

The Structure of 3,3'-Dithiodi-2-pyridinecarboxylic Acid

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Abstract. $C_{12}H_8N_2O_4S_2$, monoclinic, $C2$, $a = 21.603$ (4), $b = 6.034$ (2), $c = 4.877$ (2) Å, $\beta = 99.35$ (2)°, $Z = 2$, $D_m = 1.64$ (1), $D_c = 1.63$ Mg m⁻³, m.p. = 452 (1) K. Final $R = 0.026$ for 627 reflections. The compound studied is an oxidation product of 3-thiopicolinic acid. A crystallographic twofold axis passes through the midpoint of the disulphide bond. The C–S–S–C torsion angle is 80.1°, and the disulphide bond is nearly coplanar with each of the heterocyclic rings, the 1,4 C–S distance being 3.149 Å.

Introduction. When 3-thiopicolinic acid (a gift from Dr C. E. Berkoff, Smith, Kline and French Laboratories) is dissolved in water and the solution is held at 323 K in air for a few hours, the acid is oxidized to the dimeric product 3,3'-dithiodi-2-pyridinecarboxylic acid. This compound crystallizes as transparent yellow plates when the solution is allowed to cool slowly to room temperature. The $2/m$ diffraction symmetry and the systematic absences of hkl , $h + k = 2n + 1$, obtained from precession photographs, indicated that the crystal system was monoclinic and that the space group was $C2$, Cm or $C2/m$. Unit-cell dimensions and intensity data were measured on a Supper automatic two-circle diffractometer using Ni-filtered Cu $K\alpha$ radiation ($\lambda = 1.5418$ Å). The unit-cell dimensions were calculated from data obtained from the zero levels of two crystals. Packing considerations for the two molecules in the unit cell led to the conclusion that the space group must be $C2$; this was confirmed by the structure solution and refinement. The intensity data were collected with the $\theta/2\theta$ scan technique using one crystal mounted about b ($0.213 \times 0.128 \times 0.075$ mm) for layers $k = 0-5$, and another mounted about c^* ($0.225 \times 0.175 \times 0.063$ mm) for layers $l = 0-4$. Absorption corrections were applied ($\mu = 3.89$ mm⁻¹) using the analytical method (de Meulenaer & Tompa, 1965). The intensities of the reflections were scaled and averaged (Rae, 1965) to give data for 627 unique reflections.

The structure was solved by using Patterson and Fourier methods and refined by full-matrix least-squares calculations, minimizing $\sum w(\Delta F)^2$ where $w =$

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$\sigma^{-2}(F_o)$. The values for $\sigma(F_o)$ were obtained from a combination of counting statistics and mean deviations for those reflections measured more than once, and counting statistics alone for the remainder. The positions of all H atoms were clearly defined in difference maps. Scattering factors for S, O, N, C and H were taken from *International Tables for X-ray Crystallography* (1974); the curve used for H was that calculated by Stewart, Davidson & Simpson (1965). The real part of the anomalous-dispersion correction for S ($f' = 0.110$) was applied. The parameters refined included a scale factor, positional and anisotropic temperature factor coefficients for the non-hydrogen atoms and positional and isotropic thermal parameters for the H atoms. The final R was 0.026 and R_w 0.034 for the 627 reflections included in the refinement. A final difference map showed no remarkable features: the highest positive region was less than 0.2 e Å⁻³. Final atomic coordinates are listed in Table 1.* Atom labelling, bond lengths and angles are shown in Fig. 1. The final refinement cycles were calculated with *ICRFMLS* (Carrell, 1975).

* Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 35595 (5 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. Atomic coordinates

The y coordinate of S(3) was not varied during the refinement. H-atom temperature factors = $\exp[-B \sin^2 \theta/\lambda^2]$. B_{eq} is defined by Willis & Pryor (1975).

	x	y	z	B_{eq}/B (Å ²)
N(1)	0.1831 (1)	0.5240 (4)	0.1241 (5)	2.19
C(2)	0.1478 (1)	0.3552 (5)	0.1880 (6)	1.78
C(3)	0.0864 (1)	0.3191 (5)	0.0465 (6)	1.90
S(3)	0.0396 (1)	0.1000	0.1483 (2)	2.54
C(4)	0.0643 (1)	0.4635 (6)	-0.1699 (6)	2.46
C(5)	0.1002 (1)	0.6331 (6)	-0.2363 (6)	2.80
C(6)	0.1605 (1)	0.6598 (6)	-0.0833 (7)	2.54
C(7)	0.1759 (1)	0.2075 (6)	0.4175 (7)	2.00
O(1)	0.2350 (1)	0.2534 (4)	0.5117 (5)	3.03
O(2)	0.1466 (1)	0.0627 (5)	0.5052 (5)	3.77
H(4)	0.024 (1)	0.454 (6)	-0.255 (6)	2.3 (4)
H(5)	0.086 (1)	0.751 (6)	-0.396 (7)	2.5 (4)
H(6)	0.187 (1)	0.771 (7)	-0.108 (7)	3.4 (3)
H(O1)	0.257 (2)	0.159 (9)	0.648 (9)	6 (1)

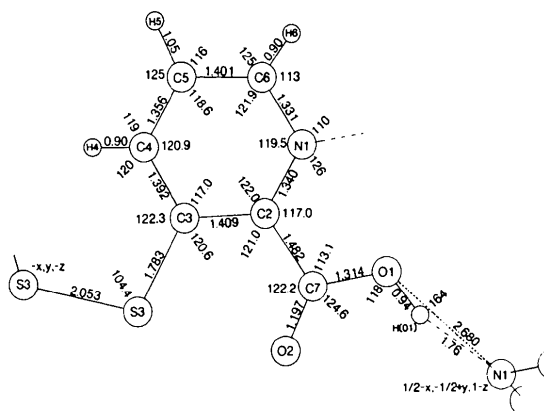


Fig. 1. Interatomic distances (Å) and angles ($^{\circ}$). Standard deviations are: C—C(N,O), 0.005; C—S, 0.004; S—S, 0.002; C—H, 0.08 Å; and 0.2° in angles not involving H, 2° in the remainder.

Discussion. The title compound was prepared and its structure was investigated during a study of 3-thiopicolinic acid and related compounds that inhibit gluconeogenesis.

The two equivalent parts of the molecule are related by a crystallographic twofold rotation axis which passes through the midpoint of the disulphide bond (Fig. 2). The conformation about the disulphide linkage is similar to that found in a number of aromatic disulphides (Raghavan & Seff, 1977) in that the S—S bond is close to being coplanar with each pyridine ring and the C—S—S—C torsion angle is within 10° of 90° , viz C(3)—S(3)—S'(3)—C'(3) is -80.1° , and S'(3)—S(3)—C(3)—C(2) and S'(3)—S(3)—C(3)—C(4) are -173.8 and $+7.4^{\circ}$ respectively. The coplanarity of

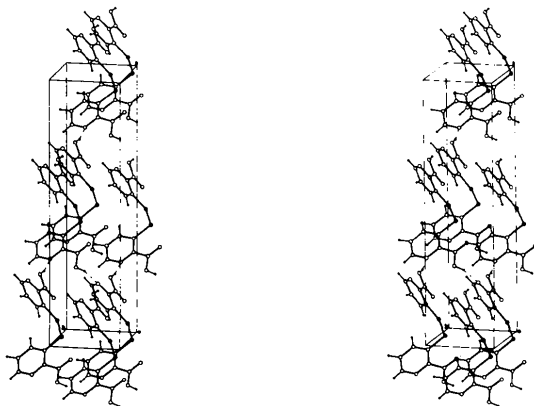


Fig. 2. A stereoscopic diagram of the structure drawn by *VIEW* (Carrell, 1979). Hydrogen bonds are shown as dashed lines. The positive direction of the *a* axis is towards the top of the page with *b* horizontal and to the left and *c* towards the viewer.

the S—S bond with the aromatic ring and the (consequent) close approach of S'(3) to C(4) [in this structure the relevant distances are S'(3)—C(4) = 3.149 and S'(3)—H(4) = 2.64 Å] have been interpreted either in terms of an attractive non-bonded 1,4 C—S interaction (Van Wart, Shipman & Scheraga, 1975) or to be a consequence of minimizing repulsive interactions between lone-pair electrons on the S atoms (Raghavan & Seff, 1977). In di-2-pyridyl disulphide, as noted by Raghavan & Seff (1977), the exocyclic angles corresponding to S(3)—C(3)—C(4) and S(3)—C(3)—C(2) differ from one another by an average of 12° , whereas in this structure these angles are nearly equal and show little indication of distortion caused by 1,4 steric overcrowding. All other distances and angles in the molecule are normal. The plane of the carboxyl group is at an angle of 5.6° to that of the pyridine ring.

There is an intermolecular hydrogen bond between O(1) of the carboxyl group and the pyridine ring N(1) atom (Fig. 1). These hydrogen bonds link the molecules in spirals about the 2_1 axis throughout the crystal (Fig. 2).

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