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Synthesis and characterization of 4,6-*O*-butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine: crystal structures of 4,6-*O*-butylidene-α-D-glucopyranose, 4,6-*O*-butylidene-β-D-glucopyranosylamine and 4,6-*O*-butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine

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Abstract

4,6-*O*-Butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine was synthesized and characterized using analytical, spectral and single-crystal X-ray diffraction methods. ^{1}H and ^{13}C NMR studies showed the presence of the β-anomer, which has also been confirmed by the crystal structure. The molecular structure of this compound showed the presence of the tridentate ONO ligation-core. Both precursors, 4,6-*O*-butylidene-α-D-glucopyranose and 4,6-*O*-butylidene-β-D-glucopyranosylamine were characterized using single crystal X-ray diffraction. The α-anomeric nature of the former and β-anomeric nature of the latter were proposed based on ^{1}H NMR studies and were confirmed by determining the crystal structures. In addition, the crystal structure of 4,6-*O*-butylidene-β-D-glucopyranosylamine revealed the C-1–N-glycosylation. In all the three molecules, the saccharide unit exhibits a $^{4}C_{1}$ chair conformation. In the lattice, the molecules are connected by hydrogen-bond interactions. The conformation of 4,6-*O*-butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine is stabilized via an O–H···N intramolecular interaction, and each molecule in the lattice interacts with three neighboring molecules through hydrogen bonds of the type O–H···O and C–H···O.

Keywords: Glycosyl amines; 4,6-*O*-Butylidene-α-D-glucopyranose; 4,6-*O*-Butylidene-β-D-glucopyranosylamine; 4,6-*O*-Butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine; Single-crystal X-ray diffraction

1. Introduction

Glycosyl amines are of synthetic, biological and pharmaceutical importance. These are important intermediates in the synthesis of N-nucleosides and glycosylamino heterocycles and are active site directed reversible inhibitors of glycosidases that are known to mimic insulin bioactivity.[1] We have been recently working on the synthesis, characterization and structure determination of protected saccharides, glycosyl amines, saccharide-based imine containing (C-1–N=C–) molecules and metal ion complexes[2–11] of these systems.

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Synthesis and characterization of glycosylamines derived from 4,6-*O*-butylidene-α-D-glucopyranose[12] brings in the necessity to determine the crystal structure of its precursor, viz., 4,6-*O*-butylidene-α-D-glucopyranose and 4,6-*O*-butylidene-β-D-glucopyranosylamine particularly to establish the C-1 glycosylation, anomeric nature and the binding motif. Establishing the structures of these molecules is expected to assist in drawing appropriate comparisons between the precursor and resulting glycosyl amine products. Therefore, in continuation with our on going effort in the field of derivatization of saccharides and their metal ion interactions, this paper deals with the synthesis, characterization and crystal structure determination of the precursors 4,6-*O*-butylidene-α-D-glucopyranose (**1**) and 4,6-*O*-butylidene-β-D-glucopyranosylamine (**2**), and the final product, 4,6-*O*-butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine (**3**).

2. Experimental

D-Glucose was procured from Aldrich Chemical Co., and butyraldehyde from Fluka Chemical Co. All solvents were purified and dried immediately before use. Elemental analysis was carried out on a ThermoQuest EA1112. FTIR spectra were recorded on a Nicolet Magna IR 550. The specific rotations were measured on a Jasco DIP-370 Digital polarimeter. The specific rotations were measured thrice using fresh solutions and the mean value is reported. ^{1}H NMR spectra were recorded on a Varian VXR 300S. The GC-mass spectrum was recorded on a 5989 B MS engine model of Hewlett–Packard, USA make. The FAB mass spectrum was recorded on a JEOL SX 102/DA-6000 mass spectrometer data system using argon/xenon (6 Kv, 10 mA) as the FAB gas. The accelerating voltage was 10 kV, and the spectrum was recorded at rt with *m*-nitrobenzyl alcohol (NBA) as the matrix. ''BUY'' refers to the butylidene moiety of the 4,6-*O*-protection.

4,6-O-*Butylidene*-α-D-*glucopyranose* (**1**).—This compound was synthesized as per the procedure reported in 1951.[13a] This was also synthesized by a different procedure as reported in 1965.[13b] However, both these reports do not provide spectral characterization. Slow evaporation of the concentrated ethanolic solution of **1** resulted in the formation of single crystals. (11.70 g, 25%), mp: 164–165 °C; IR (KBr); *ν* 3494 (m) *ν*(O–H), 2971 (s), 2872 (s) and 2930 (s) *ν*(C–H), 1099 (s) *δ*(C–O) cm^{-1}; $[\alpha]_D^{25}$ $+50° \pm 1.2°$ (*c* 1, Me_2SO); ^{1}H NMR (Me_2SO-d_6): *δ* 0.867 (t, 3 H, CH_3 of BUY), 1.290–1.413 (m, 2 H, CH_2 of BUY), 1.471–1.541 (m, 2 H, CH_2 of BUY), 3.031–3.662 (m, 5 H, H-2, H-3, H-4, H-6), 3.898–3.947 (m, H, H-5), 4.523 (t, H, CH of BUY), 4.719 (d, H, 3-OH or 2-OH), 4.917 (d, H, $^3J_{H\text{-}1\text{–}H\text{-}2}$ 3.7 Hz, H-1), 5.0 (d, H, 3-OH or 2-OH), 6.452 (d, H, 1-OH) ppm; ^{13}C NMR (Me_2SO-d_6): *δ* 93.1 (C-1), 62.2–81.3 (C-2 to C-6), 101.4 (CH unit of BUY), 36.1 (CH_2 unit of BUY), 17.1 (CH_2 unit of BUY), 13.9 (CH_3 unit of BUY) ppm; FABMS: *m*/*z* 234 $[M]^+$, 10%, Anal. Calcd for $C_{10}H_{18}O_6$: C, 51.28; H, 7.75. Found: C, 51.30; H, 7.60.

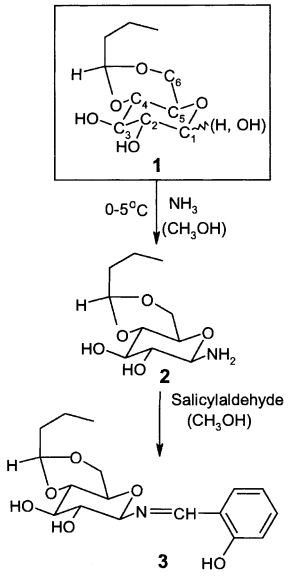
4,6-O-*Butylidene*-β-D-*glucopyranosylamine* (**2**).—This was synthesized and characterized as reported by us recently.[12] The single crystals of **2** were obtained from the reaction mixture when left overnight. $[\alpha]_D^{25}$ $-12.5° \pm 2°$ (*c* 1, Me_2SO).

4,6-O-*Butylidene*-N-(*2-hydroxybenzylidene*)-β-D-*glucopyranosylamine* (**3**).—To an ethanolic suspension of 4,6-*O*-butylidene-α-D-glucopyranosylamine (**2**) (50 mL, 4.7 g, 20.15 mmol), salicylaldehyde (2.6 mL, 20.96 mmol) was added. The reaction mixture was refluxed for 3 h and was allowed to cool to rt. The crystalline product that separated was filtered and washed with cold EtOH. Single crystals suitable for XRD were obtained from slow evaporation of the concentrated solution of the compound in EtOH. (4.08 g, 60%); mp 150–152 °C; IR (KBr); 3451 (m) and 3372 (m) *ν*(O–H), 2970 (s), 2933 (s), and 2875 (s) *ν*(C–H), 1635 (s) *ν*(CH=N), 1071 (s) *δ*(C–O) cm^{-1}; $[\alpha]_D^{25}$ $-59° \pm 0.6°$ (*c* 1, Me_2SO); ^{1}H NMR (Me_2SO-d_6): *δ* 0.888 (t, 3 H, CH_3 of BUY), 1.335–1.427 (m, 2 H, CH_2 of BUY), 1.515–1.566 (m, 2 H, CH_2 of BUY), 3.08–3.567 (m, 5 H, H-2, H-3, H-4, H-6), 4.072–4.108 (m, H, H-5), 4.587–4.612 (m, H, CH of BUY), 4.56 (d, H, $^3J_{H\text{-}1\text{–}H\text{-}2}$ 8.32 Hz, H-1), 5.333 (d, H, 3-OH or 2-OH), 5.55 (d, H, 3-OH or 2-OH), 6.893–7.543 (m, 4 H, Ar–H), 8.586 (s, H, CH=N), 12.92 (s, H, phenol-OH) ppm; ^{13}C NMR (Me_2SO-d_6): *δ* 95.3 (C-1), 67.3–80 (C-2–C-6), 101.2 (CH unit of BUY), 35.8 (CH_2 unit of BUY), 17.0 (CH_2 unit of BUY), 13.8 (CH_3 unit of BUY), 116.4–160.2 (Ar-6 C), 165.1 (CH=N) ppm; GCMS: *m*/*z* 337 $[M]^+$; Anal. Calcd for $C_{17}H_{23}NO_6$: C, 60.52; H, 6.87; N, 4.15. Found: C, 60.25; H, 7.27; N, 4.09.

X-ray crystallography.—Diffraction data of **1**, **2** and **3** were collected on a Nonius Kappa CCD instrument in the ϕ scan + ω scan mode using MoK_α radiation. The structure **1** was solved using SIR92[14] and refined using SHELXL-97.[15] Structures **2** and **3** were solved and refined using SHELXS-97 program packages. The diagrams were generated using the ORTEP3[16] program. The Cremer–Pople and asymmetry parameters[17–19] were obtained using the program, PLATON 99. Full-matrix least-squares refinement with anisotropic thermal parameters for all non-hydrogen atoms was used. Hydrogen atom positions in case of 1-OH, 2-OH, 3-OH and $-NH_2$ were obtained from difference Fourier maps. All the hydrogens were treated as riding atoms with fixed thermal parameters. Other details of data collection and structure refinement are provided in Table 1.

Table 1
Summary of crystallographic data for **1**, **2** and **3**

	1	**2**	**3**
Molecular formula	$C_{10}H_{18}O_6$	$C_{10}H_{19}NO_5$	$C_{17}H_{23}NO_6$
Formula weight	234.25	233.26	337.36
T (K)	173(2)	293(2)	293(2)
Crystal system	monoclinic	monoclinic	monoclinic
Space group	$P2_1$ (no. 4)	$P2_1$	$P2_1$
Unit cell dimensions			
a (Å)	16.694(1)	4.808(2)	9.206(5)
b (Å)	6.794(1)	6.305(3)	6.247(5)
c (Å)	20.864(1)	18.898(9)	14.847(5)
β (°)	111.25(1)	94.900(5)	91.583(5)
V (Å^3)	2205.5(4)	570.8(5)	853.5(9)
Z	8	2	2
D_{calcd} (Mg/m^3)	1.411	1.357	1.313
Reflections collected	14497	3662	5832
Independent reflections	8820	2044	3329
Final R indices	$R_1 = 0.0369$	$R_1 = 0.0370$	$R_1 = 0.0334$
$[I > 2\sigma(I)]$	$wR_2 = 0.0927$	$wR_2 = 0.0707$	$wR_2 = 0.0796$
R indices (all data)	$R_1 = 0.0469$	$R_1 = 0.0619$	$R_1 = 0.0466$
	$wR_2 = 0.0992$	$wR_2 = 0.0806$	$wR_2 = 0.0868$



Scheme 1. Schematic representation of the synthesis of **3**. Figure shown in the box depicts the nomenclature used for discussions.

3. Results and discussion

4,6-*O*-Butylidene-*N*-(2-hydroxybenzylidene)-β-D-glucopyranosylamine (**3**) was synthesized as shown in the Scheme 1. Its formation and purity were confirmed by TLC, elemental analysis, FTIR, ^{1}HNMR and mass spectral data.

Proton resonances of OH and NH_2 groups were further cross-checked by exchanging these with D_2O addition followed by spectral measurement. The peak corresponding to C-1–NH_2 observed in **2** at 2.35 ppm disappears in **3** and a new peak appears at 8.586 ppm arising from –CH=N indicating that the –NH_2 group present in the former was converted to its Schiff's base in **3**. In **3**, H-1 was found at 4.56 ppm with a coupling constant $^3J_{H\text{-}1\text{–}H\text{-}2}$ of 8.32 Hz, a value that supports the presence of β-anomer. Thus, on going from **1** → **2** → **3**, the anomeric nature changes from α → β → β type. Conversion to β-anomeric form in **2** and **3** is justified owing to the stability acquired upon going from the protected saccharide to the glycosyl amines. The appearance of a C-1 resonance in the ^{13}C NMR spectrum at 95.3 ppm supports the presence of the β-anomer. Thus, the conclusions derived based on ^{1}H NMR spectra are also supported by ^{13}C. The specific rotations of **1** ($+50° \pm 1.2°$), **2** ($-12.5° \pm 2°$) and **3** ($-59° \pm 0.6°$) are supportive of the corresponding anomeric structures. The sharp band observed at 1635 cm^{-1}in **3** is assigned to CH=N, and –NH_2 which is observed at 1627 cm^{-1} in **2**, disappears in the spectrum of **3** due to the conversion of this –NH_2 group into an imine moiety. The molecular-ion peak observed at m/z 337 in **3** confirms the molecular weight of the compound.

Molecular and crystal structure of **1**.—This compound crystallizes in $P2_1$ with four molecules present in each asymmetric unit. The molecular structure of **1** is provided in Fig. 1(a) as an ORTEP plot. The molecule **1** adapts a pyranose structure with positions 4 and 6 connected by butylidene moiety to result in a six-membered C_4O_2 heterocyclic ring. Cremer–Pople puckering parameters and asymmetry parameters are given in Table 2. The conformation of the pyranose ring is a $^4C_1$ chair type, and the saccharide moiety is present in the α-anomeric form, as also derived from NMR studies. These features can be clearly understood from the stereo view given in Fig. 1(b). Comparison of bond lengths and bond angles present in each molecule of the asymmetric unit indicates almost no change in the data from one molecule to the other. Further, the metric data (Table 3) was found to be quite normal and agrees well with the reported values for similar bonds. Selected torsion angles are also provided in Table 3 to represent the conformation of the molecule. The torsion angle, O-3–C-2–C-4–O-5, implies that O-3–C-2 is gauche with respect to C-4–O-5, and this also supports the α-anomeric form at C-1.

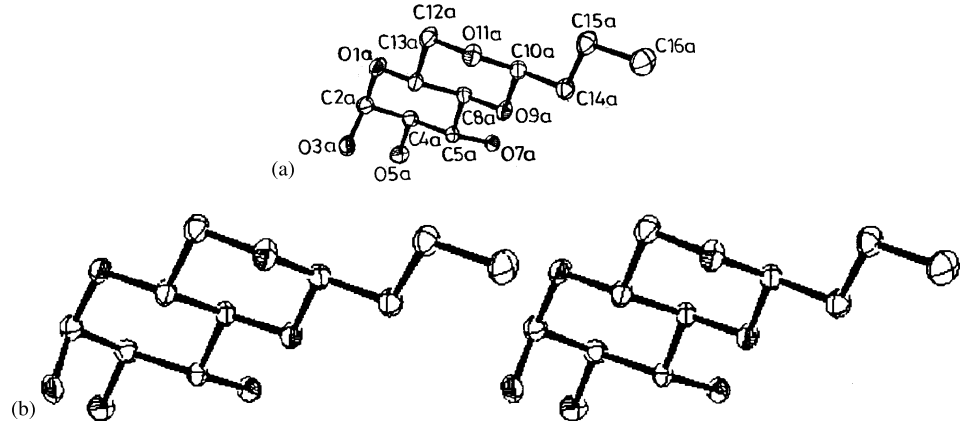


Fig. 1. (a) Molecular structure, and (b) stereo view of **1**.

Each molecule in the lattice interacts with four neighboring molecules through O–H···O interactions, and the corresponding metric data are given in Table 4. Thus each molecule acts as a donor for three interactions and an acceptor for three interactions, thereby totally exhibiting six H-bond interactions with its neighbors. This can be seen from Fig. 2.

Molecular and crystal structure of **2**.—The molecular structure of **2** is shown in Fig. 3(a) as an ORTEP plot. Structure **2** reveals the presence of the C-1 glycosylation of the saccharide moiety upon reaction with ammonia to result in 4,6-*O*-butylidene-β-D-glucopyranosylamine. Cremer–Pople and asymmetry parameters are given in Table 2, and the conformation of the pyranose ring is the $^4C_1$ chair type. Based on the torsion angle O-4–C-9–C-10–N-1, it was noted that the C-10–N-1 bond is gauche oriented with respect to the C-9–O-4 bonds. Thus, the glycosylation clearly resulted in a change in the state of the anomeric form from α to β. The configuration and conformation of the saccharide is evidenced by the stereo view shown in Fig. 3(b), and also through the corresponding torsion angles provided in Table 3. The bond lengths and bond angles exhibited by **2** are quite normal and are given in Table 3.

Each molecule in the lattice interacts with four neighboring molecules through H-bond interactions, and the corresponding metric data are given in Table 4. Thus each molecule acts as a donor for four interactions (two N–H···O and two O–H···O) and an acceptor for four interactions (one N···H–O, one O···H–C, and two O···H–O) thereby totally exhibiting eight H-bond interactions with its neighbors. This can be seen in Fig. 4. Such interactions are manifested in the formation of chains of molecules. The lattice structure is shown in Fig. 7. Comparison of the lattice structure of **2** with that of **1** reveals that the C-2–OH is involved in H-bond interaction only in case of **2** but not in **1**.

Molecular and crystal structure of **3**.—Structure of **3** is shown in Fig. 5(a) as an ORTEP plot. This structure reveals the condensation that took place between $-NH_2$ of **2** and the –CHO of the salicylaldehyde to result in the formation of C-1(saccharide)–N=C– moiety in **3**. Cremer–Pople and asymmetry parameters for **3** are given in Table 2 for both the six membered rings. The

Table 2
Cremer–Pople puckering and asymmetry parameters for **1**, **2** and **3**

1
O(1A)-C(2A)-C(4A)-C(6A)-C(8A)-C(13A)
ΔCs (O-1A, C-6A) = 0°, ΔCs (C-2A, C-8A) = 0°, ΔCs (C-4A, C-13A) = 0°
$Q = (0.585A°)$, $\theta = (1.6°)$, $\phi = (292.69°)$

O(9A)–C(8A)–C(13A)–C(12A)–O(11A)–C(10A)
ΔCs (O-9A, C-12A) = 0°, ΔCs (C-8A, O-11A) = 0°, ΔCs (C-13A, C-10A) = 0°
$Q = (0.595A°)$, $\theta = (3.3°)$, $\phi = (136.68°)$

2
O(1)–C(4)–O(2)–C(5)–C(6)–C(7)
ΔCs (O-1, C-5) = 0°, ΔCs (C-4, C-6) = 0°, ΔCs (O-2, C-7) = 0°
$Q = (0.570A°)$, $\theta = (179.4°)$, $\phi = (43.14°)$

O(3)–C(6)–C(7)–C(8)–C(9)–C(10)
ΔCs (O-3, C-8) = 0°, ΔCs (C-6, C-9) = 0°, ΔCs (C-7, C-10) = 0°
$Q = (0.590A°)$, $\theta = (174.3°)$, $\phi = (268.94°)$

3
O(1)–C(13)–C(12)–C(11)–O(2)–C(14)
ΔCs (O-1, C-11) = 0°, ΔCs (C-13, O-2) = 0°, ΔCs (C-12, C-14) = 0°
$Q = (0.585A°)$, $\theta = (2.0°)$, $\phi = (26.68°)$

O(3)–C(8)–C(9)–C(10)–C(11)–C(12)
ΔCs (O-3, C-10) = 0°, ΔCs (C-8, C-11) = 0°, ΔCs (C-9, C-12) = 0°
$Q = (0.600A°)$, $\theta = (177.3°)$, $\phi = (86.30°)$

ΔCs (I–J), asymmetry parameters for bond I–J. Q (A°), θ (°), ϕ (°), Cremer–Pople puckering parameters.

Table 3
Selected bond lengths (Å), bond angles (°) and torsion angles (°) for **1**, **2** and **3**

1		**2**		**3**	
Bond lengths					
C-2–O-3	1.403(2)	O-3–C-6	1.427(2)	O-3–C-12	1.432(2)
C-2–O-1	1.431(2)	O-3–C-10	1.446(2)	O-3–C-8	1.435(2)
C-2–C-4	1.541(2)	N-1–C-10	1.431(3)	O-4–C-10	1.422(2)
C-4–O-5	1.416(2)	C-9–C-8	1.518(3)	O-5–C-9	1.420(2)
C-4–C-6	1.530(2)	C-9–C-10	1.530(3)	C-11–C-10	1.499(2)
C-6–C-8	1.512(2)	C-8–C-7	1.510(3)	C-11–C-12	1.515(2)
C-8–C-13	1.525(2)	C-7–C-6	1.513(3)	N-1–C-7	1.266(2)
C-13–O-1	1.425(2)	C-9–O-4	1.433(2)	N-1–C-8	1.445(2)
C-6–O-7	1.426(2)	C-8–O-5	1.431(3)	C-10–C-9	1.524(2)
				C-9–C-8	1.533(2)
Bond angles					
O-3–C-2–O-1	111.61(11)	C-6–O-3–C-10	111.97(14)	C-7–N-1–C-8	121.15(16)
O-3–C-2–C-4	108.05(12)	O-4–C-9–C-8	110.93(17)	O-4–C-10–C-11	109.05(13)
O-1–C-2–C-4	109.7(11)	C-8–C-9–C-10	112.07(18)	O-4–C-10–C-9	112.03(14)
O-5–C-4–C-6	108.27(12)	O-5–C-8–C-9	111.64(19)	O-5–C-9–C-8	108.4(14)
O-5–C-4–C-2	110.87(11)	C-8–C-7–C-6	108.3(19)	C-10–C-9–C-8	110.11(14)
C-6–C-4–C-2	111.18(11)	O-3–C-6–C-7	109.93(16)	O-3–C-8–N-1	110.91(14)
O-7–C-6–C-8	109.75(11)	N-1–C-10–O-3	109.20(16)	N-1–C-8–C-9	109.33(14)
O-7–C-6–C-4	110.87(11)	N-1–C-10–C-9	111.08(19)	N-1–C-7–C-6	121.44(18)
				O-5–C-9–C-10	111.02(13)
Torsion angles					
O-3–C-2–C-4–O-5	55.33(14)	O-4–C-9–C-8–O-5	60.4(13)	O-4–C-10–C-9–O-5	−64.25(18)
O-1–C-2–C-4–O-5	177.21(11)	C-10–C-9–C-8–O-5	−179.84(17)	O-4–C-10–C-9–C-8	175.7(13)
O-5–C-4–C-6–O-7	62.81(15)	C-9–C-8–C-7–O-1	177.82(18)	C-7–N-1–C-8–O-3	3.4(2)
C-2–C-4–C-6–O-7	−175.17(11)	O-5–C-8–C-7–C-6	−177.59(18)	C-7–N-1–C-8–C-9	124.91(17)
O-7–C-6–C-8–O-9	−63.96(14)	O-4–C-9–C-10–N-1	−64.1(2)	O-5–C-9–C-8–N-1	59.66(18)
		O-4–C-9–C-10–O-3	175.08(15)	O-5–C-9–C-8–O-3	−178.27(12)
				C-1–C-6–C-7–N-1	−1.0(3)

Table 4
Hydrogen bond data for **1**, **2** and **3**

D-H···A	d(D···H) (Å)	d(H···A) (Å)	d(D···A) (Å)	∠(DHA) (°)	Symmetry
1					
O-3A–H-3A···O-7A	0.8404	2.4966	3.1336	133.34	$x, -1+y, z$
O-3A–H-3A···O-9A	0.8404	2.3880	3.1416	149.57	$x, -1+y, z$
O-7A–H-7A···O-3A	0.8102	2.0175	2.8137	167.35	$1-x, 1/2+y, 1-z$
2					
N-1–H-1N···O-4	0.8856	2.3357	3.1870	161.23	$1+x, y, z$
N-1–H-2N···O-5	0.8665	2.4093	3.0730	133.86	$1+x, -1+y, z$
O-4–H-4O···N-1	1.0482	1.7537	2.7614	159.84	$2-x, 1/2+y, 1-z$
O-5–H-5O···O-4	0.8883	1.9491	2.8348	174.73	-do-
C-8–H-8···O-3	1.0257	2.3770	3.0416	176.73	$-1+x, y, z$
3					
O-4–H-4O···O-2	0.9698	1.8097	2.7691	169.56	$2-x, 1/2+y, -z$
O-5–H-5O···O-4	0.8600	2.0875	2.9413	171.79	$2-x, 1/2+y, -z$
O-6–H-6O···N-1	0.9025	1.8333	2.6194	144.26	
C-4–H-4···O-1	1.0604	2.4951	3.4173	144.87	$2-x, 3/2+y, 1-z$

D and A refer to the donor and acceptor of hydrogens, respectively.

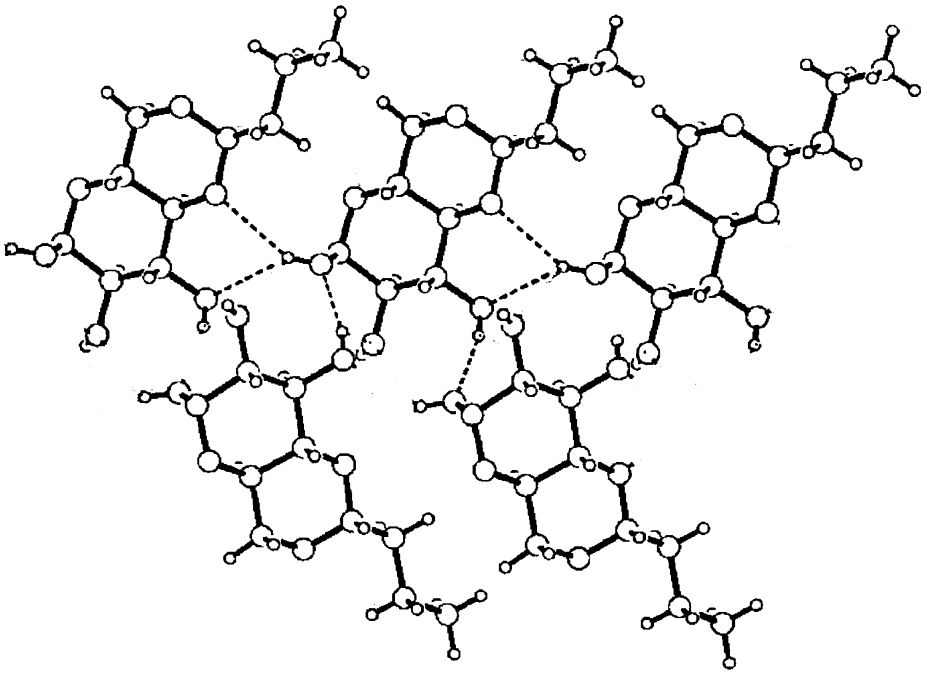


Fig. 2. Typical hydrogen bonding observed in the lattice of **1**.

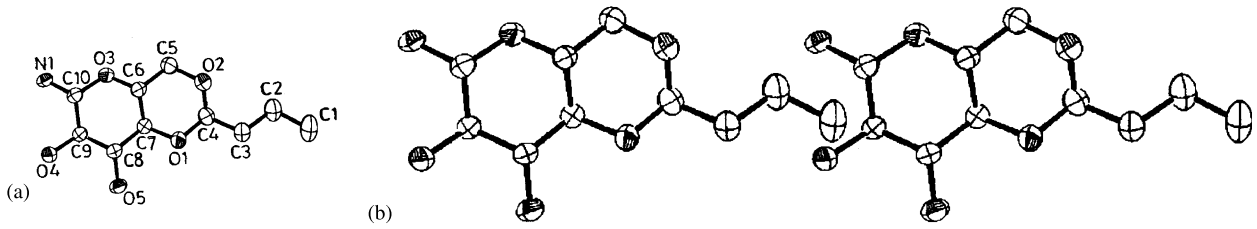


Fig. 3. (a) Molecular structure, and (b) stereo view of **2**.

stereo view of the molecule shown in Fig. 5(b) reveals a chair conformation for both the six-membered rings where the pyranose ring of the saccharide unit exists in the $^4C_1$ conformation. The same view also indicates the presence of a tridentate O-5–N-1–O-6 (ONO) ligation-core that is capable of forming bis-chelate when binding to a metal ion. Based on the torsion angle, O-5–C-9–C-8–N-1, it was noted that the C-8–N-1 bond is gauche oriented with respect to the C-9–O-5 bonds, which supports the presence of β-anomeric form. The torsional angles given in Table 3 show trans geometry with respect the –CH=N– moiety. The bond lengths and bond angles present in **3** are quite normal and are given in Table 3.

The conformation of **3** is stabilized by an intramolecular 6-atom O–H···N interaction. In the lattice, each molecule interacts with its three neighbors through five H-bond interactions (Fig. 6), by acting as a donor in three cases (two O–H···O, one C–H···O) and as an acceptor in two cases (O···H–O). Thus the molecule in the lattice uses its C-2–OH, C-3–OH, C-4–O and Ar–C–H groups in exhibiting hydrogen-bond interac-

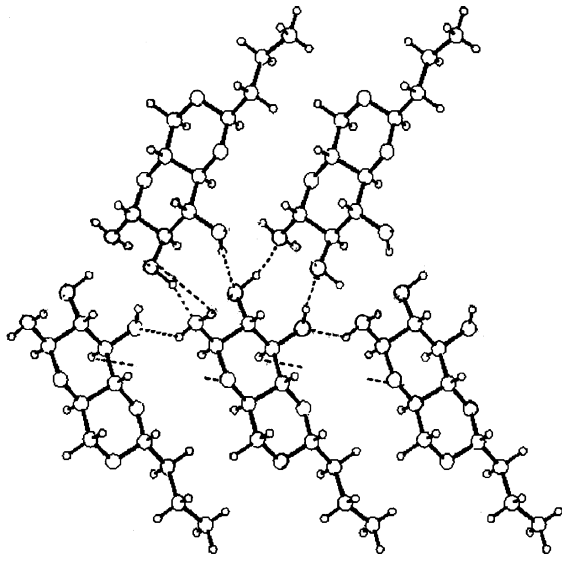


Fig. 4. Typical hydrogen bonding observed in the lattice of **2**.

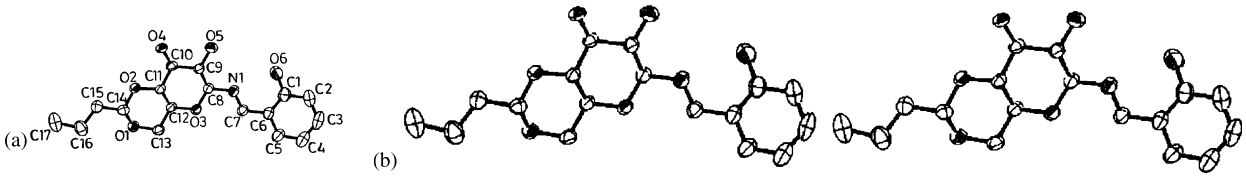


Fig. 5. (a) Molecular structure, and (b) stereo view of **3**.

tions. Corresponding hydrogen-bond data are listed in Table 4. Comparison of the lattice structure of **3** with that of **2** clearly indicates the loss of H-bond interactions in the former due to the conversion of the C-1–NH_2 (in **2**) to the C-1–N=C– moiety (in **3**).

4. Conclusions and correlations

While the 4,6-*O*-ethylidene α-D-glucopyranose exhibits five donor type and five acceptor type H-bond interactions[2] in its lattice, its analogue, 4,6-*O*-butylidene α-D-glucopyranose (**1**) exhibits only three donor type and three acceptor type hydrogen bond interactions owing to the increase in the chain length of the protecting group, on going from ethylidene to butylidene, that would prevent the molecules coming closer. On going from α-anomer in **1** (C-1–α-OH) to the β-anomer in **2** (C-1–β-NH_2), the number of weak interactions exhibited with the neighbor molecules in the lattice increase from six to eight. This increase in interactions is attributed to the change in the anomeric nature of these two molecules. When **2** is converted to **3**, the saccharide portion is involved in only four H-bond interactions where two are of the donor type and two more are of the acceptor type. This is explainable based on the conversion of C-1–NH_2 to C-1–N=C(H)–C_6H_4(*o*-OH) by extending the saccharide with a lipophilic phenyl moiety. The conformation of **3** is stabilized by an intramolecular O–H···N interaction. In all the three cases, **1**, **2** and **3**, the pyranose unit is in the $^4C_1$ chair conformation.

The corresponding anomeric nature of these compounds was confirmed by ^{1}H NMR, optical rotation and by single-crystal XRD. During our studies, we noticed that the anomeric form at C-1 was dependent on the nature of the amine used for glycosylation. Thus, the glycosyl amines derived from 2-(*o*-aminophenyl)benzimidazole using 4,6-protected and unprotected saccharides exhibited primarily the α-anomer, but in the case of D-arabinose and D-xylose a mixture of both α- and β-anomers was observed.[4] Furthermore, the literature reveals that the glycosyl amines could exist as either an open-chain Schiff base or as a glycosylamine in the solid state.[20] The X-ray crystal structure studies also showed existence of a *gg*-side-chain orientation that is unfavorable for monosaccharides having the $^4C_1$-D-galacto configuration in case of a semicarbazide derivative of D-galactose.[21] The α-glycosyl amine indicates a conformational preference about the C-1–N bond in which $n_N \rightarrow \sigma^*_{c-o}$ exo-anomeric interactions are expressed in the solid state but not in the solution state, but in the case of the β-glycosyl amine, both in the solid and solution state, it permits the expression of $n_N \rightarrow \sigma^*_{c-o}$ exo-anomeric interactions.[22]

5. Supplementary material:

Full crystallographic details, excluding structure factors, have been deposited with the Cambridge Crystallographic Data Centre for structure **1** (CCDC 188429), structure **2** (CCDC 188430) and structure **3** (CCDC 188431). These data may be obtained, on request, from the CCDC, 12 Union Road, Cambridge CBZ 1EZ, UK (Tel.: +44-1223-336408; fax: +44-1223-336033; e-mail: deposit@ccdc.cam.ac.uk or www: http://www.ccdc.cam.ac.uk)

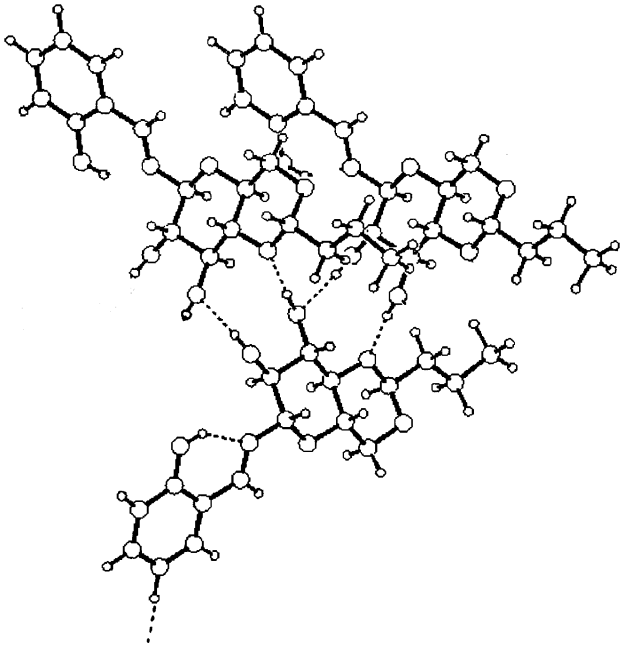


Fig. 6. Typical hydrogen bonding observed in the lattice of **3**.

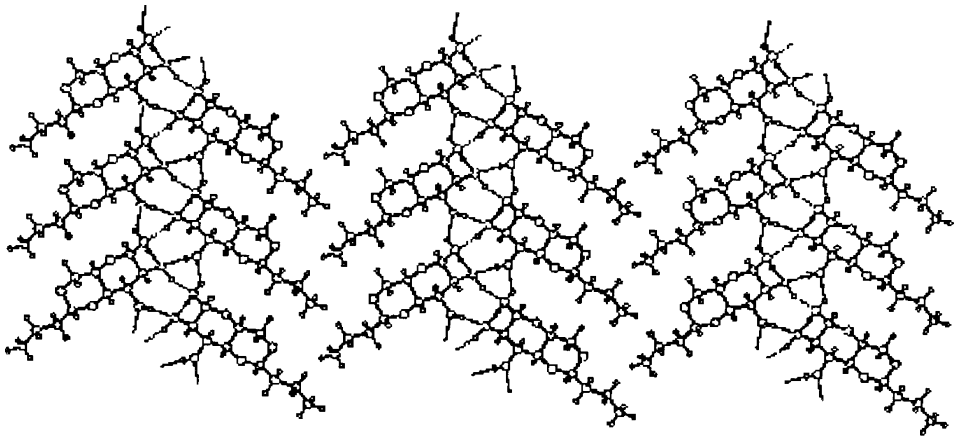


Fig. 7. Lattice structure of **2**.

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