

Cyclic trihydroxamic acid derivatives

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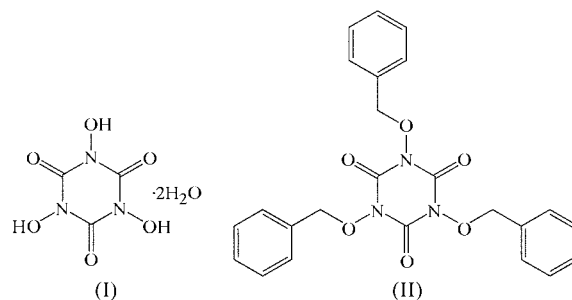
In the crystal structures of two cyclic trihydroxamic acid derivatives containing the same substructure unit, *viz.* 1,3,5-trihydroxy-1,3,5-triazinane-2,4,6-trione dihydrate, C₃H₃N₃O₆·2H₂O, (I), and 1,3,5-benzyloxy-1,3,5-triazinane-2,4,6-trione, C₂₄H₂₁N₃O₆, (II), there is no significant difference in the geometric parameters. In (I), there are 11 hydrogen bonds of the O—H···O type interconnecting the molecules in a three-dimensional network, while in (II) there are only two weak C—H···O hydrogen bonds. The results of IR spectroscopic analysis are in good agreement with the crystallographic study.

Comment

1,3,5-Trihydroxy-1,3,5-triazinane-2,4,6-trione has recently been applied as an aerobic oxidation catalyst (Hirai *et al.*, 2003, 2004). Jadrijević-Mladar Takač *et al.* (2006) reported for this compound and its derivatives (acetyl and pivaloyl esters) physico-chemical analyses and properties, such as pK_a, FT-IR, NMR, MS and TGA, and indicated some metal binding properties. Caira *et al.* (2006) investigated the ability of this compound to act as a host for a series of solvents. Among other triazinones and numerous cyclic amines, the compound has already been involved in the investigation of sulfur dioxide removal from fluids containing SO₂ (Christiansen *et al.* 1992). On the other hand, using a pharmacophore query developed through a molecular modelling study of a class of known HIV-1 integrase inhibitors, the oxygen-substituted derivative 1,3,5-trihydroxymethyl-1,3,5-triazinane-2,4,6-trione has been observed as one of the four most potent candidates (IC₅₀ < 30 μmol dm⁻³), with the triazinone molecule being a promising lead compound for the development of new anti-AIDS drugs.

Although the structure of 1,3,5-trihydroxy-1,3,5-triazinane-2,4,6-trione hosting three dimethylformamide molecules has already been published (Caira *et al.*, 2006), no X-ray data for 1,3,5-trihydroxy-1,3,5-triazinane-2,4,6-trione dihydrate, (I), have been published so far. Therefore, as part of our work on the structure evaluation of hydroxamic acids (Matković-

Čalogović *et al.*, 2003; Đilović *et al.*, 2006), we present here the crystal structures of (I) and its precursor 1,3,5-benzyloxy-1,3,5-triazinane-2,4,6-trione, (II), as examples of unsubstituted and substituted cyclic trihydroxamic acids.



There is no significant difference in the bond distances and angles in (I) and (II) (Tables 1 and 3). The geometric parameters are comparable to the corresponding values reported in the literature (Larsen, 1976; Đilović *et al.*, 2006). The six-membered heterocyclic rings are almost planar [the largest displacements of the C and N atoms from the mean planes of the triazine rings are, respectively, 0.031 (1) and 0.023 (1) Å for (I), and 0.024 (1) and 0.029 (1) Å for (II)], but show considerable deviation from the ideal hexagonal form. The internal C—N—C angles are considerably greater than 120° [the minimum and maximum values are 126.91 (10) and 128.05 (14)°], while the internal N—C—N angles are smaller than 120° [the minimum and maximum values are 111.94 (14) and 112.87 (10)°]. Thus, aromaticity is achieved only by the contribution of lone-pair electrons located at the N atoms.

The crystal packing of (I) is characterized by strong hydrogen-bonding interactions between the host and water molecules (Fig. 3 and Table 2). Voids in the crystal structure of the host molecule are occupied by water molecules which ‘transfer’ the hydrogen-bond interactions throughout the crystal structure, interconnecting the molecules into an infinite three-dimensional framework.

Comparison of *N,N,N'*-tribenzyloxydicarbonimidic diamide (Đilović *et al.*, 2006) with (II) reveals a difference in the crystal packing of two molecules containing the (CO)₂NO-CH₂C₆H₅ substructure unit in non-cyclic and cyclic systems.

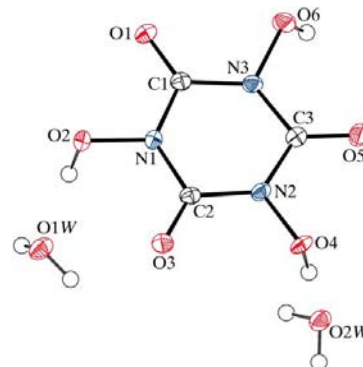


Figure 1

A view of the molecular structure of (I), showing the atom-labelling scheme and displacement ellipsoids at the 50% probability level.

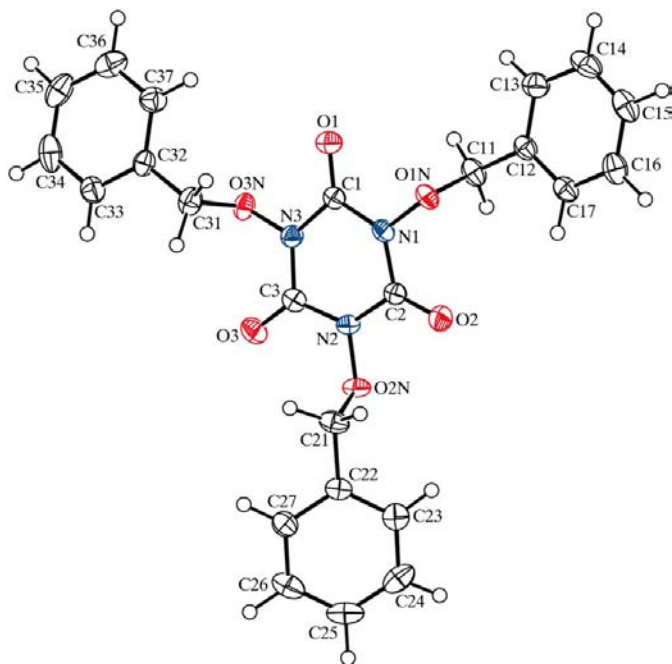


Figure 2
A view of the molecular structure of (II), showing the atom-labelling scheme and displacement ellipsoids at the 50% probability level.

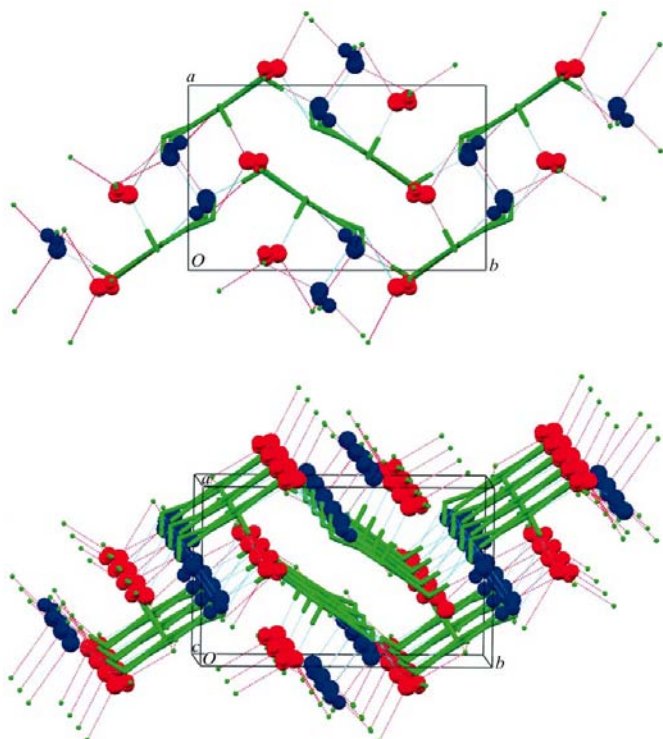


Figure 3
Two views of the crystal packing of (I). Hydrogen bonds are indicated with dashed lines. Water molecules are represented in ball-and-stick style, while the other molecules are represented in capped-stick style. All molecules are coloured by symmetry equivalence.

Because of the conformation, molecules of (II) are packed into 'stepwise' chains with dominating weak hydrogen-bond interactions (Fig. 4 and Table 4) and relatively close H...H

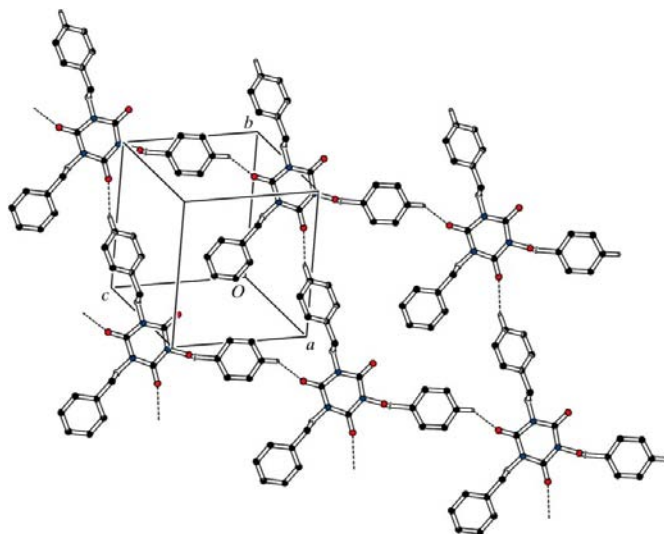


Figure 4
The crystal packing of (II). Only one layer of molecules is shown. Hydrogen bonds are indicated with dashed lines and H atoms not involved in hydrogen bonds have been omitted.

contacts (2.283 Å). Chains parallel to the crystallographic plane (111) are connected through π - π (3.340 Å) and C-H... π interactions (2.891 Å). The presence of additional conformational freedom in the non-cyclic system results in sheets of centrosymmetric dimers, which are interconnected by strong hydrogen bonds. In addition to the above-mentioned interactions, C-H... π contacts between the terminal phenyl groups and weaker hydrogen-bond interactions are also present in the crystal structure.

Experimental

Compounds (I) and (II) were synthesized according to a previously published procedure (Butula *et al.*, 2000). The structure and purity of both were confirmed by means of thin-layer chromatography, FT-IR and NMR analysis. Compound (I) was crystallized from a saturated acetone/diethyl ether (9:1) solution and (II) from a saturated acetone/diethyl ether (1:1) solution by slow evaporation at room temperature (beakers containing each solution were covered with aluminium foil to slow down evaporation). Colourless crystals of good quality were obtained after three weeks, and these were stable for months when exposed to the atmosphere.

Compound (I)

Crystal data

$C_3H_3N_3O_6 \cdot 2H_2O$
 $M_r = 213.12$
 Monoclinic, $P2_1/a$
 $a = 7.5109$ (12) Å
 $b = 11.9244$ (17) Å
 $c = 8.1794$ (12) Å
 $\beta = 98.405$ (13)°
 $V = 724.70$ (19) Å³

$Z = 4$
 $D_x = 1.953$ Mg m⁻³
 Mo $K\alpha$ radiation
 $\mu = 0.20$ mm⁻¹
 $T = 113$ (2) K
 Prism, colourless
 $0.50 \times 0.43 \times 0.36$ mm

Data collection

Oxford Diffraction Xcalibur CCD
 diffractometer
 ω scans
 4408 measured reflections

1634 independent reflections
 1451 reflections with $I > 2\sigma(I)$
 $R_{int} = 0.015$
 $\theta_{max} = 27.5^\circ$

Refinement

Refinement on F^2
 $R[F^2 > 2\sigma(F^2)] = 0.034$
 $wR(F^2) = 0.088$
 $S = 1.12$
 1634 reflections
 157 parameters
 All H-atom parameters refined

$$w = 1/[\sigma^2(F_o^2) + (0.0432P)^2 + 0.3604P]$$

where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\max} = 0.001$
 $\Delta\rho_{\max} = 0.28 \text{ e } \text{\AA}^{-3}$
 $\Delta\rho_{\min} = -0.23 \text{ e } \text{\AA}^{-3}$

Table 1

Selected geometric parameters (\AA , $^\circ$) for (I).

C1—O1	1.2084 (15)	C2—N1	1.3804 (16)
C1—N1	1.3808 (16)	C3—O3	1.2063 (15)
C1—N3	1.3814 (16)	C3—N2	1.3809 (16)
C2—O2	1.2071 (16)	C3—N3	1.3843 (16)
C2—N2	1.3802 (16)		
C1—N3—C3	127.27 (11)	N1—C1—N3	112.43 (10)
C2—N1—C1	127.48 (11)	N2—C2—N1	112.87 (10)
C2—N2—C3	126.91 (10)	N2—C3—N3	112.80 (10)

Table 2

Hydrogen-bond geometry (\AA , $^\circ$) for (I).

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
O1N—H1O \cdots O1W ⁱ	0.88 (2)	2.39 (2)	3.0060 (15)	127 (2)
O1N—H1O \cdots O2W ⁱⁱ	0.88 (2)	2.05 (2)	2.7758 (15)	140 (2)
O2N—H2O \cdots O2W ⁱⁱⁱ	0.89 (2)	1.69 (2)	2.5803 (14)	175 (2)
O3N—H3O \cdots O1W ⁱⁱⁱ	0.84 (2)	1.73 (2)	2.5754 (15)	173 (2)
O1W—H11W \cdots O1 ^{iv}	0.86 (3)	2.05 (2)	2.8889 (15)	165 (2)
O1W—H11W \cdots O1N ^{iv}	0.86 (3)	2.45 (2)	2.9775 (14)	120 (2)
O1W—H12W \cdots O2	0.82 (2)	1.96 (2)	2.7685 (14)	170 (2)
O2W—H21W \cdots O2N ^v	0.82 (2)	2.35 (2)	3.0294 (15)	141 (2)
O2W—H21W \cdots O3 ^v	0.82 (2)	2.11 (2)	2.8052 (14)	144 (2)
O2W—H22W \cdots O1N	0.80 (2)	2.54 (2)	3.1543 (15)	136 (2)
O2W—H22W \cdots O3N ^{vi}	0.80 (2)	2.21 (2)	2.8544 (14)	138 (2)

Symmetry codes: (i) $-x, -y + 1, -z + 1$; (ii) $x - \frac{1}{2}, -y + \frac{3}{2}, z$; (iii) $-x + \frac{1}{2}, y - \frac{1}{2}, -z + 1$; (iv) $x, y, z - 1$; (v) $-x + 1, -y + 1, -z + 1$; (vi) $-x + 1, -y + 1, -z + 2$.

Compound (II)

Crystal data

$C_{24}H_{21}N_3O_6$
 $M_r = 447.44$
 Triclinic, $P\bar{1}$
 $a = 7.765$ (2) \AA
 $b = 12.139$ (3) \AA
 $c = 12.783$ (3) \AA
 $\alpha = 66.36$ (2) $^\circ$
 $\beta = 76.78$ (2) $^\circ$
 $\gamma = 82.79$ (2) $^\circ$

Data collection

Oxford Diffraction Xcalibur CCD diffractometer
 ω scans
 8404 measured reflections

Refinement

Refinement on F^2
 $R[F^2 > 2\sigma(F^2)] = 0.055$
 $wR(F^2) = 0.167$
 $S = 1.05$
 4600 reflections
 382 parameters

$V = 1073.8$ (5) \AA^3
 $Z = 2$
 $D_x = 1.384$ Mg m^{-3}
 Mo $K\alpha$ radiation
 $\mu = 0.10$ mm^{-1}
 $T = 113$ (2) K
 Prism, colourless
 $0.82 \times 0.68 \times 0.44$ mm

All H-atom parameters refined
 $w = 1/[\sigma^2(F_o^2) + (0.1119P)^2]$
 where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\max} < 0.001$
 $\Delta\rho_{\max} = 0.53 \text{ e } \text{\AA}^{-3}$
 $\Delta\rho_{\min} = -0.35 \text{ e } \text{\AA}^{-3}$

Table 3

Selected geometric parameters (\AA , $^\circ$) for (II).

C1—O1	1.201 (2)	C2—N1	1.383 (2)
C1—N1	1.385 (2)	C3—O3	1.203 (2)
C1—N3	1.386 (2)	C3—N3	1.389 (2)
C2—O2	1.206 (2)	C3—N2	1.392 (2)
C2—N2	1.383 (2)		
N1—C1—N3	112.21 (14)	C2—N1—C1	128.05 (14)
N2—C2—N1	111.96 (14)	C2—N2—C3	127.98 (14)
N3—C3—N2	111.94 (14)	C1—N3—C3	127.62 (14)

Table 4

Hydrogen-bond geometry (\AA , $^\circ$) for (II).

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
C15—H15 \cdots O3 ⁱ	1.02 (2)	2.54 (2)	3.350 (3)	136 (2)
C25—H25 \cdots O1 ⁱⁱ	1.00 (2)	2.46 (3)	3.423 (3)	161 (2)

Symmetry codes: (i) $x + 1, y, z - 1$; (ii) $x - 1, y + 1, z$.

The positions of H atoms were obtained from a difference Fourier map and they were included in the refinement process with isotropic displacement parameters [$C-H = 0.92$ (2)– 1.05 (2) \AA].

For both compounds, data collection: *CrysAlis CCD* (Oxford Diffraction, 2003); cell refinement: *CrysAlis CCD*; data reduction: *CrysAlis RED* (Oxford Diffraction, 2003); program(s) used to solve structure: *SHELXS97* (Sheldrick, 1990); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *MERCURY* (Macrae *et al.*, 2006) [for (I) only] and *ORTEP-3* (Farrugia, 1997); software used to prepare material for publication: *PLATON* (Spek, 2003).

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: AV3046). Services for accessing these data are described at the back of the journal.

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