

- CLARK, J. R., APPLEMAN, D. E. & PAPIKE, J. J. (1969). *Miner. Soc. Amer. Spec. Pap.* **2**, 31–50.
- FLEET, M. E. (1974). *Amer. Min.* **59**, 1083–1093
- FLEET, M. E. (1975). *Acta Cryst.* **B31**, 183–187.
- GIBBS, G. V., HAMIL, M. M., LOUISNATHAN, S. J., BARTTELL, L. S. & YOW, H. (1972). *Amer. Min.* **57**, 1578–1613.
- LOUISNATHAN, S. J. & GIBBS, G. V. (1972a). *Amer. Min.* **57**, 1614–1642.
- LOUISNATHAN, S. J. & GIBBS, G. V. (1972b). *Amer. Min.* **57**, 1643–1663.
- NOVAK, G. A. & GIBBS, G. V. (1971). *Amer. Min.* **56**, 791–825.
- PAULING, L. (1929). *J. Amer. Chem. Soc.* **51**, 1010–1026.
- PAULING, L. (1960). *The Nature of the Chemical Bond*, 3rd ed. Ithaca: Cornell Univ. Press.
- SHANNON, R. D. & PREWITT, C. T. (1969). *Acta Cryst.* **B25**, 925–946.

*Acta Cryst.* (1975). **B31**, 1097

## The Crystal Structure of the $\gamma$ -Lactone of 2,2-Dimethyl-3,4-dihydroxy-5-phenylvaleric Acid: a Degradation Product of Neoantimycin

BY ETTORE BENEDETTI AND PAOLO GANIS

*Laboratorio di Chimica Generale e Inorganica, Università di Napoli, Via Mezzocannone 4, 80134-Napoli, Italy*

GABRIELLA BOMBIERI

*Laboratorio di Chimica e Tecnologia dei Radioelementi del C.N.R., Via Vigonovese 52, 35100-Padova, Italy*

LUCIANO CAGLIOTI

*Istituto di Chimica Organica, Università di Roma, Roma, Italy*

AND GABRIEL GERMAIN

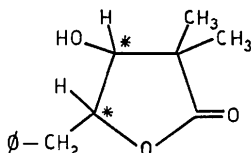
*Laboratoire de Chimie Physique et Cristallographie, Bâtiment Lavoisier, Université de Louvain, Place L. Pasteur 1, Louvain-la-Neuve, Belgium*

(Received 7 November 1974; accepted 10 December 1974)

The  $\gamma$ -lactone of 2,2-dimethyl-3,4-dihydroxy-5-phenylvaleric acid,  $C_{13}H_{16}O_3$ , crystallizes in the space group  $P2_1$  with  $a=8.373$  (4),  $b=6.373$  (3),  $c=11.234$  (5) Å,  $\beta=97.85$  (8)°,  $Z=2$ . Data for 820 reflexions were collected on a Siemens automated diffractometer. The crystal structure was solved by direct methods; refinement was carried out by full-matrix least-squares procedures including anisotropic thermal parameters. The lactone ring is puckered at the  $\beta$ -carbon atom which deviates by about 0.47 Å from the best plane formed by the four remaining atoms. The relative configuration of the two adjacent asymmetric carbon atoms of the molecule is  $RR$  (or  $SS$ ). The molecules are held together in the crystal by hydrogen bonds ( $O \cdots O$  2.76 Å) along twofold axes.

### Introduction

Recently, the structure of neoantimycin, an antibiotic obtained from *Streptovercillum orinoci* has been determined by chemical and spectroscopic methods (Cassinelli, Grein, Orezzi, Pennella & Sanfilippo, 1967; Caglioti, Misiti, Mondelli, Selva, Arcamone & Cassinelli, 1969). Acidification of an alkaline solution of hydrolysed neoantimycin yields the  $\gamma$ -lactone of 2,2-dimethyl-3,4-dihydroxy-5-phenylvaleric acid



The molecule contains two adjacent asymmetric carbon atoms. The relative configuration of these atoms has not been determined so far. In order to solve this configurational problem and to gain more information on the structure of the antibiotic itself we undertook the X-ray single-crystal analysis of the title compound.

### Experimental

Accurate cell constants were obtained by a least-squares treatment of 15 high-angle reflexions recorded with Cu  $K\alpha$  radiation.

### Crystal data

$C_{13}H_{16}O_3$ , F.W. 220.3, space group  $P2_1$ ,  $a=8.373$  (4),  $b=6.373$  (3),  $c=11.234$  (5) Å,  $\beta=97.85^\circ$  (8),  $U=593.8$  Å<sup>3</sup>,  $D_m=1.23$  g cm<sup>-3</sup>,  $D_c=1.233$  g cm<sup>-3</sup> for  $Z=2$ ,

Cu  $K\alpha$ ,  $\lambda = 1.5418 \text{ \AA}$ . Crystal size:  $0.2 \times 0.4 \times 0.2 \text{ mm}$ . Crystal shape: needle.

Intensity data were collected on a computer-controlled Siemens A.E.D. four-circle automated diffractometer, using nickel-filtered Cu  $K\alpha$  radiation ( $\lambda = 1.5418 \text{ \AA}$ ).

Reflexions with  $2\theta < 100.0^\circ$  were scanned in the  $\theta-2\theta$  mode and with the five-points measuring procedure. 968 independent reflexions were measured of which 820 had  $I > 2\sigma(I)$  and were used in the refinement.

The data were corrected for Lorentz and polarization effects but not for absorption.

An overall temperature factor ( $B = 3.9 \text{ \AA}^2$ ) and scale factor were calculated (Wilson, 1942) and used to compute normalized structure factors ( $E$ ) (Karle & Hauptman, 1956). The statistics of the  $E$ 's confirmed a non-centrosymmetric structure. The structure was solved by weighted multisolution tangent refinement (Germain, Main & Woolfson, 1971). The 160 largest  $E$ 's were used.

The starting set of phases selected by iterative procedure (CONVERGE) was:

$hkl$	Phase	} origin fixing
$21\bar{5}$	0	
507	0	
021	$\pi/4$ (enantiomorph-fixing)	
041	$\pi/4, 3/4\pi, 5/4\pi, 7/4\pi$	
525	$\pi/4, 3/4\pi, 5/4\pi, 7/4\pi$	
645	$\pi/4, 3/4\pi, 5/4\pi, 7/4\pi$	

Of the 64 possible solutions judging by probability characteristics only one set of phases seemed to be correct. The corresponding  $E$  map revealed the whole structure apart from the hydrogen atoms.

The structure was then refined by a total of 11 full-matrix least-squares cycles; anisotropic thermal factors were assigned to all the non-hydrogen atoms after the sixth cycle when the conventional  $R$  value ( $= \sum |F_o| - |F_c| / \sum |F_o|$ ) was 0.12. A difference Fourier synthesis calculated after the 11th cycle of refinement when the  $R$  value was 0.083 revealed the approximate positions of the 16 hydrogen atoms of the asymmetric unit. However, they were included in the successive calculations in the geometrically calculated positions and with isotropic thermal factors equal to the isotropic thermal factor of the carrier atom; they were not refined. The  $R$  index dropped to 0.057. The function minimized was  $\sum (w|F_c - kF_o|)^2$ .

The form of Cruickshank's (1949) weighting function was:

$$w = (0.11111 + 1.92 \times 10^{-3} F_{o\min} + 3.12 \times 10^{-6} F_{o\max}^2)$$

The atomic scattering factors were calculated from the analytical constants given by Moore (1963). No corrections were included for anomalous scattering. The final positional and thermal parameters together

with the corresponding standard deviations (for the non-hydrogen atoms) are listed in Table 1.\*

\* The table of structure factors has been deposited with the British Library Lending Division as Supplementary Publication No. SUP 30826 (3 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 13 White Friars, Chester CH1 1NZ, England.

Table 1. Final atomic parameters with their estimated standard deviations

(a) Positional parameters

	$x/a$	$y/b$	$z/c$
C(1)	0.1247 (6)	0.3260 (8)	-0.2300 (4)
C(2)	0.1996 (6)	0.6997 (10)	-0.1853 (5)
C(3)	0.1764 (5)	0.4837 (8)	-0.1300 (4)
C(4)	0.0456 (5)	0.5085 (7)	-0.0481 (4)
C(5)	0.2878 (5)	0.5358 (9)	0.0734 (4)
C(6)	0.3222 (5)	0.4244 (8)	-0.0378 (4)
C(7)	0.3585 (6)	0.4451 (10)	0.1939 (5)
C(8)	0.3259 (5)	0.5774 (9)	0.2990 (4)
C(9)	0.4009 (7)	0.7706 (11)	0.3204 (5)
C(10)	0.3700 (9)	0.8956 (12)	0.4164 (6)
C(11)	0.2654 (9)	0.8315 (15)	0.4907 (5)
C(12)	0.1906 (8)	0.6371 (15)	0.4712 (5)
C(13)	0.2222 (6)	0.5160 (13)	0.3761 (5)
O(1)	0.3449 (4)	0.2036 (6)	-0.0216 (3)
O(2)	-0.0987 (3)	0.5143 (7)	-0.0801 (3)
O(3)	0.1089 (3)	0.5292 (6)	0.0643 (3)
HO(1)	0.317	0.106	-0.078
HC(1)1	0.217	0.304	-0.285
HC(1)2	0.015	0.385	-0.285
HC(1)3	0.094	0.177	-0.192
HC(2)1	0.296	0.695	-0.238
HC(2)2	0.223	0.816	-0.117
HC(2)3	0.089	0.743	-0.244
HC(5)	0.327	0.700	0.070
HC(6)	0.429	0.490	-0.069
HC(7)1	0.307	0.290	0.202
HC(7)2	0.488	0.428	0.197
HC(9)	0.484	0.827	0.260
HC(10)	0.432	1.046	0.433
HC(11)	0.238	0.933	0.564
HC(12)	0.109	0.582	0.532
HC(13)	0.161	0.366	0.362

(b) Thermal parameters in the form:

$$T = \exp \left[ -\frac{1}{4}(B_{11}h^2a^{*2} + B_{22}k^2b^{*2} + B_{33}l^2c^{*2} + 2B_{12}hka^*b^* + 2B_{13}hla^*c^* + 2B_{23}klb^*c^*) \right]$$

	$B_{11}$	$B_{22}$	$B_{33}$	$B_{12}$	$B_{13}$	$B_{23}$
C(1)	4.6 (2)	4.4 (2)	5.6 (2)	-0.8 (2)	0.8 (2)	-1.0 (2)
C(2)	5.6 (2)	4.6 (3)	4.9 (2)	-1.0 (2)	0.9 (2)	0.2 (2)
C(3)	3.6 (2)	2.9 (2)	4.3 (2)	-0.6 (1)	0.9 (1)	-0.6 (2)
C(4)	3.9 (2)	2.1 (2)	5.3 (2)	0.0 (2)	-0.1 (1)	0.3 (2)
C(5)	2.5 (2)	4.4 (2)	6.3 (2)	0.1 (2)	0.7 (1)	-0.3 (2)
C(6)	3.5 (2)	4.0 (2)	5.7 (2)	-0.5 (2)	1.7 (2)	-0.7 (2)
C(7)	4.2 (2)	5.2 (3)	5.9 (3)	0.4 (2)	-0.1 (2)	0.0 (2)
C(8)	3.9 (2)	5.8 (3)	4.4 (2)	0.5 (2)	0.2 (2)	0.4 (2)
C(9)	6.0 (3)	5.9 (3)	6.3 (3)	-1.2 (3)	0.8 (2)	-0.3 (3)
C(10)	8.7 (4)	5.9 (3)	6.5 (3)	-0.6 (3)	-0.4 (3)	-0.7 (3)
C(11)	9.0 (4)	8.6 (5)	5.1 (3)	1.9 (4)	0.7 (3)	-0.2 (3)
C(12)	7.0 (3)	9.2 (5)	5.7 (3)	0.4 (3)	1.1 (2)	0.7 (3)
C(13)	5.4 (2)	7.0 (3)	5.2 (2)	0.0 (3)	-0.2 (2)	0.7 (3)
O(1)	3.9 (1)	3.9 (2)	7.2 (2)	0.8 (1)	1.4 (1)	-0.6 (1)
O(2)	3.4 (1)	4.2 (2)	7.2 (2)	0.3 (1)	0.3 (1)	-0.2 (2)
O(3)	2.9 (1)	4.1 (1)	5.9 (2)	0.3 (1)	1.2 (1)	0.0 (1)

## Description of the structure

The most important conformational parameters of the molecule are listed in Table 2 and reported in Fig. 1. Most of them do not require any comment since they are quite normal. The bond distances C(5)—O(3) 1.488 Å and C(10)—C(11) 1.354 Å are slightly longer and shorter respectively than the usual values; no specific explanation, apart from casual errors in the intensity data, could be suggested for these deviations. Noteworthy among the bond angles is the divergence from the tetrahedral value of the angles C(1)—C(3)—C(6)

(117°) and C(6)—C(5)—C(7) (118°) due to the strain imposed by the non-bonded interactions C(1)···O(1) and O(1)···C(7). Some bond angles close to 100° in the five-membered ring are not unexpected. The conformation of the five-membered ring shows that C(6) is puckered out of the mean plane C(3)—C(4)—O(3)—C(5) at a distance of ~0.47 Å.\* The internal rotation

\* The equation of the best mean plane referred to the crystallographic axes is  $-0.0018X - 0.9907Y + 0.1353Z = -3.2648$ . (Deviations from the plane are: C(3) 0.011, C(4) -0.020, O(3) 0.020, C(5) -0.011 Å.)

Table 2. Molecular geometry

Bond distances (Å)		Bond angles (°)		Internal rotation angles (°)	
C(1)—C(3)	1.521 (6)	C(1)—C(3)—C(2)	109.4 (2)	C(1)—C(3)—C(4)—O(2)	-40
C(2)—C(3)	1.534 (8)	C(1)—C(3)—C(4)	111.1 (2)	C(1)—C(3)—C(4)—O(3)	142
C(3)—C(4)	1.534 (6)	C(1)—C(3)—C(6)	117.1 (2)	C(2)—C(3)—C(4)—O(2)	79
C(4)—O(2)	1.216 (5)	C(2)—C(3)—C(4)	106.8 (2)	C(2)—C(3)—C(4)—O(3)	261
C(3)—C(6)	1.536 (6)	C(2)—C(3)—C(6)	111.2 (2)	C(1)—C(3)—C(6)—O(1)	-28
C(4)—O(3)	1.305 (5)	C(4)—C(3)—C(6)	100.7 (2)	C(1)—C(3)—C(6)—C(5)	209
C(5)—O(3)	1.488 (5)	C(3)—C(4)—O(2)	126.0 (2)	C(2)—C(3)—C(6)—O(1)	206
C(5)—C(6)	1.499 (7)	C(3)—C(4)—O(3)	111.3 (2)	C(2)—C(3)—C(6)—C(5)	83
C(6)—O(1)	1.427 (7)	O(2)—C(4)—O(3)	122.7 (2)	C(3)—C(4)—O(3)—C(7)	-23
C(5)—C(7)	1.517 (7)	C(4)—O(3)—C(5)	110.0 (1)	C(3)—C(4)—O(3)—C(5)	4
C(7)—C(8)	1.506 (8)	O(3)—C(5)—C(6)	103.6 (2)	C(4)—O(3)—C(5)—C(6)	-24
C(8)—C(9)	1.389 (9)	O(3)—C(5)—C(7)	108.5 (2)	C(4)—O(3)—C(5)—C(7)	210
C(9)—C(10)	1.391 (9)	C(6)—C(5)—C(7)	117.8 (2)	O(2)—C(4)—O(3)—C(5)	185
C(10)—C(11)	1.354 (10)	C(5)—C(6)—O(1)	113.5 (2)	O(3)—C(5)—C(6)—C(3)	33
C(11)—C(12)	1.390 (13)	C(5)—C(6)—C(3)	102.8 (2)	O(3)—C(5)—C(6)—O(1)	270
C(12)—C(13)	1.381 (10)	O(1)—C(6)—C(3)	114.0 (2)	C(5)—C(6)—C(3)—C(4)	-31
C(13)—C(8)	1.363 (7)	C(5)—C(7)—C(8)	113.4 (2)	C(6)—C(3)—C(4)—O(3)	17
		C(7)—C(8)—C(9)	120.5 (3)	C(6)—C(3)—C(4)—O(2)	196
		C(7)—C(8)—C(13)	122.4 (3)	O(3)—C(5)—C(7)—C(8)	-67
		C(8)—C(9)—C(10)	121.0 (3)	C(3)—C(6)—C(5)—C(7)	153
		C(9)—C(10)—C(11)	120.7 (3)	O(1)—C(6)—C(5)—C(7)	30
		C(10)—C(11)—C(12)	119.3 (3)	C(6)—C(5)—C(7)—C(8)	176
		C(11)—C(12)—C(13)	119.2 (3)	O(3)—C(5)—C(7)—C(8)	-67
		C(12)—C(13)—C(8)	122.7 (3)	C(5)—C(7)—C(8)—C(9)	-70
		C(13)—C(8)—C(9)	117.1 (3)	C(5)—C(7)—C(8)—C(13)	110

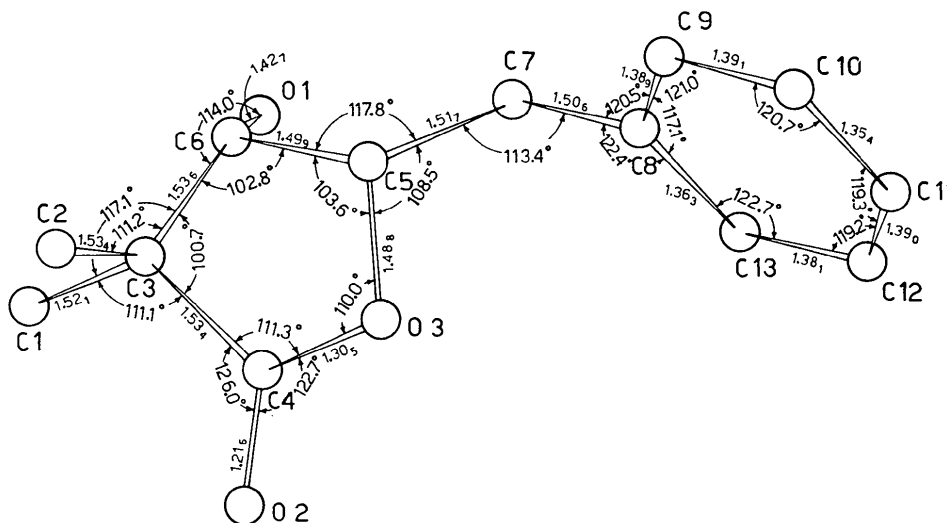


Fig. 1. A view of the molecule as seen along the [010] direction with some final geometrical parameters.

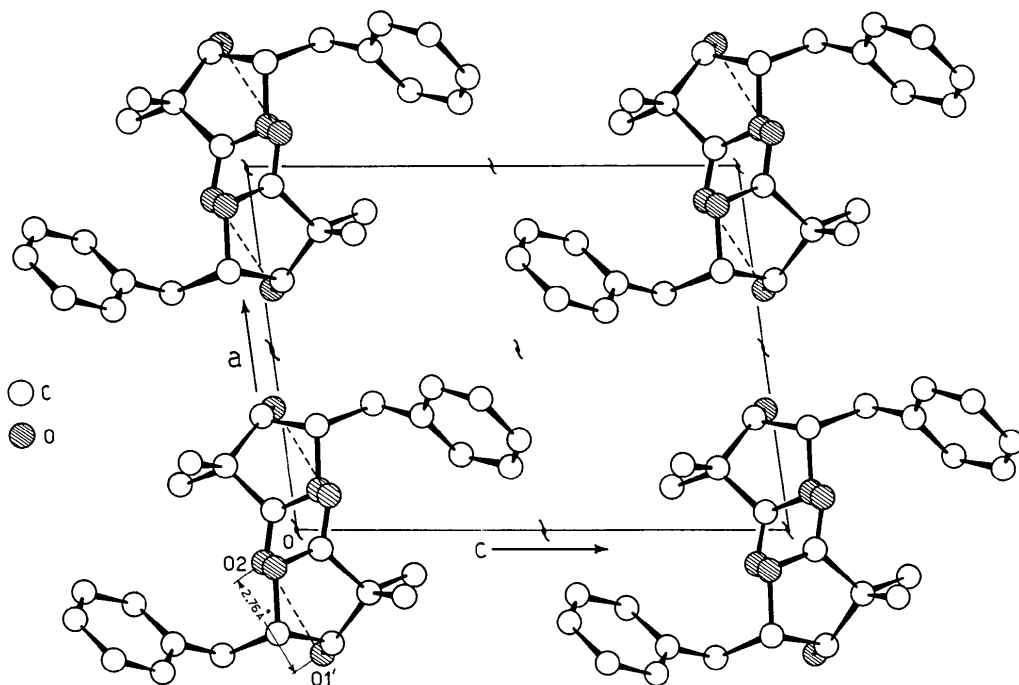


Fig. 2. Mode of packing of the title compound along the [010] direction; broken lines indicate the hydrogen-bond distances.

angles  $C(1)-C(3)-C(6)-O(1)$  and  $C(7)-C(5)-C(6)-O(1)$  are  $\sim|40^\circ|$  and  $\sim|28^\circ|$  which correspond to a nearly eclipsed conformation, and are related to the large bond angles  $C(1)-C(3)-C(6)$  and  $C(7)-C(5)-C(6)$  discussed above. The bond  $C(7)-C(8)$  is *trans* to  $C(6)-C(5)$  [the internal rotation angle  $C(6)-C(5)-C(7)-C(8)$  is  $\sim 176^\circ$ ] and the phenyl ring is in an almost skew conformation with respect to the bond  $C(7)-C(8)$  [ $C(5)-C(7)-C(8)-C(13) \sim 110^\circ$ ] as is usually found. The relative configuration of  $C(6)$  and  $C(5)$ , the two asymmetric atoms of the molecule, is *RR* (or *SS*), following the nomenclature of Cahn, Ingold & Prelog (1956).

Fig. 2 shows a projection of the structure of the title compound along the  $b$  axis.

Molecules related by twofold axes at  $x=0, z=0$ , are linked by hydrogen bonds between the carbonyl oxygens of molecules in  $xyz$  and the carboxylic oxygens of molecules in  $\bar{x}, \frac{1}{2}+y, \bar{z}$ . The hydrogen-bond length

$O(2) \cdots H-O(1)$  is  $2.76 \text{ \AA}$ . There are no other particularly short contacts  $< 3.6 \text{ \AA}$  between the molecules.

#### References

- CAGLIOTI, L., MISITI, D., MONDELLI, R., SELVA, A., ARCAMONE, F. & CASSINELLI, G. (1969). *Tetrahedron*, **25**, 2193-2221.
- CAHN, R. S., INGOLD, C. K. & PRELOG, V. (1956). *Experientia*, **12**, 81-94.
- CASSINELLI, G., GREIN, A., OREZZI, P., PENNELLA, P. & SANFILIPPO, A. (1967). *Arch. Mikrobiol.* **55**, 358-368.
- CRUICKSHANK, D. W. J. (1949). *Acta Cryst.* **2**, 65-82.
- GERMAIN, G., MAIN, P. & WOOLFSON, M. M. (1971). *Acta Cryst. A* **27**, 368-376.
- KARLE, J. & HAUPTMAN, H. (1956). *Acta Cryst.* **9**, 635-651.
- MOORE, F. H. (1963). *Acta Cryst.* **16**, 1169-1175.
- WILSON, A. J. C. (1942). *Nature, Lond.* **150**, 151-152.