

ture corresponding to the (21 $\bar{3}$ ) plane with an interplanar spacing of 3.59 Å and within the layer the cations form rows along the [2 $\bar{1}1$ ] direction. Even in the present study, the anions are arranged in two-dimensional layers and three atoms of the tetrahedral cations [Te(1), C(71) and C(81) for cation K1 and Te(2), C(72) and C(92) translated along the *b* axis for cation K2] lie in the anion layer plane. In fact, the layers correspond to a (21 $\bar{3}$ ) plane with an interlayer distance of 3.623 Å and within the anion plane the cations are arranged in rows along the [2 $\bar{1}1$ ] directions.

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## Structure of a Platinum(II) Complex of Levamisole

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**Abstract.** Chloro(ethylenediamine){(-)-2,3,5,6-tetrahydro-6-phenylimidazo[2,1-*b*]thiazole}platinum(II) chloride, [PtCl(C<sub>2</sub>H<sub>8</sub>N<sub>2</sub>)(C<sub>11</sub>H<sub>12</sub>N<sub>2</sub>S)]Cl, *M*<sub>r</sub> = 530.39, orthorhombic, *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub>, *a* = 31.676 (11), *b* = 8.190 (2), *c* = 6.6242 (6) Å, *V* = 1718.5 (7) Å<sup>3</sup>, *Z* = 4, *D*<sub>x</sub> = 2.050 g cm<sup>-3</sup>, λ(Mo *K*α) = 0.71069 Å, μ = 86.8 cm<sup>-1</sup>, *F*(000) = 1016, *T* = 296 K, final *R* = 0.030 for 1646 unique observed reflections [*F* > 4σ(*F*)]. The Pt coordination is square planar, bonded to three N atoms (one from the levamisole and two from the ethylenediamine moiety) and to one Cl atom.

**Introduction.** The antitumor activity of platinum(II) triamine complexes has been reported recently (Hollis, Amundsen & Stern, 1989) and implies that the criteria established for the design of platinum-containing cancer drugs be re-evaluated to include an

investigation of this class of compounds so as to provide additional structure-activity relationships. This and the promising leads afforded by Pt imidazole and thiazole compounds (van Kralingen, de Ridder & Reedijk, 1979; Graves, Hodgson, van Kralingen & Reedijk, 1978; Hacker, Douple & Krafkoff, 1984; van Beusichem & Farrel, 1992) prompted us to a study of Pt triamine species coordinated to a series of imidazo[2,1-*b*]thiazoles which themselves possess relevant biological activity (Bhargava, Lee, Huang, Cunningham, Agrawal & Sartorelli, 1977; Preston, 1986). We describe the structure of one such complex here.

**Experimental.** To 2.18 g (6.7 mmol) PtCl<sub>2</sub>(C<sub>2</sub>H<sub>8</sub>N<sub>2</sub>) in 15 ml of dimethylformamide (DMF) was added 1.19 g (7 mmol) AgNO<sub>3</sub>. The mixture was stirred in the dark for 12 h and then filtered. To the filtrate was added 1.63 g (8 mmol) of (-)-2,3,5,6-tetrahydro-6-phenylimidazo[2,1-*b*]thiazole in 10 ml DMF. After

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4 h, the reaction was brought to dryness, then crystallized from 0.1 M HCl, yielding 2.40 g of a white solid (68%). Colorless crystals were obtained from methanol. Analysis for  $C_{13}H_{20}Cl_2N_4PtS$ : calc. C 29.44, H 3.80, N 10.56%; found C 29.13, H 3.85, N 10.22%.

A colorless crystal of dimensions  $0.48 \times 0.22 \times 0.10$  mm, Enraf-Nonius CAD-4 diffractometer, graphite-monochromatized Mo  $K\alpha$  radiation,  $\omega$ -2 $\theta$  scan, scan width  $(1.50 + 0.14 \tan \theta)^\circ$ , max.  $2\theta = 50^\circ$ , 25 reflections ( $9 < \theta < 18^\circ$ ) for accurate unit-cell parameters, 1787 total unique reflections of which 1646 had  $I > 2\sigma(I)$ ;  $hkl$ ,  $0 \leq h \leq 37$ ,  $0 \leq k \leq 9$ ,  $0 \leq l \leq 7$ , standard reflections 4,3,14,  $\overline{4}24$ ,  $3\overline{2}$ ,  $\overline{2}0$  measured every 2 h showed no intensity loss over 35.5 h exposure; empirical absorption by  $\psi$  scan, relative  $T_{\max} = 100$ ,  $T_{\min} = 44.9\%$ . The systematic absences conform to the space group  $P2_12_12_1$ , which was confirmed by Weissenberg photographs. The intensities were corrected for Lorentz, polarization and absorption with the Enraf-Nonius program package *MolEN* (Fair, 1990). Structure solved by heavy-atom Patterson methods using *SHELXS86* (Sheldrick, 1986); full-matrix least-squares refinement of  $F$  using *SHELX76* (Sheldrick, 1976), anisotropic thermal parameters for non-H atoms. Eight H atoms were located from a difference map, the remainder were placed at calculated positions and refined as riding on corresponding atoms with a common isotropic parameter,  $U = 0.08 \text{ \AA}^2$ . Final  $R = 0.030$ ,  $wR = 0.035$ ;  $w = k/(\sigma^2 F + gF^2)$ ,  $k = 4.9462$  and  $g = 0.000195$ . ( $R = 0.047$ ,  $wR = 0.058$  for the opposite configuration, which was rejected with high probability.)  $(\Delta/\sigma)_{\max} < 0.01$ , 190 parameters, max. residual electron density  $0.35 \text{ e \AA}^{-3}$  (min.  $-0.41 \text{ e \AA}^{-3}$ ); atomic scattering factors from *International Tables for X-ray Crystallography* (1974, Vol. IV), least-squares planes and torsion-angle calculations using *MolEN*, performed on a MicroVAX 3900 computer.

**Discussion.** Final atomic coordinates of non-H atoms are listed in Table 1\* and selected bond lengths and angles are in Table 2. Fig. 1 shows an *ORTEP* plot of the molecule with the atomic numbering scheme and Fig. 2 gives the contents of the unit cell. The key intermolecular interactions involve the chloride anion Cl2, which forms a contact of  $3.21 \text{ \AA}$  with atom N1 and a contact of  $3.34 \text{ \AA}$  with atom N2. These contacts connect the complex and the anion into chains along the  $b$  axis. A second  $Cl2 \cdots N2$

Table 1. Atomic coordinates and equivalent isotropic temperature factors ( $\text{\AA}^2$ )

$U_{eq}$  is defined as one third of the trace of the orthogonalized  $U_{ij}$  tensor.

	$x$	$y$	$z$	$U_{eq}$
Pt	0.1759 (1)	0.8228 (1)	0.91540 (1)	30.8 (1)
N1	0.1981 (3)	0.9102 (12)	1.1809 (16)	36 (2)
C1	0.2428 (3)	0.8547 (15)	1.2028 (22)	47 (3)
C2	0.2444 (4)	0.6769 (17)	1.1465 (20)	46 (3)
N2	0.2231 (3)	0.6596 (12)	0.9441 (16)	40 (2)
Cl1	0.1572 (1)	0.7250 (4)	0.6028 (6)	54 (1)
N3	0.1295 (2)	0.9880 (11)	0.9150 (18)	36 (2)
C3	0.1217 (3)	1.1045 (16)	0.7899 (19)	36 (3)
S	0.1475 (1)	1.1604 (4)	0.5698 (6)	42 (1)
C4	0.1140 (4)	1.3408 (16)	0.5488 (22)	57 (4)
C5	0.0966 (4)	1.3742 (16)	0.7570 (24)	53 (3)
N4	0.0898 (3)	1.2068 (13)	0.8402 (16)	41 (3)
C6	0.0808 (4)	1.1769 (17)	1.0542 (21)	49 (3)
C7	0.0987 (3)	1.0020 (15)	1.0833 (22)	44 (3)
C8	0.0668 (3)	0.8665 (15)	1.0750 (24)	43 (3)
C9	0.0414 (3)	0.8428 (17)	0.9068 (26)	55 (3)
Cl10	0.0128 (4)	0.7144 (19)	0.9058 (32)	72 (5)
Cl11	0.0091 (4)	0.6107 (20)	1.0586 (33)	69 (5)
Cl12	0.0335 (5)	0.6321 (20)	1.2304 (32)	78 (5)
Cl13	0.0630 (5)	0.7607 (19)	1.2378 (28)	68 (4)
Cl12	0.1934 (1)	1.3006 (4)	1.1427 (5)	48 (1)

Table 2. Interatomic distances ( $\text{\AA}$ ) and angles ( $^\circ$ ) with *e.s.d.*'s in parentheses

Pt—N1	2.024 (10)	N4—C3	1.36 (1)
Pt—N2	2.014 (9)	C4—S	1.82 (1)
P5—Cl1	2.298 (4)	C4—C5	1.51 (2)
Pt—N3	1.999 (8)	N4—C5	1.49 (2)
Cl1—N1	1.49 (1)	C6—N4	1.47 (2)
Cl1—C2	1.50 (2)	C6—C7	1.55 (2)
C2—N2	1.51 (2)	C7—N3	1.48 (2)
C3—N3	1.29 (2)	C7—C8	1.50 (2)
C3—S	1.73 (1)		
N2—Pt—N1	84.0 (4)	N4—C3—S	113.2 (9)
Cl1—Pt—N1	174.6 (3)	C4—S—C3	90.3 (6)
Cl1—Pt—N2	92.6 (3)	C5—C4—S	106.8 (9)
N3—Pt—N1	91.0 (4)	C5—N4—C3	112 (1)
N3—Pt—N2	174.6 (5)	N4—C5—C4	103 (1)
N3—Pt—Cl1	92.6 (3)	C6—N4—C5	123 (1)
Cl1—N1—Pt	107.8 (8)	C6—C7—N3	103 (1)
C2—Cl1—N1	107.5 (9)	C7—C6—N4	102 (1)
C2—N2—Pt	110.6 (8)	C8—C7—N3	111 (1)
C3—N3—Pt	130.0 (8)	C8—C7—C6	116 (1)
C7—N3—Pt	122.3 (8)	C9—C8—C7	121 (1)
C7—N3—C3	107.5 (9)	N4—C3—N3	116.2 (11)
S—C3—N3	130.4 (9)		

contact ( $3.33 \text{ \AA}$ ) connects molecules related by the twofold screw axis parallel to the  $c$  axis. Atom Cl2 also interacts with the S atom at  $3.38 \text{ \AA}$ .

The Pt atom is bonded to the N atoms of the ethylenediamine ligand, the N atom of the dihydroimidazol ring of levamisole and a Cl atom with distances that compare well to published values (Lippert, Lock & Speranzini, 1981; Hollis *et al.*, 1989). Deviations from the least-squares plane calculated through Pt, N1, N2, N3 and Cl1 [ $-0.001$  (1),  $0.12$  (1),  $-0.03$  (1),  $-0.03$  (1) and  $0.016$  (5)  $\text{\AA}$ , respectively] are reasonable for a platinum-ethylenediamine ring (Iball & Scrimgeour, 1974; Neidle, Taylor & Robins, 1978).

\* Lists of structure factors, anisotropic thermal parameters, H-atom parameters, torsion angles, least-squares planes and intermolecular distances have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 55978 (18 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: HH1049]

The arrangement of atoms around N3 of levamisole is planar. In theory, this ligand can be considered ambidentate, with coordination *via* the S atom possible. Calculations based on thiazole itself favor N binding because of its net negative charge. Complexes of Pt<sup>II</sup>, Pd<sup>II</sup> and Rh<sup>III</sup> with thiazole moieties bound *via* N rather than S have been characterized (Rong, Muir, Cadiz & Muir, 1991; Muir, Gomez, Muir, Cadiz, Cox & Barnes, 1988; Muir, Gomez, Muir & Cadiz, 1990; Churchill, Wasserman & Young, 1980; Muir, Rong & Muir, 1989) and an NMR study suggested the coordination of levamisole *via* the N atom of its dihydroimidazolyl ring to the Co atom of a Co<sup>III</sup> porphyrin complex (Abraham, Plant, Bedford & Wright, 1984). Thus, levamisole coordination through the dihydroimidazolyl ring N atom instead of the thiazoline S atom is not unexpected.

The dihydroimidazolyl ring of the levamisole system forms a half-chair conformation, while the thiazolidine ring [with C6—C7—N3—C3 torsion angle of  $-15(1)^\circ$ ] adopts an envelope conformation with C6 as the unique atom. Conformations for fused and unfused imidazoline and thiazolidine rings range from planar to either half-chair or envelope

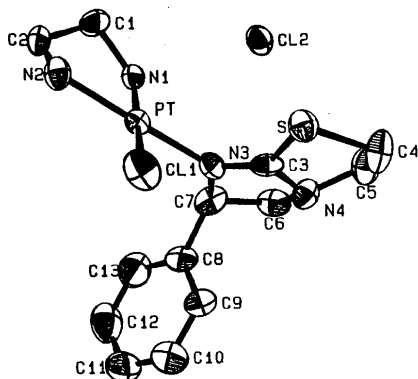


Fig. 1. Plot of the title compound showing the labeling of atoms (50% probability ellipsoids).

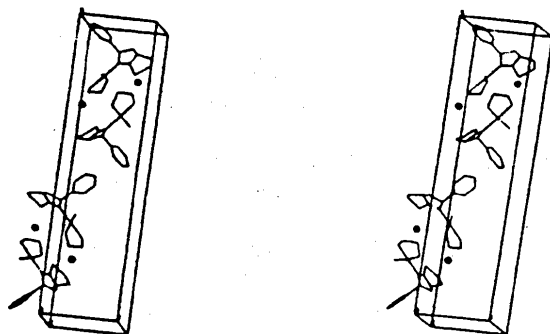


Fig. 2. Stereoscopic view of the unit cell with Cl2 having a 0.25 Å radius.

forms (Cameron, Cameron & Duncanson, 1981). The C6—C7—C8—C9 torsion angle between the levamisole and phenyl moieties is  $58(2)^\circ$ . All phenyl bond lengths and angles are normal.

Imidazo[2,1-*b*]thiazoles and their quaternary salts are prone to hydrolysis and other ring-opening reactions at C3 and C4 (Preston, 1986). This structure shows unambiguously that the levamisole moiety remains intact upon coordination. We have, therefore, initiated antitumor assays and will report the results elsewhere.

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