

The Crystal and Molecular Structure of 1-Phenyl-4,5-(D-glycero-L-gluco-heptofurano)-imidazolidine-2-thione

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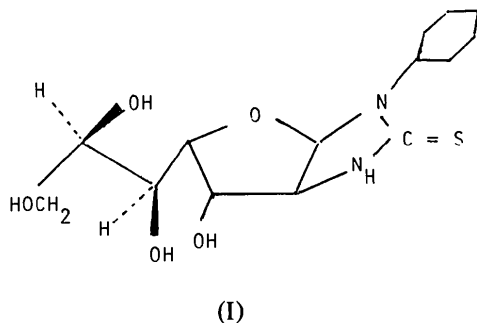
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The crystal structure has been determined from three-dimensional X-ray data. Crystals are monoclinic, space group $P2_1$, with $a = 14.753$ (7), $b = 10.643$ (3), $c = 4.961$ (1) Å, $\beta = 93.6$ (1)°, $Z = 2$. The structure was solved by direct methods and refined with anisotropic temperature factors by full-matrix least-squares procedures. The final R value for 1648 independent reflexions is 0.033. The imidazolidine and phenyl rings are both planar, with the imidazolidine plane twisted 71.6° about the N–C(aromatic) bond with respect to the phenyl plane. The dihedral angle between the imidazolidine and the tetrahydrofurano mean planes is 72.5°. The pucker of the tetrahydrofurano ring is 4T_0 . The crystal structure consists of molecules linked by van der Waals contacts and hydrogen bonds.

Introduction

The crystal structure has been determined as part of a continuing investigation in this laboratory of the conformational aspects of glucimidazoles and imidazole C-nucleosides.

Crystals of (I), supplied by Professor J. Fernández-Bolaños (Departamento de Química Orgánica of this University), were obtained by the reaction of 2-amino-2-deoxy-D-glycero-L-gluco-heptose with phenyl isothiocyanate. They are colourless prisms, needle-shaped and elongated along c .



Preliminary rotation and Weissenberg photographs indicated monoclinic symmetry. The condition for reflexion was observed to be $0k0$, $k = 2n$, and the possible space groups consistent with this observation are $P2_1$ and $P2_1/m$.

The statistical distribution of $|E|$ values and the value $Z = 2$ suggested by a density calculation indicated the space group $P2_1$, and the structure determination and refinement were successfully carried out in this space group.

The unit-cell parameters were determined by least-squares methods from 25 accurate 2θ values measured on an automatic four-circle diffractometer.

Crystal data

Molecular formula $C_{14}H_{18}N_2SO_5$, $M_r = 326$, monoclinic $a = 14.753$ (7), $b = 10.643$ (3), $c = 4.691$ (1) Å, $\beta = 93.6$ (1)°; space group $P2_1$, $Z = 2$, $D_x = 1.47$ g cm $^{-3}$, $V = 735.1$ (7) Å 3 .

Intensity data were collected by the θ - 2θ scan method on a Philips automated four-circle diffractometer with graphite-monochromated Mo $K\alpha$ radiation ($\lambda = 0.7107$ Å). Reflexions were collected to a maximum value of $\sin\theta/\lambda = 0.60$. Three reference reflexions were measured after every 50 reflexions during the data collection. The variation in intensity was observed to be less than 2% of its mean value.

The intensities of 2265 independent reflexions were measured of which 1648 had $I > 2\sigma(I)$ and were used in the structure analysis. The Lorentz and polarization factors were applied but no absorption corrections were made ($\mu R < 0.1$).

Structure determination and refinement

Structure factor amplitudes were placed on an absolute scale and normalized by using the scale factor and the overall temperature factor obtained from Wilson's (1942) statistics.

The structure was solved by multiresolution tangent formula refinement (Germain, Main & Woolfson, 1971). The set of phases with the highest figure of merit proved to give a sensible structure. An E map was computed with this set of phases (255 reflexions

with $E > 1.50$). Most of the atoms appeared clearly in the map; the remaining atoms were easily obtained from successive Fourier syntheses. The R value was 0.22. At this point a sequence of full-matrix least-squares refinement was begun, allowing for the simultaneous variation of coordinates, isotropic temperature factors and scale factor. After three cycles R was 0.12. Anisotropic temperature factors were then used in further refinement and R became 0.059. A full-matrix

Table 1. Atomic coordinates ($\times 10^4$) for non-hydrogen atoms

	x	y	z
S	2351 (1)	4150 (3)	699
O(1)	2927 (2)	8239 (3)	5363 (6)
O(2)	4887 (2)	7918 (3)	7419 (6)
O(3)	3850 (2)	11363 (3)	117 (6)
O(4)	2896 (2)	11808 (3)	5030 (7)
O(5)	4894 (2)	9487 (3)	1977 (6)
N(1)	2270 (2)	6253 (4)	3847 (8)
N(2)	3582 (2)	5273 (3)	4290 (8)
C(1)	2732 (3)	5247 (4)	3002 (9)
C(2)	2778 (3)	6970 (4)	6180 (9)
C(3)	3737 (2)	6308 (4)	6270 (9)
C(4)	4378 (3)	7312 (4)	5092 (9)
C(5)	3704 (3)	8228 (4)	3589 (9)
C(6)	1300 (3)	6464 (5)	3361 (10)
C(7)	1002 (3)	7533 (5)	1841 (11)
C(8)	60 (4)	7722 (6)	1541 (11)
C(9)	-548 (3)	6919 (6)	2733 (13)
C(10)	-231 (3)	5890 (6)	4203 (14)
C(11)	710 (3)	5615 (5)	4532 (13)
C(12)	4057 (3)	9580 (4)	3262 (9)
C(13)	3366 (3)	10360 (4)	1340 (9)
C(14)	2585 (3)	10881 (4)	3018 (11)

Table 2. Atomic coordinates for H atoms ($\times 10^3$)

	x	y	z
H(O2)	547	737	856
H(O3)	355	1178	-182
H(O4)	275	1275	475
H(O5)	491	911	5
H(N2)	424	462	409
H(C2)	229	688	783
H(C3)	395	603	822
H(C4)	500	704	377
H(C5)	341	803	162
H(C7)	167	810	114
H(C8)	-30	849	40
H(C9)	-146	710	264
H(C10)	-89	540	512
H(C11)	107	488	566
H(C12)	420	1006	509
H(C13)	297	981	-21
H1(C14)	217	1019	405
H2(C14)	185	1120	179

least-squares program written by Busing, Martin & Levy (1962) was employed. A difference Fourier synthesis calculated with $\sin \theta$ up to 0.35 revealed the positions of the 18 H atoms. A further cycle of refinement, including the H atoms with isotropic temperature factors and varying only the parameters of non-hydrogen atoms, reduced R to 0.033. The weighting scheme $w = 1/\sigma_F^2$ was used. The shifts in the last cycle of refinement were less than 0.1σ for all parameters. The correct enantiomorph was chosen in accordance with the configuration of 2-amino-2-deoxy-D-glycero-L-gluco-heptose used in the preparation of the title compound. The atomic coordinates from the final least-squares cycle are given in Tables 1 and 2. The standard deviations were determined from the diagonal elements of the inverse matrix in the least-squares procedure. The atomic scattering factors for S, O, N and C were those of Cromer & Mann (1968); that for H was from *International Tables for X-ray Crystallography* (1962).*

Results and discussion

The bond lengths and angles with the estimated standard deviations are given in Table 3. The average bond distances involving H atoms are: C—H 1.1 (2), O—H 1.1 (1) and N—H 1.1 (1) Å.

Phenyl ring

The mean aromatic C—C bond length of 1.390 Å shows good agreement with the accepted value of 1.395 Å. The least-squares plane passing through the six benzene C atoms is given by equation I (Table 4). It can be seen that all six atoms are coplanar within the experimental deviation. The one substituent atom on the phenyl ring, N(1), shows no significant deviation from the plane. The C(6)—N(1) bond of 1.45 Å agrees with the values reported by Vega, Hernández-Montis & López-Castro (1976) and Jiménez-Garay, López-Castro & Márquez (1976). The average phenyl-ring bond angle is 120°.

Tetrahydrofurano-imidazolidine group

Most of the bond lengths and angles have reasonable values and there are no significant deviations from values found in analogous compounds. S—C(1), C(1)—N(1) and C(1)—N(2) show the effect of the thiourea resonance system (Jiménez-Garay, López-Castro & Márquez, 1974; Vega, Hernández-Montis & López-

* Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 32913 (10 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.

Castro, 1976). The C(2)—C(3) bond length of 1.58 Å, though rather long, is comparable with the C—C distances observed by Hoge & Nordman (1974) (1.579 Å) and Vega, Hernández-Montis & López-Castro (1976) (1.57 Å). The imidazolidine ring is planar, as expected. The least-squares plane for the atoms of the ring and the corresponding deviations are given in Table 4. The substituents S and C(6) (not included when calculating the plane) are 0.11 and 0.17 Å from the least-squares plane. There is a discrepancy between the C(2)—O(1) and C(5)—O(1) distances, 1.43 and 1.46 Å respectively, which may be due to the anomeric effect (Berman, Chu & Jeffrey, 1967; Conde, Moreno & Márquez, 1975; Vega, Hernández-Montis & López-Castro, 1976).

Molecular conformation

The conformation of the molecule is characterized by the valency angles (Table 3) and the torsional angles of the individual bonds, which are given in Table 5. The pucker of the tetrahydrofurano ring is such that, relative to the mean plane through the five atoms of

Table 3. Bond lengths and angles in the molecule

(a) Bond lengths (Å) (with standard deviations in parentheses)

S—C(1)	1.665 (4)	C(12)—O(5)	1.411 (5)
C(1)—N(2)	1.358 (5)	C(12)—C(13)	1.557 (6)
C(1)—N(1)	1.342 (6)	C(13)—O(3)	1.425 (5)
N(1)—C(2)	1.497 (6)	C(13)—C(14)	1.539 (7)
N(2)—C(3)	1.449 (5)	C(14)—O(4)	1.422 (6)
C(2)—C(3)	1.577 (6)	N(1)—C(6)	1.451 (5)
C(2)—O(1)	1.425 (5)	C(6)—C(7)	1.398 (7)
O(1)—C(5)	1.457 (5)	C(7)—C(8)	1.403 (6)
C(3)—C(4)	1.552 (6)	C(8)—C(9)	1.382 (8)
C(4)—C(5)	1.533 (6)	C(9)—C(10)	1.361 (9)
C(4)—O(2)	1.439 (5)	C(10)—C(11)	1.418 (6)
C(5)—C(12)	1.541 (6)	C(11)—C(6)	1.392 (7)

(b) Bond angles (°) (standard deviations in the range 0.3–0.5)

S—C(1)—N(2)	124.6	C(3)—C(2)—O(1)	106.1
S—C(1)—N(1)	126.4	C(2)—C(3)—C(4)	111.7
C(1)—N(1)—C(6)	126.2	N(2)—C(3)—C(4)	104.4
C(1)—N(1)—C(2)	112.5	C(3)—C(4)—O(2)	109.9
C(6)—N(1)—C(2)	118.6	C(3)—C(4)—C(5)	102.1
N(1)—C(6)—C(11)	118.2	O(2)—C(4)—C(5)	110.9
N(1)—C(6)—C(7)	118.9	C(2)—O(1)—C(5)	106.6
C(6)—C(11)—C(10)	117.2	O(1)—C(5)—C(4)	104.6
C(11)—C(10)—C(9)	121.6	O(1)—C(5)—C(12)	109.3
C(10)—C(9)—C(8)	118.4	C(4)—C(5)—C(12)	115.3
C(9)—C(8)—C(7)	122.3	C(5)—C(12)—O(5)	106.6
C(8)—C(7)—C(6)	116.6	C(5)—C(12)—C(13)	110.1
C(7)—C(6)—C(11)	122.9	O(5)—C(12)—C(13)	110.4
N(1)—C(1)—N(2)	108.9	C(12)—C(13)—O(3)	107.9
C(1)—N(2)—C(3)	113.8	C(12)—C(13)—C(14)	112.3
N(2)—C(3)—C(2)	102.6	O(3)—C(13)—C(14)	110.2
N(1)—C(2)—C(3)	101.5	C(13)—C(14)—O(4)	111.6
N(1)—C(2)—O(1)	111.5		

the ring, C(5) has a maximum deviation of 0.24 Å, on the same side as C(2), C(3), N(1) and N(2) (these last two not included in calculating the plane), and O(1) has the next largest deviation, 0.22 Å, on the opposite side of the mean plane. From the last five torsion angles listed in Table 5 and in accordance with Sundaralingam (1973), the conformation of the tetrahydrofurano ring is ⁴T₀.

The position of the exocyclic O atoms with respect to the trihydroxypropyl chain corresponds to the conformation *D-glycero-L-gluco*-heptofurano.

The dihedral angle between the mean planes of the phenyl and imidazolidine rings is 71.6° and that between the imidazolidine and tetrahydrofurano rings is 72.5°.

Molecular packing

Fig. 1 shows the contents of the cell in projection down *c*. The molecular packing is clearly dominated by hydrogen bonds. The geometry of some intermolecular distances and angles is listed in Table 6. There are three hydrogen bonds: one, O(2)⋯O(3), of 2.70 Å between atoms related by a twofold screw axis, and the others, O(5)⋯O(2) and O(3)⋯O(4), of 2.71 and 2.74 Å, respectively, between atoms of two nearest-neighbour molecules translated one unit cell along *c*.

Table 4. Least-squares planes in the molecule

(a) Equations of various planes in the standard orthogonal system in the form $Ax + By + Cz = D$

Plane	A	B	C	D
(I) Phenyl ring	0.0035	0.5319	0.8463	4.9950
(II) Imidazolidine ring	-0.3611	-0.5752	0.7340	-3.6637
(III) Tetrahydrofurano ring	0.2278	0.4425	0.8373	6.8247

(b) Deviations in Å from the planes

	I	II	III
S		0.112*	
O(1)		-0.093*	0.222
O(2)			1.566*
N(1)	0.085*	-0.049	-1.551*
N(2)		0.005	-1.392*
C(1)		0.029	
C(2)		0.045	-0.094
C(3)		-0.030	-0.046
C(4)		-1.392*	0.163
C(5)			-0.244
C(6)	0.006	0.171*	
C(7)	0.006		
C(8)	-0.011		
C(9)	0.004		
C(10)	0.008		
C(11)	-0.013		
C(12)			0.419*

* Atom not included in the plane calculation.

Table 5. Torsion angles ($^{\circ}$)

C(7)–C(6)–N(1)–C(1)	–120.7 (4)
S–C(1)–N(2)–C(3)	–178.0 (2)
C(2)–O(1)–C(5)–C(12)	–165.7 (3)
O(2)–C(4)–C(5)–C(12)	38.7 (4)
O(2)–C(4)–C(5)–C(2)	–105.1 (4)
O(1)–C(5)–C(12)–O(5)	169.7 (3)
C(5)–C(12)–C(13)–C(14)	82.5 (4)
C(5)–C(12)–C(13)–O(3)	–155.7 (4)
C(4)–C(5)–C(12)–C(13)	172.0 (3)
O(5)–C(12)–C(13)–C(14)	–169.9 (3)
O(3)–C(13)–C(14)–O(4)	–52.6 (4)
C(5)–O(1)–C(2)–C(3)	29.3 (4)
O(1)–C(2)–C(3)–C(4)	–6.1 (4)
C(2)–C(3)–C(4)–C(5)	–17.6 (3)
C(3)–C(4)–C(5)–O(1)	35.6 (3)
C(4)–C(5)–O(1)–C(2)	–41.7 (3)

Table 6. Geometry of some short intermolecular distances

Symmetry key				
	(i) $x, y, 1+z$		(ii) $1-x, -\frac{1}{2}+y, 1-z$	
$a-b \cdots c$	$a \cdots c$	$a-b$	$b \cdots c$	$\angle a-b \cdots c$
O(5)–H \cdots O(2 ⁱ)	2.713 (4) Å	0.99 (3) Å	1.76 (4) Å	158 (4) $^{\circ}$
O(3)–H \cdots O(4 ⁱ)	2.735 (4)	1.08 (4)	1.72 (4)	156 (5)
O(2)–H \cdots O(3 ⁱⁱ)	2.698 (4)	1.15 (6)	1.57 (6)	168 (5)
N(2)–H \cdots O(5 ⁱⁱ)	2.888 (5)	1.19 (7)	2.18 (4)	114 (5)
C(3)–H \cdots O(5 ⁱⁱ)	2.884 (5)	0.99 (3)	2.38 (7)	112 (5)

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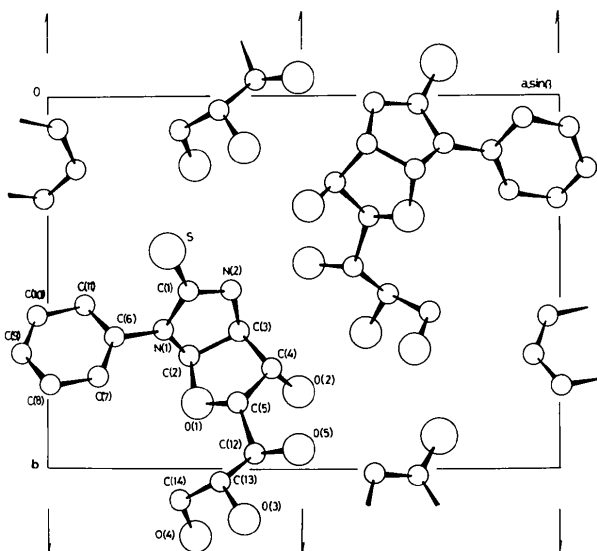


Fig. 1. Projection of the structure along the c axis.

In addition, there are two intermolecular interactions, N(2) \cdots O(5) of 2.89 Å and C(3) \cdots O(5) of 2.88 Å, both between molecules related by a twofold screw axis which, in spite of the non-linearity (Kroon & Kanters, 1975), could have some hydrogen-bond character. The effect is to produce a three-dimensional packing.

Computations were carried out on a DCT 2000 terminal of the Computing Centre of this University, connected to a Univac 1108 computer.