Formation of *ortho*-Menthenes by Acid-catalysed Ring Opening of Pin-2-ene Derivatives

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Several pin-2-ene derivatives substituted at C-4 were prepared. *ortho*-Menthenes were produced from these by cleavage of the 5,C-bond in reactions which proceed through C-4 carbocations.

THE synthesis of *p*-menthenes by acid-catalysed ring opening of pinene derivatives is widely employed both in the laboratory and in industry.[1] It seemed of interest to explore routes for the alternative opening of the dimethylmethylene bridge in pin-2-enes to form *o*-menthene derivatives. Publications on the chemistry of *o*-menthanes are sparse,[2] and few methods for their preparation are available.[2,3]

The acidic cleavage of pinenes to *p*-menthenes proceeds[4] through a C-2 carbocation. We assumed that

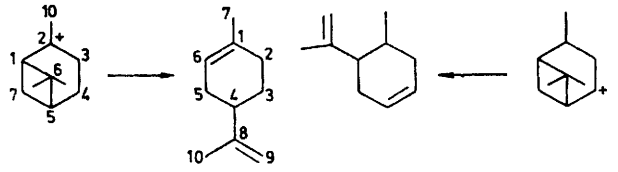
[1] J. L. Simonsen and L. N. Owen, ' The Terpenes,' vols. I and II, Cambridge University Press, London, 2nd edn., 1953 and 1954, respectively; Y.-R. Naves, *Russ. Chem. Rev.*, 1968, **37**, 779; A. F. Thomas in ' The Total Synthesis of Natural Products,' vol. 2, ed. J. ApSimon, Wiley–Interscience, New York, 1974, pp. 1—195, and references therein.

[2] S. H. Harper in ' Rodd's Chemistry of Carbon Compounds,' Supp. to vols, 11A and 11B, ed. M. F. Ansell, Elsevier, Amsterdam, 1974, pp. 183—184; M. G. Ferretti-Alloise, A. Jacot-Guillarmod, and Y.-R. Naves, *Helv. Chim. Acta*, 1970, **53**, 1339, and references therein.

[3] A. F. Thomas, B. Willhalm, and G. Ohloff, *Helv. Chim. Acta*, 1959, **52**, 1249; J. M. Coxon, R. A. Garland, and M. P. Hartshorn, *Chem. Comm.*, 1971, 1131.

[4] D. V. Banthorpe and D. Whittaker, *Quart. Rev.*, 1966, **20**, 373; C. M. Williams and D. Whittaker, *J. Chem. Soc.* (*B*), 1971, 668; G. Valkanas and N. Iconomou, *Helv. Chim. Acta*, 1963, **46**, 1089.

prevention of the formation of this ion, concomitant with the establishment of a positive charge at C-4, would lead to cleavage of the 5, 6-bond and formation of *o*-menthenes (see Scheme).



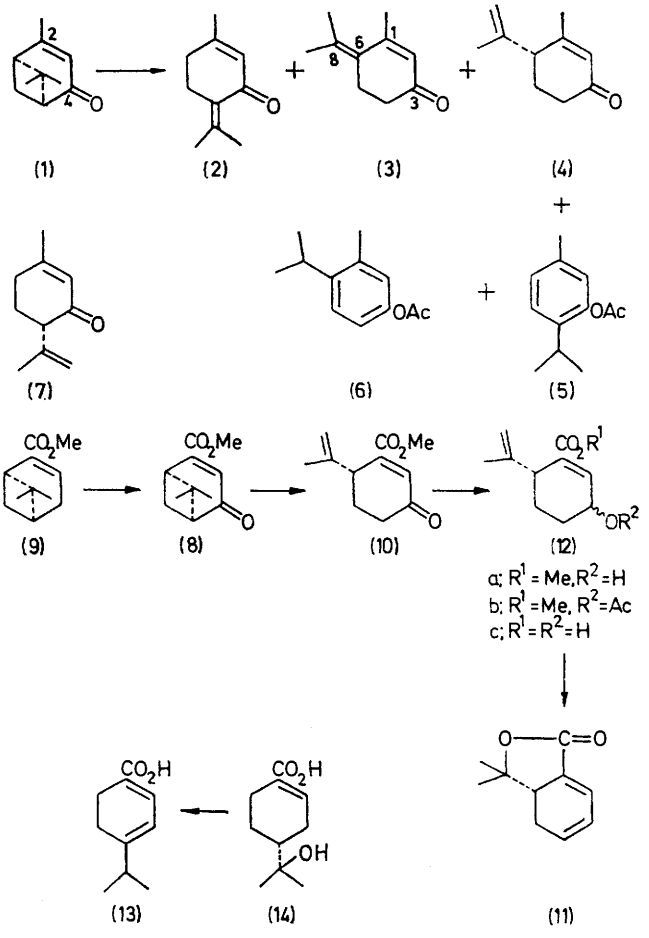
SCHEME

In 1924 two groups [5] found that acids cleave verbanone to *o*-menthanes. However more recently an Argentine group [6] claimed that treatment of 2,3-epoxyverbanone with acid gave a *p*-menthane in which the epoxide group was retained. We now report the formation of *o*-menthenes from several derivatives of pin-2-ene, *via* a C-4 carbocation.

Verbenone (pin-2-en-4-one) (1) [7] on boiling with toluene-*p*-sulphonic acid in acetic acid and acetic anhydride gave a complicated mixture from which we isolated piperitenone [*p*-mentha-1,4(8)-dien-3-one] (2) [8,9] (6.6%), *o*-piperitenone [*o*-mentha-1,6(8)-dien-3-one] (3) (10.2%), *o*-isopiperitenone (*o*-mentha-1,8-dien-3-one) (4) (4.2%), and a mixture of the *p*- and *o*-cymene derivatives (5) and (6) (together 45.3%).[10]

In this reaction the existence of both C-2 and C-4 carbocations could be envisaged, hence the formation of both *o*- and *p*-menthenes was not unexpected. In order to minimize the localization of positive charge at C-2, we repeated the reaction with methyl 4-oxomyrtenate (methyl 6,6-dimethyl-4-oxonorpin-2-ene-2-carboxylate) (8), obtained by oxidation of methyl myrtenate (9) [11] with sodium chromate. The only product was the *o*-menthene derivative (10) (46.7%) yield). The product (10) was reduced by lithium hydridotri-t-butoxyaluminate to the alcohol (12a), which on treatment with toluene-*p*-sulphonic acid in benzene gave the lactone (11), identified from spectra (*e.g.* $\lambda_{max.}$ 296 nm; $\nu_{max.}$ 1 740 cm^{-1}). For comparison 4-isopropylcyclohexa-1,3-dienecarboxylic acid (13) was prepared from oleuropeic acid (14) [12] ($\lambda_{max.}$ 298 nm; $\nu_{max.}$ 1 675 cm^{-1}).

A further example of an acid-catalysed ring opening of a pin-2-en-4-one is that of 4-oxomyrtenyl acetate (4-oxopin-2-en-10-yl acetate) (15), obtained (30% yield) by oxidation of myrtenyl acetate (16)[13] with sodium chromate and accompanied by small amounts of 6-oxo-*p*-mentha-1,8-dien-10-yl acetate (17) [14] and 4'-methylacetophenone (18). Boiling compound (15) in acetic acid–acetic anhydride containing toluene-*p*-sulphonic acid gave a complicated mixture. The *o*-menthadiene derivative (19) was obtained as expected, in a lower yield than that of the corresponding carboxylic acid derivative (10) (above). The ring opening of (15) apparently resembles that of the verbenone (1), rather than that of methyl 4-oxomyrtenate (8). We also obtained a mixture which we were unable to separate by t.l.c., apparently consisting of the two aromatic derivatives (20) and (21) (identified by n.m.r.).



Compound (19) showed spectral data similar to those of the *para*-isomer (22),[14] but their $CH_3{\cdot}C{:}CH_2$ chemical shifts were different [(22) δ 1.72; (19) 1.82], and so were the distances on the n.m.r. spectral curves between the positions of the two methyl signals for each substance.

[5] H. Wienhaus and P. Schumm, *Annalen*, 1924, **439**, 20; O. Wallach, *ibid.*, 1924, **437**, 187.

[6] J. A. Retamar, V. R. Medel, O. A. Arpesella, A. Orlando, and D. A. De Iglesias, *Arch. Bioquim. Quim. farm.*, 1968, **14**, 139 (*Chem. Abs.*, 1969, **71**, 91672a).

[7] W. G. Dauben, M. Lorber, and D. S. Fullerton, *J. Org. Chem.*, 1969, **34**, 3587; G. Dupont, R. Dulov, and O. Murdov, *Bull. Soc. chim. France*, 1952, 433.

[8] Y.-R. Naves, *Helv. Chim. Acta*, 1942, **25**, 732; E. D. Bergmann and P. Bracha, *J. Org. Chem.*, 1961, **26**, 4685.

[9] W. F. Erman, *J. Amer. Chem. Soc.*, 1967, **89**, 3828.

[10] P. J. Porcaro and V. D. Johnston, *Analyt. Chem.*, 1962, **34**, 1071; M. S. Carpenter and W. M. Easter, *J. Org. Chem.*, 1955, **20**, 401.

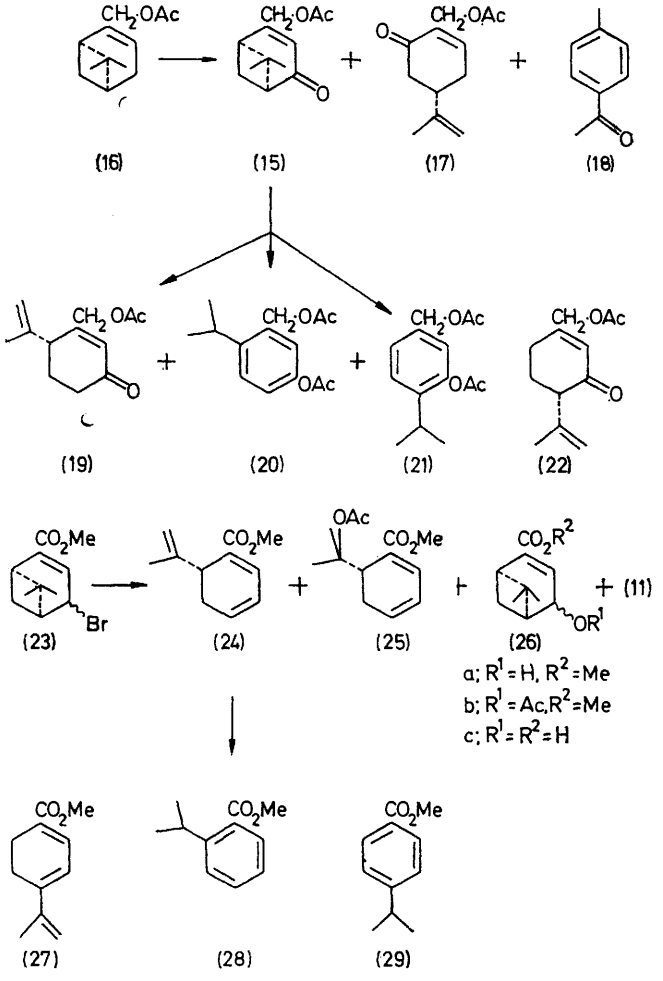
[11] L. Borowiecki and E. Reca, *Roczniki Chem.*, 1971, **45**, 493, 573.

[12] R. Mechoulam, N. Danieli, and Y. Mazur, *Tetrahedron Letters*, 1962, 709; see also W. Herz and H. J. Wahlborg, *J. Org. Chem.*, 1962, **27**, 1032.

[13] D. Dupont and W. Zacharewicz, *Bull. Soc. chim. France*, 1935, 533; G. W. Eigenmann and R. T. Arnold, *J. Amer. Chem. Soc.*, 1959, **81**, 3440; G. Zwifel and C. C. Whitney, *J. Org. Chem.*, 1966, **31**, 4178.

[14] N. Lander, Z. Ben-Zvi, R. Mechoulam, B. Martin, M. Nordqvist, and S. Agurell, *J.C.S. Perkin I*, 1976, 8.

The fingerprint regions of the i.r. spectra also showed significant differences.



A further route to an *o*-menthene involves the reaction of methyl 4-bromomyrtenate (23) [11] with silver acetate, giving the triene (24) (43.6%), the diene acetate (25) (18.5%), the lactone (11), and methyl 4-acetoxymyrtenate (26b). The structure of the triene (24) follows from its n.m.r. spectrum [five well defined olefinic proton signals and one proton (δ 3.1—3.5) allylic to two double bonds], and its u.v. spectrum (methoxycarbonyl group conjugated to a diene, $\lambda_{max.}$ 293 nm). The alternative triene (27) contains only four olefinic protons and would not have exhibited the δ 3.1—3.5 resonance. The u.v. spectrum should have been that of a triene conjugated to a methoxycarbonyl group. Furthermore, (24) was isomerized with phosphoryl chloride in benzene to methyl 2-isopropylbenzoate (28), which differed from authentic methyl 4-isopropylbenzoate (29).[12]

Methyl 4-acetoxymyrtenate (26b) obtained in this reaction was identical (spectra) with material prepared by reduction and acetylation of methyl 4-oxomyrtenate (8) (see later). However the product of the silver acetate reaction appeared to be a mixture (probably of the two possible 4-acetoxy-isomers). Thus the C-4 proton n.m.r. signal is a multiplet (rather than a triplet) and there are two methyl signals (δ 0.92 and 0.82).

The reaction of methyl 4-bromomyrtenate (23) with silver acetate is reported [11] to give methyl 4-acetoxymyrtenate (26b) (in 75% yield) as the only product isolated. However, no structural proof was presented.

Formation of a C-4 carbocation intermediate in a pin-2-ene system formed from an allylic alcohol also leads to 5,6-bond cleavage. Reduction of methyl 4-oxomyrtenate (8) with lithium hydridotri-t-butoxyaluminate gave the 4-hydroxymyrtenate (26a). The hydroxy-group in (26a) is probably *cis* to the dimethylmethylene bridge, as attack by the bulky reducing agent would be expected to proceed from the less hindered side of the molecule. Treatment of (26a) with acid led to the triene ester (24), albeit in surprisingly low yield (13.7%). However, no *p*-menthene derivatives were isolated; starting material [as the acetate (26b)] was also present. Apparently the strongly acidic conditions caused further reactions.

In their u.v. spectra the conjugated enone pinene derivatives [*e.g.* (8), (15), and (26b)] generally absorb at a longer wavelength (by *ca.* 20 nm or more), but have a lower intensity of absorption, than the corresponding monocyclic compounds which possess the same chromophore [(10), (19) or (22), and (12b), respectively]. This effect has been noted previously [15] and is assumed to be due to localization of part of the strain energy of the bicyclic ring in such a manner as to reduce the energy of excitation of the chromophore.

The foregoing ring cleavages of the pin-2-ene system leading to *ortho*- rather than to *para*-menthenes are being further investigated for the possible preparation of new perfumery substances as well as for the synthesis of new isomeric types of cannabinoid.

A recent publication [16] reported the isolation of the lactone (11) from the urine of the koala, *Phascolarctos cinereus*, feeding on the leaves of *Eucalyptus punctata*. As this plant contains [17] pin-2-ene, we assume that the koala first oxidizes it to myrtenic acid; functionalization at C-4 may then afford 4-hydroxymyrtenic acid (26c). During the reported acidic hydrolysis of the urine extract, the lactone (11) could be formed as an artefact.

EXPERIMENTAL

Unless otherwise stated the following apply. Optical rotations were determined for solutions in ethanol and i.r. spectra for solutions in carbon tetrachloride. N.m.r. spectra were determined at 60 MHz. T.l.c. was performed on 0.3 mm thick silica gel plates; p.l.c. was carried out on 1.3 mm silica gel plates (Merck Kieselgel 60, PF 254); column chromatography was performed on silica gel (Merck Kieselgel 60, 70—230 mesh). G.l.c. analyses were performed on a Packard, 7821 chromatograph with flame ionization detection [2 m × 6 mm i.d. column, at 155 °C, with nitrogen at 30—40 ml min^{-1} filled with either (A) 3% SE 30 or (B) 4% OV-17, both on GasChrom Q (100—120 mesh)].

[15] R. N. Moore and G. S. Fisher, *J. Amer. Chem. Soc.*, 1956, **78**, 4362.

[16] I. A. Southwell, *Tetrahedron Letters*, 1975, 1885.

[17] I. A. Southwell, *Phytochemistry*, 1973, **12**, 1341.

Reaction of Verbenone (*Pin-2-en-4-one*) (1) *with Toluene-p-sulphonic Acid.*—Verbenone (1) (306 mg, 2 mmol), $[\alpha]_D$ −168°, prepared by oxidation of pin-2-ene, $[\alpha]_D$ −45.1°, with t-butyl chromate,[7] was dissolved in acetic acid (7.5 ml) and acetic anhydride (1.5 ml). Toluene-*p*-sulphonic acid (50 mg) was added. The solution was boiled under reflux in nitrogen for 3 h. Ether (50 ml) and water (50 ml) were then added and the organic layer was washed with saturated aqueous sodium hydrogen carbonate (2 × 50 ml), dried ($MgSO_4$), and evaporated. The oil obtained was separated by p.l.c. (elution with 10% ether–light petroleum) to give four fractions. The least polar was a mixture [two peaks on g.l.c.; conditions (A) except that 1% SE 30 was used] of 6-isopropyl- (5) and 4-isopropyl-3-tolyl acetate (6) [10] (87 mg, 45.3%), $\lambda_{max.}$ 266 nm (ε 519); $\nu_{max.}$ 1 760 (acetate), 1 495, 1 580, and 1 610 (aromatic bands), and 1 210 cm^{-1} (acetate); δ (CCl_4) 1.19 (d, *J* 7.5 Hz) and 1.22 (d, *J* 7.5 Hz) (6H, CMe_2), 2.15 and 2.25 (OAc), 2.7—3.4 (m, 8-H), and 6.72—7.25 (3H, m, ArH); *m/e* 192 (M^+, 7%), 150 (35), 135 (100), and 91 (15).

The next, more polar product, was piperitenone [*p*-mentha-1,4(8)-dien-3-one] (2), identified by comparison with an authentic sample [supplied by Smith Kline and French, Philadelphia, and purified by p.l.c. (elution by 10% ether–light petroleum)] by i.r., n.m.r., g.l.c., and t.l.c.; the physical data are compatible with those reported.[9] The next product was o-*isopiperitenone* (o-*mentha*-1,8-*dien*-3-*one*) (4) (12.7 mg, 4.2%); $[\alpha]_D$ −24.8°; $\lambda_{max.}$ 234 (ε 9 910) and 292sh nm (ε 520); $\nu_{max.}$ 1 670 (unsat. C=O) and 895 cm^{-1} (C=CH_2); δ (CCl_4) 1.80 and 1.86 (CH_3 groups), 2.15 (m, 4-H_2), 2.84 (t, 6-H), 4.73 and 4.91 (9-H_2), and 5.82 (2-H); *m/e* 150 (M^+, 18%), 135 (13), 122 (29), 107 (13), 94 (70), and 79 (100) (Found: M^+, 150.1037. $C_{10}H_{14}O$ requires *M*, 150.1045). For comparison, in *p*-isopiperitenone (7) [9] the two methyl signals are at δ (CCl_4) 10 70 and 10 91; there is no significant difference between the chemical shifts of the C-4 proton in (7) and the C-6 proton in (4). The i.r. spectra of (4) and (7) differ in their fingerprint regions; however the u.v. spectra are essentially the same [$\lambda_{max.}$ of (7) 233 nm (ε 9 400)].

The least polar compound was *o*-piperitenone (3) (30.8 mg, 10.2%), $\lambda_{max.}$ 229sh (ε 4 200) and 299 nm (8 625); $\nu_{max.}$ 1 665 cm^{-1}; δ (CCl_4) 1.88, 1.92, and 2.16 (3 CH_3), 2.24 (1H, t), 2.31 (1H, t), 2.61 (2H, t), and 5.68 (2-H); *m/e* 150 (M^+, 96%), 135 (22), 122 (22), 107 (100), and 94 (40) (Found: M^+; 150.1012. $C_{10}H_{14}O$ requires *M*, 150.1045), different from *p*-piperitenone (2) (spectral comparison).

Methyl 4-*Oxomyrtenate* (*Methyl* 6,6-*Dimethyl*-4-*oxonorpin*-2-*ene*-2-*carboxylate*) (8).—Methyl myrtenate (9) [11] (250 mg, 1.4 mmol), $[\alpha]_D$ −47°, was dissolved in acetic acid (2 ml) and acetic anhydride (1 ml). Anhydrous sodium chromate (300 mg, 1.8 mmol) was added in portions, the temperature being kept throughout at 35 °C. The mixture was stirred under nitrogen, at 35 °C, for 48 h. Water (50 ml) and ether (50 ml) were added. The organic layer was washed with 10% sodium hydrogen carbonate solution, then with brine, dried, and evaporated. The oil obtained was purified by p.l.c. (silica gel; elution with 20% ether–light petroleum) to give *methyl* 4-*oxomyrtenate* (8) (116 mg, 42.7%); $[\alpha]_D$ −204°; $\lambda_{max.}$ 257 nm (ε 6 470); $\nu_{max.}$ (neat) 1 710 and 1 670 cm^{-1}; δ (CCl_4) 0.98 and 1.55 (CH_3), 2.62—3.05 (m, 1- and 5-H), 3.78 (CH_3), and 6.45 (3-H) (Found: C, 67.8; H, 7.45%; M^+, 194. $C_{11}H_{14}O_3$ requires C, 68.05; H, 7.2%; *M*, 194). After purification on acid-washed alumina the yield was 35%.

Reaction of Methyl 4-*Oxomyrtenate* (8) *with Toluene-p-sulphonic Acid.*—The ester (8) (700 mg, 3.6 mmol) was dissolved in acetic acid (15 ml) and acetic anhydride (3 ml). Wet toluene-*p*-sulphonic acid (100 mg) was added and the solution was boiled, under nitrogen, for 4 h. Ether (50 ml) and water (50 ml) were added and the organic layer was washed with saturated aqueous sodium hydrogen carbonate and dried. Evaporation gave an oil which was purified by p.l.c. (elution with 15% ether–light petroleum) to afford *methyl* 3-*oxo*-o-*mentha*-1,8-*dien*-7-*oate* (10) (327 mg, 46.7%); $[\alpha]_D$ −123°; $\lambda_{max.}$ 233 nm (ε 14 025); $\nu_{max.}$ 1 735, 1 690, and 900 cm^{-1}; δ (CCl_4) 1.95 (CH_3), 2.0—2.5 (4-H_2), 3.42 (6-H), 3.78 (CH_3), 4.58 and 4.90 (9-H_2), and 6.65 (2-H) (Found: M^+, 194.0946. $C_{11}H_{14}O_3$ requires *M*, 194.0942).

Methyl 3-*Hydroxy*-o-*mentha*-1,8-*dien*-7-*oate* (12a).—The ester (10) (83 mg, 0.43 mmol) was dissolved in dry tetrahydrofuran (16 ml). Over 10 min a suspension of lithium hydridotri-t-butoxyaluminate (1.16 g, 4.6 mmol) in dry tetrahydrofuran (7 ml) was added and the mixture was stirred at 0 °C, under nitrogen, for 3 h. Acetic acid (0.3 ml) and water (5 ml) and were added and stirring was continued for a further 0.5 h at room temperature. The mixture was filtered and the precipitate was washed with chloroform. The chloroform solution was washed with water, dried, and evaporated. The oily product was purified by p.l.c. (elution with 40% ether–light petroleum).

The hydroxy-ester (12a) (37 mg, 45%) was obtained as an oil, $[\alpha]_D$ −82°; $\lambda_{max.}$ 217 nm (ε 11 368); $\nu_{max.}$ 3 510, 1 730, and 905 cm^{-1}; δ (CCl_4) 1.82 (CH_3), 3.07 (m, 6-H), 3.70 (CH_3), 4.24 (3-H), 4.89 and 4.59 (9-H_2), and 6.92 (2-H); *m/e* 196 (M^+, 10%), 164 (59), 149 (50), 121 (23), and 91 (100). Acetylation gave the 3-*acetate* (12*b*); $[\alpha]_D$ −42°; $\lambda_{max.}$ 215 nm (ε 9 140); $\nu_{max.}$ 1 725 and 905 cm^{-1}; δ (CCl_4) 1.8 and 2.0 (CH_3), 3.07 (6-H), 3.65 (CH_3), 4.5 and 4.8 (9-H_2), 5.27 (3-H), and 6.7 (2-H); *m/e* 238 (M^+, 6%), 196 (38), 178 (100), 164 (30), 150 (42), 119 (48), 105, (34), and 91 (54) [Found (M^+ −42), 196.1086. $C_{11}H_{16}O_3$ requires (*M* −42), 196.1099]. The ester (12b) (273 mg, 1.4 mmol) in ethanol (2 ml) was hydrolysed with sodium hydroxide (8%; 20 ml) for 1.5 h at room temperature; the solution was then acidified (N-hydrochloric acid) and extracted with ether. The extract was dried and evaporated to give the *acid* (12c) (121 mg, 48%), m.p. 179—181° (from acetone–chloroform); $[\alpha]_D$ −115°; $\lambda_{max.}$ 221 nm (ε 9 100); $\nu_{max.}$ (KBr) 3 450, 1 690, and 895 cm^{-1}; δ (CD_3OD) 1.81 (CH_3), 3.3 (6-H), 4.6 (3-H), 4.9 (9-H_2), and 6.9 (2-H); *m/e* 182 (M^+, 13%), 164 (78), 149 (50), 121 (65), and 91 (100) [Found: (M^+ −18), 164.0843. $C_{10}H_{12}O_2$ (M^+ −18) requires 164.0837].

Cyclization of the Hydroxy-ester (12a).—A solution of the ester (12a) (72 mg, 0.38 mmol) and toluene-*p*-sulphonic acid (345 mg) in benzene (10 ml) was boiled under reflux for 50 min, the solution was washed with saturated aqueous sodium hydrogen carbonate and extracted with ether, and the extract was dried and evaporated. The oil obtained was purified by p.l.c. (three elutions with 12% ether–light petroleum) to give the *lactone* (11) (24 mg, 38%), $[\alpha]_D$ −109.5°; $\nu_{max.}$ ($CHCl_3$) 1 740 cm^{-1}; $\lambda_{max.}$ 296 nm (ε 6 300); δ (CCl_4) 1.30 and 1.50 (s, 2 CH_3), 2.10—2.9 (allylic), 6.15 (2 H, m, 3- and 4-H), and 6.75br (2-H) (Found M^+, 164.0843. $C_{10}H_{12}O_2$ requires *M*, 164.0837).

Oxidation of Myrtenyl Acetate (16) *with Sodium Chromate.*—Anhydrous sodium chromate (3.2 g, 20 mmol) was added to a solution of myrtenyl acetate [11,13] (1.95 g, 10 mmol) in acetic acid (24 ml) and acetic anhydride (12 ml). The mixture was stirred, at 35 °C under nitrogen, for 48 h. Cold water was added and the mixture was extracted with ether.

The organic layer was washed with aqueous sodium hydrogen carbonate, dried, and evaporated. Chromatography on acid-washed alumina (activity IV) (elution with 10% ether–light petroleum) gave *4-oxomyrtenyl acetate* (*4-oxopin-2-en-10-yl acetate*) (15) (620 mg, 29.8%), an oil, $[\alpha]_D$ −168°; $\lambda_{max.}$ 218sh (ε 4 160) and 247 nm (7 453); $\nu_{max.}$ 1 760 and 1695 cm^{-1}; δ ($CDCl_3$) 1.025, 1.52, and 2.10 (CH_3), 2.32—2.96 (allylic and cyclobutane), 4.70 (d, 7-H_2), and 5.85 (2-H) (Found: C, 69.35; H, 7.75%; M^+, 208. $C_{12}H_{16}O_3$ requires C, 69.25; H, 7.7%; *M*, 208); racemic 6-oxoperillylacetate (17) [14] (620 mg, 30%), identical with an authentic sample (spectral data, t.l.c., and g.l.c.); and *p*-methylacetophenone (18),[18] identified on the basis of its spectral data. When the oxidation was undertaken with t-butyl chromate the yield of oxo-acetate (15) was considerably lower.

Reaction of 4-Oxomyrtenyl Acetate (15) *with Toluene-p-sulphonic Acid.*—4-Oxomyrtenyl acetate (15) (196 mg, 0.94 mmol) was dissolved in acetic acid (7.5 ml) and acetic anhydride (2.5 ml). Wet toluene-*p*-sulphonic acid (50 mg) was added and the solution was boiled, under nitrogen, for 4.5 h. The solution was cooled, ether and water were added, and the ether layer was washed with saturated aqueous sodium hydrogen carbonate, then with brine, dried, and evaporated. The residue was separated by p.l.c. (6 runs; elution with 30% ether–light petroleum). Two fractions were identified. The less polar was a mixture [by g.l.c. conditions (B)] of 3-acetoxy-6- (20) and 3-acetoxy-4-isopropylbenzyl acetate (21) (40 mg, 17%), $\nu_{max.}$ 1 755 and 1 730 cm^{-1}; δ (CCl_4) 1.20 (d, *J* 7.5 Hz) and 1.25 (d, *J* 7.5 Hz) (CMe_2), 2.02 (OAc), 2.20 (OAc), 5.05 (CH_2O), and 6.9—7.4 (m, Ar). The other fraction was *3-oxo-o-mentha-1,8-dien-7-yl acetate* (19) (23 mg, 12%), $[\alpha]_D$ −106°; $\lambda_{max.}$ 228 (ε 10 700) and 301sh nm (280); $\nu_{max.}$ 1 740, 1 670, 1 225, and 895 cm^{-1}; δ (CCl_4) 1.82 and 2.05 (CH_3) 2.9 (m, 6-H), 4.55 (d, 7-H_2), 4.75 and 4.95 (9-H_2), and 5.95 (2-H); *m/e* 208 (M^+, 10%), 193 (6), 166 (72), 148 (100) 133 (64), 106 (56), 105 (64), and 91 (64) (Found: C, 70.05; H, 7.9%; M^+, 208. $C_{12}H_{16}O_3$ requires C, 69.25; H, 7.7%; *M*, 208), which differed from the isomer (22) [14] prepared by oxidation of perillyl acetate {i.r., n.m.r., and g.l.c. [conditions (A) at 180°]}.

Reaction of Methyl 4-Bromomyrtenate (23) *with Silver Acetate.*—Methyl 4-bromomyrtenate (23) [11] (4.5 g, 17.3 mmol) was dissolved in acetic acid (10 ml). Silver acetate (3.66 g, 21.9 mmol) was added. The mixture was boiled under reflux for 0.5 h, and was then poured slowly into saturated aqueous sodium hydrogen carbonate. It was then extracted with ether; the extract was washed with brine, dried, and evaporated. The oil obtained was chromatographed on neutral alumina (activity III). Elution with light petroleum gave *methyl o-mentha-1,3,8-trien-7-oate* (24) (1.34 g, 43.6%); $[\alpha]_D$ −113°; $\lambda_{max.}$ 293 nm (ε 6 150); $\nu_{max.}$ ($CHCl_3$) 1 710 and 900 cm^{-1}; δ ($CDCl_3$) 1.62 (CH_3), 2.5 (2 H, 5-H_2), 3.1—3.5 (1 H, 6-H), 3.62 (CH_3), 4.62 (2 H, 9-H_2), 5.95br (2H, d, 3- and 4-H), and 7.05 (2-H); *m/e* 178 (M^+, 80%) 163 (36); 145 (24), 137 (19), 131 (15), 119 (100), 117 (39), 115 (18), 105 (74), and 91 (38) (Found: M^+, 178.0983. $C_{11}H_{14}O_2$ requires *M*, 178.0993), followed by methyl 4-acetoxymyrtenate (26b) (270 mg, 6.5%); $[\alpha]_D$ +5.6°; $\nu_{max.}$ ($CHCl_3$) 1 720 and 1 215 cm^{-1}; δ ($CDCl_3$) 0.82, 0.92, 1.34, 2.00, and 3.68 (CH_3), 5.32—5.62 (4-H), and 6.62br (3-H). This n.m.r. spectrum apparently indicates the presence of two isomers (at C-4). A pure sample of (26b) is described later. Further elution with light petroleum gave *methyl 8-acetoxy-o-mentha-1,3-diene-7-oate* (25) (760 mg, 18.5%); $[\alpha]_D$ −73°; $\lambda_{max.}$ 290 nm (ε 3 440); $\nu_{max.}$ ($CHCl_3$) 1 710 and 1 220 cm^{-1}; δ ($CDCl_3$) 1.32, 1.37, and 1.82 (CH_3), 2.32—2.55 (2 H, 5-H_2), 3.15—3.40 (1 H, 6-H), 3.65 (CH_3), 5.90 (2 H, t, 3- and 4-H), and 6.95 (2-H); *m/e* 238 (M^+, 1%), 178 (31), 147 (75), 138 (85), 137 (100), 119 (31), 105 (85), and 99 (53) (Found: C, 65.55; H, 7.75; M^+, 238. $C_{13}H_{18}O_4$ requires C, 65.55; H, 7.55%; *M*, 238). Further elution with 5% ether–light petroleum, gave the lactone (11), identical with that obtained before {i.r. and n.m.r. spectra and t.l.c. and g.l.c. [conditions (A), except that 3% SE-30 was used]}.

Aromatization of Methyl o-Mentha-1,3,8-trien-7-oate (24).—The ester (24) (200 mg, 1.12 mmol) was dissolved in benzene (5 ml). Phosphoryl chloride (5 drops) was added and the solution was boiled for 30 min under reflux. Ice and ether (50 ml) were added. The organic layer was washed with aqueous 10% sodium hydrogen carbonate and was then dried and evaporated. The oily material was purified by p.l.c. (elution with 10% ether–light petroleum) to give methyl 2-isopropylbenzoate (28) [19] as an oil, $\lambda_{max.}$ 229 (ε 4 780) and 277 nm (750); $\nu_{max.}$ 1 725 cm^{-1}; δ (CCl_4) 1.25 (d, CH_3), 3.8 (s, CH_3), and 7.0—7.8 (m, ArH); *m/e* 178 (M^+, 30%), 163 (15), 146 (45), 131 (100), and 91 (33), which differed from methyl 4-isopropylbenzoate (29),[12] δ 7.13 (d, *J* 9 Hz) and 7.83 (d, *J* 9 Hz) (ArH).

Methyl 4α-Hydroxymyrtenate (26a).—Methyl 4-oxomyrtenate (8) (60 mg, 0.31 mmol) in tetrahydrofuran (13 ml) was reduced with lithium hydridotri-t-butoxyaluminate (0.84 g, 3 mmol) in tetrahydrofuran (6 ml) as described for the reduction of (8) (see above). The yield was quantitative. The hydroxy-ester (26a) was obtained as an oil, [α] +35.9°; $\lambda_{max.}$ 237 nm (ε 4 550); $\nu_{max.}$ 3 600, 1 725, and 1 250 cm^{-1}; δ (CCl_4) 0.95, 1.37, and 3.62 (CH_3), 4.47 (m, 4-H), and 6.6 (m, 3-H); *m/e* 196 (1%), 164 (54), 149 (19), 121 (100), and 91 (91). The *acetate* (26b) was an oil, $[\alpha]_D$ +46°; $\lambda_{max.}$ 234 nm (ε 6 310); $\nu_{max.}$ 1 725 and 1 225 cm^{-1}; δ (CCl_4) 0.95, 1.37, 1.97, and 3.67 (CH_3), 5.5 (4-H), and 6.6 (3-H) [Found: (M^+ −60), 178.0983; M^+, 238. $C_{11}H_{14}O_2$ requires 178.0994; *M* ($C_{13}H_{18}O_4$) 238].

Reaction of Methyl 4α-Hydroxymyrtenate (26a) *with Toluene-p-sulphonic Acid.*—The ester (26a) (200 mg, 1.02 mmol) and toluene-p-sulphonic acid (30 mg) were dissolved in acetic acid (5 ml) and acetic anhydride (1 ml). The solution was boiled under reflux in nitrogen for 40 min. The reaction was worked up as described for the reaction of verbenone (1) (see above). P.l.c. (elution with 5% ether–light petroleum) gave two main fractions. The major, more polar one, after acetylation, was shown to be acetylated starting material (26b) (36 mg, 14.8%). The less polar one was shown to be methyl *o*-mentha-1,3,8-trien-7-oate (24) (comparison by t.l.c., g.l.c., i.r., and n.m.r.).

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