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L-Histidinium hemihydrochloride tartrate tartaric acid dihydrate

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Key indicators

Single-crystal X-ray study
T = 293 K
Mean σ(C–C) = 0.005 Å
H-atom completeness 99%
R factor = 0.038
wR factor = 0.109
Data-to-parameter ratio = 6.2

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

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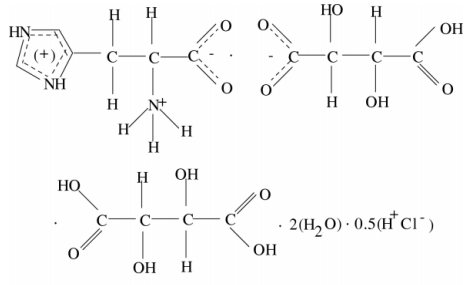
In the title compound, $C_6H_{10}N_3O_2^+\cdot C_4H_5O_6^-\cdot 0.5HCl\cdot C_4H_6O_6\cdot 2H_2O$, histidine exists, in the zwitterionic form, as a cation with a protonated amino group, a protonated ring N atom and a deprotonated carboxylic acid group. The tartaric acid molecules exist as a semi-tartrate anion and a neutral tartaric acid molecule. The chloride ion sits on a special position. The structure is stabilized by a number of O—H···O, N—H···O and O—H···Cl hydrogen bonds, in addition to van der Waals interactions. Water molecules are also found to mediate O—H···O hydrogen-bonded interactions among amino acid and tartaric acid molecules. In the crystal structure, the histidinium cation exists in an open conformation I, which is sterically the most favourable; the imidazole group is *trans* to the carboxyl group and *gauche* to the amino N atom.

Comment

Single-crystal X-ray investigations of complexes of amino acids with carboxylic acids are interesting in view of their geometrical features, non-covalent interactions, stoichiometry, ionization states and aggregation patterns that might possibly have occurred in pre-biotic polymerization (Vijayan, 1988; Prasad & Vijayan, 1993*a*). The present study reports the crystal structure of a complex of histidine hydrochloride with tartaric acid, (I).



(I)

Histidine itself exists in orthorhombic and monoclinic forms (Madden, McGandy & Seeman, 1972; Madden, McGandy, Seeman *et al.*, 1972). Neutron and X-ray investigations on histidine hydrochloride have already been reported (Fuess & Bartunik, 1976; Donohue & Caron, 1964). X-ray studies on the following crystalline complexes have also been reported: DL- and L-histidine with succinic acid (Prasad & Vijayan, 1993*b*), L-histidine with glutaric acid (Saraswathi & Vijayan, 2001), L-histidine with L-aspartic acid (Bhat & Vijayan, 1978), two forms of L-histidine with acetic acid (Suresh *et al.*, 1994), L-histidine with formic acid (Suresh & Vijayan, 1995), L- and

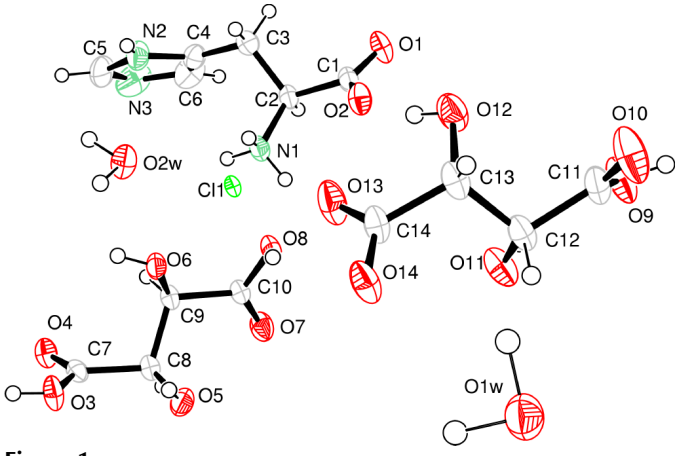


Figure 1
The molecular structure of (I), with the atom-numbering scheme and 50% probability displacement ellipsoids.

DL-histidine with glycolic acid (Suresh & Vijayan, 1996). Recently in our laboratory, the structures of sarcosinium tartrate (Krishnakumar *et al.*, 2001), L-prolinium tartrate (Subha Nandhini *et al.*, 2001) and L-alaninium tartrate (Rajagopal *et al.*, 2002) have been elucidated. Histidine is a particularly interesting amino acid because it can act as a proton donor, a proton acceptor, a nucleophilic agent and a ligand to metal ions (Madden *et al.*, 1972). It plays a crucial role in the catalytic activity of numerous enzymes.

In the histidinium cation, the α-amino and imidazole groups are protonated and positively charged, while the carboxyl group is deprotonated and negatively charged. The cation is thus zwitterionic and carries a net positive charge. In (I), the asymmetric unit contains one histidinium cation, a semi-tartrate anion, one tartaric acid molecule, two water molecules and a hemi-hydrochloride, the Cl^- ion sitting on a special position. The situation is somewhat similar to those in L-histidine formate formic acid and L-histidine semi-succinate trihydrate. The crystallographically independent tartaric acid molecules (Okaya *et al.*, 1966) exist as semi-tartrate anions and uncharged tartaric acid molecules.

The conformation of the histidine side chain can be described by the two torsion angles, χ^1 and χ^{21} or χ^{22} (IUPAC–IUB Commission on Biochemical Nomenclature, 1970). Because of the planarity of the imidazole group, χ^{21} and χ^{22} differ by 180°. χ^1, which defines the disposition of the side chain with respect to the main chain, can take values in the neighbourhood of −60, 60 or 180°, corresponding to the open conformation I (g^-), closed conformation (g^+) and open conformation II (t), respectively (Krause *et al.*, 1991). Though the preferred values of χ^{21} are −90° and +90°, the angle often deviates from these ideal values, due to interactions of the imidazole with other groups in the structure. In (I), the cation adopts the sterically most favourable open conformation I, with χ^1 = −61.5 (4)° and χ^{21} = 115.4 (5)°; the imidazole group is *trans* to the carboxyl group and *gauche* to the amino N atom. The corresponding values observed in other complexes are: L-histidine formate formic acid (−60 and −60.9°), DL-histidine formate monohydrate (−60 and −67.5°), L-histidine glycolate

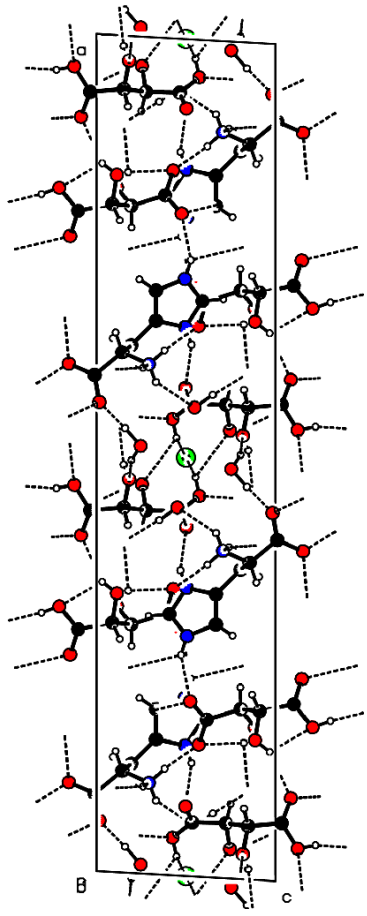


Figure 2
Packing of the molecules of (I), viewed down the *b* axis.

(58.2 and −96.8°), DL-histidine glycolate (57.2 and −123°), monoclinic L-histidine acetate [−61.2 (5) and 99.2 (5)°]; L-histidine semisuccinate trihydrate (59 and 69°); DL-histidine hemisuccinate dihydrate (−62 and −86°); L-histidine hydrochloride monohydrate (71 and −120°) (Oda & Koyama, 1972) and L-histidine semiglutarate monohydrate [−66.0 (5) and −70.0 (5)°].

The angle between the planes of the two halves of the semi-tartrate ion, O9/O10/C11/C12/O11 and O13/O14/C14/C13/O12, is 53.6 (1)°, which agrees well with the values observed in tartaric acid [54.6 (4)°; Okaya *et al.*, 1966] and in L-alaninium tartrate [53.0 (1)°], but deviates substantially from the values observed in sarcosinium tartrate [65.0 (1)°] and L-prolinium tartrate [71.4 (1)°]. The angle between the planes of the two halves of the tartaric acid molecule, O3/O4/C7/C8/O5 and O8/O7/C10/C9/O6, is 66.9 (3)°. The carbon skeletons of the semi-tartrate ion and tartaric acid molecule are essentially planar [torsion angles C11—C12—C13—C14 = 173.4 (3)° and C7—C8—C9—C10 = −173.9 (3)°].

The crystal structure of (I) is stabilized by hydrogen bonds (Table 2), in addition to van der Waals interactions. The crystal packing pattern, viewed down the *b* axis, is shown in Fig. 2. The α-amino group takes part as a proton donor in three hydrogen bonds, one involving atom O4 of a tartaric acid molecule, a second involving O13 of a semi-tartrate ion and

the third involving O1*W* of a water molecule. The N atoms of the imidazole group interact with semi-tartrate ions and tartaric acid molecules through N—H···O hydrogen bonds. Symmetry-related molecules form layers in the *ac* plane. These layers are interlinked, in the form of chains, by N—H···O, O—H···O and O—H···Cl hydrogen bonds, leading to a characteristic, three-dimensional aggregation pattern, parallel to the *bc* plane. Interestingly, no head-to-tail hydrogen bonds are observed among the histidinium cations, as is the case in the structures of sarcosinium tartrate and L-alaninium tartrate. Water molecules are also found to mediate interactions between the cations and tartaric acid molecules.

Experimental

Colourless prismatic single crystals of (I) were grown from a saturated aqueous solution containing L-histidine hydrochloride and tartaric acid in a 1:2 stoichiometric ratio.

Crystal data

$C_6H_{10}N_3O_2^+\cdot C_4H_5O_6^-\cdot 0.5HCl\cdot C_4H_6O_6\cdot 2H_2O$
$M_r = 509.10$
Monoclinic, *C*2
$a = 35.857\ (6)$ Å
$b = 7.4806\ (8)$ Å
$c = 7.6783\ (12)$ Å
$\beta = 93.192\ (18)^\circ$
$V = 2056.4\ (5)$ Å^3
$Z = 4$
$D_x = 1.644$ Mg m^{-3}
$D_m = 1.65\ (2)$ Mg m^{-3}
D_m measured by flotation using a liquid mixture of xylene and bromoform
Cu $K\alpha$ radiation
Cell parameters from 25 reflections
$\theta = 2$–67°
$\mu = 1.90$ mm^{-1}
$T = 293\ (2)$ K
Prism, colourless
0.40 × 0.35 × 0.20 mm

Data collection

Enraf–Nonius CAD-4 diffractometer
ω–2θ scans
Absorption correction: ψ scan (North *et al.*, 1968)
$T_{min} = 0.491$, $T_{max} = 0.692$
2054 measured reflections
2019 independent reflections
1982 reflections with $I > 2\sigma(I)$
$R_{int} = 0.017$
$\theta_{max} = 68.0^\circ$
$h = 0 \rightarrow 42$
$k = 0 \rightarrow 8$
$l = -9 \rightarrow 9$
2 standard reflections
every 200 reflections
intensity decay: <1%

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.038$
$wR(F^2) = 0.109$
$S = 0.95$
2019 reflections
327 parameters
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0778P)^2 + 3.7591P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.002$
$\Delta\rho_{max} = 0.84$ e Å^{-3}
$\Delta\rho_{min} = -0.43$ e Å^{-3}
Extinction correction: *SHELXL*97
Extinction coefficient: 0.0072 (5)

Table 1
Selected geometric parameters (Å, °).

O1—C1	1.254 (5)	O8—C10	1.264 (5)
O2—C1	1.245 (5)	O9—C11	1.295 (5)
O3—C7	1.294 (5)	O10—C11	1.217 (5)
O4—C7	1.220 (5)	O13—C14	1.227 (5)
O7—C10	1.237 (5)	O14—C14	1.268 (5)
O2—C1—C2—N1	−15.7 (5)	C5—N2—C4—C3	−177.9 (4)
O1—C1—C2—N1	164.0 (4)	C2—C3—C4—C6	−63.9 (6)
N1—C2—C3—C4	−61.5 (4)	C2—C3—C4—N2	115.4 (5)
C1—C2—C3—C4	174.3 (3)	C6—N3—C5—N2	1.3 (7)
C5—N2—C4—C6	1.5 (6)		

Table 2
Hydrogen-bonding geometry (Å, °).

D—H···A	D—H	H···A	D···A	D—H···A
O1*W*—H2*W*1···O1^{i}	0.95	1.76	2.706 (4)	174
O3—H3···O8^{ii}	0.82	1.69	2.493 (4)	167
O5—H5···O3^{iii}	0.82	2.04	2.828 (4)	162
O6—H6···O2^{ii}	0.82	1.89	2.699 (4)	168
O8—H8···Cl1	0.82	1.98	2.437 (3)	114
O9—H9···O14^{iv}	0.82	1.73	2.537 (4)	166
O11—H11···O9	0.82	2.18	2.620 (4)	114
O11—H11···O4^{v}	0.82	2.19	2.940 (4)	152
O8—H8···O6^{v}	0.82	2.58	3.158 (4)	128
O12—H12···O13	0.82	2.13	2.616 (4)	118
O12—H12···O1^{vi}	0.82	2.22	2.898 (4)	141
N1—H1*A*···O4^{iv}	0.89	1.99	2.818 (5)	154
N1—H1*B*···O13^{v}	0.89	1.85	2.722 (4)	164
N1—H1*C*···O1*W*^{vii}	0.89	2.14	2.931 (4)	148
N3—H3*A*···O14^{vii}	0.86	2.03	2.818 (5)	151
O1*W*—H1*W*1···O7^{viii}	0.97	1.97	2.920 (5)	165
O2*W*—H1*W*2···O2^{v}	1.03	1.70	2.711 (4)	166
O2*W*—H2*W*2···O5^{ix}	0.95	1.90	2.776 (4)	151
N2—H2···O7^{ix}	0.86	2.03	2.835 (5)	155

Symmetry codes: (i) $x-\frac{1}{2}, \frac{1}{2}+y, 1+z$; (ii) $x, y, 1+z$; (iii) $1-x, y, 2-z$; (iv) $x, y, z-1$; (v) $1-x, y, 1-z$; (vi) $1-x, y, -z$; (vii) $\frac{1}{2}+x, y-\frac{1}{2}, z$; (viii) $x-\frac{1}{2}, y-\frac{1}{2}, z$; (ix) $x, y-1, z$.

No Friedel pairs were measured. All the H atoms, with the exception of those of the water molecules, were positioned geometrically and were allowed to ride on their respective carrier atoms, with C—H = 0.96 Å, N—H = 0.89 Å, O—H = 0.82 Å and U_{iso} = 0.05 Å^2. The positions of the water H atoms were calculated using the *HYDROGEN* program (Nardelli, 1999), with O—H = 0.85 Å and H—O—H = 107°; U_{iso}(H) values were set to 0.05 Å^2 and these parameters were not refined.

Data collection: *CAD*-4 *Software* (Enraf–Nonius, 1989); cell refinement: *CAD*-4 *Software*; data reduction: *CAD*-4 *Software*; program(s) used to solve structure: *SHELXS*97 (Sheldrick, 1990); program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 1999); software used to prepare material for publication: *SHELXL*97.

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