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Brucinium 2-carboxy-6-nitrophthalate dihydrate: the 1:1 proton-transfer compound of brucine with 3-nitrophthalic acid

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In the title compound (systematic name: 2,3-dimethoxy-10-oxostrychnidinium 2-carboxy-6-nitrophthalate dihydrate), $C_{23}H_{27}N_2O_4^+\cdot C_8H_4NO_6^-\cdot 2H_2O$, the carboxylic acid and carboxylate groups of the hydrogenphthalate anions form head-to-tail catemeric chains of strong intermolecular O—H···O hydrogen bonds [O···O distance = 2.563 (5) Å] along the 2_1 screw axes parallel to the *a* axis. The chains further associate with the water molecules, forming sheet structures parallel to (010). The protonated N atom at the 19-position of the brucine molecule forms a peripheral intermolecular hydrogen bond with the carboxylate group of the anion.

Key indicators

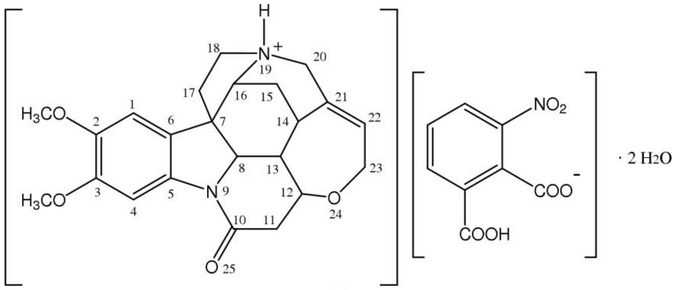
Single-crystal X-ray study
T = 297 K
Mean σ(C–C) = 0.006 Å
R factor = 0.065
wR factor = 0.179
Data-to-parameter ratio = 9.4

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

Comment

The alkaloids brucine and strychnine have been employed on a hit-or-miss basis for enantiomeric separation of racemic mixtures of chiral organic compounds since the time of Fischer (1899), while the crystal structures of their compounds with chiral organic compounds have allowed determination of the absolute configuration, based on the known absolute configuration of the parent strychnine (Peerdeman, 1956). These structures include the original Fischer-type proton-transfer compounds with *N*-benzoyl protected amino acids (Gould & Walkinshaw, 1984; Gould *et al.*, 1985). Although regarded mainly as agents for complex formation with chiral molecules, brucine and strychnine give complexes equally well with achiral species, the formation and separation process being clearly identified as one of molecular recognition (Gould & Walkinshaw, 1984; Gould *et al.*, 1985; Dijksma *et al.*, 1998; Oshikawa *et al.*, 2002; Białońska & Ciunik, 2004*a*). Brucine commonly forms regular undulating parallel-chain host structures, which extend along 2_1 screw axes in the crystal structure (Gould & Walkinshaw, 1984; Dijksma *et al.*, 1998), whereas with strychnine, such regularity is not usually found. The compatible guest species occupy the interstitial cavities and hydrogen-bond with the brucine host structure, while water or other molecules of solvation may also be accommodated in the channels. Thus the solvates of brucine, such as brucine–ethanol–water (1/1/2) (Glover *et al.*, 1985), brucine–propan-2-ol–water (1/1/2) (Białońska & Ciunik, 2004*b*) and brucine–acetone (1/1) (Białońska & Ciunik, 2004*b*), may be considered as host–guest compounds.

Our particular interest lies in the hydrogen bonding in proton-transfer compounds of achiral aromatic carboxylic acids with Lewis bases, and both brucine and strychnine (pK_{a2} = 11.7) presented interesting possibilities for a molecular recognition study. A limited number of crystal structures of proton-transfer compounds of mostly brucine with achiral carboxylic acids have been reported, *e.g.* with fumaric and maleic acids (brucine) (Dijksma *et al.*, 1998), 4-hydroxybenzoic acid (brucine) (Sada *et al.*, 1998), 3-nitrobenzoic acid (brucine) (Oshikawa *et al.*, 2002) and 2,2′-dimethoxy-1-oxonaphthalene-4-carboxylic acid (brucine) (Cheung *et al.*, 1999). Similar proton-transfer brucine compounds with 2,2′-bis(3-phenyl-1-naphthol)phosphoric acid (Bao *et al.*, 1996), and 4-nitrophenol (Guo *et al.*, 2001) and 8-aminonaphthalene-2-sulfonic acid (strychnine) (Smith, Wermuth, Healy & Young, 2005), have also been reported. Oshikawa *et al.* (2002) observed that brucine had a recognitive affinity for the *meta*-substituted nitro-, chloro- and bromo-substituted benzoic acids but not the *ortho*- or *para*-isomers. This fact prompted us to look at the reactions of substituted salicylic acids. We subsequently prepared and established the crystal structures of the brucinium compounds with 5-nitrosalicylic acid, 3,5-dinitrosalicylic acid and 5-sulfosalicylic acid (Smith, Wermuth & Healy, 2005), as well as those of the strychninium compounds with 5-nitrosalicylic acid and 3,5-dinitrosalicylic acid (Smith, Wermuth & White, 2005).



(I)

3-Nitrophthalic acid (NPA) may be considered a special example of a *meta*-substituted benzoic acid and has been reported to a limited extent from structural studies on its proton-transfer compounds, *e.g.* the 3-nitrohydrogenphthalates of 3-iodoaniline (Glidewell *et al.*, 2005) and 4-iodoaniline (Glidewell *et al.*, 2003*b*) (both 1:1), and the (1:1) piperazine salt (Guo, 2004), in which the phthalate is dianionic. We therefore reacted 3-nitrophthalic acid with brucine in 50% ethanol–water, resulting in the formation of large orange–yellow crystals of the title compound, (I). No crystalline product was given in a parallel reaction with strychnine.

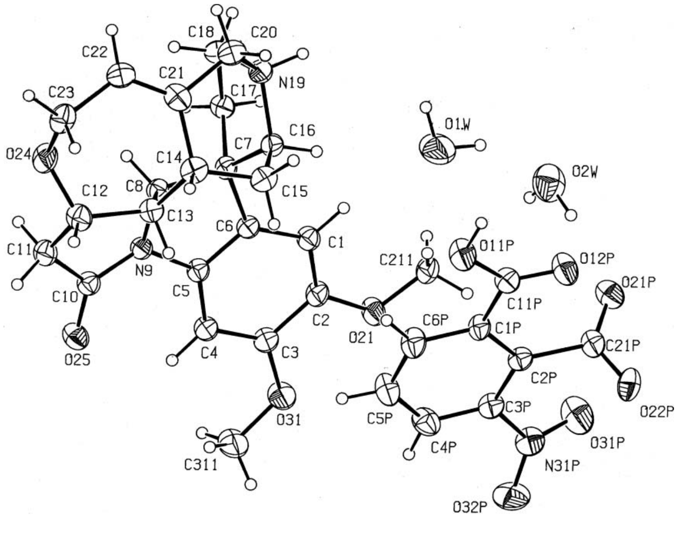


Figure 1

Molecular configuration and atom-numbering scheme for the brucinium cation, the 3-NPA anion and the two water molecules in (I). Non-H atoms are shown as 30% probability displacement ellipsoids.

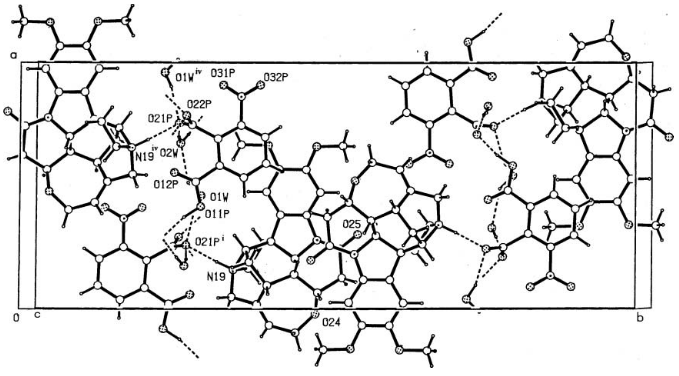


Figure 2

The packing of (I) in the unit cell, viewed down the *c* axis, showing the catemeric chains of screw-related NPA anions along the *a* axis with their associated water molecules and the peripheral hydrogen-bonded brucinium cations. Hydrogen-bonding associations are shown as broken lines. [Symmetry code: (iv) $x + \frac{1}{2}, -y + \frac{1}{2}, -z + 1$. For others, see Table 1.]

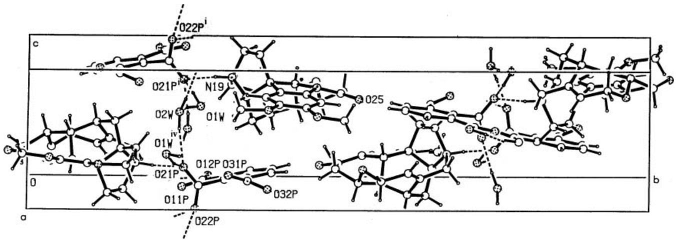


Figure 3

The unit-cell contents viewed down the *a* axis, showing the layered nature of the cations and anions down *c*, consistent with the perfect crystal cleavage across that direction.

In (I), the expected proton transfer to N19 of the brucine ring occurs (Fig. 1). The introduction of a new chiral centre at N19 (*S*) gives for the brucinium cations the overall Cahn–Ingold–Prelog configuration (Eliel, 1962) as C7(*S*), C8(*S*), C12(*S*), C13(*R*), C14(*R*), C16(*S*), N19(*S*), common to all proton-transfer compounds of both brucine and strychnine. The brucinium donor group (N19) then forms a single cation–anion hydrogen bond (Table 1) with one of the carboxylate O-atom acceptors (O21*P*) of the deprotonated acid group at C2 of the hydrogenphthalate anion. These anions form a two-dimensional hydrogen-bonding network parallel to (010) (Figs. 2 and 3) comprising primary head-to-tail catemeric hydrogen-bonded carboxylic acid–carboxylate chains along the *a* axis (O11*P*—H11*P*···O22*P*^{ii}; for symmetry code, see Table 1), together with water–carboxylate and water–water interactions. There are no intermolecular associations involving O-atom acceptors of the nitro group or the second carboxylic acid O atom (O12*P*). The brucinium cations are peripherally attached to the hydrogen-bonded sheet structures *via* an N—H···O hydrogen bond. The organic cations and anions lie approximately parallel to the (001) plane. This is consistent with the perfect cleavage of (I) across the prism axis (*c* axis).

Within the anion in (I), the structural features are similar to those found in the known 3-nitrohydrogenphthalate salts (Glidewell *et al.*, 2003*b*, 2005). The deprotonated C2 carboxylate group is approximately perpendicular to the benzene ring [C1*P*–C2*P*–C21*P*–O22*P* = 102.1 (5)°], while the C1 carboxylic acid group is essentially coplanar [C2*P*–C1*P*–C11*P*–O11*P* = 178.3 (4)°]. However, unlike the parent acid (Glidewell *et al.*, 2003*a*), where the C3 nitro group is also almost coplanar with the benzene ring, in (I) this group is inclined [C2*P*–C3*P*–N31*P*–O32*P* = 152.3 (5)°].

Experimental

The title compound (I) was synthesized by heating 1 mmol quantities of brucine and 3-nitrophthalic acid (NPA) in 50% ethanol–water (50 ml) for 10 min under reflux. After concentration to *ca* 30 ml, partial room-temperature evaporation of the hot-filtered solution gave yellow–orange pseudo-hexagonal prisms of (I) (m.p. 491.4–494.4 K).

Crystal data

$C_{23}H_{27}N_2O_4^+ \cdot C_8H_4NO_6^- \cdot 2H_2O$
$M_r = 641.62$
Orthorhombic, $P2_12_12_1$
$a = 12.7001\ (14)$ Å
$b = 32.015\ (5)$ Å
$c = 7.3041\ (19)$ Å
$V = 2969.8\ (10)$ Å^3
$Z = 4$
$D_x = 1.435$ Mg m^{-3}

Mo $K\alpha$ radiation
Cell parameters from 25 reflections
$\theta = 12.7–17.2°$
$\mu = 0.11$ mm^{-1}
$T = 297\ (2)$ K
Prism, orange–yellow
0.40 × 0.35 × 0.35 mm

Data collection

Rigaku AFC-7*R* diffractometer
ω–2θ scans
Absorption correction: none
5089 measured reflections
3974 independent reflections
2953 reflections with $F^2 > 2\sigma(F)^2$
$R_{\rm int} = 0.028$

$\theta_{\rm max} = 27.7°$
$h = -7 \rightarrow 16$
$k = -41 \rightarrow 18$
$l = -4 \rightarrow 9$
3 standard reflections
frequency: 150 min
intensity decay: 2.1%

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)] = 0.065$
$wR(F^2) = 0.179$
$S = 1.17$
3974 reflections
424 parameters
H atoms treated by a mixture of independent and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.1P)^2 + 0.4458P]$
where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{\rm max} = 0.002$
$\Delta\rho_{\rm max} = 0.42$ e Å^{-3}
$\Delta\rho_{\rm min} = -0.36$ e Å^{-3}
Extinction correction: *SHELXL97*
Extinction coefficient: 0.0072 (15)

Table 1
Hydrogen-bond geometry (Å, °).

D—H···A	D—H	H···A	D···A	D—H···A
N19—H19···O21$P^{\rm i}$	0.96 (5)	1.82 (5)	2.776 (5)	174 (4)
O11P—H11P···O22$P^{\rm ii}$	1.01 (9)	1.57 (9)	2.563 (5)	169 (9)
O1W—H11W···O2W	0.95	2.08	2.919 (6)	146
O1W—H12W···O21$P^{\rm i}$	1.01	1.98	2.921 (5)	153
O2W—H21W···O22$P^{\rm iii}$	0.93	2.06	2.984 (6)	177
O2W—H22W···O21P	0.89	2.06	2.943 (6)	172

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

H atoms potentially involved in hydrogen-bonding interactions were located in difference-density maps, but with the exception of atoms H11*P* and H19 their positional and isotropic displacement parameters were not refined. Other H atoms were positioned geometrically and treated as riding in the refinement, with $U_{\rm iso}$(H) = $1.2U_{\rm eq}$(C) (C—H = 0.95–0.98 Å and O—H = 0.89–1.01 Å). The atom-numbering scheme (Fig. 1) follows the original Robinson convention (Holmes, 1952). Friedel-pair reflections were merged, since the anomalous scattering effect was negligible. The absolute configuration determined for the parent strychnine (Peerdeman, 1956) was invoked, giving for the protonated species the overall Cahn–Ingold–Prelog absolute stereochemistry [C7(*S*), C8(*S*), C12(*S*), C13(*R*), C14(*R*), C16(*S*), N19(*S*)].

Data collection: *MSC*/*AFC Diffractometer Control Software* (Molecular Structure Corporation, 1999); cell refinement: *MSC*/*AFC Diffractometer Control Software*; data reduction: *TEXSAN for Windows* (Molecular Structure Corporation, 1999); program(s) used to solve structure: *SIR92* (Altomare *et al.*, 1994); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 2003); software used to prepare material for publication: *PLATON*.

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