

(3*R*,4*S*,5*S*,8*S*,10*R*,13*R*)-3-Hydroxykaura-9(11),16-dien-18-oic acid

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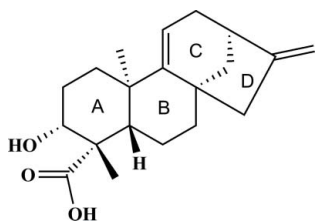
Received 19 September 2011; accepted 18 January 2012

Key indicators: single-crystal X-ray study; $T = 296$ K; mean $\sigma(\text{C}-\text{C}) = 0.005$ Å; R factor = 0.044; wR factor = 0.112; data-to-parameter ratio = 7.3.

The title compound, $\text{C}_{20}\text{H}_{28}\text{O}_3$, was isolated during our investigation into the chemical composition and pharmacological activity of *Centipeda cunninghamii* (DC.) A. Braun & Asch. (Asteraceae). The enantiopure compound, a diterpene with a carbon skeleton, is composed of three six- and one five-membered rings in chair, twist-boat, half-chair and envelope conformations, respectively. Each molecule makes one intra- and one intermolecular $\text{O}-\text{H}\cdots\text{O}$ hydrogen bond in the crystal lattice, forming hydrogen-bonded chains along [010]. The absolute configuration of the compound was assigned on the basis of optical rotation measurements.

Related literature

For the characterization of related kaurane diterpenes, see: Reynolds *et al.* (1991); Piozzi *et al.* (1972). For literature on the occurrence of the 3*S* isomer of the title compound isolated from *Ichthyothere terminalis* and *Pseudognaphalium cheiranthifolium*, see: Bohlmann *et al.* (1982); Mendoza & Urzúa (1998). For the antibacterial activity of the 3*S* isomer, see: Mendoza *et al.* (1997). For phytopharmacological aspects of *Centipeda cunninghamii*, see: Campbell (1973); Cribb (1988); D'Amelio & Mirhom, (1998); Maiden (1975); Webb (1948). For optical rotation data of related compounds, see: Bohlmann *et al.* (1982); Brieskorn & Pöhlmann (1968); Reynolds *et al.* (1991).



Experimental

Crystal data

$\text{C}_{20}\text{H}_{28}\text{O}_3$
 $M_r = 316.4$
 Monoclinic, $P2_1$
 $a = 8.064$ (2) Å
 $b = 10.775$ (3) Å
 $c = 10.462$ (4) Å
 $\beta = 109.70$ (2)°
 $V = 855.8$ (5) Å³
 $Z = 2$
 Mo $K\alpha$ radiation
 $\mu = 0.08$ mm⁻¹
 $T = 296$ K
 $0.30 \times 0.25 \times 0.10$ mm

Data collection

Enraf-Nonius CAD-4 diffractometer
 1586 measured reflections
 1586 independent reflections
 1254 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.000$
 1 standard reflections every 30 min
 intensity decay: none

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.044$
 $wR(F^2) = 0.112$
 $S = 1.05$
 1586 reflections
 218 parameters
 1 restraint
 H atoms treated by a mixture of independent and constrained refinement
 $\Delta\rho_{\text{max}} = 0.15$ e Å⁻³
 $\Delta\rho_{\text{min}} = -0.17$ e Å⁻³

Table 1

Hydrogen-bond geometry (Å, °).

$D-\text{H}\cdots A$	$D-\text{H}$	$\text{H}\cdots A$	$D\cdots A$	$D-\text{H}\cdots A$
$\text{O3}-\text{H1O3}\cdots\text{O1}^i$	0.82 (5)	1.83 (5)	2.637 (4)	169 (5)
$\text{O1}-\text{H1O1}\cdots\text{O2}$	0.96 (7)	1.94 (6)	2.651 (4)	129 (5)

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

Data collection: *CAD-4 Software* (Enraf-Nonius, 1989); cell refinement: *CAD-4 Software*; data reduction: *CAD-4 Software*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *ORTEP-3 for Windows* (Farrugia, 1997) and *Mercury* (Macrae *et al.*, 2008); software used to prepare material for publication: *publCIF* (Westrip, 2010).

We would like to acknowledge Dr Kim Dastlick from the Institute of Molecular Biosciences at The University of Queensland for performing optical rotations, and the Chemical Analysis Laboratories, Bulleen, Victoria, for performing high resolution-mass spectrometric analyses. This research was supported by the Centre for Phytochemistry and Pharmacology at Southern Cross University and the University of New South Wales. KB is grateful to the Australian Federal Government for an Australian Postgraduate Award and to Bioactive Exports Pty. Ltd for financial assistance.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: QK2025).

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Acta Cryst. (2012). E68, o526-o527 [doi:10.1107/S1600536812002206]

(3*R*,4*S*,5*S*,8*S*,10*R*,13*R*)-3-Hydroxykaura-9(11),16-dien-18-oic acid

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Comment

The title compound C₂₀H₂₈O₃ [Fig. 1., systematic name (3*R*,4*S*,5*S*,8*S*,10*R*,13*R*)-3-hydroxykaura-9(11),16-dien-18-oic acid], a diterpene, was isolated during our investigation into the chemical composition and pharmacological activity of active components of *Centipeda cunninghamii*. The herb is native to Australia and New Zealand and has been utilized by the Aborigines to treat infection (Campbell, 1973; Cribb, 1988; D'Amelio & Mirhom, 1998) and inflammation (Maiden, 1975; Webb, 1948). Compound (I) crystallizes in the monoclinic chiral space group *P*2₁. The carbon skeleton is composed of three six- and one five-membered rings in chair (ring A), twist-boat (ring B), half-chair (ring C) and envelope conformations (ring D). In the unit cell, two symmetry equivalent molecules make an intramolecular O—H...O bond between the 3-OH (O1) and the carbonyl oxygen (O2) and are linked by intermolecular O—H...O hydrogen bonds involving the carboxylic hydroxyl group (O3, donor) and the 3-OH group (O1, acceptor) into infinite chains extending parallel to the *b* axis (Fig. 2; Table 1).

The majority of the *ent*-kaurane diterpenes characteristically exhibit negative values for optical rotation with the exception of those that feature a double bond between C9 and C11. Piozzi and co-workers (Piozzi *et al.*, 1972) have demonstrated that sequential catalytic hydrogenation of the exocyclic C16—C17 and the endocyclic C9—C11 double bonds in grandiflorenic acid [(4*α*)-kaura-9(11),16-dien-18-oic acid] transforms the optical rotation from +38 to +43° and subsequently to -80° in the saturated product. More recently Reynolds and co-workers (Reynolds *et al.*, 1991) have analysed the solid state and solution characteristics of grandiflorenic acid, and have determined that the introduction of the C9—C11 double bond in grandiflorenic acid has a drastic effect on the molecular conformation and consequently on optical rotation, whereby the *B* ring adopts a boat conformation compared to the regular chair conformation in kaurenoic acid. In the case of compound (I) the observed rotation is $[\alpha]_{\text{D}}^{22} + 30.8^{\circ}$ (*c* 0.12, MeOH), which is in agreement with values for the methyl ester derivative of the 3*S* isomer, +15° (Bohlmann *et al.*, 1982) and the closely related grandiflorenic acid +32.1° (Brieskorn & Pöhlmann, 1968) and +46° (Reynolds *et al.*, 1991) and establishes the 3*R*,4*S*,5*S*,8*S*,10*R*,13*R* absolute stereochemistry of compound (I). The 3*S* isomer of compound (I) has been obtained previously from *Ichthyothere terminalis* (Bohlmann *et al.*, 1982) and *Pseudognaphalium cheiranthifolium* (Mendoza & Urzúa, 1998). The antibacterial activity of the 3*S* isomer has also been evaluated and is described in Mendoza *et al.* (1997).

Experimental

The whole, air-dried flowers of *Centipeda cunninghamii* (100 g) were extracted in 100% ethanol (1 L) overnight at ambient temperatures with stirring. The resulting extract was filtered and then partitioned with hexane (3 × 200 ml). The hexane soluble fraction (2.8 g, 2.8% yield *w/w*) was evaporated and then subjected to reverse phase preparative HPLC (Gilson preparative HPLC system; Phenomenex Luna C18 column, 5 μm, 50 mm × 21.2 mm; sample loading 50 - 100 mg/injection). The column was eluted using a stepwise gradient of H₂O/CH₃CN containing 0.05% CF₃COOH (3:2 to 1:3 over 16.4 min; 1:3 isocratic for 3.6 min; then 1:3 to 1:9 over 1.0 min; then 1:9 isocratic for 7 minutes) at a flow rate of 15 ml/min. Crystals suitable for X-ray diffraction were obtained by slow evaporation of the H₂O/CH₃CN HPLC eluent of (I).

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(3*R*,4*S*,5*S*,8*S*,10*R*,13*R*)- 3-Hydroxykaura-9(11),16-dien-18-oic acid (I): Colourless needles (ACN/H₂O) (26.5 mg, 1.0% yield w/w, not optimized); $[\alpha]_D^{22} + 30.8^\circ$ (*c* 0.12, MeOH); ¹H NMR (500 MHz, CD₃OD): δ 5.26 (1*H*, t, *J* = 3.3 Hz, H-11), 4.89 (1*H*, d, *J* = 1.1 Hz, H-17*a*), 4.77 (1*H*, br s, H-17*b*), 3.17 (1*H*, dd, *J* = 4.4, 12.1 Hz, H-3), 2.74 (1*H*, br s, H-13), 2.61 (1*H*, br d, *J* = 14.8 Hz, H-15*a*), 2.44 - 2.40 (1*H*, m, H-12*a*), 2.41 - 2.35 (1*H*, m, H-6*a*), 2.29 - 2.16 (1*H*, m, H-2*a*), 2.20 - 2.16 (1*H*, m, H-15*b*), 2.04 (1*H*, m, H-1*a*), 1.99 - 1.95 (1*H*, m, H-7*a*), 1.99 - 1.95 (1*H*, m, H-12*b*), 1.93 - 1.85 (1*H*, m, H-6*b*), 1.68 - 1.74 (1*H*, m, H-2*b*), 1.65 - 1.62 (1*H*, m, H-5), 1.63 - 1.60 (1*H*, m, H-14*a*), 1.51 - 1.47 (1*H*, m, H-7*b*), 1.51 - 1.47 (1*H*, m, H-14*b*), 1.38 - 1.32 (1*H*, m, H-1*b*), 1.36 (3*H*, s, H-19), 1.10 (3*H*, s, H-20); Lit. (3*S* isomer as the methyl ester derivative, see Bohlmann *et al.*, 1982); ¹³C NMR (126 MHz, CD₃OD): δ 180.1 (C, C-18), 159.6 (C, C-16), 157.3 (C, C-9), 116.3 (CH, C-11), 106.2 (CH₂, C-17), 79.4 (CH, C-3), 51.5 (CH₂, C-15), 51.3 (C, C-4), 47.0 (CH, C-5), 46.2 (CH₂, C-14), 43.6 (C, C-8), 42.8 (CH, C-13), 40.4 (CH₂, C-1), 39.7 (C, C-10), 39.1 (CH₂, C-12), 31.0 (CH₂, C-7), 29.9 (CH₂, C-2), 24.6 (CH₃, C-19), 24.4 (CH₃, C-20), 19.8 (CH₂, C-6); (+)-LRAPCIMS *m/z* (*rel. int.*): 316 [*M*+H⁺, 0%], 299 (100), 271 (59), 253 (93), 225 (6); (+)-HRAPCIMS *m/z* (*rel. int.*): 317.2109 calcd for C₂₀H₂₉O₃, 317.2118 (Δ 0.0009 a.m.u.).

Refinement

C-bonded H-atoms were positioned geometrically (C–H = 0.93–0.98 Å) and refined as riding with $U_{\text{iso}}(\text{H}) = xU_{\text{eq}}(\text{C})$, where $x = 1.5$ for methyl and $x = 1.2$ for the rest. The two O-bonded H-atoms were fully refined. The absolute configuration was assigned by comparison of a similar moiety using NMR spectral data and optical rotation, see section Comment. No Friedel pairs were measured and the refined Flack absolute structure parameter, 1(2), was inconclusive.

Figures

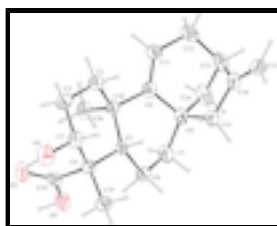


Fig. 1. View of (I) with atom numbering scheme. Displacement ellipsoids for non-H atoms are drawn at the 40% probability level.

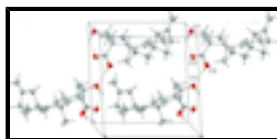


Fig. 2. Packing diagram of (I) viewed down the *a* axis depicting intra and inter molecular O—H...O hydrogen bonding.

(3*R*,4*S*,5*S*,8*S*,10*R*,13*R*)- 3-Hydroxykaura-9(11),16-dien-18-oic acid

Crystal data

C₂₀H₂₈O₃

$M_r = 316.4$

Monoclinic, $P2_1$

Hall symbol: P 2yb

$a = 8.064$ (2) Å

$b = 10.775$ (3) Å

$F(000) = 344$

$D_x = 1.228$ Mg m⁻³

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

Cell parameters from 11 reflections

$\theta = 10\text{--}11^\circ$

$\mu = 0.08$ mm⁻¹

$c = 10.462 (4) \text{ \AA}$
 $\beta = 109.70 (2)^\circ$
 $V = 855.8 (5) \text{ \AA}^3$
 $Z = 2$

$T = 296 \text{ K}$
 Block, colourless
 $0.30 \times 0.25 \times 0.10 \text{ mm}$

Data collection

Enraf–Nonius CAD-4 diffractometer
 Radiation source: fine-focus sealed tube
 graphite
 ω -2 θ scans
 1586 measured reflections
 1586 independent reflections
 1254 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.000$
 $\theta_{\text{max}} = 25.0^\circ$, $\theta_{\text{min}} = 2.1^\circ$
 $h = -9 \rightarrow 9$
 $k = 0 \rightarrow 12$
 $l = 0 \rightarrow 12$
 1 standard reflections every 30 min
 intensity decay: none

Refinement

Refinement on F^2
 Least-squares matrix: full
 $R[F^2 > 2\sigma(F^2)] = 0.044$
 $wR(F^2) = 0.112$
 $S = 1.05$
 1586 reflections
 218 parameters
 1 restraint
 Primary atom site location: structure-invariant direct methods

Secondary atom site location: difference Fourier map
 Hydrogen site location: inferred from neighbouring sites
 H atoms treated by a mixture of independent and constrained refinement
 $w = 1/[\sigma^2(F_o^2) + (0.0704P)^2]$
 where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\text{max}} = 0.001$
 $\Delta\rho_{\text{max}} = 0.15 \text{ e \AA}^{-3}$
 $\Delta\rho_{\text{min}} = -0.17 \text{ e \AA}^{-3}$
 Absolute structure: deduced from optical rotation

Special details

Geometry. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s 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 $F^2 > \sigma(F^2)$ 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 (\AA^2)

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
O1	0.3554 (4)	0.4597 (3)	0.9863 (3)	0.0658 (8)

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O2	0.4220 (4)	0.2189 (3)	0.9850 (2)	0.0620 (7)
O3	0.5758 (4)	0.1598 (3)	0.8595 (3)	0.0678 (9)
C1	0.0447 (4)	0.3543 (4)	0.6459 (4)	0.0521 (10)
C2	0.1154 (5)	0.3753 (4)	0.7994 (4)	0.0511 (9)
C3	0.2956 (5)	0.4335 (3)	0.8438 (3)	0.0473 (9)
C4	0.4293 (4)	0.3558 (3)	0.8032 (3)	0.0395 (8)
C5	0.3551 (4)	0.3369 (3)	0.6461 (3)	0.0359 (7)
C6	0.4877 (5)	0.2789 (4)	0.5853 (3)	0.0520 (9)
C7	0.4047 (5)	0.2222 (4)	0.4458 (3)	0.0572 (10)
C8	0.2344 (4)	0.2860 (4)	0.3602 (3)	0.0460 (8)
C9	0.1005 (4)	0.2857 (3)	0.4348 (3)	0.0435 (8)
C10	0.1677 (4)	0.2779 (3)	0.5907 (3)	0.0399 (8)
C11	-0.0703 (5)	0.2924 (4)	0.3625 (4)	0.0587 (10)
C12	-0.1416 (5)	0.3019 (4)	0.2107 (4)	0.0667 (12)
C13	0.0059 (6)	0.3158 (4)	0.1511 (4)	0.0609 (11)
C14	0.1503 (6)	0.2238 (4)	0.2209 (4)	0.0645 (11)
C15	0.2579 (5)	0.4187 (4)	0.3156 (3)	0.0499 (9)
C16	0.0971 (5)	0.4395 (4)	0.1910 (3)	0.0485 (9)
C17	0.0429 (5)	0.5449 (4)	0.1297 (4)	0.0567 (10)
C18	0.4701 (4)	0.2379 (3)	0.8902 (3)	0.0422 (8)
C19	0.6049 (5)	0.4288 (4)	0.8399 (4)	0.0578 (10)
C20	0.1658 (5)	0.1410 (4)	0.6329 (4)	0.0518 (9)
H1A	0.0241	0.4344	0.6009	0.062*
H1B	-0.0679	0.3121	0.6225	0.062*
H1O1	0.353 (7)	0.381 (6)	1.029 (6)	0.11 (2)*
H1O3	0.598 (6)	0.104 (5)	0.916 (5)	0.070 (14)*
H2A	0.0352	0.4289	0.8251	0.061*
H2B	0.1212	0.2965	0.8455	0.061*
H3A	0.2844	0.5133	0.7966	0.057*
H5	0.3378	0.4215	0.6096	0.043*
H6A	0.5700	0.3427	0.5799	0.062*
H6B	0.5545	0.2152	0.6467	0.062*
H7A	0.3802	0.1353	0.4561	0.069*
H7B	0.4886	0.2262	0.3977	0.069*
H11	-0.1504	0.2912	0.4089	0.070*
H12A	-0.2197	0.3730	0.1847	0.080*
H12B	-0.2097	0.2281	0.1736	0.080*
H13	-0.0373	0.3044	0.0524	0.073*
H14A	0.2340	0.2154	0.1732	0.077*
H14B	0.1024	0.1429	0.2294	0.077*
H15A	0.2618	0.4781	0.3863	0.060*
H15B	0.3652	0.4260	0.2937	0.060*
H17A	-0.0600	0.5480	0.0549	0.068*
H17B	0.1071	0.6171	0.1610	0.068*
H19A	0.6417	0.4530	0.9336	0.087*
H19B	0.5881	0.5014	0.7839	0.087*
H19C	0.6936	0.3771	0.8250	0.087*
H20A	0.0491	0.1080	0.5929	0.078*
H20B	0.2006	0.1356	0.7300	0.078*

H20C 0.2464 0.0942 0.6021 0.078*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.094 (2)	0.0543 (18)	0.0541 (17)	-0.0171 (15)	0.0310 (15)	-0.0191 (14)
O2	0.0852 (18)	0.0558 (16)	0.0539 (14)	0.0077 (16)	0.0353 (14)	0.0151 (14)
O3	0.0799 (19)	0.0664 (19)	0.0635 (19)	0.0311 (16)	0.0324 (16)	0.0300 (16)
C1	0.0394 (19)	0.061 (2)	0.054 (2)	0.0037 (18)	0.0125 (16)	0.0050 (19)
C2	0.053 (2)	0.046 (2)	0.060 (2)	0.0081 (18)	0.0275 (18)	-0.0023 (18)
C3	0.067 (2)	0.0321 (18)	0.047 (2)	-0.0034 (17)	0.0240 (17)	-0.0033 (16)
C4	0.0405 (18)	0.0345 (18)	0.0401 (18)	-0.0065 (15)	0.0094 (14)	-0.0001 (15)
C5	0.0370 (16)	0.0337 (16)	0.0352 (16)	0.0009 (14)	0.0100 (13)	0.0038 (14)
C6	0.0451 (18)	0.066 (2)	0.0468 (19)	0.0127 (19)	0.0179 (16)	0.0072 (19)
C7	0.070 (2)	0.056 (2)	0.052 (2)	0.020 (2)	0.0293 (18)	0.008 (2)
C8	0.055 (2)	0.0439 (19)	0.0368 (17)	0.0057 (18)	0.0120 (15)	0.0002 (16)
C9	0.053 (2)	0.0355 (16)	0.0396 (17)	-0.0086 (17)	0.0127 (15)	-0.0014 (15)
C10	0.0408 (18)	0.0368 (18)	0.0406 (18)	-0.0055 (16)	0.0119 (15)	-0.0012 (15)
C11	0.052 (2)	0.065 (2)	0.051 (2)	-0.020 (2)	0.0080 (18)	0.004 (2)
C12	0.063 (2)	0.070 (3)	0.048 (2)	-0.025 (2)	-0.0063 (19)	0.004 (2)
C13	0.085 (3)	0.054 (3)	0.0337 (18)	0.001 (2)	0.0073 (19)	-0.0051 (16)
C14	0.095 (3)	0.047 (2)	0.047 (2)	0.007 (2)	0.019 (2)	-0.0020 (19)
C15	0.052 (2)	0.055 (2)	0.0442 (19)	-0.0005 (18)	0.0193 (16)	0.0042 (18)
C16	0.059 (2)	0.049 (2)	0.0421 (19)	0.0009 (18)	0.0233 (16)	0.0043 (17)
C17	0.049 (2)	0.058 (2)	0.065 (2)	0.0036 (19)	0.0203 (17)	0.009 (2)
C18	0.0398 (17)	0.0418 (18)	0.0397 (17)	-0.0048 (16)	0.0061 (15)	-0.0008 (16)
C19	0.052 (2)	0.057 (2)	0.058 (2)	-0.017 (2)	0.0090 (18)	0.0025 (19)
C20	0.064 (2)	0.042 (2)	0.046 (2)	-0.0102 (18)	0.0138 (17)	-0.0012 (17)

Geometric parameters (Å, °)

O1—C3	1.432 (4)	C8—C15	1.536 (5)
O1—H1O1	0.96 (7)	C8—C14	1.538 (5)
O2—C18	1.198 (4)	C9—C11	1.331 (5)
O3—C18	1.312 (4)	C9—C10	1.537 (4)
O3—H1O3	0.82 (5)	C10—C20	1.541 (5)
C1—C2	1.529 (5)	C11—C12	1.499 (5)
C1—C10	1.544 (5)	C11—H11	0.9300
C1—H1A	0.9700	C12—C13	1.525 (6)
C1—H1B	0.9700	C12—H12A	0.9700
C2—C3	1.505 (5)	C12—H12B	0.9700
C2—H2A	0.9700	C13—C16	1.511 (6)
C2—H2B	0.9700	C13—C14	1.516 (6)
C3—C4	1.534 (5)	C13—H13	0.9800
C3—H3A	0.9800	C14—H14A	0.9700
C4—C18	1.532 (5)	C14—H14B	0.9700
C4—C19	1.551 (5)	C15—C16	1.514 (5)
C4—C5	1.562 (4)	C15—H15A	0.9700
C5—C6	1.549 (5)	C15—H15B	0.9700

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C5—C10	1.559 (4)	C16—C17	1.305 (6)
C5—H5	0.9800	C17—H17A	0.9300
C6—C7	1.514 (5)	C17—H17B	0.9300
C6—H6A	0.9700	C19—H19A	0.9600
C6—H6B	0.9700	C19—H19B	0.9600
C7—C8	1.527 (5)	C19—H19C	0.9600
C7—H7A	0.9700	C20—H20A	0.9600
C7—H7B	0.9700	C20—H20B	0.9600
C8—C9	1.531 (5)	C20—H20C	0.9600
C3—O1—H1O1	105 (4)	C9—C10—C1	109.0 (3)
C18—O3—H1O3	107 (3)	C20—C10—C1	109.5 (3)
C2—C1—C10	114.4 (3)	C9—C10—C5	108.8 (2)
C2—C1—H1A	108.7	C20—C10—C5	112.7 (3)
C10—C1—H1A	108.7	C1—C10—C5	107.9 (3)
C2—C1—H1B	108.7	C9—C11—C12	124.1 (4)
C10—C1—H1B	108.7	C9—C11—H11	118.0
H1A—C1—H1B	107.6	C12—C11—H11	118.0
C3—C2—C1	111.4 (3)	C11—C12—C13	111.5 (3)
C3—C2—H2A	109.3	C11—C12—H12A	109.3
C1—C2—H2A	109.3	C13—C12—H12A	109.3
C3—C2—H2B	109.3	C11—C12—H12B	109.3
C1—C2—H2B	109.3	C13—C12—H12B	109.3
H2A—C2—H2B	108.0	H12A—C12—H12B	108.0
O1—C3—C2	110.8 (3)	C16—C13—C14	102.7 (3)
O1—C3—C4	112.0 (3)	C16—C13—C12	110.4 (3)
C2—C3—C4	112.5 (3)	C14—C13—C12	108.5 (3)
O1—C3—H3A	107.1	C16—C13—H13	111.6
C2—C3—H3A	107.1	C14—C13—H13	111.6
C4—C3—H3A	107.1	C12—C13—H13	111.6
C18—C4—C3	108.6 (3)	C13—C14—C8	101.2 (3)
C18—C4—C19	106.2 (3)	C13—C14—H14A	111.5
C3—C4—C19	108.8 (3)	C8—C14—H14A	111.5
C18—C4—C5	116.5 (3)	C13—C14—H14B	111.5
C3—C4—C5	107.9 (3)	C8—C14—H14B	111.5
C19—C4—C5	108.7 (3)	H14A—C14—H14B	109.4
C6—C5—C10	113.6 (3)	C16—C15—C8	104.0 (3)
C6—C5—C4	114.4 (3)	C16—C15—H15A	111.0
C10—C5—C4	115.1 (2)	C8—C15—H15A	111.0
C6—C5—H5	104.0	C16—C15—H15B	111.0
C10—C5—H5	104.0	C8—C15—H15B	111.0
C4—C5—H5	104.0	H15A—C15—H15B	109.0
C7—C6—C5	114.6 (3)	C17—C16—C13	125.5 (3)
C7—C6—H6A	108.6	C17—C16—C15	126.8 (4)
C5—C6—H6A	108.6	C13—C16—C15	107.7 (3)
C7—C6—H6B	108.6	C16—C17—H17A	120.0
C5—C6—H6B	108.6	C16—C17—H17B	120.0
H6A—C6—H6B	107.6	H17A—C17—H17B	120.0
C6—C7—C8	113.7 (3)	O2—C18—O3	120.7 (3)
C6—C7—H7A	108.8	O2—C18—C4	124.7 (3)

C8—C7—H7A	108.8	O3—C18—C4	114.4 (3)
C6—C7—H7B	108.8	C4—C19—H19A	109.5
C8—C7—H7B	108.8	C4—C19—H19B	109.5
H7A—C7—H7B	107.7	H19A—C19—H19B	109.5
C7—C8—C9	110.5 (3)	C4—C19—H19C	109.5
C7—C8—C15	114.8 (3)	H19A—C19—H19C	109.5
C9—C8—C15	109.7 (3)	H19B—C19—H19C	109.5
C7—C8—C14	112.5 (3)	C10—C20—H20A	109.5
C9—C8—C14	108.7 (3)	C10—C20—H20B	109.5
C15—C8—C14	100.2 (3)	H20A—C20—H20B	109.5
C11—C9—C8	118.8 (3)	C10—C20—H20C	109.5
C11—C9—C10	122.3 (3)	H20A—C20—H20C	109.5
C8—C9—C10	118.9 (3)	H20B—C20—H20C	109.5
C9—C10—C20	108.8 (3)		
C10—C1—C2—C3	54.8 (4)	C2—C1—C10—C20	72.3 (4)
C1—C2—C3—O1	176.4 (3)	C2—C1—C10—C5	-50.7 (4)
C1—C2—C3—C4	-57.4 (4)	C6—C5—C10—C9	-55.0 (4)
O1—C3—C4—C18	55.0 (3)	C4—C5—C10—C9	170.5 (3)
C2—C3—C4—C18	-70.5 (3)	C6—C5—C10—C20	65.7 (4)
O1—C3—C4—C19	-60.1 (4)	C4—C5—C10—C20	-68.7 (3)
C2—C3—C4—C19	174.4 (3)	C6—C5—C10—C1	-173.2 (3)
O1—C3—C4—C5	-177.9 (3)	C4—C5—C10—C1	52.3 (4)
C2—C3—C4—C5	56.6 (3)	C8—C9—C11—C12	-0.8 (6)
C18—C4—C5—C6	-67.3 (4)	C10—C9—C11—C12	179.1 (4)
C3—C4—C5—C6	170.3 (3)	C9—C11—C12—C13	-5.6 (6)
C19—C4—C5—C6	52.5 (4)	C11—C12—C13—C16	-67.3 (5)
C18—C4—C5—C10	66.8 (4)	C11—C12—C13—C14	44.5 (5)
C3—C4—C5—C10	-55.6 (3)	C16—C13—C14—C8	42.4 (4)
C19—C4—C5—C10	-173.4 (3)	C12—C13—C14—C8	-74.4 (4)
C10—C5—C6—C7	26.2 (5)	C7—C8—C14—C13	-171.1 (3)
C4—C5—C6—C7	161.1 (3)	C9—C8—C14—C13	66.3 (4)
C5—C6—C7—C8	30.5 (5)	C15—C8—C14—C13	-48.7 (4)
C6—C7—C8—C9	-56.6 (4)	C7—C8—C15—C16	156.9 (3)
C6—C7—C8—C15	68.0 (4)	C9—C8—C15—C16	-78.1 (3)
C6—C7—C8—C14	-178.2 (3)	C14—C8—C15—C16	36.2 (3)
C7—C8—C9—C11	-154.9 (4)	C14—C13—C16—C17	161.6 (4)
C15—C8—C9—C11	77.6 (4)	C12—C13—C16—C17	-82.9 (5)
C14—C8—C9—C11	-31.1 (5)	C14—C13—C16—C15	-19.9 (4)
C7—C8—C9—C10	25.3 (4)	C12—C13—C16—C15	95.6 (4)
C15—C8—C9—C10	-102.2 (3)	C8—C15—C16—C17	167.9 (3)
C14—C8—C9—C10	149.1 (3)	C8—C15—C16—C13	-10.5 (4)
C11—C9—C10—C20	85.3 (5)	C3—C4—C18—O2	-8.6 (4)
C8—C9—C10—C20	-94.8 (4)	C19—C4—C18—O2	108.2 (4)
C11—C9—C10—C1	-34.0 (5)	C5—C4—C18—O2	-130.6 (4)
C8—C9—C10—C1	145.8 (3)	C3—C4—C18—O3	176.3 (3)
C11—C9—C10—C5	-151.5 (4)	C19—C4—C18—O3	-66.9 (4)
C8—C9—C10—C5	28.3 (4)	C5—C4—C18—O3	54.3 (4)
C2—C1—C10—C9	-168.8 (3)		

supplementary materials

Hydrogen-bond geometry (Å, °)

<i>D</i> —H··· <i>A</i>	<i>D</i> —H	H··· <i>A</i>	<i>D</i> ··· <i>A</i>	<i>D</i> —H··· <i>A</i>
O3—H1O3···O1 ⁱ	0.82 (5)	1.83 (5)	2.637 (4)	169 (5)
O1—H1O1···O2	0.96 (7)	1.94 (6)	2.651 (4)	129 (5)

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

Fig. 1

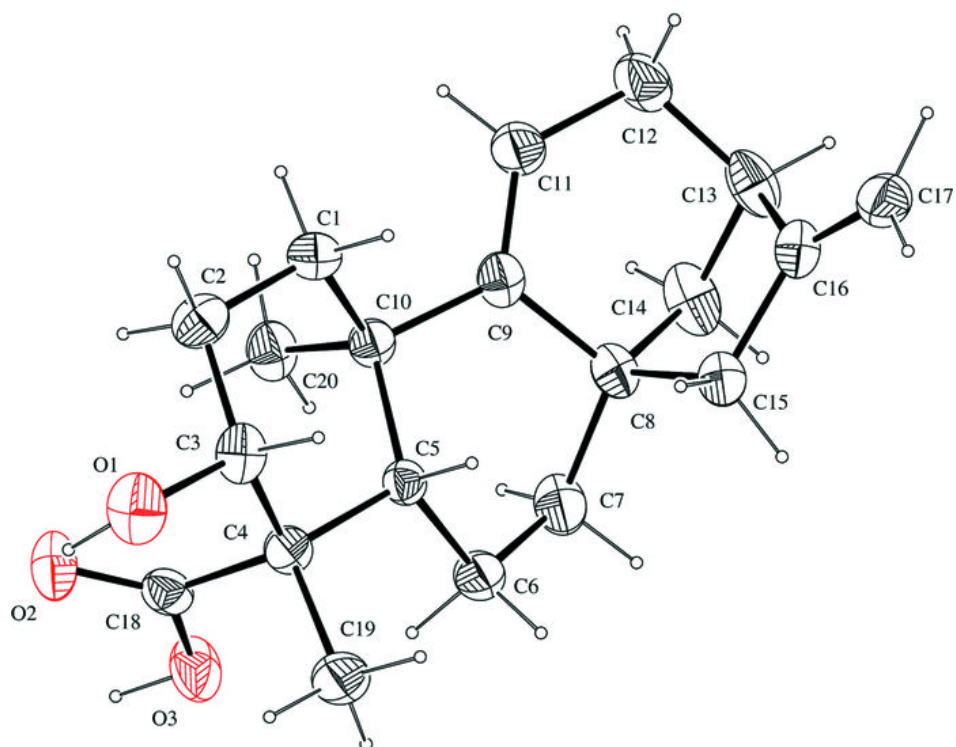


Fig. 2

