Acta Cryst E
CRYSTALLOGRAPHIC COMMUNICATIONS
ISSN 2056-9890

Crystal structure of 3,6-dihydroxy-4,5-dimethylbenzene-1,2-dicarbaldehyde

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Received 23 July 2018
Accepted 4 September 2018

Edited by L. Van Meervelt, Katholieke Universiteit Leuven, Belgium

Keywords: crystal structure; alkylating agents; chiral crystallization.

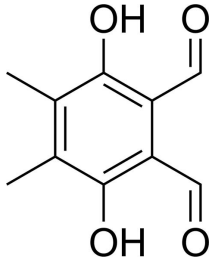
CCDC reference: 1865811

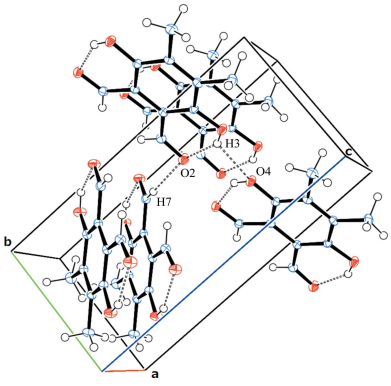
Supporting information: this article has supporting information at journals.iucr.org/e

The title compound, $C_{10}H_{10}O_4$, was synthesized from tetramethyl-1,4-benzoquinone. In the crystal, the almost planar molecule (r.m.s. deviation = 0.024 Å) forms intramolecular hydrogen bonds between the aldehyde and hydroxy groups and exhibits C_{2v} symmetry. This achiral molecule crystallizes in the chiral space group $P2_1$ with intermolecular O—H···O and C—H···O hydrogen bonding and C—H···π and C═O···π interactions stabilizing the crystal packing.

1. Chemical context

A number of benzo- and naphthoquinone derivatives with one or two side chains being capable of alkylation after reduction were found to exhibit inhibitory activity against the growth of transplantable tumours in mice. Furthermore, inhibition of nucleic acid biosynthesis and of the activities of coenzyme Q mediated enzyme systems are also known for related compounds composed of 3,6-dihydroxy-4,5-dimethylbenzene-1,2-dicarbaldehyde (Lin & Loo, 1977; Lin *et al.*, 1978). According to the literature, these compounds are synthesized from tetramethyl-1,4-benzoquinone (Lin & Loo, 1977; Lin *et al.*, 1978). Here we report the molecular and crystal structure of an achiral derviative crystallizing in a chiral space group.





2. Structural commentary

The molecular structure of the title compound consists of a benzene ring substituted by two methyl groups, two hydroxy groups and two aldehyde groups (Fig. 1). The molecular point group symmetry is C_{2v} (H atoms excluded). The C—C bond lengths of the methyl substituents are 1.511 (2) and 1.508 (2) Å, the C—O bond lengths of the hydroxy substituents are 1.354 (2) and 1.350 (2) Å, and the C—C bond lengths of the aldehyde substituents are 1.464 (2) and 1.462 (2) Å. Two intramolecular O—H···H hydrogen bonds between the hydroxy and aldehyde functions are observed

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

*Cg*1 is the centroid of ring C1–C6.

D—H···A	D—H	H···A	D···A	D—H···A
O3—H3···O2	0.84	1.87	2.6079 (19)	146
O4—H4···O1	0.84	1.82	2.5592 (19)	146
O3—H3···O4^{i}	0.84	2.40	3.036 (2)	133
O4—H4···O2^{ii}	0.84	2.34	2.809 (2)	116
C7—H7···O2^{iii}	0.95	2.51	3.427 (2)	162
C10—H10B···Cg1^{iv}	0.98	3.13	3.645	114

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

(Table 1 and Fig. 1). The molecule is essentially planar (r.m.s. deviation = 0.024 Å), with the largest deviation found for atom O2 [0.047 (1) Å].

3. Supramolecular features

In the crystal, molecules are connected along the *b* axis by O—H···O hydrogen bonds and along the *c* axis by C—H···O hydrogen bonds (Table 1 and Fig. 2). As a result, chiral crystals composed of achiral molecules are formed. Many examples of such chiral crystals forming from achiral molecules have been reported for decades, but the prediction of chiral crystallization is still impossible (Koshima & Matsuura, 1998; Matsuura & Koshima, 2005).

The C8═O2 carbonyl group is stacked on top of the aromatic ring, with the O2···*Cg*1 distance being 3.4846 (19) Å (*Cg*1 is the centroid of ring C1–C6).

In addition, a weak C—H···π interaction C10—H10B···*Cg*1 (3.131 Å) is also found (Table 1 and Fig. 3).

4. Database survey

A search in the Cambridge Structural Database (CSD, Version 5.39, update May 2018; Groom *et al.*, 2016) for similar 1,2-dicarbaldehyde structures returned five relevant entries: benzene-1,2-dicarbaldehyde [IHEMAJ (Britton, 2002) and IHEMAJ01 (Mendenhall *et al.*, 2003)], naphthalene-1,2-dicarbaldehyde (FIYQOT; Britton, 1999), a chromene-5,6-dicarbaldehyde derivative (IDUCUH; am Ende *et al.*, 2013) and a cobalt benzene-1,2-dicarbaldehyde complex (JUKZAQ; Lenges *et al.*, 1999). In the first four structures, the aldehyde functions show C—H···O interactions (H···O distances from 2.226 to 2.360 Å). This is not the case for the cobalt complex JUKZAQ, where the two aldehyde O atoms are facing each

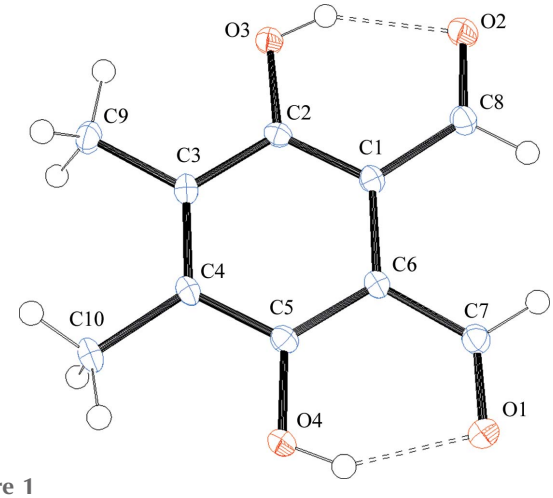

Figure 1
The molecular structure of the title compound, showing the atom-numbering scheme and displacement ellipsoids drawn at the 50% probability level.

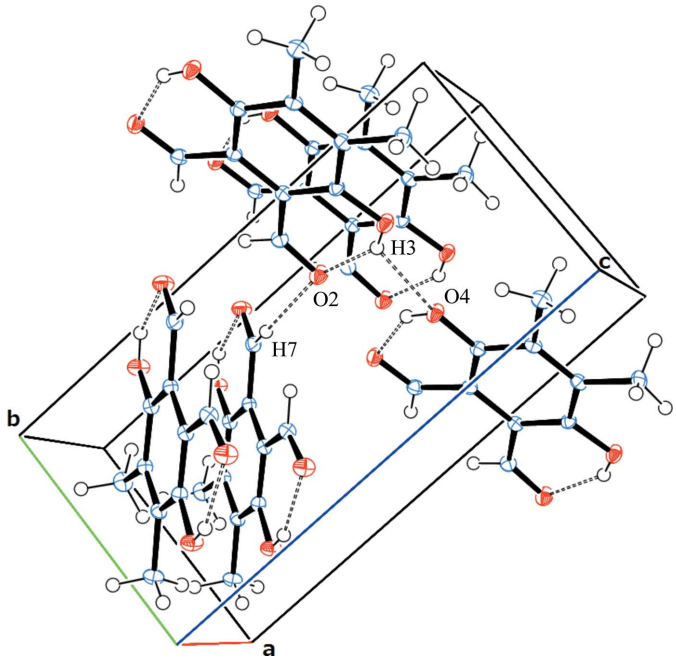

Figure 2
A view of the O—H···O hydrogen bonds (dashed lines) present in the crystal lattice of the title compound.

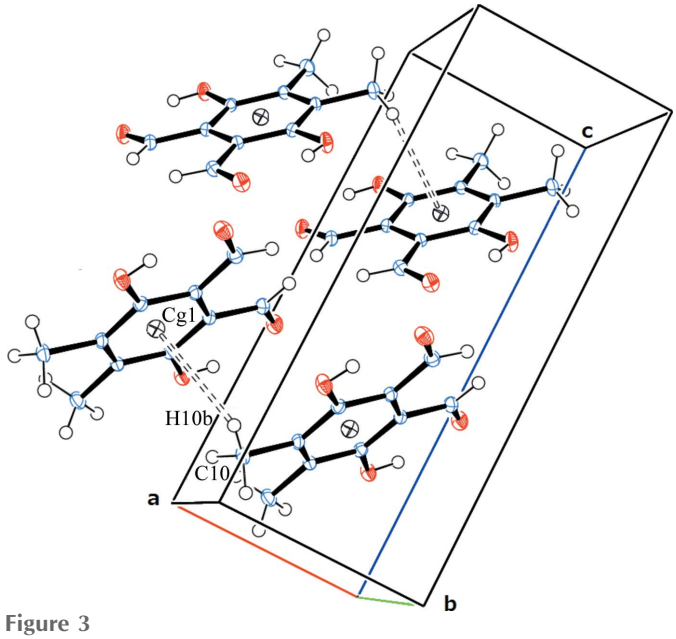

Figure 3
Part of the crystal packing showing the C—H···π stacking interactions.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{10}H_{10}O_4$
M_r	194.18
Crystal system, space group	Monoclinic, $P2_1$
Temperature (K)	100
a, b, c (Å)	5.251 (2), 6.317 (2), 12.999 (5)
β (°)	91.643 (4)
V (Å^3)	431.0 (3)
Z	2
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.12
Crystal size (mm)	0.38 × 0.30 × 0.13
Data collection	
Diffractometer	Bruker APEXII CCD
Absorption correction	Multi-scan (*SADABS*; Bruker, 2001)
T_{min}, T_{max}	0.785, 0.785
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	2328, 1228, 1207
R_{int}	0.014
$(\sin \theta/\lambda)_{max}$ (Å^{-1})	0.650
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.029, 0.082, 1.06
No. of reflections	1228
No. of parameters	131
No. of restraints	1
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.25, −0.22
Absolute structure	Flack x determined using 179 quotients $[(I^+)-(I^-)]/[(I^+)+(I^-)]$ (Parsons *et al.*, 2013)
Absolute structure parameter	0.5 (6)

Computer programs: *APEX2* and *SAINT* (Bruker, 2014), *SHELXT2014* (Sheldrick, 2015*a*), *SHELXL2014* (Sheldrick, 2015*b*), *SHELXTL* (Sheldrick, 2008), *WinGX* (Farrugia, 2012), *Mercury* (Macrae *et al.*, 2006) and *publCIF* (Westrip, 2010).

other and complexed with cobalt, nor with the title compound where the two aldehyde O atoms are involved in intramolecular hydrogen bonds and the two aldehyde H atoms are facing each other.

The intramolecular O—H···O interaction between the 1-carbaldehyde and 2-hydroxy groups is also observed in compounds such as 1,8-dihydroxy-2-naphthaldehyde (BABXUA; Peng *et al.*, 2015) and 2,4,6-trihydroxybenzene-1,3,5-tricarbaldehyde (WEPPUE; von Richthofen *et al.*, 2013).

5. Synthesis and crystallization

A mixture of tetramethyl-1,4-benzoquinone (2.0406 g, 12.4 mmol) and concentrated piperidine (98.0%, 35 ml) was stirred at room temperature for 35 h. The mixture was evaporated and a white intermediate product was obtained. To a solution of the obtained intermediate product dissolved in acetic acid (18 ml), a mixture of CrO_3 (1.77 g) and 50% acetic acid (35 ml) was added dropwise at 353 K. After 10 min, the reaction mixture was poured onto crushed ice (100 g). The solution was filtered by vacuum filtration and a crude compound was obtained. The crude compound was dissolved in toluene and purified by silica column chromatography to afford 0.567 g (yield 23.5%) of the title compound as a yellow solid (single crystals served for X-ray analysis). IR (KBr, cm^{-1}): 1633 (*s*), 3436 (*m*).

6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. All H atoms were located in difference Fourier maps. C-bound H atoms were constrained using a riding model [C—H = 0.98 Å and $U_{iso}(H) = 1.5U_{eq}(C)$ for methyl H atoms, and C—H = 0.95 Å and $U_{iso}(H) = 1.2U_{eq}(C)$ for the aldehyde H atoms]. O-bound H atoms were constrained using a riding model [O—H = 0.84 Å and $U_{iso}(H) = 1.5U_{eq}(O)$ for hydroxy H atoms].

References

Britton, D. (1999). *Acta Cryst.* C**55**, 978–980.
Britton, D. (2002). *Acta Cryst.* C**58**, o637–o639.
Bruker (2001). *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.
Bruker (2014). *APEX2* and *SAINT*. Bruker AXS Inc., Madison, Wisconsin, USA.
Ende, C. W. am, Zhou, Z. & Parker, K. A. (2013). *J. Am. Chem. Soc.* **135**, 582–585.
Farrugia, L. J. (2012). *J. Appl. Cryst.* **45**, 849–854.
Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* B**72**, 171–179.
Koshima, H. & Matsuura, T. (1998). *J. Synth. Org. Chem. Jpn*, **56**, 466–477.
Lenges, C. P., Brookhart, M. & White, P. S. (1999). *Angew. Chem. Int. Ed.* **38**, 552–555.
Lin, A. J. & Loo, T. L. (1977). *J. Am. Chem. Soc.* **99**, 558–561.
Lin, A. J., Shansky, C. W. & Sartorelli, A. C. (1978). *J. Med. Chem.* **23**, 268–272.
Macrae, C. F., Edgington, P. R., McCabe, P., Pidcock, E., Shields, G. P., Taylor, R., Towler, M. & van de Streek, J. (2006). *J. Appl. Cryst.* **39**, 453–457.
Matsuura, T. & Koshima, H. (2005). *J. Photochem. Photobiol. Photochem. Rev.* **6**, 7–24.
Mendenhall, D. G., Luck, R. L., Bohn, R. K. & Castejon, H. J. (2003). *J. Mol. Struct.* **645**, 249–258.
Parsons, S., Flack, H. D. & Wagner, T. (2013). *Acta Cryst.* B**69**, 249–259.
Peng, C.-Y., Shen, J.-Y., Chen, Y.-T., Wu, P.-J., Hung, W.-Y., Hu, W.-P. & Chou, P.-T. (2015). *J. Am. Chem. Soc.* **137**, 14349–14357.
Richthofen, C.-G. von, Feldscher, B., Lippert, K.-A., Stammler, A., Bögge, H. & Glaser, T. (2013). *Z. Naturforsch. Teil B*, **68**, 64–86.
Sheldrick, G. M. (2008). *Acta Cryst.* A**64**, 112–122.
Sheldrick, G. M. (2015*a*). *Acta Cryst.* A**71**, 3–8.
Sheldrick, G. M. (2015*b*). *Acta Cryst.* C**71**, 3–8.
Westrip, S. P. (2010). *J. Appl. Cryst.* **43**, 920–925.

supporting information

Acta Cryst. (2018). E**74**, 1424-1426 [https://doi.org/10.1107/S2056989018012495]

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Computing details

Data collection: *APEX2* (Bruker, 2014); cell refinement: *SAINT* (Bruker, 2014); data reduction: *SAINT* (Bruker, 2014); program(s) used to solve structure: SHELXT2014 (Sheldrick, 2015a); program(s) used to refine structure: *SHELXL2014* (Sheldrick, 2015b); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXTL* (Sheldrick, 2008), *WinGX* (Farrugia, 2012), *Mercury* (Macrae *et al.*, 2006) and *publCIF* (Westrip, 2010).

3,6-Dihydroxy-4,5-dimethylbenzene-1,2-dicarbaldehyde

Crystal data

$C_{10}H_{10}O_4$
M_r = 194.18
Monoclinic, $P2_1$
a = 5.251 (2) Å
b = 6.317 (2) Å
c = 12.999 (5) Å
β = 91.643 (4)°
V = 431.0 (3) Å^3
Z = 2
F(000) = 204
D_x = 1.496 Mg m^{-3}
Mo $K\alpha$ radiation, λ = 0.71073 Å
Cell parameters from 2083 reflections
θ = 3.1–27.5°
μ = 0.12 mm^{-1}
T = 100 K
Prism, yellow
0.38 × 0.30 × 0.13 mm

Data collection

Bruker APEXII CCD diffractometer
Radiation source: fine-focus sealed tube
Detector resolution: 8.3333 pixels mm^{-1}
φ and ω scans
Absorption correction: multi-scan (SADABS; Bruker, 2001)
T_{min} = 0.785, T_{max} = 0.785
2328 measured reflections
1228 independent reflections
1207 reflections with $I > 2\sigma(I)$
R_{int} = 0.014
θ_{max} = 27.5°, θ_{min} = 1.6°
$h = -6 \rightarrow 6$
$k = -3 \rightarrow 8$
$l = -16 \rightarrow 16$

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.029
$wR(F^2)$ = 0.082
S = 1.06
1228 reflections
131 parameters
1 restraint
Hydrogen site location: inferred from neighbouring sites
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0523P)^2 + 0.0966P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max}$ = 0.25 e Å^{-3}
$\Delta\rho_{min}$ = −0.22 e Å^{-3}
Absolute structure: Flack x determined using 179 quotients [(I+)-(I-)]/[(I+)+(I-)] (Parsons *et al.*, 2013)
Absolute structure parameter: 0.5 (6)

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	*y*	*z*	U_{iso}*/U_{eq}
O4	0.7944 (2)	0.8239 (2)	0.27690 (9)	0.0183 (3)
H4	0.7357	0.8998	0.3237	0.027*
O2	−0.0040 (2)	0.1772 (2)	0.38214 (9)	0.0193 (3)
O1	0.5175 (2)	0.9141 (2)	0.42970 (9)	0.0190 (3)
O3	0.2530 (2)	0.0865 (2)	0.21917 (9)	0.0174 (3)
H3	0.1418	0.0689	0.2635	0.026*
C3	0.5775 (3)	0.3220 (3)	0.17026 (11)	0.0136 (3)
C8	0.1144 (3)	0.3446 (3)	0.38843 (12)	0.0150 (4)
H8	0.0717	0.4408	0.4414	0.018*
C4	0.7113 (3)	0.5092 (3)	0.18410 (12)	0.0133 (3)
C1	0.3173 (3)	0.4049 (3)	0.31924 (12)	0.0128 (3)
C2	0.3797 (3)	0.2696 (3)	0.23855 (12)	0.0129 (3)
C7	0.3981 (3)	0.7489 (3)	0.41517 (12)	0.0153 (4)
H7	0.2619	0.7174	0.4592	0.018*
C5	0.6521 (3)	0.6468 (3)	0.26629 (12)	0.0134 (4)
C6	0.4550 (3)	0.5985 (3)	0.33345 (12)	0.0125 (3)
C9	0.6387 (3)	0.1702 (3)	0.08493 (12)	0.0177 (4)
H9A	0.6259	0.2441	0.0187	0.027*
H9B	0.5177	0.0521	0.0848	0.027*
H9C	0.8122	0.1159	0.0958	0.027*
C10	0.9192 (3)	0.5739 (3)	0.11251 (13)	0.0179 (4)
H10A	1.0138	0.4482	0.0915	0.027*
H10B	1.0356	0.6726	0.1481	0.027*
H10C	0.8431	0.6429	0.0515	0.027*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O4	0.0187 (6)	0.0167 (7)	0.0198 (6)	−0.0064 (6)	0.0074 (5)	−0.0031 (5)
O2	0.0174 (5)	0.0194 (6)	0.0214 (6)	−0.0060 (6)	0.0049 (4)	−0.0018 (5)
O1	0.0228 (6)	0.0164 (6)	0.0180 (5)	−0.0036 (6)	0.0033 (5)	−0.0035 (5)
O3	0.0179 (5)	0.0158 (6)	0.0186 (6)	−0.0052 (6)	0.0051 (4)	−0.0035 (5)
C3	0.0127 (7)	0.0166 (8)	0.0117 (7)	0.0021 (7)	0.0015 (6)	−0.0001 (7)
C8	0.0130 (7)	0.0172 (9)	0.0148 (7)	−0.0010 (7)	0.0022 (6)	0.0000 (7)
C4	0.0108 (6)	0.0163 (8)	0.0130 (7)	0.0007 (6)	0.0024 (5)	0.0020 (7)
C1	0.0109 (6)	0.0151 (8)	0.0123 (6)	0.0000 (7)	0.0009 (5)	0.0007 (7)
C2	0.0115 (6)	0.0128 (9)	0.0144 (7)	−0.0017 (6)	0.0000 (6)	0.0010 (6)
C7	0.0162 (7)	0.0154 (8)	0.0142 (7)	0.0003 (7)	0.0018 (6)	0.0012 (7)
C5	0.0114 (6)	0.0151 (9)	0.0137 (7)	−0.0014 (7)	0.0001 (5)	0.0011 (7)

C6	0.0115 (6)	0.0139 (8)	0.0120 (7)	0.0001 (6)	0.0011 (5)	0.0011 (7)
C9	0.0185 (7)	0.0192 (9)	0.0157 (7)	0.0000 (7)	0.0034 (6)	−0.0048 (7)
C10	0.0146 (7)	0.0227 (9)	0.0166 (7)	−0.0003 (7)	0.0062 (6)	0.0012 (7)

Geometric parameters (Å, º)

O4—C5	1.350 (2)	C4—C10	1.511 (2)
O4—H4	0.84	C1—C2	1.399 (2)
O2—C8	1.228 (2)	C1—C6	1.431 (2)
O1—C7	1.229 (2)	C7—C6	1.462 (2)
O3—C2	1.354 (2)	C7—H7	0.95
O3—H3	0.84	C5—C6	1.406 (2)
C3—C4	1.385 (3)	C9—H9A	0.98
C3—C2	1.424 (2)	C9—H9B	0.98
C3—C9	1.508 (2)	C9—H9C	0.98
C8—C1	1.464 (2)	C10—H10A	0.98
C8—H8	0.95	C10—H10B	0.98
C4—C5	1.419 (2)	C10—H10C	0.98
C5—O4—H4	109.5	C6—C7—H7	118.4
C2—O3—H3	109.5	O4—C5—C6	122.08 (14)
C4—C3—C2	119.60 (14)	O4—C5—C4	116.85 (13)
C4—C3—C9	121.36 (14)	C6—C5—C4	121.06 (16)
C2—C3—C9	119.04 (16)	C5—C6—C1	118.92 (14)
O2—C8—C1	123.97 (16)	C5—C6—C7	118.66 (16)
O2—C8—H8	118.0	C1—C6—C7	122.42 (13)
C1—C8—H8	118.0	C3—C9—H9A	109.5
C3—C4—C5	119.97 (14)	C3—C9—H9B	109.5
C3—C4—C10	121.60 (15)	H9A—C9—H9B	109.5
C5—C4—C10	118.43 (17)	C3—C9—H9C	109.5
C2—C1—C6	119.38 (13)	H9A—C9—H9C	109.5
C2—C1—C8	119.46 (16)	H9B—C9—H9C	109.5
C6—C1—C8	121.15 (15)	C4—C10—H10A	109.5
O3—C2—C1	122.45 (14)	C4—C10—H10B	109.5
O3—C2—C3	116.47 (14)	H10A—C10—H10B	109.5
C1—C2—C3	121.05 (16)	C4—C10—H10C	109.5
O1—C7—C6	123.30 (15)	H10A—C10—H10C	109.5
O1—C7—H7	118.4	H10B—C10—H10C	109.5
C2—C3—C4—C5	0.4 (2)	C3—C4—C5—O4	178.32 (14)
C9—C3—C4—C5	−178.85 (15)	C10—C4—C5—O4	−2.5 (2)
C2—C3—C4—C10	−178.81 (15)	C3—C4—C5—C6	−1.3 (2)
C9—C3—C4—C10	2.0 (2)	C10—C4—C5—C6	177.94 (14)
O2—C8—C1—C2	1.9 (2)	O4—C5—C6—C1	−178.18 (14)
O2—C8—C1—C6	−177.34 (15)	C4—C5—C6—C1	1.4 (2)
C6—C1—C2—O3	−178.32 (13)	O4—C5—C6—C7	2.0 (2)
C8—C1—C2—O3	2.5 (2)	C4—C5—C6—C7	−178.41 (15)
C6—C1—C2—C3	−0.2 (2)	C2—C1—C6—C5	−0.6 (2)

C8—C1—C2—C3	−179.44 (14)	C8—C1—C6—C5	178.56 (15)
C4—C3—C2—O3	178.56 (14)	C2—C1—C6—C7	179.16 (16)
C9—C3—C2—O3	−2.2 (2)	C8—C1—C6—C7	−1.6 (2)
C4—C3—C2—C1	0.4 (2)	O1—C7—C6—C5	−1.6 (2)
C9—C3—C2—C1	179.61 (14)	O1—C7—C6—C1	178.61 (14)

Hydrogen-bond geometry (Å, º)

Cg1 is the centroid of ring C1-C6.

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3···O2	0.84	1.87	2.6079 (19)	146
O4—H4···O1	0.84	1.82	2.5592 (19)	146
O3—H3···O4^{i}	0.84	2.40	3.036 (2)	133
O4—H4···O2^{ii}	0.84	2.34	2.809 (2)	116
C7—H7···O2^{iii}	0.95	2.51	3.427 (2)	162
C10—H10···*Cg*1^{iv}	0.98	3.13	3.645	114

Symmetry codes: (i) *x*−1, *y*−1, *z*; (ii) *x*+1, *y*+1, *z*; (iii) −*x*, *y*+1/2, −*z*+1; (iv) *x*+1, *y*, *z*.