Structure of Carba-bicyclomycin I

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Abstract. 2-Ethenyl-1-hydroxy-7,9-bis(4-methoxyphenyl)-7,9-diazabicyclo[4.2.2]decane-5,8-dione, $C_{26}H_{30}N_2O_5$, $M_r = 450 \cdot 5$, triclinic, $P\bar{1}$, $a = 7 \cdot 727$ (3), $b = 11 \cdot 559$ (4), $c = 13 \cdot 004$ (5) Å, $\alpha = 87 \cdot 96$ (3), $\beta = 75 \cdot 38$ (3), $\gamma = 78 \cdot 58$ (3)°, $V = 1101 \cdot 5$ (8) Å^3, $Z = 2$, $D_x = 1 \cdot 36$ g cm^{-3}, λ(Mo $K\alpha$) = $0 \cdot 7107$ Å, $\mu = 0 \cdot 9$ cm^{-1}, $F(000) = 480$, $T = 112$ K, $R = 0 \cdot 075$ ($wR = 0 \cdot 086$) for 2860 unique observed reflections. The tricyclic (eight-, eight-, and six-membered) heteroatom ring system contains two amide groups.

Experimental. Crystals (colorless prisms) of $C_{26}H_{30}N_2O_5$ [hereafter (1)] were obtained from Dr Kim Hee-Doo and Professor Robert M. Williams (Colorado State University). Crystal size $0 \cdot 22 \times 0 \cdot 36 \times 0 \cdot 54$ mm. Nicolet $R3m$ diffractometer, unit-cell constants from least-squares fit of setting angles for 25 reflections ($2\theta_{av} = 23 \cdot 06°$). Data collected ($\theta/2\theta$ scans) to $(\sin\theta)/\lambda = 0 \cdot 5947$ Å^{-1}, $0 \le h \le 9$, $-13 \le k \le 13$, $-15 \le l \le 15$ at a minimum scan speed of $8°$ min^{-1}. Three standard reflections (200, 020, 003) every 97, no change in intensity; Lorentz and polarization corrections; no absorption correction applied due to low absorption coefficient; 3887 unique reflections, 2860 reflections with $F_o > 2 \cdot 5\sigma(F_o)$ observed.

(1)
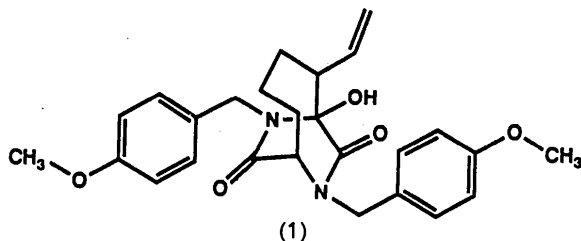
Structure solved by direct methods (*SOLV*); block-diagonal (max. 103 parameters/block, 308 parameters total, data/parameters = 9·3) weighted $\{w = [\sigma^2(F) + gF^2]^{-1}$, $g = 2 \cdot 16 \times 10^{-3}\}$ least-squares refinement on F. H atom of OH group located by difference map and refined using an isotropic thermal parameter. All other H atoms in idealized posi-

tions [C—H = $0 \cdot 96$ Å, U(H) = $1 \cdot 2 \times U_{iso}$(C)]. Non-H atoms refined with anisotropic thermal parameters. At convergence [$(\Delta/\sigma)_{max} = -0 \cdot 062$, $(\Delta/\sigma)_{mean} = 0 \cdot 016$ for last four cycles] $R = 0 \cdot 075$, $wR = 0 \cdot 086$, $S = 1 \cdot 231$, slope of normal probability plot = $1 \cdot 083$, $(\Delta\rho)_{max} = 0 \cdot 41$, $(\Delta\rho)_{min} = -0 \cdot 38$ e Å^{-3}. Neutral-atom scattering factors and anomalous-dispersion corrections used (*International Tables for X-ray Crystallography*, 1974, Vol. IV); all calculations performed on a Data General Eclipse S/140 computer using the *SHELXTL* program library (Sheldrick, 1983). Table 1 gives atomic coordinates, Table 2 gives bond lengths and angles.† Fig. 1 shows the structure of (1) and the numbering scheme used.

Related literature. Five compounds that contain a diketopiperazine with a hydroxyl group attached to one of the C atoms have been structurally characterized: bicyclomycin (Tokuma, Koda, Miyoshi & Morimoto, 1974), fumitremorgin A (Eickman, Clardy, Cole & Kirksey, 1975), fumitremorgin B (Yamazaki, Suzuki, Fujimoto, Akiyama, Sankawa & Iitaka, 1980), bicyclomycin-3′-ethyl carbamate (Kohn, Abuzar, Korp, Zektzer & Martin, 1988), and verruculogen (Fayos, Lokensgard, Clardy, Cole & Kirksey, 1974). The title compound (1) differs from these related compounds in that it contains a four-carbon bridge between two C atoms of the diketopiperazine structure. Two compounds have been structurally characterized by this laboratory that contain a similar heteroatom ring system with two amide groups–1,4-dimethyl-3-{3′-[(*tert*-butyldimethylsilyl)oxy]propyl}-6-(2″-pyridylthio)-2,5-piperazinedione (Williams, Anderson, Armstrong, Josey, Meyers & Eriksson, 1982) and 5-demethylene-6-O-[(1,1-dimethylethyl)dimethylsilyl]-7,9-dimethyl-2′,3′-O-(1-methylethylidene)bicyclomycin (Williams *et al.*, 1982). In the structure of (1), hydrogen bonds from the bridgehead hydroxyl group to the amide oxygen

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† Lists of anisotropic thermal parameters, H-atom coordinates and structure factors have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 54033 (26 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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Table 1. *Atomic coordinates and isotropic thermal parameters* ($\text{Å}^2 \times 10^3$) *for* (1)

U_{eq} is defined as one third of the trace of the orthogonalized U_{ij} tensor.

	x	y	z	U_{eq}
C(1)	0·9999 (4)	−0·4943 (3)	0·7045 (3)	16 (1)
C(2)	1·1564 (5)	−0·4487 (3)	0·6252 (3)	17 (1)
C(3)	1·2782 (5)	−0·4222 (3)	0·7787 (3)	18 (1)
C(4)	1·0881 (5)	−0·4035 (3)	0·8495 (3)	18 (1)
C(5)	1·3943 (5)	−0·5370 (3)	0·8053 (3)	20 (1)
C(6)	1·3048 (5)	−0·6460 (3)	0·8164 (3)	22 (1)
C(7)	1·2507 (5)	−0·6798 (3)	0·7173 (3)	21 (1)
C(8)	1·0531 (5)	−0·6312 (3)	0·7094 (3)	18 (1)
C(9)	0·9179 (5)	−0·6826 (3)	0·7946 (3)	21 (1)
C(10)	0·8218 (5)	−0·7582 (3)	0·7735 (3)	29 (1)
C(11)	1·4239 (5)	−0·3571 (3)	0·5960 (3)	21 (1)
C(12)	1·3565 (5)	−0·2272 (3)	0·5802 (3)	19 (1)
C(13)	1·3183 (8)	−0·1451 (3)	0·6629 (3)	47 (2)
C(14)	1·2556 (8)	−0·0275 (4)	0·6485 (4)	53 (2)
C(15)	1·2318 (5)	0·0124 (3)	0·5519 (3)	27 (1)
C(16)	1·2684 (5)	−0·0670 (3)	0·4683 (3)	28 (1)
C(17)	1·3308 (5)	−0·1857 (3)	0·4847 (3)	29 (1)
C(18)	1·1620 (6)	0·1775 (3)	0·4441 (3)	35 (2)
C(19)	0·7708 (4)	−0·4157 (3)	0·8763 (3)	17 (1)
C(20)	0·6649 (5)	−0·2899 (3)	0·8791 (3)	18 (1)
C(21)	0·4845 (5)	−0·2643 (3)	0·9353 (3)	20 (1)
C(22)	0·3793 (5)	−0·1514 (3)	0·9401 (3)	23 (1)
C(23)	0·4594 (5)	−0·0601 (3)	0·8877 (3)	22 (1)
C(24)	0·6395 (5)	−0·0836 (3)	0·8317 (3)	24 (1)
C(25)	0·7417 (5)	−0·1973 (3)	0·8277 (3)	24 (1)
C(26)	0·1819 (5)	0·0816 (3)	0·9403 (3)	30 (1)
N(1)	1·2811 (4)	−0·4120 (2)	0·6657 (2)	17 (1)
N(2)	0·9571 (4)	−0·4336 (2)	0·8093 (2)	16 (1)
O(1)	0·8416 (3)	−0·4620 (2)	0·6673 (2)	19 (1)
O(2)	1·1627 (3)	−0·4476 (2)	0·5298 (2)	23 (1)
O(3)	1·0569 (3)	−0·3653 (2)	0·9408 (2)	23 (1)
O(4)	1·1706 (4)	0·1317 (2)	0·5460 (2)	37 (1)
O(5)	0·3692 (4)	0·0549 (2)	0·8862 (2)	28 (1)
H(O1)	0·880 (7)	−0·468 (4)	0·597 (4)	66 (15)*

* U_{iso}.

Table 2. *Bond lengths* (Å) *and angles* (°) *for* (1)

|			
C(1)—C(2)	1·545 (5)	C(1)—C(8)	1·558 (4)
C(1)—N(2)	1·485 (4)	C(1)—O(1)	1·406 (5)
C(2)—N(1)	1·349 (5)	C(2)—O(2)	1·228 (5)
C(3)—C(4)	1·502 (5)	C(3)—C(5)	1·530 (5)
C(3)—N(1)	1·464 (5)	C(4)—N(2)	1·356 (5)
C(4)—O(3)	1·231 (4)	C(5)—C(6)	1·538 (5)
C(6)—C(7)	1·537 (6)	C(7)—C(8)	1·547 (5)
C(8)—C(9)	1·511 (5)	C(9)—C(10)	1·329 (6)
C(11)—C(12)	1·514 (5)	C(11)—N(1)	1·474 (4)
C(12)—C(13)	1·396 (6)	C(12)—C(17)	1·361 (6)
C(13)—C(14)	1·372 (6)	C(14)—C(15)	1·366 (6)
C(15)—C(16)	1·385 (6)	C(15)—O(4)	1·373 (4)
C(16)—C(17)	1·390 (5)	C(18)—O(4)	1·422 (5)
C(19)—C(20)	1·518 (4)	C(19)—N(2)	1·461 (4)
C(20)—C(21)	1·380 (5)	C(20)—C(25)	1·394 (5)
C(21)—C(22)	1·388 (5)	C(22)—C(23)	1·398 (5)
C(23)—C(24)	1·377 (5)	C(23)—O(5)	1·375 (4)
C(24)—C(25)	1·388 (5)	C(26)—O(5)	1·418 (4)
C(2)—C(1)—C(8)	108·6 (2)	C(2)—C(1)—N(2)	110·5 (3)
C(8)—C(1)—N(2)	113·9 (3)	C(2)—C(1)—O(1)	108·0 (3)
C(8)—C(1)—O(1)	110·1 (3)	N(2)—C(1)—O(1)	105·6 (2)
C(1)—C(2)—N(1)	117·1 (3)	C(1)—C(2)—O(2)	119·6 (3)
N(1)—C(2)—O(2)	123·3 (3)	C(4)—C(3)—C(5)	111·0 (3)
C(4)—C(3)—N(1)	112·7 (3)	C(5)—C(3)—N(1)	113·4 (3)
C(3)—C(4)—N(2)	117·2 (3)	C(3)—C(4)—O(3)	120·2 (4)
N(2)—C(4)—O(3)	122·5 (3)	C(3)—C(5)—C(6)	115·4 (3)
C(5)—C(6)—C(7)	115·5 (3)	C(6)—C(7)—C(8)	117·7 (3)
C(1)—C(8)—C(7)	115·2 (3)	C(1)—C(8)—C(9)	112·3 (2)
C(7)—C(8)—C(9)	111·0 (3)	C(8)—C(9)—C(10)	123·0 (4)
C(12)—C(11)—N(1)	112·0 (2)	C(11)—C(12)—C(13)	121·3 (3)
C(11)—C(12)—C(17)	121·4 (3)	C(13)—C(12)—C(17)	117·3 (3)
C(12)—C(13)—C(14)	121·1 (4)	C(13)—C(14)—C(15)	120·7 (4)
C(14)—C(15)—C(16)	119·6 (3)	C(14)—C(15)—O(4)	115·8 (3)
C(16)—C(15)—O(4)	124·5 (4)	C(15)—C(16)—C(17)	118·8 (4)
C(12)—C(17)—C(16)	122·5 (4)	C(20)—C(19)—N(2)	114·4 (3)
C(19)—C(20)—C(21)	119·3 (3)	C(19)—C(20)—C(25)	123·1 (3)
C(21)—C(20)—C(25)	117·7 (3)	C(20)—C(21)—C(22)	122·2 (3)
C(21)—C(22)—C(23)	119·0 (3)	C(22)—C(23)—C(24)	119·7 (3)
C(22)—C(23)—O(5)	124·4 (3)	C(24)—C(23)—O(5)	115·9 (3)
C(23)—C(24)—C(25)	120·2 (3)	C(20)—C(25)—C(24)	121·2 (3)
C(2)—N(1)—C(3)	122·2 (3)	C(2)—N(1)—C(11)	119·9 (3)
C(3)—N(1)—C(11)	117·9 (3)	C(1)—N(2)—C(4)	122·2 (3)
C(1)—N(2)—C(19)	119·2 (3)	C(4)—N(2)—C(19)	118·3 (3)
C(15)—O(4)—C(18)	117·1 (3)	C(23)—O(5)—C(26)	117·4 (3)
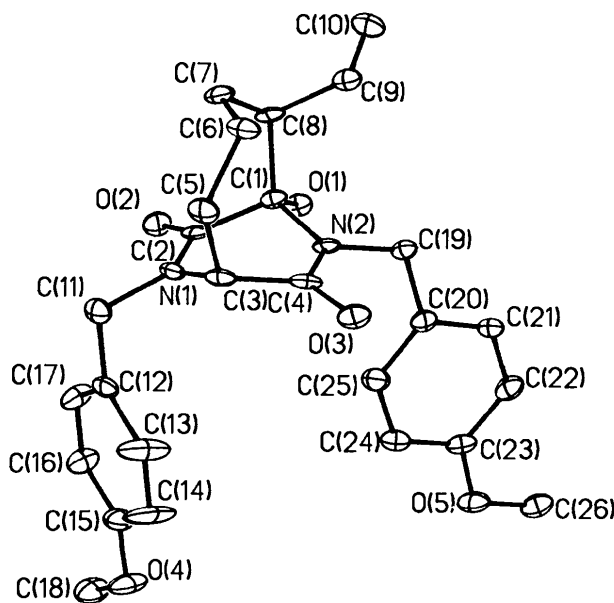
Fig. 1. The structure of (1) (50% probability thermal ellipsoids). H atoms have been omitted for clarity.

atom [O(2)] link molecules of (1) into dimers [O(1)—O(2)ⁱ, 2·812, O(2)ⁱ—H(O1), 2·065 Å; O(1)—H(O1)—O(2)ⁱ, 140·6°].

The out-of-plane deformation of the amide groups in (1) can be described by three parameters: χ_N, χ_C and τ (Winkler & Dunitz, 1971). The deviation from planarity of the N(1)—C(2)—O(2) amide has values of $\chi_N = 1·4$ and $\chi_C = -0·3°$. The torsional angles $\omega_1[C(1)—C(2)—N(1)—C(3)] = 4·3$ and $\omega_2[O(2)—C(2)—N(1)—C(11)] = 6·0°$ added together give the twist angle $\tau = 10·3°$. N(1) is 0·01 Å out of the plane through the C atoms bound to the N atom [C(2), C(3) and C(11)]. Corresponding parameters for the N(2)—C(4)—O(3) amide are $\chi_N = 6·0$, $\chi_C = 2·2$, $\omega_1[C(3)—C(4)—N(2)—C(1)] = 6·4$, $\omega_2[O(3)—C(4)—N(2)—C(19)] = 2·2$ and $\tau = 8·6°$, and the amide nitrogen is 0·04 Å out of the corresponding plane.

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Phenylacetic Acid

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Abstract. $C_8H_8O_2$, $M_r = 136\cdot1$, monoclinic, $P2_1/a$, $a = 10\cdot201$ (5), $b = 4\cdot9568$ (14), $c = 14\cdot437$ (10) Å, $\beta = 99\cdot17$ (5)°, $V = 720\cdot6$ (6) Å^3, $Z = 4$, $D_m = 1\cdot25$ (2), $D_x = 1\cdot255$ g cm^{-3}, Mo $K\alpha$ ($\lambda = 0\cdot71073$ Å), $\mu = 0\cdot084$ mm^{-1}, $F(000) = 288$, $T = 295$ K, $R = 0\cdot0412$, $wR = 0\cdot0388$ for 903 unique observed reflections. The compound is formed by decarboxylation of phenylmalonic acid by CaO in aqueous medium under mild conditions. The hydrogen-bonding pattern in the crystals is the centrosymmetric head-to-tail form normally seen in carboxylic acids.

Experimental. Colorless hexagonal plates obtained from the apparent decarboxylation of phenylmalonic acid in the presence of CaO in aqueous medium. D_m by flotation. Crystal of dimensions $1\cdot13 \times 0\cdot70 \times 0\cdot25$ mm. Nicolet $R3m/V$ diffractometer, Mo $K\alpha$ radiation, graphite monochromator; lattice parameters obtained by least-squares analysis of 28 reflections in the range $20\cdot0 \le 2\theta(\text{Mo}) \le 30\cdot0°$; data collected in $\theta/2\theta$ scan mode up to $50\cdot0°$ in 2θ; $0 \le h \le 12$, $0 \le k \le 5$, and $-17 \le l \le 17$; 1513 total reflections, 1270 independent reflections $[F > 6\sigma(F)]$. Absorption correction not applied. The intensities of four standard reflections, measured after every 50 reflections, exhibited a maximum fluctuation of $1\cdot7\%$. Structure solved by direct methods. Non-H atoms refined anisotropically, H atoms refined isotropically. Function minimized was $\Sigma w(F_o - F_c)^2$, $w = [\sigma^2(F) + 0\cdot00001F^2]^{-1}$. Final $R = 0\cdot0412$, $wR = 0\cdot0388$, $S = 3\cdot467$ for 903 reflections, 123 parameters, $(\Delta/\sigma)_{max} = 0\cdot199$, $\Delta\rho_{max} = 0\cdot14$, $\Delta\rho_{min} = 0\cdot00$ e Å^{-3}. All calculations and scattering factors using the Nicolet *SHELXTL-Plus* system (Sheldrick, 1987).

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Table 1. *Atomic coordinates* ($\times 10^4$) *and equivalent isotropic displacement parameters* (Å$^2 \times 10^3$) *for phenylacetic acid*

U_{eq} is defined as one third of the trace of the orthogonalized U_{ij} tensor.

	x	y	z	U_{eq}
O(1)	897 (1)	524 (3)	1053 (1)	89 (1)
O(2)	1099 (2)	−2850 (3)	102 (1)	96 (1)
C(1)	1439 (2)	−1534 (4)	881 (1)	70 (1)
C(2)	2533 (3)	−2869 (6)	1530 (2)	100 (1)
C(1P)	3055 (2)	−1297 (4)	2392 (1)	71 (1)
C(2P)	4031 (2)	542 (5)	2384 (2)	91 (1)
C(3P)	4541 (3)	2009 (6)	3155 (3)	115 (1)
C(4P)	4065 (4)	1611 (7)	3969 (2)	119 (1)
C(5P)	3111 (4)	−194 (8)	4012 (2)	119 (1)
C(6P)	2579 (3)	−1688 (6)	3227 (2)	99 (1)

Table 2. *Bond lengths* (Å) *and angles* (°) *for phenylacetic acid*

O(1)—C(1)	1·205 (3)	O(2)—C(1)	1·298 (3)
C(1)—C(2)	1·493 (4)	C(2)—C(1P)	1·493 (4)
C(1P)—C(2P)	1·351 (3)	C(1P)—C(6P)	1·383 (4)
C(2P)—C(3P)	1·361 (4)	C(3P)—C(4P)	1·355 (5)
C(4P)—C(5P)	1·331 (6)	C(5P)—C(6P)	1·389 (4)

O(1)—C(1)—O(2)	122·4 (2)	O(1)—C(1)—C(2)	124·6 (2)
O(2)—C(1)—C(2)	113·0 (2)	C(1)—C(2)—C(1P)	115·1 (2)
C(2)—C(1P)—C(2P)	120·7 (2)	C(2)—C(1P)—C(6P)	121·7 (2)
C(2P)—C(1P)—C(6P)	117·6 (2)	C(1P)—C(2P)—C(3P)	122·7 (3)
C(2P)—C(3P)—C(4P)	119·2 (3)	C(3P)—C(4P)—C(5P)	120·2 (3)
C(4P)—C(5P)—C(6P)	121·0 (3)	C(1P)—C(6P)—C(5P)	119·3 (3)

Atomic parameters are listed in Table 1,† and interatomic distances and angles are presented in Table 2. A view of a single molecule, giving the atomic

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† Lists of structure amplitudes, anisotropic thermal parameters, and H-atom parameters have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 54013 (8 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.