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## 3-(3,5-Dichlorophenyl)benzene-1,2-diol

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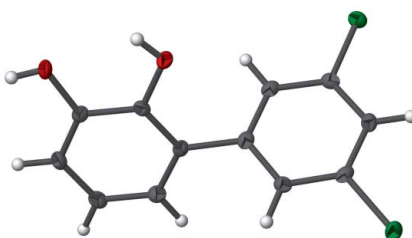
**Keywords:** dihedral angle; hydroxylated compound; metabolite; polychlorinated biphenyl; PCB; crystal structure.

CCDC reference: 1950307

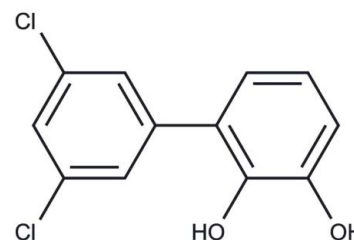
**Structural data:** full structural data are available from [iucrdata.iucr.org](http://iucrdata.iucr.org)

The title structure, C<sub>12</sub>H<sub>8</sub>Cl<sub>2</sub>O<sub>2</sub>, is a putative metabolite of 3,5-dichlorobiphenyl (PCB 14). The dihedral angle between the two benzene rings of the title compounds is 58.86 (4)°. In the crystal, it displays intra- and intermolecular O—H···O hydrogen bonding and intermolecular O—H···Cl hydrogen···chlorine interactions. The intermolecular interactions form a two-dimensional network parallel to (010).

### 3D view



### Chemical scheme

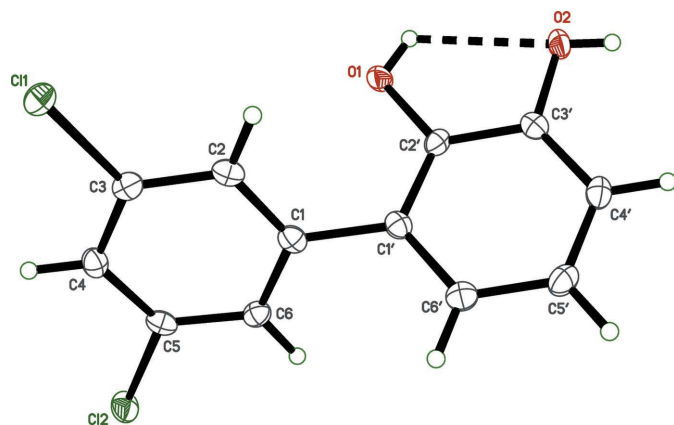


### Structure description

Humans are exposed to polychlorinated biphenyls (PCBs), a class of persistent organic pollutants, *via* their diet (Schechter *et al.*, 2010; Shin *et al.*, 2015) and by inhalation (Dhakal *et al.*, 2014; Hu *et al.*, 2010). In particular, lower chlorinated PCBs are oxidized by cytochrome P450 enzymes to the corresponding monohydroxylated and further to dihydroxylated compounds (Grimm *et al.*, 2015; Kania-Korwel & Lehmler, 2016). Dihydroxylated PCBs can be oxidized to reactive PCB quinones. Both dihydroxylated PCBs and the corresponding quinones are highly toxic, for example because they can promote oxidative stress or bind to nucleophilic sites on cellular macromolecules (Grimm *et al.*, 2015). To better understand the mechanism(s) of toxicity of these molecules in living organisms, it is important to characterize the three-dimensional structure of these PCB metabolites (Lehmler, Parkin *et al.*, 2002; Shaikh *et al.*, 2008).

3-(3,5-Dichlorophenyl)benzene-1,2-diol (Fig. 1) is a putative metabolite of PCB 14 (3,5-dichlorobiphenyl). The dihedral angle between the least-squares planes of the two benzene rings is 58.84 (4)°. For comparison, the dihedral angle of other PCB derivatives with one OH group *ortho* to the phenyl–phenyl bond ranges from 48 to 59.5° (Lehmler, Robertson *et al.*, 2002; Perrin *et al.*, 1987). Dihedral angles of PCB derivatives without any *ortho* chlorine substituents are in the range 4.9 to 43.9° (Dhakal *et al.*, 2019a), whereas PCB derivatives with one *ortho* chlorine substituent range from 47.34 to 59.92° (Dhakal





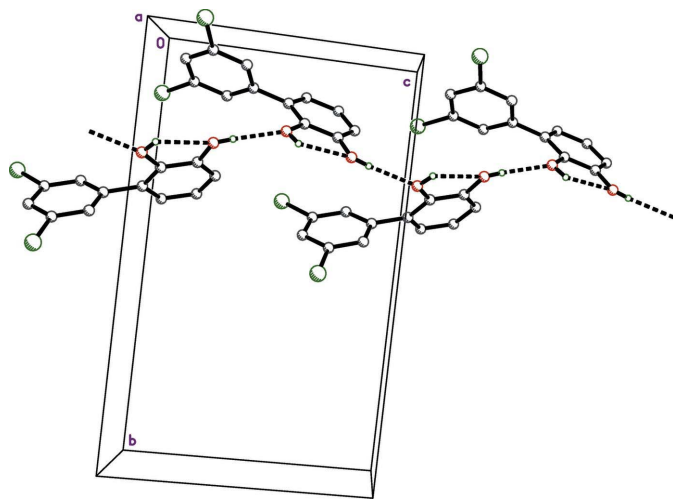
**Figure 1**

View of the title compound showing the atom-labelling scheme. Displacement ellipsoids are drawn at the 50% probability level. The intramolecular hydrogen bond is shown as a dashed line. For information regarding the hydrogen-bond geometry, see Table 1.

*et al.*, 2019b). The title compound crystallizes in the monoclinic space group  $P2_1/c$  and displays intra- and intermolecular molecular  $O-H\cdots O$  hydrogen bonding (Fig. 2, Table 1) and intermolecular  $O-H\cdots Cl$  interactions (Fig. 3, Table 1). The intermolecular interactions lead to the formation of a two-dimensional network parallel to (010).

### Synthesis and crystallization

The title compound was synthesized *via* a Suzuki cross-coupling reaction of 1-bromo-3,5-dichlorobenzene with 2,3-dimethoxyphenyl boronic acid in the presence of  $Pd(PPh_3)_4$ , and a 2 M aqueous solution of  $Na_2CO_3$  followed by demethylation with  $BBr_3$  (Bauer *et al.*, 1995). Crystals suitable for crystal-structure analysis were obtained by recrystallization from diethyl ether:hexanes (approximately 1:3, *v/v*) as described by Bauer *et al.* (1995).



**Figure 2**

A packing plot viewed approximately along the *a* axis. Intra- and intermolecular hydrogen bonds are drawn as thick dashed lines. For information regarding the hydrogen-bond geometry, see Table 1.

**Table 1**

Hydrogen-bond geometry (Å, °).

<i>D</i> —H··· <i>A</i>	<i>D</i> —H	H··· <i>A</i>	<i>D</i> ··· <i>A</i>	<i>D</i> —H··· <i>A</i>
O1—H1O···Cl2 <sup>i</sup>	0.79	2.73	3.2538 (12)	126
O1—H1O···O2	0.79	2.20	2.6459 (16)	117
O2—H2O···O1 <sup>ii</sup>	0.77	2.02	2.7708 (16)	169

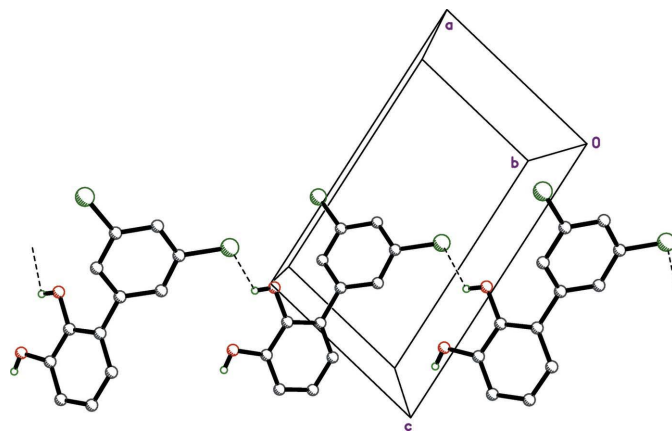
Symmetry codes: (i)  $x + 1, -y + \frac{1}{2}, z + \frac{1}{2}$ ; (ii)  $x, -y + \frac{1}{2}, z + \frac{1}{2}$ .

**Table 2**

Experimental details.

Crystal data	
Chemical formula	$C_{12}H_8Cl_2O_2$
$M_r$	255.08
Crystal system, space group	Monoclinic, $P2_1/c$
Temperature (K)	90
<i>a</i> , <i>b</i> , <i>c</i> (Å)	6.2198 (3), 16.9271 (8), 10.4460 (5)
$\beta$ (°)	101.013 (3)
<i>V</i> (Å <sup>3</sup> )	1079.53 (9)
<i>Z</i>	4
Radiation type	Mo $K\alpha$
$\mu$ (mm <sup>-1</sup> )	0.58
Crystal size (mm)	0.28 × 0.25 × 0.25
Data collection	
Diffractometer	Nonius KappaCCD diffractometer
Absorption correction	Multi-scan ( <i>SCALEPACK</i> ; Otwinowski & Minor, 2006)
$T_{min}$ , $T_{max}$	0.855, 0.869
No. of measured, independent and observed [ $I > 2\sigma(I)$ ] reflections	6641, 2470, 2029
$R_{int}$	0.037
( $\sin \theta/\lambda$ ) <sub>max</sub> (Å <sup>-1</sup> )	0.650
Refinement	
$R[F^2 > 2\sigma(F^2)]$ , $wR(F^2)$ , <i>S</i>	0.033, 0.074, 1.04
No. of reflections	2470
No. of parameters	149
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$ , $\Delta\rho_{min}$ (e Å <sup>-3</sup> )	0.31, -0.28

Computer programs: *COLLECT* (Nonius, 1998), *SCALEPACK* and *DENZO-SMN* (Otwinowski & Minor, 2006), *XP* in *SHELXTL*, *SHELXS* and *SHELX* (Sheldrick, 2008), *SHELXL2018/3* (Sheldrick, 2015) and *CIFFIX* (Parkin, 2013).



**Figure 3**

A packing plot viewed approximately along the *b* axis. Intermolecular hydrogen···chlorine interactions are drawn as thin dashed lines. For information regarding the hydrogen-bond geometry, see Table 1.

## Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2.

## Acknowledgements

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## Funding information

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## References

- Bauer, U., Amaro, A. R. & Robertson, L. W. (1995). *Chem. Res. Toxicol.* **8**, 92–95.
- Dhakal, K., Uwimana, E., Adamcakova-Dodd, A., Thorne, P. S., Lehmler, H.-J. & Robertson, L. W. (2014). *Chem. Res. Toxicol.* **27**, 1411–1420.
- Dhakal, R., Parkin, S. & Lehmler, H.-J. (2019a). *IUCrData*, **4**, x190518.
- Dhakal, R., Parkin, S. & Lehmler, H.-J. (2019b). *IUCrData*, **4**, x190662.
- Grimm, F. A., Hu, D., Kania-Korwel, I., Lehmler, H.-J., Ludewig, G., Hornbuckle, K. C., Duffel, M. W., Bergman, A. & Robertson, L. W. (2015). *Crit. Rev. Toxicol.* **45**, 245–272.
- Hu, X., Adamcakova-Dodd, A., Lehmler, H.-J., Hu, D., Kania-Korwel, I., Hornbuckle, K. & Thorne, P. S. (2010). *Environ. Sci. Technol.* **44**, 6893–6900.
- Kania-Korwel, I. & Lehmler, H.-J. (2016). *Environ. Sci. Pollut. Res. Int.* **23**, 2042–2057.
- Lehmler, H.-J., Parkin, S. & Robertson, L. W. (2002). *Chemosphere*, **46**, 485–488.
- Lehmler, H.-J., Robertson, L. W., Parkin, S. & Brock, C. P. (2002). *Acta Cryst.* **B58**, 140–147.
- Nonius (1998). *COLLECT*. Nonius BV, Delft, The Netherlands.
- Otwinowski, Z. & Minor, W. (2006). *International Tables for Crystallography*, Vol. F, *Crystallography of Biological Macromolecules*, edited by M. G. Rossmann & E. Arnold, ch. 11.4, pp. 226–235. Chester, England: International Union of Crystallography.
- Parkin, S. (2013). *CIFFIX*, <https://xray.uky.edu/Resources/scripts/ciffix>
- Perrin, M., Bekkouch, K. & Thozet, A. (1987). *Acta Cryst.* **C43**, 980–982.
- Schechter, A., Colacino, J., Haffner, D., Patel, K., Opel, M., Pöpke, O. & Birnbaum, L. (2010). *Environ. Health Perspect.* **118**, 796–802.
- Shaikh, N. S., Parkin, S., Luthe, G. & Lehmler, H.-J. (2008). *Chemosphere*, **70**, 1694–1698.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.
- Sheldrick, G. M. (2015). *Acta Cryst.* **C71**, 3–8.
- Shin, E. S., Nguyen, K. H., Kim, J., Kim, C. I. & Chang, Y. S. (2015). *Environ. Pollut.* **207**, 403–412.

## full crystallographic data

*IUCrData* (2019). 4, x191202 [https://doi.org/10.1107/S2414314619012021]

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## 3-(3,5-Dichlorophenyl)benzene-1,2-diol

*Crystal data*

$C_{12}H_8Cl_2O_2$

$M_r = 255.08$

Monoclinic,  $P2_1/c$

$a = 6.2198$  (3) Å

$b = 16.9271$  (8) Å

$c = 10.4460$  (5) Å

$\beta = 101.013$  (3)°

$V = 1079.53$  (9) Å<sup>3</sup>

$Z = 4$

$F(000) = 520$

$D_x = 1.569$  Mg m<sup>-3</sup>

Mo  $K\alpha$  radiation,  $\lambda = 0.71073$  Å

Cell parameters from 5954 reflections

$\theta = 1.0$ – $27.5$ °

$\mu = 0.58$  mm<sup>-1</sup>

$T = 90$  K

Block, colourless

$0.28 \times 0.25 \times 0.25$  mm

*Data collection*

Nonius KappaCCD

diffractometer

Radiation source: fine-focus sealed-tube

Detector resolution: 9.1 pixels mm<sup>-1</sup>

$\varphi$  and  $\omega$  scans at fixed  $\chi = 55$ °

Absorption correction: multi-scan

(Scalepack; Otwinowski & Minor, 2006)

$T_{\min} = 0.855$ ,  $T_{\max} = 0.869$

6641 measured reflections

2470 independent reflections

2029 reflections with  $I > 2\sigma(I)$

$R_{\text{int}} = 0.037$

$\theta_{\max} = 27.5$ °,  $\theta_{\min} = 2.3$ °

$h = -7 \rightarrow 8$

$k = -21 \rightarrow 21$

$l = -11 \rightarrow 13$

*Refinement*

Refinement on  $F^2$

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)] = 0.033$

$wR(F^2) = 0.074$

$S = 1.04$

2470 reflections

149 parameters

0 restraints

Primary atom site location: structure-invariant

direct methods

Secondary atom site location: difference Fourier map

Hydrogen site location: difference Fourier map

H atoms treated by a mixture of independent

and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.0259P)^2 + 0.363P]$

where  $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\max} = 0.001$

$\Delta\rho_{\max} = 0.31$  e Å<sup>-3</sup>

$\Delta\rho_{\min} = -0.28$  e Å<sup>-3</sup>

*Special details*

**Experimental.** The crystal was mounted using polyisobutene oil on the tip of a fine glass fibre, which was fastened in a copper mounting pin with electrical solder. It was placed directly into the cold gas stream of a liquid-nitrogen based cryostat.

Diffraction data were collected with the crystal at 90K, which is standard practice in this laboratory for the majority of flash-cooled crystals.

**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.

**Refinement.** H atoms were found in difference Fourier maps. Carbon-bound H atoms were subsequently included in the refinement using riding models, with constrained distances set to 0.95 Å (C<sub>sp2</sub>H). Hydroxyl O—H distances were refined.  $U_{\text{iso}}(\text{H})$  parameters were set to values of either  $1.2U_{\text{eq}}$  or  $1.5U_{\text{eq}}$  (OH only) of the attached atom.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å<sup>2</sup>)*

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
Cl1	1.06252 (7)	0.51040 (2)	0.70416 (4)	0.02025 (12)
Cl2	0.30147 (7)	0.35884 (3)	0.52162 (4)	0.02112 (13)
O1	0.98156 (18)	0.29232 (7)	1.03073 (11)	0.0180 (3)
H1O	1.064 (3)	0.2671 (12)	1.0814 (15)	0.027*
O2	0.98599 (18)	0.25308 (7)	1.27641 (11)	0.0189 (3)
H2O	0.9675 (16)	0.2391 (11)	1.343 (2)	0.028*
C1	0.6550 (3)	0.38712 (9)	0.88020 (16)	0.0151 (4)
C2	0.8333 (3)	0.43045 (9)	0.85610 (16)	0.0156 (4)
H2	0.948128	0.444585	0.926113	0.019*
C3	0.8430 (3)	0.45292 (10)	0.72976 (16)	0.0157 (4)
C4	0.6808 (3)	0.43163 (9)	0.62473 (16)	0.0165 (4)
H4	0.689666	0.446218	0.538081	0.020*
C5	0.5060 (3)	0.38841 (10)	0.65118 (16)	0.0162 (4)
C6	0.4880 (3)	0.36663 (9)	0.77716 (16)	0.0154 (4)
H6	0.363533	0.338240	0.792445	0.018*
C1'	0.6450 (3)	0.36330 (9)	1.01653 (16)	0.0146 (3)
C2'	0.8112 (3)	0.31794 (9)	1.08832 (16)	0.0140 (3)
C3'	0.8095 (3)	0.29685 (9)	1.21704 (16)	0.0145 (4)
C4'	0.6384 (3)	0.32091 (10)	1.27509 (16)	0.0171 (4)
H4'	0.636353	0.307008	1.362959	0.020*
C5'	0.4694 (3)	0.36558 (10)	1.20385 (17)	0.0193 (4)
H5'	0.351157	0.382046	1.243162	0.023*
C6'	0.4723 (3)	0.38623 (10)	1.07594 (17)	0.0190 (4)
H6'	0.355134	0.416388	1.028058	0.023*

*Atomic displacement parameters (Å<sup>2</sup>)*

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Cl1	0.0179 (2)	0.0205 (2)	0.0225 (2)	−0.00488 (18)	0.00431 (17)	0.00181 (18)
Cl2	0.0210 (2)	0.0269 (2)	0.0137 (2)	−0.00667 (18)	−0.00082 (17)	−0.00019 (17)
O1	0.0150 (6)	0.0252 (7)	0.0139 (6)	0.0082 (5)	0.0030 (5)	0.0026 (5)
O2	0.0195 (6)	0.0251 (7)	0.0123 (6)	0.0048 (5)	0.0041 (5)	0.0055 (5)
C1	0.0169 (8)	0.0130 (8)	0.0150 (8)	0.0045 (7)	0.0022 (7)	−0.0008 (7)
C2	0.0149 (8)	0.0138 (8)	0.0170 (8)	0.0020 (7)	0.0000 (7)	−0.0026 (7)
C3	0.0151 (8)	0.0113 (8)	0.0211 (9)	0.0004 (7)	0.0045 (7)	−0.0002 (7)
C4	0.0193 (9)	0.0152 (8)	0.0152 (8)	0.0022 (7)	0.0039 (7)	0.0018 (7)
C5	0.0145 (8)	0.0158 (8)	0.0164 (8)	0.0014 (7)	−0.0018 (7)	−0.0021 (7)
C6	0.0143 (8)	0.0140 (8)	0.0183 (9)	0.0003 (7)	0.0041 (7)	−0.0001 (7)

C1'	0.0157 (8)	0.0138 (8)	0.0135 (8)	-0.0017 (7)	0.0008 (7)	-0.0011 (7)
C2'	0.0139 (8)	0.0154 (8)	0.0134 (8)	-0.0024 (7)	0.0045 (7)	-0.0047 (7)
C3'	0.0156 (8)	0.0116 (8)	0.0153 (8)	-0.0019 (7)	0.0006 (7)	-0.0002 (7)
C4'	0.0201 (9)	0.0176 (8)	0.0142 (8)	-0.0041 (7)	0.0052 (7)	-0.0006 (7)
C5'	0.0182 (9)	0.0215 (9)	0.0198 (9)	0.0010 (8)	0.0079 (7)	-0.0029 (7)
C6'	0.0171 (9)	0.0201 (9)	0.0199 (9)	0.0030 (7)	0.0040 (7)	0.0005 (7)

*Geometric parameters (Å, °)*

C11—C3	1.7386 (17)	C4—H4	0.9500
C12—C5	1.7445 (16)	C5—C6	1.392 (2)
O1—C2'	1.3842 (18)	C6—H6	0.9500
O1—H10	0.79 (2)	C1'—C2'	1.387 (2)
O2—C3'	1.3704 (19)	C1'—C6'	1.395 (2)
O2—H20	0.77 (2)	C2'—C3'	1.393 (2)
C1—C6	1.390 (2)	C3'—C4'	1.383 (2)
C1—C2	1.392 (2)	C4'—C5'	1.390 (2)
C1—C1'	1.493 (2)	C4'—H4'	0.9500
C2—C3	1.386 (2)	C5'—C6'	1.385 (2)
C2—H2	0.9500	C5'—H5'	0.9500
C3—C4	1.389 (2)	C6'—H6'	0.9500
C4—C5	1.381 (2)		
C2'—O1—H10	109.5	C5—C6—H6	120.6
C3'—O2—H20	109.5	C2'—C1'—C6'	118.12 (15)
C6—C1—C2	119.67 (15)	C2'—C1'—C1	120.19 (15)
C6—C1—C1'	120.70 (15)	C6'—C1'—C1	121.69 (15)
C2—C1—C1'	119.64 (15)	O1—C2'—C1'	119.45 (14)
C3—C2—C1	119.85 (15)	O1—C2'—C3'	119.12 (14)
C3—C2—H2	120.1	C1'—C2'—C3'	121.42 (15)
C1—C2—H2	120.1	O2—C3'—C4'	125.29 (15)
C2—C3—C4	121.61 (15)	O2—C3'—C2'	114.97 (14)
C2—C3—C11	118.58 (13)	C4'—C3'—C2'	119.73 (15)
C4—C3—C11	119.81 (13)	C3'—C4'—C5'	119.48 (15)
C5—C4—C3	117.39 (15)	C3'—C4'—H4'	120.3
C5—C4—H4	121.3	C5'—C4'—H4'	120.3
C3—C4—H4	121.3	C6'—C5'—C4'	120.41 (16)
C4—C5—C6	122.57 (15)	C6'—C5'—H5'	119.8
C4—C5—C12	118.82 (13)	C4'—C5'—H5'	119.8
C6—C5—C12	118.61 (13)	C5'—C6'—C1'	120.82 (16)
C1—C6—C5	118.87 (15)	C5'—C6'—H6'	119.6
C1—C6—H6	120.6	C1'—C6'—H6'	119.6
C6—C1—C2—C3	0.1 (2)	C2—C1—C1'—C6'	121.12 (18)
C1'—C1—C2—C3	-179.80 (15)	C6'—C1'—C2'—O1	178.10 (14)
C1—C2—C3—C4	-1.6 (2)	C1—C1'—C2'—O1	-2.6 (2)
C1—C2—C3—C11	177.41 (12)	C6'—C1'—C2'—C3'	-1.3 (2)
C2—C3—C4—C5	1.3 (2)	C1—C1'—C2'—C3'	178.05 (15)

C11—C3—C4—C5	-177.66 (12)	O1—C2'—C3'—O2	1.7 (2)
C3—C4—C5—C6	0.4 (2)	C1'—C2'—C3'—O2	-178.96 (14)
C3—C4—C5—C12	-178.77 (12)	O1—C2'—C3'—C4'	-178.90 (14)
C2—C1—C6—C5	1.6 (2)	C1'—C2'—C3'—C4'	0.5 (2)
C1'—C1—C6—C5	-178.52 (15)	O2—C3'—C4'—C5'	179.68 (15)
C4—C5—C6—C1	-1.9 (2)	C2'—C3'—C4'—C5'	0.3 (2)
C12—C5—C6—C1	177.29 (12)	C3'—C4'—C5'—C6'	-0.3 (3)
C6—C1—C1'—C2'	121.97 (18)	C4'—C5'—C6'—C1'	-0.5 (3)
C2—C1—C1'—C2'	-58.2 (2)	C2'—C1'—C6'—C5'	1.3 (3)
C6—C1—C1'—C6'	-58.8 (2)	C1—C1'—C6'—C5'	-178.00 (16)

*Hydrogen-bond geometry (Å, °)*

<i>D</i> —H $\cdots$ <i>A</i>	<i>D</i> —H	H $\cdots$ <i>A</i>	<i>D</i> $\cdots$ <i>A</i>	<i>D</i> —H $\cdots$ <i>A</i>
O1—H1O $\cdots$ C12 <sup>i</sup>	0.79	2.73	3.2538 (12)	126
O1—H1O $\cdots$ O2	0.79	2.20	2.6459 (16)	117
O2—H2O $\cdots$ O1 <sup>ii</sup>	0.77	2.02	2.7708 (16)	169

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