199. *Studies in the Synthesis of Terpenes. Part VIII.* The Absolute Configuration of Elemol.*

By T. G. HALSALL, D. W. THEOBALD, and K. B. WALSHAW.

The absolute configuration of elemol has been proved to be as shown in formula (V) by a synthesis of eleman-2,3,11-triol (XXXIII) from (+)-epi-α-cyperone (XI), a sesquiterpene of known absolute configuration.

ELEMOL is a crystalline, unsaturated, tertiary-alcoholic sesquiterpene which has structure (I).[1,2] No decisive proof of its absolute configuration has been published. An indication of its relative stereochemistry is given by the formation of the lactone (III) from dihydroelemol (II), while the isolation [3] of eudesmane (IV) on hydrogenation of the mixed hydrocarbons obtained by pyrolysis of elemyl benzoate or *p*-nitrobenzoate suggests, but does not prove, that the absolute configuration is as in structure (V). This has now

---

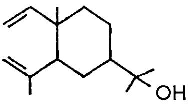
* Part VII, *J.*, 1961, 4211.

[1] Ruzicka and Pfeiffer, *Helv. Chim. Acta*, 1962, **9**, 841; Ruzicka and van Veen, *Annalen*, 1929, **476**, 70.

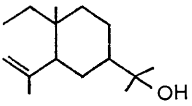
[2] Sýkora, Herout, Pliva, and Šorm, *Coll. Czech. Chem. Comm.*, 1954, **19**, 124; Sýkora, Černy, Herout, and Šorm, *ibid.*, p. 566; Sýkora, Herout, and Šorm, *ibid.*, 1955, **20**, 220.

[3] Wicki, Kalvoda, and Jeger, *Croat. Chem. Acta*, 1957, **29**, 263.

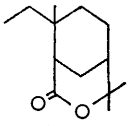
been proved by relating elemol to the sesquiterpene (+)-epi-α-cyperone (XI) of known absolute configuration. Elemol has, therefore, the stereochemistry of the eudesmane group of sesquiterpenes,[4] such as β-eudesmol (VI) and santonin (VII). The nomenclature used is based upon the hydrocarbons eudesmane (IV) and elemane (VIII).



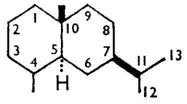
(I)



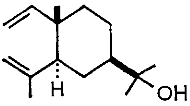
(II)



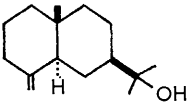
(III)



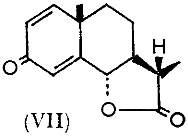
(IV)



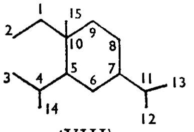
(V)



(VI)



(VII)



(VIII)

(+)-Epi-α-cyperone (XI) was chosen as a suitable starting point for the preparation of an elemol derivative of known configuration because of its availability. It was initially prepared by a modification of McQuillin's method,[5] from (—)-dihydrocarvone (IX), 1-diethylaminopentan-3-one methiodide, and sodamide in ether–pyridine to give the ketol (X), dehydration of which gave (+)-epi-α-cyperone. It was later found that the yield of ketol was much improved by using (—)-dihydrocarvone, 1-chloropentan-3-one, and sodium hydride in tetrahydrofuran. The absolute configuration of (—)-dihydrocarvone has been rigorously proved.[6,7] The evidence for the stereochemistry of the ketol (X) is mainly due to McQuillin.[5] In particular it was suggested on the grounds of conformational analysis and the resistance of the double bond of the isopropenyl side-chain to migration induced by hydrogenation catalysts that the ketol existed as the " non-steroidal " conformer (XII). This conformation is supported [8] by the rotatory dispersion curve of the ketol ($a = +97°$) now recorded.

The ready isolation of the ketol (X) rather than the dehydration product (XI) can be explained on the grounds that its dehydration might be slow because of the necessity of proceeding *via* the unfavourable conformer (XIII) which is subject to severe steric compression. Recently, however, it has been found that in the reaction of ethyl 2-oxocyclohexanecarboxylate and methyl vinyl ketone the dehydration is much slower than the initial alkylation.[9]

The ketol (X) was smoothly dehydrated at 0° in ethanolic hydrochloric acid. At 20° 5% of (+)-eudesma-4,6-dien-3-one (XIV) was detected spectroscopically. Its formation presumably reflects the relief of strain which occurs when C-7 becomes trigonal and the side-chain is no longer axial. The reduction of the ketone (XI) with lithium in liquid ammonia gave the saturated ketone (XV) with a *trans* ring-fusion.[10] Prolonged reaction with this reagent in the presence of ethanol led to reduction of the isopropenyl group as well as of the enone system. Only a few examples of the reduction of isolated double bonds are known.[11]

With the formation of the *trans* ring-fusion accomplished the next stage was the

---

[4] Cocker and McMurry, *Tetrahedron*, 1960, **8**, 181.

[5] McQuillin, *J.*, 1955, 528; Howe and McQuillin, *J.*, 1955, 2423; 1956, 2671.

[6] Hückel, *J. prakt. Chem.*, 1941, **157**, 225; *FIAT Review of Theor. Org. Chem.*, 1948, Pt. 1 (1939—1946), 58; Birch, *Ann. Reports*, 1950, **47**, 191.

[7] Fredga and Leskinen, *Arkiv Kemi, Min. Geol.*, 1945, **19***B*, No. 1; Fredga, *ibid.*, 1946, **23***B*, No. 2; 1947, **24***A*, No. 32; *Acta Chem. Scand.*, 1947, **1**, 371; *Tetrahedron*, 1960, **8**, 126; Freudenberg and Lwowski, *Annalen*, 1955, **594**, 76.

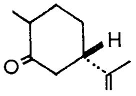
[8] Cf. Djerassi, " Optical Rotatory Dispersion," McGraw-Hill Book Co., Inc., New York, 1960, p. 185.

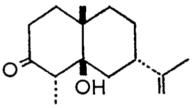
[9] Ferry and McQuillin, *J.*, 1962, 103.

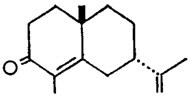
[10] Barton and Robinson, *J.*, 1954, 3045; Birch, Smith, and Thornton, *ibid.*, 1957, 1339.

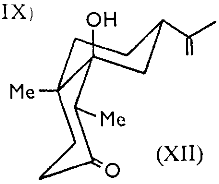
[11] King, *J.*, 1951, 898; Greenfield, Friedel, and Orchin, *J. Amer. Chem. Soc.*, 1954, **76**, 1258.

development of a method for epimerising the side-chain at C-7. The ketone (XV) was converted in high yield with osmium tetroxide in pyridine into the diol (XVI) which was oxidised with sodium metaperiodate to the norketone (XVII). The acetyl group of this norketone is in the less stable axial conformation and was epimerised easily by hot dilute ethanolic sulphuric acid to the more stable equatorial conformation. The resulting diketone (XVIII) was identical with a ketone prepared by Simonsen and his co-workers [12] from natural α-cyperone; its structure is therefore securely established.

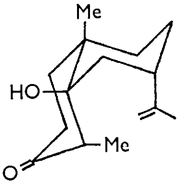

(IX)


(X)

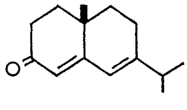

(XI)

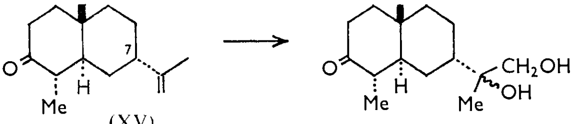


(XII)

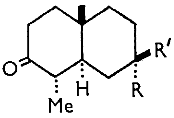


(XIII)


(XIV)



(XV) (XVI)



(XVII : R = COMe ; R' = H)
(XVIII : R = H ; R' = COMe)

The scission of the 2–3 bond in ring A was the next objective. Oxidation of a 3-oxo-derivative with per-acid to a lactone [13] appeared a possibility. This reaction, however, does not appear to depend on the preferred direction of enolisation of the ketone, which in the case of compounds with partial structure (XIX) should be in the desired C-2 direction. In fact, the mechanism suggested for the reaction predicts the formation of the lactone of type (XX) rather than (XXI). This was confirmed in the case of the oxidation of 4α-methylcholestan-3-one with perfluoroacetic acid. The resulting lactone was reduced with lithium aluminium hydride to a diol which was oxidised with chromic acid to an oxo-acid, the methyl ester of which had absorption bands of equal intensity at 1745 and 1710 cm.$^{-1}$. The lactone must therefore have the partial structure (XX).

A more promising approach was suggested by the preferred directions of enolisation of 3-ketosteroids. Those with a *trans* fused A/B ring-junction give Δ^2-enes, and enol acetylation of 3-oxo-5α-steroids might be expected to give 3-acetoxy-2-enes. The situation in practice, however, is not as simple as this.[14] In particular, of the two enol acetates formed from the system (XIX), the isomer (XXII) is the thermodynamically more stable, and despite the initial preferential formation of the isomer (XXIII) the final reaction product is usually a mixture of the two. The proportion of the enol acetate (XXII) can be minimised by using isopropenyl acetate and toluene-*p*-sulphonic acid as reagent.

The diol (XVI) was acetylated first with acetic anhydride–pyridine to the 12-monoacetate and then with isopropenyl acetate and toluene-*p*-sulphonic acid at 20° [15] to the diacetate. Enol acetylation with the isopropenyl acetate reagent gave only the enol

---

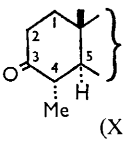
[12] Bradfield, Hedge, Rao, Simonsen, and Gillam, *J.*, 1936, 672.

[13] Baeyer and Villiger, *Ber.*, 1899, **32**, 362; Hassall, *Org. Reactions*, 1957, **9**, 75; Doering and Speers, *J. Amer. Chem. Soc.*, 1950, **72**, 5515; Doering and Dorfmann, *ibid.*, 1953, **75**, 5595; Wilt and Danielzadeh, *J. Org. Chem.*, 1958, **23**, 920; Hawsthorne, Emmons, and McCallum, *J. Amer. Chem. Soc.*, 1958, **80**, 6393; Prelog, Ruzicka, Meister, and Wieland, *Helv. Chim. Acta*, 1945, **28**, 618; Ruzicka, Prelog, and Meister, *ibid.*, p. 1651.

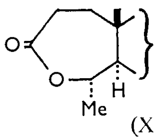
[14] Berkoz, Chavez, and Djerassi, *J.*, 1962, 1323; Hartshorn and Jones, *J.*, 1962, 1312.

[15] Oliveto, Gerold, Hershberg, Weber, Jorgensen, and Rausser, *J. Amer. Chem. Soc.*, 1953, **75**, 5486.

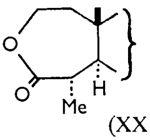
acetate (XXIV). Ozonolysis of this followed by oxidative fission of the ozonide with hydrogen peroxide gave an acid whose dimethyl ester (XXV) showed complete absence of ketonic carbonyl absorption in its infrared spectrum. The ester was reduced with lithium aluminium hydride to the tetraol (XXVI) which gave the oxo-diol (XXVII) with sodium metaperiodate in aqueous ethanol. This oxo-diol was heated under reflux in ethanolic sulphuric acid to epimerise the 7-acetyl group to the more stable equatorial conformation, the oxo-diol (XXVIII) being formed.



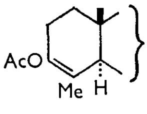
(XIX)



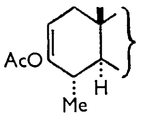
(XX)



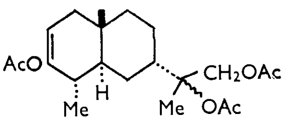
(XXI)



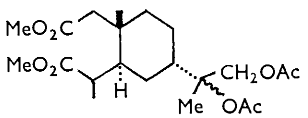
(XXII)



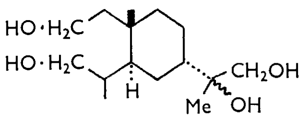
(XXIII)



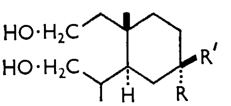
(XXIV)



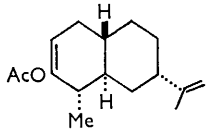
(XXV)



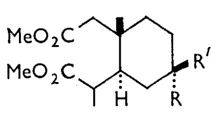
(XXVI)



(XXVII : R = COMe, R' = H)
(XXVIII : R = H, R' = COMe)

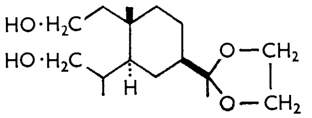


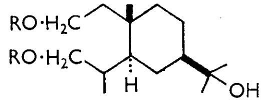
(XXIX)



(XXX : R = COMe, R' = H)
(XXXI : R = H, R' = COMe)

(XXXII)





(XXXIII : R = H)
(XXXIV : R = CPh₃)

Another route to the oxo-diol (XXVIII) was also explored. Enol acetylation of the ketone (XV) gave the enol acetate (XXIX) in 50—60% yield. Ozonolysis of this and fission of the ozonide with hydrogen peroxide afforded a keto-diacid, whose dimethyl ester (XXX) was converted into its 7α(H) epimer (XXXI). Its carbonyl group was protected by ethylene-ketal formation, and reduction with lithium aluminium hydride then gave the ketal diol (XXXII) which was hydrolysed to the oxo-diol (XXVIII).

The remaining problem was the correlation of this diol (XXVIII) with some derivative of elemol. Pure elemol was obtained from citronella oil. During its purification through its 3,5-dinitrobenzoate a new sesquiterpene 3,5-dinitrobenzoate was obtained. Hydroboration[16] of elemol gave the triol (XXXIII) in 30% yield, the rest of the elemol being converted into partly hydrated products. The triol gave a diacetate and a crystalline ditrityl ether (XXXIV). The oxo-diol (XXVIII) was converted with methylmagnesium iodide *via* its tetrahydropyranyl ether into a triol (XXXIII), which afforded a diacetate and a ditrityl ether (XXXIV) identical in all respects with that from elemol (V); the absolute configuration of which is hence as shown.

EXPERIMENTAL

Melting points were determined on a Kofler block and are corrected. Alumina used for chromatography was Peter Spence's grade H, deactivated with 5% of 10% acetic acid unless otherwise stated. Rotations were measured for chloroform solutions at room temperature. Light petroleum refers to the fraction of b. p. 60—80°.

(+)-*Carvone.*—" Terpeneless " oil of caraway was purified by distillation. (+)-Carvone

---

[16] Brown, " Hydroboration," Benjamin, San Francisco, 1961.

was collected as an oil, b. p. 111—112°/18 mm., n_D^{23} 1·4970, $[\alpha]_D$ +50° (*c* 2·9). Widmark and Holm[17] give b. p. 112—112·5°/14 mm., n_D^{25} 1·4969, $[\alpha]_D$ +57°.

(−)-*Dihydrocarvone* (IX).[18]—A vigorously stirred mixture of (+)-carvone (80 g.), water (350 g.), zinc dust (100 g.), sodium hydroxide (100 g.), and ethanol (800 ml.) was heated under reflux for 5 hr. Most of the ethanol was removed by distillation, and the (−)-dihydrocarvone was separated by steam distillation. Isolation with ether, and distillation, gave (−)-dihydrocarvone (52 g.), b. p. 99—102°/12 mm., n_D^{25} 1·4710, $[\alpha]_D$ −13° (*c* 8·1). Widmark and Holm[17] give n_D^{25} 1·4698, $[\alpha]_D$ −15° (in ethanol).

1-*Chloropentan*-3-*one*.—Powdered, anhydrous aluminium chloride (160 g.) was slowly added to vigorously stirred propionyl chloride (93 g.) at −20°. Cooled methylene chloride (600 ml.) was then added, and dry ethylene bubbled through the stirred solution at −10° for 5 hr. The solution was poured on to a mixture of ice (600 g.) and aqueous hydrochloric acid, and the organic layer was separated, washed with dilute hydrochloric acid, dried ($MgSO_4$), and concentrated. Distillation gave 1-chloropentan-3-one (64 g.), b. p. 62—64°/19 mm., n_D^{20} 1·4356 (lit., b. p. 62—65°/15 mm., n_D^{22} 1·4361;[19] b. p. 32·3—33·3°/2·5 mm., n_D^{20} 1·4361[20]). The 2,4-*dinitrophenylhydrazone* crystallised from ethanol as orange needles, m. p. 135° (Found: N, 18·3. $C_{11}H_{13}ClN_4O_4$ requires N, 18·6%).

(−)-5β-*Hydroxy*-4β,7β(H)-*eudesm*-11-*en*-3-*one* (X).—(−)-Dihydrocarvone (20·8 g.) was added to a suspension of sodium hydride (3·5 g.) in dry tetrahydrofuran (100 ml.) under nitrogen. A few drops of ethanol were added to start the reaction, which was completed by heating under reflux for 2 hr. Freshly distilled 1-chloropentan-3-one (16·6 g.) was added at 25°, and the mixture stirred for 1 hr. The excess of sodium hydride was destroyed with dilute aqueous acetic acid at 0°. The product was isolated with ether and separated by distillation into the following fractions: (i) b. p. 80—110°/0·4 mm. (7 g.), largely (−)-dihydrocarvone, (ii) 110—120°/0·4 mm. (12 g.) and (iii) b. p. 120—130°/0·4 mm. (6 g.). Fractions (ii) and (iii) crystallised from light petroleum to give (−)-5β-hydroxy-4β,7β(*H*)-eudesm-11-en-3-one (10 g.) as prisms, m. p. 108°, $[\alpha]_D$ −48° (*c* 2·3); $\nu_{max.}$ (in Nujol) 3635, 1710, 1640, and 893 cm.$^{-1}$; R.D. in EtOH [α] (6000 Å) 0°, (5000) −140°, (4000) −210°, (3070) +1690° (peak), (2820) −2700° (Found: C, 76·2; H, 10·3. Calc. for $C_{15}H_{24}O_2$: C, 76·2; H, 10·2%). McQuillin[5] gives m. p. 106°, $[\alpha]_{5461}$ −54° (*c* 4·14).

(+)-7β(H)-*Eudesma*-4,11-*dien*-3-*one* (XI).—A solution of the ketol (X) (1 g.) in ethanol (15 ml.) containing concentrated hydrochloric acid (1·8 ml.) was kept for 7 days at 0°. Isolation with ether gave an oil (950 mg.) which was adsorbed on alumina (50 g.). Elution with light petroleum–benzene (5 : 1) followed by distillation gave (+)-7β(*H*)-eudesma-4,11-dien-3-one (800 mg.), b. p. 130°/0·5 mm., n_D^{20} 1·5334, $[\alpha]_D$ +192° (*c* 1·7); $\nu_{max.}$ (film) 1675, 1605, and 893 cm.$^{-1}$; $\lambda_{max.}$ (in ethanol) 2520 Å (ε 14,200) (Found: C, 82·2; H, 10·0. Calc. for $C_{15}H_{22}O$: C, 82·6; H, 10·1%). McQuillin[5] gives b. p. 91°/0·1 mm., n_D^{20} 1·5337, $[\alpha]_{5461}$ +210° (*c* 3·5), $\lambda_{max.}$ 2520 Å (ε 14,100).

(+)-4β,7β(H)-*Eudesm*-11-*en*-3-*one* (XV).—(+)-7β(*H*)-Eudesma-4,11-dien-3-one (XI) (2·0 g.) in dry ether (75 ml.) was added to a solution of lithium (2·0 g.) in liquid ammonia (600 ml.). The blue solution was stirred for 1 hr. Dry ammonium chloride was added to discharge the colour, and the product was isolated with ether as an oil (2·0 g.) which was filtered in light petroleum through alumina (100 g.) to give (+)-4β,7β(*H*)-eudesma-11-en-3-one as prisms from light petroleum at −60°; it had m. p. 50°, $[\alpha]_D$ +17° (*c* 2·5), $\nu_{max.}$ (in Nujol) 1705, 1640, and 893 cm.$^{-1}$. The 2,4-dinitrophenylhydrazone crystallised from ethanol as needles, m. p. 195° (Found: N, 13·7. Calc. for $C_{21}H_{28}N_4O_4$: N, 14·0%). McQuillin[5] gives m. p. 48°, $[\alpha]_{5461}$ +26° (*c* 3·2); 2,4-dinitrophenylhydrazone, m. p. 192°.

(−)-11ξ,12-*Dihydroxy*-4β,7β(H)-*eudesman*-3-*one* (XVI).—A solution of (+)-4β,7β(*H*)-eudesm-11-en-3-one (XV) (500 mg.) in dry ether (5 ml.) was added to osmium tetroxide (700 mg.) dissolved in dry pyridine (10 ml.). After 8 days at 20°, the solvents were removed *in vacuo*, and the residue was heated under reflux with potassium hydroxide (5 g.), mannitol (5 g.), ethanol (55 ml.), benzene (30 ml.), and water (25 ml.) for 6 hr. under nitrogen to give an oil which was adsorbed on alumina (40 g.). Benzene–ether (2 : 1) eluted (−)-11ξ,12-*dihydroxy*-4β,7β(H)-*eudesman*-3-*one* (390 mg.) as an oil, b. p. 140—150°(bath)/10·1 mm., n_D^{20} 1·5152, $[\alpha]_D$

---

[17] Widmark and Holm, *Arkiv Kemi*, 1957, **11**, 227.

[18] Whitham, personal communication.

[19] Behr, B.Sc. Thesis, Oxford, 1958.

[20] McMahon, Roper, Utermohler, Hasek, Harris, and Brant, *J. Amer. Chem. Soc.*, 1948, **70**, 2971.

$-36°$ (c 2·3); $\nu_{max.}$ (film) 3370, 1705, 1125, and 1040 cm.$^{-1}$ (Found: C, 70·5; H, 10·1. $C_{15}H_{26}O_3$ requires C, 70·9; H, 10·2%). The *semicarbazone* crystallised from benzene–methanol as plates, m. p. 174—176° (Found: C, 61·6; H, 9·1. $C_{16}H_{29}N_3O_3$ requires C, 61·7; H, 9·3%).

(+)-4β,7β(H)-12-*Noreudesmane*-3,11-*dione* (XVII).—A solution of the oxo-diol (XVI) (280 mg.) in methanol (30 ml.) was added to one of sodium metaperiodate (1·02 g.) in water (10 ml.). The solution was kept at 20° for 72 hr. and the product (220 mg.) then recovered with ether. (+)-4β,7β(H)-12-*Noreudesmane*-3,11-*dione* crystallised from methanol at $-60°$ as prisms, m. p. 62—63°, $[\alpha]_D$ +7° (c 3·1); $\nu_{max.}$ (in Nujol) 1710 cm.$^{-1}$ (Found: C, 75·5; H, 9·8. $C_{14}H_{22}O_2$ requires C, 75·7; H, 9·9%). The *dioxime* (from aqueous alcohol) had m. p. 164° (Found: C, 66·4; H, 9·5. $C_{14}H_{24}N_2O_2$ requires C, 66·6; H, 9·5%).

(−)-4β,7α(H)-12-*Noreudesmane*-3,11-*dione* (XVIII).—The dione (XVII) (100 mg.) was heated under reflux for 2 hr. in ethanol (10 ml.) containing sulphuric acid (0·5 ml. of 20% aqueous acid). The product was isolated with ether and dissolved in light petroleum–benzene (1 : 1), and the solution filtered through alumina (8 g.). (−)-4β,7α(*H*)-12-Noreudesmane-3,11-dione (85 mg.) was obtained as an oil, b. p. 130—135°(bath)/0·1 mm., n_D^{20} 1·4993, $[\alpha]_D$ −31° (c 1·8), $\nu_{max.}$ (film) 1710 cm.$^{-1}$. The infrared spectrum of this ketone differed appreciably in detail from that of its 7β(H)-epimer. The *bis*-2,4-*dinitrophenylhydrazone* (from ethanol–chloroform) had m. p. 275—277° (Found: C, 53·9; H, 5·2. $C_{26}H_{30}N_8O_8$ requires C, 53·6; H, 5·2%). The bissemicarbazone (from butanol) had m. p. 252°. The dioxime (from butanol) had m. p. 259°. Bradfield, Hedge, Rao, Simonsen, and Gillam[12] give bis-semicarbazone, m. p. 251—252°; dioxime, m. p. 258—259°.

(−)-12-*Acetoxy*-11ξ-*hydroxy*-4β,7β(H)-*eudesman*-3-*one*.—The oxo-diol (XVI) (260 mg.) was dissolved in pyridine (2 ml.), acetic anhydride (0·3 ml.) was added, and the mixture kept at 20° for 22 hr. The oily product (280 mg.) was filtered in benzene through alumina (15 g.) to give (−)-12-*acetoxy*-11ξ-*hydroxy*-4β,7β(H)-*eudesman*-3-*one* (270 mg.), n_D^{25} 1·4991, $[\alpha]_D$ −33 (c 2·5); $\nu_{max.}$ (in CS_2) 3650, 1745, 1705, 1230, and 1035 cm.$^{-1}$. The *semicarbazone* (from benzene–methanol) had m. p. 163—164° (Found: N, 11·5. $C_{18}H_{31}N_3O_4$ requires N, 11·9%).

(−)-11ξ,12-*Diacetoxy*-4β,7β(H)-*eudesman*-3-*one*.—(*a*) Acetic anhydride (3 ml.) was added to a solution of (−)-12-acetoxy-11-hydroxy-4β,7β(*H*)-eudesman-3-one (220 mg.) in pyridine (5 ml.), and the solution refluxed for 6 hr. The product was filtered in benzene through alumina (20 g.) to give (−)-11ξ,12-diacetoxy-4β,7β(*H*)-eudesman-3-one (200 mg.), n_D^{25} 1·4875, $[\alpha]_D$ −33° (c 2·0).

(*b*) A solution of (−)-12-acetoxy-11ξ-hydroxy-4β,7β(*H*)-eudesman-3-one (278 mg.) and toluene-*p*-sulphonic acid (130 mg.) in isopropenyl acetate (20 ml.) was kept at 20° for 20 hr. Solid sodium hydrogen carbonate was added, and the product was recovered with ether and filtered in benzene through alumina (25 g.). (−)-11ξ,12-*Diacetoxy*-4β,7β(H)-*eudesman*-3-*one* was obtained as an oil (250 mg.), b. p. 140—145°(bath)/0·1 mm., n_D^{25} 1·4872, $[\alpha]_D$ −35° (c 5·0); $\nu_{max.}$ (in CS_2) 1743, 1710, 1245, 1230, 1045, and 1020 cm.$^{-1}$ (Found: C, 68·0; H, 8·8. $C_{19}H_{30}O_5$ requires C, 67·5; H, 8·9%). The *semicarbazone* crystallised from benzene–light petroleum as prisms, m. p. 176—178° (Found: N, 10·8. $C_{20}H_{33}N_3O_5$ requires N, 10·6%).

(−)-3,11ξ,12-*Triacetoxy*-4β,7β(H)-*eudesm*-2-*ene* (XXIV).—A solution of (−)-11ξ,12-diacetoxy-4β,7β(*H*)-eudesman-3-one (600 mg.) and toluene-*p*-sulphonic acid (400 mg.) in isopropenyl acetate (70 ml.) was heated under reflux for 5 hr. Solid sodium hydrogen carbonate was added to the cooled solution. The product was adsorbed on to alumina (90 g.). Light petroleum–benzene (2 : 1) (2200 ml.) eluted the crude enol acetate (320 mg.). Elution with light petroleum–benzene (2 : 1) to benzene gave starting material (230 mg.). The crude enol acetate was further purified by chromatography to give (−)-3,11ξ,12-*triacetoxy*-4β,7β(H)-*eudesm*-2-*ene* (300 mg.), b. p. 148°(bath)/0·1° mm., n_D^{25} 1·4828, $[\alpha]_D$ −20° (c 2·2); $\nu_{max.}$ (in CS_2) 1745, 1690, 1245, 1215, 1040, and 1015 cm.$^{-1}$ (Found: C, 66·7; H, 8·3. $C_{21}H_{32}O_6$ requires C, 66·3; H, 8·4%).

11ξ,12-*Diacetoxy*-2,3-*seco*-7β(H)-*eudesmane*-2,3-*dioic Acid*.—A solution of the triacetate (XXIV) (320 mg.) in purified ethyl acetate (90 ml.) was ozonised (5% ozone) at −60° for 1 hr. Excess of ozone was removed with nitrogen. The ozonide in the ethyl acetate was stirred for 24 hr. at 20° with potassium hydrogen carbonate solution (5%; 50 ml.) and hydrogen peroxide (30%; 25 ml.). The aqueous layer was acidified and the product recovered with ether. 11ξ,12-Diacetoxy-2,3-seco-7β(*H*)-eudesmane-2,3-dioic acid (280 mg.) was obtained as a glass, $\nu_{max.}$ (in $CHCl_3$) 1745 and 1710 cm.$^{-1}$, not further characterised. Treatment with an excess of ethereal diazomethane at 0° gave the *dimethyl ester* (XXV), b. p. 150—154°(bath)/0·1° mm.,

n_{D}^{25} 1·4725, $[\alpha]_{\text{D}}$ −21° (*c* 2·4); $\nu_{\text{max.}}$ (in CS_2) 1745, 1245, 1220, 1160, 1045, and 1015 cm.$^{-1}$ (Found: C, 60·4; H, 8·6. $C_{21}H_{34}O_8$ requires C, 60·9; H, 8·2%).

(−)-2,3-*Dihydroxy*-2,3-*seco*-7β(H)-12-*noreudesman*-3-*one* (XXVII).—A solution of dimethyl 11ξ,12-diacetoxy-2,3-seco-7β(*H*)-eudesmane-2,3-dioate (XXV) (250 mg.) in dry ether (5 ml.) was added to a solution of lithium aluminium hydride (500 mg.) in dry ether (40 ml.) to give (−)-2,3-seco-7β(*H*)-eudesmane-2,3,11ξ,12-tetraol (XXVI) (120 mg.), $[\alpha]_{\text{D}}$ −10° (*c* 2·4 in EtOH). This was not further characterised. A solution of it (360 mg.) in ethanol (30 ml.) was added to a solution of sodium metaperiodate (5·4 ml. of a saturated aqueous solution), and the mixture kept at 20° for 20 hr. Recovery with ether gave (−)-2,3-*dihydroxy*-2,3-*seco*-7β(H)-12-*noreudesman*-11-*one* (270 mg.), b. p. 125—130°(bath)/0·2 mm., n_{D}^{25} 1·4854, $[\alpha]_{\text{D}}$ −5° (*c* 4·1); $\nu_{\text{max.}}$ (film) 3360 and 1705 cm.$^{-1}$; this was characterised as its *semicarbazone* (from aqueous ethanol), m. p. 150—151° (Found: N, 13·8. $C_{15}H_{29}N_3O_3$ requires N, 14·1%).

(−)-2,3-*Dihydroxy*-2,3-*seco*-7α(H)-12-*noreudesman*-11-*one* (XXVIII).—(−)-2,3-dihydroxy-2,3-seco-7β(H)-12-noreudesman-11-one (270 mg.) was heated under reflux for 3 hr. in ethanol (15 ml.) containing sulphuric acid (0·9 ml. of 20% aqueous acid). The product was recovered with ether as an oil, which was adsorbed on alumina (25 g.). Elution with ether–methanol (10 : 1) gave (−)-2,3-*dihydroxy*-2,3-*seco*-7α(H)-12-*noreudesman*-11-*one* (240 mg.), b. p. 125°(bath)/0·2 mm., n_{D}^{25} 1·4860, $[\alpha]_{\text{D}}$ −14° (*c* 3·6); $\nu_{\text{max.}}$ (film) 3350 and 1710 cm.$^{-1}$ (Found: C, 69·1; H, 10·5. $C_{14}H_{26}O_3$ requires C, 69·4; H, 10·7%). A repetition of this treatment did not affect the value of $[\alpha]_{\text{D}}$. The *semicarbazone* crystallised from aqueous ethanol as small plates, m. p. 188—189° (Found: N, 14·0. $C_{15}H_{29}N_3O_3$ requires N, 14·1%).

(−)-3-*Acetoxy*-4β,7β(H)-*eudesma*-2,11-*diene* (XXIX).—A solution of (+)-4β,7β(*H*)-eudesm-11-en-3-one (XV) (1 g.) and toluene-*p*-sulphonic acid (120 mg.) in isopropenyl acetate (25 ml.) was heated under reflux for 6 hr. Sodium hydrogen carbonate solution was added to the mixture when cool, and the oily product isolated with ether. It was adsorbed on alumina (140 g.). Elution with light petroleum (600 ml.) gave (−)-3-*acetoxy*-4β,7β(H)-*eudesma*-2,11-*diene* (550 mg.), b. p. 100—110°(bath)/0·1 mm., n_{D}^{25} 1·4958, $[\alpha]_{\text{D}}$ −13° (*c* 2·9); $\nu_{\text{max.}}$ (film) 1750, 1680, 1635, 1220, and 893 cm.$^{-1}$ (Found: C, 77·9; H, 10·0. $C_{17}H_{26}O_2$ requires C, 77·9; H, 9·9%). Further elution with light petroleum gave starting material (400 mg.).

11-*Oxo*-2,3-*seco*-7β(H)-12-*noreudesmane*-2,3-*dioic Acid*.—Ozonised oxygen (12% ozone) was bubbled through a solution of (−)-3-acetoxy-4β,7β(*H*)-eudesme-2,11-diene (400 mg.) in carbon tetrachloride (60 ml.) at 0° for 2 hr. The excess of ozone was removed with nitrogen. The ozonide in the carbon tetrachloride was stirred at 20° for 18 hr. with potassium hydrogen carbonate solution (5%; 40 ml.) and hydrogen peroxide solution (30%; 20 ml.). The aqueous layer was acidified and the product isolated by ether extraction. 11-Oxo-2,3-seco-7β(*H*)-noreudesman-2,3-dioic acid was obtained as a glass (310 mg.), $\nu_{\text{max.}}$ (CCl_4) 1710 cm.$^{-1}$, not further characterised. Treatment with an excess of diazomethane in ether at 0° gave the crude dimethyl ester, which was adsorbed on alumina (20 g.). Elution with benzene gave the *dimethyl ester* (XXX) (300 mg.), b. p. 135°(bath)/0·05 mm., n_{D}^{25} 1·4790, $[\alpha]_{\text{D}}$ −12° (*c* 2·1), $\nu_{\text{max.}}$ (film) 1745 and 1710 cm.$^{-1}$.

(−)-*Dimethyl* 11-*Oxo*-2,3-*seco*-7α(H)-12-*noreudesmane*-2,3-*dioate* (XXXI).—The dimethyl ester (XXX) (500 mg.) was heated under reflux for 3 hr. in methanol (20 ml.) containing sulphuric acid (1·5 ml. of 20% aqueous acid). Isolation with ether gave (−)-*dimethyl* 11-*oxo*-2,3-*seco*-7α(H)-12-*noreudesmane*-2,3-*dioate* (XXXI) (480 mg.), b. p. 125—130°(bath)/0·1 mm., n_{D}^{20} 1·4824, $[\alpha]_{\text{D}}$ −20° (*c* 6·0); $\nu_{\text{max.}}$ (film) 1745 and 1710 cm.$^{-1}$ (Found: C, 64·3; H, 8·6. $C_{16}H_{26}O_5$ requires C, 64·4; H, 8·7%).

(−)-2,3-*Dihydroxy*-2,3-*seco*-7α(H)-12-*noreudesman*-11-*one* (XXVIII).—A solution of the dimethyl ester (XXXI) (600 mg.), ethylene glycol (600 mg.), and toluene-*p*-sulphonic acid (110 mg.) in dry benzene (60 ml.) was heated under reflux for 48 hr., water being separated in the usual way. An excess of sodium methoxide was added to the cooled solution, and the product was recovered with ether. Dimethyl 11,11-ethylenedioxy-2,3-seco-7α(*H*)-12-noreudesmane-2,3-dioate was obtained as an oil (590 mg.), $\nu_{\text{max.}}$ (film) 1745 cm.$^{-1}$, which was not further characterised but reduced directly with an excess of lithium aluminium hydride (600 mg.) in ether (100 ml.) to give 11,11-ethylenedioxy-2,3-seco-7α(*H*)-12-noreudesmane-2,3-diol (XXXII) (550 mg.), $\nu_{\text{max.}}$ (film) 3350 cm.$^{-1}$. This compound (550 mg.) was dissolved in ethanol (20 ml.) containing sulphuric acid (10 ml. of 5% aqueous acid), and the solution was heated under reflux for 2 hr. Isolation with ether afforded an oil, which was filtered through alumina (25 g.) in benzene–ether (1 : 4) to give (−)-2,3-dihydroxy-2,3-seco-7α(*H*)-12-noreudesman-11-one

(XXVIII) (450 mg.), b. p. 120—130°(bath)/0·1 mm., n_D^{25} 1·4857, $[\alpha]_D$ −13° (*c* 5·0), $\nu_{max.}$ (film) 3350 and 1710 cm.$^{-1}$. The semicarbazone had m. p. 187—188°, from aqueous ethanol.

(−)-2,3-*Seco*-7α(H)-*eudesmane*-2,3,11-*triol* (XXXIII).—A solution of the oxo-diol (XXVIII) (300 mg.), toluene-*p*-sulphonic acid (30 mg.), and dihydropyran (2 ml.) in dry benzene (15 ml.) was kept at 20° for 18 hr. Isolation with ether gave the ditetrahydropyranyl ether as an oil (310 mg.).

A solution of methylmagnesium iodide was prepared from methyl iodide (1·5 g.) and magnesium (0·25 g.) in ether (40 ml.). About two-thirds of the ether was distilled away and replaced by dry benzene. To the stirred solution of Grignard reagent was added the tetrahydropyranyl ether (310 mg.) in dry benzene (15 ml.). The mixture was stirred for 12 hr. and then heated under reflux under nitrogen for 3 hr. Dilute hydrochloric acid was added at 0° to decompose the complex and excess of methylmagnesium iodide, and the mixture was stirred in the cold for a further 12 hr. to decompose the tetrahydropyranyl ether. Continuous extraction with ether gave a glass (250 mg.), which was adsorbed on alumina (10 g.). Elution with ether–methanol (10 : 1) gave (−)-2,3-seco-7α(*H*)-eudesmane-2,3,11-triol (XXXIII) as a glass (210 mg.), $[\alpha]_D$ −11° (*c* 6·3), which was characterised as its *diacetate*, b. p. 170—180°(bath)/0·1 mm., n_D^{25} 1·4780, $[\alpha]_D$ −13° (*c* 4·0), $\nu_{max.}$ (film) 3350 and 1740 cm.$^{-1}$ (Found: C, 67·0; H, 10·0. $C_{19}H_{34}O_5$ requires C, 66·7; H, 9·9%), and its *ditrityl ether* (XXXIV), which was prepared with triphenylmethyl chloride in pyridine and which crystallised from methanol as prisms, m. p. 88—90°, $[\alpha]_D$ −7° (*c* 9·0) (Found: C, 83·7; H, 7·8. $C_{53}H_{58}O_3,CH_3OH$ requires C, 83·7; H, 8·0%).

The Isolation of Elemol (V).—The Java citronella oil from which elemol was isolated had n_D^{25} 1·4701; $\nu_{max.}$ (film) 3370, 2710, 1745, 1725, 1710, 1665, 1640, 1230, 1110, 1020, 910, 893, and 833 cm.$^{-1}$. This oil (370 g.) was separated under reduced pressure into the following fractions: (i) b. p. 104—120°/20 mm. (155 g.), n_D^{15} 1·4585, $\nu_{max.}$ (film) 3370, 2710, 1745, 1725, 1710, 1665, 1230, 1110, 1020, and 833 cm.$^{-1}$; (ii) b. p. 120—130°/20 mm. (67 g.), n_D^{25} 1·4686, $\nu_{max.}$ (film) 3390, 2710, 1745, 1725, 1710, 1665, 1640, 1230, 1110, 1020, 910, and 893 cm.$^{-1}$; (iii) b. p. 130—175°/20 mm. (120 g.), n_D^{25} 1·4822, $\nu_{max.}$ (film) 3390, 1725, 1710, 1665, 1640, 1230, 1020, 910, and 893 cm.$^{-1}$. The intensity of the bands at 1745, 1725, 1710, and 1665 cm.$^{-1}$ decreased as the boiling point was raised, while the intensity of those at 1640, 910, and 893 cm.$^{-1}$ simultaneously increased.

Fraction (iii) was separated into the following fractions: (*a*) b. p. 120—140°/20 mm. (43 g.), n_D^{25} 1·4762, $\nu_{max.}$ (film) 3390, 1725, 1710, 1640, 910, and 893 cm.$^{-1}$; (*b*) 140—150°/20 mm. (6 g.), n_D^{25} 1·4891, $\nu_{max.}$ (film) 3390, 3050, 1725, 1710, 1640, 1500, 1230, 910, and 893 cm.$^{-1}$; (*c*) b. p. 150—160°/20 mm. (12 g.), n_D^{25} 1·4943, $\nu_{max.}$ (film) 3390, 3050, 1710, 1640, 910, and 893 cm.$^{-1}$.

Fraction (*c*), after redistillation, had b. p. 150—154°/20 mm., n_D^{25} 1·4945 (Found: C, 81·1; H, 11·8. Calc. for $C_{15}H_{26}O$: C, 81·1; H, 11·7%). The analysis figures and infrared spectrum indicated that this fraction was almost pure elemol.

Elemol 3,5-*Dinitrobenzoate*.—Almost pure elemol (10 g.) and 3,5-dinitrobenzoyl chloride (10 g.) were dissolved in pyridine (100 g.), and the mixture kept for 18 hr. at 20° and then for 2 hr. at 100°. Isolation with ether gave a dark red gum which was adsorbed on alumina (400 g.). Light petroleum (250 ml.) eluted a yellow oil, probably a hydrocarbon. Further elution with light petroleum (1250 ml.) gave a sesquiterpene 3,5-dinitrobenzoate, crystallising from aqueous ethanol as *needles* (500 mg.), m. p. 175° (Found: C, 63·5; H, 6·8; N, 6·9. $C_{22}H_{28}N_2O_6$ requires C, 63·4; H, 6·8; N, 6·7%). Further elution with light petroleum (1000 ml.) gave elemol 3,5-dinitrobenzoate (3 g.), m. p. 118—120°, from aqueous ethanol (Found: C, 63·4; H, 6·8; N, 7·1. Calc. for $C_{22}H_{28}N_2O_6$: C, 63·4; H, 6·7; N, 6·7%).

Elemol Benzoate.—This was obtained in a similar way from nearly pure elemol as an oil, b. p. 146—148°/0·1 mm., n_D^{25} 1·5206, $[\alpha]_D$ −6° (*c* 7·0); $\nu_{max.}$ (film) 3080, 1715, 1640, 1605, 1590, 1280, 1115, 910, 893, and 715 cm.$^{-1}$ (Found: C, 81·1; H, 9·4. Calc. for $C_{22}H_{30}O_2$: C, 81·0; H, 9·2%). Semmler and Lias [21] give b. p. 214—218°/10 mm., n_D 1·5378, $[\alpha]_D$ −6°; Jansch and Fantl [22] give b. p. 210—213°/10 mm., n_D^{18} 1·5408; Ruzicka and Pfeiffer [1] give b. p. 135—150°/12 mm.

Elemol.—Elemol benzoate (1 g.) was hydrolysed with ethanolic potassium hydroxide to give an oil, which was adsorbed on alumina (16 g.). Elution with light petroleum–benzene (1 : 1) gave elemol (600 mg.), b. p. 100—105°/0·1 mm., m. p. 48—49°, $[\alpha]_D$ −3° (*c* 4·0); $\nu_{max.}$

---

[21] Semmler and Lias, *Ber.*, 1916, **49**, 794; 1917, **50**, 1286.

[22] Jansch and Fantl, *Ber.*, 1923, **56**, 1363.

(film) 3330, 3075, 1640, 910, and 893 cm.$^{-1}$ (Found: C, 80·8; H, 11·7. Calc. for $C_{15}H_{26}O$: C, 81·1; H, 11·7%). Sýkora, Herout, Plíva, and Šorm [2] give m. p. 49·5—52°; Semmler and Lias [21] give $[\alpha]_D$ $-5°$.

(−)-*Elemane*-2,3,11-*triol* (XXXIII).—Boron trifluoride etherate (6 g.) dissolved in ether (50 ml.) was added dropwise under nitrogen to a stirred solution of elemol (360 mg.) and lithium aluminium hydride (4 g.) in ether (100 ml.). The opaque mixture was stirred for 3 hr. at 20°. Saturated sodium sulphate solution was cautiously added to destroy the excess of lithium aluminium hydride and the crude boron alkyl was isolated with ether. It was oxidised at 0° with hydrogen peroxide (1 g.) and potassium hydroxide (0·4 g.) in ethanol (8 ml.) and water (2 ml.). The crude hydration product was isolated with ether as a gum and was adsorbed on alumina (15 g.). Benzene–ether (4 : 1) (200 ml.) eluted a gum (130 mg.); $\nu_{max.}$ (in $CHCl_3$) 1640, 910, and 893 cm.$^{-1}$. Ether (300 ml.) eluted a gum (70 mg.), $\nu_{max.}$ (in $CHCl_3$) 1640 and 910 cm.$^{-1}$. Ether–methanol (10 : 1; 150 ml.) eluted (−)-*elemane*-8,10,12-*triol* (110 mg.) as a glass, $[\alpha]_D$ $-10°$ (*c* 4·2) (Found: C, 69·4; H, 11·5. $C_{15}H_{30}O_3$ requires C, 69·8; H, 11·6%).

The *diacetate* was obtained as an oil, b. p. 180—185°(bath)/0·01 mm., n_D^{25} 1·4785, $[\alpha]_D$ $-12°$, (*c* 2·7), $\nu_{max.}$ (film) 3350 and 1745 cm.$^{-1}$ (Found: C, 66·9; H, 10·2. $C_{19}H_{34}O_5$ requires C, 66·7; H, 9·9%). The ditrityl ether (XXXIV) crystallised from methanol as prisms, m. p. 88—91°, $[\alpha]_D$ $-8°$ (*c* 7·4), mixed m. p. 89—90° with the ditrityl derivative prepared from (−)-2,3-seco-7α(*H*)-eudesmane-2,3,11-triol (XXXIII). The infrared spectra of the two derivatives were identical in hexachlorobutadiene.

The authors thank Dr. G. H. Whitham for information concerning the preparation of (−)-dihydrocarvone. One of them (D. W. T.) gratefully acknowledges the tenure of a D.S.I.R. Research Studentship during part of this work.

THE DYSON PERRINS LABORATORY, THE UNIVERSITY, OXFORD.
FACULTY OF TECHNOLOGY, THE UNIVERSITY, MANCHESTER. [*Received, February 26th,* 1963.]