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Key indicators

Single-crystal X-ray study T = 298 K Mean σ (C–C) = 0.004 Å R factor = 0.041 wR factor = 0.117 Data-to-parameter ratio = 12.2

For details of how these key indicators were automatically derived from the article, see http://journals.iucr.org/e.

4,4'-(2-Methyl-1*H*-imidazole-4,5-diyl)bis[2(*S*)methyl-3-azoniabutanoate] acetic acid monohydrate

In the title compound, $C_{12}H_{20}N_4O_4 \cdot C_2H_4O_2 \cdot H_2O$, the main fragment contains two L-alanine residues with a zwitterionic structure. The crystal structure is characterized by a two-dimensional network of $O-H \cdots O$, $O-H \cdots N$ and $N-H \cdots O$ hydrogen bonds.

Comment

The preparation and characterization of imidazole derivatives is of current interest, because of their ability to form metal complexes with a wide variety of chemical, magnetic and catalytic properties (Baesjou *et al.*, 1998; Colacio *et al.*, 2000; Kamaraj *et al.*, 2003). In previous work (Mendoza-Díaz *et al.*, 1996, 2002), we have reported the synthesis and crystal structures of ligands obtained *via* the Mannich addition of primary amines on 2-methylimidazole, to give a tenmembered cyclic diazecine, incorporating two imidazoles and two amines. Following this line of research, we now describe a non-cyclic ligand, (I), obtained from a similar reaction between 2-methylimidazole and L-alanine, and crystallized with acetic acid and water.



The asymmetric unit of (I) consists of a zwitterion of formula $C_{12}H_{20}N_4O_4$, an acetic acid molecule and a water molecule. The main molecule contains two alanine groups bonded, *via* two methylene groups, to positions 4 and 5 of a 2-methylimidazole group (Fig. 1). The geometry of the imidazole ring is as expected (Table 1), with C=C and C=N bond lengths ranging from 1.329 (3) to 1.378 (3) Å. Atom H1 is clearly bonded to N1, and no evidence can be found, at least in the solid state, for a tautomerism in this heterocycle. The imidazole group thus has potential for coordination through atom N3. Both alanine groups have zwitterionic structures, with both carboxylate groups having similar C=O bond lengths [1.231 (3)–1.259 (3) Å] and protonated amine groups displaying characteristic C-N single bond lengths of around

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Figure 1 The structure of (I), with displacement ellipsoids at the 30% probability level.

1.50 Å [1.497 (3)–1.502 (3) Å]. This zwitterionic structure for alanine has recently been observed in a phosphorus-functionalized trimeric alanine derivative (Raghuraman *et al.*, 2003), with a geometry identical, within the s.u. values, to that observed in (I).

It should be emphasized that the above description of (I) is unambiguous, since high-resolution diffraction data (0.71 Å) allowed the precise determination of the positions of H atoms bonded to N and O atoms. Moreover, the distribution of charges is consistent with pK_a values determined potentiometrically; amine functional groups have pK_a values of 9.81 and 7.67, while acid groups have pK_a values of 2.04 and 1.97. Since (I) was crystallized at pH ~5.7, the expected zwitterions in the solid state for the alanine moieties are those actually observed. Regarding the imidazole group ($pK_a = 3.79$), it should compete with acetic acid, which has a pK_a of 4.72. The solid state structure indicates that the corresponding H atom is essentially localized on the acetate rather than on the imidazole ring. However, a small contribution of an imidazolium form should not be completely ruled out.

As expected, a complex hydrogen-bonding scheme (Table 2) is observed in (I), involving all H atoms bonded to N and O atoms (Fig. 2). The strongest hydrogen bonds arise from the acetic acid molecule, which forms an $R_2^2(9)$ motif with imidazole atom N3 and protonated amine atom N15. A striking feature is the geometry of the strong O23-H3···N3 bond, where the H atom is placed close to the mid-point of the formal donor and acceptor atoms, with an angle very close to an ideal value of 180°. As previously described, this situation is a direct consequence of the close pK_a values of the acetic acid and imidazole NH function. The water molecule serves as donor and acceptor, giving $R_2^1(9)$ and $R_1^2(4)$ motifs with the alanine functional groups. Finally, two symmetry-related molecules are bonded through an $R_2^2(9)$ motif, including the N1/H1 functionality of the imidazole ring. The overall connectivity generates a two-dimensional network, based on [010] and [001] vectors.



Figure 2

Part of the crystal structure of (I), viewed almost down the *b* axis, showing the hydrogen-bonding scheme (dashed lines). Two zwitterions, two acetic acid molecules and four water molecules are shown in order to depict all the hydrogen bonds listed in Table 2. For clarity, H atoms not participating in hydrogen bonding, *i.e.* belonging to methyl, methylene and methine groups, have been omitted. [Symmetry codes: (i) -x, $y - \frac{1}{2}$, 1 - z; (ii) -x, $y - \frac{1}{2}$, -z; (iii) -x, $y - \frac{1}{2}$, -z.]

Experimental

Compound (I) was obtained by mixing L-alanine (3.56 g, 40 mmol) and 2-methylimidazole (1.642 g, 20 mmol), each previously dissolved in water (20 ml). To this mixture, a 37% formaldehyde solution (4.8 ml, 60 mmol) was added dropwise with stirring, followed by the dropwise addition of a concentrated solution of KOH, until the pH reached a value of 12.5. The mixture was stirred at 328 K for 24 h, after which acetic acid was added to lower the pH to 5.7. This solution was concentrated to one-third of its original volume and left to stand. Transparent crystals of (I) suitable for X-ray diffraction were collected after two days (yield 44%). Analysis found: C 47.13, H 7.09, N 15.90%; calculated for $C_{14}H_{26}N_4O_7$: C 46.40, H 7.23, N, 15.46%.

| Crystal data | |
|---|---|
| $C_{12}H_{20}N_4O_4 \cdot C_2H_4O_2 \cdot H_2O$ $M_r = 362.39$ Monoclinic, $P2_1$ a = 13.337 (3) Å b = 5.3977 (14) Å c = 14.312 (4) Å $\beta = 109.898$ (19)° V = 968.8 (4) Å ³ Z = 2 | $D_x = 1.242 \text{ Mg m}^{-3}$ Mo K α radiation Cell parameters from 38 reflections $\theta = 3.3-13.1^{\circ}$ $\mu = 0.10 \text{ mm}^{-1}$ T = 298 (1) K Prism, colorless $0.48 \times 0.26 \times 0.26 \text{ mm}$ |
| Data collection | |
| Bruker P4 diffractometer ω scans 4070 measured reflections 3107 independent reflections 2403 reflections with $I > 2\sigma(I)$ $R_{\text{int}} = 0.032$ $\theta_{\text{max}} = 30.0^{\circ}$ | $h = -1 \rightarrow 18$ $k = -1 \rightarrow 7$ $l = -20 \rightarrow 19$ 3 standard reflections every 97 reflections intensity decay: 1% |

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Refinement

| Refinement on F^2 | $w = 1/[\sigma^2(F_0^2) + (0.0655P)^2]$ |
|---------------------------------|--|
| $R[F^2 > 2\sigma(F^2)] = 0.041$ | + 0.0268P] |
| $wR(F^2) = 0.117$ | where $P = (F_0^2 + 2F_c^2)/3$ |
| S = 1.03 | $(\Delta/\sigma)_{\rm max} < 0.0001$ |
| 3107 reflections | $\Delta \rho_{\rm max} = 0.22 \text{ e} \text{ \AA}^{-3}$ |
| 254 parameters | $\Delta \rho_{\rm min} = -0.21 \text{ e } \text{\AA}^{-3}$ |
| H atoms treated by a mixture of | |
| independent and constrained | |
| refinement | |

Table 1

Selected geometric parameters (Å, °).

| N1-C2 | 1.332 (3) | C10-O12 | 1.238 (2) |
|-------------|-------------|-------------|-----------|
| N1-C5 | 1.374 (3) | C14-N15 | 1.499 (3) |
| C2-N3 | 1.329 (3) | N15-C16 | 1.499 (2) |
| N3-C4 | 1.378 (3) | C17-O18 | 1.231 (3) |
| C7-N8 | 1.502 (3) | C17-O19 | 1.255 (3) |
| N8-C9 | 1.497 (3) | C22-O24 | 1.212 (3) |
| C10-O11 | 1.259 (3) | C22-O23 | 1.280 (4) |
| O12-C10-O11 | 127.25 (18) | O19-C17-C16 | 115.4 (2) |
| O12-C10-C9 | 119.45 (19) | O24-C22-O23 | 123.0 (3) |
| O11-C10-C9 | 113.26 (16) | O24-C22-C21 | 120.7 (3) |
| O18-C17-O19 | 125.5 (2) | O23-C22-C21 | 116.3 (3) |
| O18-C17-C16 | 119.05 (17) | | |

| Ta | ble | e 2 |
|----|-----|-----|
|----|-----|-----|

Hydrogen-bond geometry (Å, °).

| $D - H \cdot \cdot \cdot A$ | D-H | $H \cdot \cdot \cdot A$ | $D \cdots A$ | $D - \mathbf{H} \cdots A$ |
|-----------------------------|----------|-------------------------|--------------|---------------------------|
| O23−H3···N3 | 1.06 (3) | 1.51 (3) | 2.569 (3) | 177 (3) |
| N8-H8a···O25 | 0.94 (3) | 1.90 (3) | 2.823 (2) | 170 (3) |
| N15−H15a···O25 | 0.89 (3) | 1.97 (3) | 2.817 (2) | 159 (3) |
| N15-H15bO24 | 0.93 (3) | 1.90 (3) | 2.832 (3) | 174 (3) |
| $N1-H1\cdots O11^{i}$ | 0.90 (3) | 1.70 (3) | 2.585 (2) | 168 (4) |
| $N8-H8b\cdots O12^{i}$ | 0.99 (3) | 1.85 (3) | 2.815 (2) | 167 (3) |
| $O25-H251\cdots O19^{ii}$ | 0.87 (4) | 1.78 (4) | 2.636 (3) | 169 (3) |
| $O25-H252\cdots O18^{iii}$ | 0.85 (4) | 1.99 (4) | 2.838 (2) | 172 (3) |
| $O25-H252\cdots O19^{iii}$ | 0.85 (4) | 2.42 (4) | 3.027 (3) | 129 (3) |

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

In the absence of significant anomalous scattering effects, Friedel pairs were merged. The absolute configuration of (I) was assigned on the basis of the known configuration of the L-alanine used as starting material. H atoms bonded to C atoms were placed at idealized positions and refined using a riding model, with $U_{iso}(H) = xU_{eq}$ (parent C atom). The constrained distances and x parameters are the default values in *SHELXTL-Plus* (Sheldrick, 1998): methine: C– H = 0.98 Å, x = 1.2; methylene: C–H = 0.97 Å, x = 1.2; methyl: C– H = 0.96 Å, x = 1.5. Other H atoms were found in difference maps and refined with free coordinates and fixed isotropic displacement parameters [$U_{iso}(H) = 1.5U_{eq}$ (parent atom)]. In the case of H3, atom N3 [$U_{eq} = 0.046$ (1) Å²] was chosen as parent atom rather than O23 [$U_{eq} = 0.104$ (1) Å²]. Refinement attempts with O23 as parent atom for H3 resulted in an O23–H3 bond length of 1.15 (6) Å, while the present refinement yields O23–H3 = 1.06 (3) Å, which seems to be more reasonable for a hydroxy group. This atom H has been labeled H3 even though formally belonging to the acetate group.

Data collection: XSCANS (Siemens, 1996); cell refinement: XSCANS; data reduction: XSCANS; program(s) used to solve structure: SHELXTL-Plus (Sheldrick, 1998); program(s) used to refine structure: SHELXTL-Plus; molecular graphics: SHELXTL-Plus and MERCURY (Bruno et al., 2002); software used to prepare material for publication: SHELXTL-Plus.

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