

Pseudopolymorphism in hydroxybenzophenones: the dihydrate of 2,2',4,4'-tetrahydroxybenzophenone

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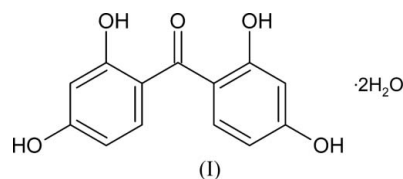
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A dihydrate pseudopolymorph of bis(2,4-dihydroxyphenyl)methanone, $C_{13}H_{10}O_5 \cdot 2H_2O$, (I), was obtained during polymorphism screening of hydroxybenzophenone derivatives. This structure, in which the molecule sits on a twofold axis, was compared with the known anhydrous form of (I) [Schlemper (1982). *Acta Cryst.* B38, 554–559]. The role of water in the crystal assembly was established on the basis of the known monohydrate pseudopolymorph of 3,4-dihydroxybenzophenone [Landre, Souza, Corrêa, Martins & Doriguetto (2010). *Acta Cryst.* C66, o463–o465].

Comment

To increase our knowledge of polymorphism in molecular compounds and pharmaceuticals (Legendre *et al.*, 2012; Bonfilio *et al.*, 2012; Martins, Bocelli *et al.*, 2009; Martins, Papatidis *et al.*, 2009; Martins, Doriguetto & Ellena, 2010; Martins, Legendre *et al.*, 2010; Martins, Dos Santos *et al.*, 2011; Martins, Lima *et al.*, 2011; Landre *et al.*, 2010; Corrêa *et al.*, 2006; Doriguetto *et al.*, 2004), we have studied 2,2',4,4'-tetrahydroxybenzophenone. Hydroxybenzophenones are found in sun-screening compounds in a variety of plastics and synthetic fabrics, due to their absorption bands in the near-UV (Furukawa *et al.*, 1995; Ito *et al.*, 1994; Onishi *et al.*, 1987). They have also shown anti-inflammatory and anti-oxidant activity (Doriguetto *et al.*, 2007). Structural relationships and the role of water in crystal assembly have been established on the basis of the anhydrous (Cox *et al.*, 2008) and monohydrate (Landre *et al.*, 2010) forms of 3,4-dihydroxybenzophenone. In the present study, a monoclinic dihydrate pseudopolymorph of 2,2',4,4'-tetrahydroxybenzophenone, (I), is reported in the space group $C2/c$ and compared with its known anhydrous form [space group $P\bar{1}$; cell parameters $a = 9.950$ (2), $b =$

12.479 (2), $c = 9.334$ (1) Å, $\alpha = 98.80$ (1), $\beta = 93.22$ (1), $\gamma = 72.45$ (1)°, $V = 1091.9$ Å³; Schlemper, 1982].



In the chosen asymmetric unit, the molecule (Fig. 1) sits on a twofold axis at $(\frac{1}{2}, y, \frac{1}{4})$, with the $C7=O1$ carbonyl group residing on the symmetry element. The two solvent water molecules per benzophenone molecule in (I) are related by symmetry.

The extended least-squares plane through the aromatic ring (r.m.s. deviation = 0.0216 Å; ring A in Fig. 1) also nearly incorporates the exocyclic atoms O1, O2, O3 and C7, which deviate from the plane by -0.055 (2), 0.328 (2), 0.115 (2) and 0.042 (2) Å, respectively. The least-squares planes through rings A and B form an angle of 35.36 (7)°. This value is smaller than those observed in 2,2',4-trihydroxybenzophenone [44.74 (6)°; Doriguetto *et al.*, 2007] and 3,4-dihydroxybenzophenone [56.3 (4)°; Landre *et al.*, 2010]. It represents a compromise between steric hindrance involving the 6- and 6'-positions, which mitigates for a larger angle, and the combination of the intramolecular hydrogen bonding to the carbonyl group and the presence of the OH group at the 4-position, which mitigate towards smaller dihedral angles. Comparing these three different benzophenones, it is possible to conclude that the angle between the rings is smaller in (I) than in 2,2',4-trihydroxybenzophenone due to the former having an extra OH group at the 4'-position. The largest dihedral angle observed, that in 3,4-dihydroxybenzophenone, is due to the absence of an acceptor-bifurcated intramolecular hydrogen bond and of conjugation effects involving hydroxy groups *para* to the carbonyl group. However, when the angle

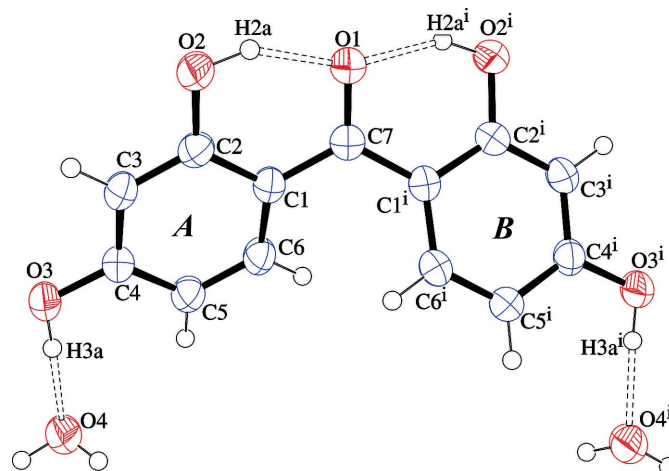


Figure 1

The molecular structure of (I), showing the atom-numbering scheme. Displacement ellipsoids are drawn at the 50% probability level and dashed lines indicate hydrogen bonds. [Symmetry code: (i) $-x + 1, y, -z + \frac{1}{2}$]

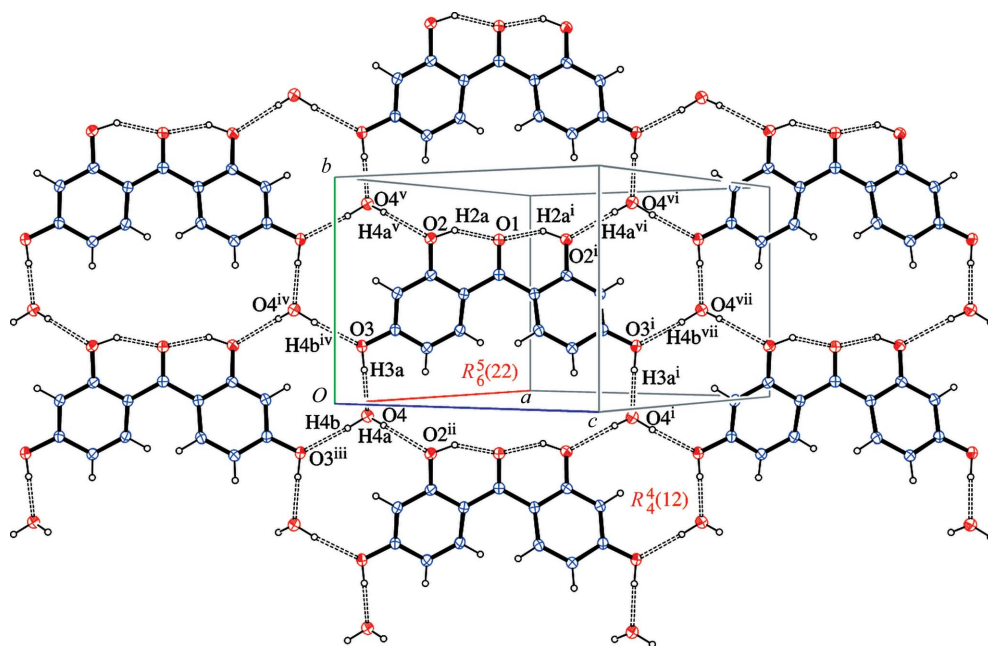


Figure 2

The packing of (I), projected onto $(20\bar{1})$. Hydrogen bonds are shown as dashed lines. [Symmetry codes: (i) $-x + 1, y, -z + \frac{1}{2}$; (ii) $x, y - 1, z$; (iii) $-x + \frac{1}{2}, y - \frac{1}{2}, -z - \frac{1}{2}$; (iv) $-x + \frac{1}{2}, y + \frac{1}{2}, -z - \frac{1}{2}$; (v) $x, y + 1, z$; (vi) $-x + 1, y + 1, -z + \frac{1}{2}$; (vii) $x + \frac{1}{2}, y + \frac{1}{2}, z + 1$.]

between the rings in (I) is compared with that in its anhydrous form (Schlemper, 1982), it is possible to conclude, as expected, that the molecular shape does not necessarily manifest itself in a predictable manner in the crystal structure in terms of only intramolecular forces. The two benzophenone molecules present in the asymmetric unit of the anhydrous form of (I) have angles between rings A and B of 41.7 and 43.5°, which are similar to the value observed in 2,2',4-trihydroxybenzophenone (Doriguetto *et al.*, 2007). Therefore, the deviation from planarity of the two-ring system in hydroxybenzophenones is the result of a delicate balance between a range of intra- and intermolecular forces. From the present study and that reported by Landre *et al.* (2010), the solvent water molecule appears to play an important role in both the packing and the molecular shape of the hydroxybenzophenone molecule.

Another important conformational difference between the anhydrous and hydrated forms of (I) is the *para*-hydroxy H-atom orientations. In (I) (Fig. 1), both *para*-hydroxy O—H bonds are oriented *anti* to the C7—O1 carbonyl group. In the anhydrous form, one of the two molecules present in the asymmetric unit has both O—H bonds at the 4- and 4'-positions *syn* to the analogous carbonyl group. The second molecule in the anhydrous form has one *para*-position O—H bond *syn* to the carbonyl group and the other *anti* to it. Thus, the orientation of the hydroxy H atoms in hydroxybenzophenone is a result of crystal packing forces or intermolecular bonding motifs, with the water in the structure once again playing an important role in this intramolecular feature.

The intramolecular geometry of (I) was also analysed using *Mogul* (Bruno *et al.*, 2004), a knowledge base of molecular geometry derived from the Cambridge Structural Database (CSD; Allen, 2002). This analysis revealed that the C1—C7

single bond is shorter than the average value [mean = 1.49 (2) Å and C1—C7 = 1.4644 (16) Å], while the C7=O1 double bond is longer than expected [mean = 1.23 (2) and C7=O1 = 1.260 (2) Å]. This geometric feature is due to a resonance phenomenon caused by conjugation between the C7=O1 carbonyl group and rings A and B. The small O1—C7—O1—C2 torsion angle [-18.33 (14)°] corroborates this conjugation. Therefore, resonance-assisted hydrogen bonds (RAHBs) (Gilli *et al.*, 1989) occur around the carbonyl and both *ortho*-hydroxy groups. The intramolecular hydrogen-bond geometry (Table 1) agrees well with that found by Schlemper (~2.6 Å) for the anhydrous form.

The packing of (I) is governed by an infinite planar two-dimensional network in the $(20\bar{1})$ plane, stabilized by intermolecular hydrogen bonds (Fig. 2). There are no direct hydrogen bonds between molecules of (I); all three intermolecular hydrogen bonds involve water (O4 in Fig. 2, Table 1). These interactions bridge the *para*-OH group of one

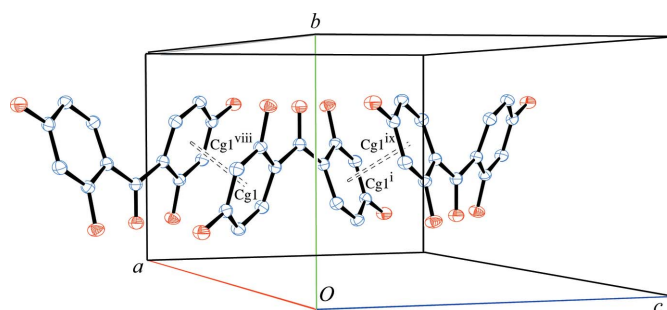


Figure 3

The aromatic rings of (I), linked along the $[001]$ direction via π — π interactions. H atoms have been omitted for clarity. Centroid—centroid ($Cg \cdots Cg$) separations are shown as dashed lines. [Symmetry codes: (i) $-x + 1, y, -z + \frac{1}{2}$; (viii) $-x + 1, -y + 1, -z$; (ix) $x, -y + 1, z + \frac{1}{2}$.]

molecule (O3, Fig. 2) and the *ortho*-OH group (O2ⁱⁱ) of the molecule related by a translation of [010] (symmetry code defined in the caption of Fig. 2). The aggregation in (201) includes R₆⁵(22) and R₄⁴(12) assemblies (Fig. 2) [see Bernstein *et al.* (1995) for nomenclature of hydrogen-bond motifs]. The two-dimensional networks parallel to (201) are themselves connected along the [001] direction *via* π - π interactions (Fig. 3), completing the three-dimensional network. The centroids of the aromatic rings are 3.703 (1) Å apart, with a substantial slippage of 1.374 Å, which indicates that these π - π interactions are weak.

Experimental

Commercial 2,2',4,4'-tetrahydroxybenzophenone (Sigma-Aldrich) was used. Colourless prismatic crystals of (I) were obtained from a water-methanol solution (1:1 v/v) by slow evaporation at room temperature.

Crystal data

C ₁₃ H ₁₀ O ₅ ·2H ₂ O	V = 1278.57 (8) Å ³
M _r = 282.24	Z = 4
Monoclinic, C2/c	Mo K α radiation
a = 15.1394 (4) Å	μ = 0.12 mm ⁻¹
b = 7.7629 (3) Å	T = 295 K
c = 11.0690 (4) Å	0.05 × 0.05 × 0.05 mm
β = 100.628 (2)°	

Data collection

Nonius KappaCCD area-detector diffractometer	1240 independent reflections
7103 measured reflections	981 reflections with I > 2 σ (I)
	R _{int} = 0.051

Refinement

R[F ² > 2 σ (F ²)] = 0.043	H atoms treated by a mixture of independent and constrained refinement
wR(F ²) = 0.126	$\Delta\rho_{\max}$ = 0.14 e Å ⁻³
S = 1.04	$\Delta\rho_{\min}$ = -0.15 e Å ⁻³
1240 reflections	
101 parameters	

Aromatic H atoms were observed in a difference Fourier synthesis but were refined using a riding model, with C-H = 0.93 Å and U_{iso}(H) = 1.2U_{eq}(C). Hydroxy H atoms were located by difference Fourier synthesis and refined with free coordinates and with U_{iso}(H) = 1.5U_{eq}(O). Water H atoms were placed in positions located in a difference Fourier map, and then the water molecule was refined as a rigid group, with U_{iso}(H) = 1.5U_{eq}(O4). Two reflections (110 and 111) were omitted from the refinement because their intensities appeared to be significantly reduced behind the shadow of the beam-stop.

Data collection: COLLECT (Nonius, 1999); cell refinement: SCALEPACK (Otwinowski & Minor, 1997); data reduction: DENZO (Otwinowski & Minor, 1997) and SCALEPACK; program(s) used to solve structure: SHELXS97 (Sheldrick, 2008); program(s) used to refine structure: SHELXL97 (Sheldrick, 2008); molecular graphics: ORTEP-3 for Windows (Farrugia, 1997); software used to prepare material for publication: WinGX (Farrugia, 1999).

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Table 1

Hydrogen-bond geometry (Å, °).

D—H...A	D—H	H...A	D...A	D—H...A
O2—H2A...O1	0.94 (2)	1.71 (2)	2.556 (1)	150 (2)
O3—H3A...O4	0.88 (2)	1.75 (2)	2.636 (2)	176 (2)
O4—H4A...O2 ⁱⁱ	0.83	2.14	2.954 (2)	167
O4—H4B...O3 ⁱⁱⁱ	0.86	1.95	2.797 (2)	167

Symmetry codes: (ii) x, y - 1, z; (iii) -x + 1/2, y - 1/2, -z - 1/2.

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Supplementary data for this paper are available from the IUCr electronic archives (Reference: FA3271). Services for accessing these data are described at the back of the journal.

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