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THE STRUCTURE OF 6-BENZYLAMINO-6-DEOXY-1,2:3,4-DI-*O*-ISOPROPYLIDENE-L-*glycero*-α-D-*galacto*-HEPTOPYRANURONONITRILE: CONFORMATION OF THE SIX- AND FIVE-MEMBERED RINGS

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ABSTRACT

The structure of the title compound has been determined by X-ray analysis. The conformations of the saturated six-membered and the 1,3-dioxolane rings in the *cis,trans,cis* system of di-*O*-isopropylidene derivatives of α-D-galactopyranose, β-D-fructopyranose, and di-*O*-tosyl-L-*chiro*-inositol have been analysed in the solid state.

INTRODUCTION

The X-ray structural analysis of the title compound (**1**) was undertaken in order to determine the configuration at C-6. The conformations of the saturated six-membered and the 1,3-dioxolane rings in the *cis,trans,cis* system of di-*O*-isopropylidene derivatives of α-D-galactopyranose[1–6] (**1–7**), β-D-fructopyranose[7] (**9**), and di-*O*-tosyl-L-*chiro*-inositol[8] (**8**) have been analyzed in order to establish their common conformation in the solid state.

EXPERIMENTAL*

Crystal data for **1**. — M_w 374.4. Monoclinic, space group $P2_1$, a = 10.423(5), b = 10.553(5), c = 10.011(5) Å, α = 90, β = 110.63(5), γ = 90.0°, V = 1030.5(1) Å^3, D_c = 1.207 Mg.m^{-3}, Z = 2, $F(000)$ = 400.0; Cu-K_α radiation, λ 1.54178 Å, μ(Cu-K_α) 0.634 mm^{-1}. Crystal dimensions, 0.2 × 0.2 × 0.3 mm.

Data collection and processing. — Four-circle Philips PW 1100 diffractometer, graphite-monochromated Cu-K_α radiation, θ–2θ scan technique up to 2θ = 130°. The intensity fluctuations were random. 1776 reflexions had intensities higher than $2\sigma(I)$. No correction was applied for absorption.

*Lists of observed and calculated structure factors, anisotropic thermal parameters, and fractional coordinates of H atoms are deposited with, and can be obtained from, Elsevier Science Publishers B.V., BBA Data Deposition, P.O. Box 1527, Amsterdam, The Netherlands. Reference should be made to No. BBA/DD/414/*Carbohydr. Res.*, 195 (1989) 1–10.

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Structure analysis. — The structure was solved with the multisolution technique[9] (270 E > 1.4), and the H atoms were located from difference synthesis. The full-matrix least-squares refinement[10] of all the heavy atoms anisotropically, and the H atoms isotropically [except H(91), H(92), and H(93)], yielded a final $R = (\Sigma \| F_o| - |F_c \|)/\Sigma|F_o|$ of 0.08 and $R_w = \{[\Sigma w(|F_o| - |F_c|)^2]/\Sigma w F_o^2\}^{1/2}$ of 0.12; $w = 1/[\sigma^2(F_o) + 0.006224 F_o^2]$. The weighting scheme was chosen so that averages of $w(\Delta F)^2$ were constant for different ranges of F_o and sin θ/λ. The scattering factors for the heavy atoms were from ref. 11, and for H from ref. 12. The residual electron density in the final difference map was within 0.35 eÅ^{-3}. Illustrations were prepared with ORTEP[13].

RESULTS AND DISCUSSION

The final atomic parameters along with their e.s.d.'s are given in Table I. A perspective view of **1** with the atomic numbering is shown in Fig. 1, and the bond lengths and bond angles in Fig. 2.

The average C–O distance [1.421(6) Å] (excluding the C-5–O-5, O-5–C-1, and C-1–O-1 bonds) is in good agreement with the calculated mean [1.43(1) Å] of 70 C–O bond lengths in **2–7** and **9**. Because of the anomeric effect in α-D-pyranose derivatives, the O-5–C-1 and C-1–O-1 bonds are shorter than the C-5–O-5 bond. The shortening of C–C bonds [⟨C–C⟩ = 1.36(3) Å] of the phenyl ring is related to the strong thermal motion of the atoms, especially of C-17, C-18 and C-19. The plane passing through C-5, C-6, N-2, C-14, and C-15 forms an angle of 49° with the plane of the phenyl ring. The C-13–N-1 bond is slightly bent towards the C-6–C-13 bond (the C-6–C-13–N-1 bond angle is 178.3°) as observed in most of the nitrile-substituted compounds.

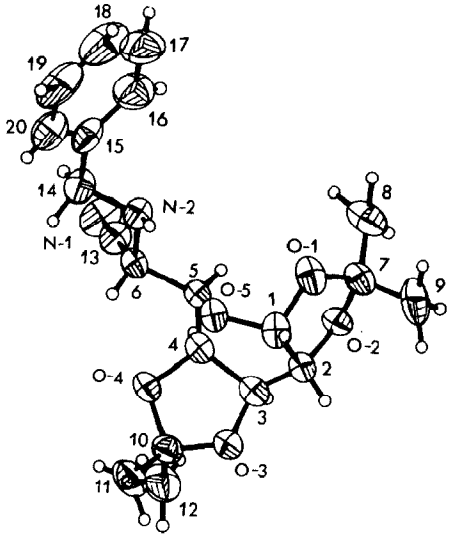


Fig. 1. Perspective view and atomic numbering of **1**.

TABLE I

FRACTIONAL ATOMIC COORDINATES (× 10^4) AND EQUIVALENT ISOTROPIC DISPLACEMENT FACTORS (×10^3)

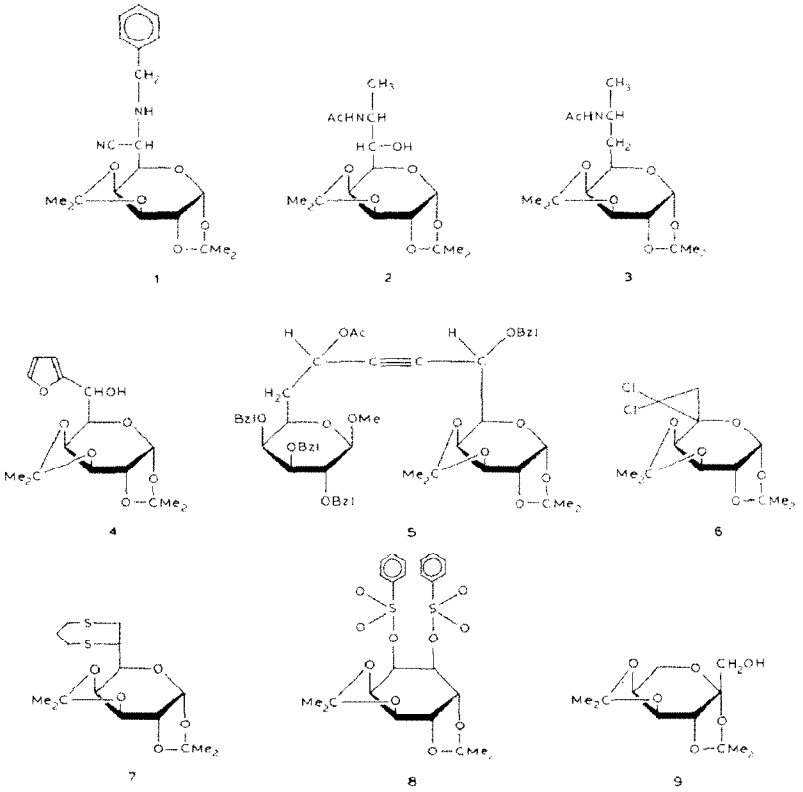
Atom	*x/a*	*y/b*	*z/c*	U_{eq} ($Å^2$)[a]
C-1	4763(4)[b]	10535(4)[b]	10810(5)[b]	66(5)[b]
C-2	4657(4)	11755(4)	11613(4)	53(4)
C-3	5982(4)	12468(4)	12231(4)	54(4)
C-4	6888(4)	12491(4)	11320(4)	49(4)
C-5	6414(4)	11554(4)	10088(4)	48(3)
O-5	6000(3)	10402(3)	10555(3)	61(3)
O-1	3665(4)	10606(4)	9496(4)	63(4)
O-2	3706(3)	12500(3)	10542(3)	58(3)
O-3	6789(3)	11843(5)	13501(3)	73(4)
O-4	8210(3)	12091(4)	12292(3)	59(3)
C-6	7510(4)	11172(4)	9473(4)	47(4)
C-7	2804(5)	11653(5)	9506(5)	55(5)
C-8	2361(8)	12316(9)	8098(7)	91(10)
C-9	1661(5)	11195(8)	9963(8)	96(10)
C-10	8170(5)	12021(6)	13690(4)	62(5)
C-11	8968(7)	10870(10)	14425(8)	113(10)
C-12	8721(7)	13242(9)	14489(8)	82(11)
N-2	6937(4)	10251(4)	8324(4)	62(4)
C-13	7967(5)	12288(5)	8911(5)	70(5)
N-1	8296(7)	13182(6)	8445(6)	120(9)
C-14	7945(6)	9746(6)	7773(6)	72(7)
C-15	7270(6)	8792(6)	6599(6)	83(7)
C-16	6023(8)	9015(11)	5547(7)	95(11)
C-17	5387(11)	8124(17)	4517(8)	114(19)
C-18	6001(14)	6997(11)	4501(11)	125(19)
C-19	7185(14)	6753(9)	5503(12)	156(17)
C-20	7853(8)	7660(7)	6541(8)	114(9)

[a] $U_{eq} = 1/3 \sum_i \sum_j U_{ij} a_i^* a_j^* a_i a_j$. [b] The e.s.d.s. in parentheses apply to the last significant digit.

Conformation of the pyranose and 1,3-dioxolane rings. — The equation of the least-squares planes for **1** and the deviation of atoms from these planes are listed in Table II. Table III contains the torsion angles. The asymmetry and polar puckering parameters[14] of the six- and five-membered rings in **1–9** are given in Table IV.

For **1**, the least-squares plane of the pyranose passing through C-1, C-3, C-4, and C-5 (χ^2 556) and the polar puckering parameters Q 0.633(8) Å, ϕ 329.1(5)°, and θ 78.1(5)° define the conformation of the pyranoid ring as being midway between the ideal twist-boat $^OT_2$ (ϕ 330°, θ 90°) and skew-boat $^OS_5$ (ϕ 330°, θ 67.5°)[15].

The mean of the polar puckering parameters [ϕ 327(3)° and θ 80(3)°] calculated from the corresponding values for **2–6** and **8** confirm the $^OT_2 \leftrightarrow {}^OS_5$ conformation for the galactopyranose and cyclohexane. For β-D-fructopyranose, the conformation is reversed, namely $^2T_O \leftrightarrow {}^5S_O$. The boat conformation in **7** is probably a consequence of the steric crowding at C-5.



The best planes of the 1,3-dioxolane rings passing through three atoms, along with the torsional angles, puckering, and asymmetry parameters, establish the twist ${}^{2}_{3}T$ and ${}^{1}_{2}T$ conformations for the 1,2- and 3,4-*O*-isopropylidene rings, respectively, of **1**. In seven out of eleven molecules, the 1,2-*O*-isopropylidene ring is in form of envelope ${}_{3}E$ or ${}^{3}E$ (in fructopyranose), with phase angle averages of 254(4)° and 78.4(7)° in the pseudorotational pathway (O-1–C-7–O-2–C-2–C-1). In the remainder, the 1,2-*O*-isopropylidene ring is in the form of twist ${}^{2}_{3}T$, the mean of the phase angle being 237(2)°.

The preponderant conformation of the 3,4-*O*-isopropylidene ring is twist ${}^{1}_{2}T$ or ${}^{1}_{5}T$ in the pseudorotational pathway (O-3–C-10–O-4–C-4–C-3).

Molecular packing. — The molecular packing is illustrated in Fig. 3. The molecules linked through short van der Waals contacts [O-1 · · · C-4, 3.390(5) and N-1 · · · C-9, 3.55(1) Å] and a hydrogen bond [N-2–H · · · O-2, 2.63(5) Å] extend in infinite helical chains along the *b*-axis. The molecular chains are further cross-linked through methyl C-12^{i} · · · methyl C-11^{ii} short contacts of 3.58(1) Å (i = x, y, z; ii = $2 - x$, $0.5 + y$, $-z$).

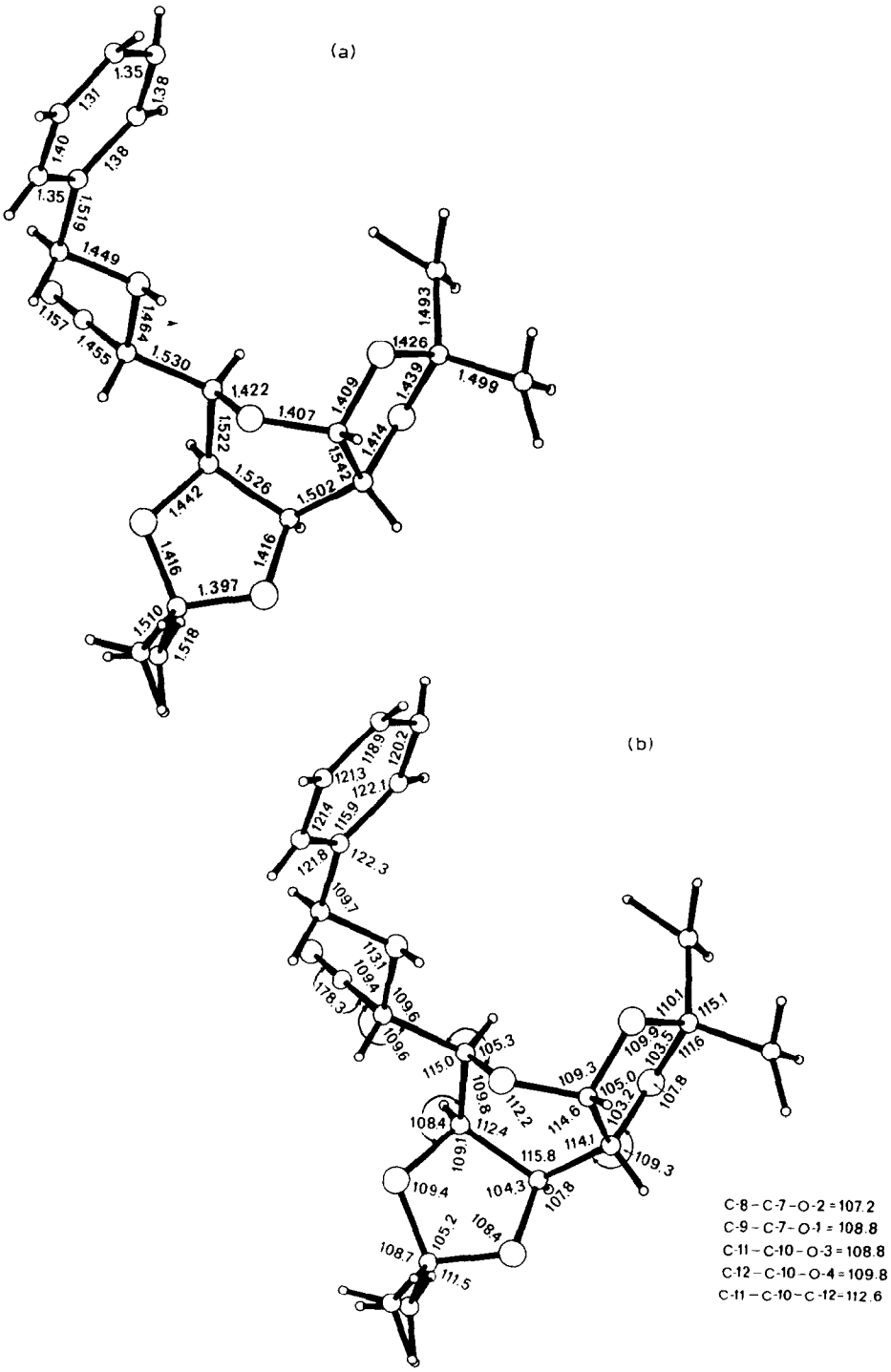


Fig. 2. (a) Bond lengths (Å) for **1**; the e.s.d.'s are 0.005 for C–O, 0.007 for C–N and C–C, and 0.015 for the C–C bonds of the phenyl ring; (b) bond angles (°) for **1**; the e.s.d.'s are 0.4 for C–O–C and C–C–N, 0.3 for O–C–O, and 0.8 for the bond angles of the phenyl ring.

TABLE II

EQUATIONS OF THE LEAST-SQUARES PLANES[a] AND DEVIATIONS (d_i IN Å) OF ATOMS FROM THEM FOR **1**

Pyranose ring		*1,2-O-Isopropylidene ring*		*3,4-O-Isopropylidene ring*	
Plane 1 $\chi^2 = 556$		Plane 2		Plane 3	
$-0.5049X - 0.6181Y -$		$0.7832X - 0.4742Y -$		$-0.1589X - 0.9519Y -$	
$0.6025Z + 9.9472 = 0$		$0.4022Z + 4.4931 = 0$		$0.2620Z + 3.8934 = 0$	
Atoms	d_i	*Atoms*	d_i	*Atoms*	d_i
C-1*	0.027(5)	C-1*	0.000	C-3*	0.000
C-3*	−0.044(4)	C-2*	0.000	C-4*	0.000
C-4*	0.066(4)	O-1*	0.000	O-4*	0.000
C-5*	−0.049(4)	C-7	0.190(5)	O-3	0.254(5)
C-2	−0.515(4)	O-2	−0.299(3)	C-10	−0.190(6)
O-5	0.666(3)				

[a]Atoms included in the least-squares calculations of the planes are denoted by *. The e.s.d.'s in parentheses apply to the last significant digit.

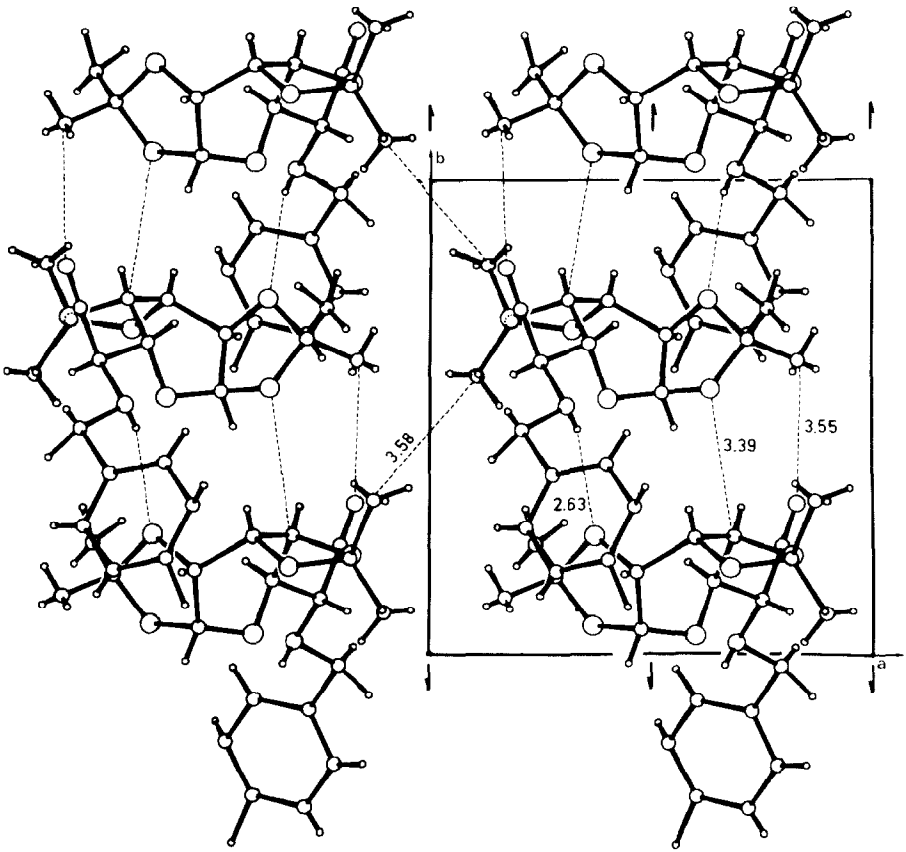


Fig. 3. Molecular packing viewed along the *c* axis (distances in Å).

TABLE III

TORSION ANGLES (°)[a]

Pyranose or cyclohexane ring

Compound	*O-5–C-1–C-2–C-3*	*C-1–C-2–C-3–C-4*	*C-2–C-3–C-4–C-5*	*C-3–C-4–C-5–O-5*	*C-4–C-5–O-5–C-1*	*C-5–O-5–C-1–C-2*
1	−11.1(4)	37.8(4)	−11.8(4)	−40.6(4)	71.2(4)	−43.3(4)
2	−12	42	−17	−36	71	−44
3	−14	42	−15	−37	68	−41
4	−17.7(8)	37.3(7)	−5.5(7)	−45.6(6)	70.6(5)	−36.1(6)
5	−8.6(5)	29.2(5)	−2.0(5)	−45.3(5)	70.6(4)	−41.4(5)
6A[b]	−15.2(9)	36(1)	−10(1)	−36.5(8)	63.7(8)	−34.4(9)
6B	−12.5(9)	35(1)	−9(1)	−40.6(9)	67.2(8)	−37.6(8)
7	−19.5(4)	24.2(4)	14.0(4)	−57.3(4)	65.4(4)	−25.9(4)
	C-6–C-1–C-2–C-3	*C-5–C-6–C-1–C-2*	*C-4–C-5–C-6–C-1*	*C-3–C-4–C-5–C-6*	*C-2–C-3–C-4–C-5*	*C-1–C-2–C-3–C-4*
8	−14	36	−14	−27	49	−27
	O-6–C-2–C-3–C-4	*C-2–C-3–C-4–C-5*	*C-3–C-4–C-5–C-6*	*C-4–C-5–C-6–O-6*	*C-5–C-6–O-6–C-2*	*C-6–O-6–C-2–C-3*
9A	18.8(5)	−45.2(7)	15.7(6)	38.4(7)	−69.6(6)	38.4(6)
9B	17.8(10)	−45.0(9)	17.0(9)	36.6(9)	−68.9(9)	38.6(9)
Mean values	15(3)	37(5)	12(5)	40(5)	67(6)	37(5)

1,2-O-Isopropylidene ring

Compound	*C-2–C-1–O-1–C-7*	*C-1–O-1–C-7–O-2*	*O-1–C-7–O-2–C-2*	*C-7–O-2–C-2–C-1*	*O-2–C-2–C-1–O-1*
1	−8.1(4)	25.2(4)	−33.9(4)	28.6(4)	−12.5(4)
2	−2	21	−32	30	−18
3	0	19	−32	31	−19
4	2.1(7)	−17.7(8)	−31.9(7)	32.8(6)	−21.1(6)
5	−9.6(4)	27.2(4)	−34.5(4)	28.4(4)	−11.6(4)
6A	−2.7(8)	22.3(8)	−34.2(7)	32.2(7)	−17.5(7)
6B	−9.7(8)	28.4(8)	−36.0(7)	30.5(7)	−12.9(7)
7	−3.9(4)	17.4(4)	−32.8(4)	34.7(4)	−23.1(4)
8	−10	29	−37	30	−12

	C-3–C-2–O-2–C-7	*C-2–O-2–C-7–O-3*	*O-2–C-7–O-3–C-3*	*C-7–O-3–C-3–C-2*	*O-3–C-3–C-2–O-2*
9A	−3.4(4)	−17.7(4)	33.0(4)	−35.1(4)	23.4(4)
9B	−2.6(4)	−18.1(4)	33.0(4)	−34.6(4)	22.7(4)
Mean values					
${}_3E$	2(1)	19(2)	33(1)	33(2)	21(2)
${}^2_3T$	9(1)	27(1)	35(1)	30(1)	12.3(5)

3,4-O-Isopropylidene ring

Compound	*C-4–C-3–O-3–C-10*	*C-3–O-3–C-10–O-4*	*O-3–C-10–O-4–C-4*	*C-10–O-4–C-4–C-3*	*O-4–C-4–C-3–O-3*
1	26.4(4)	−31.9(4)	24.3(4)	−8.1(4)	−10.7(4)
2	29.3	−24.9	9.5	8.1	−22.6
3	31.8	−29.3	14.5	4.8	−22.1
4	23.7(6)	−31.3(6)	27.0(7)	−12.3(6)	−7.1(6)
5	23.4(4)	−34.9(4)	33.2(4)	−18.2(4)	−3.1(4)
6A	−24.0(8)	31.6(8)	−26.3(9)	11.3(8)	7.7(8)
6B	−25.4(8)	−32.4(8)	−26.8(9)	11.2(8)	9.8(8)
7	13.0(4)	−33.8(4)	41.5(4)	−32.5(4)	12.0(4)
8	30	−37	29	−10	−12
	C-5–C-4–O-4–C-10	*C-4–O-4–C-10–O-5*	*O-4–C-10–O-5–C-5*	*C-10–O-5–C-5–C-4*	*O-5–C-5–C-4–O-4*
9A	−26.0(4)	23.1(4)	−10.1(4)	−5.8(4)	19.4(4)
9B	−29.7(5)	28.7(5)	−15.3(5)	−2.9(5)	19.9(4)

[a]The e.s.d.'s in parentheses apply to the last significant digit. [b]For compounds **6** and **9**, two molecules (A and B) are observed in the asymmetric unit.

TABLE IV

POLAR PARAMETERS OF PUCKERING, ASYMMETRY PARAMETERS, AND CONFORMATIONS OF THE PYRANOSE, CYCLOHEXANE, AND1,3-DIOXOLANE RINGS FOR **1–9**

Pyranose or cyclohexane ring

Puckering parameters	**1**	**2**	**3**	**4**	**5**	**6A**	**6B**	**7**	**8**	**9A**	**9B**	*Averages*	*Idealized*	
													Twist-boat	*Skew boat*
Q(Å)	0.633(8)	0.65(1)	0.65(1)	0.63(1)	0.592(8)	0.56(1)	0.67(1)	0.595(8)	0.50(2)	0.664(5)	0.653(5)	0.62(5)		
θ(°)	78.1(5)	81(1)	81(1)	79(1)	73.5(5)	81(1)	85(1)	72.3(5)	83(2)	97.0(4)	96.5(5)	80(3)	90	67.5
ϕ(°)	329.1(5)	332(1)	329(1)	321(1)	324.3(5)	324.8(5)	323.9(5)	305.3(5)	330(2)	147.5(4)	149.1(5)	327(3)	330	330
Conformation	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{O}S_{5}\leftrightarrow{}^{O}T_{2}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	$B_{3,6}$	${}^{O}T_{2}\leftrightarrow{}^{O}S_{5}$	${}^{2}T_{O}\leftrightarrow{}^{5}S_{O}$	${}^{2}T_{O}\leftrightarrow{}^{5}S_{O}$		${}^{O}T_{2}$	${}^{O}S_{5}$

1,2-*O*-Isopropylidene ring O-1–C-7–O-2–C-2–C-1

	1	**2**	**3**	**4**	**5**	**6A**	**6B**	**7**	**8**	**9A**	**9B**	*Mean values for*		*Idealized*	
												Envelope	*Twist*	*Envelope*	*Twist*
q_2(Å)	0.300(8)	0.30(1)	0.30(1)	0.31(1)	0.304(8)	0.31(1)	0.31(1)	0.324(8)	0.33(2)	0.326(5)	0.323(5)	0.31(1)			
ϕ(°)	239.6(5)	250(1)	253(1)	257(1)	237.1(5)	248.7(5)	233.3(5)	260.0(5)	236(2)	78.9(7)	77.9(7)	254(4)	237(2)	252	234
ΔC_s(°)		2	0.4	2.5(7)		3.7(8)		4.3(4)		4.3(4)	3.4(4)				
ΔC_2(°)	3.9(4)				1.7(4)		2.7(8)		1.5						
Conformation	${}^{2}_{3}T$	${}_{3}E$	${}_{3}E$	${}_{3}E$	${}^{2}_{3}T$	${}_{3}E$	${}^{2}_{3}T$	${}_{3}E\leftrightarrow{}^{4}_{3}T$	${}^{2}_{3}T$	${}^{3}E$	${}^{3}E$				

3,4-*O*-Isopropylidene ring O-3–C-10–O-4–C-4–C-3

	1	**2**	**3**	**4**	**5**	**6A**	**6B**	**7**	**8**	**9A**	**9B**
q_2(Å)	0.274(8)	0.27(1)	0.29(1)	0.28(1)	0.313(8)	0.27(1)	0.29(1)	0.368(8)	0.33(2)	0.239(5)	0.278(5)
ϕ(°)	14.3(5)	342(1)	350(1)	22(1)	30.4(5)	20.7(5)	18.6(5)	54.2(5)	16	166(1)	173(1)
ΔC_s(°)			5.7		3.9(4)						3.3(4)
ΔC_2(°)	2.4(4)	1.9	8.5	4.4(7)		3(8)	1.4(8)	1.2(4)	1.5	4.1(4)	
Conformation	${}^{1}_{2}T$	${}^{1}_{2}T$	${}^{1}_{2}T\leftrightarrow{}^{1}E$	${}^{1}_{2}T$	${}_{2}E$	${}^{1}_{2}T$	${}^{1}_{2}T$	${}^{3}_{2}T$	${}^{1}_{2}T$	${}^{5}_{1}T$	${}_{1}E$

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