



Crystal structure of (+)-*N*-[(1*R*,5*S*,6*S*,9*S*)-5-hydroxymethyl-3,3,9-trimethyl-8-oxo-2,4,7-trioxabicyclo[4.3.0]nonan-9-yl]acetamide

Takeshi Oishi,^{a*} Shun Tsuzaki,^b Tomoya Sugai,^b Takaaki Sato^b and Noritaka Chida^b

^aSchool of Medicine, Keio University, Hiyoshi 4-1-1, Kohoku-ku, Yokohama 223-8521, Japan, and ^bDepartment of Applied Chemistry, Faculty of Science and Technology, Keio University, Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223-8522, Japan. *Correspondence e-mail: oec@keio.jp

Received 18 April 2016

Accepted 22 April 2016

Edited by H. Ishida, Okayama University, Japan

Keywords: crystal structure; bicyclic compound; 1,3-dioxane; oxolane; hydrogen bond; hydroxy group.

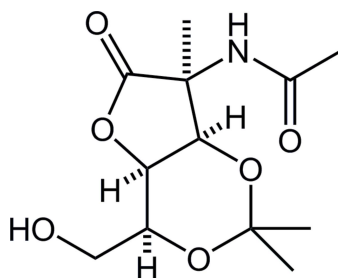
CCDC reference: 1475848

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

In the title compound, C₁₂H₁₉NO₆, the six-membered 1,3-dioxane ring adopts a chair-like conformation. The seat of this chair, containing two O atoms, is essentially planar, with a maximum deviation of 0.0021 (12) Å. The five-membered oxolane ring *cis*-fused to the 1,3-dioxane ring adopts an envelope form. The bridgehead C atom at the flap, which is bonded to the tetrasubstituted C atom of the oxolane ring, deviates from the mean plane of other ring atoms by 0.539 (4) Å. In the crystal, classical O—H···O and N—H···O hydrogen bonds link the molecules into a sheet structure enclosing an *R*_s⁴(24) graph-set motif. Weak intermolecular C—H···O interactions support the sheet formation.

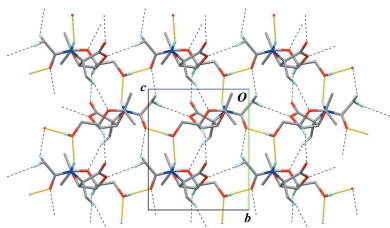
1. Chemical context

Sphingofungin F [systematic name: (2*S*,3*R*,4*R*,5*S*,*E*)-2-amino-3,4,5-trihydroxy-2-methyl-14-oxoicos-6-enoic acid] was isolated from the fermentation broth of *Paecilomyces variotii* by Horn *et al.* (1992). It shows antifungal activity by inhibition of the serine palmitoyltransferase to suppress the early step of biosynthesis of the sphingosines (Zweerink *et al.*, 1992). The structure of sphingofungin F features a hydrophilic α,α -disubstituted α -amino acid moiety possessing four contiguous stereocenters, connected to a hydrophobic carbon chain by *E*-olefin. The title compound, which is equivalent to the hydrophilic part with correct stereochemistry, was provided in the total synthesis of sphingofungin F (Tsuzaki *et al.*, 2015).



2. Structural commentary

The molecular structure of the title compound is shown in Fig. 1. The 1,3-dioxane ring (C1/O2/C3/O4/C5/C6) is in a chair-like conformation with puckering parameters of $Q = 0.497$ (3) Å, $\theta = 169.6$ (3)°, $\varphi = 116.8$ (16)°, $Q(2) = 0.090$ (3) Å



OPEN ACCESS

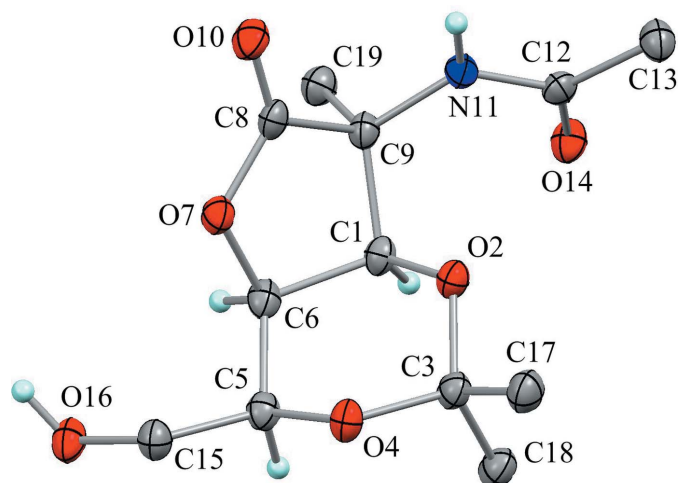


Figure 1
The molecular structure of the title compound, showing the atom labeling. Displacement ellipsoids are drawn at the 50% probability level. Only H atoms connected to N, O and chiral C atoms are shown for clarity.

and $Q(3) = -0.489(3) \text{ \AA}$. The seat of this chair (C1/O2/O4/C5) is essentially planar with a maximum deviation of $0.0021(12) \text{ \AA}$ for O4, and atoms C6 and C3, positioned at the headrest and the footrest, respectively, deviate from the mean plane of the seat by $0.524(4)$ and $-0.646(3) \text{ \AA}$. The equatorially oriented C5–C15 and C3–C17 bonds make angles with the normal of the *Cremer & Pople* plane being $63.41(18)$ and $63.35(18)^\circ$, respectively, while the C1–C9 bond is a little tilted from the ideal equatorial position with an angle of $50.50(17)^\circ$ due to the ring-fusion system. The oxolane ring (C1/C6/O7/C8/C9), which is *cis*-fused to the 1,3-dioxane ring, adopts an envelope form with puckering parameters of $Q(2) = 0.345(3) \text{ \AA}$ and $\varphi(2) = 254.7(4)^\circ$. The bridgehead atom C1 deviates from the mean plane of the other four ring atoms by $0.539(4) \text{ \AA}$.

3. Supramolecular features

In the crystal, an O–H···O hydrogen bond (O16–H16···O14ⁱ; Table 1) connects the molecules into a chain structure running along the *c* axis, with a *C*(10) graph-set motif

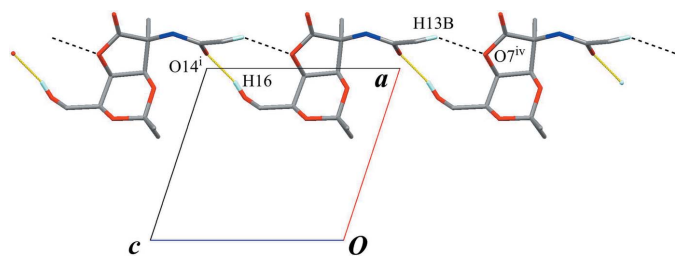


Figure 2
A partial packing diagram, viewed down the *b* axis, showing the chain structure running along the *c* axis. Yellow lines indicate the intermolecular O–H···O hydrogen bonds. Black dashed lines indicate weak intermolecular C–H···O interactions. Only H atoms involved in the hydrogen bonds are shown for clarity. [Symmetry codes: (i) $x, y, z + 1$; (iv) $x, y, z - 1$.]

Table 1
Hydrogen-bond geometry ($\text{\AA}, ^\circ$).

<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>
O16–H16···O14 ⁱ	0.84	1.91	2.742(2)	168
N11–H11···O16 ⁱⁱ	0.88	2.28	2.928(3)	131
C5–H5···O10 ⁱⁱⁱ	1.00	2.42	3.289(3)	145
C19–H19A···O4 ⁱⁱⁱ	0.98	2.52	3.386(3)	147
C13–H13B···O7 ^{iv}	0.98	2.55	3.433(3)	150
C13–H13C···O14 ^v	0.98	2.62	3.424(3)	140

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

(Fig. 2). A weak C–H···O interaction (C13–H13B···O7^{iv}; Table 1) supports formation of the chain. The chains are linked into a sheet structure parallel to (100) by an N–H···O hydrogen bond (N11–H11···O16ⁱⁱ; Table 1) which generates a *C*(8) graph-set motif (Fig. 3). Weak C–H···O interactions (C5–H5···O10ⁱⁱⁱ, C19–H19A···O4ⁱⁱⁱ and C13–H13C···O14^v; Table 1) are also observed between the chains. In this sheet structure, the classical O–H···O and N–H···O

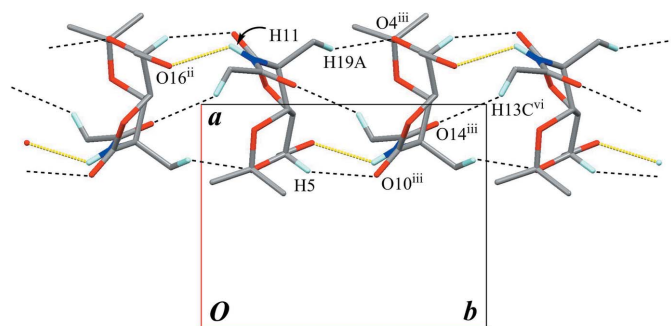


Figure 3
Another partial packing diagram, viewed down the *c* axis, showing the sheet structure parallel to (100). Yellow lines indicate the intermolecular N–H···O hydrogen bonds. Black dashed lines indicate weak intermolecular C–H···O interactions. Only H atoms involved in the hydrogen bonds are shown for clarity. [Symmetry codes: (ii) $-x + 2, y - \frac{1}{2}, -z + 1$; (iii) $-x + 2, y + \frac{1}{2}, -z + 1$; (vi) $x, y + 1, z + 1$.]

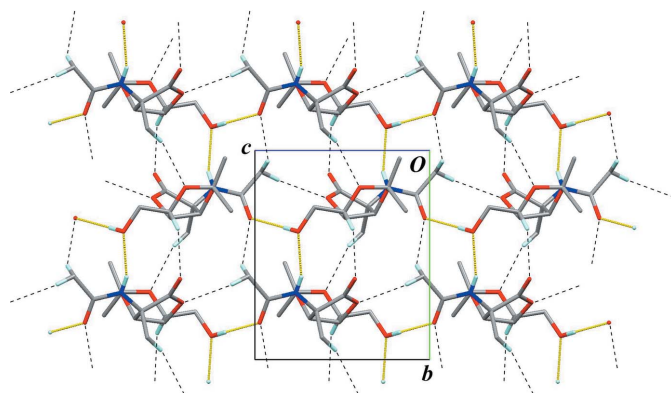


Figure 4
A packing diagram, viewed down the *a* axis, showing the hydrogen bonds in the sheet structure parallel to (100). Yellow lines indicate intermolecular O–H···O and N–H···O hydrogen bonds. Black dashed lines indicate weak intermolecular C–H···O interactions. Only H atoms involved in the hydrogen bonds are shown for clarity.

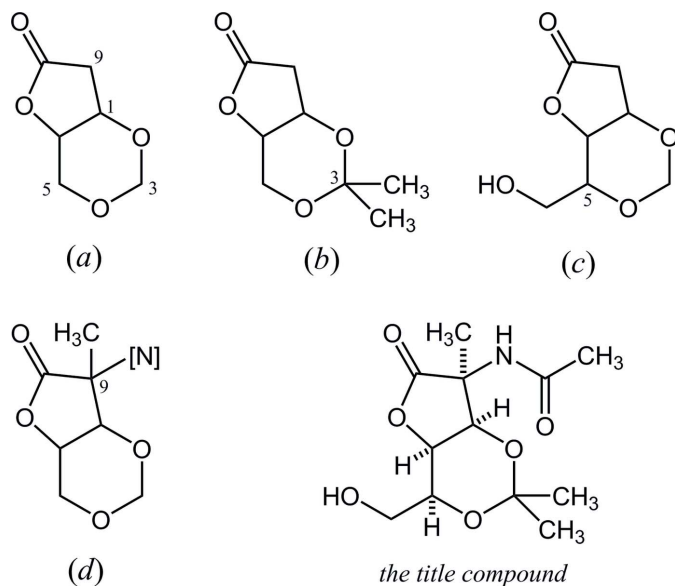


Figure 5
The core structures for database survey: (a) 2,4,7-trioxabicyclo[4.3.0]nonan-8-one, and its derivatives with (b) 3,3-dimethyl, (c) 5-hydroxymethyl and (d) 9-methyl-9-*N*-substituents.

hydrogen bonds enclose an $R_4^4(24)$ graph-set motif, and the other weak C—H...O interactions add to the stability of the network (Fig. 4).

4. Database survey

In the Cambridge Structural Database (CSD, Version 5.37, November 2015; Groom *et al.*, 2016), 18 structures containing a 2,4,7-trioxabicyclo[4.3.0]nonan-8-one skeleton, (a), are registered (Fig. 5). These include five compounds (YISHIR and YISHUD: Han *et al.*, 1994; LAVVIO: Watkin *et al.*, 2005; ZINDEH and ZINDIL: Glawar *et al.*, 2013) with 3,3-dimethyl substituents, (b); one compound (NUIJAS: Henkel *et al.*, 1998) with 5-hydroxymethyl substituent, (c); and one compound (QIFFUH: Hotchkiss *et al.*, 2007) possessing a tetrasubstituted carbon with nitrogen at the C-9 position, (d). The conformations of the bicyclic systems in these seven structures are similar to those in the title compound: the 1,3-dioxane rings adopt chair-like forms, and the *cis*-fused oxolane rings adopt envelope forms with bridgehead C-1 position at the flap.

5. Synthesis and crystallization

The title compound was afforded in the total synthesis of sphingofungin F from a D-ribose derivative (Tsunami *et al.*, 2015). Purification was carried out by silica gel column chromatography, and colorless crystals were obtained from an ethyl acetate solution under a hexane-saturated atmosphere, by slow evaporation at ambient temperature. M.p. 497–498 K. $[\alpha]_D^{28} + 157.7$ (c 1.04, CHCl₃). HRMS (ESI) m/z calculated for C₁₂H₁₉NO₆Na⁺ [$M + Na$]⁺: 296.1110; found: 296.1104.

Table 2
Experimental details.

Crystal data	
Chemical formula	C ₁₂ H ₁₉ NO ₆
M_r	273.28
Crystal system, space group	Monoclinic, $P2_1$
Temperature (K)	90
a, b, c (Å)	8.2102 (3), 9.9513 (3), 8.7480 (3)
β (°)	108.142 (2)
V (Å ³)	679.20 (4)
Z	2
Radiation type	Cu $K\alpha$
μ (mm ⁻¹)	0.91
Crystal size (mm)	0.14 × 0.14 × 0.07
Data collection	
Diffractometer	Bruker D8 Venture
Absorption correction	Multi-scan (SADABS; Bruker, 2014)
T_{\min} , T_{\max}	0.88, 0.94
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	8304, 2386, 2235
R_{int}	0.039
($\sin \theta/\lambda$) _{max} (Å ⁻¹)	0.596
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.032, 0.068, 1.00
No. of reflections	2386
No. of parameters	177
No. of restraints	1
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{\text{max}}$, $\Delta\rho_{\text{min}}$ (e Å ⁻³)	0.20, -0.18
Absolute structure	Flack x determined using 941 quotients $[(I^+) - (I^-)] / [(I^+) + (I^-)]$ (Parsons <i>et al.</i> , 2013)
Absolute structure parameter	0.13 (11)

Computer programs: APEX2 and SAINT (Bruker, 2014), SHELXS2013 (Sheldrick, 2008), SHELXL2014 (Sheldrick, 2015), Mercury (Macrae *et al.*, 2006), publCIF (Westrip, 2010) and PLATON (Spek, 2009).

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 $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ or $1.5U_{\text{eq}}(\text{methyl C})$. The hydroxy H atom was placed guided by difference maps, with O—H = 0.84 Å and with $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{O})$. The amide H atom was also placed guided by difference maps, with N—H = 0.88 Å and with $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{N})$.

Acknowledgements

This research was partially supported by the Keio Gijuku Fukuzawa Memorial Fund for the Advancement of Education and Research. We also thank Professor S. Ohba (Keio University, Japan) for his valuable advice.

References

- Bruker (2014). APEX2, SAINT and SADABS. Bruker AXS Inc., Madison, Wisconsin, USA.
 Glawar, A. F. G., Jenkinson, S. F., Newberry, S. J., Thompson, A. L., Nakagawa, S., Yoshihara, A., Akimitsu, K., Izumori, K., Butters, T. D., Kato, A. & Fleet, G. W. J. (2013). *Org. Biomol. Chem.* **11**, 6886–6899.

- Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* **B72**, 171–179.
- Han, S.-Y., Joullié, M. M., Fokin, V. V. & Petasis, N. A. (1994). *Tetrahedron Asymmetry*, **5**, 2535–2562.
- Henkel, S., Frey, W., Remen, L., Gracza, T. & Jäger, V. (1998). *Z. Kristallogr. New Cryst. Struct.* **213**, 71–72.
- Horn, W. A., Smith, J. L., Bills, G. F., Raghoobar, S. L., Helms, G. L., Kurtz, M. B., Marrinan, J. A., Frommer, B. R., Thornton, R. A. & Mandala, S. M. (1992). *J. Antibiot.* **45**, 1692–1696.
- Hotchkiss, D. J., Jenkinson, S. F., Booth, K. V., Fleet, G. W. J. & Watkin, D. J. (2007). *Acta Cryst.* **E63**, o2168–o2170.
- Macrae, C. F., Edgington, P. R., McCabe, P., Pidcock, E., Shields, G. P., Taylor, R., Towler, M. & van de Streek, J. (2006). *J. Appl. Cryst.* **39**, 453–457.
- Parsons, S., Flack, H. D. & Wagner, T. (2013). *Acta Cryst.* **B69**, 249–259.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.
- Sheldrick, G. M. (2015). *Acta Cryst.* **C71**, 3–8.
- Spek, A. L. (2009). *Acta Cryst.* **D65**, 148–155.
- Tsuzaki, S., Usui, S., Oishi, H., Yasushima, D., Fukuyasu, T., Oishi, T., Sato, T. & Chida, N. (2015). *Org. Lett.* **17**, 1704–1707.
- Watkin, D. J., Parry, L. L., Hotchkiss, D. J., Eastwick-Field, V. & Fleet, G. W. J. (2005). *Acta Cryst.* **E61**, o3302–o3303.
- Westrip, S. P. (2010). *J. Appl. Cryst.* **43**, 920–925.
- Zweerink, M. M., Edison, A. M., Wells, G. B., Pinto, W. & Lester, R. L. (1992). *J. Biol. Chem.* **267**, 25032–25038.

supporting information

Acta Cryst. (2016). E72, 756-759 [doi:10.1107/S2056989016006800]

Crystal structure of (+)-*N*-[(1*R*,5*S*,6*S*,9*S*)-5-hydroxymethyl-3,3,9-trimethyl-8-oxo-2,4,7-trioxabicyclo[4.3.0]nonan-9-yl]acetamide

Takeshi Oishi, Shun Tsuzaki, Tomoya Sugai, Takaaki Sato and Noritaka Chida

Computing details

Data collection: *APEX2* (Bruker, 2014); cell refinement: *SAINT* (Bruker, 2014); data reduction: *SAINT* (Bruker, 2014); program(s) used to solve structure: *SHELXS2013* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL2014* (Sheldrick, 2015); molecular graphics: *Mercury* (Macrae *et al.*, 2006); software used to prepare material for publication: *pubCIF* (Westrip, 2010) and *PLATON* (Spek, 2009).

(+)-*N*-[(1*R*,5*S*,6*S*,9*S*)-5-Hydroxymethyl-3,3,9-trimethyl-8-oxo-2,4,7-trioxabicyclo[4.3.0]nonan-9-yl]acetamide

Crystal data

$C_{12}H_{19}NO_6$	$D_x = 1.336 \text{ Mg m}^{-3}$
$M_r = 273.28$	Melting point = 497–498 K
Monoclinic, $P2_1$	Cu $K\alpha$ radiation, $\lambda = 1.54178 \text{ \AA}$
$a = 8.2102 (3) \text{ \AA}$	Cell parameters from 5609 reflections
$b = 9.9513 (3) \text{ \AA}$	$\theta = 5.3\text{--}66.5^\circ$
$c = 8.7480 (3) \text{ \AA}$	$\mu = 0.91 \text{ mm}^{-1}$
$\beta = 108.142 (2)^\circ$	$T = 90 \text{ K}$
$V = 679.20 (4) \text{ \AA}^3$	Prism, colorless
$Z = 2$	$0.14 \times 0.14 \times 0.07 \text{ mm}$
$F(000) = 292$	

Data collection

Bruker D8 Venture diffractometer	8304 measured reflections
Radiation source: fine-focus sealed tube	2386 independent reflections
Multilayered confocal mirror monochromator	2235 reflections with $I > 2\sigma(I)$
Detector resolution: 10.4167 pixels mm^{-1}	$R_{\text{int}} = 0.039$
φ and ω scans	$\theta_{\text{max}} = 66.8^\circ$, $\theta_{\text{min}} = 5.3^\circ$
Absorption correction: multi-scan (<i>SADABS</i> ; Bruker, 2014)	$h = -9 \rightarrow 9$
$T_{\text{min}} = 0.88$, $T_{\text{max}} = 0.94$	$k = -11 \rightarrow 11$
	$l = -10 \rightarrow 10$

Refinement

Refinement on F^2	Primary atom site location: structure-invariant direct methods
Least-squares matrix: full	Secondary atom site location: difference Fourier map
$R[F^2 > 2\sigma(F^2)] = 0.032$	Hydrogen site location: inferred from neighbouring sites
$wR(F^2) = 0.068$	H-atom parameters constrained
$S = 1.00$	$w = 1/[\sigma^2(F_o^2) + 0.324P]$
2386 reflections	where $P = (F_o^2 + 2F_c^2)/3$
177 parameters	
1 restraint	

$(\Delta/\sigma)_{\max} < 0.001$
 $\Delta\rho_{\max} = 0.20 \text{ e } \text{Å}^{-3}$
 $\Delta\rho_{\min} = -0.18 \text{ e } \text{Å}^{-3}$

Absolute structure: Flack x determined using
 941 quotients $[(F^-)-(F)]/[(F^+)+(F)]$ (Parsons *et al.*,
 2013)
 Absolute structure parameter: 0.13 (11)

Special details

Experimental. IR (KBr): 3311, 2967, 2896, 1785, 1658, 1539, 1170, 1117, 1057 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3): δ (p.p.m.) 5.91 (s, 1H; H11), 4.82 (d, $J = 2.0$ Hz, 1H; H1), 4.37 (dd, $J = 2.0, 1.7$ Hz, 1H; H6), 4.21 (ddd, $J = 7.2, 5.5, 1.7$ Hz, 1H; H5), 3.92–3.79 (m, 2H; H15AB), 2.05 (bs, 1H; H16), 2.00 (s, 3H; H14ABC), 1.60 (s, 3H; H19ABC), 1.46 (s, 3H; H18ABC), 1.35 (s, 3H; H17ABC); ^{13}C NMR (125 MHz, CDCl_3): δ (p.p.m.) 176.9 (C), 170.1 (C), 98.8 (CH), 71.6 (CH), 71.5 (CH), 68.9 (CH), 62.3 (CH_2), 61.6 (C), 29.1 (CH_3), 23.5 (CH_3), 19.2 (CH_3), 18.0 (CH_3).

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.

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

	x	y	z	$U_{\text{iso}}^*/U_{\text{eq}}$
C1	0.9761 (3)	0.3025 (3)	0.3147 (3)	0.0188 (6)
H1	0.9423	0.3845	0.2459	0.023*
O2	0.8860 (2)	0.18536 (19)	0.2398 (2)	0.0201 (4)
C3	0.7125 (3)	0.1762 (3)	0.2378 (3)	0.0206 (6)
O4	0.7068 (2)	0.17674 (19)	0.3987 (2)	0.0210 (4)
C5	0.7792 (3)	0.2941 (3)	0.4887 (3)	0.0204 (6)
H5	0.7051	0.3729	0.4412	0.024*
C6	0.9578 (3)	0.3214 (3)	0.4822 (3)	0.0199 (6)
H6	0.9921	0.4151	0.5201	0.024*
O7	1.0816 (2)	0.22653 (18)	0.5827 (2)	0.0209 (4)
C8	1.2000 (3)	0.1928 (3)	0.5118 (3)	0.0197 (6)
C9	1.1663 (3)	0.2685 (3)	0.3525 (3)	0.0188 (6)
O10	1.3137 (2)	0.1152 (2)	0.5716 (2)	0.0250 (5)
N11	1.2014 (3)	0.1803 (2)	0.2341 (2)	0.0189 (5)
H11	1.2597	0.1056	0.2656	0.023*
C12	1.1456 (3)	0.2118 (3)	0.0764 (3)	0.0199 (6)
C13	1.1567 (4)	0.1008 (3)	-0.0361 (3)	0.0243 (6)
H13A	1.2479	0.0382	0.0198	0.037*
H13B	1.1822	0.139	-0.1294	0.037*
H13C	1.0471	0.0528	-0.0722	0.037*
O14	1.0868 (2)	0.32336 (19)	0.0272 (2)	0.0232 (4)
C15	0.7705 (4)	0.2708 (3)	0.6581 (3)	0.0223 (6)
H15A	0.6511	0.2505	0.6536	0.027*
H15B	0.8432	0.1931	0.7074	0.027*
O16	0.8286 (2)	0.3877 (2)	0.7522 (2)	0.0251 (4)
H16	0.9172	0.3693	0.8284	0.038*
C17	0.6531 (4)	0.0385 (3)	0.1716 (3)	0.0265 (6)

H17A	0.735	-0.0292	0.2314	0.04*
H17B	0.6455	0.035	0.0577	0.04*
H17C	0.54	0.0202	0.1828	0.04*
C18	0.6035 (4)	0.2878 (3)	0.1367 (3)	0.0248 (6)
H18A	0.646	0.3752	0.1842	0.037*
H18B	0.484	0.2765	0.1339	0.037*
H18C	0.6104	0.2834	0.027	0.037*
C19	1.2807 (3)	0.3934 (3)	0.3836 (3)	0.0225 (6)
H19A	1.2492	0.4528	0.4593	0.034*
H19B	1.2653	0.4411	0.2821	0.034*
H19C	1.4009	0.3663	0.4295	0.034*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C1	0.0219 (13)	0.0169 (14)	0.0158 (12)	-0.0014 (11)	0.0034 (10)	0.0009 (11)
O2	0.0200 (9)	0.0209 (10)	0.0178 (8)	-0.0027 (8)	0.0033 (7)	-0.0019 (8)
C3	0.0201 (13)	0.0240 (14)	0.0163 (12)	-0.0004 (12)	0.0036 (10)	0.0020 (13)
O4	0.0253 (10)	0.0196 (10)	0.0165 (9)	-0.0042 (8)	0.0044 (7)	-0.0005 (8)
C5	0.0235 (14)	0.0174 (14)	0.0190 (13)	0.0008 (11)	0.0049 (10)	-0.0018 (12)
C6	0.0247 (15)	0.0149 (14)	0.0179 (13)	0.0023 (11)	0.0035 (11)	-0.0008 (11)
O7	0.0227 (10)	0.0232 (11)	0.0155 (9)	0.0015 (8)	0.0038 (7)	0.0010 (8)
C8	0.0202 (13)	0.0199 (14)	0.0162 (12)	-0.0041 (11)	0.0016 (10)	-0.0031 (12)
C9	0.0217 (14)	0.0185 (14)	0.0150 (12)	0.0001 (10)	0.0039 (10)	-0.0021 (11)
O10	0.0265 (11)	0.0251 (11)	0.0199 (10)	0.0042 (9)	0.0021 (8)	0.0016 (9)
N11	0.0204 (11)	0.0182 (11)	0.0168 (11)	0.0034 (9)	0.0040 (8)	-0.0010 (10)
C12	0.0160 (12)	0.0230 (15)	0.0196 (13)	-0.0034 (11)	0.0043 (10)	-0.0029 (12)
C13	0.0298 (16)	0.0242 (15)	0.0185 (13)	0.0026 (12)	0.0069 (11)	-0.0003 (12)
O14	0.0292 (10)	0.0189 (11)	0.0190 (9)	0.0018 (8)	0.0040 (8)	0.0024 (8)
C15	0.0244 (15)	0.0226 (15)	0.0191 (13)	-0.0023 (11)	0.0057 (11)	-0.0022 (12)
O16	0.0310 (11)	0.0215 (10)	0.0188 (10)	0.0032 (9)	0.0018 (8)	-0.0035 (9)
C17	0.0260 (15)	0.0288 (16)	0.0223 (14)	-0.0040 (12)	0.0040 (12)	-0.0041 (13)
C18	0.0223 (14)	0.0299 (17)	0.0195 (13)	-0.0006 (12)	0.0028 (11)	0.0035 (13)
C19	0.0229 (14)	0.0216 (14)	0.0219 (14)	-0.0021 (11)	0.0053 (11)	-0.0020 (13)

Geometric parameters (Å, °)

C1—O2	1.426 (3)	N11—H11	0.88
C1—C6	1.530 (4)	C12—O14	1.233 (3)
C1—C9	1.530 (4)	C12—C13	1.501 (4)
C1—H1	1.0	C13—H13A	0.98
O2—C3	1.422 (3)	C13—H13B	0.98
C3—O4	1.423 (3)	C13—H13C	0.98
C3—C17	1.509 (4)	C15—O16	1.419 (3)
C3—C18	1.525 (4)	C15—H15A	0.99
O4—C5	1.431 (3)	C15—H15B	0.99
C5—C6	1.510 (4)	O16—H16	0.84
C5—C15	1.523 (4)	C17—H17A	0.98

C5—H5	1.0	C17—H17B	0.98
C6—O7	1.463 (3)	C17—H17C	0.98
C6—H6	1.0	C18—H18A	0.98
O7—C8	1.349 (3)	C18—H18B	0.98
C8—O10	1.199 (3)	C18—H18C	0.98
C8—C9	1.532 (4)	C19—H19A	0.98
C9—N11	1.453 (3)	C19—H19B	0.98
C9—C19	1.530 (4)	C19—H19C	0.98
N11—C12	1.348 (3)		
O2—C1—C6	110.4 (2)	C12—N11—H11	119.7
O2—C1—C9	105.5 (2)	C9—N11—H11	119.7
C6—C1—C9	102.6 (2)	O14—C12—N11	122.6 (3)
O2—C1—H1	112.6	O14—C12—C13	122.0 (2)
C6—C1—H1	112.6	N11—C12—C13	115.4 (2)
C9—C1—H1	112.6	C12—C13—H13A	109.5
C3—O2—C1	115.6 (2)	C12—C13—H13B	109.5
O2—C3—O4	109.22 (18)	H13A—C13—H13B	109.5
O2—C3—C17	105.4 (2)	C12—C13—H13C	109.5
O4—C3—C17	106.1 (2)	H13A—C13—H13C	109.5
O2—C3—C18	111.4 (2)	H13B—C13—H13C	109.5
O4—C3—C18	112.1 (2)	O16—C15—C5	109.3 (2)
C17—C3—C18	112.2 (2)	O16—C15—H15A	109.8
C3—O4—C5	114.3 (2)	C5—C15—H15A	109.8
O4—C5—C6	111.6 (2)	O16—C15—H15B	109.8
O4—C5—C15	105.8 (2)	C5—C15—H15B	109.8
C6—C5—C15	113.9 (2)	H15A—C15—H15B	108.3
O4—C5—H5	108.5	C15—O16—H16	109.5
C6—C5—H5	108.5	C3—C17—H17A	109.5
C15—C5—H5	108.5	C3—C17—H17B	109.5
O7—C6—C5	111.2 (2)	H17A—C17—H17B	109.5
O7—C6—C1	103.9 (2)	C3—C17—H17C	109.5
C5—C6—C1	113.6 (2)	H17A—C17—H17C	109.5
O7—C6—H6	109.3	H17B—C17—H17C	109.5
C5—C6—H6	109.3	C3—C18—H18A	109.5
C1—C6—H6	109.3	C3—C18—H18B	109.5
C8—O7—C6	110.5 (2)	H18A—C18—H18B	109.5
O10—C8—O7	122.3 (2)	C3—C18—H18C	109.5
O10—C8—C9	127.5 (2)	H18A—C18—H18C	109.5
O7—C8—C9	110.1 (2)	H18B—C18—H18C	109.5
N11—C9—C19	111.8 (2)	C9—C19—H19A	109.5
N11—C9—C1	113.3 (2)	C9—C19—H19B	109.5
C19—C9—C1	112.8 (2)	H19A—C19—H19B	109.5
N11—C9—C8	109.3 (2)	C9—C19—H19C	109.5
C19—C9—C8	108.1 (2)	H19A—C19—H19C	109.5
C1—C9—C8	100.9 (2)	H19B—C19—H19C	109.5
C12—N11—C9	120.6 (2)		

C6—C1—O2—C3	51.4 (3)	C6—O7—C8—C9	1.5 (3)
C9—C1—O2—C3	161.5 (2)	O2—C1—C9—N11	33.6 (3)
C1—O2—C3—O4	-59.9 (3)	C6—C1—C9—N11	149.3 (2)
C1—O2—C3—C17	-173.5 (2)	O2—C1—C9—C19	161.8 (2)
C1—O2—C3—C18	64.6 (3)	C6—C1—C9—C19	-82.5 (3)
O2—C3—O4—C5	59.4 (3)	O2—C1—C9—C8	-83.1 (2)
C17—C3—O4—C5	172.6 (2)	C6—C1—C9—C8	32.6 (3)
C18—C3—O4—C5	-64.6 (3)	O10—C8—C9—N11	39.2 (4)
C3—O4—C5—C6	-52.2 (3)	O7—C8—C9—N11	-141.7 (2)
C3—O4—C5—C15	-176.5 (2)	O10—C8—C9—C19	-82.7 (3)
O4—C5—C6—O7	-74.1 (3)	O7—C8—C9—C19	96.4 (2)
C15—C5—C6—O7	45.7 (3)	O10—C8—C9—C1	158.7 (3)
O4—C5—C6—C1	42.7 (3)	O7—C8—C9—C1	-22.2 (3)
C15—C5—C6—C1	162.4 (2)	C19—C9—N11—C12	-75.4 (3)
O2—C1—C6—O7	79.1 (2)	C1—C9—N11—C12	53.3 (3)
C9—C1—C6—O7	-32.9 (2)	C8—C9—N11—C12	164.9 (2)
O2—C1—C6—C5	-41.8 (3)	C9—N11—C12—O14	11.3 (4)
C9—C1—C6—C5	-153.9 (2)	C9—N11—C12—C13	-167.6 (2)
C5—C6—O7—C8	142.6 (2)	O4—C5—C15—O16	-175.7 (2)
C1—C6—O7—C8	20.1 (3)	C6—C5—C15—O16	61.4 (3)
C6—O7—C8—O10	-179.4 (2)		

Hydrogen-bond geometry (\AA , $^\circ$)

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
O16—H16 \cdots O14 ⁱ	0.84	1.91	2.742 (2)	168
N11—H11 \cdots O16 ⁱⁱ	0.88	2.28	2.928 (3)	131
C5—H5 \cdots O10 ⁱⁱⁱ	1.00	2.42	3.289 (3)	145
C19—H19A \cdots O4 ⁱⁱⁱ	0.98	2.52	3.386 (3)	147
C13—H13B \cdots O7 ^{iv}	0.98	2.55	3.433 (3)	150
C13—H13C \cdots O14 ^v	0.98	2.62	3.424 (3)	140

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