Acta Cryst. (1970). B26, 1038

The Crystal and Molecular Structure of Eunicellin Dibromide, $C_{28}H_{42}O_9Br_2$

BY OLGA KENNARD* AND D. G. WATSON
University Chemical Laboratory, Cambridge, England

AND L. RIVA DI SANSEVERINO
Istituto di Mineralogia e Petrografia, Università di Bologna, Italy

(*Received* 9 *September* 1969)

The structure of a compound extracted from *Eunicella stricta* has been determined from an analysis of the dibromide derivative. The dibromide crystallizes in space group $C2$ with cell parameters $a=20{\cdot}1$, $b=11{\cdot}15$, $c=15{\cdot}94$ Å, $\beta=116{\cdot}4\pm4°$, $Z=4$. The structure was solved by the heavy-atom method and found to be a diterpenoid containing a ten-membered ether-bridged ring system. The refinement was terminated at $R=13\%$. Values for the torsional angles in the ring systems are reported.

Introduction

Eunicellin is one of the new naturally occurring organic compounds isolated by Djerassi and co-workers from marine invertebrates (Tursch, Barrets & Sharapin, 1963; Tursch, de Souza-Guimarães, Gilbert, Aplin, Duffield & Djerassi, 1967; Rüdiger, Klose, Tursch, Houvenaghel-Crevecoeur & Budzikiewicz, 1968). Its structure was established by parallel chemical and crystallographic investigations. The principal chemical findings have been reported elsewhere (Kennard, Watson, Riva di Sanseverino, Tursch, Bosmans & Djerassi, 1968) and the present communication records the structural parameters and results of the analysis of the conformational angles in the molecule.

Experimental

Crystal data

Eunicellin dibromide, $C_{28}H_{42}O_9Br_2$. Small, colourless, irregular prisms; m.p. 211–213 °C. Monoclinic, $a=20{\cdot}1\pm1$, $b=11{\cdot}15\pm2$, $c=15{\cdot}94\pm6$ Å, $\beta=116{\cdot}4\pm4°$ $D_c=1{\cdot}42$ g.cm^{-3}, $Z=4$, $V=3204$ Å^3, $F(000)=1268$. The space group $C2$ was assigned from absent reflexions, the appearance of the three-dimensional Patterson function and the successful solution of the structure. The cell constants and intensities were obtained using Cu $K\alpha$ radiation. Equi-inclination Weissenberg photographs were taken for nine layers along the b axis and the intensities estimated visually. 2550 independent reflexions were measured. The intensities were corrected for the usual factors other than absorption. 2247 terms were used for the analysis.

Determination of the structure and refinement procedure

The bromine positions were derived from the three-dimensional Patterson function. After four cycles of structure factor – Fourier calculations it was possible to locate all atoms in the empirical formula. The oxygen atom positions were identified from the peak heights in the electron density maps. When the atoms had been located and those within acceptable bonding distances were linked a chemically reasonable structure emerged.

The atomic positions were refined through one cycle of full-matrix and seven cycles of block-diagonal least-squares calculations. Only the bromine atoms were assigned anisotropic temperature coefficients. Since the principal object of the X-ray analysis was the determination of the gross chemical structure, the analysis was terminated when the isotropic refinement converged at $R=13\%$. At this stage the average ratio of shift to error was 0·335 for the 174 parameters being refined.

The X-ray 63 system of programs, compiled by Stewart (1964) was used for these calculations. Table 1 lists the final atomic coordinates and thermal parameters. A list of observed and calculated structure factors is available from the authors on request.

Molecular geometry and conformation

The chemical structure and the numbering system adopted for the analysis are illustrated in Fig. 1.

The molecule consists essentially of a ten-membered ring system, *cis* fused to a six-membered substituted cyclohexane ring. The two rings carry substituents including four acetate groups which are planar within experimental error. The ten-membered ring is bridged at C(2) and C(5) by an oxygen atom, forming a five-membered ring. The carbon skeleton is biogenetically acceptable since it can be made up of four isoprene units, linked head-to-tail.

Eunicellin is an unusual diterpenoid and no comparable structure in the literature could be found for which atomic positions have been reported. The bond lengths calculated from the final atomic coordinates and listed in Table 2 are unexceptional within the

* External Staff, Medical Research Council.

accuracy of the analysis. Most of the bond angles (Table 2) are also near the normal values except at junctions of considerable strain.

To analyse the conformation of the molecule the relevant torsional angles were calculated. Values for the ten-membered ring are illustrated in Fig. 2(*a*). Although the average C–C–C angle within this ring is 113°, the torsional angles show large fluctuations and the conformation is far from the stable cyclodecane conformation discussed by Dunitz in a recent review (Dunitz & Ibers, 1968). There is considerable strain introduced at the junction between the six- and ten-membered rings. This is reflected both in the large external angle of 120° at C(12)–C(3)–C(2) and the small torsional angle of 30° between bonds C(2)–C(3) and C(4)–C(5) about bond C(3)–C(4). The misfit at the *cis* junction is probably due to the ether linkage at C(2). It also influences the torsional angle of 88·2° between bonds C(2)–C(3) and C(4)–C(15) about the ring junction C(3)–C(4). The other torsional angle, between bonds C(12)–C(13) and C(4)–C(5), is 163°, near the expected value.

The six-membered ring is in the chair form with an average valency angle of 113° and average torsional angle of 49·6°.

The five-membered ring, consisting of O(1), C(2), C(3), C(4), C(5) has a conformation intermediate between a half chair and an envelope. C(9) is displaced from the best plane through the other four atoms by 0·53 Å. The torsional angles are illustrated in Fig. 2(*b*). The values are similar to those calculated by Romers, Altona, Buys & Havinga (1969) for D-galactono-γ-lactone based on the coordinates determined by Jeffrey, Rosenstein & Vlasse (1967).

Table 1. *Positional and thermal parameters for eunicellin dibromide*

	x/a	*y/b*	*z/c*	*B* (Å)
Br(1)	0·2034 (3)	0·0050 (–)	0·5059 (3)	*
Br(2)	0·4318 (3)	0·1754 (7)	0·5728 (3)	*
O(1)	0·3782 (11)	0·0345 (25)	0·3521 (14)	2·6 (4)
O(2)	0·2293 (14)	−0·0936 (28)	0·2294 (17)	3·5 (5)
O(3)	0·1822 (21)	−0·2768 (42)	0·2339 (26)	6·6 (8)
O(4)	0·3860 (14)	−0·0994 (30)	0·5951 (18)	3·9 (5)
O(5)	0·4723 (20)	−0·2210 (42)	0·5825 (25)	6·2 (8)
O(6)	0·2027 (13)	0·2614 (28)	0·0928 (16)	3·1 (4)
O(7)	0·1108 (15)	0·1934 (36)	0·1288 (18)	4·5 (5)
O(8)	0·3818 (14)	0·3695 (32)	0·2676 (18)	4·0 (5)
O(9)	0·4171 (20)	0·5212 (47)	0·2079 (25)	6·4 (8)
C(2)	0·3345 (21)	0·1422 (45)	0·3411 (26)	3·9 (7)
C(3)	0·2796 (16)	0·1578 (38)	0·2343 (20)	2·7 (5)
C(4)	0·3156 (18)	0·0705 (39)	0·1881 (22)	3·0 (6)
C(5)	0·3518 (17)	−0·0252 (37)	0·2640 (21)	2·9 (6)
C(6)	0·3068 (18)	−0·1420 (40)	0·2611 (22)	3·0 (6)
C(7)	0·3376 (23)	−0·1990 (50)	0·3559 (28)	4·5 (8)
C(8)	0·3134 (21)	−0·1477 (47)	0·4294 (26)	3·7 (7)
C(9)	0·3656 (20)	−0·0550 (44)	0·4989 (25)	3·4 (7)
C(10)	0·3352 (21)	0·0711 (45)	0·4994 (26)	3·7 (7)
C(11)	0·2874 (21)	0·1248 (44)	0·3992 (26)	3·8 (7)
C(12)	0·2589 (21)	0·2799 (43)	0·1922 (25)	3·6 (7)
C(13)	0·3229 (19)	0·3400 (41)	0·1742 (23)	3·4 (6)
C(14)	0·3512 (21)	0·2547 (48)	0·1245 (26)	4·0 (7)
C(15)	0·3770 (20)	0·1362 (41)	0·1699 (24)	3·5 (7)
C(16)	0·3070 (25)	−0·2230 (53)	0·1865 (31)	5·0 (9)
C(17)	0·2944 (27)	0·0952 (56)	0·5601 (33)	5·3 (9)
C(18)	0·2329 (22)	0·3646 (49)	0·2453 (27)	4·1 (7)
C(19)	0·4080 (21)	0·0538 (44)	0·1160 (26)	4·0 (7)
C(20)	0·3553 (29)	0·0451 (59)	0·0108 (36)	5·8 (1·0)
C(21)	0·4856 (29)	0·0973 (61)	0·1308 (36)	5·9 (1·1)
C(22)	0·1718 (29)	−0·1665 (61)	0·2202 (35)	5·9 (1·0)
C(23)	0·1031 (34)	−0·0972 (72)	0·2026 (43)	7·3 (1·3)
C(24)	0·4391 (21)	−0·1791 (47)	0·6286 (26)	3·9 (7)
C(25)	0·4533 (26)	−0·2251 (56)	0·7239 (32)	5·4 (9)
C(26)	0·1342 (22)	0·2233 (46)	0·0704 (28)	4·3 (8)
C(27)	0·0914 (27)	0·1964 (64)	−0·0333 (34)	5·8 (1·0)
C(28)	0·4213 (24)	0·4662 (49)	0·2715 (30)	4·8 (9)
C(29)	0·4786 (31)	0·4924 (77)	0·3742 (39)	7·1 (1·2)

* Anisotropic temperature factors

	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
Br(1)	0·0046	0·0115	0·0064	0·0003	0·0026	0·0004
Br(2)	0·0046	0·0105	0·0059	−0·0003	0·0020	−0·0003

$$T=\exp\left[-(\beta_{11}h^2+\beta_{22}k^2+\beta_{33}l^2+2\beta_{13}hl+2\beta_{12}hk+2\beta_{23}kl)\right].$$

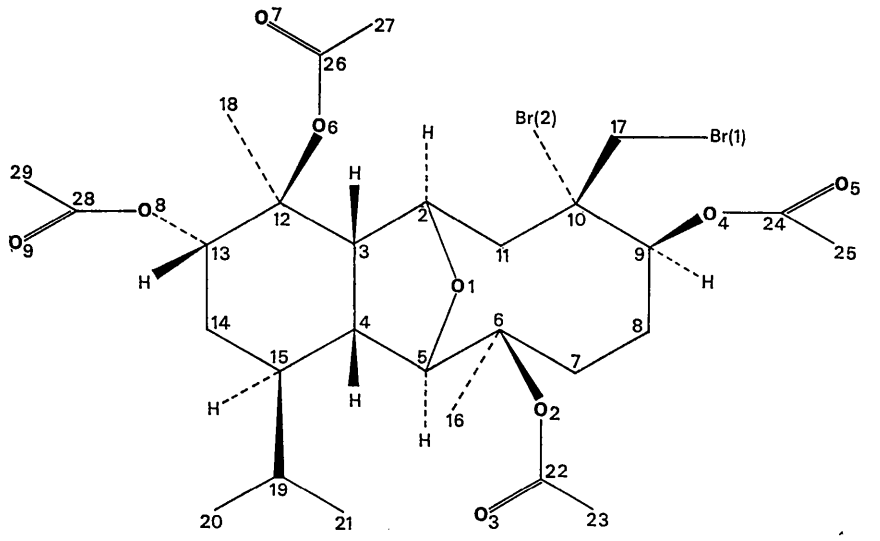

Fig. 1. Structural formula for eunicellin dibromide showing the atomic numbering used in the X-ray analysis. Some of the hydrogen atoms are omitted and the bond types are indicated by the usual chemical conventions.

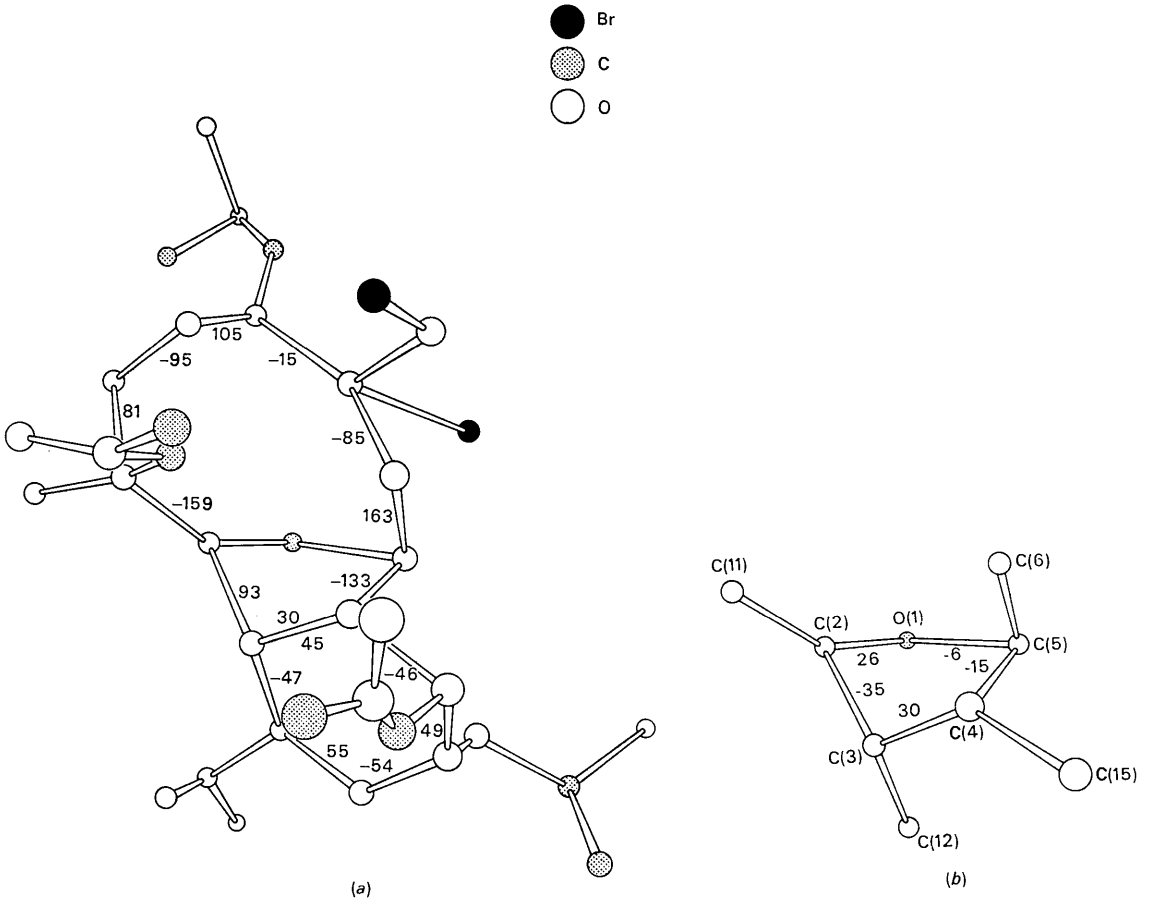

Fig. 2. Perspective view of eunicellin dibromide with torsional angles in (*a*) the ten-membered and six-membered rings, and (*b*) the five-membered rings.

Table 2. *Interatomic distances and angles*

O(1)–C(2)	1·47 Å	C(2)–O(1)–C(5)	110°
O(1)–C(5)	1·42		
C(2)–C(3)	1·56	O(1)–C(2)–C(3)	107
C(2)–C(11)	1·59	O(1)–C(2)–C(11)	107
		C(3)–C(2)–C(11)	111
C(3)–C(4)	1·58	C(2)–C(3)–C(4)	103
C(3)–C(12)	1·49	C(2)–C(3)–C(12)	120
		C(4)–C(3)–C(12)	116
C(4)–C(5)	1·53	C(3)–C(4)–C(5)	102
C(4)–C(15)	1·56	C(3)–C(4)–C(15)	111
		C(5)–C(4)–C(15)	110
C(5)–C(6)	1·56	C(4)–C(5)–C(6)	120
		O(1)–C(5)–C(4)	107
		O(1)–C(5)–C(6)	111
C(6)–C(7)	1·49	C(5)—C(6)–C(7)	110
C(6)–C(16)	1·50	C(5)—C(6)–C(16)	108
C(6)–O(2)	1·49	C(5)—C(6)–O(2)	102
		C(7)—C(6)–C(16)	114
		C(7)—C(6)–O(2)	112
		C(16)–C(6)–O(2)	109
C(7)–C(8)	1·57	C(6)—C(7)–C(8)	119
C(8)–C(9)	1·52	C(7)—C(8)–C(9)	117
C(9)–C(10)	1·53	C(8)—C(9)–C(10)	119
C(9)–O(4)	1·49	C(8)—C(9)–O(4)	108
		C(10)–C(9)–O(4)	103
C(10)–C(11)	1·56	C(9)—C(10)–C(11)	114
C(10)–C(17)	1·54	C(9)—C(10)–C(17)	119
C(10)–Br(2)	2·09	C(9)—C(10)–Br(2)	104
		C(11)–C(10)–C(17)	109
		C(11)–C(10)–Br(2)	110
		C(17)–C(10)–Br(2)	99
		C(2)—C(11)–C(10)	114
C(12)–C(13)	1·58	C(3)—C(12)–C(13)	113
C(12)–C(18)	1·51	C(3)—C(12)–C(18)	114
C(12)–O(6)	1·47	C(3)—C(12)–O(6)	106
		C(13)–C(12)–C(18)	111
		C(13)–C(12)–O(6)	99
		C(18)–C(12)–O(6)	114
C(13)–C(14)	1·50	C(12)–C(13)–C(14)	111
C(13)–O(8)	1·46	C(12)–C(13)–O(8)	104
		C(14)–C(13)–O(8)	111
C(14)–C(15)	1·48	C(13)–C(14)–C(15)	116
C(15)–C(19)	1·56	C(14)–C(15)–C(4)	112
		C(14)–C(15)–C(19)	113
		C(4)—C(15)–C(19)	112
C(17)–Br(1)	1·90	C(10)–C(17)–Br(1)	107
C(19)–C(20)	1·53	C(15)–C(19)–C(20)	114
C(19)–C(21)	1·53	C(15)–C(19)–C(21)	111
		C(20)–C(19)–C(21)	109
C(22)–C(23)	1·48	C(23)–C(22)–O(2)	112
C(22)–O(2)	1·35	C(23)–C(22)–O(3)	120
C(22)–O(3)	1·24	O(2)—C(12)–O(3)	128
C(24)–C(25)	1·51	C(25)–C(24)–O(4)	113
C(24)–O(4)	1·29	C(25)–C(24)–O(5)	123
C(24)–O(5)	1·28	O(4)—C(24)–O(5)	123

Table 2 (*cont.*)

C(26)–C(27)	1·51	C(27)–C(25)–O(6)	112
C(26)–O(6)	1·31	C(27)–C(26)–O(7)	123
C(26)–O(7)	1·26	O(6)—C(26)–O(7)	124
C(28)–C(29)	1·54	C(29)–C(28)–O(8)	110
C(28)–O(8)	1·31	C(29)–C(28)–O(9)	124
C(28)–O(9)	1·16	O(8)—C(28)–O(9)	126

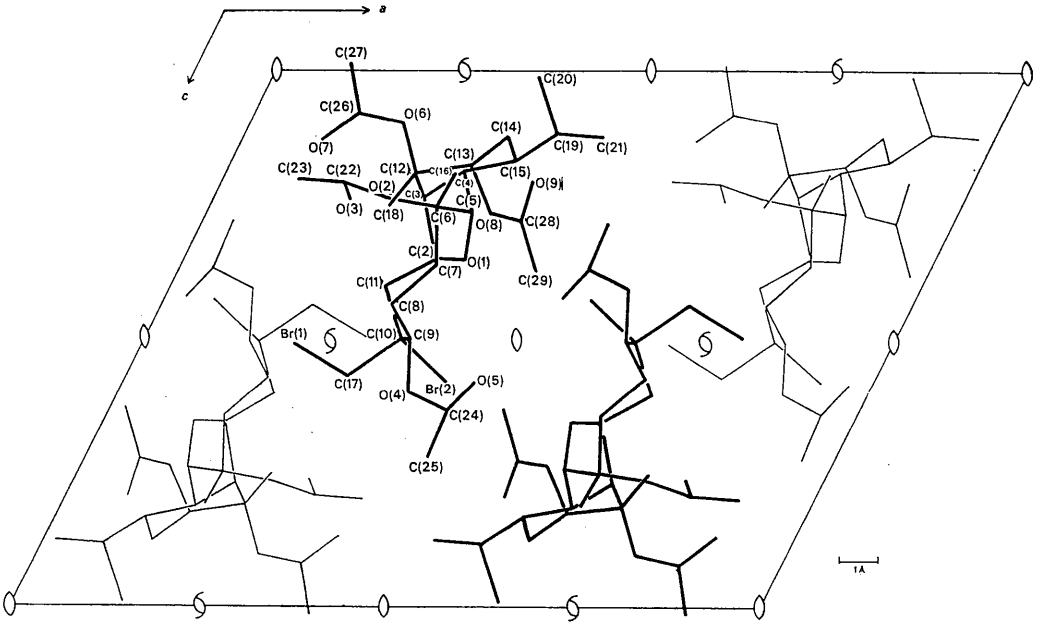

Fig. 3. Projection along the *b* axis of the contents of one unit cell, showing the packing of four molecules of eunicellin dibromide in the crystal structure.

Intermolecular distances less than 3·5 Å are listed in Table 3.

Table 3. *Intermolecular distances less than* 3·5 Å *in the crystal structure of eunicellin dibromide*

	Symmetry operation			Distance
O(9)—C(16)	x	$1+y$	z	3·50 Å
C(29)–O(5)	$1-x$	$1+y$	$1-z$	3·31
O(5)—O(5)	$1-x$	y	$1-z$	3·29
C(7)—O(5)	$1-x$	y	$1-z$	3·46
C(17)–O(3)	$\frac{1}{2}-x$	$\frac{1}{2}+y$	$1-z$	3·42
O(7)—C(25)	$\frac{1}{2}-x$	$\frac{1}{2}+y$	$1-z$	3·28
O(9)—C(27)	$\frac{1}{2}+x$	$\frac{1}{2}-y$	$1+z$	3·34

The authors thank Professor C. Djerassi, Dr B. Tursch and Dr C. Romers for their collaboration, Dr J. Harley-Mason for discussions and the Centre for Computing and Automation at Imperial College, London, for computing facilities. They are grateful to the Medical Research Council and the Office for Scientific and Technical Information for financial support.

References

DUNITZ, J. & IBERS, J. (1968). *Perspectives in Structural Chemistry*, Vol. 2. New York: John Wiley.

JEFFREY, G. A., ROSENSTEIN, R. D. & VLASSE, M. (1967). *Acta Cryst.* **22**, 725.

KENNARD, O., WATSON, D. G., RIVA DI SANSEVERINO, L., TURSCH, B., BOSMANS, R. & DJERASSI, C. (1968). *Tetrahedron Letters*, **24**, 2879.

ROMERS, C., ALTONA, C., BUYS, H. R. & HAVINGA E. (1969). *Rec. Trav. Chem. Pays-Bas*. In the press.

RÜDIGER, W., KLOSE, W., TURSCH, B., HOUVENAGHEL-CREVECOEUR, N. & BUDZIKIEWICZ, H. (1968). *Liebigs Ann.* **713**, 209.

STEWART, J. M. (1964). TR-64-6, Univ. of Maryland, U.S.A.

TURSCH, B., BARRETS, H. & SHARAPIN, N. (1963). *Bull. Soc. chim. Belg.* **72**, 807.

TURSCH, B., GUIMARÃES, I. S. DE SOUZA, GILBERT, B., APLIN, R. T., DUFFIELD, A. M. & DJERASSI, C. (1967). *Tetrahedron*, **23**, 761.