The interaction between e_A of the prismane part and π^* of the CO group causes an electron transfer from the prismane, especially the upper three-membered ring moiety, to the CO group. As a consequence the antibonding character of C(1)—C(6) and the bonding character of C(1)—C(2) and C(2)—C(6), respectively, are reduced. This leads to the bond alternation for (3).

We thank Ursula Huber-Patz and Hans Rodewald for assistance in data collection and calculations. We are grateful to Professor Wynberg for instruction on the synthesis of Dewar benzenes. Financial support was given by the Deutsche Forschungsgemeinschaft and the Fonds der Chemischen Industrie.

References

Allen, F. H. (1980). *Acta Cryst.* B**36**, 81–96.

Binkley, J. S., Whiteside, R. A., Hariharan, P. C., Seeger, R., Pople, J. A., Hehre, W. J. & Newton, M. D. (1978). Quantum Chemistry Program Exchange, **14**, 468.

Dewar, M. J. S. & Dougherty, R. C. (1975). *The PMO Theory of Organic Chemistry*. New York: Plenum.

Dewar, M. J. S. & Thiel, W. (1977). *J. Am. Chem. Soc.* **99**, 4899–4907.

Dopper, J. H., Greijdanus, B. & Wynberg, H. (1975). *J. Am. Chem. Soc.* **97**, 216–218.

Frenz, B. A. (1982). *Enraf–Nonius Structure Determination Package*. College Station, Texas, and Enraf–Nonius, Delft.

Heilbronner, E. & Bock, H. (1968). *Das HMO-Modell und seine Anwendung*. Weinheim: Verlag Chemie.

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

Johnson, C. K. (1976). *ORTEP*II. Report ORNL-5138. Oak Ridge National Laboratory, Tennessee.

Karl, R. R., Wang, Y. C. & Bauer, S. H. (1975). *J. Mol. Struct.* **25**, 17–34.

Maier, G., Bauer, I., Huber-Patz, U., Jahn, R., Kallfass, D., Rodewald, H. & Irngartinger, H. (1986). *Chem. Ber.* **119**, 1111–1116.

Main, P., Fiske, S. J., Hull, S. E., Lessinger, L., Germain, G., Declercq, J.-P. & Woolfson, M. M. (1982). *MULTAN*11/82. *A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data*. Univs. of York, England, and Louvain, Belgium.

Newton, M. N., Schulman, J. M. & Manus, M. M. (1974). *J. Am. Chem. Soc.* **96**, 17–23.

Acta Cryst. (1987). C**43**, 269–272

Structure and Stereochemistry of 2-(*N*-Methylaniline)-3-(*N*-methoxyaceto)-7-(*p*-chlorophenyl)-8-methoxy-4,5-benzo-3-aza-1-nonem*†

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Abstract. $C_{28}H_{26}ClN_3O_4$, $M_r = 504{\cdot}0$, monoclinic, $P2_1/n$, $a = 7{\cdot}468$ (3), $b = 33{\cdot}316$ (8), $c = 10{\cdot}467$ (4) Å, $\beta = 100{\cdot}28$ (3)°, $Z = 4$, $D_x = 1{\cdot}31$ Mg m^{-3}, Mo $K\alpha$, $\lambda = 0{\cdot}7107$ Å, $\mu = 0{\cdot}184$ mm^{-1}, $F(000) = 1056$, $T = 293$ K, final $R = 0{\cdot}075$ for 2003 reflections. The structure established chemically is confirmed. The seven-membered ring adopts a boat-shaped conformation. The dihedral angles between the best planes through the methoxyacetyl group and the phenyl ring of the *N*-methylanilino group at C(2), and between the *p*-chlorophenyl ring and methoxy group at C(8) are 128·0 (8) and 53·6 (8)°, respectively, and thus reduce the crowding of these bulky groups on the diazepine ring. The packing in the crystal is entirely due to van der Waals forces.

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* 2a-(*p*-Chlorophenyl)-2-methoxy-5-(2-methoxyacetyl)-4-(*N*-methylanilino)-1,2,2a,5-tetrahydroazeto[1,2-*a*][1,5]benzodiazepin-1-one.

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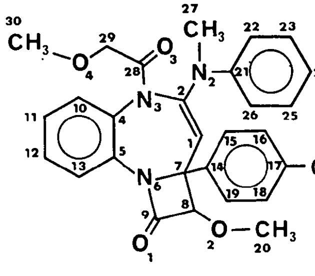
Introduction. A great number of studies have been devoted to the search for structural analogues of cephalosporin and penicillin with specific activity (Guthikonda, Cama & Christensen, 1974; Bose, Ram, Hoffman, Hutchinson & Manhas, 1979; Itil, Saletu & Marasa, 1974). As part of our studies (Cortés & Martínez, 1983) on the total synthesis of new antibiotics that combine the two functionalities of cephalosporin and penicillin, in which the β-lactam moiety is integrated into the benzodiazepine system, and to investigate their pharmacological profile, synthesis of the title compound (1) (Cortés, Romero & Ceballos, 1986) was performed. We have undertaken the X-ray structure analysis of (1) in order to establish its molecular structure and stereochemistry.



(1)

Experimental. Single crystals of (1) were prepared and crystallized by Cortés *et al.* (1986). Prismatic crystal, 0·10 × 0·30 × 0·34 mm. Nicolet *R*3 four-circle,diffractomer, graphite-monochromated Mo $K\alpha$, lattice parameters from 24 machine-centred reflections with $4{\cdot}6 < 2\theta < 13{\cdot}7°$. 5858 measured reflections with $3 < 2\theta < 55°$, 2003 independent with $I > 3{\cdot}0\sigma(I)$, index range $h \pm 8$, $k\,0\rightarrow 42$, $l\,0\rightarrow 13$, ω-scan mode, variable scan speed, scan width 1·0 ($\theta°$). Two standard reflections ($02\bar{1}$, $\bar{1}70$) monitored every 50 measurements throughout data collection process showed no significant changes in intensity. Intensities corrected for Lorentz–polarization factor but not for absorption. Data adjusted to an approximately absolute scale and an overall U value of 0·042 Å^2. Structure solved by direct methods and refined by least squares using a cascade-matrix procedure; coordinates and anisotropic temperature factors refined for the non-H atoms; H atoms in calculated positions with fixed isotropic $U = 0{\cdot}06$ Å^2. Final $R = 0{\cdot}075$, $wR = 0{\cdot}086$. $\sum w(\Delta F)^2$ minimized; $w^{-1} = |\sigma^2(F_o) + 0{\cdot}002(F_o)^2|$, where σ is the standard deviation of the observed amplitudes, based on counting statistics. In the last cycle $(\Delta/\sigma)_{\max} = 0{\cdot}147$. Residual electron density in final difference map within $\pm 0{\cdot}4$ e Å^{-3}. Atoms O(4), C(20) and C(30) of peripheral methoxy groups may be affected by some disorder (see thermal parameters in Table 1), giving rise to high values of R and wR. Atomic scattering factors from *International Tables for X-ray Crystallography* (1974); isotropic extinction parameter $X = 0{\cdot}00025$; $S = 1{\cdot}236$. All computations performed on a Nova 4S computer and plots drawn on a Tektronix plotter with the *SHELXTL* system of programs (Sheldrick, 1981).

Discussion. The shape of the molecule and the atomic numbering are shown in Fig. 1. Final atomic coordinates are given in Table 1* and bond distances in Table 2. Calculations of the least-squares planes passing through the diazepine, benzo, and four-membered β-lactam rings and the two phenyl rings and the deviations of individual atoms from the planes and interplanar angles have been deposited.

The molecule consists of a benzodiazepine ring with methoxyacetyl, *N*-methylanilino and *p*-chlorophenyl groups with different orientations and a four-membered β-lactam ring with a methoxy group.

The conformation of the diazepine ring may best be seen in Fig. 1. It can be described as approximately boat-shaped; maximum deviations from the best plane are –0·495 (8), –0·407 (8) and 0·353 (8) Å for N(3), C(7) and C(1), respectively. This conformation is the same as that in 2-methylthio-7-(*p*-bromophenyl)-8-phenoxy-4,5-benzo-3-aza-2-nonem (Soriano-García, Toscano, Cortés & Martínez, 1984) and in classical benzodiazepines (Hamor & Martin, 1983; Butcher & Hamor, 1985). The angle between the mean planes of phenyl rings C(5)–C(4)–C(10)–C(11)–C(12)–C(13) and C(14) through C(19) is 93·7 (8)°. Similar interplanar angles occur in 2-methylthio-7-(*p*-bromophenyl)-8-phenoxy-4,5-benzo-3-aza-2-nonem (Soriano-

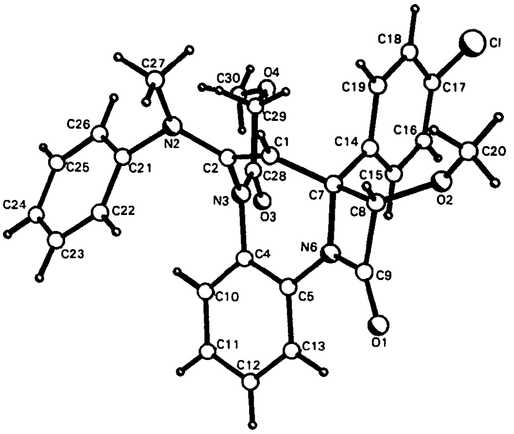


Fig. 1. View of molecule (1), showing the atom labelling.

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* Lists of structure amplitudes, anisotropic thermal parameters, H-atom coordinates, bond angles and the results of the mean-plane calculations have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 43332 (17 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

García *et al.*, 1984) with a value of 85·9 (4)° and in clonazepan (Chananont, Hamor & Martin, 1979) where the halogen substituent is in the *ortho* position, with values of 83·7 and 77·8° for the two independent molecules.

The bond lengths C(5)—N(6) and N(6)—C(9) show the influence of conjugation between the keto group at C(9) and the phenyl ring C(5)—C(4)—C(10)—C(11)—C(12)—C(13). The considerable double-bond character in the C(5)—N(6) and N(6)—C(9) bonds is indicated by the shortening of these bonds by 0·024 and 0·066 Å compared with the C(4)—N(3) bond length.

Table 1. *Atomic coordinates* (×10⁴) *and equivalent isotropic temperature factors* (Å² ×10³)

$$U_{eq} = (U_{11}U_{22}U_{33})^{1/3}.$$

	x	y	z	U_{eq}
Cl	464 (3)	−665 (1)	7593 (2)	78 (1)
N(2)	112 (6)	1563 (2)	9731 (5)	37 (2)
N(3)	1689 (6)	1330 (1)	8089 (4)	29 (2)
N(6)	−541 (7)	1289 (1)	5534 (5)	39 (2)
O(1)	−2283 (7)	1502 (2)	3540 (5)	75 (2)
O(2)	−3934 (6)	738 (1)	4791 (5)	68 (2)
O(3)	4350 (5)	990 (1)	8259 (5)	57 (2)
O(4)	3584 (9)	493 (2)	10143 (8)	124 (3)
C(1)	−1592 (8)	1309 (2)	7668 (6)	37 (2)
C(2)	−47 (8)	1407 (2)	8486 (6)	32 (2)
C(4)	2127 (8)	1556 (2)	7006 (6)	36 (2)
C(5)	1065 (8)	1527 (2)	5761 (6)	34 (2)
C(7)	−1506 (7)	1074 (2)	6460 (6)	35 (2)
C(8)	−3245 (9)	1103 (2)	5346 (7)	52 (3)
C(9)	−2052 (9)	1334 (2)	4571 (7)	51 (3)
C(10)	3646 (8)	1808 (2)	7218 (7)	47 (3)
C(11)	4110 (10)	2025 (2)	6194 (9)	62 (3)
C(12)	3133 (11)	1987 (2)	4958 (8)	62 (3)
C(13)	1608 (10)	1735 (2)	4738 (7)	55 (3)
C(14)	−907 (8)	639 (2)	6749 (5)	35 (2)
C(15)	523 (9)	462 (2)	6275 (7)	48 (3)
C(16)	983 (9)	61 (2)	6564 (7)	53 (3)
C(17)	1 (9)	−153 (2)	7307 (7)	50 (3)
C(18)	−1402 (10)	22 (2)	7819 (7)	54 (3)
C(19)	−1842 (9)	417 (2)	7535 (7)	47 (3)
C(20)	−5590 (11)	680 (4)	4640 (16)	266 (12)
C(21)	1525 (8)	1857 (2)	10142 (6)	39 (2)
C(22)	1594 (9)	2209 (2)	9450 (7)	46 (3)
C(23)	2987 (11)	2481 (2)	9848 (8)	60 (3)
C(24)	4304 (11)	2401 (3)	10891 (8)	65 (3)
C(25)	4268 (10)	2054 (3)	11582 (7)	62 (3)
C(26)	2843 (10)	1783 (2)	11206 (6)	53 (3)
C(27)	−1560 (9)	1607 (2)	10262 (7)	60 (3)
C(28)	2923 (7)	1033 (2)	8628 (6)	38 (2)
C(29)	2326 (8)	775 (2)	9660 (6)	43 (2)
C(30)	5062 (17)	546 (4)	10832 (13)	249 (11)

Table 2. *Bond lengths* (Å) *with e.s.d.'s in parentheses*

Cl—C(17)	1·757 (7)	N(2)—C(2)	1·388 (8)
N(2)—C(21)	1·448 (8)	N(2)—C(27)	1·461 (9)
N(3)—C(2)	1·453 (8)	N(3)—C(4)	1·447 (8)
N(3)—C(28)	1·400 (7)	N(6)—C(5)	1·423 (7)
N(6)—C(7)	1·490 (8)	N(6)—C(9)	1·381 (8)
O(1)—C(9)	1·202 (9)	O(2)—C(8)	1·408 (8)
O(2)—C(20)	1·233 (10)	O(3)—C(28)	1·205 (8)
O(4)—C(29)	1·362 (9)	O(4)—C(30)	1·218 (14)
C(1)—C(2)	1·349 (8)	C(1)—C(7)	1·498 (9)
C(4)—C(5)	1·403 (8)	C(4)—C(10)	1·397 (8)
C(5)—C(13)	1·394 (10)	C(7)—C(8)	1·586 (8)
C(7)—C(14)	1·529 (8)	C(8)—C(9)	1·516 (11)
C(10)—C(11)	1·386 (12)	C(11)—C(12)	1·373 (12)
C(12)—C(13)	1·400 (11)	C(14)—C(15)	1·387 (9)
C(14)—C(19)	1·385 (9)	C(15)—C(16)	1·398 (9)
C(16)—C(17)	1·362 (10)	C(17)—C(18)	1·387 (11)
C(18)—C(19)	1·376 (10)	C(21)—C(22)	1·384 (9)
C(21)—C(26)	1·370 (8)	C(22)—C(23)	1·387 (10)
C(23)—C(24)	1·359 (11)	C(24)—C(25)	1·366 (12)
C(25)—C(26)	1·399 (11)	C(28)—C(29)	1·508 (9)

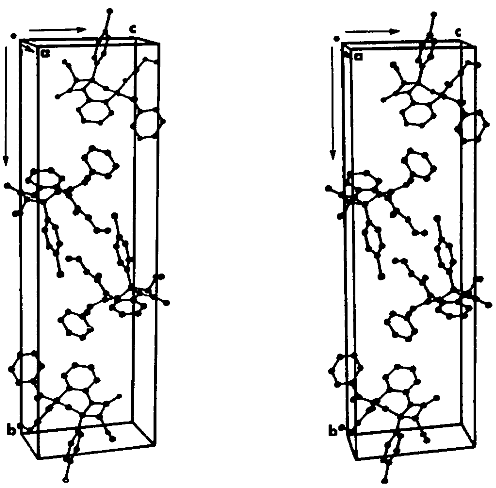

Fig. 2. Stereoscopic view of the unit cell.

There is no conjugation between the seven-membered diazepine ring and the phenyl substituent at C(7). Owing to steric inhibition, caused by the neighbouring O(3) and O(4) of the methoxyacetyl group at N(3), and O(2) of the methoxy group at C(8), the *p*-chlorophenyl ring is rotated by an angle of 87·9 (7)° from the mean plane of the diazepine ring. The planes formed by the atoms of the methoxyacetyl group and the phenyl ring C(21) through C(26) make a dihedral angle of 128·0 (8)°. The phenyl rings show normal geometries, 1·380 Å and 120° for the mean $C(sp^2)$—$C(sp^2)$ bond distance and the mean internal angle. This mean bond distance is close to that given by Sutton (1965) [1·395 (5) Å] and Brisse & Sygusch (1974) (1·379 Å).

The four-membered *β*-lactam ring and the three phenyl rings are planar to a good approximation.

The molecular packing is shown in Fig. 2. There are only four intermolecular approaches of non-hydrogen atoms <3·41 Å, C(1)···O(3)(−1 + *x*, *y*, *z*) 3·371 (7); C(18)···O(4)(−*x*, −*y*, 2 − *z*) 3·375 (7) Å, and O(1)··· Cl and C(16)···C(16)(−*x*, −*y*, 1 − *z*) 3·406 (7), 3·365 (7) Å, respectively. The molecules are, therefore, held in the crystal by van der Waals forces.

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References

Bose, A. K., Ram, B., Hoffman, W. A. III, Hutchinson, A. J. & Manhas, M. S. (1979). *J. Heterocycl. Chem.* **16**, 1313–1316.

Brisse, F. & Sygusch, J. (1974). *Acta Cryst.* B**30**, 480–486.
Butcher, H. J. & Hamor, T. A. (1985). *Acta Cryst.* C**41**, 265–266.
Chananont, P., Hamor, T. A. & Martin, I. L. (1979). *Cryst. Struct. Commun.* **8**, 393–400.
Cortés, E. & Martínez, R. (1983). *J. Heterocycl. Chem.* **20**, 161–167.
Cortés, E., Romero, M. C. & Ceballos, I. (1986). *J. Heterocycl. Chem.* In the press.
Guthikonda, R. M., Cama, L. D. & Christensen, B. G. (1974). *J. Am. Chem. Soc.* **96**, 7584–7585.
Hamor, T. A. & Martin, I. L. (1983). *Prog. Med. Chem.* **20**, 157–223.
International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor D. Reidel, Dordrecht.)
Itil, T. M., Saletu, B. & Marasa, J. (1974). *Pharmakopsychiatr./Neuro-Psychopharmakol.* **7**, 265–280.
Sheldrick, G. M. (1981). *SHELXTL*, revision 3. *An Integrated System for Solving, Refining and Displaying Crystal Structures from Diffraction Data*. Univ. of Göttingen.
Soriano-García, M., Toscano, R. A., Cortés, E. & Martínez, R. (1984). *Acta Cryst.* C**40**, 1460–1462.
Sutton, L. E. (1965). *Tables of Interatomic Distances and Configuration in Molecules and Ions*. Spec. Publ. No. 18. London: The Chemical Society.

Acta Cryst. (1987). C**43**, 272–274

Structure and Stereochemistry of 2-Hydroxy-12(*S*)-hydroxyneoclerodane-3,13(14)-diene-15,16;19,20-diolide (Semiatrin), a Diterpene*

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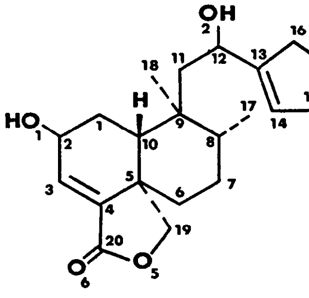
Abstract. $C_{20}H_{26}O_6$, $M_r = 362{\cdot}4$, orthorhombic, $P2_12_12_1$, $a = 8{\cdot}564\,(3)$, $b = 10{\cdot}550\,(4)$, $c = 20{\cdot}456\,(5)$ Å, $V = 1848\,(1)$ Å^3, $Z = 4$, $D_x = 1{\cdot}30$ Mg m^{-3}, Mo $K\alpha$, $\lambda = 0{\cdot}7107$ Å, $\mu = 0{\cdot}089$ mm^{-1}, $F(000) = 776$, $T = 293$ K, final $R = 0{\cdot}061$ for 1284 reflections. The structure determination of (1) establishes the configuration at C(12) to be 12*S*. The cyclohexene and cyclohexane rings are *trans*-fused and adopt half-chair and chair conformations, respectively. The γ-lactone has an α-envelope conformation whilst the 13(16*H*)-furanone ring is planar to within $\pm 0{\cdot}02$ (1) Å. Bond lengths and angles are normal. The crystal structure is stabilized by intra- and intermolecular hydrogen bonds and C—H···O hydrogen-bond interactions.

Introduction. In a previous paper (Esquivel, Hernández, Ramamoorthy, Cárdenas & Rodríguez-Hahn, 1986) the isolation and structure determination of semiatrin (1) from *Salvia semiatratha* was described. The structure of (1) was assigned mainly on spectroscopic grounds. The *trans*-neoclerodane structure proposed for it and the 2*S* configuration at C(2) were deduced by careful analysis of the ^{1}H and ^{13}C NMR spectra and comparison with data reported for similar structures. The configuration at C(12) could not be ascertained from the proton resonance data (Pinhey, Simpson & Batey, 1971; Tschesche & Streuff, 1978; Esquivel, Méndez, Ortega, Soriano-García, Toscano & Rodríguez-Hahn, 1985; Bohlmann, Zdero & Huneck, 1985), although they suggested a 12*S* configuration. This prompted us to undertake the X-ray structure analysis of (1) in order to confirm the structure proposed for it and establish the configuration at C(12).



(1)

Experimental. Colourless transparent cube-shaped crystals prepared by slow evaporation of Me_2CO–hexane, dimensions $0{\cdot}36 \times 0{\cdot}38 \times 0{\cdot}38$ mm. Nicolet *R*3 four-circle diffractometer, graphite-monochromated Mo $K\alpha$, lattice parameters from 25 machine-centred reflections with $4{\cdot}0 < 2\theta < 20{\cdot}0°$ accurately measured on the diffractometer. 2430 independent measured reflections, $2\theta_{\max}$ 55°, 1284 considered observed [$I >$

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