Structure and Conformation of Ethyl 6-*O*-Benzoyl-4-iodo-2,3,4-trideoxy-α-D-hex-2-enopyranoside

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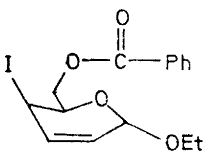
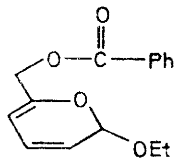
Crystals of the title compound were orthorhombic, space group $P2_12_12_1$, a = 4.652(7), b = 17.577(15), c = 19.857(19) Å, Z = 4. The structure was solved by heavy-atom methods from 1 067 observed reflections measured on a diffractometer and refined by full-matrix least squares to R 0.095. The six-membered pyranose ring has a slightly distorted half chair (${}^0H_5$) conformation.

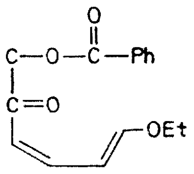
MANY branched-chain sugars are used as antibiotics or pharmacologically active substances.[1] An intermediate product thought to be of structure (I) was prepared in attempted syntheses of some biologically active compounds. However compound (II) was not obtained in the elimination of HI from (I). Compound (I) also gave anomalous ^{1}H n.m.r. chemical shifts for the hydrogens attached to C(3) and C(5) (see later), and its validity was in doubt. Compound (II) was believed to be an important intermediate in the synthesis of branched-chain pyranosides.[2] The present *X*-ray diffraction study confirmed the structure of (I) to be correct and showed the pyranose ring to have a half-chair ${}^0H_5$ conformation. The results suggest that (II) is unstable and rearranges to give compound (III).



(I)



(II)



(III)

EXPERIMENTAL

Crystals of (I) from methanol are fine long needles elongated along *a*. It was difficult to find crystals suitable for *X*-ray diffraction because the crystal did not break cleanly when cut perpendicular to the needle axis, but left a brush-like end at the cut. The compound also decomposes slowly at room temperature, gradually becoming dark brown, probably due to the release of iodine. Preliminary oscillation, Weissenberg, and precession photographs indicated the crystal to be orthorhombic, and systematic absences corresponded to space group $P2_12_12_1$, one of the most probable for optical active molecules[3] and also for most sugar derivatives.[4] Cell constants were determined from film data and refined by least-squares methods based on the 2θ values of 15 reflections measured on the diffractometer.

Crystal Data.—$C_{15}H_{17}IO_4$. Orthorhombic, M = 388.2, a = 4.652(7), b = 17.577(15), c = 19.857(19) Å, U = 1 623.7 Å^3, D_m = 1.584, Z = 4, D_c = 1.586 g cm^{-3}, $F(000)$ = 768.0. Mo-K_α radiation, λ = 0.7107 Å; μ(Mo-K_α) = 2.0. cm^{-1}; $\mu R(_{\text{max}})$ = 0.54. Space group $P2_12_12_1$.

The intensities of 1 796 reflections with $2\theta \leq 50°$ were measured on a General Electric XRD 6 automatic diffractometer, equipped with scintillation counter and pulse-height analyser. A cylindrical crystal *ca*. diameter 0.06 mm and length 0.27 mm was mounted with *a* along the φ axis of the goniostat. The stationary-crystal–stationary-counter technique was employed, each reflection being counted for 30 s. Three strong reflections were monitored between each 100 reflections and used as standards for the correction of fluctuation (5%) in intensity during data collection, but no appreciable decline in intensity was observed owing to the rapid data collection. In a previous attempt by the θ—2θ scan method, the intensities of the three strong reflections fell to only 30% of their initial value, and this method was abandoned.

Of 1 708 independent reflections measured, 1 067 having $I > 1.5\ \sigma(I)$ were considered observed. Lorentz-polarization factors are supplied to derive the structure amplitudes.

Structure Analysis.—The position of the iodine atom was derived from a three-dimensional Patterson map. Its *x* co-ordinate had a value close to $\frac{1}{4}$ and the Fourier synthesis based on the phase of the heavy atom had a pseudomirror plane at $x = \frac{1}{4}$. A Fourier projection of the *bc* plane (a = 4.652 Å) revealed the backbone of the structure. By use of both the projection and three-dimensional Fourier maps, it was possible to build a model in agreement with that expected on the basis of the synthetic history of the compound. This model was then refined by full-matrix least-squares methods using a revised version of ORFLS (Doedens and Ibers). Atomic scattering curves from ref. 5 were used, with an anomalous scattering correction for iodine. At the final stages of refinement, 5 reflections (*e.g.* 077, 066, *etc.*) lying in the streaks of some strong reflections were given zero weight. The function minimized was $\Sigma w(F_c - F_o)^2$ where $w = (40.15 - |F_o| + 0.0075|F_o|^2)^{-1}$ for 1 062 observed reflections. The final R factor was 9.5% and weighted factor R' 9.3%. An attempt to obtain better crystals was not rewarded. Even though chemical evidence[2] had undoubtedly proven that the

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[2] M. B. Yunker, Ph.D. Thesis, University of Waterloo, Waterloo, Ontario, Canada, 1975.

[3] A. I. Kitaigorodskii, ' Organic Chemical Crystallography,' translation from Russian, Consultants Bureau, New York, 1957.

[4] G. A. Jeffrey and R. D. Rosenstein, *Adv. Carbohydrate Chem.*, 1964, **19**, 7.

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TABLE 1

Final positional parameters (fractional co-ordinates) and anisotropic thermal parameters,* with estimated standard deviations in parentheses; parameters $\times 10^4$ for I, $\times 10^3$ for other atoms

Atom	x	y	z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
I	2 108(4)	1 315(1)	1 169(1)	429(8)	31(1)	29(4)	−2(3)	6(3)	−10(1)
C(1)	−009(8)	234(2)	134(1)	6(21)	7(1)	0(1)	5(5)	−10(4)	0(1)
C(2)	−014(7)	281(2)	075(2)	37(16)	4(1)	5(1)	10(4)	−8(4)	−1(1)
C(3)	114(8)	347(2)	063(2)	94(21)	3(1)	3(1)	8(4)	−5(4)	−1(1)
C(4)	336(5)	372(1)	115(1)	56(14)	3(1)	2(1)	6(4)	9(4)	−2(1)
C(5)	132(6)	289(2)	194(1)	33(17)	6(1)	1(1)	−3(4)	−2(3)	1(1)
C(6)	199(11)	241(2)	255(1)	99(22)	6(1)	2(1)	−5(6)	1(4)	−1(1)
C(7)	437(9)	280(2)	352(2)	96(21)	4(1)	4(1)	2(5)	1(4)	−2(1)
C(8)	391(9)	488(2)	190(2)	86(25)	4(1)	8(1)	−4(5)	−13(5)	−2(1)
C(9)	269(12)	548(2)	216(2)	153(34)	4(2)	8(1)	4(9)	2(9)	−2(1)
C(R1)	478(8)	339(2)	404(1)	822(22)	5(1)	1(1)	1(5)	1(4)	1(1)
C(R2)	664(9)	320(2)	459(2)	72(23)	5(1)	3(1)	1(5)	4(4)	−1(1)
C(R3)	692(9)	372(2)	510(1)	110(22)	4(1)	3(1)	14(7)	1(4)	−1(1)
C(R4)	548(8)	443(2)	508(2)	76(24)	6(2)	3(1)	−10(6)	2(4)	−2(1)
C(R5)	366(9)	461(2)	454(2)	95(28)	6(2)	3(1)	3(6)	−6(5)	−1(1)
C(R6)	342(10)	409(2)	402(2)	111(26)	6(1)	1(1)	−1(5)	−1(4)	−0(1)
O(1)	374(7)	320(1)	168(1)	33(11)	5(1)	2(1)	−1(3)	−1(2)	−2(1)
O(2)	258(7)	300(1)	307(1)	119(18)	7(1)	1(1)	7(5)	−3(4)	0(1)
O(3)	569(6)	221(2)	355(1)	85(15)	6(1)	5(1)	10(4)	−6(3)	−1(1)
O(4)	193(5)	440(1)	145(1)	58(12)	2(1)	3(1)	8(3)	−3(3)	(1)

* B_{ij} in the expression $\exp[-(\beta_{11}h^2 + \beta_{22}k^2 + \beta_{33}l^2 + 2\beta_{12}hk + 2\beta_{13}hl + 2\beta_{23}kl)]$.

molecule is in the D form, an attempt was made to find crystallographic evidence for this configuration. Refinements based on $F(\bar{h}\bar{k}\bar{l})$ gave a slightly higher R value of 9.7%. Because the crystal used had decomposed at this stage, further analysis was prevented. Nevertheless, there was sufficient evidence for us to conclude that the molecule has the D form. Atomic co-ordinates and thermal parameters are given in Table 1 and observed and calculated structure factor are deposited in Supplementary Publication No. SUP 21601 (10 pp., 1 microfiche).*

RESULTS AND DISCUSSION

The six-membered pyranose ring has a slightly distorted half-chair of $^0H_5$ conformation.[6] Equations of mean planes for some atoms of the pyranose ring are given in Table 2. C(1)—(4) [plane (1)] are required to be planar owing to the presence of the C(2)=C(3) bond (maximum displacement 0.04 Å). The ring oxygen and C(5) are 0.16 and −0.60 Å above and below the plane respectively. The ring torsion or interplanar angles are also included. The conformation agrees surprisingly well with that predicted.[7] The ethoxy-group of C(1) and the iodine atom on C(4) are forced into a quasi-axial position by the double bond in the ring and the benzoate group is in a quasi-equatorial position. The two bulky groups at C(1) and C(6) are forced as far apart as possible. The configuration is mainly determined by intramolecular interactions.

TABLE 2

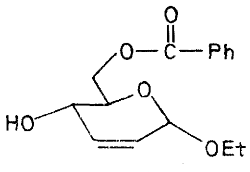
Equations of mean planes and interplanar angles

(a) Equations of mean plane in the form $lX + mY + nZ = P$ where X, Y, and Z are co-ordinates in Å referred to a, b, and c

Plane atoms	l	m	n	p
(1) C(1)—(4)	0.7214	−0.5320	−0.4435	−3.374
(2) C(1), O(1), C(5)	−0.5305	0.7757	−0.3419	2.299
(3) C(4), C(5), O(1)	0.0572	−0.7532	−0.6554	−6.326

(b) Interplanar angles (°)

(1)—(2) 130, (1)—(3) 43, (2)—(3) 113



(IV)

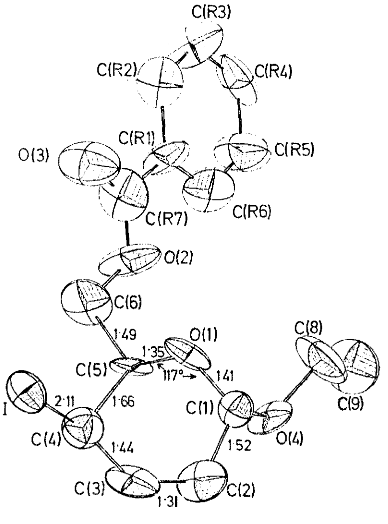


FIGURE 1 ORTEP plot of the molecule, showing some important bond lengths (σ 0.04 Å)

Note that the ^{1}H n.m.r. chemical shift of the hydrogen on C(3) is 0.7 p.p.m. downfield compared with that on

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* See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1975, Index issue.

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[7] R. J. Ferrier and G. H. Sankey, *J. Chem. Soc. (C)*, 1966, 2345.

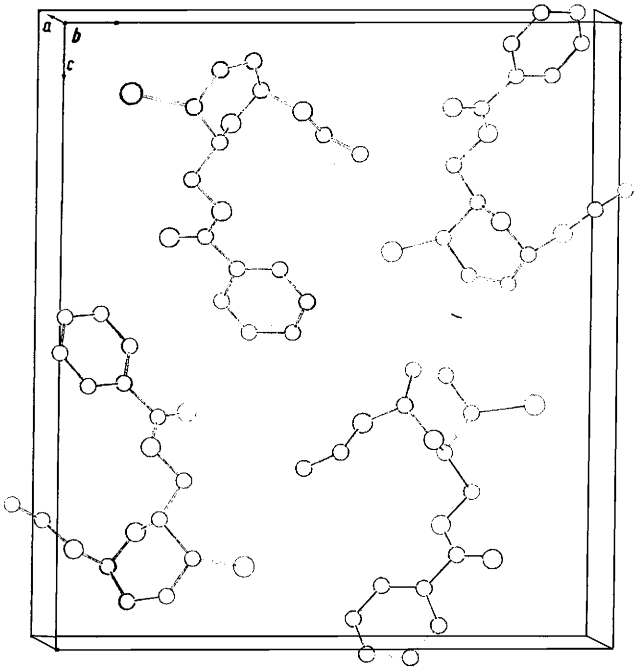

Figure 2 Packing of the molecules in the unit cell

C(2), and the chemical shift of that on C(5) is 0.7 p.p.m. upfield when compared to H-5 in (IV).[2] These results appear to be consistent with the bond distances shown in Figure 1 which are also in accord with considerations of steric hindrance, since both C(4) and C(5) have bulky groups attached to them. The most important intramolecular interaction is, of course, that of the two hydrogen atoms on C(6) with the iodine bonded to C(4).

The ring C–O distances of monosaccharides have been of some interest.[4,8] The present values [1.41(4) and 1.35(4) Å] are low compared with those for most pyranoid sugars (means 1.40—1.45 Å).

The packing diagram is shown in Figure 2. There is no hydrogen bonding in the structure. The molecule is rather flat, the flat face being almost perpendicular to the needle axis, *a*. This is in accord with the softness of the crystals, and with the fact that they exist as very long needles as a result of stacking of the flat molecules.

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[5/955 *Received, May 20th,* 1975]

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