

## Structure of Methyl 8,9-Methylenedioxy-2-oxo-1,2,3,4,4a $\alpha$ ,5,6,10b $\beta$ -octahydro-phenanthridine-5-carboxylate

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**Abstract.** C<sub>16</sub>H<sub>17</sub>NO<sub>5</sub>·0.38H<sub>2</sub>O,  $M_r = 310.16$ , monoclinic,  $C2/c$ ,  $a = 16.23$  (1),  $b = 5.88$  (1),  $c = 29.88$  (2) Å,  $\beta = 96.61$  (7)°,  $V = 2834$  (7) Å<sup>3</sup>,  $Z = 8$ ,  $D_x = 1.454$  g cm<sup>-3</sup>,  $\lambda(\text{Mo } K\alpha) = 0.71069$  Å,  $\mu = 1.03$  cm<sup>-1</sup>,  $F(000) = 1310$ ,  $T = 296$  K,  $R = 0.049$  for 1018 unique observed reflections. Like the *Amaryllidaceae* alkaloids, our synthetic compound possesses a *trans* configuration at C(4a)—H(4a) and C(10b)—H(10b). Unexpectedly, the structure contains a molecule of water linking two molecules of the title compound *via* hydrogen bonding with O(4) of the respective carbonyl groups.

**Experimental.** The photocyclization (Lenz, 1976; Ninomiya, Kiguchi, Yamamoto & Naito, 1979) of *N*-(4-acetoxycyclohex-1-enyl)-*N*-allylpiperonylamide followed by reduction (lithium aluminium hydride), removal of the allyl group (rhodium trichloride), carbamylation (methyl chloroformate), and oxidation (pyridinium chlorochromate) provided the title compound. The compound, recrystallized from methylene chloride, melted at 468–470 K.

The crystal used for data collection was  $0.07 \times 0.22 \times 0.29$  mm, colorless, and tabular. Data were collected with a Rigaku AFC-5S diffractometer using graphite-monochromated Mo  $K\alpha$  radiation,  $\omega$  scans, and a scan speed of  $2^\circ \text{ min}^{-1}$  (in  $\omega$ ). Weak reflections [ $I < 10.0\sigma(I)$ ] were rescanned (maximum of two rescans) and the counts accumulated to improve accuracy. The lattice parameters were obtained from a least-squares fit of 23 strong reflections in the  $2\theta$  range  $21\text{--}33^\circ$ . Several crystals were mounted and all exhibited split or asymmetric peak shapes; thus relatively wide scans ( $1.70 + 0.30\tan\theta$ )° were necessary to insure that the entire peak area was measured. In addition, both vertical and horizontal detector slits

were used to prevent peak overlap which resulted from the large  $c$  axial length. A total of 2754 independent reflections were measured [ $h$  0 to 19,  $k$  0 to 7,  $l$  -35 to 35,  $(\sin\theta/\lambda)_{\text{max}} = 0.60$  Å<sup>-1</sup>] and 1736 reflections were considered unobserved with [ $I < 3\sigma(I)$ ] leaving a data set comprised of 1018 unique reflections. Three standard reflections ( $\bar{1}\bar{1}\bar{2}$ ,  $\bar{3}\bar{1}0$ ,  $\bar{3}\bar{1}\bar{2}$ ) changed by 0.2, 0.5 and 1.2%, respectively; no decay correction was applied. The data were corrected for Lorentz and polarization effects, no absorption correction was applied,  $R_{\text{int}}$  (based on  $F^2$ ) = 0.048 (112 averaged reflections). The direct-methods program *SHELXS86* (Sheldrick, 1985) provided the locations of all non-H atoms. Full-matrix least-squares refinement was performed to minimize  $\sum w(|F_o| - |F_c|)^2$  where  $w = 4F_o^2/\sigma^2(F_o^2)$  and  $\sigma^2(F_o^2) = [S^2(C + R^2B) + (pF_o^2)^2]/Lp^2$  ( $S$  = scan rate,  $C$  = total integrated peak count,  $R$  = ratio of scan time to background counting time,  $B$  = total background count,  $Lp$  = Lorentz-polarization factor, and  $p = 0.03$ ). The refinement converged at an  $R$  of 0.12 and a difference Fourier synthesis showed a large and unexpected peak at an intermolecular position. Further refinement showed this peak to be a partially occupied (76%) O atom of an H<sub>2</sub>O group. After convergence methyl, methylene and phenyl H atoms were placed at assumed positions ( $C\text{—}H = 0.95$  Å,  $B = 1.2 \times B_{\text{eq}}$  of associated C atom) and fixed, methyl-group orientations were determined on the basis of H positions obtained from a difference Fourier synthesis. The model was again refined to convergence and the two methine H atoms and the partially occupied water H atom were located from an ensuing difference Fourier synthesis. The final stages of refinement were performed with 216 variables including all non-H positional and anisotropic thermal parameters, positional and isotropic thermal parameters of the two methine H atoms, positional parameters of the partially occupied water H atom, one scale factor, and a secondary-extinction coefficient [ $0.20$  (6)  $\times 10^{-6}$ ]. Convergence yielded  $R =$

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Table 1. Fractional atomic coordinates and equivalent isotropic temperature factors with e.s.d.'s in parentheses

$$B_{eq} = (8\pi^2/3)[U_{22} + (1/\sin^2\beta)(U_{11} + U_{33} + 2U_{13}\cos\beta)].$$

	x	y	z	B <sub>eq</sub> (Å <sup>2</sup> )
O(1)	0.3961 (2)	1.2293 (7)	0.4595 (1)	4.6 (2)
O(2)	0.6642 (2)	0.1908 (7)	0.4732 (1)	4.4 (2)
O(3)	0.6913 (2)	0.0376 (7)	0.4051 (1)	4.7 (2)
O(4)	0.3719 (2)	0.3654 (7)	0.2652 (1)	4.1 (2)
O(5)	0.2821 (2)	0.4880 (7)	0.3122 (1)	3.6 (2)
C(1)	0.4495 (3)	0.869 (1)	0.4403 (2)	3.4 (3)
C(2)	0.3899 (3)	1.066 (1)	0.4349 (2)	3.2 (3)
C(3)	0.3201 (3)	1.046 (1)	0.3974 (2)	3.9 (3)
C(4)	0.3433 (4)	0.935 (1)	0.3545 (2)	3.7 (3)
C(4a)	0.3929 (3)	0.717 (1)	0.3650 (2)	2.7 (3)
N(5)	0.4133 (3)	0.6042 (7)	0.3237 (1)	2.9 (2)
C(6)	0.5015 (3)	0.585 (1)	0.3174 (2)	3.4 (3)
C(6a)	0.5480 (3)	0.483 (1)	0.3590 (2)	2.7 (2)
C(7)	0.6013 (3)	0.298 (1)	0.3571 (1)	3.2 (3)
C(8)	0.6362 (3)	0.214 (1)	0.3977 (2)	3.2 (3)
C(9)	0.6197 (3)	0.307 (1)	0.4381 (2)	2.9 (3)
C(10)	0.5681 (3)	0.487 (1)	0.4406 (2)	3.0 (3)
C(10a)	0.5317 (3)	0.578 (1)	0.3996 (2)	2.6 (2)
C(10b)	0.4728 (3)	0.777 (1)	0.3956 (2)	2.8 (3)
C(11)	0.7042 (4)	0.009 (1)	0.4525 (2)	4.3 (3)
C(12)	0.3578 (3)	0.477 (1)	0.2977 (2)	2.9 (3)
C(13)	0.2168 (3)	0.359 (1)	0.2876 (2)	4.3 (3)
H(4a)	0.360 (2)	0.614 (8)	0.381 (1)	2 (1)
H(10b)	0.503 (3)	0.901 (8)	0.381 (2)	3 (1)
O(W)*	↓	0.043 (2)	↓	5.9 (5)
H(W)*	0.456 (4)	0.13 (1)	0.256 (3)	7.1

\* Site occupancy 0.76.

Table 2. Selected bond distances (Å) and bond angles (°) with e.s.d.'s in parentheses

O(1)—C(2)	1.209 (6)	N(5)—C(6)	1.470 (6)
O(2)—C(9)	1.381 (6)	N(5)—C(12)	1.348 (6)
O(2)—C(11)	1.428 (7)	C(6)—C(6a)	1.504 (7)
O(3)—C(8)	1.372 (6)	C(6a)—C(7)	1.393 (7)
O(3)—C(11)	1.417 (7)	C(6a)—C(10a)	1.388 (7)
O(4)—C(12)	1.216 (6)	C(7)—C(8)	1.370 (7)
O(5)—C(12)	1.350 (6)	C(8)—C(9)	1.381 (7)
O(5)—C(13)	1.435 (6)	C(9)—C(10)	1.359 (7)
C(1)—C(2)	1.503 (8)	C(10)—C(10a)	1.405 (7)
C(1)—C(10b)	1.530 (7)	C(10a)—C(10b)	1.507 (7)
C(2)—C(3)	1.503 (7)	C(4a)—H(4a)	0.96 (4)
C(3)—C(4)	1.526 (7)	C(10b)—H(10b)	1.00 (5)
C(4)—C(4a)	1.525 (8)	O(W)—H(W)	0.91 (7)
C(4a)—N(5)	1.473 (6)	H(W)—O(4)	1.99 (7)
C(4a)—C(10b)	1.539 (7)	O(W)—O(4)	2.888 (8)
C(9)—O(2)—C(11)	105.4 (4)	O(2)—C(9)—C(8)	109.4 (5)
C(8)—O(3)—C(11)	105.7 (4)	O(2)—C(9)—C(10)	128.0 (5)
C(12)—O(5)—C(13)	117.1 (4)	C(8)—C(9)—C(10)	122.6 (5)
C(2)—C(1)—C(10b)	113.6 (5)	C(9)—C(10)—C(10a)	116.7 (5)
O(1)—C(2)—C(1)	122.6 (5)	C(6a)—C(10a)—C(10)	120.4 (5)
O(1)—C(2)—C(3)	121.1 (5)	C(6a)—C(10a)—C(10b)	115.4 (5)
C(1)—C(2)—C(3)	116.3 (5)	C(10)—C(10a)—C(10b)	124.2 (5)
C(2)—C(3)—C(4)	114.9 (5)	C(1)—C(10b)—C(4a)	108.8 (4)
C(3)—C(4)—C(4a)	111.2 (5)	C(1)—C(10b)—C(10a)	115.3 (5)
C(4)—C(4a)—N(5)	111.7 (5)	C(4a)—C(10b)—C(10a)	110.7 (5)
C(4)—C(4a)—C(10b)	108.8 (5)	O(2)—C(11)—O(3)	108.8 (4)
N(5)—C(4a)—C(10b)	110.2 (4)	O(4)—C(12)—O(5)	123.0 (5)
C(4a)—N(5)—C(6)	117.3 (4)	O(4)—C(12)—N(5)	125.9 (5)
C(4a)—N(5)—C(12)	122.4 (5)	O(5)—C(12)—N(5)	111.1 (5)
C(6)—N(5)—C(12)	118.6 (4)	C(1)—C(10b)—H(10b)	107 (3)
N(5)—C(6)—C(6a)	109.2 (4)	C(4a)—C(10b)—H(10b)	110 (3)
C(6)—C(6a)—C(7)	122.2 (5)	C(10a)—C(10b)—H(10b)	105 (3)
C(6)—C(6a)—C(10a)	115.6 (5)	C(4)—C(4a)—H(4a)	109 (3)
C(7)—C(6a)—C(10a)	122.2 (5)	N(5)—C(4a)—H(4a)	108 (3)
C(6a)—C(7)—C(8)	116.1 (5)	C(10b)—C(4a)—H(4a)	110 (3)
O(3)—C(8)—C(7)	127.7 (5)	H(W)—O(W)—H(W)	112 (11)
O(3)—C(8)—C(9)	110.2 (5)	O(4)—O(W)—O(4)	97.9 (3)
C(7)—C(8)—C(9)	122.1 (6)	O(W)—H(W)—O(4)	169 (8)

0.049,  $wR = 0.048$ ,  $S = 1.44$  and  $(\Delta/\sigma)_{\max} = 0.003$ . Final difference synthesis produced  $(\Delta\rho)_{\max} = 0.23$  and  $(\Delta\rho)_{\min} = -0.23 \text{ e } \text{Å}^{-3}$ . Atomic scattering factors and anomalous-dispersion corrections from *International Tables for X-ray Crystallography* (1974, Vol. IV, pp. 71, 148). All computer programs were from the *TEXSAN* package (Molecular Structure Corporation, 1985). Table 1 lists the final atomic coordinates and equivalent isotropic temperature factors while Table 2 presents selected interatomic distances and angles\* and the hydrogen-bonding geometry. Fig. 1 shows the atom-numbering scheme, the thermal motion and the hydrogen-bonding scheme, which effectively produces pairs of hydrogen-bonded molecules. Fig. 2 illustrates the packing of the molecular pairs within the unit cell; H(W)-to-acceptor distances are incorrectly shown as bonds due to the inability of the software to produce dotted lines.

**Related literature.** The title compound was prepared as part of the studies of the synthesis of anticancer agents lycorine and pancratistatin (Pettit, Gaddamidi, Herald, Singh, Cragg, Schmidt, Boettner,

\* Lists of structure factors, H-atom parameters, anisotropic thermal parameters, intermolecular distances, torsion angles, and selected least-squares planes have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 54447 (22 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

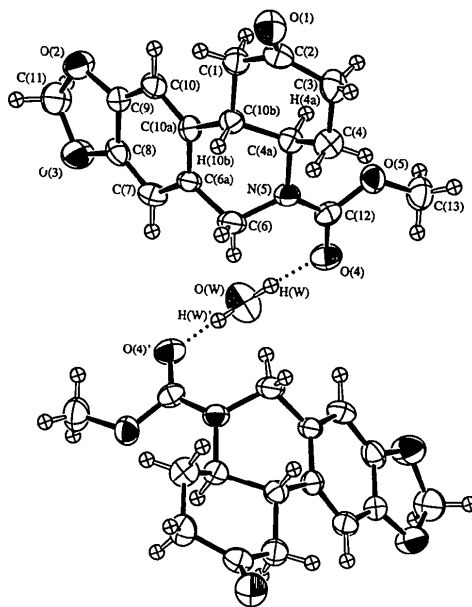


Fig. 1. Molecular configuration and atom-numbering scheme, thermal ellipsoids at the 50% probability level. H atoms are shown as isotropic spheres with  $B$ 's of  $1.0 \text{ Å}^2$ ; only the refined H atoms are labeled. Primed and unprimed atoms are related by a twofold axis of symmetry which passes through O(W).

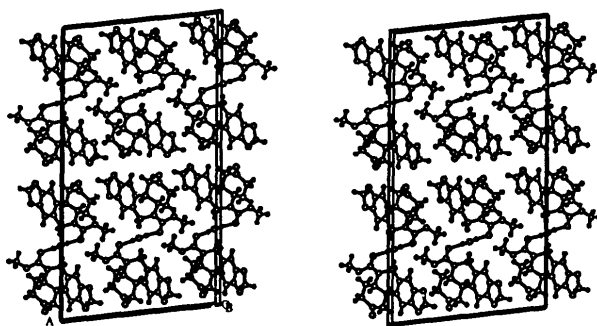


Fig. 2. Stereoscopic illustration of the molecular packing. H(W) to O(4) acceptor atoms are incorrectly shown as solid (rather than dotted) lines due to software limitations.

Williams & Sagawa, 1986) via the asymmetric addition reaction of allylphosphonamides (Hua, Chan, McKie & Myer, 1987). Of the related alkaloids, only one structure of dihydrolycorine hydrobromide (Shiro, Sato & Koyama, 1966), one of narciclasine (Immirzi & Fuganti, 1972), and another of pancratistatin (Pettit, Gaddamidi, Cragg, Herald & Sagawa, 1984) have been reported. This study firmly estab-

lishes the structure of our synthetic compound, from photocyclization, and identifies the *trans* orientation of C(4a)—H(4a) and C(10b)—H(10b), the key feature of the *Amaryllidaceae* alkaloids.

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