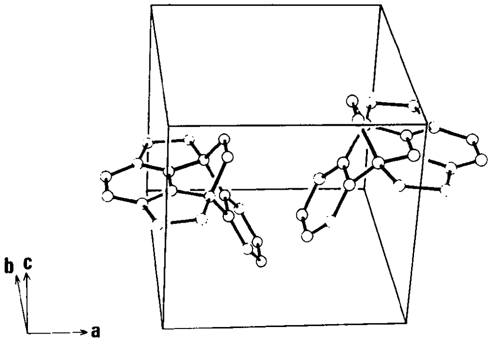

Fig. 2. The molecular packing arrangement.

(Hamor & Hamor, 1979) and pyracene (Simmons & Lingafelter, 1961). However, the two ethano bridges make the geometry of each side of the molecule unsymmetrical: the lengths of C(3)—C(3′) and C(3)—C(4) on the bridged side [1·366 (8), 1·487 (6) Å, respectively] are significantly shorter than the corresponding bonds on the non-bridged side, C(5)—C(5′) and C(4)—C(5) [1·451 (7), 1·533 (5) Å, respectively]. This ethano-bridge effect is more distinct about the bond angles: for example, C(3)—C(4)—C(10) of 99·4 (3)° on the bridged side is much smaller than the corresponding C(5)—C(4)—C(10) of 121·3 (3)° on the non-bridged side. The values of both angles deviate significantly from the ideal sp^3 angle of 109·5°, suggesting the existence of a large distortion at the bridgehead C(4) atom. Similar unusual bond angles have also been observed at the bridgehead of 1,10:6,7-bis(ethano)-9-methoxytriptycene (Fukazawa, Kikuchi, Kajita & Ito, 1984). In contrast, the bond angles at the bridgehead of non-bridged bicyclo[2.2.2] compounds do not deviate as much from the tetrahedral angle (Sawyer, Gomes & Yates, 1986).

Two benzene rings are planar within their e.s.d.'s, forming a dihedral angle of 118·3 (1)°, which is almost equal to that observed in 1,10:6,7-bis(ethano)-9-methoxytriptycene (Fukazawa, Kikuchi, Kajita & Ito, 1984). The five-membered ring C(2)—C(3)—C(4)—C(10)—C(9) is also planar within ±0·02 Å. Molecular packing in a unit cell is illustrated in Fig. 2. There are no intermolecular atomic contacts less than the sum of the van der Waals radii.

References

Fukazawa, Y., Kikuchi, M., Kajita, O. & Ito, S. (1984). *Tetrahedron Lett.* **25**, 1505–1508.

Hamor, M. J. & Hamor, T. A. (1979). *Acta Cryst.* B**35**, 1377–1381.

International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)

Johnson, C. K. (1976). *ORTEP*II. Report ORNL-3794. Oak Ridge National Laboratory, Tennessee, USA.

Main, P., Germain, G. & Woolfson, M. M. (1984). *MULTAN84. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data.* Univs. of York, England, and Louvain, Belgium.

Mori, N., Takemura, T. & Tsuchiya, K. (1988). *J. Chem. Soc. Chem. Commun.* pp. 575–576.

Sakurai, T. (1967). Editor. *Universal Crystallographic Computation Program System.* The Crystallographic Society of Japan, Tokyo, Japan.

Sawyer, J. F., Gomes, A. & Yates, P. (1986). *Acta Cryst.* C**42**, 708–711.

Simmons, G. L. & Lingafelter, E. C. (1961). *Acta Cryst.* **14**, 872–874.

Acta Cryst. (1989). C**45**, 1391–1393

Structure of *N*,*N*-Dimethyl-3-{[1-(phenylmethyl)cycloheptyl]oxy}-1-propanamine Fumarate (Bencyclane Hydrogen Fumarate)

By A. Carpy, A. Lemrabett and M. Laguerre

Laboratoire de Chimie Analytique, URA 50 *CNRS, Faculté de Pharmacie,* 3 *place de la Victoire,*
33076 *Bordeaux CEDEX, France*

(*Received* 13 *October* 1988; *accepted* 31 *January* 1989)

Abstract. $C_{19}H_{32}NO^+.C_4H_3O_4^-$, vasodilator, spasmolytic, Ca^{2+} antagonist, $M_r = 405{\cdot}54$, triclinic, $P\bar{1}$, $a = 6{\cdot}461\ (1)$, $b = 9{\cdot}063\ (1)$, $c = 19{\cdot}607\ (5)$ Å, $\alpha = 80{\cdot}82\ (2)$, $\beta = 87{\cdot}48\ (2)$, $\gamma = 88{\cdot}78\ (1)°$, $V = 1132$ Å^3, $Z = 2$, $D_x = 1{\cdot}19$ g cm^{-3}, λ(Cu $K\alpha$) = 1·54178 Å, $\mu = 6{\cdot}78$ cm^{-1}, $F(000) = 440$, room temperature, $R = 0{\cdot}079$ for 2143 observed reflections. The aliphatic chain is almost completely extended and the cycloheptane ring is in a twist-chair conformation. The molecules are held together by N—H···O hydrogen bonds and van der Waals contacts.

Introduction. First prepared nearly 25 years ago (Pallos, Zolyomi, Budai, Komlos & Petocz, 1965),

0108-2701/89/091391-03$03.00

Table 1. *Atomic coordinates* (× 10^4) *and equivalent isotropic temperature factors*

$$B_{eq} = \tfrac{4}{3}\textstyle\sum_i\sum_j\beta_{ij}\mathbf{a}_i.\mathbf{a}_j.$$

	x	y	z	B_{eq}(Å^2)
C(1)	7366 (7)	3362 (6)	1595 (3)	4·3 (3)
C(2)	5541 (8)	2237 (8)	1636 (3)	6·1 (4)
C(3)	3996 (9)	2579 (9)	1062 (4)	6·9 (4)
C(4)	4582 (10)	1879 (9)	437 (4)	7·0 (4)
C(5)	6396 (10)	2596 (8)	−6 (3)	6·3 (4)
C(6)	8379 (8)	2778 (7)	372 (3)	5·0 (3)
C(7)	8207(8)	3921 (6)	868 (3)	4·4 (3)
O(8)	9138 (4)	2573 (4)	1927 (2)	3·7 (2)
C(9)	8788 (7)	1780 (7)	2605 (3)	4·7 (3)
C(10)	10913 (7)	1293 (5)	2864 (2)	3·5 (2)
C(11)	10707 (7)	442 (5)	3598 (3)	3·8 (3)
N(12)	12806 (6)	7 (4)	3875 (2)	3·9 (2)
C(13)	12574 (10)	−644 (7)	4623 (3)	5·8 (4)
C(14)	13963 (9)	−1027 (6)	3483 (3)	5·3 (3)
C(15)	6728 (9)	4682 (7)	1965 (3)	5·8 (4)
C(16)	8290 (17)	5891 (7)	1920 (3)	6·1 (4)
C(17)	8015 (15)	7255 (8)	1482 (4)	9·1 (5)
C(18)	9567 (18)	8342 (8)	1428 (5)	10·8 (7)
C(19)	11353 (18)	8122 (10)	1785 (5)	10·5 (7)
C(20)	11650 (14)	6781 (9)	2232 (5)	8·8 (6)
C(21)	10103 (11)	5696 (7)	2296 (4)	6·5 (4)
C(22)	5558 (6)	4780 (5)	4108 (3)	3·3 (2)
C(23)	7585 (6)	4784 (5)	4112 (3)	3·2 (2)
C(24)	4342 (6)	3467 (5)	3979 (2)	3·0 (2)
O(25)	2421 (4)	3636 (4)	3936 (2)	4·7 (2)
O(26)	5303 (4)	2289 (3)	3900 (2)	3·8 (2)
C(27)	8725 (7)	6132 (5)	4222 (3)	3·6 (2)
O(28)	10762 (4)	6011 (4)	4196 (2)	4·6 (2)
O(29)	7870 (5)	7270 (4)	4333 (2)	5·3 (2)

bencyclane is used in therapeutics as a vasodilator and as a spasmolytic drug. The recent discovery of its anticalcic properties has renewed interest in it. In the course of our studies on conformational and electronic analogies and discrepancies of non-dihydropyridine Ca antagonists (Laguerre & Carpy, 1989) the crystal structure determination of the title compound was undertaken.

Experimental. Bencyclane theophylline acetate was basified with a 2*M* NaOH solution and extracted with $CHCl_3$. The dried solution was evaporated, dissolved in a minimum amount of dry THF and added to a saturated solution of fumaric acid in THF. The resulting clear solution was slowly concentrated at room temperature.

White platelets, dimensions 0·37 × 0·30 × 0·10 mm. Density not measured. Unit-cell parameters and intensity data obtained on an Enraf–Nonius CAD-4 diffractometer with graphite-monochromated Cu $K\alpha$ radiation in ω/θ scan mode ($0 < \theta < 65°$). Cell dimensions refined by least-squares fitting of θ values of 25 reflections. No appreciable drop in intensity of two standard reflections (100 and 020) checked every 5400 s. 3858 independent reflections collected in $\pm h$, $\pm k$, l range -7, -10, 0 to 7, 10, 23; 2143 with $I \geq 3\sigma(I)$ used in subsequent calculations. Intensities corrected for Lorentz and polarization effects but not for absorption. Scattering factors for non-H atoms from *International Tables for X-ray Crystallography* (1974) and for H from Stewart, Davidson & Simpson (1965). The Wilson statistical test showed a centrosymmetric intensity distribution. Structure solved with *MULTAN*80 (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980) and standard Fourier techniques. H atoms located by ΔF synthesis. Block-diagonal-matrix least-squares refinement on F of observed reflections, $w = 1$ if $|F_o| < P$, $P = [F_o^2(\max)/10]^{1/2}$, $w = (P/F_o)^2$ if $|F_o| > P$; anisotropic thermal parameters for all non-H atoms and isotropic ones for H. Final $R = 0{\cdot}079$, $wR = 0{\cdot}093$, $S = 0{\cdot}921$ (2143 reflections, 402 parameters). In final cycle mean and max. Δ/σ 0·1 and 0·3. Residual electron density within $\pm 0{\cdot}3$ e Å^{-3}. Calculations carried out on a Mini 6-92 CII-Honeywell–Bull computer (programs *CRISTA, CRISAF, CRISEC, UTIL*, Crystallography Laboratory, University of Bordeaux I, Talence).* The rather high R value was a result of only five reflections per parameter.

Discussion. The atomic parameters are given in Table 1 with the numbering scheme shown in Fig. 1. Bond distances and angles are listed in Table 2.

In bencyclane, the cycloheptane ring is in a twist-chair conformation and does not show any disorder. This conformation was found to be the predominant one in the crystal structures of 1-aminocycloheptane-carboxylic acid hydrobromide monohydrate $C_8H_{16}NO_2^+.Br^-.H_2O$ (Chacko, Srinivasan & Zand, 1971) and 1-dimethylphosphono-1-hydroxycycloheptane (Birnbaum, Buchanan & Morin, 1977), and the most stable one on the basis of theoretical work

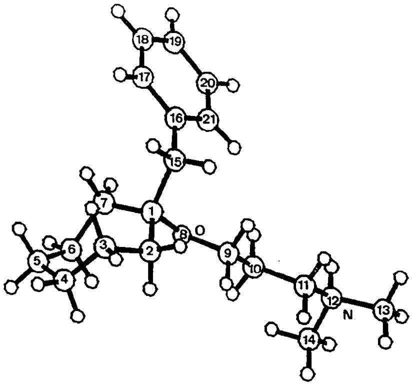

Fig. 1. View of the molecule showing the numbering of atoms. The fumarate ion is not represented [labels from C(22) to O(29)].

---

* Lists of structure amplitudes, anisotropic thermal parameters, H-atom coordinates and least-squares-planes data have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 51931 (27 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 2. *Bond distances* (Å) *and angles* (°)

C(1)—C(2)	1·569 (9)	C(15)—C(16)	1·495 (10)
C(1)—C(7)	1·513 (8)	C(16)—C(17)	1·401 (12)
C(1)—O(8)	1·460 (7)	C(16)—C(21)	1·406 (11)
C(1)—C(15)	1·538 (9)	C(17)—C(18)	1·414 (14)
C(2)—C(3)	1·527 (10)	C(18)—C(19)	1·374 (15)
C(3)—C(4)	1·500 (11)	C(19)—C(20)	1·398 (15)
C(4)—C(5)	1·525 (11)	C(20)—C(21)	1·409 (13)
C(5)—C(6)	1·533 (10)	C(22)—C(23)	1·309 (7)
C(6)—C(7)	1·531 (9)	C(22)—C(24)	1·501 (7)
O(8)—C(9)	1·419 (7)	C(23)—C(27)	1·490 (7)
C(9)—C(10)	1·519 (8)	C(24)—O(25)	1·251 (6)
C(10)—C(11)	1·524 (7)	C(24)—O(26)	1·252 (6)
C(11)—N(12)	1·505 (7)	C(27)—O(28)	1·317 (6)
N(12)—C(13)	1·493 (8)	C(27)—O(29)	1·205 (7)
N(12)—C(14)	1·477 (8)		
C(2)—C(1)—C(7)	114·5 (5)	C(13)—N(12)—C(14)	111·0 (5)
C(2)—C(1)—O(8)	108·3 (5)	C(1)—C(15)—C(16)	115·5 (6)
C(2)—C(1)—C(15)	110·3 (5)	C(15)—C(16)—C(17)	120·5 (7)
C(7)—C(1)—O(8)	103·3 (4)	C(15)—C(16)—C(21)	121·8 (6)
C(7)—C(1)—C(15)	110·4 (5)	C(17)—C(16)—C(21)	117·7 (7)
O(8)—C(1)—C(15)	109·6 (5)	C(16)—C(17)—C(18)	118·9 (8)
C(1)—C(2)—C(3)	115·3 (6)	C(17)—C(18)—C(19)	122·9 (9)
C(2)—C(3)—C(4)	113·2 (6)	C(18)—C(19)—C(20)	119·1 (10)
C(3)—C(4)—C(5)	115·2 (7)	C(19)—C(20)—C(21)	118·5 (9)
C(4)—C(5)—C(6)	116·1 (5)	C(16)—C(21)—C(20)	122·8 (8)
C(5)—C(6)—C(7)	114·6 (5)	C(23)—C(22)—C(24)	123·5 (5)
C(1)—C(7)—C(6)	116·6 (5)	C(22)—C(23)—C(27)	121·4 (5)
C(1)—O(8)—C(9)	117·0 (4)	C(22)—C(24)—O(25)	117·7 (4)
O(8)—C(9)—C(10)	105·6 (4)	C(22)—C(24)—O(26)	118·4 (4)
C(9)—C(10)—C(11)	109·7 (4)	O(25)—C(24)—O(26)	123·9 (5)
C(10)—C(11)—N(12)	110·6 (4)	C(23)—C(27)—O(28)	115·8 (4)
C(11)—N(12)—C(13)	109·5 (4)	C(23)—C(27)—O(29)	123·1 (5)
C(11)—N(12)—C(14)	113·1 (4)	O(28)—C(27)—O(29)	121·1 (5)

Table 3. *Torsion angles* (°) *in the twist-chair conformation of the cycloheptane ring*

	a	*b*	*c*
C(1)—C(2)—C(3)—C(4)	+89·1	+88·6	+86·1
C(2)—C(3)—C(4)—C(5)	−73·0	−69·8	−68·5
C(3)—C(4)—C(5)—C(6)	+52·4	+50·8	+52·4
C(4)—C(5)—C(6)—C(7)	−68·5	−68·6	−73·0
C(5)—C(6)—C(7)—C(1)	+86·1	+84·5	+89·1
C(6)—C(7)—C(1)—C(2)	−39·3	−35·7	−38·2
C(7)—C(1)—C(2)—C(3)	−38·2	−42·0	−39·3

Notes: (*a*) experimental values found in bencyclane, (*b*) experimental values found in 1-dimethylphosphono-1-hydroxycycloheptane (Birnbaum *et al.*, 1977), (*c*) calculated values obtained with program *CONCORD* (Rusinko, Skell, Balducci & Pearlman, 1987).

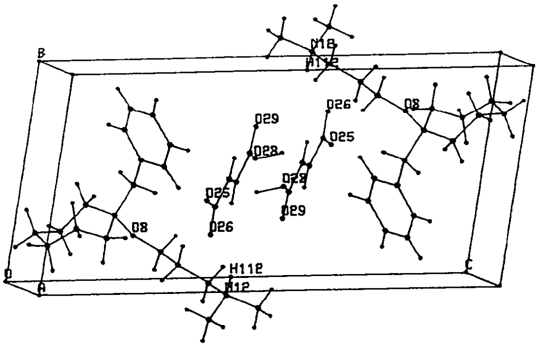

Fig. 2. Contents of the unit cell.

(Pauncz & Ginsburg, 1960; de Kok & Romers, 1980). The torsion angles defining the twist-chair conformation are given in Table 3. This conformation can be described in terms of a mean plane of four atoms: C(3), C(4), C(6), C(7), with C(1), C(2) and C(5) at +0·946 (6), +1·273 (7) and −0·671 (7) Å, respectively (Fig. 1). The shortest distance for non-bonded C atoms is found for C(2)···C(4) = 2·528 Å with a corresponding H···H distance of 2·190 Å for H(102) and H(104). Strong deviations were found from the strictly tetrahedral bond angles: all are higher than the 109·28° value in the range 113·2 (6)–116·6 (5)° (average value 115·1°).

The aliphatic chain C(1)—O(8)—C(9)—C(10)—C(11)—N(12)—C(13) is nearly completely extended, the torsion angles C(1)—O(8)—C(9)—C(10), O(8)—C(9)—C(10)—C(11), C(9)—C(10)—C(11)—N(12) and C(10)—C(11)—N(12)—C(13) being −171, 179, −178 and 173°, respectively. This conformation was also found in different diphenylalkylamine calcium antagonists such as fendiline [3,3-diphenyl-*N*-(1-phenylethyl)propylamine] (Carpy & Lemrabett, 1989).

The molecules are held together by N—H···O hydrogen bonds with geometry N(12)···O(26)(1 + *x*, *y*, *z*) = 2·658 (8), H(112)···O(26) = 1·67 (7) Å, N(12)—H(112)···O(26) = 171 (7)°, and by van der Waals contacts. A view of the unit cell is presented in Fig. 2.

The authors acknowledge the gift of a sample of bencyclane theophylline acetate by 'Doctor Andreu, SA' (Barcelona, Spain).

References

Birnbaum, G. I., Buchanan, G. W. & Morin, F. G. (1977). *J. Am. Chem. Soc.* **99**, 6652–6656.
Carpy, A. & Lemrabett, A. (1989). *Acta Cryst.* **C45**, 273–275.
Chacko, K. K., Srinivasan, R. & Zand, R. (1971). *J. Cryst. Mol. Struct.* **1**, 213–224.
International Tables for X-ray Crystallography (1974). Vol. IV, pp. 201–209. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)
Kok, A. J. de & Romers, C. (1980). *Acta Cryst.* **B36**, 1887–1893.
Laguerre, M. & Carpy, A. (1989). *Quantitative Structure–Activity Relationships (QSAR) in Drug Design*, edited by J. L. Fauchere. Amsterdam: Elsevier.
Main, P., Fiske, S. J., Hull, S. E., Lessinger, L., Germain, G., Declercq, J.-P. & Woolfson, M. M. (1980). *MULTAN80. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data.* Univs. of York, England, and Louvain, Belgium.
Pallos, L., Zolyomi, G., Budai, Z., Komlos, E. & Petocz, L. E. (1965). Hungarian Patent 151, 865, 17 pp.
Pauncz, R. & Ginsburg, D. (1960). *Tetrahedron*, **9**, 40–52.
Rusinko, A., Skell, J. M., Balducci, R. & Pearlman, R. (1987). *CONCORD*. Program for a rapid and automatic generation of high-quality approximate 3-dimensional molecular structures. College of Pharmacy, Univ. of Texas, USA.
Stewart, R. F., Davidson, E. R. & Simpson, W. T. (1965). *J. Chem. Phys.* **42**, 3175–3187.