Acta Cryst E CRYSTALLOGRAPHIC COMMUNICATIONS

ISSN 2056-9890

Crystal structure of (+)-(1*S*,5*S*,6*S*,7*S*,10*S*,11*S*,16*S*)-16-hydroxy-7-(methoxymethoxy)-11,15,18,18-tetramethyl-3,13-dioxo-2,4-dioxatetracyclo-[12.3.1.$0^{1,5}$.$0^{6,11}$]octadec-14-en-10-yl benzoate

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Received 27 October 2021
Accepted 31 October 2021

Edited by H. Ishida, Okayama University, Japan

Keywords: crystal structure; paclitaxel; taxane skeleton; dioxolane; cyclohexane; cyclohexene; cyclooctane; hydrogen bond.

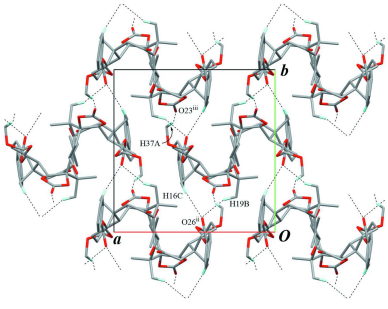
CCDC reference: 2119373

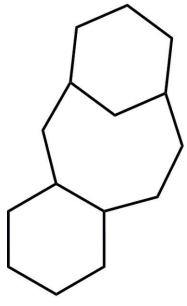
Supporting information: this article has supporting information at journals.iucr.org/e

In the fused tetracyclic system of the title compound, $C_{29}H_{36}O_9$, the five-membered dioxolane ring adopts a twist conformation; the two adjacent C atoms deviate alternately from the mean plane of the other three atoms by −0.252 (6) and 0.340 (6) Å. The cyclohexane, cyclohexene and central cyclooctane rings show chair, half-chair and boat-chair forms, respectively. There are three intramolecular C—H···O interactions supporting the molecular conformation, with one *S*(6) and two *S*(7) graph-set motifs. In the crystal, intermolecular O—H···O hydrogen bonds connect the molecules into a helical chain running along the *c*-axis direction, generating a *C*(7) graph-set motif. The chains are further linked by intermolecular C—H···O interactions to construct a three-dimensional network. There is no valid C—H···π interaction.

1. Chemical context

Paclitaxel (systematic name: (1*S*,2*S*,3*R*,4*S*,7*R*,9*S*,10*S*,12*R*,15*S*)-4,12-diacetoxy-1,9-dihydroxy-15-{[(2*R*,3*S*)-3-benzoylamino-2-hydroxy-3-phenyl]propanoyl}oxy-10,14,17,17-tetramethyl-11-oxo-6-oxa-tetracyclo[11.3.1.$0^{3,10}$.$0^{4,7}$]heptadec-13-en-2-yl benzoate) is a well-known natural diterpenoid containing a taxane framework (tricyclo[9.3.1.$0^{3,8}$]pentadecane; Fig. 1), with potent antitumor activity (Wall & Wani, 1995). Its highly complicated structure and significant bioactivity have attracted wide chemical and medicinal interest.





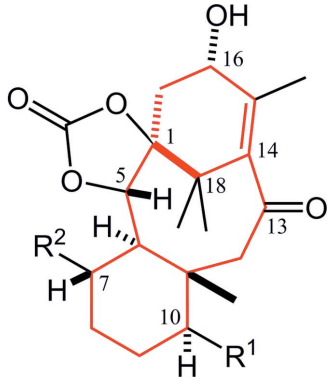
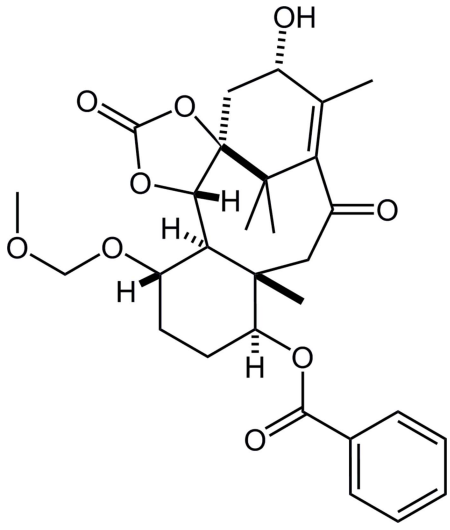


Figure 1
Left: Structure of tricyclo[9.3.1.$0^{3,8}$]pentadecane (taxane) skeleton. Right: Core structure of the title compound. Red lines indicate the taxane skeleton. R^1 = OC(=O)Ph, R^2 = OCH_2OCH_3.



The title compound, which has a fused tetracyclic core composed of a taxane skeleton with an external cyclic carbonate, was afforded as a chiral form in an improved synthesis of paclitaxel (Iiyama *et al.*, 2021). Several closely related structures (Oishi, Yamaguchi *et al.*, 2015; Oishi, Fukaya *et al.*, 2015*a*,*b*) obtained in another synthetic pathway (Fukaya, Tanaka *et al.*, 2015; Fukaya, Kodama *et al.*, 2015) have been reported previously as racemic crystals.

2. Structural commentary

The molecular structure of the title compound is shown in Fig. 2. The dioxolane ring (C1/C2/O22/C21/O20) adopts a twisted form with puckering parameters of $Q(2)$ = 0.351 (2) Å and $\varphi(2)$ = 56.6 (4)°. Atoms C1 and C2 deviate from the mean plane of the other three atoms by −0.250 (6) and 0.342 (6) Å, respectively. The cyclohexane ring (C3–C8) adopts a chair form with puckering parameters of Q = 0.580 (2) Å, θ = 8.0 (2)°, φ = 296.5 (17)°, $Q(2)$ = 0.083 (2) Å and $Q(3)$ = 0.574 (2) Å. The large substituents at C3, C4, C7 and C8 are in equatorial positions. The cyclohexene ring (C1/C14/C13/C12/C11/C15) adopts a half-chair form with puckering parameters of Q = 0.657 (3) Å, θ = 108.2 (3)°, φ = 135.8 (2)°, $Q(2)$ = 0.624 (3) Å and $Q(3)$ = −0.205 (3) Å. Atoms C1 and C14 deviate by 1.123 (4) and 0.811 (4) Å respectively, from the mean plane of the other four atoms with a maximum deviation of 0.0314 (15) Å at C12. The tetrasubstituted olefin (C10/C15/C11═C12/C13/C18) is skewed from an ideal planar structure owing to strain in the fused-ring system. The torsion angles C10—C11═C12—C18, C15—C11═C12—C13, C10—C11═C12—C13 and C15—C11═C12—C18 are −14.1 (4), −7.0 (3), 159.6 (2) and 179.3 (2)°, respectively, and the dihedral angle between the C10/C11/C15 and C18/C12/C13 planes is 19.70 (17)°. The central cyclooctane ring (C1–C3/C8–C11/C15) adopts a boat-chair form with puckering parameters of Q = 1.200 (2) Å, $Q(2)$ = 0.948 (2) Å, $\varphi(2)$ = 183.33 (15)°, $Q(3)$ = 0.588 (2) Å, $\varphi(3)$ = 3.3 (2)° and $Q(4)$ = 0.444 (2) Å.

There are three intramolecular C—H···O interactions (C35—H35*A*···O22, C18—H18*A*···O33 and C14—H14*B*···O34; Table 1), generating *S*(7), *S*(6) and *S*(7) graph-set motifs, respectively (Fig. 3). The absolute structure was confirmed by the Flack parameter of 0.01 (7) with 1649 quotients $[(I^+) - (I^-)]/[(I^+) + (I^-)]$ (Parsons *et al.*, 2013).

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

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O38—H38···O33^{i}	0.84	2.49	3.251 (2)	151
C14—H14*B*···O34	0.99	2.57	3.423 (3)	145
C18—H18*A*···O33	0.98	2.53	3.244 (3)	130
C35—H35*A*···O22	0.99	2.36	2.990 (3)	121
C16—H16*C*···O26^{ii}	0.98	2.43	3.331 (3)	153
C19—H19*B*···O26^{ii}	0.98	2.59	3.534 (3)	162
C37—H37*A*···O23^{iii}	0.98	2.52	3.445 (3)	158

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

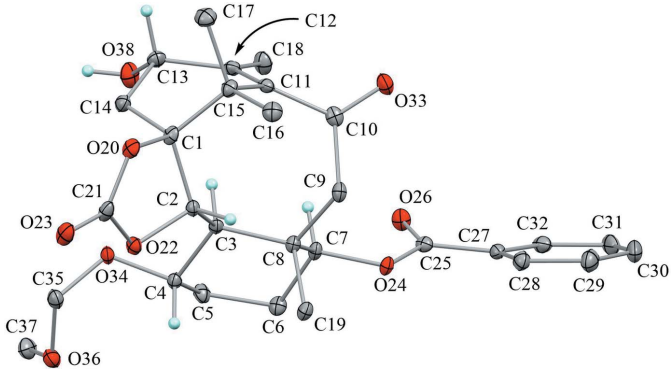


Figure 2
The molecular structure of the title compound with the atom labels. Displacement ellipsoids are drawn at the 30% probability levels. Only H atoms connected to O and chiral C atoms are shown for clarity.

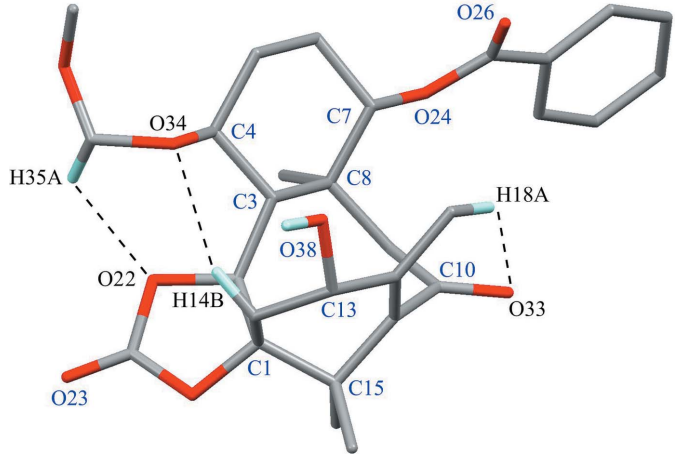


Figure 3
The molecular conformation with the intramolecular C—H···O interactions (black dashed lines). Only H atoms involved in these interactions and the hydroxy H atom are shown for clarity.

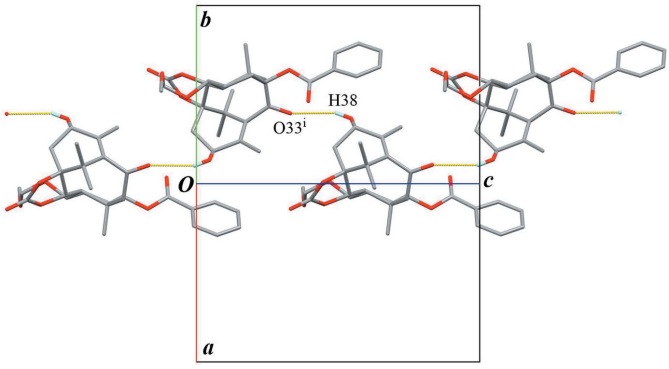


Figure 4
A partial packing diagram viewed down [110]. Yellow lines indicate the intermolecular O—H···O hydrogen bonds. Only H atoms involved in the hydrogen bonds are shown for clarity. [Symmetry code: (i) $-x+\frac{1}{2}, -y+1, z-\frac{1}{2}$.]

3. Supramolecular features

The crystal packing is stabilized by an O—H···O hydrogen bond (O38—H38···O33^{i}; symmetry code as given in Table 1), connecting the molecules into a helical chain running along the *c*-axis direction, with a *C*(7) graph-set motif (Fig. 4). The chains are linked by an intermolecular C—H···O hydrogen bond (C16—H16*C*···O26^{ii}; Table 1) to build a three-dimensional architecture. Furthermore, two weak C—H···O interactions (C37—H37*A*···O23^{iii} and C19—H19*B*···O26^{ii}; Table 1) support to form the network densely (Figs. 5 and 6). There is no valid C—H···π interaction.

4. Database survey

In the Cambridge Structural Database (CSD Version 5.42, last update September 2021; Groom *et al.*, 2016), 113 structures containing a tricyclo[9.3.1.0^{3,8}]pentadec-11-ene skeleton, (*a*),

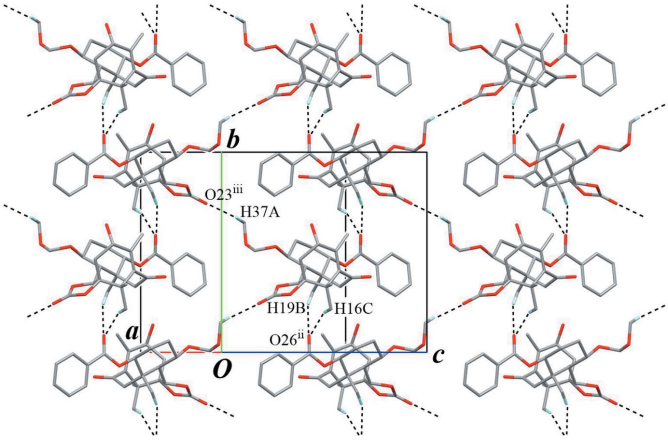


Figure 5
A partial packing diagram, showing the intermolecular C—H···O interactions (black dashed lines) making a layer structure parallel to the (100) plane. Only H atoms involved in these interactions are shown for clarity. [Symmetry codes: (ii) $-x+1, y-\frac{1}{2}, -z+\frac{3}{2}$; (iii) $-x+1, y+\frac{1}{2}, -z+\frac{1}{2}$.]

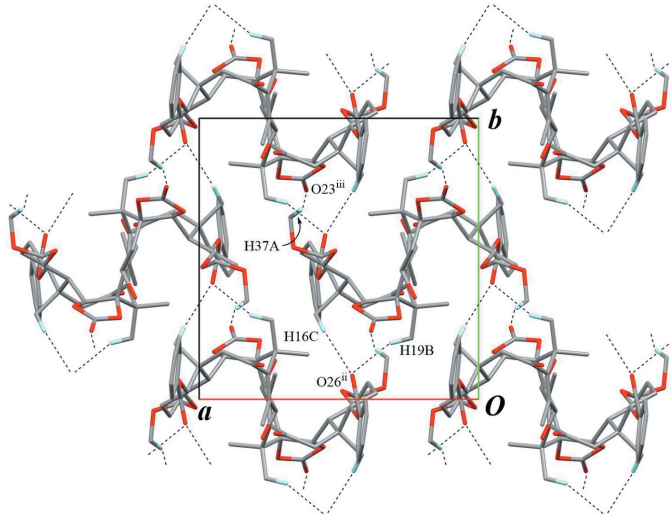


Figure 6
A packing diagram viewed down the *c* axis. Overlapping molecules (projected as 'N′ and inverted 'N′ letter shapes) indicate the helical chains running along the *c* axis, which are connected by the intermolecular C—H···O interactions (black dashed lines). Only H atoms involved in these interactions are shown for clarity. [Symmetry codes: (ii) $-x+1, y-\frac{1}{2}, -z+\frac{3}{2}$; (iii) $-x+1, y+\frac{1}{2}, -z+\frac{1}{2}$.]

are registered (Fig. 7). These include two chiral compounds (CSD refcodes NEGBOQ; Poujol *et al.*, 1997 and SUBQAJ; Hirai *et al.*, 2015) possessing a 2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadec-14-ene skeleton, (*b*), composed

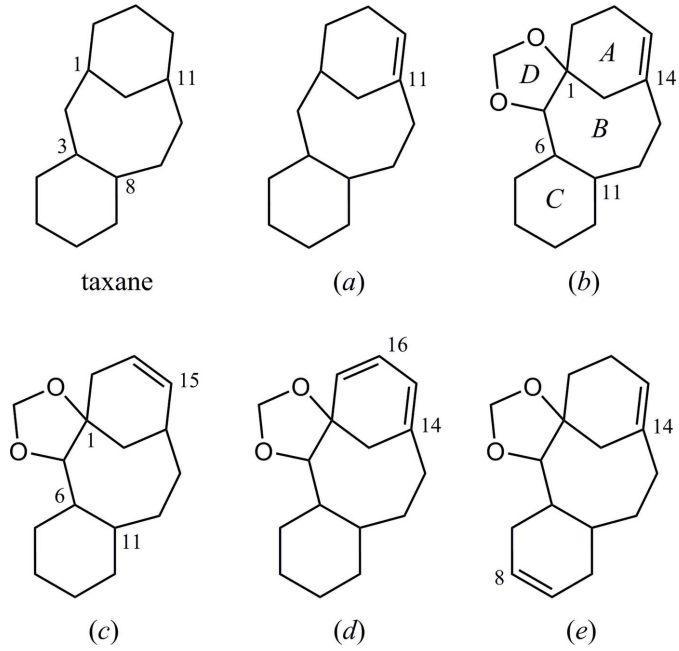


Figure 7
Core structures for database survey; tricyclo[9.3.1.0^{3,8}]pentadecane (taxane) and its (*a*) 11-ene derivative, (*b*) 2,4-dioxatetracyclo-[12.3.1.0^{1,5}.0^{6,11}]octadec-14-ene as the main frame of the title compound with ring-labelling, and its (*c*) regioisomer of olefin, (*d*) 16,17-dehydro or (*e*) 8,9-dehydro derivatives. The geometries of ring-fusion are similar to the title compound in every related structures, as *syn-AB*, *anti-BC* and *anti-BD*.

of *syn-AB*, *anti-BC* and *anti-BD* fused-ring systems similar to the title compound. Their ring conformations of the fused tetracycles (dioxolane, cyclohexane, cyclohexene and central cyclooctane) in the former structure are envelope, chair, half-chair and boat-chair forms, respectively, while those in the latter one are similar to the title compound as twist, chair, half-chair and boat-chair, respectively.

Four racemic structures closely related to the title compound, afforded by our previous synthesis, were also documented (XULNAV, XULMOI and XULMUO; Oishi, Fukaya *et al.*, 2015*a* and GUHWUD; Oishi, Fukaya *et al.*, 2015*b*). For the former three structures, possessing a 2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadec-15-ene core, (*c*), their ring conformations of the tetracycles (dioxolane, cyclohexane, cyclohexene and central cyclooctane) are similar to one another as essentially planar, chair, half-chair and chair-chair forms, respectively. For the latter structure with a 2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadeca-14,16-diene skeleton, (*d*), the ring conformations of dioxolane, cyclohexane, cyclohexene and central cyclooctane are twist, chair, half-boat and boat-chair forms, respectively. Although two crystalline compounds with a 2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadeca-8,14-diene skeleton, (*e*), have been reported (Nicolaou, Ueno *et al.*, 1995; Nicolaou, Yang *et al.*, 1995), they are not registered in the CSD.

5. Synthesis and crystallization

The title compound was provided in an improved chiral synthesis of paclitaxel (Iiyama *et al.*, 2021). The cyclohexene unit (C1/C14/C13/C12/C11/C15) was prepared according to the reported procedure (Nicolaou, Liu *et al.*, 1995) from cyclohexane-1,3-dione, while the tetrasubstituted chiral cyclohexane unit (C3–C8) was derived from 3-methoxytoluene (Fukaya *et al.*, 2016). Coupling reaction of these two units by utilizing a Shapiro reaction (Nicolaou, Liu *et al.*, 1995) led to generate the taxane framework, and further manipulations of the functional groups afforded the title compound. Purification was carried out by silica gel chromatography, and colorless crystals were obtained from a benzene solution under pentane-saturated atmosphere, by slow evaporation at ambient temperature. M.p. 505–508 K. $[\alpha]^{27}_{D}$ + 13.2 (*c* 0.99, $CHCl_3$). HRMS (ESI) *m/z* calculated for $C_{29}H_{36}O_9Na^+$ [*M* + Na]$^+$: 551.2257; found: 551.2249.

6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. C-bound H atoms were positioned geometrically with C—H = 0.95–1.00 Å, and constrained to ride on their parent atoms with U_{iso}(H) = 1.2U_{eq}(C) or 1.5U_{eq}(methyl C). The hydroxy H atom was located in a difference map and was allowed to refine as riding, with O—H = 0.84 Å, and with U_{iso}(H) = 1.5U_{eq}(O).

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{29}H_{36}O_9$
M_r	528.58
Crystal system, space group	Orthorhombic, $P2_12_12_1$
Temperature (K)	90
a, *b*, *c* (Å)	13.2073 (2), 13.2580 (2), 14.8563 (2)
V (Å^3)	2601.37 (7)
Z	4
Radiation type	Cu *Kα*
μ (mm^{-1})	0.83
Crystal size (mm)	0.27 × 0.14 × 0.09
Data collection	
Diffractometer	Bruker D8 Venture
Absorption correction	Multi-scan (*SADABS*; Bruker, 2016)
T_{min}, T_{max}	0.84, 0.93
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	17552, 4488, 4049
R_{int}	0.041
(sin $\theta/\lambda)_{max}$ (Å^{-1})	0.595
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, *S*	0.028, 0.058, 1.01
No. of reflections	4488
No. of parameters	349
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.19, −0.17
Absolute structure	Flack *x* determined using 1649 quotients $[(I^+)-(I^-)]/[(I^+)+(I^-)]$ (Parsons *et al.*, 2013).
Absolute structure parameter	0.01 (7)

Computer programs: *APEX3* and *SAINT* (Bruker, 2016), *SHELXT2014* (Sheldrick, 2015*a*), *SHELXL2014* (Sheldrick, 2015*b*), *Mercury* (Macrae *et al.*, 2020), *publCIF* (Westrip, 2010) and *PLATON* (Spek, 2020).

Acknowledgements

We thank Professor S. Ohba (Keio University, Japan) for his fruitful advice.

Funding information

Funding for this research was provided by: Keio Gijuku Fukuzawa Memorial Fund for the Advancement of Education and Research.

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supporting information

Acta Cryst. (2021). E**77**, 1234-1238 [https://doi.org/10.1107/S2056989021011518]

Crystal structure of (+)-(1*S*,5*S*,6*S*,7*S*,10*S*,11*S*,16*S*)-16-hydroxy-7-(methoxymethoxy)-11,15,18,18-tetramethyl-3,13-dioxo-2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadec-14-en-10-yl benzoate

Takeshi Oishi, Keisuke Fukaya, Takaaki Sato and Noritaka Chida

Computing details

Data collection: *APEX3* (Bruker, 2016); cell refinement: *SAINT* (Bruker, 2016); data reduction: *SAINT*(Bruker, 2016); program(s) used to solve structure: *SHELXT2014* (Sheldrick, 2015*a*); program(s) used to refine structure: *SHELXL2014* (Sheldrick, 2015*b*); molecular graphics: *Mercury* (Macrae *et al.*, 2020); software used to prepare material for publication: *publCIF* (Westrip, 2010) and *PLATON* (Spek, 2020).

(+)-(1*S*,5*S*,6*S*,7*S*,10*S*,11*S*,16*S*)-16-Hydroxy-7-(methoxymethoxy)-11,15,18,18-tetramethyl-3,13-dioxo-2,4-dioxatetracyclo[12.3.1.0^{1,5}.0^{6,11}]octadec-14-en-10-yl benzoate

Crystal data

$C_{29}H_{36}O_9$
M_r = 528.58
Orthorhombic, $P2_12_12_1$
a = 13.2073 (2) Å
b = 13.2580 (2) Å
c = 14.8563 (2) Å
V = 2601.37 (7) Å^3
Z = 4
F(000) = 1128
D_x = 1.350 Mg m^{-3}
Melting point = 508–505 K
Cu $K\alpha$ radiation, λ = 1.54178 Å
Cell parameters from 6149 reflections
θ = 4.5–66.6°
μ = 0.83 mm^{-1}
T = 90 K
Needle, colorless
0.27 × 0.14 × 0.09 mm

Data collection

Bruker D8 Venture diffractometer
Radiation source: fine-focus sealed tube
Multilayered confocal mirror monochromator
Detector resolution: 10.4167 pixels mm^{-1}
φ and ω scans
Absorption correction: multi-scan (*SADABS*; Bruker, 2016)
T_{min} = 0.84, T_{max} = 0.93
17552 measured reflections
4488 independent reflections
4049 reflections with $I > 2\sigma(I)$
R_{int} = 0.041
θ_{max} = 66.6°, θ_{min} = 4.5°
h = −15→15
k = −13→15
l = −17→17

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.028
$wR(F^2)$ = 0.058
S = 1.00
4488 reflections
349 parameters
0 restraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring sites
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + 0.9512P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max} = 0.19$ e Å^{-3}
$\Delta\rho_{min} = -0.17$ e Å^{-3}
Absolute structure: Flack *x* determined using 1649 quotients $[(I^+)-(I^-)]/[(I^+)+(I^-)]$ (Parsons *et al.*, 2013).
Absolute structure parameter: 0.01 (7)

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.

Refinement. Refinement of F^2 against ALL reflections. The weighted *R*–factor *wR* and goodness of fit *S* are based on F^2, conventional *R*–factors *R* are based on *F*, with *F* set to zero for negative F^2. The threshold expression of $F^2 > 2\sigma(F^2)$ is used only for calculating *R*–factors(gt) *etc.* and is not relevant to the choice of reflections for refinement. *R*–factors based on F^2 are statistically about twice as large as those based on *F*, and *R*–factors based on ALL data will be even larger. Problematic ten reflections (1 7 0, 0 9 1, 5 1 5, 0 0 8, 1 11 1, 2 7 0, –2 13 2, 2 1 7, 1 12 2, 2 13 2) with $|I(obs)-I(calc)|/\sigma W(I)$ greater than 10 have been omitted in the final refinement.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2)

	x	*y*	*z*	U_{iso}*/U_{eq}
C1	0.29313 (18)	0.36157 (17)	0.52288 (15)	0.0185 (5)
C2	0.40702 (17)	0.34711 (17)	0.54120 (14)	0.0165 (5)
H2	0.4148	0.2822	0.5748	0.02*
C3	0.46542 (17)	0.42818 (16)	0.59392 (14)	0.0154 (5)
H3	0.4159	0.4832	0.6073	0.019*
C4	0.55414 (18)	0.47775 (16)	0.54327 (14)	0.0170 (5)
H4	0.6045	0.4258	0.524	0.02*
C5	0.60464 (18)	0.55792 (19)	0.60195 (15)	0.0222 (5)
H5A	0.6669	0.5815	0.5713	0.027*
H5B	0.5584	0.6164	0.6072	0.027*
C6	0.63253 (18)	0.52209 (18)	0.69649 (15)	0.0199 (5)
H6A	0.6888	0.4729	0.6928	0.024*
H6B	0.6558	0.5802	0.7328	0.024*
C7	0.54246 (17)	0.47339 (16)	0.74180 (14)	0.0171 (5)
H7	0.4881	0.525	0.7503	0.02*
C8	0.49959 (17)	0.38399 (17)	0.68729 (14)	0.0163 (5)
C9	0.41449 (18)	0.33002 (18)	0.74281 (15)	0.0190 (5)
H9A	0.405	0.2628	0.7151	0.023*
H9B	0.4427	0.3181	0.8036	0.023*
C10	0.30917 (18)	0.37388 (17)	0.75641 (16)	0.0192 (5)
C11	0.25421 (17)	0.40784 (17)	0.67406 (15)	0.0184 (5)
C12	0.24790 (18)	0.50668 (17)	0.65522 (16)	0.0194 (5)
C13	0.22472 (18)	0.54081 (18)	0.55976 (15)	0.0219 (5)
H13	0.1498	0.5487	0.5533	0.026*
C14	0.26259 (19)	0.46571 (18)	0.48757 (15)	0.0206 (5)
H14A	0.2085	0.4568	0.4421	0.025*
H14B	0.3217	0.4959	0.4566	0.025*
C15	0.22581 (18)	0.32944 (18)	0.60119 (15)	0.0203 (5)

C16	0.23971 (19)	0.21823 (17)	0.62803 (16)	0.0240 (5)
H16A	0.2024	0.1751	0.5859	0.036*
H16B	0.2137	0.2078	0.6891	0.036*
H16C	0.3118	0.2009	0.6262	0.036*
C17	0.11267 (19)	0.3400 (2)	0.57840 (17)	0.0283 (6)
H17A	0.0972	0.4108	0.5652	0.042*
H17B	0.072	0.3175	0.6298	0.042*
H17C	0.0967	0.2985	0.5257	0.042*
C18	0.2724 (2)	0.58910 (19)	0.72090 (16)	0.0278 (6)
H18A	0.2873	0.5595	0.7799	0.042*
H18B	0.2143	0.6347	0.7262	0.042*
H18C	0.3314	0.6269	0.6995	0.042*
C19	0.58214 (18)	0.30291 (17)	0.67462 (16)	0.0197 (5)
H19A	0.6384	0.3312	0.6398	0.03*
H19B	0.5536	0.245	0.6424	0.03*
H19C	0.6069	0.281	0.7336	0.03*
O20	0.28228 (12)	0.29062 (12)	0.44657 (10)	0.0221 (4)
C21	0.37150 (19)	0.28495 (18)	0.40342 (16)	0.0220 (5)
O22	0.44552 (12)	0.33066 (11)	0.45053 (10)	0.0193 (4)
O23	0.38417 (14)	0.24438 (14)	0.33279 (11)	0.0302 (4)
O24	0.57161 (12)	0.43307 (11)	0.82891 (10)	0.0175 (3)
C25	0.56613 (17)	0.49480 (17)	0.90059 (15)	0.0177 (5)
O26	0.54871 (13)	0.58399 (12)	0.89538 (11)	0.0247 (4)
C27	0.57910 (17)	0.43860 (18)	0.98644 (15)	0.0184 (5)
C28	0.56861 (19)	0.33481 (19)	0.99105 (16)	0.0241 (6)
H28	0.5596	0.2971	0.9373	0.029*
C29	0.5710 (2)	0.2853 (2)	1.07304 (17)	0.0320 (6)
H29	0.5636	0.2141	1.0758	0.038*
C30	0.5845 (2)	0.3411 (2)	1.15120 (17)	0.0355 (7)
H30	0.5836	0.3082	1.208	0.043*
C31	0.5993 (2)	0.4441 (2)	1.14701 (16)	0.0326 (7)
H31	0.6116	0.4812	1.2006	0.039*
C32	0.59611 (17)	0.4935 (2)	1.06494 (16)	0.0237 (6)
H32	0.6055	0.5645	1.0622	0.028*
O33	0.27312 (13)	0.37839 (13)	0.83187 (11)	0.0279 (4)
O34	0.51273 (12)	0.52911 (12)	0.46645 (10)	0.0189 (4)
C35	0.56149 (19)	0.50924 (19)	0.38360 (15)	0.0235 (5)
H35A	0.559	0.4358	0.3719	0.028*
H35B	0.5235	0.5433	0.3348	0.028*
O36	0.66209 (13)	0.54080 (13)	0.38042 (11)	0.0262 (4)
C37	0.6726 (2)	0.6481 (2)	0.37659 (18)	0.0299 (6)
H37A	0.6369	0.674	0.3236	0.045*
H37B	0.7445	0.6657	0.3725	0.045*
H37C	0.6436	0.6782	0.4311	0.045*
O38	0.27143 (15)	0.63683 (12)	0.54668 (12)	0.0311 (4)
H38	0.2602	0.6569	0.494	0.047*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C1	0.0221 (13)	0.0182 (13)	0.0153 (12)	−0.0001 (9)	−0.0062 (10)	−0.0049 (9)
C2	0.0206 (12)	0.0169 (13)	0.0121 (11)	0.0014 (9)	0.0000 (9)	0.0006 (9)
C3	0.0181 (12)	0.0143 (12)	0.0139 (10)	0.0033 (9)	−0.0001 (10)	−0.0004 (9)
C4	0.0198 (12)	0.0166 (13)	0.0146 (11)	0.0021 (9)	−0.0008 (10)	0.0015 (9)
C5	0.0231 (13)	0.0230 (14)	0.0204 (12)	−0.0060 (10)	0.0013 (11)	0.0029 (10)
C6	0.0221 (13)	0.0172 (14)	0.0204 (12)	−0.0046 (9)	−0.0034 (10)	−0.0015 (9)
C7	0.0237 (13)	0.0151 (13)	0.0124 (11)	0.0021 (9)	−0.0030 (9)	0.0005 (9)
C8	0.0187 (12)	0.0156 (12)	0.0148 (11)	−0.0003 (9)	−0.0017 (10)	0.0007 (9)
C9	0.0251 (14)	0.0174 (12)	0.0144 (11)	−0.0032 (9)	−0.0033 (10)	0.0012 (9)
C10	0.0255 (13)	0.0129 (12)	0.0193 (13)	−0.0056 (9)	0.0010 (11)	−0.0023 (9)
C11	0.0141 (12)	0.0226 (14)	0.0184 (11)	0.0001 (9)	0.0031 (10)	−0.0020 (9)
C12	0.0162 (11)	0.0219 (13)	0.0202 (12)	0.0033 (9)	0.0029 (10)	−0.0032 (9)
C13	0.0218 (13)	0.0201 (13)	0.0238 (12)	0.0048 (10)	0.0001 (10)	0.0005 (10)
C14	0.0207 (13)	0.0241 (13)	0.0169 (11)	0.0034 (10)	−0.0029 (10)	−0.0004 (9)
C15	0.0196 (13)	0.0208 (13)	0.0204 (12)	−0.0012 (10)	−0.0026 (10)	−0.0003 (10)
C16	0.0246 (13)	0.0214 (13)	0.0258 (13)	−0.0052 (10)	−0.0020 (11)	−0.0016 (10)
C17	0.0220 (14)	0.0322 (16)	0.0308 (14)	−0.0043 (11)	−0.0020 (11)	−0.0027 (11)
C18	0.0402 (16)	0.0227 (14)	0.0206 (12)	0.0036 (11)	0.0015 (12)	−0.0039 (10)
C19	0.0241 (13)	0.0185 (13)	0.0166 (11)	0.0019 (9)	−0.0047 (10)	0.0001 (9)
O20	0.0252 (9)	0.0228 (9)	0.0182 (8)	0.0006 (7)	−0.0064 (7)	−0.0071 (7)
C21	0.0291 (14)	0.0180 (13)	0.0190 (12)	0.0069 (10)	−0.0067 (11)	−0.0015 (10)
O22	0.0238 (9)	0.0204 (9)	0.0138 (8)	0.0029 (7)	−0.0007 (7)	−0.0039 (6)
O23	0.0401 (11)	0.0314 (11)	0.0189 (9)	0.0117 (8)	−0.0075 (8)	−0.0098 (8)
O24	0.0239 (9)	0.0150 (9)	0.0134 (7)	0.0014 (6)	−0.0047 (7)	−0.0004 (6)
C25	0.0161 (11)	0.0186 (14)	0.0183 (11)	−0.0016 (9)	−0.0003 (10)	−0.0035 (9)
O26	0.0350 (10)	0.0170 (10)	0.0221 (9)	0.0007 (7)	0.0006 (8)	−0.0025 (7)
C27	0.0149 (12)	0.0245 (14)	0.0159 (11)	0.0008 (9)	−0.0006 (10)	0.0000 (9)
C28	0.0253 (14)	0.0276 (15)	0.0193 (12)	−0.0007 (11)	−0.0033 (11)	0.0005 (10)
C29	0.0337 (15)	0.0334 (16)	0.0287 (15)	−0.0021 (12)	−0.0025 (12)	0.0114 (11)
C30	0.0332 (16)	0.055 (2)	0.0186 (13)	0.0010 (13)	−0.0009 (12)	0.0112 (12)
C31	0.0275 (14)	0.055 (2)	0.0150 (12)	0.0018 (13)	−0.0016 (11)	−0.0082 (12)
C32	0.0188 (13)	0.0300 (15)	0.0224 (13)	0.0014 (10)	−0.0001 (10)	−0.0056 (10)
O33	0.0354 (10)	0.0296 (10)	0.0188 (9)	0.0012 (8)	0.0062 (8)	0.0013 (7)
O34	0.0247 (9)	0.0197 (9)	0.0124 (8)	0.0025 (6)	0.0011 (7)	0.0023 (6)
C35	0.0290 (14)	0.0253 (14)	0.0163 (12)	0.0019 (11)	0.0031 (10)	0.0004 (9)
O36	0.0272 (10)	0.0276 (10)	0.0236 (9)	0.0022 (7)	0.0067 (7)	0.0051 (7)
C37	0.0298 (15)	0.0291 (16)	0.0307 (14)	−0.0024 (11)	0.0034 (12)	0.0113 (11)
O38	0.0482 (12)	0.0182 (10)	0.0269 (9)	0.0012 (8)	0.0030 (9)	0.0029 (7)

Geometric parameters (Å, º)

C1—O20	1.480 (3)	C15—C17	1.539 (3)
C1—C14	1.531 (3)	C16—H16A	0.98
C1—C15	1.525 (3)	C16—H16B	0.98
C1—C2	1.541 (3)	C16—H16C	0.98

C2—O22	1.456 (3)	C17—H17A	0.98
C2—C3	1.537 (3)	C17—H17B	0.98
C2—H2	1.0	C17—H17C	0.98
C3—C4	1.540 (3)	C18—H18A	0.98
C3—C8	1.572 (3)	C18—H18B	0.98
C3—H3	1.0	C18—H18C	0.98
C4—O34	1.437 (3)	C19—H19A	0.98
C4—C5	1.528 (3)	C19—H19B	0.98
C4—H4	1.0	C19—H19C	0.98
C5—C6	1.528 (3)	O20—C21	1.344 (3)
C5—H5A	0.99	C21—O23	1.191 (3)
C5—H5B	0.99	C21—O22	1.346 (3)
C6—C7	1.512 (3)	O24—C25	1.345 (3)
C6—H6A	0.99	C25—O26	1.207 (3)
C6—H6B	0.99	C25—C27	1.487 (3)
C7—O24	1.452 (3)	C27—C28	1.385 (4)
C7—C8	1.543 (3)	C27—C32	1.393 (3)
C7—H7	1.0	C28—C29	1.384 (3)
C8—C19	1.543 (3)	C28—H28	0.95
C8—C9	1.567 (3)	C29—C30	1.389 (4)
C9—C10	1.521 (3)	C29—H29	0.95
C9—H9A	0.99	C30—C31	1.380 (4)
C9—H9B	0.99	C30—H30	0.95
C10—O33	1.219 (3)	C31—C32	1.385 (4)
C10—C11	1.492 (3)	C31—H31	0.95
C11—C12	1.343 (3)	C32—H32	0.95
C11—C15	1.547 (3)	O34—C35	1.414 (3)
C12—C18	1.500 (3)	C35—O36	1.394 (3)
C12—C13	1.520 (3)	C35—H35A	0.99
C13—O38	1.428 (3)	C35—H35B	0.99
C13—C14	1.547 (3)	O36—C37	1.431 (3)
C13—H13	1.0	C37—H37A	0.98
C14—H14A	0.99	C37—H37B	0.98
C14—H14B	0.99	C37—H37C	0.98
C15—C16	1.538 (3)	O38—H38	0.84

O20—C1—C14	106.57 (17)	H14A—C14—H14B	107.5
O20—C1—C15	110.51 (18)	C16—C15—C1	113.3 (2)
C14—C1—C15	111.1 (2)	C16—C15—C11	115.70 (19)
O20—C1—C2	98.67 (17)	C1—C15—C11	101.82 (18)
C14—C1—C2	115.5 (2)	C16—C15—C17	105.1 (2)
C15—C1—C2	113.56 (18)	C1—C15—C17	111.90 (19)
O22—C2—C1	101.31 (16)	C11—C15—C17	109.2 (2)
O22—C2—C3	113.62 (18)	C15—C16—H16A	109.5
C1—C2—C3	119.53 (18)	C15—C16—H16B	109.5
O22—C2—H2	107.2	H16A—C16—H16B	109.5
C1—C2—H2	107.2	C15—C16—H16C	109.5
C3—C2—H2	107.2	H16A—C16—H16C	109.5

C4—C3—C2	115.54 (18)	H16B—C16—H16C	109.5
C4—C3—C8	111.83 (18)	C15—C17—H17A	109.5
C2—C3—C8	109.45 (17)	C15—C17—H17B	109.5
C4—C3—H3	106.5	H17A—C17—H17B	109.5
C2—C3—H3	106.5	C15—C17—H17C	109.5
C8—C3—H3	106.5	H17A—C17—H17C	109.5
O34—C4—C5	106.83 (17)	H17B—C17—H17C	109.5
O34—C4—C3	107.50 (18)	C12—C18—H18A	109.5
C5—C4—C3	110.50 (18)	C12—C18—H18B	109.5
O34—C4—H4	110.6	H18A—C18—H18B	109.5
C5—C4—H4	110.6	C12—C18—H18C	109.5
C3—C4—H4	110.6	H18A—C18—H18C	109.5
C6—C5—C4	114.42 (19)	H18B—C18—H18C	109.5
C6—C5—H5A	108.7	C8—C19—H19A	109.5
C4—C5—H5A	108.7	C8—C19—H19B	109.5
C6—C5—H5B	108.7	H19A—C19—H19B	109.5
C4—C5—H5B	108.7	C8—C19—H19C	109.5
H5A—C5—H5B	107.6	H19A—C19—H19C	109.5
C7—C6—C5	110.63 (19)	H19B—C19—H19C	109.5
C7—C6—H6A	109.5	C21—O20—C1	108.42 (17)
C5—C6—H6A	109.5	O23—C21—O22	124.0 (2)
C7—C6—H6B	109.5	O23—C21—O20	124.7 (2)
C5—C6—H6B	109.5	O22—C21—O20	111.32 (19)
H6A—C6—H6B	108.1	C21—O22—C2	107.14 (17)
O24—C7—C6	110.20 (18)	C25—O24—C7	117.86 (17)
O24—C7—C8	106.39 (17)	O26—C25—O24	123.7 (2)
C6—C7—C8	112.53 (18)	O26—C25—C27	124.6 (2)
O24—C7—H7	109.2	O24—C25—C27	111.59 (19)
C6—C7—H7	109.2	C28—C27—C32	119.6 (2)
C8—C7—H7	109.2	C28—C27—C25	121.9 (2)
C19—C8—C7	109.88 (18)	C32—C27—C25	118.3 (2)
C19—C8—C9	104.65 (18)	C27—C28—C29	120.8 (2)
C7—C8—C9	109.74 (17)	C27—C28—H28	119.6
C19—C8—C3	110.79 (17)	C29—C28—H28	119.6
C7—C8—C3	106.39 (17)	C28—C29—C30	119.1 (3)
C9—C8—C3	115.39 (18)	C28—C29—H29	120.5
C10—C9—C8	123.5 (2)	C30—C29—H29	120.5
C10—C9—H9A	106.5	C31—C30—C29	120.5 (2)
C8—C9—H9A	106.5	C31—C30—H30	119.7
C10—C9—H9B	106.5	C29—C30—H30	119.7
C8—C9—H9B	106.5	C30—C31—C32	120.2 (2)
H9A—C9—H9B	106.5	C30—C31—H31	119.9
O33—C10—C11	123.3 (2)	C32—C31—H31	119.9
O33—C10—C9	119.9 (2)	C31—C32—C27	119.7 (3)
C11—C10—C9	116.8 (2)	C31—C32—H32	120.2
C12—C11—C10	119.7 (2)	C27—C32—H32	120.2
C12—C11—C15	119.7 (2)	C35—O34—C4	115.45 (17)
C10—C11—C15	119.28 (19)	O36—C35—O34	114.06 (19)

C11—C12—C18	124.2 (2)	O36—C35—H35A	108.7
C11—C12—C13	119.8 (2)	O34—C35—H35A	108.7
C18—C12—C13	115.7 (2)	O36—C35—H35B	108.7
O38—C13—C12	107.78 (19)	O34—C35—H35B	108.7
O38—C13—C14	109.87 (19)	H35A—C35—H35B	107.6
C12—C13—C14	112.97 (19)	C35—O36—C37	113.11 (19)
O38—C13—H13	108.7	O36—C37—H37A	109.5
C12—C13—H13	108.7	O36—C37—H37B	109.5
C14—C13—H13	108.7	H37A—C37—H37B	109.5
C1—C14—C13	115.35 (19)	O36—C37—H37C	109.5
C1—C14—H14A	108.4	H37A—C37—H37C	109.5
C13—C14—H14A	108.4	H37B—C37—H37C	109.5
C1—C14—H14B	108.4	C13—O38—H38	109.5
C13—C14—H14B	108.4		

O20—C1—C2—O22	34.44 (19)	C15—C1—C14—C13	34.9 (3)
C14—C1—C2—O22	−78.6 (2)	C2—C1—C14—C13	−96.3 (2)
C15—C1—C2—O22	151.38 (18)	O38—C13—C14—C1	134.1 (2)
O20—C1—C2—C3	160.10 (18)	C12—C13—C14—C1	13.7 (3)
C14—C1—C2—C3	47.0 (3)	O20—C1—C15—C16	51.3 (2)
C15—C1—C2—C3	−83.0 (3)	C14—C1—C15—C16	169.37 (19)
O22—C2—C3—C4	−0.3 (3)	C2—C1—C15—C16	−58.5 (3)
C1—C2—C3—C4	−119.9 (2)	O20—C1—C15—C11	176.24 (17)
O22—C2—C3—C8	−127.57 (19)	C14—C1—C15—C11	−65.7 (2)
C1—C2—C3—C8	112.8 (2)	C2—C1—C15—C11	66.4 (2)
C2—C3—C4—O34	62.8 (2)	O20—C1—C15—C17	−67.3 (3)
C8—C3—C4—O34	−171.15 (16)	C14—C1—C15—C17	50.8 (3)
C2—C3—C4—C5	179.00 (18)	C2—C1—C15—C17	−177.11 (19)
C8—C3—C4—C5	−54.9 (2)	C12—C11—C15—C16	177.6 (2)
O34—C4—C5—C6	167.08 (19)	C10—C11—C15—C16	10.9 (3)
C3—C4—C5—C6	50.4 (3)	C12—C11—C15—C1	54.3 (3)
C4—C5—C6—C7	−51.3 (3)	C10—C11—C15—C1	−112.5 (2)
C5—C6—C7—O24	175.86 (18)	C12—C11—C15—C17	−64.2 (3)
C5—C6—C7—C8	57.3 (3)	C10—C11—C15—C17	129.1 (2)
O24—C7—C8—C19	−61.5 (2)	C14—C1—O20—C21	91.8 (2)
C6—C7—C8—C19	59.3 (2)	C15—C1—O20—C21	−147.45 (19)
O24—C7—C8—C9	53.1 (2)	C2—C1—O20—C21	−28.2 (2)
C6—C7—C8—C9	173.87 (19)	C1—O20—C21—O23	−170.0 (2)
O24—C7—C8—C3	178.56 (17)	C1—O20—C21—O22	10.3 (2)
C6—C7—C8—C3	−60.7 (2)	O23—C21—O22—C2	−165.5 (2)
C4—C3—C8—C19	−60.1 (2)	O20—C21—O22—C2	14.2 (2)
C2—C3—C8—C19	69.2 (2)	C1—C2—O22—C21	−31.1 (2)
C4—C3—C8—C7	59.2 (2)	C3—C2—O22—C21	−160.57 (18)
C2—C3—C8—C7	−171.41 (18)	C6—C7—O24—C25	88.2 (2)
C4—C3—C8—C9	−178.81 (18)	C8—C7—O24—C25	−149.56 (18)
C2—C3—C8—C9	−49.5 (2)	C7—O24—C25—O26	−8.0 (3)
C19—C8—C9—C10	−168.0 (2)	C7—O24—C25—C27	169.16 (18)
C7—C8—C9—C10	74.2 (3)	O26—C25—C27—C28	160.2 (2)

C3—C8—C9—C10	−45.9 (3)	O24—C25—C27—C28	−17.0 (3)
C8—C9—C10—O33	−130.2 (2)	O26—C25—C27—C32	−15.8 (4)
C8—C9—C10—C11	50.9 (3)	O24—C25—C27—C32	167.0 (2)
O33—C10—C11—C12	77.9 (3)	C32—C27—C28—C29	2.4 (4)
C9—C10—C11—C12	−103.3 (3)	C25—C27—C28—C29	−173.5 (2)
O33—C10—C11—C15	−115.4 (3)	C27—C28—C29—C30	−0.2 (4)
C9—C10—C11—C15	63.4 (3)	C28—C29—C30—C31	−2.5 (4)
C10—C11—C12—C18	−14.1 (4)	C29—C30—C31—C32	3.0 (4)
C15—C11—C12—C18	179.3 (2)	C30—C31—C32—C27	−0.7 (4)
C10—C11—C12—C13	159.6 (2)	C28—C27—C32—C31	−2.0 (4)
C15—C11—C12—C13	−7.0 (3)	C25—C27—C32—C31	174.1 (2)
C11—C12—C13—O38	−150.6 (2)	C5—C4—O34—C35	110.5 (2)
C18—C12—C13—O38	23.6 (3)	C3—C4—O34—C35	−130.85 (19)
C11—C12—C13—C14	−29.0 (3)	C4—O34—C35—O36	−63.4 (3)
C18—C12—C13—C14	145.2 (2)	O34—C35—O36—C37	−71.5 (3)
O20—C1—C14—C13	155.30 (19)		

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O38—H38···O33^{i}	0.84	2.49	3.251 (2)	151
C14—H14*B*···O34	0.99	2.57	3.423 (3)	145
C18—H18*A*···O33	0.98	2.53	3.244 (3)	130
C35—H35*A*···O22	0.99	2.36	2.990 (3)	121
C16—H16*C*···O26^{ii}	0.98	2.43	3.331 (3)	153
C19—H19*B*···O26^{ii}	0.98	2.59	3.534 (3)	162
C37—H37*A*···O23^{iii}	0.98	2.52	3.445 (3)	158

Symmetry codes: (i) −*x*+1/2, −*y*+1, *z*−1/2; (ii) −*x*+1, *y*−1/2, −*z*+3/2; (iii) −*x*+1, *y*+1/2, −*z*+1/2.