

Crystal and Molecular Structure of 2,3,6,7-Tetrahydro-6-phenyl-5H-imidazo[2,1-b]thiazolium Chloride

By Roy W. Baker* and Peter J. Pauling, William Ramsay, Ralph Forster, and Christopher Ingold Laboratories, University College London, 20 Gordon Street, London WC1H 0AJ

The structure of the title compound has been determined by single-crystal *X*-ray diffraction. Crystals are orthorhombic with $Z = 4$ in a unit cell of dimensions: $a = 12.952(4)$, $b = 14.710(5)$, $c = 5.943(3)$ Å, spacegroup $P2_12_12_1$. The structure was solved by Patterson and Fourier methods and refined by least-squares using 1197 observed three-dimensional diffractometer data to R 0.050. The imidazothiazolium group is almost planar and the angle between the normals to the mean plane and the phenyl group is 31° . The formal double-bond $C(7)=N(7)$ does not exist, and electron delocalisation over $N(7)$, $C(7)$, $N(4)$, and $S(1)$, causes this group to be planar. A hydrogen bond between the chlorine atom and $N(7)$ was found.

TETRAMISOLE has been found to be a broad-spectrum anthelmintic. The resolution of the optical isomers has been described¹ and the absolute configuration of the optical isomers has been established.² We report here the molecular structure of the (–)-(*S*)-tetramisole as determined by *X*-ray diffraction of a single crystal.

¹ M. W. Bullock, J. J. Hand, and E. Waletzky, *J. Medicin. Chem.*, 1968, **11**, 169.

EXPERIMENTAL

Crystals are colourless prisms elongated in the c direction and showing the pinacoids: {010}, {110}, and {2 $\bar{1}$ 0}. The ends of the prism are badly developed.

Crystal Data.— $C_{11}H_{13}ClN_2S$, $M = 240.76$. Orthorhombic, $a = 12.952(4)$, $b = 14.710(5)$, $c = 5.943(3)$, $U = 1132$ Å³,

² A. H. M. Raeymaekers, L. F. C. Roevens, and P. A. J. Janssen, *Tetrahedron Letters*, 1967, 1467.

$D_m = 1.40(1)$ (by flotation), $Z = 4$, $D_o = 1.41$. Systematic absences: $h00$ for $h = 2n + 1$, $0k0$ for $k = 2n + 1$, $00l$ for $l = 2n + 1$, spacegroup $P2_12_12_1$. Mo- K_α radiation $\lambda = 0.7107 \text{ \AA}$; μ (Mo- K_α) = 4.5 cm^{-1} .

Cell parameters were derived from Weissenberg oscillation and precession photographs and refined parameters and standard deviations by the method described in ref. 3.

Intensity Measurements.—Three-dimensional X-ray diffraction data from a small single crystal (*ca.* $0.34 \times 0.28 \times 0.14 \text{ mm}$) were collected on a computer-controlled³ four-circle diffractometer by use of Mo- K_α radiation with graphite

synthesis⁴ using observed data phased with the two heavy atoms produced a satisfactory trial structure and at the same time confirmed the designation of atom type to each of the heavy atoms. After successive cycles of full-matrix least-squares refinement⁵ a difference electron-density synthesis revealed all the hydrogen atom positions. Hydrogen atoms were included in the calculation of structure factors but not refined.

The final refinement of the non-hydrogen atoms by full-matrix least-squares was carried out until all parameter shifts were $\leq 0.1 \sigma$. The function minimised was

TABLE 1

Fractional co-ordinates ($\times 10^4$) and thermal motion parameters ($\times 10^4$) * derived from least-squares refinement, with estimated standard deviations in parentheses

Atom	x	y	z	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}
Cl	3290(1)	1602(1)	9692(3)	348(8)	427(11)	412(9)	-5(10)	-43(8)	131(9)
S(1)	5991(1)	3365(1)	7906(3)	289(8)	482(11)	403(9)	-29(10)	33(8)	13(9)
C(2)	6725(5)	4076(5)	5929(15)	365(34)	647(44)	827(63)	135(39)	144(45)	337(47)
C(3)	6050(5)	4321(5)	3966(12)	314(34)	537(44)	399(38)	-101(34)	-4(31)	4(35)
N(4)	5070(4)	3862(3)	4260(10)	314(25)	373(22)	435(32)	-106(19)	-2(25)	75(27)
C(5)	4090(5)	3962(5)	3067(12)	374(34)	548(44)	376(39)	-111(29)	-49(33)	102(35)
C(6)	3399(4)	3266(4)	4324(11)	314(25)	296(33)	363(32)	-53(24)	14(25)	-20(29)
N(7)	3982(4)	3123(3)	6448(9)	297(25)	438(33)	381(30)	24(24)	0(25)	86(24)
C(7)	4935(6)	3432(5)	6154(13)	263(25)	318(33)	403(34)	-29(29)	16(25)	-47(33)
C(8)	2295(4)	3587(4)	4681(11)	297(25)	263(33)	403(34)	-58(24)	-51(29)	-35(29)
C(9)	1756(5)	3343(5)	6627(12)	323(25)	471(33)	431(38)	19(34)	27(31)	-31(38)
C(10)	0700(5)	3551(5)	6782(13)	331(34)	471(44)	514(45)	-24(29)	-45(33)	-128(38)
C(11)	0205(5)	3986(5)	5072(14)	331(34)	460(33)	689(57)	72(29)	-133(41)	-111(42)
C(12)	0731(6)	4225(5)	3174(15)	442(42)	537(44)	667(57)	58(39)	-174(43)	60(44)
C(13)	1778(6)	4033(5)	2968(13)	476(34)	526(44)	449(41)	53(34)	-60(41)	58(38)

* The Debye-Waller factor is defined as $T = \exp[-2\pi^2 \sum_i \sum_j a_i^* a_j^* h_i h_j U_{ij}]$. The units of U_{ij} are \AA^2 .

monochromator (002). A coupled θ - 2θ step scan with $\Delta 2\theta$ 0.04, a counting time of 5 s per step, and a peakwidth of 1.6° were used. In the range 2θ 5- 60° , 1197 intensities out of a possible 1942 in the positive octant of reciprocal space ($+h, +k, +l$) had $I \geq 3\sigma(I)$. The data were corrected for Lorentz and polarisation effects but not for absorption or extinction.

TABLE 2

Fractional co-ordinates ($\times 10^3$) for hydrogen atoms * derived from difference Fourier synthesis

Atom	x	y	z
H(2,1)	698	463	675
H(2,2)	736	374	546
H(3,1)	598	501	376
H(3,2)	637	411	247
H(5,1)	423	364	146
H(5,2)	385	454	274
H(6,1)	338	272	334
H(7,1)	377	261	803
H(9,1)	213	303	788
H(10,1)	035	338	813
H(11,1)	-056	420	483
H(12,1)	036	454	192
H(13,1)	214	421	156

* Numbered according to the atom to which they are bonded. In the structure factor calculations a thermal motion parameter $T = \exp[-8\pi^2 U \sin^2 \theta / \lambda^2]$ with $U = 0.045 \text{ \AA}^2$ was included for the hydrogen atoms.

Structure Solution and Refinement.—The positions of the heavy atoms (S and Cl) in the asymmetric unit were found from an unsharpened Patterson synthesis.⁴ A Fourier

³ W. R. Busing, R. D. Ellison, H. A. Levy, S. P. King, and R. T. Roseberry, 'The Oak Ridge Computer Controlled X-Ray Diffractometer,' U.S. At. Energy Commission Report ORNL 143, 1968.

$\sum w(|F_o| - |F_c|)^2$ with $w = 4I/\sigma^2$ where $\sigma = \sigma(I) + 0.05I$. The term $0.05I$ was included in the estimate of σ to allow

TABLE 3

Interatomic distances (\AA) and bond angles ($^\circ$) for non-hydrogen atoms

(a) Distances			
S(1)-C(2)	1.838(8)	C(6)-C(8)	1.522(8)
S(1)-C(7)	1.723(6)	N(7)-C(7)	1.326(7)
C(2)-C(3)	1.502(11)	C(8)-C(9)	1.397(9)
C(3)-N(4)	1.449(8)	C(8)-C(13)	1.384(10)
N(4)-C(5)	1.461(8)	C(9)-C(10)	1.405(9)
N(4)-C(7)	1.303(9)	C(10)-C(11)	1.326(11)
C(5)-C(6)	1.551(9)	C(11)-C(12)	1.364(12)
C(6)-N(7)	1.486(8)	C(12)-C(13)	1.390(10)
(b) Angles			
C(2)-S(1)-C(7)	89.5(3)	N(7)-C(7)-S(1)	129.7(4)
S(1)-C(2)-C(3)	109.4(5)	N(7)-C(7)-N(4)	113.9(6)
C(2)-C(3)-N(4)	107.7(6)	N(4)-C(7)-S(1)	116.3(4)
C(3)-N(4)-C(5)	131.0(6)	C(6)-C(8)-C(9)	120.3(5)
C(3)-N(4)-C(7)	116.6(5)	C(6)-C(8)-C(13)	120.0(5)
C(5)-N(4)-C(7)	110.6(5)	C(9)-C(8)-C(13)	119.3(6)
N(4)-C(5)-C(6)	101.6(5)	C(8)-C(9)-C(10)	119.0(6)
C(5)-C(6)-N(7)	102.1(5)	C(9)-C(10)-C(11)	120.8(7)
C(5)-C(6)-C(8)	113.8(5)	C(10)-C(11)-C(12)	120.2(7)
N(7)-C(6)-C(8)	113.8(4)	C(11)-C(12)-C(13)	120.5(7)
C(6)-N(7)-C(7)	108.2(5)	C(12)-C(13)-C(8)	120.2(6)

for the random long-term fluctuation in intensity measurement of a standard reflection which was taken after every 25 observations. Atomic scattering factors for neutral carbon, nitrogen, and sulphur and for the chloride ion were

⁴ J. Dollimore, A Fourier Program for LUNA, University of London Institute of Computer Science, Circular No. 12.

⁵ G. Shearing, A Crystallographic SFLS Program in AA, University of Manchester, 1965.

taken from ref. 6 and for hydrogen from ref. 7. The final R was 0.050. Positional and thermal parameters for non-hydrogen atoms are listed in Table 1 and the hydrogen atom positions derived from the difference-Fourier synthesis in Table 2. Bond distances and angles are given in Table 3. Observed and calculated structure factors are listed in Supplementary Publication No. 20583 (10 pp., 1 microfiche).†

All computational work was carried out on the University of London ATLAS computer and University College IBM 360 computer.

DISCUSSION

Description of the Molecular Structure.—The atom numbering is shown in Figure 1. Torsion angles are

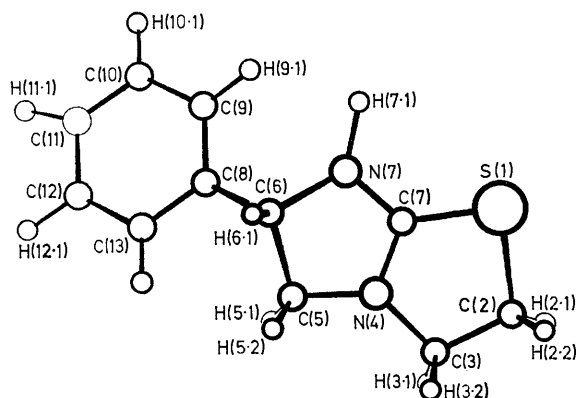


FIGURE 1 The molecule projected on the mean plane through N(4), C(7), N(7), and S(1)

listed in Table 4. The eight non-hydrogen atoms of the imidazothiazolium group are approximately planar (Table 5) and the angle between the normals to the mean planes through these eight atoms and the six carbon atoms of the phenyl group is *ca.* 31°. The four atoms S(1), C(7), N(4), and N(7) are coplanar (Table 5) and the values of the bond lengths N(4)–C(7) 1.303(9), N(7)–C(7) 1.326(7), and S(1)–C(7) 1.723(6) Å suggest that the formal double-bond between C(7) and N(7) does not exist. The expected value⁸ for C=N is 1.265 and for C–N 1.474 Å.⁸ It appears that both C(7)–N(7) and C(7)–N(4) have some double-bond character. The same is true for the bond S(1)–C(7) since the expected C–S bond length is 1.82 and C=S 1.61 Å.⁹ N(7) is protonated and so carries a formal positive charge. The electron pair forming the double bond C(7)–N(7), the lone pair on N(4), and one of the lone pairs on S(1) could well be delocalised over the four atoms S(1), C(7), N(7), and N(4) which may be thought to form a substituted thiourea skeleton. This delocalisation could explain the bond lengths observed. Bond lengths and

† For details see Notice to Authors No. 7 in *J. Chem. Soc. (A)*, 1970, Issue No. 20.

⁶ D. T. Cromer and J. T. Waber, *Acta Cryst.*, 1965, **18**, 104.

⁷ 'International Tables for X-Ray Crystallography,' vol. III, Kynoch Press, Birmingham, 1962.

⁸ J. Donohue, L. R. Lavine, and J. S. Rollett, *Acta Cryst.*, 1956, **9**, 655.

⁹ S. C. Abrahams, *Quart. Rev.*, 1956, **10**, 407.

¹⁰ J. L. Flippen and I. L. Karle, *J. Phys. Chem.*, 1970, **74**, 769.

bond angles are typical of those found in other compounds which contain similar heterocyclic groups.¹⁰⁻¹⁷

TABLE 4

Torsion angles for non-hydrogen atoms

S(1)–C(2)–C(3)–N(4)	–3
S(1)–C(7)–N(4)–C(5)	–173
S(1)–C(7)–N(4)–C(3)	–7
S(1)–C(7)–N(7)–C(6)	–174
C(2)–S(1)–C(7)–N(7)	–175
C(2)–S(1)–C(7)–N(4)	4
C(2)–C(3)–N(4)–C(7)	7
C(2)–C(3)–N(4)–N(5)	169
C(3)–C(2)–S(1)–C(7)	0
C(3)–N(4)–C(5)–C(6)	–179
C(3)–N(4)–C(7)–N(7)	172
N(4)–C(5)–C(6)–N(7)	18
N(4)–C(5)–C(6)–C(8)	141
C(5)–C(6)–N(7)–C(7)	–16
C(5)–N(4)–C(7)–N(7)	6
C(6)–C(5)–N(4)–C(7)	–15
C(6)–N(7)–C(7)–N(4)	8
C(6)–C(8)–C(13)–C(12)	172
C(6)–C(8)–C(9)–C(10)	–172
C(8)–C(6)–N(7)–C(7)	–139
C(9)–C(10)–C(11)–C(12)	0
C(9)–C(8)–C(13)–C(12)	–1
C(9)–C(8)–C(6)–C(5)	–146
C(9)–C(8)–C(6)–N(7)	–29
C(10)–C(9)–C(8)–C(13)	1
C(10)–C(11)–C(12)–C(13)	–1
C(11)–C(10)–C(9)–C(8)	0
C(11)–C(12)–C(13)–C(8)	1
C(13)–C(8)–C(6)–C(5)	42
C(13)–C(8)–C(6)–N(7)	158

TABLE 5

Equations * of mean planes and in square brackets deviations (Å) of atoms from the planes

Plane (1):

$$S(1), C(2), C(3), N(4), -0.308X + 0.823Y + 0.478Z = 9.025$$

C(5), C(6), N(7),
C(7)

$$[S(1) 0.00, C(2) 0.00, C(3) 0.01, N(4) -0.07, C(5) 0.10, C(6) -0.11, N(7) 0.09, C(7) 0.00]$$

Plane (2):

$$S(1), N(4), N(7), C(7) -0.263X + 0.861Y + 0.435Z = 9.004$$

$$[S(1) 0.00, N(4) 0.00, N(7) 0.00, C(7) -0.01, C(2) 0.14, C(3) 0.17, C(5) 0.15, C(6) -0.18]$$

Plane (3):

$$C(8)-(13) 0.225X + 0.882Y + 0.413Z = 6.486$$

$$[C(8) 0.00, C(9) 0.00, C(10) 0.00, C(11) 0.00, C(12) 0.00, C(13) 0.00]$$

* Based on orthogonal axes X, Y, Z where X is parallel to crystallographic a axis, Y is perpendicular to a in the plane ab , and Z is perpendicular to ab and completes a right-handed set of axes X, Y, Z .

Description of the Crystal Structure.—Figure 2 shows the packing of four molecules in the unit cell together

¹¹ V. Amirthalngam and K. V. Muralidharan, *Chem. Comm.*, 1969, 986.

¹² J. Karle, J. Flippen, and I. L. Karle, *Z. Krist.*, 1967, **125**, 201.

¹³ R. A. L. Miller, J. M. Robertson, G. A. Sim, R. C. Clapp, L. Long, and T. Hasselstrom, *Nature*, 1964, **202**, 287.

¹⁴ G. J. Palenik, *Acta Cryst.*, 1965, **19**, 47.

¹⁵ L. Cavalca, G. F. Gasparri, A. Mangia, and G. Pelizzi, *Acta Cryst.*, 1969, **B**, **25**, 2349.

¹⁶ G. J. Kruger and G. Gafner, *Acta Cryst.*, 1971, **B**, **27**, 326.

¹⁷ S. Abrahamsson and A. Westerdahl, *Acta Chem. Scand.*, 1967, **21**, 442.

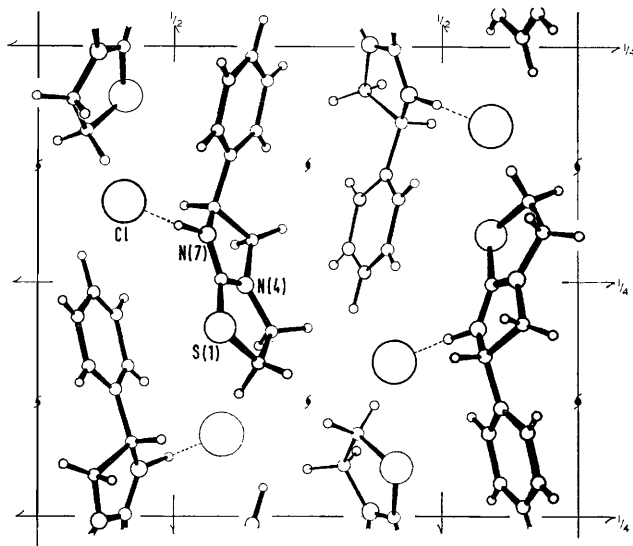


Figure 2 Packing of the molecules in the unit cell

with the symmetry axes relating them. A hydrogen bond exists between a chloride ion and the protonated nitrogen atom N(7). The distance $\text{Cl} \cdots \text{H}(7,1)$ is *ca.*

1.9, $\text{N}(7)\text{-H}(7,1)$ *ca.* 1.2, and $\text{Cl} \cdots \text{N}(7)$ 3.086(5) Å. The chloride ion makes three other contacts < 3.6 Å with non-hydrogen atoms: $\text{Cl} \cdots \text{S}(1^{\text{I}})$ 3.302(2), $\text{Cl} \cdots \text{C}(3)^{\text{II}}$ 3.553(7), and $\text{Cl} \cdots \text{C}(2^{\text{I}})$ 3.446(8) Å.* The van der Waals radii for neutral sulphur and chlorine are given as¹⁸ 1.80 and 1.75 Å, making the expected $\text{Cl} \cdots \text{S}$ contact 3.55 Å. In this structure the chlorine atom is formally charged $-1e$ and the sulphur atom may well carry a positive charge caused by the delocalisation already mentioned. It is possible, therefore, for a weak electrostatic bond to be formed between Cl and S which would explain the shorter contact distance of 3.302 Å. Two non-hydrogen intermolecular contacts < 3.6 Å exist: $\text{C}(10) \cdots \text{C}(7^{\text{IV}})$ 3.540(9) and $\text{C}(11) \cdots \text{N}(7^{\text{IV}})$ 3.598(8) Å.

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* Roman numerals denote the following equivalent positions: I $-\frac{1}{2} + x, \frac{1}{2} - y, 2 - z$; II $1 - x, -\frac{1}{2} + y, \frac{3}{2} - z$; III $-\frac{1}{2} + x, \frac{1}{2} - y, 2 - z$; IV $-\frac{1}{2} + x, \frac{1}{2} - y, 1 - z$

¹⁸ A. Bondi, *J. Phys. Chem.*, 1964, **68**, 441.