IUCrData

ISSN 2414-3146

(3β,5α,25R)-12-(Hydroxyimino)spirostan-3-yl acetate

Alan Carrasco-Carballo,[a] Gabriel Guerrero-Luna,[a] María-Guadalupe Hernández Linares[a] and Sylvain Bernès[b]*

[a]Laboratorio de Investigación del Jardín Botánico, Instituto de Ciencias, Benemérita Universidad Autónoma de Puebla, Edif. 113 Complejo de Ciencias CU, San Manuel, 72570 Puebla, Pue., Mexico, and [b]Instituto de Física, Benemérita Universidad Autónoma de Puebla, Av. San Claudio y 18 Sur, 72570 Puebla, Pue., Mexico. *Correspondence e-mail: sylvain_bernes@hotmail.com

Received 22 March 2017
Accepted 29 March 2017

Edited by K. Fejfarova, Institute of Biotechnology CAS, Czech Republic

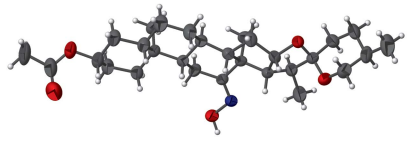
Keywords: crystal structure; oxime steroid; spirostan; hecogenin; hydrogen bonding.

CCDC reference: 1540985

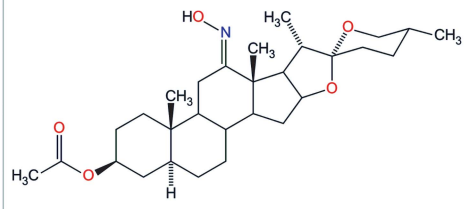
Structural data: full structural data are available from iucrdata.iucr.org

The title steroid, $C_{29}H_{45}NO_5$, obtained by condensation of hecogenin acetate [systematic name: (3β,5α,25*R*)-12-oxospirostan-3-yl acetate] with NH_2OH, has the oxime group substituting the C-12 site on the *C* ring of the steroid nucleus. The introduction of this functional group allows the formation of chain motifs, using the oxime OH group as a donor and the O atom of the *E* ring as an acceptor. The *C*(8) chains formed by this intermolecular hydrogen bond are oriented parallel to the short cell axis *a*. The structural features of this compound are very close to those of $C_{29}H_{43}NO_5$, the derivative with a C14=C15 double bond in the *D* ring, which crystallizes in the same space group and with similar unit-cell parameters.

3D view



Chemical scheme



Structure description

The synthesis of steroidal oximes has been of significant relevance in recent years, reflected in some reports in the literature about the possible anticancer properties of this class of compounds (Bansal & Acharya, 2014; Cui *et al.*, 2009). Research regarding the selective synthesis of oximes and polyoximes of naturally occurring steroids is thus active. For example, we reported the functionalization of 23-acetyl-sarsasapogenin acetate on the position C-23 in ring *F*, by condensation with hydroxyl amine, affording an oxime, which seems to be rearranged to its zwitterionic form while recrystallized in slightly acidic media (Hernández Linares *et al.*, 2009). More recently, we reported the synthesis and analysis of the antiproliferative activity of oximes derived from diosgenin (Sánchez-Sánchez *et al.*, 2016). We are now focused on the synthesis of oximes of other sapogenins, including hecogenin [IUPAC name: (25*R*)-3β-hydroxy-5α-spirostan-12-one], a natural

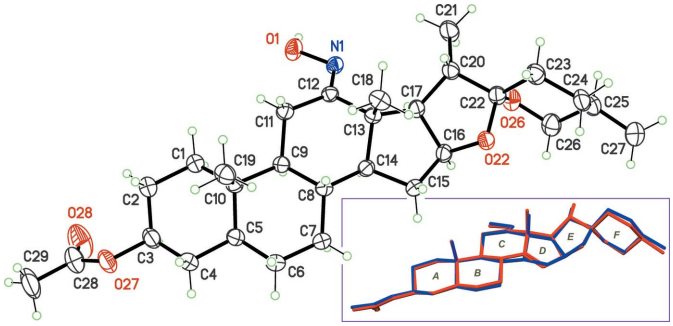


Figure 1
The asymmetric unit of the title compound, with displacement ellipsoids for non-H atoms at the 30% probability level. The inset is a fit computed over all non-H atoms, comparing the title compound (blue) and the $\Delta^{14,15}$ compound characterized by Wartchow & Brunck (2015) (red).

steroid found in many agaves. The present report is of the crystal structure of the product obtained through the condensation reaction between hecogenin acetate and NH_2OH.

As expected, the condensation functionalizes the C-12 position of the *C* ring (Fig. 1). The spirostan *A*–*F* nucleus presents a conformation identical to that reported for the parent compounds, hecogenin hydrate (Soriano-García *et al.*, 1984) and hecogenin acetate (Slavyanov *et al.*, 1982; Rajnikant *et al.*, 2005), and close to that observed for the $\Delta^{14,15}$ compound, which has been deposited in the CSD with refcode LUBDIX (Wartchow & Brunck, 2015; see Fig. 1, inset). For example, a fit between the title compound and LUBDIX gives an r.m.s. deviation of 0.21 Å. In the oximes, the C-12 centre retains the sp^2 hybridization of hecogenin, and the *C* ring has a conformation close to the chair form: for the title compound,

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

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O1—H1···O22^{i}	0.91 (4)	1.89 (4)	2.781 (2)	166 (3)

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

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{29}H_{45}NO_5$
M_r	487.66
Crystal system, space group	Orthorhombic, $P2_12_12_1$
Temperature (K)	295
a, *b*, *c* (Å)	8.3161 (2), 9.9302 (5), 33.0414 (11)
V (Å^3)	2728.58 (18)
Z	4
Radiation type	Ag *Kα*, λ = 0.56083 Å
μ (mm^{-1})	0.05
Crystal size (mm)	0.30 × 0.25 × 0.12
Data collection	
Diffractometer	Stoe Stadivari
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	46178, 6173, 4035
R_{int}	0.057
$(\sin\theta/\lambda)_{max}$ (Å^{-1})	0.656
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, *S*	0.044, 0.107, 0.92
No. of reflections	6173
No. of parameters	324
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.15, −0.17

Computer programs: *X-AREA* (Stoe & Cie, 2015), *SHELXT2014/5* (Sheldrick, 2015*a*), *SHELXL2016/6* (Sheldrick, 2015*b*), *XP* in *SHELXTL-Plus* (Sheldrick, 2008), *Mercury* (Macrae *et al.*, 2008) and *publCIF* (Westrip, 2010).

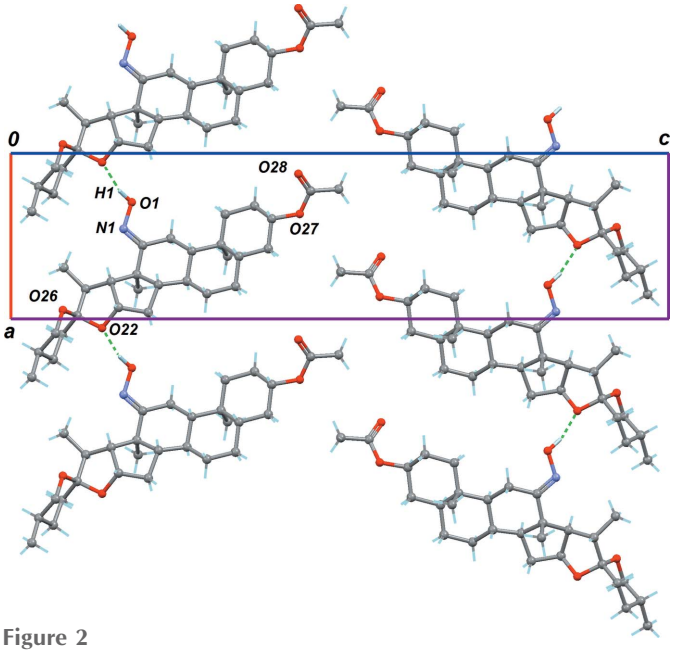


Figure 2
Part of the crystal structure, viewed down the *b* axis. Six molecules in two chains are represented, and intermolecular O1—H1···O22^{i} hydrogen bonds (Table 1) are shown as dashed bonds [symmetry code: (i) $x-1, y, z$].

the puckering parameters for this ring are $\theta = 7.8\ (2)^\circ$ and $\varphi = 315.1\ (19)^\circ$ (ideal value for a chair form: $\theta = 0^\circ$). The oxime group is configured *trans*, which is known to be favoured compared to the *cis* configuration.

The oxime functionality is a good donor group for hydrogen bonding, and as a result, $C(8)$ chain motifs are formed in the crystal, based on intermolecular O—H···O hydrogen bonds of medium strength (Table 1). The chains are oriented in the [100] direction, and no interchain contacts are observed, consistent with a true one-dimensional supramolecular structure (Fig. 2).

Synthesis and crystallization

In a round-bottom flask, $NH_2OH{\cdot}HCl$ (0.209 g, 3.00 mmol) was added to a solution of hecogenin acetate (1.0 g, 2.12 mmol) and KOAc (0.294 g, 3.00 mmol) in EtOH (30 ml), and the mixture was allowed to stir at reflux. After a period of 1 h, organic extraction was performed (CH_2Cl_2, 3 × 10 ml), the organic phase was washed with distilled water (2 × 15 ml), dried over Na_2SO_4 and concentrated under reduced pressure. The title oxime was obtained as a colourless solid (0.982 g,

95%), and was recrystallized from CH_2Cl_2; m.p. = 318–320°C, $[\alpha]_D = -2.6°$ (c = 0.01, $CHCl_3$), IR/ν_{max} = 3498, 1732, 1350, 1060 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$), δ/p.p.m.: 4.65 (1*H*, *m*, H-3), 4.32 (1*H*, *m*, H-16), 3.49 (1*H*, *dd*, $J_{26,25}$ = 4 Hz, J_{gem} = 11 Hz, H-26*a*), 3.37 (1*H*, *d*, J_{gem} = 11 Hz, H-26*e*), 2.64 (1*H*, *dd*, $J_{23a,24e}$ = 4.2 Hz, $J_{23a,24a}$ = 12.0 Hz, H-23*a*), 2.54 (1*H*, *dc*, $J_{17,20}$ = 10 Hz, H-17), 2.37 (1*H*, *ddd*, $J_{24e,23a}$ = 4 Hz, $J_{gem} = J_{24e,25a}$ = 13 Hz, H-24*e*), 2.20 (1*H*, *dd*, $J_{24a,23a} = J_{gem}$ = 10 Hz, H-24*a*), 1.04 (3*H*, *d*, $J_{21,20}$ = 6.0 Hz, CH_3-21), 0.91 (3*H*, *s*, CH_3-19), 0.87 (3*H*, *s*, CH_3-18), 0.84 (3*H*, *d*, $J_{27,25}$ = 6.0 Hz, CH_3-27). ^{13}C-NMR (125 MHz, $CDCl_3$), δ/p.p.m.: 12.0 (C-18), 12.9 (C-21), 16.0 (C-19), 17.0 (C-27), 28.3 (C-6), 29.7 (C-5), 30.9 (C– 7), 31.2 (C-1), 31.6 (C-2), 32.0 (C-4), 34.1 (C-8), 36.1 (C-15), 36.4 (C-10), 37.7 (C-24), 37.8 (C-11), 38.8 (C-9), 44.6 (C-25), 52.3 (C-20), 55.3 (C-13), 55.4 (C-14), 55.5 (C-17), 66.1 (C-26), 70.8 (C-3), 79.4 (C-16), 109.3 (C-22), 170.7 (CH_3COO-3), 164.9 (C-12).

Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. The absolute configuration was assigned following that of hecogenin, since diffraction data were collected at room temperature and using a silver target (λ = 0.56083 Å).

Acknowledgements

The reported structure is the first one collected using the new X-ray facility installed at IF-UAP, Puebla. The authors thank the funding agency (CONACyT), VIEP–BUAP for support, and the companies involved in the installation: Spectramex SA de CV (Mexico), and Stoe & Cie GmbH (Darmstadt, Germany), with special thanks to Dr rer. nat. Jens Meyer and Dipl.-Phys. Steffen Sandner. MGHL thanks BUAP for financial support (PRODEP-NPTC-DSA/103.5/16/10420).

Funding information

Funding for this research was provided by: Consejo Nacional de Ciencia y Tecnología (award No. 268178, Infraestructura); Benemérita Universidad Autónoma de Puebla (award No. PRODEP-NPTC-DSA/103.5/16/10420).

References

Bansal, R. & Acharya, P. C. (2014). *Chem. Rev.* **114**, 6986–7005.
Cui, J.-G., Fan, L., Huang, L.-L., Liu, H.-L. & Zhou, A.-M. (2009). *Steroids*, **74**, 62–72.
Hernández Linares, M.-G., Sandoval Ramírez, J., Meza Reyes, S., Montiel Smith, S. & Bernès, S. (2009). *Acta Cryst.* E**65**, o2954–o2955.
Macrae, C. F., Bruno, I. J., Chisholm, J. A., Edgington, P. R., McCabe, P., Pidcock, E., Rodriguez-Monge, L., Taylor, R., van de Streek, J. & Wood, P. A. (2008). *J. Appl. Cryst.* **41**, 466–470.
Rajnikant, Dinesh, Mousmi, Aziz, N. & Varghese, B. (2005). *Indian J. Phys. A*, **79**, 285–287.
Sánchez-Sánchez, L., Hernández-Linares, M. G., Escobar, M. L., López-Muñoz, H., Zenteno, E., Fernández-Herrera, M. A., Guerrero-Luna, G., Carrasco-Carballo, A. & Sandoval-Ramírez, J. (2016). *Molecules*, **21**, 1533.
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.
Slavyanov, E. V., Lobkovskaya, R. M., Biyushkin, V. N., Kintya, P. K. & Bobeiko, V. A. (1982). *Chem. Nat. Compd.* **18**, 582–585.
Soriano-García, M., Toscano, R. A., López, I., Hernández, A. & Enríquez, P. (1984). *Acta Cryst.* C**40**, 2116–2118.
Stoe & Cie (2015). *X-AREA*. Stoe & Cie, Darmstadt, Germany.
Wartchow, R. & Brunck, A. (2015). Private communication (No. 1043206). CCDC, Cambridge, England.
Westrip, S. P. (2010). *J. Appl. Cryst.* **43**, 920–925.

full crystallographic data

IUCrData (2017). **2**, x170491 [https://doi.org/10.1107/S2414314617004916]

(3*β*,5*α*,25*R*)-12-(Hydroxyimino)spirostan-3-yl acetate

Alan Carrasco-Carballo, Gabriel Guerrero-Luna, María-Guadalupe Hernández Linares and Sylvain Bernès

(3*β*,5*α*,25*R*)-12-(Hydroxyimino)spirostan-3-yl acetate

Crystal data

$C_{29}H_{45}NO_5$
M_r = 487.66
Orthorhombic, $P2_12_12_1$
a = 8.3161 (2) Å
b = 9.9302 (5) Å
c = 33.0414 (11) Å
V = 2728.58 (18) Å^3
Z = 4
F(000) = 1064
D_x = 1.187 Mg m^{-3}
Melting point: 591 K
Ag $K\alpha$ radiation, λ = 0.56083 Å
Cell parameters from 20674 reflections
θ = 2.4–22.4°
μ = 0.05 mm^{-1}
T = 295 K
Prism, colourless
0.30 × 0.25 × 0.12 mm

Data collection

Stoe Stadivari diffractometer
Radiation source: Sealed X-ray tube, Axo Microfocus source
Mirror monochromator
Detector resolution: 5.81 pixels mm^{-1}
ω scans
46178 measured reflections
6173 independent reflections
4035 reflections with $I > 2\sigma(I)$
R_{int} = 0.057
θ_{max} = 21.6°, θ_{min} = 2.4°
h = −10→10
k = −12→12
l = −43→42

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.044
$wR(F^2)$ = 0.107
S = 0.92
6173 reflections
324 parameters
0 restraints
0 constraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map
Hydrogen site location: mixed
H atoms treated by a mixture of independent and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.0584P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max}$ = 0.15 e Å^{-3}
$\Delta\rho_{min}$ = −0.17 e Å^{-3}

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

	x	*y*	*z*	U_{iso}*/U_{eq}
N1	0.4565 (2)	0.3652 (2)	0.17143 (7)	0.0458 (5)
O1	0.29552 (19)	0.3875 (2)	0.18376 (7)	0.0615 (6)

H1	0.229 (4)	0.347 (4)	0.1656 (12)	0.092*
C1	0.3684 (3)	0.3767 (3)	0.32591 (9)	0.0512 (7)
H1A	0.322387	0.450401	0.310503	0.061*
H1B	0.323926	0.293524	0.315371	0.061*
C2	0.3182 (3)	0.3917 (3)	0.37039 (10)	0.0604 (8)
H2A	0.349856	0.479883	0.380159	0.072*
H2B	0.202113	0.384921	0.372465	0.072*
C3	0.3952 (3)	0.2842 (3)	0.39652 (9)	0.0586 (7)
H3A	0.349549	0.196019	0.389748	0.070*
C4	0.5759 (3)	0.2801 (3)	0.39124 (9)	0.0587 (7)
H4A	0.619638	0.205676	0.406731	0.070*
H4B	0.622273	0.362793	0.401670	0.070*
C5	0.6224 (3)	0.2638 (3)	0.34682 (9)	0.0495 (6)
H5A	0.574969	0.178673	0.337702	0.059*
C6	0.8034 (3)	0.2500 (3)	0.34148 (9)	0.0614 (8)
H6A	0.855311	0.333362	0.349474	0.074*
H6B	0.842995	0.178824	0.358939	0.074*
C7	0.8464 (3)	0.2182 (3)	0.29809 (9)	0.0552 (7)
H7A	0.810830	0.127506	0.291867	0.066*
H7B	0.962476	0.220425	0.295228	0.066*
C8	0.7722 (3)	0.3154 (2)	0.26752 (8)	0.0416 (6)
H8A	0.825583	0.402949	0.270190	0.050*
C9	0.5905 (2)	0.3350 (2)	0.27503 (8)	0.0397 (6)
H9A	0.541506	0.246186	0.271105	0.048*
C10	0.5517 (3)	0.3757 (2)	0.31936 (8)	0.0414 (6)
C11	0.5147 (3)	0.4270 (3)	0.24284 (9)	0.0482 (6)
H11A	0.398821	0.425772	0.246059	0.058*
H11B	0.551137	0.518566	0.247296	0.058*
C12	0.5557 (2)	0.3861 (2)	0.20016 (8)	0.0393 (5)
C13	0.7324 (2)	0.3645 (2)	0.19139 (8)	0.0390 (6)
C14	0.7937 (2)	0.2660 (2)	0.22433 (8)	0.0417 (6)
H14A	0.727003	0.185012	0.221931	0.050*
C15	0.9604 (3)	0.2262 (3)	0.20888 (9)	0.0529 (7)
H15A	1.038538	0.296761	0.213862	0.063*
H15B	0.997228	0.143281	0.221326	0.063*
C16	0.9301 (2)	0.2076 (3)	0.16373 (8)	0.0462 (6)
H16A	0.916898	0.111718	0.157528	0.055*
C17	0.7749 (2)	0.2855 (3)	0.15244 (8)	0.0425 (6)
H17A	0.688788	0.221047	0.146506	0.051*
C18	0.8192 (3)	0.4999 (3)	0.19340 (9)	0.0527 (7)
H18A	0.931705	0.486828	0.188266	0.079*
H18B	0.805128	0.538533	0.219805	0.079*
H18C	0.775201	0.559593	0.173391	0.079*
C19	0.6199 (4)	0.5157 (3)	0.32935 (10)	0.0559 (7)
H19A	0.733597	0.516461	0.324314	0.084*
H19B	0.600208	0.535985	0.357323	0.084*
H19C	0.568539	0.582112	0.312653	0.084*
C20	0.8193 (3)	0.3617 (3)	0.11361 (9)	0.0518 (7)

H20A	0.839680	0.455722	0.120975	0.062*
C21	0.6906 (3)	0.3608 (5)	0.08069 (11)	0.0822 (11)
H21A	0.728206	0.410653	0.057666	0.123*
H21B	0.594082	0.401579	0.090894	0.123*
H21C	0.668478	0.269625	0.072789	0.123*
C22	0.9805 (3)	0.2987 (3)	0.10090 (8)	0.0473 (6)
O22	1.05437 (17)	0.26438 (19)	0.13869 (6)	0.0489 (5)
C23	1.0943 (3)	0.3887 (3)	0.07784 (10)	0.0576 (7)
H23A	1.124973	0.464031	0.094844	0.069*
H23B	1.039656	0.424359	0.054218	0.069*
C24	1.2442 (3)	0.3141 (3)	0.06447 (10)	0.0648 (9)
H24A	1.306859	0.371419	0.046686	0.078*
H24B	1.309526	0.293263	0.087968	0.078*
C25	1.2019 (3)	0.1848 (3)	0.04254 (10)	0.0665 (8)
H25A	1.147316	0.208560	0.017243	0.080*
C26	1.0866 (3)	0.1051 (3)	0.06821 (11)	0.0661 (8)
H26A	1.054221	0.024975	0.053508	0.079*
H26B	1.141189	0.076299	0.092668	0.079*
O26	0.9463 (2)	0.1799 (2)	0.07908 (6)	0.0590 (5)
C27	1.3511 (4)	0.1021 (4)	0.03202 (13)	0.0933 (12)
H27A	1.420097	0.153832	0.014691	0.140*
H27B	1.319152	0.021065	0.018363	0.140*
H27C	1.407643	0.079391	0.056413	0.140*
O27	0.3659 (3)	0.3137 (2)	0.43916 (7)	0.0703 (6)
C28	0.2274 (5)	0.2758 (4)	0.45557 (12)	0.0844 (11)
O28	0.1243 (4)	0.2166 (4)	0.43712 (11)	0.1265 (12)
C29	0.2163 (6)	0.3213 (5)	0.49833 (12)	0.1153 (16)
H29A	0.304051	0.284095	0.513545	0.173*
H29B	0.116352	0.291509	0.509754	0.173*
H29C	0.221460	0.417872	0.499312	0.173*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
N1	0.0350 (8)	0.0568 (13)	0.0456 (15)	0.0015 (9)	−0.0037 (9)	−0.0028 (10)
O1	0.0355 (7)	0.0914 (15)	0.0576 (15)	0.0036 (9)	−0.0045 (8)	−0.0161 (11)
C1	0.0498 (12)	0.0575 (16)	0.046 (2)	0.0045 (12)	0.0016 (12)	0.0016 (13)
C2	0.0613 (14)	0.0718 (19)	0.048 (2)	0.0082 (15)	0.0084 (14)	0.0013 (15)
C3	0.0713 (16)	0.0646 (18)	0.040 (2)	0.0006 (14)	0.0069 (14)	0.0002 (14)
C4	0.0680 (15)	0.0657 (18)	0.042 (2)	0.0115 (14)	0.0011 (14)	0.0083 (14)
C5	0.0581 (13)	0.0486 (15)	0.0418 (18)	0.0087 (12)	0.0010 (12)	0.0034 (12)
C6	0.0619 (14)	0.076 (2)	0.046 (2)	0.0208 (15)	−0.0041 (14)	0.0093 (15)
C7	0.0536 (13)	0.0654 (18)	0.0468 (19)	0.0197 (13)	0.0000 (12)	0.0070 (14)
C8	0.0413 (10)	0.0438 (13)	0.0396 (17)	0.0041 (10)	−0.0042 (10)	0.0028 (11)
C9	0.0423 (10)	0.0379 (12)	0.0388 (16)	0.0002 (9)	−0.0019 (10)	−0.0004 (10)
C10	0.0466 (11)	0.0412 (12)	0.0365 (17)	0.0012 (11)	−0.0025 (11)	−0.0005 (11)
C11	0.0464 (11)	0.0585 (15)	0.0397 (19)	0.0111 (11)	−0.0071 (11)	−0.0047 (12)
C12	0.0383 (10)	0.0407 (12)	0.0388 (16)	0.0012 (10)	−0.0051 (10)	−0.0004 (11)

C13	0.0366 (9)	0.0415 (13)	0.0389 (16)	−0.0024 (10)	−0.0050 (10)	−0.0008 (11)
C14	0.0387 (10)	0.0419 (13)	0.0445 (17)	0.0024 (10)	0.0002 (11)	0.0009 (11)
C15	0.0429 (11)	0.0685 (17)	0.047 (2)	0.0135 (12)	0.0003 (12)	0.0064 (13)
C16	0.0372 (10)	0.0562 (15)	0.0451 (18)	0.0000 (11)	0.0039 (11)	−0.0007 (12)
C17	0.0355 (10)	0.0530 (14)	0.0391 (17)	−0.0037 (10)	−0.0009 (10)	−0.0036 (12)
C18	0.0583 (14)	0.0509 (15)	0.049 (2)	−0.0131 (12)	−0.0062 (13)	0.0027 (13)
C19	0.0732 (16)	0.0485 (15)	0.046 (2)	−0.0019 (13)	−0.0038 (15)	−0.0047 (13)
C20	0.0425 (11)	0.0718 (18)	0.0413 (19)	0.0020 (12)	−0.0011 (11)	0.0046 (14)
C21	0.0481 (13)	0.152 (3)	0.046 (2)	0.0102 (18)	−0.0069 (14)	0.015 (2)
C22	0.0408 (11)	0.0627 (16)	0.0383 (17)	−0.0033 (11)	−0.0045 (11)	−0.0036 (13)
O22	0.0362 (7)	0.0722 (12)	0.0383 (12)	−0.0022 (8)	−0.0024 (7)	−0.0006 (8)
C23	0.0510 (13)	0.0698 (18)	0.052 (2)	−0.0077 (13)	0.0011 (13)	0.0043 (15)
C24	0.0506 (13)	0.092 (2)	0.052 (2)	−0.0025 (14)	0.0115 (13)	0.0122 (17)
C25	0.0643 (15)	0.094 (2)	0.041 (2)	0.0110 (16)	0.0077 (15)	0.0012 (17)
C26	0.0676 (16)	0.074 (2)	0.057 (2)	−0.0006 (15)	0.0025 (15)	−0.0153 (16)
O26	0.0514 (9)	0.0753 (13)	0.0503 (14)	−0.0099 (9)	−0.0010 (9)	−0.0140 (10)
C27	0.088 (2)	0.121 (3)	0.072 (3)	0.030 (2)	0.024 (2)	0.006 (2)
O27	0.0795 (13)	0.0911 (16)	0.0404 (14)	−0.0015 (12)	0.0103 (11)	−0.0018 (11)
C28	0.091 (2)	0.103 (3)	0.059 (3)	−0.006 (2)	0.025 (2)	0.003 (2)
O28	0.115 (2)	0.171 (3)	0.094 (3)	−0.055 (2)	0.0312 (19)	−0.017 (2)
C29	0.127 (3)	0.167 (5)	0.052 (3)	0.004 (3)	0.033 (3)	−0.010 (3)

Geometric parameters (Å, º)

N1—C12	1.275 (3)	C15—H15B	0.9700
N1—O1	1.416 (2)	C16—O22	1.439 (3)
O1—H1	0.91 (4)	C16—C17	1.551 (3)
C1—C2	1.535 (4)	C16—H16A	0.9800
C1—C10	1.539 (3)	C17—C20	1.534 (4)
C1—H1A	0.9700	C17—H17A	0.9800
C1—H1B	0.9700	C18—H18A	0.9600
C2—C3	1.515 (4)	C18—H18B	0.9600
C2—H2A	0.9700	C18—H18C	0.9600
C2—H2B	0.9700	C19—H19A	0.9600
C3—O27	1.459 (4)	C19—H19B	0.9600
C3—C4	1.513 (4)	C19—H19C	0.9600
C3—H3A	0.9800	C20—C21	1.526 (4)
C4—C5	1.526 (4)	C20—C22	1.538 (3)
C4—H4A	0.9700	C20—H20A	0.9800
C4—H4B	0.9700	C21—H21A	0.9600
C5—C6	1.522 (3)	C21—H21B	0.9600
C5—C10	1.551 (4)	C21—H21C	0.9600
C5—H5A	0.9800	C22—O26	1.412 (3)
C6—C7	1.511 (4)	C22—O22	1.433 (3)
C6—H6A	0.9700	C22—C23	1.508 (4)
C6—H6B	0.9700	C23—C24	1.516 (4)
C7—C8	1.528 (4)	C23—H23A	0.9700
C7—H7A	0.9700	C23—H23B	0.9700

C7—H7B	0.9700	C24—C25	1.515 (4)
C8—C14	1.520 (4)	C24—H24A	0.9700
C8—C9	1.543 (3)	C24—H24B	0.9700
C8—H8A	0.9800	C25—C26	1.506 (4)
C9—C11	1.537 (4)	C25—C27	1.528 (4)
C9—C10	1.554 (4)	C25—H25A	0.9800
C9—H9A	0.9800	C26—O26	1.429 (3)
C10—C19	1.537 (4)	C26—H26A	0.9700
C11—C12	1.507 (4)	C26—H26B	0.9700
C11—H11A	0.9700	C27—H27A	0.9600
C11—H11B	0.9700	C27—H27B	0.9600
C12—C13	1.512 (3)	C27—H27C	0.9600
C13—C18	1.528 (3)	O27—C28	1.328 (4)
C13—C17	1.548 (4)	C28—O28	1.205 (5)
C13—C14	1.550 (4)	C28—C29	1.486 (5)
C14—C15	1.529 (3)	C29—H29A	0.9600
C14—H14A	0.9800	C29—H29B	0.9600
C15—C16	1.524 (4)	C29—H29C	0.9600
C15—H15A	0.9700		

C12—N1—O1	111.9 (2)	C14—C15—H15B	111.4
N1—O1—H1	109 (2)	H15A—C15—H15B	109.2
C2—C1—C10	113.9 (2)	O22—C16—C15	113.38 (19)
C2—C1—H1A	108.8	O22—C16—C17	105.3 (2)
C10—C1—H1A	108.8	C15—C16—C17	108.2 (2)
C2—C1—H1B	108.8	O22—C16—H16A	109.9
C10—C1—H1B	108.8	C15—C16—H16A	109.9
H1A—C1—H1B	107.7	C17—C16—H16A	109.9
C3—C2—C1	111.2 (2)	C20—C17—C13	120.0 (2)
C3—C2—H2A	109.4	C20—C17—C16	104.29 (18)
C1—C2—H2A	109.4	C13—C17—C16	104.05 (19)
C3—C2—H2B	109.4	C20—C17—H17A	109.3
C1—C2—H2B	109.4	C13—C17—H17A	109.3
H2A—C2—H2B	108.0	C16—C17—H17A	109.3
O27—C3—C4	106.4 (2)	C13—C18—H18A	109.5
O27—C3—C2	109.7 (2)	C13—C18—H18B	109.5
C4—C3—C2	111.9 (2)	H18A—C18—H18B	109.5
O27—C3—H3A	109.6	C13—C18—H18C	109.5
C4—C3—H3A	109.6	H18A—C18—H18C	109.5
C2—C3—H3A	109.6	H18B—C18—H18C	109.5
C3—C4—C5	111.4 (2)	C10—C19—H19A	109.5
C3—C4—H4A	109.3	C10—C19—H19B	109.5
C5—C4—H4A	109.3	H19A—C19—H19B	109.5
C3—C4—H4B	109.3	C10—C19—H19C	109.5
C5—C4—H4B	109.3	H19A—C19—H19C	109.5
H4A—C4—H4B	108.0	H19B—C19—H19C	109.5
C6—C5—C4	111.8 (2)	C21—C20—C17	115.1 (2)
C6—C5—C10	111.8 (2)	C21—C20—C22	114.5 (2)

C4—C5—C10	112.9 (2)	C17—C20—C22	103.8 (2)
C6—C5—H5A	106.6	C21—C20—H20A	107.7
C4—C5—H5A	106.6	C17—C20—H20A	107.7
C10—C5—H5A	106.6	C22—C20—H20A	107.7
C7—C6—C5	111.3 (2)	C20—C21—H21A	109.5
C7—C6—H6A	109.4	C20—C21—H21B	109.5
C5—C6—H6A	109.4	H21A—C21—H21B	109.5
C7—C6—H6B	109.4	C20—C21—H21C	109.5
C5—C6—H6B	109.4	H21A—C21—H21C	109.5
H6A—C6—H6B	108.0	H21B—C21—H21C	109.5
C6—C7—C8	113.6 (2)	O26—C22—O22	109.4 (2)
C6—C7—H7A	108.9	O26—C22—C23	111.3 (2)
C8—C7—H7A	108.9	O22—C22—C23	108.22 (19)
C6—C7—H7B	108.9	O26—C22—C20	107.67 (19)
C8—C7—H7B	108.9	O22—C22—C20	103.5 (2)
H7A—C7—H7B	107.7	C23—C22—C20	116.4 (2)
C14—C8—C7	111.6 (2)	C22—O22—C16	106.66 (16)
C14—C8—C9	107.89 (19)	C22—C23—C24	112.0 (2)
C7—C8—C9	111.6 (2)	C22—C23—H23A	109.2
C14—C8—H8A	108.5	C24—C23—H23A	109.2
C7—C8—H8A	108.5	C22—C23—H23B	109.2
C9—C8—H8A	108.5	C24—C23—H23B	109.2
C11—C9—C8	111.4 (2)	H23A—C23—H23B	107.9
C11—C9—C10	114.36 (19)	C25—C24—C23	111.3 (2)
C8—C9—C10	112.82 (19)	C25—C24—H24A	109.4
C11—C9—H9A	105.8	C23—C24—H24A	109.4
C8—C9—H9A	105.8	C25—C24—H24B	109.4
C10—C9—H9A	105.8	C23—C24—H24B	109.4
C19—C10—C1	109.2 (2)	H24A—C24—H24B	108.0
C19—C10—C5	112.5 (2)	C26—C25—C24	108.9 (3)
C1—C10—C5	107.3 (2)	C26—C25—C27	111.2 (3)
C19—C10—C9	111.2 (2)	C24—C25—C27	112.1 (3)
C1—C10—C9	109.9 (2)	C26—C25—H25A	108.2
C5—C10—C9	106.61 (19)	C24—C25—H25A	108.2
C12—C11—C9	113.3 (2)	C27—C25—H25A	108.2
C12—C11—H11A	108.9	O26—C26—C25	112.8 (3)
C9—C11—H11A	108.9	O26—C26—H26A	109.0
C12—C11—H11B	108.9	C25—C26—H26A	109.0
C9—C11—H11B	108.9	O26—C26—H26B	109.0
H11A—C11—H11B	107.7	C25—C26—H26B	109.0
N1—C12—C11	126.5 (2)	H26A—C26—H26B	107.8
N1—C12—C13	117.6 (2)	C22—O26—C26	113.50 (19)
C11—C12—C13	115.9 (2)	C25—C27—H27A	109.5
C12—C13—C18	109.0 (2)	C25—C27—H27B	109.5
C12—C13—C17	116.93 (19)	H27A—C27—H27B	109.5
C18—C13—C17	112.0 (2)	C25—C27—H27C	109.5
C12—C13—C14	105.97 (19)	H27A—C27—H27C	109.5
C18—C13—C14	111.69 (19)	H27B—C27—H27C	109.5

C17—C13—C14	100.90 (19)	C28—O27—C3	118.8 (3)
C8—C14—C15	120.3 (2)	O28—C28—O27	123.3 (4)
C8—C14—C13	114.6 (2)	O28—C28—C29	125.8 (4)
C15—C14—C13	103.1 (2)	O27—C28—C29	110.8 (4)
C8—C14—H14A	105.9	C28—C29—H29A	109.5
C15—C14—H14A	105.9	C28—C29—H29B	109.5
C13—C14—H14A	105.9	H29A—C29—H29B	109.5
C16—C15—C14	102.04 (19)	C28—C29—H29C	109.5
C16—C15—H15A	111.4	H29A—C29—H29C	109.5
C14—C15—H15A	111.4	H29B—C29—H29C	109.5
C16—C15—H15B	111.4		

C10—C1—C2—C3	−54.9 (3)	C17—C13—C14—C8	179.03 (18)
C1—C2—C3—O27	171.1 (2)	C12—C13—C14—C15	168.8 (2)
C1—C2—C3—C4	53.2 (3)	C18—C13—C14—C15	−72.6 (3)
O27—C3—C4—C5	−174.3 (2)	C17—C13—C14—C15	46.5 (2)
C2—C3—C4—C5	−54.5 (3)	C8—C14—C15—C16	−170.7 (2)
C3—C4—C5—C6	−176.1 (3)	C13—C14—C15—C16	−41.6 (2)
C3—C4—C5—C10	56.7 (3)	C14—C15—C16—O22	137.2 (2)
C4—C5—C6—C7	173.6 (2)	C14—C15—C16—C17	20.8 (3)
C10—C5—C6—C7	−58.6 (3)	C12—C13—C17—C20	97.2 (3)
C5—C6—C7—C8	52.1 (3)	C18—C13—C17—C20	−29.5 (3)
C6—C7—C8—C14	−170.0 (2)	C14—C13—C17—C20	−148.44 (19)
C6—C7—C8—C9	−49.1 (3)	C12—C13—C17—C16	−146.8 (2)
C14—C8—C9—C11	−54.0 (3)	C18—C13—C17—C16	86.5 (2)
C7—C8—C9—C11	−177.0 (2)	C14—C13—C17—C16	−32.4 (2)
C14—C8—C9—C10	175.84 (19)	O22—C16—C17—C20	12.7 (3)
C7—C8—C9—C10	52.8 (3)	C15—C16—C17—C20	134.2 (2)
C2—C1—C10—C19	−67.8 (3)	O22—C16—C17—C13	−113.9 (2)
C2—C1—C10—C5	54.4 (3)	C15—C16—C17—C13	7.6 (3)
C2—C1—C10—C9	170.0 (2)	C13—C17—C20—C21	−106.5 (3)
C6—C5—C10—C19	−62.1 (3)	C16—C17—C20—C21	137.6 (3)
C4—C5—C10—C19	65.1 (3)	C13—C17—C20—C22	127.6 (2)
C6—C5—C10—C1	177.7 (2)	C16—C17—C20—C22	11.7 (3)
C4—C5—C10—C1	−55.1 (3)	C21—C20—C22—O26	−42.8 (3)
C6—C5—C10—C9	60.0 (3)	C17—C20—C22—O26	83.5 (3)
C4—C5—C10—C9	−172.8 (2)	C21—C20—C22—O22	−158.6 (2)
C11—C9—C10—C19	−62.9 (3)	C17—C20—C22—O22	−32.3 (2)
C8—C9—C10—C19	65.7 (3)	C21—C20—C22—C23	82.9 (3)
C11—C9—C10—C1	58.1 (3)	C17—C20—C22—C23	−150.8 (2)
C8—C9—C10—C1	−173.2 (2)	O26—C22—O22—C16	−72.4 (2)
C11—C9—C10—C5	174.1 (2)	C23—C22—O22—C16	166.2 (2)
C8—C9—C10—C5	−57.2 (2)	C20—C22—O22—C16	42.2 (2)
C8—C9—C11—C12	50.0 (3)	C15—C16—O22—C22	−152.7 (2)
C10—C9—C11—C12	179.39 (19)	C17—C16—O22—C22	−34.5 (2)
O1—N1—C12—C11	1.1 (3)	O26—C22—C23—C24	−52.4 (3)
O1—N1—C12—C13	179.3 (2)	O22—C22—C23—C24	67.9 (3)
C9—C11—C12—N1	127.4 (3)	C20—C22—C23—C24	−176.2 (2)

C9—C11—C12—C13	−50.8 (3)	C22—C23—C24—C25	51.2 (3)
N1—C12—C13—C18	113.2 (2)	C23—C24—C25—C26	−51.5 (3)
C11—C12—C13—C18	−68.4 (3)	C23—C24—C25—C27	−175.1 (3)
N1—C12—C13—C17	−15.0 (3)	C24—C25—C26—O26	55.2 (3)
C11—C12—C13—C17	163.4 (2)	C27—C25—C26—O26	179.3 (3)
N1—C12—C13—C14	−126.4 (2)	O22—C22—O26—C26	−63.4 (3)
C11—C12—C13—C14	51.9 (3)	C23—C22—O26—C26	56.2 (3)
C7—C8—C14—C15	−52.0 (3)	C20—C22—O26—C26	−175.2 (2)
C9—C8—C14—C15	−175.0 (2)	C25—C26—O26—C22	−59.0 (3)
C7—C8—C14—C13	−175.77 (19)	C4—C3—O27—C28	−155.5 (3)
C9—C8—C14—C13	61.2 (2)	C2—C3—O27—C28	83.2 (3)
C12—C13—C14—C8	−58.6 (2)	C3—O27—C28—O28	0.8 (6)
C18—C13—C14—C8	59.9 (3)	C3—O27—C28—C29	−176.8 (3)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
O1—H1···O22^{i}	0.91 (4)	1.89 (4)	2.781 (2)	166 (3)
C15—H15*A*···O1^{ii}	0.97	2.52	3.320 (3)	139

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