). Upon acetylation of the above mentioned mixture (acetic anhydride–pyridine), the chromato-

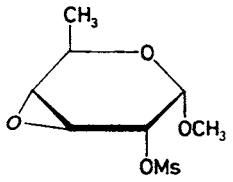
graphy yielded methyl 3-acetamido-2,4-di-O-acetyl-3,6-dideoxy-α-D-gulopyranoside (*XIII*) (ref.[29]) in 19% yield and 2,3,4-tri-O-acetyl-6-deoxy-α-D-gulopyranoside (*XIV*) (ref.[25]) in 22% yield. Thus, the oxirane ring in compound *I* is opended by the azide



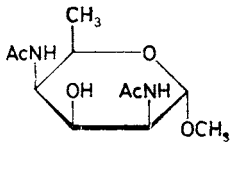
I



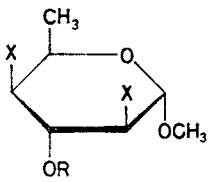
II, R = H ; Y = CH_3COO ; X = OH
III, R = Ms ; Y = CH_3COO ; X = CH_3SO_2O
VI, R = Ms ; Y = OH ; X = N_3
VII, R = Ms ; Y = CH_3COO ; X = CH_3CONH
X, R = Ms ; Y = CH_3COO ; X = N_3
XIII, R = Ac ; Y = CH_3CONH ; X = CH_3COO
XIV, R = Ac ; Y = CH_3COO ; X = CH_3COO



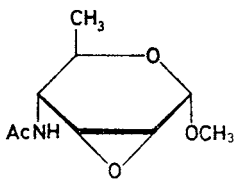
IV



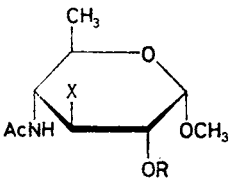
XI



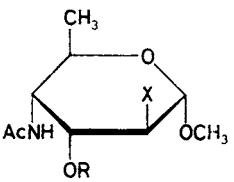
V, R = H ; X = N_3
VIII, R = H ; X = CH_3CONH
IX, R = Ac ; X = N_3



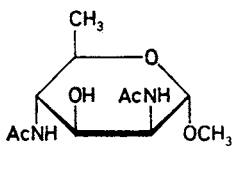
XV



XII, R = H ; X = OH
XVI, R = C_2H_5OCO ; X = OH
XVIII, R = H ; X = N_3
XXIII, R = H ; X = CH_3CONH
XXIV, R = Ac ; X = CH_3CONH



XVII, R = H ; X = N_3
XIX, R = H ; X = NH_2
XX, R = Ac ; X = CH_3CONH
XXI, R = H ; X = CH_3CONH



XXII

In formulae Ac = CH_3CO, Ms = CH_3SO_2

ion predominantly at the position 4. However, competing reaction to azidolysis is solvolysis under the participation of the O-acetyl group[25] in the position 2. Nevertheless, the compound *I* is favored over methyl 3,4-anhydro-6-deoxy-α-D-galactopyranoside as the starting compound for the preparation of compound *XII*. Compound *XII* was subjected to the reaction with the triphenylphosphine–diethyl azodicarboxylate mixture[31-34] in chloroform.* We obtained the methyl 4-acetamido-2,3-anhydro-6-deoxy-α-D-allopyranoside (*XV*) in 99% yield, a compound we have prepared earlier[30] from 3-O-methanesulfonyl derivative of compound *XII*. Treatment of the anhydro derivative *XV* with sodium azide in 95% aqueous 2-methoxyethanol yielded methyl 4-acetamido-2-azido-2,4,6-trideoxy-α-D-altropyranoside (*XVII*) and methyl 4-acetamido-3-azido-3,4,6-trideoxy-α-D-glucopyranoside (*XVIII*) in 40 : 60 ratio. Hydrogenation of the azido derivative *XVII* gave the amino derivative *XIX* that gave methyl 2,4-diacetamido-3-O-acetyl-2,4,6-trideoxy-α-D-altropyranoside (*XX*) upon acetylation (acetic anhydride in pyridine). Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-altropyranoside *XXI* was prepared either by acetylation of the amino derivative *XIX* (acetic anhydride–methanol) or by deacetylation of compound *XX*. Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-mannopyranoside *XXII* was obtained by its reaction with methanesulfonyl chloride in pyridine followed by solvolysis of the reaction product with sodium acetate in 2-methoxyethanol. Hydrogenation of

TABLE I
Chemical shifts (in ppm) in ^{13}C NMR spectra of acetamido derivatives

Compound	C(1)	C(2)	C(3)	C(4)	C(5)	C(6)	CH_3O	CH_3—C	CO—N
VIII	100·5	55·1	69·5	55·0	66·9	15·2	56·9	23·0 23·3	175·4 175·5
XI	101·5	51·5	66·5	52·8	66·3	16·7	56·1	23·2 23·3	175·8 176·5
XXI	100·6	53·0	68·5	51·9	64·4	10·8	56·5	23·1 23·2	175·0 175·2
XXII	100·9	53·2	68·0	54·5	68·4	17·9	56·0	23·1 23·3	175·9 176·1
XXIII	100·0	70·9	53·3	56·3	67·8	18·0	56·3	23·1 23·2	175·3 175·9

* It is essential to carry out this reaction in chloroform devoid of ethanol. In its presence, the methyl 4-acetamido-4,6-dideoxy-2-O-ethoxycarbonyl-α-D-glucopyranoside (*XVI*) is formed in 5—10% yield.

the azide derivative *XVIII* transformed this compound to an amino derivative that was converted by acetylation (acetic anhydride in methanol or pyridine) into methyl 3,4-diacetamido-3,4,6-trideoxy-α-D-glucopyranoside (*XXIII*) or its 2-O-acetyl derivative *XXIV*, respectively. The structures of compounds *VII*, *VIII*, *XI*, *XV*, *XVII*, *XVIII*, and *XX*–*XXIV* were confirmed by ^{1}H NMR spectra that contained corresponding number of signals due to N-acetyl or O-acetyl groups; magnitudes of coupling constants were in agreement[35,36] with the proposed structures. The position of acetamido groups in compounds *VII*, *XV*, *XVII*, *XVIII*, *XX*, and *XXIV* was inferred from the coupling of the NH protons to the corresponding CH protons of the saccharide skeleton; ^{13}C NMR spectra (Table I) were employed with compounds *VIII*, *XI*, *XXI*, *XXII*, and *XXIII*. Signals of carbon atoms bearing the nitrogen atom appeared at relatively high field (51–57 ppm).

EXPERIMENTAL

Melting points were determined on a Kofler apparatus and were not corrected. Optical rotations were measured by an Opton instrument in 20 cm cuvettes at 20°C and concentration $c = 1{\cdot}0 \pm 0{\cdot}3$. Thin-layer chromatography (TLC) was performed on silica gel according to Stahl (Merck, Darmstadt), particle size 10–40 μm; plate size 25 × 75 mm; layer thickness 0·2–0·3 mm. The detection was made by spraying with 1% cerium(IV) sulfate in 10% sulfuric acid followed by heating. Preparative chromatography was made on silica gel column with particle size 100 to 160 μm (Lachema, Brno). Solvents were removed *in vacuo* (water pump) at bath temperature below 50°C. ^{1}H NMR spectra were measured on a Bruker WM-250 spectrometer at 30°C. ^{13}C NMR spectra were measured on a Bruker AM-300 spectrometer at 30°C using methanol as an internal standard. Chemical shifts are given in the δ-scale. Signal assignments are based on the homonuclear decoupling and signal multiplicity (^{1}H NMR) and on the selective heteronuclear decoupling experiments (^{13}C NMR).

Methyl 3-O-acetyl-6-deoxy-2,4-di-O-methanesulfonyl-α-D-gulopyranoside (*III*)

Methanesulfonyl chloride (3·5 ml) was added at −70°C to the mixture of *II* (3·32 g; 15·1 mmol) and pyridine (30 ml). After 48 h standing at −15°C the mixture was decomposed with water and diluted with chloroform. The solution was extracted with cold 15% sulfuric acid, water, 5% sodium hydrogen carbonate, and with water. The extract was dried, chloroform evaporated and the residue was recrystallized from the ethyl acetate–petroleum ether mixture. Total 5 g of *III*, m.p. 156–158°C, $[\alpha]_D$ +99° (chloroform) was obtained. Evaporation of mother liquors and recrystallization of the residue provided another 0·15 g of *III*; total yield was 91%. For $C_{10}H_{20}O_{10}S_2$ (376·4) was calculated: 35·10% C, 5·35% H, 17·04% S; found: 35·12% C, 5·56% H, 17·19% S.

Methyl 3,4-anhydro-6-deoxy-2-O-methanesulfonyl-α-D-allopyranoside (*IV*)

Methanolic solution of sodium methoxide (6 ml; 1 mol l^{-1}) was added during 30 min to the stirred suspension of *III* (1·88 g; 5 mmol) in methanol (25 ml) at 50°C. The mixture was stirred another 1 h at 50°C and then evaporated. The residue was dissolved in chloroform (50 ml), the solution was extracted with water (20 ml), dried over magnesium sulfate and evaporated. The

residue was crystallized from the mixture ethyl acetate–petroleum ether and provided *IV* (1·10 g; 92%), m.p. 121—123°C, $[\alpha]_D$ +44° (chloroform). For $C_8H_{14}O_6S$ (238·3) was calculated: 40·33% C, 5·92% H, 13·46% S; found: 40·63% C, 5·93% H, 13·15% S.

Methyl 4-azido-4,6-dideoxy-2-O-methanesulfonyl-α-D-gulopyranoside (*VI*)

Mixture of *IV* (450 mg; 1·9 mmol), 2-methoxyethanol (6 ml), water (0·6 ml), sodium azide (500 mg), and ammonium chloride (320 mg) was boiled 3 h, evaporated and the residue was extracted with boiling acetone. Acetone was evaporated and the rest was crystallized from the mixture ethanol–petroleum ether. Compound *VI* was obtained (438 mg; 82%), m.p. 111—113°C, $[\alpha]_D$ +67° (chloroform). For $C_8H_{15}N_3O_6S$ (281·3) was calculated: 34·16% C, 5·37% H, 14·94% N, 11·40% S; found: 34·41% C, 5·25% H, 14·84% N, 11·40% S.

Methyl 2,4-diazido-2,4,6-trideoxy-α-D-idopyranoside (*V*)

A) Mixture of *VI* (203 mg; 0·72 mmol), N,N-dimethylformamide (5 ml), and sodium azide (500 mg) was boiled for 6 h. Solvent was distilled off at 100 Pa and the residue was purified by column chromatography on silica gel (15 g) in the system benzene–ethanol 100 : 1. Compound *V* (124 mg; 75%), $[\alpha]_D$ +76° (methanol) was obtained. Ref.[18] gives $[\alpha]_D$ + 86° (methanol).

B) Mixture of di(methanesulfonyl) derivative *III* (1·08 g; 2·87 mmol), N,N-dimethylformamide (30 ml), and sodium azide (1·8 g) was boiled 6 h and then worked-up as in *A*. The yield of *V* was 262 mg (40%).

Methyl 4-acetamido-3-O-acetyl-4,6-dideoxy-2-O-methanesulfonyl-α-D-
-gulopyranoside (*VII*)

Platinum dioxide was added to the solution of *VI* (110 mg; 0·39 mmol) in methanol (7 ml) and the mixture was stirred 2 h under hydrogen atmosphere. The catalyst was then filtered off and the filtrate was evaporated. Pyridine (4 ml) and acetic anhydride (0·5 ml) were added and after 24 h standing at room temperature the mixture was decomposed with water, solvent was several times evaporated, toluene was added and evaporated again. The residue was purified by column chromatography on silica gel (15 g) in the system benzene–acetone 8 : 2. The obtained sirupy residue (117 mg; 88%) crystallized upon addition of ethyl acetate and one drop of water. Re-crystallization from the mixture wet ethyl acetate–petroleum ether gave *VII*, m.p. 130—132°, $[\alpha]_D$ +81·7° (chloroform). For $C_{12}H_{21}NO_8S$ (339·4) was calculated: 42·47% C, 6·24% H, 4·13% N, 9·45% S; found: 42·49% C, 6·13% H, 3·91% N, 9·46% S. ^{1}H NMR spectrum (C^2HCl_3): 1·19 (3 H, d, $J(5, 6) = 6·5$ Hz, H-6), 2·10 (3 H, s, CH_3CON), 2·16 (3 H, s, CH_3COO), 3·10 (3 H, s, CH_3SO_2), 3·48 (3 H, s, CH_3O), 4·16 (dq, $J(4, NH) = 8·4$ Hz, H-4), 4·52 (dq, $J(4, 5) = 2·1$ Hz, H-5), 4·83—4·86 (2 H, H-1, 2), 5·36 (m, $J(3, 4) = 4·2$ Hz, H-3), 6·13 (d, NH).

Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-idopyranoside (*VIII*)

Methanolic solution of *V* (50 ml; 690 mg; 3·02 mmol) was stirred 3 h in the presence of platinum dioxide in hydrogen atmosphere. The catalyst was then filtered off, filtrate evaporated, and methanol (10 ml) and acetic anhydride (1 ml) were added to the residue. After 12 h standing at room temperature, the solvents were removed and the residue was subjected to column chromatography on silica gel (20 g) in the system chloroform–ethanol 100 : 15. The yield of compound *VIII*, recrystallized from ethanol, was 613 mg (78%), mp. 258—260°C, $[\alpha]_D$ +84° (methanol); +78° (water). Ref.[18] gives m.p. 251°C, $[\alpha]_D$ +65° (methanol). ^{1}H NMR spectrum (^2H_2O):

1·22 (3 H, d, $J(5, 6) = 6·6$ Hz, H-6), 2·04 (3 H, s, CH_3CON), 2·06 (3 H, s, CH_3CON), 3·43 (3 H, s, CH_3O), 3·75–3·90 (2 H, m, H-2,3), 3·95 (m, H-4), 4·40 (dq, $J(4, 5) = 4·6$ Hz, H-5), 4·71 (d, $J(1, 2) = 5·5$ Hz, H-1).

Short-term Reaction of *III* with Sodium Azide

Mixture of *III* (1·62 g; 4·3 mmol), N,N-dimethylformamide (45 ml), and sodium azide (2·7 g) was boiled 50 min and then evaporated. The residue was subjected to column chromatography on silica gel (100 g) in the system ether–petroleum ether 4 : 1. We obtained 227 mg of mixture *IX* and *V* (TLC benzene–acetone 8 : 2), 400 mg of compound *X* containing 2–3 impurities (TLC benzene–acetone 8 : 2), and 260 mg of compound *VI*, m.p. 111–113°C (crystallized from ethyl acetate–petroleum ether). Compounds with lower R_F values (TLC ether–petroleum ether 4 : 1), obtained in small amounts, were not identified. The mixture of *IX* and *V* (227 mg) was rechromatographed on silica gel column (20 g) in benzene or benzene–ethanol 100 : 1 mixture, respectively. Compounds *IX* (68 mg; 6%) and *V* (156 mg; 16%) were eluted. Chemical shifts and coupling constants in ^{1}H NMR spectra of compound *IX* measured in deuteriochloroform or deuteriomethanol, agree with those reported[18]; $[\alpha]_D$ +62° (chloroform), ref.[18] gives +63° (chloroform). Compound *V* was according to its ^{1}H NMR spectrum identical with *V* prepared from the compound *III* or described in the ref.[18]. Re-chromatography of the portion containing *X* (400 mg) on silica gel column (40 g) in the system benzene–acetone 95 : 5 afforded *X* as sirupy liquid (272 mg; 19·5%), $[\alpha]_D$ +100° (chloroform). IR spectrum (chloroform): 1 760 cm^{-1} (C=O), 2 100 cm^{-1} (—N_3). ^{1}H NMR spectrum (C^2HCl_3): 1·28 (3 H, d, $J(5, 6) = 6·6$ Hz, H-6), 2·18 (3 H, s, CH_3CO), 3·10 (3 H, s, CH_3SO_2), 3·48 (3 H, s, CH_3O), 3·80 (dd, $J(3, 4) = 6·5$ Hz, H-3), 4·36 (dq, $J(4, 5) = 3·5$ Hz, H-5), 4·82 (d, $J(1, 2) = 3·0$ H_2, H-1), 4·96 (t, H-2), 5·22 (dd, $J(2, 3) = 3·8$ Hz, H-4).

Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-talopyranoside (*XI*)

Methanesulfonyl chloride (0·6 ml) was added at −76°C to the solution of *VIII* (326 mg; 1·25 mmol) in pyridine (15 ml) and the mixture was left at −15°C overnight. According to TLC analysis (chloroform–ethanol 100 : 15), all *VIII* was consumpted. Solution of sodium hydrogen carbonate (5%; 30 ml) was added to the reaction mixture, evaporated and the residue was extracted with chloroform. The solvent was removed and 2-methoxyethanol (30 ml), water (1·5 ml), and sodium acetate (1·7 g) were added to the residue. The mixture was boiled 3 h, evaporated and the residue was subjected to column chromatography on silica gel (20 g) in the system benzene–ethanol 10 : 1. Compound *XI* was obtained (230 mg; 70%), m.p. 194–196°C (ethyl acetate), $[\alpha]_D$ +66° (methanol). For $C_{11}H_{20}N_2O_5$ (260·3) was calculated: 50·76% C, 7·75% H, 10·76% N; found: 50·53% C, 7·78% H, 10·69% N. ^{1}H NMR spectrum ($C^2H_3O^2H$): 1·10 (3 H, d, $J(5, 6) = 6·1$ Hz, H-6), 1·96 (3 H, s, CH_3CON), 1·99 (3 H, s, CH_3CON), 3·30 (3 H, s, CH_3O), 4·03 (t, $J(2, 3) = 4·7$ Hz, H-3), 4·05 (dq, $J(4, 5) = 2·5$ Hz, H-5), 4·08 (dd, $J(1, 2) = 1·6$ Hz, H-2), 4·13 (dd, $J(3, 4) = 4·5$ Hz, H-4), 4·60 (d, H-1).

Azidolysis of Compound *I*

Mixture of *I* (1·9 g; 9·3 mmol), 2-methoxyethanol (30 ml), water (2 ml), ammonium chloride (1·1 g), and sodium azide (1·9 g) was refluxed 24 h and then evaporated. The residue was extracted with boiling acetone and the extract was evaporated. The residue was dissolved in methanol (40 ml), platinum dioxide was added and the mixture was stirred 8 h in hydrogen atmosphere. The catalyst was filtered off, acetic anhydride (6 ml) was added to the filtrate and the mixture

was allowed to stand overnight at room temperature. After that were the solvents removed and the residue was chromatographed on a silica gel column (80 g) in the system benzene–ethanol 10 : 1 or 5 : 1, respectively. Eluted were the mixture of two components (830 mg, TLC benzene–ethanol 5 : 1) with higher R_F and compound *XII* (940 mg; 46%),m.p. 192—193°C(ethyl acetate), $[\alpha]_D$ +174° (water). Ref.[29] gives m.p. 191—192°C, $[\alpha]_D$ +173 ± 1° (water), ref.[37] gives m.p. 188—189°C, $[\alpha]_D$ +151° (water). The mixture of compounds with higher R_F (830 mg) was dissolved in pyridine (20 ml), acetic anhydride (5 ml) was added and the mixture was allowed to stand 24 h at room temperature. It was then decomposed with water, evaporated, toluene was added and evaporated again. The residue was subjected to column chromatography on silica gel (100 g) in the system benzene–ethanol 100 : 1 or 100 : 5, respectively. Compound *XIV* (555 mg; 19·5%), m.p. 78—79°C (petroleum ether), $[\alpha]_D$ +108° (chloroform), was obtained. Its IR spectrum (chloroform) was identical with that of authentic sample[28] having m.p. 82—83°C and $[\alpha]_D$ +107·5° (chloroform). We further obtained compound *XIII* (630 mg; 22%), m.p. 126—127°C (ethyl acetate–petroleum ether), $[\alpha]_D$ +100° (chloroform). Its IR spectrum was identical with that of authentic sample[29] having m.p. 127—128°C and $[\alpha]_D$ +101° (chloroform).

Methyl 4-acetamido-2,3-anhydro-4,6-dideoxy-α-D-allopyranoside (*XV*)

Triphenylphosphine (2·0 g) was added to the solution of *XII* (630 mg; 2·9 mmol) in ethanol-free chloroform (50 ml); after 15 min stirring, diethyl azodicarboxylate (1·3 g) was dropwise added. The mixture was stirred 4 h at room temperature and then allowed to stand overnight. Solvents were removed and the residue was subjected to column chromatography on silica gel (60 g). Balast compounds were eluted with benzene–ethanol 100 : 2; compound *XV* (570 mg; 99%), m.p. 181—183°C (after crystallization from ethyl acetate m.p. 185—186°C, $[\alpha]_D$ +205° (chloroform) was eluted with benzene–ethanol 100 : 5. Ref.[30] gives m.p. 186—187°C, $[\alpha]_D$ +209° (chloroform). ^{1}H NMR spectrum (C^2HCl_3): 1·15 (3 H, d, J_5(5, 6) = 6·1 Hz, H-6), 2·00 (3 H, s, CH_3CON), 3·35 (dd, J(2, 3) = 4·0 Hz, H-3), 3·40 (3 H, s, CH_3O), 3·50 (dd, J(1, 2) = 3·2 Hz, H-2), 3·59 (dq, J(4, 5) = 9·5 Hz, H-5), 4·15 (dt, J(3, 4) = 1·8 Hz, H-4), 4·86 (d, H-1), 6·24 (d, J(4, NH) = 9·0 Hz, NH).

The yield of compound *XV* was about 85% in the experiments in which the chloroform stabilized with ethanol was used. Re-chromatography of fractions containing the mixture of compounds *XV* and *XVI* on silica gel in the system benzene–acetone 3 : 1 provided the compound *XVI*, m.p. 170—172°C (ethyl acetate), $[\alpha]_D$ +153° (chloroform), in 5—10% yield. For $C_{12}H_{21}NO_7$ (291·3) was calculated: 49·47% C, 7·27% H, 4·81% N; found: 49·21% C, 7·22% H, 4·77% N. ^{1}H NMR spectrum (C^2HCl_3, instrument Bruker AM 400): 1·23 (3 H, d, J(5, 6) = 5·3 Hz, H-6), 1·31 (3 H, t, $J(CH_2, CH_3)$ = 7·1 Hz, CH_3), 2·04 (3 H, s, CH_3COO), 3·38 (3 H, s, CH_3O), 3·75 to 3·79 (2 H, m, H-4, 5), 3·94 (t, J(3, 4) = 9·0 Hz, H-3), 4·07 (s, OH), 4·21 (q, CH_2O), 4·63 (dd, J(2, 3) = 9·6 Hz, H-2), 4·92 (d, J(1, 2) = 3·6 Hz, H-1), 6·51 (d,J(4, NH) = 11 Hz, NH).

Azidolysis of Compound *XV*

Mixture of compound *XV* (588 mg; 2·9 mmol), 2-methoxyethanol (20 ml), water (1 ml), sodium azide (600 mg), and ammonium chloride (360 mg) was boiled 4 h, then evaporated and the residue was chromatographed on silica gel column (80 g) in the system benzene–ethanol 100 : 3 and 100 : 5, respectively. Compounds *XVII* (274 mg) and *XVIII* (396 mg) were obtained (yield 94%). *XVII* was recrystallized from the mixture ethyl acetate–petroleum ether, m.p. 108—109°C, $[\alpha]_D$ +94·5° (chloroform). For $C_9H_{16}N_4O_4$ (244·2) was calculated: 44·25% C, 6·60% H, 22·94% N; found: 44·50% C, 6·64% H, 23·15% N. IR spectrum: 2 100 cm^{-1} (—N_3). ^{1}H NMR spectrum (C^2HCl_3): 1·28 (3 H, d, J(5, 6) = 6·4 Hz, H-6), 2·02 (3 H, s, CH_3CON), 3·45 (3 H, s,

CH_3O), 3·76 (dq, $J(4, 5) = 9·6$ Hz, H-5), 3·75–3·85 (2 H, m, H-2, 3), 4·10 (dt, $J(3, 4) = 2·6$ Hz, H-4), 4·76 (t, $J(1, 2) = J(1, 3) = 1·5$ Hz, H-1), 6·00 (d, $J(4, NH) = 9·0$ Hz, NH).

Compound *XVIII* was re-crystallized from the mixture ethyl acetate–petroleum ether and had m.p. 173–174°C, $[\alpha]_D$ +228° (chloroform). For $C_9H_{16}N_4O_4$ (244·2) was calculated: 44·25% C, 6·60% H, 22·94% N; found: 43·96% C, 6·84% H, 22·94% N. IR spectrum: 2 100 cm^{-1} ($-N_3$). ^1H NMR spectrum (C^2HCl_3): 1·23 (3 H, d, $J(5, 6) = 6·8$ Hz, H-6), 2·06 (3 H, s, CH_3CON), 3·46 (3 H, s, CH_3O), 3·60–3·75 (3 H, m, H-2, 3, 4), 3·80 (dq, $J(4, 5) = 11·5$ Hz, H-5), 4·75 (d, $J(1, 2) = 4·0$ Hz, H-1), 5·82 (d, $J(4, NH) = 10·0$ Hz, NH).

Methyl 4-acetamido-2-amino-2,4,6-trideoxy-α-D-altropyranoside (*XIX*)

Mixture of compound *XVII* (168 mg; 0·69 mmol), methanol (20 ml), and platinum oxide was stirred 3 h under hydrogen atmosphere, the catalyst was filtered off and the solvent was removed. The residue (144 mg; 96%) was re-crystallized from the mixture ethanol–petroleum ether, m.p. 189–191°C, $[\alpha]_D$ +154° (ethanol). For $C_9H_{18}N_2O_4$ (218·2) was calculated: 49·53% C, 8·31% H, 12·84% N; found: 49·56% C, 8·36% H, 12·63% N.

Methyl 2,4-diacetamido-3-O-acetyl-2,4,6-trideoxy-α-D-altropyranoside (*XX*)

Mixture of *XIX* (210 mg; 0·96 mmol), pyridine (5 ml), and acetic anhydride (2 ml) was left standing overnight, decomposed with water, evaporated and the residue was purified by column chromatography on silica gel (30 g) in the system benzene–ethanol 100 : 5. Compound *XX* (291 mg; 100%), m.p. 178–180°C (melts at 111–113°C and then solidifies again), $[\alpha]_D$ +119° (chloroform) was obtained. In an another experiments isolated compound *XX* had m.p.147–149°C and ^1H NMR spectrum identical with that of higher melting sample. For $C_{13}H_{22}N_2O_6.H_2O$ (320·3) was calculated: 48·74% C, 7·55% H, 8·74% N; found: 48·61% C, 7·48% H, 8·71% N. Ref.[16] gives for the L-enantiomer $[\alpha]_D$ −168 ± 1·6° (chloroform) and m.p. 272°C. ^1H NMR spectrum (C^2HCl_3): 1·26 (3 H, d, $J(5, 6) = 6·0$ Hz, H-6), 2·00 (3 H, s, CH_3CON), 2·01 (3 H, s, CH_3CON), 2·10 (3 H, s, CH_3COO), 3·35 (3 H, s, CH_3O), 3·98 (dq, $J(4, 5) = 9·0$ Hz, H-5), 4·20 (dt, $J(3, 4) = 3·4$ Hz, H-4), 4·35 (dd, $J(1, 2) = 1·6$ Hz, H-2), 4·51 (d, H-1), 4·85 (t, $J(2, 3) = 3·7$ Hz, H-3), 5·74 (d, $J(4, NH) = 9·2$ Hz, 4-NH), 6·08 (d, $J(2, NH) = 8·3$ Hz, 2-NH).

Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-altropyranoside (*XXI*)

One drop of methanolic sodium methoxide (1 mol l^{-1}) was added to the solution of compound *XX* (120 mg; 0·4 mmol) in methanol (10 ml). The mixture was left overnight, evaporated and the residue was purified by column chromatography on silica gel (10 g) in the system benzene–ethanol 10 : 1. Amorphous compound *XXI* (100 mg; 96%), $[\alpha]_D$ +118° (methanol) was obtained For $C_{11}H_{20}N_2O_5$ (260·3) was calculated: 50·75% C, 7·74% H, 10·76% N; found: 50·58% C, 7·66% H, 10·50% N. The same compound was obtained from the amino derivative *XIX* (30 mg) by acetylation with acetic anhydride (0·3 ml) in methanol (3 ml). ^1H NMR spectrum (^2H_2O): 1·25 (3 H, d, $J(5, 6) = 6·0$ Hz, H-6), 2·06 (6 H, s, 2 CH_3CON), 3·42 (3 H, s, CH_3O), 3·84 (t, $J(3, 4) = 3·4$ Hz, H-3), 3·94 (dd, $J(4, 5) = 9·6$ Hz, H-4), 4·08 (dq, H-5), 4·09 (d, $J(2, 3) = 3·5$ Hz, H-2), 4·69 (d, H-1).

Methyl 2,4-diacetamido-2,4,6-trideoxy-α-D-mannopyranoside (*XXII*)

Using the same procedure as described for compound *XI*, was from 110 mg of *XXI* (0·2 ml of methanesulfonyl chloride in 5 ml of pyridine, solvolysis of the mesyl derivative accomplished with 0·6 g of sodium acetate in 10 ml of 2-methoxyethanol and 0·5 ml of water) we prepared 70 mg

of *XXII*, m.p. 148–149°C (ethyl acetate–petroleum ether), $[\alpha]_D$ +43° (methanol). For $C_{11}H_{20}N_2O_5$ (260·3) was calculated: 50·75% C, 7·74% H, 10·76% N; found: 50·40% C, 7·47% H, 10·48% N. ^{1}H NMR spectrum ($C^2H_3O^2H$): 1·13 (3 H, d, J(5, 6) = 6·0 Hz, H-6), 1·92 (3 H, s, CH_3CON), 1·97 (3 H, s, CH_3CON), 3·28 (3 H, s, CH_3O), 3·56 (dq, J(4, 5) = 9·6 Hz, H-5), 3·73 (t, J(3, 4) = 10·2 Hz, H-4), 3·86 (dd, J(2, 3) = 4·3 Hz, H-3), 4·18 (dd, J(1, 2) = 1·6 Hz, H-2), 4·50 (d, H-1).

Methyl 3,4-diacetamido-3,4,6-trideoxy-α-D-glucopyranoside (*XXIII*)

Mixture of *XVIII* (320 mg; 1·3 mmol), methanol (25 ml), and platinum oxide was stirred 4 h under hydrogen atmosphere, filtered, and evaporated to dryness. Methanol (20 ml) and acetic anhydride (1·5 ml) were added to the residue; upon 12 h standing at room temperature, the mixture was evaporated and the residue crystallized from the mixture ethanol–petroleum ether. Compound *XXIII* (320 mg), m.p. 286–288°C, $[\alpha]_D$ +255° (methanol), was obtained. For $C_{11}H_{20}N_2O_5$ (260·3) was calculated: 50·75% C, 7·74% H, 10·76% N; found: 50·70% C, 7·44% H, 10·48% N. ^{1}H NMR spectrum (^2H_2O): 1·21 (3 H, d, J(5, 6) = 5·8 Hz, H-6), 1·99 (3 H, s, CH_3CON), 2·00 (3 H, s, CH_3CON), 3·47 (3 H, s, CH_3O), 3·63 (t, J(3, 4) = 10·2 Hz, H-4), 3·74 (dd, J(1, 2) = 3·6 Hz, H-2), 3·90 (dq, J(4, 5) = 9·9 Hz, H-5), 4·08 (t, J(2, 3) = 10·1 Hz, H-3), 4·83 (d, H-1).

Methyl 2,4-diacetamido-3-O-acetyl-2,4,6-trideoxy-α-D-glucopyranoside (*XXIV*)

Using the procedure described above for compound *XXIII*, corresponding amino derivative was prepared from compound *XVIII* (370 mg; 1·5 mmol). Pyridine (6 ml) and acetic anhydride (3 ml) were added and the mixture was left standing 24 h at room temperature, then decomposed with water, evaporated and the residue was chromatographed on a silica gel column (50 g) in the system chloroform–ethanol 100 : 5. Compound *XXIV* was obtained (383 mg; 84%), m.p. 274 to 276°C (ethanol–petroleum ether), $[\alpha]_D$ +185° (ethanol). For $C_{13}H_{22}N_2O_6$ (302·3) was calculated: 51·64% C, 7·34% H, 9·27% N; found: 51·67% C, 7·37% H, 9·02% N. ^{1}H NMR spectrum (C^2HCl_3): 1·23 (3 H, d, J(5, 6) = 6·0 Hz, H-6), 1·93 (3 H, s, CH_3CON), 1·95 (3 H, s, CH_3CON), 2·10 (3 H, s, CH_3COO), 3·42 (3 H, s, CH_3O), 3·73 (dq, J(4, 5) = 10·2 Hz, H-5), 3·80 (dt, J(4, NH) = 8·6 Hz, H-4), 4·42 (dt, J(3, 4) = 10·2 Hz, H-3), 4·77 (d, J(1, 2) = 3·4 Hz, H-1), 4·85 (dd, J(2, 3) = 10·8 Hz, H-2), 5·99 (d, J(3, NH) = 9·1 Hz, 3-NH), 6·01 (d, 4-NH).

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Translated by P. Sedmera.