

The Structure of 1,4,7,10,13,16-Hexaoxa-2,6-cyclooctadecanedione (2,6-Diketo-18-crown-6)

BY N. K. DALLEY AND S. B. LARSON

Department of Chemistry, Thermochemical Institute, Brigham Young
University, Provo, Utah 84602, USA*

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Abstract. $C_{12}H_{20}O_8$, monoclinic, $P2_1/c$, $a = 10.617$ (1), $b = 18.576$ (2), $c = 7.785$ (1) Å, $\beta = 112.718$ (7)°, $Z = 4$, $D_c = 1.37$ Mg m⁻³, colorless crystals, m.p. 351.5–352.5 K. The molecule is nearly circular and consists of an ester portion and an ether portion.

Introduction. The compound was synthesized by G. Maas (Maas, Bradshaw, Izatt & Christensen, 1977) and was recrystallized from hot hexane. The space group and approximate lattice parameters were obtained from precession camera photographs. Cell parameters and intensity data were measured on a Syntex $P1$ autodiffractometer using Mo $K\alpha$ radiation (0.71073 Å) with a graphite monochromator. The data were recorded with a scintillation counter. Accurate lattice parameters were determined by a least-squares refinement of 30 reflections, $20^\circ < 2\theta < 26^\circ$. The crystal used for intensity measurements was shaped approximately to a sphere with a radius of about 0.17 mm. No absorption corrections were calculated as $\mu(\text{Mo}) = 0.124$ mm⁻¹. Five check reflections measured every 95 reflections showed no significant change. A total of 2612 independent reflections were measured to a 2θ limit of 50° ($\sin \theta/\lambda = 0.595$ Å⁻¹). These included 98 reflections which were systematically extinct ($0k0$, $k = 2n + 1$, and $h0l$, $l = 2n + 1$) and 586 reflections which were considered unobserved as $I < 2\sigma(I)$. During the data collection, an instrumental malfunction occurred occasionally and eight reflections were measured at the wrong ϕ settings. These reflections were not included in the refinement. The trial structure was obtained using direct methods. An E map calculated from the most consistent set of signs from *MULTAN* (Germain, Main & Woolfson, 1971) gave positions for all of the non-hydrogen atoms. The model was refined using a full-matrix least-squares procedure (Busing, Martin & Levy, 1962). Positions of all H atoms were obtained from a ΔF map. The positional parameters of all the atoms and the anisotropic thermal parameters of the non-hydrogen atoms and isotropic

ones of the H atoms were refined. The positional parameters of the atoms are listed in Table 1. The final R was 0.052 while the weighted R was 0.023.† The weights were based on counting statistics with allowance for some experimental error (Stout & Jensen, 1968). Atomic scattering factor tables for O and C were obtained from Cromer & Waber (1965) and the table for H was taken from *International Tables for X-ray Crystallography* (1968).

Discussion. The conformation of the molecule and atomic labels are shown in Fig. 1. The bond lengths (Table 2) show clearly that two of the O atoms, O(1) and O(7), of the ring are ester rather than ether oxygens. The C=O and C–O bond lengths are in the

† Lists of structure factors, thermal parameters and H atom positional parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34352 (19 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. *Atomic parameters in fractional coordinates ($\times 10^4$) with e.s.d.'s in parentheses*

	<i>x</i>	<i>y</i>	<i>z</i>
O(1)	10131 (1)	1472 (1)	7547 (1)
C(2)	10848 (1)	1970 (1)	7105 (2)
C(3)	10328 (1)	2722 (1)	7124 (2)
O(4)	9220 (1)	2726 (1)	7708 (1)
C(5)	8587 (2)	3407 (1)	7521 (2)
C(6)	7747 (1)	3635 (1)	5534 (2)
O(7)	7405 (1)	3085 (1)	4361 (1)
C(8)	6525 (2)	3225 (1)	2421 (2)
C(9)	5203 (2)	2836 (1)	1983 (2)
O(10)	5450 (1)	2088 (1)	1978 (1)
C(11)	4276 (2)	1659 (1)	1630 (2)
C(12)	4664 (2)	887 (1)	1615 (2)
O(13)	5581 (1)	690 (1)	3433 (1)
C(14)	6156 (2)	–0 (1)	3472 (2)
C(15)	7218 (2)	–133 (1)	5372 (2)
O(16)	8385 (1)	294 (1)	5611 (1)
C(17)	9383 (2)	261 (1)	7438 (2)
C(18)	10557 (2)	726 (1)	7548 (2)
O(19)	11822 (1)	1847 (1)	6722 (2)
O(20)	7422 (1)	4251 (1)	5130 (1)

* Contribution No. 157.

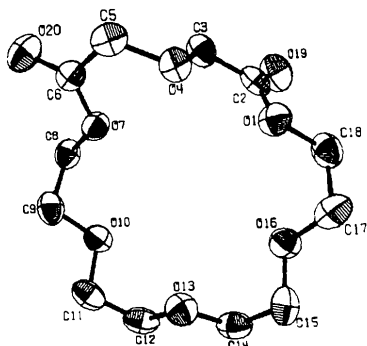


Fig. 1. ORTEP (Johnson, 1965) drawing of 2,6-diketo-18-crown-6 with 50% probability thermal ellipsoids. The hydrogen atoms are omitted.

expected range (Kroon & Kanters, 1973). The C—C and C—O bonds in the ether portion of the molecule [averages 1.494 (2) and 1.416 (4) Å, respectively] are shorter than normal C—C and C—O bonds, e.g. 1.523 and 1.423 Å in gaseous 1,4-dioxane (Davis & Hassel, 1963). This abnormality has been observed in all cyclic polyethers (Dalley, 1978). The presence of two ester groups in the crown-6 molecule causes it to assume an ordered conformation similar to that found in complexed crown-6 polyethers. This type of conformation is characterized by an approximately circular cavity with all the donor atoms directed into the interior of the ring. This is in contrast to most uncomplexed cyclic polyethers such as 18-crown-6 (Dunitz & Seiler, 1974) or the two isomers of dicyclohexano-18-crown-6 (Dalley, Smith, Larson, Matheson, Christensen & Izatt, 1975) as these molecules are elliptical in shape with some of the oxygens pointing out of the ring. The ordering is reflected in the torsion angles (Table 2) and the ring-oxygen—ring-oxygen interatomic distances (Table 3). All of the O—C—O torsion angles in the ether portion of the molecule are close to 60°, a feature found in all ordered crown-6 complexes (Dalley, 1978), and also in 1,10-diaza-18-crown-6 (Herceg & Weiss, 1972), the only other ordered uncomplexed polyether. The interatomic distances between adjacent ring O atoms are all about 2.8 Å, the sum of the van der Waals radii of two oxygen atoms (Pauling, 1960), while the distances between opposite O atoms (5.30–5.51 Å) indicate that the cavity is nearly circular.

The bond angles are listed in Table 2. These values also show the presence of two rather normal ester groups in the molecule. The bond angles in the ester portion of the ring average about 120° while in the ether portion of the ring, C(8) to C(18), the bond angles about C range from 107.3 to 109.0° and those about O range from 112.2 to 113.8°.

Deviations from the least-squares plane calculated for the six ring O atoms indicate that these atoms are not planar. The deviations range from +0.31 to -0.57

Table 2. Bond lengths (Å) and bond and torsion angles (°) for non-hydrogen atoms

				1-2	1-2-3	1-2-3-4
O(1)	C(2)	C(3)	O(4)	1.326 (2)	113.3 (1)	3.0 (1)
C(2)	C(3)	O(4)	C(5)	1.505 (2)	111.2 (1)	-172.4 (1)
C(3)	O(4)	C(5)	C(6)	1.415 (2)	113.1 (1)	72.0 (5)
O(4)	C(5)	C(6)	O(7)	1.414 (2)	115.1 (1)	19.2 (2)
C(5)	C(6)	O(7)	C(8)	1.517 (2)	112.6 (1)	176.4 (1)
C(6)	O(7)	C(8)	C(9)	1.324 (2)	118.2 (1)	-115.7 (2)
O(7)	C(8)	C(9)	O(10)	1.460 (2)	108.6 (1)	-69.3 (3)
C(8)	C(9)	O(10)	C(11)	1.496 (2)	108.5 (1)	178.4 (1)
C(9)	O(10)	C(11)	C(12)	1.415 (2)	113.8 (1)	178.6 (1)
O(10)	C(11)	C(12)	O(13)	1.414 (2)	108.5 (1)	66.1 (6)
C(11)	C(12)	O(13)	C(14)	1.493 (2)	108.9 (1)	-171.1 (2)
C(12)	O(13)	C(14)	C(15)	1.422 (2)	112.2 (1)	173.8 (2)
O(13)	C(14)	C(15)	O(16)	1.415 (2)	109.0 (1)	-73.0 (3)
C(14)	C(15)	O(16)	C(17)	1.494 (2)	108.8 (1)	173.6 (2)
C(15)	O(16)	C(17)	C(18)	1.422 (2)	112.7 (1)	-179.9 (1)
O(16)	C(17)	C(18)	O(1)	1.409 (2)	108.6 (1)	74.0 (4)
C(17)	C(18)	O(1)	C(2)	1.492 (3)	107.3 (1)	-161.2 (2)
C(18)	O(1)	C(2)	C(3)	1.457 (2)	117.0 (1)	179.5 (1)

Distances and angles involving atoms outside the ring

C(18)	O(1)	C(2)	O(19)	<i>a</i>	<i>a</i>	-0.5 (2)
O(19)	C(2)	C(3)	O(4)	1.203 (2)	122.2 (1)	-177.0 (1)
O(4)	C(5)	C(6)	O(20)	<i>a</i>	<i>a</i>	-162.3 (2)
O(20)	C(6)	O(7)	C(8)	1.202 (2)	125.4 (1)	-2.1 (2)
O(1)	C(2)	O(19)		<i>a</i>	124.5 (2)	
C(5)	C(6)	O(20)		<i>a</i>	121.9 (1)	

The average C—H distance is 1.008 (19) Å.

^a Listed earlier in the table.

Table 3. Interatomic distances between ring oxygens (Å)

O(1)···O(4)	2.544 (1)	O(7)···O(10)	2.865 (1)
O(1)···O(7)	4.239 (1)	O(7)···O(13)	4.794 (1)
O(1)···O(10)	5.307 (1)	O(7)···O(16)	5.303 (1)
O(1)···O(13)	4.873 (1)		
O(1)···O(16)	2.886 (1)	O(10)···O(13)	2.814 (1)
		O(10)···O(16)	4.690 (1)
O(4)···O(7)	2.659 (1)		
O(4)···O(10)	4.851 (1)	O(13)···O(16)	2.894 (1)
O(4)···O(13)	5.511 (1)		
O(4)···O(16)	4.767 (1)		

Å. The O atoms can be described better by a least-squares plane determined by O(1), O(7), O(10), and O(16) with O(4) and O(13) being 0.85 and 0.83 Å, respectively, out of the plane and on the same side of it. None of the atoms which determine this plane deviate from it by more than 0.036 Å. If one considers the ring O atoms alone, they are in a boat conformation. Deviations from the least-squares planes calculated for the two ester groups indicate that these groups are planar within experimental error.

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(±)-6-*epi*-Eriolanin

BY GEORGE T. DETITTA AND SUZANNE FORTIER*

Medical Foundation of Buffalo, Inc., 73 High Street, Buffalo, NY 14203, USA

AND PAUL A. GRIECO

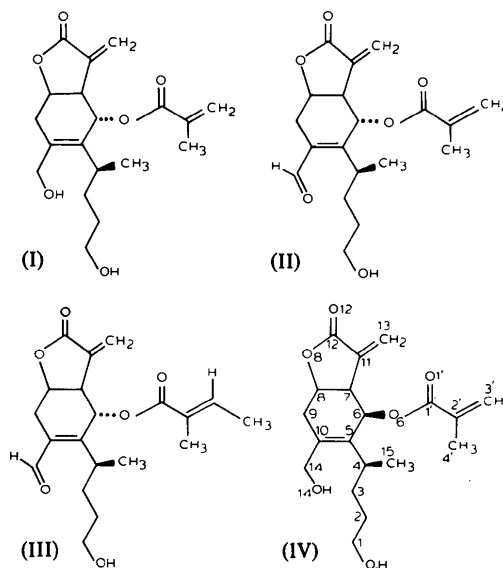
Department of Chemistry, University of Pittsburgh, Pittsburgh, PA 15260, USA

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Abstract. C₁₉H₂₆O₆, monoclinic, *P*2₁/*c*, *a* = 9.4729 (6), *b* = 12.064 (1), *c* = 16.426 (2) Å, β = 97.60 (1)°, *V* = 1860.7 Å³, ρ_o = 1.26 (by flotation), ρ_c = 1.25 Mg m⁻³ (for *Z* = 4). The structure determination was undertaken to establish the relative stereochemistry at the 6-position of this synthetic analog of eriolanin. Relative to the bicyclic ring system of the closely related dehydroeriolanin, epimerization at the 6-position causes an *endo* to *exo* conformational flip of the 1,4-diplanar (boat) cyclohexene ring. The structure has been refined to a residual of *R* = 0.064 for 2229 observable data measured with copper radiation.

Introduction. Eriolanin (I) is a naturally occurring anti-leukemic 1,10-secoeudesmanolide isolated from *Eriophyllum lanatum* Forbes (Compositae) by Kupchan, Baxter, Chiang, Gilmore & Bryan (1973). Structural elucidation of eriolanin was by a combination of spectral and X-ray diffraction studies, the latter work performed by Bryan & Gilmore (1975). They studied a mixed crystal of dehydroeriolanin (DE,

II) and dehydroeriolangin (III) in which the two eudesmanolides had co-crystallized. As part of a search for analogs of natural products with anti-leukemic properties, one of us (PAG) synthesized the 6-epimer of



* Present address: National Research Council of Canada, Department of Biological Sciences, Ottawa, Ontario, Canada K1A 0RA.