

## 2-Amino-3-hydroxy-4-phenylthiazolium chloride: $\pi$ -stacked hydrogen-bonded chains of edge-fused $R_4^2(11)$ rings

Christopher Glidewell,<sup>a\*</sup> John N. Low,<sup>b</sup> Janet M. S. Skakle<sup>b</sup> and James L. Wardell<sup>c</sup>

<sup>a</sup>School of Chemistry, University of St Andrews, Fife KY16 9ST, Scotland,

<sup>b</sup>Department of Chemistry, University of Aberdeen, Meston Walk, Old Aberdeen AB24 3UE, Scotland, and <sup>c</sup>Instituto de Química, Departamento de Química Inorgânica, Universidade Federal do Rio de Janeiro, 21945-970 Rio de Janeiro, RJ, Brazil

Correspondence e-mail: cg@st-andrews.ac.uk

Received 23 February 2004

Accepted 2 March 2004

Online 31 March 2004

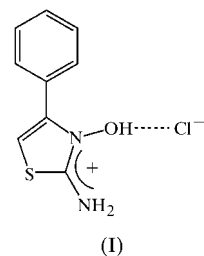
In the title compound,  $C_9H_9N_2OS^+\cdot Cl^-$ , the cations exhibit amidinium-type delocalization of the positive charge. The ions are linked by one  $O-H\cdots Cl$  hydrogen bond and two  $N-H\cdots Cl$  hydrogen bonds into chains of edge-fused  $R_4^2(11)$  rings. The chains are linked into sheets by a  $\pi$ - $\pi$  stacking interaction.

### Comment

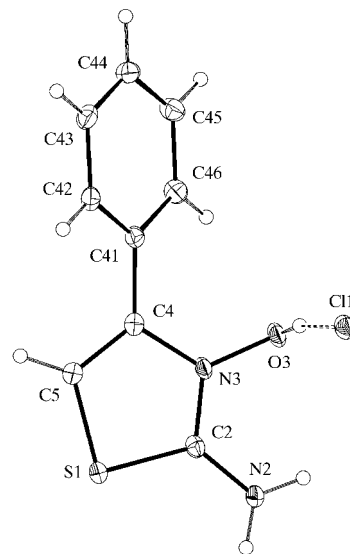
Masaki *et al.* (1966) reported the preparation of 3-hydroxy-4-phenyl-2(3*H*)-thiazolimine, from the condensation reaction of the oxime of bromomethyl phenyl ketone,  $BrCH_2C(Ph)=NOH$ , with barium thiocyanate, and these authors characterized the heterocycle as the picrate salt. The mass spectrum of the title compound, the hydrochloride salt (I), was reported by Entenmann (1975) as exhibiting a significant peak assigned to  $[M - 16]^+$ , corresponding to the loss of an O atom, which suggested that the O atom was not protonated. In solution, the picrate salt was reported to give a positive phenol test with iron(III) chloride. However, in neither report was the constitution of the cation definitively established; in particular, neither report gave any indication of the solid-state structure, and hence the determination now reported was undertaken.

Compound (I) consists of an ion pair containing a short  $O-H\cdots Cl$  hydrogen bond (Fig. 1, and Tables 1 and 2). In the cation, the heterocyclic ring is planar, as expected, and the dihedral angle between this plane and the plane of the benzene ring is  $41.9(2)^\circ$ . There are considerable differences between the corresponding pairs of exocyclic angles at atoms C2, N3 and C4. The very small interbond angle at atom S1 is also notable. The C2—N2 and C2—N3 bonds are similar in

length and both are significantly shorter than the N3—C4 bond. The bond orders, calculated using the recent recalibration by Kotelevskii & Prezhdo (2001) of the original equation relating bond order to bond length (Gordy, 1947), for the C2—N2, C2—N3 and C3—N4 bonds are 1.77, 1.72 and 1.33, respectively, suggesting amidinium-type delocalization of the positive charge between atoms N2 and N3, as indicated in the scheme below.



The amine group acts as a double donor in  $N-H\cdots Cl$  hydrogen bonds involving two different anions (Table 2). In the shorter and more nearly linear of these two interactions, amine atom N2 acts as a hydrogen-bond donor, *via* atom H2A, to atom Cl1 at  $(x, y - 1, z)$ , so generating by translation a  $C_2^1(7)$  chain (Bernstein *et al.*, 1995) running parallel to the [010] direction (Fig. 2). Four chains of this type pass through each unit cell and these chains are linked into pairs by the second  $N-H\cdots Cl$  hydrogen bond. In this interaction, atom N2 acts as a hydrogen-bond donor, this time *via* atom H2B, to atom Cl1 at  $(\frac{1}{2} - x, y - \frac{1}{2}, \frac{1}{2} - z)$ , so forming a  $C_2^1(4)$  chain generated by the  $2_1$  screw axis along  $(\frac{1}{4}, y, \frac{1}{4})$  (Fig. 2). The combination of the  $C_2^1(4)$  and  $C_2^1(7)$  motifs then produces a chain of edge-fused  $R_4^2(11)$  rings. This chain of rings, containing the  $2_1$  axis along  $(\frac{1}{4}, y, \frac{1}{4})$ , lies within the domain  $0 < x < \frac{1}{2}$ , and a second chain, related to the first by inversion



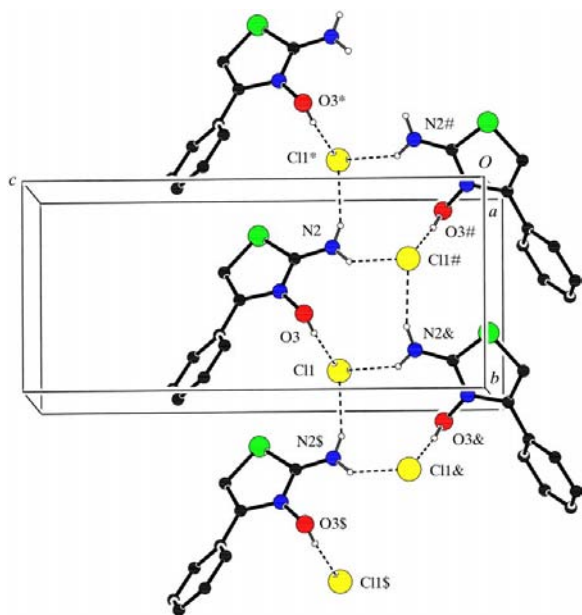
**Figure 1**

The independent ions in (I), showing the atom-labelling scheme. Displacement ellipsoids are drawn at the 30% probability level.

and containing the  $2_1$  axis along  $(\frac{3}{4}, y, \frac{3}{4})$ , lies in the domain  $\frac{1}{2} < x < 1$ .

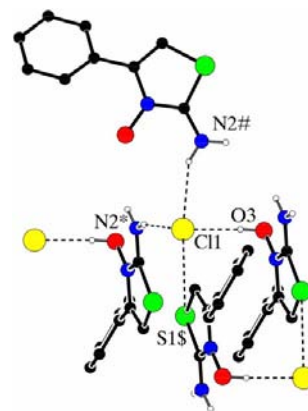
The only direction-specific interaction between adjacent chains of rings is a weak  $\pi$ - $\pi$  stacking interaction between the heterocyclic rings of the cations related by a centre of symmetry. These rings are parallel, with an interplanar spacing of 3.631 (2) Å. The ring-centroid separation is 3.778 (2) Å, corresponding to a centroid offset of 1.044 (2) Å. These cations at  $(x, y, z)$  and  $(1 - x, 1 - y, 1 - z)$  lie, respectively, in the chains of rings along  $(\frac{1}{4}, y, \frac{1}{4})$  and  $(\frac{3}{4}, -y, \frac{3}{4})$ , so that propagation of this stacking interaction links the chain into a  $(10\bar{1})$  sheet. However, there are no  $\pi$ - $\pi$  stacking interactions involving the phenyl ring, nor are there any C-H... $\pi$ (arene) hydrogen bonds.

As well as acting as a threefold acceptor of hydrogen bonds, the anion at  $(x, y, z)$  also forms a short contact with the S atom of the molecule at  $(1 - x, 1 - y, 1 - z)$ . This S...Cl distance is 3.3275 (7) Å, somewhat less than the sum of the van der Waals radii (3.50 Å; Bondi, 1964). The overall coordination polyhedron at atom Cl1, including the secondary bond (Alcock, 1972) involving the S atom, takes the form of a distorted trigonal bipyramid of VSEPR (valence-shell electron-pair repulsion) type  $MX_4E$  (Gillespie, 1972; Gillespie & Hargittai, 1991; Burdett, 1997), where  $X$  represents a bonding pair of electrons at the central atom  $M$  (here  $M = \text{Cl}$ ) and  $E$  represents the equatorial lone pair of non-bonding electrons (Fig. 3). The angles at atom Cl1 are as follows: O3...Cl1...N2\* = 110.79 (5)°, O3...Cl1...N2# = 78.64 (5)°, O3...Cl1...S1\$ = 91.92 (3)°, N2\*...Cl1...N2# = 92.69 (5)°.



**Figure 2**

Part of the crystal structure of (I), showing the formation of a chain of edge-fused  $R_4^2(11)$  rings along the  $b$  axis. For clarity, H atoms bonded to C atoms have been omitted. Atoms marked with an asterisk (\*), a hash (#), a dollar sign (\$) or an ampersand (&) are at the symmetry positions  $(x, y - 1, z)$ ,  $(\frac{1}{2} - x, y - \frac{1}{2}, \frac{1}{2} - z)$ ,  $(x, y + 1, z)$  and  $(\frac{1}{2} - x, \frac{1}{2} + y, \frac{1}{2} - z)$ , respectively.



**Figure 3**

Part of the crystal structure of (I), showing the coordination at the anion. For clarity, H atoms bonded to C atoms have been omitted. Atoms marked with an asterisk (\*), a hash (#) or a dollar sign (\$) are at the symmetry positions  $(x, y + 1, z)$ ,  $(\frac{1}{2} - x, \frac{1}{2} + y, \frac{1}{2} - z)$  and  $(1 - x, 1 - y, 1 - z)$ , respectively.

$\text{N2}^* \cdots \text{Cl1} \cdots \text{S1}\$ = 109.99 (4)^\circ$  and  $\text{N2}\# \cdots \text{Cl1} \cdots \text{S1}\$ = 157.30 (4)^\circ$ , where atoms marked with an asterisk (\*), a hash (#) or a dollar sign (\$) are at the symmetry positions  $(x, y + 1, z)$ ,  $(\frac{1}{2} - x, \frac{1}{2} + y, \frac{1}{2} - z)$  and  $(1 - x, 1 - y, 1 - z)$ , respectively.

## Experimental

The neutral heterocycle 3-hydroxy-2-imino-4-phenylthiazole was prepared according to the method reported by Masaki *et al.* (1966). The hydrochloride salt, (I), was prepared by treating the neutral heterocycle in ethanol solution with aqueous HCl (6 mol dm<sup>-3</sup>) and was recrystallized from ethanol. Compound (I) slowly darkened on heating and decomposed before melting.

### Crystal data

$\text{C}_9\text{H}_9\text{N}_2\text{OS}^+\cdot\text{Cl}^-$   
 $M_r = 228.69$   
 Monoclinic,  $P2_1/n$   
 $a = 9.2663 (5) \text{ \AA}$   
 $b = 7.0716 (4) \text{ \AA}$   
 $c = 15.461 (1) \text{ \AA}$   
 $\beta = 90.194 (2)^\circ$   
 $V = 1013.12 (10) \text{ \AA}^3$   
 $Z = 4$   
 $D_x = 1.499 \text{ Mg m}^{-3}$

Mo  $K\alpha$  radiation  
 Cell parameters from 2247 reflections  
 $\theta = 3.2\text{--}27.4^\circ$   
 $\mu = 0.55 \text{ mm}^{-1}$   
 $T = 120 (2) \text{ K}$   
 Plate, colourless  
 $0.32 \times 0.24 \times 0.12 \text{ mm}$

### Data collection

Nonius KappaCCD diffractometer  
 $\varphi$  scans, and  $\omega$  scans with  $\kappa$  offsets  
 Absorption correction: multi-scan (SORTAV; Blessing, 1995, 1997)  
 $T_{\text{min}} = 0.827$ ,  $T_{\text{max}} = 0.934$   
 9736 measured reflections  
 2247 independent reflections

1751 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.067$   
 $\theta_{\text{max}} = 27.4^\circ$   
 $h = -11 \rightarrow 11$   
 $k = -8 \rightarrow 9$   
 $l = -19 \rightarrow 19$

### Refinement

Refinement on  $F^2$   
 $R[F^2 > 2\sigma(F^2)] = 0.045$   
 $wR(F^2) = 0.119$   
 $S = 1.04$   
 2247 reflections  
 128 parameters  
 H-atom parameters constrained

$w = 1/[\sigma^2(F_o^2) + (0.0703P)^2 + 0.159P]$   
 where  $P = (F_o^2 + 2F_c^2)/3$   
 $(\Delta/\sigma)_{\text{max}} = 0.001$   
 $\Delta\rho_{\text{max}} = 0.53 \text{ e \AA}^{-3}$   
 $\Delta\rho_{\text{min}} = -0.41 \text{ e \AA}^{-3}$

**Table 1**

Selected geometric parameters (Å, °).

S1—C2	1.718 (2)	C5—S1	1.737 (2)
C2—N3	1.330 (3)	C2—N2	1.321 (3)
N3—C4	1.405 (3)	N3—O3	1.377 (2)
C4—C5	1.341 (3)	C4—C41	1.476 (3)
S1—C2—N3	110.64 (15)	N2—C2—N3	123.58 (19)
C2—N3—C4	116.04 (18)	C2—N3—O3	119.73 (17)
N3—C4—C5	110.03 (19)	O3—N3—C4	124.22 (17)
C4—C5—S1	113.00 (17)	N3—C4—C41	121.81 (19)
C5—S1—C2	90.29 (11)	C5—C4—C41	128.2 (2)
S1—C2—N2	125.72 (17)		
N3—C4—C41—C42	−139.2 (2)	N3—C4—C41—C46	43.1 (3)
C5—C4—C41—C42	40.7 (3)	C5—C4—C41—C46	−136.9 (2)

**Table 2**

Hydrogen-bonding geometry (Å, °).

<i>D</i> —H... <i>A</i>	<i>D</i> —H	H... <i>A</i>	<i>D</i> ... <i>A</i>	<i>D</i> —H... <i>A</i>
O3—H3...Cl <sup>i</sup>	0.84	2.11	2.929 (2)	167
N2—H2A...Cl <sup>i</sup>	0.88	2.30	3.131 (2)	157
N2—H2B...Cl <sup>ii</sup>	0.88	2.46	3.217 (2)	145

Symmetry codes: (i)  $x, y - 1, z$ ; (ii)  $\frac{1}{2} - x, y - \frac{1}{2}, \frac{1}{2} - z$ .

All H atoms were located from difference maps and subsequently treated as riding atoms, with C—H distances of 0.95 Å, N—H distances of 0.88 Å and an O—H distance of 0.84 Å.

Data collection: *KappaCCD Server Software* (Nonius, 1997); cell refinement: *DENZO-SMN* (Otwinowski & Minor, 1997); data reduction: *DENZO-SMN*; program(s) used to solve structure: *OSCAIL* (McArdle, 2003) and *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *OSCAIL* and *SHELXL97* (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 2003); software used to prepare material for publication: *SHELXL97* and *PRPKAPPA* (Ferguson, 1999).

X-ray data were collected at the EPSRC X-ray Crystallographic Service, University of Southampton, England; the authors thank the staff for all their help and advice. JNL thanks NCR Self-Service, Dundee, for grants that have provided computing facilities for this work. JLW thanks CNPq and FAPERJ for financial support.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: OB1172). Services for accessing these data are described at the back of the journal.

## References

- Alcock, N. W. (1972). *Advances in Inorganic Radiochemistry*, Vol. 15, edited by H. J. Emeléus & A. G. Sharpe, pp. 1–58. San Diego: Academic Press.
- Bernstein, J., Davis, R. E., Shimon, L. & Chang, N.-L. (1995). *Angew. Chem. Int. Ed. Engl.* **34**, 1555–1573.
- Blessing, R. H. (1995). *Acta Cryst.* **A51**, 33–37.
- Blessing, R. H. (1997). *J. Appl. Cryst.* **30**, 421–426.
- Bondi, A. (1964). *J. Phys. Chem.* **68**, 441–451.
- Burdett, J. K. (1997). In *Chemical Bonds*. Chichester: John Wiley.
- Entenmann, G. (1975). *Org. Mass Spectrom.* **10**, 831–835.
- Ferguson, G. (1999). *PRPKAPPA*. University of Guelph, Canada.
- Gillespie, R. J. (1972). In *Molecular Geometry*. London: Van-Nostrand Rheinhold.
- Gillespie, R. J. & Hargittai, I. (1991). In *The VSEPR Model of Molecular Geometry*. Needham Heights, MA, USA: Allyn and Bacon.
- Gordy, W. (1947). *J. Chem. Phys.* **15**, 305–310.
- Kotelevskii, S. I. & Prezhdo, O. V. (2001). *Tetrahedron*, **57**, 5715–5729.
- McArdle, P. (2003). *OSCAIL for Windows*. Version 10. Crystallography Centre Chemistry Department, NUI Galway, Ireland.
- Masaki, M., Sugiyama, M., Tayama, M. & Ohta, M. (1966). *Bull. Chem. Soc. Jpn.* **39**, 2745–2749.
- Nonius (1997). *KappaCCD Server Software*. Windows 3.11 Version. Nonius BV, Delft, The Netherlands.
- Otwinowski, Z. & Minor, W. (1997). *Methods in Enzymology*, Vol. 276, *Macromolecular Crystallography*, Part A, edited by C. W. Carter Jr & R. M. Sweet, pp. 307–326. New York: Academic Press.
- Sheldrick, G. M. (1997). *SHELXS97* and *SHELXL97*. University of Göttingen, Germany.
- Spek, A. L. (2003). *J. Appl. Cryst.* **36**, 7–13.