

# Crystal Structure of 2-Aminopyrimidine Hydrochloride Hemihydrate

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The title compound crystallizes in the space group  $P\bar{1}$ , with  $a=9.881(3)$ ,  $b=8.693(3)$ ,  $c=9.821(4)$  Å,  $\alpha=110.70(1)^\circ$ ,  $\beta=83.67(1)^\circ$ , and  $\gamma=59.56(1)^\circ$  (at 110 K). The structure was derived from 5440 counter data and refined to  $R=0.030$ . Estimated standard deviations in bond lengths and angles involving non-hydrogen atoms are 0.001–0.002 Å and 0.1°, respectively. Comparison with 2-aminopyrimidine shows that highly significant changes in bond lengths and angles occur on protonation. The components are linked together in the crystals by hydrogen bonds.

The protonation of pyrimidine and other nitrogen heterocycles has been investigated by  $^1\text{H}$  NMR,<sup>1</sup> UV,<sup>2</sup> and  $^{13}\text{C}$  NMR-spectroscopy,<sup>3</sup> as well as by X-ray crystallographic methods. The crystal structures of some pyrimidinium salts have been reported.<sup>4</sup> An interesting case is provided by the aminopyrimidines because of the strong and variable conjugation between the ring and the amino group. In connection with our earlier work on pyrimidines, including 2-aminopyrimidine,<sup>5</sup> we have therefore determined the crystal structure of the hydrochloride of this compound.

## EXPERIMENTAL. STRUCTURE ANALYSIS

The compound was prepared by mixing equimolar amounts of 2-aminopyrimidine and hydrochloric acid in alcoholic solution. Large crystals were obtained by evaporation. A fragment of dimensions  $0.21 \times 0.28 \times 0.32$  mm was used for the structure analysis.

Weissenberg photographs and diffractometer measurements showed the crystals to be triclinic, with  $a=9.881(3)$ ,  $b=8.693(3)$ ,  $c=9.821(4)$  Å,  $\alpha=$

$110.70(1)^\circ$ ,  $\beta=83.67(1)^\circ$ , and  $\gamma=59.56(1)^\circ$ . The space group was assumed to be  $P\bar{1}$  and this was confirmed by the structure analysis, which also showed the presence of a water molecule. The asymmetric unit consists of two mono-protonated 2-aminopyrimidines, two chloride ions, and one water molecule. The calculated density is  $1.47 \text{ g cm}^{-3}$ .

The intensities were measured on a SYNTEX automatic diffractometer at a temperature of 110 K, using monochromatic  $\text{MoK}\alpha$  radiation ( $\lambda=0.71069$  Å). The  $\omega/2\theta$  scan mode was employed. The intensities of three test reflections did not vary significantly during the data collection. Reflections with  $\sin \theta/2 < 0.81 \text{ \AA}^{-1}$  were measured, in all 5912, of which 5440 had  $I > 3\sigma(I)$  and were used in the structure analysis. Corrections for extinction and absorption ( $\mu=5.1 \text{ cm}^{-1}$ ) were not applied. The atomic form factors were those of Doyle and Turner,<sup>6</sup> except for hydrogen.<sup>7</sup>

The structure was solved by vector and Fourier methods and the hydrogen positions were derived from a difference Fourier map. Refinements were by full-matrix least squares analysis with weights based on counter statistics and 2% fluctuation in diffractometer stability. Anisotropic temperature factors were applied to the non-hydrogen atoms, isotropic ones to the hydrogens. The final parameters for the non-hydrogen atoms were derived from high-order reflections only ( $\sin \theta/\lambda > 0.60 \text{ \AA}^{-1}$ , 3309 reflections). The value of  $R$  is 0.031 for high-order data, 0.030 for all data. The corresponding values of  $R_w$  are 0.032 and 0.038, of "goodness of fit" 2.2 and 1.6. The atomic coordinates are given in Table 1 and the bond lengths and angles in Table 2. Lists of structure factors and temperature coefficients may be obtained from the authors (S.F.).

Rigid-body thermal motion analysis was carried out.<sup>8</sup> The r.m.s. difference between the atomic vibration tensor components and those derived from the model is  $0.0003 \text{ \AA}^2$  for both molecules. The

Table 1. Positional parameters,  $\times 10^5$  for non-hydrogens,  $\times 10^3$  for hydrogens.

Molecule A				Molecule B		
	x	y	z	x	y	z
N1	76333(9)	8090(12)	40534(9)	69600(9)	38613(10)	10726(9)
N3	105926(8)	-13973(11)	30546(9)	46822(9)	72470(11)	19221(10)
N7	90298(11)	-25012(14)	36432(12)	42255(10)	49410(13)	20660(11)
C2	90833(10)	-10372(13)	35820(9)	52896(9)	53552(11)	16891(9)
C4	105989(10)	1101(12)	30138(10)	57907(11)	75876(12)	15347(11)
C5	91379(11)	20503(13)	35013(11)	75376(11)	61095(13)	9148(11)
C6	76482(11)	23386(4)	40139(11)	80925(11)	42154(12)	6974(11)
Cl	39214(2)	26514(3)	48990(3)	24260(3)	1604(3)	96343(3)
O	19986(16)	36179(15)	26318(14)			
H1	666(2)	100(3)	433(2)	728(2)	263(2)	88(2)
H4	1168(2)	-20(2)	266(1)	537(2)	892(2)	169(1)
H5	916(2)	310(2)	348(2)	826(2)	638(2)	65(1)
H6	659(2)	356(2)	434(2)	927(2)	305(2)	28(1)
H7	995(2)	-365(2)	336(2)	312(2)	590(2)	238(2)
H8	811(2)	-229(2)	401(2)	456(2)	384(3)	186(2)
H9	244(2)	326(3)	321(2)			
H10	218(2)	257(3)	191(2)			

corrected distances are given in Table 2 and Fig. 1. Corrections to bond angles are negligible.

A final residual electron density map in the ring plane showed peaks in the range  $0.2-0.4 \text{ e } \text{Å}^{-3}$ , due to bonding and lone pair electrons.

All calculations were carried out on CYBER-74 using the programs of Ref. 9.

## RESULTS AND DISCUSSION

*Molecular structure.* The two independent cationic molecules A and B have closely similar

structures, the largest differences between corresponding parameters being  $0.006 \text{ Å}$  in bond lengths and  $1.0^\circ$  in bond angles. These small variations may in part be caused by packing forces. The discussion will be based on mean values corrected for libration (Fig. 1).

The molecules are essentially planar, the largest deviation from the least squares plane through the heavy atoms being  $0.011 \text{ Å}$  (N1 in mol. B). However, the slightly curved shape characteristic of pyrimidines<sup>5</sup> is evident, with C5 and N7 at the "bows". The hydrogen atoms of the ring lie within

Table 2. Bond lengths (Å) and angles ( $^\circ$ ). Lower values are corrected for libration. The e.s.d.'s are  $0.001-0.002 \text{ Å}$  and  $0.1^\circ$  for lengths and angles, respectively. See also Fig. 1.

	Mol. A	Mol. B		Mol. A	Mol. B
N1-C2	1.357	1.353	N1-C2-N3	120.6	121.6
	1.360	1.356	C2-N3-C4	117.7	117.1
N1-C6	1.351	1.350	N3-C4-C5	123.9	123.8
	1.354	1.352	C4-C5-C6	116.3	116.9
C2-N3	1.354	1.349	C5-C6-N1	120.1	119.3
	1.357	1.353	C6-N1-C2	121.3	121.2
C2-N7	1.322	1.328	N7-C2-N1	120.0	119.0
	1.325	1.331	N7-C2-N3	119.4	119.4
N3-C4	1.328	1.322			
	1.331	1.325			
C4-C5	1.403	1.403			
	1.406	1.407			
C5-C6	1.363	1.367			
	1.365	1.370			

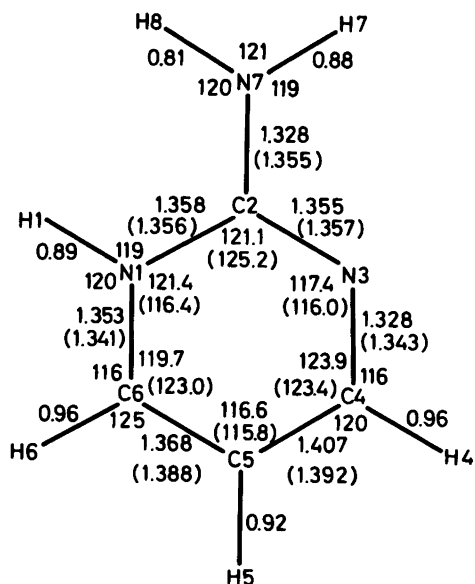
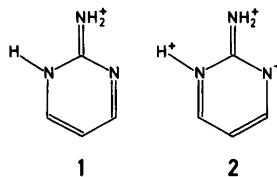


Fig. 1. Mean bond lengths and angles. C–C and C–N distances are corrected for libration. In parentheses, the corresponding values for 2-aminopyrimidine ( $\sigma = 0.002 - 0.003$  Å,  $0.2^\circ$ ).

0.02 Å from this plane, except that bonded to N1, which is at a distance of 0.07 Å in both molecules. The amino hydrogens are on the same side of the molecular plane at distances 0.04 and 0.02 Å in A, and 0.07 and 0.06 Å in B. The angle between the ring plane and that of the amino group is  $4.2^\circ$  in A and  $10.2^\circ$  in B. In 2-aminopyrimidine this angle was found to be much larger ( $17.9^\circ$ ).<sup>5</sup> This is in agreement with the increased double bond character of the C2–NH<sub>2</sub> bond in the protonated species.

The Fourier difference map shows directly that protonation takes place at a ring nitrogen atom

(N1), in agreement with previous results.<sup>1</sup> It brings about profound changes in the molecule, as is seen when comparing bond lengths and bond angles in the free base and the conjugate acid (Fig. 1). As is generally found for nitrogen hetero-aromatics, the ring angle at the protonation site increases by about  $5^\circ$ .<sup>10</sup> This is accommodated by decreases of the adjacent ring angles at C2 and C6, and also the remaining angles are altered. All bond lengths except C2–N1 and C2–N3 are significantly changed. The greatest changes occur in C2–N7 and C6–C5, which are shortened by 0.027 and 0.020 Å, respectively. The main effect of the protonation on bond lengths may be rationalized by assuming valence bond structure 1 to make a greater contribution to the molecular structure than 2. The corresponding structures for the base are both of type 2 and the contribution from structures containing doubly bonded amino groups is smaller for the base than for the protonated base. The properties of protonated 4-aminopyrimidine have been similarly explained.<sup>11</sup>



We have previously determined the crystal structures of the hydrochlorides of pyrimidine and pyrimidine-2-one.<sup>4</sup> The structural changes occurring on the protonation may be derived by comparison with the parent compounds<sup>5,12</sup> although differences in intermolecular forces complicate matters. The effects on bond angles are essentially similar to those found in the present work, but the patterns of bond length changes are

Table 3. Hydrogen bonds X–H...Y with distances (Å) and angles ( $^\circ$ ). E.s.d. in X...Y is 0.001 Å.<sup>a</sup>

X–H...Y	X...Y	X–H	H...Y	$\angle$ X–H–Y
N7B–H7B...N3A (V)	3.071	0.90	2.18	168
N7A–H7A...O (III)	2.817	0.86	1.96	176
N1A–H1A...ClA (I)	3.024	0.88	2.20	155
N7A–H8A...ClA (II)	3.189	0.83	2.39	161
N7B–H8B...ClB (II)	3.476	0.77	2.84	142
N1B–H1B...ClB (II)	3.019	0.89	2.15	169
O–H9...ClB (IV)	3.172	0.85	2.34	167
O–H10...ClA (I)	3.148	0.80	2.36	167

<sup>a</sup> Symmetry codes: (I)  $x, y, z$ , (II)  $1 - x, -y, 1 - z$ , (III)  $x + 1, y - 1, z$ , (IV)  $x, y, z - 1$ , (V)  $x - 1, y + 1, z$ .

