Structure of a Key Intermediate in the Synthesis of (−)-5-Carboxytetrahydroalstonine and (−)-Tetrahydroalstonine

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Abstract. Methyl [4aS*-(4α,4aβ,7β,13bβ,14aβ)]-7,8, 13,13b,14,14a-hexahydro-4-methyl-5-oxo-4H-indolo-[2,3-a]pyrano[3,4-g]quinolizine-7-carboxylate acetone solvate, $C_{22}H_{22}N_2O_4.C_3H_6O$, $M_r = 424.50$, triclinic, $P\bar{1}$, $a = 9.9955$ (13), $b = 10.8523$ (14), $c = 11.9352$ (14) Å, $\alpha = 63.189$ (9), $\beta = 72.286$ (9), $\gamma = 72.901$ (10)°, $V = 1081.8$ (2) Å^3, $Z = 2$, $D_x = 1.30$ g cm^{-3} (198 K), $\mu = 0.8554$ cm^{-1}, Mo $K\alpha$ radiation, $\lambda = 0.7107$ Å, $F(000) = 452$, $T = 198$ K, $R = 0.0435$ for 3842 reflections, $F_o \geq 4\sigma(F_o)$. The acetone solvent is hydrogen bonded to the indole NH group with relevant parameters: N13$\cdots$O1A 2.982 (2), H13$\cdots$O1A 2.10 (2) Å, N—H$\cdots$O 164 (2)°. The conformation at the C and D ring junction is quasi-*cis* [relevant torsion angles are C7—N6—C13B—C13A 9.4 (2)° and C5—N6—C13B—C14 46.7 (2)°] while the conformation at the D and E ring junction is *cis* [relevant torsion angles are 37.8 (2)° for C5—C4A—C14A—C14 and 41.3 (2)° for C4—C4A—C14A—C1].

Experimental. Compound (1) was synthesized *via* a hetero Diels–Alder reaction in analogy with closely related cycloadditions previously reported (Martin, Benage & Hunter, 1988). Full details of the synthetic procedure will appear elsewhere (Martin & Corbett, 1990).
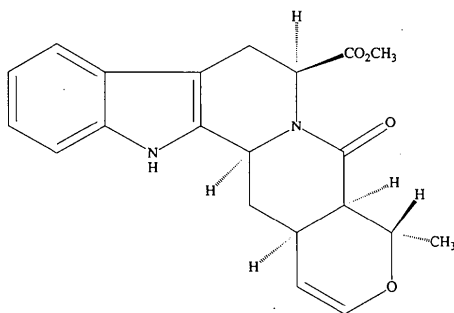
Crystals were obtained by slow evaporation of an acetone solution. The data crystal was a clear, colorless block of approximate dimensions $0.30 \times 0.57 \times 0.70$ mm that was cut from a much larger crystal.

The data were collected on a Nicolet $R3$ diffractometer using a graphite monochromator and a Nicolet LT-2 low-temperature delivery system. Lattice parameters were obtained from the least-squares refinement of 50 reflections with $22.0 < 2\theta < 27.8°$. The data were collected using the ω-scan technique with a 2θ range from 4.0–$55.0°$, with a $1.2°$ ω scan at 3–$6°$ min^{-1} ($h = 0 \rightarrow 13$, $k = -14 \rightarrow 14$, $l = -15 \rightarrow 15$). A total of 5268 reflections were collected of which 4980 were unique ($R_{int} = 0.0125$). Four reflections ($\bar{2}3\bar{6}$, $3\bar{5}2$, 315, $33\bar{3}$) were remeasured every 96 reflections to monitor instrument and crystal stability. A smoothed curve of the intensities of these check reflections was used to scale the data. The scaling factor ranged from 0.9460–1.021. The data were also corrected for Lp effects but not absorption. The data reduction and decay correction were applied using the Nicolet *XRD SHELXTL-Plus* software package (Sheldrick, 1987). Reflections having $F_o < 4\sigma(F_o)$ were considered unobserved (1138 reflections). The structure was solved by direct methods (Sheldrick, 1987) and refined by full-matrix least squares (Sheldrick, 1976). 392 parameters were refined. The non-H atoms were refined with anisotropic thermal parameters. All H-atom positions were obtained from a ΔF map and refined with isotropic thermal parameters. The function, $\sum w(|F_o| - |F_c|)^2$, was minimized, where $w = 1/[\sigma(F_o)]^2$ and $\sigma(F_o) = (0.5kI - \frac{1}{2}\{[\sigma(I)]^2 + (0.02I)^2\}^{1/2})$. The intensity, I, is given by $(I_{peak} - I_{background}) \times$ (scan rate); where 0.02 is a factor to downweight intense reflections and to account for instrument instability and k is the correction due to Lp effects and decay. $\sigma(I)$ was estimated from counting statistics; $\sigma(I) = [(I_{peak} + I_{background})^{1/2} \times$ (scan rate)]. The final $R = 0.0435$ for 3842 reflections, with $wR = 0.0543$ ($R_{all} = 0.0572$, $wR_{all} = 0.0564$) and a goodness of fit $= 1.851$. The maximum $|\Delta/\sigma| < 0.1$ in the final refinement cycle and the minimum and maximum peaks in the final ΔF map were -0.20 and 0.25 e Å^{-3}, respectively. The scattering factors for the non-H atoms were taken from Cromer & Mann (1968), with anomalous-dispersion corrections taken from the work of Cromer & Liberman (1970). The scattering

Table 1. *Fractional coordinates and equivalent iso-tropic thermal parameters* (Å^2) *for the non-H atoms of* $(1).(CH_3)_2CO$

	x	y	z	U_{eq}
C1	−0·1803 (2)	0·6098 (2)	0·3130 (2)	0·0447 (7)
C2	−0·1600 (2)	0·5982 (2)	0·2036 (2)	0·0454 (8)
O3	−0·14455 (13)	0·70388 (12)	0·08427 (11)	0·0462 (5)
C4	−0·1762 (2)	0·8442 (2)	0·0816 (2)	0·0418 (7)
C4A	−0·1258 (2)	0·84946 (15)	0·18732 (14)	0·0367 (6)
C5	0·0351 (2)	0·83054 (14)	0·16255 (13)	0·0361 (6)
N6	0·08482 (13)	0·83574 (12)	0·25414 (11)	0·0339 (5)
C7	0·2391 (2)	0·80669 (15)	0·24366 (13)	0·0348 (6)
C8	0·2820 (2)	0·8878 (2)	0·29951 (15)	0·0401 (7)
C8A	0·1960 (2)	0·85644 (15)	0·43247 (13)	0·0370 (6)
C8B	0·2296 (2)	0·84653 (15)	0·54455 (14)	0·0384 (6)
C9	0·3473 (2)	0·8671 (2)	0·5699 (2)	0·0461 (8)
C10	0·3450 (2)	0·8455 (2)	0·6940 (2)	0·0515 (9)
C11	0·2273 (2)	0·8037 (2)	0·7922 (2)	0·0517 (8)
C12	0·1089 (2)	0·7847 (2)	0·76999 (15)	0·0472 (8)
C12A	0·1098 (2)	0·80736 (15)	0·64463 (14)	0·0403 (7)
N13	0·0088 (2)	0·79655 (13)	0·59419 (12)	0·0396 (6)
C13A	0·0626 (2)	0·82676 (14)	0·46524 (13)	0·0361 (6)
C13B	−0·0180 (2)	0·83590 (15)	0·37473 (13)	0·0347 (6)
C14	−0·1060 (2)	0·7215 (2)	0·42385 (15)	0·0404 (7)
C14A	−0·1864 (2)	0·7449 (2)	0·32233 (14)	0·0386 (7)
C15	−0·3350 (2)	0·8998 (2)	0·0869 (2)	0·0547 (9)
O16	0·11452 (13)	0·81779 (12)	0·06580 (10)	0·0462 (5)
C17	0·2927 (2)	0·6489 (2)	0·30357 (14)	0·0376 (7)
O18	0·22166 (13)	0·56087 (12)	0·34338 (13)	0·0573 (6)
O19	0·43166 (13)	0·61903 (13)	0·30289 (13)	0·0583 (6)
C20	0·4930 (3)	0·4704 (2)	0·3520 (3)	0·0701 (12)
O1A	−0·2785 (2)	0·76622 (14)	0·76443 (13)	0·0665 (7)
C2A	−0·3005 (2)	0·6666 (2)	0·8642 (2)	0·0452 (8)
C3A	−0·1975 (3)	0·5325 (3)	0·8939 (3)	0·0776 (13)
C4A	−0·4331 (3)	0·6764 (3)	0·9625 (3)	0·0704 (13)

factors for the H atoms were obtained from Stewart, Davidson & Simpson (1965). Values used to calculate the linear absorption coefficient are from *International Tables for X-ray Crystallography* (1974, Vol. IV, p. 55). Figures were generated using *SHELXTL-Plus* (Sheldrick, 1987). The positional and thermal parameters for non-H atoms are listed in Table 1,* while the bond lengths and angles for the non-H atoms are listed in Table 2. The atom-labelling scheme is shown in Fig. 1. Other computer programs used in this work are listed in reference 11 of Gadol & Davis (1982).

Related literature. The structure of (1) was determined as part of a generalized approach to the syntheses of alkaloids of the indole family (Martin, Benage & Hunter, 1988). The isolation and the structural assignment for (−)-5-methoxycarbonyltetra-hydroalstonine has been reported by Brown & Charlambides (1974) while the isolation and structural assignment of (−)-tetrahydroalstonine has been reported by Elderfield & Gray (1951).

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* Lists of structure factors, anisotropic thermal parameters, bond distances and angles involving H atoms, torsion angles and H-atom parameters and a unit-cell packing diagram have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 53420 (39 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.
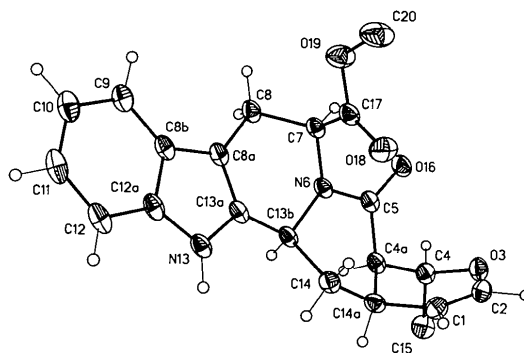
Table 2. *Bond lengths* (Å) *and angles* (°) *for non-*H *atoms of* $(1).(CH_3)_2CO$

1	2	3	1-2	1-2-3
C2	C1	C14A	1·317 (3)	123·51 (14)
C14A	C1		1·501 (3)	
O3	C2	C1	1·365 (2)	126·3 (2)
C4	O3	C2	1·449 (2)	115·34 (15)
C4A	C4	C15	1·522 (3)	112·3 (2)
C4A	C4	O3		112·57 (12)
C15	C4	O3	1·516 (3)	108·5 (2)
C5	C4A	C14A	1·513 (2)	111·80 (12)
C5	C4A	C4		112·18 (13)
C14A	C4A	C4	1·553 (2)	112·3 (2)
N6	C5	O16	1·359 (3)	122·3 (2)
N6	C5	C4A		114·20 (13)
O16	C5	C4A	1·227 (2)	123·4 (2)
C7	N6	C13B	1·458 (2)	122·18 (14)
C7	N6	C5		117·88 (13)
C13B	N6	C5	1·493 (2)	118·22 (13)
C8	C7	C17	1·525 (3)	112·99 (14)
C8	C7	N6		111·38 (13)
C17	C7	N6	1·523 (2)	110·03 (13)
C8A	C8	C7	1·493 (2)	107·5 (2)
C8B	C8A	C13A	1·427 (3)	107·83 (13)
C8B	C8A	C8		130·9 (2)
C13A	C8A	C8	1·362 (2)	121·2 (2)
C9	C8B	C12A	1·400 (3)	119·9 (2)
C9	C8B	C8A		134·14 (14)
C12A	C8B	C8A	1·418 (2)	106·0 (2)
C10	C9	C8B	1·386 (3)	118·7 (2)
C11	C10	C9	1·400 (3)	120·6 (2)
C12	C11	C10	1·377 (4)	122·0 (2)
C12A	C12	C11	1·400 (3)	117·8 (2)
N13	C12A	C8B	1·377 (3)	108·2 (2)
N13	C12A	C12		130·8 (2)
C8B	C12A	C12		121·0 (2)
C13A	N13	C12A	1·382 (2)	108·26 (14)
C13B	C13A	C8A	1·487 (3)	125·39 (13)
C13B	C13A	N13		124·79 (15)
C8A	C13A	N13		109·7 (2)
C14	C13B	N6	1·527 (3)	109·1 (2)
C14	C13B	C13A		116·05 (11)
N6	C13B	C13A		108·64 (13)
C14A	C14	C13B	1·541 (3)	110·82 (12)
C1	C14A	C4A		108·23 (15)
C1	C14A	C14		111·76 (13)
C4A	C14A	C14		112·0 (2)
O18	C17	O19	1·195 (2)	123·11 (14)
O18	C17	C7		125·2 (2)
O19	C17	C7	1·328 (2)	111·62 (15)
C20	O19	C17	1·451 (2)	115·1 (2)
C2A	O1A		1·206 (2)	
C3A	C2A	C4A	1·476 (3)	118·0 (2)
C3A	C2A	O1A		121·5 (2)
C4A	C2A	O1A	1·493 (3)	120·5 (2)

Fig. 1. View of (1) showing the atom-labeling scheme. The non-H atoms are scaled to the 30% probability level while the H atoms are drawn to an arbitrary size. The methyl H atoms have been omitted for clarity.

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6-Oxo-2,2,4,4,6-pentaphenoxycyclotri-λ⁵-phosphazane-1,3-diene

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Abstract. $C_{30}H_{26}N_3O_6P_3$, $M_r = 617.48$, monoclinic, $P2_1/n$, $a = 13.200$ (4), $b = 16.714$ (3), $c = 13.438$ (9) Å, $\beta = 96.38$ (3)°, $V = 2946.3$ Å³, $Z = 4$, $D_x = 1.392$ Mg m⁻³, $\lambda(Mo\ K\alpha) = 0.71073$ Å, $\mu = 0.23$ mm⁻¹, $F(000) = 1280$, $T = 293$ (1) K, $R = 0.037$ for 4089 observed data with $I > 3\sigma(I)$. The P_3N_3 ring has a boat conformation with a P atom and an N atom 0.396 (1) and 0.118 (2) Å, respectively, out of the plane of the remaining atoms of the ring. One of the P atoms involves a double bond P=O [1.470 (1) Å] and a P—N single bond [1.683 (1) Å]. The P—O single bonds and P—N ring bonds range between 1.564 (1) and 1.594 (1) Å [mean 1.576 (1) Å] and 1.546 (1) and 1.607 (1) Å [mean 1.574 (1) Å], respectively.

Experimental. The title compound (1) was synthesized by the hydrolysis of pentaphenoxymonochlorocyclotriphosphazene, $N_3P_3(OC_6H_5)Cl$, in dioxane. Well formed prismatic crystals of the title compound were grown from a solution in acetone by slow evaporation at room temperature. A crystal of approximate size $0.42 \times 0.50 \times 0.36$ mm was cut from a large plate for data collection. Accurate cell constants and an orientation matrix were determined by a least-squares refinement of the setting angles of 25 reflections with θ in the range 10–15°. Intensity

data in the range $2 < \theta < 25°$ ($h\ 0 \rightarrow 15$, $k\ 0 \rightarrow 19$, $l\ -15 \rightarrow 15$) were collected on an Enraf–Nonius CAD-4 diffractometer using the $\omega/2\theta$ scan method, variable scan speed (1.25–2.35° min⁻¹) and monochromatized Mo $K\alpha$ radiation. The intensities of three standard reflections measured every 2 h of exposure time did not show any decay of the crystal. The data were corrected for Lorentz, polarization and absorption effects (North, Phillips & Matthews, 1968); the max. and min. relative transmission coefficients were 0.99 and 0.91, respectively. Of the 5160 unique ($R_{int} = 0.011$) reflections, 4089 with $I > 3\sigma(I)$ were labeled observed and used in all subsequent calculations.

(1)
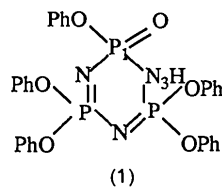
The structure was solved by direct methods in *MULTAN*82 (Main *et al.*, 1982) and refined by full-matrix least-squares calculations using F's initially with isotropic and finally with anisotropic temperature factors for the non-H atoms. A difference map calculated at an intermediate stage revealed the positions of H atoms which were included and allowed to refine with an overall fixed

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