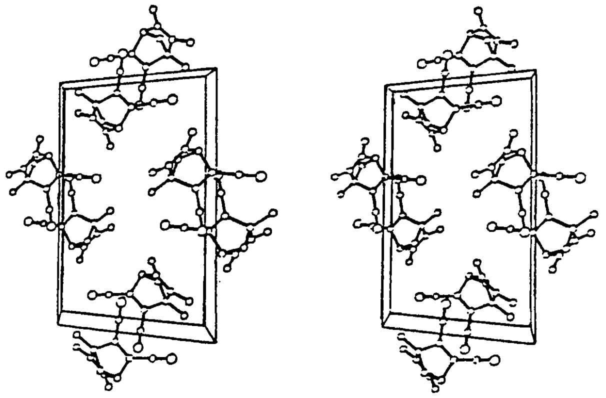

Fig. 2. Stereoview of the packing of the molecules. The origin is at the lower left-hand corner, **a** is vertical, **b** is horizontal and **c** towards the viewer.

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References

Ashida, T. (1973). *The Universal Crystallographic Computing System – Osaka.* The Computation Center, Osaka Univ., Japan.
Fujii, S. (1979). *The Universal Crystallographic Computing System – Osaka.* The Computation Center, Osaka Univ., Japan.
Hamilton, W. C. (1959). *Acta Cryst.* **12**, 609–610.
International Tables for X-ray Crystallography (1974). Vol. IV, pp. 71–151. Birmingham: Kynoch Press.
Langer, V., Huml, K. & Reck, G. (1982). *Acta Cryst.* B**38**, 298–300.
Morino, Y., Kuchitsu, K. & Yokozeki, A. (1967). *Bull. Chem. Soc. Jpn*, **40**, 1552.
Takenaka, A. (1977). *A Computer Program System for The Interactive Graphic Display of Crystal and Molecular Structures.* Laboratory of Chemistry for Natural Products, Tokyo Institute of Technology, Nagatsuta, Midori-ku, Yokohama 227, Japan.
Yoshida, Z. (1981). Abstr. 43th Natl Meet. Chem. Soc. Jpn. Vol. II, p. 847.

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Structure of the Melampolide Sesquiterpene Lactone Alloschkuhriolide, $C_{15}H_{18}O_4$

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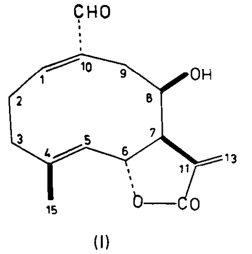
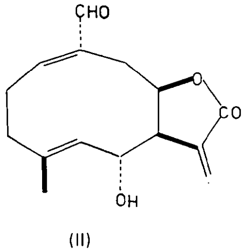
Abstract. $M_r = 262{\cdot}3$, orthorhombic, $P2_12_12_1$, $a = 5{\cdot}7993\,(6)$, $b = 14{\cdot}945\,(1)$, $c = 15{\cdot}730\,(2)$ Å, $U = 1363{\cdot}3\,(3)$ Å^3, $Z = 4$, $D_m = 1{\cdot}26$, $D_x = 1{\cdot}28$ Mg m^{-3}, Cu $K\alpha$, $\lambda = 1{\cdot}54184$ Å, $\mu = 0{\cdot}67$ mm^{-1}, $F(000) = 560$, $T = 295$ K, $R = 0{\cdot}058$ for 1049 observed reflections. Alloschkuhriolide (I) is the C(6), C(7) *trans*-fused product of relactonization of schkuhriolide (II), a naturally occurring C(7),C(8) *cis*-fused sesquiterpene lactone. The relactonization does not alter the gross conformation of the cyclodecadiene skeleton. It seems, however, that it results in a certain release of strain in the molecule.

Introduction. Recently we have reported the crystal structure of schkuhriolide monohydrate, a naturally occurring sesquiterpene lactone of the melampolide type, which is exceptional among melampolides in possessing a *cis* lactone ring closed at C(8) (Rychlewska, 1982). Comparison of this structure with other melampolides studied by X-ray methods has revealed considerable conformational similarity in these compounds. The conformation of the ten-membered ring in melampolides seemed to be mainly determined by the *cis, trans* nature of the double bonds within the ring. It was, therefore, of interest to learn the extent to which the γ-lactone orientation affects the ten-membered-ring conformation. Our previous results showed that relactonization of a 7,8-*cis*-lactonized melampolide to a 6,7-*trans*-lactonized compound proceeds without much conformational change within the molecule. As a complementary study we have undertaken an X-ray analysis of alloschkuhriolide (I), which is the product of schkuhriolide (II) relactonization upon strong alkaline treatment and subsequent acidification (Samek, Holub, Błoszyk & Drożdż, 1979).



(I)



(II)

0108-2701/83/091303-03$01.50

Experimental. Crystals grown from mixture of chloroform and diisopropyl ether, D_m by flotation. Weissenberg photographs indicated orthorhombic symmetry, space group $P2_12_12_1$, cell parameters by least-squares refinement of setting angles of 15 reflections centered on Enraf–Nonius diffractometer; crystal 0·3 × 0·4 × 0·45 mm, θ–2θ scan, variable scan rate, graphite-monochromated Cu $K\alpha$ radiation, 1107 reflections, $2\theta \leq 115°$, h 0–6, k 0–16, l 0–13, background and integrated intensity for each reflection evaluated from profile analysis according to the Lehmann & Larsen (1974) method using *PRARA* program (Jaskólski, 1981), no absorption correction, 1056 reflections with $I \geq 1{\cdot}96\,\sigma(I)$ considered significant, seven additional reflections omitted because of secondary extinction; structure solved with *MULTAN* (Germain, Main & Woolfson, 1971), refined with *SHELX*76 (Sheldrick, 1976); anisotropic refinement of nonhydrogen atoms followed by difference syntheses led to location of all the H atoms [except those attached to C(1) and C(15) which were placed by calculation]; most H atoms included in the refinement as fixed contributions, but positional parameters of hydroxyl hydrogen allowed to refine freely, and methyl H atoms refined as rigid methyl group; all hydrogen atoms given fixed isotropic temperature factor ($U = 0{\cdot}06$ Å^2); function minimized $\sum w(|F_o| - |F_c|)^2$, $w = k/(\sigma_F^2 + gF^2)$, g refined, $R = 0{\cdot}058$ ($R_w = 0{\cdot}089$) with $k = 1{\cdot}0$ and $g = 0{\cdot}0126$; $S = 0{\cdot}85$ for $m = 1049$ observations and $n = 178$ refined parameters; in final cycle of refinement average and maximum shift/error were 0·04 and 0·68, respectively, maximum shift corresponded to rotation of methyl group; residual fluctuations in the difference map within the range ± 0·2 e Å^{-3}; atomic scattering factors of *SHELX*76 used.

Discussion. Final atomic coordinates are given in Table 1.* The absolute configuration of alloschkuhriolide (I), assigned by comparison with that of schkuhriolide (II) (Rychlewska, 1982), is illustrated in Fig. 1 together with the atom numbering (*PLUTO*78, Motherwell & Clegg, 1978). Bond lengths and angles are given in Table 2 and torsional angles in Table 3.

The basic skeleton of alloschkuhriolide comprises a macrocyclic *cis*-1(10)-*trans*-4-cyclodecadiene, *trans*-fused at C(6)—C(7) with a five-membered γ-lactone. The hydroxyl group at C(8) is β-oriented.

The ten-membered ring adopts a distorted chair–boat conformation. The lactone ring has a conformation intermediate between 7α,6β-half-chair and 7α-envelope.

Table 1. *Final fractional coordinates* (× 10^4) *and equivalent isotropic thermal parameters* (Å^2 × 10^3)

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

	x	y	z	U_{eq}
O(1)	1987 (5)	95 (2)	7968 (2)	57 (1)
O(2)	559 (7)	801 (2)	9101 (2)	71 (1)
O(3)	3193 (7)	6509 (2)	9295 (2)	76 (1)
O(4)	7631 (5)	8745 (2)	8842 (2)	55 (1)
C(1)	3458 (8)	6680 (2)	7074 (3)	57 (1)
C(2)	4503 (9)	6950 (3)	6240 (3)	65 (2)
C(3)	3435 (9)	7797 (3)	5862 (2)	61 (1)
C(4)	4154 (8)	8586 (2)	6388 (2)	49 (1)
C(5)	2823 (7)	8835 (2)	7050 (2)	46 (1)
C(6)	3572 (7)	9354 (2)	7796 (2)	46 (1)
C(7)	3466 (6)	8774 (2)	8603 (2)	40 (1)
C(8)	5603 (6)	8204 (2)	8791 (2)	41 (1)
C(9)	6110 (7)	7475 (2)	8126 (2)	47 (1)
C(10)	4132 (8)	6897 (2)	7863 (2)	49 (1)
C(11)	2836 (7)	9459 (2)	9268 (2)	46 (1)
C(12)	1660 (7)	9803 (3)	8813 (2)	51 (1)
C(13)	3191 (10)	9461 (4)	91 (3)	71 (2)
C(14)	2762 (10)	6470 (2)	8540 (3)	61 (1)
C(15)	6528 (8)	8959 (3)	6192 (3)	64 (2)

Table 2. *Bond lengths* (Å) *and valency angles* (°), *with e.s.d.'s in parentheses*

C(1)–C(2)	1·500 (6)	C(7)–C(11)	1·508 (5)
C(1)–C(10)	1·341 (6)	C(11)–C(12)	1·482 (5)
C(2)–C(3)	1·529 (7)	C(11)–C(13)	1·311 (5)
C(3)–C(4)	1·498 (6)	C(12)–O(1)	1·351 (5)
C(4)–C(5)	1·349 (5)	C(12)–O(2)	1·194 (5)
C(4)–C(15)	1·517 (7)	C(8)–O(4)	1·429 (5)
C(5)–C(6)	1·472 (5)	C(8)–C(9)	1·537 (5)
C(6)–C(7)	1·540 (5)	C(9)–C(10)	1·495 (6)
C(6)–O(1)	1·465 (5)	C(10)–C(14)	1·474 (6)
C(7)–C(8)	1·532 (5)	C(14)–O(3)	1·216 (6)
C(10)–C(1)–C(2)	128·7 (4)	C(7)–C(11)–C(13)	130·4 (3)
C(1)–C(2)–C(3)	113·5 (3)	C(13)–C(11)–C(12)	123·2 (3)
C(2)–C(3)–C(4)	108·9 (3)	C(11)–C(12)–O(1)	109·1 (3)
C(3)–C(4)–C(5)	119·0 (3)	C(11)–C(12)–O(2)	128·7 (3)
C(3)–C(4)–C(15)	115·5 (3)	O(2)–C(12)–O(1)	122·3 (3)
C(5)–C(4)–C(15)	125·0 (3)	C(12)–O(1)–C(6)	110·9 (3)
C(4)–C(5)–C(6)	126·3 (3)	O(4)–C(8)–C(7)	111·2 (3)
C(5)–C(6)–C(7)	110·4 (3)	O(4)–C(8)–C(9)	106·4 (3)
C(5)–C(6)–O(1)	111·2 (3)	C(7)–C(8)–C(9)	114·7 (3)
O(1)–C(6)–C(7)	104·4 (3)	C(8)–C(9)–C(10)	116·8 (3)
C(6)–C(7)–C(8)	116·1 (3)	C(9)–C(10)–C(1)	128·4 (3)
C(6)–C(7)–C(11)	101·5 (3)	C(9)–C(10)–C(14)	117·6 (3)
C(8)–C(7)–C(11)	116·1 (3)	C(14)–C(10)–C(1)	114·0 (3)
C(7)–C(11)–C(12)	106·4 (3)	C(10)–C(14)–O(3)	125·1 (4)

Table 3. *Torsion angles* (°) *for* (I), *alloschkuhriolide* (*present work*), *and* (II), *its parent lactone, schkuhriolide* (*Rychlewska*, 1982)

(*a*) The ten-membered ring

	(I)	(II)
C(10)–C(1)–C(2)–C(3)	92·2 (5)	-90·2 (6)
C(1)–C(2)–C(3)–C(4)	70·7 (4)	72·8 (6)
C(2)–C(3)–C(4)–C(5)	90·3 (4)	–87·2 (5)
C(3)–C(4)–C(5)–C(6)	157·1 (5)	164·9 (5)
C(4)–C(5)–C(6)–C(7)	–113·2 (4)	121·1 (5)
C(5)–C(6)–C(7)–C(8)	86·3 (4)	64·9 (4)
C(6)–C(7)–C(8)–C(9)	-64·4 (3)	38·2 (5)
C(7)–C(8)–C(9)–C(10	48·1 (4)	64·6 (4)
C(8)–C(9)–C(10)–C(1)	131·6 (5)	135·5 (5)
C(9)–C(10)–C(1)–C(2)	0·4 (6)	2·8 (6)

(*b*) The lactone ring

(I)		(II)	
O(1)–C(6)–C(7)–C(11)	27·3 (3)	O(1)–C(8)–C(7)–C(11)	35·3 (4)
C(6)–C(7)–C(11)–C(12)	24·4 (3)	C(8)–C(7)–C(11)–C(12)	30·4 (4)
C(7)–C(11)–C(12)–O(1)	12·7 (4)	C(7)–C(11)–C(12)–O(1)	14·6 (4)
C(11)–C(12)–O(1)–C(6)	5·9 (4)	C(11)–C(12)–O(1)–C(8)	9·5 (4)
C(12)–O(1)–C(6)–C(7)	21·6 (3)	C(12)–O(1)–C(8)–C(7)	29·2 (5)

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* Lists of structure factors, anisotropic thermal parameters and hydrogen-atom coordinates have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 38652 (8 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

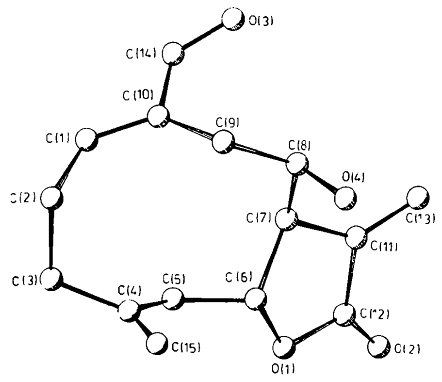

Fig. 1. View of the β face of the molecule of alloschkuhriolide and atom-numbering scheme.

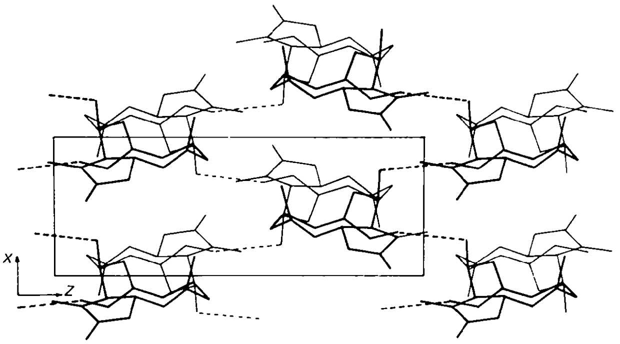

Fig. 2. Crystal structure of alloschkuhriolide projected along the b axis showing the hydrogen-bonding scheme.

The sum of the five endocyclic torsion-angle moduli is 91·9° and the asymmetry parameters (Daux & Norton, 1975) are $\Delta C_2^{6,7} = 5{\cdot}2$, $\Delta C_s^7 = 6{\cdot}6$, $\Delta C_s^6 = 13{\cdot}7°$.

A comparison of the torsion angles observed in alloschkuhriolide with the values found in schkuhriolide is shown in Table 3. Both cyclodecadiene and lactone rings exhibit almost the same type of deformation and the two molecules are very much alike. Some differences in the molecular conformation appear at the ring fusion; in order to accommodate a *cis*-fused lactone, the junction torsion angles in both rings should have nearly identical values and should ideally lie in the vicinity of 20°, corresponding to the torsion angle in the minimum-energy conformation of an isolated α-glycololactone (Guy, Sim & White, 1976). This would, however, introduce a significant amount of distortion in the ten-membered macrocycle. In schkuhriolide, a compromise is achieved in that the required flattening of the ten-membered ring is minimized by the simultaneous puckering of the γ-lactone. The necessary flattening of the cyclodecadiene ring is accomplished by closing of the junction torsion angle [−38·2 (5)°] and by the valence-angle deformation [C(7)–C(8)–C(9) 124·8 (4)°]. *trans* annelation of the lactone ring in alloschkuhriolide affects the ten-membered-ring conformation to a much lesser extent. The cyclodecadiene conformation is more closely related to those of other melampolides (Watkins, Fisher & Bernal, 1973; Kartha, Go & Joshi, 1972), and the lactone ring adopts a conformation more closely resembling the minimum-energy form (Guy, Sim & White, 1976). It may thus be concluded that the formation of alloschkuhriolide *via* the lactone rearrangement in its parent lactone, schkuhriolide, results in a certain relief of strain in the molecule without affecting the general topology of the macrocyclic skeleton.

In spite of the conformational similarities of the two molecules, their crystal packing arrangements are somewhat different. In alloschkuhriolide (Fig. 2) the hydroxyl substituent at C(8) forms an intermolecular hydrogen bond with the aldehyde oxygen atom O(3) at $x-\frac{1}{2}, -y-\frac{1}{2}, -z$. The O(4)···O(3) and H(O4)···O(3) distances are 2·973 (4) and 2·55 (5) Å, respectively, and the O(4)–H(O4)···O(3) angle is 140 (3)°. The atom H(O4) lies 0·91 (5) Å from O(4). These interactions link the molecules into helices with the long axis parallel to the crystallographic a axis. In schkuhriolide, the water of hydration participates in hydrogen bonds running along the a axis and the hydrogen-bonding network is more extensive.

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References

Duax, W. L. & Norton, D. A. (1975). *Atlas of Steroid Structure*, Vol. 1. New York: Plenum.

Germain, G., Main, P. & Woolfson, M. M. (1971). *Acta Cryst.* A**27**, 368–376.

Guy, M. H. P., Sim, G. A. & White, D. N. J. (1976). *J. Chem. Soc. Perkin Trans.* 2, pp. 1917–1920.

Jaskólski, M. (1981). *PRARA. Program for Data Reduction from Syntex Data Tapes on IBM Computers.* Univ. of Poznań, Poland.

Kartha, G., Go, K. T. & Joshi, B. S. (1972). *J. Chem. Soc. Chem. Commun.* pp. 1327–1328.

Lehmann, M. S. & Larsen, F. K. (1974). *Acta Cryst.* A**30**, 580–584.

Motherwell, W. D. S. & Clegg, W. (1978). *PLUTO78. Program for Plotting Molecular and Crystal Structures*. Univ. of Cambridge, England.

Rychlewska, U. (1982). *J. Chem. Soc. Perkin Trans.* 2, pp. 1641–1644.

Samek, Z., Holub, M., Błoszyk, E. & Drożdż B. (1979). *Z. Chem.* **19**, 449–450.

Sheldrick, G. M. (1976). *SHELX76*. Program for crystal structure determination. Univ of Cambridge, England.

Watkins, S. F., Fisher, N. H. & Bernal, I. (1973). *Proc. Natl Acad. Sci. USA*, **70**, 2434–2438.