Acta Cryst. (1983). C39, 1240–1241

1-Amino(imino)methyl-2-hydroxypyrrolidine-2-carboxylic Acid Monohydrate, $C_6H_{11}N_3O_3.H_2O$. A Cyclic Form of the α-Keto Acid Derived from Arginine

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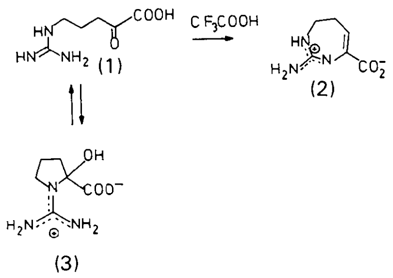
(*Received* 15 *February* 1983; *accepted* 10 *May* 1983)

Abstract. $M_r = 191\cdot19$, monoclinic, $P2_1/c$, $a = 6\cdot597\,(3)$, $b = 11\cdot713\,(3)$, $c = 11\cdot945\,(4)$ Å, $\beta = 112\cdot14\,(2)°$, $V = 854\cdot9\,(4)$ Å^3, $Z = 4$, $D_x = 1\cdot49$ g cm^{-3}, Mo $K\alpha$, $\lambda = 0\cdot71069$ Å, $\mu = 1\cdot17$ cm^{-1}, $F(000) = 408$, room temperature, $R = 0\cdot041$ for 973 unique reflections with $I > 2\sigma(I)$. The title compound exists in the zwitterionic form with its five-membered ring exhibiting a half-chair conformation. The substituted guanidino moiety is planar with all three C—N bonds statistically equivalent [1·329 (7) Å]. The structure contains a water of hydration which participates in an extensive network of hydrogen bonds.

Introduction. The α-keto acid of arginine (1) is of considerable biochemical interest. Recently, the α-keto acids have been associated with interferences in amino acid metabolism and may be associated with physiopathological disturbances (Marescau, Lintens, Lowgnthal & Terheggen, 1979). In the past (1) has been obtained by enzymatic procedures (Cooper & Meister, 1978); however, recently it has been prepared by direct synthesis from arginine (Klein, Schulz & Steglich, 1983). Treatment of (1) with strong acids led *via* ring closure to the diazepine derivative (2). ^{1}H and ^{13}C NMR spectra in aqueous solution indicated an equilibrium between the open-chain keto acid (1) and a cyclic form which was tentatively identified as the proline derivative (3). Both forms could be obtained by recrystallization from aqueous solutions. They may be easily differentiated by their IR spectra (KBr): (1) shows a strong carbonyl absorption at 1720 cm^{-1} which is missing in (3). The five-membered-ring structure has been confirmed by the present analysis and the compound shown to be the zwitterionic form.



Experimental. Compound (3) was recrystallized from water and a parallelepiped-shaped crystal was used for all X-ray measurements; 0·37 × 0·28 × 0·10 mm, Syntex $P2_1$, θ:2θ scan, $2\theta_{\max} = 49°$, graphite-monochromated Mo $K\alpha$, lattice parameters from least-squares refinement of 15 medium-angle reflections, angles measured by centering routine associated with the diffractometer system, systematic absences $l = 2n+1$ for $h0l$ and $k = 2n+1$ for $0k0$, monitored reflection showed no change in intensity greater than $3\sigma(I)$, 1353 independent reflections measured ($0 \leq h \leq 7$, $0 \leq k \leq 13$, $-13 \leq l \leq 12$), 973 with $I > 3\sigma(I)$, Lorentz and polarization corrections, no absorption; direct methods (*MULTAN*78: Main, Hull, Lessinger, Germain, Declercq & Woolfson, 1978), all H atoms from difference Fourier map, full-matrix least-squares anisotropic refinement (H atoms isotropic), $R = 0\cdot041$, $R_w = 0\cdot039$, $S = 3\cdot06$, $\sum w(|F_o| - |F_c|)^2$ minimized, $w = 1/\sigma^2(F_o)$, largest peak in final difference Fourier 0·2 e Å^{-3}, average and maximum shift/error 0·08 and 0·60, atomic scattering factors from XRAY76 (Stewart, Machin, Dickinson, Ammon, Heck & Flack, 1976). Locally written programs were used for data reduction and initial block-diagonal least-squares refinement, *MULTAN*78 was used for the direct-methods calculations and *XRAY*76 was used for all other computations.*

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* Lists of structure factors, anisotropic thermal parameters and torsion angles have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 38589 (13 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Discussion. Table 1 lists atomic positional parameters and U_{eq} values while Table 2 gives bond lengths, valence angles and possible hydrogen bonds.

Fig. 1 is an *ORTEP*II drawing (Johnson, 1971) of the zwitterionic form (3) of compound (1). The five-membered ring exhibits torsion angles of +13·6 (5), +9·0 (5), −28·4 (5), +37·6 (5), and −30·7 (5)° which are indicative of a half-chair conformation (Bucourt, 1974). Least-squares planes fitted to N(1)C(6)N(7)-N(8) (plane 1) and C(2)C(10)O(11)O(12) (plane 2) indicate the groups are essentially planar with maximum deviations of 0·002 Å by C(6) in plane 1 and 0·02 Å by C(10) in plane 2. The three C(6)—N bonds have statistically equivalent lengths with an average value of 1·329 (7) Å while the two equivalent C=O bonds average 1·241 (7) Å. These values are consistent with the zwitterionic form in which there is delocalization throughout the substituted guanidino moiety. A least-squares plane fitted to the puckered five-membered ring makes interplanar angles of 3·5 (8) and 89·5 (8)° with planes 1 and 2.

Table 1. *Atomic positional parameters* (×10⁴, *for* H ×10³) *and* U_{eq} (Å² ×10³)

$U_{eq} = (U_{11}U_{22}U_{33})^{1/3}$.

	x	y	z	U_{eq}
N(1)	756 (4)	4544 (2)	2082 (2)	21 (2)
C(2)	−1087 (5)	4655 (3)	2506 (3)	23 (2)
C(3)	−257 (6)	5607 (3)	3448 (3)	30 (2)
C(4)	2220 (6)	5521 (3)	3932 (3)	32 (2)
C(5)	2701 (6)	5211 (3)	2824 (3)	29 (2)
C(6)	699 (5)	3888 (3)	1157 (3)	24 (2)
N(7)	−1162 (5)	3387 (3)	460 (3)	31 (2)
N(8)	2476 (5)	3717 (3)	921 (3)	40 (2)
O(9)	−3070 (4)	4905 (2)	1546 (2)	25 (2)
C(10)	−1407 (6)	3526 (3)	3113 (3)	31 (2)
O(11)	−3303 (4)	3274 (2)	2982 (2)	55 (2)
O(12)	265 (4)	2996 (2)	3751 (2)	45 (2)
O(*W*)	4120 (4)	2860 (3)	8921 (2)	38 (2)
H(3*a*)	−95 (5)	553 (3)	408 (3)	*
H(3*b*)	−72 (5)	630 (3)	304 (3)	
H(4*a*)	277 (5)	489 (3)	454 (3)	
H(4*b*)	301 (5)	619 (3)	432 (3)	
H(5*a*)	408 (5)	477 (3)	303 (3)	
H(5*b*)	296 (5)	592 (3)	233 (3)	
H(7*a*)	−247 (5)	363 (3)	39 (3)	
H(7*b*)	−113 (5)	301 (3)	−14 (3)	
H(8*a*)	369 (5)	379 (3)	138 (3)	
H(8*b*)	241 (5)	325 (3)	26 (3)	
H(9)	−336 (5)	556 (3)	142 (3)	
H(*W*1)	496 (5)	261 (3)	863 (3)	
H(*W*2)	324 (6)	255 (3)	888 (4)	

* Hydrogen isotropic thermal parameter fixed at 0·05 Å².

Table 2. *Interatomic distances* (Å), *valence angles* (°), *and possible hydrogen bonds* (Å,°)

N(1)–C(2)	1·488 (5)	C(3)–C(4)	1·517 (5)
N(1)–C(5)	1·478 (4)	C(4)–C(5)	1·516 (6)
N(1)–C(6)	1·336 (4)	C(6)–N(7)	1·332 (4)
C(2)–C(3)	1·531 (5)	C(6)–N(8)	1·320 (5)
C(2)–O(9)	1·408 (3)	C(10)–O(11)	1·237 (5)
C(2)–C(10)	1·560 (5)	C(10)–O(12)	1·245 (4)
C(2)–N(1)–C(5)	112·7 (3)	C(2)–C(3)–C(4)	105·5 (3)
C(2)–N(1)–C(6)	124·0 (2)	C(3)–C(4)–C(5)	103·5 (3)
C(5)–N(1)–C(6)	123·2 (3)	N(1)–C(5)–C(4)	103·3 (3)
N(1)–C(2)–C(3)	101·6 (3)	N(1)–C(6)–N(7)	120·2 (3)
N(1)–C(2)–O(9)	111·6 (3)	N(1)–C(6)–N(8)	120·9 (3)
N(1)–C(2)–C(10)	110·8 (3)	N(7)–C(6)–N(8)	118·9 (3)
C(3)–C(2)–O(9)	114·3 (3)	C(2)–C(10)–O(11)	116·9 (3)
C(3)–C(2)–C(10)	110·4 (3)	C(2)–C(10)–O(12)	117·6 (3)
O(9)–C(2)–C(10)	107·9 (3)	O(11)–C(10)–O(12)	125·3 (4)

A–H···B	A–H	A···B	H···B	∠A–H···B
N(7)–H(71)···O(W^{i})	0·88 (4)	3·023 (4)	2·45 (3)	124 (1)
N(7)–H(71)···O(9^{ii})	0·88 (4)	2·767 (5)	2·17 (4)	125 (1)
N(7)–H(72)···O(12^{iii})	0·86 (4)	3·021 (5)	2·21 (4)	158 (1)
N(8)–H(81)···O(11^{iv})	0·78 (3)	2·986 (4)	2·26 (3)	154 (1)
N(8)–H(82)···O(12^{iii})	0·95 (3)	3·166 (4)	2·34 (3)	146 (1)
N(8)–H(82)···O(W^{v})	0·95 (3)	3·138 (6)	2·32 (4)	144 (1)
O(9)–H(9)···O(W^{vi})	0·79 (3)	2·712 (4)	1·92 (3)	179 (1)
O(9)···H(81)–N(8^{vii})	0·78 (3)	3·078 (4)	2·45 (3)	138 (1)
O(11)···H(1*W*)–O(W^{viii})	0·81 (4)	2·710 (5)	1·91 (4)	168 (1)
O(12)···H(2*W*)–O(W^{iii})	0·67 (4)	2·670 (4)	2·01 (4)	166 (1)

Symmetry code: (i) $x-1, y, z-1$; (ii) x, y, z; (iii) $x, 0·5-y, z-0·5$; (iv) $x+1, y, z$; (v) $x, y, z-1$; (vi) $-x, 1-y, 1-z$; (vii) $x-1, y, z$; (viii) $x-1, 0·5-y, z-0·5$.

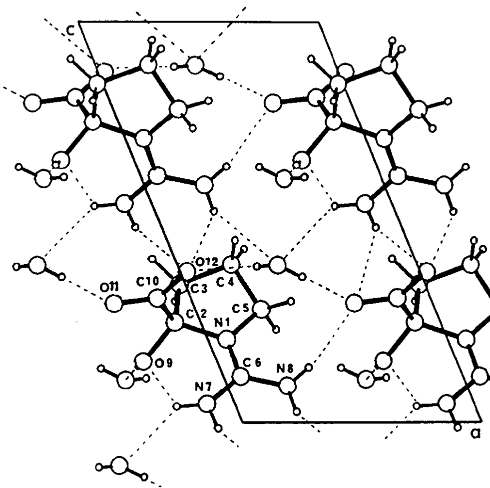

Fig. 1. *ORTEP*II drawing of the title compound. The extensive network of hydrogen bonds is indicated by the dashed lines.

Extensive hydrogen bonding is present as is indicated by the values listed in Table 2.

We thank The Robert A. Welch Foundation (P-024) for its financial support. This is FASTBIOS Publication No. 103.

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