IUCrData

ISSN 2414-3146

(23*R*,23^1*S*,25*S*)-23^1,26-Epoxy-23-ethylfurost-20(22)-en-3β-ol

Gabriel Guerrero-Luna,[a] María-Guadalupe Hernández-Linares,[a,b] Maura Cárdenas García[c] and Sylvain Bernès[d]*

[a]Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla, Av. San Claudio y 18 Sur, 72570 Puebla, Pue., Mexico, [b]Laboratorio de Investigación del Jardín Botánico, Benemérita Universidad Autónoma de Puebla, Av. San Claudio y 18 Sur, 72570 Puebla, Pue., Mexico, [c]Facultad de Medicina, Benemérita Universidad Autónoma de Puebla, 13 Sur 2702, 72420 Puebla, Pue., Mexico, and [d]Instituto de Física, Benemérita Universidad Autónoma de Puebla, Av. San Claudio y 18 Sur, 72570 Puebla, Pue., Mexico. *Correspondence e-mail: sylvain_bernes@hotmail.com2256805

Received 12 April 2023
Accepted 16 April 2023

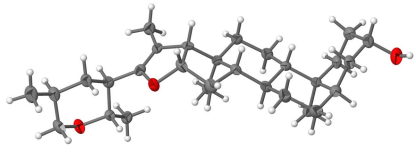
Edited by M. Bolte, Goethe-Universität Frankfurt, Germany

Keywords: crystal structure; tetrahydropyran; sarsasapogenin; rearrangement reaction; hydrogen bond.

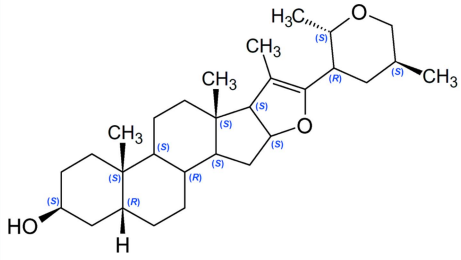
Structural data: full structural data are available from iucrdata.iucr.org

The title compound, $C_{29}H_{46}O_3$, is a steroid synthesized through a rearrangement of a sarsasapogenin derivative in acidic medium. The newly formed ring *F* is a tetrahydro-2*H*-pyran heterocycle substituted by two methyl groups placed in equatorial positions. This ring displays a chair conformation, while dihydrofuran ring *E*, to which it is bonded, has an envelope conformation. The molecules are associated by weak O—H···O hydrogen bonds to form chains running in the [101] direction in the crystal.

3D view



Chemical scheme



Structure description

The title steroid (**2**) was synthesized, starting from a derivative of sarsasapogenin (**1**), through a cleavage of ring *F* in acidic medium, followed by a Michael-type nucleophilic attack that affords a tetrahydro-2*H*-pyran ring bonded to the steroidal *E* ring (Fig. 1). The crystal structure of **1**·0.5H_2O has been reported previously (Viñas-Bravo *et al.*, 2003). On the other hand, the mechanism for the rearrangement **1**→**2** was described previously using a diosgenin derivative as substrate, instead of sarsasapogenin (del Río *et al.*, 2006). As expected from this mechanism, both methyl groups substituting the pyran ring in **2** are placed in equatorial positions, defining the stereochemistry for atoms C25 and C27 as *S*,*S* (Fig. 2). The pyran ring adopts a chair conformation, characterized by a puckering amplitude q = 0.578 (4) Å. Surprisingly, the Cambridge Structural Database (Version 5.43, with all updates; Groom *et al.*, 2016) does not contain any structure including the same heterocycle. However, many polysubstituted monocyclic tetrahydro-2*H*-pyran structures have been characterized by X-ray diffraction, showing that the chair confor-

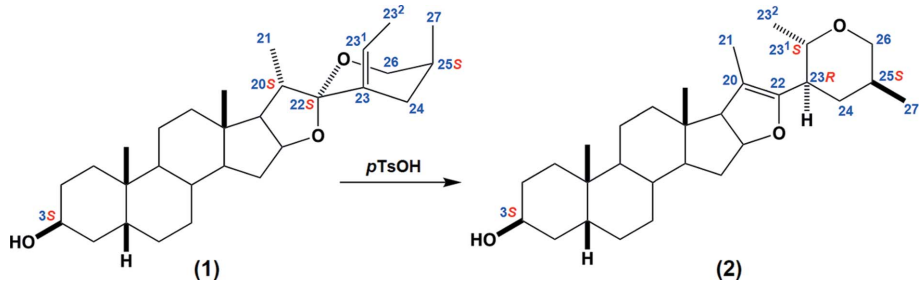


Figure 1
The synthesis of the title compound, **2**, starting from **1**. The atom-numbering scheme follows the recommendations of IUPAC (Moss, 1989). Key *R*/*S* configurations are displayed in red. *p*TsOH is *p*-toluenesulfonic acid.

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

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3*A*···O26^{i}	0.87 (4)	2.11 (4)	2.943 (4)	159 (5)

Symmetry code: (i) $x+1, y, z+1$.

mation is almost always stabilized (*e.g.* Burton *et al.*, 2007). Only a few exceptions to this rule are known, for some large molecules with steric hindrance issues (*e.g.* Aydillo *et al.*, 2013).

The 2,3-dihydrofuran ring *E* in **2** is close to being planar due to the presence of the C20═C22 double bond [1.324 (5) Å], also evidenced by a vibration at 1627 cm^{-1} in the IR spectrum. The conformation can be described as an envelope with atom C16 as the flap, which belongs to the C—C bond fusing the *D* and *E* rings. The *E* ring has a small puckering amplitude, q = 0.184 (4) Å. A very similar conformation was observed in other steroids having the same *E* ring (Shen *et al.*, 2013; Jeong & Fuchs, 1994). The remainder of the molecular structure, *i.e.* the *A*/*B*/*C*/*D* steroidal nucleus, is identical to that of sarsasapogenin, with *cis*-fused *A*/*B* rings.

The crystal structure is very simple, since it is based on a single weak O—H···O hydrogen bond, involving the hydroxy group at C3 and the O-atom acceptor of the tetrahydro-2*H*-pyran ring, O26 (Table 1 and Fig. 3). The molecules form infinite chains, running in the [101] direction. Neighbouring chains in the crystal are related by the twofold screw axis parallel to [010] in the space group $P2_1$.

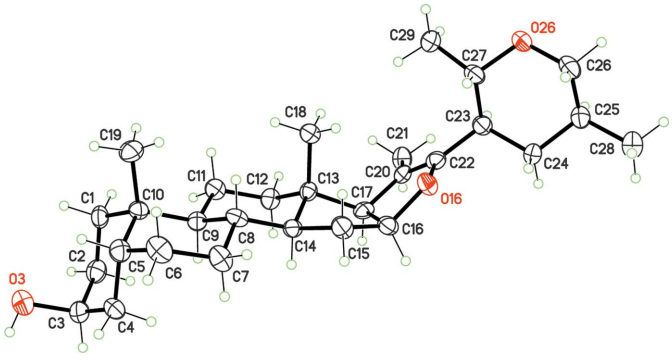


Figure 2
The molecular structure of the title compound, **2**, with displacement ellipsoids for non-H atoms drawn at the 50% probability level.

The molecular structure of **2** is embedded in a broader project aimed at targeting steroidal compounds which could interact with signalling pathways that control skeletal muscle atrophy and hypertrophy (Cohen *et al.*, 2015). Indeed, the web tool *SwissTargetPrediction* (Daina *et al.*, 2019) predicts that compound **2** presents a binding affinity for androgen and estrogen receptors, as well as for PI3K enzyme.

Synthesis and crystallization

In a round-bottomed flask was dissolved 275 mg (0.62 mmol) of **1** and 150 mg of *p*TsOH (*ca* 0.9 mmol) in 5 ml of benzene, and this mixture was refluxed for 30 min. The crude was then evaporated and the resulting solid dissolved in CH_2Cl_2, washed with distilled H_2O, dried over Na_2SO_4 and evaporated *in vacuo* to dryness. The residue was purified by chromatography over silica gel with hexane/EtOAc (4:1 *v*:*v*) as eluent, to give 268 mg of **2** (97% yield). IR (ν, cm^{-1}): 2998 (C—H), 1627 (C═C). ^{1}H NMR (500 MHz, $CDCl_3$): δ (ppm) 4.70 (1*H*, *m*, H-16), 4.08 (1*H*, *m*, H-3), 3.79 (1*H*, *ddd*, $J_{26eq,26ax}$ = 11.0, $J_{26eq,25}$ = 3.4 Hz, $J_{26eq,24eq}$ = 1.4, H-26eq), 3.36 (1*H*, *dq*, $J_{23\,(1),23}$ = 9.54, $J_{23\,(1),23\,(2)}$ = 6.2 Hz, H-23^1), 2.98 (1*H*, *dd*, $J_{26ax,26eq}$ = $J_{26ax,25}$ = 11.0 Hz, H-26ax), 2.46 (1*H*, *d*, $J_{17,16}$ = 10.0 Hz, H-17), 2.40 (1*H*, *ddd*, $J_{23,23\,(1)}$ = 9.54, $J_{23,24eq}$ = 3.4, $J_{23,24ax}$ = 11.0 Hz, H-23), 1.57 (3*H*, *s*, CH_3-21), 1.11 (3*H*, *d*, $J_{23\,(2),23\,(1)}$ = 6.5 Hz, C-23^2), 0.95 (3*H*, *s*, CH_3-19), 0.76 (3*H*, *d*, $J_{27,25}$ = 7.0 Hz, CH_3-27), 0.67 (3*H*, *s*, CH_3-18). ^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm) 152.5 (C-22), 105.0 (C-20), 85.0

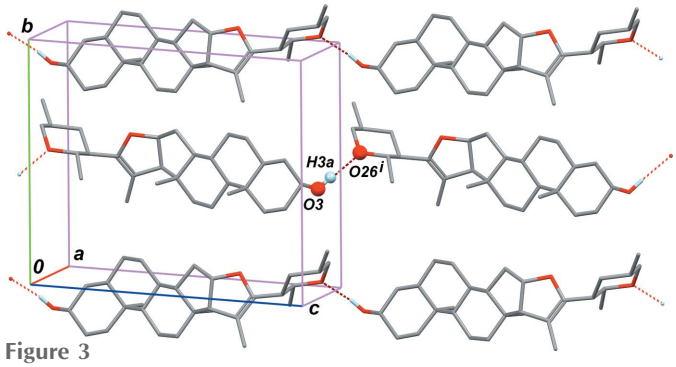


Figure 3
Part of the crystal structure of the title compound, **2**, showing chains formed *via* O—H···O hydrogen bonds (dashed bonds). For symmetry code (i), see Table 1.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{29}H_{46}O_3$
M_r	442.66
Crystal system, space group	Monoclinic, $P2_1$
Temperature (K)	153
a, b, c (Å)	6.3829 (7), 12.6897 (8), 15.9539 (17)
β (°)	101.308 (8)
V (Å^3)	1267.1 (2)
Z	2
Radiation type	Ag $K\alpha$, λ = 0.56083 Å
μ (mm^{-1})	0.05
Crystal size (mm)	0.24 × 0.16 × 0.07
Data collection	
Diffractometer	Stoe Stadivari
Absorption correction	Multi-scan (*X-AREA*; Stoe & Cie, 2018)
T_{min}, T_{max}	0.519, 1.000
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	15499, 4669, 2283
R_{int}	0.102
(sin $\theta/\lambda)_{max}$ (Å^{-1})	0.624
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.043, 0.077, 0.70
No. of reflections	4669
No. of parameters	298
No. of restraints	1
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.16, −0.18

Computer programs: *X-AREA* (Stoe & Cie, 2018), *SHELXT2018* (Sheldrick, 2015*a*), *SHELXL2018* (Sheldrick, 2015*b*), *XP* in *SHELXTL-Plus* (Sheldrick, 2008), *Mercury* (Macrae *et al.*, 2020) and *publCIF* (Westrip, 2010).

(C-16), 73.4 (C-23^1), 73.3 (C-26), 67.1 (C-3), 64.3 (C-17), 55.1 (C-14), 44.0 (C-9), 41.5 (C-10), 41.3 (C-23), 40.1 (C-5), 39.8 (C-4), 36.5 (C-6), 36.3 (C-15), 35.3 (C-1), 35.0 (C-12), 30.9 (C-2), 30.0 (C-13), 27.9 (C-7), 26.7 (C-8), 26.5 (C-25), 23.9 (C-24), 21.7 (C-11), 20.1 (CH_3-23^2), 17.0 (CH_3-19), 14.8 (CH_3-27), 14.3 (CH_3-18), 11.9 (CH_3-21).

Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. All H atoms were placed in calculated positions, with C—H = 1.00 (methine CH), 0.99 (methylene CH_2) or 0.98 Å (methyl CH_3). Atom H3*A* (of the hydroxy group) was refined with free coordinates. Isotropic displacement parameters for the H atoms were calculated as $U_{iso}(H) = xU_{eq}$(carrier atom), with x = 1.5 for methyl groups and the hydroxy H atom, and x = 1.2 for the other H atoms. The methyl groups were allowed to rotate but not to tip. Due to the absence of anomalous scatterers, the absolute configuration could not be determined and was set according to the starting material.

Funding information

Funding for this research was provided by: Consejo Nacional de Ciencia y Tecnología (grant Nos. 168178 and 171508).

References

Aydillo, C., Navo, C. D., Busto, J. H., Corzana, F., Zurbano, M. M., Avenoza, A. & Peregrina, J. M. (2013). *J. Org. Chem.* **78**, 10968–10977.
Burton, S., Fronczek, F. R. & Maverick, A. W. (2007). *Acta Cryst.* E**63**, o2661–o2662.
Cohen, S., Nathan, J. A. & Goldberg, A. L. (2015). *Nat. Rev. Drug Discov.* **14**, 58–74.
Daina, A., Michielin, O. & Zoete, V. (2019). *Nucleic Acids Res.* **47**, W357–W364.
Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* B**72**, 171–179.
Jeong, J. U. & Fuchs, P. L. (1994). *J. Am. Chem. Soc.* **116**, 773–774.
Macrae, C. F., Sovago, I., Cottrell, S. J., Galek, P. T. A., McCabe, P., Pidcock, E., Platings, M., Shields, G. P., Stevens, J. S., Towler, M. & Wood, P. A. (2020). *J. Appl. Cryst.* **53**, 226–235.
Moss, G. P. (1989). *Pure Appl. Chem.* **61**, 1783–1822.
Río, R. E. del, Santillán, R., Sandoval-Ramírez, J., Meza-Reyes, S., Montiel-Smith, S., Viñas-Bravo, O. & Farfán, N. (2006). *J. Mex. Chem. Soc.* **50**, 119–125.
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.
Shen, L. Q., Tang, Y. & Huang, S. Y. (2013). *Res. Chem. Intermed.* **39**, 2043–2047.
Stoe & Cie (2018). *X-AREA* and *X-RED32*. Stoe & Cie, Darmstadt, Germany.
Viñas-Bravo, O., Hernández-Linares, G., Mata-Esma, M. Y., Martínez-Pascual, R., Montiel-Smith, S., Meza-Reyes, S., Bernès, S., Sandoval-Ramírez, J. & Iglesias-Arteaga, M. A. (2003). *Arkivoc*, part xi, pp. 163–171.
Westrip, S. P. (2010). *J. Appl. Cryst.* **43**, 920–925.

full crystallographic data

IUCrData (2023). **8**, x230344 [https://doi.org/10.1107/S2414314623003449]

(23*R*,23^1*S*,25*S*)-23^1,26-Epoxy-23-ethylfurost-20(22)-en-3β-ol

Gabriel Guerrero-Luna, María-Guadalupe Hernández-Linares, Maura Cárdenas García and Sylvain Bernès

(23*R*,23^1*S*,25*S*)-23^1,26-Epoxy-23-ethylfurost-20(22)-en-3β-ol

Crystal data

$C_{29}H_{46}O_3$
M_r = 442.66
Monoclinic, $P2_1$
a = 6.3829 (7) Å
b = 12.6897 (8) Å
c = 15.9539 (17) Å
β = 101.308 (8)°
V = 1267.1 (2) Å^3
Z = 2
$F(000)$ = 488
D_x = 1.160 Mg m^{-3}
Ag $K\alpha$ radiation, λ = 0.56083 Å
Cell parameters from 7481 reflections
θ = 2.4–27.7°
μ = 0.05 mm^{-1}
T = 153 K
Irregular, colourless
0.24 × 0.16 × 0.07 mm

Data collection

Stoe Stadivari diffractometer
Radiation source: Sealed X-ray tube, Axo Astix-f Microfocus source
Graded multilayer mirror monochromator
Detector resolution: 5.81 pixels mm^{-1}
ω scans
Absorption correction: multi-scan (X-AREA; Stoe & Cie, 2018)
T_{min} = 0.519, T_{max} = 1.000
15499 measured reflections
4669 independent reflections
2283 reflections with $I > 2\sigma(I)$
R_{int} = 0.102
θ_{max} = 20.5°, θ_{min} = 2.4°
h = −7→7
k = −15→15
l = −19→19

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.043
$wR(F^2)$ = 0.077
S = 0.70
4669 reflections
298 parameters
1 restraint
0 constraints
Primary atom site location: dual
Secondary atom site location: difference Fourier map
Hydrogen site location: mixed
H atoms treated by a mixture of independent and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.0188P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max}$ = 0.16 e Å^{-3}
$\Delta\rho_{min}$ = −0.17 e Å^{-3}
Extinction correction: (SHELXL2018; Sheldrick 2015*b*), $Fc^* = kFc[1+0.001xFc^2\lambda^3/\sin(2\theta)]^{-1/4}$
Extinction coefficient: 0.0100 (10)

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

	x	*y*	*z*	U_{iso}*/U_{eq}
C1	0.7075 (7)	0.3112 (3)	0.7615 (3)	0.0303 (10)
H1A	0.621334	0.309403	0.806762	0.036*
H1B	0.674723	0.246376	0.726844	0.036*
C2	0.9432 (7)	0.3097 (3)	0.8037 (3)	0.0335 (11)
H2A	0.972593	0.247124	0.841295	0.040*
H2B	1.030808	0.303861	0.759143	0.040*
C3	1.0065 (6)	0.4089 (3)	0.8563 (2)	0.0353 (10)
H3	1.165276	0.410355	0.875704	0.042*
O3	0.9070 (5)	0.4036 (2)	0.93021 (18)	0.0447 (8)
H3A	0.972 (8)	0.449 (3)	0.967 (3)	0.067*
C4	0.9355 (6)	0.5075 (3)	0.8039 (2)	0.0313 (10)
H4A	1.024977	0.515500	0.760204	0.038*
H4B	0.961535	0.569582	0.842168	0.038*
C5	0.7003 (7)	0.5073 (3)	0.7592 (2)	0.0304 (10)
H5	0.612950	0.506869	0.804783	0.036*
C6	0.6443 (7)	0.6089 (3)	0.7069 (3)	0.0369 (12)
H6A	0.487038	0.614593	0.689524	0.044*
H6B	0.695409	0.670465	0.743349	0.044*
C7	0.7433 (7)	0.6119 (3)	0.6272 (2)	0.0332 (11)
H7A	0.900717	0.615808	0.644573	0.040*
H7B	0.693851	0.675862	0.593581	0.040*
C8	0.6827 (6)	0.5142 (3)	0.5712 (2)	0.0257 (9)
H8	0.524350	0.514261	0.550355	0.031*
C9	0.7450 (6)	0.4127 (3)	0.6240 (2)	0.0234 (9)
H9	0.902181	0.417847	0.646833	0.028*
C10	0.6379 (6)	0.4079 (3)	0.7034 (2)	0.0255 (9)
C11	0.7125 (7)	0.3130 (3)	0.5679 (3)	0.0287 (10)
H11A	0.775839	0.252065	0.602689	0.034*
H11B	0.557409	0.299583	0.549940	0.034*
C12	0.8121 (7)	0.3202 (3)	0.4879 (2)	0.0283 (10)
H12A	0.969689	0.322403	0.505309	0.034*
H12B	0.773442	0.256685	0.452232	0.034*
C13	0.7352 (6)	0.4182 (3)	0.4354 (2)	0.0229 (9)
C14	0.7897 (6)	0.5144 (3)	0.4943 (2)	0.0235 (9)
H14	0.947049	0.511511	0.517207	0.028*
C15	0.7515 (7)	0.6089 (3)	0.4321 (2)	0.0314 (11)
H15A	0.597790	0.626844	0.416707	0.038*
H15B	0.832343	0.671696	0.457074	0.038*
C16	0.8341 (7)	0.5686 (3)	0.3548 (2)	0.0288 (10)
H16	0.975553	0.601243	0.352721	0.035*
O16	0.6841 (4)	0.58617 (17)	0.27418 (16)	0.0291 (7)
C17	0.8563 (6)	0.4468 (3)	0.3631 (3)	0.0251 (10)
H17	1.010420	0.427022	0.380546	0.030*
C18	0.4938 (5)	0.4103 (3)	0.3978 (2)	0.0277 (9)
H18A	0.466708	0.349055	0.359841	0.042*

H18B	0.446279	0.474441	0.365412	0.042*
H18C	0.415055	0.402417	0.444388	0.042*
C19	0.3914 (5)	0.4007 (4)	0.6764 (3)	0.0373 (10)
H19A	0.339983	0.455995	0.634456	0.056*
H19B	0.326656	0.410169	0.726717	0.056*
H19C	0.351771	0.331534	0.650887	0.056*
C20	0.7720 (5)	0.4121 (3)	0.2728 (2)	0.0246 (9)
C21	0.7993 (7)	0.3020 (3)	0.2430 (3)	0.0340 (11)
H21A	0.720725	0.253044	0.273020	0.051*
H21B	0.951313	0.283437	0.255138	0.051*
H21C	0.743733	0.297329	0.181338	0.051*
C22	0.6775 (6)	0.4928 (3)	0.2281 (2)	0.0261 (10)
C23	0.5667 (6)	0.5036 (3)	0.1365 (2)	0.0268 (9)
H23	0.585841	0.436189	0.106392	0.032*
C24	0.6676 (6)	0.5930 (3)	0.0927 (2)	0.0300 (10)
H24A	0.662424	0.659391	0.124732	0.036*
H24B	0.819359	0.576203	0.093234	0.036*
C25	0.5498 (7)	0.6076 (3)	0.0008 (3)	0.0338 (10)
H25	0.565143	0.541937	−0.032062	0.041*
C26	0.3142 (7)	0.6251 (3)	0.0011 (3)	0.0381 (12)
H26A	0.297184	0.690286	0.033231	0.046*
H26B	0.235255	0.634484	−0.058357	0.046*
O26	0.2251 (4)	0.53738 (19)	0.03962 (17)	0.0344 (8)
C27	0.3263 (6)	0.5230 (3)	0.1284 (2)	0.0276 (10)
H27	0.304525	0.587849	0.161257	0.033*
C28	0.6418 (7)	0.6999 (3)	−0.0415 (3)	0.0475 (13)
H28A	0.612316	0.765851	−0.014044	0.071*
H28B	0.575716	0.702249	−0.102335	0.071*
H28C	0.796571	0.690815	−0.035290	0.071*
C29	0.2096 (6)	0.4323 (3)	0.1596 (3)	0.0335 (11)
H29A	0.059098	0.451242	0.155687	0.050*
H29B	0.274301	0.416708	0.219255	0.050*
H29C	0.219447	0.370062	0.124274	0.050*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C1	0.036 (3)	0.033 (2)	0.022 (2)	−0.002 (2)	0.008 (2)	0.004 (2)
C2	0.037 (3)	0.032 (2)	0.033 (3)	0.002 (2)	0.010 (2)	0.007 (2)
C3	0.031 (2)	0.048 (2)	0.027 (2)	−0.004 (2)	0.005 (2)	0.007 (2)
O3	0.050 (2)	0.0554 (19)	0.0292 (19)	−0.0094 (18)	0.0075 (16)	−0.0026 (17)
C4	0.033 (3)	0.035 (2)	0.024 (2)	−0.004 (2)	0.001 (2)	−0.002 (2)
C5	0.031 (3)	0.032 (2)	0.028 (2)	0.002 (2)	0.007 (2)	0.000 (2)
C6	0.042 (3)	0.032 (2)	0.035 (3)	0.008 (2)	0.004 (2)	−0.006 (2)
C7	0.045 (3)	0.0236 (19)	0.029 (3)	0.005 (2)	0.002 (2)	0.0007 (19)
C8	0.025 (2)	0.0226 (19)	0.026 (2)	0.000 (2)	−0.0029 (19)	−0.003 (2)
C9	0.022 (2)	0.0236 (17)	0.025 (2)	0.004 (2)	0.0046 (18)	0.001 (2)
C10	0.020 (2)	0.031 (2)	0.024 (2)	0.002 (2)	0.0025 (19)	0.001 (2)

C11	0.033 (3)	0.022 (2)	0.030 (2)	0.0007 (19)	0.004 (2)	0.002 (2)
C12	0.030 (3)	0.026 (2)	0.029 (3)	0.0032 (18)	0.007 (2)	0.0023 (19)
C13	0.023 (2)	0.0224 (18)	0.024 (2)	0.002 (2)	0.0064 (18)	0.0032 (19)
C14	0.022 (2)	0.0216 (18)	0.025 (2)	−0.0012 (19)	0.0010 (19)	0.004 (2)
C15	0.040 (3)	0.0238 (19)	0.029 (3)	−0.004 (2)	0.001 (2)	0.0005 (19)
C16	0.030 (3)	0.026 (2)	0.027 (2)	−0.0041 (18)	−0.003 (2)	0.0039 (19)
O16	0.0371 (18)	0.0245 (14)	0.0235 (16)	0.0008 (13)	0.0006 (14)	0.0011 (12)
C17	0.015 (2)	0.028 (2)	0.032 (3)	0.0028 (16)	0.004 (2)	0.0017 (18)
C18	0.028 (2)	0.0282 (18)	0.026 (2)	0.000 (2)	0.0025 (18)	−0.001 (2)
C19	0.025 (2)	0.049 (2)	0.039 (3)	0.001 (2)	0.009 (2)	−0.004 (2)
C20	0.022 (2)	0.0290 (19)	0.025 (2)	−0.001 (2)	0.0094 (18)	0.001 (2)
C21	0.042 (3)	0.031 (2)	0.031 (3)	0.004 (2)	0.010 (2)	0.003 (2)
C22	0.024 (2)	0.029 (2)	0.027 (2)	−0.0041 (19)	0.008 (2)	−0.0045 (19)
C23	0.028 (2)	0.0256 (19)	0.026 (2)	0.000 (2)	0.0030 (19)	0.000 (2)
C24	0.030 (3)	0.033 (2)	0.027 (2)	−0.0035 (19)	0.006 (2)	0.0073 (19)
C25	0.037 (3)	0.035 (2)	0.028 (2)	−0.005 (2)	0.003 (2)	0.006 (2)
C26	0.037 (3)	0.043 (2)	0.030 (3)	0.001 (2)	−0.005 (2)	0.009 (2)
O26	0.0336 (18)	0.0410 (17)	0.0252 (17)	−0.0081 (14)	−0.0027 (14)	0.0052 (13)
C27	0.025 (2)	0.034 (2)	0.022 (2)	0.0020 (19)	0.0002 (19)	−0.0017 (19)
C28	0.050 (4)	0.056 (3)	0.036 (3)	−0.006 (3)	0.008 (3)	0.014 (2)
C29	0.030 (3)	0.043 (3)	0.029 (2)	−0.002 (2)	0.010 (2)	0.003 (2)

Geometric parameters (Å, º)

C1—C2	1.523 (5)	C15—H15A	0.9900
C1—C10	1.551 (5)	C15—H15B	0.9900
C1—H1A	0.9900	C16—O16	1.462 (4)
C1—H1B	0.9900	C16—C17	1.556 (4)
C2—C3	1.523 (5)	C16—H16	1.0000
C2—H2A	0.9900	O16—C22	1.391 (4)
C2—H2B	0.9900	C17—C20	1.501 (5)
C3—O3	1.446 (4)	C17—H17	1.0000
C3—C4	1.524 (5)	C18—H18A	0.9800
C3—H3	1.0000	C18—H18B	0.9800
O3—H3A	0.87 (4)	C18—H18C	0.9800
C4—C5	1.531 (5)	C19—H19A	0.9800
C4—H4A	0.9900	C19—H19B	0.9800
C4—H4B	0.9900	C19—H19C	0.9800
C5—C6	1.539 (5)	C20—C22	1.324 (5)
C5—C10	1.550 (5)	C20—C21	1.498 (5)
C5—H5	1.0000	C21—H21A	0.9800
C6—C7	1.527 (5)	C21—H21B	0.9800
C6—H6A	0.9900	C21—H21C	0.9800
C6—H6B	0.9900	C22—C23	1.500 (5)
C7—C8	1.532 (5)	C23—C27	1.535 (5)
C7—H7A	0.9900	C23—C24	1.538 (5)
C7—H7B	0.9900	C23—H23	1.0000
C8—C14	1.517 (5)	C24—C25	1.522 (5)

C8—C9	1.548 (5)	C24—H24A	0.9900
C8—H8	1.0000	C24—H24B	0.9900
C9—C11	1.540 (5)	C25—C26	1.521 (5)
C9—C10	1.554 (5)	C25—C28	1.525 (5)
C9—H9	1.0000	C25—H25	1.0000
C10—C19	1.550 (5)	C26—O26	1.441 (4)
C11—C12	1.537 (5)	C26—H26A	0.9900
C11—H11A	0.9900	C26—H26B	0.9900
C11—H11B	0.9900	O26—C27	1.449 (4)
C12—C13	1.525 (5)	C27—C29	1.507 (5)
C12—H12A	0.9900	C27—H27	1.0000
C12—H12B	0.9900	C28—H28A	0.9800
C13—C14	1.538 (5)	C28—H28B	0.9800
C13—C18	1.543 (5)	C28—H28C	0.9800
C13—C17	1.552 (5)	C29—H29A	0.9800
C14—C15	1.545 (5)	C29—H29B	0.9800
C14—H14	1.0000	C29—H29C	0.9800
C15—C16	1.521 (5)		

C2—C1—C10	114.6 (3)	C16—C15—H15A	111.2
C2—C1—H1A	108.6	C14—C15—H15A	111.2
C10—C1—H1A	108.6	C16—C15—H15B	111.2
C2—C1—H1B	108.6	C14—C15—H15B	111.2
C10—C1—H1B	108.6	H15A—C15—H15B	109.1
H1A—C1—H1B	107.6	O16—C16—C15	113.0 (3)
C3—C2—C1	111.4 (3)	O16—C16—C17	105.0 (3)
C3—C2—H2A	109.3	C15—C16—C17	107.8 (3)
C1—C2—H2A	109.3	O16—C16—H16	110.3
C3—C2—H2B	109.3	C15—C16—H16	110.3
C1—C2—H2B	109.3	C17—C16—H16	110.3
H2A—C2—H2B	108.0	C22—O16—C16	106.4 (3)
O3—C3—C2	107.4 (3)	C20—C17—C13	120.5 (3)
O3—C3—C4	110.7 (3)	C20—C17—C16	101.5 (3)
C2—C3—C4	111.0 (3)	C13—C17—C16	104.2 (3)
O3—C3—H3	109.2	C20—C17—H17	109.9
C2—C3—H3	109.2	C13—C17—H17	109.9
C4—C3—H3	109.2	C16—C17—H17	109.9
C3—O3—H3A	107 (3)	C13—C18—H18A	109.5
C3—C4—C5	114.5 (3)	C13—C18—H18B	109.5
C3—C4—H4A	108.6	H18A—C18—H18B	109.5
C5—C4—H4A	108.6	C13—C18—H18C	109.5
C3—C4—H4B	108.6	H18A—C18—H18C	109.5
C5—C4—H4B	108.6	H18B—C18—H18C	109.5
H4A—C4—H4B	107.6	C10—C19—H19A	109.5
C4—C5—C6	110.7 (3)	C10—C19—H19B	109.5
C4—C5—C10	112.8 (3)	H19A—C19—H19B	109.5
C6—C5—C10	111.4 (3)	C10—C19—H19C	109.5
C4—C5—H5	107.2	H19A—C19—H19C	109.5

C6—C5—H5	107.2	H19B—C19—H19C	109.5
C10—C5—H5	107.2	C22—C20—C21	128.3 (4)
C7—C6—C5	112.4 (3)	C22—C20—C17	109.3 (3)
C7—C6—H6A	109.1	C21—C20—C17	122.4 (3)
C5—C6—H6A	109.1	C20—C21—H21A	109.5
C7—C6—H6B	109.1	C20—C21—H21B	109.5
C5—C6—H6B	109.1	H21A—C21—H21B	109.5
H6A—C6—H6B	107.9	C20—C21—H21C	109.5
C6—C7—C8	111.5 (3)	H21A—C21—H21C	109.5
C6—C7—H7A	109.3	H21B—C21—H21C	109.5
C8—C7—H7A	109.3	C20—C22—O16	114.2 (3)
C6—C7—H7B	109.3	C20—C22—C23	132.4 (4)
C8—C7—H7B	109.3	O16—C22—C23	113.4 (3)
H7A—C7—H7B	108.0	C22—C23—C27	111.7 (3)
C14—C8—C7	111.6 (3)	C22—C23—C24	110.6 (3)
C14—C8—C9	109.5 (3)	C27—C23—C24	110.2 (3)
C7—C8—C9	110.3 (3)	C22—C23—H23	108.1
C14—C8—H8	108.5	C27—C23—H23	108.1
C7—C8—H8	108.5	C24—C23—H23	108.1
C9—C8—H8	108.5	C25—C24—C23	110.9 (3)
C11—C9—C8	112.1 (3)	C25—C24—H24A	109.5
C11—C9—C10	114.2 (3)	C23—C24—H24A	109.5
C8—C9—C10	111.6 (3)	C25—C24—H24B	109.5
C11—C9—H9	106.0	C23—C24—H24B	109.5
C8—C9—H9	106.0	H24A—C24—H24B	108.1
C10—C9—H9	106.0	C26—C25—C24	108.5 (3)
C19—C10—C5	109.9 (3)	C26—C25—C28	110.9 (3)
C19—C10—C1	106.0 (3)	C24—C25—C28	111.1 (3)
C5—C10—C1	106.8 (3)	C26—C25—H25	108.8
C19—C10—C9	111.2 (3)	C24—C25—H25	108.8
C5—C10—C9	109.4 (3)	C28—C25—H25	108.8
C1—C10—C9	113.5 (3)	O26—C26—C25	111.2 (3)
C12—C11—C9	113.7 (3)	O26—C26—H26A	109.4
C12—C11—H11A	108.8	C25—C26—H26A	109.4
C9—C11—H11A	108.8	O26—C26—H26B	109.4
C12—C11—H11B	108.8	C25—C26—H26B	109.4
C9—C11—H11B	108.8	H26A—C26—H26B	108.0
H11A—C11—H11B	107.7	C26—O26—C27	112.1 (3)
C13—C12—C11	111.3 (3)	O26—C27—C29	105.4 (3)
C13—C12—H12A	109.4	O26—C27—C23	110.4 (3)
C11—C12—H12A	109.4	C29—C27—C23	113.6 (3)
C13—C12—H12B	109.4	O26—C27—H27	109.1
C11—C12—H12B	109.4	C29—C27—H27	109.1
H12A—C12—H12B	108.0	C23—C27—H27	109.1
C12—C13—C14	107.6 (3)	C25—C28—H28A	109.5
C12—C13—C18	110.5 (3)	C25—C28—H28B	109.5
C14—C13—C18	112.2 (3)	H28A—C28—H28B	109.5
C12—C13—C17	116.4 (3)	C25—C28—H28C	109.5

C14—C13—C17	100.5 (3)	H28A—C28—H28C	109.5
C18—C13—C17	109.3 (3)	H28B—C28—H28C	109.5
C8—C14—C13	114.1 (3)	C27—C29—H29A	109.5
C8—C14—C15	118.8 (3)	C27—C29—H29B	109.5
C13—C14—C15	103.6 (3)	H29A—C29—H29B	109.5
C8—C14—H14	106.5	C27—C29—H29C	109.5
C13—C14—H14	106.5	H29A—C29—H29C	109.5
C15—C14—H14	106.5	H29B—C29—H29C	109.5
C16—C15—C14	102.9 (3)		

C10—C1—C2—C3	56.8 (4)	C18—C13—C14—C15	−70.0 (4)
C1—C2—C3—O3	70.1 (4)	C17—C13—C14—C15	46.1 (4)
C1—C2—C3—C4	−51.1 (4)	C8—C14—C15—C16	−166.3 (3)
O3—C3—C4—C5	−68.4 (4)	C13—C14—C15—C16	−38.5 (4)
C2—C3—C4—C5	50.8 (4)	C14—C15—C16—O16	131.1 (3)
C3—C4—C5—C6	−179.1 (3)	C14—C15—C16—C17	15.5 (4)
C3—C4—C5—C10	−53.6 (5)	C15—C16—O16—C22	−135.1 (3)
C4—C5—C6—C7	71.5 (4)	C17—C16—O16—C22	−17.8 (4)
C10—C5—C6—C7	−54.9 (5)	C12—C13—C17—C20	95.8 (4)
C5—C6—C7—C8	54.7 (4)	C14—C13—C17—C20	−148.4 (3)
C6—C7—C8—C14	−177.2 (3)	C18—C13—C17—C20	−30.2 (5)
C6—C7—C8—C9	−55.3 (4)	C12—C13—C17—C16	−151.3 (3)
C14—C8—C9—C11	−49.8 (4)	C14—C13—C17—C16	−35.5 (4)
C7—C8—C9—C11	−173.0 (4)	C18—C13—C17—C16	82.6 (4)
C14—C8—C9—C10	−179.5 (3)	O16—C16—C17—C20	17.8 (4)
C7—C8—C9—C10	57.4 (4)	C15—C16—C17—C20	138.5 (3)
C4—C5—C10—C19	167.6 (3)	O16—C16—C17—C13	−108.1 (4)
C6—C5—C10—C19	−67.1 (4)	C15—C16—C17—C13	12.7 (4)
C4—C5—C10—C1	53.1 (4)	C13—C17—C20—C22	102.3 (4)
C6—C5—C10—C1	178.3 (4)	C16—C17—C20—C22	−12.0 (4)
C4—C5—C10—C9	−70.1 (4)	C13—C17—C20—C21	−78.2 (5)
C6—C5—C10—C9	55.1 (4)	C16—C17—C20—C21	167.5 (3)
C2—C1—C10—C19	−173.3 (3)	C21—C20—C22—O16	−178.3 (3)
C2—C1—C10—C5	−56.1 (4)	C17—C20—C22—O16	1.2 (5)
C2—C1—C10—C9	64.5 (4)	C21—C20—C22—C23	0.7 (7)
C11—C9—C10—C19	−64.1 (4)	C17—C20—C22—C23	−179.9 (4)
C8—C9—C10—C19	64.5 (4)	C16—O16—C22—C20	11.1 (4)
C11—C9—C10—C5	174.4 (3)	C16—O16—C22—C23	−168.1 (3)
C8—C9—C10—C5	−57.0 (4)	C20—C22—C23—C27	112.5 (5)
C11—C9—C10—C1	55.3 (4)	O16—C22—C23—C27	−68.5 (4)
C8—C9—C10—C1	−176.2 (3)	C20—C22—C23—C24	−124.5 (5)
C8—C9—C11—C12	49.6 (4)	O16—C22—C23—C24	54.5 (4)
C10—C9—C11—C12	177.9 (3)	C22—C23—C24—C25	−177.5 (3)
C9—C11—C12—C13	−53.6 (4)	C27—C23—C24—C25	−53.6 (4)
C11—C12—C13—C14	56.6 (4)	C23—C24—C25—C26	54.9 (4)
C11—C12—C13—C18	−66.2 (4)	C23—C24—C25—C28	177.0 (3)
C11—C12—C13—C17	168.4 (3)	C24—C25—C26—O26	−58.8 (4)
C7—C8—C14—C13	180.0 (3)	C28—C25—C26—O26	179.0 (3)

C9—C8—C14—C13	57.6 (4)	C25—C26—O26—C27	62.2 (4)
C7—C8—C14—C15	−57.3 (4)	C26—O26—C27—C29	177.6 (3)
C9—C8—C14—C15	−179.7 (3)	C26—O26—C27—C23	−59.3 (4)
C12—C13—C14—C8	−61.0 (4)	C22—C23—C27—O26	177.7 (3)
C18—C13—C14—C8	60.7 (4)	C24—C23—C27—O26	54.4 (4)
C17—C13—C14—C8	176.8 (3)	C22—C23—C27—C29	−64.2 (4)
C12—C13—C14—C15	168.3 (3)	C24—C23—C27—C29	172.6 (3)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O3—H3*A*···O26^{i}	0.87 (4)	2.11 (4)	2.943 (4)	159 (5)

Symmetry code: (i) *x*+1, *y*, *z*+1.