PREPARATION OF β-D-GLUCOPYRANOSYL DERIVATIVES OF 1,6:2,3- AND 1,6:3,4-DIANHYDRO-β-D-HEXOPYRANOSES AND THEIR ^{1}H AND ^{13}C NMR SPECTRA*

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The corresponding acetylated and free 2-*O*- and 4-*O*-glucosyl derivatives of dianhydrohexoses *Ib* – *VIIb* and *Ic* – *VIIc* have been obtained by the reactions of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (*IX*) with 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses (*Ia* – *VIIa*). Structure of the products and the effects of glycosylation upon chemical shifts and conformations of the disaccharides prepared have been studied using ^{1}H and ^{13}C NMR spectra.

Suitably protected 1,6-anhydro-β-D-hexopyranoses can serve as useful starting materials in syntheses of some disaccharides and oligosaccharides[1–4]. In spite of that, the relatively easily accessible 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses (*Ia* – *VIIIa*) with a single free hydroxyl group have been adopted in oligosaccharide syntheses only sporadically so far[1,4], e.g. the reaction of 6-*O*-acetyl-2,3,4-tri-*O*-benzyl-α-D-mannopyranosyl bromide with 1,6:2,3-dianhydro-β-D-mannopyranose[1].

Therefore we decided to investigate the possibilities of glycosylation of all the eight isomeric dianhydrohexopyranoses *Ia* – *VIIIa* with 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (*IX*) and to find which of the anhydrodisaccharides *Ib* – *VIIIb* would be accessible in this way for further synthetic applications. In addition, we considered it useful to determine the stereochemistry of these compounds and publish their NMR data.

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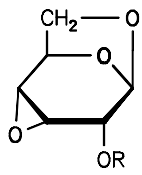
RESULTS AND DISCUSSION

The starting dianhydro derivatives were prepared by known procedures from 1,6-anhydro-β-D-glucopyranose[5–10] or from the corresponding anhydro derivatives with D-*manno*- and D-*galacto*-configuration[5]. They were glycosylated with glucosyl bromide *IX* under conditions very often used, i.e. in dichloromethane in the presence of silver silicate[2]. The obtained acetylated β-D-glucopyranosyl derivatives *Ib – VIIb* were deacetylated by transesterification with methanol to give the compounds *Ic – VIIc* (Table I). The structures of both the acetates *Ib – VIIb* and hydroxy derivatives *Ic – VIIc* were proved by means of their ^{1}H and ^{13}C NMR spectra.



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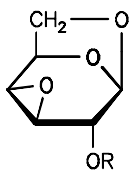

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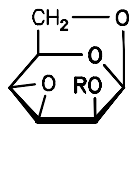

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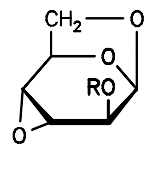

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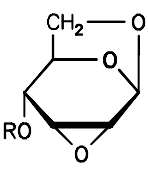

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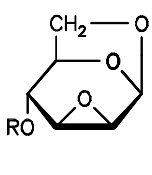

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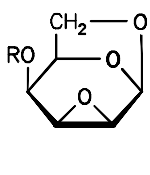

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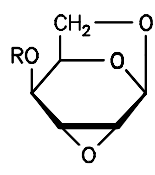
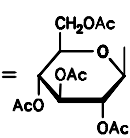
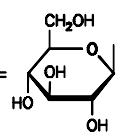
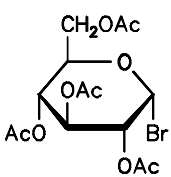


VIII

In formulae *I – VIII* : *a*, R = H; *b*, R =  ; *c*, R = 



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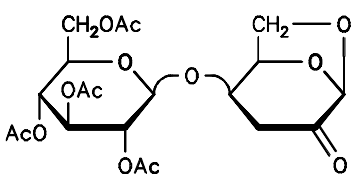
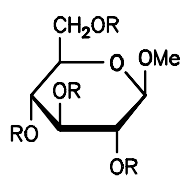


X



XI, R = Ac

XII, R = H

SCHEME 1

Whereas the glycosylation of 1,6:3,4-dianhydro derivatives *Ia* – *IVa* and 1,6:2,3-dianhydro derivatives *Va*, *VIa* proceeded with yields of 62 – 81%, the dianhydro derivative *VIIa* with free hydroxyl group at C-4 position showed lower reactivity (yield 21%). Compound *VIIIa* completely failed in giving the expected product *VIIIb*, and the only pure product which could be isolated from the complex reaction mixture was the glucosylated 2-oxo-3-deoxy derivative *X* (yield 2.5%) which is most likely formed from the product *VIIIb* by rearrangement of epoxide in the reaction medium. Its structure was unambiguously proved by means of ^{1}H and ^{13}C NMR spectra (see Experimental). The lowered reactivity in the glycosylation of dianhydro derivative *VIIa* can be due to a lowered steric accessibility of the hydroxyl group at C-4 position caused by the proximity of the methylene group of 1,6-anhydride bridge or also to the effect of intra-

TABLE I
Characteristics of β-D-glucopyranosyl derivatives of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses *Ic* – *VIIc* and their tetraacetates *Ib* – *VIIb*

Compound	M.p., °C	$[\alpha]_D$, ° (*c*)[a]	Formula (M.w.)	Calculated		Found	
				% C	% H	% C	% H
			Acetates				
Ib	205 – 207	–79.9 (1.04)	$C_{20}H_{26}O_{13}$ (474.4)	50.63	5.52	50.47	5.41
IIb	177 – 178	–34.0 (0.93)				50.55	5.48
IIIb	211 – 219	–27.0 (0.81)				50.48	5.49
IVb	194 – 197	–60.7 (0.64)				50.54	5.44
Vb	205 – 209	+15.6 (1.02)				50.51	5.48
VIb	197 – 209	–29.7 (0.73)				50.49	5.48
VIIb	178 – 188	–51.0 (0.77)				50.63	5.52
			Free disaccharides				
Ic	[b]	–111.1 (0.45)	$C_{12}H_{18}O_9$ (306.3)	47.06	5.92	46.84	5.84
IIc	[b]	–45.5 (0.94)				46.85	5.84
IIIc	[b]	–23.6 (0.27)				46.91	5.95
IVc	229 – 236	–90.3 (0.35)				46.81	5.91
Vc	[b]	+25.6 (0.94)				46.91	5.92
VIc	[b]	–37.0 (0.45)				46.83	5.82
VIIc	[b]	[c]				[c]	[c]

[a] Measured in chloroform. [b] Amorphous compound. [c] Not determined due to very small quantity of sample.

molecular hydrogen bonds[11,12]. This is in accordance with an earlier finding concerning the reactivity of dianhydrohexoses *Ia – VIIIa* in the methylations with iodomethane in the presence of silver oxide[11].

NMR Spectra

The signals in ^{1}H NMR spectra of both acetates *Ib – VIIb* and free disaccharides *Ic – VIIc* (Tables II and III) were structurally assigned on the basis of chemical shifts, signal multiplicities, spin-spin coupling, and comparison with spectra of sugar units – dianhydrohexopyranoses *Ia – VIIIa* and methyl β-D-glucoside *XII* and/or its tetraacetate *XI* (Table IV). In some cases, the complex character of spectrum (overlap of signals of strongly interacting hydrogens) made impossible the extraction of all NMR parameters from the 200 MHz spectra. This is particularly true for the signals of H-2′ to H-5′ hydrogens of the β-D-glucopyranose section in the free disaccharides *Ic – VIIc*. In some cases (*IIIc*, *Vc*) the complete assignment was achieved by combining the 1D and 2D-COSY spectra measured at 500 MHz (see the example of compound *Ic* in Fig. 1). The comparison of *J*(H,H) coupling constants shows almost identical values for both the disaccharides and monomeric sugar units (the observed differences of less than 0.3 Hz are comparable with accuracy of the measurement). This means that the conformations of the sugar units remain practically unchanged during the formation of the disaccharide: the energetically favoured chair form $^4C_1$ with all its substituents in equatorial positions and the twist-chair form ^5T_O for β-D-glucopyranose and dianhydrohexopyranose, respectively.

The proton-decoupled ^{13}C NMR spectra of acetates *Ib – VIIb* and free disaccharides *Ic – VIIc* (measured by the pulse sequence APT – ref.[13]) were structurally assigned (Tables V and VI) by comparing with the spectra of the monomeric sugar units *Ia – VIIa* (Table IV). The changes of chemical shifts of hydrogen and carbon atoms of dianhydrohexopyranose residue which are connected with the introduction of 2,3,4,6-tetra-*O*-acetylated β-D-glucose (in $CDCl_3$) are given in Table VII (the reference ^{1}H and ^{13}C NMR data of dianhydro derivatives *Ia – VIIa* in D_2O necessary for expressing the effect of introduction of free β-D-glucose are missing). From Table VII it follows that the glycosylation shifts of hydrogens are generally small (< 0.2 ppm), and neither their direction nor their magnitude is sufficiently characteristic of the glycosylation position. On the other hand, the observed glycosylation shifts of carbons – a downfield shift of +5.2 to +7.8 ppm at α-position and upfield shifts of −0.9 to −3.9 ppm at the neighbouring β-positions – are significant for the glycosylation position.

EXPERIMENTAL

The melting points were determined with a Boetius melting-point microapparatus and were not corrected. The optical rotation was measured with a Bendix–Ericsson ETL-143 A polarimeter at 21 °C,

TABLE II

Proton NMR parameters of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl derivatives of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses[a] *Ib – VIIb* in $CDCl_3$

Parameter	*Ib*	*IIb*	*IIIb*	*IVb*	*Vb*	*VIb*	*VIIb*
Proton			chemical shifts, ppm				
H-1	5.31	5.34	5.35	5.30	5.62	5.68	5.65
H-2	3.77	3.69	3.92	3.87	3.05	3.46	3.57
H-3	3.27	2.98	3.32	3.20	3.33	3.30	3.29
H-4	3.16	3.55	3.69	3.10	3.75	3.78	4.31
H-5	4.73	4.76	4.77	4.70	4.62	4.43	4.48
H-6en	3.94	3.88	4.04	4.09	3.66	~3.71	3.96
H-6ex	3.75	3.44	3.55	3.84	3.92	~3.71	3.58
H-1′	4.91	4.67	4.87	4.68	5.02 – 5.32	4.76	4.86
H-2′	5.03	4.95	5.08	5.03		5.03	5.03
H-3′	5.26	5.15	5.25	5.23		5.24	5.25
H-4′	5.10	5.01	5.09	5.07		5.09	5.08
H-5′	3.76	3.68	3.75	3.74	3.75	3.74	3.75
H-6′a	4.27	4.19	4.25	4.27	~4.21	4.27	4.23
H-6′b	4.15	4.07	4.16	4.14	~4.21	4.15	4.17
OAc	2.08(2)	2.05	2.07	2.09	2.07(2)	2.08	2.09(2)
	2.03	1.98	2.06	2.06	2.04	2.06	2.04
	2.02	1.96	2.03	2.03	2.02	2.04	2.02
		1.94	2.01	2.01		2.02	
H_i,H_j			coupling constants, Hz				
1,2	0.8	0.8	3.4	2.8	1.2	3.1	2.9
2,3	4.3	~0	3.4	~0	3.9	3.7	4.1
3,4	4.1	4.1	4.3	3.9	4.8	0.7	2.9
4,5	1.7	5.0	4.6	1.5	0.8	1.1	6.2
5,6en	0.6	<1	~0	0.6	2.1	[b]	1.7
5,6ex	4.6	4.8	4.7	4.4	6.8	[b]	6.2
6en,6ex	7.4	6.6	6.6	7.5	8.2	[b]	7.5
1,3	2.2	1.5	1.2	2.4	0.7	~0	~0
2,4	~0	~0	~0	0.8	~0	0.8	~0
3,5	0.6	~0	~0	0.6	2.0	1.5	1.1
1′,2′	7.9	7.8	8.0	7.9	[b]	7.9	7.9
2′,3′	9.1	9.5	9.3	9.5	[b]	9.5	9.8
3′,4′	9.4	9.2	9.4	9.3	[b]	9.2	9.2
4′,5′	9.6	9.6	9.8	9.9	[b]	9.8	10.0
5′,6′a	4.8	5.1	4.8	5.0	[b]	4.9	5.0
5′,6′b	2.6	2.6	2.8	2.5	[b]	2.6	2.5
6′a,6′b	12.4	12.4	12.4	12.4	[b]	12.4	12.3

[a] The compound *VIIIb* was not synthesized. [b] Parameter value could not be determined.

TABLE III

Proton NMR parameters of β-D-glucopyranosyl derivatives of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses[a] *Ic* – *VIIc* in D_2O

Parameter	*Ic*	*IIc*	*IIIc*	*IVc*	*Vc*	*VIc*	*VIIc*
Proton			chemical shifts, ppm				
H-1	5.47	5.49	5.51	5.50	5.73	5.85	5.82
H-2	3.98	3.98	4.12	4.05	3.29	[b]	3.80
H-3	3.56	3.35	[b]	[b]	3.59	[b]	3.58
H-4	3.51	3.83	3.94	[b]	4.06	4.22	4.50
H-5	4.91	5.04	5.01	4.88	4.67	~4.69	4.74
H-6en	4.11	3.98	3.96	4.19	3.82	[b]	5.03
H-6ex	3.80	3.55	[b]	3.88	3.95	[b]	3.67
H-1′	4.72	4.69	4.67	4.65	4.64	4.69	4.76
H-2′	3.36	3.26 – 3.52	[b]	[b]	3.33 – 3.53	[b]	3.34
H-3′	3.53		[b]	[b]		[b]	3.53
H-4′	3.43		[b]	[b]		[b]	3.42
H-5′	3.50		[b]	[b]	~3.73	[b]	3.50
H-6′a	3.92	3.91	3.90	3.91	3.91	[b]	3.90
H-6′b	3.75	3.72	3.73	3.73	3.73	[b]	3.74
H_i,H_j			coupling constants, Hz				
1,2	0.8	0.7	3.6	2.9	1.4	3.2	3.0
2,3	4.4	0.5	3.5	~0	4.1	[b]	4.2
3,4	4.5	4.1	4.6	[b]	4.8	[b]	3.1
4,5	1.7	5.0	4.6	[b]	0.8	[b]	6.1
5,6en	<1	0.7	~0	0.6	2.4	[b]	1.7
5,6ex	4.6	4.7	4.7	4.5	6.8	[b]	6.2
6en,6ex	7.8	7.0	7.0	7.9	8.5	[b]	7.7
1,3	2.1	1.6	1.2	2.3	0.6	[b]	~0
2,4	~0	0.8	~0	0.9	~0	[b]	~0
3,5	<1	~0	~0	[b]	2.0	[b]	0.8
1′,2′	7.8	7.8	7.7	7.7	7.6	7.7	7.9
2′,3′	9.4	[b]	[b]	[b]	[b]	[b]	9.4
3′,4′	9.0	[b]	[b]	[b]	[b]	[b]	9.0
4′,5′	9.8	[b]	[b]	[b]	[b]	[b]	9.9
5′,6′a	2.2	2.1	2.0	1.9	1.8	[b]	2.2
5′,6′b	5.6	5.3	5.2	5.0	5.0	[b]	5.5
6′a,6′b	12.4	12.4	12.4	12.4	12.5	[b]	12.4

[a] The compound *VIIIc* was not synthesized. [b] Parameter value could not be determined.

TABLE IV

Proton and carbon-13 NMR parameters of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses[a] *Ia – VIIIa* in $CDCl_3$, methyl β-D-glucopyranoside[b] (*XII*) in D_2O, and its tetraacetate[c] *XI* in $CDCl_3$

Parameter	*Ia*	*IIa*	*IIIa*	*IVa*	*Va*	*VIa*	*VIIa*	*VIIIa*	*XI*	*XII*
Proton	proton chemical shifts, ppm									
H-1	5.20	5.23	5.28	5.32	5.60	5.69	5.65	5.59	4.44	4.27
H-2	3.59	3.79	3.77	3.83	3.13	3.45	3.57	3.06	4.98	3.15
H-3	3.34	3.13	3.32	3.00	3.39	3.14	3.29	3.06	5.21	3.38
H-4	3.22	3.60	3.77	3.13	3.62	3.91	4.31	4.26	5.09	3.27
H-5	4.69	4.81	4.79	4.73	4.40	4.42	4.48	4.41	3.71	3.36
H-6en	3.96	4.01	3.95	4.05	3.66	3.78	3.96	4.19	4.28	3.82
H-6ex	3.78	3.53	3.53	3.87	3.89	3.74	3.58	3.80	4.15	3.62
H_iH_j	interproton coupling constants, Hz									
1,2	0.7	0.7	3.6	3.1	1.3	3.1	2.9	1.0	7.9	8.2
2,3	4.5	0.3	3.6	0	4.1	3.8	4.1	4.0	9.6	9.6
3,4	4.1	4.0	4.3	4.0	4.7	0.8	3.1	0	9.3	9.6
4,5	1.7	4.8	4.5	1.6	0.8	1.2	6.4	5.3	9.8	9.6
5,6en	0.6	0.6	0.6	0.6	2.3	2.3	1.5	1.9	2.4	2.4
5,6ex	4.6	5.0	4.8	4.7	6.8	7.0	5.9	6.4	4.6	6.4
6en,6ex	7.5	6.8	6.8	7.5	8.3	7.4	7.7	8.4	12.2	12.8
1,3	2.1	1.6	1.0	2.3	0.7	~0	~0	0.5	–	–
2,4	~0	0.6	~0	0.8	~0	0.9	~0	0.7	–	–
3,5	0.7	~0	~0	0.6	2.0	1.6	1.0	1.8	–	–
Carbon	carbon-13 chemical shifts, ppm									
C-1	102.6	100.8	98.1	100.8	97.2	97.7	98.2	96.9	101.5	104.0
C-2	65.9	65.8	66.8	68.1	49.2	54.3	58.4	48.8	71.2	74.1
C-3	49.4	50.0	50.4	52.5[d]	50.2	49.4	51.1	53.1	72.8	76.8
C-4	50.6	53.0	57.3	51.5[d]	66.5	67.0	67.2	63.1	68.4	70.6
C-5	69.5	72.2	71.8	71.0	78.0	74.2	72.1	73.3	71.7	76.8
C-6	65.9	65.0	64.1	66.7	65.0	65.7	63.9	63.4	61.8	61.8

[a] Proton NMR data taken from ref.[17], ^{13}C NMR data from ref.[16] (compound *VIIa* was measured in CD_3OD). [b] Proton and ^{13}C NMR data taken from ref.[18] (the additional signals – OMe at δ 3.46 and 58.1 in ^1H and ^{13}C, respectively). [c] The additional signals – ^1H NMR: 3.51 s (OMe); 2.09 s, 2.05 s, 2.02 s, 2.00 s (4 × OAc). ^{13}C NMR: 57.0 (OMe), 170.7, 170.3, 169.3 (2×), 20.6 (2×) and 20.5 (2×) (4 × OAc). [d] The assignment of signals may be interchanged.

and the IR spectra with a Zeiss UR-20 spectrophotometer. The ^1H and ^{13}C NMR spectra were measured with an FT NMR spectrometer Varian XL-200 at 200 and 50.3 MHz, respectively, in $CDCl_3$ (acetates *Ib – VIIb*) or D_2O (free disaccharides *Ic – VIIc*). The ^1H NMR spectra of compounds *Ic*, *VIIb*, *VIIc*, and *X* were also measured with a Varian UNITY-500 apparatus at 500 MHz. The preparative column chromatography was performed on silica gel Merck (70 – 325 mesh) or HPLC on LiChrosorb Si 100 (Merck 100 μm). The TLC was carried out on Silikagel G (Fluka), layer thickness 0.25 – 0.30 mm on glass plates, detection by spraying with 50% sulfuric acid and mineralization or according to ref.[14]. The samples were dried at 40 °C and 10 Pa over phosphorus pentoxide.

Preparation of Ag-Silicate Catalyst (refs[1,2,15], modified procedure). A solution of water glass was prepared by dissolving silica gel Merck (10 g; 70 – 325 mesh) in 10% NaOH (100 ml) and 30 min boiling. After filtration through glass wool the filtrate was diluted with water to a volume of 160 ml. Aluminium oxide (15 g; Reanal, Brockman II, neutral) was suspended in a solution of $AgNO_3$ (17 g)

TABLE V

Carbon-13 chemical shifts (ppm) of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl derivatives of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses[a] *Ib – VIIb* in $CDCl_3$

Carbon	*Ib*	*IIb*	*IIIb*	*IVb*	*Vb*	*VIb*	*VIIb*
C-1	99.1	99.3	97.2	97.6	97.1	97.6	96.9
C-2	72.0	73.6	73.2	73.5	49.0	54.5	57.6
C-3	46.5	48.3	49.5	50.1	47.7	48.1	47.2
C-4	48.3	52.9	55.9	50.1	72.9	74.7	72.4[b]
C-5	69.3	71.5	72.0	70.0	75.6	71.8	69.5
C-6	65.2	64.5	64.5	67.3	65.8	65.7	63.6
C-1′	101.3	101.3	99.9	101.2	99.3	100.2	99.1
C-2′	71.2	71.2	70.8	71.1	71.1	71.2	71.0
C-3′	72.7	72.7	72.7	72.5	72.8	72.6	72.5[b]
C-4′	68.3	68.1	68.3	68.2	68.4	68.2	68.3
C-5′	72.0	72.0	72.2	72.1	72.1	72.1	72.1
C-6′	61.8	61.8	61.8	61.8	61.9	61.8	61.8
OAc	170.6	170.6	170.6	170.6	170.6	170.2	170.5
	170.3	170.2	170.2	170.2	170.2	169.3	170.2
	169.5	169.3	169.5	169.3	169.5	169.2(2)	169.4(2)
	169.4	169.0	169.3	169.2	169.4	20.7	20.7
	20.7(2)	20.7	20.7(2)	20.7	20.7(2)	20.6(3)	20.6(3)
	20.6(2)	20.6(2)	20.6(2)	20.6(3)	20.6(2)		
		20.5					

[a] The compound *VIIIb* was not synthesized. [b] The assignment of signals may be interchanged.

in water (110 ml), and the water glass solution (110 ml) was added dropwise. The precipitate formed was treated as in ref.[2]. The catalyst was kept at room temperature in the dark.

General Procedure for Preparation of *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→2)-1,6:3,4-dianhydro-β-D-allopyranose (*Ib*), *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→2)-1,6:3,4-dianhydro-β-D-galactopyranose (*IIb*), *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→2)-1,6:3,4-dianhydro-β-D-talopyranose (*IIIb*), *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→2)-1,6:3,4-dianhydro-β-D-altropyranose (*IVb*), *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→4)-1,6:2,3-dianhydro-β-D-allopyranose (*Vb*), *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→4)-1,6:2,3-dianhydro-β-D-mannopyranose (*VIb*), and *O*-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl-(1→4)-1,6:2,3-dianhydro-β-D-talopyranose (*VIIb*)

The glycosylations were carried out in a 30 ml vessel made of dark-brown glass closed with a 2 mm silicon rubber septum. Both reaction components were predried at room temperature under reduced pressure (5 – 10 Pa) for 2 h. A solution of 1,6:2,3- or 1,6:3,4-dianhydro-β-D-hexopyranose *Ia* – *VIIa* (1.0 g; 6.93 mmol) in dichloromethane (12 ml, dried with $CaCl_2$ and distilled immediately before use) was stirred in the reaction vessel with Ag-silicate catalyst (3.5 g) and molecular sieve 4A (2 g) for 2 h. Then a solution of 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (*IX*) (4.15 g, 10.1 mmol) in dichloromethane (12 ml) was added by means of a syringe (before the addition, this solution was stirred with molecular sieve 4A (2 g) in a closed vessel in darkness for 1 h). The reaction mixture was stirred at room temperature 20 h. The reaction course was monitored by TLC using chloroform–

TABLE VI

Carbon-13 chemical shifts (ppm) of β-D-glucopyranosyl derivatives of 1,6:3,4- and 1,6:2,3-dianhydro-β-D-hexopyranoses[a] *Ic* – *VIc* in D_2O

Carbon	*Ic*	*IIc*	*IIIc*	*IVc*	*Vc*	*VIc*
C-1	103.5	101.7	98.9	100.2	99.2	99.8
C-2	74.9	74.9	77.3	75.5	52.6	56.9
C-3	50.0	51.1	52.9	53.3	51.1	51.1
C-4	52.5	56.1	59.9	53.3	75.6	76.7
C-5	72.0	74.6	74.7	72.6	77.9	74.6
C-6	68.0	67.6	67.0	69.8	67.4	68.0
C-1′	104.3	105.4	105.6	105.9	104.5	104.9
C-2′	75.8	75.7	75.7	75.7	76.0	75.7
C-3′	78.7[b]	78.7[b]	78.7[b]	78.7[b]	78.7[b]	78.7[b]
C-4′	72.2	72.2	72.1	72.1	72.2	72.2
C-5′	78.2[b]	78.3[b]	78.3[b]	78.3[b]	78.3[b]	78.3[b]
C-6′	63.3	63.3	63.3	63.2	63.4	63.3

[a] The compound *VIIIc* was not synthesized; the compound *VIIc* was not measured due to very small quantity of the sample. [b] The assignment of signals may be interchanged.

methanol 10 : 1 mixture. After disappearance of the starting dianhydrohexose, the reaction mixture was diluted with chloroform to a volume of 40 ml and filtered through a 2 cm column of neutral aluminium oxide which was then washed with chloroform (2 × 5 ml). The filtrate was evaporated to dryness under reduced pressure below 40 °C. The syrupy evaporation residue was dissolved in 50 ml chloroform and extracted with water (3 × 50 ml). The chloroform solution was heated under a reflux condenser with 10% aqueous K_2CO_3 (50 ml) with vigorous stirring at 60 °C for 10 – 15 min. Then the dark-brown aqueous phase was separated and the whole procedure was repeated several times (3 – 4 times) until the aqueous solution ceased to turn brown. Thereafter the chloroform solution was extracted with water (3 × 50 ml), dried with anhydrous $CaCl_2$, and evaporated until dry. The products obtained

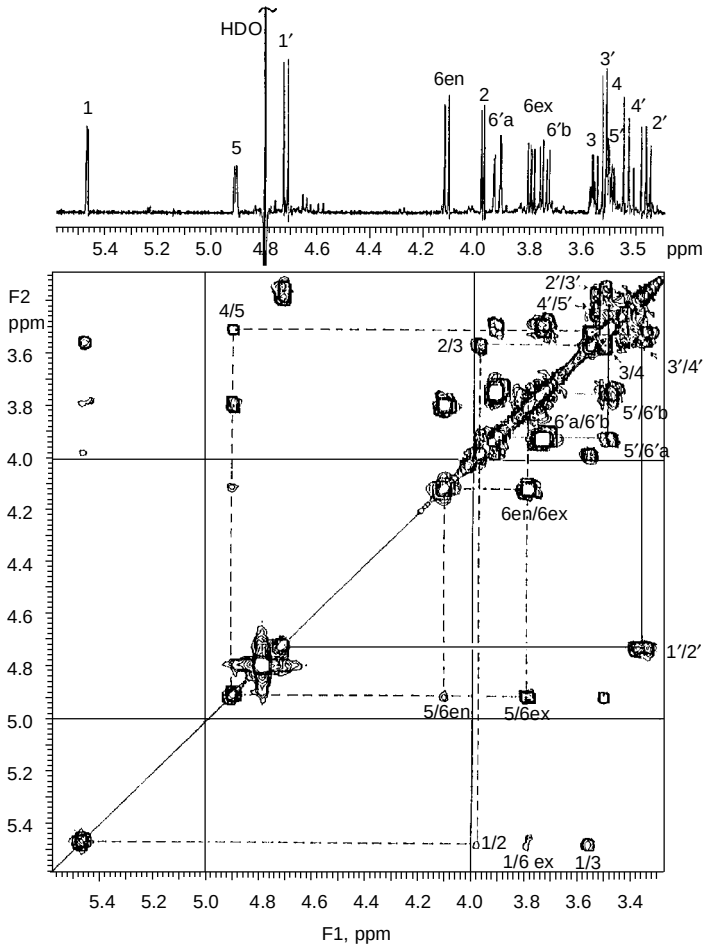


FIG. 1

Proton 2D-COSY spectrum of *O*-(β-D-glucopyranosyl)-(1→2)-1,6:3,4-dianhydro-β-D-allopyranose (*Ic*) in D_2O (at 500 MHz). The assignment of vicinal protons is indicated with a dashed line for dianhydrohexopyranose and with a full line for glucopyranose part

in this way (Table I) were recrystallized from methanol. If a product failed to crystallize, it was subjected to column chromatography using LiChrosorb (HPLC) and a chloroform–methanol system (50 : 1 and 25 : 1). The melting points, optical rotation values, and analytical data are given in Table I. The ^{1}H and ^{13}C NMR spectra are presented in Tables II and V.

O-(2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl)-(1→4)-1,6-anhydro-3-deoxy-β-D-threo-hexopyranos-2-ulose (*X*)

The title compound was obtained in the yield of 2.5% as the only isolable pure product in the glycosylation of compound *VIIIa* with glucosyl bromide *IX* according to the above-given procedure. M.p. 133 – 145 °C, $[\alpha]_D$ –13.0° (*c* 0.45; $CHCl_3$). Mass spectrum (FAB) *m/z*, for $C_{20}H_{26}O_{13}$ calculated: 474; found: 497 (M + Na), 475 (M + H), 415 (M + H – AcOH), 331 ($C_{14}H_{19}O_9$), 289 (331 – CH_2CO), 229 (289 – AcOH), 169 (229 – AcOH), 127 ($C_6H_7O_3$), 109 (169 – AcOH). ^{1}H NMR spectrum

TABLE VII
Glucosylation shifts (ppm) observed in proton and carbon-13 NMR spectra of tetraacetates[a] *Ib* – *VIIb* in $CDCl_3$

Parameter	2α-OGlc		2β-OGlc		4α-OGlc		4β-OGlc
	Ib	*IIb*	*IIIb*	*IVb*	*Vb*	*VIb*	*VIIb*
Proton	proton glucosylation shifts						
H-1	0.11	0.11	0.07	–0.02	0.02	–0.01	0
H-2	0.18	–0.10	0.15	0.04	–0.08	0.01	–0.04
H-3	–0.07	–0.15	0	0.20	–0.06	0.16	–0.05
H-4	–0.06	–0.05	–0.08	–0.03	0.13	–0.13	0.07
H-5	0.04	–0.05	0.02	–0.03	0.22	0.01	0.07
H-6en	–0.02	–0.13	0.09	0.04	0	~–0.07	–0.05
H-6ex	–0.03	–0.11	0.02	–0.03	0.03	~–0.03	0.07
Carbon	carbon-13 glucosylation shifts						
C-1	–3.5	–1.5	–0.9	–3.2	–0.1	–0.1	–1.3
C-2	6.1	7.8	6.5	5.4	–0.2	0.2	–0.8
C-3	–2.9	–1.7	–0.9	–2.4	–2.5	–1.3	–3.9
C-4	–2.3	–0.1	–1.4	–1.4	6.4	7.7	5.2
C-5	–0.2	–0.7	0.2	–1.0	–2.4	–2.4	–2.6
C-6	–0.7	–0.5	0.4	0.6	0.8	0	–0.3

[a] For the configuration at positions 2 and 4 we use the symbols α and β in this paper: the symbol β for the substituent in the *endo* position (*cis* with respect to the 1,6-anhydro bridge) and the symbol α for the substituent in the position *exo* (*trans* to the 1,6-anhydro bridge).

($CDCl_3$): 5.71 d, 1 H (H-1, $J(1,3\alpha)$ = 1.2); 5.19 t, 1 H (H-3′, $J(3',2')$ = 9.6; $J(3',4')$ = 9.4); 5.07 dd, 1 H (H-4′, $J(4',3')$ = 9.4; $J(4',5')$ = 10.0); 5.00 dd, 1 H (H-2′, $J(2',1')$ = 8.0; $J(2',3')$ = 9.6); 4.58 d, 1 H (H-1′, $J(1',2')$ = 8.0); 4.53 dm, 1 H (H-5, $J(5,3\alpha) \approx 1.2$; $J(5,4)$ = 1.2; $J(5,6en) < 1$, $J(5,6ex)$ = 5.3); 4.25 dd, 1 H (H-6′a, $J(6'a,5')$ = 5.2; $J(6'a,6'b)$ = 12.3); 4.15 dd, 1 H (H-6′b, $J(6'b,5')$ = 2.5; $J(6'b,6'a)$ = 12.3); 4.00 dd, 1 H (H-4, $J(4,3\alpha)$ = 3.1; $J(4,3\beta)$ = 6.9; $J(4,5)$ = 1.2); 3.92 bd, 1 H (H-6en, $J(6en,5) < 1$, $J(6en,6ex)$ = 8.2); 3.85 dd, 1 H (H-6ex, $J(6ex,5)$ = 5.3; $J(6ex,6en)$ = 8.2); 3.71 ddd, 1 H (H-5′, $J(5',4')$ = 10.0; $J(5',6'a)$ = 5.2; $J(5',6'b)$ = 2.5; 2.72 dd, 1 H (H-3β, $J(3\beta,3\alpha)$ = 17.5; $J(3\beta,4)$ = 6.9); 2.50 ddt, 1 H (H-3α, $J(3\alpha,1)$ = 1.2; $J(3\alpha,3\beta)$ = 17.5; $J(3\alpha,4)$ = 3.1; $J(3\alpha,5) \approx 1.2$); 2.10 s, 2.03 s, 2.02 s, 2.00 s, 4 × 3 H (4 × OAc). ^{13}C NMR spectrum ($CDCl_3$): 203.0 (C-2), 170.6, 170.3, 169.4, 169.3 (4 × C=O (Ac)), 101.9 (C-1′), 100.4 (C-1), 79.0 (C-4), 77.0 (C-5), 72.6 (C-3′), 72.0 (C-5′), 71.0 (C-2′), 68.19 (C-4′), 66.7 (C-6), 61.8 (C-6′), 39.3 (C-3), 20.7, 20.5 (3×) (4 × CH_3 (Ac)).

General Procedure for Preparation of *O*-(β-D-Glucopyranosyl)-(1→2)-1,6:3,4-dianhydro-β-D-allopyranose (*Ic*), *O*-(β-D-Glucopyranosyl)-(1→2)-1,6:3,4-dianhydro-β-D-galactopyranose (*IIc*), *O*-(β-D-Glucopyranosyl)-(1→2)-1,6:3,4-dianhydro-β-D-talopyranose (*IIIc*), *O*-(β-D-Glucopyranosyl)-(1→2)-1,6:3,4-dianhydro-β-D-altropyranose (*VIc*), *O*-(β-D-Glucopyranosyl)-(1→4)-1,6:2,3-dianhydro-β-D-allopyranose (*Vc*), *O*-(β-D-Glucopyranosyl)-(1→4)-1,6:2,3-dianhydro-β-D-mannopyranose (*VIc*), and *O*-(β-D-Glucopyranosyl)-(1→4)-1,6:2,3-dianhydro-β-D-talopyranose (*VIIc*)

Acetyl derivatives *Ib* – *VIIb* (100 mg, 0.21 mmol) were treated with 0.036 M solution of sodium methoxide in methanol (1 ml) at room temperature, whereupon the mixture was stirred for ca 2 h to complete the deacetylation (the reaction course was monitored by means of TLC (chloroform–methanol 3 : 1)). Then the solution was diluted with the same volume of methanol and neutralized with cation exchanger Amberlite CG-120 (130 mg, H^+ cycle), filtered, and evaporated at 40 °C in vacuum until dry. Most products obtained after drying at 5 Pa over phosphorus pentoxide were amorphous (yields ≈ 90%) and some of them were purified by column chromatography (silica gel, chloroform–methanol 10 : 1) and/or recrystallized from a methanol–ether mixture. The melting points, optical rotation values, and analytical data are given in Table I; the ^1H and ^{13}C NMR spectra are presented in Tables III and VI.

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