Tetrahedron Vol. 41, No. 18, pp. 3875 to 3886, 1985
Printed in Great Britain.

0040-4020/85 $3.00 + .00

CONFORMATIONAL DEPENDENCE OF PYRANOID RINGS 1,2-CIS-FUSED TO DIOXOLANE RINGS ON THE CONFIGURATION OF THE DIOXOLANE RINGS IN ACETYLATED DERIVATIVES OF D-GLUCO AND D-GALACTOPYRANOSE. CHIRALITY ASSESSMENT OF CARBOHYDRATES FROM CRYSTALLOGRAPHIC TORSION ANGLES

FELIX H. CANO, CONCHA FOCES-FOCES

Departamento de Rayos X, Instituto de Química Física "Rocasolano", CSIC, Serrano 119, 28006 Madrid (Spain)

MANUEL BERNABE*, JESUS JIMENEZ-BARBERO, MANUEL MARTIN-LOMAS, AND SOLEDAD PENADES-ULLATE

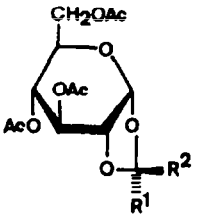
Instituto de Química Orgánica, CSIC, Juan de la Cierva 3, 28006 Madrid (Spain)

(*Received in UK 3 June 1985*)

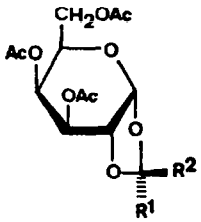
Abstract.- X-Ray and ^{1}H N.M.R. studies on pyranoid rings 1,2-cis-fused to dioxolane rings in acetylated D-gluco- and D-galactopyranose derivatives demonstrate that the configuration of the dioxolane ring influences the conformation of the pyranoid ring in the D-gluco but not in the D-galactopyranose series. The crystal structure of 3,4,6-tri-O-acetyl-1,2-O-(R)-(1-cyano-ethylidene)-α-D-glucopyranose (1) and 3,4,6-tri-O-acetyl-1,2-O-(R)-(1-cyano-ethylidene)-α-D-galactopyranose (2) have been determined by X-ray analysis. Lattice parameters for 1 are a=20.6021 (11), b=8.0438 (2), c=5.5541 (1) Å and β=95.588 (3)° for a cell with $P2_1$ symmetry. These parameters for 2 are a=20.3361 (7), b=10.0907 (2), c=18.9115 (5) Å, β=112.399 (2)°, C2, with two crystallographycally independent molecules. The conformation of the pyranoid ring in both compounds can be described as flattened $^4C_1$ and that of the dioxolane ring as distorted E_1. The importance of the torsion angles for describing problems of configuration is remarked and the use of relative configurational angles is stressed. The ^{1}H N.M.R. spectra of 1 and 2 and 3,4,6-tri-O-acetyl-1,2-O-(S)- and (R)-ethylidene-α-D-glucopyranose (5 and 7), 3,4,6-tri-O-acetyl-1,2-O-(S)- and (R)-ethylidene-α-D-galactopyranose (6 and 8), and 3,4,6-tri-O-acetyl-1,2-O-(S)- and (R)-benzylidene-α-D-glucopyranose (9 and 10) have been analyzed by using iterative computer methods and N.O.E. measurements. The results indicate that the major solution conformation of the pyranoid ring of the derivatives in the D-gluco series 1, 5 and 9 may be described as flattened $^4C_1$ and that of 7 and 10 as $^2S_5$. The major solution conformation of the pyranoid ring in all compounds in the D-galacto series (2,4,6,8) may be described as flattened $^4C_1$.

Several communications have dealt with the solid state and solution conformation of 1,2-O-alkylidene-α-D-hexopyranoses[1-16]. The conformational tendency of the pyranoid ring of these molecules remains uncertain especially in derivatives of D-glucopyranose 1,2-cis-fused to five- membered rings. Contradictory results on this subject have been published[2-4, 6-7] and probably much of the reported data need to be re-evaluated. We have previously shown that the solid state conformation of the pyranoid ring of 3,4,6-tri-O-acetyl-1,2-O-(S)-(1-cyanoethylidene)-α-D-

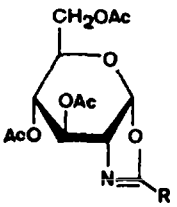
-glucopyranose (3)[8] and 2-phenyl-(3,4,6-tri-O-acetyl-1,2-dideoxy-α-D-glucopyrano--[2.1.d]-2-oxazoline (11)[15] could be described as $^2S_5$. The analysis of the ^{1}H N.M.R. spectra of these compounds and several tri-O-acetylated-1,2-O-alkylidene-α-D--glucopyranose derivatives, in which the methyl group always occupies an endo orientation, could also be interpreted as indicative of average conformations in solution similar to those found in the solid state[9,10,15]. From these results it could be assumed that 1,2-cis-fusion of a five membered ring to a peracetylated glucopyranose ring causes the pyranoid ring to adopt a skew-boat conformation.



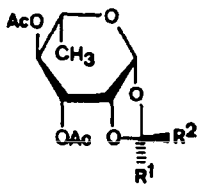
1 R^1 = CN , R^2 = Me
3 R^1 = Me , R^2 = CN
5 R^1 = H , R^2 = Me
7 R^1 = Me , R^2 = H
9 R^1 = H , R^2 = Ph
10 R^1 = Ph , R^2 = H



2 R^1 = CN , R^2 = Me
4 R^1 = Me , R^2 = CN
6 R^1 = H , R^2 = Me
8 R^1 = Me , R^2 = H
12 R^1 = Me , R^2 = O-t-Bu



11 , R = Ph



13 R^1 = Me , R^2 = CN
14 R^1 = CN , R^2 = Me

However, we have also shown[10] that the solid state conformation of the pyranoid ring of 3,4,6-tri-O-acetyl-1,2-O-(R)-(1-tert-butoxyethylidene)-α-D-galactopyranose (12) is a flattened $^4C_1$ and that the complete analysis of the ^{1}H N.M.R. spectra of this and other tri-O-acetyl-1,2-O-alkylidene-α-D-galactopyranose derivatives[9,10], all of them bearing a methyl group endo oriented, indicates that the weighted average of conformers with appreciable population in the conformational equilibrium could be described as a flattened chair as well. These results seem to indicate a different conformational tendency of the pyranoid ring in the D-glucose and D--galactose series. Furthermore, the crystal structure of 3,4,6-tri-O-acetyl-1,2-O--(R)-(1-cyanoethylidene)-α-D-glucopyranose (1) has been determined by russian workers[12] which have reported that, contrary to our early finding for 3[8], the conformation of the pyranoid ring of 1 in the solid state is distorted $^4C_1$. A

similar conformational difference in the pyranoid rings of 1,2-O-acylspyroorthoesters of 3,4,6-tri-O-acetyl-α-D-glucopyranose depending on the configuration of the dioxolane ring has been reported[11] on the basis of ^{1}H N.M.R. spectroscopy.

In order to obtain reliable data which may be of interest in the understanding of this conformational problem, we report now new X-ray and ^{1}H N.M.R. studies on 1,2-O-alkylidene derivatives of 3,4,6-tri-O-acetyl-α-D-gluco- and -galactopyranose which unambiguously indicate that the pyranoid ring adopts different conformation in each series and that the configuration of the dioxolane ring strongly influences the conformation of the pyranoid ring in the tri-O-acetylated-D-glucopyranose compounds but not in the tri-O-acetylated-D-galactopyranose derivatives.

The crystal structure of 1 has been studied in order to determine the influence of the configuration of the dioxolane ring on the conformation of the pyranoid ring. When the structural study was finished it came to our knowledge that the structure of 1 had been already solved[12]. When going through this paper[12] for comparison purposes, some discrepancies were apparent concerning the configuration of the molecules there studied as they came out from the drawings versus the published co-ordinates and the nomenclature used. This gave us the opportunity to prove the wealth of using the torsion angles in the description of problems dealing with configurations in crystallography, especially in the carbohydrate field.

RESULTS AND DISCUSSION

Details of the X-ray analyses of compounds 1 and 2 are given in Table 1[17-19]. A view of the molecules with the atomic numbering is given in Fig 1a and 1b. In compound 1 the thermal factors for H-8a, H-8b and H-12b and all parameters for H-10a, H-10b and H-10c had to be fixed in the last cycles of the least-squares refinement.

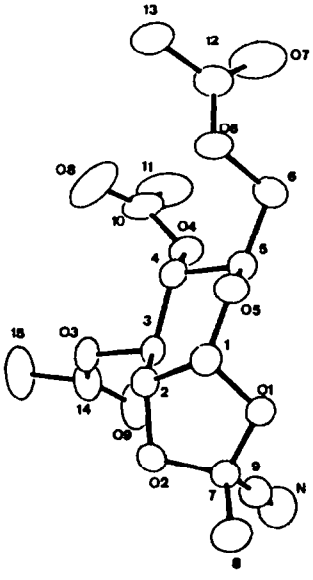


Fig 1a. A view of compound 1 showing the atomic numbering.

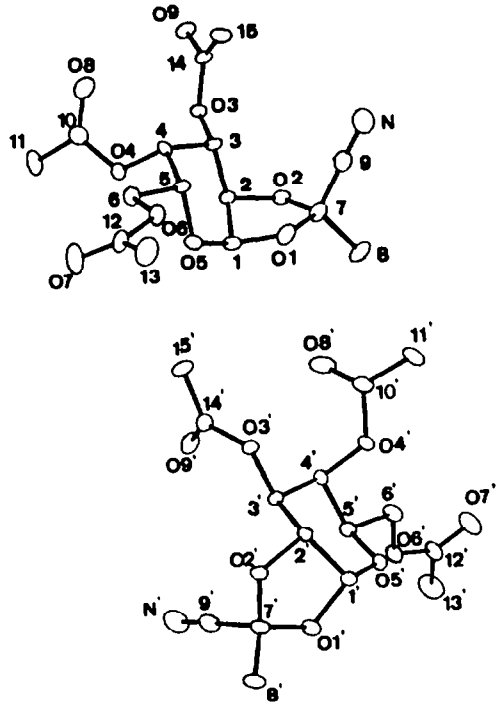


Fig 1b. A view of molecules 2 and 2' showing the atomic numbering.

TABLE 1. Crystal Analysis parameters at room temperature

Crystal data:	Compound 1	Compound 2
Formula	$C_{15}H_{19}NO_9$	$C_{15}H_{19}NO_9$
Crystal habit	Colourless, Transparent, parallepipedic	
Crystal size (mm)	0.17x0.17x0.40 (Inside capillar)	0.33x0.20x0.12
Symmetry	Monoclinic, $P2_1$	Monoclinic C2
Unit cell determination:		
least-squares fit to	63 reflexions, θ(Cu)<45°	82 reflexions, θ(Cu)<45°
Unit cell dimensions (Å)	20.6021(11), 8.0438(2), 5.5541(1), β=95.588(3)°	20.3361(7), 10.0907(2), 18.9115(5) β=112.399(2)°
Packing: V(Å^3), Z	916.05(1), 2	3588.0(2), 8
D(g.cm^{-3}), M, F(000)	1.295, 357.316, 376	1.323, 357.316, 1504
Experimental data:		
Radiation & technique	CuK_α, PW1100 diffractometer, bisecting geometry	
Monochromator	Graphite oriented	
Collection mode	w/2θ, θ<65°, 1°x1° det. apertures, 1 min/ref., 1.5° scan width	
Total independent data	1655	3037
Observed data	1560, I>2σ(I)	2553, I>2σ(I)
Stability	Two reflexions every 90 min., no variation	
Solution and refinement:		
Solution	MULTAN80[17], X-RAY76[18], Vax11/750	
Refinement	Least-squares on F's, observed reflexions	
	two blocks	three blocks
Final shift/error	0.13	0.33
Number of variables	287 (See text)	602
Degrees of freedom	1273	1951
Ratio of freedom	5.4	4.2
Weigthing scheme	Empirical as to give no trends in $\langle w\Delta^2 \rangle$ vs. $\langle Fo \rangle$ or $\langle \sin\theta/\lambda \rangle$	
Max. thermal values (Å^2)	U22(07)=0.33(1)	U22(C13')=0.29(2)
Final ΔF peaks	0.20 eÅ-3	0.21 eÅ-3
Final R, Rw	0.050, 0.048	0.065, 0.053
Atomic factors	International Tables for X-Ray Crystallography[19]	

Compound 2 presented two crystalographycally independent molecules (2 and 2'). Empirical weighting schemes, giving no trends in $\langle w\Delta^2 \rangle$ versus |Fo| or $\langle \sin \theta/\lambda \rangle$, were employed in the final stages of the refinement and their adequacy analized by δRw probability methods[20]. Tables 7 give the final co-ordinates according to the atomic numbering shown in Figs 1a and 1b. Results for 1 were compared with those obtained by the russian workers[12] using normal probability analysis[20] and the main differences sought (in the range 2.5 to 5.3 times the pooled e.s.d., $(\sigma_1^2 + \sigma_2^2)^{\frac{1}{2}}$) are those marked with an asterisk in Table 3.

TABLE 2. Torsion Angles (°) of Molecules 1, 2, and 2'

ANGLE	1	2	2'
C2-C1-O5-C5	-45.4(4)	-44.1(7)	-38.0(7)
O5-C1-C2-C3	37.5(4)	37.5(7)	32.5(7)
C1-C2-C3-C4	-44.2(3)	-42.9(7)	-42.1(7)
C2-C3-C4-C5	57.3(3)	55.5(6)	57.0(6)
C3-C4-C5-O5	-63.0(3)	-60.3(6)	-61.3(6)
C4-C5-O5-C1	57.3(3)	55.8(6)	53.0(7)
O1-C1-C2-O2	37.4(3)	34.8(5)	32.6(5)
C2-C1-O1-C7	-31.5(3)	-28.1(6)	-25.8(6)
C1-O1-C7-O2	13.4(3)	10.8(7)	9.1(6)
C2-O2-C7-O1	11.8(3)	13.3(7)	13.4(6)
C1-C2-O2-C7	-30.1(3)	-29.9(6)	-28.9(6)
C2-C3-O3-C14	-130.8(3)	-154.6(5)	-153.3(5)
C4-C3-O3-C14	109.1(3)	81.4(6)	84.7(6)
C3-O3-C14-C15	-172.2(3)	-175.8(5)	-179.0(7)
C3-O3-C14-O9	6.1(5)	4.8(9)	1.6(9)
C6-O6-C12-C13	179.0(4)	-170.3(6)	-168.9(9)
O5-C1-C2-O2	157.7(2)	157.1(5)	152.5(5)
C4-C3-C2-O2	-157.6(2)	-156.8(5)	-157.9(5)
C5-O5-C1-O1	70.8(3)	72.3(6)	76.8(6)
C3-C2-C1-O1	-82.7(3)	-84.9(6)	-87.4(6)
C1-C2-C3-O3	-162.7(2)	-167.3(5)	-164.4(5)
C5-C4-C3-O3	176.0(2)	176.9(5)	177.1(5)
C2-C3-C4-O4	174.3(2)	-64.2(6)	-60.4(6)
O5-C5-C4-O4	179.5(2)	60.0(6)	58.2(6)
C3-C4-C5-C6	178.1(3)	-177.9(5)	179.2(5)
C1-O5-C5-C6	-179.8(3)	177.1(5)	175.1(5)
C1-O1-C7-C8	-106.4(4)	-110.9(7)	-112.1(6)
C2-O2-C7-C8	134.0(3)	136.7(6)	136.9(5)
C1-O1-C7-C9	130.0(3)	127.0(6)	124.6(6)
C2-O2-C7-C9	-103.1(3)	-101.2(7)	-100.3(6)
C3-C4-O4-C10	111.7(3)	-103.0(7)	-101.9(6)
C5-C4-O4-C10	-130.5(3)	137.6(6)	140.0(6)
C4-O4-C10-O8	-1.6(6)	5.5(9)	3.2(9)
C4-O4-C10-C11	179.2(4)	180.0(6)	-177.3(7)
C4-C5-C6-O6	52.9(4)	-154.8(5)	-150.0(6)
O5-C5-C6-O6	-66.8(4)	84.5(6)	88.6(6)
C5-C6-O6-C12	-150.4(4)	-160.4(6)	-167.7(6)
C6-O6-C12-O7	-2.8(8)	11.7(9)	12.2(9)

Tables 2 and 3 show the resulting structural characteristics for molecules 1, 2, and 2'. The two independent molecules in compound 2 have very similar molecular dimensions. Bond length and angles in the dioxolane rings are as usual in both compounds[21] as well as those in the pyranoid rings[22] showing the anomeric effect (C-1—O-5<C-5—O-5). The angles C-2—C-1—O-5, O-1—C-1—O-5 and C-1—O-5—C-5 are higher than usual. The conformation of the pyranoid ring is $^4C_1$ in both compounds, the chair being less puckered around the 1,2-cis-fusion. Thus the solid state conformation of the pyranoid ring of compound 1 is different from that found for compound 3[8] while that of compound 2 seems to be very similar to the average solution conformation determined for 4 on the basis of ^{1}H N.M.R. data[9,10] and to the solid state conformation determined for compound 12 on the basis of X-ray analysis[10]. The dioxolane rings present a distorted envelope E_1 conformation in bot 1 and 2.

TABLE 3. Bond Distances (Å) and Bond Angles (°) of Molecules 1, 2, and 2'

BOND	1	2	2'	BOND	1	2	2'
C1-O1	1.425(4)	1.429(8)	1.450(9)	C5-O5	1.423(4)	1.450(7)	1.451(7)
C1-C2	1.522(4)	1.543(9)	1.536(7)	*C5-C6	1.508(5)	1.510(7)	1.494(9)
*C1-O5	1.400(4)	1.354(7)	1.365(8)	C6-O6	1.445(5)	1.438(8)	1.401(9)
O1-C7	1.412(4)	1.404(9)	1.399(8)	C12-O7	1.182(9)	1.173(9)	1.166(9)
*C2-O2	1.427(4)	1.427(8)	1.434(8)	C12-C13	1.472(8)	1.493(9)	1.483(9)
C2-C3	1.512(4)	1.512(8)	1.510(8)	C12-O6	1.304(5)	1.324(9)	1.327(9)
*O2-C7	1.426(4)	1.405(8)	1.419(8)	O8-C10	1.186(6)	1.170(9)	1.195(9)
O3-C3	1.448(4)	1.431(7)	1.430(6)	C10-C11	1.497(7)	1.454(9)	1.463(9)
O3-C14	1.341(4)	1.365(8)	1.359(7)	O9-C14	1.201(5)	1.175(8)	1.185(9)
C3-C4	1.515(4)	1.519(9)	1.523(9)	C14-C15	1.485(6)	1.487(9)	1.487(9)
C4-O4	1.435(4)	1.447(7)	1.445(6)	*C7-C9	1.483(6)	1.484(9)	1.515(9)
C4-C5	1.528(5)	1.499(8)	1.508(8)	C7-C8	1.512(7)	1.520(9)	1.501(9)
O4-C10	1.353(5)	1.370(8)	1.364(9)	C9-N	1.136(7)	1.143(9)	1.142(9)
ANGLE	**1**	**2**	**2'**	**ANGLE**	**1**	**2**	**2'**
*C2-C1-O5	116.5(2)	118.1(3)	117.9(5)	*C1-O5-C5	116.2(2)	115.6(4)	117.3(5)
*O1-C1-O5	110.0(1)	112.1(3)	110.3(5)	C5-C6-O6	108.0(3)	108.9(5)	110.2(6)
*O1-C1-C2	102.6(2)	100.7(3)	100.7(5)	C13-C12-O6	112.7(4)	111.6(7)	114.0(9)
C1-O1-C7	106.9(2)	108.9(5)	109.7(5)	O7-C12-O6	121.5(5)	122.0(8)	122.1(9)
*C1-C2-C3	112.9(2)	111.7(4)	113.7(5)	O7-C12-C13	125.8(4)	126.4(8)	123.9(9)
*C1-C2-O2	101.0(2)	102.3(4)	103.2(4)	O4-C10-O8	123.4(4)	119.2(8)	121.5(7)
O2-C2-C3	112.3(3)	111.7(5)	110.7(5)	O8-C10-C11	126.5(5)	128.0(9)	127.2(8)
C2-O2-C7	107.7(2)	107.5(5)	107.6(4)	O4-C10-C11	110.1(4)	112.5(7)	111.3(7)
C3-O3-C14	117.8(2)	115.6(5)	116.7(5)	C6-O6-C12	117.3(3)	116.2(5)	117.0(6)
C2-C3-O3	108.3(2)	107.4(4)	107.7(4)	O3-C14-O9	122.9(3)	123.3(5)	121.9(6)
O3-C3-C4	108.2(2)	112.8(4)	111.4(4)	O9-C14-C15	126.0(4)	126.7(6)	127.2(8)
C2-C3-C4	110.7(2)	112.1(5)	111.2(5)	O3-C14-C15	111.1(3)	109.9(5)	110.9(8)
*C3-C4-C5	109.0(2)	108.9(5)	108.4(5)	O1-C7-O2	107.5(2)	108.0(6)	107.7(5)
C3-C4-O4	108.6(2)	110.2(5)	110.6(5)	O2-C7-C8	108.8(3)	110.0(7)	109.5(5)
O4-C4-C5	107.5(2)	109.2(5)	107.4(5)	O2-C7-C9	108.9(3)	108.5(6)	108.3(5)
C4-O4-C10	117.5(3)	117.9(5)	116.6(5)	O1-C7-C8	112.6(3)	112.7(6)	113.2(5)
C4-C5-C6	113.4(3)	111.9(5)	111.8(5)	O1-C7-C9	106.5(3)	106.0(7)	105.5(6)
C4-C5-O5	108.5(3)	110.9(5)	110.6(5)	C9-C7-C8	112.5(3)	111.4(7)	112.4(6)
O5-C5-C6	107.2(3)	105.5(5)	107.3(5)	C7-C9-N	178.8(4)	178.8(9)	179.1(9)

The discrepancies with the results published for compound 1 by the russian workers[12] appeared when examining the configuration of the dioxolane ring (C-7 in the drawings and thereafter) in compound 1.

In our study the configurational angles were being used. These angles give the respective situation, in a chiral tetrahedral atom, of two substituents referred to a relative path between the other two substituents: Let the chiral center be C* with substituents S-1 to S-4. If the S-4 substituent is chosen as origin and the sequence S-3—C*—S-4 as the reference relative path (3,4 the less "heavy", for example, to match the R-S criterion), the three torsion angles C—S-3—C*—Si (i=1, 2,4), C being any other center, real or imaginary, bonded to S-3. The configurational angles for the S-1 and S-2 substituents, relative to the chosen reference path, are then defined as:

$$\rho(C^*—S\text{-}1) = \tau(C—S\text{-}3—C^*—S\text{-}1) - \tau(C—S\text{-}3—C^*—S\text{-}4)$$

$$\rho(C^*—S\text{-}2) = \tau(C—S\text{-}3—C^*—S\text{-}2) - \tau(C—S\text{-}3—C^*—S\text{-}4)$$

From this definition is clear that ρ(C*-Si) with respect to the path C—S-3——C*—S-4, is opposite to ρ(C*—S-4) with respect to the path C—S-3—C*—Si; more over, the so defined ρ-angles will have values around ± 120°, small deviations being due to distortions of the actual tetrahedron. Any relative configuration is characterized by the reference path and the couple of signs of these ρ-values.

In any ring it may be used as reference path one way of circulating the cycle and therefore the configurational angle of any substituent will be τe-τi (the exocyclic substituent torsion angle minus the corresponding endocyclic one) both having two consecutive ring bonds in common. When going in the opposite circulating sense, approximately (due to distortions in the tetrahedral arrangement) opposite

values for the ρ's will be found. Thus, in the dioxolane rings of the molecules here studied, using the membering of the figures, and with reference to the sense C-1——O-1—C-7—O-2—C-2—C-1, we have:

$$\rho(C\text{-}7\text{—}C\text{-}9) = \tau(C\text{-}1\text{—}O\text{-}1\text{—}C\text{-}7\text{—}C\text{-}9) - \tau(C\text{-}1\text{—}O\text{-}1\text{—}C\text{-}7\text{—}O\text{-}2).$$

The value of this angle and that of the angle for (C-7—C-8) are shown in Table 4 for the molecules 1, 2 and 2', 3 and the L-rhamnopyranose derivatives 13 and 14 previously studied by the russian workers[12]. It appears that the endo orientation of the cyano group is characterized by the couple of signs (+,-) for (C-7—C-9) and (C-7—C-8) respectively, and the exo orientation of the cyano group by (-,+) with respect to this circulating sense.

TABLE 4. The "Endo" and "Exo" Configurations. Angles in Degrees

Compound	C7-C-9	C7-C8	Configurations
1	+109.6	-119.8	endo
2	+116.2	-121.7	endo
2'	+115.5	-121.2	endo
3[8]	-118.8	+120.6	exo
13[12]	+115.8	-119.4	endo
14[12]	+116.9	-124.6	endo

On the other hand, the calculated endocyclic angles in the pyranoid ring of 1 and 13, appear in the mentioned paper[12] with opposite values as expected after calculating them following the Klyne and Prelog criterion[23] while 14 appears with the correct ones. This seems to indicate that the values published for 1[12] are not correct. In order to clarify this situation the chiral centers of the pyranoid rings were analyzed by mean of the configurational angles, using the reference sequence C-1—C-2....O-5 and only non-hydrogen substituents, O-1....C-6. In the Fisher proyection formulae ρ(C-5—O-5) = -ρ(C-5—C-6) and it can be concluded that: The sign of ρ(C-5—O-5) is + for D-compounds and - for L-compounds, O-5 being the reference atom for the other substituents. The sign of ρ(C-1—O-1) is equal (e) to that of ρ(C-5—O-5) in compounds with α configuration and different (d) for compounds with β configuration. The configuration of all other carbons is defined by the sequence of coincidences (e) or differences (d) between the signs of ρ(C-2—O-2) ρ(C-3—O-3) and ρ(C-4—O-4), and that of ρ(C-5—O-5). This is to say the same side or the opposite side versus O-5 in the Fisher projection formula.

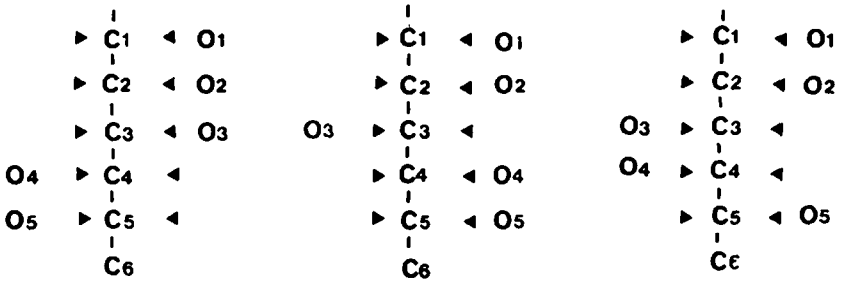
Following the Klyne and Prelog criterion[23] and using the published co-ordinates for compounds 1 and 13[12] the values presented in Table 5 are obtained. From these values the molecules can be characterized as follows:

1:D,α,e,d,e; 3:D,α,e,d,e; 2 and 2':D,α,e,d,d; 12:D,β,d,d,e; 13:L,β,d,d,e.

TABLE 5. Configuration angles (°, mod 2π) for the non-hydrogen first substituents at the chiral centers of the pyranoid rings, following the sequence ... C1, C2, ...

Angle	1	2	2'	3	13	14
[C5-O5]	+118.9	+117.6	+119.5	+120.9	+116.2	-119.2
[C1-O1]	+116.2	+116.4	+114.8	+116.4	-110.3	+109.5
[C2-O2]	+120.2	+119.6	+120.0	+119.2	-118.6	+119.9
[C3-O3]	-118.5	-124.4	-122.3	-115.5	-119.5	+123.6
[C4-O4]	+116.8	-119.0	-117.4	+119.0	+116.7	-116.8

As can be seen, in the mentioned paper[12], compound 13 appears in the enantiomeric form and compound 1 with incorrect values of the torsional angles. After the appropriate corrections the Fisher projection formulae indicated below are obtained in which the right-left orientation of the subtituents stand for +,- signs of Table 5.



13 and 14 1 and 3 2

The ρ angles can also be used for describing the equatorial/axial (eq./a) character of the substituents refered to an original conformation of the ring by correcting the actual exocyclic torsion angles for the internal puckering. The original reference conformation of the ring may be defined by a set of endocyclic torsion angles, τ_0. For example, the chair $^4C_1$ defined by τ_0(C-5—O-5—C-1—C-2)<0 or the chair $^1C_4$ defined by the same angle but with positive value, and, consequently, the values of the remaining five endocyclic angles. The orientation of any substituent may also be defined by the torsion angle τ_s that it will adopt in the reference ring conformation: $\tau_s = \rho + \tau_0 = (\tau_e - \tau_i) + \tau_0$, and so τ_s= a/ eq. +δ, δ being the deformation from the theoretical values a=±60°, for axial, and eq=180° for equatorial orientation. Each substituent may be characterized by two exocyclic angles τ_s's so the sense of circulating the ring has to be defined as in the calculation of ρ values and according to them (see Table 6).

TABLE 6. Conformational character (eq, a) for the substituents of the pyranoid rings (1, 2 and 2'), refered to the $^1C_4$ ring conformation and to the same sequence than in Table 5 (all values in degrees): character + distortion = $\rho + \tau_0$

Substituent	1	2	2'
O1	eq - 3.8	eq - 3.6	eq - 5.2
O2	+ a + 0.2	+ a - 0.4	+ a
O3	- a + 0.5	- a - 4.4	- a - 2.3
O4	+ a - 3.2	eq + 0.3	eq - 2.3
C6	- a + 1.1	- a + 2.4	- a + 0.5

The 300 MHz ^{1}H N.M.R. spectra of compounds 1, 5, 7, 9 and 10, in the D-gluco-pyranose series, and 2, 6, and 8, in the D-galactopyranose series, were analysed iteratively and the best computed values of the chemical shifts and coupling constants are given in Table 8 which also includes the values previously obtained for 3[8,10], 11[15] and 12[10] which have been previously studied by us using both X-ray and N.M.R. spectroscopy.

In the D-glucopyranose derivatives in which a methyl or phenyl group at C-7 are in an exo orientation (1, 5, 9), the values of $J_{2,3}$ and $J_{3,4}$ are larger than in the derivatives having the methyl or phenyl group in an endo-orientation (3, 7, 10). These latter compounds (3, 7, 10), show a large positive long-range coupling

$J_{2,4}$ which has been previously taken as an indication of planar arrangement of H-2 and H-4 and, hence, of a boat-like conformation ($^2S_5$) of the pyranoid ring. These results demonstrate that the major conformation of the pyranoid ring of these D-glucopyranose derivatives in solution, depends on the configuration at C-7 of the dioxolane ring as it occurs in the solid state. The compounds having an endo methyl or phenyl group (3, 7, 10) seem to have a $^2S_5$ major solution conformation similar to that determined in the solid state for 3[8]. The compounds having an exo methyl or phenyl group seem to have a flattened $^4C_1$ major solution conformation similar to that determined in the solid state for 1[12].

TABLE 7a. Final atomic coordinates and thermal parameters for compound 1 as: UEQ=(1/3). SUM(UIJ.AI*.AJ*.AI.AJ.COS(AI,AJ)). 10**4

ATOM	X/A	Y/B	Z/C	UEQ
C1	.1959(2)	-.3750(0)	.5249(6)	523(10)
O1	.1512(1)	-.3457(3)	.3151(4)	550(7)
C2	.1742(1)	-.2463(4)	.7025(5)	479(9)
O2	.1052(1)	-.2484(3)	.6462(4)	565(7)
O3	.1973(1)	.0209(3)	.8831(4)	522(7)
C3	.2031(1)	-.0763(4)	.6670(5)	425(8)
C4	.2748(1)	-.0902(4)	.6303(5)	460(9)
O4	.2984(1)	.0715(3)	.5736(4)	587(7)
C5	.2824(2)	-.2028(4)	.4131(6)	522(10)
O5	.2597(1)	-.3645(3)	.4663(5)	577(7)
C6	.3520(2)	-.2207(6)	.3550(8)	691(14)
C12	.4519(2)	-.2252(8)	.5979(9)	875(17)
O7	.4751(2)	-.1502(13)	.4446(11)	1925(39)
C13	.4866(2)	-.2810(11)	.8279(11)	1100(23)
O8	.3592(2)	.0848(5)	.9295(8)	1241(16)
C10	.3415(2)	.1454(5)	.7397(9)	748(14)
O9	.1501(2)	.2287(4)	.6638(5)	911(12)
O6	.3909(1)	-.2715(4)	.5731(5)	708(8)
C11	.3613(3)	.3111(6)	.6488(16)	1174(27)
C14	.1723(2)	.1745(4)	.8560(6)	629(12)
C15	.1780(4)	.2657(6)	1.0895(8)	1006(22)
C7	.0922(1)	-.2899(5)	.3905(6)	569(10)
C9	.0737(2)	-.1365(6)	.2584(7)	719(13)
N	.0586(2)	-.0189(7)	.1544(8)	1066(19)
C8	.0392(2)	-.4206(8)	.3700(11)	931(19)

In the D-galactopyranose derivatives the vicinal coupling constants do not show any dependence on the configuration at C-7. This results demonstrate that the major solution conformational of the pyranoid ring of these compounds does not depend on the configuration at C-7 and that in all compounds studied this conformation may be described as $^4C_1$ as determined in the solid state for 2 and 12[10].

The vicinal proton torsion angles calculated using the empirical generalization of the Karplus equation proposed by Altona[24] are presented in Table 9. The same angles determined by X-ray crystallography are shown in Table 10. In spite of the fact that individual molecules may show a typical behaviour in the solid state and care should be taken when comparing the torsion angles estimated from N.M.R with those determined by X-ray, a reasonable agreement is found.

Furthermore, there is additional experimental evidence of a $^2S_5$ major solution conformation of the pyranoid ring of 3, 7 and 10 and $^4C_1$ of 1, 5 and 9 in the D-gluco series, and also in all compounds studied in the D-galacto one (2, 4, 6, 8). Irradiation of the signal of the endo-methyl group of compound 7 induced a 9% increase of the integrated intensity of the signal assigned to H-5 and no change in the signal assigned to H-3 as expected for a skew-boat $^2S_5$ major solution conformation. Similar NOE experiment on the acetalic proton of 9 caused a 4% increase as expected for a chair-like ($^4C_1$) conformation of the intensity of H-3. When the NOE experiment was carried out in the D-galactopyranose derivatives 4 and 8 the

intensity of both signals H-3 (6% in 4 and 7% in 8) and H-5 (4% in the spectra of both compounds) were enhanced. These results are in agreement with the assigned major $^4C_1$ conformation of the pyranoid ring of these D-galactopyranose derivatives.

TABLE 7b. Final atomic coordinates and thermal parameters for molecules 2 and 2' as: UEQ=(1/3). SUM(UIJ.AI*.AJ*.AI.AJ. COS(AI,AJ)). 10**3

ATOM	X/A	Y/B	Z/C	UEQ
C1	0.2651(4)	0.3524(0)	0.3783(3)	65(3)
O1	0.1973(2)	0.4162(5)	0.3520(2)	84(2)
C2	0.2635(3)	0.2774(6)	0.4487(3)	55(3)
O2	0.1903(2)	0.2419(4)	0.4249(2)	63(2)
C3	0.2873(3)	0.3645(6)	0.5191(3)	51(2)
O3	0.2993(2)	0.2801(4)	0.5836(2)	55(2)
C4	0.3521(3)	0.4471(6)	0.5265(3)	51(2)
O4	0.4124(2)	0.3619(4)	0.5374(2)	63(2)
C5	0.3357(3)	0.5259(6)	0.4546(3)	51(2)
O5	0.3188(2)	0.4393(5)	0.3889(2)	66(2)
C6	0.3987(3)	0.6069(7)	0.4565(3)	62(3)
O6	0.3735(2)	0.7188(4)	0.4063(2)	64(2)
C7	0.1504(4)	0.3395(8)	0.3735(4)	77(3)
O7	0.4755(3)	0.7280(9)	0.3931(4)	164(4)
C8	0.0924(5)	0.2751(10)	0.3055(4)	118(4)
N	0.0977(4)	0.5006(9)	0.4476(5)	129(5)
O8	0.4543(4)	0.4024(10)	0.6607(3)	156(4)
C9	0.1200(4)	0.4306(9)	0.4147(5)	87(4)
O9	0.2744(3)	0.4495(5)	0.6457(2)	80(2)
C10	0.4634(4)	0.3510(9)	0.6097(5)	88(4)
C11	0.5210(4)	0.2626(10)	0.6129(6)	110(5)
C12	0.4204(3)	0.7767(9)	0.3834(4)	88(3)
C13	0.3926(5)	0.9042(10)	0.3430(5)	125(5)
C14	0.2929(3)	0.3392(7)	0.6456(3)	62(3)
C15	0.3119(4)	0.2434(8)	0.7101(4)	85(3)
C1'	0.1477(3)	0.5155(7)	-0.1170(3)	60(3)
O1'	0.1935(2)	0.4573(5)	-0.1515(2)	75(2)
C2'	0.2033(3)	0.5726(6)	-0.0431(3)	45(2)
O2'	0.2608(2)	0.6093(4)	-0.0654(2)	53(2)
C3'	0.2281(3)	0.4752(6)	0.0224(3)	48(2)
O3'	0.2634(2)	0.5487(4)	0.0912(2)	54(2)
C4'	0.1661(3)	0.3956(6)	0.0266(3)	53(2)
O4'	0.1146(2)	0.4823(4)	0.0383(2)	59(2)
C5'	0.1293(3)	0.3267(7)	-0.0490(3)	57(3)
O5'	0.1015(2)	0.4228(5)	-0.1104(2)	59(2)
C6'	0.0680(4)	0.2445(8)	-0.0494(4)	81(4)
O6'	0.0582(2)	0.1358(4)	-0.0984(3)	71(2)
C7'	0.2590(3)	0.5233(6)	-0.1254(3)	54(2)
O7'	-0.0495(3)	0.1079(9)	-0.1022(4)	164(4)
C8'	0.2712(4)	0.6017(8)	-0.1867(3)	76(3)
N	0.3559(5)	0.3350(9)	-0.0664(5)	130(5)
O8'	0.1592(4)	0.4299(8)	0.1625(3)	137(4)
C9'	0.3146(5)	0.4164(9)	-0.0919(5)	82(4)
O9'	0.3292(3)	0.3717(6)	0.1435(3)	88(2)
C10'	0.1157(4)	0.4887(8)	0.1108(4)	76(3)
C11'	0.0592(6)	0.5746(12)	0.1145(7)	95(6)
C12'	-0.0019(4)	0.0682(9)	-0.1160(5)	93(4)
C13'	-0.0029(10)	-0.0593(22)	-0.1555(14)	193(11)
C14'	0.3139(4)	0.4833(9)	0.1496(4)	68(3)
C15'	0.3451(7)	0.5706(13)	0.2176(5)	97(5)

EXPERIMENTAL

Materials. Compounds 1-4 and 5-10 were prepared as reported[25,26]

X-Ray measurements*. The characteristics of the crystal used for the data collection and those of the structure solution and refinement are given in Table 1. All hydrogen atoms were located by difference Fourier synthesis.

N.M.R. data. The ^1H N.M.R. spectra ($CDCl_3$, internal Me_4Si) were recorded at 300 MHz with a Varian XL-300 spectrometer. Analyses were performed by using a PANIC program. The experimental and calculated spectra from the resulting best values matched satisfactorily.

TABLE 8. ^{1}H N.M.R. spectral parameters $\nu(\delta)$ and J(Hz) of compounds 1 12

Parameter	Compound											
	1	2	3[10]	4	5	6	7	8	9	10[15]	11	12[10]
ν_1	5.721	5.753	5.817	5.869	5.584	5.633	5.568	5.555	5.741	5.749	6.184	5.755
ν_2	4.332	4.399	4.347	4.317	4.240	4.276	4.032	4.051	4.211	4.245	4.391	4.250
ν_3	5.470	5.436	5.190	4.969	5.240	5.061	5.188	5.027	5.347	5.299	5.431	5.054
ν_4	4.980	5.532	4.896	5.397	4.931	5.440	4.895	5.400	4.975	4.936	4.982	5.421
ν_5	4.220	4.432	4.022	4.321	4.005	4.296	4.098	4.383	4.176	4.173	3.673	4.315
ν_{6a}	4.192	4.108	4.222	4.127	4.130	4.097	4.179	5.129	4.206	4.167	4.184	4.119
ν_{6b}	4.342	4.200	4.199	4.163	4.276	4.143	4.205	4.162	4.301	4.170	4.166	4.162
$J_{1,2}$	4.8	4.6	5.1	4.8	4.8	4.7	5.1	4.8	4.6	5.1	7.4	4.8
$J_{1,5}$	-0.5	-0.5	-0.7	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.6	-0.7	-0.5
$J_{2,3}$	4.5	7.4	2.9	7.0	5.1	7.6	3.0	7.0	4.5	3.0	2.6	6.5
$J_{2,4}$	0.0	0.0	0.9	0.0	0.0	0.0	0.9	0.0	0.0	0.8	1.2	0.0
$J_{3,4}$	6.1	3.0	2.5	3.5	6.2	3.0	2.4	3.5	4.6	2.7	2.1	3.5
$J_{4,5}$	9.0	2.4	9.5	1.9	9.6	1.9	9.7	2.0	9.6	9.4	9.1	2.6
$J_{5,6a}$	2.4	6.5	2.8	6.1	2.4	6.2	2.5	6.2	2.4	2.3	3.0	6.3
$J_{5,6b}$	5.2	6.8	5.6	4.0	5.0	6.8	5.5	7.0	5.2	5.7	5.8	6.9
$J_{6a,6b}$	-12.2	-11.6	-12.2	-11.6	-12.3	-11.4	-12.2	-11.4	-12.3	-12.2	-12.3	-11.3

TABLE 9. Vicinal proton torsion angles (°) for compounds 1-12 deduced from ^{1}H N.M.R. data

Compound	Angle			
	$\phi_{1,2}$	$\phi_{2,3}$	$\phi_{3,4}$	$\phi_{4,5}$
1	40	-139	150	-162
2	42	-156	54	-45
3[10]	-18	-67	128	-170
4	40	-154	50	-49
5	40	-143	150	-172
6	41	-158	54	-49
7	-19	-67	126	-175
8	40	-154	50	-48
9	43	-139	140	-172
10	-19	-67	128	-168
11[15]	26	61	120	-
12[10]	40	-151	50	-43

TABLE 10. Vicinal proton torsion angles (°) from X-Ray analysis

Compound	Angle			
	$\phi_{1,2}$	$\phi_{2,3}$	$\phi_{3,4}$	$\phi_{4,5}$
1	34(4)	-161(3)	176(3)	-175(3)
2	40(5)	-157(5)	64(5)	-73(5)
2'	16(6)	-152(5)	52(5)	-55(5)
3[8]	-18(5)	-67(6)	95(7)	-148(5)
11[15]	-11(4)	-69(4)	91(4)	-143(4)
12[10]	24(8)	-167(7)	64(7)	-53(7)

Supplementary material. List of observed and calculated structure factors, final anisotropic parameters for heavy atoms, positional and thermal parameters for hydrogens atoms have been deposited at the Cambridge Crystallographic Data Center

ACKNOWLEDGEMENTS

We thank the C.A.I.C.Y.T. and the C.S.I.C. for finantial support, the Ministerio de Educación y Ciencia for a fellowship (J. J. B.) and Miss S. Jordán de Urries for technical assistence.

REFERENCES

1 D. Horton and J. D. Wander, Carbohydr. Res. 39, 141 (1975)

2 B. Coxon and L. D. Hall, Tetrahedron 20, 1685 (1964)

3 R. U. Lemieux and A. R. Morgan, Can. J. Chem. 43, 2199 (1965)

4 R. U. Lemieux and D. H. Detert, Can J. Chem. 46, 1039 (1968)

5 R. G. Rees, A. R, Tatchell and R. D. Wells, J. Chem. Soc. C, 1768 (1967)

6 J. Trotter and J. K. Fawcett, Acta Crystallogr. 21, 366 (1966)

7 J. A. Heitmann, G. F. Richards, and L. R. Schroeder, Acta Crystallogr. Sect. B 30, 2322 (1974)

8 C. Foces-Foces, F. H. Cano, and S. García Blanco, Acta Crystallogr. Sect. B 32, 3029 (1976)

9 M. Martín-Lomas, M. Bernabé, and M. E. Chacón-Fuertes, An. Quim. 75, 718 (1979)

10 C. Foces-Foces, A. Alemany, M. Bernabé, and M. Martín-Lomas, J. Org. Chem. 45, 3502 (1980)

11 R. U. Lemieux, and O. Hindsgaul, Carbohydr. Res. 82, 195 (1980)

12 L. G. Vorontsova, O. S. Dekaprilevich, O. S. Chizhov, L. V. Backinowsky, M. U. Betaneli, and M. V. Ovchinnikov, Izv. Nauk. SSSR, Ser Khim. 10, 2312 (1980)

13 M. A. Nashed, C. W. Slife, M. Kiso, and L. Anderson, Carbohydr. Res. 82, 237 (1980)

14 V. K. Srivastava, Carbohydr. Res. 103, 286 (1982)

15 C. Foces-Foces, F. H. Cano, M. Bernabé, S. Penadés-Ullate, and M. Martín-Lomas, Carbohydr. Res. 135, 1 (1984)

16 F. H. Cano, C. Foces-Foces, A. Alemany, M. Bernabé, M. L. Jimeno, and M. Martín-Lomas, Carbohydr. Res. (in press)

17 P. Main, S. J. Fiske, S. E. Hull, L. Lessinger, G. Germain, J. P. Declerk, and M. M. Woolfson. "Multan 80 System" (1980). University of York, (England)

18 J. M. Stewart, P. A. Machin, C. W. Dickinson, H. L. Ammon, H. Heck, and H. Flack. "The X-Ray Sistem". (1976). University of Maryland. USA

19 International Tables for X-Ray Crystallography. (1974), Vol. IV, Birmingham Kynoch Press

20 S. C. Abrahams, and E. T. Keve, Acta Crystallogr. Sect. A 27, 157 (1971)

21 C. Riche, and C. Pascard-Billy, Acta Crystallogr. Sect. B 31, 2565 (1975)

22 S. Arnott, and W. E. Scott, J. Chem. Soc. Perkin II, 324 (1972)

23 W. Klyne, and V. Prelog. Experientia (1980)

24 C. A. G. Haasnoot, F. A. A. M. De Leeuw, and C. Altona, Tetrahedron 36, 2783 (1980)

25 V. I. Betaneli, M. V. Ovchinnikov, L. V. Backinowsky, and N. K. Kochetkov, Carbohydr. Res. 107, 285 (1982)

26 V. I. Betanely, M. V. Ovchinnikov, L. V. Backinowsky, and N. K. Kochetkov, Carbohydr. Res. 68, C11 (1979)