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CYCLIZATION OF CEMBRANE DITERPENOIDS. VI. PRODUCTS OF THE CYCLIZATION OF 5β-ACETOXYISOCEMBROL

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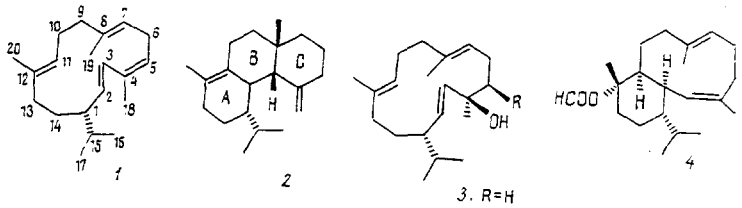
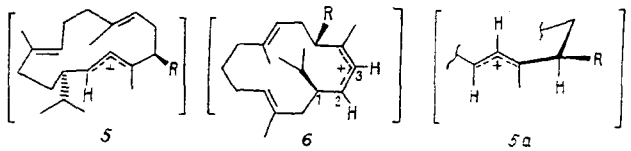
The structures and the stereochemistries of all the main products of the carbocyclization of 5β-acetoxyisocembrol on its interaction with aqueous formic acid in chloroform have been established. This reaction takes place more selectively than the cyclization of cembrene under the same conditions and is distinguished by the complete predominance in its last stage of the 1,5-hydride shift from C-15 to C-4 over the splitting out of a proton from the C(4)-methyl group.

The diterpene hydrocarbon cembrene (**1**) is very interesting from the point of view of the occurrence of processes of intramolecular cyclization in it. Under the action of $HClO_4$ in boiling aqueous acetone it gives a mixture of hydrocarbon products [1, 2] the structure of one of which (substance **2**) has been established by the XSA method. The same mixture is obtained in the analogous reaction of isocembrol (**3**) [2]. Under milder conditions ($HCOOH/H_2O/CHCl_3$, 20°C) cembrene gives a mixture of hydrocarbons, formates, and alcohols [3]. The hydrocarbon fraction of the products was not investigated, and the main formates and alcohols were compounds of a stereochemically different type from the hydrocarbon (**2**), their molecules having the *trans*-linkage of rings *B* and *C* [3, 4]. Among the formates, product (**4**) was also found in small amount, its deacyl derivative being a precursor of hydrocarbon (**2**) [5]. Although the composition of the hydrocarbon products of the cyclization of cembrene still requires refinement, it is already clear that this reaction proceeds in at least two alternative directions. In [5]



it was suggested that the cyclization took place of both the 2-*trans*,3-*trans*-cation (**5**) (R = H) formed initially and of the product of its double allyl isomerization — the 2-*cis*,3-*cis*-cation (**6**) (R = H). In this connection it may be mentioned that, as recently shown [6], in $CHCl_3$ solution the cembrene molecule retains the configuration in which it is present in the crystal [7], and, consequently, the cation (**5**) (R = H) formed through protonation at C-5 will initially be present in a similar conformation, a fragment of which has the form (**5a**). As a consideration of Dreiding models shows, the presence of a group R, different from a H atom, should substantially affect the subsequent fate of cation (**5**). It will be additionally stabilized by a pseudoequatorial orientation of this group, and isomerization into its 2-*cis*,3-*cis*- isomer will be extremely unlikely because of the pronounced overlapping of the methyl fragment of the isopropyl group and the substituent R.



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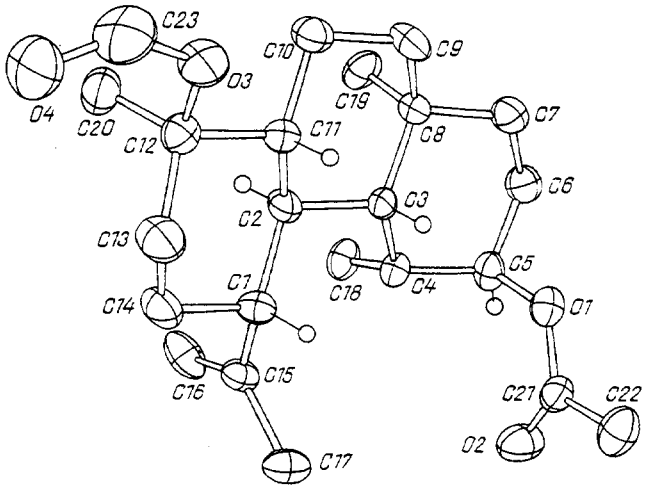
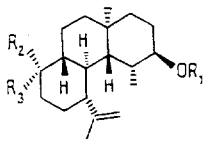


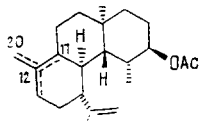
Fig. 1. Crystal structure of the diester (**8**).

A second feature of the cyclization of cembrene is the occurrence of a 1,5-hydride shift from C-15 to C-4 in its last stage, competing with the splitting out of a proton from the C(4)-methyl group [3]. In a preceding communication [8] it was shown that this shift predominates absolutely if a bromine atom is present in the 5β- position. It may be assumed that the reason for this consists of steric factors, and another voluminous group in the 5β- position will lead to a similar selectivity of the process.

In order to check these hypotheses, we have investigated the products of the interaction of 5β-acetoxyisocembrol (**7**) with HCOOH under the same conditions as were used earlier for cembrene [3]. The choice of model compound (**7**) proved to be fortunate, since the acetoxy group is a chiral marker for establishing the absolute configuration of the molecules of the products, and, judging from Dauben's results [2], the generation of the intermediate primary carbocation by the heterolysis of a C(4)–O bond is more effective than protonation at a Δ^4-double bond. In actual fact, after 10 h the initial compound could no longer be detected in the reaction mixture by TLC. The mixture of products consisted of acetates, diesters, and hydroxyacetates, and this was separated by chromatography on SiO_2, leading the isolation of compounds (**8**)-(**15**) with a combined yield of 92% of the total reaction products and 96% of the sum of the substances obtained after chromatography.



8, 9, 10, 16, 17, 18



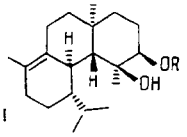
11, 12, 13

	R_1	R_2	R_3
8	Ac	OOCH	CH_3
9	Ac	CH_3	OOCH
10	Ac	OH	CH_3
16	H	OH	CH_3
17	H	CH_3	OH
18	Ac	CH_3	OH

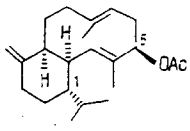
11 Δ^{11}

12 Δ^{12}, 11β-H

13 $\Delta^{12(20)}$, 11β-H



14, R = Ac
19, R = H



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The diester fraction was the main one in the mixture of reaction products and consisted of two crystalline compounds, (**8**) and (**9**) (yields 46.0 and 15.6%, respectively). The structures of their molecules were established by the XSA method, and are shown in Figs. 1 and 2. The six-membered rings in their molecules have the chair form, and in each of them the isopropyl group is equatorial and the acetoxy group axial. The torsional angles C(14)–C(1)–C(15)–C(16), C(4)–C(5)–O(1)–C(21), and C(11)–C(12)–O(3)–C(22) in the molecule of (**8**) practically coincide with those for (**9**). We may mention the increase in the lengths of the bonds as compared with the expected values [10], (Å): C(1)–C(2) — 1.573(6) and 1.55(1), C(2)–C(3) — 1.570(6) and 1.59(1), C(3)–C(4) — 1.562(6) and 1.56(1), and C(12)–C(13) — 1.500(7) and 1.46(1) for (**8**) and (**9**), respectively. This lengthening is apparently caused by steric factors.

TABLE 1. Chemical Shifts (ppm) and Multiplicities of the Signals in the ^{13}C NMR spectra of Compounds (**10**), (**18**), (**14**), and (**20**) (c = 40, 20, 30, and 40 mg/ml, respectively)

Atom	10	18	14	20
C-1	50.24 d	51.76 d	38.78 d	41.63 d
C-2	38.17 d	38.11 d	38.34 d	38.69 d
C-3	48.93 d	48.20 d	53.57 d	64.16 d
C-4	32.89 d	33.03 d	96.10 s	211.89 s
C-5	75.00 d	75.17 d	79.09 d	105.02 d
C-6	21.16 t	21.28 t	23.19 t	26.57 t
C-7	36.71 t	36.85 t	35.20 t	38.14 t
C-8	34.16 s	34.08 s	36.54 s	37.07 s
C-9	45.00 t	45.09 t	46.35 t	39.45 t
C-10	40.85 t	39.24 t	27.27 t	28.35 t
C-11	53.96 d	50.47 d	133.53 s	131.12 s
C-12	72.09 s	71.21 s	122.72 s	124.04 s
C-13	31.55 t	29.71 t	28.06 t	27.60 t
C-14	20.59 t	20.86 t	21.35 t	21.19 t
C-15	149.70 s	150.01 s	27.74 d	27.64 d
C-16	110.42 t	110.41 t	21.32 q	20.88 q
C-17	20.66 q	22.99 q	21.41 q	21.52 q
C-18	15.97 q	16.00 q	19.72 q	28.35 q
C-19	20.66 q	20.64 q	21.30 q	20.46 q
C-20	21.55 q	29.25 q	18.85 q	18.81 q
C=O	170.24 s	170.15 s	170.14 s	-
CH_3CO	21.35 q	21.43 q	21.32 q	-
CH_3O	-	-	-	52.56 q
CH_3O	-	-	-	52.70 q

The structure of the diacetate (**10**) (yield 4.1%) was shown by the synthesis of this compound from (**8**) by reduction with lithium tetrahydroaluminate in diethyl ether to the diol (**16**), followed by acetylation with acetic anhydride in pyridine at 0°C. Analogously, the hydroxyacetate (**18**) was obtained from the diester (**9**) via the diol (**17**), and we used it as a marker in the search (TLC, PMR, GLC) for this compound among the minor products of the cyclization of (**7**). It was established that it was actually present in the mixture of cyclization products, but its amount was less than 1%, which correlates with the relative amount of products (**8**)-(**10**).

The ^{13}C NMR spectrum (Table 1) and the ^{1}H NMR spectrum of the hydroxyacetate (**18**) were interpreted with the use of two-dimensional $^{13}C-^{1}H$ (COSY, COLOC) and $^{1}H-^{1}H$ (COSY, COSYLR) NMR spectra. The following important SSCC in the PMR spectrum may be mentioned: $J_{1,2}$ = 1.5 Hz, $J_{2,11}$ = 9.0 Hz, $J_{2,3}$ = 10.5 Hz, $J_{3,4}$ = $J_{4,5}$ = 4 Hz, and also the presence of of long-range spin-spin coupling (SSC) of the W type [11] between H-4 and H-6β, between 3H-19 and H-3, between H-7β, and H-9β, and between H-5 and H-7α, which, independently of the XSA results for (**8**) and (**9**), show the *trans*-linkage of rings *B* and *C*, present in the chair conformation, and the axial orientations of the H-1 proton, the secondary methyl group, and the formate group. The ^{13}C NMR sectrum (Table 1) and the ^{1}H NMR spectrum of the hydroxyacetate (**10**) were interpreted analogously, using the results for (**18**).

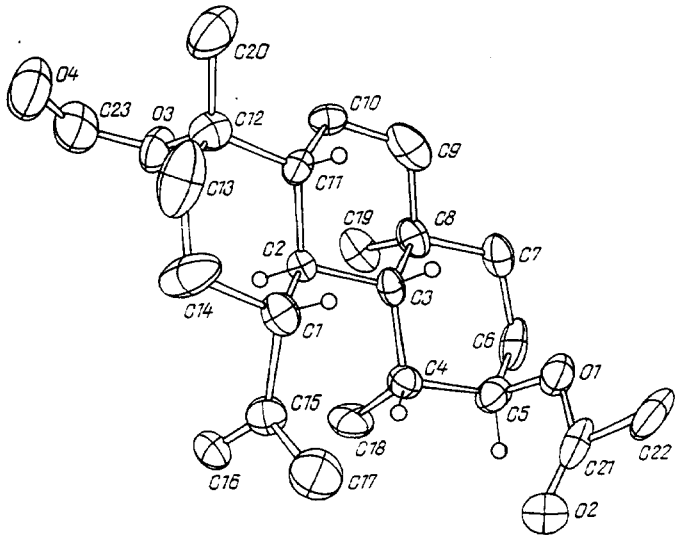
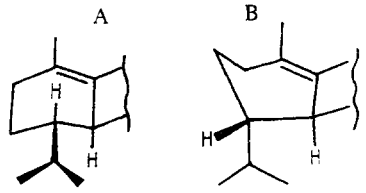


Fig. 2. Crystal structure of the diester (**9**).

The acetates (**11**)-(**13**) were isolated with yields of 4, 1, and 3%, respectively, by the chromatography on SiO_2 + 5% of $AgNO_3$ of the total mixture of acetates produced by the cyclization of (**7**). Their structures were shown by the fact that they were formed on mild dehydration of the hydroxyacetate (**10**) by $POCl_3$ in pyridine at 0°C. The acetate (**11**) was undoubtedly a secondary product and was formed from the hydroxyacetate (**10**), since under the conditions of the cyclization of (**7**) it underwent 14% conversion into a mixture of the acetates (**11**)-(**13**) containing 90% of compound (**11**) (PMR spectrum). Under the same conditions, hydroxyacetate (**18**) gave 16.7% of a mixture of the actetates (**11**)-(**13**) (6:1:1).

The structure of the molecule of the liquid product (**14**) (yield 17.4%) was established by two-dimensional $^{13}C-^{1}H$ (COSY, COLOC) and $^{1}H-^{1}H$ (COSY, COSYLR) NMR spectroscopy. The observation in the $^{1}H-^{1}H$ COSY spectrum of cross-peaks between 3H-19 and H-3, H-7β, and H-9β; between 3H-20 and H-2, H-10β, and H-13a; between H-5 and H-7α; and between 3H-18 and H-3 proved to be important for the interpretation of the ^{13}C and ^{1}H NMR spectra (Tables 1 and 2) of the (**14**) molecule and the determination of its stereochemistry. The existence of SSC beteen H-1 and H-2 (SSCC less than 1 Hz) was observed only in the $^{1}H-^{1}H$ COSY spectrum and did not appear clearly in the form of signals for these protons in the PMR spectrum. The H-2 signal had the form of a doublet ($J_{2,3}$ = 10.7 Hz) with broad components ($W_{1/2}$ = 5 Hz). A consideration of Dreiding models showed that ring *A* in the (**14**) molecule may adopt two conformations, in one of which the isopropyl group is pseudoequatorial (conformation *A*) while in the other it is pseudoaxial (conformation *B*). Calculation by the method of molecular mechanics (the MMX method) of the optimized conformations *A* and *B* of the (**14**) molecule showed that the strain energies for them were 40.7 and 37.1 kcal/mole, respectively, and the barrier



to the conformational transition between them (ΔH^{*}) was $\approx$ 15 kcal/mole. Thus, the calculated figures show that ring *A* in the (**14**) molecule should be present in the energetically more favorable *B* conformation. In it the dihedral angle H−C(1)−C(2)−H is about 90° and, consequently $J_{1,2}$ will be less than 1 Hz, which agrees with experiment. By using the parameters of conformations *A* and *B* and a modified Karplus equation [12], we found that for the *A* conformation the values of $J_{1,2}$, $J_{1,15}$, and $J_{2,3}$ were 9.5, 0.5, and 12.3 Hz, , and for *B* 0.9, 11.6, and 13.2, respectively. The experimental values of these SSCC (less than 1 Hz, 10.5, and 13.7 Hz) are close to those calculated for the *B* conformation with a pseudoaxial isopropyl group.

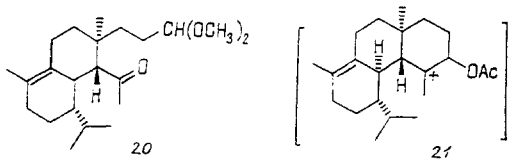


TABLE 2. CS (ppm), Multiplicities, and SSCC (Hz, shown in parentheses) for the Signals in the PMR Spectra of Compounds (**14**) and (**20**)

Hi	14	20
H-1	2.16 br.dt (10.5; 3.4; 3.4)	0.74 br.dt (9.5; 3.5; 3.5)
H-2	2.24 br.d (10.7)	2.44 br.d (11.5)
H-3	1.63 d (10.7)	2.64 d (11.5)
H-5	4.58 t (2.9)	4.24 t (5.6)
H-6a	1.87 m	1.57 m
H-6б	1.73 m	1.57 m
H-7β	1.36 ddd (13.0; 13.0; 5.0)	1.25 m
H-7α	1.12 br.d (13.0)	1.25 m
H-9α	1.40 ddd (13.0; 4.0; 2.8)	1.50 m
H-9β	1.16 ddd (13.0; 13.0; 4.0)	1.20 m
H-10β	2.48 ddd (13.0; 4.0; 2.8)	2.45 ddd (13.0; 4.0; 4.0)
H-10α	1.85 m	1.81 m
H-13a	1.94 m	1.95 m
H-13б	1.72 br.dd (13; 6)	1.95 m
H-14a	1.62 m	1.60 m
H-14б	1.57 m	1.55 m
H-15	1.49 septet d (6.6; 10.5)	1.45 septet d (6.6; 9.5)
3H-16	0.91 d (6.6)	0.83 d (6.6)
3H-17	0.96 d (6.6)	0.87 d (6.6)
3H-18	1.24 s	2.10 s
3H-19	1.09 br.s	1.07 s
3H-20	1.60 br.s	1.58 br.s
$OCOCH_3$	2.10 s	–
OCH_3	–	3.27 s
OCH_3	–	3.28 s

In order to confirm the vicinal arrangement of the oxygen-containing substituents in the (**14**) molecule, we performed the following chemical transformations. The reduction of the hydroxyacetate (**14**) with lithium tetrahydroaluminate in diethyl ether gave the diol (**19**), which, under the action of HIO_4 was converted quantitatively into the dimethyl acetal (**20**), the ^{13}C and ^1H NMR spectra of which (Tables 1 and 2) were interpreted by the use of $^{13}C-^1H$ and $^1H-^1H$ two-dimensional spectra.

On considering the PMR spectrum of (**20**), three features of it may be noted — the retention of the form of the H-1 and H-2 signals (in comparison with the PMR spectrum of (**14**)), the powerful screening of the H-1 proton (δ 0.74 ppm, as compared with 2.16 ppm for (**14**)), and the magnetic nonequivalence of the ^1H and ^{13}C nuclei of the methoxy groups separated from the asymmetric center at C-8 by a sterically unhindered chain of four atoms. The retention of the forms of the signals for H-1 and H-2 on passing from (**14**) to (**20**) showed that ring *A* had the same conformation in the two molecules and that the reason for the realization of this conformation with a pseudoaxial isopropyl group is the presence of the Δ^{11} double bond.

The acetate (**15**) was obtained in low yield (1%). By means of $^1H-^1H$ two-dimensional NMR (COSY) the fragment from C(2)H to C(8) with two double bonds was revealed in its molecule. These bonds had the (*E*)- configuration, as was established on the basis the CSs for C-18 and C-19 (15.34 and 15.59 ppm, see [13]). The presence of this fragment and of

TABLE 3. Coordinates ($\times 10^4$, in fractions of the cell) and Temperature Factors ($\times 10^3$, $Å^2$) of the Nonhydrogen Atoms in the Diesters (**8**) and (**9**)

Atom	x	y	z	U eq
		The diester (**8**)		
C1	2754 (8)	3608 (3)	6492 (2)	47
C2	1661 (7)	4576 (3)	6685 (2)	41
C3	1176 (7)	5277 (3)	6178 (2)	39
C4	3 (7)	4809 (3)	5675 (2)	46
C5	−16 (7)	5525 (4)	5177 (2)	51
C6	−807 (9)	6528 (4)	5321 (2)	63
C7	258 (10)	6951 (4)	5831 (2)	65
C8	323 (8)	6300 (3)	6344 (2)	48
C9	1738 (9)	6754 (3)	6794 (2)	58
C10	2060 (9)	6109 (4)	7292 (2)	57
C11	3010 (7)	5128 (3)	7097 (2)	43
C12	3759 (9)	4513 (4)	7605 (2)	55
C13	4934 (11)	3638 (4)	7382 (2)	69
C14	3597 (10)	3041 (4)	6990 (2)	63
C15	1540 (10)	2864 (3)	6160 (2)	57
C16	−213 (11)	2498 (4)	6335 (3)	78
C17	2512 (11)	2468 (5)	5629 (2)	84
C18	−2092 (8)	4436 (4)	5781 (2)	58
C19	−1819 (8)	6255 (5)	6607 (2)	63
C20	2121 (10)	4256 (5)	8018 (2)	73
C21	2763 (8)	5011 (4)	4599 (2)	52
C22	4856 (8)	5210 (5)	4440 (2)	72
C23	6209 (12)	4921 (6)	8343 (3)	93
O1	2052 (5)	5658 (3)	4964 (1)	55
O2	1812 (7)	4323 (3)	4425 (2)	82
O3	5232 (7)	5201 (3)	7877 (1)	70
O4	6212 (11)	4173 (4)	8583 (2)	109
C1	8223 (19)	7019 (5)	3084 (5)	60
C2	7313 (14)	6290 (5)	2722 (4)	37
C3	7080 (17)	5570 (5)	3229 (5)	46
C4	5738 (16)	5757 (6)	3874 (5)	50
C5	5845 (18)	5075 (7)	4375 (5)	59
C6	5264 (20)	4310 (7)	4068 (6)	79

TABLE 3 (continued)

Atom	x	y	z	U_{eq}
		The diester (**9**)		
C7	6563 (19)	4157 (6)	3410 (5)	66
C8	6477 (17)	4819 (6)	2884 (6)	53
C9	8095 (21)	4638 (6)	2316 (7)	85
C10	8352 (21)	5275 (6)	1810 (5)	64
C11	8862 (17)	6059 (6)	2145 (5)	50
C12	9279 (18)	6676 (8)	1610 (6)	64
C13	9942 (26)	7410 (9)	1959 (9)	132
C14	8779 (26)	7638 (7)	2533 (7)	114
C15	6881 (21)	7449 (6)	3611 (5)	59
C16	5051 (21)	7707 (7)	3478 (6)	76
C17	7969 (25)	7653 (7)	4266 (6)	106
C18	3496 (16)	5967 (7)	3761 (6)	75
C19	4329 (17)	4821 (6)	2537 (6)	79
C20	10915 (20)	6444 (9)	1098 (6)	114
C21	8480 (21)	5446 (9)	5195 (6)	71
C22	10572 (20)	5224 (8)	5408 (5)	94
C23	7076 (25)	7267 (9)	752 (9)	114
O1	7929 (12)	4961 (4)	4637 (4)	66
O2	7395 (17)	5907 (5)	5431 (4)	96
O3	7310 (13)	6769 (5)	1258 (4)	75
O4	8296 (19)	7686 (7)	495 (6)	139

isopropyl and exomethylene groups (PMR spectrum), and the multiplicities of the signals of sp^3-hybridized C atoms in the ^{13}C NMR spectrum permitted the proposal for the compound under consideration of structure (**15**), similar to the structure of the formate (**4**). obtained previously from cembrene [5]. The sum of the SSCCs $J_{1,2}$ and $J_{2,11}$ amounted to about 4 Hz, which excludes a *trans*-linkage of the rings in the (**15**) molecule. The inadequate amount of the sample available to us did not allow us to perform a complete analysis of the PMR spectrum for a reliable establishment of its structure.

It is interesting to note that the addition of one drop of 85% HCOOH to the NMR bulb (solution of (**15**) in $CDCl_3$) caused no change in the acetate (**15**) over a day. A consideration of Dreiding models showed that it is just the *cis*-linkage of the rings in the molecule that weakens some steric strain of the 10-membered ring and the inconvenient arrangement for cyclization of the trisubstituted double bonds.

Thus, the three tricyclic reaction products of the hydroxyacetate (**7**) have the *trans*-linkage of rings *B* and *C* and cannot have the 2-*cis*,3-*trans*- cation (**6**) (R = OAc) as precursor. The presence of the 5β-OAc group weakens the predominance of the 1,5-hydride shift over the splitting out of a proton from Me-18 in the last stage of cyclization. The absence of such a process in the formation of compound (**14**) only confirms its realization on the formation of products (**8**)-(**10**), since, in carbocation (**21**) — the precursor of the hydroxyacetate (**14**) — this shift is impossible because of the pseudoaxial orientation of the isopropyl group and, accordingly, the remoteness of H-15 from the carbocationic center at C-4.

EXPERIMENTAL

NMR spectra were recorded om a Bruker AM-400 instrument (400.13 MHz for ^1H and 100.614 MHz for ^{13}C) for solutions in $CDCl_3$ (CSs — relative to the residual signals of the solvent — 7.24 ppm for ^1H and 76.90 ppm for ^{13}C, δ scale).

The COLOC and the homo- and heteronuclear COSY experiments were carried out by standard Bruker programs. IR spectra were recorded for solutions in CCl_4 on a UR-20. Angles of optical rotation were measured on a POLAMAT A polarimeter for solutions in $CHCl_3$. Melting points were determined on a Kofler stage. For chromatography we used "Armsorb" brand silica gel (the firm of Akunk, Erevan), the eluent being a mixture of petroleum ether (PE) and diethyl ether (DE). The starting compound (**7**) was obtained from cembrene as described in (**9**).

Interaction of Compound (7) with HCOOH and Isolation of the Products. A solution of 1.09 g of the ester (**7**) in 20 ml of $CHCl_3$ was treated with 20 ml of 85% HCOOH, and the mixture was stirred for 2 h at 20°C, after which it was left overnight in a refrigerator (+5°C). After the reaction mixture had been worked up as described in [3], followed by chromatography (eluent — PE containing from 3 to 30% of DE), 0.13 g of an acetate fraction, 0.17 g of the diester (**9**), 0.50 g of the diester (**8**), 0.045 g of the hydroxyester (**10**), 0.01 g of a mixture of products, and 0.19 g of the hydroxyester (**14**) were obtained successively. By chromatographing the acetate fraction on SiO_2 + 5% of $AgNO_3$, we isolated successively 0.03 g of a mixture of unidentified products, 0.01 g of the acetate (**12**), 0.04 g of the acetate (**11**), 0.03 g of the acetate (**13**) and 0.01 g of the acetate (**15**) (eluent — PE with 1-3% of DE).

(1R,2R,3R,4R,7S,10R,11R,14R)-4-Acetoxy-11-formyloxy-14-isopropenyl-3,7,11-trimethyltricyclo-[8.4.0.0^{2,7}]-tetradecane (8)*. Crystals with mp 89-90°C (from hexane), $[\alpha]_{580}^{20}$ −20.0°C (c 0.60).

(1R,2R,3R,4R,7S,10R,11S,14R)-4-Acetoxy-11-formyloxy-14-isopropenyl-3,7,11-trimethyltricyclo[8.4.0.0^{2,7}]-tetradecane (9). Crystals with mp 106-107°C (from hexane), $[\alpha]_{580}^{20}$+52.2° (c 0.31).

The X-Ray Structural Investigation of Compounds (8) and (9) was conducted on a SYNTEX $P2_1$ diffractometer (CuK_α radiation, $\theta/2\theta$ scanning, $2\theta < 120$ for (**8**), $2\theta < 114$ for (**9**). The crystals of (**8**) were rhombic: a = 6.627(1), b = 1.3623(3), c = 23.729(5)Å, V = 2143.7(8)Å^3, space group, $P2_12_12_1$, $C_{23}H_{36}O_4$, Z = 4, d_{calc} = 1.17 g/cm^3.

The crystals of (**9**) were also rhombic: a = 6.488(3), b = 17.191, c = 19.434(11)Å, V = 2167(2)Å^2, space group, $P2_12_12_1$, $C_{23}H_{36}O_4$, Z = 4, d_{calc} = 1.15 g/cm^3.

Corrections were made to the absorption in the light of the real form of the crystals (transmission 0.87-0.95 for (**8**) and 0.94-0.98 for (**9**). The structure was interpreted by the direct method and was refined in the full-matrix anisotropic approximation to R = 0.058. R_w = 0.067, S = 0.6, 1441 reflections with $I > 2\sigma$ for (**8**), and to R = 0.069, R_w = 0.069, S = 1.6, 967 reflections with $I > 2\sigma$ for (**9**) (SHELX 76 and SHELX 86 programs). The positions of the hydrogen atoms were calculated geometrically and were not refined. The atomic coordinates obtained are given in Table 3.

(1R,2R,3R,4R,7S,10R,11R,14R)-4-Acetoxy-14-isopropenyl-3,7,11-trimethyltricyclo[8.4.0.0^{2,7}]tetradecan-11-ol (10). Crystals, mp 123.5-124.5°C (from hexane), $[\alpha]_{580}^{20}$ — 26.2° (c 0.33). PMR spectrum: 0.77 (3H, d, J = 7.0 Hz, Me-4), 0.90, 1.16, 1.75 and 2.04 (each 3H, singlets, Me-8, Me-12, Me-15 and $OCOC\underline{H}_3$, respectively), 1.05 (1H, ddd, J = 12.4, 10.5 and 3.5 Hz, H-1), 1.16 (1H, dd, J = 10.5 and 4.0 Hz, H-3), 1.65 (1H, m, H-11), 2.16 (1H, m, H-4), 4.65 and 4.71 (each 1H, narrow multiplets, $C{=}C\underline{H}_2$), 4.69 (1H, br.q., J = 3 Hz, H-5) ppm. IR spectrum: 1740 (C=O), 3610 (OH) cm^{-1}. For the ^{13}C NMR spectrum, see Table 1.

Synthesis of the Hydroxyester (10) from the Diester (8). A solution of 0.05 g of (**8**) in 30 ml of DE was treated with 0.05 g of lithium tetrahydroaluminate, and the mixture was stirred at 20°C for 1 h. After the usual working up, 0.04 g of the diol (**16**) was obtained (IR spectrum: no absorption bands of C=O groups) and then a solution of this in 10 ml of Py and 5 ml of Ac_2O was left at 20-22°C for 12 h. After the usual working up and chromatography, 0.03 g of substance (**10**) with mp 123-124°C (from hexane) was isolated, its PMR spectrum coinciding with that for a sample obtained after the reaction of (**7**) with HCOOH.

The hydroxy ester (18) was obtained analogously from the diester (**9**). Yield 0.01 g from 0.02 g of (**9**). Oil; IR spectrum: 1740 (C=O), 3610 (OH) cm^{-1}. PMR spectrum: 0.79 (3H, d, J = 7.2 Hz, Me-4), 0.91, 1.18 and 2.03 (each 3H, singlets, Me-8, Me-12 and $OCOC\underline{H}_3$, respectively), 1.72 (3H, br.s, Me-15), 4.70 and 4.72 (each 1H, narrow multiplets, $C{=}C\underline{H}_2$).

The Acetate (11). Oil; PMR spectrum: 0.84 (3H, d, J = 7.0 Hz, Me-4), 1.08 (3H, s, Me-8), 1.17 (1H, ddd, J = 13.0, 13.0 and 4.0 Hz, H-9a), 1.25 (1H, m, H-7a), 1.40 (1H, m, H-7b), 1.57 (3H, br.s, Me-12), 1..63 (1H, br.d, J = 4.0 Hz, H-3), 1.72 (3H, br.s, Me-15), 2.02 (3H, s, $OCOG\underline{H}_3$), 2.12 (1H, br.d, J = 11.5 Hz, H-2, 2.19 (1H, br.ddd, J = 10.5, 3.4 and 3.4 Hz, H-1), 2.49 (1H, ddd, J = 14.0, 3.5 and 3.5 Hz, H-10a), 4.61 and 4.78 (each 1H, narrow multiplets, $C{=}C\underline{H}_2$), 4.83 (1H, br.q, J = 3 Hz, H-5) ppm.

*The numbering of the atoms adopted for the cembranoids is used.

The Acetate (12). Oil; PMR spectrum: 0.73 (3H, d, J = 7.0 Hz, Me-4), 0.91, 1.61, 1.72 and 2.08 (each 3H, singlets,, Me-8, Me-12, Me-15 and $OCOC\underline{H}_3$ respectively), 4.54 and 4.61 (each 1H, narrow multiplets, $C{=}C\underline{H}_2$), 4.77 (1H, br.q, J = 3 Hz, H-5), 5.58 (1H, m, H-13) ppm.

The Acetate (13). Oil; PMR spectrum: 0.77 (3H, d, J = 77.0 Hz, Me-4), 0.90, 1.72 and 2.06 (each 3H, singlets, Me-8, Me-15 and $OCOC\underline{H}_3$ respectively), 4.67 and 4.70 (each 1H, narrow multiplets, $C(16)H_2$), 4.65 and 4.67 (each 1H, narrow multiplets, $C(20)H_2$), 4.71 (br.q, J = 3 Hz H-5) ppm.

(1S,2R,3R,4R,7S,14S)-5-Acetoxy-14-isopropyl-3,7,11-trimethyltricyclo[8.4.0.$0^{2,7}$]tetradec-10-en-4-ol (14). Oil with $[\alpha]_{580}^{20} -97°$ (c 0.68); IR spectrum, cm^{-1}: 1740 (C=O), 3600 (OH). For the PMR spectrum, see Table 2, and, for the ^{13}C NMR spectrum, Table 1.

The Dimethyl Acetal (20). A solution of 0.045 g of (**14**) in 20 ml of DE was treated with 0.1 g of lithium tetrahydroaluminate. After being stirred at 20°C for 1 h, the mixture was worked up in the usual way, to give 0.026 g of diol (**19**), 0.007 g of which was dissolved in 5 ml of MeOH. The resulting solution was treated with 70 mg of HIO_4 in 10 ml of MeOH and the mixture was heated to 35°C for 1 h, after which it was poured into saturated aqueous NaCl solution. The product was extracted with DE, and, after chromatography on SiO_2, 0.006 g of the dimethyl acetal (**20**) was obtained in the form of an oil. IR spectrum, cm^{-1}: 1705 (C=O). For the ^{13}C and ^1H NMR spectra, see Tables 1 and 2, respectively.

Dehydration of the Hydroxyesters (10) and (18). a) At 0°C, 0.2 ml of $POCl_3$ was added to a solution of 0.30 g of (**10**) in 10 ml of Py and the resulting mixture was left at 0°C for 12 h. After the usual working up and chromatography of the product on SiO_2, 0.012 g of a mixture of the acetates (**11**)-(**13**) (4:1:3) was obtained.

b) A solution of 0.050 g of (**10**) in 5 ml of $CHCl_3$ was treated with 5 ml of 85% aqueous HCOOH, and the mixture was stirrd at 20°C for 2 h and was then left at +5°C for 12 h. After the usual working up and chromatography on SiO_2 0.006 g of a mixture of (**11**)-(**13**) (14:1:0.5, according to the PMR spectrum) was isolated. Analogously, 0.030 g of (**18**) gave 0.008 g of a mixture of acetates (**11**)-(**13**) (6:1:1, PMR spectrum).

The Acetate (15). Oil; PMR spectrum: 0.84 and 0.89 (each 3H, doublets, J = 7.0 Hz each, 2Me-15), 1.45, 1.49 (each 3H, br. singlets, Me-8 and Me-4 respectively), 2.11 (3H, s, $OCOC\underline{H}_3$), 1.71 (1H, m, H-1), 2.21 (1H, m, H-6a, 2.40 (1H, ddd, J = 14.5, 11.5 and 3.5 Hz, H-6b), 3.09 (1H, br.dd, H-2, $J_{2,3}$ = 7.5 Hz, J = 3.0 Hz), 4.52 and 4.57 (each 1H, br. singlets, $C{=}C\underline{H}_2$), 4.94 (1H, br.d, J = 11.5 Hz, H-7), 5.18 (1H, t, J = 3.0 Hz, H-5), 5.50 (1H, br.d, J = 7.5 Hz, H-3) ppm. ^{13}C NMR spectrum: singlets at 169.79 ($OCOCH_3$), 153.10 C-4), 136.20 (C-8), 132.39 (C-12) ppm, doublets at 128.49, 121.56, 76.36 (C-5), 47.33, 46.61, 38.99, 28.84 ppm; triplets at 103.36 (C-20), 33.44, 30.92, 29.64, 25.98 and 25.26 ppm; quartets at 21.27 ($OCO\underline{C}H_3$ and C-16), 20.78 (C-17), 15.59 and 15.34 C-18, C-19) ppm.

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